Getting Started with Mathematica

Clinton Wolfe, August 1999

Introduction

What is Mathematica?

Mathematica is a computer program for doing mathematics. It is often used for instruction, homework, research, and writing. Mathematica is extraordinary well-rounded. It is suitable for both numeric and symbolic work, and it has remarkable word-processing capabilities as well. Mathematicians can (and often do) search for a working model, do intensive calculation, and write a dissertation on the project (including complex graphics) -- all from within Mathematica.

Its weaknesses include a somewhat steep learning curve, an interface that is difficult to use from the command line, and rather complex installation procedures.

Philosophical issues

Mathematica is more than just a program. It is an attempt to redefine the interaction between mathematician and computer. *Every* command, function, option, button, menu, or object in Mathematica fits into this philosophy in a standard way. In the mid-to-long term, this makes Mathematica a very easy-to-use, enjoyable tool. For the new user, Mathematica can seem opaque and threatening.

Mathematica was created by a mathematician for other mathematicians. A user of Mathematica should be comfortable dealing with abstraction, generalization, and pattern discovery. If you feel you do not fit this profile, you might want to learn Maple first.

How to use this document

This document is intended for new users of Mathematica. No prior math software experience is assumed, though we do point out differences between the major packages along the way. We assume you are familiar with your operating system, so we will not cover clicking, dragging, etc. Since Mathematica is quite visually oriented, we assume you will be using it on a computer with a windowing system (such as Windows, Macintosh, or X-windows). If you intend to use Mathematica from the command line, it would be best to first learn it in a graphic environment, and then learn to Use Math Software under UNIX.

We will use a few conventions throughout this document.

Example	Explanation
File -> Open	Select *Open* from the *File* menu.
3,Ctl-6,5	Press 3, then hold the Control key and press 6, then press 5.
`2+2`	Input to be typed at the Mathematica prompt.
`4`	Output from Mathematica
TIP	An important tip.
	A tip for Maple users.
	A tip for Matlab users.

Where to find Mathematica

Mathematica is available in all Macintosh, SGI, and Sun computer labs at IUB. It is also available on Steel and the SP (node sp09).

Mathematica is also available for sale in the IU Bookstore.

How to start and exit Mathematica

To start mathematica, follow these instructions.

- Unix: from a command line, type "mathematica &"
- Macintosh: Apple Menu->Stat/Math->Mathematica

TIP	If you are using X windows and you get a stream of font errors, follow these instructions from the Knowledge Base.

To exit Mathematica, you can:

- Choose File->Exit
- Type `Quit[]`.

Orientation

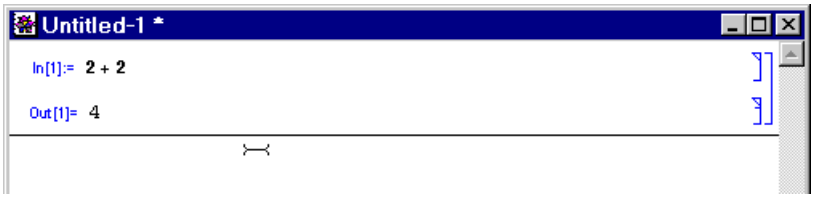
When you first start Mathematica, you should see a "splash" screen with the Mathematica logo, version, and license

information. When the program loads, you should see several objects on the screen. We will now describe what they are and what they do.

TIP	You may wish to turn on your speakers (or bring headphones if you are in an STC). Mathematica uses audio cues to notify the user of errors, finished calculations, etc.

Notebooks

A notebook is a collection of Mathematica statements, output, and graphics. The concept is like that of a "document" in a word processor. You enter information and commands into the notebook window, and the output (if any) is displayed there.



If the notebook has been modified since it was last saved, an asterisk (*) will appear in the title bar. To save your work, choose File->Save As... or File->Save.

If Mathematica is ready for new input, the cursor will flip sideways (see above). Just start typing to enter information. Try typing this (don't press return yet):

```
2 + 2
```

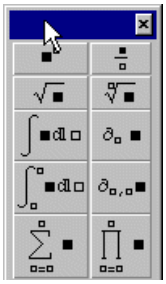
To tell Mathematica to evaluate this expression, hold down Shift and type Return. Since Mathematica is also a word processor, it needs to know if you want to evaluate the expression, or just insert a carriage return-linefeed. This can be quite confusing to the new user.

System	Evaluate	Linefeed
Macintosh	Enter *or* Shift-Return	Return
Windows	Shift-Enter	Enter
X	Shift-Return	Return

Next, look at the blue symbols along the right side of the notebook. Each group of statements enclosed by the triangle-brackets ( ) is called a *cell*. The cell is the smallest unit of work in Mathematica. A cell may contain input or output, math or comments, text or graphics.

	Cells in Mathematica are like *execution groups* in Maple.

Palettes



You should see a box with a lot of symbols floating on the right side of your Mathematica window. This is called a *palette*. Palettes allow you to easily insert complicated mathematical notation. For example, to compute the cube root of 34, you could click on the . Type `34`, which should appear under the root sign. Then click on the small square above the root, and type `3` in the box. Finally, evaluate the expression.

Using the default palette, you can enter fractions, integrals, summations, matrices, subscripts, and most greek letters. Of course, there are many other palettes available - choose File->Palettes to see a list.

Kernels

Mathematica is actually split into two conceptual pieces, the *front-end* and the *kernel*. When you start Mathematica, you are actually only starting the front-end.

The front-end handles input and output to the user, access to the file system, and creates graphics on your screen. Most users will deal primarily with the front-end.

The kernel does nearly all computation (excluding graphics rendering). When you evaluate any expression, the kernel does the hard work and sends the results back to the front-end, which then displays it in an attractive format for the user.

Most users will run the front-end and the kernel on the same computer. If your computer is connected to a network, you can run the kernel on a more powerful machine, while running the front-end on your favorite computer. To learn how to do this, choose Kernel->Kernel Configuration Options, click Add, and then click Help.

TIP	How to stop a runaway calculation: • Macintosh - Command-Comma or Control-C • Windows and X - Alt-Comma or Control-C This will bring up a menu that allows you to view the state of the kernel, abort the calculation, etc.

Help system

Mathematica has an excellent help system. To get general help, choose Help->Help Browser. Browse among the topics listed.

Mathematica comes with an excellent resource, *The Mathematica Book*. It is available through the Help Browser. See also the Getting Started section, which contains several excellent tutorials.

Doing Math

Arithmetic

Basic arithmetic operations are easy to enter in Mathematica. You may use your choice of notation, and you may choose to enter symbols via the palettes or the keyboard.

Keystrokes	Input	Output	Comments
4, ,+, ,4 3,-,1,6	`4+4` `3-16`	`8` `-13`	Addition, subtraction. Spaces are optional.

4,*,4
4, ,4
4,4
4,Esc,*,Esc,4
	`4*4`
	`4 4`
	`44`
	`4×4`
		`16`
		`16`
		`44`
		`16`
			Multiplication.
			A space can mean multiplication as well...
			...but you should be careful.
			You can also use the symbol.

3,/,4
3,Esc,d,i,v,Esc,4
3,Ctl-/,4
	`3/4`
	`3÷4`
	$\frac{3}{4}$
		$\frac{3}{4}$
		$\frac{3}{4}$
		$\frac{3}{4}$
			Exact division.

3,^,5 3,Ctl-^,5	`3^5` 3^5	`243` `243`	The text version The symbolic version

3,^,(,1,/,2,)
Ctl-@,3
N,[,Ctl-@,3,Ctl-Space,]
	`3^(1/2)`
	$\sqrt{3}$
	`N[`$\sqrt{3}$`]`
		$\sqrt{3}$
		$\sqrt{3}$
		`1.73205`
			An approximation.

%,Ctl-^,2	$\%^2$	`3.`	Square last output.

Mathematica's data restrictions are as follows:

- Integers can be of any size, up to your computer's memory.
- Real and complex operations are carried out with arbitrary (limitless) precision, up to your computer's memory, unless `N` is used.
- See Help->Help Browser: Numerical Computation->Numerical Precision->N, and section 1.4.9 of *The Mathematica Book*.

	• Mathematica does not set limits on the size of matrices, as Maple does. • `N[...]` is just like Maple's *feval*.
	If you want to use double precision, you must explicitly say so. See above.

Algebra

Mathematica is more than a calculator, of course. We will now try out some of Mathematica's Computer Algebra System (CAS) features.

Keystrokes	Input	Output	Comments
a	`a`	`a`	All names are symbols.
a,=,4	`a=4`	`4`	Defining a constant.
Esc,a,l,p,h,a,Esc,=,3	`α=3`	`3`	Greek letters (see palettes).
(,x,+,1,),Ctl-^,2	$(x+1)^2$	$(x+1)^2$	An expression.
E,x,p,a,n,d,[,%,]	`Expand[%]`	$1+2x+x^2$	Algebraic expansion....
S,i,m,p,l,i,f,y,[,%,]	`Simplify[%]`	$(x+1)^2$	...and simplification.

From this point onward, we will assume that you know how to enter keystrokes.

Input	Output	Comments
$p=x^3+3x^2+3x+1$	x^3+3x^2+3x+1	`p` is now an alias for the expression. This is not mathematical equality.

`Solve[p==0]`	`{{x->-1},`
	`{x->-1},`
	`{x->-1}}`
		Solve the *equation* `p==0`. Mathematica returns
		a set of *transformation rules*.
		The system has three identical solutions.

`p /. x->2`	`27`	Substitute 2 for x (temporarily).
`p==0 /. x->2`	`False`	27 does not equal 0.

	Transformation rules are like the *subs* command in Maple.
TIP	Go exploring in the Algebra Palette: File->Palettes->AlgebraicManipulation.

Functions

Using them

A *function* in Mathematica is a formalized, named transformation rule. A function may return a symbol, a real

number, a complex matrix, another function.... Any mathematical object is an acceptable value for a function. We have seen several built-in functions so far: **Solve**, **Expand** , and **N** are a few examples. A function may be written using mathematical notation, it may be created using programming constructs (like for, if/then, etc.), or it could even be written in another language entirely (Fortran, C, etc.).

All built-in Mathematica functions are named with InitialCapitalLetters (**FullSimplify**) and some use abbreviations (**NDSolve** - Numerical Differential Equation Solver).

Creating them

Input	Output	Comments
`f[x_]:=x^2`	(none)	A simple function definition. Note the underscore (_) that follows the dependent variable name.
`f[2]` `f[y+z]`	`4` `(y+z)^2`	The function works with numbers and expressions.
`f[f[f[2]]]`	`16348`	You can nest functions.

`?f`	`Global`
	`'f`
	`f[x_]`
	`:= x^2`
		What is f?

`g[x_,y_]` `:= x*y`	(none)	You can have as many arguments as you like.
`Clear[f]`	(none)	Deletes the definition of f.

Procedural Functions

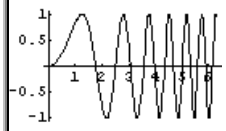
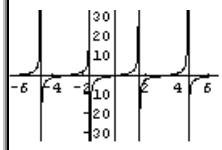
You may wish to create more complex functions. Suppose that you wanted to count to 100, and print out a list of each number that is divisible by the argument. Here is one way that you could do it:

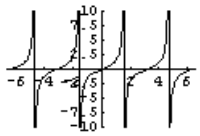
```
sillyCount[n_] := ( Do[ If[Mod[i,n]==0, Print[i]] ,{i,100}]; )
```

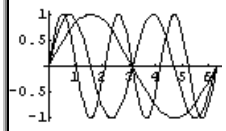
For more information on programming in Mathematica, see the online help.

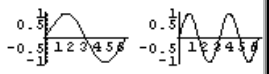
Graphics

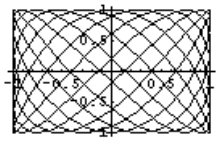
2-D Graphics

Input	Output	Comments
`Plot[Sin[x^2],{x,0,2Pi}]`		A simple plot.
`Plot[Tan[x], {x, -2Pi, 2Pi}]`		If the plot has singularities, Mathematica will try to choose a suitable scale....

`Plot[`
`  Tan[x],`
`  {x, -2Pi, 2Pi},`
`  PlotRange -> {-10,10}]`
		...or you can set it manually.

`Plot[`
`  {Sin[x],Sin[2x],Sin[3x]},`
`  {x, 0, 2Pi}]`
		You can plot multiple functions by
		including them in curly brackets.

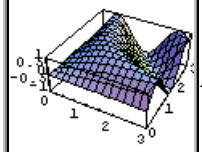
`Show[GraphicsArray[`
`  {Plot[Sin[x],{x,0,Pi}],`
`  Plot[Sin[2x],{x,0,2Pi}]`
`  }]]`
		Plot two plots, side-by-side.

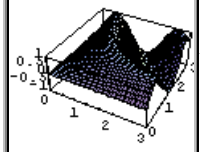
`ParametricPlot[`
`  {Cos[7t],Sin[11t]},`
`  {t, 0, 2Pi}]`
		Parametric plot.

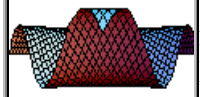
For more information, see section 1.9.1 in *The Mathematica Book*.

3-D Graphics

Input	Output	Comments

`Plot3D[`
`  Sin[x y],`
`  {x,0, 3},`
`  {y, 0, 3}]`
		A basic surface plot.

`Plot3D[`
`  Sin[x y],`
`  {x, 0, 3},`
`  {y, 0, 3},`
`  PlotPoints -> 40]`
		You can get a finer plot if you increase the number of sample points.

`Plot3D[ Sin[x y],`
`  {x, 0, 3},`
`  {y, 0, 3},`
`  ViewPoint -> {1, 1, 0},`
`  PlotPoints -> 40,`
`  Boxed -> False,`
`  Axes -> False]`
		A variety of options.
		Most important is the ViewPoint option, which tells where to put the "camera".

For more information, see section 1.9.7 of *The Mathematica Book*.

Further Reading

If you have enjoyed working with Mathematica, you will almost certainly enjoy *The Mathematica Book*. It is available on the web, through Stat/Math Center Sales, at your local bookstore, and in the online help.

In addition, be sure to wander through the Wolfram Research Documentation Center, where you will find reference works on any topic imaginable.

You can find other people who use Mathematica in the following usenet newsgroups:

- comp.soft-sys.math.mathematica
- sci.math.symbolic (Mostly Maple discussion, but some Mathematica)

In addition, your local bookstore or library probably has several books about Mathematica or one of its applications. WRI keeps a list of current books on their website.

Please send comments and suggestions to: statmath@indiana.edu
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URL `http://www.indiana.edu/~statmath/math/mma/gettingstarted/index.html`

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Scientist, Creator of *Mathematica*®, and Author of *A New Kind of Science*

About
Stephen Wolfram

Publications by
Stephen Wolfram

- Books
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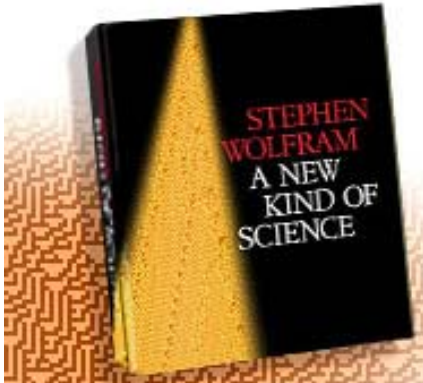
Interviews and
Publications about
Stephen Wolfram

Wolfram's landmark work
released May 14, 2002



Q & A with
Stephen Wolfram

The Life and Times
of Stephen Wolfram:
A Scrapbook

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Maple

- Information
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    - Differential Equations in Maple
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Last modified: Tuesday, 10-Oct-2000 08:54:21 EST
URL `/~statmath/math/maple/index.html`

Using Math Software Under UNIX

Clinton Wolfe (April 1999)
with material from Dave Hart

Also availible: printer-friendly version in Adobe PDF(183KB).

- Introduction
  - Purpose
  - Who this document will help
  - How to use this document
- UNIX - The absolute least you need to know
- Using the Math Software
- Using graphics over the network
- Using batch processing
- Further Reading

Introduction

Purpose

Distributed computing puts into practice a favorite Hoosier proverb: "Use the right tool for the job." As distributed computing continues to grow, the network is becoming one vast virtual machine, with different parts performing different functions. UITS provides a variety of hardware platforms, from large shared computers to desktop workstations in Student Technology classrooms and labs. Workstations typically provide superior graphics and a more convenient user interface, and offer

powerful logical and arithmetic processing capabilities, but generally lack the large memory that shared computers provide. On a shared computer, you can use Maple to manipulate formulas thousands of lines long, or use Matlab to perform billions of computations -- all within minutes. Using workstations in conjunction with multiuser systems, via the network, can combine the best functionality of both.

Who this document will help

This document is intended for users of Maple, Matlab, and Mathematica who need the computing power of very large computers. This is *not* a tutorial for any of these software packages; instead see Getting Started with Maple, Matlab, or Mathematica. We assume that you are fairly familiar with one of these packages. We also assume you are comfortable using the basic functionality of network utilities such as FTP and Telnet (or SSH). Our goal is to ease the transition from a window-style desktop environment to a command-line based UNIX environment.

The standard math tools at IUB -- Maple, Mathematica, and Matlab -- have versions that can run on many different platforms. The microcomputer version offers a relatively friendly interface, while the mainframe version offers raw power. For everyday problems, you'll find the microcomputer version fast and easy to use. Even when you need the power of the mainframe, you may still want to develop algorithms and debug code on your desktop, then turn to shared systems for production runs that require large storage or extended number-crunching.

This document is designed for users at Indiana University (Bloomington or IUPUI campuses), who have accounts on either the SP system, Steel, Cobalt, Nations, DaVinci, or Ships. The information contained herein may not be appropriate for your specific circumstances (especially when refering to characteristics of specific computers).

How to use this document

Everyone should read the UNIX - The Least You Need to Know and Starting the Math Software sections, unless you already know this information. You may then pick among the remaining sections to fit your needs.

Please send errors, omissions, comments, etc. to statmath@indiana.edu, or post to iu.statmath.

Next : UNIX - The least you need to know

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Last modified: Wednesday, 19-Jan-2000 17:08:32 EST
URL `/~statmath/math/all/mathunix/index.html`

In Unix, using the X Window System with the display on my workstation, how do I fix the fonts to run Mathematica?

Mathematica makes heavy use of specialized fonts to display mathematical notation. While you can run Mathematica without these fonts, your display may be unintelligible. Mathematica expects to find these fonts on your local computer, rather than on the remote Unix computer.

To avoid known conflicts, UITS recommends that you install the fonts in a separate place from your standard X Window System fonts. You can get the fonts for Mathematica 3.0 and 4.0 in PCF format from Wolfram, the makers of Mathematica, at:

`http://support.wolfram.com/mathematica/systems/unix/interface/pcf.html`

If you need help installing new fonts, see your X Server documentation.

To fix your installed fonts to display properly in Mathematica, follow the directions below:

1. After you have installed the fonts, connect to Steel, Ships, Nations, da Vinci, or the Research SP systems using telnet or ssh. Start your X Server and enter the following at the remote prompt:

   ```
   mathematica &
   ```

   Mathematica should launch in your local X Server.

2. Errors may appear at the remote prompt. You can safely ignore the following error message:

   "Warning: Cannot convert string '....' to type FontStruct".

   However, you will need to issue further commands if one of the following errors appears:

"xset: bad font path element (#1)"

"assertion `GenericUnicodeFont != 0' at MathEditFont.c:43 failed"

3. In the case above, before you run Mathematica, you need to issue the following commands at the remote prompt:

```
xset fp+path_to_fonts

xset fp rehash
```

Replace `path_to_fonts` with the absolute path to the directory containing `fonts.dir` on your **local** computer. You can also use this technique if you have a local copy of Mathematica installed.

For additional information about Mathematica, see the Mathematica Resources at Indiana University Web page at:

`http://www.indiana.edu/~statmath/math/mma/index.html`

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Last updated on September 21, 2001

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A General Overview of Maple

Maple is a general purpose computer algebra system, designed to solve mathematical problems and produce high-quality technical graphics. It is easy to learn, but powerful enough to calculate difficult integrals in seconds. Maple incorporates a high-level programming language which allows the user to define his own procedures; it also has packages of specialized functions which may be loaded to do work in group theory, linear algebra, and statistics, as well as in other fields. It can be used interactively or in batch mode, for teaching or research.

Maple is classified by UITS as a General Purpose Software. Documentation is available in all Student Technology Centers and the Center for Statistical and Mathematical Computing. UITS Public Facilities consultants can provide assistance in accessing the program. The Center for Statistical and Mathematical Computing (812/855-4724 or email to statmath@iu.edu) can answer basic to advanced questions. NOTE: If you are a student using Maple for a class exercise, questions about your class work should be directed first to your instructors.

Program Functionality: Excellent

Breadth of Functionality: Excellent

Maple has over 2500 functions available. A basic core collection is loaded at startup, and specialized packages are available, for topics from statistics to geometry.

Reliability and Robustness: Good

Maple is very robust, and reliable. However, no computer program can replace

understanding! People do mathematics, computers don't.

State of the Art: Excellent

Maple is one of the leading mathematics programs, noted for its algebraic and analytic prowess. Export to LaTeX or HTML are provided.

Maple is relatively good about not returning "wrong" answers. Inverse functions remain the big problem for computer algebra systems. They appear in places where they might not be expected (definite integrals, for example), so any result from a CAS should be checked. Maple handles inverse functions fairly well, although the resulting fastidiousness can be surprising. Maple can [to some extent] handle assumption, such as "*n* is an integer" or "*theta* lies between 0 and Pi/2", which increases its power and precision, and makes it possible to deal with convergence conditions and inverse functions relatively well.

User Friendliness: Fair

Maple is the most user-friendly of the mathematical software available at IUB, but Maple's command-line language requires some investment in training before the program can be easily used.

Maple's language is easily understood by those trained with any procedural language (such as Basic or C); its command names and syntax are mostly straightforward and easily understood.

Electronic Help Resources: Excellent

Network-based help: Excellent

The Knowledge Base has answers to several frequently asked Maple questions.

Program Help System: Excellent

The Help System is excellent; it includes examples and discussion as well as syntax. A "New Users' Tour" makes it easy to get started, with hyperlinks to additional topics.

To get help on a known command, use the **?** command -- for example, ?plot . "?" by itself gets help on the help system. When the command is unknown, you can search

for a topic, or do a full-text search of the help system. At the top of a help window is a "Help Browser" which lists topics by category, with up to five levels of increasing detail.

Local Availability: Excellent

Indiana University at Bloomington has a site license for Maple; IUPUI also owns such a license. Consequently, the latest version of Maple [as of a month before the current semester started] will be installed in all UITS public computing facilities, and many of the UITS timesharing systems.For details, see the Math Software Availability page.

Further, Maple may be obtained at greatly reduced prices for departmental and personal workstations at these locations: see the Sales page for more information.

Local Support & Training: Excellent

Document Availability: Excellent

Locally produced documents are also available free of charge from UITS Stat/Math Center.

UITS makes basic manuals available in document racks in the Student Technology Centers. Full documentation is available for reference and short term loan from various Software Manual Locations. Documents are also available for reference at the UITS Stat/Math Center.

Training Availability: Excellent

UITS offers Jumpstart classes for Getting Started With Maple free of charge to IUB students. Instructors may request a specially arranged class for introducing their students to Maple by contacting UITS Education Group (855-3499).

User Group: Good

To join the international Maple Users' Group [mailing list], send e-mail to majordomo@daisy.uwaterloo.ca containing the line `subscribe maple-list`.

UITS Consulting Support: Full Support

Consulting support is available from Stat/Math Consulting from 9 am to 5 pm (M-F) via email, phone, and for walkins (an appointment is recommended for walkin consulting).

Other Consulting Support: Good

Registered Maple license owners can contact the vendor directly with the number provided with the license agreement: phone 800-267-6563. Students with the student edition should contact Brooks-Cole at 800-214-2661, or send e-mail to support@brookscole.com.

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IU Mathematical Software Availability

- IUB
- IUPUI

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Sales

One of our primary functions is to provide software sales and service to the university. Our goal is to be largely self-sufficient while offering the buying power of the university to the individual.

Our Sales area has recently been reorganized into the following sections:

- Who Can Buy
- About Licensing
- About Installation
- Price List
- How to Buy

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Maple Licensing Information

Current Version Information

Maple 7 is a computer algebra system with numerical and graphical capabilities. It features a built-in programming language including libraries for number theory, group theory, linear algebra, statistics, etc., that can be used to solve a range of problems, from the most abstract mathematical ones to down-to-earth design tasks. Maple 7 is available on a number of platforms.

License Terms

- Indiana University (IU) faculty and staff may install Maple 7 on their university-owned computers, and on other computers used in support of their IU administrative, research, and teaching activities. Our current license does not allow sales to students. However, students may purchase a student version of Maple 7 from their campus bookstore.
- Faculty and staff Maple 7 licenses are available only on an annual basis. This annual lease includes any upgrades put out by the vendor as well as program maintenance.
- Students may obtain a perpetual license for Maple 5.1 from the Stat/Math Center. The package comes on two CDs from which the student installs the program. While no upgrades are available with this license, there are no renewal fees.
- For faculty and staff, installation must be done by a UITS representative and is included in the price of the package. UITS retains the program disks; however, a UITS representative will return for installation service as needed. Service fees may be assessed, depending upon the services provided. UITS cannot make house calls off campus. If you want Maple installed on a personally-owned computer located off campus, you must bring it to campus

for the installation.

- No manuals are supplied with the lease. Please contact the Stat/Math Center for information on getting manuals.

Hardware and Software Requirements

The following are *minimum* requirements.

Package	OS version	Chip	RAM	HD
Maple 7 for Windows	95, 98, NT 4.0, Windows 2000	Pentium-compatible	32MB (64 MB recommended)	80
Maple 7 for Macintosh	8.6, 9.0, 9.1	604 processor, G3, or G4	24 (64 recommended)	80
Maple 7 for Linux x86	kernel 2.2, glibc 2.1, x86 compatible	Pentium 90 or better	32	70
Maple 7 for DEC Alpha	Digital UNIX 4.0F,5.1 or Compaq Tru64	Any Alpha	32	60
Maple 7 for HP/9000	HP-UX 11	All PA-RISC	32	70
Maple 7 for IBM RS/6000	AIX 4.3.3	All RS/6000 CPU's	32	70
Maple 7 for SGI	IRIX 6.5.X	MIPS R4000	32	70
Maple 7 for Solaris	Solaris 2.6,2.7,2.8	All Sparc and x86	32	70

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Getting Started with Maple

Prepared by the staff of the Stat/Math Center 1
Revised August 2001

This document is available in the following formats:

Web-based Tutorial
One Long Web Page
Adobe Acrobat 4.0 (for printing)

Table of Contents

- Introduction
  - What is Maple?
  - How to use this tutorial
  - Where to find Maple
  - Starting and Exiting Maple
- Finding Your Way Around
  - The Toolbar
  - The Kernel
  - Worksheets
- Using the Help system
- Maple Syntax and Built-in Data Capabilities
  - Maple Syntax
  - Data Capabilities
- Using symbolic computation (variables)
- Creating your own mathematical functions

- Using packages
- Basic Plotting
- Further Reading

1. Jefferson Davis, David Hart, and Clinton Wolfe worked on this document and on subsequent revisions.

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Basic Algebra in Maple

Original by Dave Hart
Updated by Clinton Wolfe
Also available as a Maple 5.1 worksheet

Basic Polynomial Manipulation

```
> z:=(x+y)^2 + 9*(2+x)*(x+y);
```

$$z := (x+y)^2 + 9\,(2+x)\,(x+y)$$

Here an algebraic expression has been typed. Maple reads in the statement, assigns the right hand side to the variable z, and "prettyprints" it. The letters x, y, and z are here considered variables; legal variables start with a letter and have at most 494 characters. Examples of legal variable names are: g, G, new_term, x13a, and the_answer_is. Maple is case sensitive, so the variables g and G are distinct.

Notice also that the line ends with a semicolon. All commands entered in Maple must end in with a semicolon. If one is not entered at the end of the line, then Maple will wait for one to be entered on the next line.

```
> expand(z);
```

$$10\,x^2 + 11\,x\,y + y^2 + 18\,x + 18\,y$$

This command expanded the algebraic expression assigned to z.

```
> %^3;
```

$$(10\,x^2 + 11\,x\,y + y^2 + 18\,x + 18\,y)^3$$

Here, this command tells Maple to take the previous result and cube it. (The percent sign refers to the most recent result.) Maple does not expand the result. To see the multiplication explicitly, the following command is issued:

```
> expand(%);
```

$$1000\,x^6 + 3300\,x^5\,y + 3930\,x^4\,y^2 + 1991\,x^3\,y^3 + 393\,x^2\,y^4 + 33\,x\,y^5 + y^6 + 5400\,x^5 + 17280\,x^4\,y + 19494\,x^3\,y^2 + 8802\,x^2\,y^3 + 1242\,x\,y^4 + 54\,y^5 + 9720\,x^4 + 30132\,x^3\,y + 32076\,x^2\,y^2 + 12636\,x\,y^3 + 972\,y^4 + 5832\,x^3 + 17496\,x^2\,y + 17496\,x\,y^2 + 5832\,y^3$$

Notice that Maple does not list the elements in any specific order.

```
> sort(%);
```

$$1000\,x^6 + 3300\,x^5\,y + 3930\,x^4\,y^2 + 1991\,x^3\,y^3 + 393\,x^2\,y^4 + 33\,x\,y^5 + y^6 + 5400\,x^5 + 17280\,x^4\,y + 19494\,x^3\,y^2 + 8802\,x^2\,y^3 + 1242\,x\,y^4 + 54\,y^5$$

$$+9720\,x^4+30132\,x^3\,y+32076\,x^2\,y^2+12636\,x\,y^3+972\,y^4+5832\,x^3+17496\,x^2\,y+17496\,x\,y^2+5832\,y^3$$

Use the "sort" command to see it in a prettier form.

```
> factor(%);
```

$$(x+y)^3\,(10\,x+y+18)^3$$

Here Maple factors the previous result. Notice that the result does not look like the expressions previously entered. Maple will not always be able to return an expression to its previous form.

Operations on Polynomials

```
> integrate(x/(1-x^3), x);
```

$$-\frac{1}{3}\ln(x-1)+\frac{1}{6}\ln(x^2+x+1)-\frac{1}{3}\sqrt{3}\,\arctan\left(\frac{1}{3}(2\,x+1)\sqrt{3}\right)$$

Maple integrates x/(1-x^3) with respect to x. Because any letter used in a Maple session is considered a variable, you must specify with respect to what variable differentiation and integration should occur.

```
> diff(%, x);
```

$$-\frac{1}{3}\frac{1}{x-1}+\frac{1}{6}\frac{2\,x+1}{x^2+x+1}-\frac{2}{3}\frac{1}{1+\frac{1}{3}(2\,x+1)^2}$$

Differentiation.

The result is not exactly like the integrand, but it is in a form similar enough to recognize that they are the same expression. Simplification is a difficult problem.

```
> series(exp(-x)*sin(2*x), x);
```

$$2\,x-2\,x^2-\frac{1}{3}x^3+x^4-\frac{19}{60}x^5+O(x^6)$$

The command will find a series (either Taylor, Laurent, or generalized) around the point x=0 if no value is given. Generally, the last term of the series will be the order term, where the order is decided by a global Maple variable which can be defined by the user.

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URL /~statmath/math/maple/algebra/index.html

Maple ODE Examples

Here's a basic ODE:

```
> deq := diff(y(x),x) + y(x) = 0: deq;
```

$$\left(\frac{\partial}{\partial x} y(x)\right) + y(x) = 0$$

Here's the basic form of the command for solving differential equations:

```
> soln := dsolve( deq, y(x) );
```

$$soln := y(x) = e^{(-x)} _C1$$

We can add initial conditions, to determine the "integration constant" _C1:

```
> subs(x=0, y(0)=y0, soln); solve(", _C1): subs(_C1=",
soln);
```

$$y0 = e^{0} _C1$$

$$y(x) = e^{(-x)} y0$$

This could be done in one step:

```
> dsolve( {diff(y(x),x) + y(x) = 0, y(0)=y0}, y(x) );
```

$$y(x) = e^{(-x)} y0$$

```
> dsolve({diff(y(x),x$2) + y(x) = x*cos(x), y(0) = y0,
D(y)(0) = v0}, y(x));
```

$$y(x) = \frac{1}{4} x \cos(x) - \frac{1}{8} \sin(x) + \frac{1}{4} \sin(x)\, x^2 + y0 \cos(x) + \left(-\frac{1}{8} + v0\right) \sin(x)$$

```
> sys := diff(y(x),x)=z(x), diff(z(x),x)=y(x): sys;
inits := y(0)=0, z(0)=1: inits;
fcns := {y(x), z(x)}:
```

$$\frac{\partial}{\partial x} y(x) = z(x), \frac{\partial}{\partial x} z(x) = y(x)$$

$$y(0) = 0, z(0) = 1$$

```
> dsolve({sys} union {inits}, fcns);
```

$$\left\{y(x) = \frac{1}{2} e^{x} - \frac{1}{2} e^{(-x)}, z(x) = \frac{1}{2} e^{x} + \frac{1}{2} e^{(-x)}\right\}$$

```
> dsolve({sys, y(0)=0, z(0)=1}, fcns, type=series);
```

$$\left\{y(x) = x + \frac{1}{6} x^{3} + \frac{1}{120} x^{5} + O\left(x^{6}\right), z(x) = 1 + \frac{1}{2} x^{2} + \frac{1}{24} x^{4} + O\left(x^{6}\right)\right\}$$

This next example (the pendulum equation) is not solvable in terms of elementary functions. Maple obtains a "reduction to quadratures" for the inverse functions.

```
> dsolve({diff(y(x),x$2) + sin(y(x)) = 0}, y(x));
```

$$x = \int_{0}^{y(x)} -\frac{1}{\sqrt{2 \cos(y1) + _C1}} \, dy1 - _C2, x = \int_{0}^{y(x)} \frac{1}{\sqrt{2 \cos(y2) + _C1}} \, dy2 - _C2$$

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Fourier Series

Fourier Series are a **projection** method. Here's some code for calculating the coefficients:

```
> fe := proc(f) fnormal(evalf(f)); end:
> a := proc(f, n)
if n=0 then fe((1/(2*Pi))*Int(f, x=-Pi..Pi));
else fe((1/Pi)*Int( f*cos(n*x), x=-Pi..Pi));
fi;
end:
> b := proc(f, n)
if n=0 then 0;
else fe((1/Pi)*Int( f*sin(n*x), x=-Pi..Pi));
fi;
end:
> fs := (f, n) -> sum('a(f, k)*cos(k*x) + b(f, k)*sin(k*x)',
k=0..n);
```

Note that we have chosen to convert the coefficients to floating-point form, to standardize the interval length [to the circumference of the unit circle], and to make the coefficients functions [whose arguments are expressions]. Other choices also work. Here are some examples of the result:

```
> fs1 := fs(x, 10);
```

```
fs1 := 1.999999999 sin(x) - .9999999999 sin(2 x)

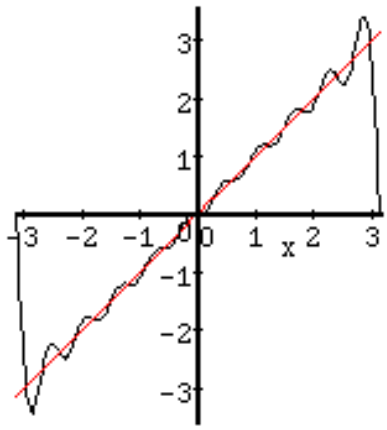
       + .6666666664 sin(3 x) - .4999999999 sin(4 x)

       + .3999999998 sin(5 x) - .3333333332 sin(6 x)

       + .2857142856 sin(7 x) - .2499999999 sin(8 x)

       + .2222222222 sin(9 x) - .1999999999 sin(10 x)
```

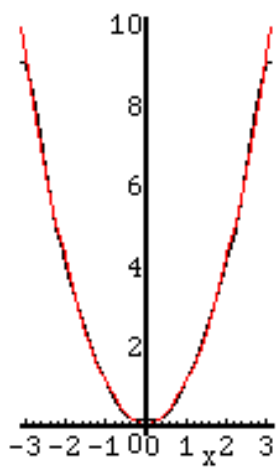
```
> plot({ x, fs1 }, x=-Pi .. Pi, scaling=constrained);
```




```
> fs2 := fs(x^2,4):
```

$$fs2 := 3.289868133 - 3.999999998 \cos(x) + .9999999999 \cos(2\,x) - .4444444445 \cos(3\,x) + .2499999999 \cos(4\,x)$$

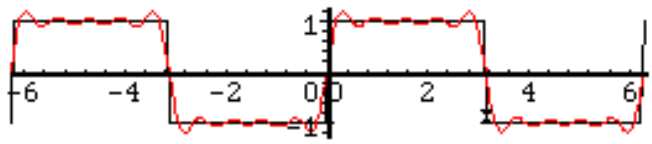
```
> plot({ x^2, fs2 }, x=-Pi .. Pi, scaling=constrained);
```




```
> f3 := x -> signum(sin(x)): > fs3 := fs(f3(x),10);
```

$$fs3 := 1.273239544 \sin(x) + .4244131814 \sin(3\,x) + .2546479089 \sin(5\,x) + .1818913635 \sin(7\,x) + .1414710605 \sin(9\,x)$$

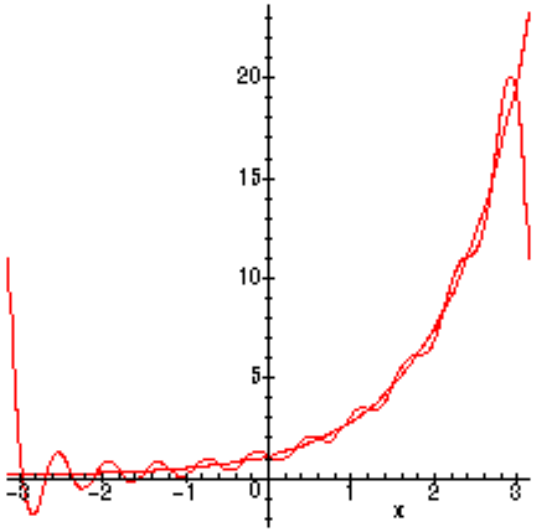
```
> plot({ f3(x), fs3 }, x=-2*Pi .. 2*Pi, scaling=constrained);
```




```
>fsexp := fs(exp(x), 10): fsexp;
```

$$3.676077909 - 3.676077910 \cos(x) + 3.676077910 \sin(x) + 1.470431164 \cos(2\,x) - 2.940862328 \sin(2\,x) - .7352155817 \cos(3\,x) + 2.205646746 \sin(3\,x) + .4324797542 \cos(4\,x) - 1.729919016 \sin(4\,x) - .2827752238 \cos(5\,x) + 1.413876119 \sin(5\,x) + .1987069140 \cos(6\,x) - 1.192241484 \sin(6\,x) - .1470431164 \cos(7\,x) + 1.029301815 \sin(7\,x) + .1131100895 \cos(8\,x) - .9048807162 \sin(8\,x) - .08966043682 \cos(9\,x) + .8069439313 \sin(9\,x) + .07279362198 \cos(10\,x) - .7279362198 \sin(10\,x)$$

```
> plot({ exp(x), fsexp }, x=-Pi .. Pi, color=red);
```



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Linear Algebra with Maple

The output here is in character mode, rather than the default "high-resolution" mode. It's still formatted in two dimensions, so you need a monospaced font (for preformatted material) and a "sufficiently" wide window.

```
> with(linalg);
```

```
BlockDiagonal, GramSchmidt, JordanBlock, Wronskian, add,
    addcol, addrow, adj, adjoint, angle, augment, backsub, band,
    basis, bezout, blockmatrix, charmat, charpoly, col, coldim
    colspace, colspan, companion, concat, cond, copyinto,
    crossprod, curl, definite, delcols, delrows, det, diag,
    diverge, dotprod, eigenvals, eigenvects, entermatrix, equal,
    exponential, extend, ffgausselim, fibonacci, frobenius,
    gausselim, gaussjord, genmatrix, grad, hadamard, hermite,
    hessian, hilbert, htranspose, ihermite, indexfunc,
    innerprod, intbasis, inverse, ismith, iszero, jacobian,
    jordan, kernel, laplacian, leastsqrs, linsolve, matrix,
    minor, minpoly, mulcol, mulrow, multiply, norm, normalize,
    nullspace, orthog, permanent, pivot, potential, randmatrix,
    randvector, rank, ratform, row, rowdim, rowspace, rowspan,
    rref, scalarmul, singularvals, smith, stack, submatrix,
    subvector, sumbasis, swapcol, swaprow, sylvester, toeplitz,
    trace, transpose, vandermonde, vecpotent, vectdim, vector
```

This is a list of the functions added by loading the "linalg" package. To find out more about *vector*, for example, type **?vector**

```
> v := vector(3, [a, b, c]); m := matrix(2,2, [[a, b], [c, d]]);
```

```
                        v := [ a, b, c ]

                              [ a  b ]
                         m := [      ]
                              [ c  d ]
```

```
> evalm( m &* [2,3] );
```

```
                    [2 a + 3 b, 2 c + 3 d]
```

```
> linsolve(m,[2,3]);
```

```
                  - 2 d + 3 b     - 2 c + 3 a
                [ -----------, - ----------- ]
                   b c - a d       b c - a d
```

```
> det(m);
```

```
                          a d - b c
```

```
> eigenvals(m);
```

```
                            2             2          1/2
      1/2 a + 1/2 d + 1/2 (a  - 2 a d + d  + 4 b c)   ,

                            2             2          1/2
          1/2 a + 1/2 d - 1/2 (a  - 2 a d + d  + 4 b c)
```

```
> eigenvects(m, radical);
```

```
                                  - 1/2 a + 1/2 d - 1/2 %1
[1/2 a + 1/2 d + 1/2 %1, 1, {[ - ------------------------, 1 ]}]
                                              c

    ,

                                   - 1/2 a + 1/2 d + 1/2 %1
 [1/2 a + 1/2 d - 1/2 %1, 1, {[ - ------------------------, 1 ]}]
                                               c


                          2             2          1/2
     %1 :=            (a  - 2 a d + d  + 4 b c)
```

A **common error** is trying to compute the determinant, or eigenvalues, of a large symbolic ***n*** by ***n*** matrix. The problem is called *combinatorial explosion* -- there might be n^2 expressions in the answer which are each ***n!*** terms long!

The Hilbert matrix is a favorite example of numeric (as opposed to symbolic) linear algebra.

```
> H5 := hilbert(5);
```

```
                    [  1   1/2  1/3  1/4  1/5 ]
                    [                         ]
                    [ 1/2  1/3  1/4  1/5  1/6 ]
                    [                         ]
```

```
                 H5 := [ 1/3  1/4  1/5  1/6  1/7 ]
                       [                         ]
                       [ 1/4  1/5  1/6  1/7  1/8 ]
                       [                         ]
                       [ 1/5  1/6  1/7  1/8  1/9 ]
```

The Hilbert matrix is badly conditioned, which means that it corresponds to a system of linear equations which are hard to solve accurately.

```
> cond(H5);
```

```
                                943656
```

This means that errors [for example in the measured values of the right-hand side of the equations] may be multiplied by a factor of nearly a million!

A curious feature of the Hilbert matrix is that the entries of its inverse are all integers. Maple computes them exactly:

```
> inverse(H5);
```

```
           [   25    -300     1050    -1400     630  ]
           [                                         ]
           [  -300   4800    -18900   26880   -12600 ]
           [                                         ]
           [  1050  -18900   79380   -117600   56700 ]
           [                                         ]
           [ -1400   26880  -117600   179200  -88200 ]
           [                                         ]
           [  630   -12600   56700    -88200   44100 ]
```

The method for finding eigenvectors of m that Maple used above would not be appropriate for this matrix; if it were symbolic, this matrix would be too big; but more importantly, since it's numeric, there is another method [the QR method] which is less sensative to the numeric instability implied by a big condition number, and is also computed more quickly. Maple uses that method, if the inputs are floating-point [decimal] numbers.

```
> eigsys := eigenvects( map( evalf, H5) );
```

```
eigsys :=

[.01140749151, 1,
   { [ .2142136245, -.7241021311, -.1204532771, .3095739659, .5651934124 ] }],

[1.567050691, 1,
   { [ .7678547356, .4457910609, .3215782948, .2534389442, .2098226368 ] }],

[.2085342186, 1,
   { [-.6018714786, .2759134174, .4248766220, .4439030401, .4290133540 ] }],
                -5
```

```
[.3288052655*10  , 1,
   { [ .006173874786, -.1166928633, .5061638445, -.7671911293, .3762453886 ] }],

[.0003058977746, 1,
   { [ .04716180523, -.4326673028, .6673503032, .2330247284, -.5576000510 ] }]
```

"eigsys" is a list of compound objects: the eigenvalues, each with its multiplicity and corresponding eigenvector.

To select the second component of the second eigenvector, do this:

```
> eigsys[2][3][1][2];
```

```
                                .4457910609
```

To sort this out, examine in turn

- **eigsys[2]***(the "system:" second eigenvector, its eigenvalue and multiplicity),*
- **eigsys[2][3]***(the set consisting of the second eigenvector system's vector),*
- **eigsys[2][3][1]***(the vector itself).*

CAUTION: The order of the eigensystem cannot be predicted, from one session to the next.

The next command finds the singular values to 4 floating-point digits, among other things.

```
> svdlist := evalf(Svd(H5, 'U', 'V'), 4);
```

```
     svdlist := [ 1.567, .2086, .01136, .0002933, .00001142
```

```
> d := diag( seq(svdlist[k], k=1..5));
```

```
             [ 1.567    0       0        0         0     ]
             [                                           ]
             [   0    .2086     0        0         0     ]
             [                                           ]
        d := [   0      0    .01136      0         0     ]
             [                                           ]
             [   0      0       0    .0002933      0     ]
             [                                           ]
             [   0      0       0        0     .00001142 ]
```

This next command checks the accuracy of the result just computed, carrying 20 digits:

```
> evalf(evalm( (transpose(U) &* H5 &* V) - d), 20);
```

```
      [                                                                    ]
      [       -18            -19            -19            -19            -19    ]
      [ -.1*10         -.5*10         .4*10         -.2*10        -.3*10       ]
```

```
[                                                                    ]
[       -20            -19           -20            -20           -20    ]
[ -.9*10         -.1*10         .2*10          .4*10         .5*10       ]
[                                                                    ]
[         -19           -20                          -21            -20   ]
[ -.108*10        .61*10        0              .9*10        -.49*10      ]
[                                                                    ]
[           -19           -20           -20           -20            -20 ]
[ -.27040*10     -.3301*10      .6147*10      -.973*10      -.5038*10    ]
[                                                                    ]
[            -20            -20           -20            -20         -21 ]
[ -.395257*10    -.619981*10    .750459*10    -.182306*10    .7701*10    ]
[                                                                    ]
```

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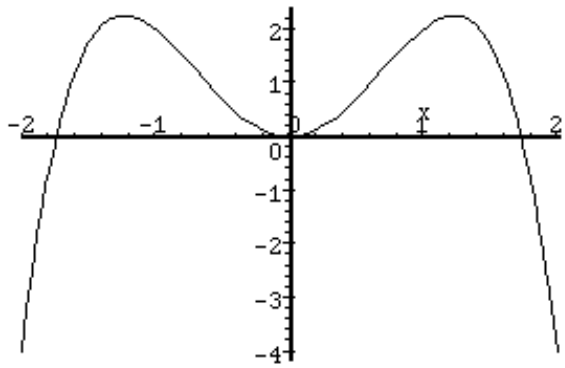
URL /~statmath/math/maple/linalg.html

Plotting with Maple

The plot Command

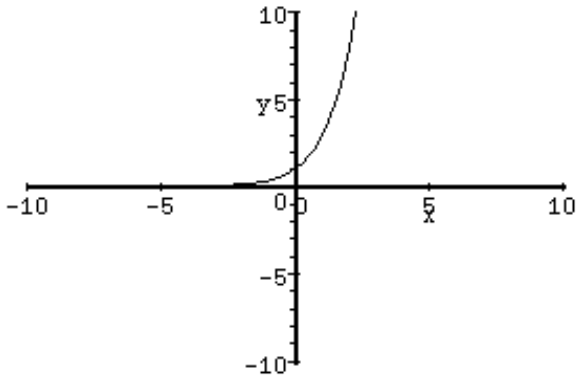
The basic plot command:

```
> plot( 3*x^2 - x^4, x = -2 .. 2 );
```



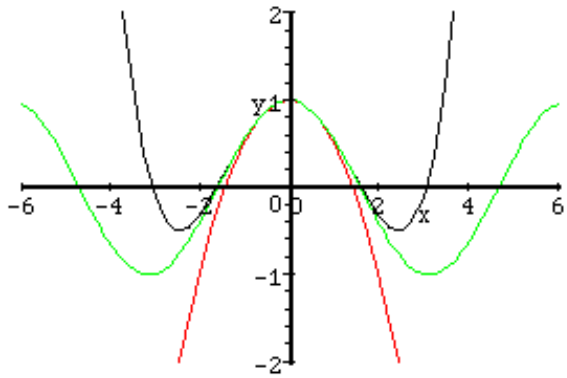
Add a restriction on the range:

```
> plot( exp(x), x=-10..10, y=-10..10);
```



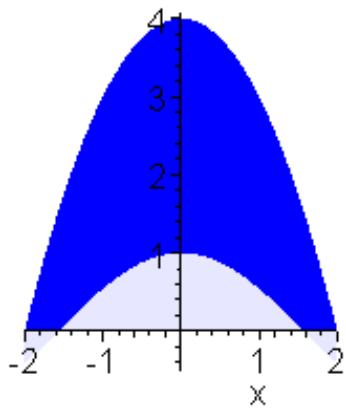
Plot several curves simultaneously:

```
> plot( {cos(x), 1 - x^2/2, 1 - x^2/2 + x^4/24}, x=-6..6, y=-2..2);
```



Fill areas in various colors (one custom, one standard):

```
> plot([cos(x),4-x^2], x=-2..2, filled=true, color=[COLOR(RGB,.9,.9,.99),
blue],scaling=constrained);
```



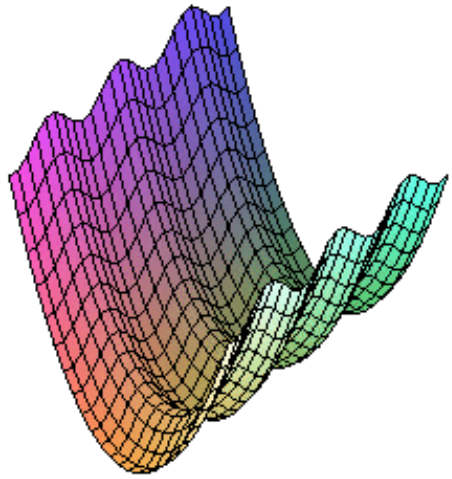
Fill a more complicated area:

```
> plot([min(max(sin(x),cos(x)),0), max(min(sin(x),cos(x)),0), sin(x),
cos(x)],
x=-8.75*Pi..11.25*Pi, filled=true, color=[white,white,red,red],
xtickmarks=[], scaling=constrained );
```

The `plot3d` Command

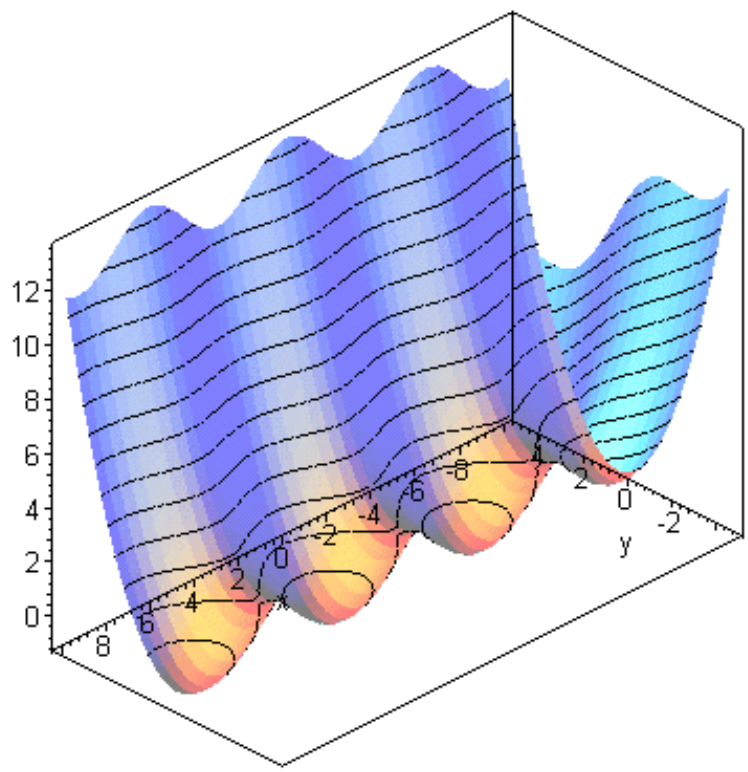
A basic 3D plot:

```
> plot3d( cos(x) + y^2/2, x=-10..10, y=-2..2);
```



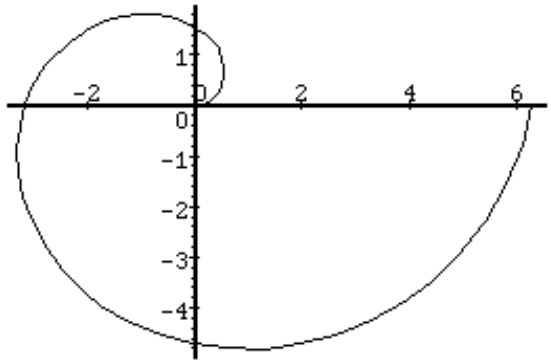
Add some options [most options can also be selected interactively, from menus]:

```
> plot3d( cos(x) + y^2/2, x=-10..10, y=-5..5,
scaling=constrained, style=patchcontour, axes=boxed,
orientation=[135,120], shading=none, lightmodel=light2, numpoints=2000);
```



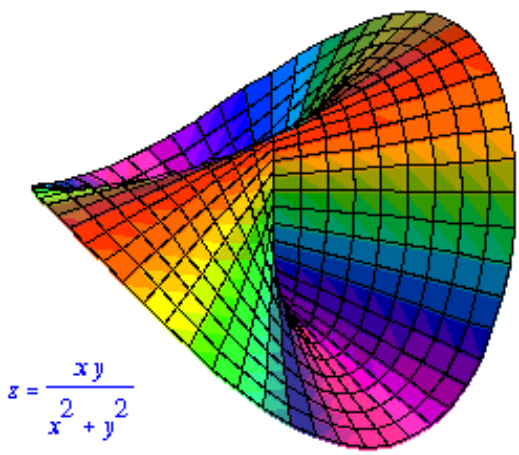
Plot a parametric curve in $\mathbf{R}^2$:

```
> plot( [ t*cos(t), t*sin(t), t = 0 .. 2*Pi ] );
```



and a parametric surface in $\mathbf{R}^3$:

```
> plot3d( [ r*cos(th), r*sin(th), cos(th)*sin(th) ],
r = 0 .. 1, th = 0 .. 2*Pi, grid = [10,60],
orientation=[100,25], shading=zhue, lightmodel=light2, style=patch);
z = x*y/(x^2 + y^2);
```



For more information on plot, plot3d, and their options, from the Maple Help menu do a Topic Search on plot. Select from any of approximately 100 related topics.

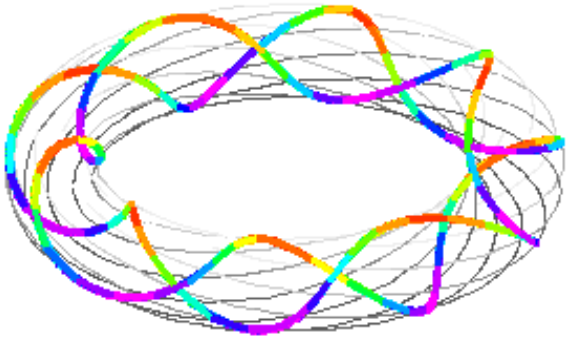
The `plots` Package

The "plots" package contains additional, more specialized plotting functions.

```
> with(plots):
```

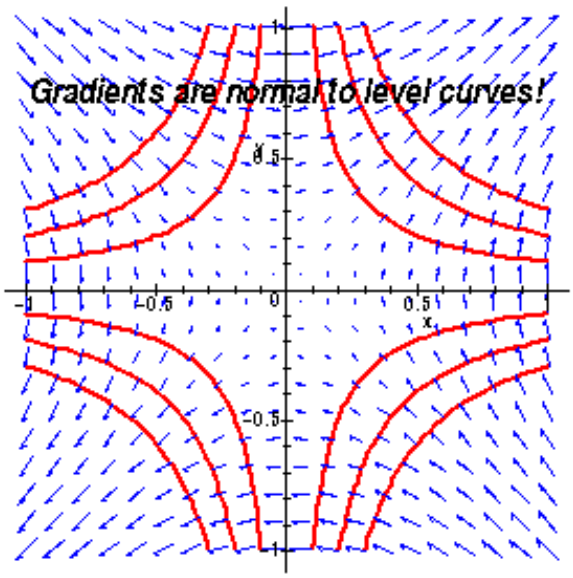
Plot parametric curves in 3D:

```
> plotopts:= t=0..20*Pi, orientation=[0,60], numpoints=1000,
scaling=constrained:
> p1:=spacecurve([cos(1.1*t)*(5+sin(t)),sin(1.1*t)*(5+sin(t)),cos(t)],
plotopts, shading=ZGREYSCALE, thickness=1):
> p2:=spacecurve([cos(2*t)*(5+sin(9*t)),sin(2*t)*(5+sin(9*t)),cos(9*t)],
plotopts, shading=zhue, thickness=3):
> display({p1,p2});
```



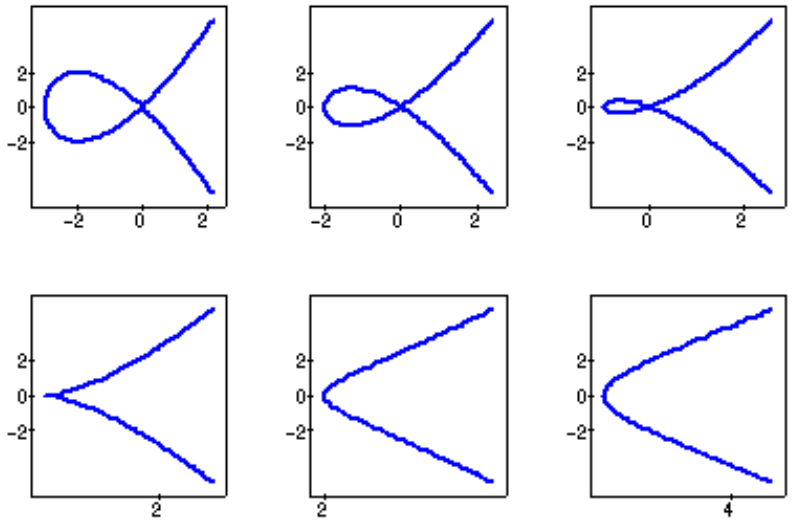
Display different types of plots, together:

```
> p1 := gradplot(x*y,x=-1..1,y=-1..1, color=blue):
> p2 := implicitplot( {x*y=.1, x*y=.2, x*y=.3, x*y=-.1, x*y=-.2, x*y=-.3},
x=-1..1, y=-1..1, color=red, thickness=2):
> p3 := textplot( [0, .75, `Gradients are normal to level curves!`],
font=[HELVETICA,BOLDOBLIQUE,14] );
> display({p1,p2,p3});
```



Some elliptic curves, plotted together:

```
> plotopts := x=-5..5, y=-5..5, numpoints=2500, color=blue, thickness=2,
axes=boxed, xtickmarks=[-2,0,2,4], ytickmarks=[-2,0,2]:
> for i to 7 do
q.i := implicitplot(y^2 = x^3 + (4-i)*x^2,plotopts):
od:
> B := array(1..2,1..3,[[q1,q2,q3],[q4,q6,q7]]): display(B);
```



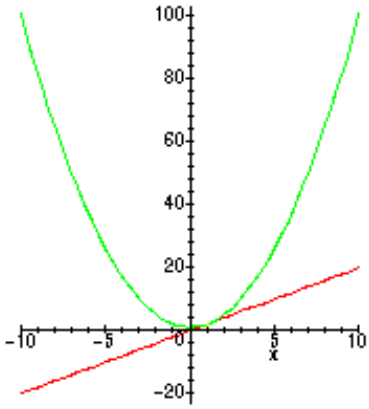
A fancy 3D plot, using the tubeplot command:

```
> f:= [(t-5*Pi)*sin(t)/3, (t-5*Pi)*cos(t)/3, (t-5*Pi)*.9, t=0 .. 5*Pi]:
> tubeplot(f, radius = (t-5*Pi)*.2,
tubepoints = 25, style=PATCH
lightmodel=light3, shading=zhue, orientation = [-75,90]);
```

This is one of many examples distributed with Maple.

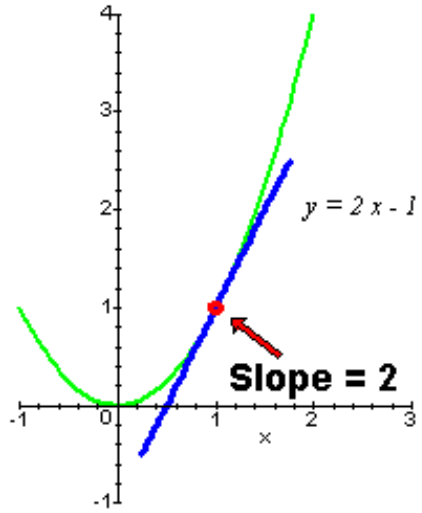
Often there is more than one way to approach a problem.

```
> with(student); > showtangent(x^2, x=1);
```




```
> with(plots): with(plottools):
```

```
> p1:=plot(x^2, x = -1..2, thickness=2, color=green):
p2:=plot(2*x-1, x = .25 .. 1.75, thickness=3, color=blue):
p3:=circle([1, 1], .05, color=red, thickness=3):
p4:=textplot( [2, .25, `Slope = 2`], font=[HELVETICA,BOLDOBLIQUE,14] ):
p5:=arrow([1.65,.5],[-.5,.4],.05,.2,.2, color=red):
# On PCs, go to ^^^^^^ [1.05,.9] #
p6:=textplot( [2.5, 2, `y = 2 x - 1`], view=[-1..3, -1..4],
font=[TIMES,ITALIC,10]):
> display({p1,p2,p3,p4,p5},scaling=constrained);
```



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Other Math Links

- **Discussion of Mathematical Computing**
  - Mathematical Software Guide
  - IMACS Conferences on Applications of Computer Algebra
  - Berkeley computer algebra papers(Richard Fateman *et.al.*)
  - Computer Algebra Performance (Heinz Kredel)
  - Review of CAS Mathematical Capabilities (Michael Wester)
  - Computer Algebra and Problem Solving Environments (Stanly Steinberg)
  - PSEware Project of the IU CS Department's Scientific Computing Group *et al*
  - Problem Solving Environments page at Purdue
  - Database of Existing Mechanized Reasoning Systems
- **General Archives**
  - CAIN (Computer Algebra Information Network)
  - INRIA Sophia Antipolis (SAFIR)
  - SymbolicNet at Kent State University
  - OpenMath Project
  - NAOMI - The North American OpenMath Initiative
  - Mathematics Archives
- **Commercial Vendors and Packages**
  - Waterloo Maple, Inc.(Maple)
    - IU Maple Page
  - The MathWorks (Matlab)
    - IU Matlab Page
  - Wolfram Research Inc. (Mathematica)
    - IU Mathematica Page
  - Key Curriculum Press (Geometer's SketchPad)

        - IU Geometer's SketchPad Page
    - MathTools (MIDEVA, MATCOM)
    - MathWare Inc. (Derive, GyroGraphics)
    - MathSoft Inc. (MathCad, S-Plus)
    - REDUCE
    - Magma
    - *f(z)*, "The Complex Variables Program for people who love mathematics."
    - Future Graph, Inc (*f(g)*) -- "integrating the functionality of a graphing calculator, a spreadsheet, and a drawing package."
    - Logic Software from CSLI
    - Software for Science - reseller of software
- **Shareware/Freeware Vendors and Packages**
    - Math Shareware Archive at Washington University
    - Downloadable Software from the Geometry Center.
    - CONTENT dynamical system software
    - Fermat - a CAS for polynomial and matrix computation, for Mac and PC.
    - FORM from the Dutch National Institute for Nuclear and High-Energy Physics
    - GAP - Groups, Algorithms and Programming - system for computational discrete algebra
    - Groups and Graphs, a software package for graphs, digraphs, combinatorial designs, and their automorphism groups.
    - NTL C++ number theory library
    - SAML Simple Algebraic Math Library in C (Thierry Bousch, Université Paris-Sud)
    - Solutions
- **Other Resources**
    - Mathematics page of the WWW Virtual Library at Florida State
    - Mathematics Software section of the Big List of Mathematics Information Servers at Penn State

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- UNIX - The absolute least you need to know
  - Accounts
  - Choosing a machine
  - Logging in and Logging out
  - Learning More About UNIX
- Using the Math Software
- Using graphics over the network
- Using batch processing
- Further Reading

UNIX - The absolute least you need to know

UNIX is an operating system (like Windows, DOS, or Macintosh System 8) that is designed for very large computers. More than one person (in fact, ususally hundreds!) can use a UNIX machine at the same time.

Accounts

Every person who uses a shared computer has an *account*. An account means that you have a place to put files (your "home directory"), permission to use the machine (to "log in"), and a way to identify yourself (your "username"). For example, the Shakespeare email system at IUB is a UNIX system.

You will need an account on one of the following systems: DaVinci, Ships, Nations, the SP (formerly STARRS), Cobalt, or Steel to use this guide. If you don't have one, you may get one from The UITS Accounts System. Or, if you have your own UNIX machine (such as a Sun, Linux, FreeBSD, etc) and you have a copy of the math software, you may use your own machine.

Choosing a machine

As of now (August 1999), if you want to run math software on a large computer at IUB, you have the option of using the SP System, Cobalt, or Steel.
If you just want to run math software under UNIX, you could also use the DaVinci, Ships, or Nations cluster, or your own machine.

You must be faculty (or have a faculty sponsor) to get an account on the SP, since it is a research-only system. In addition, the SP is really only designed for batch processing (which we discuss in the Batch Processing section), and logging in is a little complex. More information on the SP is availible here.

Steel is open to all IUB faculty and students, as well as some members of the IUPUI community. Its is a "general purpose" system; in other words, you aren't required to do batch processing. If you'd like to know Steel's specifications, you can find it here.

The DaVinci cluster is a cluster of SGI O^2 workstations located in FA 215. While not designed for heavy computational use, you can still use the DaVinci cluster to get a feel for using Mathematica under UNIX. To connect to any DaVinci machine, telnet to `davinci.ucs.indiana.edu.` All IUB faculty, staff and students may apply for an account on the DaVinci cluster.

To simplify this document, we assume you will be using Steel unless otherwise noted.

Keep in mind that you will be running the math software on the machine you connect to, *not* the machine you are sitting at.

Logging in

Since you are (presumably) not in the same physical room as Steel, you will need to log on using Telnet. The address is
`steel.ucs.indiana.edu` .

- From a UITS NT cluster, go to Start Menu -> Programs -> Communications -> Other WCC Computers -> Steel.
- From a UITS Mac cluster, go to Apple Menu ->Telnet->Steel.

Enter your username and password. If this is your first time logging in, you may be presented with some information about the system. You should eventually see the UNIX prompt, which should be a $ or a %.

Learning more about UNIX

At this point, you should have a UNIX prompt in front of you. This is really all you need to get the basic functionality of the math software.

However, your UNIX experience will be much more satisfactory if you follow an in-depth tutorial. We recommend:

- Research Computing at IU: The Basics. A comprehensive guide to using research computers at IU. It is IU-specific, but not campus specific.
- UnixTools.com. A good web directory of UNIX help. Includes history, flavor-specific help, and tutorials.

Previous: Introduction
Next: Starting the Math Software

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Starting the Math Software

Modes of Use

Before you use the math software, you should be aware of the different ways of using it. On a desktop computer, it is only possible to use it in a fully interactive setting. On UNIX, it may be preferable to use it in a different way.
There are three ways of running most software under UNIX:

- Interactive mode. You type in input directly, and output is displayed on your screen. The interface may be a full window with pretty graphics, or it could be a terminal-based system.
- Non-interactive mode. Over a terminal, you can put all of your input into one file, then have the software process the commands and save the output to a file. You can be doing other tasks while it runs. Graphics output is limited to saving plots as images.
- Batch mode. You create an input file as for non-interactive mode, but you also create a "job script", which tells the system software to execute the math software (with your input) at a later

time. Jobs are queued, so you may have to wait a while for your results. Batch jobs allow you access to more memory and processor power than the other modes, so it is best for extensive number crunching.

At IU, most batch jobs should be done on the SP system. We'll discuss batch mode later, in the Batch Processing Section. In addition, we'll discuss only terminal-based modes here, and we'll cover interactive graphics later, in the X Windows Section.

Maple

Interactive Mode
To start maple, just type `maple` at the UNIX prompt. Maple will start, and you will see the familiar ">" Maple prompt.
To leave Maple, type `quit;` at the Maple prompt.
All of the standard packages are available, and you should find that Maple behaves just like it does on your desktop.

Non-interactive Mode
You can load plain text files with maple commands (one per line, ending in a semicolon - the usual). Be sure the last command is `quit;`. Then type at the UNIX prompt:

```
maple filename > results.txt
```

This will return you to the UNIX prompt while Maple executes the commands in `filename` and saves the results in `results.txt` .
To learn more about Maple's file input and output abilities, run Maple interactively and type the following:

```
?writeto
?echo
?save
?read
?interface
```

Matlab

Interactive Mode
To start Matlab, type `matlab`. Matlab will start, and you will see the familiar ">>" prompt.
Type `quit` at the Matlab prompt to exit.
IUB has licenses to most of the Matlab toolboxes. Use them as you would at your desktop. Be forewarned that most graphics functions simply won't do anything if your terminal doesn't support graphics. Matlab always looks for m-files in the directory from which it started (as well as the standard library locations).

Non-interactive Mode
Put all of your commands in a plain text file as if you had typed them into Matlab. Be sure the last command is `quit`. Then type

```
matlab < filename > results.txt &
```

This runs Matlab, executes the commands in `filename` and saves the results to `results.txt` , while you are returned to the UNIX prompt.
To load and save Matlab variables, type the following at the Matlab prompt:

```
help load
help save
help diary
```

Mathematica

Interactive Mode
To start Mathematica, type `math`. You should see the familiar Mathematica prompt, "In[1]=". To exit Mathematica, type `Quit`.

This actually starts the Mathematica Kernel and lets you type directly into it. There is no terminal-based front-end, since the kernel itself can function in this manner. However, you will have primitive graphics or plotting capabilities (but you will not have the ability to export to an image file).

Non-interactive Mode
Save all your commands, one per line, in a file. Be sure the last command is `Quit`. Then type

```
math < filename > results.txt &
```

This runs Mathematica, executes the commands in `filename` and saves the results to `results.txt` , while you are returned to the UNIX prompt.

For more information on saving and loading work, type at the Mathematica prompt:

```
?Save
?>>
?<<
```

Previous: UNIX - the least you need to know
Next: Using Graphics over the Network

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  - Postscript, VRML, and GIF output
  - X Windows
  - Mathlink
- Using batch processing
- Further Reading

Using Graphics Over the Network

Advice on graphics

The goal of this section is to help you use the graphics features of the math packages. There is no perfect way of doing this. Before you attempt any method other than typewriter graphics, you should ask yourself if you really need graphics output from your UNIX session. UNIX machines are designed to crunch a lot of numbers quickly, but they are *not* designed to draw pretty pictures. Desktop versions of the math software *are* designed to draw pretty pictures.

One good way out of this is to use the UNIX machine to do all the hard work, save the results in a file, transfer the file to your desktop machine, and then use your desktop package to visualize and interpret the results.

This area of this document is still changing as we perfect the methods. If you have any problems, suggestions, etc. with the techniques used here, please post to iu.statmath, or email statmath@indiana.edu.

Typewriter Graphics

Typewriter graphics is the default behavior for all three packages (but if you are running an X-server and you have set the DISPLAY variable, all three default to X graphical output.). Typewriter graphics simply means that the program will try to draw a picture using ASCII characters. While not pretty (or accurate, for that matter), typewriter graphics are good for drawing formulae with a bit more clarity than straight text.

Postscript, VRML, and GIF Output

All three major math packages offer graphics output to other file formats. This may be your best graphics option if you plan to publish your results on the web, use graphics in other applications (such as word processors), or if you are doing batch processing. All three packages will place output files in the current directory if a full path is not given, so make sure that you have write permission on the current directory. After you are done, you will need to retrieve your files using FTP.

Maple

Maple provides good export capability. See
`?plottools,vrml` - export 2d or 3d graphics to vrml
`?plot,device` - export to gif, jpeg, Postscript, and other formats.
`?plot,device,ps` - options for Postscript output.
`?plotsetup` - output options - especially see section on `plotoutput` variable.

Matlab

Matlab provides extensive export capability. Type the following in Matlab for more information:
`help vrml` -export a graphics object to VRML 2.0
`help imwrite` -write out a graphics object to a wide variety of formats
`help saveas` -save a graphics object to Postscript
`help print` -save a graphics object to Postscript

Mathematica

Graphics output requires the use of a front-end. Since the only front-end availible for UNIX is the X-windows client, this method is less useful (since you would already have graphics capability directly

from within Mathematica). However, you can still redirect output to other file formats. You can use the following command to redirect plot output to a GIF file.

```
    Plot3d[[Sin[x y],{x,0,4},{y,0,4}, DisplayFunction->
Function[Display["foo.gif",#,"GIF"]]
```

You use this option with all plot, play, and show commands. Be sure that your current working directory is something reasonable, since that is where the file will end up. You may also use a full path for the filename. Read about other file formats by using the Mathematica help browser, under "Built-in Functions": Graphics and Sound -> Graphics Exporting -> Display.

