

Instructions for Use of Maple in Mathematics 251

Fall 2004

This document These instructions are made available in two formats with the same contents. A printed version is distributed at the meeting in the **IML** during a recitation period early in the term, and a **PDF** version is available from the course web page:

<http://www.math.rutgers.edu/courses/251/>

Getting started The purpose of the Maple assignments is partly to learn about Maple, a powerful and very useful program for symbolic, numerical, and graphical computations, and partly to help you understand the material in the course. Rutgers has a license that allows Maple to be available on many systems, including **eden**, the PC labs, and departmental networks. Facility with Maple that you learn in this course can help you with all of your studies. It is an important part of this course because it can graph curves and surfaces in three dimensions, solve complicated systems of equations, and perform all of the differentiation and integration operations met in this course. The **Student package** allows you to examine the steps of many of these operations (through Calculus I in Maple9, but a Multivariate Calculus package was added to Maple9.5).

The current version of Maple is **Maple9.5**, which was released in the summer of 2004. The student labs may continue to use Maple9, but this should not limit your ability to do everything required for the labs. No features of Maple9.5 will be included in the lab projects, although features introduced in Maple9 are being added. On all systems, there is a **text based** version and **graphical worksheet interface** versions. Only the graphical version will be used here. On Unix systems, like eden, this graphical version is called **xmaple**, since it is customized to run under the X windows system. Since there are no longer X-terminals in the student labs, most work will be done on PCs where all versions of Maple are usually installed on the “Course Related Software” section of the *Start Menu*. It is also expected that the Microsoft Windows desktop on the lab PCs will be taught to recognize Maple worksheets so that you can start Maple by selecting the file that you want to open. The commands you use to do mathematics with Maple will be the same on all these machines, although there may be differences in the way that files are opened, saved, and printed.

It is important that you be able to save worksheets to allow editing of your initial results. The best place to save worksheets is in your eden directory. One way to do this, that is readily available is the *Weeble web-based file manager* (see <http://www.eden.rutgers.edu/tools.php>). To use this, you will need to note where the worksheet is stored on your local machine in order to copy it to your **eden account** after you exit Maple, but before you log out of the machine. As part of the transition to **secure services** (see <http://www.nbcs.rutgers.edu/secure-services.php>), it is expected that **Remote Drive Mapping** using *Samba* will be available to allow a **special subdirectory** of your home directory on eden to be mounted on a PC. The same system — using a different subdirectory — allows you to manage your personal web site in the same way. Although not available on eden when this **Introduction** was written (August 2004), it has been available on RCI. That implementation uses a special password and requires prior registration, so you should consult the web pages mentioned above (which are linked to the on-line version of this **Introduction**) for more information on using the system.

Starting with Maple 9, each worksheet opens in its own window with a **Menu Bar**, consisting of a row of **menu buttons** (**File**, **Edit** etc.) At the top of the window. Underneath the row of menu buttons is the **Tool Bar**, most of which are shortcuts to menu commands. Directly below the Tool Bar is the **Context Bar**, which consists of more buttons that are shortcuts to menu commands. If you have enabled **Tool Tips** from the **Interface** page of the **Options** notebook accessible from the **Tools** menu, when you place the mouse pointer on any of these buttons, a rough idea of what the button does will appear. The rest of the window,

except for a small **Status Bar** at the bottom is devoted to the worksheet. You can now give an instruction to Maple by placing the mouse pointer on the worksheet (just to the right of the prompt `>`), typing a Maple command, and then a carriage return. Maple carries out the command and prints a response. For example, if you type `1 + 1;`, Maple will respond with `2`. Note that each Maple command ends with a semicolon (if you forget the semicolon, Maple will remind you) or a colon. Both the colon and semicolon mark the end of a command. Usually the semicolon is used since this shows the output of the command; the colon suppresses output in cases where it would clutter the worksheet.

If you select part of the worksheet, the right mouse button brings up a **Context menu** that can be useful in editing the worksheet.

In order to guard against computer problems, you should save your worksheets often. Clicking on the **diskette icon** on the **Tool Bar** of your Maple window is a convenient way to save the current worksheet. You can also enable **Auto Save** from the **General** page of the **Options** notebook that is available from the **Tools** menu.

You can open several worksheets in the same Maple session, although each project in this course is expected to be done in a single worksheet. Prior to Maple9, the standard behavior was for all worksheets in a session to share the same Maple kernel so that instructions in one worksheet would be known to all worksheets in that session. Maple9 changed the standard to confine the effect of instructions to the worksheet in which they are entered. This is known as the **parallel kernel mode**. The setting may be checked (or changed) on the **General** page of the **Options** notebook.

If you assign the result of a Maple computation to a name, that name will refer to that value for the rest of your Maple session unless you make another assignment to that name or use the `restart;` command. Erasing the instruction from the worksheet will **not** remove its effect. Also, only the **order of executing** instructions, **not the position of the instructions in the worksheet** affects the values of named variables.

On the other hand, if you open a previously saved worksheet, **none of results** of that worksheet are known, even though they are visible in the worksheet. Your new session will learn those results by executing the instructions, either one at a time by hitting the **Enter key** on each line, or all at once using the **Execute... Worksheet** item in the **Edit Menu**. This step is also useful to check that results in your worksheet appear in the same order as the instructions. **This consistency is expected in the printed worksheets that you submit.**

Getting Help from Maple Since you will not be given a Maple manual, you should learn to use Maple by using the built in **Help** facility. There is a **Help Menu** at the right end of the menu bar. Selecting any of the items in this menu will open the **Help Browser Window** (introduced in Maple 9 — a less convenient set of help window were used in earlier versions). New users are presented with this **Help Browser Window** when Maple starts.