X Windows

X Windows is a distributed Graphical User Interface (GUI) environment. In other words, you can run a program on a UNIX machine, but have the window appear on your local machine. This gives you the full functionality of using the graphical interface, while still having the power of a large UNIX computer. The program you are running is called an X-windows *client*. You local machine must be able to interpret and display the windowing commands that your client sends - in other words, your local machine must act as an X-windows *server*. Most Solaris, Linux, and IRIX (SGI) workstations are capable of acting in this manner directly. For Mac and Windows users, you must run a seperate program that will provide this capability. Please note that using X-windows requires a fast network connection, so using this option over a dial-up line is not recommended.

- For Mac users, you will have to install a third-party X-windows server (this is different from the Mac OS X Unix Server). UITS does not support or endorse the use of these programs in the public clusters (STCs). However, you may purchase, install, and use these programs on your own Mac. MI/X is a free X-server for the Mac. UITS provides this link as a service to customers and in no way endorses or supports this product.
- For Windows (3.x, 9x, and NT) users, you will have to install a third party X-windows server. UITS does not support or endorse the use of these programs in the public clusters (STCs). However, you may purchase, install, and use these programs on your own PC. Popular X-windows servers include X-WinPro , Exceed, and MI/X (free). UITS provides these links as a service to customers and in no way endorses or supports these products.
- For UNIX workstation users, the Ships and DaVinci machines have X already installed.

To use math software as an X-windows client, follow these steps.

1. Setup the X-windows server on your local machine.
    - If you are using a UNIX local machine, you will have to give the client machine permission to connect to your X-server. Do this by issuing the command `xhost +steel.ucs.indiana.edu`
    - PC and Mac users should start their X-server software. Refer to the documentation of the software.
2. Connect to the remote machine using telnet.

3. You need to tell the remote machine where you are. To do this, you must set the DISPLAY environment variable to your local hostname.
    - Find out what shell you use by typing `echo $SHELL`
    - If you use csh, type `setenv DISPLAY hostname:0`
    - If you use bash, type `DISPLAY=hostname:0;export DISPLAY`
4. Start the X-client version of the math software from your telnet session.
    - Maple - issue the command `xmaple &`
    - Matlab - issue the command `matlab`. If your X-server is setup properly, you should be able to enter matlab commands in the telnet window, but have graphics displayed in a "pretty" new window. Type `demo` to try this out.
    - Mathematica - issue the command `mathematica &`. You may see errors about fonts. If so, follow these instructions.
5. Do your work, and exit from the math software.
6. Un-setup your X-server
    - For UNIX machines, make sure you issue the command `xhost -steel.ucs.indiana.edu` after you are done.
    - For PC and Mac users, consult your X-server's documentation.

Please note that using the X-windows system may open security holes on your system (more info). More information on the X-windows system may be found at www.x11.org.

Mathlink

Note: This information applies to the Mac edition of Mathematica 4.0.

Mathlink is a feature of Mathematica. Users familiar with Mathematica will recall that it is made up of two parts:

- The Kernel - does all processing, manages variables, and loads packages
- The Front-end - does all graphics work, input, and output.

Mathlink is a proprietary protocol that allows the kernel and front-end to run on seperate machines. (It also allows compiled programs to access a remote kernel - but that topic is well outside the scope of this document). To use Mathlink, do the following steps:

- Go to the Kernel menu and select Kernel Configuration Options,
- Select Kernels and Tasks,
- Click the Add button to add a new kernel
- Assign the new kernel a name. For example, if using Mathematica on DaVinci, you may want to use DaVinci as the name of the new kernel.
- Under Basic Options, click on Remote Machine.
- Click the Connections button and under Connection Settings Method, select VersaTerm Telnet

Tool.

- In the Host TCP/IP Address box, type in either the hostname or IP address of the remote host and click OK.
- If connecting to a Unix system, click on the Terminal button and select VT102 under Terminal Settings Emulation. You may also customize your keyboard mapping here.
- Note, by default Mathematica looks for the > symbol before launching the program on a remote system. If the default prompt on the remote system is not >, then you must either change the default prompt or the start up option in the new kernel settings. To change the prompt locally, click on Advance Options and in the Communications Toolbox Login box, change the > to whatever the last character in your login prompt is. For example, if you were accessing Mathematica on a Unix system with the default prompt for Korn shell, you would change > to **$**.
- Once all the settings are correct, click OK twice.
- In the Kernel menu, choose Notebooks Kernel and select the Connection from the list of available kernels.
- Again from the Kernel menu, choose Start Kernel and select the Connection from the list of available kernels.

You will then be asked to supply a username and password for the remote system.

Previous: Starting the Math Software
Next: Using Batch Processing

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URL `/~statmath/math/all/mathunix/graphics.html`

- Introduction
- UNIX - The absolute least you need to know
- Using the Math Software
- Using graphics over the network
- Using batch processing
  - Using the SP
  - Preparing to batch process
  - Writing LoadLeveler scripts
- Further Reading

Using Batch Processing

Using the SP

Batch processing is an extremely powerful way to do computationally-intensive work. The main system for doing batch processing at IU (for research purposes) is the IBM RS/6000 Scalable POWERParallel System, known as the Research SP System.

The Research SP System is made up of several different nodes. Matlab, Maple and Mathematica are available on aries09. The first time you log in to the SP, log into `libra.ucs.indiana.edu`. Libra manages the SP's password records, and will initialize your account on all the nodes. Then you may telnet or SSH to `aries09.ucs.indiana.edu`. If you're doing batch processing, you can log into any node and (assuming you follow the instructions) the job will execute on the right node.

Please note that the SP is intended for use only as a batch processing system. All processes that accumulate more than 20 minutes of CPU time in an interactive (non-batch) setting will be terminated.

Preparing to batch process

If this is your first time batch processing, we recommend you first attempt a "smaller" version of your task. Don't try to solve your research problem on the first attempt.

Create a text file that has the exact command you which to run. This file will be fed into your math package as if you typed it in. In other words, each line in the text file should be the exact same thing as what you would type at the Maple, Matlab, or Mathematica prompt. You are free to have your text file load other files or worksheets, but be sure to use the *full path* when specifying filenames. You can find out the full path by typing `pwd` . This tells you the "present working directory". For example, if you want to load a file in your home directory named "work.mws", you should give the filename as "/N/u/john_smith/work.mws". The same goes for all output commands.

Remember, you won't be able to interact with the math software while it is running. This means you need to save the results of your work in some way. You should probably use the math package's built-in save function. For graphical output, we recommend outputting to a file format such as VRML, GIF, or JPEG.

Also, you *must* test your plain text file before executing it on the SP. We recommend testing it on Steel. If you saved your text file as "foo.txt", you can test it using the command `maple < foo.txt > foo.out` (or matlab, or math). This feeds foo.txt to Maple one line at a time, and any output that would normally go to the screen is redirected to a new file called foo.out. Make sure that your list of commands does exactly what you think it will.

After you have perfected your math package command script, you are ready to batch proccess it.

Writing a LoadLeveler Script

The SP uses a program called LoadLeveller to do batch processing. You wrap up all the commands neccesary to do your job in a file called a LoadLeveller Script.
A good tutorial on using LoadLeveller is The UITS Research SP System - Submitting Batch Jobs to the LoadLeveler .
Sample scripts can be found in the `/N/u/statmath/SP/scripts` directory on the SP.

Previous: Using Graphics over the Network
Next: Further Reading

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- Further Reading

Further Reading

For general questions, including questions about various platforms and their terminal and X window software, call the UITS Support Center at 855-6789, or use the WWW to browse the UITS Knowledge Base.

More information on the X Window System is available from the Unix System Support Group. If you have questions about statistical or mathematical software, call the UITS Stat/Math Center at 855-4724, or send e-mail to statmath@indiana.edu.

Previous: Batch Processing
Up: Introduction

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How to Search | Advanced Search

Searching tips:

- Use more than one word
- Use only important words

Good examples:

- `norton antivirus scan disk`
- `microsoft exchange forward e-mail`
- `locate e-mail address`

Bad examples:

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- `how do I locate my cousin's e-mail address at Cornell?` (too specific; too many words)
- `analysis of social change` (not related to computing or Indiana University)

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- Menus: A selection of popular Knowledge Base documents organized by topic; a good starting place
- Glossary: An alphabetical list of Knowledge Base documents that define common computing terms

---

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Getting Started With MATLAB

Revised by Clinton Wolfe (June 1999)
Original by David Hart

Printer-friendly version: Adobe PDF, 307 KB (Get Acrobat Reader 4.0)

- Introduction
  - What is Matlab?
  - How to use this tutorial
  - Where to find Matlab
  - How to start and exit Matlab
- Finding your way around the window
- Matlab Syntax
- More on Matrices
- Graphics
- Programming
- Further Reading

What is Matlab?

MATLAB is a computer program for people doing numerical computation, especially linear algebra (matrices). It began as a "MATrix LABoratory" program, intended to provide interactive access to the libraries Linpack and Eispack. It has since grown well beyond these libraries, to become a powerful tool for visualization, programming, research, engineering, and communication.

Matlab's strengths include cutting-edge algorithms, enormous data handling abilities, and powerful programming tools. Matlab is not designed for symbolic computation, but it makes up for this weakness by allowing the user to directly link to Maple. The interface is mostly text-based, which may be disconcerting for some users.

Matlab is packaged as a core program with several "toolboxes", sold seperately. We will only cover the core package. The current (June 1999) version is Matlab 5.3 release 11.

How to use this document

This document is intended to be used while sitting at a computer running either NT or the X windows system. It is assumed that you will enter the commands shown, and then think about the result.

The reader of this document should have at least a passing familiarity with linear algebra and be comfortable using computers. In order to be more broadly understood, we will not cover any engineering topics (e.g. signal processing, spectral analysis), though Matlab is commonly used for these tasks. No previous math software experience is necessary, though we will point out important differences between the various packages along the way.

If you are using Matlab over a text-based terminal (such as Telnet or SSH), you might want to follow the Using Math Software under UNIX tutorial after you are finished with this one.

Throughout this document, we will use the following conventions.

Example	Explanation
File -> Open	Choose the file menu, and select Open.
`a = 5`	Input to be typed at the Matlab prompt.
`a =` `5`	Output from Matlab.
TIP	An important tip.

Where to find Matlab

MATLAB is available for many different kinds of computers at Indiana University Bloomington.

- All Windows NT Student Technology Centers

- Ships, Nations, and DaVinci UNIX clusters
- Several of the large timesharing systems - see the availability chart for details.

A student edition is available from local bookstores for your personal Windows, Macintosh, and Linux systems.

How to Start and Exit Matlab

To start Matlab:

- On windows NT, choose Start Menu ->Programs->Statistics-Math->Matlab.
- On Ships, Nations, Davinci, and all timesharing systems, type `matlab` to run it interactively. Note that plots will be displayed in an X-window, if you have set the DISPLAY variable. You may also type `matlab -display hostname:0`.

Note that Matlab typically takes 10-15 seconds to load.
Eventually, you should see:

```
To get started, type one of these: helpwin, helpdesk, or demo.
For product information, type tour or visit www.mathworks.com.
      >>
```

The line >> is the Matlab prompt.
To exit Matlab, type (at the matlab prompt) `quit` or choose File->Exit MATLAB.

Next: Finding your way around the window

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Mathematica

- Information
  - Overview of Mathematica
  - Availability - where to find Mathematica
  - Sales - how to buy Mathematica
  - Licensing Mathematica
- Support
  - Local Resources
    - Getting Started with Mathematica
    - Using Math Software under UNIX
  - Web Resources
    - Mathematica Links
- See Also
  - Math Sites

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What is Unix?

Unix is a powerful multi-user environment designed primarily for servers and advanced users. It has a steeper learning curve than other operating systems, such as Windows or Mac OS, but offers superb flexibility and stability. Though inexperienced users sometimes find its complexity daunting, Unix is very popular, and in recent years it has become more accessible.

Unix was developed at Bell Labs in 1969, but in the past three decades many others have contributed to its evolution. In reality, Unix is not so much a single operating system as it is a standard upon which organizations and companies base their own systems. Examples of Unix implementations include AIX (IBM), Solaris (Sun Microsystems), IRIX (SGI), BSD/OS (BSDi), and Linux (GNU). To the casual user, these different systems are very similar because they all provide a common interface through the Unix shell.

As with other operating systems, there are many kinds of applications available on a Unix system. E-mail, newsreading, programming, statistics, and graphics are some of the areas for which Unix software exists. Unix was once distinct from other operating systems because of its high level of integration with the network and its multi-user environment. Each user who logs in can have an environment distinct from any other user. In recent years, however, this distinction has blurred as other operating systems have developed these capacities. With the increasing popularity of free Unix systems like Linux and FreeBSD, as well as the advanced graphical user interface the X Window system offers, more individuals are also using Unix as the operating system for their personal workstations.

Related online NETg tutorials (IU only)

Unix Fundamentals

If you haven't used NETg before, see the Knowledge Base document What do I need to know about accessing NETg from the Knowledge Base?

Also see:

- Introduction to Unix commands
- What books are available for Unix and where can I find them?
- In Unix, what is the man command, and how do I use it to read manual pages?
- What are some equivalent commands in the electronic mail programs Berkeley mail, Pine, and Elm?
- Where can I learn about the history of Unix?
- In Unix, what do some obscurely named commands stand for?
- For Unix, where can I find an online tutorial?
- What does Unix stand for?

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What is UITS?

University Information Technology Services (UITS) at Indiana University, with offices on the Bloomington and Indianapolis campuses, is responsible for the continued development of a modern information technology environment throughout the university in support of IU's vision for excellence in research, teaching, outreach, and lifelong learning.

The information technology environment at IU includes tools and services that support the academic and administrative work of the university. Computing tools include a variety of timesharing computers; hundreds of public-access, Internet-connected, fully equipped workstations; and a number of supercomputers. A high-speed network links these resources.

The four divisions of UITS (Teaching and Learning Information Technologies, Telecommunications, University Information Systems, and Research and Academic Computing) and the Advanced Information Technology Laboratory work together to support IU in its use of information technology. UITS reports to the Office of the Vice President for Information Technology.

For a complete listing of UITS services, see the UITS Services Directory (a `.pdf` file) at:

`http://www.indiana.edu/%7Eocmhp/092801/text/UITSdirectory.pdf`

Visit the UITS home page at:

`http://www.indiana.edu/~uits/`

This information came from the Office of the Vice President for Information Technology.

Also see:

- What is the policy for making copies of UITS publications?
- Where can I find information about jobs with Indiana University's UITS (University Information

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- UITS Directory: Some important phone numbers and addresses

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What is the X Window System?

The X Window System, often known as X, is a windowing system for graphics workstations developed at MIT with support from DEC. It is based on a client/server model: a networked computer or workstation runs an X server, and client programs running on connected workstations request services from the server. The server handles input and output devices and generates the graphical displays used by the clients.

Like many popular graphical user interfaces, the X Window System displays information and applications in rectangular windows arrayed on a desktop-style screen, known as the root window. Windows can be resized, moved, and otherwise manipulated with a mouse. The use of multiple windows lets you perform tasks concurrently in ways that are cumbersome or impossible in text-only displays. For example, in a particular X session, you could have several windows open at the same time containing login sessions to different computers, an editor, a paint program, and a mathematical application, and be able to cut and paste information between the windows.

For more information about X, visit X.Org's Web page at:

`http://www.X.org/`

X.Org is part of the Open Group and is responsible for managing development of the X Window System.

On many Unix computers, X user applications are in the `/usr/bin/X11/` directory, but in Solaris, they are in `/usr/openwin/bin`, while in most Linux distributions, they are in `/usr/bin`.

X server programs exist for many platforms, including all modern Unix implementations (e.g., Solaris, Linux, AIX, IRIX, FreeBSD), as well as Mac OS, Mac OS X, Windows, and even VMS.

Also see:

- In the X Window System, what is a window manager, and how do I find out which ones are available?

- Why does my X Window System application fail with the message "Cannot open display"?
- Do you have an introduction to installing and using the X Window System?
- For the X Window system, what programs can I use to view graphics?

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Where do I get PCF versions of the *Mathematica* fonts?

In the most recent releases of *Mathematica* 3.0 and 4.0, the PCF fonts are available directly from the CD in the following directory (mounted as a Unix volume).

`/cdrom/Unix/Files/SystemFiles/Fonts/PCF`

The files cannot be copied from the CD on Windows because the `pcf` file extension will be removed.

If you do not have these fonts on your CD (from using the initial *Mathematica* 3.0 release), you can download the PCF version of the fonts from the following URL's.

http://support.wolfram.com/mathematica/systems/unix/interface/PCF.tar.Z
http://support.wolfram.com/mathematica/systems/unix/interface/PCF.zip

The compressed tar archive is intended for Unix systems; the zip archive is intended for Windows and Macintosh systems.

Extracting these archives creates a directory `PCF`.

Last modified January 18, 2000.

Questions or comments about this FAQ? Send email to support@wolfram.com.

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What is Steel?

Steel is a cluster of four Sun UltraSPARC workstations running Solaris 2.8. Each workstation is equipped with dual 200MHz processors and 1GB of memory. Though there are four computers in the cluster, if you have a Steel account, you access it via SSH or SFTP through a single address: `steel.ucs.indiana.edu`. User files are stored on the NFS system.

In addition to the four UltraSPARCs, the Steel cluster has a silent partner, an applications server named Forge. While the front end Steels provide CPU cycles to users, Forge provides the mettle that makes Steel a viable system. As a user, you do not log into Forge, but rather access the software, licenses, databases, etc., which are served from Forge. By having a single applications server, you are assured of seeing a consistent suite of products and services on Steel.

Forge is a Sun E3500 server running Solaris 2.8, configured with:

- Four 400MHz UltraSPARC-II processors
- 4GB memory
- 10/100Mb Ethernet and Gigabit Ethernet
- 4mm tape drive
- Sun A1000 disk array with 80GB RAID disk

Steel's primary purpose is to provide an interactive environment for general purpose Unix computing. It is also the location for editing personal Web pages served by Php. While research computing tools are available, instructional and general-purpose computing takes precedence. CPU-intensive batch jobs should be run on dedicated research systems, such as the Research SP.

You can find more information about what software is available on Steel at:

`http://www.indiana.edu/~rats/research/steel/software.shtml`

All IU students, staff, and faculty may have accounts on Steel. To create one, point your Web browser (which must support secure authentication) to the Network ID Services page:

`https://iuaccts.ucs.indiana.edu/`

At IUPUI, to add Steel privileges to your Network ID, point your Web browser to the Network ID Web page at:

`https://iupui-accts.iupui.edu/`

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What are the Ships?

The Ships are a cluster of SGI workstations located in Student Building 230 at IU Bloomington. The Ships machines are equipped with CD-ROM drives.

Students, faculty, and staff may create accounts on the Ships cluster by visiting the Network ID Services page at:

`https://iuaccts.ucs.indiana.edu/`

You will not be able to use the workstations in Student Building 230 until you have created a Ships account.

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What is the Nations cluster?

The Nations cluster, presently located in Geology 226, originally opened in Student Building 231 in October 1996.

This site consists of 21 Sun Ultra 10 workstations. Each workstation is equipped with 256MB of RAM, a CD-ROM drive, a floppy disk drive, a 9GB hard drive, and 24-bit color graphics on a 21" monitor. The site also has an HP LaserJet 8000 for PostScript printing.

Primarily a development site, the Nations cluster offers C, C++, Pascal, Fortran 77 and 90, and the Java Development Kit.

Other available software includes a suite of Stat/Math and GIS software and a wide variety of public domain packages. Netscape Navigator 4.7 is the standard Web browser.

Note: As with the other Unix systems in the Student Technology Centers, you will need to obtain an account on these computers in order to use them. You need to get a Nations account to use this facility even if you had an account on the old Nations cluster. To request an account, visit the Network ID Services page at:

`https://iuaccts.ucs.indiana.edu/`

Also see:

- Descriptions of available accounts at Indiana University Bloomington

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What is the da Vinci cluster in Fine Arts 215, and how do I get an account?

The da Vinci Student Technology Center (STC) in FA 215, available to all IUB students, faculty, and staff, provides high-end visual arts computing tools on Mac OS and SGI computers. To use the da Vinci SGIs, you must first create a da Vinci account through Network ID Services at:

`https://iuaccts.ucs.indiana.edu/`

You do not need a da Vinci account to use the Mac OS computers in the da Vinci STC.

For more information on what is available in the da Vinci lab, see the Student Technology Centers Web page about FA 215 at:

`http://stcweb.uits.indiana.edu/apps/public/labs.cfm?lab_id=173`

For information regarding policies governing the STCs, see:

`http://stcweb.uits.indiana.edu/apps/public/policylist.cfm`

Also see:

- Where can I find information about Silicon Graphics (SGI) systems and software?

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What is the Research SP system?

The Research SP cluster is dedicated to the research needs of IU Bloomington and IUPUI faculty, staff, and graduate students. Over 600 researchers from over 60 departments on the IUB and IUPUI campuses currently have accounts on the Research SP. Graduate students and staff who would like to have an account on the Research SP must have a faculty sponsor.

The Research SP currently consists of 11 frames containing a 2-CPU 332MHz PowerPC (aka Silver) thin node, a 2-CPU 375MHz Power3+ wide node, 126 4-CPU 375MHz Power3+ thin (aka Winterhawk2) nodes, four 16-CPU 375MHz Power3+ high (aka Nighthawk2) nodes, and a 16-cpu 1.3GHz Power4 node, for a total of 144 nodes and 632 processors. The Research SP's theoretical peak capacity is about 1 trillion floating point operations per second.

Operating system and networking

Each node on the Research SP runs its own copy of IBM's flavor of Unix, AIX. Additional IBM software, PSSP (Parallel System Support Program), allows the nodes to function as one system, facilitating their use, administration, and maintenance. All nodes are interconnected with the Research SP high-speed switch.

This crossbar switch provides four paths between any pair of nodes at 150MB/second peak bandwidth, an aggregate bandwidth of 1.2GB/second, and an application latency of less than 40 microseconds transfer; it supports both IP protocol and the proprietary US (user space) protocol developed by IBM.

An externally connected specialized router allows the Research SP switch network to connect to the other Research SP switch, 10/100Mb Ethernet, Gigabit Ethernet, FDDI, HIPPI, or ATM networks. The Research SP's routers connect to the HPSS Research SP switch network, as well as to the 10/100Mb Ethernet and Gigabit Ethernet networks within Wrubel Computing Center.

Accessing the Research SP

All Research SP nodes are accessible via SSH. The hostnames are `aries01-127.ucs.indiana.edu` and `orion01-09.ucs.indiana.edu` . The aries nodes are called the Aries Complex and the orion nodes are called the Orion Complex.

Software and programming tools

IBM compilers, commercial stat/math products, and several public domain software packages are available on the Research SP.

Several IBM software products designed to use the Research SP switch for message transfer are available on all Research SP nodes. These products include Parallel ESSL, High-Performance Fortran, Distributed Debugger, and Parallel Environment. In addition, these products offer tools for compiling, running, monitoring, profiling, tuning, and debugging parallel programs.

The Research SP nodes process batch jobs via the LoadLeveler load balancing, batch queuing system. You may submit both serial and parallel jobs to the Research SP nodes. UITS discourages interactive use of Research SP nodes, and strictly enforces a limit of 20 minutes of elapsed CPU time per interactive process.

History

The Research SP began in July of 1996, when UITS (then University Computing Services) acquired an IBM SP for research computing. The original 24-node system was expanded to 47 nodes in September of 1998, and was expanded again to 71 research nodes in December of 1999. In subsequent expansions (the latest in January 2002), the Research SP has grown to its present configuration.

For more information on the Research SP, see:

`http://sp-www.iu.edu/`

Also see:

- What are CISC and RISC technologies, and how do they compare?
- What is superscalar architecture?
- At Indiana University, where can I find high performance computing documentation online?

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What is telnet?

Telnet is a protocol that allows you to connect to remote computers (called hosts) over a TCP/IP network (such as the Internet). There is a telnet server on the remote host, which the telnet client negotiates with to establish a connection. Once connected, the client becomes a virtual terminal, and allows you to interface with the host computer from your computer. In most cases, you'll be asked to log into the remote system. This usually requires an account on that host. Occasionally you can log in as `guest` or `public` without having an account.

There are telnet clients available for all major operating systems.

Command-line telnet clients are built into most versions of Mac OS X, Windows (95 and later), Unix, and Linux. To use them, go to their respective command lines (i.e., the shell or DOS prompt), and then enter:

```
telnet host
```

Replace `host` with the name of the remote computer you wish to connect to.

Also see:

- I have a functioning PPP connection using Windows 95, 98, Me, NT, or 2000. What can I do now?
- What is FTP, and how do I use it to transfer files?
- With MacSSH, BetterTelnet, and NCSA Telnet, how do I use FTP to transfer files between my computer and a remote host?
- What is PPP (Point-to-Point Protocol), and why would I want it?
- What are SSH and SSH2?
- In Mac OS, with MacSSH, NCSA Telnet, or BetterTelnet, why do I get an error that says "Host or Gateway not Responding"?

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What are SSH and SSH2?

The program SSH (Secure Shell) is a secure replacement for telnet and the Berkeley r-utilities (`rlogin`, `rsh`, `rcp`, and `rdist`). It provides an encrypted channel for logging into another computer over a network, executing commands on a remote computer, and moving files from one computer to another. SSH provides strong host-to-host and user authentication as well as secure encrypted communications over an insecure Internet.

SSH2 is a more secure, efficient, and portable version of SSH that includes SFTP, an SSH2 tunneled FTP. At Indiana University Bloomington, UITS has upgraded most central systems from SSH to SSH2, and encourages users who are concerned with secure communications to connect using an SSH2 client.

IU licenses the SSH Communications Security SSH Secure Shell software for Windows and MacSSH for Mac OS. If you are an IU student, staff member, or faculty member, you can download this software from IUware Online at:

`http://iuware.iu.edu/`

Note: To access this software on IUware, you must be connected to the Internet from an on-campus Ethernet connection, through the IU modem pools, or through the IU VPN.

When connecting to a server for the first time, SSH Secure Shell will ask you to confirm that you wish to save the new host key to the local database. Click the **`Yes`** button in order to avoid this message the next time you connect.

Rather than validating identities via passwords, SSH2 can also use public key encryption to authenticate remote hosts. For example, if you were to connect to a remote host called `global.conspiracy.org` (also running SSH2), SSH2 would use this system to verify that the remote system is the real `global.conspiracy.org` and not a computer set up to imitate it. If you wish, you can set up SSH2 to use public key authentication rather than passwords for logging into your other accounts, much like the Unix `rlogin` program. For more information on how to set up SSH and SSH2 to use public key authentication, see the Knowledge Base document In SSH and SSH2 for Unix, how do I set up public

key authentication?

You can find additional information on SSH and SSH2 at these sites:

- The ITSO SSH2 Howto Guide at:

  http://www.itso.iu.edu/howto/ssh2.epl

- The SSH FAQ at:

  http://www.employees.org/~satch/ssh/faq/ssh-faq.html

- The SSH Communications Security SSH Secure Shell home page at:

  http://www.ssh.com/products/ssh/

- The OpenSSH home page at:

  http://www.openssh.org

- The IU Unix Workstation Support Group security resources page at:

  http://uwsg.iu.edu/security/

Also see:

- What is cryptography, and where can I find more information about it?
- What is PGP?
- In SSH and SSH2 for Unix, how do I set up public key authentication?
- For Unix, what are ssh-agent and ssh-add, and how do I use them?
- For Mac OS, what is MacSSH, and where can I get it?

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Indiana University Knowledge Base

The Knowledge Base is a database of over 7,500 answers to questions about computing at Indiana University. Searches will return documents that contain **all** the words you enter in the search box.

Enter your search terms: Search

How to Search | Advanced Search

Searching tips:

- Use more than one word
- Use only important words

Good examples:

- `norton antivirus scan disk`
- `microsoft exchange forward e-mail`
- `locate e-mail address`

Bad examples:

- `e-mail` (too general; will return hundreds of documents)
- `how do I locate my cousin's e-mail address at Cornell?` (too specific; too many words)
- `analysis of social change` (not related to computing or Indiana University)

Other ways to access Knowledge Base information:

- Menus: A selection of popular Knowledge Base documents organized by topic; a good starting place
- Glossary: An alphabetical list of Knowledge Base documents that define common computing terms

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Software Manuals by Location

- Bloomington Campus Libraries
  - Business-SPEA Library
  - Education Library
  - Language and Computer Lab
  - Swain Hall Library
- Indianapolis Campus Libraries
  - IUPUI University Library
- Student Technology Centers
  - Business 101
  - Education 2011
  - HPER 154
  - Lindley Hall
  - Psychology 120
  - SPEA 151
  - Student Building
  - Woodburn 211
  - Wylie 125

Bloomington Campus Libraries

Package	Title	Location	Loan Policy	Call Number
Business-SPEA Library				

AMOS	AMOS User's Guide v 3.6	Business-SPEA	4 hour	CM-248
AUTOCAD	Release 13, Command Reference	Business-SPEA	4 hour	CM-256
AUTOCAD	Release 13, Customization Guide	Business-SPEA	4 hour	CM-254
AUTOCAD	Release 13, Installation Guide for DOS	Business-SPEA	4 hour	CM-253
AUTOCAD	Release 13, Installation Guide for Windows	Business-SPEA	4 hour	CM-252
AUTOCAD	Release 13, Master Index	Business-SPEA	4 hour	CM-251
AUTOCAD	Release 13, User's Guide	Business-SPEA	4 hour	CM-255
AUTOCAD	Release 14, Command Reference	Business-SPEA	4 hour	CM-260
AUTOCAD	Release 14, Customization Guide	Business-SPEA	4 hour	CM-258
AUTOCAD	Release 14, Installation Guide	Business-SPEA	4 hour	CM-257
AUTOCAD	Release 14, User's Guide	Business-SPEA	4 hour	CM-259
BMDP	ANOVA and Regression with BMDP 5V	Business-SPEA	4 hour	CM-120
BMDP	BMDP Statistical Software Manual, Vol. 1	Business-SPEA	4 hour	CM-117
BMDP	BMDP Statistical Software Manual, Vol. 2	Business-SPEA	4 hour	CM-118
BMDP	BMDP Statistical Software Manual, Vol. 3	Business-SPEA	4 hour	CM-119

BMDP	Graphical BMDP User's Guide	Business-SPEA	4 hour	CM-115
DBMS/COPY	The Tool for Software Connectivity, Version 5.0, Windows & DOS	Business-SPEA	4 hour	CM-250
DBMS/COPY	The Tool for Software Connectivity, Version 5.10 Addendum	Business-SPEA	4 hour	CM-249
DBMS/COPY	Version 6	Business-SPEA	4 hour	CM-261
GAUSS	Applications, Descriptive Statistics	Business-SPEA	4 hour	CM-157
GAUSS	Applications, Linear Programming	Business-SPEA	4 hour	CM-158
GAUSS	Applications, Linear Regression	Business-SPEA	4 hour	CM-155
GAUSS	Applications, Loglinear Analysis	Business-SPEA	4 hour	CM-162
GAUSS	Applications, Maximum Likelihood	Business-SPEA	4 hour	CM-156
GAUSS	Applications, Nonlinear Equations	Business-SPEA	4 hour	CM-159
GAUSS	Applications, Optimization	Business-SPEA	4 hour	CM-154
GAUSS	Applications, Quantal Response	Business-SPEA	4 hour	CM-160
GAUSS	Applications, Time Series	Business-SPEA	4 hour	CM-161
GAUSS	GAUSS Applications: Constrained Maximum Likelihood	Business-SPEA	4 hour	CM-22

GAUSS	GAUSS Applications: Constrained Optimization	Business-SPEA	4 hour	CM-23
GAUSS	GAUSS Version 3.0 Command Reference, Vol. 2	Business-SPEA	4 hour	CM-27
GAUSS	GAUSS Version 3.0 System and Graphics Manual, Vol. 1	Business-SPEA	4 hour	CM-26
GAUSS	GAUSS Version 3.0 System and Graphics Manual, Volume 1	Business-SPEA	4 hour	CM-28
GAUSS	GAUSS Version 3.0 System and Graphics Manual, Volume 2	Business-SPEA	4 hour	CM-29
GAUSS	GAUSS Version 3.1 System & Graphics Manual, Vol. 1	Business-SPEA	4 hour	CM-24
GAUSS	GAUSS Version 3.1 System & Graphics Manual, Vol. 2	Business-SPEA	4 hour	CM-25
GAUSS	Markov Version 2.0: A Statistical Environment for GAUSS 3.1	Business-SPEA	4 hour	CM-145
GAUSS	Markov, Version 2.0, Statistical Environment for GAUSS 3.1	Business-SPEA	4 hour	CM-168
GLIM	GLIM 4	Business-SPEA	4 hour	CM-185
GSP	Geometer's Sketchpad, User Guide & Reference Manual Windows Version	Business-SPEA	4 hour	CM-164

GSP	User Guide & Reference Manual, Macintosh	Business-SPEA	4 hour	CM-200
GSP	User Guide & Reference Manual, Windows	Business-SPEA	4 hour	CM-199
IMSL	C/Math/Library	Business-SPEA	4 hour	CM-226
IMSL	C/Stat/Library	Business-SPEA	4 hour	CM-225
IMSL	IMSL: Math/Library Quick Reference	Business-SPEA	4 hour	CM-30
IMSL	IMSL: Math/Library: Fortran Subroutines for Math Applications	Business-SPEA	4 hour	CM-31
IMSL	IMSL: Stat/Library: Fortran Subroutines for Statistical Analysis	Business-SPEA	4 hour	CM-35
IMSL	Math/Library Special Functions: Fortran Subroutines for Mathematical Applications	Business-SPEA	4 hour	CM-212
IMSL	Math/Library: Fortran Subroutines for Mathematical Applications, Volume 1	Business-SPEA	4 hour	CM-213
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IMSL	Stat/Library: Fortran Subroutines for Statistical Applications, Volume 1	Business-SPEA	4 hour	CM-215
IMSL	Stat/Library: Fortran Subroutines for Statistical Applications, Volume 2	Business-SPEA	4 hour	CM-216
LIMDEP	Reference Guide, Version 7.0	Business-SPEA	4 hour	CM-220
LIMDEP	User's Manual, Version 7.0	Business-SPEA	4 hour	CM-219
LIMDEP	Version 6.0, Abridged User's Manual	Business-SPEA	4 hour	CM-104
LIMDEP	Version 6.0, Quick Reference Guide	Business-SPEA	4 hour	CM-106
LIMDEP	Version 6.0, User's Manual and Reference Guide	Business-SPEA	4 hour	CM-105
LISREL	LISREL 7 User's Reference Guide	Business-SPEA	4 hour	CM-112
LISREL	LISREL 8	Business-SPEA	4 hour	CM-147
LISREL	LISREL 8: Structural Equation Modeling with the SIMPLIS Command Language	Business-SPEA	4 hour	CM-206
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MAPLE	Maple 5, Programming Guide	Business-SPEA	4 hour	CM-236
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MAPLE	Maple V, Programming Guide	Business-SPEA	4 hour	CM-264
MAPLE	Maple V: First Leaves: A Tutorial to Introduction to Maple, 3rd ed.	Business-SPEA	4 hour	CM-44
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MATLAB	5.2 Product Family New Features, Version 5	Business-SPEA	4 hour	CM-269

MATLAB	Application Program Interface Guide, Version 5	Business-SPEA	4 hour	CM-268
MATLAB	Building GUIs with MATLAB, Version 5	Business-SPEA	4 hour	CM-266
MATLAB	ECONOMETRICS TOOLKIT, Version 3.0	Business-SPEA	4 hour	CM-205
MATLAB	Getting Started with MATLAB, Version 5	Business-SPEA	4 hour	CM-270
MATLAB	IMAGE PROCESSING TOOLBOX for Use with MATLAB	Business-SPEA	4 hour	CM-204
MATLAB	NEURAL NETWORK TOOLBOX for Use with MATLAB	Business-SPEA	4 hour	CM-201
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MATLAB	Using MATLAB Graphics, Version 5	Business-SPEA	4 hour	CM-267

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MINITAB	Minitab for the PC, Release 8	Business-SPEA	4 hour	CM-49
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MINITAB	User's Guide 1: Data, Graphics, and Macros, Release 12, Windows 95 & NT	Business-SPEA	4 hour	CM-274
MINITAB	User's Guide 2: Data Analysis and Quality Tools, Release 12, Windows 95 & NT	Business-SPEA	4 hour	CM-275
NAG	Fortran Library Manual, Mark 17, Vol. 1	Business-SPEA	4 hour	CM-51
NAG	Fortran Library Manual, Mark 17, Vol. 10	Business-SPEA	4 hour	CM-60
NAG	Fortran Library Manual, Mark 17, Vol. 11	Business-SPEA	4 hour	CM-60.1

NAG	Fortran Library Manual, Mark 17, Vol. 12 (incomplete)	Business-SPEA	4 hour	CM-60.15
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SAS	ETS User's Guide, Ver. 6 ed.	Business-SPEA	4 hour	CM-75
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SAS	Language & Procedures: Introduction, Ver. 6	Business-SPEA	4 hour	CM-68

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SAS	Procedures Guide, Version 6, 3rd ed.	Business-SPEA	4 hour	CM-98
SAS	QC Software, Reference, Version 6	Business-SPEA	4 hour	CM-101
SAS	QC Software, Usage & Reference, Vol. 1	Business-SPEA	4 hour	CM-217
SAS	QC Software, Usage & Reference, Vol. 2	Business-SPEA	4 hour	CM-218
SAS	SAS/STAT User's Guide, 6.03	Business-SPEA	4 hour	CM-143
SAS	Screen Control Language, Reference, Version 6	Business-SPEA	4 hour	CM-99
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SPSS	Advanced Statistics User's Guide	Swain Hall	3 day	swn UITS 045
SPSS	Base System User's Guide	Swain Hall	3 day	swn UITS 039

SPSS	Base System User's Guide, Part 2	Swain Hall	3 day	swn UITS 092
SPSS	Base System, Part 1, UNIX	Swain Hall	3 day	swn UITS 091
SPSS	Categories	Swain Hall	3 day	swn UITS 043
SPSS	Categories 8.0	Swain Hall	3 day	swn UITS 098
SPSS	Categories 8.0	Swain Hall	3 day	swn UITS 107
SPSS	Conjoist 8.0	Swain Hall	3 day	swn UITS 099
SPSS	Data Entry Builder 1.0	Swain Hall	3 day	swn UITS 100
SPSS	Interactive Graphics 9.0	Swain Hall	3 day	swn UITS 104
SPSS	Introductory Statistics Student Guide	Swain Hall	3 day	swn UITS 040
SPSS	Professional Statistics 7.5	Swain Hall	3 day	swn UITS 095
SPSS	Reference Guide	Swain Hall	3 day	swn UITS 038
SPSS	Regression Models 9.0	Swain Hall	3 day	swn UITS 105

SPSS	SPSS Base 9.0 Applications Guide	Swain Hall	3 day	swn UITS 101
SPSS	SPSS Base 9.0 Syntax Reference Guide	Swain Hall	3 day	swn UITS 097
SPSS	SPSS Base 9.0 User's Guide	Swain Hall	3 day	swn UITS 102
SPSS	SPSS for UNIX Operations Guide	Swain Hall	3 day	swn UITS 404
SPSS	Tables 8.0	Swain Hall	3 day	swn UITS 103
SPSS	Trends 6.1	Swain Hall	3 day	swn UITS 094
SPSS	User Code	Swain Hall	3 day	swn UITS 090
STATA	Reference Manual Release 4: vol. 1	Swain Hall	3 day	swn UITS 195
STATA	Reference Manual Release 4: vol. 2	Swain Hall	3 day	swn UITS 196
STATA	Reference Manual Release 4: vol. 3	Swain Hall	3 day	swn UITS 197
SYSTAT	(Macintosh) Data	Swain Hall	3 day	swn UITS 288
SYSTAT	(Macintosh) Getting Started	Swain Hall	3 day	swn UITS 287

SYSTAT	(Macintosh) Graphics	Swain Hall	3 day	swn UITS 286
SYSTAT	(Macintosh) Statistics	Swain Hall	3 day	swn UITS 289
SYSTAT	(Windows) Command Reference	Swain Hall	3 day	swn UITS 284
SYSTAT	(Windows) Data	Swain Hall	3 day	swn UITS 283
SYSTAT	(Windows) Graphics	Swain Hall	3 day	swn UITS 282
SYSTAT	(Windows) New Statistics	Swain Hall	3 day	swn UITS 284a
SYSTAT	(Windows) Statistics	Swain Hall	3 day	swn UITS 285
TSP	Reference Manual ver. 4.3	Swain Hall	3 day	swn UITS 281
TSP	User's Guide ver. 4.3	Swain Hall	3 day	swn UITS 280
MATLAB	Image Processing Toolbox User's Guide	Swain Hall	3 day	swn UITS 265K

Indianapolis Campus Libraries

Package	Title	Location	Loan Policy	Call Number
IUPUI University Library				

AMOS	AMOS User's Guide v 4.0	IUPUI University Library	1 week	
ANSWERTREE	AnswerTree 1.0 User's Guide	IUPUI University Library	1 week	
AUTOCAD	Command Reference	IUPUI University Library	1 week	
AUTOCAD	Customization Guide	IUPUI University Library	1 week	
AUTOCAD	Installation Guide	IUPUI University Library	1 week	
AUTOCAD	User's Guide	IUPUI University Library	1 week	
BMDP	BMDP Statistical Software Manual, Vol. 1	IUPUI University Library	1 week	
BMDP	BMDP Statistical Software Manual, Vol. 2	IUPUI University Library	1 week	
BMDP	BMDP Statistical Software Manual, Vol. 3	IUPUI University Library	1 week	
BMDP	User's Digest	IUPUI University Library	1 week	
DBMS/COPY	Databases, Spreadsheets, Statistics	IUPUI University Library	1 week	
DBMS/COPY	Version 7.0	IUPUI University Library	1 week	

ETHNOGRAPH	Ethnograph v. 5.0 A User's Guide	IUPUI University Library	1 week	
MAPLE	Introduction to MAPLE	IUPUI University Library	1 week	
MAPLE	Introduction to Maple (release 6)	IUPUI University Library	1 week	
MAPLE	Learning Guide (release 6)	IUPUI University Library	1 week	
MATLAB	Release 11 New Features	IUPUI University Library	1 week	
MATLAB	Getting Started with MATLAB (ver. 5)	IUPUI University Library	1 week	
MATLAB	MATLAB Notebook User's Guide	IUPUI University Library	1 week	
MATLAB	Using MATLAB (ver. 5) (ver. 5)	IUPUI University Library	1 week	
MATLAB	Using MATLAB Graphics (ver. 5)	IUPUI University Library	1 week	
MATLAB	MATLAB Application Program Interface Guide (ver. 5)	IUPUI University Library	1 week	
MATLAB	Mapping Toolbox User's Guide (ver. 1)	IUPUI University Library 1 week		
MATLAB	Excel Link User's Guide	IUPUI University Library	1 week	

MATLAB	Control System Toolbox User's Guide (ver. 4)	IUPUI University Library	1 week	
MATLAB	Fuzzy Logic Toolbox User's Guide (ver. 2)	IUPUI University Library	1 week	
MATLAB	Image Processing Toolbox User's Guide (ver. 2)	IUPUI University Library	1 week	
MATLAB	Neural Network Toolbox User's Guide (ver. 3)	IUPUI University Library	1 week	
MATLAB	Optimization Toolbox User's Guide (ver. 2)	IUPUI University Library	1 week	
MATLAB	Building GUIs with MATLAB (ver. 5)	IUPUI University Library	1 week	
MATLAB	Partial Differential Equation Toolbox User's Guide (ver. 1)	IUPUI University Library	1 week	
MATLAB	Spline Toolbox User's Guide (ver. 2)	IUPUI University Library	1 week	
MATLAB	Statistics Toolbox: User's Guide (ver. 2)	IUPUI University Library	1 week	
MATLAB	Symbolic Math Toolbox User's Guide (ver. 2)	IUPUI University Library	1 week	
MATLAB	Wavelet Toolbox User's Guide (ver. 1)	IUPUI University Library	1 week	
MATLAB	Signal Processing Toolbox User's Guide (ver. 4)	IUPUI University Library	1 week	

MATLAB	SIMULINK Dynamic System Simulation for MATLAB: Using SIMULINK (ver. 3)	IUPUI University Library	1 week	
MATLAB	SIMULINK Writing S-Functions (ver. 3)	IUPUI University Library	1 week	
MATLAB	DSP Blockset for Use with Simulink User's Guide (ver. 3)	IUPUI University Library	1 week	
MINITAB	Minitab Reference Manual (release 9)	IUPUI University Library	1 week	
MINITAB	Mintab Quality Control Manual (release 9)	IUPUI University Library	1 week	
MINITAB	User's Guide 1: Data, Graphics, and Macros (release 13)	IUPUI University Library	1 week	
MINITAB	User's Guide 2: Data Analysis and Quality Tools (release 13)	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Introduction Guide	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 1	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 10	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 11	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 12	IUPUI University Library	1 week	

NAG	FORTRAN Mark 17 Volume 2	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 3	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 4	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 5	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 6	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 7	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 8	IUPUI University Library	1 week	
NAG	FORTRAN Mark 17 Volume 9	IUPUI University Library	1 week	
NUDIST	Merge User Guide Rel. 4	IUPUI University Library	1 week	
NUDIST	User Guide Rel. 4	IUPUI University Library	1 week	
RATS	CATS in RATS (Cointegration Analysis of Time Series)	IUPUI University Library	1 week	
RATS	RATS (Regression Analysis of Time Series)	IUPUI University Library	1 week	

RESAMPLING STATS	User's Guide	IUPUI University Library	1 week	
SAS	Procedures Guide, Version 6	IUPUI University Library	1 week	
SAS	User's Guide, Version 6, Volume 1	IUPUI University Library	1 week	
SAS	User's Guide, Version 6, Volume 1	IUPUI University Library	1 week	
SAS	What's New in SAS Software for Version 8	IUPUI University Library	1 week	
SAS	SAS Companion for the Microsoft Windows Environment, Version 8	IUPUI University Library	1 week	
SAS	SAS Companion for UNIX Environments, Version 8	IUPUI University Library	1 week	
SAS	User's Guide, Version 8, Volume 1	IUPUI University Library	1 week	
SAS	User's Guide, Version 8, Volume 2	IUPUI University Library	1 week	
SAS	User's Guide, Version 8, Volume 3	IUPUI University Library	1 week	
SAS	Procedures Guide, Version 8, Volume 1	IUPUI University Library	1 week	
SAS	Procedures Guide, Version 8, Volume 2	IUPUI University Library	1 week	

SAS	SAS Language Reference : Dictionary, Version 8, Volume 1	IUPUI University Library	1 week	
SAS	SAS Language Reference : Dictionary, Version 8, Volume 2	IUPUI University Library	1 week	
SAS	SAS Macro Language Reference : Concepts, Version 8	IUPUI University Library	1 week	
SAS	SAS Language Reference : Concepts, Version 8	IUPUI University Library	1 week	
SAS	Complete Guide to the SAS Output Delivery System, Version 8	IUPUI University Library	1 week	
SIGMAPLOT	SigmaPlot 5.0 Programming Guide	IUPUI University Library	1 week	
SIGMAPLOT	SigmaPlot 5.0 User's Guide	IUPUI University Library	1 week	
SIGMAPLOT	Transforms and Regressions for Windows 95, NT & 3.1:	IUPUI University Library	1 week	
SIGMAPLOT	User's Manual 4.0 for Windows 95, NT & 3.1	IUPUI University Library	1 week	
SPSS	SPSS Advanced Models 9.0	IUPUI University Library	1 week	
SPSS	SPSS Advanced Statistics 7.5	IUPUI University Library	1 week	

SPSS	SPSS Base 8.0 Applications Guide	IUPUI University Library	1 week	
SPSS	SPSS Base 8.0 Syntax Reference Guide	IUPUI University Library	1 week	
SPSS	SPSS Base 8.0 User's Guide	IUPUI University Library	1 week	
SPSS	SPSS Base 9.0 Applications Guide	IUPUI University Library	1 week	
SPSS	SPSS Base 9.0 Syntax Reference Guide	IUPUI University Library	1 week	
SPSS	SPSS Base 9.0 User's Guide	IUPUI University Library	1 week	
SPSS	SPSS Categories 8.0	IUPUI University Library	1 week	
SPSS	SPSS Conjoint 8.0	IUPUI University Library	1 week	
SPSS	SPSS Data Entry Builder 1.0 User's Guide	IUPUI University Library	1 week	
SPSS	SPSS Exact Tests 7.0 for Windows	IUPUI University Library	1 week	
SPSS	SPSS Interactive Graphics 8.0	IUPUI University Library	1 week	
SPSS	SPSS Interactive Graphics 9.0	IUPUI University Library	1 week	

SPSS	SPSS Professional Statistics 7.5	IUPUI University Library	1 week	
SPSS	SPSS Regression Models 9.0	IUPUI University Library	1 week	
SPSS	SPSS Tables 8.0	IUPUI University Library	1 week	
SPSS	SPSS Trends. 6.1	IUPUI University Library	1 week	
STATA	Stata Graphics Manual Release 6	IUPUI University Library	1 week	
STATA	Stata Reference Manual Release 6 Vol. 1 A-G	IUPUI University Library	1 week	
STATA	Stata Reference Manual Release 6 Vol. 2 H-O	IUPUI University Library	1 week	
STATA	Stata Reference Manual Release 6 Vol. 3 P-St	IUPUI University Library	1 week	
STATA	Stata Reference Manual Release 6 Vol. 4 Su-Z	IUPUI University Library	1 week	
STATA	Stata User's Guide Release 6	IUPUI University Library	1 week	
SYSTAT	6.0 for Windows: Command Reference	IUPUI University Library	1 week	
SYSTAT	6.0 for Windows: Data	IUPUI University Library	1 week	

SYSTAT	6.0 for Windows: Graphics	IUPUI University Library	1 week	
SYSTAT	6.0 for Windows: Statistics	IUPUI University Library	1 week	
SYSTAT	7.0 Command Reference	IUPUI University Library	1 week	
SYSTAT	7.0 New Statistics	IUPUI University Library	1 week	

Student Technology Centers

Package	Title	Location	Loan Policy	Call Number
Business 101 STC				
MAPLE	MapleV Learning Guide	STC (BUS 101)	On-Site	
MAPLE	MapleV Programming Guide	STC (BUS 101)	On-Site	
MATLAB	Matlab Reference Guide (UNIX)	STC (BUS 101)	On-Site	
MATLAB	Matlab User's Guide (UNIX)	STC (BUS 101)	On-Site	
SAS	SAS 6.03 Statistics	STC (BUS 101)	On-Site	
SAS	SAS 6.03 Users Guide	STC (BUS 101)	On-Site	
SPSS	SPSS 7.0 Applications Guide	STC (BUS 101)	On-Site	
SPSS	SPSS 7.0 Base User's Guide	STC (BUS 101)	On-Site	
SPSS	SPSS 7.0 Syntax Reference Guide	STC (BUS 101)	On-Site	

Education 2011 STC				
MAPLE	MapleV First Leaves: A Tutorial to Introduction to Maple	STC (EDUC 2011)	On-Site	
MAPLE	MapleV Flight Manual	STC (EDUC 2011)	On-Site	
MAPLE	MapleV Library	STC (EDUC 2011)	On-Site	
MAPLE	MapleV Reference	STC (EDUC 2011)	On-Site	
MAPLE	Matlab Reference Guide (UNIX)	STC (EDUC 2011)	On-Site	
MATLAB	Matlab User's Guide (UNIX)	STC (EDUC 2011)	On-Site	
SAS	Language	STC (EDUC 2011)	On-Site	
SAS	Procedures	STC (EDUC 2011)	On-Site	
SPSS	SPSS 4 Base System	STC (EDUC 2011)	On-Site	
SPSS	SPSS 4 User's Guide	STC (EDUC 2011)	On-Site	
SPSS	SPSS 6.0 Syntax Reference Guide	STC (EDUC 2011)	On-Site	
SPSS	SPSS 6.0 User's Guide	STC (EDUC 2011)	On-Site	

SYSTAT	Systat 5 Data	STC (EDUC 2011)	On-Site	
SYSTAT	Systat 5 Getting Started	STC (EDUC 2011)	On-Site	
SYSTAT	Systat 5 Graphics	STC (EDUC 2011)	On-Site	
SYSTAT	Systat 5 Statistics	STC (EDUC 2011)	On-Site	
HPER 154 STC				
MAPLE	MapleV First Leaves: A Tutorial to Introduction to Maple	STC (HPER 154)	On-Site	
MAPLE	MapleV Programming Guide	STC (HPER 154)	On-Site	
MAPLE	MapleV Reference Guide	STC (HPER 154)	On-Site	
MATLAB	Matlab Reference Guide (UNIX)	STC (HPER 154)	On-Site	
MATLAB	Matlab User's Guide (UNIX)	STC (HPER 154)	On-Site	
OTHER	Econometric Toolkit	STC (HPER 154)	On-Site	
SAS	Language and Procedures	STC (HPER 154)	On-Site	
SAS	Stat User's Guide vol 1 & 2	STC (HPER 154)	On-Site	

SPSS	SPSS 4 Base System	STC (HPER 154)	On-Site	
SPSS	SPSS 4 Reference Guide	STC (HPER 154)	On-Site	
SPSS	SPSS 7.0 - Applications Guide	STC (HPER 154)	On-Site	
SPSS	SPSS 7.0 Syntax Reference Guide	STC (HPER 154)	On-Site	
SPSS	SPSS 7.0 User's Guide	STC (HPER 154)	On-Site	
Lindley Hall STCs				
MATLAB	Matlab Reference Guide (UNIX)	STC (Lindley Hall)	On-Site	
MATLAB	Matlab Users Guide (UNIX)	STC (Lindley Hall)	On-Site	
SAS	Companion for Windows	STC (Lindley Hall)	On-Site	
SAS	Language and Procedures Intro	STC (Lindley Hall)	On-Site	
SAS	Stat User's Guide vol 1 & 2	STC (Lindley Hall)	On-Site	
SPSS	SPSS 6.1 Syntax Reference Guide	STC (Lindley Hall)	On-Site	
SYSTAT	Systat 7 Command Reference	STC (Lindley Hall)	On-Site	

SYSTAT	Systat 7 Graphics	STC (Lindley Hall)	On-Site	
SYSTAT	Systat 7 New Statistics	STC (Lindley Hall)	On-Site	
SYSTAT	Systat 7 Statistics	STC (Lindley Hall)	On-Site	
Psychology 120 STC				
MAPLE	MapleV Learning Guide	STC (Psych 120)	On-Site	
MAPLE	MapleV Programming Guide	STC (Psych 120)	On-Site	
MATLAB	Matlab Reference Guide	STC (Psych 120)	On-Site	
MINITAB	Minitab 11 Reference	STC (Psych 120)	On-Site	
SAS	Language and Procedures Usage	STC (Psych 120)	On-Site	
SAS	Procedures	STC (Psych 120)	On-Site	
SPSS	SPSS 6.1 Syntax Reference Guide	STC (Psych 120)	On-Site	
SYSTAT	Systat 6 Command Reference	STC (Psych 120)	On-Site	
SYSTAT	Systat 6 for Windows Data	STC (Psych 120)	On-Site	

SYSTAT	Systat 6 for Windows Graphics	STC (Psych 120)	On-Site	
SYSTAT	Systat 6 for Windows Statistics	STC (Psych 120)	On-Site	
SPEA 151 STC				
MAPLE	MapleV First Leaves: A Tutorial to Introduction to Maple	STC (SPEA 151)	On-Site	
MAPLE	MapleV Learning Guide	STC (SPEA 151)	On-Site	
MAPLE	MapleV Programming Guide	STC (SPEA 151)	On-Site	
MATLAB	Matlab Reference Guide (UNIX)	STC (SPEA 151)	On-Site	
MATLAB	Matlab User's Guide (UNIX)	STC (SPEA 151)	On-Site	
MINITAB	Minitab 11 Reference	STC (SPEA 151)	On-Site	
OTHER	Econometric Toolkit	STC (SPEA 151)	On-Site	
SAS	Companion for Windows	STC (SPEA 151)	On-Site	
SAS	Language and Procedures	STC (SPEA 151)	On-Site	
SPSS	SPSS 4 Reference Guide	STC (SPEA 151)	On-Site	

SPSS	SPSS 7.0 Applications Guide	STC (SPEA 151)	On-Site	
SPSS	SPSS 7.0 Syntax Reference Guide	STC (SPEA 151)	On-Site	
SPSS	SPSS 7.0 User's Guide	STC (SPEA 151)	On-Site	
SYSTAT	Systat 6 Command Reference	STC (SPEA 151)	On-Site	
SYSTAT	Systat 6 for Windows Data	STC (SPEA 151)	On-Site	
SYSTAT	Systat 6 for Windows Graphics	STC (SPEA 151)	On-Site	
SYSTAT	Systat 6 for Windows Statistics	STC (SPEA 151)	On-Site	
Student Building STCs				
MAPLE	MapleV Reference	STC (Student Building)	On-Site	
MATLAB	Matlab Reference Guide (UNIX)	STC (Student Building)	On-Site	
MATLAB	Matlab Users Guide (UNIX)	STC (Student Building)	On-Site	
MINITAB	Minitab 11 Reference	STC (Student Building)	On-Site	
OTHER	Econometric Toolkit	STC (Student Building)	On-Site	

RATS	Rats 386	STC (Student Building)	On-Site	
SAS	Companion for Windows	STC (Student Building)	On-Site	
SAS	Language & Procedures	STC (Student Building)	On-Site	
SAS	Stat vol. 1 & 2	STC (Student Building)	On-Site	
SPSS	SPSS 4 Reference guide	STC (Student Building)	On-Site	
SPSS	SPSS 7.0 Applications Guide	STC (Student Building)	On-Site	
SPSS	SPSS 7.0 Syntax Reference Guide	STC (Student Building)	On-Site	
SPSS	SPSS 7.0 User's Guide	STC (Student Building)	On-Site	
SYSTAT	Systat 6 Command Reference	STC (Student Building)	On-Site	
SYSTAT	Systat 6 for Windows Data	STC (Student Building)	On-Site	
SYSTAT	Systat 6 for Windows Graphics	STC (Student Building)	On-Site	
SYSTAT	Systat 6 for Windows Statistics	STC (Student Building)	On-Site	
Woodburn 211 STC				

BMDP	BMDP Statistical Software Manual, Vol. 1	WH 211 STC	On-Site	
BMDP	BMDP Statistical Software Manual, Vol. 2	WH 211 STC	On-Site	
MAPLE	MapleV Reference Library	STC (Woodburn 211)	On-Site	
MATLAB	Matlab Reference Guide (UNIX)	STC (Woodburn 211)	On-Site	
MATLAB	Matlab User's Guide (UNIX)	STC (Woodburn 211)	On-Site	
SPSS	SPSS 4 Reference Guide	STC (Woodburn 211)	On-Site	
SPSS	SPSS 4 User's Guide	STC (Woodburn 211)	On-Site	
SPSS	SPSS 7.0 Applications Guide	STC (Woodburn 211)	On-Site	
SPSS	SPSS 7.0 Syntax Reference Guide	STC (Woodburn 211)	On-Site	
SPSS	SPSS 7.0 User's Guide	STC (Woodburn 211)	On-Site	
SYSTAT	Systat 6 Command Reference	STC (Woodburn 211)	On-Site	
SYSTAT	Systat 6 for Windows Data	STC (Woodburn 211)	On-Site	
SYSTAT	Systat 6 for Windows Graphics	STC (Woodburn 211)	On-Site	

SYSTAT	Systat 6 for Windows Statistics	STC (Woodburn 211)	On-Site	
Wylie 125 STC				
RATS	Rats 4.2 - complete documentation	STC (Wylie 125)	On-Site	
SYSTAT	Systat 7.0 - complete documentation	STC (Wylie 125)	On-Site	

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IUB Math Software Availability

	Microcomputers		Workstations			Shared	Research Systems
	Mac	Windows	Ships	Nations	DaVinci	Steel	Aries09
Matlab	-	A	A	A	A	A	A
Maple	A	A	A	A	A	A	A
Mathematica	B	-	B	B	B	B	B
Geometer's SketchPad	C	C	-	-	-	-	-
LINDO	-	-	-	-	-	-	B
LINGO	-	B	-	-	-	-	-

Support Levels:

A = General Purpose Software B = Special Purpose Software
C = Departmental Software D = To Be Retired

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IUPUI Mathematical Software Availability

	Microcomputers	
	Mac	Windows
Maple	-	**A**

Note: IUPUI researchers can also request accounts on IUB Shared Systems. Contact the IUPUI UITS Support Center for more information (helpdesk@iupui.edu, 317-274-HELP).

Support Levels:

A = General Purpose Software

B = Special Purpose Software

C = Departmental (Customer Sponsored) Software

D = To Be Retired

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Phone Numbers

- Stat/Math Main Line: (812) 855-4724, M-F, 9am-5pm
- After hours, call (812) 855-6789 (UITS Support Center) for computer assistance
- Stat/Math Fax Number: (812) 855-8802

E-mail

Note: Unfortunately, we do not have the resources to provide computing support for persons not associated with Indiana University. This means, unless you are a student, faculty, or staff member of Indiana University, your questions will probably not be answered.

To: Stat/Math Center, IU <*statmath@indiana.edu*>
Your Name:

Email Address:

Subject:

Send

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Introduction

What is Maple?

Maple is a computer program for people doing mathematics. Using Maple to do your calculations should make the work more interesting, allow you to focus more on the concepts, and help you to avoid mistakes in calculation.

How to use this tutorial

This document is intended to get you started, and show you how to learn more. It is intended to be used while sitting at a terminal running Maple in a windowed environment, by entering the commands and thinking about the output.

To use any software effectively, some knowledge of the computer's operating system is required. This document will assume that you are already familiar with the rudiments of windows -- things like point, click and drag, how to use menus, and the standard way to open and close files. Maple is essentially the same on Microsoft Windows, Macintosh, and the X windows system, but there are minor differences in their interface.

This tutorial assumes that you are running Maple in one of the previously listed environments. If you are using a character-based terminal, for example in a telnet session, the Maple commands will be the same although the interface is different (no mouse, no menus, and typewriter graphics). If you are using Maple over telnet, ssh, or through any other terminal, you may wish to read Using Math Software under UNIX after you are done with this tutorial.

In order to be more broadly understood, we don't include some things which require a lot of mathematical knowledge, for example linear algebra. Subject oriented

guides are also available -see our By Subject page.

We'll be using some standard conventions throughout this document.

Example	Explanation
File -> Open	Choose the file menu, and select Open.
`a := 5;`	Input to be typed at the Maple prompt.
a := 5	Output from Maple.
TIP	An important tip.

Where to find Maple

Maple is available for many different kinds of computers at Indiana University Bloomington.

- All Windows and Macintosh Student Technology Centers.
- Ships, Nations, and DaVinci UNIX clusters
- Several of the large timesharing systems - see the availability chart for details.

How to start and exit Maple

To start maple:

- On Windows 2000 computers, go to Start Menu -> Programs -> Statistics and Math -> Maple 7 -> Maple 7
- On Macintosh computers, go to Apple Menu -> Statistics and Math -> Maple 7.
- On UNIX workstations, the X windows version is invoked by the command `xmaple &`.

To exit Maple in a windowed environment choose File -> Exit. To exit from a terminal session type **`quit;`**.

Next: Finding Your Way Around
Up: Table of Contents

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In order to be more broadly understood, we don't include some things which require a lot of mathematical knowledge, for example linear algebra. Subject oriented guides are also available -see our By Subject page.

We'll be using some standard conventions throughout this document.

Example	Explanation
File -> Open	Choose the file menu, and select Open.
`a := 5;`	Input to be typed at the Maple prompt.

`a := 5`	Output from Maple.
TIP	An important tip.

Where to find Maple

Maple is available for many different kinds of computers at Indiana University Bloomington.

- All Windows and Macintosh Student Technology Centers.
- Ships, Nations, and DaVinci UNIX clusters
- Several of the large timesharing systems - see the availability chart for details.

How to start and exit Maple

To start maple:

- On Windows 2000 computers, go to Start Menu -> Programs -> Statistics and Math -> Maple 7 -> Maple 7
- On Macintosh computers, go to Apple Menu -> Statistics and Math -> Maple 7.
- On UNIX workstations, the X windows version is invoked by the command `xmaple &`.

To exit Maple in a windowed environment choose File -> Exit. To exit from a terminal session type `quit;`.

Finding your way around the window

The Toolbar

First of all, locate the toolbar at the top of the window. On Windows, it looks like this:

Other operating systems have a similar toolbar.

Every time you work with maple, you will use a "worksheet". The worksheet is the big, blank area in the middle of the screen. You may have more than one worksheet open at a time. The following toolbar buttons let you work with the worksheet.

The first five buttons on the toolbar, in order, do the following: open a new, blank worksheet; open an existing worksheet; open a hyperlink; save the current worksheet; and print the current worksheet.

The next three buttons are the standard cut, copy, and paste functions.

The next two buttons let you "undo" and "redo" your last action.

The next three buttons let you manage what "mode" Maple is currently in. The standard mode is represented by the capital Sigma button. This means that anything you type will be considered to be mathematical input. If you click the capital T, Maple switches to Text mode. Anything you type will be considered as text commentary, and Maple won't try to treat it as math. To switch back to math input mode, click the [> button. Notice that the prompt in the worksheet window changes to let you know what mode you are in.

The next two buttons let you un-indent and indent lines in your worksheet.

The next button has a stop sign on it. It is used as a "panic" button. If you start a computation and you would like to stop, click the stop sign. (Cntl-C will also do this.)

The next three buttons control the amount of zoom.

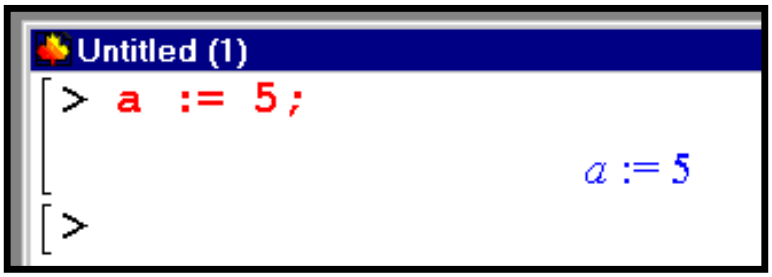
The next button displays non-printing characters in the worksheet.

The next button expands the active worksheet to fill the available space.

The last button clears all variables of their values. It is the same as typing the maple command
restart;

The Kernel

The kernel is the part of Maple that does the actual calculation. The kernel is invisible, but you do need to know about it. You talk to the kernel by typing mathematical statements and commands at the Maple prompt. Here is an example.



If you're using a graphics-enabled browser, you'll notice that input appears in red. Output from the kernel appears in blue, with variable names in italics.

The Maple prompt looks like [>.

The kernel will execute when you press the Enter key. The kernel decides what to execute by looking at the current *execution group*. An execution group is a set of input lines connected (along the left-hand margin) by a long, thin [. When you press Enter anywhere in the execution group, the entire group is executed. By default, each input line (along with its output) is an execution group unto itself. You can join execution groups together using the F4 key, or split them apart using the F3 key.

TIP Execution only occurs when you press the Enter key, or if you choose Edit->Execute->Worksheet. Execution *does not* occur when you open a worksheet.

Worksheets

The worksheet is the basic unit of work in Maple, like a document in a word processor. A worksheet stores every line of input *and* every line of output.

To save your worksheet, choose File->Save As.

To open a worksheet, choose File->Open.

You may have more than one worksheet open at a time. However, they all share the same kernel. So any work you do in one worksheet is accessible from another open worksheet. This can lead to confusing results.

Using the Help System

Maple has an extremely in-depth help system. To access it, choose Help -> Topic Search. Enter the word you are looking for (e.g., matrix) and you should see a list of topics. Clicking on one will open a "help browser", a window that lets you wander through related topics. We suggest that you "surf" the help system - casually browse, looking at anything that seems interesting. That way you will have some idea of what is available to you in the future.

If you know exactly what you need help on, you may also type (in Maple)

```
? simplify
```

(for example) to get help on the Maple command "simplify".

A very useful feature of the help system is the examples section. Use the Edit->Copy Examples menu command to copy the examples. Then switch to your worksheet (or open a fresh one) and use the Edit->Paste menu command. Now you can execute the examples, and experiment until you are comfortable with the commands.

Maple Syntax and Built-in Data Capabilities

Syntax

As with any computer language, Maple has its own syntax. As a new user of Maple, you can save yourself a lot of head-scratching if you get to know these symbols.

Enter the commands given or make up similar problems.

Symbol	Description	Examples	Sample Output
;	End-of-line. Tells Maple to process the line and show the output.	`hello;`	`hello`
:	End-of-line. Tells Maple to process the line and hide the output.	`hello:`	
:=	Assignment. Lets you assign values to variables.	`a := 3;` `a;`	`a := 3` `3`
+, -	Addition, subtraction.	`1 + 3;` `1 - 3;`	`4` `-2`

*, /	Multiplication, division	`3*412;`
		`1236/3;`
		`7/3;`
			`1236`
			`412`
			`7/3`

^, sqrt	Power, square root	`2^3;`
		`sqrt(2);`
		`2^(1/2);`
			`8`
			$\sqrt{2}$
			$\sqrt{2}$

evalf, .	Floating-point (decimal) evaluation	`evalf(7/3);` `7.0/3;`	`2.333333333` `2.333333333`

I,Pi	Imaginary unit, Pi.	`2 + 3*I;`
		`(2*I)^2;`
		`evalf(Pi);`
			`2+3I`
			`-4`
			`3.141592654`

%, %%	Recall the last output, recall the second-to-last output, etc.	`%;` `%%%;`	`3.141592654` `-4`

Some syntactical caveats:

- Maple is case sensitive. **`foo`**, **`Foo`**, and **`FOO`** are three different things.
- Maple requries you to show multiplication with the **`*`** character. Entering **`x*y`** gives the product of `x` and `y`, but entering **`xy`** gives one variable with the name `xy`.
- To get the constant `e` use **`exp(1)`**.
- Using the **`%`** operator can give confusing results. It always returns the last output from the Kernel, which may have nothing to do with where the cursor is (or which worksheet is active).
- If Maple doesn't recognize something, it will assume it is a variable. For example, typing **`i^2`** will give you i^2, while you may have wanted `-1`.
- You can move your cursor up to a previous line, press Enter, and the line will re-execute.
- When copying and pasting using a mouse, by sure to also highlight the execution group symbol ([). If you don't, the lines will be pasted in reverse order due to a bug.
- Spaces are optional.
- Greek letters may be entered by spelling their name. For example, **`alpha`** is always displayed

as α, and **Gamma** is displayed as Γ (note upper-case).

Built-in Data Capabilities

Maple can handle arbitrary-precision floating point numbers. In other words, Maple can store as many digits for a number as you like, up to the physical limits of your computer's memory. To control this, use the **Digits** variable.

```
sqrt(2.0);
   1.414213562
Digits := 20:
sqrt(2.0);
   1.4142135623730950488
```

Maple sets Digits to be 10 by default. You can also temporarily get precision results by calling evalf with a second argument.

```
evalf(sqrt(2), 15);
   1.41421356237310
```

Large integers are handled automatically.

Using symbolic computation

The main feature of Maple is symbolic computation. In other words, Maple does algebra. Here are some examples.

Example	Output	Comments
`(x + y)^2;`	$(x + y)^2$	A basic expression.
`k := x*y + y^2;`	$k := xy + y^2$	k is now an alias for the expression. Note that k is simply another name for the expression - they are not equal in the mathematical sense.
`p := k /(x+y);`	$p := \frac{x\,y + y^2}{x + y}$	You can now use k to refer to the expression. Maple immediately substitutes the value of k.
`k := 'k';`	k	You can unassign a variable by assigning it to its own name in single quotes.

`simplify(p);`	y	The **simplify** command does algebraic simplification.
`p := x^2 - 8*x +15;`	$p := x^2 - 8x + 15$	Maple doesn't mind if you re-use names. The old value is lost.
`solve(p=3,x);`	2,6	Use the **solve** command to solve equations. Note the use of the **=** sign. Here, it is used in a mathematical sense. Maple will try different values for x until it finds all of them that make the mathematical statement $x^2 - 8x + 15 = 3$ true.
`dpdx := diff(p,x);`	dpdx := 2x - 8	The **diff** command differentiates an expression with respect to a variable.
`int(p,x);`	$\frac{1}{3}x^3 - 4x^2 + 15x$	The **int** command integrates an expression. Note that the constant of integration is left off.
`subs(x=4,p);` `subs(x=t^2,p);`	-1 $t^4 - 8t^2 + 15$	The subs command substitutes expressions into other expressions. Notice that p's value is unchanged.

Each of the commands listed here has many powerful, advanced features. See the help files for more information.

TIP Use the **restart;** command to unassign all variables, reset built-in variables (such as **Digits**) to their original values, and unload all packages. Of course, this should be used with care.

Creating your own Mathematical Functions

We have been working with expressions so far. Maple also supports the mathematical notion of a function. To define a function, you must specify a rule for going from one number to another. Consider the following commands:

`f := x^2;`	$f := x^2$	This defines f to be an abbreviation for the expression x^2.
`f := x -> x^2;`	$f := x \to x^2$	This defines f to be a function, such that $f(x) = x^2$.
`f(3);` `f(t);`	9 t^2	The function works as standard notation.

TIP A common mistake is to write **`f(x) := x^2;`**. This does not define a function. Instead, it makes the four characters on the left an abbreviation for the three characters on the right.

Functions are often more useful than expressions. However, many Maple commands (for example, **`diff`**) expect an expression as input. If **`f := x -> x^2`**, then **`diff(f,x);`** doesn't work. However, **`diff(f(x),x);`** will work, since **`f(x)`** produces the expression x^2.

To convert an expression into a function, use the **`unapply`** command.

```
p := x^3 + 1;
   p := x^3 + 1
f := unapply(p, x); f(3);
   f := x -> x^3 + 1
   28
```

Using packages

When you first load Maple, it knows how to execute several different functions. For example, we used the **`evalf`** and **`simplify`** functions without having to load them first. Maple comes with a *huge* number of other useful functions, bundled up in units known as packages. Maple has a modular design -- not all of its functions are loaded at startup. The more specialized capabilities must be explicitly loaded.

For example, if you want to work with matrices and vectors, you would want to load the **`linalg`** package.

```
with(linalg);
```

The output from **`with`** is a list of the new commands that you now have access to. If you don't want to see the list (which can be rather long), use a colon as your end-of-line marker.

```
with(linalg):
```

Even if you use a colon, you may see warning messages. These usually indicate that a command has a new definition. In most cases, this should not be a concern.

Some Maple functions are not in packages; instead, they are stored in the older library format. For example, to add the multivarate Taylor series function, **`mtaylor`**, use the command

```
readlib(mtaylor);
```

Go exploring among the packages. These are some of the most commonly used packages:

student Includes commands for use in a classroom/homework setting.

plots Tools for graphics, 3-d, animation, and visualization.

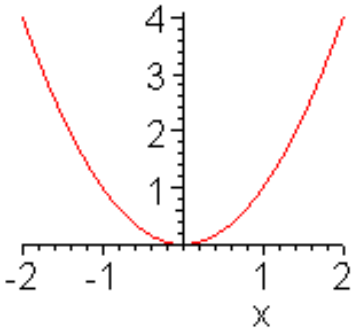
TIP **linalg** Matrices, vectors, and many linear algebra functions.

detools Tools for working with ODEs and PDEs.

To get a comprehensive list of available packages, choose Help->Introduction, then browse to Mathematics->Packages->Overview.

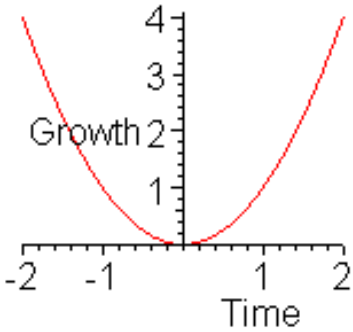
Basic Plotting

Maple can produce graphs very easily. Here are some examples, showcasing the basic capabilities.



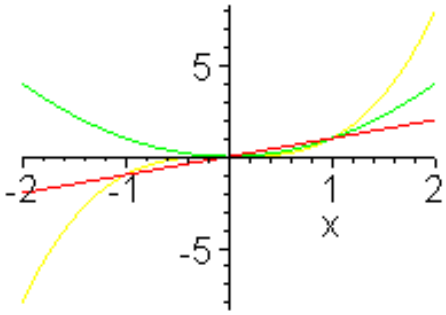
plot(x^2, x=-2..2);

A basic plot.



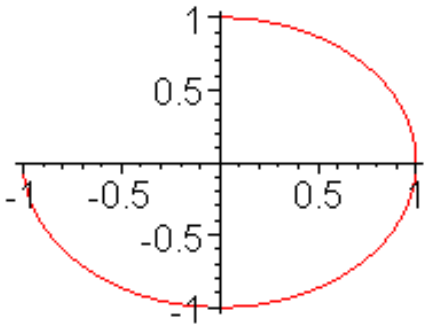
plot(x^2, x=-2..2, y=-10..10);

A plot with vertical axis control.



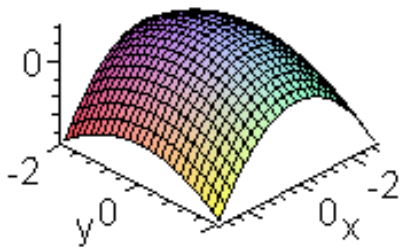
plot([x, x^2, x^3], x=-2..2);

Plot multiple expressions by enclosing them in brackets.



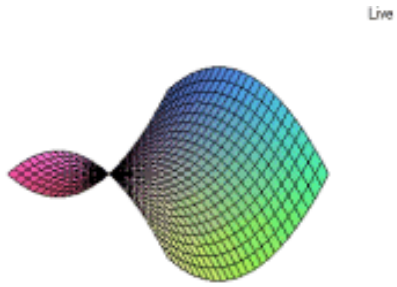
plot([sin(t),cos(t),t=0..3*Pi/2]);

Parametric plots include the plotting range in the brackets.



`plot3d(4-x^2-y^2, x=-3..3, y=-2..2);`

A basic 3-d plot.



`smartplot3d(x^2-y^2);`

Using smartplot to let maple set it's own scaling.

You can control where plots are drawn by choosing Options->Plot Display->Inline or Window. Either way, if you select a plot with the mouse, you can use the toolbar to change the rendering style, axes, and lighting.

To copy a plot to the clipboard (as a graphics file), right-click (or Option-Click for Mac users) on the plot and select Copy.

TIP

Look into these commonly used plotting commands:

`textplot`, **`textplot3d`**	Draw text anywhere in a plot
`display`	Display several plots at once
`animate`, **`animate3d`**	Adds a dimension of time to your plot.
`plotoptions`	Various options, including line weight, color, sampling, etc.

Further Reading

For further guidance as a new user, try the tour. Choose Help->New User's Tour.

Other sources of information include:

- The UITS Knowledge Base
- UITS Education Program
- Software Manual Locations
- If you are affiliated with Indiana University, you may also get use Stat/Math Consulting .

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Last modified: Monday, 25-Feb-2002 15:59:22 EST
URL `/~statmath/math/maple/gettingstarted/giant.html`

Introduction

What is Maple?

Maple is a computer program for people doing mathematics. Using Maple to do your calculations should make the work more interesting, allow you to focus more on the concepts, and help you to avoid silly calculation mistakes.

How to use this tutorial

This document is intended to get you started, and show you how to learn more. It is intended to be used while sitting at a terminal running Maple in a windowed environment, by entering the commands and thinking about the output.

To use any software effectively, some knowledge of the computer's operating system is required. This document will assume that you are already familiar with the rudiments of windows -- things like point, click and drag, how to use menus, and the standard way to open and close files. Maple is essentially the same on Microsoft Windows, Macintosh, and the X windows system, but there are minor differences in their interface.

This tutorial assumes that you are running Maple V release 5.1 in one of the previously listed environments. If you are using a character-based terminal, for example in a telnet session, the Maple commands will be the same although the interface is different (no mouse, no menus, and typewriter graphics). If you are using Maple over telnet, ssh, or through any other terminal, you may wish to read Using Math Software under UNIX after you are done with this tutorial.

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We'll be using some standard conventions throughout this document.

Example	Explanation
File -> Open	Choose the file menu, and select Open.
a := 5;	Input to be typed at the Maple prompt.
a := 5	Output from Maple.
TIP	An important tip.

Where can I find Maple?

Maple is available in all IUB Student Technology Centers.

- On NT (PC) computers, go to Start Menu -> Programs -> Statistics and Math -> Maple V Release 5.1 -> Maple V Release 5.1.

- On Macintosh computers, go to Apple Menu -> Statistics and Math -> Maple V Release 5.1 (PowerPC).
- On UNIX workstations, the X windows version is invoked by the command `xmaple &`.
- Maple is also available on most IU central systems - see the Availability page.

How to start and exit Maple

To start maple:

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- On UNIX workstations, the X windows version is invoked by the command `xmaple &`.

To exit Maple, choose File -> Exit or type exit;.

Finding your way around the window

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First of all, locate the toolbar at the top of the window. On NT, it looks like this:

Other operating systems have a similar toolbar.

Every time you work with maple, you will use a "worksheet". The worksheet is the big, blank area in the middle of the screen. You may have more than one worksheet open at a time. The following toolbar buttons let you work with the worksheet.

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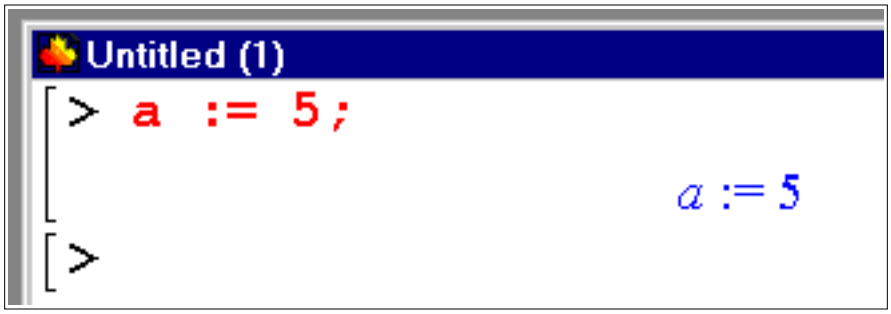

If you're using a graphics-enabled browser, you'll notice that input appears in red. Output from the kernel appears in blue, with variable names in italics.

The Maple prompt looks like [>.

The kernel will execute when you press the Enter key. The kernel decides what to execute by looking at the current *execution group*. An execution group is a set of input lines connected (along the left-hand margin) by a long, thin [. When you press Enter anywhere in the execution group, the entire group is executed. By default, each input line (along with its output) is an execution group unto itself. You can join execution groups together using the F4 key, or split them apart using the F3 key.

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The worksheet is the basic unit of work in Maple, like a document in a word processor. A worksheet stores every line of input *and* every line of output.

To save your worksheet, choose File->Save As.

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If you know exactly what you need help on, you may also type (in Maple)

> ? simplify

(for example) to get help on the Maple command "simplify".

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+, -	Addition, subtraction.	1 + 3; 1 - 3;	4 -2
*, /	Multiplication, division	3*412; 1236/3; 7/3;	1236 412 7/3

^, sqrt	Power, square root	2^3; sqrt(2); 2^(1/2);	8 $\sqrt{2}$ $\sqrt{2}$
evalf, .	Floating-point (decimal) evaluation	evalf(7/3); 7.0/3;	2.333333333 2.333333333
I,Pi	Imaginary number, Pi.	2 + 3*I; (2*I)^2; evalf(Pi);	2+3I -4 3.141592654
%, %%	Recall the last output, recall the second-to-last output, etc.	%; %%%;	3.141592654 -4

Some syntactical caveats:

- Maple is case sensitive. foo, Foo, and FOO are three different things.
- Using the % operator can give confusing results. It always returns the last output from the Kernel, which may have nothing to do with where the cursor is (or which worksheet is active).
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  1.414213562
Digits := 20:
sqrt(2.0);
  1.4142135623730950488
```

Maple sets Digits to be 10 by default. You can also temporarily get precision results by calling evalf with a second argument.

```
evalf(sqrt(2), 15);
  1.41421356237310
```

Large integers are handled automatically.

Using symbolic computation

The main feature of Maple is symbolic computation. In other words, Maple does algebra. Here are some examples.

Example	Output	Comments
(x + y)^2;	$(x + y)^2$	A basic expression.
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p := k /(x+y);	$p := \frac{x\,y + y^2}{x + y}$	You can now use k to refer to the expression. Maple immediately substitutes the value of k.
k := 'k';	k	You can unassign a variable by assigning it to its own name in single quotes.
simplify(p);	y	The simplify command does algebraic simplification.
p := x^2 - 8*x +15;	$p := x^2 - 8x + 15$	Maple doesn't mind if you re-use names. The old value is lost.
solve(p=3,x);	2,6	Use the solve command to solve equations. Note the use of the = sign. Here, it is used in a mathematical sense. Maple will try different values for x until it finds all of them that make the mathematical statement $x^2 - 8x + 15 = 3$ true.
dpdx := diff(p,x);	dpdx := 2x - 8	The diff command differentiates an expression with respect to a variable.
int(p,x);	$\frac{1}{3}x^3 - 4\,x^2 + 15\,x$	The int command integrates an expression. Note that the constant of integration is left off.

subs(x=4,p); subs(x=t^2,p);	-1 $t^4 - 8t^2 + 15$	The subs command substitutes expressions into other expressions. Notice that p's value is unchanged.

Each of the commands listed here has many powerful, advanced features. See the help files for more information.

TIP Use the restart; command to unassign all variables, reset built-in variables (such as Digits) to their original values, and unload all packages. Of course, this should be used with care.

Creating your own Mathematical Functions

We have been working with expressions so far. Maple also supports the mathematical notion of a function. To define a function, you must specify a rule for going from one number to another. Consider the following commands:

f := x^2;	f := x^2	This defines f to be an abbreviation for the expression x^2.
f := x -> x^2;	f := x -> x^2	This defines f to be a function, such that f(x) = x^2.
f(3); f(t);	9 t^2	The function works as standard notation.

TIP A common mistake is to write f(x) := x^2;. This does not define a function. Instead, it makes the four characters on the left an abbreviation for the three characters on the right.

Functions are often more useful than expressions. However, many Maple commands (for example, diff) expect an expression as input. If f := x -> x^2, then diff(f,x); doesn't work. However, diff(f(x),x); will work, since f(x) produces the expression x^2.

To convert an expression into a function, use the unapply command.

p := x^3 + 1;

$p := x^3 + 1$

f := unapply(p, x); f(3);

$f := x \to x^3 + 1$

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Using packages

When you first load Maple, it knows how to execute several different functions. For example, we used the evalf and simplify functions without having to load them first. Maple comes with a *huge* number of other useful functions, bundled up in units known as packages. Maple has a modular design -- not all of

its functions are loaded at startup. The more specialized capabilities must be explicitly loaded.

For example, if you want to work with matrices and vectors, you would want to load the linalg package.

```
with(linalg);
```

The output from with is a list of the new commands that you now have access to. If you don't want to see the list (which can be rather long), use a colon as your end-of-line marker.

```
with(linalg):
```

Even if you use a colon, you may see warning messages. These usually indicate that a command has a new definition. In most cases, this should not be a concern.

Some Maple functions are not in packages; instead, they are stored in the older library format. For example, to add the multivarate Taylor series function, mtaylor, use the command

```
readlib(mtaylor);
```

Go exploring among the packages. These are some of the most commonly used packages:

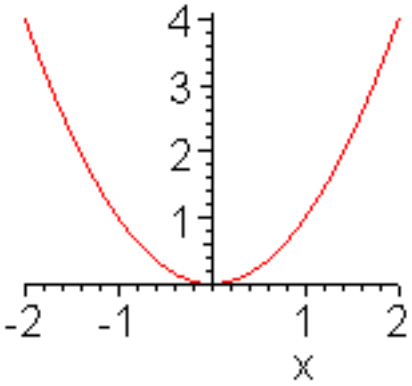
TIP

student	Includes commands for use in a classroom/homework setting.
plots	Tools for graphics, 3-d, animation, and visualization.
linalg	Matrices, vectors, and many linear algebra functions.
detools	Tools for working with ODEs and PDEs.

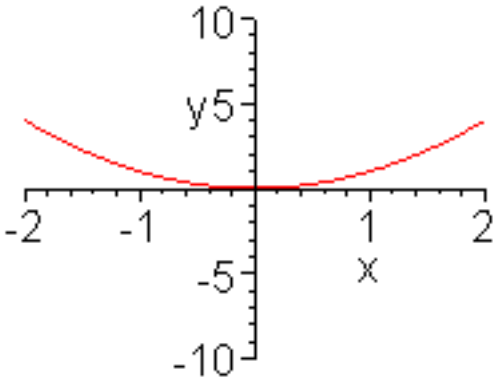
To get a comprehensive list of available packages, choose Help->Introduction, then browse to Mathematics->Packages->Overview.

Basic Plotting

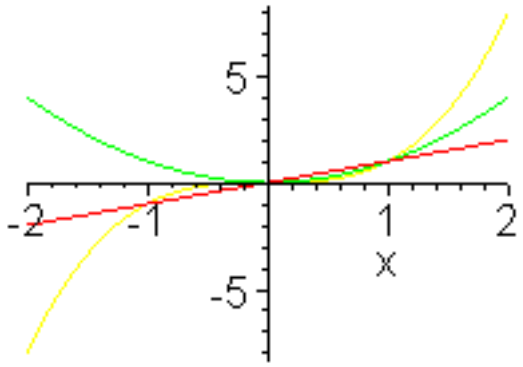
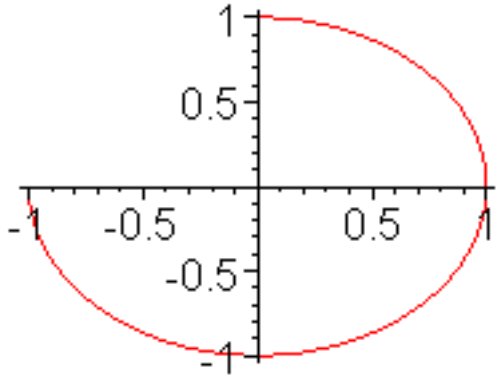
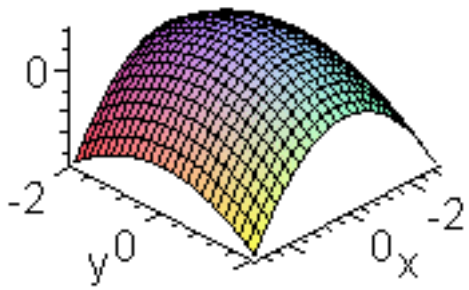
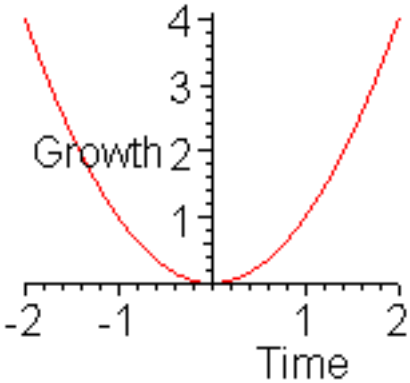
Maple can produce graphs very easily. Here are some examples, showcasing the basic capabilities.



plot(x^2, x=-2..2);
A basic plot.



plot(x^2, x=-2..2, y=-10..10);
A plot with vertical axis control.

 plot([x, x^2, x^3], x=-2..2); Plot multiple expressions by enclosing them in brackets.	 plot([sin(t),cos(t),t=0..3*Pi/2]); Parametric plots include the plotting range in the brackets.
 plot3d(4-x^2-y^2, x=-3..3, y=-2..2); A basic 3-d plot.	 plot(x^2, x=-2..2, labels=["Time","Growth"]); A basic plot, with axis labels.

You can control where plots are drawn by choosing Options->Plot Display->Inline or Window. Either way, if you select a plot with the mouse, you can use the toolbar to change the rendering style, axes, and lighting.

To copy a plot to the clipboard (as a graphics file), right-click (or Option-Click for Mac users) on the plot and select Copy.

Look into these commonly used plotting commands:

textplot, textplot3d	Draw text anywhere in a plot
display	Display several plots at once
animate, animate3d	Adds a dimension of time to your plot.
plotoptions	Various options, including line weight, color, sampling, etc.

Further Reading

For further guidance as a new user, try the tour. Choose Help->New User's Tour.

Other sources of information include:

- The UITS Knowledge Base
- UITS Education Program
- Software Manual Locations
- If you are affiliated with Indiana University, you may also get use Stat/Math Consulting .

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URL `/~statmath/math/maple/gettingstarted/printable.html`

Finding your way around the window

The Toolbar

First of all, locate the toolbar at the top of the window. On Windows, it looks like this:

Other operating systems have a similar toolbar.

Every time you work with maple, you will use a "worksheet". The worksheet is the big, blank area in the middle of the screen. You may have more than one worksheet open at a time. The following toolbar buttons let you work with the worksheet.

The first five buttons on the toolbar, in order, do the following: open a new, blank worksheet; open an existing worksheet; open a hyperlink; save the current worksheet; and print the current worksheet.

The next three buttons are the standard cut, copy, and paste functions.

The next two buttons let you "undo" and "redo" your last action.

The next three buttons let you manage what "mode" Maple is currently in. The standard mode is represented by the capital Sigma button. This means that anything you type will be considered to be mathematical input. If you click the capital T, Maple switches to Text mode. Anything you type will be considered as text commentary, and Maple won't try to treat it as math. To switch back to math input mode, click the [> button. Notice that the prompt in the worksheet window changes to let you know what mode you are in.

The next two buttons let you un-indent and indent lines in your worksheet.

The next button has a stop sign on it. It is used as a "panic" button. If you start a computation and you would like to stop, click the stop sign. (Cntl-C will also do this.)

The next three buttons control the amount of zoom.

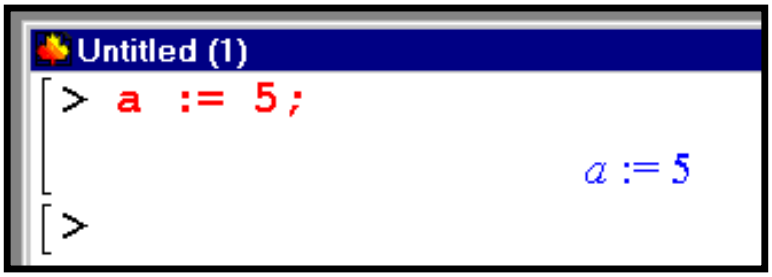
The next button displays non-printing characters in the worksheet.

The next button expands the active worksheet to fill the available space.

The last button clears all variables of their values. It is the same as typing the maple command
`restart;`

The Kernel

The kernel is the part of Maple that does the actual calculation. The kernel is invisible, but you do need to know about it. You talk to the kernel by typing mathematical statements and commands at the Maple prompt. Here is an example.



If you're using a graphics-enabled browser, you'll notice that input appears in red. Output from the kernel appears in blue, with variable names in italics.

The Maple prompt looks like [>.

The kernel will execute when you press the Enter key. The kernel decides what to execute by looking at the current *execution group*. An execution group is a set of input lines connected (along the left-hand margin) by a long, thin [. When you press Enter anywhere in the execution group, the entire group is executed. By default, each input line (along with its output) is an execution group unto itself. You can join execution groups together using the F4 key, or split them apart using the F3 key.

TIP Execution only occurs when you press the Enter key, or if you choose Edit->Execute->Worksheet. Execution *does not* occur when you open a worksheet.

Worksheets

The worksheet is the basic unit of work in Maple, like a document in a word processor. A worksheet stores every line of input *and* every line of output.

To save your worksheet, choose File->Save As.

To open a worksheet, choose File->Open.

You may have more than one worksheet open at a time. However, they all share the same kernel. So any work you do in one worksheet is accessible from another open worksheet. This can lead to confusing results.

Next: Help
Prev: Introduction
Up: Table of Contents

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URL `/~statmath/math/maple/gettingstarted/2.html`

Using the Help System

Maple has an extremely in-depth help system. To access it, choose Help -> Topic Search. Enter the word you are looking for (e.g., matrix) and you should see a list of topics. Clicking on one will open a "help browser", a window that lets you wander through related topics. We suggest that you "surf" the help system - casually browse, looking at anything that seems interesting. That way you will have some idea of what is available to you in the future.

If you know exactly what you need help on, you may also type (in Maple)

```
? simplify
```

(for example) to get help on the Maple command "simplify".

A very useful feature of the help system is the examples section. Use the Edit->Copy Examples menu command to copy the examples. Then switch to your worksheet (or open a fresh one) and use the Edit->Paste menu command. Now you can execute the examples, and experiment until you are comfortable with the commands.

Next: Maple Syntax
Prev: Finding Your Way Around
Up: Table of Contents

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Maple Syntax and Built-in Data Capabilities

Syntax

As with any computer language, Maple has its own syntax. As a new user of Maple, you can save yourself a lot of head-scratching if you get to know these symbols.

Enter the commands given or make up similar problems.

Symbol	Description	Examples	Sample Output
;	End-of-line. Tells Maple to process the line and show the output.	`hello;`	`hello`
:	End-of-line. Tells Maple to process the line and hide the output.	`hello:`	
:=	Assignment. Lets you assign values to variables.	`a := 3;` `a;`	`a := 3` `3`
+, -	Addition, subtraction.	`1 + 3;` `1 - 3;`	`4` `-2`

*, /	Multiplication, division	`3*412;`
		`1236/3;`
		`7/3;`
			`1236`
			`412`
			`7/3`

^, sqrt	Power, square root	`2^3;`
		`sqrt(2);`
		`2^(1/2);`
			8
			$\sqrt{2}$
			$\sqrt{2}$

evalf, .	Floating-point (decimal) evaluation	`evalf(7/3);` `7.0/3;`	2.333333333 2.333333333

I,Pi	Imaginary unit, Pi.	`2 + 3*I;`
		`(2*I)^2;`
		`evalf(Pi);`
			2+3I
			-4
			3.141592654

%, %%	Recall the last output, recall the second-to-last output, etc.	`%;` `%%%;`	3.141592654 -4

Some syntactical caveats:

- Maple is case sensitive. **foo**, **Foo**, and **FOO** are three different things.
- Maple requries you to show multiplication with the ***** character. Entering **x*y** gives the product of x and y, but entering **xy** gives one variable with the name xy.
- To get the constant e use **exp(1)**.
- Using the **%** operator can give confusing results. It always returns the last output from the Kernel, which may have nothing to do with where the cursor is (or which worksheet is active).
- If Maple doesn't recognize something, it will assume it is a variable. For example, typing **i^2** will give you i^2, while you may have wanted -1.
- You can move your cursor up to a previous line, press Enter, and the line will re-execute.
- When copying and pasting using a mouse, by sure to also highlight the execution group symbol ([). If you don't, the lines will be pasted in reverse order due to a bug.
- Spaces are optional.
- Greek letters may be entered by spelling their name. For example, **alpha** is always displayed as α, and **Gamma** is displayed as Γ (note upper-case).

Built-in Data Capabilities

Maple can handle arbitrary-precision floating point numbers. In other words, Maple can store as many digits for a number as you like, up to the physical limits of your computer's memory. To control this, use the **Digits** variable.

```
sqrt(2.0);
   1.414213562
Digits := 20:
sqrt(2.0);
   1.4142135623730950488
```

Maple sets Digits to be 10 by default. You can also temporarily get precision results by calling evalf with a second argument.

```
evalf(sqrt(2), 15);
   1.41421356237310
```

Large integers are handled automatically.

Next: Using Symbolic Computation (Variables)
Prev: Help
Up: Table of Contents

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URL /~statmath/math/maple/gettingstarted/4.html

Using symbolic computation

The main feature of Maple is symbolic computation. In other words, Maple does algebra. Here are some examples.

Example	Output	Comments
`(x + y)^2;`	$(x + y)^2$	A basic expression.
`k := x*y + y^2;`	$k := xy + y^2$	k is now an alias for the expression. Note that k is simply another name for the expression - they are not equal in the mathematical sense.
`p := k /(x+y);`	$p := \frac{x\,y + y^2}{x + y}$	You can now use k to refer to the expression. Maple immediately substitutes the value of k.
`k := 'k';`	k	You can unassign a variable by assigning it to its own name in single quotes.

`simplify(p);`	`y`	The **`simplify`** command does algebraic simplification.
`p := x^2 - 8*x +15;`	$p := x^2 - 8x + 15$	Maple doesn't mind if you re-use names. The old value is lost.
`solve(p=3,x);`	`2,6`	Use the **`solve`** command to solve equations. Note the use of the **`=`** sign. Here, it is used in a mathematical sense. Maple will try different values for x until it finds all of them that make the mathematical statement $x^2 - 8x + 15 = 3$ true.
`dpdx := diff(p,x);`	`dpdx := 2x - 8`	The **`diff`** command differentiates an expression with respect to a variable.
`int(p,x);`	$\frac{1}{3}x^3 - 4x^2 + 15x$	The **`int`** command integrates an expression. Note that the constant of integration is left off.
`subs(x=4,p);` `subs(x=t^2,p);`	`-1` $t^4 - 8t^2 + 15$	The subs command substitutes expressions into other expressions. Notice that p's value is unchanged.

Each of the commands listed here has many powerful, advanced features. See the help files for more information.

TIP Use the **`restart;`** command to unassign all variables, reset built-in variables (such as **`Digits`**) to their original values, and unload all packages. Of course, this should be used with care.

Next: Functions
Prev: Syntax
Up: Table of Contents

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URL `/~statmath/math/maple/gettingstarted/5.html`

Creating your own Mathematical Functions

We have been working with expressions so far. Maple also supports the mathematical notion of a function. To define a function, you must specify a rule for going from one number to another. Consider the following commands:

`f := x^2;`	$f := x^2$	This defines f to be an abbreviation for the expression x^2.
`f := x -> x^2;`	$f := x \to x^2$	This defines f to be a function, such that $f(x) = x^2$.
`f(3);` `f(t);`	9 t^2	The function works as standard notation.

TIP A common mistake is to write `f(x) := x^2;`. This does not define a function. Instead, it makes the four characters on the left an abbreviation for the three characters on the right.

Functions are often more useful than expressions. However, many Maple commands (for example, `diff`) expect an expression as input. If `f := x -> x^2`, then `diff(f,x);` doesn't work. However, `diff(f(x),x);` will work, since `f(x)` produces the expression x^2.

To convert an expression into a function, use the `unapply` command.

```
p := x^3 + 1;
```

$$p := x^3 + 1$$

```
f := unapply(p, x); f(3);
```

```
f := x -> x^3 + 1
28
```

Next: Using Packages
Prev: Symbolic Computation
Up: Table of Contents

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Using packages

When you first load Maple, it knows how to execute several different functions. For example, we used the **`evalf`** and **`simplify`** functions without having to load them first. Maple comes with a *huge* number of other useful functions, bundled up in units known as packages. Maple has a modular design -- not all of its functions are loaded at startup. The more specialized capabilities must be explicitly loaded.

For example, if you want to work with matrices and vectors, you would want to load the **`linalg`** package.

```
with(linalg);
```

The output from **`with`** is a list of the new commands that you now have access to. If you don't want to see the list (which can be rather long), use a colon as your end-of-line marker.

```
with(linalg):
```

Even if you use a colon, you may see warning messages. These usually indicate that a command has a new definition. In most cases, this should not be a concern.

Some Maple functions are not in packages; instead, they are stored in the older library format. For example, to add the multivarate Taylor series function, **`mtaylor`**, use the command

```
readlib(mtaylor);
```

Go exploring among the packages. These are some of the most commonly used packages:

student	Includes commands for use in a classroom/homework setting.
plots	Tools for graphics, 3-d, animation, and visualization.
linalg	Matrices, vectors, and many linear algebra functions.
detools	Tools for working with ODEs and PDEs.

To get a comprehensive list of available packages, choose Help->Introduction, then browse to Mathematics->Packages->Overview.

Next: Plotting
Prev: Functions
Up: Table of Contents

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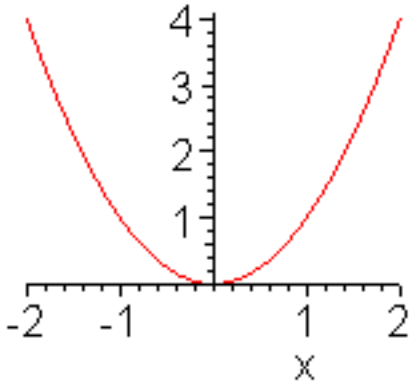
URL `/~statmath/math/maple/gettingstarted/7.html`

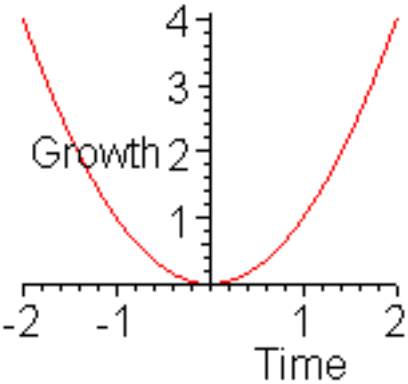
Basic Plotting

Maple can produce graphs very easily. Here are some examples, showcasing the basic capabilities.



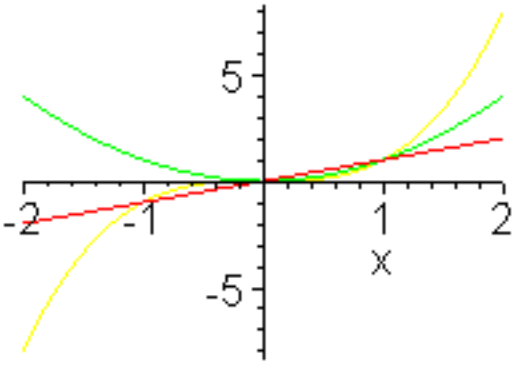
`plot( x^2, x=-2..2);`

A basic plot.



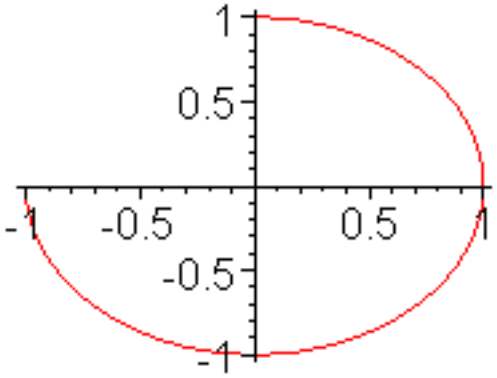
`plot( x^2, x=-2..2, y=-10..10);`

A plot with vertical axis control.



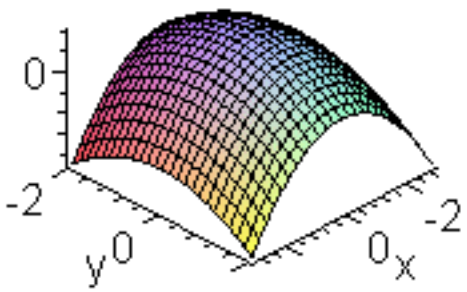
`plot([x, x^2, x^3], x=-2..2);`

Plot multiple expressions by enclosing them in brackets.



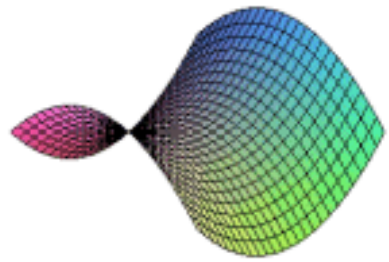
`plot([sin(t),cos(t),t=0..3*Pi/2]);`

Parametric plots include the plotting range in the brackets.



`plot3d(4-x^2-y^2, x=-3..3, y=-2..2);`

A basic 3-d plot.



`smartplot3d(x^2-y^2);`

Using smartplot to let maple set it's own scaling.

You can control where plots are drawn by choosing Options->Plot Display->Inline or Window. Either way, if you select a plot with the mouse, you can use the toolbar to change the rendering style, axes, and lighting.

To copy a plot to the clipboard (as a graphics file), right-click (or Option-Click for Mac users) on the plot and select Copy.

Look into these commonly used plotting commands:

`textplot`, **`textplot3d`**	Draw text anywhere in a plot
`display`	Display several plots at once
`animate`, **`animate3d`**	Adds a dimension of time to your plot.
`plotoptions`	Various options, including line weight, color, sampling, etc.

Next: Further Reading
Prev: Packages
Up: Table of Contents

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Further Reading

For further guidance as a new user, try the tour. Choose Help->New User's Tour.

Other sources of information include:

- The UITS Knowledge Base
- UITS Education Program
- Software Manual Locations
- If you are affiliated with Indiana University, you may also get use Stat/Math Consulting .

Prev: Plotting
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{VERSION 3 0 "IBM INTEL NT" "3.0" }
{USTYLETAB {CSTYLE "Maple Input" -1 0 "Courier" 0 1 255 0 0 1 0 1 0 0
1 0 0 0 0 }{CSTYLE "2D Math" -1 2 "Times" 0 1 0 0 0 0 0 0 2 0 0 0 0 0
0 }{CSTYLE "2D Output" 2 20 "" 0 1 0 0 255 1 0 0 0 0 0 0 0 0 0 }
{PSTYLE "Normal" -1 0 1 {CSTYLE "" -1 -1 "" 0 1 0 0 0 0 0 0 0 0 0 0 0
0 0 }0 0 0 -1 -1 -1 0 0 0 0 0 0 -1 0 }{PSTYLE "Heading 1" 0 3 1
{CSTYLE "" -1 -1 "" 1 18 0 0 0 0 0 1 0 0 0 0 0 0 0 }1 0 0 0 8 4 0 0 0
0 0 0 -1 0 }{PSTYLE "Maple Output" 0 11 1 {CSTYLE "" -1 -1 "" 0 1 0 0
0 0 0 0 0 0 0 0 0 0 0 }3 3 0 -1 -1 -1 0 0 0 0 0 0 -1 0 }{PSTYLE "" 11
12 1 {CSTYLE "" -1 -1 "" 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 }1 0 0 -1 -1
-1 0 0 0 0 0 0 -1 0 }{PSTYLE "Title" 0 18 1 {CSTYLE "" -1 -1 "" 1 18
0 0 0 0 0 1 1 0 0 0 0 0 0 }3 0 0 -1 12 12 0 0 0 0 0 0 19 0 }{PSTYLE "A
uthor" 0 19 1 {CSTYLE "" -1 -1 "" 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 }3 0
0 -1 8 8 0 0 0 0 0 0 -1 0 }}
{SECT 0 {EXCHG {PARA 18 "" 0 "" {TEXT -1 22 "Basic Algebra in Maple" }
}{PARA 19 "" 0 "" {TEXT -1 21 "Original by Dave Hart" }}{PARA 19 "" 0
"" {TEXT -1 24 "Updated by Clinton Wolfe" }}{PARA 0 "" 0 "" {TEXT -1
0 "" }}{PARA 0 "" 0 "" {TEXT -1 0 "" }}}{SECT 0 {PARA 3 "" 0 "" {TEXT
-1 29 "Basic Polynomial Manipulation" }}{EXCHG {PARA 0 "> " 0 ""
{MPLTEXT 1 0 27 "z:=(x+y)^2 + 9*(2+x)*(x+y);" }}{PARA 11 "" 1 ""
{XPPMATH 20 "6#>%\"zG,&*$),&%\"xG\"\"\"%\"yGF*\"\"#\"\"\"F**&,&F,F*F)F
*F*F(F*\"\"*" }}}{EXCHG {PARA 0 "" 0 "" {TEXT -1 632 "Here an algebrai
c expression has been typed. Maple reads in the\nstatement, assigns th
e right hand side to the variable z, and\n\"prettyprints\" it. The let
ters x, y, and z are here considered\nvariables; legal variables start
 with a letter and have at most 494\ncharacters. Examples of legal var
iable names are: g, G, new_term,\nx13a, and the_answer_is. Maple is ca
se sensitive, so the variables g\nand G are distinct. \n\nNotice also \+
that the line ends with a semicolon. All commands entered \nin Maple m
ust end in with a semicolon. If one is not entered at the \nend of the
 line, then Maple will wait for one to be entered on the \nnext line.
" }}}{EXCHG {PARA 0 "> " 0 "" {MPLTEXT 1 0 10 "expand(z);" }}{PARA 11
"" 1 "" {XPPMATH 20 "6#,,*$)%\"xG\"\"#\"\"\"\"#5*&F&\"\"\"%\"yGF+\"#6*
$)F,F'F(F+F&\"#=F,F0" }}}{EXCHG {PARA 0 "" 0 "" {TEXT -1 61 "This comm
and expanded the algebraic expression assigned to z." }}}{EXCHG {PARA
0 "> " 0 "" {MPLTEXT 1 0 4 "%^3;" }}{PARA 11 "" 1 "" {XPPMATH 20 "6#*$
),,*$)%\"xG\"\"#\"\"\"\"#5*&F(\"\"\"%\"yGF-\"#6*$)F.F)F*F-F(\"#=F.F2\"
\"$F*" }}}{EXCHG {PARA 0 "" 0 "" {TEXT -1 231 "Here, this command tell
s Maple to take the previous result and cube\nit. (The percent sign re
fers to the most recent result.) \nMaple does not expand the result. T
o see the\nmultiplication explicitly, the following command is issued:
 " }}}{EXCHG {PARA 0 "> " 0 "" {MPLTEXT 1 0 10 "expand(%);" }}{PARA
12 "" 1 "" {XPPMATH 20 "6#,N*$)%\"xG\"\"'\"\"\"\"%+5*&)F&\"\"&F(%\"yG
\"\"\"\"%+L*&)F&\"\"%F()F-\"\"#F(\"%IR*&)F&\"\"$F()F-F8F(\"%\"*>*&)F&F
4F()F-F2F(\"$$R*&F&F.)F-F,F(\"#L*$)F-F'F(F.*$F+F(\"%+a*&F1F(F-F(\"&!G<
&F7F(F3F(\"&%\\>&F<F(F9F(\"%-))*&F&F(F=F(\"%U7*$F@F(\"#a*$F1F(\"%?(*
&F7F(F-F(\"&K,$*&F<F(F3F(\"&w?$&F&F(F9F(\"&OE\"*$F=F(\"$s**$F7F(\"%K
e*&F<F(F-F(\"&'\\<*&F&F(F3F(Fgn*$F9F(Fen" }}}{EXCHG {PARA 0 "" 0 ""
{TEXT -1 68 "Notice that Maple does not list the elements in any speci
fic order. " }}}{EXCHG {PARA 0 "> " 0 "" {MPLTEXT 1 0 8 "sort(%);" }}
{PARA 12 "" 1 "" {XPPMATH 20 "6#,N*$)%\"xG\"\"'\"\"\"\"%+5*&)F&\"\"&F(
%\"yG\"\"\"\"%+L*&)F&\"\"%F()F-\"\"#F(\"%IR*&)F&\"\"$F()F-F8F(\"%\"*>*
&)F&F4F()F-F2F(\"$$R*&F&F.)F-F,F(\"#L*$)F-F'F(F.*$F+F(\"%+a*&F1F(F-F(
\"&!G<*&F7F(F3F(\"&%\\>*&F<F(F9F(\"%-))*&F&F(F=F(\"%U7*$F@F(\"#a*$F1F(
\"%?(**&F7F(F-F(\"&K,$*&F<F(F3F(\"&w?$*&F&F(F9F(\"&OE\"*$F=F(\"$s**$F7
F(\"%Ke*&F<F(F-F(\"&'\\<*&F&F(F3F(Fgn*$F9F(Fen" }}}{EXCHG {PARA 0 ""
0 "" {TEXT -1 52 "Use the \"sort\" command to see it in a prettier for
m." }}}{EXCHG {PARA 0 "> " 0 "" {MPLTEXT 1 0 10 "factor(%);" }}{PARA
11 "" 1 "" {XPPMATH 20 "6#*&),&%\"xG\"\"\"%\"yGF'\"\"$\"\"\"),(F&\"#5F
(F'\"#=F'F)F*" }}}{EXCHG {PARA 0 "" 0 "" {TEXT -1 195 "Here Maple fact
ors the previous result. Notice that the result does \nnot look like t

he expressions previously entered. Maple will not \nalways be able to \+
return an expression to its previous form." }}}}{SECT 0 {PARA 3 "" 0 "
" {TEXT -1 25 "Operations on Polynomials" }}{EXCHG {PARA 0 "> " 0 ""
{MPLTEXT 1 0 24 "integrate(x/(1-x^3), x);" }}{PARA 11 "" 1 ""
{XPPMATH 20 "6#,(-%#lnG6#,&%\"xG\"\"\"!\"\"F)#F*\"\"$-F%6#,(*$)F(\"\"#
\"\"\"F)F(F)F)F)#F)\"\"'*&-%%sqrtG6#F,F3-%'arctanG6#,$*&,&F(F2F)F)F)F7
F3#F)F,F)F+" }}}{EXCHG {PARA 0 "" 0 "" {TEXT -1 208 "Maple integrates \+
x/(1-x^3) with respect to x. Because any letter used\nin a Maple sessi
on is considered a variable, you must specify with\nrespect to what va
riable differentiation and integration should \noccur." }}}{EXCHG
{PARA 0 "> " 0 "" {MPLTEXT 1 0 11 "diff(%, x);" }}{PARA 11 "" 1 ""
{XPPMATH 20 "6#,(*&\"\"\"F%,&%\"xG\"\"\"!\"\"F(!\"\"#F)\"\"$*&,&F'\"\"
#F(F(F%,(*$)F'F/F%F(F'F(F(F(F*#F(\"\"'*&F%F%,&F(F(*$)F.F/F%#F(F,F*#!\"
#F," }}}{EXCHG {PARA 0 "" 0 "" {TEXT -1 16 "Differentiation." }}{PARA
0 "" 0 "" {TEXT -1 170 "The result is not exactly like the integrand, \+
but it is in a form \nsimilar enough to recognize that they are the sa
me expression. \nSimplification is a difficult problem." }}}{EXCHG
{PARA 0 "> " 0 "" {MPLTEXT 1 0 28 "series(exp(-x)*sin(2*x), x);" }}
{PARA 11 "" 1 "" {XPPMATH 20 "6#+/%\"xG\"\"#\"\"\"!\"#\"\"##!\"\"\"\"$
\"\"$\"\"\"\"\"%#!#>\"#g\"\"&-%\"OG6#F-\"\"'" }}}{EXCHG {PARA 0 "" 0 "
" {TEXT -1 269 "The command will find a series (either Taylor, Laurent
, or \ngeneralized) around the point x=0 if no value is given. General
ly, \nthe last term of the series will be the order term, where the or
der \nis decided by a global Maple variable which can be defined by th
e \nuser." }}}}}{MARK "2 6 0 0" 2 }{VIEWOPTS 1 1 0 1 1 1803 }

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- ACA'2002 to be held in Volos, Greece (June 25-June 28)
- ACA'2001 held in Albuquerque, New Mexico, USA (May 31-June 3) (electronic proceedings)
- ACA'2000 held in Saint Petersburg, Russia (June 25-28) (electronic proceedings)
- ACA'99 held in El Escorial, Spain (June 24-27) (electronic proceedings)
- ACA'98 held in Prague, Czech Republic (August 9-11) (electronic proceedings)
- IMACS-ACA'97 held in Wailea, Maui, Hawaii, USA (July 24-26) (electronic proceedings)
- IMACS-ACA'96 held at RISC, Linz, Austria (July 17-20)
- IMACS-ACA'95 held in Albuquerque, New Mexico, USA (May 16-19) (electronic proceedings)

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Upcoming Computer Algebra Conferences

For more information on symbolic computing or computer algebra, consult the Computer Algebra Nederlands WWW server and the SymbolicNet directory at Kent State. For more information on computer algebra in education, consult the Computer Algebra Systems in Education (CASE) Newsletter page.

Stanly Steinberg (stanly@math.unm.edu) & Michael Wester (wester@math.unm.edu)

Here's an index to some recent and some older papers. A number of them have appeared in Proceedings of the International Symposium on Symbolic and Algebraic Computation (ISSAC), an annual conference usually co-sponsored by the Association for Computing Machinery's Special Interest Group on Symbolic and Algebraic Manipulation (SIGSAM), along with other cooperating organizations. If you wish to refer to material listed here that is not specifically marked as published, send me a note so I can tell you its current status.

Rough drafts of two papers concerning code-generation from mathematical program descriptions are stored here: Compiling functional pipe/stream abstractions into conventional programs: Software Pipelines Code generation: evaluating polynomials

Richard Fateman and Eylon Caspi: Parsing TeX into Mathematics, presented at a poster session at ISSAC-99 in Vancouver. Powerpoint slides for it are available as well. or look at this html slides for it are available as well.

Richard Fateman and Timothy James: Analysis of a Web User Interface for Mathematics: Experiences with Integral Queries for TILU (Table of Integrals Look Up) , was presented at Workshop on Internet Accessible Mathematical Computation at ISSAC-99. See the powerpoint slides for a somewhat different presentation that is based loosely on the paper but shows more recent statistics and also discusses what we hope to do next,

Richard Fateman: Network Servers for Symbolic Mathematics, ISSAC-97, Hawaii July, 1997.

Richard Fateman: A review of the CD ROM version of the 5th edition of the Gradshteyn and Rhyzik Table of Integrals and Series. This is a (mostly negative) review of the technological transformation of a book to an electronic form. It could have been much better. I sent this to the SIGSAM Bulletin. There is in fact another version being put together by Daniel Zwillinger, taking into account some of the issues raised in the review.

My current views of what computer algebra systems should do for problem solving environments appears in this paper recently (1999) revised for a book-length collection of PSE papers edited by E. Houstis and published by Kluwer Problem Solving Environments and Symbolic Computation .

Here's a paper on the use of symbolic execution for diagnostics, and a kind of shortcut implementation using the "Not a Number" or NaN operands in IEEE 754 standard binary floating-point numbers: Symbolic Execution and NaNs: Diagnostic Tools for Tracking Scientific Computation. After sitting around for 8 years or so, this was presented as a poster at ISSAC-99. See the powerpoint slides for a somewhat different presentation that arose as I was reviewing the paper for presentation.

Here's a paper on some work showing how one might incorporate (for example) David H. Bailey's

MPFUN multiprecision floating point package into Lisp: Importing Pre-packaged Software into Lisp: Experience with Arbitrary-Precision Floating-Point Numbers}. This will be presented as a poster at ISSAC-2000 (St. Andrews, Scotland UK, August, 2000).

Why Computer Algebra Systems Can't Solve Simple Equations ACM SIGSAM Bulletin. vol. 30, no. 2, June 1996, Issue 116, 8-11.

Richard Fateman and Mark Hayden: Speeding up Lisp-based Symbolic Mathematics ACM SIGSAM Bulletin. vol. 30 no. 1 (issue 115) March, 1996 25-30.

A survey of Symbolic Mathematics System Evaluators appears in Proceedings ISSAC-96. Actually, this on-line version is 16 pages long and contains about twice as much material as was permitted for publication in the Proceedings. A newer (longish) version appears as a chapter in Michael Wester's ``Computer Algebra Systems" published by Wiley, 1999.

Ted Einwohner and Richard Fateman: Searching Techniques for Integral Tables appeared in ISSAC-95.

H-C (Phil) Liao and Richard Fateman: Evaluation of the Heuristic Polynomial GCD appeared in ISSAC-95.

Richard Fateman, Kevin A. Broughan, Diane K. Willcock, and Duane Rettig: Fast Floating-Point Processing in Common Lisp appeared in ACM Trans. on Math. Software, vol 21 no. 1, March 1995, 26-62.

Adam Dingle and Richard Fateman: Branch Cuts in Computer Algebra appeared in ISSAC-94.

Benjamin Berman and Richard Fateman: Optical Character Recognition for Typeset Mathematics appeared in ISSAC-94.
But you might prefer the longer, more recent, and more polished paper (with Taku Tokuyasu, Benjamin P. Berman, and Nicholas Mitchell) Optical Character Recognition and Parsing of Typeset Mathematics. that appeared Journal of Visual Communication and Image Representation vol 7 no. 1 (March 1996), pages 2-15. (This is the version as sent to them.) They re-typeset it by hand.

In 1993 I attended a conference on problem solving environments (3rd IMACS International Conference on Expert Systems for Numerical Computing), and wrote a paper for that, relating computer algebra to such matters. In my view, researchers "selling" Problem Solving Environments, and the people "buying" for them (i.e. the funding agencies) are not particularly matched up with a commitment to computer algebra. I think they would rather spend money on the nearly infinite sink of parallel computing. Anyway, the paper has continued to grow and change. I've sent it to various places for publication, but so far no one has been so keen on it as to publish it. Frankly, there are lot of small neat ideas that can and

should be adopted by a problem solving environment. There are no revolutionary general ideas that have emerged. That is not to say that there are no really good specific ideas for particular tasks. Anyway, you can read a version of it as Problem Solving Environments and Symbolic Computing. And as previously noted, a more concise and recently updated version of some of the ideas, plus some new ones, appears in the Excerpts from a proposal to the National Science Foundation on Programming Environments and Tools for Advanced Scientific Computation .

Here's a paper that influenced the Macintosh graphing program that comes with every PowerPC based system. This paper, Honest Plotting, Global Extrema, and Interval Arithmetic appeared in ISSAC-92.

A serious critique of Mathematica appears in Review of Mathematica from the J. of Symbolic Computation (13, no. 5, May 1992) in its postscript form (instead of html), Although it is now quite a few years old (especially for a paper about a computer program that continues to evolve), I think a careful reading shows that the broad comments are still valid.

Some people (Dec '96) on sci.math.symbolic have expressed interest in computing with 1/0. Here is a (previously) unpublished paper by R. Fateman and Tak W. Yan from 1994 that discusses such things: Computing with the Extended Rational Numbers.

Here's a link to A Lisp-language Mathematica-to-Lisp Translator, a paper which first appeared in SIGSAM Bulletin 24, no. 2 p 19-21 (April, 1990). It ws also reprinted in Computer Algebra Nederland Nieuwsbrief 6, October, 1990.

On the Design and Construction of Algebraic Manipulation Systems contrasts computer algebra system building approaches as prototype/hacker vs. mathematical-hierarchy approach. Some people feel I've maligned their systems in this paper because the anomalies I report have since been fixed. This was an invited paper presented at ISSAC-90 (Tokyo). The posted text is based on a slightly revised version presented to an American Society of Mechanical Engineers annual conference. The mini-proceedings, which by the way is an excellent collection of application articles, was edited by A.K. Noor, I. Elishakoff, G. Hulbert, and appears as Symbolic Computations and their Impact on Mechanics, PVP Vol. 205, Amer. Soc. of Mech. Eng. 1990.

Series solutions of algebraic and differential equations is an ISSAC '91 paper that discusses Newton and Hensel iteration in the solution of parameterized algebraic and differential equations. Newton (quadratic) convergence is only marginally faster than Hensel (linear) convergence because the Hensel iteration takes much less time per step.

Improving Exact Integrals From Symbolic Algebra Systems is a paper with W. Kahan that appeared as technical report PAM 386, (1986) of the Center for Pure and Applied Mathematics University of California, Berkeley, The paper has changed since that time, but is in some respects still a work in progress. This will be presented as a poster at ISSAC-2000 (St. Andrews, Scotland UK, August, 2000)

Symbolic Computation of Divided Differences is a rather old paper (circa 1985, but with parts from circa 1975) with W. Kahan that has not appeared in print. I recently successfully converted it to PDF.

Computer Algebra Benchmarks

Benchmark Initiative, Computer Algebra Fachgruppe of GI, DMV and GAMM

Abstract:
The initiative will discuss, develop, define, collect all facettes of this challenging problem. It should analyse and develop test suites but also define standard examples for the various topics of computer algebra where algorithm and system developer can test their newly developed and improved methods. Furthermore, all kinds of test examples should be collected and consolidated.

- Directory of Activities (new)
- Slides of the Meeting at ISSAC'98

Computer Algebra Benchmarks Collection from July 1998.

The CASBENCH Computer Algebra Benchmarks, a proposal from 1995 for the beginning of some computer algebra benchmarking, discussed by the Computer Algebra Fachgruppe.

More Links:

Additional Computer Algebra WWW Pages

CAIS der Computeralgebra Fachgruppe

This servers homepage

Heinz Kredel, e-mail: kredel@rz.uni-mannheim.de

Last modified: Mon Jun 28 16:50:34 MEST 1999

A Critique of the Mathematical Abilities of CA Systems

This article can be found in *Computer Algebra Systems: A Practical Guide* (1999).
A PostScript version of the article (last revised January 4, 1999) [40 pages].

An earlier review of the same ilk is A Review of CAS Mathematical Capabilities. Also see a Comparison of Polynomial-Oriented Computer Algebra Systems for some timing studies.

Results:

Boolean Logic and Quantifier Elimination
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Set Theory
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Numbers
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Numerical Analysis
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Statistics
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Combinatorial Theory
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Number Theory
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Algebra
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Trigonometry
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Special Functions
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
The Complex Domain
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Determining Zero Equivalence
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Equations
Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce
Inequalities

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Vector Analysis

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Matrix Theory

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Tensor Analysis

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Sums

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Products

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Limits

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Calculus

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Indefinite Integrals

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Definite Integrals

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Series

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Transforms

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Axiom,

Ordinary Difference and Differential Equations

Axiom, Derive, Derive (ODE), Macsyma, Maple, Mathematica, MuPAD, Reduce

Partial Differential Equations

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce (Heat equation)

Operators

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Programming and Miscellaneous

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce (differentiation)

Mathematics vs Computer Science

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce (local variables)

Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD, Reduce (matching)

A one-page table of CAS synonyms.

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Helmer Aslaksen, ``Multiple-valued complex functions and computer algebra", *SIGSAM Bulletin*, Volume 30, Number 2, June 1996, 12-20. (original)

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Richard J. Fateman, ``Symbolic Mathematics System Evaluators", *Proceedings of the 1996 International Symposium on Symbolic and Algebraic Computation*, 1996, 86-94. (original)

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Dominik Gruntz, *On Computing Limits in a Symbolic Manipulation System*, Ph.D. dissertation, Swiss Federal Institute of Technology, Zürich, Switzerland, Diss. ETH No. 11432, 1996. (original)

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W. Hereman, ``Review of Symbolic Software for the Computation of Lie Symmetries of Differential Equations", *Euromath Bulletin*, Volume 1, Number 2, 1994, 45-79.

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Wolfram Koepf, ``Efficient Computation of Orthogonal Polynomials in Computer Algebra", Konrad-Zuse-Zentrum für Informationstechnik Berlin (ZIB), Preprint SC 95-42, December 1995.

(original)

[Pos96]
Frank Postel and Paul Zimmermann, ``A review of the ODE solvers of Axiom, Derive, Macsyma, Maple, Mathematica, MuPAD and Reduce", submitted to the 5th Rhine Workshop on Computer Algebra to be held in Saint-Louis, France, April 1-3, 1996. (original)

[Rob93]
Nicolas Robidoux, ``Does Axiom Solve Systems of O.D.E.'s Like Mathematica?", LA-UR-93-2235, Los Alamos National Laboratory, Los Alamos, New Mexico, 1993.

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Barry Simon, ``Comparative CAS Reviews", *Notices of the American Mathematical Society*, Volume 39, Number 7, September 1992, 700-710.

[Sim95]
Barry Simon, ``Symbolic Math Powerhouses", *Desktop Engineering*, Volume 1, Issue 1, September/October 1995, 42-51.

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Paul Zimmermann, ``Wester's test suite in MuPAD 1.2.2", *Computer Algebra Nederland Nieuwsbrief*, Number 14, April 1995, ISSN 1380-1260, 53-64. (original)

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Paul Zimmermann, ``Wester's test suite in MuPAD 1.3", *The SAC Newsletter*, Number 1, December 1996, 53-69. (original)

See also the page on Computer Algebra Performance as well as the CAIN and Symbolic Net repositories.

Several of the above papers were presented in the ACA'96 session on *Comparative CAS Reviews and Philosophy*.

Michael Wester's home page

Computer Algebra and Problem Solving Environments

Stanly Steinberg (stanly@math.unm.edu)

in *Comparative CAS Reviews and Philosophy*, organized by Michael Wester

Abstract:

Problem Solving Environments provide a promising new approach for solving modeling problems that occur in engineering and science [1]. Such environments will provide easy access to integrated symbolic and numeric computing and this will greatly enhance the tools available to modelers. However, this will place new demands on computer algebra systems.

1. It is important to have a true paper and pencil system. Such systems will not assume that the user wishes to compute something, but that the user wishes to reason about some problem and then, possibly later, either compute something numerically or symbolically. The attitude of "I know the chain rule and will use it if I can" must be replaced by a system that can apply the chain rule in the standard way, or apply it in reverse, and have tools for helping decide which is appropriate. Clearly, heuristic reasoning systems are critical.
2. Computer algebra systems should be able to write both numerical and symbolic programs in their own language. It will then be a relatively simple matter to translate such programs to other languages. In some sense this can be done in all CASs, but the available utilities are not helpful. This will be illustrated by some work the author is doing on a problem solving environment called SciNapse.
3. The geometric parts of modeling problems are typically the most difficult and the most expensive, so the problem solving environment must contain, or have access to, a geometric modeler. Then, at least for simple problems, it should be possible to answer simple questions like, is a given region convex? It should always be possible to compute an integral of some function over the region being considered and to apply Stokes' theorem to the region.
4. There still are important basic algorithms that are missing from CASs, for example, quantifier-elimination algorithms. Fast "approximate" algorithms are critically needed. Good "approximate" algorithms for simplifying polynomial inequalities are desperately needed (these are special QE algorithms).
5. The are numerous advanced applied mathematics areas that are poorly represented in CASs. For example, in the early part of this century, mathematicians and physicists built an algebraic theory for analysis: the theory of Hilbert and Banach spaces. The fact that this theory is algebraic (and geometric) implies that it should be easy to implement in a CAS system, but then there is the question of convergence.
6. The online documentation should allow the user to look up any term commonly used in mathematics textbooks and find all relevant information in the system. This doesn't mean a list of

commands available.

Some things that are done pretty well now are the basic symbolic algorithms, particularly for multivariate polynomials, integrals, and ordinary differential equations, notebook interfaces, equation display, graphics, and inter-program communication.

[1] Future Research Directions in Problem Solving Environments for Computational Science, E. Gallopoulos, E. Houstis, J.R. Rice, 1991.

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Topics in Mathematics

Teaching materials, software, WWW links organized by Mathematical Topics. Searchable database.

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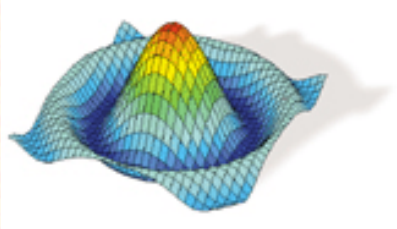

the popular symbolic algebra program.

Math software should be useful and thought- provoking as well as an aid to the teacher who wants to challenge students. Derive 5, Mathematica, Mathpert Plus, and Scientific Notebook represent creative and intelligently designed software that can be used to learn algebra, trig, pre-calculus, and calculus.

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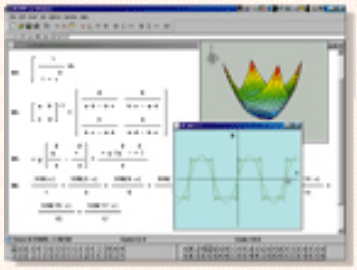

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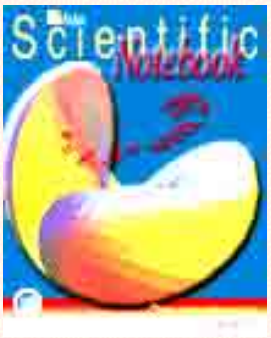

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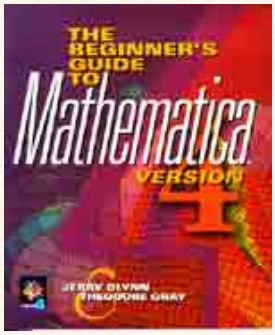

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May 2002: Magma version 2.9 is ready for export. See Release Notes 2.9 for the release notes.

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---

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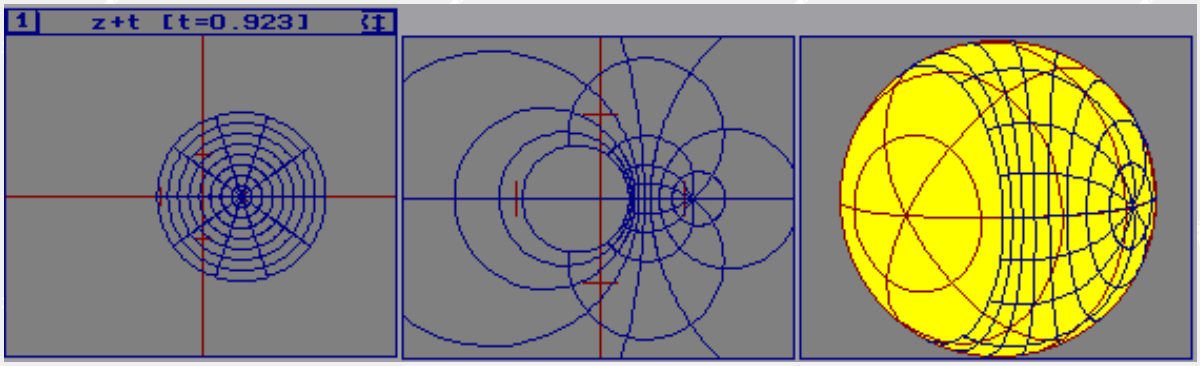

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f(z) and the literature. See a list of Complex Variables textbooks that refer to f(z).

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Logic Software from CSLI

By Jon Barwise and John Etchemendy

Prospective Users

The award-winning text/software packages described here -- **Hyperproof, The Language of First-order Logic, Tarski's World** and **Turing's World** -- are all published by the Center for the Study of Language and Information and distributed by Cambridge University Press. Click here for ordering information.

new We also have an exciting text/software package for use in introductory logic courses. **Language, Proof and Logic** is published by CSLI Publications, where individual or examination copies may be ordered.

Current Users

If you already own any of these packages, click here for up-to-date version information and other information of interest to current users. We welcome your comments, suggestions or questions.

new Turing's World users: There's a new six-state Busy Beaver candidate.

new We also have a text/software package for use in introductory logic courses. **Language, Proof and Logic** is published by CSLI Publications, where individual or examination copies

may be ordered.

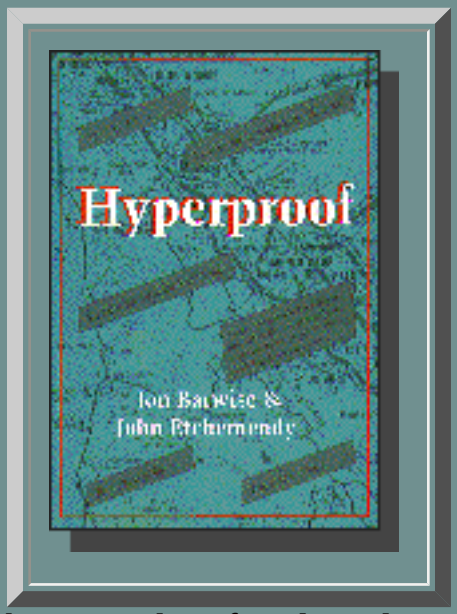
Educom Medal

Barwise and Etchemendy were awarded the 1997 Educom Medal for the innovative software described on this page. A description of the Educom Medal Awards Program is available at the EDUCAUSE site, created by the 1998 consolidation of CAUSE and Educom.

Paper Available

If you would like to read a 1996 paper by Barwise and Etchemendy explaining why they developed this software and how it has changed their view of logic, check out "Computers, Visualization, and the Nature of Reasoning." You will need Adobe's Acrobat Reader to read this file.

Hyperproof



Hyperproof is a system for learning the principles of analytical reasoning and proof construction, consisting of a text and a Macintosh software program. Unlike traditional treatments of first-order logic, Hyperproof combines graphical and sentential information, presenting a set of logical rules for

integrating these different forms of information. This strategy allows students to focus on the information content of proofs rather than the syntactic structure of sentences. It also reflects the heterogeneity of information encountered in everyday reasoning.

Using **Hyperproof** the student learns to construct proofs of both consequence and non-consequence using an intuitive proof system that extends the standard set of sentential rules to incorporate information represented graphically. Proofs of consistency and inconsistency are also covered as well as independence proofs. The **Hyperproof** software checks the logical validity of each type of proof.

Hyperproof is compatible with various natural-deduction-style proof systems, including the system used in the authors' **The Language of First-order Logic.**

> "**Hyperproof** is wonderful! With it you can construct and check proofs in an expanded version of the language of **Tarski's World**. And there is more, much more, another whole dimension. **Hyperproof** lets you use pictorially-presented information and pictorially-oriented deduction techniques, in combination with sentences and syntactic rules, to reason about its block worlds. It is an extraordinarily impressive programming achievement. **Hyperproof** will make learning first-order logic enormously more fun." --Carl Ginet, Cornell University

Hyperproof is designed to be used in a first course in logic. Since it presupposes familiarity with the program **Tarski's World** , it should be used in tandem with either the textbook **The Language of First-order Logic** or the stand-alone version of **Tarski's World** (**Tarski "Lite"**). **Hyperproof** is currently available only for the Macintosh.

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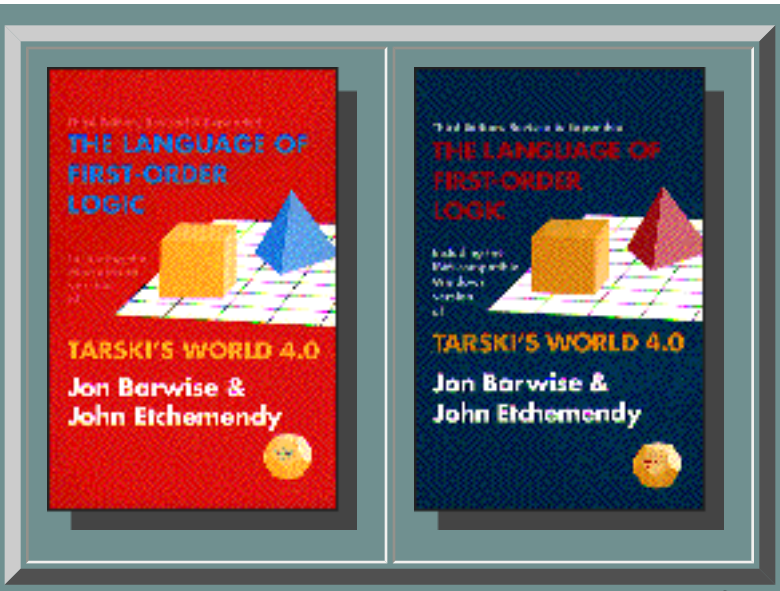
The Language of First-order Logic (Mac or PC)



The Language of First-order Logic presents a new approach to teaching first-order logic. Taking advantage of the accompanying program **Tarski's World,** the text skillfully balances the semantic conception of logic with methods of proof. The book contains eleven chapters, in four parts. Part I is about propositional logic and Part II covers quantifier logic. Part III contains chapters on set theory and inductive definitions. Part IV contains advanced topics in logic, including topics of importance in applications of logic in computer science. **The Language of First-order Logic** contains hundreds of problems and exercises.

An instructor's manual and instructor's disk are available to accompany this book. The instructor's manual, written by Ruth Eberle, provides a wealth of material to make grading exercises and teaching from the text easier. The instructor's disk allows you to grade most of the **Tarski's World** problems automatically, directly off the student's disks. It is possible to grade both IBM PC and Macintosh disks using the Macintosh version of the program.

> "[**The Language of First-order Logic**] is packed with interesting exercises and problems which make imaginative use of [**Tarski's World**]. This is an excellent package and we recommend it highly as the basis of either a complete first course in logic or as an initial part of such a course." --Doug Goldson, Steve Reeves and Richard Bornat, University of London
>
> **"The Language of First-order Logic** and **Tarski's World** redress one of the main shortcomings of traditional beginning-level logic texts which emphasize the formal aspects of logic and pay scant attention to semantics. **Tarski's World** sets a high standard for those who follow." --Kevin Compton, Journal of Symbolic Logic.
>
> "The emphasis throughout is on the user doing logic by working the many problems in the text. Recommended unreservedly as a fascinating approach to a fascinating subject." --R. J. Wernick, Choice

The Language of First-order Logic comes packaged with the program **Tarski's World.** Since

Hyperproof uses an extension of the natural-deduction-style proof system taught in **The Language of First-order Logic,** it can be used to accompany this text. **The Language of First-order Logic** is available in versions for Macintosh and Microsoft Windows. A version of the software for computers running NeXTstep is also available. To receive it, purchase a copy of either the Macintosh or Windows version and follow the instructions contained in the book.

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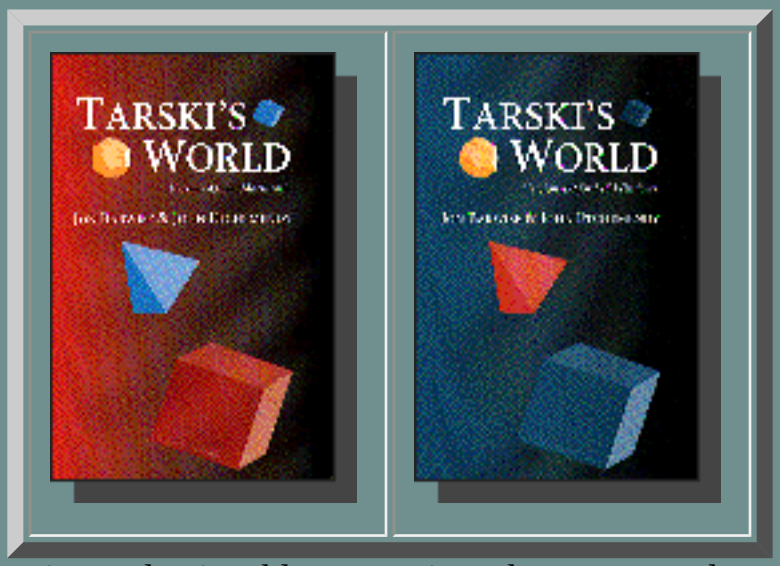
Tarski "Lite" (Mac or PC)



Tarski's World is an innovative and enjoyable way to introduce your students to the language of first-order logic. Using this program students quickly master the meaning of the connectives and quantifiers, and soon become fluent in the symbolic language at the core of modern logic. **Tarski's World** allows the students to build three-dimensional worlds and to describe them in first-order logic. They evaluate the sentences in the constructed worlds and if their evaluation is incorrect, the program provides them with a game that leads them to understand where they went wrong.

Tarski's World is available in two ways, either alone (called **Tarski's World 4.0** or **Tarski "Lite"**) or as part of the logic textbook/software package called **The Language of First-order Logic.**

Tarski "Lite", the stand-alone package, is intended as a supplement to any standard logic text or for use

by anyone who wants to learn the language. The disk and manual contain over a hundred exercises from very basic to highly sophisticated.

> "If you have had a small amount of experience with a Macintosh and enjoy logical matters, then you will almost certainly enjoy using (or just playing with) this software for the Mac." --George Boolos, Journal of Symbolic Logic

> "The authors are pioneers. [**Tarski's World**] is the only program that I know for teaching first-order semantics, and it sets a high standard. I warmly recommend it." --Wilfrid Hodges, Queen Mary College

Tarski "Lite" is available for Macintosh or Microsoft Windows. A version of the software for computers running NeXTstep is also available. To receive it, purchase a copy of either the Macintosh or Windows version and follow the instructions contained in the book.

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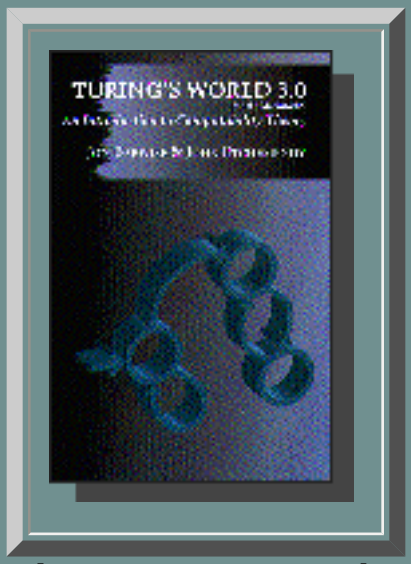
Turing's World



Turing's World is a self-contained introduction to Turing machines, one of the fundamental notions of logic and computer science. The text and accompanying diskette allow the user to design, debug, and run sophisticated Turing machines in a graphical environment on the Macintosh.

Turing's World introduces users to the key concepts in computability theory through a sequence of over 100 exercises and projects. Within minutes, users learn to build simple Turing machines using a convenient package of graphical functions. Exercises then progress through a significant portion of elementary computability theory, covering such topics as the Halting problem, the Busy Beaver function, recursive functions, and undecidability.

Version 3.0 is an extensive revision and enhancement of earlier releases of the program, allowing the construction of one-way and two-way finite state machines (finite automata), as well as nondeterministic Turing and finite-state machines. Special exercises allow users to expore these alternative machines.

> "**Turing's World** is a delight.... I heartily recommend [it]." --James Moor, Teaching Philosophy
>
> "**Turing's World** quite literally revolutionizes the way the fundamental theoretical issues of computing can be taught." --Keith Devlin, The Guardian
>
> "There is not the slightest hint of jargon anywhere in [**Turing's World**]. The explanations are so direct that a beginner will understand them and an old hand will enjoy them." --Wilfrid Hodges, Queen Mary College
>
> "The program and manual are the best introduction to Turing machines the reviewer knows of, or can imagine." --George Boolos, Journal of Symbolic Logic

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John Etchemendy (left) and Jon Barwise (right)

Jon Barwise is a professor of philosophy, mathematics, and computer science at Indiana University in Bloomington. His email address is barwise@cs.indiana.edu.

John Etchemendy is a professor of philosophy and symbolic systems at Stanford University. His email address is etch@csli.stanford.edu.

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The Math archive has been removed from wuarchive.

Please go to the source, which is up-to-date:
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Saturday, February 23, 2002
-dpd (David P. Discher)

Return-Path:
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Subject: Re: Mathematics Archives at WUARCHIVE.wustl.edu
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David-

Yes, this is quite out of date. You can remove the mirror.

Best,
Larry

On Sat, 23 Feb 2002, David P. Discher wrote:

>
>
> It appears that the "Mathematics Archives" has a mirror at
> wuarchive.wustl.edu at the following URL:
>
> ftp://wuarchive.wustl.edu/edu/math/
>
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>
> I would ideally like to remove this mirror as it seems like you may already
> have suitable hosting resources. Please advise our your current use of
> wuarchive and needs.
>
> Thank you.
>
> -- ********** --
> | David P. Discher * (314) 518-3795 * |
> | * AOL/MSN: "DavidDPD" * ICQ:4222899 |
> -- ********** --

>
>

--

Larry Husch phone: 865-974-4162 fax: 865-974-6576
Mathematics Department
University of Tennessee Co-Director, Mathematics Archives
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Downloadable Software:

Part of the mission of the Geometry Center is to develop software tools to support the computation and visualization of mathematics. A considerable portion of the Center's efforts have gone to designing such tools, and to making them available to the mathematical and scientific communities, and to the world at large.

With the exception of WebEQ, the packages listed below may be obtained free of charge, but, unless otherwise stated, are subject to our copyright statement. A free evaulation copy of WebEQ is available, but it is commercial software, and is subject to its own licensing terms.

Binaries can be downloaded for the architectures listed in parentheses.

Main Attractions:

- **WebEQ 2.2**: Full-featured Java software suite for creating and displaying interactive math equations. The most powerful, complete MathML implementation available. *(Win 95/NT, MacOS, most Unix)*
- **HTML2LaTeX**: A Perl script that converts an HTML file (with WebEQ applets) into a LaTeX2e file. *(source)*

- **Geomview**: 3D object viewer *(SGI, Sun, NeXT, HP, Linux, IBM RS/6000, Dec Alpha, source)*
- **StageTools**: Geomview animation tools *(TCL/TK code and documentation for Geomview external modules)*

  For an interactive use of a Java version of Geomview, go to ScienceU

- **Orrery**: Solar System Visualizer *(requires Geomview)*

  For an interactive web Orrery, Night Sky planetarium and more, go to ScienceU

- **Evolver**: Surface evolver *(unix, Mac, Windows, DOS, source)*
- **Snappea**: Hyperbolic manifold analyzer *(Mac, OS/2, Win95)*
- **qhull**: Computes convex hulls, Delaunay triangulations, Voronoi diagrams, and halfspace intersections *(source, Win32, Mac)*

- **KaleidoTile:** Creates tilings of the sphere, plane, or hyperbolic space *(SGI, Mac)*
- **Kali:** 2D symmetry pattern editor *(Java/source, Mac binaries, SGI source/binary)*

For more about tilings and symmetry, go to ScienceU

- **IDVI:** Java DVI viewer *(java, source)*
- **W3Kit:** World-Wide Web application builder *(SGI, Sun, source)*
- **WebOOGL:** Integrates 3D graphics with the World-Wide Web *(SGI,Sun,source)*
- **Mpeg_play:** Animation player *(SGI, Sun, HP, Dec Alpha)*

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Directory of Computational Geometry Software on the Web
A Brief Guide to Tiling Software on the Web

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Comments to: webmaster@geom.umn.edu
Created: Feb 27 1995 --- Last modified: Tue Apr 28 00:00:11 1998

Fermat

Above graphic created with the float version of Fermat.

(For best viewing, set your monitor to at least thousands of colors.)

Fermat is a computer algebra system for Macintosh and Windows by me, Robert H. Lewis of Fordham University, that does arithmetic of arbitrarily long integers and fractions, symbolic calculations, matrices over polynomial rings, graphics, and other numerical calculations. It is extremely fast and extremely economical of space. The main version that I care most about is oriented toward polynomial and matrix algebra over the rationals **Q**and finite fields (hence the name "QFermat"). On the Mac side, there are versions that run under MPW for 68K Macs and stand-alone versions for PPC. There is also a "float" version for graphics. All versions are available here.

Fermat is a state-of-the-art research tool for real problems.

See for example:

NEW Compare Your Computer Algebra System. Take the Fermat Tests!

There are now three tests. One test involves evaluation of rational functions, the second involves Smith Normal Form, the third resultants.

NEW Fermat Very Impressive in Comparison of Computer Algebra Systems

Look at this preprintof a comparison of small polynomial-oriented computer algebra systems. This paper appeared in the SIGSAM Bulletin in January 2000.

NEW New HTML and PDF Versions of the Manuals

There are revised (January 20, 2002) HTML versions of the QFermat manual, for both Windows and Mac, and of the FFermat manual (FFermat, the float version, is Mac only). In addition, there are revised pdf versions of the manuals. See below.

NEW Version 2.6.4 is here, January 20, 2002. Improved Polynomial gcd algorithms. Excellent interface for Windows.

Fermat version 2.0 was a major overhaul (click here to see the changes that were made then, in February 1998). The 2.2 revision for both Mac and Windows had vastly improved Smith Normal Form procedures. The graphics version added color graphics capabilities. 2.4 added new matrix functions for large powers and LU decompositions. 2.5.x speeds up rational number arithmetic and integer division. 2.6.0 has massive revisions and new features, mostly concerning sparse arrays. New builtin functions, new sparse array functions, significant speedups of many kinds. 2.6.2 has significant improvements in Pseudet, SDivide, and storage management in general. The Windows version has a great new interface, a Viewer to replace the crude DOS window. 2.6.3 and 2.6.4 are mostly concerned with even faster polynomial gcd algorithms, thereby speeding up

almost all computations. More details on revision history are here.

- **Fermat for Windows95/98/NT/whatever.**

- **Macintosh Downloading Instructions**

- **Fermat FAQ frequently asked questions.**

- **Why should I use this system?**

Because it works. Fermat has proven to be extremely good at what it does. If you tackle real problems with computer algebra you have probably found that some well known systems are too slow, use too much space, crash too often, or have weird limitations built into them. If all you do is make up examples for your undergraduate students, you probably don't need Fermat. If you try to compute the characteristic polynomial of a 400 X 400 matrix over **Q**, you need Fermat or something like it. Time and again, Fermat has bested the well known expensive systems in both time and space, often by enormous, almost unbelievable, ratios. Look at this paperthat later appeared in the SIGSAM Bulletin.

Fermat is especially good at polynomial and rational function arithmetic; Smith normal form (extended and improved with version 2.6, December 2000); determinant, normal forms, and inverse of matrices with multivariate polynomial entries over **Z, Q, Z**p, finite fields, or more complex fields; sparse matrices; characteristic polynomials; and gcd of multivariate polynomials over **Z**, **Z**p, or finite fields. In addition, I have striven to make it easy to use. For example, in the Mac version it is very easy to edit the output of Fermat (on the screen) and make it the input. This is a great boon in experiments with matrices. Extensive facilities exist for saving data to files and reading such data. Fermat has the ability to be interrupted and then later return to the computation, picking up where it left off. On the Mac side, this is very useful if you are running a long program on your home computer and your five year old daughter wants to use KidPix. With Windows95/98/NT, the operating system itself makes some of this possible -- but not all.

To retrieve the two ReadMe files click here and here.

The ReadMes contain the latest update information, especially the second one. The first one has some history. The second is about the Mac PPC versions and the Windows version.

Fermat Features Summary

To get a quick idea of the polynomial and matrix features of QFermat (the rational version), look at this html version of Appendix 4of the Windows manual. If you viewing on a Mac, you need to go to the "View" menu of your browser, then under "Character Set" set it to "Western(Mac Roman)." (Apparently, on a PC there is less choice so no need to do this. I don't know what happens on UNIX.)

Fermat in Actual Use

Some research projects that used Fermat -- and needed it!

Brumer, Armand. "The Rank of Jo(N)," Asterisque **228** (1995) p. 41-68.

Lewis, Robert H. and Peter F. Stiller, "Solving the recognition problem for six lines using the Dixon resultant," Mathematics and Computers in Simulation 49 (1999) 205-219. download pdf version.

Lewis, Robert H. and George Nakos, "Solving the Six Line Problem with Resultants," presented to the "Grand Challenges" session at IMACS, Prague, August 1998.

Lewis, Robert H. "The Six Line Problem and Resultants," presented to the "Grand Challenges" session at IMACS, Hawaii, July 1997.

Lewis, Robert H. and Guy D. Moore. "Computer Search for Nilpotent Complexes," Experimental Mathematics **6**:3 (1997) p. 239-246.

Lewis, Robert H. and Sal Liriano. "Isomorphism Classes and Derived Series of Almost-Free Groups," Experimental Mathematics **3** (1994) p.255-258.

The Manual

HTML versions of the QFermat manual for both Mac and Windows are available, and of the FFermat manual (FFermat, the float version, is Mac only). They were produced from the TeX versions by the program TTH (TeX to HTML), http://hutchinson.belmont.ma.us/tth/. You can find the Mac manual here and the Windows manual here. The FFermat Manual is here.

PDF: In addition there are now pdf versions of all three Windows and Mac manuals. They contain all the graphic images and are much more convenient than earlier postscript or dvi versions of the manual.

- Download the Windows manual.
- Download the Mac manual.
- Download the FFermat manual.

Update History

January 20, 2002: Version 2.6.4. Significant speedups in polynomial gcd, up to 50% saved on some benchmark problems. The Macintosh MPW version, which works under MPW on 68K Macs, no longer requires an fpu or a math coprocessor chip. This also makes it easy to use on PPC Macs (any Mac bought in the last five years or so), as a software fpu is no longer required. See the second ReadMe.

October 15, 2001: Version 2.6.3. Modularmode (i.e., ground ring Z/p) is now implemented for modulus up to 2^24 - 1 = 16,777,215. The limit had been 2^16 - 1 = 65535. Improved the speed of polygcd by handling content better. Removed a few annoying features of saving data to a file. See the second ReadMe.

July 13, 2001: New improved Viewer for Windows95/98/whatever. Full support for change of fonts, non-ASCII characters. The Windows interface is now better than the Mac interface, thanks to Bill Hastings of Fordham University.

June 24, 2001: All Version 2.6.2 manuals now available. See above.

June 20, 2001: Version 2.6.2. New Viewer interface for the Windows version, otherwise mostly geared towards memory management efficiency. See the second ReadMe.

March 22, 2001: Version 2.6.1. Fixed a small bug in 2.6.0. for-loops wouldn't parse when a third

control value for indexing was present. New toggle switch command &b. When set, if a syntax error occurs when reading a file, the file is closed immediately. This makes it easier to return to a word processor and edit the file.

January 30, 2001: New revised manuals (pdf and html) for version 2.6.0 of QFermat and 2.1 of FFermat now on the web site. See above.

December 28, 2000: Version 2.6.0 of QFermat. Massive revisions and new features, mostly concerning sparse arrays. None of these are documented in the manuals. New builtin functions Equal and Equalneg, new sparse array functions Minors and Rowreduce, significant speedups of many kinds. See the second ReadMe.

September 5, 2000: Version 2.5.8 of QFermat. A few small new features. Fixed some small bugs in all versions. Fixed some more annoying problems in the Windows version. See the second ReadMe.

August 28, 2000: Version 2.5.7 of QFermat. Fixed two bugs in multivariate polynomial gcd. See the second ReadMe.

August 3, 2000: small patch to 2.5.6 of QFermat for Windows. The parser would fail at times to recognize the keywords Trans and Diag. The Mac version is unaffected.

June 14, 2000: Version 2.5.6 of QFermat. Sped up integer division and fixed a few small bugs. See the second ReadMe.

February 12, 2000: Version 2.5.5 of QFermat. Changed the syntax of booleans, comments, and some loops in the Mac version to match the Windows version. Added flexibility to characteristic polynomial for sparse matrices. See the second ReadMe.

September 29, 1999: Version 2.5 of QFermat. Some small improvements, including speed up of rational number arithmetic by improving the integer gcd algorithm. See the second ReadMe.

May 9, 1999: PDF (Adobe Acrobat) version of the Mac manual.

May 4, 1999: Added a very complete HTML version of the FFermat (float version) manual. See this page.

April 27, 1999: Changed the names of the auxiliary files in the Windows version to conform to the DOS standard "eight characters dot three." Then put it all in a zip archive. Some people had trouble with the previous names, which were more than eight characters.

April 11, 1999: PDF (Adobe Acrobat) version of the Windows manual.

April 6, 1999: Version 2.4 of QFermat for Mac and Windows, with new functions MPowermod, for raising matrices to large powers modulo an integer or polynomial, and fraction-free matrix LU factorization functions FFLU and FFLUC. See the second Readme above for details.

March 6, 1999: HTML versions of the QFermat manual for both Mac and Windows.

December 11, 1998: Version 2.3 of QFermat for Mac and Windows, with one bug fix and a revision of functions Mcoef (monomial coefficient) and Mfact (monomial factor). See the second Readme above for details.

October 7, 1998: Added two more challenges to the "Fermat Test" page (see above for link).

September 30, 1998: Produced a manual specific to the Windows version. Fixed a few small mistakes in the Mac manual, the changes document (Mac to Windows), and the file of Windows examples.

September 25, 1998: Updated the manual to reflect recent extentions to Smith Normal Form. New versions of the plain ASCII files, the postscript versions, etc. are on the web pages.

September 22, 1998: Added the Fermat Test (see above for link).

August 4, 1998: Version 2.2.1, a small revision of 2.2. Smith and MSmith now return strictly non-negative matrices. MHermite wasn't working, so I disabled it. See the second Readme above for details.

July 24, 1998: Version 2.2 of QFermat for Mac and Windows. Some bug fixes, and greatly improved and expanded Smith and Hermite Normal Form procedures. Sparse matrices with thousands of rows and columns can be handled in seconds. See the second Readme above for details.

June 16, 1998: Version 2.1 of QFermat for Mac and Windows. Many bug fixes and new features. See the second Readme (above) for more details. The Windows version is more user friendly than before.

Legal Matters

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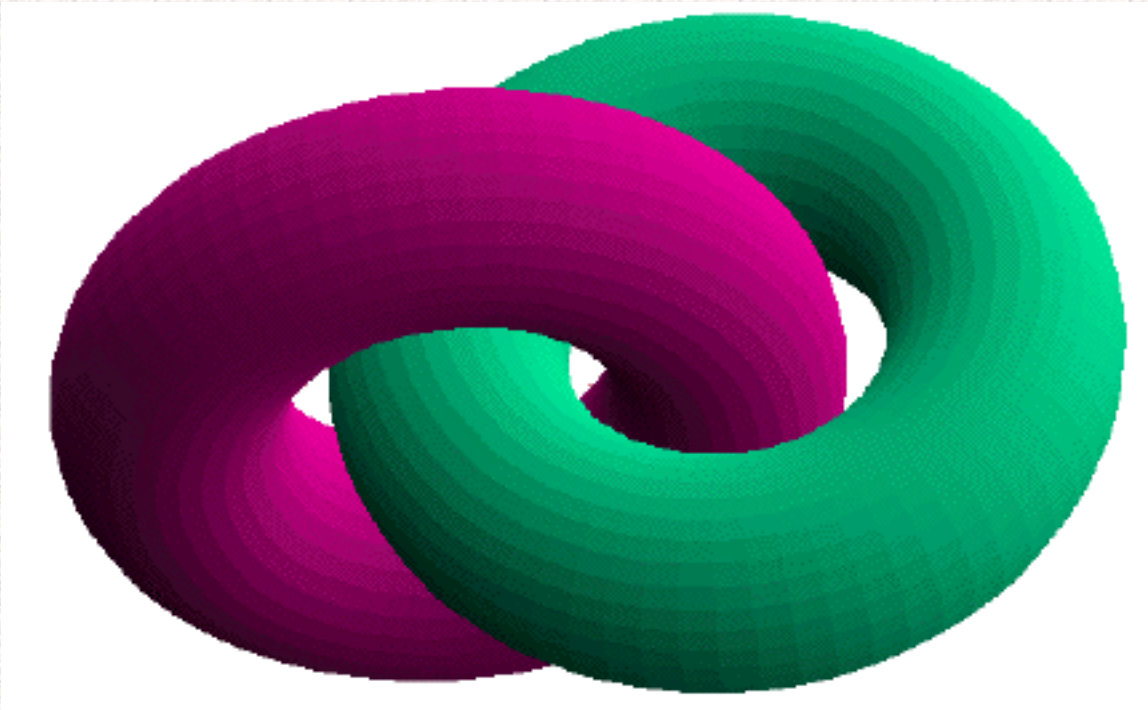

(Linked toruses: another graphic created with Fermat)

More Comments, Questions, etc.

You can also send comments or questions to me at:

E-mail

rlewis@fordham.edu

The address of this web page is http://www.bway.net/~lewis/

Made With A Mac

GAP - Groups, Algorithms and Programming.

This is the home page of GAP at Mathematical Sciences Institute , Australian National University.

This page is no longer being maintained as of 2001. PLease refer to the UK site for the latest version.

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GAP is a free system for computational discrete algebra.

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GAP Group (gap@dcs.st-and.ac.uk), 21 Dec 00

Groups & Graphs

Last update = July 9, 2001.

Groups & Graphs

is a software package for graphs, digraphs, geometric configurations, combinatorial designs, and their automorphism groups. New in version 3.0 is support for torus maps. A new file structure allows the Mac and Windows versions to read and write the same files. Normalizer and centralizer subgroups can now be computed.

Current versions

Groups & Graphs 3.1.0 for Macintosh.
Groups & Graphs 0.9 for Windows.

Click for info on **using G&G**. The overview contains sample graph, digraph, group, torus, and projective plane windows. It also contains sources of information for some of the **algorithms**.

Some Features of G&G

- Visual graph/digraph editor;
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- Graph certificate which identifies a graph uniquely up to isomorphism;
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- Orbits, generators, elements of permutation groups;
- Block systems, commutator subgroups, stabilisers, quotient groups, Sylow subgroups;
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Free? What's the catch?

None. Solutions was originally developped by me (Paul Dubé) when I was a student. After a

while, my friend (Louis-Marius Gendreau) and I decided to start our own software company. We worked 60 hours a week for 3 years to port Solutions from the Atari ST to the Windows platform, to complete the software and to test it.

We really wanted to commercialize the software but we became internet providers along the way. This has been keeping us so busy, that we have not had the time to work on Solutions since. Instead of letting it gather cosmic particules on our hard drive, we think the software would be put to much better use by a million students and scientists! So, we have decided to give it away...

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Numerical Recipes Software (nr.com)
Octave
O-Matrix (Visual Data Analysis)
Otter (ANL)
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PARAMAX
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Tela
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The UNDERSTANDING MATH Programs
VisSim
Visual Software Support Lab
WWWMath Mathematica email discussion group

Contents
Penn State Overview Page

Finding Your Way Around the Window

- The Command Window
- The Toolbar
- The Help System

The Command Window

The Command window is where you can interact with Matlab directly. Try typing the following:

```
foo = ones(2)
```

The output should look like this:

```
foo =

     1     1
     1     1
```

This represents a 2x2 matrix of ones. Matlab inserts extra blank lines between practically everything. To turn off this feature, type

```
format compact
```

Unlike Maple and Mathematica, previous input lines cannot be edited. You can recall previous input lines by typing the "up" cursor button (similar to bash and DOSKEY).

Cutting, copying and pasting is supported using the standards for your operating system.

The Toolbar

Systems that support graphics have a toolbar at the top of the screen, like this:

The buttons have the following functions:

New File, Open File

Cut, Copy, and Paste

Undo last action

Workspace Browser. Use this to graphically edit variables.

Path browser. Use this to edit the paths that Matlab will look in for functions.

Simulink Library Browser (not covered in this tutorial).

Open help window.

The Help System

Unfortunately for the new user, Matlab's help system is rather primitive.

Built-in Help
If you know the name of a Matlab function you need help with, type
`help function-name`
to see the "helpful" information contained in the function definition itself. If you don't know the name of the function you need, try `lookfor keyword` . However, the search is very slow, and often deluges the user with a great many unhelpful items. In addition, a search for a concept, such as "matrix" will almost never return what you need.

You can get the same "helpful" information by choosing Help -> Help Window, or typing `helpwin` .

HTML Help
A more useful (but more difficult to access) set of help files is included in HTML. To access it, choose

Help->Help Desk, or type `helpdesk` .
This will launch your system's default web browser and open a web page. This process can fail in entertaining ways on UNIX systems. Even more frustrating, the system makes extensive use of Javascript, Adobe PDF, frames, and Java, so lynx users may wish to avoid it altogether.

While the content is essentially the same as the built-in help, it is presented in a much less hostile format. The Java-based full-text search and index-by-subject are two extremely useful features. In addition, the entire set of printed manuals is available as Adobe PDF documents.

TIP Most of the help files list function names in all capital letters.
This is extremely misleading - all built-in matlab functions are in small letters.

Next: Matlab Syntax
Previous: Introduction

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Last modified: Wednesday, 19-Jan-2000 17:08:34 EST
URL `/~statmath/math/matlab/gettingstarted/findyourway.html`

Syntax

- How Matlab works
- Symbols and Punctuation
- Controlling Output

How Matlab Works

Matlab works by executing the mathematical statements you enter in the command window. By default, any output is immediately printed to the window.

You are also allowed to assign a name to an expression for your convenience. Keep in mind that the name you assign is only a name, and it does not represent a mathematical variable (as it would in Maple, for example). Every name must have a value at all times. If you try to read the value of an unassigned name, you will get an error.

Nearly everything in Matlab in a matrix, whether it looks like it or not. This takes some getting used to. We'll be introducing matrix-style operations along with their scalar counterparts so you can understand the patterns that arise in the syntax.

Symbols and Punctuation

Matlab was designed to use fairly standard notation. Try these examples on your own computer.

Input	Output	Comments

2 + 3 7-5 34*212 1234/5786 2^5	ans = 5 ans = 2 ans = 7208 ans = 0.2173 ans = 32	Arithmetic works as expected. Note that the result is given the name "ans" each time.
a = sqrt(2)	a = 1.4142	You can choose your own names for things.
b = a, pi, 2 + 3i	b = 1.4142 ans = 3.1416 ans = 2.0000 + 3.0000i	You can use commas to put more than one command on a line. Pi, i, and j are contants.
c = sin(pi) eps	c = 1.2246e-016 ans = 2.2204e-016	"eps" is the current limit of precision. Anything smaller than eps is probably zero. Note that Matlab understands (and expects you to understand!) scientific notation.
d = [1 2 3 4 5 6 7 8 9] e = [1:9] f = 1:9	d = 1 2 3 4 5 6 7 8 9 e = 1 2 3 4 5 6 7 8 9 f = 1 2 3 4 5 6 7 8 9	"d", "e", and "f" are all vectors. They are equal. Note the use of the ":" operator - it counts (by ones) from one number to the next.
g = 0:2:10 f(3) f(2:7) f(:)	g = 0 2 4 6 8 10 ans = 3 ans = 2 3 4 5 6 7 1 2 3 4 5 6 7 8 9	More uses of the colon. Note that you can use it to get slices of a vector (or matrix, or cube, etc), or get the whole thing.
h = [1 2 3]; h'	(nothing) ans = 1 2 3	A semi-colon ";" will prevent the output from being displayed. A single quote " ' " computes the transpose of a matrix, or in this case, switches between row and column vectors.

`h * h'`
`h .* h`
`h + h`
	`ans = 14`
	`ans = 1 4 9`
	`ans = 2 6 8`
		Operations on vectors. * is matrix multiplication, and so the dimensions must line up correctly.
		" .* " is entry-by-entry multiplication.

`g = [ 1 2 3; 4 5 6; 7 8 9]`	`g = 1 2 3`
	`4 5 6`
	`7 8 9`
		Entering a matrix.

`g(2,3)`
`g(3,:)`
`g(2,3) = 4`
	`ans = 6`
	`ans = 7 8 9`
	`g = 1 2 3`
	`4 5 4`
	`7 8 9`
		Accessing matrix elements. Note use of ":" to access an entire row.

`g^2`
 	
`g .^ 2`
	`ans = 30 36 42`
	`66 81 96`
	`102 126 150`
	`ans = 1 4 9`
	`16 25 36`
	`49 64 81`
		The first multiplies the matrix by itself. The second squares each entry in the matrix.

How to Control Output

Before we go any deeper into matrices, it would be wise to mention formatting issues.

The command to know is `format` .

- To control linespacing, use `format compact` .
- To see all 15 digits that were used in calculation, use `format long` .
- To see just 5 digits, use `format short` .
- To supress output completely, use a semi-colon at the end of the command.

To see other options, type `help format` .

Note that Matlab *always* uses "double" precision (about 15 digits) in its calculations. These commands merely adjust the display.

Next: More on Matrices
Previous: Finding Your Way Around

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Last modified: Wednesday, 19-Jan-2000 17:08:34 EST
URL `/~statmath/math/matlab/gettingstarted/syntax.html`

More on Matrices

- More ways of contructing matrices
- More Matrix operations
- Using matrices to solve systems of equations
- Saving and loading matrices

More ways of contructing matrices

Built-in Constructions

There are many built-in matrix constructions. Here are a few:

Input	Output	Comments

`rand(2)`
`rand(2,3)`
	`ans = 0.9501 0.6068`
	`0.2311 0.4860`
	`ans = 0.8913 0.4565 0.8214`
	`0.7621 0.0185 0.4447`
		Generates a matrix with entries randomly distributed between 0 and 1

`zeros(2)`
`ones(2)`
	`ans = 0 0`
	`0 0`
	`ans = 1 1`
	`1 1`
		Generates a 2x2 matrix with all zero (or all ones) entries.

`eye(2)`	`ans = 1 0` `0 1`	Identity matrix I.

`hilb(3)`	`ans = 1.0000 0.5000 0.3333`
	`0.5000 0.3333 0.2500`
	`0.3333 0.2500 0.2000`
		3x3 Hilbert matrix.

To get more information on these, look at the help page for special matrices- type `help elmat` .

Concatenation

New matrices may be formed out of old ones. Suppose we have

```
a = [1 2; 3 4]
a = 1 2
    3 4
```

Then we can make a new matrix in any of the following ways.

Input	Output
`[a, a, a]`	`ans = 1 2 1 2 1 2` `3 4 3 4 3 4`

`[a; a; a]`	`ans = 1 2`
	`3 4`
	`1 2`
	`3 4`
	`1 2`
	`3 4`

`[a, zeros(2); zeros(2), a']`	`ans = 1 2 0 0`
	`3 4 0 0`
	`0 0 1 3`
	`0 0 2 4`

Programming

Matrices may also be constructed by programming. Here is an example using two "for" loops.

```
for i=1:10,
   for j=1:10,
      t(i,j) = i/j;
   end
end
```

Notice that there isn't any output, since the only line that would produce any (`t(i,j) = i/j;`) ends in a semi-colon. Without the semi-colon, Matlab would print the matrix t 100 times!

We'll cover programming in more detail later.

More matrix operations

As we saw earlier, +, -, *, and / are defined in an intuitive manner for matrices. When there is ambiguity about whether an operation will do matrix arithmetic (versus entry-by-entry arithmetic), note that ".*" (dot-star) will multiply entry-by-entry, and "*" (star) will do matrix multiplication.

Scalars

A scalar is just a number. Matlab stores them internally as 1x1 matrices, but treats them as if they were numbers.

All operation involving a scalar and a matrix affect the matrix on an entry-by-entry basis, with one exception: the power ("^") operator. With a as defined above, try these:

Input	Output	Comments
`b=2`	`b=2`	Define b to be a scalar.
`a + b`	`ans = 3 4` `5 6`	Addition works entry-by-entry.
`a * b`	`ans = 2 4` `6 8`	So does multiplication.
`a ^ b`	`ans = 7 10` `15 22`	This is *matrix* power - a*a
`a .^ b`	`ans = 1 4` `9 16`	Entry-by-entry power.

Vectors

A vector is just a matrix with only one row (or column). Matlab makes a distinction between row vectors and column vectors, and will complain if it doesn't get what it expects.

In all arithmetic operations, Matlab treats a vector as a matrix, so we already know how to multiply a vector by a scalar. Matlab also gives you the following operations:

Input	Output	Comments
`v = [1 2 3]` `u = [3 2 1]`	`v = [1 2 3]` `u = [3 2 1]`	Define a pair of vectors.
`v * u`	`Error`	The dimensions don't agree.
`v * u'`	`ans = 10`	Taking the transpose works.
`dot(v,u)`	`ans = 10`	The dot product is the same thing.
`cross(v,u)`	`ans = -4 8 -4`	The cross product works only for 3-d vectors.

Matrices
Matlab has all the common operations built-in, as well as most of the obscure ones.

Input	Output	Comments

`k = 16  2  3`
`  5 11 10`
`  9  7  6`
	`k = 16  2  3`
	`  5 11 10`
	`  9  7  6`
		Define a matrix.

`rref(k)`	`ans = 1  0  0`
	`  0  1  0`
	`  0  0  1`
		Row-reduced echelon form

`rank(k)`	`ans = 3`	The rank.
`det(k)`	`ans = -136`	The determinant.

`inv(k)`	`ans =  0.0294 -0.0662  0.0956`
	`  -0.4412 -0.5074  1.0662`
	`  0.4706  0.6912 -1.2206`
		Inverse of the matrix

`[vec,val] = eig(k)`	`vec = -0.4712 -0.4975 -0.0621`
	`  -0.6884  0.8282 -0.6379`
	`  -0.5514  0.2581  0.7676`
	`val = 22.4319  0  0`
	`  0 11.1136  0`
	`  0  0 -0.5455`
		Eigenvectors and eigenvalues of the matrix.
		The columns of "vec" are the eigenvectors,
		and the diagonal entries of "val" are the eigenvaules.

There are many more functions like these. Type `help matfun` to see them all.

Solving Equations

One of the main uses of matrices is in representing systems of linear equations. If `a` is a matrix containing the coefficients of a system of linear equations, `x` is a column vector containing the "unknowns," and `b` is the column vector of "right-hand sides," the constant terms, then the matrix equation

$$a\,x = b$$

represents the system of equations.

If you know a little linear algebra, you could use the Matlab commands from above to augment the matrix and then find the row-reduced echelon form. However, Matlab provides a more simple mechanism for solving linear equations:
`x = a \ b`
This can be read "x equals a-inverse times b."

Try it with
```
a = [1 2 3; 4 5 6; 7 8 10]; b = [1 1 1]';
```
You should get
```
x = -1 1 0
```
To verify this assertion, try this:
```
a*x, a*x - b, eps
```
The results are:
```
ans = 1 1 1
ans = 1.0e-015 *
    -0.1110
    -0.6661
    -0.2220
ans = 2.2204e-016
```
Notice that `a*x - b` is very close to `eps` - which means that it is as close to zero as possible.

If there is no solution, a "least-squares" solution is provided (a*x - b is as small as possible). Enter
```
a(3,3) = 9; b = [1 1 0]';
```
(which makes the matrix singular and changes b) and enter the above commands again, using the up-arrow to recall them. Notice that the solution is quite inaccurate.

Saving and loading matrices

Unlike Maple and Mathematica, Matlab has no notion of a "worksheet." When you exit Matlab, you will not be prompted to save your work.

If you would like a record of your work, you can turn on "logging" by typing

`diary 'c:\scratch\session.txt'` on NT machines
`diary '~/session.txt'` on UNIX.

Notice that output will be saved alongside your input, so the file can't be used directly as a script.

You may just want to save one or more matrices. The diary is a very clumsy way to do this.
To save the value of the variable "`x`" to a plain text file named "x.value" use
```
save x.value x -ascii
```
To save all variables in a file named "mysession.mat" in reloadable format, use
```
save mysession
```
To restore the session, use
```
load mysession
```
Then, to see the saved files from your session, on UNIX systems type the commands:

```
% more session.txt
% more x.value
```

Under Windows NT, open the appropriate file with Notepad.

Next: Graphics
Previous: Syntax

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URL /~statmath/math/matlab/gettingstarted/morematrices.html

Graphics

- Concepts
- Basic 2-D Graphics
- Basic 3-D Graphics
- Advanced Plotting

Matlab has outstanding graphics capabilities (you must be using a terminal which supports graphics to use them). However, graphing in Matlab is conceptually different than graphing in Maple or Mathematica.

Graphics Concepts

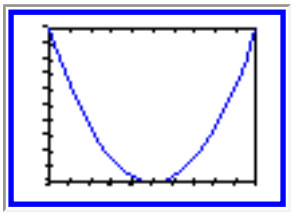
Before looking at the plotting capabilities of Matlab, consider what a graph really *is*. A graph is a collection of points, in 2,3 or even 4 dimensions, that may or may not be connected by lines or polygons. Most math software packages hide this from the user by sampling a continuous function to generate the points.

Matlab is designed to work with matrices, rather than functions. Matrices are a convenient way to store a collection of numbers - which is exactly what is needed when graphing. Thus all graphing commands in Matlab accept *matrices* as their argument, rather than a function. If you are used to function-style plotting, Matlab may take some getting used to. On the other hand, Matlab's approach makes it very easy to visualize data and to create graphics based on lists of points.

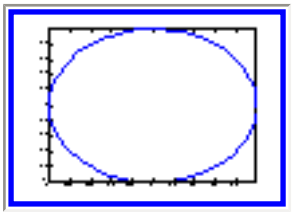
Another unique feature of Matlab's graphics engine is the way in which it displays graphical output. In Matlab, there is (usually) only one plotting window. Subsequent plotting commands will add to the old plot, unless you request a new one be made. This allows a plot to be made, then adjusted later to suit your needs.

Basic 2-D Graphics

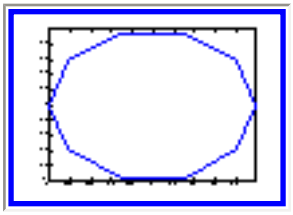
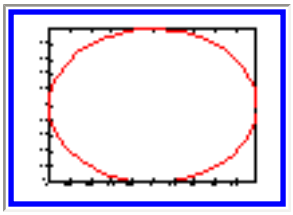
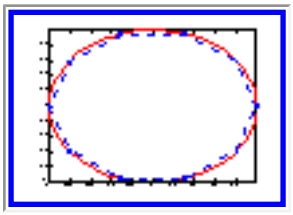
Now that you understand a bit more about graphing, try these examples. Be sure to follow along exactly, or you may not get the same results.

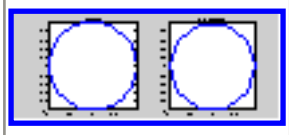
Input	Output	Comments
`x = -10:0.5:10;` `y = x .^ 2;`	(none)	Create a 1x41 matrix that counts from -10 to 10, and a 1x41 matrix made by squaring the entries of the first matrix.
`plot(x,y)`		Plot the points. Each pair is plotted, so <x(1), y(1)> is a point, <x(2), y(2)> is a point, etc.

`t = 0:0.1:2*pi;`
`x = cos(t);`
`y = sin(t);`
	(none)	Generate some new 1x63 matrices.

`plot(x,y)`		Plot the points. This is called a parametric plot. Notice that it replaces the previous plot.

`t = 0:pi/5:2*pi;`
`u = cos(t);`
`v = sin(t);`
	(none)	Generate some new 1x11 matrices. This shows how to control the "resolution" of the plot.

`figure` `plot(u,v)`		Create a new plot window, and plot the points. Notice how jagged the circle is, since we only used 11 sample points.
`plot(x,y, 'ro-')`		Plot the hi-res version again in red, with circles at the data points, connected by lines.
`plot(x,y, 'r-', u,v,'b*:')`		On the same plot, plot the hi-res version in red, and plot the lo-res version with blue stars at the data points and dotted lines.

`figure`
`subplot(1,2,1)`
`plot(x,y)`
`title('Fine Mesh')`
`subplot(1,2,2)`
`plot(u,v)`
`title('Coarse Mesh')`
		Create a new figure.
		Divide it into one row, two columns, and pay attention to the first cell.
		Plot.
		Give the current plot a title.
		Pay attention to the second cell.
		Plot.
		Give it a title.

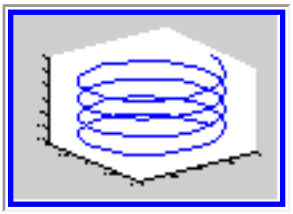
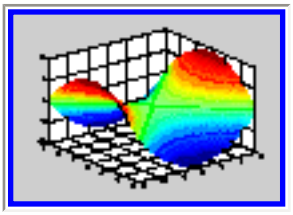
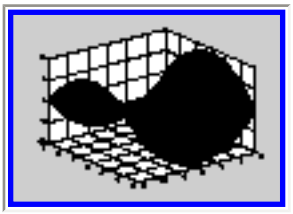
See the following help files for more options and ideas: `help plot`, `help comet`, `help semilogy` and `help fill`.

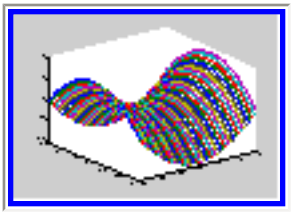
Matlab provides very powerful features in the figure window. Use the toolbar at the top to add arrows, lines, and text comments to your plot.

Basic 3-D Graphics

Input	Output	Comments

`t = -4*pi:pi/16:4*pi;`
`x = cos(t);`
`y = sin(t);`
`z = t;`
	(none)	Generate the data...

`plot3(x,y,z)`		... and draw a helix.
`[x, y] = meshgrid(-3:0.1:3,-3:0.1:3);` `z = x.^2 - y.^2;`	(none)	Generate data for a surface plot.
`mesh(x,y,z)`		Draw the surface using a mesh.
`surf(x,y,z)`		Draw the surface as a "patched" surface.

`plot3(x,y,z)`		Notice that it still plots, but as a set of arches.

Advanced Plotting

Of course, Matlab can do a lot more than these simple exercises. If you'd like to know more, try these help files:
`help slice`, `help movie`, `help getframe`, `help graph2d`, `help graph3d`, `help graphics`.

Next: Programming
Previous: More on Matrices

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URL `/~statmath/math/matlab/gettingstarted/graphics.html`

Programming

- How to program
- Functions
- Batch programming
- Programming ideas

How to program

Matlab statements can be prepared with any editor, and stored in a file for later use. The file is referred to as a script, or an "m-file" (since they must have names of the form `foo.m`). You may prefer to do this, if you use the same data repeatedly, or have an editor that you like to use. Writing m-files will make you much more productive.

Select File -> New ->M-file to open Matlab's built-in editor/debugger, or use your favorite editor. Then create the following file, and save it as sketch.m:

```
[x y] = meshgrid(-3:.1:3, -3:.1:3);
z = x.^2 - y.^2;
mesh(x,y,z);
```

Next, in Matlab, be sure that the directory where the m-file resides is in the path. Check this by typing `pathtool` and making sure that your directory is present. (Users without graphics can use `addpath` *`directory`* .)

Now enter
`sketch`
The result is the same as if you had entered the three lines of the file, at the prompt.

You can also enter data this way: if a file named mymatrix.m in the current working directory contains the lines

```
A = [2 3 4; 5 6 7; 8 9 0];
```

then the command `mymatrix` reads that file and generates A. However, for large matrices, Matlab's own `save` and `load` commands are much safer to use.

Functions

Functions are like any other m-file, but they accept arguments, and they are compiled the first time they are used in a given session (for speed).

Use your favorite editor to create a file named sqroot.m, containing the following lines.

```
function sqroot(x)
% Compute square root by Newton's method

% Initial guess
xstart = 1;

for i = 1:100
        xnew = ( xstart + x/xstart)/2;
        disp(xnew);
        if abs(xnew - xstart)/xnew < eps, break, end;
        xstart = xnew;
end
```

In Matlab enter the commands
`format long`
`sqroot(19)`
You should see the output from your function.

Two caveats:

- A function has access to the variables in the "workspace" from which it was called, but the variables created within the function (xstart and xnew, in the preceeding example) are local, which means that they are not shared with the calling workspace. For more information, see the chapter "M-File Programming" in the manual, *Using Matlab*.
- Note: if you edit a function during a session, use `clear function_name` to remove the

compiled version, so that the new one will be read.

Batch Programming

MATLAB may be ran in "batch mode," in a very similar way. If a file named "test.m" contains the (non-graphics) commands you want processed, at the UNIX prompt type:

```
% matlab < test.m > homework.out
```

This is read, "Run MATLAB, with input from test.in, and output to test.out." The input file does not need to be named "something-dot-m," but it **must** end with `quit` .

Programming ideas

The "m-files" which came with MATLAB provide lots of examples! To find their location, use `path` .This will also lead you to some demos.

You might also try typing `demo` to get a feel for the breadth of tasks that can be accomplished with Matlab.

See `help function` for an exercise for programmers.

Next: Further Reading
Previous: Graphics

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Further Reading

- The Matlab page should be especially useful.
- If you use UNIX, Using Math Software under UNIX may be helpful.
- Manuals for statistical and mathematical software are kept in the Swain Hall, Business/SPEA, Education, and IUPUI University Libraries, and at the IU Center for Statistical and Mathematical Computing. The manuals which come with Matlab are especially good, and provide much more information than this short course.
- If you are affiliated with Indiana University, you may also get help from the Stat/Math Center.

Up: Introduction

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A General Overview of Mathematica

Standard disclaimers apply!

Mathematica is an interactive system for doing mathematical computation. It handles numerical, graphic, and symbolic calculations, and it incorporates a high-level programming language which allows the user to define his own procedures.

Program Functionality: Good

Breadth of Functionality: Excellent

Mathematica has hundreds of functions available. A large core collection is loaded at startup, and specialized packages are available for many topics, from statistics to geometry. Mathematica also has a wide variety of specialized packages written by users and available from the electronic library, MathSource, maintained by the vendor.

Reliability and Robustness: Fair

Mathematica has fewer bugs as time goes on, generally. However, no computer program can replace understanding! People do mathematics, computers don't.

State of the Art: Excellent

Mathematica is one of the leading mathematics programs, noted for its outstanding graphics and its pattern-matching language.

User Friendliness: Fair

Mathematica's language, command names and syntax are mostly straightforward, and easily understood by anyone proficient in C and Perl, but Mathematica requires a major investment in training before the program can be easily used.

Help Resources: Good

Network-based help: Fair

The UITS Knowledge Base has answers to several frequently asked Mathematica questions. In addition, Wolfram Research provides some technical FAQs on its web site.

Program Help System: Good

For information on a topic, enter ? -- for example, ?NIntegrate returns

```
NIntegrate[f, {x, xmin, xmax}] gives a numerical approximation to
the integral of f with respect to x over the interval xmin to xmax.
```

For a bit more information, enter ??. The name of the topic must be known, and spelled correctly: for example, ?plot returns an error message -- ?Plot is needed, and no hint about the problem is offered. However, the menu at the top contains a choice, Help, which brings down a list containing Help, which brings up a Help Browser, with up to four levels of detail [for example Graphics and Sound, 2D Plots, Plot], and also access to *The Mathematica Book*, 600 Mb of documentation.

Local Availability: Fair

Mathematica is classified by UITS as Special Purpose software. See the Software Availability Matrix for details about where Mathematica is installed.

Local Support & Training: Minimal

Document Availability: Fair

UITS makes full documentation is available for reference via short term loan from various locations. Documents are also available for reference at the UITS Stat/Math Center.

Training Availability: None

User Goup: None

UITS Consulting Support: Full Support

The UITS Center for Statistical and Mathematical Computing (call 812/855-4724 or send email to statmath@indiana.edu) can answer basic to advanced questions about the use of Mathematica.

Note: If you are a student using Mathematica for a class exercise, questions about your class work should be first directed to your instructors.

Other Consulting Support: Minimal

Anyone using Mathematica licenses belonging to UITS must obtain support through the UITS Stat/Math Center; such users are not eligible for technical support from Wolfram Research, and they have been known to refuse it.

Registered Mathematica license owners may contact the vendor directly, with the license number provided with their license agreement: phone 217-398-6500 [there is no toll-free support number], or send e-mail to support@wri.com.

WRI Technical Support states that students with the student edition will not receive technical support beyond help with installation.

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Getting Started with Mathematica

Clinton Wolfe, August 1999

Also availible: Printer-Friendly Version in Adobe PDF 4.0(120 KB) (Get Acrobat Reader 4.0)

- Introduction
  - What is Mathematica?
  - Philosophical Issues
  - How to Use this Document
  - Where to Find Mathematica
  - How to Start and Exit Mathematica
- Orientation
- Doing Math
- Functions
- Graphics
- Further Reading

Introduction

What is Mathematica?

Mathematica is a computer program for doing mathematics. It is often used for instruction, homework, research, and writing. Mathematica is extraordinary well-rounded. It is suitable for both numeric and symbolic work, and it has remarkable word-processing capabilities as well. Mathematicians can (and often do) search for a working model, do intensive calculation, and write a dissertation on the project

(including complex graphics) -- all from within Mathematica.

Its weaknesses include a somewhat steep learning curve, an interface that is difficult to use from the command line, and rather complex installation procedures.

Philosophical issues

Mathematica is more than just a program. It is an attempt to redefine the interaction between mathematician and computer. *Every* command, function, option, button, menu, or object in Mathematica fits into this philosophy in a standard way. In the mid-to-long term, this makes Mathematica a very easy-to-use, enjoyable tool. For the new user, Mathematica can seem opaque and threatening.

Mathematica was created by a mathematician for other mathematicians. A user of Mathematica should be comfortable dealing with abstraction, generalization, and pattern discovery. If you feel you do not fit this profile, you might want to learn Maple first.

How to use this document

This document is intended for new users of Mathematica. No prior math software experience is assumed, though we do point out differences between the major packages along the way. We assume you are familiar with your operating system, so we will not cover clicking, dragging, etc. Since Mathematica is quite visually oriented, we assume you will be using it on a computer with a windowing system (such as Windows, Macintosh, or X-windows). If you intend to use Mathematica from the command line, it would be best to first learn it in a graphic environment, and then learn to Use Math Software under UNIX.

We will use a few conventions throughout this document.

Example	**Explanation**
File -> Open	Select *Open* from the *File* menu.
3,Ctl-6,5	Press 3, then hold the Control key and press 6, then press 5.
2+2	Input to be typed at the Mathematica prompt.
4	Output from Mathematica
TIP	An important tip.
	A tip for Maple users.
	A tip for Matlab users.

Where to find Mathematica

Mathematica is available in all Macintosh, SGI, and Sun computer labs at IUB. It is also available on Steel and the SP (node sp09).

Mathematica is also available for sale in the IU Bookstore.

How to start and exit Mathematica

To start mathematica, follow these instructions.

- Unix: from a command line, type "mathematica &"
- Macintosh: Apple Menu->Stat/Math->Mathematica

TIP	If you are using X windows and you get a stream of font errors, follow these instructions from the Knowledge Base.

To exit Mathematica, you can:

- Choose File->Exit
- Type **`Quit[]`**.

Next:Orientation

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Other Tutorials On the Web

- Wolfram Research Inc. - the vendor
  - Mathematica Support
  - *The Mathematica Journal*
  - Mathematica Users' Group
- In English
  - Colorado University - Boulder
  - University of Illinois Urbana-Champaign Excellent tutorial
  - Imperial College (postscript)
  - Los Alamos National Laboratory
  - Purdue University
  - South Alabama
  - University of Tennessee, Knoxville
  - Texas
  - Yale
- In German
  - Humboldt-Universität zu Berlin

Teaching Resources

- Graphics for calculus, Doug Arnold
- *Mathematica in Education and Research*
- Technology Based Problems in Calculus, Rose-Hulman

Examples Using Mathematica

By Academic Subject

- Basic Math
  - Interactive Exercises on Conic Sections (in Finnish)
- Calculus
  - Calculus and Differential Equations with Mathematica, Indiana University of Pennsylvania
  - Calculus and Mathematica, University of Illinois, Urbana-Champaign
  - Graphics for calculus, Doug Arnold
  - Technology Based Problems in Calculus, Rose-Hulman
- Other
  - Some planar isospectral domains, by Peter Buser, John Conway, Peter Doyle, and Klaus-Dieter Semmler

Graphics

- Mathematica Gallery

Packages

These bundles of related functions let you easily extend Mathematica's functionality.

- Archives of Mathematica Packages
  - Stanford University
  - Technion
  - Mathematische Physik / Computeralgebra (in English)
- MathTensor
- EinS is a package for calculations involving sums of indexed objects (e.g., tensors).
- Mathsym is a Mathematica based software package to assist in the computation of Lie point symmetries.

Accessories

These accessories add versatility to Mathematica.

- Mathematica-to-Matlab Converter -Harri Ojanen at Rutgers University
- Mathematica-to-Maple Converter (MapleForm)

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URL `/~statmath/math/mma/links.html`

Introduction to Unix commands

This is a very brief introduction to some useful Unix commands, including examples of how to use each command. For more extensive information about any of these commands, use the `man` command as described below.

cal	find	man	rmdir
cat	finger	mesg	set
cd	jobs	mkdir	vi
chmod	kill	more	w
cp	less	mv	who
date	lpr and lp	pwd	
du	ls	rm	

At the end of this document you will find sources for more information.

cal

This command will print a calendar for a specified month and/or year.

To show this month's calendar, enter:

```
cal
```

To show a twelve-month calendar for 2000, enter:

```
cal 2000
```

To show a calendar for just the month of June, 1970, enter:

```
cal 6 1970
```

For more detailed information, see the Knowledge Base document In Unix, how can I display a calendar?

cat

This command outputs the contents of a text file. You can use it to read brief files or to concatenate files together.

To append `file1` onto the end of `file2`, enter:

```
cat file1 >> file2
```

To view the contents of a file named `myfile`, enter:

```
cat myfile
```

Because `cat` displays text without pausing, its output may quickly scroll off your screen. Use the `less` command (described below) or an editor for reading longer text files.

For more detailed information, see the Knowledge Base document In Unix, how do I combine several files into a single file?

cd

This command changes your current directory location. By default, your Unix login session begins in your home directory.

To switch to a subdirectory (of the current directory) named `myfiles`, enter:

```
cd myfiles
```

To switch to a directory named `/home/dvader/empire_docs`, enter:

```
cd /home/dvader/empire_docs
```

To move to the parent directory of the current directory, enter:

```
cd ..
```

To move to the root directory, enter:

```
cd /
```

To return to your home directory, enter:

```
cd
```

chmod

This command changes the permission information associated with a file. Every file (including directories, which Unix treats as files) on a Unix system is stored with records indicating who has permission to read, write, or execute the file, abbreviated as r, w, and x. These permissions are broken down for three categories of user: first, the owner of the file; second, a group with which both the user and the file may be associated; and third, all other users. These categories are abbreviated as u for owner (or user), g for group, and o for other.

To allow yourself to execute a file that you own named `myfile`, enter:

```
chmod u+x myfile
```

To allow anyone who has access to the directory in which `myfile` is stored to read or execute `myfile`, enter:

```
chmod o+rx myfile
```

You can view the permission settings of a file using the `ls` command, described below.

Note: Be careful with the `chmod` command! If you tamper with the directory permissions of your home directory, for example, you could lock yourself out or allow others unrestricted access to your account and its contents.

For more detailed information, see the Knowledge Base document In Unix, how do I change the permissions for a file?

cp

This command copies a file, preserving the original and creating an identical copy. If you already have a file with the new name, `cp` will overwrite and destroy the duplicate. For this reason, it's safest to always add `-i` after the `cp` command, to force the system to ask for your approval before it destroys any files. The general syntax for `cp` is:

```
cp -i oldfile newfile
```

To copy a file named `meeting1` in the directory `/home/dvader/notes` to your current directory, enter:

```
cp -i /home/dvader/notes/meeting1 .
```

The `.` (period) indicates the current directory as destination, and the `-i` ensures that if there is another file named `meeting1` in the current directory, you will not overwrite it by accident.

To copy a file named `oldfile` in the current directory to the new name `newfile` in the `mystuff` subdirectory of your home directory, enter:

```
cp -i oldfile ~/mystuff/newfile
```

The `~` character (tilde) is interpreted as the path of your home directory.

Note: You must have permission to read a file in order to copy it.

date

The `date` command displays the current day, date, time, and year.

To see this information, enter:

```
date
```

du

This command reports disk usage (i.e., the amount of space taken up by a group of files). `du` descends all subdirectories from the directory in which you enter the command, reporting the size of their contents, and finally reporting a total size for all the files it finds.

To find out how much disk space your files take up, switch to your home directory with the cd command, and enter:

```
du
```

The numbers reported are the sizes of the files; on different systems, these sizes will be in units of either 512 byte blocks or kilobytes. To learn which is the case, use the man command, described below. On most systems, `du -k` will give sizes in kilobytes.

find

The `find` command lists all of the files within a directory and its subdirectories that match a set of conditions. This command is most commonly used to find all of the files that have a certain name.

To find all of the files named `myfile.txt` in your current directory and all of its subdirectories, enter:

```
find . -name myfile.txt -print
```

To look in your current directory and its subdirectories for all of the files that end in the extension `.txt` , enter:

```
find . -name "*.txt" -print
```

In these examples, the `.` (period) represents your current directory. It can be replaced by the full pathname of another directory to search. For instance, to search for files named `myfile.txt` in the directory `/home/user/myusername` and its subdirectories, enter:

```
find /home/user/myusername/ -name myfile.txt -print
```

On some systems, omitting the final `/` (slash) after the directory name can cause `find` to fail to return any results.

As a shortcut for searching in your home directory, enter:

```
find "$HOME/" -name myfile.txt -print
```

For more detailed information, see the Knowledge Base document In Unix, what is the find command, and how do I use it to search through directories for files?

finger

The `finger` command reports information about an account holder, including name, office, phone number (if any), last login, and other optional information.

To find out more about user `dvader`, enter:

```
finger dvader
```

If the computer on which `dvader` has his account is different from the system you are using, you may need to specify the other computer's name, for example:

```
finger dvader@deathstar
```

If `dvader` has his account on a computer at a different campus, university, or organization, you will need to specify his complete address, for example:

```
finger dvader@deathstar.empire.gov
```

For more detailed information, see the Knowledge Base document In Unix, what is the finger command?

jobs

This command reports any programs that you suspended and still have running or waiting in the background (if you had pressed `Ctrl-z` to suspend an editing session, for example). For a list of suspended jobs, enter:

```
jobs
```

Each job will be listed with a number; to resume a job, enter `%` (percent sign) followed by the number of the job. To restart job number two, for example, enter:

```
%2
```

This command is only available in the csh, bash, tcsh, and ksh shells.

kill

Use this command as a last resort to destroy any jobs or programs that you suspended and are unable to restart. Use the `jobs` command to see a list of suspended jobs. To kill suspended job number three, for example, enter:

```
kill %3
```

Now check the `jobs` command again. If the job has not been cancelled, harsher measures may be necessary. Enter:

```
kill -9 %3
```

less

This utility displays the contents of a text file one screen at a time, waiting for you to press the Spacebar between screens. This lets you read text without it scrolling quickly off your screen. The `less` utility is a more flexible and powerful version of `more`. For example, unlike `more`, `less` allows you to scroll backwards by pressing `b` .

To read the contents of a file named `textfile` in the current directory, enter:

```
less textfile
```

The `less` utility is often used for reading the output of other commands. For example, to read the output of the `ls` command one screen at a time, enter:

```
ls -la | less
```

To exit `less` after viewing the file, press `q` .

Note: Don't use `less` with executables (binary files), such as output files produced by compilers. Doing so will display garbage and may lock up your terminal.

lpr and lp

These commands print a file on a printer connected to the computer network. The `lpr` command is used on BSD systems, and the `lp` command is used in System V.

To print a file named `myfile` on a printer named `lp1` with `lpr`, enter:

```
lpr -Plp1 myfile
```

To print the same file to the same printer with `lp`, enter:

```
lp -dlp1 myfile
```

Note: Do not print to a printer whose name or location is unfamiliar to you; you may annoy its owners.

For more detailed information, see the Knowledge Base document In Unix, how do I print files and list or remove print jobs?

ls

This command will list the files stored in a directory. To see a brief, multi-column list of the files in the current directory, enter:

```
ls
```

To also see "dot" files (configuration files that begin with a period, such as `.login`), enter:

```
ls -a
```

To see the file permissions, owners, and sizes of all files, enter:

```
ls -la
```

If the listing is long and scrolls off your screen before you can read it, combine `ls` with the less utility, for example:

```
ls -la | less
```

For more detailed information, see the Knowledge Base document In Unix, how do I list the files in a directory?

man

This command displays the manual page for a particular command. If you are unsure how to use a command or want to find out all its options, you might want to try using `man` to view the manual page.

For example, to learn more about the `ls` command, enter:

```
man ls
```

To learn more about `man`, enter:

```
man man
```

If you aren't sure of the exact command name, you can use `man` with the `-k` option to help you find the command you need. To see one line summaries of each reference page that contains the keyword you specify, enter:

```
man -k keyword
```

Replace `keyword` in the above example with the keyword which you want to reference. Also see the Knowledge Base document [In Unix, what is the man command, and how do I use it to read manual pages?]

mesg

This command toggles permission for others to send messages to your terminal. If someone were bothering you with requests to use `talk`, for example, you could disable the messages and ignore the person by entering:

```
mesg n
```

If you had a change of heart, you could again enable messages by entering:

```
mesg y
```

Note: In most applications, you can restore screen contents that were disrupted by incoming messages by pressing `Ctrl-l` (the letter l).

mkdir

This command will make a new subdirectory.

To create a subdirectory named `mystuff` in the current directory, enter:

```
mkdir mystuff
```

To create a subdirectory named `morestuff` in the existing directory named `/tmp`, enter:

```
mkdir /tmp/morestuff
```

Note: To make a subdirectory in a particular directory, you must have permission to write to that

directory.

more

This utility displays the contents of a text file, one screen at a time, waiting for you to press the Spacebar between screens. This lets you read text without it scrolling quickly off your screen. `less`, described above, is a more powerful version of `more`.

To read the contents of a file named `textfile` in the current directory, enter:

```
more textfile
```

The `more` utility is often used for reading the output of other commands. For example, to read the output of the `ls` command one screen at a time, enter:

```
ls -la | more
```

Note: Don't use `more` with executables (binary files), such as output files produced by compilers. Doing so will display garbage and may lock up your terminal.

mv

This command will move a file. You can use `mv` not only to change the directory location of a file, but also to rename files. Unlike the `cp` command, `mv` will not preserve the original file.

Note: As with the `cp` command, you should always use `-i` to make sure you don't overwrite an existing file.

To rename a file named `oldname` in the current directory to the new name `newname`, enter:

```
mv -i oldname newname
```

To move a file named `hw1` from a subdirectory named `newhw` to another subdirectory named `oldhw` (both subdirectories of the current directory), enter:

```
mv -i newhw/hw1 oldhw
```

If, in this last operation, you also wanted to give the file a new name, such as `firsthw`, you would enter:

```
mv -i newhw/hw1 oldhw/firsthw
```

pwd

This command reports the current directory path. Enter the command by itself:

```
pwd
```

For more detailed information, see the Knowledge Base document In Unix, how do I determine my current working directory?

rm

This command will remove (destroy) a file. You should enter this command with the `-i` option, so that you'll be asked to confirm each file deletion. To remove a file named `junk`, enter:

```
rm -i junk
```

Note: Using `rm` will remove a file permanently, so be sure you really want to get rid of the file before you use `rm`.

rmdir

This command will remove a subdirectory. To remove a subdirectory named `oldstuff`, enter:

```
rmdir oldstuff
```

Note: The directory you specify for removal must be empty. To clean it out, switch to the directory and use the `ls` and `rm` commands to inspect and delete files.

set

This command displays or changes various settings and options associated with your Unix session.

To see the status of all settings, enter the command without options:

```
set
```

If the output scrolls off your screen, combine `set` with `less`:

```
set | less
```

The syntax used for changing settings is different for the various kinds of Unix shells; see the `man` entries for `set` and the references listed at the end of this document for more information.

vi

This command starts the vi text editor. To edit a file named `myfile` in the current directory, enter:

```
vi myfile
```

The vi editor works fairly differently from other text editors. If you haven't used it before, you should probably look at a tutorial, such as the Knowledge Base document How do I use the vi text editor? Another helpful document for getting started with vi is A quick reference list of vi editor commands.

The very least you need to know to start using vi is that in order to enter text, you need to switch the program from command mode to insert mode by pressing `i` . To navigate around the document with the cursor keys, you must switch back to command mode by pressing `Esc`. To execute any of the following commands, you must switch from command mode to ex mode by pressing `:` (the colon key): Enter `w` to save; `wq` to save and quit; `q!` to quit without saving.

w

This command lists all users currently logged into the computer, and includes brief information about what they are doing. To see the listing, just enter `w` .

who

This command will list all users logged into the computer, and the dialup connection or host computer from which they are connected. To see the listing, just enter `who` .

More information

See the UITS publications Unix Commands: A Quick Guide and Unix: The least you need to know, as well as the online manual pages. You can also view a collection of Unix tutorials and introductory help files at:

http://www.mcsr.olemiss.edu/unixhelp/

Related online NETg tutorials (IU only)

Unix Fundamentals

Also see:

- In Unix, how do I list the files in a directory?
- In Unix, what dot files do the various shells use?
- In Unix, how do I set an environment variable?
- In Unix, how do I change my password?
- In Unix, what is chsh, and how do I use it to change my shell?
- In Unix, what is a symbolic link, and how do I create one?
- For Unix, where can I find an online tutorial?
- What books are available for Unix and where can I find them?
- In Unix, how do I define, view, and delete aliases?
- In Unix, how can I find the correct path to an executable file?
- In Unix, how do I get a printed copy of a manual page?
- In Unix, how do I undelete a file?
- In Unix, how do I change the permissions for a file?
- In Unix, how do I remove a directory?
- In Unix, where can I get information on differences between the various shells?
- In Unix, how do I remove files with names that contain strange characters, such as spaces, semicolons, and backslashes?
- In Unix, how do I set my default (preferred) editor?
- In Pine, how do I access Unix commands?
- In Unix, what is the find command, and how do I use it to search through directories for files?
- In Unix, how can I split large files into a number of smaller files?
- In Unix, how do I combine several files into a single file?

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STC\Agent [1]

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Please visit often for updated news, announcements, tools and lots more.

Links

- STC Home Page
- Lab Information
- Adaptive Technology Center
- Request For Services
- Reserve A Center
- Policies
- Printing Services
- Schedule of Reserved STCs
- Suggestions
- Consulting Information
- UITS

Tour of Student Technology Centers

STC Labs

Ashton-Aley AL195
Ballantine Hall 104
Ballantine Hall 107
Ballantine Hall 108
Ballantine Hall 118
Ballantine Hall 121
Ballantine Hall 308
Briscoe 001
Briscoe 184
Briscoe 243
Business 101
Business 407
Business 415
Business 417
Campus View 115
Collins-Greene 006
Education 2011
Education 2025
Eigenmann 101
Eigenmann 102
Eigenmann 136G
Ernie Pyle Hall 212
Evermann 123
Fine Arts 215
Forest 243
Foster-Gresham 103
Geology 226
HPER 154
HPER 155
Indiana Memorial Union 089
Indiana Memorial Union Infostat
Jordan Hall 224
Jordan Hall Atrium
Lindley Hall 023
Lindley Hall 025
Lindley Hall 026
Lindley Hall 030
LT 100 Infostations 100
Main Library 049
Main Library 101E
Main Library 102
Main Library 157A
Main Library 199
Main Library 199B
Main Library 502
Main Library 503
Main Library ATC
McNutt 006
Psychology 120
Read-Landes 4001
School of Music 160
School of Music 360
School of Music 373
SPEA 150
SPEA 151
SPEA 199G
Speech and Hearing Clinic 164
Student Building 220
Student Building 221
Student Building 222
Student Building 230
Student Building 231
Swain Hall East 045
Sycamore Hall 0006
Teter 150
Tulip Tree 405
University West 022
Woodburn Hall 211

Fine Arts 137

Wylie Hall 125

indicates that the lab is wheelchair accessible

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IUPUI Student Technology Centers

The Student Technology Centers:

- BS 3000 Business
- CA 231 Cavanaugh Hall
- DS 122 Dental School
- ES 2116/2124/2119/2121 Education Consortium
- HF 305 Herron
- IH 235 Law School
- NU 342 Nursing
- SL 070 Science / Engineering / Technology
- UC 2137 University College
- UL 3135 Adaptive Learning Center

Helpful Links:

Consulting and Lab Information

Handy Student Information Web Page

Student Technology Center Baseline Software

Instructor Software Installation Request Form

Copyright Information

Changing/Synchronizing Your Password

Student Technology Center Equipment Index

Note:

Some of the Technology Centers are reservable for classes. When the centers are occupied by classes they are not available for public use. Room reservation times are posted in the Learning Centers.

Use of these facilities is contingent upon adherence to the Computer Users' Privileges and Responsibilities .

Original: 09 March 1995 Dale Bewley - IT
Updated: May 14, 2002 cdf - UITS
Comments: STCTR

URL: http://www.iupui.edu/~stctr

Support By Subject

Please note this feature is still in development

Statistical Topics

- Data Management
  - Data Sources - where to find data
  - Input - how to get the data into your program
- *Visualization - generating and customizing plots, charts, and graphs*
- Statistical Analysis
  - Parametric Techniques
  - *Non-Parametric Techniques*
- Other Statistical Resources

Mathematical Topics

- Algebra
  - General Algebra - equations, polynomials
  - Linear Algebra - matrices, vectors
  - Abstract Algebra - groups, rings, fields
- Applied Mathematics
  - Numerical Computing
  - Operations Research and Decision Support
  - Signal Processing
- Calculus
  - General Calculus
  - Differential Equations - ODE's and PDE's

    - Analysis
- Formatting - TEX, MathML, and web publishing.
- Programming
    - *Interfacing math software with programming languages - Maple, Matlab, C, Fortran*
    - *Subroutine libraries - NAG, IMSL*
- Teaching and Education
- Visualization
    - Simple Plotting
    - 3,4,5-D Plotting
- Other Math Resources
    - Mathematical Organizations
    - *Math Journals*
    - Other Math Links

Qualitative Analysis

- *Data Management*
    - *Data Sources - where to find surveys, etc.*
    - *Input - how to enter data*
- *Analysis - techniques*
- *Other Qualitative Analysis Resources*

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URL `/~statmath/bysubject/index.html`

Windows/MSDos Software Collection

Public domain and shareware software for Windows/MSDOS computers on the Mathematics Archives has been organized by the mathematics courses in which they can be used. If the software is suitable for several classes, then it is placed in each of those categories. In addition, information on many commercial packages is also provided together with links to other sites which have additional information on the packages.

Choose one of the following subjects:

- Advanced Calculus
- Advanced Differential Equations
- Calculus
- College Algebra
- Complex Variables
- Discrete Mathematics
- Dynamics
- Fractals
- Geometry
- Graphing Programs
- K-12
- Life Sciences
- Linear and Matrix Algebra
- Miscellaneous
- Modelling
- Modern Algebra
- Number Theory
- Numerical Analysis
- Numerical Partial Differential Equations

Ordinary Differential Equations
Partial Differential Equations
Probability
Statistics
Utilities

This collection is maintained by Larry Husch. If you know of any Windows/MSDOS programs which are not listed in this collection and which you think are useful in the teaching of mathematics, then write Larry.

You are invited to submit materials to be stored on the Mathematics Archives; this may include software, reviews of software or teaching materials utilizing technology. For more information on uploading materials, read this.

This page is best viewed with either Netscape 4.0 (or higher) or Microsoft's Internet Explorer 4.0 (or higher)

K-12 Teaching Materials

The following are Internet sites which contain significant collections of materials which can be used in the teaching of mathematics at the K-12 level. We have organized these materials into the following categories:

- **Lesson Plans**
- **Software**
- **Topics in Mathematics**
- **Contests and Competitions**
- **Professional Societies**
- **Other**

Lesson Plans

Columbia Education Center Mathematics Lesson Plans

Computers & Maths Teaching

Peter Hobson, a teacher in Canberra, Australia, created these pages containing "Low cost ... Resources for years 11 & 12". Included are worksheets designed to be used with a maths class working on graph sketching in a computer lab, spreadsheets, assessment items, worksheets on modelling, and information on shareware and graphics.

Explorer

The Explorer is part of the Unified Network Informatics Technology for Education (UNITE) efforts at the University of Kansas. The Explorer is part of a research and development effort to establish an on time and user friendly means of delivering a full range of information resources to educators and students. This site includes information on software, lab materials, lesson plans, video tapes, etc. for the teaching of mathematics at the k-12 grade levels.

ExploreMath.com

Lesson Plans for the Graphing Calculator

Lesson Plans using Geometer's Sketchpad

Math Activities for K-12 Teachers

In December, 1997, NASA Dryden Flight Research Center funded Dan Biezad, Professor of Aerospace Engineering, and Robin Ward, Assistant Professor of Mathematics, both of California Polytechnic State University, San Luis Obispo, to develop materials for K-12 teachers based on aeronautical themes and NASA projects. One major goal of this project was to make the learning of mathematics more engaging and realistic for students, by using real-world applications.

Math Central's Resource Room

Math Forum's Math Lesson Plans

MEPP - Learning Units

Neufeld & Associates

Publishers of **The UNDERSTANDING MATH Programs**, collection of programs for interactive learning for grades 6-10. Topics include algebra, equations, exponents, geometry and integers. Software is available in both English and French. Demos are available. The company also provides lessons plans related to these packages and organizes workshops.

New York Times - Daily Lesson Plans - Mathematics

Partnership for Excellence

The Partnership for Excellence represents a collaborative alliance between the University of South Carolina Spartanburg and the school districts in Cherokee, Greenville, Spartanburg, and Union Counties in South Carolina. Formed in 1990-91, the alliance focuses its efforts on increasing teachers' knowledge of content and pedagogy, and promoting the sense of community and professionalism among area mathematics teachers.

PI Mathematics

PI Mathematics, a collaborative project, using the concept of PI as the focus, is a home page on the WWW. This multidisciplinary project which includes math, history, English and thinking skills is designed for fifth through eighth graders. It will allow students to discover the approximate value of PI, an irrational number, using measurement and reporting the data, applying formulas, problem solving and participating in a collaborative project utilizing Internet resources. Students will also explore the history of PI, using Internet references.

Project Interactivate

The goals of Project Interactivate are the creation, collection, evaluation, and dissemination of java-based courseware for middle school mathematics explorations. "Interactivated" lessons, discussions, and activities enable the teacher to extend hands-on activities and to teach new content areas with professional competence and confidence, incorporating technology in appropriate ways.

PUMAS - Practical Uses of Math and Science

PUMAS (poo' · mas) -- is a collection of one-page examples of how math and science topics taught in K-12 classes can be used in interesting settings, including everyday life. The examples are written primarily by scientists and engineers, and are available to teachers, students, and other interested parties via the PUMAS Web Site.

SCORE Mathematics Lessons

These SCORE Mathematics Lessons have been written by teachers selected to participate in SCORE Mathematics workshops. This page is designed especially for mathematics teachers and students in California. Its contents and links reflect our state's Mathematics Standards and the NCTM Standards.

SMILE - Science and Mathematics Initiative for Learning Enhancement

The SMILE program is designed to enhance the elementary and high school learning of Science and Mathematics through the use of the phenomenological approach. Since 1986 each summer session participant has been asked to create and publish a single concept lesson plan. These lesson plans include the materials needed, a suggested strategy and expected outcomes. There are currently almost 800 lesson plans available.

South Carolina SSI K-12 Lesson Plans for Math and Science

Mostly a collection of links to other sites; the value of this site is the short description of many lesson plans.

Spacelink - Lesson Plans from NASA

Various lessons plans about space and mathematics from NASA. Most lesson plans are in pdf format.

Teachers Helping Teachers - Math Section

A collection of teaching ideas and tips for k-12 mathematics teachers.

Teacher Talk Forum - Math Section

Teacher's Edition Online - Lesson Ideas

Tennessee Sports Math Project

The project was designed to provide sports-related activities for mathematics teachers in the sixth through ninth grade classrooms. Our goal is to stimulate "at-risk" students who might be willing to do activities related to their interests.

University of Missouri - Lesson Plans

This site contains well over 100 lesson plans that are helpful for anyone in elementary education. They include some of Kyle Yamnitz's own assignments and lesson plans that were developed during his work at the University of Missouri as well as a collection of lesson plans written by other members of the University.

Weather Here and There

WEATHER HERE AND THERE is an integrated weather unit which incorporates interaction with the Internet and hands-on collaborative, problem solving activites for students in grades four through six. This unit is divided into six lessons. The lessons integrate math, science, geography, and language arts in the process of teaching and learning about weather phenomena.

WNETSchool - Mathematics Lesson Plans

Our original lesson plans are developed by wNetSchool Master Teachers. Starting with tried-and-true lessons that work in the classroom, our Web-savvy teachers have built Web-based activities that use the rich resources of Thirteen/WNET and the Internet.

Software

Since this page has been getting quite long, we have separated the software entries into a separate page. You have two choices:

- List of all K-12 software sites.
- You can choose specific categories and platforms on the Mathematics Archives' Other Software Sites Page.

Topics in Mathematics

Materials covering specific areas of mathemtics are listed in these pages. Icons are used to indicated the level of a significant part of the materials:

K6 K-6 Pre-Algebra
HS 7-12 High School Mathematics

Topics of interest to K-12:

- **Algebra**
- **Arithmetic**
- **Art & Music**
- **Calculus**
- **Combinatorics**
- **Fractals**
- **Geometry**
- **History of Mathematics**
- **Pre-Calculus**
- **Statistics**
- **Trigonometry**

Two of other pages on the Mathematics which may be of interest to students and teachers at the K-12 level is **POPMathematics** and **Numbers**.

Contests and Competitions

We have now included all of the links to contests and competitions on the Math Archives' Mathematics Contests, Competitions, and Problem Sets Page.

Professional Societies

We have now included all of the links to Professional Societies on the Math Archives' Professional Societies page. The icon K-12 indicates those societies that have a significant amount of materials for K-12 teachers.

Other K-12 Internet Sites

AAAS Project 2061

Project 2061 of the American Association for the Advancement of Science is a long-term initiative to reform K-12 education nationwide so that all high-school graduates are science literate. In the first stage of its work, Project 2061 commissioned panels of scientists, mathematicians, and technologists to identify the knowledge and skills students should have in five subject areas. These panel reports--Biological and Health Sciences, Mathematics, Physical & Information Sciences and Engineering, Social and Behavioral Sciences, and Technology were integrated into the Project's 1989 report, Science for All Americans (SFAA), which outlines what all students should know and be able to do in science, mathematics, and technology after 13 years of schooling.

Abacus

The Abacus is a publication that focuses on the needs of the elementary mathematics teacher.

Advocates for Women in Science, Engineering and Mathematics

The mission of AWSEM is to create and support a regional network of science and technology practitioners, educators, parents, businesses and community organizations committed to the enrichment of opportunities in Science, Engineering and Mathematics for young women.

AIMS Education Foundation

AIMS is the acronym for "Activities Integrating Mathematics and Science." The mission of the AIMS Education Foundation is to enrich the education of students in K-9 through hands-on activities that integrate mathematics, science, and other disciplines. AIMS implements the recommendations put forth in reform documents such as Science for All Americans (American Association for the Advancement of Science),Curriculum and Evaluation Standards for School Mathematics (National Council of Teachers of Mathematics) and the National Research Council's Standards.

Alan Selby's Home Page

Alan Selby is the author of three books on Understanding and Explaining Math and Reason.

AP Calculus - College Board

Contains information about the College Board's AP Calculus Exams and Courses.

Appalachia Educational Laboratory - Math & Science Education

The mission of the Eisenhower Regional Consortium for Mathematics and Science Education at AEL is to promote and support systemic reform in mathematics and science education in Kentucky, Tennessee, Virginia, and West Virginia.

ARC Center

The ARC Center promotes the wide-scale and effective implementation of standards-based mathematics curricula. The Center consults with school and districts and provides information and resources to support teacher enhancement, leadership development, and public awareness of mathematics.

Ask Dr. Math!

Ask Dr. Math is an Internet project based at Swarthmore College and staffed mainly by Swarthmore students, staff, and faculty where questions about Mathematics from K-12 students and their teachers are answered.

AskERIC

This site is under development for use as an automated information outlet for the AskERIC project, a pilot project of the ERIC system and the Department of Education. The Educational Resources Information Center (ERIC) is a federally-funded national information system that provides access to an extensive body of education-related literature. ERIC provides a variety of services and products at all education levels. AskERIC is an Internet-based question-answering service for teachers, library media specialists, and administrators. Anyone involved with K-12 education can send a message to AskERIC. Drawing on the extensive resources of the ERIC system, AskERIC staff will respond with an answer within 48 working hours. Many of these resources are accessible on this link.

Aunty Math - Fun Math Challenges for Kids!

Balanced Assessment in Mathematics Project

Balanced Assessment in Mathematics is a National Science Foundation project charged with developing new approaches to the assessment of mathematical competence in the elementary and secondary grades. This project has created a type of mathematics assessment that contrasts sharply with traditional forms of testing, which rely primarily on multiple-choice questions. Balanced Assessment focuses on rich, mathematically complex work that requires students to create a plan, make a decision, or solve a problem -- and then justify their thinking.

Blue Web'n Applications: Mathematics Resources

In our daily work designing applications for Internet and Videoconferencing, we see a multitude of web pages for students, educators, and librarians. This webspace is our attempt to share the best of these sites in an organized manner. In addition to the Mathematics Resources they also have Mathematics Activities.

Calculus&Mathematica Distance Education Program

The Calculus&Mathematica Distance Education Program (C&M DEP) runs on the electronic highway to bring top rural and inner city high school students to the university and to send top university undergraduates to rural and inner city high schools to form a human, electronic community devoted to mathematics learning.

The California Math Show

The California Math Show is a portable, interactive math exhibit based on the idea of symmetry. Some web pages developed by the California Math Show which are appropriate for teachers to use in the classroom include the 4 plane symmetries, reflections, Symmetric tessellations, Symmetric polyhedra and Designs with Circles.

California Mathematics Framework

California Mathematics Project

The California Mathematics Project (CMP) vigorously pursues its mandate to improve the quality of mathematics education in California for all students at all grade levels. To achieve this goal, the CMP directs, through its seventeen regional sites, collaborative professional development programs founded on the idea that increased teacher understanding of mathematics and effective pedagogies for teaching mathematics are the keys to improving student achievement.

Canadian Forum on Education in Mathematics

The Canadian Forum for Education in Mathematics was designed to bring together participants in mathematics education in Canada (government, teachers - kindergarten through graduate school and industry) with the intent of providing a unique opportunity to talk about mathematics from elementary school to the workplace.

Canadian Mathematics Society's List of Projects for Science Fairs

To date there have not been a lot of mathematics projects in the science fairs and we believe that one reason for this might be that it is not at all clear what a mathematics project might involve. To help shed some light on this problem we have prepared a list of possible projects and many references on topics that could make exciting and interesting projects.

Centre for the Advancement of Science and Mathematics Education

Centre for the Advancement of Science and Mathematics Education (CASME) is a non-profit, education development agency dedicated to the professional development of science, mathematics

and technology education in South Africa.

Center for Research in Mathematics & Science Education

Established in 1985 within the College of Sciences at SDSU, the Center for Research in Mathematics and Science Education (CRMSE) brings together researchers interested in studying how individuals acquire knowledge in mathematics and science.

Center of Excellence for Science and Mathematics Education (CESME)

The Center of Excellence for Science and Mathematics Education (CESME) is located at the University of Tennessee at Martin in Martin, Tennessee. The mission of the CESME is to encourage and support the improvement of science and mathematics education at all levels. The purpose of this WWW site is to serve as a resource for teachers who are looking for ways to improve their science or mathematics teaching.

Center for Polymer Studies

The Center for Polymer Studies (CPS) is a scientific visualization research center in the Physics Department at Boston University devoted to interdisciplinary research in aspects of polymeric, random, or fractal systems. CPS utilizes expertise in interdisciplinary physics research to develop experimental and computational materials for K-12 and undergraduate education. Of interest to mathematics teachers are their programs: Patterns In Nature and The Dance of Chance.

Centre for Teaching Mathematics

The Centre for Teaching Mathematics is a research and resource development Centre of The University of Plymouth, England. Its broad aims are to promote the teaching and learning of mathematics in a way that will motivate students and make the subject interesting. These activities are reflected in the main activities of the Centre: the development of new teaching resources and strategies, research into the teaching and learning of mathematics, the implications of technology in the teaching and learning of mathematics, curriculum development, provision of courses for teachers and students.

CESAME - Center for the Enhancement of Science and Mathematics Education

CESAME brings together the resources of teachers, scientists, engineers, and mathematicians in order to improve Massachusetts school children's access to, excitement about, and understanding of mathematics and science.

Challenger Center for Space Science Education

Challenger Center for Space Science Education is a not-for-profit organization committed to promoting science, math and technology education. Partnering with museums, science centers, schools, universities and communities across North America, Challenger Center uses the theme of space exploration to: create positive learning experiences, foster interest in math, science and technology, and motivate young people to explore.

Cisco Education Archive

The educational resource center sponsored by Cisco Systems Incorporated which provides information helping educators and schools connect to the wealth of educational resources available on the World Wide Web, as well as connections to resources worldwide that demonstrate the power of networking in education. The Cisco Educational Archive and Resources Catalog home page (CEARCH) offers "one-stop shopping" to access hypermedia resources of interest to educational organizations.

Classroom Compass

Classroom Compass is a collection of ideas and resources for teachers interested in improving instruction in science and mathematics. To make these subjects more accessible to more students, teachers must engage students in real problems and tie lessons to what students already know, while analyzing and measuring what they are learning. The Classroom Compass examines such issues, offering suggestions and discussing ways of thinking about effective instruction.

Community of Mathematics Learners

The goal of the project is to deepen the teachers' understanding of mathematical ideas that underlie the curriculum they teach and to share exemplary curricular materials and teaching methods. Particular attention will be given to exploring ways of connecting mathematical ideas to real life problems and to sharing classroom experiences among participants.

Connect

CONNECT is Colorado's NSF-funded statewide systemic initiative in mathematics and science.

Connected Mathematics Project (CMP)

This website has been designed to help teachers, administrators, parents, and students learn more about this middle school curriculum. The curriculum comprises 24 student units (8 in each grade level) and each unit typically focuses on one major content strand in mathematics -- number, geometry and measurement, probability, statistics, or algebra.

Core-Plus Mathematics Project

The Core-Plus Mathematics Project (CPMP) is a five-year project funded by the National Science Foundation to develop student and teacher materials for a complete three-year high school mathematics curriculum for all students, plus a fourth-year course continuing the preparation of students for college mathematics. The curriculum builds upon the theme of mathematics as sense-making. Throughout it acknowledges, values, and extends the informal knowledge of data, shape, change, and chance that students bring to situations and problems.

Cornell Theory Center Math and Science Gateway

The Cornell Theory Center Math and Science Gateway is a service of the Cornell Theory Center which is committed to providing a wide range of educational services to the national community.

This Gateway provides links to resources in mathematics and science for educators and students in grades 9-12. It includes an extensive section for secondary school educators, containing information on curriculum, lesson plans, software for the classroom, and how to set up web servers in the schools.

Delaware Mathematics Coalition

The Delaware Mathematics Coalition is an alliance of Delaware leaders representing education, government, business, and the community dedicated to support efforts to improve the mathematical literacy of the citizens of the State of Delaware.

Dynamical Systems and Technology Project

This project is a National Science Foundation sponsored project designed to help secondary school and college teachers of mathematics bring contemporary topics in mathematics (chaos, fractals, dynamics) into the classroom, and to show them how to use technology effectively in this process. At this point, there are several interactive papers available. These are designed to help teachers understand the mathematics behind such topics as iterated function systems (the chaos game) and the Mandelbrot and Julia sets.

E-MAIL MATH

Email math involves using the electronic mail service of the internet in order to exchange math story problems with other math classes in Canada or around the world.

E-MATH - A Guide to E-mail Based Volunteer Programs Designed to Help Students Master Challenging Mathematics, Science and Technology

Early Mathematics Placement Testing (EMPT)

We are a high school mathematics intervention program designed to help high school students make decisions about taking mathematics courses. The Ohio EMPT Program tests are administered to high school sophomores, juniors, and seniors to give them an indication of where they stand in terms of mathematics knowledge.

EASYMATHS SA - Mathematics Web Association of South Africa

This is a free South African Community Website with mathematics resources for teachers, parents and learners.

Educational Resources for K-12 Mathematics Teachers

This site at the University of Utah contains a very nice well-organized collection of annotated links to various sites of resources for K-12 mathematics teachers.

Eisenhower High Plains Consortium for Mathematics and Science

The mission of HPC is to promote and support systemic reform in mathematics and science

education in the seven-state region. To facilitate change, HPC collaborates with state departments of education, postsecondary institutions, National Science Foundation (NSF)-funded initiatives, and other state and federal agencies.

Eisenhower National Clearinghouse

The purpose of the Eisenhower National Clearinghouse (ENC) is to provide K-12 teachers with a central source of information on mathematics and science curriculum materials and to encourage the adoption and use of such materials in order to support national goals to improve teaching and learning in mathematics and science. The United States Department of Education funds ENC through a contract with The Ohio State University.

E P G Y: Education Program for Gifted Youth

The Education Program for Gifted Youth (EPGY) is a continuing project at Stanford University offering computer-based courses in mathematics and the mathematical sciences for bright young students through the Stanford Continuing Studies Program. They have been actively involved in the education of gifted students since the late 1950s and have been working with computer based education since the mid 1960s.

EQUALS Programs

The EQUALS programs at the Lawrence Hall of Science provide workshops and curriculum development for teachers, parents, counselors, administrators, and other educators. These programs include the six day EQUALS Workshop in mathematics and equity, one and two day SEQUALS Workshops on a variety of educational topics, and the Family Math Program. EQUALS programs work to increase access and equity in mathematics for traditionally under-represented students, including females, students of color, those from low-income families, and those from language minority groups.

Erdos 4 Kids

An electronic journal for the exploration of open problems in mathematics.

Explorer

The Explorer is part of the Unified Network Informatics Technology for Education (UNITE) efforts at the University of Kansas. The Explorer is part of a research and development effort to establish an on time and user friendly means of delivering a full range of information resources to educators and students. This site includes information on software, lab materials, lesson plans, video tapes, etc. for the teaching of mathematics at the k-12 grade levels.

EXTEND - Perspectives on Mathematics Education

EXTEND is a national Internet forum on mathematics education intended to involve new constituencies, to engage new voices, and to examine new perspectives. Major topics will be explored through forum reports, position papers, and reader commentary:

Access | Expectations | Articulation | Technology | Accountability

These topics are addressed from many perspectives, including those of educators and employers, business leaders and public officials. To contribute to the discussion, send e-mail to: extend@stolaf.edu. In addition, EXTEND provides information on innovative programs and links to important documents related to reform of mathematics education in schools, colleges, and universities.

Family Math

Family Math is a program developed by EQUALS, at Lawrence Hall of Science, University of California, Berkeley, California. The goal of FAMILY MATH is to encourage underrepresented groups (especially girls and minority students) to enter careers that use mathematics. FAMILY MATH is, of course, family-based.

Fermi Questions

Fermi questions emphasize estimation, numerical reasoning, communicating in mathematics, and questioning skills. Students often believe that "word problems" have one exact answer and that the answer is derived in a unique manner. Fermi questions encourage multiple approaches, emphasize process rather than "the answer", and promote non-traditional problem solving strategies.

Figure This!

Mathematics Challenges for Families provides interesting math challenges that middle-school students can do at home with their families.

Florida Atlantic University - Teacher Enhancement Project

The Formula For Success - A Business Leader's Guide to Supporting Math and Science Achievement

This guide offers strategies for how businesses can work with schools to improve math and science achievement.

Freudenthal Institute

The Feudenthal Institute was founded (under the name IOWO) in 1971 and at present forms part of the Department of Mathematics and Computer Science at Utrecht University. The Fi is also part of the Center for Science and Mathematics Education. The Fi is internationally renowned as an institute for the development of mathematics and computer science education. Research projects, conducted by the Fi for the Netherlands Department of Education, have resulted in the implementation of new curricula for secondary education. New curricula for primary education were influenced and developed by the institute in a more informal manner.

Function

Function is a mathematics refereed journal addressed principally to students in the upper years of secondary schools, and more generally to anyone who is interested in mathematics.

Games Pages from the Centre for Innovation in Mathematics Teaching at the University of Exeter

Pages concerning games for the mathematics classroom; on mathematical games, their rationale and ways of using them in the classroom.

Genesee Area Mathematics/Science/Technology Center

The Genesee Area Mathematics/Science/Technology Center seeks to harness community resources for supporting the dedicated parents, students, and educators. GAMSTC seeks to provide these resources so that all learners will excel in and seek career pathways in mathematics, science, and technology.

GirlTECH '95

GirlTECH `95 was an innovative four-week teacher training program at The Rice School/La Escuela Rice. During this program, twenty teachers were given intensive training in developing and presenting materials related to gender equity and computer technology. One of the features of this site is a collection of lesson plans.

Glenn T. Seaborg Center for Teaching and Learning Science and Mathematics

Global Schoolhouse

The Global Schoolhouse is a project funded in part by the National Science Foundation and supported by many local and national businesses. The project consists of connecting schools and students nationally and internationally using the Internet and modeling classroom applications of Internet tools and resources. Collaborative research is conducted between the schools and students interact via using a variety of Internet tools including live video conferences using Macintosh and (80386/80486 based) personal computers.

GoMath

Gomath is an internet site oriented to help high school students (10 - 12th grades) of all levels with math skills. Our specially designed programs offer an interactive guide through a course and help students build up math skills as well as confidence. Here at GoMath.COM we are trying to create the most dynamic and useful math site on the Web. Our features are designed to empower students with math skills and to allow teachers, parents, and students to significantly improving mathematics and science education in elementary and secondary schools in America.

Helping Your Child Learn Math

This article by Patsy F. Kanter contains activities for children aged 5 through 13.

Honest Open Logical Debate (HOLD) on math reform

Houghton Mifflin Mathematics Center

The Houghton Mifflin Math Center contains math resources for teachers, students and parents. Included, for example, is a bibliography for experiences of math through literature for students in grades K-2, brain teasers for grades 3 and above, and many math links.

Hrothgar Project

The Hrothgar Project is an effort started by the Center for Advanced Computing Research (CACR) at Caltech to explore the utility of high end (university research caliber) computers within high school curricula.

The Hub - Regional Alliance for Mathematics and Science Education

The Hub is an Internetworked resource for mathematics and science education funded by the Eisenhower Regional Consortia and operated by TERC on behalf of the Regional Alliance for Mathematics and Science Education Reform. The Hub provides services that can help you to publish reports, curricula, projects in progress, requests for proposals. The Hub is also an important educational resource. The Hub publish newsletters, curriculum materials, and software in support of the greater educational community as well as provide references to valuable information from across the internet.

Infinity

The online version of the University of Queensland maths journal for high school students.

Institute for Technology in Mathematics

The Institute for Technology in Mathematics has been a pilot program under the New Jersey Department of Higher Education with two major objectives: to initiate curriculum transformation at the secondary level in mathematics by using technology and to prepare a cadre of teachers who would serve as leaders and resource people in their school district in providing encouragement and technical assistance to their colleagues. Check out their Lesson Plans for the Geometer's Sketchpad.

INSTRUCT - Implementing the NCTM School Teaching Recommendations Using Collaborative Telecommunications

INSTRUCT is intended to provide online teacher professional development for planning, instruction and assessment of your mathematics classes.

Integrated Math Tools Project

Integrated Math Tools Project is a joint effort of the University of Massachusetts Dartmouth and the Technical Educational Research Center, Cambridge, MA, on a project to revamp the teaching

of mathematics in grades K-6. This project involves the development of curriculum to support mathematics as captured by the NCTM standards of 1989. The University of Massachusetts Dartmouth's part in the project is to develop a series of software "tools" for use by teachers and students in the new curriculum.

Integrated Resource Packages - British Columbia

Curriculum materials for

- MATHEMATICS K TO 7
- MATHEMATICS 8 TO 10
- Introductory Mathematics 11 and Principles of Mathematics 11 and 12
- Applications of Mathematics 11 and 12

The Interactive Mathematics Program

The Interactive Mathematics Program (IMP) is a four-year, problem based mathematics curriculum for high schools. IMP is designed to meet the needs of both college-bound and non-college-bound students. The fundamental principles of IMP reflect major changes currently taking place in mathematics education. National reports issued by experts and professional organizations recognize that existing ways of teaching mathematics are inadequate in meeting the needs of today's public school students.

Internet Resources in Mathematics, Science and Technology Education

This page organized by the Office for Mathematics, Science and Technology Education, University of Illinois at Urbana-Champaign contains a well-organized collection of links to resources on the Internet.

Introduction to Math and Spreadsheets

K-12 Mathematics Curriculum Center

The K-12 Mathematics Curriculum Center's mission is to support school districts as they build an effective mathematics education program using curriculum materials developed in response to the National Council of Teachers of Mathematics' Curriculum and Evaluation Standards for School Mathematics.

Kansas Outreach School in Mathematics (KOSM)

The school's goal is to help students to excel in mathematics. It enrolls students primarily from eighth through tenth grade, although students of other grades may also be admitted. The Outreach School does not substitute for the standard school curriculum, but rather assists middle and high school students and teachers in improving and enhancing the available mathematics education.

Kassel Project from the Centre for Innovation in Mathematics Teaching at the University of Exeter

The main aim of this project is to carry out research into the teaching and learning of Mathematics in different countries, and ultimately to make recommendations about good practice in helping pupils acheive their mathematical potential. The project has grown out of collaborative work between the Centre for Innovation in Mathematics Teaching (CIMT) at the School of Education, University of Exeter in England, and the Mathematics Education Group at Kassel University in Germany. Our initial interest was centred on finding appropriate ways to use applications in the teaching of Mathematics, but this has now widened to encompass all major strands of Mathematics teaching in secondary schools.

Kentucky Virtual High School

The Kentucky Virtual High School is a statewide educational service delivering high school courses and online learning opportunity to Kentuckians. KVHS courses are delivered to public high schools through the Kentucky Education Technology System.

Kids Web - Mathematics Page

The Mathematics Page of the Kids Web is a collection of sites which are very simple to navigate and contain information about mathematics of interest to K-12 students.

Learning through Collaborative Visualization

The Lockheed Martin/UCF Academy for Mathematics and Science

The Lockheed Martin/UCF Academy for Mathematics and Science is dedicated to systemic improvement of mathematics and science teaching and learning in the K-8 schools of Central Florida. The Academy design is consistent with national curriculum, instruction, assessment and teacher preparation standards. Moreover, the Academy is committed to the creation of a network of school-based leadership in mathematics and science education as well as to the support of all teachers in their efforts to enhance the quality of mathematics and science education.

Marketplace - The UNL Center for Science, Mathematics and Computer Education

MARS - Mathematics Assessment Resource Service

The Mathematics Assessment Resource Service, works with districts and states on performance assessment design and implementation, and on professional development for designers and teachers. The aim is to help the local leadership develop local capability to meet local needs.

Materials World Modules

The Materials World Modules (MWM) is a National Science Foundation funded project to produce a series of interdisciplinary educational modules centered on aspects of materials science. The modules themselves are a collaboration among materials science researchers, educational researchers, and high school science and mathematics teachers. The modules are intended for use in high school science and math classrooms. Some of the modules are also suitable for use in

junior high settings.

Math Homework Help

In addition to providing homework help for a fee, this site has a math dictionary, a list of various formulas for high school mathematics including trig identities, geometry formulas, postulates, and theorems and practice problems from algebra.

Math League

The Math League is dedicated to bringing challenging mathematics materials to students. The Math League specializes in math contests, books, and computer software designed to stimulate interest and confidence in mathematics for students from the 4th grade through high school. Over 1 million students participate in Math League contests each year.

Math and Science Course Bulletin

A publication of courses, workshops, conferences, and awards as well as specialized in-service offerings in and out of Washington State which are of particular interest to teachers of math and science in Washington.

Math & Science Pavilion

The Mathematics & Science Pavilion of Virginia Public Education Network provides an opportunity for you to explore the wealth of mathematics and science resources (projects, lesson plans, images, calculator activities). It is part of the Electronic Academical Village, a storehouse for information on academic subjects studied in schools. Please feel at home and enjoy this treasure house compiled together by the math, science, and technology educators of Virginia!

Math Central

Math Central is site for K-12 mathematics students and teachers. It is a facility at the University of Regina Department of Mathematics and Statistics and is maintained by mathematics and education students and faculty. Math Central is designed to aid in the implementation and maintenance of the new mathematics curriculum in Saskatchewan.

Math Forum

Formerly called the *Geometry Forum*, the Math Forum has as its goal to build a community that can be a center for all who have an interest in mathematics education. They work towards this goal in several ways: hosting of newsgroups, organizing a collection of links to various mathematics resources, and involvement with the development and evaluation of Internet math materials.

Math Magazines

This site from Southwest Texas State University contains copies of two math magazines: **Math Reader** that is targeted for elementary students from grade 3 to 5 and **Math Explorer** that is

targeted for students from grade 6 to 9.

Math Night Resource Page

This page gathers together resources used for math nights at various schools in Ames, Iowa as well as serving as an index to site on the web that we think might be useful.

Math Talk

Math is meant to be talked about. Interesting problems are meant to be shared. One person's solution to a problem should be critically reviewed by another. The student body of the Maine School of Science and Mathematics is proud to present Math Talk , a journal written by high school mathematicians for high school mathematicians.

Math Teacher Link

Math Link is a new website based at the University of Illinois that is designed to deliver professional development opportunities and classroom resources to teachers of mathematics, statistics and related subjects at the high school and lower division college levels.

Math Projects for Science Fairs

Katherine Heinrich the Canadian Math Society (CMS) President (1996-98) has put together a list of possible math projects for science fairs.

Math Talk

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Math Vantage

Math Vantage is a series of videotapes and print materials that brings middle level mathematics to life. The videotapes produced for the Nebraska Math and Science Initiative project by the Nebraska Educational Television Network are high-energy, fast-paced presentations illustrating key math concepts and applications. The target audience is grades 6-9, but much of the material is applicable for other grades as well.

Mathematical Digest

Mathematical Digest is a quarterly magazine for high school pupils in South and Southern Africa.

Mathematical Education on Merseyside

Mathematical Education on Merseyside is a Registered Charity dedicated to the enjoyment of mathematics. The aim is to being together in common projects everyone concerned with the lively development of mathematics in secondary schools of every type in and around Merseyside.

Mathematical Experience Through Image Processing

The National Council of Teachers of Mathematics has identified a number of features that the grade 5-8 curriculum should include in order to help motivate students to stay interested in math. The goal of the METIP project is to use digital image processing to help meet these objectives. In particular they have developed applications that run on 386/486/Pentium based PC's under Microsoft Windows that allow students to manipulate digitized images of their choice. Teachers aid in learning by discussing the concepts students have explored on the computer. The METIP Project currently has a number of programs that allow students to explore mathematics with image processing.

Mathematical Mayhem

Mathematical Mayhem is a non-profit mathematical journal written by and for high school and undergraduate university students.

Mathematically Correct

This web site is devoted to the concerns raised by parents and scientists about the invasion of our schools by the New-New Math and the need to restore basic skills to math education.

Mathematics and Science Center

The Mathematics & Science Center is a unique educational partnership in central Virginia. Students teachers and parents are challenged after school hours by innovative programs. Weekday programs in mathematics, science, and emerging technologies enrich the student's classroom work.

Mathematics & Science Pavilion of Virginia

The Mathematics & Science Pavilion of Virginia Public Education Network provides an opportunity for you to explore the wealth of mathematics and science resources (projects, lesson plans, images, calculator activities). It is part of the Electronic Academical Village, a storehouse for information on academic subjects studied in schools.

Mathematics and Science Teaching (MAST) Center

The MAST Center at the University of Northern Colorado is committed to equitable and systemic reform in the teaching and learning of science, mathematics, and technology in elementary, middle, and secondary schools, colleges, and univerisity. MAST Center's Activites include the CONNECT project, MAST Hotline, RMTEC, and the Colorado's U S WEST Teacher Network. The MAST Center has over 20 activities that are focused on pre-service and inservice instruction for mathematics and science teachers.

Mathematics Education Partnership Program

The Mathematics Education Partnership Program (MEPP) is a National Security Agency outreach program to promote mathematics and science education. Working within the Office of the NSA

Chief Scientist, the MEPP staff coordinates the activities of hundreds of Agency volunteers. Much effort is concentrated on helping local area schools through three main programs.

Mathematics Glossary - Middle Years

The definitions included here are those that are used in the Saskatchewan Education document "Mathematics 6-9: A Curriculum Guide for the Middle Level". Various mathematics dictionaries may have different definitions. These definitions are designed to be meaningful to middle level mathematics teachers. A French version is also available.

Mathematics in Context

Mathematics in Context (MiC) is an NSF-funded, comprehensive middle-school mathematics curriculum for grades 5-8 that reflects the philosophy and pedagogy of the NCTM standards. Each of the 40 units consists of mathematical tasks and problems embedded in real-life contexts that are designed to stimulate mathematical thinking and promote discussion among students. Students explore mathematical relationships; develop and explain their reasoning and informal strategies used to solve each problem; how and when to use technology, such as graphing calculators, and to listen to, understand, and value each other's strategies.

The Mathematics Learning Forums

Become a part of a growing, nationwide community of educators interested in mathematics reform and the standards of the National Council of Teachers of Mathematics (NCTM). The Mathematics Learning Forums provide a unique experience for elementary and middle school teachers to reflect on and refine their mathematics teaching practices through on-line seminars.

Mathematics Problem Solving Task Centres

This site has been designed to assist teachers and students who use Task Centres. The aims for the A.C.T.(Mathematics Task) Centre are to give students a successful mathematical experience, to develop problem-solving strategies within the students and to encourage teachers to use concrete materials to teach mathematics with students above Year 3.

Mathématique du secondaire

This page contains suggestions by Xavier Hubaut, Professor at the Free University of Brussels, for additional topics to be used in secondary mathematics which are aesthetic, applicable or amusing. Topics include projective geometry, conic sections, polyhedra, complex numbers, Escher, and applications.

Mathmagic

Mathmagic is a K-12 telecommunications project developed in El Paso, Texas. It provides strong motivation for students to use computer technology while increasing problem-solving strategies and communications skills. MathMagic posts challenges in each of four categories (k-3, 4-6, 7-9 and 10-12) to trigger each registered team to pair up with another team and engage in a problem-solving dialog. When an agreement has been reached, one solution is posted for every pair.

Mathman

Publisher of books and videotapes; Don's Materials.

MathMol - Mathematics and Molecules K-12

MathMol is being developed at the NYU/ACF Scientific Visualization Center with assistance from the NYU Collaborative for Excellence in Teacher Preparation, District 2 in Manhattan and the YMCA Beacon Technology Center. The purpose of *MathMol* is to provide the K-12 educational community with information and materials dealing with the rapidly growing fields of molecular modeling and 3-D visualization. As the program gains momentum, databases and activities will be posted for educational use. Many activities will permit students to work interactively with molecular and mathematical images. Pages will be updated as information and activities are developed.

MathNerds

MathNerds is a free service offering assistance in many areas of mathematics.

MathScape

The MathScape: Seeing and Thinking Mathematically Curriculum Center is a national center whose mission is to support schools and districts using the MathScape: Seeing and Thinking Mathematically curriculum.

MathsNet

MathsNet is a collection of WWW pages about mathematics education, information technology and the Internet. You will find resources here on using information technology tools in school or college with students - and some straightforward "sums" too. Besides pages on logo, spreadsheets and graphs, there are also pages dedicated to users of specific educational software like WinLogo, Excel and Omnigraph. There are iteractive pages, animations, puzzles and articles, and the inevitable list of links to other good sites. The age range covered at present is mainly 11-16, thus including secondary school (UK), though many materials are suitable for younger pupils too.

MEPP - Mathematics Education Partnership Program

The Mathematics Education Partnership Program (MEPP) is a National Security Agency outreach program to promote mathematics and science education.

MegaMath - Los Alamos National Laboratory

The MegaMath project is intended to bring unusual and important mathematical ideas to elementary school classrooms so that young people and their teachers can think about them together.

MESA - Mathematics, Engineering, Scientific Achievement

MESA, one of the country's oldest and most successful educational programs to assist disadvantaged and underrepresented students become math and science professionals. A program of the University of California, MESA works with over 21,000 students throughout California from elementary through university levels. MESA is funded by the state legislature, corporate contributions, and grants. MESA four components programs---the MESA Schools Program (MSP), Success Through Collaboration (STC), MESA California Community College Program (MESA CCCP) and MESA Engineering Program (MEP)---provide academic advising, group study, career exploration, parent involvement, and other services for students.

Michigan Gateways

Michigan Gateways: The Television Program for Teachers of Mathematics and Science is a television series aimed at helping K-12 educators open gateways to mathematics and science for their students. The award winning Michigan Gateways series also appeals to everyone who is concerned about how math and science education evolve as our children prepare for success in the 21st century. Michigan Gateways is broadcast by satellite and offered on Michigan's public broadcasting stations on varying schedules.

Mid-Atlantic Eisenhower Consortium for Mathematics and Science Education

This site is designed primarily to support mathematics and science educators and reform efforts in the region, but the content should appeal to and benefit educators across the nation. The site's content focuses on six priorities: Equity Issues; Informal Education; Public Outreach; and Curriculum, Standards, & Assessment.

Missouri Middle School Mathematics

A National Science Foundation project to support investigation and implementation of innovative middle school mathematics curricula.

Mu Alpha Theta

Mu Alpha Theta was formed to engender keener interest in mathematics, to develop sound scholarship in the subject and promote enjoyment of mathematics among high school and junior college students.

- MU'S NEWS - Florida Association of Mu Alpha Theta

National Alliance of State Science and Mathematics Coalitions

NASSMC advocates the establishment and growth of state coalitions. It provides assistance and support in establishing coalitions, coordinates coalition activities nationally, links its member coalitions to state-level networks of other national organizations, and leverages human and financial resources.

National Center for Improving Student Learning and Achievement in Mathematics and Science (NCISLA)

The mission of the National Center for Improving Student Learning and Achievement in Mathematics and Science (NCISLA) is to craft, implement in schools, and validate a set of principles for the design of classrooms that promote understanding in both mathematics and science.

National Center for Research in Mathematical Sciences Education

Most of the work of the National Center for Research in Mathematical Sciences Education (NCRMSE) is represented in the Annotated Bibliography available at this site.

Networking Infrastructure for Education - National Center for Supercomputing Applications

The National Science Foundation, through the Networking Infrastructure for Education (NIE) program, seeks to explore the impact of networks on school communities. We describe here one such effort, a supplement to an on-going effort NSF-funded activity of the Education Group of the National Center for Supercomputing Applications based on educational affiliations as a mechanism to introduce and support computational science in the K-12 curriculum.

The New Jersey Mathematics Coalition Home Page

The New Jersey Mathematics Coalition was created to facilitate and encourage improvement in the teaching and learning of mathematics as recommended in national reports including the Curriculum and Evaluation Standards for School Mathematics and Professional Standards for Teaching Mathematics of the National Council of Teachers of Mathematics, collectively referred to as the Standards, and Everybody Counts and Counting on You of the Mathematical Sciences Education Board and the Board on Mathematical Sciences

New York State High School Regents Exam Prep Center

Practice questions and old Regents Exams. Covers topics in Mathematical Reasoning, Numbers & Numeration, Operations, Modeling/Multiple Representation, Measurement, Uncertainty (Probability), Patterns & Functions.

North Carolina - Mathematics Curriculum Matrix

The Northern Ireland Mathematics Forum

This site contains material produced in Northern Ireland which should be of interest to mathematics teachers at secondary level and those who train them. Included are Graphic Calculator Resources and Hypotenuse which is the Northern Ireland Mathematics Teachers' Journal.

Northwest Math Interaction

The Northwest Math Interaction (NWMI) is an effort of the Continuing Outreach Program of the IAS /Park City Mathematics Institute. The PCMI sponsors a summer institute in Park City, Utah for teachers, university mathematicians and undergraduates. The NWMI is made up of Puget

Sound secondary teachers who have completed the two-year geometry program at Park City and who are introducing new ways of teaching geometry in the classroom.

NRICH Maths - the Online Maths Club

NRICH provides extracurricular mathematics for young people and ideas to help teachers run maths clubs. NRICH is about enjoying maths and working with other people on challenging problems.

NSF Sponsored Summer Workshop for Secondary School Teachers

Ohio Mathematics and Science Coalition

The Ohio Mathematics and Science Coalition (OMSC) is an advocacy group comprised of individuals from the education, business, and public sectors, working with the common goal of revitalization and improvement of mathematics, science, and technology education, from preschool to beyond graduate school. The OMSC mission is to facilitate collaboration for continuous, systemic, and sustainable improvement in mathematics, science and technology (MST) education for Ohio's nearly 2 million students.

Ontario Mathematics Gazette

Ontario Mathematics Gazette is the major periodical for mathematics education in Ontario. Interesting, relevant articles are written by some of the most outstanding mathematicians and educators in Ontario and North America.

Ontario Science Centre

The Educational Programs section at the Ontario Science Centre, "your partner in math, science and technology education", is offers quality programs and workshops which have been presented to millions of students and teachers since their opening in 1969.

OSU Math Ed Center k-12 Resources

PALMS - Partnerships Advancing Learning in Math and Science

PALMS will be the vanguard of education reform in Massachusetts.

PBS MATHLINE

PBS MATHLINE is the first discipline-based educational service the Public Broadcasting Service (PBS) offers on its new telecommunications highway. Combining computing and telecommunications technologies, public television is creating an information highway on which there will be much more than the traditional broadcast programs usually associated with television. With electronic communication via PBS Online, public television's new computer network, PBS will be offering interactive data services in addition to interactive video and voice services for education. As an umbrella service for students, teachers, parents, policymakers, and

the public, PBS MATHLINE will support the nation in pursuit of its national education goal to be first in the world in mathematics achievement. PBS MATHLINE services are based on the mathematics standards set by the the National Council of Teachers of Mathematics (NCTM) and endorsed by the National Education Goals Panel.

Pennsylvania Governor's School for the Sciences

The Pennsylvania Governor's School for the Sciences (PGSS) first opened at Carnegie Mellon University in the summer of 1982. This rigorous five-week summer program was established to provide talented Pennsylvania high school students with enrichment experiences in the sciences and mathematics and to encourage them to pursue careers in science and technology.

Plane Math

This Instructional Design Document was generated as part of InfoUse's project entitled "An Internet-Based Curriculum on Math and Aeronautics for Children with Physical Disabilities" which was funded through a cooperative agreement with NASA. The stated mission of this project is "To stimulate and motivate students with physical disabilities in grades 4-7 to pursue aeronautics-related careers via the development and delivery of accessible math education materials on the Internet."

Project 2061

Project 2061 is the long-term initiative of the American Association for the Advancement of Science working to reform K-12 science, mathematics, and technology education nationwide. Included on the site are benchmarks and a collection of evaluations of mathematics texts.

Project MATHEMATICS!

Project MATHEMATICS! produces videotape-and-workbook modules that explore basic topics in high school mathematics in ways that cannot be done at the chalkboard or in a textbook. The goal of the project is to attract young people to mathematics through high-quality instructional modules that show mathematics to be understandable, exciting, and eminently worthwhile.

Project Skymath

The University Corporation for Atmospheric Research (UCAR) has received funding from the National Science Foundation to prepare a middle school mathematics module incorporating real-time weather data. The goal of the pilot project is to demonstrate that acquiring and using current environmental and real-time weather data in middle school classrooms, in ways that embrace the dynamic and the uncertain natures of these data, will promote the teaching and learning of significant mathematics, consistent with the standards set by the National Council of Teachers of Mathematics.

ProMath

The purpose of ProMath is to give Lexington area high school students an opportunity to work on interesting, challenging mathematical problems and to develop their problem solving skills and

taste for individual work in Mathematics. The organizers of ProMath believe that working on non-standard problems is the best (maybe the only) way to understand the true nature of Mathematics and would like to share this belief with high school students and with the community at large. They hope to be able to identify and encourage young mathematical talent.

PUMP - Pittsburgh Urban Mathematics Project

The PUMP (Pittsburgh Urban Mathematics Project) Algebra Project is a collaboration between members of the Anderson Research Group and a group of teachers in the Pittsburgh Public Schools. It is an attempt to make high school Algebra accessible to all students through the use of situational curriculum materials and an intelligent computer based tutoring system.

Quandaries and Queries

Have any nagging math problems you can't solve, or just curious about something? Ask us! We'll try to solve your problem and return an answer to you. Questions and answers are also stored in a data base that you can examine either through a table of contents (arranged by level and topic), or through a search.

Quantum

Quantum is a lively, handsomely illustrated bimonthly magazine of math and science (primarily physics). In addition to its feature articles, Quantum's departments include At the Blackboard (the beauty and usefulness of equations), In the Lab (hands-on science), Toy Store (mathematical amusements), Kaleidoscope (a collection of snippets designed to consolidate your grasp of a given topic), How Do You Figure? (challenging problems in physics and math), Brainteasers (fun problems requiring a minimum of math background), Looking Back (biographical and historical pieces), and Gallery Q (an exploration of links between art and science).

Renewing Mathematics Teaching Through Curriculum

Renewing Mathematics Teaching Through Curriculum is a federally funded project that will give Southwest Michigan communities a head start in implementing a highly acclaimed mathematics curriculum that will change the way high school mathematics is taught.

Resources for Math Teachers

Resources include guides to using journals, algebra tiles, math bags, transformational geometry, and unit plans.

The Right Angle

The Right Angle is a High School Mathematics Newsletter published by the Undergraduate Program Office in the Department of Mathematics at Texas A&M University.

The Role of Story Problems in Transition from Arithmetic to Algebra

The purpose of this project is to provide ourselves and others with electronic access to a large

collection of story problems from as many cultures and historical periods as possible.

SAMI - Science and Math Initiatives

SAMI is a clearing house of resources, funding, and curriculum for rural math and science teachers.

Saxon Publishers, Inc.

Saxon Publishers publish educational textbooks and other teaching materials for the primary and secondary education markets (Grades K-12) as well as for the home study market. Their goal is to develop a web site that can be used as a means of communication between themselves and members of the Internet community as well as a forum for the exchange of ideas, techniques, and methods for improving education in America.

School Science and Mathematics Association

The School Science and Mathematics Association is dedicated to improving instruction at all levels in and between science and mathematics by providing leadership in the field. Its primary work and publications address the needs of all of those involved in the science and mathematics teaching and learning processes.

SciMathMN

SciMathMN is a partnership of education, business and government pursuing statewide improvement in the teaching and learning of K-12 mathematics and science.

Science and Mathematics Consortium for Northwest Schools

The Science and Mathematics Consortium for Northwest Schools is one of the ten "Regional Eisenhower Consortia" established by Congress and administered by the U.S. Department of Education. We intend this web site to be used by teachers and other educators to: 1) access information and resources that may be time-consuming to find elsewhere; and 2) enhance their ability to teach mathematics and science.

Secondary Mathematics Assessment Database

This Web site in Queensland, Australia provides an opportunity for secondary maths teachers to share quality assessment items. The emphasis is on non-traditional assessment, though you will find innovative traditional exam questions here also.

The Shodor Education Foundation, Inc.

The Shodor Education Foundation, Inc. is a non-profit education and research corporation dedicated to reform and improvement of mathematics and science education by appropriate incorporation of computational and communication technologies. Beginning in 1989 as the Shodor Education Trust, and since its incorporation as a public 501(c)(3) foundation, the focus has been to identify specific needs in the education reform movement that can be addressed by

modeling and simulation technologies.

Show-Me Center

The Show-Me Center, in partnership with five NSF-sponsored middle grades curriculum development satellites (University of Wisconsin, Michigan State University, University of Montana, Institute for Research on Learning, Educational Development Center) and publishers (Dale Seymour Publications, Creative Publications, and McDougal-Littel) provides information and resources needed to support selection and implementation of standards-based middle grades mathematic curricula.

Six through Eight Mathematics (STEM) Project

The Six Through Eight Mathematics (STEM) project is a mathematics curriculum project for grades 6-8 located at the University of Montana in Missoula, Montana. STEM is developing a national level curriculum to be used by all students. It will include a complete set of student, teacher, and assessment materials. The materials are being developed over a 60-month period and are scheduled for commercial publication for the school year 1997-98.

Skymath National Weather Report Module

This is an overview of a unit in which students produce a national weather report and a report on their understanding of the phenomena under study. It is a highly condensed description. This unit focuses on the display and making sense of numerical and graphical data, discerning patterns, making conjectures based on the analysis of data, and the analysis of data sets with more than one variable. It introduces some fundamental concepts of statistics and a variety of statistical formats for displaying data. It builds extensively on measurement skills and the use of scales and symbol systems and provides opportunities for computation and use of calculators. Throughout the unit, students are engaged in mathematical reasoning, problem-solving, and communicating about mathematics.

SMART -- Science and Mathematics Advancement and Resources for Teachers

SMART -- Science and Mathematics Advancement and Resources for Teachers is an initiative of the Los Angeles Educational Partnership. The 1994-95 SMART Catalog places hundreds of enriching professional development opportunities and resources at your fingertips. Its goal is to empower you to raise your students' level of mathematics and science achievement by enhancing your own knowledge and skills.

Stepping Stones to Mathematical Modeling

The purpose of this site is to facilitate the teaching and learning of mathematical modeling in secondary school mathematics classes.

System Dynamics in Education Project

The goal of the System Dynamics in Education Project is to develop classroom projects, complete with modeling software examples when applicable, that might assist a teacher and the students in

making the educational challenge easier and more meaningful.

Teacher Talk

Teacher Talk is an electronic mailing list for the use of K-12 Saskatchewan mathematics teachers. It is intended for open discussion in the teaching of mathematics, with topics as wide ranging as the participants wish.

Teachers Using Technology in Mathematics

The purpose of the Teachers Using Technology in Mathematics project is to help teachers use multimedia-based technologies and existing software to improve their teaching. The overarching goal is to improve student learning and motivations through the appropriate use of multimedia in connection with lessons that center on big ideas in mathematics and the application of these ideas in other subject areas, especially art. To achieve this goal the University of Iowa, Cedar Rapids schools and Iowa City schools have joined together in a working partnership.

Teaching Mathematics and Its Applications

This IMA journal provides interesting and stimulating material which is of practical use in the teaching of mathematics in secondary education, and includes a micromaths section which deals with different aspects of the role played by the microcomputer in mathematics teaching.

Technology And Mathematics Education (TAME) Forum

The principal aim of the TAME Forum is to develop and support a network of mathematics educators at primary and secondary schools in their attempts to incorporate technology assisted approaches to mathematics teaching and learning. This support will extend to providing the following services: moderate an electronic forum (newsgroup) for mathematics educators to share ideas, problems and sample materials relevant to the TAME theme; maintain/support a collection of low cost software suitable for schools; information about projects currently in progress relevant to the TAME theme; provide links to other WEB resources of value to mathematics educators in schools.

Technology Tools for Secondary School mathematics

Course materials developed by Roger Day at Illinois State University.

Technology Tools for Science and Mathematics Learning

Technology Tools for Science and Mathematics Learning is a statewide inservice professional development program in advanced learning technologies for science and mathematics teachers, grades 3-12.

Tennessee State Frameworks

TERC

TERC is a nonprofit research and development organization committed to improving mathematics and science learning and teaching.

Test Masters Study Guides

Test Masters Study Guides are for state assessment exams and are organized by states.

Texas Statewide Systemic Initiative

Resources for strenghtening mathematics, science and technology education in local communities.

TIMSS - Third International Mathematics and Science Study

With data on half a million students from 41 countries, the Third International Mathematics and Science Study (TIMSS) is the largest, most comprehensive, and most rigorous international study of schools and students ever. The report, Pusuing Excellence, is a synthesis of initial findings from TIMSS on the U.S. eighth grade mathematics and science education, providing a comparative picture of education in the United States and the world that sheds new light on education in the U.S. through the prism of other countries. Also available for study are findings and sample lessons from the TIMSS Videotape Classroom report of 8th grade mathematics with Germany, Japan, and the U.S.

Tools for Understanding

This site is intended for educators who teach mathematics and are interested in integrating common technologies into their daily instruction. Our target audience includes intermediate and middle-grade teachers (particularly those who teach remedial math classes) and secondary special educators. While much of this site focuses on mathematics, there are a number of lessons and activities that are intended to blend mathematics with writing and make use of mathematical reasoning in other content areas such as social studies.

TSM: Technology for Secondary and College Mathematics

TSM is an activity based at Oundle School designed to promote a better understanding of the use of technology in the teaching of mathematics at secondary level. The main software and hardware providers are involved, together with a team of experienced tutors.

U.S. Department of Education

This WWW server is provided under the auspices of the U.S. Department of Education's (ED) Institutional Communications Network (INet) project, managed and operated by the Education Information Resources Division of the Office of Educational Research and Improvement (OERI/EIRD). Contains a list of educational resources available on the Internet.

University of California, Irvine, K-16 SCIENCE EDUCATION - Mathematics Page

This page contains a number of links to sites which provide information of use to the K-16 mathematics teachers. This is part of a project which opproximately 100 K-12 teachers,

representing more than 90 schools in Orange County, California, will be contributing for the benefit of all teachers. These teachers will be evaluating the science resources on the network according to their applicability in the classroom as they are sorted via criteria listed in the California Science Framework.

University of Hawaii, Math Dept., Curriculum Research and Development Group

The Curriculum Research & Development Group is the organized research unit in the University of Hawaii that gives attention to the functions of elementary and secondary education in Hawaii and elsewhere in the University's service area. The CRDG has a permanent staff of educators and contest scholars, plus a number of associated, part-time scholars from this and other universities. Its function is to examine the total scholarship of the universe of knowledge and to adapt selected parts of it for use in elementary and secondary schools. This page is from the Mathematics Department of the CRDG and contains information about the Hawaii Algebra Learning Project and Geometry Learning Project.

University of Toronto Mathematics Network

Sponsored by the Mathematical Sciences Departments at the University of Toronto: Department of Computer Science, Department of Mathematics, Department of Statistics, and others, the Network is designed to encourage active, hands-on participation in mathematics, provide a forum for communication and mathematical discussion, and provide exposure to active mathematics in many diverse fields.

Vermont State Mathematics Coalition

The Vermont State Mathematics Coalition will be a resource throughout the state for schools, parents, businesses and government.

Virginia Mathematics and Science Coalition

The Virginia Mathematics and Science Coalition is an alliance of leaders of the education, corporate, and public policy sectors, working together to revitalize mathematics and science education, pre-kindergarten through graduate school.

Virginia Public Schools - Mathematics Standards of Learning

Voluntary National Tests

President Clinton proposed in his State of the Union Address on February 4, 1997, a voluntary, annual reading test in English at grade 4 and a math test at grade 8. These tests will, for the first time in history, provide parents and teachers with information about how their students are progressing compared to other states, the nation, and other countries.

Wonderful Ideas

Wonderful Ideas is a newsletter featuring math activities, lessons, and games for teaching,

learning, and enjoying mathematics. At the site, there is a collection of activities and problems for teachers and students to print out for their use.

Word Problems For Kids

This Web Site contains word problems for students and teachers. The problems are classified into grade levels from Grade 5 to Grade 12. THIS IS NOT A TEST, but a set of carefully selected problems which can help you improve your problem solving skills.

The World-Wide Web Virtual Library: Educational Technology

This is a long list of links to various sites related to Eduactional Technology which is maintained by TECFA ("Technologies de Formation et Apprentissage"), a teaching and research unit within the School of Psychology and Education (Faculte de psychologie et des sciences de l'education), University of Geneva.

Zimaths

Zimaths is an electronic journal which would educate Zimbabwean schoolkids about the virtues of real maths, as opposed to the spiceless variety taught in most schools.

Acknowledgments: Many of the descriptions of the sites given above are taken or abstracted from information provided by the sites.

Visual Calculus

A collection of modules that can be used in the studying or teaching of calculus.

Tutorials

Pre-Calculus

Limits and Continuity

Derivatives

Applications of Differentiation

Integration

Applications of Integration

Sequences and Series

Information

What? | Who? | How? | Awards | Help Page

For Undergraduates

While most of the materials on the Mathematics Archives are accessible to undergraduate students, the WWW pages in the following categories are designed to give undergraduate students information written specifically for them.

- Societies
- Undergraduate Projects and Research
- Summer Programs, etc.
- Competitions
- Careers in Mathematics
- Undergraduate Publications
- Other WWW Sites

Societies

- The professional society SIAM sponsors a home page which presents a number of articles and essays written by undergraduate students and gives information about summer internships.

- One of the pages on *MAA Online* is The MAA Student's Page which contains information on student competitions, employment in mathematics, meetings of interest to students, etc.

- Pi Mu Epsilon is an honorary national mathematics society whose purpose is the promotion of scholarly activity in mathematics among students in academic institutions.

- Kappa Mu Epsilon is a specialized honor society in Mathematics. KME was founded in 1931 to promote the interest of mathematics among undergraduate students. Its chapters are located in colleges and universities of recognized standing which offer a strong mathematics major. The chapters' members are selected from students of mathematics and other closely related fields who have maintained standards of scholarship, have professional merit, and have attained academic distinction. Both men and women are eligible for membership.

- Mu Alpha Theta's mission: " ...dedicated to engendering keener interest in mathematics, the development of strong scholarship in the subject and promoting the enjoyment of mathematics

among high school and junior and community college students."

- Student Mathematical Societies in the UK and Ireland

Undergraduate Projects and Research

- The Furman University Electronic Journal of Undergraduate Mathematics is an online-only journal designed to encourage undergraduate research in the field of mathematics.
- LMS Undergraduate Project Archive is a site established by the London Math. Society to make available to hard-pressed academics a good stock of topics for undergraduate project work that have been used successfully in other institutions. Ideally this would mean, for each project, a clear description of the work involved in the project, a good set of appropriate references and some indication of the length, level and prerequisites of the project.
- Abstracts, participants and prizes of the **Undergraduate Research Poster Session** at the San Francisco Math Meetings (Jan. 1995).
- Agnes Scott College's list of Recent Independent Studies in Mathematics
- Reed College's Recent Senior Theses in Mathematics.
- St. Mary's College of Maryland's Student Projects
- Williams College's Student Thesis Abstracts

Continued Fractions

A senior Honor's Project at Calvin College by Adam Van Tuyl which gives the history, theory, applications and bibliography on the thery of continued fractions. In the section on applications there are a number of interactive programs that convert rationals (or quadratic irrationals) into a simple continued fraction, as well as the converse.

The Egyptian Fraction: The Unit Fraction Equation

Results from the Wayne State University Student Research Program.

If you have a student project on the WWW, let us know and we'll include a link here.

Summer Programs, etc.

- Math Forum - Undergraduate Research Programs in Mathematics. The Math Forum hosts a growing database of announcements for undergraduate math research programs, including: - Research Experiences for Undergraduates (REU) - Other Summer Programs (non-REU) - Research Semester Programs

- Mathematics Advanced Study Semesters (MASS) is a new semester-long program at Penn State which provides a comprehensive mathematical environment for a group of talented undergraduate students selected from U.S. colleges and universities and brought to the University Park campus. The program combines advanced learning with research initiation. It may be characterized as a "domestic study abroad" program (Fall semesters only.)

- AHPCRC Internship Program: The primary objective of this internship program funded by the National Science Foundation is to promote undergraduate research in high performance computing (HPC) in fluid dynamics, including parallel computing and advanced visualization techniques. The projects are supervised by faculty in aerospace engineering and mechanics, chemical engineering and materials science, and computer science. It is also the objective of this program to encourage the participants to pursue graduate studies in HPC and its applications in engineering and sciences.

- A list of Tentative 2001 REU Sites has been posted by the National Science Foundation.

- The (Math) REU FAQ is a guide to Math REU programs written by a student, Andy Miller, who participated in a couple of REU programs.

- The George Washington University Summer Program for Women in Mathematics (SPWM) is a four-week intensive program for mathematically talented undergraduate women who are completing their junior year and may be contemplating graduate study in the mathematical sciences. The goals of this program are to communicate an enthusiasm for mathematics, to develop research skills, to cultivate mathematical self-confidence and independence, and to promote success in graduate school.

- The Carleton/St. Olaf Colleges Summer Mathematics Program for Women is an NSF/NSA funded program to encourage and support women in their study of mathematics. The goals of the program include: introducing students to new areas of mathematics; honing students' mathematical reasoning, proof writing, problem solving, and presentation skills; building self-confidence, encouraging enthusiasm for mathematics, and increasing awareness of careers in the

mathematical sciences; connecting students into a supportive network of other female college math majors, graduates and professionals.

- Initiated by Paul Erdös, Lászsló Lovász, and Vera T. Sós, the program Budapest Semesters in Mathematics provides a unique opportunity for North American undergraduates. Through this program, mathematics and computer science majors in their junior/senior years may spend one or two semesters in Budapest and study under the tutelage of eminent Hungarian scholar-teachers.

Competitions

National Competitions:

- William Lowell Putnam Mathematical Competition
- William Lowell Putnam Mathematical Competition - Past Problem Sets

Regional Competitions:

- California State University, Fresno - Mathematics Field Day

Careers in Mathematics

- The Mathematical Association of America contains information on careers in mathematics on their page Resources for Undergraduates in Mathematics. In addition, there is information on graduate programs on mathematics including some new professional masters degrees programs.
- The American Mathematical Society (AMS) and the Society for Industrial and Applied Mathematics (SIAM) provide career information and services to the mathematics community. Their Mathematics Careers Bulletin Board allows you to learn about the careers of mathematicians in nonacademic positions.
- The Bureau of Labor Statistics provides information on average salaries, career opportunities, description of positions, etc. for mathematics majors.
- Jobs in Mathematics from Dartmouth College contains primarily information on the employment of mathematicians with Ph.D.'s.

- Check out Careers in Mathematics from the Department of Mathematics at Purdue University.
- Information on Careers in Mathematics is available from Department of Mathematics at Towson State University.
- Check out the Online Career Center from Northern Michigan University.
- Westfield State College's Career Information Page provides information about mathematical careers in Actuarial Field, Business and Management, Education, Engineering, Government, Law Enforcement, Operations Research and Statistics.
- Check out Joining the World of the Mathematician from the Department of Mathematics at Colgate University which provides, in addition to some WWW links, some titles of books concerning what type of work mathematicians do.
- The Department of Mathematics at the University of Canterbury (New Zealand) has a WWW page CAREERS IN MATHEMATICS AND STATISTICS which provides information on recent job vacancies in non-academic areas.
- The Association for Women in Mathematics publishes the pamphlet Careers in Mathematics.

Undergraduate Publications

- Mathematical Musings is an on-line journal based at St. Cloud State University, St. Cloud, MN. We are interested in (1) mathematical student research and (2) student problem solving. We want to create a site where students can present ideas that have intrigued and stimulated them, or questions that they would like answered or would like to propose.
- The Furman University Electronic Journal of Undergraduate Mathematics is an online-only journal designed to encourage undergraduate research in the field of mathematics.
- MAT 007 I News is a recreational mathematical newsletter edited by undergraduate mathematicians of the Department of Mathematics at the University of Toronto.
- Mathematical Mayhem is a non-profit mathematical journal written by and for high school and undergraduate university students.
- Mathematical Spectrum welcomes original student contributions and awards annual prizes for the best ones published.

- mathNEWS - The University of Waterloo Faculty of Mathematics Student Newspaper.

- Le Journal de Maths des Élèves de l'École normale supérieure de Lyon is a journal containing articles written by students and instructors at the latter school. Articles are about math subjects which are interesting, relevant and amusing and are introductions to these subjects. Written in French.

- Rose-Hulman Institute of Technology Undergraduate Mathematics Journal is devoted entirely to papers written by undergraduates on topics related to mathematics.

- Studies in Mathematical Science - A Collection of Undergraduate Research from Miami University of Ohio.

Other WWW Sites

- Alice T. Schafer Mathematics Prize For Excellence in Mathematics by an Undergraduate Woman

- Understanding Mathematics - a study guide The author believes that many students struggle with mathematics only because they don't know what it means to understand Mathematics and how to acquire that understanding. The purpose of this page is to help the student learn how to approach mathematics in a more effective way.

- The Top Fifty Graduate Programs in Mathematics

- Best Graduate Programs in Mathematics from U.S.News. Also includes information on the best graduate programs in Algebra, Applied Mathematics, Geometry/Topology, Logic, Mathematical Statistics and Number Theory.

- Student Corner from the Math Ed Center at Oklahoma State University.

- Applied Math Resources - This is a search of a database of schools with Applied Mathematics Programs at the graduate level. Each school supplied their areas of concentration for inclusion in the database.

- The Most Common Errors in Undergraduate Mathematics - A list distributed to students by a professor at Vanderbilt University who was tired of seeing these same old errors over and over again.

- Women And Mathematics - WAM is an advising and mentoring program whose purpose is to stimulate interest in mathematics among all students, regardless of their career choices. It is a program to motivate and inspire students, especially young women, towards careers in mathematics, science, and technology. By sharing experiences from their careers and lives, WAM consultants create excitement for learning and open new doors for growth and direction. WAM makes a difference for students.

- Conference on Undergraduate Mathematics - Rose-Hulman Institute of Technology

- Hudson River Undergraduate Mathematics Conference - HRUMC

- Nebraska Conference for Undergraduate Women in Mathematics

- APICS - Mathematics and Statistics Committee runs an annual undergraduate conference and student competition and tries to take a vigorous interest in issues related to the science curriculum in schools and universities.

- Muskingum College's Learning Strategies Database - Content-Specific Learning Strategies for Mathematics

- MathNerds is a free service offering assistance in many areas of mathematics.

University, College and Community College

Mathematics and Math Related Departments

From this page, you can access the Mathematics Departments of various community colleges, colleges and universities which have a presence on the Internet. Since the number of such Departments is quite large, we have decided against publishing a single very long list and have organized the lists alphabetically based on the first letter of the name of the school:

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |

Some of the schools are listed in several places in the lists above. For example, the University of Tennessee is listed both on the **T** and **U** lists.

On these lists, we attempt to identify the exceptional teaching and math resources which these departments have made available on the Internet.

The entries from this list were obtained from many sources including:

- Penn State University's List which is recognized as the premier list of math resources on the Internet and which is mirrored at many sites.
- Florida State University's List which was the first such major list on the WWW.
- Australian Math Society - Information about **Australian** Mathematics Departments
- CAMEL's List of sites in **Canada**.
- Cellule de Coordination Documentaire Nationale pour les Mathématiques - List of sites in **France**
- Heriot-Watt University's List of sites in the **United Kingdom**.
- Irish Mathematical Society's list of Mathematics Departments in **Ireland**.
- List of Mathematics Departments in **Italy**
- List of Mathematics Departments in Japan
- Korean Mathematical Society's list of Mathematical Departments in **Korea**.
- Lista de servidores matemáticos en México
- Polish Academy of Science's list of Mathematics Departments in **Poland**.
- Moscow State University's list of Mathematical Sites in **Russia and ex-USSR**.
- Shortcuts to Departments of Physics, Engineering, and Mathematics maintained by Fred Lemmerhirt, Waubonsee Community College

The WWW site Mathematicians of the African Diaspora maintains a listing of Mathematics Departments of the Historically Black Colleges and Universities and the Math Departments of universities in Africa.

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- Linear Algebra M-files (4.2) m-file
- Approximation/interpolation m-files (5.x) m-file
- Approximation/interpolation m-files (4.2) m-file
- Solving DDEs with MATLAB - The information on this page deals with the solution of delay differential equations (DDEs) with constant delays using MATLAB . Included are a tutorial on using the MATLAB dde23 solver to solve DDES, a manuscript containing technical details for the solver, and a manuscript dealing with the event location procedures used in dde23. In addition, the necessary M-files for the solver as well as the M-files for the problems discussed in the tutorial are available.
- A Matlab Differentiation Matrix Suite - This is a software suite designed for MATLAB 5 consisting of seventeen functions for solving differential equations by the spectral collocation (a.k.a. pseudospectral) method. It includes functions for computing differentiation matrices of arbitrary order corresponding to Chebyshev, Hermite, Laguerre, Fourier, and sinc interpolants. It also includes FFT-based routines for Fourier, Chebyshev and sinc differentiation. Auxiliary functions are included for incorporating boundary conditions, performing interpolation using barycentric formulas, and computing roots of orthogonal polynomials.
- Biharmonic Equation - The biharmonic equation is used to model the deflections arising in two dimensional rectangular orthotropic symmetric laminate plates. The plate can be subjected to external perpendicular force(q) and one is interested in the resulting deflections. Various boundary conditions can be applied to the problem. The edges can be simply supported, clamped, or free. In this work, an automatic procedure

is defined which produces the difference equations for each edge boundary case. The procedure is illustrated, using MATLAB, with numerical results for problems with and without exact analytical solutions. We define an automatic procedure to generate the difference equations for approximating the solution to the biharmonic equation under various boundary conditions.

- cumsimp.m m-file - Simpson-rule column-wise cumulative summation. Numerical approximation of a function F(x) such that Y(X) = dF/dX.
- deriv.m m-file - Column-wise derivative estimation. Computes 5-point discrete derivative estimates for each column of the input matrix U.
- DFIELD, PPLANE - The programs DFIELD and PPLANE are described in some detail in the manual Ordinary Differential Equations using MATLAB. There are several versions of the software available for use with various editions of MATLAB.
- DiffMan - DiffMan is a MATLAB toolbox for solving ordinary differential equations on manifolds, based on the concept of 'Coordinate Free Numerics'. This is, loosely speaking, the idea that (whenever possible) it is important to formulate numerical algorithms generically, independently of special representations and coordinate systems. DiffMan inherits its basic design philosophy from the C++ package SOPHUS.
- Numerical Integration Toolbox - This toolbox provides routines for 1-D, 2-D, and n-D Numerical Integration.
- ODESuite - These pages present a suite of programs for the solution of initial value problems y0 = F(t;y) on a time interval [t0;tf], given initial values y(t0) = y0 . The solvers for stiff problems allow the more general form M(t)*y0 = f(t;y) with a mass matrix M(t) that is non-singular and (usually) sparse. As in many environments, the typical problem in Matlab is solved interactively and the results displayed graphically. Generally, functions defining the differential equations are not expensive to evaluate. The typical stiff problem is either of modest size or has a highly structured Jacobian. In Matlab , linear algebra and the built- in array operations are relatively fast, and the language provides for sparse arrays. Matlab handles storage dynamically and retains copies of arrays.
- Push bound - The push bound problem is a very interesting one. When we push at a plate, sometime all of the plate goes ahead, sometime some place bounds. C. V. Coffman and R. J. Duffin[1], R. J. Duffin[2] and P. R. Garabedian[3] did some good work in this field. Here, what we are considering is, for square plates, when we push at a given point, which points will bound. Using difference method and MATLAB, we deal with common material (like glass, steel, ...) and composite material square

plates.

- quadr.m,quads.m m-file - m-files for 1-dimensional integration which are faster, more reliable and more universal than those currently available. They are both vectorized in the best MATLAB sense while fully adaptive to local function behavior.

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- Excel for Scientists and Engineers - Information on Excel for Scientists and Engineers book. Also some Tips and tricks.
- BMS Tutorial for Spreadsheet Data Analysis - A tutorial for Physiology students that illustrates the use of some of the advanced features of MS Excel to analyze data.
- EXCEL 5 for Windows - This document deals with version 5 of the Excel spreadsheet package for PCs running Microsoft Windows. It covers creating, editing and printing a spreadsheet, as well as formulae, functions and sorting.
- Excel Basics - Check your basic knowledge of Excel with the examples here. If you don't know these 21 Excel features, you may be missing some fundamental capabilities in using this tool.
- Excel Help Page - Recently added tutorials:- Return on Investment (ROI) and Return on Equity (ROE) Business Model Forecasting Techniques Comparative Ratio Analysis Business Solutions Pivot Table Example from December 1998 Journal of Accountancy article - "Add Perspective to Spreadsheets"
- Excel Tutorials - A very comprhensive Excel tutorial page, including a Business Solutions Tutorial, Chart and Graph Tutorial, VBA Fundumental and Advanced Tutorial, and many more.
- Formatting Data In Microsoft Excel - This Tutorial Workbook contains a series of hands-on exercises in formatting an Excel spreadsheet. (PDF)

- Help for Microsoft Excel Solver Users - We maintain this Web site as a service to all users of the Microsoft Excel Solver. Its content reflects our experience helping users for almost four years.
- Interactive Examples For Excel2000 - The pages in the /Interact directory allow to see formulas in action. Not only can you see actual Excel spreadsheets using the formulas, but you can change the variables. Through your web browser, you can actually see and work with the Excel formulas described on my web site.
- Introductory Exercises in Excel - This document contains a series of exercises which give an introduction to the Excel spreadsheet program (version 5). (PDF)
- Microsoft - Excel 2000 Tour - Discover better ways to analyze data and find solutions using Microsoft Excel 2000 and its streamlined spreadsheet creation tools, enhanced analysis tools, and powerful Web integration.
- Microsoft online support-search - Search the Microsoft Knowledge Base of technical support information and self-help tools for Microsoft products.
- Orientation in Excel - An Excel tutorial, built as a series of assignments for the student.
- Sheffield - Excel - Excel Help Index from the University of Sheffield.
- Tools Options Guided Tour - Tools Options Guided Tour is a WinHelp file going into detail about all the options in the Excel 5 Options dialog on the Tools menu.
- Underground Guide Series - A "behind-the-scenes" tour of Excel that helps you get real productivity out of your favorite spreadsheet. In their irreverent, off-the-wall style, the authors separate spreadsheet gold from marketing hype and show you how to take advantage of Excel features you won't find covered anywhere else in the known universe (not even in the manual).
- Visual Guide for MS Excel - Visual Guide for MS Excel is an animated spreadsheet tutorial designed to help you assess your knowledge, and focus on personally relevant topics.
- Weblinks Help File for Excel - The Microsoft® Excel 97 Weblinks Help file adds hyperlinks to Microsoft Knowledge Base articles in many Excel Help topics. So if you need more information on these help topics, expertise from Microsoft Support Technicians can be obtained with just a click.
- Writing Formulae With Microsoft Excel - This document contains a series of exercises in creating and editing formulae in an Excel (version 5) spreadsheet. (PDF)

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- Yechiel's Preferred C and C++ Sources - Yechiel's Preferred C and C++ Books and Internet Sites
- Free programming books - Free programming books covering C++, Java etc.
- Component Connection - This chapter discusses several of the issues that arise when you move from C++ to Java. Since many (if not most) Java programmers come from a C++ background, it is natural to want to carry over the skills, techniques, and code acquired in this language. Although C++ and Java were designed to address the programming needs of two very different environments, many of the same coding techniques, algorithms, and optimizations apply to both. However, as explained in Part One, Java is not "the Internet version of C++." While there are many similarities between the two languages, there are also several differences. This chapter reviews those differences and shows ways to handle some of the more challenging ones.
- C++ Streams - Internals and Applications - Although the syntax of the C++ language is based on C, many of the features and concepts of the language are quite different. In some cases, entirely new concepts have been introduced. The idea of data streams is one of these new concepts. A C++ stream is an abstract representation of data flow from one location to another. The origin of the data is usually called a producer or source, and the destination is usually referred to as a consumer or sink. Streams can be designed to handle the transfer of data in any format, from simple

fundamental types like int, char, char *, long, and double, to complex objects containing many classes and derivations. C++ streams are most often constructed from the combination of two base classes. In the current implementation of C++, these base classes are streambuf and ios. Under this design, the streambuf class object provides for the buffering and orderly passing of information from the producer to the consumer. The ios class object is then respo

- LEARN C/C++ TODAY - This is a list of a few C and C++ language tutorials available to users. The list includes interactive tutorials, public-domain code collections, books etc.
- NML Code Generator Instructions - Instructions for using the NML Code Generator to create C++ or Java NML definitions.
- Guide to C++ Classes - Runtime errors will inevitably occur in any complex software system. Independent of what may be done to recover from the error, it is important that information about the nature of the error be recorded to allow a human operator to later ascertain whether the software or the operating environment needs to be modified. A mechanism for recording of textual information pertaining to an error is provided by the OTC_Logger class. Error messages can be logged at a number of priorities, with messages being displayed to the standard error output. If required, error messages can also be saved to a file. By deriving from the OTC_Logger class you can capture the error messages and optionally save or cause them to be displayed using an alternate mechanism. For example, you may wish to have messages passed on to the UNIX syslog facility.
- Short C++ tutorial for C users - From Belgium, Eric Brasseur walks the reader through the first hours of a C programmer's fresh acquaintance with C++, introducing features like references, operators overloading, new and delete ("they are much more sweet than ... malloc and free") up to multiple inheritance.
- Porting C++ to Java - This paper is addressed to people who are considering porting their existing C++ code to Java. It provides a step-by-step approach to porting C++ to Java effectively.
- C++ Primer - Prices, description, reviews and more, about the book "C++ Primer" by Lippman/Lajoie. This book explains how to program in C++. It covers the latest ANSI/ISO standard and explains how to use C++ templates.
- Industrial Strength Programming - Here is a book that teaches not only language but also programming itself. The author of this book shares his experience in programming, teaches how to write reliable and

maintainable code, easy to understand by other members of the team; knowing advanced programming techniques such as synchronization in a multithreaded environment, effective use of virtual memory, debugging techniques, etc.

- TTT - The TTT System is a suite of files and programs aimed at providing you (the learner) with an interactive, World Wide Web based online course in the fundamentals of programming using the C++ programming language.
- The C++ Standard Library - A Tutorial and Reference - See and download all of the examples from the book "The C++ Standard Library - A Tutorial and Reference" by Nicolai M. Josuttis.
- Introduction to Object-Oriented Programming Using C++ - This tutorial is a collection of lectures to be held in the on-line course 'Introduction to Object-Oriented Programming Using C++'. In this course, object-orientation is introduced as a new programming concept which should help you in developing high quality software. Object-orientation is also introduced as a concept which makes developing of projects easier.
- From The Ground Up: A Guide to C++ - From The Ground Up: A Guide to C++. This site is a tutorial for learning the programming language C++. The site makes extensive use of Java. It also has clever scheme of remembering where you were if you return to the tutorial many times. The tutorial is geared towards Pascal programmers converting to C++, and only covers C++ basics (classes and operator overloading are the most advanced topics).
- Fatbrain - Fatbrain.com is the Internet's most comprehensive bookstore for professionals. Recently named the number two fastest-growing public company in Silicon Valley, Fatbrain.com offers a world-class selection of books, training materials and print-on-demand documentation for business, finance, math, science and technology experts. Our industry experience and in-depth knowledge of authors, topics and trends help customers find the best resources for their needs. Fatbrain.com contains a comprehensive section on C.
- C - Tutorials - This is the tutorial section of 'cprogramming.com'. It contains: PROGRAMMING IN C/C++ tutorial; GRAPHICS PROGRAMMING tutorial.
- C++ Programming for Scientists - C++ tutorial for scientists. Course notes : ANSI C, C++ as a better C, C++ classes and objects, objects in scientific computing, inheritance & polymorphism, templates, exceptions & observations, programming examples, scientific library examples.
- Books reviews with grades - This page is a collection of reviews on C++

books for advanced users.

- An Introduction to C++ - This is the first installment in a series called "Objective Viewpoint" that will teach you about C++.
- Gillius's C++ Programming - C/C++ focused page with tutorials ranging from language syntax to game development. Has FREE C/C++/Pascal source code and free games with source code.
- A TOUR OF C PROGRAMMING - This tutorial gives a complete understanding of the basics of C programming. The goal of this "guide to C" is to cover the basics of the language pretty thoroughly. After that will be introduced some more advanced things.

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- MODEL - MODEL is a numeric simulation library written to simulate systems of rate equations describing Vertical Cavity Surface Emitting Lasers (VCSELs). Try it if you need an easy way to solve some systems of ordinary differential equations.
- The Godess project - This is a Generic Ordinary Differential Equation Solver System written in C++. The solver is an initial value solver for ODEs and DAEs, with rootfinding etc. The goal of the project is to improve the state-of-the-art for timestepping methods when solving initial value problems. I was responsible for the code during my Ph.D. studies and successfully worked on Runge-Kutta methods (mostly implicit ones).
- Only C++ - This is the C++ page of the Numeric Physic WWW site, where you can find the source code of many programs that deal with differential equations.
- KASKADE - A C++ toolbox for the solution of linear scalar elliptic and parabolic problems in 1, 2, and 3 dimensions using adaptive finite element methods. The toolbox includes extensions for handling systems of equations as well as example algorithms for nonlinear methods used in obstacle, porous media, or Stefan problems. The core of the program consists of a variety of multilevel/multigrid preconditioners for the linear systems involved. The iterative solvers included in the package include: conjugate gradient (with and without 3-term recurrence), conjugate residual (with and without 3-term recurrence), several relaxation routines (Jacobi, SSOR, etc.), GMRES, bi-conjugate gradients, BiCGStab, the Sonneveld CGS algorithm, conjugate gradients for normal equations, and a nonlinear relaxation routine. Preconditioner methods include: Jacobi type, symmetric Gauss-Seidel, incomplete LU-factorization, multilevel with Jacobi-type smoothing, multilevel with symmetric Gauss-Seidel

smoothing, additiv+. It can be compiled with g++ 2.6.3 or later. The package is documented in extensive programmer's and user's guides in PostScript format.

- Diffpack - A collection of C++ object-oriented class libraries designed for the numerical solution of partial differential equations. The package also includes several UNIX utilities for general software management and numerical programming. The goal of Diffpack is to provide an environment for the rapid prototyping of simulators based on PDEs which also offers a high level of efficiency.
- A++/P++ - A++ is a C++ array class for numerical computation designed to work with structured grid computations, including work on overlapping grids and adaptive mesh refinement. P++ is the parallel version of the serial class A++. A++/P++ was designed to simplify the development of numerical software, specifically to allow an application developed in the serial environment to be run on parallel machines with little or no additional effort. It is also intended as a partial solution to a growing crisis in the development of large numerical codes that are required to run on many different serial and complex parallel architectures. The A++/P++ distribution (35 Mb uncompressed) includes the source code and the documentation. Requirements for compilation and installation include a C++ compiler (g++ will do) and a C and/or a Fortran compiler. The graphics visualization facilities of A++/P++ additionally require the Plotmtv software. The use of P++ requires a communication library. It presently w
- Clenshaw-Curtis-Quadrature - A presentation of the Numerical Automatic Integrator method, which is called "Chebyshev Series Expansion" in one dimension. The package includes source code.
- Automatic Differentiation - We want to calculate a value f(t1,...,tn) that depends on parameters t1,...,tn. But, in addition, we want to calculate the first and possibly second derivatives of f(t1,...,tn) with respect to t1,...,tn. For example, we want to find the maximum or minimum of f(t1,...,tn) and want to use an optimization method involving derivatives. The aim of the automatic differentiation package is to allow us to calculate the derivatives using a program that is just a minor modification of the program that calculates f. This greatly reduces the work involved and greatly increases the chances of getting the correct answer.
- ADOL-C (Automatic Differentiation of CC++) - The package ADOL-C facilitates the evaluation of first and higher derivatives of vector functions that are defined by computer programs written in C or C++. The resulting derivative evaluation routines may be called from C/C++, Fortran, or any other language that can be linked with C. The numerical values of

derivative vectors are obtained free of truncation errors at a small multiple of the run time and randomly accessed memory of the given function evaluation program.

- DE-Quadrature - Numerical Automatic Integrator for Improper Integral. Method: Double Exponential (DE), Transformation dimension: one.
- Diffpack - Diffpack is a comprehensive development framework for multi-physics simulation. It is available on a wide range of hardware platforms.
- PVODE - PVODE is a portable solver for ordinary differential equation systems. It is based on robust mathematical algorithms, and targeted at large systems on parallel machines. A closely related solver called KINSOL has been developed for systems of nonlinear algebraic equations, and another is in progress for systems of differential-algebraic equations.

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Although the development is stopped since Elan has merged with another company to form ClicNet Télécommunications, there is a beta version of Solutions V2.0 available. It contains a lot of new interesting features. It has not been as fully tested as V1 but it is reliable. Hint: We use V2 over V1 ;-)

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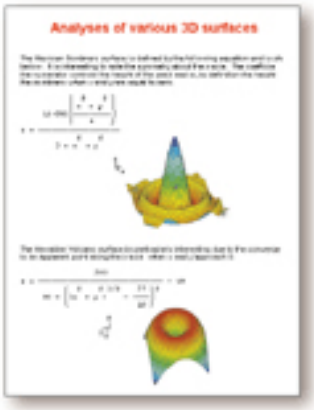

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dockable toolbars. Elements of vectors and matrices are entered using a spread-sheet like template. Limits, derivatives, integrals, sums, etc. are easily calculated using templates so you don't have to remember complicated function names or argument lists. In the worksheet, Derive displays expressions in easy to read, two-dimensional mathematical format. With the click of a mouse, subexpressions can be selected for operations such as simplifying, expanding, or factoring.

DERIVE for DOS

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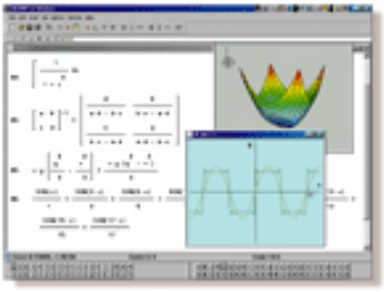
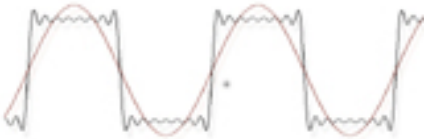


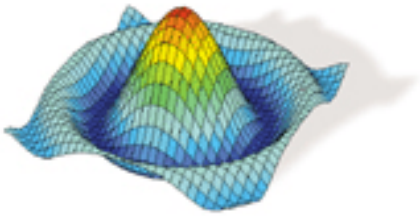
Derive can algebraically simplify, expand and factor symbolic expressions. Equations, inequalities, and systems of polynomial equations can be solved for their real and complex roots. Perform numeric operations exactly with no round-off error or approximately to thousands of digits of precision. Derive applies the rules of trigonometry, calculus, matrix algebra and vector calculus to solve your toughest math problems. In addition to the built-in capabilities, Derive comes with an extensive library of utility files that define functions for solving first and second order ordinary differential equations (both exactly and numerically), and for computing Bessel, Fresnel, elliptic integrals and other special functions. Utility files are automatically loaded on demand, so these functions are always available for use. Naturally you can create your own utility files by defining functions using either a functional or procedural programming style, as appropriate. For the latter, Derive provides flexible loop, block, and if-then-else control constructs as well as the ability to define default values for arguments.

2D graphs



Plot multiple 2D graphs to analyze and explore equations in both Cartesian and polar coordinate systems. Control the aspect ratio, scale and axis definition of your plot, and optionally view the real and imaginary parts. Trace the graph and view precise coordinates of points on the curve. Derive can even plot Boolean combinations of inequalities involving two variables!

3D surfaces



Rotate and zoom multiple shaded 3D surfaces in real-time. Plot 3D surfaces using parametrically defined functions or sets of data points. Display surfaces in rectangular, spherical or cylindrical coordinate systems. Determine coordinates of points on surfaces using movable highlighted cross lines. 2D graphs and 3D surfaces can be annotated with descriptive text, sent to the clipboard or printer, or exported in popular formats such as TIFF, JPEG, and BMP.

System Requirements

Windows® 95, 98, ME, NT, 2000 or XP compatible PC (minimum RAM and processor requirements are the same as the operating system requirements), CD ROM Drive, and less than 4 MB of disk space.

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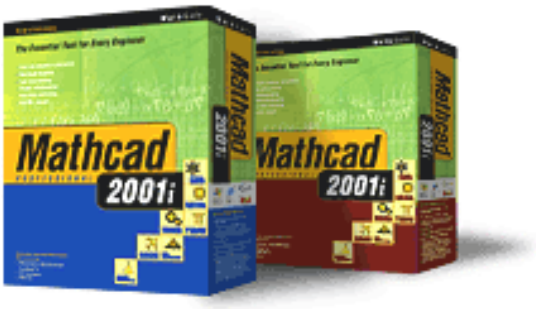

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- Go the the main Wolfram Research site.

- Introduction
- Orientation
  - Notebooks
  - Palettes
  - Kernels
  - Help System
- Doing Math
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- Graphics
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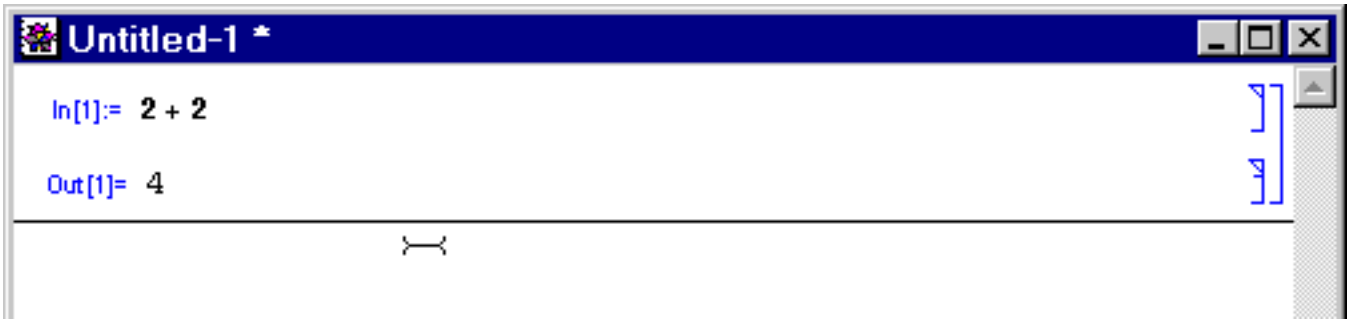
Orientation

When you first start Mathematica, you should see a "splash" screen with the Mathematica logo, version, and license information. When the program loads, you should see several objects on the screen. We will now describe what they are and what they do.

TIP	You may wish to turn on your speakers (or bring headphones if you are in an STC). Mathematica uses audio cues to notify the user of errors, finished calculations, etc.

Notebooks

A notebook is a collection of Mathematica statements, output, and graphics. The concept is like that of a "document" in a word processor. You enter information and commands into the notebook window, and the output (if any) is displayed there.



If the notebook has been modified since it was last saved, an asterisk (*) will appear in the title bar. To save your work, choose File->Save As... or File->Save.

If Mathematica is ready for new input, the cursor will flip sideways (see above). Just start typing to enter information. Try typing this (don't press return yet):

```
2 + 2
```

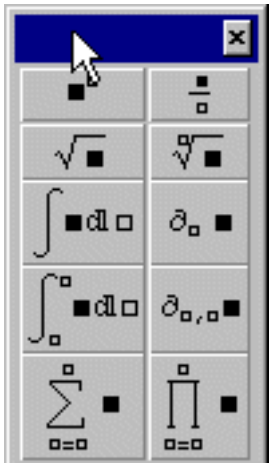
To tell Mathematica to evaluate this expression, hold down Shift and type Return. Since Mathematica is also a word processor, it needs to know if you want to evaluate the expression, or just insert a carriage return-linefeed. This can be quite confusing to the new user.

System	Evaluate	Linefeed
Macintosh	Enter *or* Shift-Return	Return
Windows	Shift-Enter	Enter
X	Shift-Return	Return

Next, look at the blue symbols along the right side of the notebook. Each group of statements enclosed by the triangle-brackets ( ) is called a *cell*. The cell is the smallest unit of work in Mathematica. A cell may contain input or output, math or comments, text or graphics.

	Cells in Mathematica are like *execution groups* in Maple.

Palettes



You should see a box with a lot of symbols floating on the right side of your Mathematica window. This is called a *palette*. Palettes allow you to easily insert complicated mathematical notation. For example, to compute the cube root of 34, you could click on the . Type **34**, which should appear under the root sign. Then click on the small square above the root, and type **3** in the box. Finally, evaluate the expression.

Using the default palette, you can enter fractions, integrals, summations, matrices, subscripts, and most greek letters. Of course, there are many other palettes available - choose File->Palettes to see a list.

Kernels

Mathematica is actually split into two conceptual pieces, the *front-end* and the *kernel*. When you start Mathematica, you are actually only starting the front-end.

The front-end handles input and output to the user, access to the file system, and creates graphics on your screen. Most users will deal primarily with the front-end.

The kernel does nearly all computation (excluding graphics rendering). When you evaluate any expression, the kernel does the hard work and sends the results back to the front-end, which then displays it in an attractive format for the user.

Most users will run the front-end and the kernel on the same computer. If your computer is connected to a network, you can run the kernel on a more powerful machine, while running the front-end on your favorite computer. To learn how to do this, choose Kernel->Kernel Configuration Options, click Add, and then click Help.

TIP	How to stop a runaway calculation: • Macintosh - Command-Comma or Control-C • Windows and X - Alt-Comma or Control-C This will bring up a menu that allows you to view the state of the kernel, abort the calculation, etc.

Help system

Mathematica has an excellent help system. To get general help, choose Help->Help Browser. Browse among the topics listed.

Mathematica comes with an excellent resource, *The Mathematica Book*. It is available through the Help Browser. See also the Getting Started section, which contains several excellent tutorials.

Next:Doing Math
Previous:Introduction

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URL `/~statmath/math/mma/gettingstarted/orientation.html`

- Introduction
- Orientation
- Doing Math
  - Arithmetic
  - Algebra
- Functions
- Graphics
- Further Reading

Doing Math

Arithmetic

Basic arithmetic operations are easy to enter in Mathematica. You may use your choice of notation, and you may choose to enter symbols via the palettes or the keyboard.

Keystrokes	Input	Output	Comments
4, ,+, ,4 3,-,1,6	4+4 3-16	8 -13	Addition, subtraction. Spaces are optional.
4,*,4 4, ,4 4,4 4,Esc,*,Esc,4	4*4 4 4 44 4×4	16 16 44 16	Multiplication. A space can mean multiplication as well... ...but you should be careful. You can also use the symbol.

3,/,4 3,Esc,d,i,v,Esc,4 3,Ctl-/,4	3/4 3÷4 $\frac{3}{4}$	$\frac{3}{4}$ $\frac{3}{4}$ $\frac{3}{4}$	Exact division.
3,^,5 3,Ctl-^,5	3^5 3^5	243 243	The text version The symbolic version
3,^,(,1,/,2,) Ctl-@,3 N,[,Ctl-@,3,Ctl-Space,]	3^(1/2) $\sqrt{3}$ N[$\sqrt{3}$]	$\sqrt{3}$ $\sqrt{3}$ 1.73205	An approximation.
%,Ctl-^,2	$\%^2$	3.	Square last output.

Mathematica's data restrictions are as follows:

- Integers can be of any size, up to your computer's memory.
- Real and complex operations are carried out with arbitrary (limitless) precision, up to your computer's memory, unless `N` is used.
- See Help->Help Browser: Numerical Computation->Numerical Precision->N, and section 1.4.9 of *The Mathematica Book*.

	• Mathematica does not set limits on the size of matrices, as Maple does. • `N[...]` is just like Maple's *feval* .
	If you want to use double precision, you must explicitly say so. See above.

Algebra

Mathematica is more than a calculator, of course. We will now try out some of Mathematica's Computer Algebra System (CAS) features.

Keystrokes	Input	Output	Comments
a	a	a	All names are symbols.
a,=,4	a=4	4	Defining a constant.
Esc,a,l,p,h,a,Esc,=,3	α=3	3	Greek letters (see palettes).

(,x,+,1,),Ctl-^,2	**(x+1)²**	(x+1)²	An expression.
E,x,p,a,n,d,[,%,]	**Expand[%]**	1+2x+x²	Algebraic expansion....
S,i,m,p,l,i,f,y,[,%,]	**Simplify[%]**	(x+1)²	...and simplification.

From this point onward, we will assume that you know how to enter keystrokes.

Input	Output	Comments
p=x³+3x²+3x+1	x³+3x²+3x+1	**p** is now an alias for the expression. This is not mathematical equality.
Solve[p==0]	{{x->-1}, {x->-1}, {x->-1}}	Solve the *equation* **p==0**. Mathematica returns a set of *transformation rules*. The system has three identical solutions.
p /. x->2	27	Substitute 2 for x (temporarily).
p==0 /. x->2	False	27 does not equal 0.

	Transformation rules are like the *subs* command in Maple.
TIP	Go exploring in the Algebra Palette: File->Palettes->AlgebraicManipulation.

Next:Functions
Previous:Orientation

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- Introduction
- Orientation
- Doing Math
- Functions
  - Using Them
  - Creating Them
  - Procedural Functions
- Graphics
- Further Reading

Functions

Using them

A *function* in Mathematica is a formalized, named transformation rule. A function may return a symbol, a real number, a complex matrix, another function.... Any mathematical object is an acceptable value for a function. We have seen several built-in functions so far: **`Solve`**, **`Expand`** , and **`N`** are a few examples. A function may be written using mathematical notation, it may be created using programming constructs (like for, if/then, etc.), or it could even be written in another language entirely (Fortran, C, etc.).

All built-in Mathematica functions are named with InitialCapitalLetters (**`FullSimplify`**) and some use abbreviations (**`NDSolve`** - Numerical Differential Equation Solver).

Creating them

Input	Output	Comments

`f[x_]:=x^2`	`(none)`	A simple function definition. Note the underscore (_) that follows the dependent variable name.
`f[2]` `f[y+z]`	`4` `(y+z)^2`	The function works with numbers and expressions.
`f[f[f[2]]]`	`16348`	You can nest functions.
`?f`	`Global 'f` `f[x_] := x^2`	What is f?
`g[x_,y_] := x*y`	`(none)`	You can have as many arguments as you like.
`Clear[f]`	`(none)`	Deletes the definition of f.

Procedural Functions

You may wish to create more complex functions. Suppose that you wanted to count to 100, and print out a list of each number that is divisible by the argument. Here is one way that you could do it:

```
sillyCount[n_] := ( Do[ If[Mod[i,n]==0, Print[i]] ,{i,100}]; )
```

For more information on programming in Mathematica, see the online help.

Next:Graphics
Previous:Doing Math

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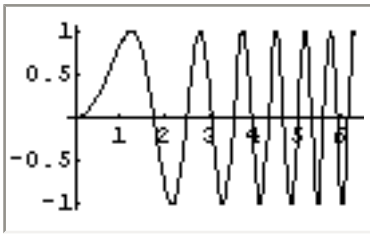
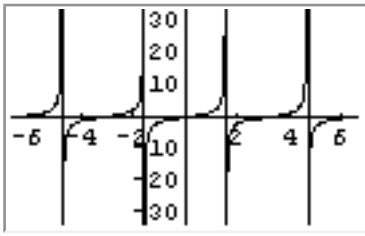
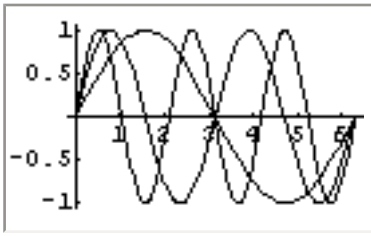
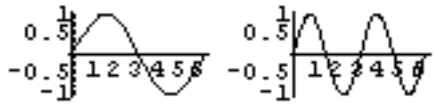
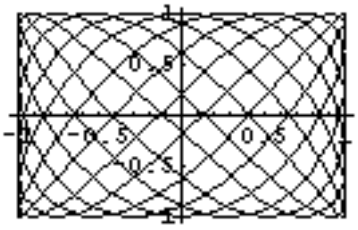
Graphics

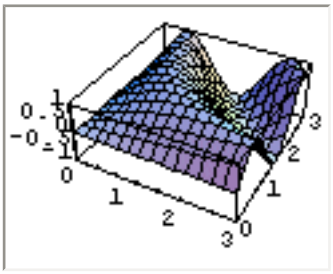
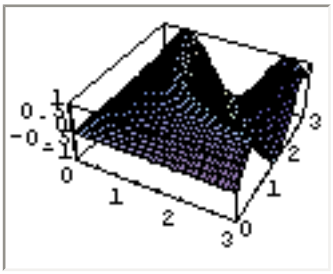
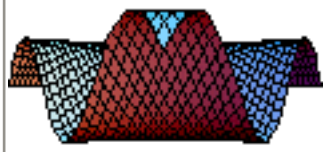
2-D Graphics

Input	Output	Comments
`Plot[Sin[x^2],{x,0,2Pi}]`		A simple plot.
`Plot[Tan[x], {x, -2Pi, 2Pi}]`		If the plot has singularities, Mathematica will try to choose a suitable scale....
`Plot[ Tan[x], {x, -2Pi, 2Pi}, PlotRange -> {-10,10}]`		...or you can set it manually.

`Plot[ {Sin[x],Sin[2x],Sin[3x]}, {x, 0, 2Pi}]`		You can plot multiple functions by including them in curly brackets.
`Show[GraphicsArray[ {Plot[Sin[x],{x,0,Pi}], Plot[Sin[2x],{x,0,2Pi}] }]]`		Plot two plots, side-by-side.
`ParametricPlot[ {Cos[7t], Sin[11t]}, {t, 0, 2Pi}]`		Parametric plot.

For more information, see section 1.9.1 in *The Mathematica Book*.

3-D Graphics

Input	Output	Comments
`Plot3D[ Sin[x y], {x,0, 3}, {y, 0, 3}]`		A basic surface plot.
`Plot3D[ Sin[x y], {x, 0, 3}, {y, 0, 3}, PlotPoints -> 40]`		You can get a finer plot if you increase the number of sample points.
`Plot3D[ Sin[x y], {x, 0, 3}, {y, 0, 3}, ViewPoint -> {1, 1, 0}, PlotPoints -> 40, Boxed -> False, Axes -> False]`		A variety of options. Most important is the ViewPoint option, which tells where to put the "camera".

For more information, see section 1.9.7 of *The Mathematica Book*.

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Further Reading

If you have enjoyed working with Mathematica, you will almost certainly enjoy *The Mathematica Book*. It is available on the web, through Stat/Math Center Sales, at your local bookstore, and in the online help.

In addition, be sure to wander through the Wolfram Research Documentation Center, where you will find reference works on any topic imaginable.

You can find other people who use Mathematica in the following usenet newsgroups:

- comp.soft-sys.math.mathematica
- sci.math.symbolic (Mostly Maple discussion, but some Mathematica)

In addition, your local bookstore or library probably has several books about Mathematica or one of its applications. WRI keeps a list of current books on their website.

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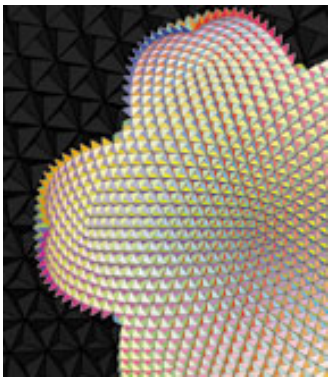

The Mathematica® Journal

VOLUME 8 ISSUE 3

DEPARTMENTS

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New Products
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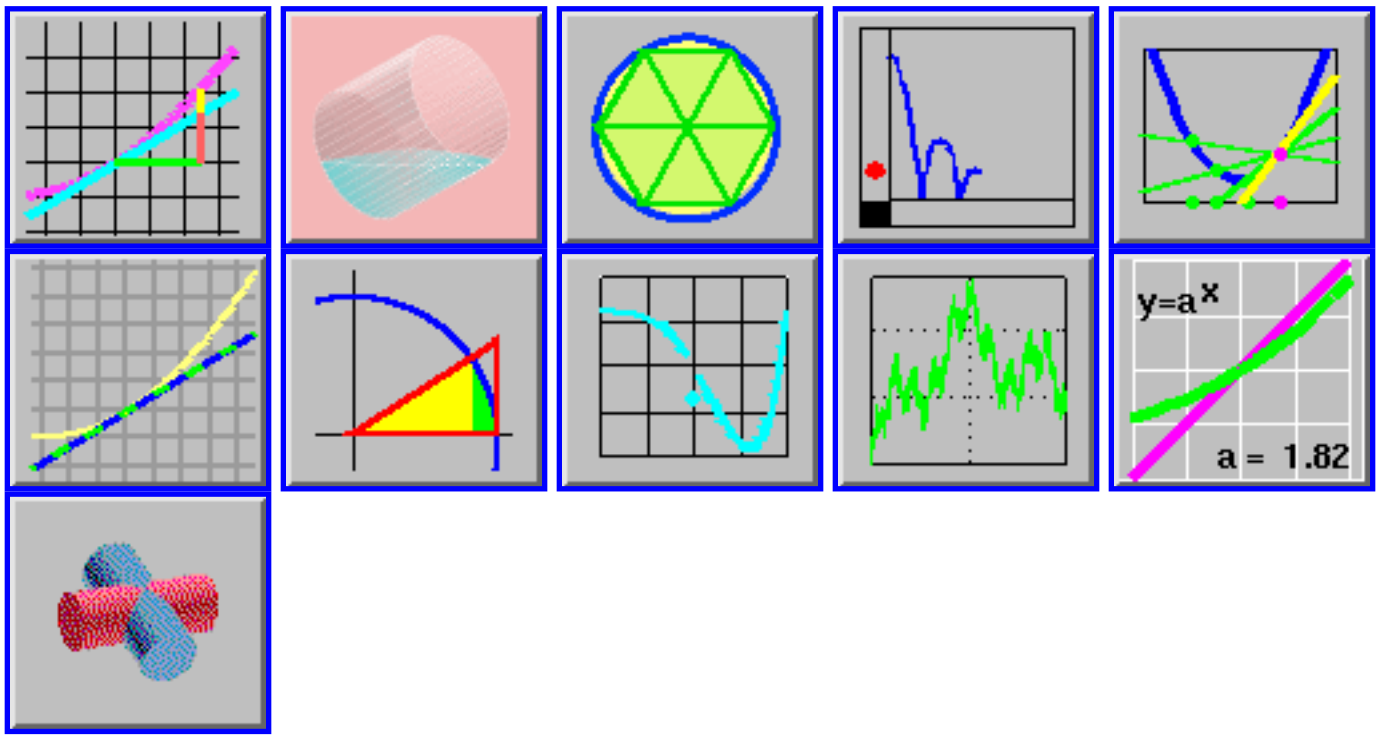
(animated GIF version)

GRAPHICS FOR THE CALCULUS CLASSROOM

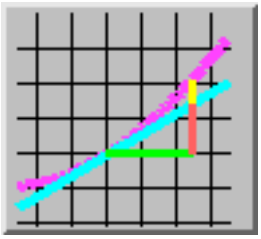
Douglas N. Arnold



These are excerpts from a collection of graphical demonstrations I developed for first year calculus. Those interested in higher math may also want to visit my page of graphics for complex analysis. This page is on the list of the most frequently linked math pages according to MathSearch.

Viewing instructions. The animations on this page use the animated GIF format. There is also a Java

version of this page. The Java animator allows you to start and stop the animation, advance through the frames manually, and control the speed. Also the animation is a bit smoother, and the frames shuttle (first to last and then backward to first, etc.), which is a bit nicer. Unfortunately, the Java versions of the animation usually take much more time to load, and the Java animator has been know to crash browsers, especially on machines without much memory. An older version of this page using the MPEG animation format is available, but no longer actively maintained, and so not recommended.



Differentials and differences

This animation expands upon the classic calculus diagram above. The diagram illustrates the local accuracy of the tangent line approximation to a smooth curve, or--otherwise stated--the closeness of the differential of a function to the difference of function values due to a small increment of the independent variable. (In the diagram the increment of the independent variable is shown in green, the differential--i.e., the product of the derivative and the increment--in red, and the difference of function values as the red segment plus the yellow segment. The point is that if the green segment is small, the yellow segment is *very* small.) A problem with the diagram is that when it is drawn large enough to be visible the increment is too large to make the point. For example, here the yellow segment is about 30% of the green segment. This animation overcomes that problem by showing two views of the diagram, each changing as the increment varies. In the left view the ``camera'' is held fixed, and so the diagram becomes very small, while in the right view the ``camera'' zooms in so that the diagram occupies a constant area on the screen, and the relationship between the segment lengths can be clearly seen. Note how the yellow segment becomes very small in the second view (while the green segment appears to be of constant length due to the zoom). Note also that as we move in the difference between the purple curve and the blue tangent line becomes insignificant.

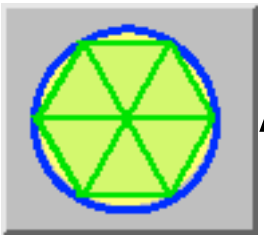
Computing the volume of water in a tipped glass

These images concern the computation of a volume by integrating cross-sectional areas. The first image

reviews the basic principle. The other images treat a specific volume, that of the wedge of water formed when a cylindrical class of equal height and diameter is tipped until the water line runs through the center of the base. The pictures are frozen frames from AVS, and can only convey a rough idea of the interactive classroom presentation (which typically lasts about 30 minutes).

- The principle
- The wedge of water formed by tipping a glass
- Cross sections perpendicular to the waterline at the base
- Three different ways to slice the same volume

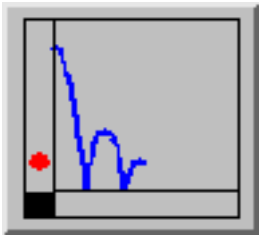
And now for the quiz: Compute the percentage of the glass filled by water using each of the the three slicings depicted in the last slide and verify that they all lead to the same answer.



Archimedes' calculation of π

In the third century B.C., Archimedes calculated the value of π to an accuracy of one accuracy of one part in a thousand. His technique was based on inscribing and circumscribing polygons in a circle, and is very much akin to the method of lower and upper sums used to define the Riemann integral. His approach is presented in the following sequence of slides.

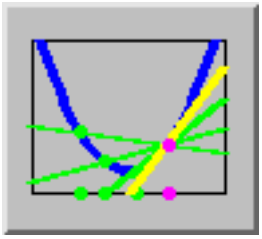
- Calculating the area of a circle
- Inscribed hexagon
- Triangulation
- A lower bound for the area
- Circumscribed hexagon: an upper bound for the area
- Refining the bounds with dodecagons
- Table of results



How the ball bounces

As a way to help students appreciate functions, their applications, and their graphs, I involve them in a small project to describe the functions determined by the height of a bouncing ball. Although I start by dropping a real tennis ball from one meter above ground, a better quantitative idea of the function can be obtained from a computer animation, including a meter stick and clock. The students view the animation (in slow motion, with manual frame advance, etc.) and try to construct the graph of the function. As a homework assignment they are asked to determine the function algebraically. This is a piecewise quadratic and helps the students to realize that piecewise defined functions do exist outside of calculus books.

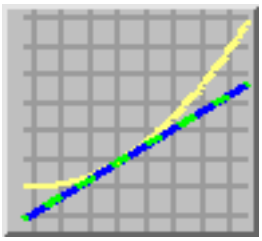
- Animation of a bouncing ball
- Animation of the ball with a graph of its height
- Animation of the ball with a graph of its height and velocity
- the Mathematica file used to construct the animations
- the student worksheet (PostScript file)



Secants and tangents

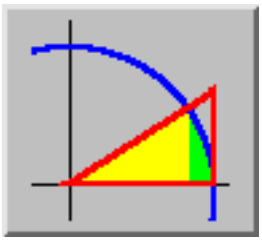
This is a pretty straightforward animation depicting the geometric convergence of secant lines to the tangent line. The slope of the secant (which converges to the derivative) is also displayed. I use various variations on this demo during the early part of a calculus course.

- Animation of secants approaching a tangent
- The same animation with the tangent shown
- Secants passing through a point of non-differentiability
- Secants approaching a vertical tangent--another form of non-differentiability
- The Mathematica file used to construct the animations.



Zooming in on a tangent line

This animation is a version of the common demonstration that a smooth curve becomes indistinguishable from its tangent line when viewed under a sufficiently high power microscope. Students can easily demonstrate this themselves using a graphics calculator equipped with a zoom button. In this animation, we provide some extra distance queueing by showing the grid and striping the tangent line. Here is the Mathematica file used to construct the animations.



A trigonometric limit

An elegant geometric proof which is well within the reach of a beginning calculus student is the proof of the fundamental trigonometric limit

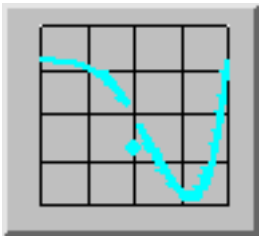
$$\lim_{x\to 0} \frac{\sin x}{x} = 1.$$

The proof is based on a diagram depicting a circular sector in the unit circle together with an inscribed and a circumscribed triangle. From the fact that the sector has area exceeding that of the inscribed triangle but less than that of the circumscribed one is lead to the inequalities

$$\frac{1}{2}\sin x \cos x \le \frac{x}{2} \le \frac{1}{2}\tan x \quad \text{and thus to} \quad \cos x \le \frac{\sin x}{x} \le \frac{1}{\cos x}.$$

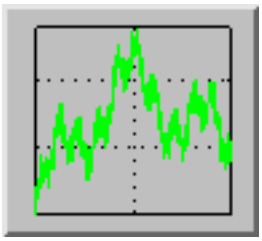
The proof then follows from the "squeeze theorem."

I usually spend about 15 minutes on this proof, including lots of class participation. The diagram is built up in three steps: first the sector only, then with the inscribed triangle, and finally with both triangles. Here are some instructions for creating it in class. During the presentation I make frequent recourse to plotting software to verify the various inequalities. For example this plot, constructed from this MATLAB file, convincingly verifies the second set of inequalities.



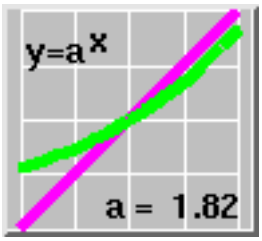
The limit

These are some simple graphs which are useful in a discussion of limits. The first three functions all have limit -5 as *x* approaches 1, emphasizing the irrelevance of the value of the function at the limit point itself. The last function has different left and right hand limits at 1, and so the limit does not exist. The graphs were constructed with this MATLAB file.



A nowhere differentiable function

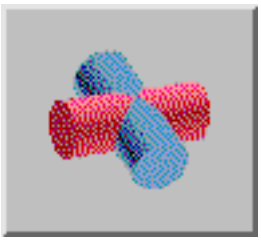
A brief graphical exploration of a continuous, nowhere differentiable function fits very well in the first semester of calculus, for example, to provide a strong counterexample to the converse of the theorem that differentiability implies continuity; or to show that it is only differentiable functions which look like straight lines under the microscope. Given good classroom graphics facilities such an exploration is easy, but it is almost hopeless without them. This plot of such a function was produced with a few lines of Matlab code following Weierstrass's classical construction. In class I zoom in on this graph several times to reveal its fractal nature. Consequently I used a very fine point spacing. On a slower machine it is preferable to use fewer points, and decrease the point spacing as you zoom in.



2.71828182845904523536028747135266 2

Students are often puzzled by the appearance of the number *e*, which is given above (to 35 decimal places). A simple explanation of its origin arises from the fact that *e* is the only number for which the tangent to the graph of $y=e^x$ through the point (0,1) has slope exactly 1. The important result that the

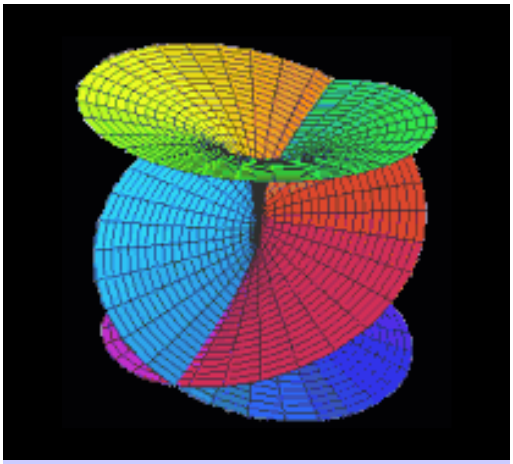
function $f(x)=e^x$ is its own derivative follows easily from this fact and the elementary laws of exponents. This animation here simply shows the graph of $y=a^x$, but with varying a. By manipulating the frame advance, you can adjust a so that the tangent has slope close to 1. The second animation is similar to the first, but drawn on a larger scale, and from it one can read off the first few decimal places of e. Here is the Mathematica file used to construct the animations.



The intersection of two cylinders

Here's a demonstration by my colleague David Sibley illustrating the computation of the volume of the region formed by two intersecting cylinders.

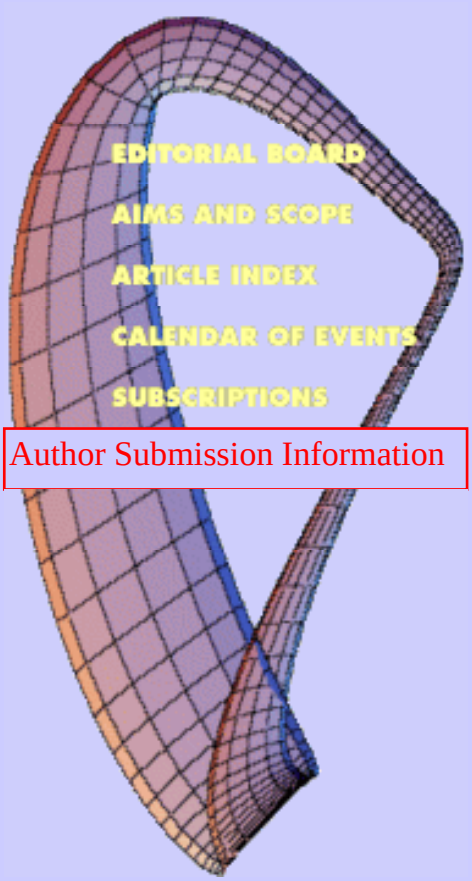
Last modified July 2, 1997 by *Douglas N. Arnold, arnold@ima.umn.edu*



Mathematica IN EDUCATION AND RESEARCH

Mathematica in Education and Research is a multidisciplinary journal that publishes articles about the use of *Mathematica* in higher education at both the undergraduate and graduate level. Each issue is available as a printed magazine, Web Pages (HTML), and *Mathematica* notebooks.

SEARCH MIER JOURNAL



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Electronic Subscriptions are composed of HTML versions of issues together with *Mathematica* notebooks and packages. These can be accessed below.

Volume 8 (1999)	Volume 7 (1998)	Volume 6 (1997)	Volume 5 (1996)
Issue 8.1	Issue 7.4	Issue 6.4	Issue 5.4
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Issue 8.3 & 8.4	Issue 7.2	Issue 6.2	Issue 5.2
	Issue 7.1	Issue 6.1	Issue 5.1

Volume 9 (2000)

Issue 9.1
Issue 9.2
Issue 9.3 & 9.4

Be sure to check the online Index for a listing of every article and column that has appeared in the *Mathematica in Education and Research* journal (1992-1999).

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Presenting Don Piele's *Mathematica* Pearls: Problems and Solutions. Don Piele has been interested in creating programming problems since he began the International Computer Problem Solving Contest in the pages of Creative Computing in 1981. In 1992, he organized the USA Computing Olympiad (USACO), which selects the top four American high school computer programmers to represent the USA at the annual International Computing Olympiad. He also writes a column, ``*Cowculations*," in Quantum Magazine, devoted to computer algorithms using *Mathematica*. The electronic version of his column for each issue of the journal is provided free below.

Volume 8 (1999)	Volume 7 (1998)	Volume 6 (1997)	Volume 5 (1996)
Pearls 8.1	Pearls 7.4	Pearls 6.4	Pearls 5.4
Pearls 8.2	Pearls 7.3	Pearls 6.3	Pearls 5.3
	Pearls 7.2	Pearls 6.2	Pearls 5.2
	Pearls 7.1	Pearls 6.1	Pearls 5.1

DOWNLOADING INFORMATION

Articles and columns are available for download as *Mathematica* notebooks. Almost all files are compressed as Gnu-zipped files for quicker transfer. Most MIER issues allow you to download a Gnu-zipped `tar` archive of all the *Mathematica* notebooks and packages for that issue. If you do not currently have software to handle these formats, they can be downloaded for Windows 95/98/NT and Macintosh. `tar` and `gzip` are already contained in most versions of Unix. If you do not have a copy of *Mathematica* 3.0, you may download the free *Mathematica* notebook viewer, *MathReader*.

Welcome to the Complex, Technology Based Problems in Calculus Home Page

What we're all about:

We offer complex, technology-based problems in calculus with applications in science and engineering. These problems have a higher level of complexity than traditional text book problems and foster use of a computer algebra system. Each problem set includes discussions of related teaching issues and solutions worked in *Mathematica*.

Each problem is provided in the following three formats:

- .html = . *Mathematica* notebook in HTML format with figures translated to GIF files. This is readable by any standard WWW viewer, but a Netscape will probably work best. Translated to HTML by nb2html.
- .ma = . *Mathematica* notebook (ver. 2.2) (ASCII). Download this version after viewing the HTML format.
- .asc = . Text as ASCII. This contains all the text of statement of problem, comments and solutions.

How to search:

- **By category:** Choose from categories that best describe the problem type desired.
- **Full text word search:** All problems with the string you enter will be listed.
- **Keyword search:** All problems come with a list of key words provided by the author(s). All matches will be listed.
- **Alphabetically:** If you know the file name for a problem set, you can find it in alphabetical order.

Here are the problems.

And here are the problem developers.

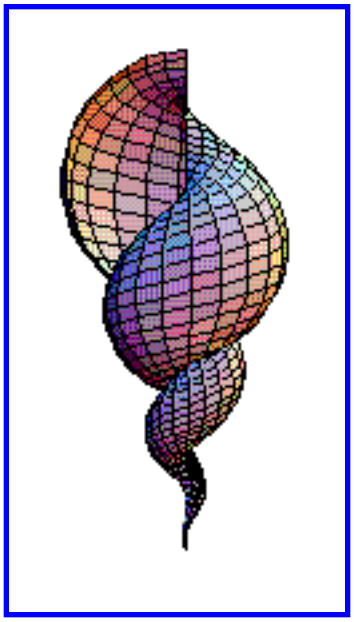
Go to the Rose-Hulman Math Department Home Page.

Go to the Rose-Hulman's Home Page.

This page is maintained Aaron Klebanoff. Questions, comments, etc. should be directed to Aaron.Klebanoff@Rose-Hulman.Edu.

Support: The production of this material is supported by the National Science Foundation under Division of Undergraduate Education grant DUE-9352849: Development Site for Complex, Technology-Based Problems in Calculus with Applications in Science and Engineering and the Arvin Foundation of Columbus IN.

Interactive Learning in Calculus and Differential Equations with Applications



Click on this picture for a description of how it was generated.

The Mathematics Department at Indiana University of Pennsylvania (IUP) established a computerized learning environment, consisting of a classroom with 31 Macintosh Centris 650s and a laboratory with 12 Macintosh LCs, all equipped with Mathematica. Mathematica's notebook feature enables science students to actively learn calculus and differential equations with guided discovery and exploration. The project was funded through a National Science Foundation Instrumentation and Laboratory Improvement grant, number DUE-9351896. IUP's project has several significant attributes.

- The Mathematics Department is fully implementing this curriculum in all sections of its science calculus sequence and in the two-semester differential equations sequence.
- Eleven faculty, comprising approximately one third of IUP's mathematics faculty, are coinvestigators.
- The curricular revisions are being coordinated with the science departments at IUP, who are also integrating active learning and technology in their courses. This collaboration, based on common pedagogical goals and software, will bring more scientific applications into mathematics courses and strengthen the use of mathematics in science courses.
- All students in the Mathematics Department are involved. Mathematics and Applied Mathematics majors are required to take Differential Equations, and Mathematics Education majors have a unit devoted to the project in the teacher preparation course, Computers and Calculators in Secondary Mathematics.

Check back later at this location for more Mathematica notebooks relating to calculus, ordinary differential equations, and partial differential equations. Some of the topics covered are:

- Finding Areas with the Gauss-Green Formula,
- Newton's Method and Fractals,
- Vibrating Drumheads
- The Drag Force on a Sphere
  (This notebook predates our project, but it fits in, so we are including it anyway)
- Advanced Mathematics for Applications
  (This is a collection of 26 Mathematica notebooks from our course of that name.)

In order to disseminate these *Mathematica* notebooks, one of the PIs in this grant wrote a program, math2html, to convert *Mathmematica* notebooks to HTML documents. This program is available to the public.

Presentations:

1. "Mathematica in the Classroom", Francisco Alarcon and Charles Bertness, Lock Haven University, February 21, 1994.
2. "IUP's Mathematica Network", Rebecca Stoudt, poster session on "Computer Laboratories in Mathematics Education", American Mathematical Society/Mathematical Association of America Joint Meeting, Cincinnati, Ohio, January 1994.
3. "Restructuring the First Differential Equations Course for Mathematics and Science Majors using Mathematica", Francisco Alarcon, in the MAA session "New Methods for Teaching Ordinary Differential Equations", American Mathematical Society/Mathematical Association of America Joint Meeting, Cincinnati, Ohio, January 15, 1994.

Francisco Alarcon, Don Balenovich, Charles Bertness, Gerald Buriok, Dan Burkett, Arlo Davis, H. Edward Donley, Gary Stoudt, Rebecca Stoudt

Related Topics

- Imperial College's Transitional Mathematics Project
- The Consortium for Ordinary Differential Equations Experiments
- PWS Publishing Differential Equations Resource Center

Read this disclaimer.

Maintained by H. Edward Donley <*hedonley@grove.iup.edu*>
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What is C&M?
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- History
- People
- Student Comments
- F.A.Q.
- News/Announcements

The Courses
- Syllabi

Students
- Homework Tips
- Homework Examples
- Apply to C&M
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- Help

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- Lab Schedule
- Grading Tips
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- CourseSpace

Links
- Netmath
- OSU Program
- Wolfram
- MathEverywhere

Calculus&*Mathematica*

News/Announcements:

- **Summer C&M courses available through NetMath**
  - Register here if you are interested.
- **Apply to work for Calculus&Mathematica for next fall!**
  - Applications can be found at the link "Apply to C&M" on the sidebar on this webpage or at http://www-cm.math.uiuc.edu/stud/apply.html

    Applications will be due on April 29. If you have any questions, please email lead@cm.math.uiuc.edu
- **Lab hours**
  - Spring semester hours for lab in 239 Altgeld are: 8a -11p M -Th, 8a -5p F, 12p -5p Sat, and 12p -11p Sun.
  - Spring semester hours for C&M in 24 Illini Hall are : 10a -5p MWF, and 11a -3p T, Th.
  - The lab schedule for 239 Altgeld and 24 Illini Hall can be found here.
- **Mathematica News**
  - Mathematica for students through ccso is now available. It can be obtained from http://www.cso.uiuc.edu/software/sls

    The cost is $25 wtihout media (45 MB download) or $30 with the CD. It expires on 8/26/02 at which time it needs to be renewed. It will be renewed most likely at $25 again and will last until the following August.

General Algebra

If you've never used math software before, we suggest using Maple for this task - read our review.
This topic covers high-school and college level algebra. It does not coverAbstract (Modern) or Linear Algebra.

- Algebra Calculation With Matlab
  - Basic arithmetic with Matlab
- Algebra Calculation With Maple
  - Algebra Examples
  - Using Variables -from Getting Started with Maple
  - Operations on Vectors and Vector fields in Maple
- Algebra Calculation With Mathematica
  - Symbolic Algebra
  - Algebratic Equations
- Other useful algebra links
  - Algebra Online

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Linear Algebra

- Linear Algebra With Matlab
  - More Matrices with Matlab
  - Archive of M-files for Linear Algebra
  - ATLAST M-files
- Linear Algebra With Maple
  - Linear Algebra With Maple
  - FTP archive of Linear Algebra packages
- Linear Algebra With Mathematica
  - ATLAST Notebooks for linear algebra
- Other Linear Algebra Resources
  - The Matrix Market - visual repository of sparse matrices
  - Dr. Math - Linear Algebra Q+A - from The Math Forum
  - ATLAST- Augment the Teaching of Linear Algebra through Software Tools

See also - Numerical Analysis - Linear Algebra

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Abstract Algebra

- Abstract Algebra With Maple
  - Packages for abstract algebra with Maple
  - A package for Algebraic Curves in Maple
- Abstract Algebra With Mathematica
  - Solving the Quintic
- Other Abstract Algebra Resources
  - Math Forum: Abstract Algebra
  - Abstract Algebra Online
  - Algebraic Number Theory Archives
  - Combinatorics - Various uses of abstract algebra.
  - Atlas of Finite Group Representations

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Calculus

- General Help
  - Various Calculus Topics
  - Calculus Graphs
  - Differential Equations
  - Calculus Links
  - More Links
- Calculus with Matlab
  - Integrations in Matlab
  - How SIMULINK performs simulations
- Calculus with Maple
  - Plotting Integral Functions
  - How to do Least Squares problems in Maple
  - Calculus and Analytical Geometry with Maple
  - Calculus 1, 2and 3 with Maple
- Calculus with Mathematica
  - Calculus and Mathematica
  - FAQs for Calculus
  - Calculus Operations
  - Some Multivariable Calculus Ideas Using Mathematica
  - Practical examples of integration
  - Pracitcal examples of Partial Derivatives

See also: Differential Equations

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Differential Equations

- General
  - A review of the ODE solvers of Axiom, Derive, Maple, Mathematica, Macsyma,MuPAD and Reduce
  - Differential Equations Course
  - HPC issues in PDE's
- Matlab
  - Getting Started with the PDE Toolbox
  - The Partial Differential Equation Toolbox in Matlab
- Maple
  - ODE Examples
  - ODE Handbook
  - ODEs with Maple
  - ODE2 Package (and graphics gallery).
- Mathematica
  - Interactive Learning with ODEs and PDEs

See also: Numerical Computing - Differential Equations

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- PD Fourier Series
- PD Line Integral
- PD P. C. Convolution

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- PD ANUM
- PD Are You Ready for Calculus 1
- PD Are You Ready for Calculus 2
- PD Are You Ready for Calculus 3
- PD Calculus Calculator
- PD Calculus and Diff. Equations
- PD Composition of Functions
- C Derive
- PD Diff
- PD Findpoly
- PD FORM
- SD Formula Wizard
- PD Function Visualizer

- PD Functions Slide Show
- SD Gdraw
- S Graphmatica
- PD Interactive Demos & Teaching Aids
- PD JKGRAPH
- PD JKMath
- PD Knox Packages
- PD Limits
- PD MAFIA
- S Mat-X
- CD Mathcad Demo
- PD Mathematics Plotting Programs
- SD Mathomatic
- PD Mathtool
- S Mercury
- C MicroCalc
- CD Natural Language Math. Calculus Tutor Demo
- PD Numerical Integration
- PD PFSA Symbolic Algebra Program
- PD Polar, Param and Polpm
- S Polyroot
- PD Root Finder
- PD Sequences and Series
- PD Slide Show for Newton's Method
- SD SymbMath
- PD TSNUM
- PD Taylor Series
- PD Taylor Series Slide Show
- PD Transitional Mathematics Project
- PD Transmath
- PD Trouble Slide Show
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List of Packages

- PD Algebra Editor
- PD Are You Ready for College Algebra v.1.02
- PD Are You Ready for Intermed. Algebra v.1.0
- PD Complex Numbers v.1.10
- SD Formula Wizard
- PD LINSYS
- PD Linear Systems v.1.05
- SD Mathomatic
- PD Polynomial Teacher
- S Polyroot
- S Prof. Weissman's Algebra Tutorial v.2.12
- S Prof. Weissman's Pre-Calculus Tutorials
- PD RPN Calculator
- PD SOLVEQ
- PD TSDRAW v.1.6

Transitional Mathematics Project

Transmath

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- PD CAL v.4.0
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- PD Complex Functions v.0.08
- PD Dynamical Systems
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List of Packages

- PD Catbox
- SD Colourful Mathematics
- PD Extended Precision Integers
- PD Graph Theory
- PD ISETL
- PD LINSOLVE
- S LP100
- PD Matrix Program
- C Models
- PD Propositional Logic Program
- PD Simplex Method
- PD TSDRAW
- PD Truth Tables Maker
- PD Truth Tables
- PD Venn Diagrams

Voting Methods

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Windows/MSDos Software Collection for Graphing

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List of Packages

- PD Composition of Functions
- PD Conics
- PD Cyclo
- PD Drawfn3d - 3d Parametric Surfaces Drawing Program
- PD Drawfunc - 2d Parametric Curves Drawing Program
- PD Fortune
- PD Function Visualizer
- PD Gnuplot
- PD Graf-It!
- S Graphmatica
- PD Identify The Function
- PD Implicit Functions
- S MATHPLOT: Math. Function Plotting Program
- PD Master-Graph
- S MathViews for Windows/32

- S Mathgraf
- PD Polar Equations
- PD Polar, Param and Polpm
- SD Powergraph
- SD TechPlot: Technical Plotting & Data Proc.
- PD Trouble
- PD Twiddle
- S Ultimate Calculator
- PD W.B. Loewer Plotting Programs
- S WPLOT

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Windows/MSDos Software Collection for Linear and Matrix Algebra

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- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- CD A Quick Tour of Maple
- S AMP - Algebraic Manipulation Program
- PD ANUMR
- PD CLA
- PD CMAT - Matrix Calculator
- PD Calculus Calculator
- CD Derive
- PD FORM
- PD GP-PARI for DOS and OS/2
- PD JKMath
- PD Knox Packages
- S LGSOLV
- PD LINSYS
- PD Linear Algebra
- C MATLAB

- PD Mat-X
- SD MathViews for Windows/32
- CD Mathcad Demos
- PD Matrices and Linear Equations Programs
- PD Matrix Calculator
- PD Matrix Package
- PD Matrix Program
- PD MINIMAT
- PD NUMERICAL METHODS
- PD Populus
- PD Small Matrix Toolbox for C Programmers
- SD SymbMath
- PD Transitional Mathematics Project
- PD Transmath
- PD Two D Maps

This collection is maintained by Larry Husch. If you know of any Windows/MSDOS programs which are not listed in this collection and which you think are useful in the teaching of mathematics, then write Larry.

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Windows/MSDos Software Collection for Modelling

The following icons indicate the type of package:

- PD Freeware or Public Domain
- S Shareware with all features enabled
- SD Shareware with some features disabled
- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- S Analysis
- PD ArborVt
- PD Automatic Differentiation of Fortan Programs
- PD Curacao
- S Curve Fitter
- S Curvefits
- PD DAUBWAVE
- PD DELP
- C Ecological Modeling
- PD FFT of Very Long Series
- S Fit2.exe
- PD Interpolation
- PD Lateblight
- PD MENSTRUA
- S MathViews for Windows/32

- CD Mathcad Demos
- C Mlab
- PD Netwrk4
- SD Nonlinear Analysis Regression Program
- C Orbits
- C Owl
- PD Parabola
- C Population Analysis System - POPSYS
- PD Populus
- PD Predictor
- C Ramas
- PD Resistan
- PD Spectrum
- SD TechPlot - Tech. Plotting & Data Analysis
- S VisualMethodos
- PD W.B. Loewer Plotting Programs
- S WPLOT

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Windows/MSDos Software Collection for Modern Algebra

The following icons indicate the type of package:

- PD Freeware or Public Domain
- S Shareware with all features enabled
- SD Shareware with some features disabled
- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- CD A Quick Tour of MAPLE
- PD CMAT - Matrix Calculator
- PD Division Algorithm
- PD FORM
- PD GAP - Groups, Algorithms & Programming
- PD GP-PARI for DOS and OS/2
- PD PFSA - Symbolic Algebra Program

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Windows/MSDos Software Collection for Number Theory

The following icons indicate the type of package:

- PD Freeware or Public Domain
- S Shareware with all features enabled
- SD Shareware with some features disabled
- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- PD Aliquot
- PD Calc
- PD GAP - Groups, Algorithms & Programming
- PD GP-PARI for DOS and OS/2
- PD MPQSHD prime factorization program
- PD Malm - a collection of UBASIC programs
- PD NUMBERS calculator
- PD UBASIC

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Windows/MSDos Software Collection for Numerical Analysis

The following icons indicate the type of package:

- PD Freeware or Public Domain
- S Shareware with all features enabled
- SD Shareware with some features disabled
- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- PD ANUM
- PD Automatic Differentiation of Fortran Programs
- SD Formula Wizard
- S LGSOLV
- PD Matrix Package
- PD NUMERICAL METHODS
- S Numerical Recipes Pascal Shareware Diskette
- PD PRAXIS
- PD Small Matrix Toolbox for C Programmers
- PD Spectrum 2.1

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Windows/MSDos Software Collection for Numerical Partial Differential Equations

The following icons indicate the type of package:

- PD Freeware or Public Domain
- S Shareware with all features enabled
- SD Shareware with some features disabled
- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- S FEMIS
- PD Laplace Equation in Two Dimensions
- PD MGLAB.FOR
- SD Quickfield - 2D Finite Element Analysis

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Windows/MSDos Software Collection for Ordinary Differential Equations

The following icons indicate the type of package:

- PD Freeware or Public Domain
- S Shareware with all features enabled
- SD Shareware with some features disabled
- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- CD A Quick Tour of MAPLE
- PD Are You Ready for Ordinary Diff. Equations
- C Biograph
- PD Calculus & Differential Equations
- CD Chaos Demonstrations
- C Chaos Simulations
- C Chaotic Dynamics Workbench
- C Chaotic Mapper
- C DEGraph
- SD Formula Wizard
- PD Graphing Separable Equations
- S Graphmatica
- C Logistic
- PD MAFIA
- C MicroCalc

- PD Midshipman Differential Equations Program
- C MLab
- C Models
- C ODE Workbench
- PD ODE
- SD ODEcalc
- PD ODE's Slide Show
- PD Ordinary Linear Differential Eq.
- C Phaser: Animator/Simulator for Dyn. Systems
- PD Populus
- PD Slopes
- SD SymbMath
- PD Transmath
- PD VisualMethodos

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Windows/MSDos Software Collection for Partial Differential Equations

The following icons indicate the type of package:

- PD Freeware or Public Domain
- S Shareware with all features enabled
- SD Shareware with some features disabled
- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- PD Calculus and Differential Equations
- PD Partial Differential Equations Slide Shows
- SD Quickfield - 2D Finite Element Analysis

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Windows/MSDos Software Collection for Probability

The following icons indicate the type of package:

- PD Freeware or Public Domain
- S Shareware with all features enabled
- SD Shareware with some features disabled
- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- PD Bayes' Theorem
- PD Buffon
- SD Formula Wizard
- PD Galton's Box
- PD ISETL Probability Package
- PD Interactive Demos & Teaching Aids 2
- PD JKMath

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Windows/MSDos Software Collection for Statistics

The following icons indicate the type of package:

- PD Freeware or Public Domain
- S Shareware with all features enabled
- SD Shareware with some features disabled
- C Commercial Software
- CD Demo of Commercial Software

List of Packages

- PD Correlation
- PD DSTATTAB
- C Easystat
- PD Epistat
- C Execustat
- SD Formula Wizard
- PD Histograms
- S Kwikstat
- S LAB STATS
- C Mlab
- S Nonlin
- S Prof. Weissman's Statistic Tutorials
- S Pvalue for Windows
- S Simstat
- C Statdisk

Statutor

Xlisp-Stat

This collection is maintained by Larry Husch. If you know of any Windows/MSDOS programs which are not listed in this collection and which you think are useful in the teaching of mathematics, then write Larry.

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Math Archives

Topics in Mathematics

Algebra

- About - The Human Internet - College Algebra HS
  ADD. KEYWORDS: Tutorial, Inequalities, Absolute Values and Exponents, Fractional and Negative Exponents, Polynomials, Factoring Polynomials, Rational Functions, Compound Fractions, Solving Equations, Word Problems, Solving Quadratic Equations, Quadratic Formula, Complex Numbers, Inequalities, Quadratic Inequalities, Graphing Equations and Circles, Lines, Functions, Applications of Functions
- Algebra HS
  ADD. KEYWORDS: Algebra Postulates, Function Basics, Composite Functions, Even and Odd Functions, Inverse Functions, Linear, Quadratic, and Cubic Functions, Monotonic Functions, Periodic Functions
- Algebra HS
  ADD. KEYWORDS: Tutorial, Real Number System, Numerical Representations In Algebra, Algebraic Techniques, Quadratic Equations and Inequalities, Graphing, Functions, Polynomial Functions, Exponential and Logarithmic Functions, Linear Algebra, Discrete Algebra
- Algebra1: Graphing Linear Equations HS Int Java
  ADD. KEYWORDS: Tutroial, Online quizzes, Ordered Pairs, Graphing Equations, Horizontal Lines, Vertical Lines, Slope, Equations And Slope, Find Equation of Line, Scatter Plots, Parallel Lines, Perpendicular Lines, Solve A System
  SOURCE: T. K. O'Brien
  TECHNOLOGY: Javascript, Java applet
- Algebra Flash! HS Int
  ADD. KEYWORDS: Simultaneous Equations, Linear Equations, Quadratic Equations
  SOURCE: David Hellam, Szymon Rutkowski, Kuwait English School
  TECHNOLOGY: Javascript, Flash, Excel
- Algebra for the Sciences LD
  ADD. KEYWORDS: Course Materials, Demonstrations, Projects, Estimation, Geometry, Lines, Quadratics, Exponentials, Logarithms, Systems
  SOURCE: Karla Oty, Brett Elliott, et al., Southeastern Oklahoma State University
- Algebra Online HS
  ADD. KEYWORDS: Lesson Plans
- Algebra/Graphing/Statistics Learning Units HS
  ADD. KEYWORDS: Lesson Plans, Equation of a line, Data Plots
- Algebra Learning Units HS
  ADD. KEYWORDS: Lesson Plans, Beginning Modeling for Linear and Quadratic Data
- Algebra Modules / Lessons HS
  ADD. KEYWORDS: Tutorials

- Algebra on the Internet HS (Algebra I)
  ADD. KEYWORDS: Tutorial, Course Materials
  SOURCE: Zee Haddad, Springfield Technical Community College
- Algebra Resource HS
  ADD. KEYWORDS: Algebra Review Sheet and Common Formulas, Algebra Review Practice Problems, Conics Review
  SOURCE: Department of Mathematics, Sierra College
- Algebra Survival Kit HS
  ADD. KEYWORDS: Published book
- Algebra Through Modeling with the TI-82, 83 Calculators HS
  ADD. KEYWORDS: Tutorial
  SOURCE: Tony Peressini and John Luker, University of Illinois
  TECHNOLOGY TI-82 and TI-83 Graphing Calculator
- Algebra Through Problem Solving HS
  ADD. KEYWORDS: Tutorial, Pascal Triangle, Fibonacci and Lucas Numbers, Factorials, Arithmetic and Geometric Progressions, Mathematical Induction, Binomial Theorem, Combinations and Permutations, Polynomial Equations, The Factor and Remainder Theorems, Integral Roots, Rational Roots, Symmetric Functions, Determinants, Vandermonde and Related Determinants, Inequalities
  SOURCE: Abraham P. Hillman, University of New Mexico and Gerald L. Alexanderson, Santa Clara University
  TECHNOLOGY: PDF Reader
- Algebra Topics HS Int Lnks
  ADD. KEYWORDS: Linear Functions, Percentages, Signed Numbers, Inequalities, Absolute Value/Inequalities, Exponents, Factoring, Complex Numbers, Fractions, Rational Expressions..simplify, Introduction to Algebra, Interactive Algebra, Basic Skills, Prealgebra, Arithmetic, Intro Algebra, PreCalculus, Intermediate Algebra, College Algebra
  SOURCE: Wyatt Washburn, University of Arkansas Community College / Batesville
- Algebra Word Problems HS
- Algebra.help HS Int Java
  ADD. KEYWORDS: Tutorials, Worksheets, Calculators, Algebra Basics, Basic Word Problems, Proportion Basics, Simplifying Equations/Expressions, Simplifying Multiple Signs, Combining Like Terms, Using the FOIL Method, Simplifying Exponents, Simplifying Using the Order of Operations, Substitution, Factoring, Greatest Common Factor(GCF), Difference Between Two Squares
  TECHNOLOGY: Java applets, Server side include programs
- AskERIC Lesson Plans - Algebra HS
- Building Blocks for Algebra K6
  ADD. KEYWORDS: Lesson Plans, Publication
- Casio TEAMS Grant - Algebra Lessons HS
  ADD. KEYWORDS: Lesson Plans, Casio Calculator

- College Algebra Activities and Worksheets HS
  ADD. KEYWORDS: Activities and worksheets for in-class cooperative learning in groups, individual assignments, or homework.
  SOURCE: Harel Barzilai, Salisbury University
- College Algebra Online HS Int Java
  ADD. KEYWORDS: Course materials, Animations, Tutorials, Cartesian Plane, Graphing Equations, Lines in the Plane, Functions, Graphs of Functions, Manipulating Graphs, Combinations of Functions, Inverse Functions, Linear Equations and Modeling, Solving Equations Graphically, Complex Numbers, Solving Equations Algebraically, Solving Inequalities, Linear Models and Scatter Plots, Quadratic Functions, Higher Order Polynomials, Rational Functions, Exponential Functions, Logarithmic Functions, Properties of Logarithms, Exponential and Logarithmic Equations, Exponential and Logarithmic Models, Nonlinear Models and Scatter Plots
  SOURCE: Jeff Brown and Russ Herman, University of North Carolina, Wilmington
  TECHNOLOGY: Java applets, Asymetrix Toolbooks, Real Video, Animated gifs
- Dan's math@home lessons - Basic Skills Topics HS
  ADD. KEYWORDS: Tutorials, Simplifying Expressions, Solving Linear Equations, Coordinates and Graphing
  SOURCE: Dan Bach, Diablo Valley College
- DAU Math Refresher LD Int
  ADD. KEYWORDS: Tutorial, Tests, Basic Arithmetic, Fractions, Exponentials & Logarithms, Equations, Series, Functions, Domains & Ranges, Intercepts, Limits, Graphing of Functions, Derivatives, Integrals
- Easymaths HS
  ADD. KEYWORDS: Tutorials, Worksheets, Diagnostic tests
  SOURCE: Mathematics Web Association
- EMR - Exercises in Math Readiness HS
  ADD. KEYWORDS: Tutorial, Real Numbers, Symbol Manipulation, Expanding Binomials, Polynomials and Roots, Partial Fraction Decompositions
- A Constant Rate of Change - Using Linear Interpolation HS
  ADD. KEYWORDS: Tutorial
- GCSE Mathematics K6
  ADD. KEYWORDS: Tutorial, Drill problems, Negative Numbers, Ratios, Fractions, Graphs, Probability, Algebra, Trigonometry, Functions and Sequences
- GoMath Tutorials HS Int
  ADD. KEYWORDS: SAT, Quadratic Equations, Pythagorean Theorem, Parallel and Perpendicular Lines, New Operational Symbols, Linear Equations, Coordinate Geometry, Circles, Inequalities, Simple Factorization, Slopes, Roots, Word Problems
- Gomath.com - Algebra HS Int
  ADD. KEYWORDS: Factorials, Associative & Distributive Property, Prime Factorization, GCF & LCM, Scientific Notation, Laws of Exponents, Logarithm, Solving Equation with one variable, Ratio & Proportion, Polynomial (Addition/Subtraction), Polynomial (Multiplication), Solving Quadratic Equations, Slope, Equation & Y-intercept, Distance & Midpoint, Pythagorean

Theorem, Word Problem - Interest Problem, Inequality, Absolute Value Equation & Inequality
SOURCE: Cubic Science, Inc
TECHNOLOGY: Server side programs

- Harcourt Animated Math Glossary K6 Int
  ADD. KEYWORDS: Shockwave
- Hawai'i Algebra Learning Project HS
  ADD. KEYWORDS: Curriculum Materials, Professional Development, NCTM Standards
- Interactive Algebra HS Int Java
- Interactive Mathematic Miscellany and Puzzles - Arithmetic and Algebra K6 Int Java
  ADD. KEYWORDS: Evolution of Algebraic Symbolism, Fundamental Theorem of Algebra, Mathematical Induction, Weierstrass Product Inequality
- Intermediate Algebra Online HS
  ADD. KEYWORDS: Course Materials, Lecture Notes
  SOURCE: Joyce Quella and David Urion, Winona State University
- Internet Projects for Algebra I HS
- An Introduction to Complex Numbers HS
  ADD. KEYWORDS: Tutorial, Polar Representation, De Moivre's Formula, Theorem of d'Alembert, Polynomials
- Learning about Algebra tiles HS
  ADD. KEYWORDS: Polynomials
- Linear Equation Solver HS Java Int
- Math 095 HS
  ADD. KEYWORDS: Tutorial, Angles, Approximating Roots, Area, Common Factors, Complex Fractions, Coordinate Geometry, Equations of lines, Difference of Cubes, Difference of Squares, Equations of lines, Equations: Linear, Quadratic, Exponents, Factoring, Difference of Cubes, Difference of Squares, Geometry, Imaginary Numbers, Inequalities, Logarithms, Parabolas, Pythagorean Theorem, Quadratic Equations, Quadratic Inequalities, Radicals, Systems of Equations
- Math Connects K6
  ADD. KEYWORDS: On-line course assignments, In-service, Patterns, Functions, Algebra
- Math Forum - K-12 Algebra HS Lnks
  ADD. KEYWORDS: Classroom Materials, Software, Newsgroups
- Math Notes.Com - Intermediate Algebra HS Int
  ADD. KEYWORDS: Drill Problems, The Real Numbers, Rational Expressions, Linear Equations and Inequalities, Roots and Radicals, Linear Equations and Inequalities in Two Variables, Functions, Quadratic Equations and Inequalities, Systems of Linear Equations, Graphs of Nonlinear Functions and Conic Sections, Polynomials, Exponential and Logarithmic Functions
- Math Notes.Com - Introductory Algebra HS Int
  ADD. KEYWORDS: Drill Problems, Prealgebra Review, Rational Expressions, The Real Number System, Linear Equations and Inequalities in Two Variables, Solving Equations and Inequalities, Linear Systems of Equations and Inequalities, Exponents and Polynomials, Roots and Radicals,

Factoring, Quadratic Equations

- Math.com - Algebra HS Int
  ADD. KEYWORDS: The Language of Algebra, Order of Operation, Writing Equations, Writing Inequalities, The Basics of Algebra, Exponents, Evaluating Expressions, Like Terms, Simplifying, Equations and Inequalities, Solving Equations, Two Step Equations and Inequalities, Graphing Equations and Inequalities, Slope and y-intercept, Linear Equation
  SOURCE: Math.com
  TECHNOLOGY: Javascript.
- Mathematics Explorations I & II HS
  ADD. KEYWORDS: Projects involving activities at NASA
  SOURCE: Capital Community College, NASA - AMATYC - NSF
  TECHNOLOGY: Adobe Acrobat Reader
- Mathematics on The Beach HS
  ADD. KEYWORDS: CBL - Calculator Based Labs
- Mathematics with Alice HS
  ADD. KEYWORDS: Tutorial
- Maths Online HS Java Int
  ADD. KEYWORDS: Drawing plane and coordinate system, Variables, terms, formulae, and identities, Equations, Analytic geometry, Functions
- Maths Online - Sets K6 Java Int
- MathMax - The Bittinger System of Instruction HS Int
  ADD. KEYWORDS: Supplementary materials for texts, Exercises, Quizzes, Chapter reviews
  SOURCE: Addison Wesley Longman, Marvin L. Bittinger
  TECHNOLOGY: Javascript, InterAct Math plug-in
- NASAexplores HS
  ADD. KEYWORDS: Lesson Plan, Space Shuttle, Formulas, Graphs
  SOURCE: Marshall Space Fight Center and is supported by NASA departments.
  TECHNOLOGY: Adobe Acrobat Reader
- National Library of Virtual Manipulatives for Interactive Mathematics - Algebra K6 Java Int
  ADD. KEYWORDS: Tangrams, Lets Make a Deal, Reflection, Triomino, Coin Problem, Multiple Base Blocks, Pentominoes, Polyominoes, Tangrams, Towers of Hanoi
  SOURCE: Lawrence O. Cannon, James T. Dorward, E. Robert Heal, Leo Edwards, Utah State University
  TECHNOLOGY: Java applets
- Notes for College Algebra and Geometry LD
- On line Math 191 - College Algebra LD
  ADD. KEYWORDS: Tutorial, Solving Equations, Functions and their Graphs, Synthetic Division, and Exponential & Logarithmic Functions
- On-Line Math Learning Center - On-line Quizzes HS Int
  ADD. KEYWORDS: Solving Equations, Problems Solving, Inequalities, Exponents, Polynomials, Factoring, Rationals

- OzeGame - Senior Level HS Int
  ADD. KEYWORDS: Algebra Problems
  SOURCE: The Web Classroom
  TECHNOLOGY: Javascript
- Partnership for Excellence - Rediscovering Algebra I HS
  ADD. KEYWORDS: Lesson Plans, Course Materials
  SOURCE: Partnership for Excellence Project, University of South Carolina Spartanburg
- Partnership for Excellence - Rediscovering Algebra II HS
  ADD. KEYWORDS: Lesson Plans, Course Materials
  SOURCE: Partnership for Excellence Project, University of South Carolina Spartanburg
- Professor Freedman's Math Help HS Java Lnks
  ADD. KEYWORDS: Syllabus, Math Anxiety, Learning Styles, Tutorials, Fun Stuff
- Project Interactivate - Functions HS Int Java
  ADD. KEYWORDS: Lesson Plans, Graphs and Functions, Coordinate Systems
- PUMP Algebra Curriculum Home Page HS
  ADD. KEYWORDS: Computer based tutoring system
- Quick Review of Algebra HS
  ADD. KEYWORDS: Tutorial
- NY State HS Regents Exam Prep Center - Mathematics A HS Int
  ADD. KEYWORDS: Sample Questions, Mathematical Reasoning, Numbers & Numeration, Operations, Modeling/Multiple Representation, Problem Solving with Algebra & Geometry, Measurement, Proportions, Uncertainty (Probability), Patterns & Functions
  SOURCE: New York High School Regents Exam Prep Center
  TECHNOLOGY: Javascript.
- Project Interactivate - Activities - Function and Algebra Concepts K6 Int Java
  ADD. KEYWORDS: Functions, Special properties of linear functions, Graphs and the coordinate plane, and Reading graphs
  SOURCE: The Shodor Education Foundation, Inc.
  TECHNOLOGY: Java Applet
- Project-Based Instruction in Mathematics for the Liberal Arts LD
  ADD. KEYWORDS: Course materials, Linear functions, Least Squares Line, Linear Modeling, Statistics and probability, Non-linear functions, Managing money with the exponential function, The logistic function – constrained growth and decay
  SOURCE: M.B. Ulmer, University of South Carolina Spartanburg
  TECHNOLOGY:Adobe Acrobat Reader
- Roots HS Int Java
  ADD. KEYWORDS: Roots of complex numbers
  SOURCE: Jerzy Kocik, Southern Illinois University
  TECHNOLOGY: Java applet
- S.O.S. Mathematics - Algebra LD
  ADD. KEYWORDS: Tutorial, Fractions, Quadratic Equations, Partial Fractions
  SOURCE: Mohamed A. Khamsi, Helmut Knaust, Nancy Marcus, Michael O'Neil, Luis G. Valdez

Sanchez from University of Texas at El Paso

- SCORE Mathematics - Algebra and Functions K6
  ADD. KEYWORDS: Lesson Plans, Standards
  SOURCE: SCORE - Schools of California Online Resources for Education
- SCORE Mathematics - Algebra I HS
  ADD. KEYWORDS: Lesson Plans, Standards
  SOURCE: SCORE - Schools of California Online Resources for Education
- SCORE Mathematics - Algebra II HS
  ADD. KEYWORDS: Lesson Plans, Standards
  SOURCE: SCORE - Schools of California Online Resources for Education
- SMILE Program Mathematics Index HS
  ADD. KEYWORDS: Lesson Plans
- Supplemental Technology (TI-85 Based) Exercises for "Clustered" College Algebra at Texas Tech University LD
  ADD. KEYWORDS: Exercises in Basic Calculation, Basic Graphing, Solving Linear Systems
- Understanding Algebra HS Java Int
  ADD. KEYWORDS: Tutorial, Word Problems, Graphing and Straight Lines, Systems of Linear Equations, Polynomials, Rational Expressions, Exponents and Roots, Quadratic Equations
  SOURCE: James Brennan, Boise State University
  TECHNOLOGY: Java applets, Javascript.
- Web-based Are You Ready Quiz/Reviews HS Int
  ADD. KEYWORDS: Online quizzes
  SOURCE: Brian Hassard, University of Buffalo
- WebAlgebra HS Int
  ADD. KEYWORDS: Tutorials with quizzes, Trigonometry, Calculus
  SOURCE: Larry Dornhoff, University of Illinois
- WebMath HS Java Int
  ADD. KEYWORDS: Graphing, Simplifying Expressions, Polynomials, Factoring Polynomials, Quadratic Equations
- Word Problems For Kids K6 HS
- Worksheet library ~ Algebra HS
  ADD. KEYWORDS: Worksheets, Expanding and Factorising, Solving simple equations, Transposing, Graphs of Equations, Quadratics, Simultaneous Equations
  SOURCE: Mike Robinson, Sheffield Hallam University
  TECHNOLOGY: Adobe Acrobat Reader

Math Archives

Topics in Mathematics

Calculus

- Calculus Resources On-Line Lnks
  ADD. KEYWORDS: Initiatives, Projects and Programs, Articles, Posters, Discussions, Software, Publisher sites, Other listings of calculus resources
- Aid for Calculus LD
  ADD. KEYWORDS: Solving problems in calculus
- AP Calculus on the Web HS Lnks
  ADD. KEYWORDS: Textbooks, 1998 Syllabus, Approved Calculators, Resources
- Are You Ready for Calculus? What you should know! LD
- Area of a Circle LD
  SOURCE: Tom Richmond, Western Kentucky University
  TECHNOLOGY: Animated Gif
- Basic EXCEL-skills for calculus and differential equations LD
  ADD. KEYWORDS: Sample worksheets, Sample problems / skills
- Better File Cabinet LD
  ADD. KEYWORDS: Database of calculus problems
  SOURCE: Eric Hsu and University of Texas at Austin
- Bisection Method Tutorial LD Int Java
- Cal Poly Linked Curriculum Program Interdisciplinary Projects LD
  ADD. KEYWORDS: Projects
- Calculus LD
- Calculus I Home Page LD
  ADD. KEYWORDS: Sample CBL Experiment: Newton's Law of Cooling, TI-85 Programs and CBL Experiment Data, Mathematica Notebooks
- Calculus 1 - Problems and Solutions LD
  ADD. KEYWORDS: Problems, Tutorial
  SOURCE: Pheng Kim Ving
- Calculus and Differential Equations LD
  ADD. KEYWORDS: Collection of articles, Curvature, Intrinsic and Extrinsic, Radial Paths in Schwarzschild Spacetime, Integrating the Bell Curve, Compressor Stalls and Mobius Transformations, Dual Failures with General Densities, The Limit Paradox, Proof That PI is Irrational, Simple Proof that e is Irrational, etc.
- Calculus Applets for the Georgia Tech Syllabus LD Int Java
  ADD. KEYWORDS: Course Materials, Experiments
- Calculus Applied to the Real World LD Int
  ADD. KEYWORDS: Tutorials, Tests

- Calculus at Pitt LD
  ADD. KEYWORDS: Course Materials, Mathematica, Tutorials, Lab Materials
- Calculus&Mathematica LD
  ADD. KEYWORDS: Course Materials, Mathematica
- Calculus&Mathematica Remote LD
  ADD. KEYWORDS: Course, Mathematica
- Calculus Concepts Using Derive® for Windows LD
  ADD. KEYWORDS: Lab Manual
- Calculus: Difference Equations to Differential Equations LD Int Java
  ADD. KEYWORDS: Course Materials
- Calculus for Biology I LD Int Java
  ADD. KEYWORDS: Course Materials, Lecture notes, Laboratories, HW Problems
  SOURCE: Joseph M. Mahaffy, San Diego State University
  TECHNOLOGY: Adobe Acrobat Reader, Excel, Java applets
- Calculus for Biology II LD
  ADD. KEYWORDS: Course Materials, Lecture notes, Laboratories, HW Problems
  SOURCE: Joseph M. Mahaffy, San Diego State University
  TECHNOLOGY: Adobe Acrobat Reader, Excel, Maple
- Calculus for Kinetic Modeling LD Int Java
  ADD. KEYWORDS: Course Materials, Finding Zeroes of Polynomial Functions, TIFs & TSFs for Polynomial Functions , Background from CKM Workspace , Finding Tangent Lines Examples, TSFs and Graphical Reprsentations, The Product and Quotient Rules, Chain Rule, D-Rules & TSFs, Exponential & Logarithmic Functions, Dissolution Models, Antidifferentiation, Area and the Riemann Integral, Fundamental Theorem of Calculus, Integrals, Area & Reversing D-Rules
  SOURCE: John Pais, Saint Louis College of Pharmacy
  TECHNOLOGY: Java applets
- Calculus-Help.com HS
  ADD. KEYWORDS: The Problem of the Week, Virtual Cheat Sheet
  SOURCE: W. Michael Kelley
  TECHNOLOGY: Flash plugin
- Calculus Learning Units HS
  ADD. KEYWORDS: Lesson Plans, Newton's Law of Cooling, Calculator Based Laboratory
- Calculus Lecture Notes - University of Toronto LD
- Calculus Offered On Line LD
  ADD. KEYWORDS: Course materials for 1st semester calculus
  SOURCE: Don Piele, University of Wisconsin-Parkside
  TECHNOLOGY: Mathematica
- Calculus Offered On Line LD
  ADD. KEYWORDS: Course materials for 2nd semester calculus
  SOURCE: Don Piele, University of Wisconsin-Parkside
  TECHNOLOGY: Mathematica

- Calculus on the Web - COW LD Int
- The Calculus Page LD Mov
  ADD. KEYWORDS: Problems with solutions, Tips on preparing for exams, Mathematica Animations
- Calculus Reform at Cornell LD
  ADD. KEYWORDS: Cooperative Learning and Projects
- Calculus Reform: Sample Materials LD
  ADD. KEYWORDS: Course Materials, Calculator Programs
- Calculus Review - San José State University LD Int
  ADD. KEYWORDS: Tutorials, On-line quizzes
  SOURCE: Linda Valdés, San José State University
  TECHNOLOGY: Javascript
- Calculus Technology Initiative LD
  ADD. KEYWORDS: Lecture Notes, Animations
  SOURCE: Arek Goetz, San Francisco State University
  TECHNOLOGY: Quicktime, Real Video, Power Point
- Calculus with Maple V LD
  ADD. KEYWORDS: Maple lessons, Homework
- Calculus with Maple V LD
  ADD. KEYWORDS: Course Materials, Maple, Lab Materials, Projects
- Calculus Workshops and Maple Labs LD
  ADD. KEYWORDS: First Year Integrated Engineering Curriculum, Maple, Lab materials
- Calculus WWW-server LD
  ADD. KEYWORDS: Course Materials, Maple, Matlab, Projects, Applications
- CalculusQuest LD
  ADD. KEYWORDS: Course Materials
- Casio TEAMS Grant - Calculus LD
  ADD. KEYWORDS: Lesson Plans, Casio Calculator
- Complex, Technology Based Problems in Calculus Home Page LD
  ADD. KEYWORDS: Problem sets, Mathematica
- Computer Labs for Math LD
  ADD. KEYWORDS: Graphing Polynomial Functions, Graphing Trigonometric Functions, One- and Two-sided Limits, Tangent and Secant Lines, Zeros of Derivatives, Graphing and Derivatives, Mean Value Theorem, Newton's Method, Riemann Sums, Numerical Integration, 1-1 and Inverse Functions, Review of Exponential and Logarithmic Functions, Inverse Trigonometric Functions, Hyperbolic Functions, Volumes of Solids of Revolution, Arc Length of Curves, Symbolic Integration, Taylor Polynomials, Parametric Functions
  SOURCE: Michael R. Anderson, West Virginia State College
  TECHNOLOGY: LaTeX, Adobe Acrobat Reader, Derive, MuPad, JKGraph
- Computer-based Calculus LD Mov
  ADD. KEYWORDS: Mathcad, Maple, Lab materials
- The Connected Curriculum Project - Montana State University LD Int Java Mov

ADD. KEYWORDS: Models, Data, and Curve Fitting, Estimation and Limits, Sequences and Discrete Dynamical Systems, Derivatives and Differention, Graphing, Optimization, Integrals and Integration, Differential Equations and Continuous Models, Series, Numerical Methods, Calculators, Maple, Mathematica

- The Connected Curriculum Project - Duke University LD
- CRAFTY - MAA Subcommittee on Calculus Reform and The First Two Years LD Lnks
  ADD. KEYWORDS: Publications, Meetings, Calculus Reform Projects, Technology, Problems
  SOURCE: Martin Flashman, Humboldt State University
- Dan's math@home lessons - Calculus LD
  ADD. KEYWORDS: Tutorial, Limits, Tangent Lines and Derivatives, Differentiation Rules, Related Rates, Max-Min Problems, Antiderivatives, Integration Rules, Calculus of Areas, Fundamental Thm of Calculus
  SOURCE: Dan Bach, Diablo Valley College
  TECHNOLOGY: Animated gifs
- DAU Math Refresher LD Int
  ADD. KEYWORDS: Tutorial, Tests, Basic Arithmetic, Fractions, Exponentials & Logarithms, Equations, Series, Functions, Domains & Ranges, Intercepts, Limits, Graphing of Functions, Derivatives, Integrals
- Dave Slomer's Calcu-Page LD
  ADD. KEYWORDS: Lesson plans, Assignments for students, TI85, TI86, TI92
- Derivative Module LD
  ADD. KEYWORDS: Motion, Speed, Velocity, Acceleration
- Developing Intuition for Concepts in Calculus through Numerical List Manipulation LD
  ADD. KEYWORDS: Article, Matlab, Mathematica, Maple, APL, HP48G, TI85
- Dr. Vogel's Gallery of Calculus Pathologies LD
- e-Calculus LD
  ADD. KEYWORDS: Tutorial
- e the EXPONENTIAL - the Magic Number of GROWTH LD
  ADD. KEYWORDS: Article, Area under the curve 1/x, The truncated Harmonic series, Euler's gamma constant, Biological growth models, Age dependent population module
  SOURCE: Keith Tognetti, University of Wollongong
  TECHNOLOGY: Adobe PDF, postscript and dvi readers
- EducETH - Interaktive Materialien LD Java Int (in German)
  ADD. KEYWORDS: Bisection Method, Finding Maxima and Minima, Finding area under a curve, Tangent Lines
  SOURCE: Werner Hartmann and EducETH.ch at ETHZ
  TECHNOLOGY: Java applets
- Experiments in Mathematics Using Maple HS
  ADD. KEYWORDS: Tutorial, Maple Worksheets
- EXPONENTIAL GROWTH AND DECAY LD
- Finding Roots of Functions Using The Bisection Method and Newton's Method LD

- Function calculator LD Int
  ADD. KEYWORDS: Evaluate functions, Calculate derivatives, Integrals, Taylor Series expansions, Roots and Extrema
- Function Plotter LD Java Int
  ADD. KEYWORDS: Taylor Polynomials
- The Gamma Function LD
  ADD. KEYWORDS: Weierstrass' formula, the Psi function, Euler's constant, Stirling's formula
- Gavin's Calculus Projects LD
- Geomath LD
  ADD. KEYWORDS: Tutorial, Differentiation, Integration
- Geomath - Further Integration
  LD
  ADD. KEYWORDS: Tutorial
- Graphing Applets for Calculus LD Java Int
  ADD. KEYWORDS: Newton's method, Riemann sums, Modulus of continuity, Fixed Points, Fundamental Theorem of Algebra, Newton-Raphson Method, Lagrange Multipliers, Secant Lines, Simpson's Rule
- Harvey Mudd College Mathematics Tutorials LD
  ADD. KEYWORDS: Antiderivatives, Arc Length, Chain Rule, Computing Integrals by Completing the Square, Computing Integrals by Substitution, Continuity, Differentiating Special Functions, First Derivative, Fundamental Theorem of Calculus, Infinite Series Convergence, Integration by Parts, L'Hopital's Rule, Limit Definition of the Derivative, Mean Value Theorem, Partial Fractions, Product Rule, Quotient Rule, Riemann Sums, Second Derivative, Special Trigonometric Integrals, Tangent Line Approximation, Taylor's Theorem, Trigonometric Substitution, Volume
- IntegGrapher LD Java Int
  ADD. KEYWORDS: Riemann Sums
- The Integrator LD Int
  ADD. KEYWORDS: Integration, Integrals, Mathematica
- Interactive Calculus Activities LD Int
  ADD. KEYWORDS: MathView Notebooks
- Interactive Calculus - Parametric Equations LD
- Interactive Calculus Software with Applications in Business and Economics LD
  ADD. KEYWORDS: Lab activities, Asymptotes, Families of Functions, From Data To Models, Compound Interest, Tangents and Slopes, Definition of Derivative, Inverses, Concavity, Optimizing Costs, Optimizing Revenue and Profits (including Elasticity of Demand), Taxes and the Optimization of Profit, Inventory Costs, Accumulation, Definite Integral, Numerical Integration, Linear Regression, Partial Derivatives, Taylor Polynomials
  SOURCE: Jean Marie McDill, California Polytechnic State University, Agnes M. Rash, St. Joseph's University
  TECHNOLOGY: Adobe PDF reader
- Interactive EXCEL LD

ADD. KEYWORDS: Excel worksheets, Calculus, Curve fitting, Partial Differential Equations, Heat Equation, Parabolic and Elliptic Partial Differential Equations, Discrete Dynamical Systems

- Interactive Learning in Calculus and Differential Equations LD Lnks
  ADD. KEYWORDS: Instructional, Mathematica, Gauss-Green formula, Newton's method, vibrating drumheads, multivariable calculus, orthogonal curvilinear coordinates, complex numbers, drag force on a sphere
- Interactive Web-Based Materials for Calculus Using LiveMath LD Int
  ADD. KEYWORDS: 2-dimensional Graphing, 3-dimensional Graphing, Polar Graphing, Fourier Series, Surface in Spherical Coordinates, Numerical Integration, Symbolic Integration, Riemann sums, Fundamental Theorem of Calculus, Limit Demonstration, Polar Integration
  SOURCE: Brian Gill, Seattle Pacific University
  TECHNOLOGY: LiveMath
- Interactive Mathematics LD Int
  ADD. KEYWORDS: Tutorial, LiveMath, Derivative, Applications of the Derivative, Differentiating Transcendental Functions, Integration, Application of Integration, Methods of Integration, Differential Equations, Fourier Series
- Internet Calculus - University of Pittsburgh LD
  ADD. KEYWORDS: Mathematica, Distance Learning
- Intersection of Cylinders LD Java Int
  ADD. KEYWORDS: Finding volumes
- Java Laboratory LD Java Int
  ADD. KEYWORDS: Definition of derivative, Riemann Sums, Fixed Points
- Java Powered Calculus LD Java Int
  ADD. KEYWORDS: Tutorial, History of Calculus
- Karl's Calculus Tutor LD
  ADD. KEYWORDS: Tutorial
- Manipula Math with JAVA LD Int Java
  ADD. KEYWORDS: Limits, Riemann Sums, Volumes, Circle of Curvature, Cycloids
- Maple Explorations for Differential Calculus LD
- Materials for Calculus LD
- Math 1205 - Calculus LD
  ADD. KEYWORDS: Course Materials, Tutorials, Limits, Derivatives, Applications of the Derivative
  SOURCE: James E. Shockley, Virginia Tech
  TECHNOLOGY: Quicktime Plug-in
- Math Forum - Calculus LD Lnks
  ADD. KEYWORDS: Classroom materials, software, newsgroups
- Math Lessons LD Int Java
  ADD. KEYWORDS: Finding Minimum, Integration and Differentiation, Fair Division, Voting, Venn Diagrams, Understanding Graphs, Equations of Lines, Acceleration, Intersecting Lines, Parabolas, Tangent Lines
  SOURCE: Faculty from Washington State University

TECHNOLOGY: Java applets and Javascript

- MATH-abundance LD
  ADD. KEYWORDS: Tutorials, Limits of Functions and Continuity, Asymptotes, Derivative and Differentiation, Problems
- Mathematica Self-Tutor for Calculus LD
  ADD. KEYWORDS: Tutorials, Mathematica Notebooks
- Mathematics Explorations I & II HS
  ADD. KEYWORDS: Projects involving activities at NASA
  SOURCE: Capital Community College, NASA - AMATYC - NSF
  TECHNOLOGY: Adobe Acrobat Reader
- Mathematical Modules in Biology and Chemistry LD
  ADD. KEYWORDS: Epidemiology, Course Materials
  SOURCE: Meghan A. Burke and Sean F. Ellermeyer from Kennesaw State University
- Maths Online LD Int Java
  ADD. KEYWORDS: Differentiation, Power series, Nowhere differentiable functions, Integration, Fourier seriesi, Limiting processes
- The MathServ Calculus Toolkit LD Int
  ADD. KEYWORDS: Computing Limits, Derivatives, and Integrals, Newton's Method, Power Series, Solid of revolution, Direction Field, Quadrature Formulas, Arc length, Center of mass
- MCP Project LD
  ADD. KEYWORDS: Lab Manual, Chemistry, Physics, MathCAD
- Moving Man Project LD Int Java
  ADD. KEYWORDS: Distance, Velocity, Acceleration
- Microsoft Excel Interactive Projects LD
  ADD. KEYWORDS: Maximzing Area, Projectile Motion
  SOURCE: Hollylynne Drier Stohl and Center for Technology and Teacher Education, University of Virginia
  TECHNOLOGY: Excel
- MSTE Java Lessons - Calculus Int Java LD
  ADD. KEYWORDS: Numerical Integration Activity, Methods for Estimating Roots, Solving Systems of Equations
  SOURCE: Nicholas Exner, University of Illinois at Urbana-Champaign
  TECHNOLOGY: Java Applets
- Multivariable Calculus Maple Laboratories LD
  ADD. KEYWORDS: Dot Products, Parametric Curves, Polar Curves, Integration, Plotting Surfaces, Surface Extrema, Sequences and Series, Koch Snowflakes
  SOURCE: Murphy Waggoner, Simpson College
  TECHNOLOGY: Maple
- Numerical Integration Tutorial LD Int Java
- Occasional Maple Worksheets for Calc II LD
  ADD. KEYWORDS: Maple, Integration Check, Numeric Integration, Error Bounds for Numeric Integration, Animating Taylor Series, Working with Power Series as Functions, Producing Slope

Field Diagrams

- Partnership for Excellence - Rediscovering Calculus: A Reformed View HS
  ADD. KEYWORDS: Lesson Plans, Course Materials
  SOURCE: Partnership for Excellence Project, University of South Carolina Spartanburg
- Pathological example for Newton's method LD Java Int
- Project CALC: Calculus As a Laboratory Course LD
- Project INTERMATH Topics - Calculus LD
  ADD. KEYWORDS: Curriculum Materials, Throwing a Baseball, Shooting an Arrow, Bungee Jumping, Determining the Center of Mass, Estimating Cut/Fill for a Earthmoving Project, Managing Water Storage, Earthquake damage to a Water Tower, Modeling a Firefighting Situation, Estimating HMO Patient Costs, Developing a Plan for Air Delivery of Supplies, Linear Regression in a Physics Lab, Modeling Economic Production, Predicting Oxygen Consumption, Describing Motion of a Pendulum, Designing a Railway Headway, Structural Analysis of a Bridge, Modeling the Trajectory of a Missile, Managing Waste Water, Avoiding Aircraft Collisions/Water Treatment, Monitoring the Flow of Water in a Town, Analyzing Water Purity, Modeling the Suspension System of a Car, Resonance in an Aircraft, Dissolved Oxygen, Spelling, Optimizing Technology, Artillery Fire Control
  SOURCE: COMAP, Carroll College, Georgia College & State University, Harvey Mudd College, Macalester College, University of Redlands, Texas Southern Consortium, West Point
  TECHNOLOGY: Adobe Acrobat Reader
- Project Links: Calculus LD Java
  ADD. KEYWORDS: Applications in Mechanics, Applications in Chemistry, Tutorial
- Reform Calculus Resources LD
  ADD. KEYWORDS: In-Class Activities, Long-Term Student Projects, Capsules & Tutorials
  SOURCE: Harel Barzilai, Salisbury University
- The Roller Coaster or Brachistochrone Problem LD
- S.O.S. Mathematics - Calculus LD
  ADD. KEYWORDS: Tutorials, Techniques of Integration, Taylor Polynomials, Series
- Sigma LD Int
  ADD. KEYWORDS: Finite Sums, Infinite sums
- SIMPLE HARMONIC MOTION LD Int
  ADD. KEYWORDS: Tutorial
- Solution Finder LD Java Int
  ADD. KEYWORDS: Newton's Method
- Surfin' Sinefeld: Flash Animated Precalculus, Calculus and Statistics Activities HS Int
  ADD. KEYWORDS: Graphing, Derivatives, Quizzes
  SOURCE: Ralph Irons, Central Shenandoah Valley Regional Governor's School
  TECHNOLOGY: Flash plugin
- Taylor Series - Why We Want Them and How We Find Them LD
- Technology Modules (TI-85 Based) to Supplement the Instruction of Calculus I at Texas Tech University LD

- TILU Table of Integrals Look Up LD Int
  ADD. KEYWORDS: Mathematica, Common Lisp
- Topics in Integral and Differential Calculus LD Int Java
  ADD. KEYWORDS: Tutorial, Introduction to Functions, Polynomial Functions, Trigonometric Functions, Exponential & Logarithmic Functions, The Derivative, Some Differentiation Formulas & the Chain Rule, Differentiating Trigonometric Functions, Some Max-Min Problems, The Definite Integral of a Continuous Function, Taylor Polynomials and Taylor Series, Plane Vectors, The Spring
  SOURCE: Teresinha Kawasaki, University of Texas at Austin
  TECHNOLOGY: Java Applets, WebEQ, TCL
- Trigonometric Integrals LD
  ADD. KEYWORDS: Tutorials
- UBC Calculus Online LD Java Int
  ADD. KEYWORDS: Course Materials, Course Notes, Labs, In class demonstrations: Falling Balls, Slope, Powers of x, Polynomials, Scaling, Radioactive Decay, Zoom, Secant Lines, Derivative as a function, Vertical Scaling, Critical Points, The Chain Rule, Implicit Differentiation, Exponentials,
  Logarithms, Derivatives of Exponentials, Radioactive Decay, Newton's Law of Cooling, Trigonometry, Derivatives of Trigonometric Functions, Oscillations, Harmonic Motion, Superposition, Inverse Tangent, Linear Approximations, Newton's Method, Euler's Method, Direction Fields, Epidemics
  SOURCE: Department of Mathematics at the University of British Columbia
  TECHNOLOGY: Java Applets
- UBC Calculus Online LD Java Int
  ADD. KEYWORDS: Course Materials, Course Notes, Labs, In class demonstrations: How Archimedes found the area of a circle, Finding areas of simple shapes, How the area changes, Lower and Upper Sums, The Fundamental Theorem of Calculus, Average value of a function, Volumes, Arc Length, Change of variables, The Trapezoidal Rule, Simpson's Rule, Introduction to Differential Equations, Initial Value Problems, Orthogonal Trajectories, The Logistic Equation, Logistic Growth with Harvesting, Predators and Prey, Center of Mass, Standard Deviation, The Normal Distribution, Series, Taylor Series, Series for sine and cosine
  SOURCE: Department of Mathematics at the University of British Columbia
  TECHNOLOGY: Java Applets
- The University of Minnesota Calculus Initiative LD Int
  ADD. KEYWORDS: Lab Materials, Applications
- USAF Mathematica Notebook Library LD
  ADD. KEYWORDS: Mathematica, Animations
- USMA MA205 Home Page LD Mov
  ADD. KEYWORDS: Course Materials, MathCad Worksheets
- USNA Calculus I Homepage LD
  ADD. KEYWORDS: Course Materials, Computer Projects, Maple
- USNA Calculus II Homepage LD

ADD. KEYWORDS: Course Materials, Computer Projects, Maple

- The Vector Cross Product - A JAVA Interactive Tutorial LD Java
  ADD. KEYWORDS: Calculus, interactive pages
- Visual Calculus LD Java Int
  ADD. KEYWORDS: Tutorial, online quizzes, drill problems, calculators, software, visualization
- Wallis' Product LD Java
  ADD. KEYWORDS: Calculus, history, pi, interactive pages
- Web-based Are You Ready Quiz/Reviews LD Int
- Webcalc LD Mov
  ADD. KEYWORDS: Course Materials, Lab Materials
- WebMath - Calculus- Derivatives LD Int
- WIMS - WWW Interactive Mathematics Server LD Int
  ADD. KEYWORDS: Online exercises, Taylor Series, Epsilon-Delta definition of limits, Maxima/Minima, Finding roots
- Worksheet library ~ Calculus LD
  ADD. KEYWORDS: Worksheets, Differentiation and Integration
  SOURCE: Mike Robinson, Sheffield Hallam University
  TECHNOLOGY: Adobe Acrobat Reader
- World Web Math - Calculus (MIT) LD
  ADD. KEYWORDS: Tutorial
- Wright State Calculus Laboratory Program LD
  ADD. KEYWORDS: Mathematica Notebooks
- Writing Assignments in Calculus LD
- Writing Assignments in Calculus LD
- www.calculus.net LD Lnks
  ADD. KEYWORDS: Problem Sets, Lab Projects, Homework, VRML and Calculus
- xFunctions xPresso LD Int Java
  ADD. KEYWORDS: animated graphs, parametric curves, derivatives, Riemann sums, integral curves, and 3D graphs.

Math Archives

Topics in Mathematics

Pre-Calculus

- Analytic Geometry (in a plane) HS
  ADD. KEYWORDS: Tutorial, Conic sections
  SOURCE: Johan Claeys
- Ballistic Trajectories HS
  ADD. KEYWORDS: Tutorial, Parametric Curves, Maple
- The Coffeecup Caustic HS Java Int
  SOURCE: Roy Williams from California Institute of Technology
  TECHNOLOGY: Java applet
- Conic Sections HS Int
- Conic Sections HS
  SOURCE: Gershon Elber from the Technion, Israel Institute of Technology
- Conic Sections HS Java Int
  SOURCE: Mark Sutherland
  TECHNOLOGY: Java applet
- The Conic Sections as the locus of Perpendicular Bisectors HS Java Int
  SOURCE: Key Curriculum Press
  TECHNOLOGY: JavaSketchpad, Java applet
- Conics as Sections of a Cone with Mathematica HS
  SOURCE: Gary S. Stoudt from Indiana University of Pennsylvania
  TECHNOLOGY: Mathematica
- Conics from Jalacy Software HS Int Java
  ADD. KEYWORDS: Conic Sections
  SOURCE: Brian and Aidan Cully
  TECHNOLOGY: Java applet, Software
- Coniques [in French] HS Int Java
  ADD. KEYWORDS: Properties of Conic Sections
  SOURCE: Gérard Chevet
  TECHNOLOGY: Java applet
- The Connected Curriculum Project - Connected before Calculus - Montana State University
  LD Int Java
  ADD. KEYWORDS: Boyle's Law, The Sound of Trigonometry, Calculators, Maple, Mathematica
- Dan's math@home lessons - Precalculus HS
  ADD. KEYWORDS: Tutroial, Factoring, Solving quadratic equations, Graphing parabolas, Trigonometry, Solving triangles, Functions and graphs, Exponential and log functions.
  SOURCE: Dan Bach, Diablo Valley College

TECHNOLOGY: Animated gifs

- DAU Math Refresher LD Int
  ADD. KEYWORDS: Tutorial, Tests, Basic Arithmetic, Fractions, Exponentials & Logarithms, Equations, Series, Functions, Domains & Ranges, Intercepts, Limits, Graphing of Functions, Derivatives, Integrals
- Easymaths HS
  ADD. KEYWORDS: Tutorials, Worksheets, Diagnostic tests
  SOURCE: Mathematics Web Association
- Ellipse Game HS Java Int
  SOURCE: John Banks from La Trobe University
  TECHNOLOGY: Java applet, Server-side program
- EMR - Exercises in Math Readiness HS
  ADD. KEYWORDS: Tutorial, Graphing Polynomials, Graphing' Rational Functions, Graphical Methods for Solving Inequalities, Conic Sections, Exponents and Exponential Functions, Logarithms
- Encyclopaedia Brittanica - Analytic geometry HS
  ADD. KEYWORDS: History, Solid analytic geometry, Special curves, Tangents and normals to curves, Conic Sections
  SOURCE: Encyclopaedia Brittanica
- Equations with Roots 2 and 5: A Pedagogical Exploration with a Relation Grapher HS
  SOURCE: James W. Wilson from the University of Georgia
- Experiments in Mathematics Using Maple HS
  ADD. KEYWORDS: Tutorial, Maple Worksheets
- ExploreMath.com HS Int
  ADD. KEYWORDS: Analytic Geometry, Inequalities, Systems, Trigonometry, Comples Numbers, Exponentials, Logarithms
- Exponential and Logarithmic Functions HS
  ADD. KEYWORDS: Tutorial
- Exponential Growth HS
  ADD. KEYWORDS: Tutorial, Bank accounts, Population growth, Catagious Disease, Maple
- Famous Curves Index HS Img Java
  ADD. KEYWORDS: Evolute, Involute, Pedal Curve, Caustic, History (too many to list!)
- FHS Precalculus Study Page HS
  ADD. KEYWORDS: Tutorial, Linear & Quadratics, Polynomial Functions, Inequalities, Functions, Exponents & Logs, Analytic Geometry, Trig Functions, Trig Equations & Apps, Triangle Trig, Trig Formulas, Polar & Complex, Sequences & Series, Limits & Rational Functions, Derivatives & Slope, Calculus
- Geomath HS
  ADD. KEYWORDS: Tutorial, Power functions, Exponentials, Logarithms
- Harvey Mudd College Mathematics Tutorials HS
  ADD. KEYWORDS: Algebra Review, Binomial Theorem, Complex Numbers, Computing Limits,

Functions and Transformations of Functions, Review of Trig, Log, Exp

- Instructional Unit on Conic Sections HS Img
  ADD. KEYWORDS: Circle, Ellipse, Hyperbola, and Parabola, Geometric Constructions, Geometry Sketchpad, Polar Coordinates
- Interactive Mathematics HS Int
  ADD. KEYWORDS: Tutorial, LiveMath, Algebra, Trigonometry, Logarithms, Complex Numbers, Systems of Equations, Graphs
- An Introduction To Conic Sections HS
  ADD. KEYWORDS: Tutorial, Ellipses, Circles, Hyperbolas, Applications, Rotation of axes
  SOURCE: James A. Sellers
- Java Applets in Mathematics [in French] HS Java Int
  ADD. KEYWORDS: Conic Sections, Parametric Curves, Polar Coordinate Graphs
- Manipula Math with Java - Conics HS Int Java
  ADD. KEYWORDS: Focus of Parabola, Ellipsograph, Problem of Hyperbola, Drawing Hyperbola, Drawing Parabola, Reflective Properties of Ellipses, Reflective Properties of Hyperbolas, Two Ellipses, Trace of Shadow
  SOURCE: IES - International Education Software
  TECHNOLOGY: Java Applets
- Math 1015 Pre-Calculus HS
  ADD. KEYWORDS: Course Materials, Online Recorded Lectures, Polynomials, Solving equations and inequalities, Circles, Functions, Lines, Composition of functions, Synthetic Division, Graphing, Inverse functions, Exponential and Logarithmic Functions, Linear Systems, Matrix Algebra, Cramer's Rule, Ellipses and Hyperbolas
  SOURCE: Virginia Tech
  TECHNOLOGY: RealAudio
- Math 108 Pre-Calculus HS
  ADD. KEYWORDS: Tutorial, Geometry Review, Long Division, Synthetic Division, Using Synthetic Division, The Fundamental Theorem of Algebra, Factored Polynomials, The Rational Roots Theorem, Descartes Rule of Signs, Bounds, Trigonometry, Polar Coordinates, Complex Numbers, Conic Sections, Sequences and Series
- Math 131 Supplementary Material Menu HS
  ADD. KEYWORDS: Tutorial, Solving Linear Equations, Lines in the Plane, Linear Modeling, Functions, Graphs of Functions, Translations of Functions, Quadratic Functions, Polynomial Functions, Rational Functions, Exponential Functions, Logarithmic Functions, Properties of Logarithms, Solving Exponential and Logarithmic Equations, Exponential and Logarithmic Applications, Linear Inequalities, Linear Programmming, Matrices and Systems of Linear Equations, 3D Demo of Row Operations, The Inverse of a Square Matrix
- Math and Problem-solving HS
  ADD. KEYWORDS: Find sizes and distances of earth, moon and sun
- Math Forum - Pre-Calculus K6 Lnks
  ADD. KEYWORDS: Classroom materials, software, newsgroups
- Mathematics Explorations I & II HS

ADD. KEYWORDS: Projects involving activities at NASA
SOURCE: Capital Community College, NASA - AMATYC - NSF
TECHNOLOGY: Adobe Acrobat Reader

- Mathematical Modules in Biology and Chemistry LD
  ADD. KEYWORDS: Epidemiology, Course Materials
  SOURCE: Meghan A. Burke and Sean F. Ellermeyer from Kennesaw State University
- Mathématikos - Les Courbes du plan [in French] HS Int Java
  ADD. KEYWORDS: Parametric curves
  SOURCE: Jean-Paul Quelen, professeur de mathématiques au lycée Jean Monnet - Strasbourg
  TECHNOLOGY: Java Applets
- The MathServ Calculus Toolkit LD Int
  ADD. KEYWORDS: Factoring polynomials, Solutions of polynomials, Fitting a polynomial, Shifting and scaling functions, Finding inverses
- Mathworld - Analytic Geometry
  ADD. KEYWORDS: Definitions, List of Theorems
  SOURCE: Eric W. Weisstein
- Occurrence of the Conics HS
  ADD. KEYWORDS: Applications of the conics
  SOURCE: Jill Britton from Camosun College
- Parabola Explorer HS Int
  ADD. KEYWORDS: Graphing parabolas
  SOURCE: 7Stones Mathematical Ideas in Science
  TECHNOLOGY: Flash plugin
- Parabolas HS Java Int
  ADD. KEYWORDS: Paper folding
  SOURCE: James P. Dildine from the University of Illinois, Urbana-Champaign
  TECHNOLOGY: Geometer's Sketchpad, JavaSketchpad
- Partnership for Excellence - Functions: A Connecting Thread for Mathematics HS
  ADD. KEYWORDS: Lesson Plans, Course Materials
  SOURCE: Partnership for Excellence Project, University of South Carolina Spartanburg
- Physics Tutorials - Logarithms HS
- Precalculus -- Preparing Students for Calculus LD
  ADD. KEYWORDS: Published Text
- Precalculus and Mathematica LD
  ADD. KEYWORDS: Mathematica labs and exams
  SOURCE: Donald G. Hazlewood, Southwest Texas State University
  TECHNOLOGY:Adobe Acrobat Reader and Mathematica
- Precalculus at UW LD
  ADD. KEYWORDS: Course Materials, Text, Additional Problems
  SOURCE: D.H. Collingwood and K.D. Prince, University of Washington
  TECHNOLOGY:Adobe Acrobat Reader

- Pre-Calculus Learning Units HS
  ADD. KEYWORDS: Lesson Plans, Graphs of Parabolas
- Precalculus Quiz Generator and Grader LD Int
- The Precalculus Weblet LD Int
  ADD. KEYWORDS: Course materials
- Project-Based Instruction in Mathematics for the Liberal Arts LD
  ADD. KEYWORDS: Course materials, Linear functions, Least Squares Line, Linear Modeling, Statistics and probability, Non-linear functions, Managing money with the exponential function, The logistic function – constrained growth and decay
  SOURCE: M.B. Ulmer, University of South Carolina Spartanburg
  TECHNOLOGY:Adobe Acrobat Reader
- The Reflective Property of the Parabola LD
  SOURCE: Marc Frantz from Indiana University - Purdue University, Indianapolis
- SCORE Mathematics - Mathematical Analysis HS
  ADD. KEYWORDS: Lesson Plans, Standards
  SOURCE: SCORE - Schools of California Online Resources for Education
- Sherware Precalculus Tools Page HS Int
  ADD. KEYWORDS: Projects
- Surfin' Sinefeld: Flash Animated Precalculus, Calculus and Statistics Activities HS Int
  ADD. KEYWORDS: Graphing, Exponential, Logarithmic and Trigonometric Functions, Quizzes
  SOURCE: Ralph Irons, Central Shenandoah Valley Regional Governor's School
  TECHNOLOGY: Flash plugin
- Spirograph K6 Java
  ADD. KEYWORDS: Interactive pages
- Spirograph HS Java Int
- Topics in Precalculus HS Lnks
- Tracés animé HS Int
  ADD. KEYWORDS: Generate graphs of a parametrized family of functions.
- Triangles and Parabolas HS
  ADD. KEYWORDS: Finding a parabola which is tangent to three lines
  SOURCE: Jemma Giddings from the University of Georgia
  TECHNOLOGY: Geometer's Sketchpad
- 2d curves HS Img
- A Visual Dictionary of Special Plane Curves HS Img Mov
  ADD. KEYWORDS: Caustics, Envelope, Evolute, Involute, Inversion, Conic Sections, Mathematica Notebooks, Geometry Sketchpad
- WIMS - WWW Interactive Mathematics Server HS Int
  ADD. KEYWORDS: Online exercises, Polynomials, Functions, Composition of Functions
- Worksheet library ~ Functions HS
  ADD. KEYWORDS: Trigonometry, The Exponential Function, The Natural Logarithm
  SOURCE: Mike Robinson, Sheffield Hallam University

TECHNOLOGY: Adobe Acrobat Reader

- Zona Land ... More Mathematics than Science HS Int Java
  ADD. KEYWORDS: Functions, Graph Paper, Trigonometry, Geometry, Fractals, VRML

Math Archives

Topics in Mathematics

Statistics

- Adventures in Statistics K6
  ADD. KEYWORDS: measurement, graphing, computation, data analysis, and presentation of results
- AMS's Materials Organized by Mathematical Subject Classification G-P Lnks
  ADD. KEYWORDS: Electronic Journals, Preprints, Web Sites, Databases
- AP Statistics HS Lnks
- Applets for the Cybergnostics project UD Int Java
  ADD. KEYWORDS: Chi-square Demonstration, Exponential Demonstration, Binomial Demonstration, Normal Approximation to the Binomial, Marden's regression, conditional probability, Confidence interval, Correlation demo, Power, F Demonstration
- AskERIC Lesson Plans - Statistics K6
- Basic Principles of Statistical Analysis UD
  ADD. KEYWORDS: Tutorial, Basics Concepts of Statistical Models, Mixed Model, Choosing between Fixed and Random Effects, Estimating variances and Covariances, Estimating Fixed Effects, Predicting Random Effects, Inference space
- Basic statistics for clinicians UD
  ADD. KEYWORDS: Hypothesis testing, 2.Interpreting study results: confidence intervals, Assessing the effects of treatment: measures of association, Correlation and regression
  SOURCE: Gordon Guyatt, Roman Jaeschke, Nancy Heddle, Deborah Cook, Harry Shannon, and Stephen Walter, of the McMaster University Health Sciences Centre
- Berrie's Statistic's Page LD Int Java Mov
  ADD. KEYWORDS: Poisson distribution, Mean and Variance in the Normal Distribution, Graph of the Normal Distribution, Binomial Distribution, Central Limit Theorem
- Bibliography for Computational Probability and Statistics G-P
- Briefbook of Data Analysis UD
  ADD. KEYWORDS: Amdahl`s Law, ANOVA, Analysis of Variance, Attenuation, Average, Bandwidth, Baud, Bayes Theorem, Bayesian Statistics, Benchmarking, Bessel Functions, Beta Distribution, Bias, Binning, Binomial Distribution, Bivariate Normal Distribution, Boolean Algebra, etc.
- Center for Industrial Statistics UD
- Central Limit Theorem Applet LD Int Java
- Chance Database LD Lnks
  ADD. KEYWORDS: Course Materials, Teaching Aids, Newsletter, Newspaper and Magazine Articles
- Computing Studio LD Int
  ADD. KEYWORDS: Mean, Median, Variance, Standard Deviation, Covariance

- Confidence Interval Applet LD Int Java
- Correspondence Analysis G-P
  ADD. KEYWORDS: Data Analysis, Factor Analysis, Contingency tables
  SOURCE: F.X. Micheloud
- CTI - Statistics LD Lnks
  ADD. KEYWORDS: Publications, Guide to Software for Teaching, Newsletter, Software Reviews, Articles, Educational Software, Mailing List, Meetings
- The CUWU Statistics Program LD Int Java
- Data Analysis Briefbook LD
  ADD. KEYWORDS: Glossary, Statistics, Computing, Analysis.
- Data Analysis Learning Units K6
  ADD. KEYWORDS: Lesson Plans, Fractions and Probability
- The Data and Story Library LD
- Data Archives on the Net LD Lnks
  ADD. KEYWORDS: Datasets
- Data Surfing on the World Wide Web HS Lnks
  ADD. KEYWORDS: Datasets
  SOURCE: Robin Lock, St. Lawrence University
- DAU Stat Refresher LD Int
  ADD. KEYWORDS: Tutorial, Tests, Probability, Random Variables, Expectations, Distributions, Data Analysis, Linear Regression, Multiple Regression, Moving Averages, Exponential Smoothing, Clustering Algorithms
- Discussiones Mathematicae Probability and Statistics G-P
  ADD. KEYWORDS: Published Journal
  SOURCE: Technical University of Zielona Góra
- DOCUMENTA MATHEMATICA - Extra Volume ICM 1998 - Section: 12. Probability and Statistics G-P
  ADD. KEYWORDS: Articles
  SOURCE: DOCUMENTA MATHEMATICA, Proceedings of the International Congress of Mathematicians
  TECHNOLOGY: Postscript and DVI readers
- ESAIM : Probabilités et Statistique G-P
  ADD. KEYWORDS: Journal
- Exact power for the Fisher Exact Test UD Java
- Exploring Data HS Lnks
  ADD. KEYWORDS: Tutorials, Course materials, Boxplots, Confidence Intervals, Curve Fitting, Datasets, Dotplots, Histograms, Hypothesis Testing, Linear Regression, Looking for Patterns, Measures of Location, Measures of Spread, Normal Distribution, Normal Plots, Probability, Sampling, Scatterplots, Stemplots
  SOURCE: Rex Boggs and Education Queensland
- FAQ: Numerical Analysis and Associated Fields Resource Guide G-P Lnks

ADD. KEYWORDS: Books, Software

- Globally Accessible Statistical Procedures LD Java
  ADD. KEYWORDS: Regression, confidence interval, histogram, central limit theorem, binomial distribution, interactive pages
- Graphical Data Analyisis Course by Jeff Banfield UD Mov
  ADD. KEYWORDS: Splus, Graphical Perception, Dot Charts, Scatter Plots, Scatter Plot Smoothing, Spatial Data and Response Surfaces, Coplots, Dynamic Graphics, Comparing Groups
- A Guide to Statistical Software UD Lnks
  ADD. KEYWORDS: Software Reviews
- Hyperstat - ein interaktives, hypertextbasiertes Statistikskript für die Varianzanalyse LD
  ADD. KEYWORDS: Matrix Algebra, Linear Models, Variance Analysis, Regression Analysis, Tutorial
- HyperStat Online LD Lnks
  ADD. KEYWORDS: Tutorial, Describing Univariate Data, Describing Bivariate Data, Introduction to Probability, Normal Distribution, Sampling Distributions, Point Estimation, Confidence Intervals, The Logic of Hypothesis Testing, Testing Hypotheses with Standard Errors, Power, Introduction to Between-Subjects ANOVA, Factorial Between-Subjects ANOVA, Within-Subjects ANOVA, Prediction, Chi Square, Distribution-Free Tests, Measuring Effect Size
- Institute of Mathematical Statistics G-P Lnks
  ADD. KEYWORDS: Society, Publications, Meetings, Resources, Statistics departments
- Institute of Statistical Mathematics G-P
  ADD. KEYWORDS: Journal, Software & Data Library
- Introduction to Descriptive Statistics HS
- Introduction to Factor Analysis UD
  ADD. KEYWORDS: Tutorial, Chemistry
- Introduction to Linear Regression HS Int
  ADD. KEYWORDS: Graphing best fit lines
  SOURCE: 7Stones Mathematical Ideas in Science
  TECHNOLOGY: Shockwave plugin
- Introductory Statistics: Concepts, Models, and Applications UD
  ADD. KEYWORDS: Lecture Notes, SPSS
- Introductory Statistics Demonstrations LD
  ADD. KEYWORDS: Animations, Variance and Standard Deviation, Z-Scores, Z-Scores and Probability, Sampling Distributions, Standard Error, Standard Error and Z-score Hypothesis Testing, Confidence Intervals, Power, Analysis of Variance (ANOVA)
- Intuitive Biostatistics: Interpreting Nonsignificant P values UD
  ADD. KEYWORDS: Chapter from book
  SOURCE: HJ Motulsky, Intuitive Biostatistics
- Java Applets LD Java
  ADD. KEYWORDS: Histograms, Normal Approximation to Binomial, Normal Density, T Distribution, Area Under Normal Curves, Z Scores and the Normal Distribution, Binomial Probabilities, Brownian Motion, Central Limit Theorem, A Gamma Process, Let's Make a Deal Game,

Confidence Intervals, Regression, Statistics Tools, Statiscope Summarizing data, T-test, Models

- Java Applets for Statistics LD Java Int
  ADD. KEYWORDS: The sample space model, Calculator(mean and deviation), Multiplication rule for counting, Permutations and Combinations, Tossing a balanced coin n times, Tossing a coin with p=P(H), Rolling a pair of dice, Venn diagram(Addition Rule), Rolling a balanced die n times, Binomial distribution, Conditional Probability, Total Probability and Bayes Rule, Normal curve, Standard Normal Distribution, Normal approximation to Binomial Distribution
  SOURCE: Shangrong Deng, Southern Polytechnic State University
  TECHNOLOGY: Java applets
- The Journal of Basketball Studies HS Int Java
  ADD. KEYWORDS: Basketball's Bell Curve, Applications of Statistics
- Journal of Statistics Education LD
  ADD. KEYWORDS: Electronic Journal
- Journal of Statistics Education - Information Service LD Lnks
  ADD. KEYWORDS: Education Resources, Newsgroups, Data Resources, Software, Organizations
- K-12 Statistics HS Lnks
  ADD. KEYWORDS: NCTM Statistics Standards, Lesson Plans
- Kovach Computing Services G-P
  ADD. KEYWORDS: Commercial Statistical Software, Excel, Population Dynamics Simulation, Circular Statistics
- List of Undergraduate Textbooks LD
  ADD. KEYWORDS: Introductory Statistics and Mathematical Statistics Textbooks, Reviews
- Math Forum - Probability & Statistics K6 Lnks
  ADD. KEYWORDS: Classroom materials, software, newsgroups
- Mathematics Explorations I & II HS
  ADD. KEYWORDS: Projects involving activities at NASA
  SOURCE: Capital Community College, NASA - AMATYC - NSF
  TECHNOLOGY: Adobe Acrobat Reader
- MathLink - Probability and Statistics HS Lnks
  ADD. KEYWORDS: Three Door Puzzle, Descriptive Statistics, Linear Regression, Chi-Square, Exponential Fit, Guessing Correlations
- Mathworld - Probability and Statistics
  ADD. KEYWORDS: Definitions, List of Theorems
- MSTE Technology Tutorials - Statistics HS Int Java
  ADD. KEYWORDS: Buffon Needle, Cereal Box Problem, Cliff Hanger, Estimation of Pi, Monty's Dilemma, Random Birthday, Relative Prime, Simulated Fishtank, Webdice, Triangle Dice
  SOURCE: Nicholas Exner and George Reese, University of Illinois at Urbana-Champaign
- National Library of Virtual Manipulatives for Interactive Mathematics - Data Analysis & Probability K6 Java Int
  ADD. KEYWORDS: Scatterplot, Histogram, Box Model
  SOURCE: Lawrence O. Cannon, James T. Dorward, E. Robert Heal, Leo Edwards, Utah State

University
TECHNOLOGY: Java applets

- NetMul G-P Int
  ADD. KEYWORDS: Multivariate analysis, software, interactive pages
- Online Data K6 Lnks
  ADD. KEYWORDS: Data Archives, Data Sets
- Online Hypothesis Tests Tutorial LD Int
- Mathématikos - Probabilités et statistiques [in French] HS Int Java
  ADD. KEYWORDS: Binomial law, Poisson distribution, Normal distribution, Galton board, Random number generator, ...
  SOURCE: Jean-Paul Quelen, professeur de mathématiques au lycée Jean Monnet - Strasbourg
  TECHNOLOGY: Java Applets
- MSTE Java Lessons - Statistics HS Int Java
  ADD. KEYWORDS: Buffon Needle, Cereal Box Problem, Cliff Hanger, Estimation of Pi, Monty's Dilemma, Random Birthday, Relative Prime, Simulated Fishtank, Webdice, Triangle Dice
  SOURCE: Nicholas Exner and George Reese, University of Illinois at Urbana-Champaign
  TECHNOLOGY: Java Applets
- Partnership for Excellence - Statistics: A Math Unifier HS
  ADD. KEYWORDS: Lesson Plans, Course Materials
  SOURCE: Partnership for Excellence Project, University of South Carolina Spartanburg
- Probability/Statistics Object Library LD Int Java
  ADD. KEYWORDS: Geometric Models, Bernoulli Trials, Finite Sampling Models, Set Theory and Combinatorics, Dice Experiments, Games of Chance, Poisson Process, Random Walk, Interacting Particle Systems, Special Distributions, Random Samples, Point Estimation, Interval Estimation, Hypothesis Testing
  SOURCE: Kyle Siegrist, Dawn Duehring, University of Alabama in Huntsville
  TECHNOLOGY: Java Applets
- Probability and Statistics UD
  ADD. KEYWORDS: Collection of articles, Evaluating Probabilities of Boolean Events, The Gambler's Ruin, Area Under the Bell Curve, The Poisson Distribution and Queues, Ratio Populations, Ratios of Normal Distributions, Failure Rates, MTBFs, All That and Boolean Expansion as Linear Interpolation, etc.
- Project Interactivate - Statistics HS Int Java
  ADD. KEYWORDS: Lesson Plans, Mean, Median and Mode, Histograms and Bar Graphs
- Project INTERMATH Topics - Probability and Statistics LD
  ADD. KEYWORDS: Curriculum Materials, Calling for Artillery Fire Reliability Problem, Electrical Circuit Analysis, Modeling Electrical Current, Estimating Water Forces on a Dam, Predicting Stock Market Performance, Measuring the "Safeness" of Air
  SOURCE: COMAP, Carroll College, Georgia College & State University, Harvey Mudd College, Macalester College, University of Redlands, Texas Southern Consortium, West Point
  TECHNOLOGY: Adobe Acrobat Reader
- Prophet StatGuide G-P

ADD. KEYWORDS: Software, Glossary, Modeling

- Regression Applet LD Int Java
- Rice Virtual Lab in Statistics LD Int Java
  ADD. KEYWORDS: Simulations, Demonstrations, Case Studies, Analysis Lab
- SCORE Mathematics - Probability and Statistics HS
  ADD. KEYWORDS: Lesson Plans, Standards
  SOURCE: SCORE - Schools of California Online Resources for Education
- SCORE Mathematics - Probability and Statistics - Advanced HS
  ADD. KEYWORDS: Lesson Plans, Standards
  SOURCE: SCORE - Schools of California Online Resources for Education
- SCORE Mathematics - Statistics, Data Analysis and Probability K6
  ADD. KEYWORDS: Lesson Plans, Standards
  SOURCE: SCORE - Schools of California Online Resources for Education
- SEQuaL - Statistics Education through Quantitative Literacy K6 Lnks
  ADD. KEYWORDS: NCTM Standards, Workshops, Lesson Plans, Software
- SEL - Statistique En Ligne [in French] LD Int Java
  ADD. KEYWORDS: Simulations, Articles, Lexicon, Tutorial
  SOURCE: Claudine Robert from INRIA Rhtne-Alpes, Bernard Ycart et al. from Université René Descartes
  TECHNOLOGY: Java applets
- SFU Statistics - Innovations in Teaching Statistics Lnks
  ADD. KEYWORDS: Computer demonstrations, Datasets for teaching, Consulting problems, Journals, Interactive Textbooks
- SIAM - World of Mathematics and Computing - Statistics G-P Lnks
- Simple Regression LD Int
- SMILE Program Mathematics Index K6
  ADD. KEYWORDS: Lesson Plans
- Some Experimental Interactive Statistics Pages UD Java
  ADD. KEYWORDS: Correlation, scatter plots, histograms, interactive pages
- The Sports Data Page HS Lnks
  ADD. KEYWORDS: Datasets
  SOURCE: Robin Lock, St. Lawrence University
- Statistical Inference on the TI-82/83/86/89/92+ LD
  ADD. KEYWORDS: Discrete and Continuous Random Variables, Binomial, Poisson, Geometric, Hypergeometric, Normal, T, Chi Square, F Distributions, Confidence Intervals, Hypothesis Tests, Anova, Projects
  SOURCE: David K. Neal, Western Kentucky University
- The Statistical Instruction Internet Palette (SIIP) LD Int
  ADD. KEYWORDS: Dr. B's Wide World of Web Data, Data Gallery, Equation Gallery, Scatterplots, Computation
- Statistical Methods for Rater Agreement LD

ADD. KEYWORDS: Raw agreement indices, Odds ratio and Yule's Q, Tests of marginal homogeneity, Tetrachoric and polychoric correlation, Latent trait models, Latent class models, Loglinear, association, and quasi-symmetry models, Kappa coefficients, Methods for Likert-type or interval-level data
SOURCE: John Uebersax

- Statistical Tests LD Int
  ADD. KEYWORDS: Probability Distributions: Binomial, Normal, Student-t, Chi-Square; One-Sample and Matched-Pairs tests: Sign Test, McNemar's Test, Wilcoxon Matched-Pairs Signed-Ranks Test, Student-t test for one sample; Two-Sample tests: Median Test, Binomial proportions, Wilcoxon Test, Student-t test for two samples; Multiple-Sample tests: Friedman Test; Correlations: Rank Correlation coefficient, Correlation coefficient, Comparing Correlation coefficients; Categorical data (Chi-square tests): Chi-square test for known distributions, Chi-square test for equality of distributions
- Statiscope LD Int Java
  ADD. KEYWORDS: Descriptive Statistics
- Statistics UD Lnks
  ADD. KEYWORDS: Data Sources, Job Announcements, Departments, Divisions and Schools of Statistics, Statistical Research Groups, Institutes, and Associations, Statistical Archives and Resources, Software, Journals, Mailing Lists, News Groups
- Statistics and Statistical Graphics Resources by Michael Friendly, York University UD Lnks
  ADD. KEYWORDS: Societies, Statistics Departments, SAS, SPSS, LispStat, S Plus, Mathematica, Data Visualization & Statistical Graphics, Psychometrics, Online courses, Data, Categorical Data Analysis, Software
- Statistics for Engineers UD
  ADD. KEYWORDS: Course Notes, Bayes' Theorem, Probabilities and Odds, Counting Theorem, Permutation and Combination, Probability Distributions, Mean, Variance and Standard Deviation of Binomial Distributions, Hypergeometric Distribution, Poisson Probability Distribution
- Statistics Glossary LD
  ADD. KEYWORDS: Basic Definitions, Presenting Data, Sampling, Probability, Confidence Intervals, Hypothesis Testing, Paired Data, Correlation and Regression, Design of Experiments and ANOVA, Categorical Data, Non-parametric Methods, Time Series Data
- Statistics Learning Units HS
  ADD. KEYWORDS: Lesson Plans, Compound Interest Formula, Data
- Statistics - The Study of Stability in Variation LD Java
  ADD. KEYWORDS: WWW textbook, calculators, interactive pages
- Statistics.Com LD Lnks
  ADD. KEYWORDS: Software & Other Tools, Courses, Employment & Career Info, Teaching Statistics, Getting Statistical Data
- STATLETS LD Int Java
  ADD. KEYWORDS: Plot, Summarize, One Sample Analysis, Two Sample Analysis, Analysis of Variance, Regression Analysis, Time Series Analysis Rates and Proportions, Quality Control
- StatLib UD

ADD. KEYWORDS: Applied Statistics algorithms, ASA Statistical Computing Section Archive, Datasets Archive, Designs Archive, Software, Genstat, Meetings, Software for Graphical Modelling, Data and Story Library

- Statnotes: An Online Textbook G-P
  ADD. KEYWORDS: Lecture Notes, ANOVA, ANCOVA, Correlation, Correspondence Analysis, Partial Correlation, Discriminant Function, Analysis, Multiple DA, Factor Analysis, Logistic Regression,
  Log-linear Models, Logit, and Probit, MANOVA/MANCOVA, Path Analysis, Regression Analysis, Structural Equation, Modeling
  SOURCE: G. David Garson, North Carolina State University
- Stats 101 LD Int Java
  ADD. KEYWORDS: Student's t-Test, ANOVA, Simple Least Squares, Spearman's Rank Correlation, Statistical Methods Decision Tree
- Statsoft LD
  ADD. KEYWORDS: Electronic textbook, ANOVA/MANOVA, Canonical Analysis, Classification Trees, Cluster Analysis, Correspondence Analysis, Data Mining Techniques, Discriminant Function Analysis, Experimental Design, Principal Components and Factor Analysis, General Linear Models, General Stepwise Regression, Graphical Analytic Techniques, Multiple Regression, Log-Linear Analysis of Frequency Tables, Multidimensional Scaling, Neural Networks, Nonlinear Estimation, Nonparametric Statistics, Partial Least Squares, Power Analysis, Process Analysis, Quality Control Charts, Reliability and Item Analysis, Structural Equation Modeling, Survival/Failure Time Analysis, Time Series Analysis
  SOURCE: StatSoft, Inc.
- SticiGui©: Statistical Tools for Internet and Classroom Instruction with a Graphical User Interface LD Int Java
  ADD. KEYWORDS: Course Materials
- Stochastic Finite Elements: A Spectral Approach G-P
  ADD. KEYWORDS: Published Book
- Surfin' Sinefeld: Flash Animated Precalculus, Calculus and Statistics Activities HS Int
  ADD. KEYWORDS: Graphing, Means, Medians, Measures of Spreads, Three and four door problems, Quizzes
  SOURCE: Ralph Irons, Central Shenandoah Valley Regional Governor's School
  TECHNOLOGY: Flash plugin
- SURFSTAT Australia LD Int Java
  ADD. KEYWORDS: Summarising and Presenting Data, Producing Data, Variation and Probability, Statistical Inference, Control Charts
- TI-83 Graphing Calculator Manual for Moore's The Basic Practice of Statistics LD
  SOURCE: David K. Neal, Western Kentucky University
- The Titanic: What Can Numbers Tell Us About Her Fatal Voyage? HS
  ADD. KEYWORDS: Spreadsheets, Databases
- Tools for Teaching and Assessing Statistical Inference LD
  ADD. KEYWORDS: Course Materials, Distributions, Measures of center, Variability, Drawing

samples, Sampling distributions, Confidence intervals, p-values, Sampling distributions, Confidence
intervals
SOURCE: Joan Garfield and Bob delMas, University of Minnesota; Beth Chance, California Polytechnic State University
TECHNOLOGY: Macintosh and Windows Software- Sampling SIM, Standard Distributions

- Triogram Models G-P Java
  ADD. KEYWORDS: Function Estimation, Bivariate Splines, Bivariate Regression, Log-Density Estimation, Modeling Data, ANOVA
- USDA-NASS Kids Page K6
  ADD. KEYWORDS: Agricultural Statistics
- Using Internet Data Meaningfully HS
  ADD. KEYWORDS: Worksheets
  SOURCE: Helen Skala, University Wisconsin - La Crosse
- Virtual Laboratories in Probability and Statistics LD Int Java
  ADD. KEYWORDS: Descriptive Statistics, Probability Spaces, Combinatorics, Distributions, Expected Value, Special Distributions, The Sample Mean, Interval Estimation
- Web Interface for Statistics Education LD Int Lnks
  ADD. KEYWORDS: Tutorials, Glossaries, Discussion Groups
- WebStat LD Int Java
  ADD. KEYWORDS: Summary Statistics, Z tests (one and two sample) for Population Means, T Tests (one and two sample) for Population Means, Chi-square Test for Population Variance, F Test for Comparing Population Variances, Regression

Limits - Numerical

Tutorial which is an introduction to limits from a numerical point of view.

- A Javascript exploration in getting numerical evidence for determining a limit.
- A Javascript demonstration which gives three examples which show problems for generating numerical evidence for the determination of a limit.
- A Javascript demonstration which shows the need for considering both right-hand and left-hand limits.
- A Javascript exploration in getting numerical evidence for determining an infinite limit.
- Computer programs which will generate numerical evidence for determining a limit. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer programs which will generate numerical evidence for determining a limit.
- Computer programs and the problems they have for generating numerical evidence for the determination of a limit. Also,
  - TI-86 Graphing Calculator [Using Flash]

Limits - Graphically

Tutorial which is an introduction to limits from a graphical point of view.

- A LiveMath notebook to explore graphically the verification of the epsilon-delta definition of limit.
- Using graphing calculators to graphically demonstrate the epsilon-delta definition of limits [Using Flash]
- Computer programs to graphically demonstrate the epsilon-delta definition of limits. Also,
  - TI-85 Graphing Calculator
- Using TI-85 graphing calculators to graphically demonstrate the epsilon-delta definition of limits.
- Computer programs and the problems that have in graphically investigating limits. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer program to evaluate limits with the greatest integer function. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- A LiveMath notebook to explore the verification of the epsilon-delta definition of limit.

Formal Definition of Limits

Tutorial on the formal definition of limits.

- Drill in finding delta given epsilon.
- Drill in verifying limits using the definition of limits.

Limits - Symbolically

Tutorial which is an introduction to limits from a symbolic point of view.

- Limit theorems [Using Flash] [Using HotEqn] [Using IBM Professional TechExplorer]
- LiveMath notebooks to explore functions which involve the Greatest Integer Function; application of squeeze theorem.
- Drill on evaluating limits.
- A quiz on evaluating limits using the limit theorems and graphs.
- Maple and the evaluation of limits.
- Maple and the limit theorems.
- Maple and finding limits of piecewise defined functions.

Continuous Functions

Tutorial which is an introduction to continuous functions.

- A quiz on using the definition of continuity.
- A LiveMath Notebook on exploring continuity of a piecewise defined function.
- Drill in determining when a piecewise defined function is continuous.
- A LiveMath notebook illustrating the problem of using computers to determine graphically whether a function is continuous.
- Computer programs and problems of using computers to determine graphically whether a function is continuous.
- Graphically exploring functions with possible removable discontinuities
  - with the TI86 graphing calculator [Using Flash]
  - with the TI85 graphing calculator.

Properties of Continuous Functions

Tutorial on the Intermediate Value Theorem, the Bisection Method and the Extreme Value Theorem.

- Javascript page illustrating the bisection method for finding roots.
- Computer programs which numerically illustrate the bisection method.
- Computer programs which graphically illustrate the bisection method.
- A quiz on using concepts involving continuity of functions and its consequences.

Horizontal Asymptotes

Tutorial on horizontal asymptotes.

- Javascript generated evidence for horizontal asymptotes.
- Javascript module on numerically determining horizontal asymptotes.
- A LiveMath notebook on graphically determining horizontal asymptotes.
- Drill in finding horizontal asymptotes.
- Computer programs which can be used to gather numerical evidence for horizontal asymptotes. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer programs and problems in gathering numerical evidence for determining horizontal asymptotes. Also,
  - TI-85 Graphing Calculator

Vertical Asymptotes

Tutorial on vertical asymptotes.

- A Javascript exploration in getting numerical evidence for determining an infinite limit.
- A LiveMath notebook to explore graphically vertical asymptotes.
- Drill on finding vertical asymptotes.
- Computer programs which can be used to gather numerical evidence for vertical asymptotes. Also,
  - TI-85 Graphing Calculator
- Determine the roots and vertical asymptotes of rational functions using a TI-85 graphing calculator.

Tangent Lines

Tutorial on tangent lines as an introduction to the derivative.

- A LiveMath notebook illustrating the tangent line as the limit of secant lines.
- A JavaScript exploration of the numerical estimates of the slope of the tangent line to the graphs of various functions.
- An animation demonstrating the estimation of the slope of the tangent by zooming in.
- A LiveMath notebook which compares graphically a function with its linear approximation.
- Javascript module which compares numerically a function with its linear approximation.
- Computer programs that graphically illustrate the tangent line as the limit of secant lines. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Another computer program that graphically illustrates the tangent line as the limit of secant lines.
- Computer programs that plot a tangent line to the graph of a given function. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Another computer program that plots the graph of a function together with the tangent line at a given point.

Linear Approximations

Tutorial on the accuracy of a linear approximation.

- A LiveMath Notebook which can be used to determine accuracy of using a linear approximation.
- Computer programs that can be used to determine accuracy of using a linear approximation. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator

Definition of Derivative at a Point

Tutorial on the definition of derivative at a point.

- Using the definition of derivative at a point, calculate the derivative of a quadratic at a point.
  [Using HotEqn] [Using IBM Techexplorer] [Using IBM Pro.Techexplorer]
- Using the definition of derivative at a point, calculate the derivative of a square root of a function at a point.

[Using HotEqn] [Using IBM Techexplorer] [Using IBM Pro.Techexplorer]

- Using the definition of derivative at a point, calculates the derivative of a rational function at a point.
  [Using HotEqn] [Using IBM Techexplorer] [Using IBM Pro.Techexplorer]
- A LiveMath Notebook illustrating how to use the definition of derivative to calculate the derivative of a quotient at a specific point.
- A LiveMath Notebook which, using the definition of derivative at a point, investigates the derivative of $\mathbf{x^{2/3}}$ at $\mathbf{x = 0}$.
- A LiveMath Notebook illustrating how to use the definition of derivative to calculate the derivative of a radical at a specific point.
- Computer programs that numerically investigate the behavior of the Newton quotient of a function at a point.
- Computer programs that numerically investigate the behavior of the Newton quotient of a function at a point. In this case, the function is not differentiable at the given point.
- Computer programs that numerically investigate the behavior of the Newton quotient of a function at a point. In this case, the function is not differentiable at the given point but the limit of the symmetric difference quotient exists.

Definition of Derivative

Tutorial on the definition of derivative.

- Using the definition of derivative, calculate the derivative of a quadratic at a point.
  [Using HotEqn] [Using IBM Techexplorer] [Using IBM Pro. Techexplorer]
- Using the definition of derivative, calculate the derivative of a square root of a function at a point.
  [Using HotEqn] [Using IBM Techexplorer] [Using IBM Pro. Techexplorer]
- Using the definition of derivative, calculate the derivative of a rational function at a point.
  [Using HotEqn] [Using IBM Techexplorer] [Using IBM Pro. Techexplorer]
- A LiveMath Notebook illustrating how to use the definition of derivative to calculate the derivative of a quadratic.
- A LiveMath Notebook illustrating how to use the definition of derivative to calculate the derivative of a quotient.
- A LiveMath Notebook illustrating how to use the definition of derivative to calculate the derivative of a radical.
- Drill problems for finding the derivative of a function using the definition of a derivative.

Differentiation Formulas

Tutorial on elementary differentiation formulas, their derivation and use. Includes the Power Formula.

- A LiveMath Notebook illustrating how to use the definition of derivative to obtain the power rule.
- A LiveMath Notebook illustrating the use of the formula for the derivative of a sum.

Derivative of the Exponential Function

Tutorial on the calculation of the derivative of the exponential function.

- A LiveMath notebook illustrating the finding of the derivative of an exponential function at **x = 0**.
- JavaScript exploration of the numerical estimates of the slope of the tangent line to the exponential function.

Product Rule

Tutorial on the Product Rule.

- A LiveMath notebook which illustrates the use of the product rule.
- Drill problems for differentiation using the product rule. (Algebraic and exponential functions).

Quotient Rule

Tutorial on the Quotient Rule.

- A LiveMath notebook which illustrates the use of the quotient rule.
- Drill problems for differentiation using the quotient rule.

Derivatives of the Trigonometric Functions

Tutorial on the calculation of the derivatives of the trigonometric functions.

- Drill problems for differentiation using the product rule. (Emphasis on trigonometric functions).
- Drill problems for differentiation using the quotient rule. (Emphasis on trigonometric functions).

The Chain Rule

Tutorial on the Chain Rule.

- A LiveMath notebook illustrating the use of the chain rule.
- Drill problems for differentiation using the chain rule.
- Computer program that graphically illustrates the chain rule.

Derivatives of Functions

- A list of differentiation formulas.
- Drill problems for differentiation using the product rule.
- Quiz on finding the derivative of functions.
- Using the TI85 graphing calculator to plot approximating the graph of a derivative with the Newton quotient.

Derivatives and Graphing

Tutorial on using the derivative to detect increasing and decreasing functions. Local maximum and local minimum are also defined. Emphasis on graphical analysis.

- A LiveMath notebook that draws the graph of a function and its derivative.
- Computer programs that draw the graph of a function and its derivative. Also,
  - TI-86 Graphing Calculator [Using Flash]
- Computer programs that draw the graph of a function and its derivative. Also,
  - TI-85 Graphing Calculator
- Computer programs that draw the graphs of a function and its derivative to illustrate the First Derivative Test.
- Computer programs that numerically find a critical point of a function.
- Computer programs that graphically, find a critical point of a function.
- Computer programs and the problems with finding graphically the critical points of a function.

Tutorial on using the second derivative to detect concavity of functions. Inflection points are also defined. Emphasis on graphical analysis.

- A LiveMath Notebook that draws the graph of a function and its second derivative.
- Computer programs that draw the graph of a function and its second derivative. Also,
  - TI-85 Graphing Calculator
- Computer programs that draw the graph of a function and its second derivative.
- Quiz which tests the ability to determine graphically information about a function and its derivatives.
- Quiz which tests the ability to determine information about the graph of a function from information about its derivatives.
- Quiz on determining which graph is the graph of a function, its derivative and its 2nd derivatives.

Tangent Lines and Parametric Curves

Tutorial on finding tangent lines to parametric curves.

- A LiveMath Notebook illustrating the finding of the equation of a tangent line to a parametric curve.
- Drill problems on finding the derivative and the equation of the tangent line to a parametric curve.
- Using the TI-85 Graphing Calculator to find and graph the tangent line to a parametric curve. Also,

Tutorial on finding tangent lines to polar curves.

Implicit Differentiation

Tutorial on implicit differentiation.

- Drill on finding the derivative and the equation of the tangent line at a given point.
- Drill problems for finding a derivative by implicit differentiation.
- A LiveMath Notebook illustrating implicit differentiation.
- Computer programs that plot the graph of a relation and calculate the derivative.
- Computer programs that plot the graph of a relation and tangent lines at various points.
- Computer programs that plot the graphs of a family of hyperbolas and an orthogonal family of hyperbolas.

Derivatives of Inverse Functions

Tutorial on finding the derivatives of inverse functions.

- Drill on finding the derivative and the tangent line to the inverse of a function.

Logarithmic Differentiation

- Drill on applying logarithmic differentiation.

Derivatives and Inverses of Trigonometric Functions

Tutorial on finding the derivatives of the inverse trig functions.

Differentials

Tutorial on differentials.

- Drill on using differentials to approximate expressions.

Maxima and Minima

Tutorial on finding the maxima and minima of a function on a closed interval.

- Drill on finding the maxima and minima of a function on a closed interval.

L'Hospital's Rule

- Drill on applying L'Hospital's Rule. (Using finite limits)
- Drill on applying L'Hospital's Rule. (Using infinite limits)

Mean Value Theorem

Tutorial on the Mean Value Theorem; includes Rolle's Theorem and the First Derivative Test.

- Drill on applying the Mean Value Theorem.
- Drill on using the First Derivative Test.
- Drill on determining the intervals of concave upward and concave downward and the inflection points of a function.
- Computer programs that can be used to illustrate the Mean Value Theorem. Also,
  - TI-85 Graphing Calculator

Optimization Problems

- Java applets illustrating the solution to finding the maximum area of a rectangle which can be inscribed in a semicircle.
- Java applet illustrating the solution to finding the longest ladder which can be carried through a hallway with a corner.
- Java applet illustrating the solution to finding the shortest time to move through the desert to a town.
- Java applet illustrating the solution to finding the shortest ladder that can lean over a fence against a building.

Newton's Method

Tutorial on Newton's Method.

- Drill problems on the use of Newton's Method.
- Computer programs that numerically illustrate the use of Newton's Method.
- Computer programs that graphically illustrate the use of Newton's Method.
- Computer programs that Graphically illustrate the use of Newton's Method and the problems with using Newton's Method.

Antiderivatives / Indefinite Integrals

A tutorial on antiderivatives and indefinite integrals. Covers the Uniqueness Theorem, inverse property and applications of indefinite integrals.

- Table of Elementary Indefinite Integrals
- An example illustrating the evaluation of an indefinite integral using properties of indefinite integrals.
  [using Flash]
- Drill on evaluating simple integrals using the Table of Elementary Integrals.
  [Using Java] [Using IBM TechExplorer] [Using IBM Pro. TechExplorer]
- Drill on evaluating simple integrals with initial conditions.
  [Using Java] [Using IBM TechExplorer] [Using IBM Pro. TechExplorer]
- Application of indefinite integrals.
  [using Flash]
- Another application of indefinite integrals.
  [using Flash]

A tutorial on slope fields with an interactive JAVA applet to explore slope fields.

- An interactive LiveMath notebook that graphs the slope field for a function and graphs antiderivatives.
- A computer program that graphs the slope field for a function.
- Another computer program that graphs the slope field for a function and graphs antiderivatives.
- An animation illustrating the different solutions for indefinite integrals using slope fields.
- Using a TI-86 graphing calculator to graph slope fields and the antiderivative of a function.
  [using Flash]
- TI-85 graphing calculator programs to graph slope fields.

Areas

A tutorial on how to find areas and approximation to areas by using inscribed and circumscribed rectangles.

- An animation illustrating the approximation of the area under the sine function by inscribed and circumscribed rectangles.
- An animation illustrating the approximation of the area under a parabola by inscribed and circumscribed rectangles.
- A computer program that illustrates the approximation of the area of a circle using inscribed polygons.
- An animation showing the approximation of the area of a circle using inscribed polygons.

- A computer program that graphically illustrates the Monte Carlo Method to find areas.

Riemann Sums

A tutorial on riemann sums from the graphical point of view followed by a tutorial from a symbolic or algebraic point of view.

- A tutorial on summations and summation notation.
- Drill in finding Riemann Sums of linear functions (using IBM TechExplorer)
- An example of a sum evaluated using the TI-85 or TI-86 graphing calculator.
- Another example of a sum evaluated using the TI-85 or TI-86 graphing calculator.
- An interactive LiveMath Notebook to evaluate Riemann Sums.
- Using a graphing calculator to evaluate Riemann Sums.
- Computer software that graphically illustrates the use of Riemann sums to approximate the area bounded by the graph of a function and the x-axis and a couple of lines.
- Computer software that graphically and numerically approximate an area.
- Computer software that graphically and numerically approximate an area by evaluating upper and lower Riemann sums.

Definite Integrals

A tutorial on the definition of definite integrals, properties of definite integrals, relationship between definite integrals and areas and the use of technology to evaluate definite integrals using the definition.

- A Flash movie illustrating the evaluation of a definite integral using the definition. [using Flash] [using Java]
- A Flash movie illustrating the finding the area by using the definition of a definite integral.
- Using a computer algebra system and Riemann sums to evaluate definite integrals.
- Computer software that can symbolically evaluate an integral using Riemann Sums.

Fundamental Theorem of Calculus

Tutorial on the Fundamental Theorem of Calculus.

- Examples illustrating use of the Fundamental Theorem of Calculus to evaluate definite integrals.
- Drill problems on evaluating definite integrals using the Fundamental Theorem of Calculus.
  [Using Java] [Using IBM TechExplorer] [Using IBM Pro. TechExplorer]
- A interactive Java applet to graphically illustrate the Fundamental Theorem of Calculus.
- An animation illustrating the Fundamental Theorem of Calculus.
  [Using animated gifs] [Using LiveMath]

- Using the graphing calculator to illustrate graphically the Fundamental Theorem of Calculus.
- An interactive LiveMath Notebook illustrating graphically the Fundamental Theorem of Calculus.
- A Maple animation illustrating graphically the Fundamental Theorem of Calculus.
- Computer programs that graphically illustrate the Fundamental Theorem of Calculus.
- Computer algebra systems and to what extent does Maple "knows" the Fundamental Theorem of Calculus.
- An interactive LiveMath Notebook which can be used to investigate to what extent the program MathView "knows" the Fundamental Theorem of Calculus.
- An interactive LiveMath Notebook which evaluates the derivative of a function which is an integral with variable limits.

Techniques of Integration - Substitution

Tutorial on integration using the method of substitution.

- Drill problems for integration using the method of substitution.
- Quiz on substitutions and elementary integrals.
- Drill on evaluating certain integrals.
  [Using Java] [Using IBM Techexplorer] [Using IBM Pro. Techexplorer]
- Drill problems for integration using the method of trigonometric substitution.
- Using Maple to illustrate the method of substitution.

Techniques of Integration - Integration by Parts

Tutorial on using Integration by Parts.

- Some drill problems using Integration by Parts.
  [Using Java] [Using IBM TechExplorer] [Using IBM Pro. TechExplorer]
- Some drill problems using Integration by Parts.
  [Using Java] [Using IBM TechExplorer] [Using IBM Pro. TechExplorer]
- Some drill problems using Integration by Parts.
  [Using Java] [Using IBM Pro. TechExplorer]
- Some more drill problems using Integration by Parts.
- Derivation of Integration by Parts formula (uses dynamic html).
- Using Maple to illustrate the method of Integration by Parts.

Techniques of Integration - Reduction Formulas

Tutorial on deriving and using recursion or reduction formulas.

- Drill problems for evaluating trigonometric integrals using recursion or reduction

formulas.
- Using Maple to obtain some reduction formulas.

Techniques of Integration - Partial Fractions

Tutorial on the method of Partial Fractions.
- Examples illustrating the the method of Partial Fractions.
- Some drill problems
  [Using Java] [Using IBM TechExplorer] [Using IBM Pro. TechExplorer]
- Drill problems for integration using the method of Partial Fractions.

Techniques of Integration

- Using Maple to evaluate indefinite integrals.

Numerical Integration

Tutorial on numerical integration.
- An animation illustrating graphically the Trapezoidal Rule.
- Using a graphing calculator to illustrate the use of the Trapezoidal Rule.
- Computer programs that graphically illustrate the use of the Trapezoidal Rule.
- An animation illustrating graphically Simpson's Rule.
- Using a graphing calculator to illustrate the use of the Simpson's Rule.
- Computer programs that graphically illustrate the use of Simpson's Rule.
- Computer programs that numerically illustrate the use of Simpson's Rule.
- TI-85 graphing calculator programs for numerical integration.
- An interactive LiveMath Notebook to approximate integrals using the Midpoint Rule.
- Computer programs that provide a graphical illustration of the Midpoint Rule.

Tutorial on numerical integration and error bounds.

Improper Integrals

Tutorial on improper integrals over unbounded intervals.
- Drill problems on evaluating improper integrals over unbounded intervals. [Using Java][Using IBM Pro. Techexplorer]
- Drill problems on evaluating improper integrals over unbounded intervals.

Tutorial on improper integrals of functions with discontinuities.

Area Between Two Curves

Tutorial on finding the area bounded by the graphs of two or more functions.

- Using a TI-85 graphing calculator to find the area between two curves.
  Discussion [Using Flash] [Using Java]
- Drill problems on finding the area bounded by the graphs of two or more functions.
- Computer programs that graphically illustrate the area between two curves.
- Tutorial on finding the area bounded by a parametric curve.
  [Using Flash] [Using Java]
- Computer programs that graphically illustrate the area bounded by a parametric curve.
- Computer programs that graphically illustrate the area bounded by a parametric curve.
- Tutorial on finding the area bounded by a polar curve.
- Computer programs that graphically illustrate the area between two curves in polar coordinates.

Volumes

Tutorial on the slab or washer method for finding volumes.

- Animation illustrating the slab or disk method for finding volumes.
- Computer programs that draw the solid of revolution of an area rotated about the x-axis.
- Computer programs that graphically illustrate the slab method for finding volumes.

Tutorial on the cylindrical shell method for finding volumes.

- Computer programs that graphically illustrate the cylindrical shell method for finding volumes.

Arc Length - 1

Tutorial on arc length.

Average Value of a Function

Tutorial on finding the average value of a function.

Work

Tutorial on work.

Moments and Center of Mass

Tutorial on moments and center of mass.

Sequences

Tutorial on sequences.

- Using computer programs to plot the graph of a sequence. Also,
  - using the TI-85 graphing calculator to plot sequences.
    Discussion [Using Flash] [Using Java]
  - Using computer programs to generate a table of values of a sequence.

Series

Tutorial on introductory material on series.

- Interactive Javascript module on generating a table of values for geometric series.
- Interactive MathView notebook evaluating the partial sums of a geometric series.
- Drill problems on geometric series, n^{th} term test, and telescoping series.
- Using computer programs to generate a table of values of partial sums.
- Using computer programs to plot the graph of the sequence of partial sums.

Tutorial on the Integral Test.

- Error estimates using the Integral Test.
- Drill problems on using the integral test.

Tutorial on Comparison Test for testing convergence of series.

Tutorial on the Limit Comparison Test.

- Drill problems on using the limit comparison test.

Tutorial on alternating series.

- Drill problems on using the alternating series test.

Tutorial on the Ratio Test.

- Drill problems on using the ratio test.

Tutorial on absolute convergence.

Drill problems on determining which test to use for convergence of a series.

Power Series

Tutorial on Power Series.

Tutorial on differentiation and integration of power series.

Tutorial on Taylor polynomials.

- Using computer programs to plot the graphs of a function and of several of related Taylor Polynomials.

Introduction to Functions

Tutorial which is an introduction to functions including the four representations of a function, domain, and range.

- Drill on finding domains of functions.
- Computer program to visualize a function as "a collection of arrows from the domain to the range."

Piecewise Defined Functions

Tutorial on piecewise defined functions.

- A LiveMath Notebook to explore the graphing of a piecewise defined function.
- Drawing the graph of a piecewise defined function with
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer programs that will drawing the graph of a piecewise defined function.

Even and Odd Functions

Tutorial on even and odd functions.

- A LiveMath Notebook to visualize when a function is symmetric with respect to the **y**-axis.
- A LiveMath Notebook to visualize when a function is symmetric with respect to the origin.
- A LiveMath Notebook to determine which function in a family of functions is odd.
- A quiz on determining which functions are even, odd or neither.
- Computer programs to determine graphically whether a function is even or odd or neither.

Polynomials

Tutorial on polynomial functions.

- A LiveMath Notebook to compare a polynomial of degree n with a monomial of degree n.
- A LiveMath Notebook to compare polynomials of different degrees.
- Finding the roots of polynomials with
  - TI-86 Graphing Calculator [Using Flash]

Rational Functions

Tutorial on rational functions.

Geometric Transformations of Functions

Tutorial on the translation, compression, stretching and reflection of graphs of functions.

- A Java applet to explore graphically the effect of transforming a graph with translations, vertical and horizontal stretching and reflections.
- A quiz to explore graphically the effect of transforming a graph with translations, vertical and horizontal stretching and reflections.
- Given a function, draw the graphs of functions obtained by shifting the graph of a given function using the
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer programs that will easily draw the graphs of functions obtained by shifting the graph of a given function.
- Computer programs that will easily draw the graphs of functions obtained by shifting the graph of a given function.

Algebra of Functions

- A LiveMath Notebook on the graphing of the sum of two functions.
- Drawing the graph of the sum of two functions with a
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator

Composition of Functions

Tutorial on the composition of functions.

- A LiveMath Notebook computing the composition of functions.
- A Java applet illustrating the geometrical construction of the composition of two functions
- Computer programs which, given the equations of two functions, easily draws the graphs of the compositions of these functions. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer program which when given the graphs of two functions will draw the graphs of the compositions of these functions.
- Drill problems on writing a function as the (nontrivial) composition of two other functions.

Trigonometric Functions

- A listing of trigonometric identities.
- Computer programs that draw the graphs of trigonometric functions, sine and cosine,

considered as circular functions.
- Computer programs that draw the graph of the tangent function considered as circular functions.

Exponential Functions

Tutorial on exponential functions.
- A Javascript module to approximate a number raised to an irrational power.
- A LiveMath animation of a family of exponential functions.
- A LiveMath Notebook which can be used to determine which of exponential functions or polynomial functions grows more rapidly.
- Computer programs which can be used to determine which of exponential functions or polynomial functions grows more rapidly. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- LiveMath animations to explore graphically and symbolically the effect of transforming exponential functions.
- A Java applet to explore graphically symbolically the effect of transforming exponential functions.
- A LiveMath Notebook to approximate the exponential function $\mathbf{y = e^x}$ by the polynomials $\mathbf{y = (1 + x/n)^n}$.

Inverses of Functions

Tutorial on inverses of functions.
- A Flash movie illustrating the use of the horizontal line test and the finding the equation of the inverse of a function.
- Using Maple to find explicitly the inverse of a function and verify that it is the inverse.
- A LiveMath Notebook to investigate which polynomials of degree 3 have inverses.
- Drill on finding the inverses of functions.
- Drill in finding the inverses of functions (includes inverse trigonometric functions).
- Computer programs that will draw the graph of a function and its inverse. Also,
  - TI-85 Graphing Calculator

Logarithms

Tutorial on logarithms.
- A LiveMath animation of a family of logarithmic functions.
- LiveMath animations to explore graphically and symbolically the effect of transforming

logarithmic functions.
- A Java applet to explore graphically and symbolically the effect of transforming logarithmic functions.
- Computer programs that draw the graphs of the exponential and logarithm functions in order to visualize that they are inverses of each other.

Parameters and Functions

Tutorial on familes of functions with parameters.
- A LiveMath animation to investigate a parameterized family of functions.
- A LiveMath animation of a parameterized family of exponential functions.
- A LiveMath animation of a family of logarithmic functions.
- Computer programs which graph a family of functions with a parameter. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer programs which graph a family of functions with two parameters. Also,
  - TI-86 Graphing Calculator [Using Flash]

Parametric Equations

Tutorial on parametric equations.
- A LiveMath notebook to explore the graphing of a system of parametric equations in the plane.
- Animation illustrating the drawing of the cycloid.
- A LiveMath animation of a family of parametric equations in the plane.
- Computer programs which graph a system of parametric equations in the plane. Also
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer programs which graph a system of parametric equations in the plane.
- Computer programs which graph a triangle using a system of parametric equations in the plane.

Polar Coordinates

Tutorial on polar coordinates.
- Computer programs which graph a function in polar coordinates. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator [Using Flash]
- Computer programs that can be used to graph a family of functions with parameters in

polar coordinates.
- Computer programs that can be used to graph a family of functions with parameters in polar coordinates.

Graphing with Technology

Tutorial on how computer programs and graphing calculators plot the graphs of functions and some of the problems that this method of plotting has.
- Problems in using a computer to draw the graph of a function. In this example, changing the number of points used in drawing the graph changes the graph significantly.
- Slide show on which the page above is based.
- A LiveMath notebook showing some problems in using a computer to draw the graph of a function. In this example, zooming in shows some features of the graph otherwise missed.
- Computer programs and their problems in drawng the graph of a function with a discontinuity.
- Computer programs and their problems in drawng the graph of the rational power of a variable.
- Computer program that will plot the graph of a finite collection of ordered pairs.

Solving Equations

Tutorial on finding the intersections of the graphs of two functions.
- A LiveMath notebook to graphically find the intersections of the graphs of two functions.
- Computer programs to find the roots of an equation graphically by zooming in.
- Find the coordinates of the points of intersections of two graphs using the
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Finding the roots of polynomials with
  - TI-86 Graphing Calculator [Using Flash]
- Drill in solving equations involving trigonometric functions.
- Computer programs that can be used to solve an inequality graphically.
- Computer programs that can be used to solve an inequality graphically.
- Computer programs that can be used to solve an inequality graphically.
- Computer programs that can be used to solve an inequality symbolically.

Curve Fitting

Tutorial on curve fitting.
- A Java applet which finds and graph the least squares regression line, quadratic and cubic models which best approximates the data.

- Computer programs to find and graph the least squares regression line. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer programs to find and graph the exponential model which best approximates the data. Also,
  - TI-86 Graphing Calculator [Using Flash]
  - TI-85 Graphing Calculator
- Computer programs to find and graph the third degree polynomial model which best approximates the data.

Conic Sections

- Computer programs that draw the graphs of various conic sections.
- Computer programs that draw the graphs of various conic sections using polar coordinates.
- A review of the concept of eccentricity through examining the effects of changing the value of the variable e in the polar equation of an ellipse.

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- **Black-Scholes and Beyond: Options Pricing Models** - This book is aimed at the MBA student, advanced undergraduate, and practitioner who want to delve into the details of option pricing models but wish to avoid a highly mathematical treatment. The book is replete with precise examples used to explain every theory in the book. Hundreds of graphs and diagrams, all developed in MATLAB, illustrate the subtleties of the subject.
- **Pricing Derivative Securities; An Interactive Dynamic Environment with Maple V and MATLAB** - Directed at an audience of MBA and advanced BBA students, this book teaches the core theoretical concepts of options pricing. The book starts by introducing the simplest model of an equity market. The no-arbitrage condition is defined and, in a subsequent chapter, is used to value simplified financial assets. Gradually, the book extends the simple model to a more realistic situation, permitting the valuation of more complicated securities. MATLAB programs help readers visualize payoffs and respond to various constraints and conditions.
- **Numerical Methods in Finance: A MATLAB-Based Introduction** - By Paolo Brandimarte. ISBN 0-471-39686-9. Written for students and practitioners of financial engineering and economics, this book covers the basics of finance and numerical analysis while bridging the gap between financial theory and computational practice with MATLAB. Topics covered include classical numerical analysis methods; optimization, including stochastic and integer programming; simulation, including low discrepancy sequences; and partial differential equations. An introduction to MATLAB is provided an appendix. In addition, MATLAB is used to solve numerous examples throughout the text.

Search

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- **Understanding Linear Algebra Using MATLAB** - Written as a supplement to an elementary linear algebra text, this book covers linear algebra topics, while focusing on MATLAB as a tool to study and implement the subject. Each topic covered in the book has a MATLAB introduction and a MATLAB exercise section.
- **Differential Equations with Graphical and Numerical Methods** - Written for a sophomore-level course in differential equations, this text introduces first-order systems in the first chapter and uses them as the main focus for the treatment of ordinary differential equations covered in the next six chapters. This allows an early and unified introduction of graphical and numerical methods along with analytical methods. The numerical and graphical theme is sustained in the chapters on partial differential equations and Fourier Series. MATLAB M-file examples for the topics covered are given in an appendix.
- **Introduction to Differential Equations and Dynamical Systems, 2e** - This second-edition text is intended for use in a differential equations course for students of pure and applied mathematics, physical sciences, and engineering. The odd-numbered chapters cover the core theory of differential equations with basic applications, while even-numbered chapters include extended applications from engineering and the physical sciences. In addition, the text includes optional coverage of dynamical systems. Where appropriate, the author has integrated technology into the text, primarily in the exercise sets.
- **Numerical Analysis, 7e** - This seventh-edition text is written for junior-level mathematics, science, and engineering courses on the theory and application of numerical approximation techniques. Topics covered include solving linear systems, matrix algebra, approximation theory, eigenvalues, and differential equations. Examples in the text are solved using MATLAB.
- **MATLAB 5.3 Programming and Its Application in Mathematical Computations** - Written in Chinese, this book focuses on programming in MATLAB. Topics covered include MATLAB graphics, programming M-files,

GUI design, and interfacing MATLAB with other languages and programs. Exercises and examples throughout the book are solved using MATLAB

- **Modellistica Numerica per Problemi Differenziali** - Numerical Modeling for Problem Differentials
- **Numerical Methods with MATLAB: Implementation and Application** - This book is an introduction to MATLAB and numerical methods, written for undergraduate students of engineering, applied mathematics, and science. The text is a modern exposition of classic numerical methods using MATLAB. The fundamental theory of each method is briefly developed. Rather than providing a detailed numerical analysis, the behavior of the methods is exposed by carefully designed numerical experiments. It teaches how the core techniques of numerical methods are used to solve otherwise unsolvable problems of modern technological significance. MATLAB is used to solve examples throughout the book.
- **Guide to Scientific Computing, 2e** - Designed for students taking a first course in numerical mathematics who need a low-level entry to the subject, this book provides an introduction to many of the problems of scientific computing, and the wide variety of methods used for their solutions. The book gives an appreciation of the need for numerical methods for the solution of different types of problems, and discusses basic approaches. Practical justification of the methods is presented through computer examples and exercises. The book includes an introduction to MATLAB, including explanations of functions and M-files.
- **Mathematics with MATLAB** - Written in German, this book is designed for the mathematical education of engineering students. It demonstrates the applications of MATLAB in mathematical areas of importance to engineers. Topics covered include Fourier and Laplace transformations, optimization (nonlinear programming), and statistics. Example problems are solved using MATLAB and toolboxes.
- **A MATLAB Companion for Multivariable Calculus** - Written to accompany a multivariable calculus class, this book covers a range of topics from vectors to the divergence theorem. The examples show the use of multivariable calculus and MATLAB in a number of applications, including economics, physics, and biology. An introduction to MATLAB allows the student to get started with programming M-files. MATLAB and the Symbolic Toolbox are used to solve the many exercises and examples throughout the book.
- **Introductory Linear Algebra With Applications, 7e** - Designed for a course at the freshman or sophomore level, this book emphasizes the computational and geometrical aspects of linear algebra. This edition incorporates recommendations from The Linear Algebra Curriculum Study Group on how

to improve instruction in linear algebra. It also has new sections including Introduction to Wavelets, Dynamical Systems, and Introduction to Fractals. Exercises are divided into three groups: routine, theoretical, and those using MATLAB. In addition, chapter 12 provides a brief introduction to the capabilities of MATLAB for solving linear algebra problems.

- **Matrix Theory and Applications with MATLAB** - This book is designed for an advanced course on linear algebra and covers the basics of the subject - from a review of matrix algebra through vector spaces to matrix calculus and unitary similarity. It integrates MATLAB throughout the text. Each chapter includes a MATLAB subsection that discusses the various commands used to do the computations and offers codes for the graphics and algorithms used in the text. All material is presented from a matrix point of view. The treatment includes optional subsections covering applications. The final chapters move beyond basic matrix theory to discuss more advanced topics, such as decompositions, positive definite matrices, graphs, and topology.
- **Spectral Methods in MATLAB** - This text provides a hands-on introduction to spectral methods in MATLAB. It is built around 40 short and powerful MATLAB programs. Users of this book include advanced undergraduate and graduate students studying numerical methods for PDEs, numerical analysts, engineers, and computationally oriented physical scientists in all areas. The reader must have reasonable exposure to linear algebra, PDEs at the practical (not theoretical) level, and MATLAB. This book presents the key ideas along with many figures, examples, and short, elegant MATLAB programs for readers to adapt to their own needs. It covers ODE and PDE boundary value problems, eigenvalues and pseudospectra, linear and nonlinear waves, and numerical quadrature.
- **Modern Matrix Algebra** - This book provides an introduction to the basic algebraic, geometric, and computational tenets of linear algebra at the sophomore level. A spiral approach gradually introduces the abstract foundations of the topics involved?linear combination, closure, subspaces, linear independence/dependence, and bases. Numerous conceptual and numerical examples, as well as MATLAB examples, provide hands-on explorations of computations and concepts.
- **A Primer for Finite Elements in Elastic Structures** - By W. F. Carroll, ISBN 0-471-28345-2 This book disassembles the entire finite element method for civil engineeringstudents and professionals, detailing its supportive theory and its mathematicaland structural underpinnings in the context of elastic structures andthe principle of virtual work. The book opens with a discussion of matrixalgebra and algebraic equation systems. In the early chapters one-dimensionalelements are described, while subsequent chapters describe in

depth manytwo-dimensional structural finite elements, including the geometry, mechanics,transformations, and mapping needed for them. An appendix describes howto use MATLAB to perform the matrix operations required for the finiteelement method, such as matrix addition, multiplication, inversion, partitioning,rearrangements, and assembly.

- **A First Course in Linear Algebra with Applications, 3e** - By Hal G. Moore & Adil Yaqub. ISBN 0-12-505760-1 Written for introductory linear algebra courses, this text presents the theory and applications of linear algebra. Topics covered include linear equations, matrices, determinants, vector and inner-product spaces, transformations, and eigenvalues. MATLAB is used to solve exercises on these topics throughout the text.
- **Accuracy and Stability of Numerical Algorithms** - By Nicholas Higham, ISBN 0-89871-355-2 A practical source for an advanced course or as a reference for specialists,this book gives a thorough, up-to-date treatment of the behavior of numericalalgorithms in finite precision arithmetic. The text combines algorithmicderivations, perturbation theory, and rounding error analysis. Softwarepracticalities are emphasized with particular reference to LAPACK andMATLAB. Topics also include floating-point summation, block LU factorization,condition number estimation, the Sylvester equation, powers of matrices,finite precision behavior of stationary iterative methods, Vandermondesystems, and fast matrix multiplication.
- **Advanced Engineering Mathematics With Mathematica and MATLAB: Volume I and II** - By Reza Malek-Madani, ISBN 0-201-59881-7 (Vol I) ISBN 0-201-32549-7 (Vol II)
- **Advanced Engineering Mathematics with MATLAB, 2e** - By Thomas L. Harman / James B. Dabney & Norman John Richert, ISBN 0-534-37164-7
- **Analisi Matematica 2: Calcolo Differenziale** - Written in Italian, this text contains elements of differential calculusfor a second course in mathematical analysis. General theory is presented,and details on specific methods are included. The book is intended toprovide students with information for applying mathematical analysis toanalytical mechanics. Problems and exercises help the reader analyze andunderstand the theory presented.
- **Analisi Numerica Metodi Modelli Applicazioni** - By Valeriano Comincioli, ISBN 88-386-0646-3 Offering a new approach to applied mathematics through numerical analysis,this book introduces science and engineering students to modeling andproblem solving using the methods, tools, and concepts of numeric computation.Modern mathematical standards of numerical analysis are combined withan understanding of the needs of the computer scientist working on practicalapplications. Where different methods for solving a problem are presented,comparisons of their applicability and

limitations are discussed. An appendixintroducing MATLAB is included.

- **Applied Numerical Analysis Using MATLAB** - By Laurene V. Fausett, ISBN 0-13-319849-9
- **Applied Numerical Analysis, 6e** - By Curtis F. Gerald & Patrick O. Wheatley, ISBN 0-201-87072-X Written as a text for sophomores and juniors in engineering, science,mathematics, and computer science, and for the practicing engineer, itcan also serve as a valuable reference book. This text incorporates abalance of theory with techniques and applications, including optionaltheory-based sections in each chapter. Sections discuss the use of MATLAB.The breadth of topics, such as partial differential equations, systemsof nonlinear equations, and matrix algebra, provide comprehensive andflexible coverage of all aspects of numerical analysis.
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- **Differential Equations: Modeling with MATLAB** - By Paul Davis, ISBN 0-13-736539-X
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Dynamic optimization is the process of determining control and state historiesfor a dynamic system over a finite time period to minimize a performanceindex. The book starts with a review of parameter optimization and thentreats dynamic optimization, first with fixed final time and no constraints,next with terminal contraints, and finally with terminal constraints andopen final time. This is followed by chapters on linear-quadratic problemsand dynamic programming. The book concludes with chapters covering neighboring-optimalfeedback control, inequality constraints, and singular problems. An appendixis included that provides a short history of dynamic optimization.

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- **Geometria Anal?tica e ?lgebra Linear** - Written in Portuguese, this book provides an introduction to linear algebra. Topics covered include matrices; linear systems; norm, scalar, and vectorial products; linear transformations; conics; and polynomials. MATLAB is used to solve exercises at the end of each chapter.
- **Handbook for Matrix Computations** - By Thomas F. Coleman & Charles F. Van Loan, ISBN 0-89871-227-0 This introduction to MATLAB and LINPACK spans several levels of practicalmatrix computations and places a strong emphasis on examples and hands-onexercises. It is recommended for an introductory numerical methods courseor a graduate-level numerical analysis course.
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Nesterov & Arkadi Nemirovskii, ISBN 0-89871-319-6 Written for users interested in optimization, this text presents the generaltheory of interior-point polynomial-time methods for convex programming.The authors try to demonstrate that all known polynomial-time interior-pointmethods can be explained on a general theory basis, and hence extendedinto a wide variety of nonlinear convex problems. This is shown by developingnew polynomial time interior-point methods for many important classesof problems. The theory presented in the text, including applicationsin control system design, are implemented in the LMI Control Toolbox developedby Pascal Gahinet, Arkadi Nemirovskii, Alan J. Laub, and Mahmoud Chilali.The toolbox may be purchased from The MathWorks.

- **Introduction to Linear Algebra, 2e** - By Gilbert Strang, ISBN 0-9614088-5-5 This is a basic textbook for linear algebra, combining the theory withthe applications. Chapters include: Introduction to Vectors, Solving LinearEquations, Vector Spaces and Subspaces, Orthogonality, Determinants, Eigenvaluesand Eigenvectors, Linear Transformations, Applications, Numerical LinearAlgebra, and Complex Vectors and Matrices. In addition, a list of MATLABteaching codes are included at the end of the book.
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Theauthor provides a complete analysis of the conjugate gradient and generalizedminimum residual iterations. In addition, recent advances include Newton-Krylovmethods, incorporation of inexactness and noise into the analysis, andnew proofs and implementations of Broyden's method. The computationalexamples and exercises are based on the MATLAB environment.

- **Iterative Methods for Optimization** - By C.T. Kelley, ISBN 0-89871-433-8
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- **Linear Algebra and Differential Equations Using MATLAB** - By Martin Golubitsky & Michael Dellnitz, ISBN 0-534-35425-4 The authors integrate linear algebra, ordinary differential equations,and the computer to help students understand these mathematical concepts,interweaving instructions on how to use MATLAB with examples and theory.The book begins by solving linear systems of equations and introducingmatrix algebra. Then it introduces simple ordinary differential equations.The text stresses the use of qualitative methods in solving nonlinearordinary differential equations. A chapter on bifurcation theory is included,as is an introduction to quasiperiodic and chaotic solutions.
- **Linear Algebra and Its Applications, 2e Update** - By David C. Lay, ISBN 0-201-34774-1 Study Guide (ISBN 0-201-64847-4) that supplements this text and providesa brief introduction to MATLAB, a discussion of MATLAB commands as neededfor the exercises, and a complete index of MATLAB commands used in thetext.

- **Linear Algebra LABS with MATLAB, 2e** - By David R. Hill & David E. Zitarelli, ISBN 0-13-505439-7 Intended for a sophomore level course in linear algebra, this supplementreinforces key concepts using a variety of class-tested exercises andthe "discovery" method. Added to this second edition are approaches totopics that use more graphically oriented M-files to provide visualizationof concepts. In addition, many of the M-files have been enhanced to takeadvantage of the GUI tools available in MATLAB. Some files use the SymbolicMath Toolbox (available from The MathWorks) .
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- **Mathematik mit MATLAB: Aufgaben und Losungen** - By Franz Bachmann / Hans Rudolf Schärer & Louis-Sepp Willimann, ISBN 3-7281-2308-0 This book, written in German, provides a compact introduction to MATLAB,including matrix operations, graphical representations, M-files, and flowcontrol. The second part of the book contains a comprehensive set of exercisesdealing with mathematic fundamentals, graphics, linear algebra and geometry.All of the exercises in the last part of the book are solved using MATLAB.Companion software: The authors have developed a set of MATLAB M-filesthat are available on a CD-ROM bound into the book or may be retrievedfrom vdf.ethz.ch.
- **MATLAB Esercitazioni di Calcolo Numerico Assistite da Calcolatore** - By Franca Caliò & Marco Frontini, ISBN 88-251-0002-7 The authors of this text have combined their teaching experiences withnumeric computation tools to present students with methods to rapidlydefine solutions, collect relevant information, and verify results forthe various problems presented. A student who approaches problems in thisway is able to work through the definition and implementation of the algorithms,learning the complete numerical process.
- **Matrices and MATLAB: A Tutorial** - By Marvin Marcus, ISBN 0-13-562901-2 This textbook is included in Prentice Hall's MATLAB Curriculum Series.Designed for a one-semester or two-quarter course in elementary matrixtheory, the text is suitable for undergraduate or graduate students whohave completed one year of calculus and are adept at high school

algebra.MATLAB is completely integrated into the study of elementary matrix theorypresented in this book.

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- **Numerical Analysis using MATLAB and Spreadsheets** - By Steven T. Karris. ISBN 0-9709511-1-6. This book presents the fundamentals of numerical analysis while teaching the reader to use MATLAB. Topics covered include root approximations, sinusoids, matrices, differential equations, linear

and parabolic regression, gamma and beta functions, and optimization methods. An introductory chapter on MATLAB is included. Numerous examples using MATLAB and the Symbolic Math Toolbox are presented throughout the book.

- **Ripples in Mathematics: The Discrete Wavelet Transform** - By A. Jensen & A. la Cour-Harbo. ISBN 3-540-41662-5. Written for undergraduate mathematics and engineering students and practicing engineers, this book presents the theory and application of the discrete wavelet transform. The book is based on an approach to discrete wavelets called lifting. The connections between lifting and filter theory are presented, and the wavelet packet transforms are defined. MATLAB is used to solve example problems and develop implementations of transforms throughout the book. The Signal Processing Toolbox is also used to solve examples.
- **Numerical Linear Algebra** - By Lloyd N. Trefethen & David Bau, III, ISBN 0-89871-361-7 Designed for use in a graduate-level course in numerical linear algebra,this book is divided into forty lectures. Each lecture is built aroundone or two central topics, emphasizing the unity between ideas. One unusualaspect of this book is that it begins with QR factorization rather thanGaussian elimination, to provide a more solid and easier-to-understandfoundation for the subsequent lectures. The last part of the book is devotedto iterative methods.
- **Numerical Linear Algebra and Applications** - By Biswa Nath Datta, ISBN 0-534-17466-3 This book is written for a first course in numerical linear algebra. Itis designed to give students a firm grasp of the basic concepts of roundofferror, stability, condition, and accuracy, as well as an appreciationfor the core numerical linear algebra algorithms. At the beginning ofeach chapter, the author presents illustrative case studies from variousapplication areas in science and engineering to encourage students tostudy numerical linear algebra. An appendix of MATLAB M-files is includedas a basis for students to build on and develop more advanced algorithms.CompanionSoftware: The author has developed a set of MATLAB M-files called theMATCOM Program, which may be retrieved from The MathWorks anonymous FTPserver at ftp.mathworks.com in /pub/books/datta/. (Download the entiredirectory as a tar archive or a zip archive.)
- **Numerical Methods for Engineers: With Programming and Software Applications, 4e** - By Steven C. Chapra & Raymond P. Canale, ISBN 0-07-243193-8 Written for undergraduate students of engineering, applied mathematics, and science, this book introduces the theory and applications of numerical methods. Topics covered include roots of equations, linear algebraic equations, optimization, curve fitting, and differential equations.

Problems from a vast range of engineering disciplines are covered, including areas such as biotechnology and biomedical. A tutorial to MATLAB is provided in an appendix. MATLAB is also used to solve many equations throughout the text.

- **Numerical Methods Using MATLAB, 2e** - By George Lindfield & John Penny, ISBN 0-13-012641-1
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- **Ordinary Differential Equations Using MATLAB, 2e** - By John C. Polking & David Arnold, ISBN 0-13-011381-6
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- **Praktisk matematik med MATLAB 5** - By Gunnar Backstrom, ISBN 91-44-

00224-6 The purpose of this text is to illustrate and explain the elements ofundergraduate mathematics required for science and enginering education,calculus, data analysis, and differential equations. At the same time,the text introduces and reviews the use of MATLAB in these areas. A chapteron the Symbolic Math Toolboxreviews its use for solving problems in symbolicalgebra, calculus, andordinary differential equations. (This book is alsoavailable in English.)

- **Probabilites et Statistiques avec MATLAB et Maple** - Written in French, this book is intended for graduate mathematics students. The book begins with an introduction to the mathematical and programming capabilities of MATLAB, such as matrices, polynomials, and complex operations. It then covers topics in probability and statistics, including Monte-Carlo methods, Markov chains, Kolmogorov methods, confidence intervals, chi-square distribution, and Gaussian distribution.
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- **The MATLAB 5 Mathematical System** - The MATLAB 5 Mathematical System V.P. Dyakonov & I.V. Abramenkova
- **Templates for the Solution of Linear Systems: Building Blocks for Iterative Methods** - By Richard Barrett / Michael Berry / Tony F. Chan / James W. Demmel / June Donato / Jack Dongarra / Victor Eijkhout / Roldan Pozo / Charles Romine & Henk van der Vorst, ISBN 4-254-11401-X Written in Japanese, this book is for computational scientists who wouldlike to incorporate state-of-the-art computational methods for solvinglarge sparse systems of linear equations. Discussions of convergence andstopping criteria, tuning, and selection of method are included. (Thisbook also available in English.)
- **Using MATLAB in Calculus** - This book is to be used as a supplement to a calculus text in the standard calculus II and III courses. Its philosophy is to show how MATLAB can be used as a tool to do the calculus being studied. The goal of the book is to teach the student enough about MATLAB that he or

she can use it effectively upon completion of the calculus sequence. MATLAB's Symbolic Math Toolbox is introduced in a few appropriate places, such as in the context of using a computer algebra system to find antiderivatives. The MATLAB instruction contained in this book is given primarily by example, with MATLAB commands described in the context of the application.

- **The MATLAB Project Book for Linear Algebra** - By Rick L. Smith, ISBN 0-13-521337-1 This book contains 34 linear algebra projects that are intended to becompleted by students on a computer using MATLAB. Also included is a MATLABtutorial. The book includes the major theorems and definitions of linear.

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- Free programming books - Free programming books covering C++, Java etc.
- Component Connection - This chapter discusses several of the issues that arise when you move from C++ to Java. Since many (if not most) Java programmers come from a C++ background, it is natural to want to carry over the skills, techniques, and code acquired in this language. Although C++ and Java were designed to address the programming needs of two very different environments, many of the same coding techniques, algorithms, and optimizations apply to both. However, as explained in Part One, Java is not "the Internet version of C++." While there are many similarities between the two languages, there are also several differences. This chapter reviews those differences and shows ways to handle some of the more challenging ones.
- C++ Streams - Internals and Applications - Although the syntax of the C++ language is based on C, many of the features and concepts of the language are quite different. In some cases, entirely new concepts have been introduced. The idea of data streams is one of these new concepts. A C++ stream is an abstract representation of data flow from one location to another. The origin of the data is usually called a producer or source, and the destination is usually referred to as a consumer or sink. Streams can be designed to handle the transfer of data in any format, from simple fundamental types like int, char, char *, long, and double, to complex objects containing many classes and derivations. C++ streams are most often constructed from the combination of two base classes. In the current implementation of C++, these base classes are streambuf and ios. Under this design, the streambuf class object provides for the buffering and orderly passing of information from the producer to the consumer. The ios class object is then respo
- LEARN C/C++ TODAY - This is a list of a few C and C++ language tutorials available to users. The list includes interactive tutorials, public-domain code collections, books etc.

- NML Code Generator Instructions - Instructions for using the NML Code Generator to create C++ or Java NML definitions.
- Guide to C++ Classes - Runtime errors will inevitably occur in any complex software system. Independent of what may be done to recover from the error, it is important that information about the nature of the error be recorded to allow a human operator to later ascertain whether the software or the operating environment needs to be modified. A mechanism for recording of textual information pertaining to an error is provided by the OTC_Logger class. Error messages can be logged at a number of priorities, with messages being displayed to the standard error output. If required, error messages can also be saved to a file. By deriving from the OTC_Logger class you can capture the error messages and optionally save or cause them to be displayed using an alternate mechanism. For example, you may wish to have messages passed on to the UNIX syslog facility.
- Short C++ tutorial for C users - From Belgium, Eric Brasseur walks the reader through the first hours of a C programmer's fresh acquaintance with C++, introducing features like references, operators overloading, new and delete ("they are much more sweet than ... malloc and free") up to multiple inheritance.
- Porting C++ to Java - This paper is addressed to people who are considering porting their existing C++ code to Java. It provides a step-by-step approach to porting C++ to Java effectively.
- C++ Primer - Prices, description, reviews and more, about the book "C++ Primer" by Lippman/Lajoie. This book explains how to program in C++. It covers the latest ANSI/ISO standard and explains how to use C++ templates.
- Industrial Strength Programming - Here is a book that teaches not only language but also programming itself. The author of this book shares his experience in programming, teaches how to write reliable and maintainable code, easy to understand by other members of the team; knowing advanced programming techniques such as synchronization in a multithreaded environment, effective use of virtual memory, debugging techniques, etc.
- TTT - The TTT System is a suite of files and programs aimed at providing you (the learner) with an interactive, World Wide Web based online course in the fundamentals of programming using the C++ programming language.
- The C++ Standard Library - A Tutorial and Reference - See and download all of the examples from the book "The C++ Standard Library - A Tutorial and Reference" by Nicolai M. Josuttis.
- Introduction to Object-Oriented Programming Using C++ - This tutorial is a collection of lectures to be held in the on-line course 'Introduction to Object-

Oriented Programming Using C++'. In this course, object-orientation is introduced as a new programming concept which should help you in developing high quality software. Object-orientation is also introduced as a concept which makes developing of projects easier.

- From The Ground Up: A Guide to C++ - From The Ground Up: A Guide to C++. This site is a tutorial for learning the programming language C++. The site makes extensive use of Java. It also has clever scheme of remembering where you were if you return to the tutorial many times. The tutorial is geared towards Pascal programmers converting to C++, and only covers C++ basics (classes and operator overloading are the most advanced topics).
- Fatbrain - Fatbrain.com is the Internet's most comprehensive bookstore for professionals. Recently named the number two fastest-growing public company in Silicon Valley, Fatbrain.com offers a world-class selection of books, training materials and print-on-demand documentation for business, finance, math, science and technology experts. Our industry experience and in-depth knowledge of authors, topics and trends help customers find the best resources for their needs. Fatbrain.com contains a comprehensive section on C.
- C - Tutorials - This is the tutorial section of 'cprogramming.com'. It contains: PROGRAMMING IN C/C++ tutorial; GRAPHICS PROGRAMMING tutorial.
- C++ Programming for Scientists - C++ tutorial for scientists. Course notes : ANSI C, C++ as a better C, C++ classes and objects, objects in scientific computing, inheritance & polymorphism, templates, exceptions & observations, programming examples, scientific library examples.
- Books reviews with grades - This page is a collection of reviews on C++ books for advanced users.
- An Introduction to C++ - This is the first installment in a series called "Objective Viewpoint" that will teach you about C++.
- Gillius's C++ Programming - C/C++ focused page with tutorials ranging from language syntax to game development. Has FREE C/C++/Pascal source code and free games with source code.
- A TOUR OF C PROGRAMMING - This tutorial gives a complete understanding of the basics of C programming. The goal of this "guide to C" is to cover the basics of the language pretty thoroughly. After that will be introduced some more advanced things.

Search

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- MODEL - MODEL is a numeric simulation library written to simulate systems of rate equations describing Vertical Cavity Surface Emitting Lasers (VCSELs). Try it if you need an easy way to solve some systems of ordinary differential equations.
- The Godess project - This is a Generic Ordinary Differential Equation Solver System written in C++. The solver is an initial value solver for ODEs and DAEs, with rootfinding etc. The goal of the project is to improve the state-of-the-art for timestepping methods when solving initial value problems. I was responsible for the code during my Ph.D. studies and successfully worked on Runge-Kutta methods (mostly implicit ones).
- Only C++ - This is the C++ page of the Numeric Physic WWW site, where you can find the source code of many programs that deal with differential equations.
- KASKADE - A C++ toolbox for the solution of linear scalar elliptic and parabolic problems in 1, 2, and 3 dimensions using adaptive finite element methods. The toolbox includes extensions for handling systems of equations as well as example algorithms for nonlinear methods used in obstacle, porous media, or Stefan problems. The core of the program consists of a variety of multilevel/multigrid preconditioners for the linear systems involved. The iterative solvers included in the package include: conjugate gradient (with and without 3-term recurrence), conjugate residual (with and without 3-term recurrence), several relaxation routines (Jacobi, SSOR, etc.), GMRES, bi-conjugate gradients, BiCGStab, the Sonneveld CGS algorithm, conjugate gradients for normal equations, and a nonlinear relaxation routine. Preconditioner methods include: Jacobi type, symmetric Gauss-Seidel, incomplete LU-factorization, multilevel with Jacobi-type smoothing, multilevel with symmetric Gauss-Seidel smoothing, additiv+. It can be compiled with g++ 2.6.3 or later. The package is documented in extensive programmer's and user's guides in PostScript format.
- Diffpack - A collection of C++ object-oriented class libraries designed for the numerical solution of partial differential equations. The package also includes several UNIX utilities for general software management and numerical

programming. The goal of Diffpack is to provide an environment for the rapid prototyping of simulators based on PDEs which also offers a high level of efficiency.

- A++/P++ - A++ is a C++ array class for numerical computation designed to work with structured grid computations, including work on overlapping grids and adaptive mesh refinement. P++ is the parallel version of the serial class A++. A++/P++ was designed to simplify the development of numerical software, specifically to allow an application developed in the serial environment to be run on parallel machines with little or no additional effort. It is also intended as a partial solution to a growing crisis in the development of large numerical codes that are required to run on many different serial and complex parallel architectures. The A++/P++ distribution (35 Mb uncompressed) includes the source code and the documentation. Requirements for compilation and installation include a C++ compiler (g++ will do) and a C and/or a Fortran compiler. The graphics visualization facilities of A++/P++ additionally require the Plotmtv software. The use of P++ requires a communication library. It presently w
- Clenshaw-Curtis-Quadrature - A presentation of the Numerical Automatic Integrator method, which is called "Chebyshev Series Expansion" in one dimension. The package includes source code.
- Automatic Differentiation - We want to calculate a value f(t1,...,tn) that depends on parameters t1,...,tn. But, in addition, we want to calculate the first and possibly second derivatives of f(t1,...,tn) with respect to t1,...,tn. For example, we want to find the maximum or minimum of f(t1,...,tn) and want to use an optimization method involving derivatives. The aim of the automatic differentiation package is to allow us to calculate the derivatives using a program that is just a minor modification of the program that calculates f. This greatly reduces the work involved and greatly increases the chances of getting the correct answer.
- ADOL-C (Automatic Differentiation of CC++) - The package ADOL-C facilitates the evaluation of first and higher derivatives of vector functions that are defined by computer programs written in C or C++. The resulting derivative evaluation routines may be called from C/C++, Fortran, or any other language that can be linked with C. The numerical values of derivative vectors are obtained free of truncation errors at a small multiple of the run time and randomly accessed memory of the given function evaluation program.
- DE-Quadrature - Numerical Automatic Integrator for Improper Integral. Method: Double Exponential (DE), Transformation dimension: one.
- Diffpack - Diffpack is a comprehensive development framework for multi-physics simulation. It is available on a wide range of hardware platforms.

- PVODE - PVODE is a portable solver for ordinary differential equation systems. It is based on robust mathematical algorithms, and targeted at large systems on parallel machines. A closely related solver called KINSOL has been developed for systems of nonlinear algebraic equations, and another is in progress for systems of differential-algebraic equations.

Search

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Getting Started With MATLAB

Revised by Clinton Wolfe (June 1999)
Original by David Hart

Introduction

What is Matlab?

MATLAB is a computer program for people doing numerical computation, especially linear algebra (matrices). It began as a "MATrix LABoratory" program, intended to provide interactive access to the libraries Linpack and Eispack. It has since grown well beyond these libraries, to become a powerful tool for visualization, programming, research, engineering, and communication.

Matlab's strengths include cutting-edge algorithms, enormous data handling abilities, and powerful programming tools. Matlab is not designed for symbolic computation, but it makes up for this weakness by allowing the user to directly link to Maple. The interface is mostly text-based, which may be disconcerting for some users.

Matlab is packaged as a core program with several "toolboxes", sold seperately. We will only cover the core package. The current (June 1999) version is Matlab 5.3 release 11.

How to use this document

This document is intended to be used while sitting at a computer running either NT or the X windows system. It is assumed that you will enter the commands shown, and then think about the result.

The reader of this document should have at least a passing familiarity with linear algebra and be comfortable using computers. In order to be more broadly understood, we will not cover any engineering topics (e.g. signal processing, spectral analysis), though Matlab is commonly used for these tasks. No previous math software experience is necessary, though we will point out important differences between the various packages along the way.

If you are using Matlab over a text-based terminal (such as Telnet or SSH), you might want to follow the Using Math Software under UNIX tutorial after you are finished with this one.

Throughout this document, we will use the following conventions.

Example	Explanation
File - Open	Choose the file menu, and select Open.
`a = 5`	Input to be typed at the Matlab prompt.

`a =` `5`	Output from Matlab.
TIP	An important tip.

Where to find Matlab

MATLAB is available for many different kinds of computers at Indiana University Bloomington.

- All Windows NT Student Technology Centers
- Ships, Nations, and DaVinci UNIX clusters
- Several of the large timesharing systems - see the availability chart for details.

A student edition is available from local bookstores for your personal Windows, Macintosh, and Linux systems.

How to Start and Exit Matlab

To start Matlab:

- On windows NT, choose Start Menu -Programs-Statistics-Math-Matlab.
- On Ships, Nations, Davinci, and all timesharing systems, type `matlab` to run it interactively.
  Note that plots will be displayed in an X-window, if you have set the DISPLAY variable. You may also type `matlab -display hostname:0`.

Note that Matlab typically takes 10-15 seconds to load.
Eventually, you should see:

```
To get started, type one of these: helpwin, helpdesk, or demo.
For product information, type tour or visit www.mathworks.com.
      >>
```

The line `>>` is the Matlab prompt.
To exit Matlab, type (at the matlab prompt) `quit` or choose File-Exit MATLAB.

Finding Your Way Around the Window

The Command Window

The Command window is where you can interact with Matlab directly. Try typing the following:

```
foo = ones(2)
```

The output should look like this:

```
foo =

       1       1
       1       1
```

This represents a 2x2 matrix of ones. Matlab inserts extra blank lines between practically everything. To turn off this feature, type

```
format compact
```

Unlike Maple and Mathematica, previous input lines cannot be edited. You can recall previous input lines by typing the "up" cursor button (similar to bash and DOSKEY).

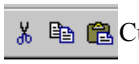
Cutting, copying and pasting is supported using the standards for your operating system.

The Toolbar

Systems that support graphics have a toolbar at the top of the screen, like this:

The buttons have the following functions:

New File, Open File

 Cut, Copy, and Paste

Undo last action

Workspace Browser. Use this to graphically edit variables.

Path browser. Use this to edit the paths that Matlab will look in for functions.

Simulink Library Browser (not covered in this tutorial).

Open help window.

The Help System

Unfortunately for the new user, Matlab's help system is rather primitive.

Built-in Help
If you know the name of a Matlab function you need help with, type
`help function-name`
to see the "helpful" information contained in the function definition itself. If you don't know the name of the function you need, try `lookfor keyword` . However, the search is very slow, and often deluges the user with a great many unhelpful items. In addition, a search for a concept, such as "matrix" will almost never return what you need.

You can get the same "helpful" information by choosing Help - Help Window, or typing `helpwin` .

HTML Help
A more useful (but more difficult to access) set of help files is included in HTML. To access it, choose Help-Help Desk, or type `helpdesk` .
This will launch your system's default web browser and open a web page. This process can fail in entertaining ways on UNIX systems. Even more frustrating, the system makes extensive use of Javascript, Adobe PDF, frames, and Java, so lynx users may wish to avoid it altogether.

While the content is essentially the same as the built-in help, it is presented in a much less hostile format. The Java-based full-text search and index-by-subject are two extremely useful features. In addition, the entire set of printed manuals is available as Adobe PDF documents.

TIP Most of the help files list function names in all capital letters.
This is extremely misleading - all built-in matlab functions are in small letters.

Syntax

How Matlab Works

Matlab works by executing the mathematical statements you enter in the command window. By default, any output is immediately printed to the window.

You are also allowed to assign a name to an expression for your convenience. Keep in mind that the name you assign is only a name, and it does not represent a mathematical variable (as it would in Maple, for example). Every name must have a value at all times. If you try to read the value of an unassigned name, you will get an error.

Nearly everything in Matlab in a matrix, whether it looks like it or not. This takes some getting used to. We'll be introducing matrix-style operations along with their scalar counterparts so you can understand the patterns that arise in the syntax.

Symbols and Punctuation

Matlab was designed to use fairly standard notation. Try these examples on your own computer.

Input	Output	Comments
2 + 3 7-5 34*212 1234/5786 2^5	ans = 5 ans = 2 ans = 7208 ans = 0.2173 ans = 32	Arithmetic works as expected. Note that the result is given the name "ans" each time.
a = sqrt(2)	a = 1.4142	You can choose your own names for things.
b = a, pi, 2 + 3i	b = 1.4142 ans = 3.1416 ans = 2.0000 + 3.0000i	You can use commas to put more than one command on a line. Pi, i, and j are contants.
c = sin(pi) eps	c = 1.2246e-016 ans = 2.2204e-016	"eps" is the current limit of precision. Anything smaller than eps is probably zero. Note that Matlab understands (and expects you to understand!) scientific notation.
d = [1 2 3 4 5 6 7 8 9] e = [1:9] f = 1:9	d = 1 2 3 4 5 6 7 8 9 e = 1 2 3 4 5 6 7 8 9 f = 1 2 3 4 5 6 7 8 9	"d", "e", and "f" are all vectors. They are equal. Note the use of the ":" operator - it counts (by ones) from one number to the next.
g = 0:2:10 f(3) f(2:7) f(:)	g = 0 2 4 6 8 10 ans = 3 ans = 2 3 4 5 6 7 1 2 3 4 5 6 7 8 9	More uses of the colon. Note that you can use it to get slices of a vector (or matrix, or cube, etc), or get the whole thing.
h = [1 2 3]; h'	(nothing) ans = 1 2 3	A semi-colon ";" will prevent the output from being displayed. A single quote " ' " computes the transpose of a matrix, or in this case, switches between row and column vectors.
h * h' h .* h h + h	ans = 14 ans = 1 4 9 ans = 2 6 8	Operations on vectors. * is matrix multiplication, and so the dimensions must line up correctly. " .* " is entry-by-entry multiplication.
g = [1 2 3; 4 5 6; 7 8 9]	g = 1 2 3 4 5 6 7 8 9	Entering a matrix.
g(2,3) g(3,:) g(2,3) = 4	ans = 6 ans = 7 8 9 g = 1 2 3 4 5 4 7 8 9	Accessing matrix elements. Note use of ":" to access an entire row.
g^2 g .^ 2	ans = 30 36 42 66 81 96 102 126 150 ans = 1 4 9 16 25 36 49 64 81	The first multiplies the matrix by itself. The second squares each entry in the matrix.

How to Control Output

Before we go any deeper into matrices, it would be wise to mention formatting issues.

The command to know is `format` .

- To control linespacing, use `format compact` .
- To see all 15 digits that were used in calculation, use `format long` .
- To see just 5 digits, use `format short` .
- To supress output completely, use a semi-colon at the end of the command.

To see other options, type `help format` .

Note that Matlab *always* uses "double" precision (about 15 digits) in its calculations. These commands merely adjust the display.

More on Matrices

More ways of contructing matrices

Built-in Constructions
There are many built-in matrix constructions. Here are a few:

Input	Output	Comments

`rand(2)`
`rand(2,3)`
	`ans = 0.9501 0.6068`
	`0.2311 0.4860`
	`ans = 0.8913 0.4565 0.8214`
	`0.7621 0.0185 0.4447`
		Generates a matrix with entries randomly distributed between 0 and 1

`zeros(2)`
`ones(2)`
	`ans = 0 0`
	`0 0`
	`ans = 1 1`
	`1 1`
		Generates a 2x2 matrix with all zero (or all ones) entries.

`eye(2)`	`ans = 1 0` `0 1`	Identity matrix I.

`hilb(3)`	`ans = 1.0000 0.5000 0.3333`
	`0.5000 0.3333 0.2500`
	`0.3333 0.2500 0.2000`
		3x3 Hilbert matrix.

To get more information on these, look at the help page for special matrices- type `help elmat` .

Concatenation
New matrices may be formed out of old ones. Suppose we have
`a = [1 2; 3 4]`

```
a = 1 2
    3 4
```

Then we can make a new matrix in any of the following ways.

Input	Output
`[a, a, a]`	`ans = 1 2 1 2 1 2` `3 4 3 4 3 4`

`[a; a; a]`	`ans = 1 2`
	`3 4`
	`1 2`
	`3 4`
	`1 2`
	`3 4`

`[a, zeros(2); zeros(2), a']`	`ans = 1 2 0 0`
	`3 4 0 0`
	`0 0 1 3`
	`0 0 2 4`

Programming
Matrices may also be constructed by programming. Here is an example using two "for" loops.

```
for i=1:10,
   for j=1:10,
      t(i,j) = i/j;
   end
end
```

Notice that there isn't any output, since the only line that would produce any (`t(i,j) = i/j;`) ends in a semi-colon. Without the semi-colon, Matlab would print the matrix t 100 times!

We'll cover programming in more detail later.

More matrix operations

As we saw earlier, +, -, *, and / are defined in an intuitive manner for matrices. When there is ambiguity about whether an operation will do matrix arithmetic (versus entry-by-entry arithmetic), note that ".*" (dot-star) will multiply entry-by-entry, and "*" (star) will do matrix multiplication.

Scalars
A scalar is just a number. Matlab stores them internally as 1x1 matrices, but treats them as if they were numbers.

All operation involving a scalar and a matrix affect the matrix on an entry-by-entry basis, with one exception: the power ("^") operator. With a as defined above, try these:

Input	Output	Comments
b=2	b=2	Define b to be a scalar.
a + b	ans = 3 4 5 6	Addition works entry-by-entry.
a * b	ans = 2 4 6 8	So does multiplication.
a ^ b	ans = 7 10 15 22	This is *matrix* power - a*a
a .^ b	ans = 1 4 9 16	Entry-by-entry power.

Vectors

A vector is just a matrix with only one row (or column). Matlab makes a distinction between row vectors and column vectors, and will complain if it doesn't get what it expects.

In all arithmetic operations, Matlab treats a vector as a matrix, so we already know how to multiply a vector by a scalar. Matlab also gives you the following operations:

Input	Output	Comments
v = [1 2 3] u = [3 2 1]	v = [1 2 3] u = [3 2 1]	Define a pair of vectors.
v * u	Error	The dimensions don't agree.
v * u'	ans = 10	Taking the transpose works.
dot(v,u)	ans = 10	The dot product is the same thing.
cross(v,u)	ans = -4 8 -4	The cross product works only for 3-d vectors.

Matrices

Matlab has all the common operations built-in, as well as most of the obscure ones.

Input	Output	Comments
k = 16 2 3 5 11 10 9 7 6	k = 16 2 3 5 11 10 9 7 6	Define a matrix.
rref(k)	ans = 1 0 0 0 1 0 0 0 1	Row-reduced echelon form

`rank(k)`	`ans = 3`	The rank.
`det(k)`	`ans = -136`	The determinant.

`inv(k)`	`ans =  0.0294 -0.0662  0.0956`
	`-0.4412 -0.5074  1.0662`
	`0.4706  0.6912 -1.2206`
		Inverse of the matrix

`[vec,val] = eig(k)`	`vec = -0.4712 -0.4975 -0.0621`
	`-0.6884  0.8282 -0.6379`
	`-0.5514  0.2581  0.7676`
	`val = 22.4319  0  0`
	`0  11.1136  0`
	`0  0  -0.5455`
		Eigenvectors and eigenvalues of the matrix.
		The columns of "vec" are the eigenvectors,
		and the diagonal entries of "val" are the eigenvaules.

There are many more functions like these. Type `help matfun` to see them all.

Solving Equations

One of the main uses of matrices is in representing systems of linear equations. If `a` is a matrix containing the coefficients of a system of linear equations, `x` is a column vector containing the "unknowns," and `b` is the column vector of "right-hand sides," the constant terms, then the matrix equation

$$a\,x = b$$

represents the system of equations.

If you know a little linear algebra, you could use the Matlab commands from above to augment the matrix and then find the row-reduced echelon form. However, Matlab provides a more simple mechanism for solving linear equations:

```
x = a \ b
```

This can be read "x equals a-inverse times b."
Try it with

```
a = [1 2 3; 4 5 6; 7 8 10]; b = [1 1 1]';
```

You should get

```
x = -1 1 0
```

To verify this assertion, try this:

```
a*x, a*x - b, eps
```

The results are:

```
ans = 1 1 1
ans = 1.0e-015 *
    -0.1110
    -0.6661
    -0.2220
ans = 2.2204e-016
```

Notice that `a*x - b` is very close to `eps` - which means that it is as close to zero as possible.

If there is no solution, a "least-squares" solution is provided (a*x - b is as small as possible). Enter

```
a(3,3) = 9; b = [1 1 0]';
```

(which makes the matrix singular and changes b) and enter the above commands again, using the up-arrow to recall

them. Notice that the solution is quite inaccurate.

Saving and loading matrices

Unlike Maple and Mathematica, Matlab has no notion of a "worksheet." When you exit Matlab, you will not be prompted to save your work.

If you would like a record of your work, you can turn on "logging" by typing

`diary 'c:\scratch\session.txt'` on NT machines
`diary '~/session.txt'` on UNIX.

Notice that output will be saved alongside your input, so the file can't be used directly as a script.

You may just want to save one or more matrices. The diary is a very clumsy way to do this.
To save the value of the variable "x" to a plain text file named "x.value" use
`save x.value x -ascii`
To save all variables in a file named "mysession.mat" in reloadable format, use
`save mysession`
To restore the session, use
`load mysession`
Then, to see the saved files from your session, on UNIX systems type the commands:

```
% more session.txt
% more x.value
```

Under Windows NT, open the appropriate file with Notepad.

Graphics

Matlab has outstanding graphics capabilities (you must be using a terminal which supports graphics to use them). However, graphing in Matlab is conceptually different than graphing in Maple or Mathematica.

Graphics Concepts

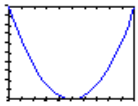
Before looking at the plotting capabilities of Matlab, consider what a graph really *is*. A graph is a collection of points, in 2,3 or even 4 dimensions, that may or may not be connected by lines or polygons. Most math software packages hide this from the user by sampling a continuous function to generate the points.

Matlab is designed to work with matrices, rather than functions. Matrices are a convenient way to store a collection of numbers - which is exactly what is needed when graphing. Thus all graphing commands in Matlab accept *matrices* as their argument, rather than a function. If you are used to function-style plotting, Matlab may take some getting used to. On the other hand, Matlab's approach makes it very easy to visualize data and to create graphics based on lists of points.

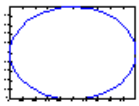
Another unique feature of Matlab's graphics engine is the way in which it displays graphical output. In Matlab, there is (usually) only one plotting window. Subsequent plotting commands will add to the old plot, unless you request a new one be made. This allows a plot to be made, then adjusted later to suit your needs.

Basic 2-D Graphics

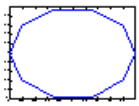
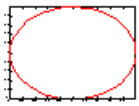
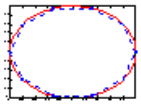
Now that you understand a bit more about graphing, try these examples. Be sure to follow along exactly, or you may not get the same results.

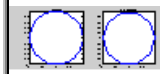
Input	Output	Comments
`x = -10:0.5:10;` `y = x .^ 2;`	(none)	Create a 1x41 matrix that counts from -10 to 10, and a 1x41 matrix made by squaring the entries of the first matrix.
`plot(x,y)`		Plot the points. Each pair is plotted, so <x(1), y(1)> is a point, <x(2), y(2)> is a point, etc.

`t = 0:0.1:2*pi;`
`x = cos(t);`
`y = sin(t);`
	(none)	Generate some new 1x63 matrices.

`plot(x,y)`		Plot the points. This is called a parametric plot. Notice that it replaces the previous plot.

`t = 0:pi/5:2*pi;`
`u = cos(t);`
`v = sin(t);`
	(none)	Generate some new 1x11 matrices. This shows how to control the "resolution" of the plot.

`figure` `plot(u,v)`		Create a new plot window, and plot the points. Notice how jagged the circle is, since we only used 11 sample points.
`plot(x,y, 'ro-')`		Plot the hi-res version again in red, with circles at the data points, connected by lines.
`plot(x,y, 'r-', u,v,'b*:')`		On the same plot, plot the hi-res version in red, and plot the lo-res version with blue stars at the data points and dotted lines.

`figure`
`subplot(1,2,1)`
`plot(x,y)`
`title('Fine Mesh')`
`subplot(1,2,2)`
`plot(u,v)`
`title('Coarse Mesh')`
		Create a new figure.
		Divide it into one row, two columns, and pay attention to the first cell.
		Plot.
		Give the current plot a title.
		Pay attention to the second cell.
		Plot.
		Give it a title.

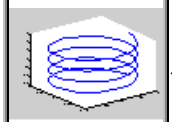
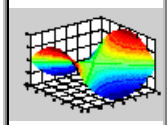
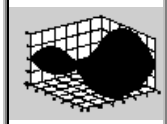
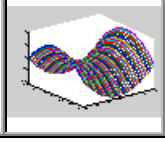
See the following help files for more options and ideas: `help plot`, `help comet`, `help semilogy` and `help fill`.

Matlab provides very powerful features in the figure window. Use the toolbar at the top to add arrows, lines, and text comments to your plot.

Basic 3-D Graphics

Input	Output	Comments

`t = -4*pi:pi/16:4*pi;`
`x = cos(t);`
`y = sin(t);`
`z = t;`
	(none)	Generate the data...

`plot3(x,y,z)`		... and draw a helix.
`[x, y] = meshgrid(-3:0.1:3,-3:0.1:3);` `z = x.^2 - y.^2;`	(none)	Generate data for a surface plot.
`mesh(x,y,z)`		Draw the surface using a mesh.
`surf(x,y,z)`		Draw the surface as a "patched" surface.
`plot3(x,y,z)`		Notice that it still plots, but as a set of arches.

Advanced Plotting

Of course, Matlab can do a lot more than these simple exercises. If you'd like to know more, try these help files: `help slice`, `help movie`, `help getframe`, `help graph2d`, `help graph3d`, `help graphics`.

Programming

How to program

Matlab statements can be prepared with any editor, and stored in a file for later use. The file is referred to as a script, or an "m-file" (since they must have names of the form `foo.m`). You may prefer to do this, if you use the same data

repeatedly, or have an editor that you like to use. Writing m-files will make you much more productive.

Select File - New -M-file to open Matlab's built-in editor/debugger, or use your favorite editor. Then create the following file, and save it as sketch.m:

```
[x y] = meshgrid(-3:.1:3, -3:.1:3);
z = x.^2 - y.^2;
mesh(x,y,z);
```

Next, in Matlab, be sure that the directory where the m-file resides is in the path. Check this by typing `pathtool` and making sure that your directory is present. (Users without graphics can use `addpath` *`directory`*.)

Now enter
`sketch`
The result is the same as if you had entered the three lines of the file, at the prompt.

You can also enter data this way: if a file named mymatrix.m in the current working directory contains the lines

```
A = [2 3 4; 5 6 7; 8 9 0];
```

then the command `mymatrix` reads that file and generates A. However, for large matrices, Matlab's own `save` and `load` commands are much safer to use.

Functions

Functions are like any other m-file, but they accept arguments, and they are compiled the first time they are used in a given session (for speed).

Use your favorite editor to create a file named sqroot.m, containing the following lines.

```
function sqroot(x)
% Compute square root by Newton's method

% Initial guess
xstart = 1;

for i = 1:100
        xnew = ( xstart + x/xstart)/2;
        disp(xnew);
        if abs(xnew - xstart)/xnew < eps, break, end;
        xstart = xnew;
end
```

In Matlab enter the commands
`format long`
`sqroot(19)`
You should see the output from your function.

Two caveats:

A function has access to the variables in the "workspace" from which it was called, but the variables created within the function (xstart and xnew, in the preceeding example) are local, which means that they are not shared with the calling workspace. For more information, see the chapter "M-File Programming" in the manual, *Using Matlab*.

- Note: if you edit a function during a session, use `clear function_name` to remove the compiled version, so that the new one will be read.

Batch Programming

MATLAB may be ran in "batch mode," in a very similar way. If a file named "test.m" contains the (non-graphics) commands you want processed, at the UNIX prompt type:

```
% matlab < test.m > homework.out
```

This is read, "Run MATLAB, with input from test.in, and output to test.out." The input file does not need to be named "something-dot-m," but it **must** end with `quit` .

Programming ideas

The "m-files" which came with MATLAB provide lots of examples! To find their location, use `path` .This will also lead you to some demos.

You might also try typing `demo` to get a feel for the breadth of tasks that can be accomplished with Matlab.

See `help function` for an exercise for programmers.

Further Reading

- The Matlab page should be especially useful.
- If you use UNIX, Using Math Software under UNIX may be helpful.
- Manuals for statistical and mathematical software are kept in the Swain Hall, Business/SPEA, Education, and IUPUI University Libraries, and at the IU Center for Statistical and Mathematical Computing. The manuals which come with Matlab are especially good, and provide much more information than this short course.
- If you are affiliated with Indiana University, you may also get help from the Stat/Math Center.

Please send comments and suggestions to: statmath@indiana.edu
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URL `http://www.indiana.edu/~statmath/math/matlab/gettingstarted/printable.pdf`