Only one Help page at a time will be visible, but the browser includes a **History** panel as well as an **index** and a **search tool**. The help pages give the **exact syntax** of Maple instructions and **examples of their use**. It is expected that you will refer to this help to get the exact format of some instructions named in the projects.

The **Help Browser** also contains pointers to **Example Worksheets**. One such, named **Basic How To** introduces some frequently used Maple commands.

Maple Worksheets The window that appears when you start Maple is called a **Maple worksheet**. To complete each computer assignment in Mathematics 251 you are asked to turn in an **edited printout** of your work. The printout should include only the numerical, symbolic, and graphical output of Maple that is appropriate for the solution of the problems assigned, plus **text material interpreting the results** obtained

by Maple. Using the **T** tool will insert a new line into the worksheet in text mode, allowing descriptive material to be added. (**Undocumented Feature:** Prior to Maple 9, this tool modified the current line, but this change is not described in the documentation.) To modify the mode of the current line, use the **Convert to** submenu of the **Format** menu. The **Insert** menu also contains items that modify the current line. Its **Execution Group** submenu may be used to add a line. This is the only way to add a line before the cursor, but lines are more easily added after the cursor using the [**>**] tool on the toolbar. Text lines can also be used to label graphical output, but better results can be obtained using the **title option** in the plot instruction. Maple includes various editing capabilities that should enable you to produce neat and coherent output, which we now describe.

To remove an unwanted portion of your Maple worksheet (e.g., a region containing commands that you typed incorrectly or that were not directly relevant to the solution of the exercises), select the region to be deleted by clicking the left mouse button at the beginning, then dragging the mouse across to the end of the portion of the worksheet you wish to delete. The region should now be highlighted. The **Delete** key will purge what you have selected. A safer approach is to choose **Cut** from the **Edit** menu or toolbar. This allows you to copy the removed region to a new location by selecting **Paste** from the **Edit** menu or toolbar. There is also a **Copy** tool and item in the **Edit** menu. that makes a region available for pasting without removing it from the worksheet. These operations are borrowed from your computer's *Window Manager*, so it should be possible to copy parts of your Maple worksheet to other applications. However, this may not work as smoothly as it does with applications that are more closely integrated with the system. You can also delete whole lines with the *Ctrl-Delete* key combination. You should experiment with the different aspects of the user interface (mouse, keyboard, menu or toolbar items) to find the method that you find easiest for customizing the appearance of your worksheet.

Sometimes it is useful to be able to place a comment after a Maple command, rather than insert text elsewhere in the worksheet. To do this, enter the sharp symbol #. Everything typed on a line following this symbol will be considered by Maple to be a comment, and therefore not executed.

To make your worksheet less cluttered, it is a good idea to have Maple suppress the output of various commands, e.g., the command `with(plots)` or a command given to assign a name to a plot. To do this, end the command with a colon (:), instead of a semicolon (;).

Obtaining the Labs in Worksheet Form In some of the labs, part of the lab will ask you to execute a string of Maple commands to learn what they do. To avoid retyping these commands, you can first obtain a modified copy of the lab in worksheet form (a “seed file”) from the course web page. This modified copy contains only strings of some of the Maple commands you are asked to execute. It particular, it omits comments containing text that gives instructions or states problems. Once you obtain this file, you can access it by following the instructions in the next section. The first time that you meet a feature of Maple, the lab description or the seed file (or both) will include the required **Maple input**, but you will usually be expected to construct the modifications needed for related cases.

Opening an Existing Worksheet To open an existing worksheet, you should choose **Open** from the **File** Menu or the toolbar. A dialog box will be shown. Navigate in that box to the correct directory and select the name of the file you wish to open and then click on the **Open** button at the bottom of the box. To continue, you will need to know some basic commands and syntax of Maple.

Arithmetic The operations addition, subtraction, multiplication, and division are indicated by **+**, **-**, *****, **/** respectively. Fractions are represented exactly, and Maple automatically reduces them to lowest terms. Thus, if you type `1/3+1/6;`, Maple will answer `1/2`. Exponentiation is also available with the

operator \wedge , but it should be used **sparingly**. Many expressions that we write using exponents are better described using the **exponential function** described in a later section.

When operating on integers or fractions, Maple will do **exact arithmetic**, rather than using decimal approximations. To get a decimal approximation, use the Maple command `evalf`. The Maple command `evalf(4/7);` produces a 10 digit approximation to $4/7$ —as will typing `4.0/7.0;`. Additional accuracy can be obtained by including a modifier: typing `evalf[20](4/7);` will produce a 20 digit approximation. (Note: this form of the `evalf` function is now standard, replacing an older form `evalf(4/7,20);`. The older form is still accepted, but no longer described in the *Help* file. You can also change precision for your whole Maple session by setting a new value to the reserved variable `Digits`.

Algebra All grouping of expressions is done with the left and right parentheses — “(” and “)”. Although the usual rules of precedence apply, you can **always** use parentheses to clarify your intent. Variables are not limited to single letter names, as in Elementary Algebra (and most Calculus texts). You can use (almost) any string of letters and numbers that starts with a letter to name a variable. As a result, the **product** xy **must** be written `x*y`, not `xy` or `x y`; if you type `xy`, Maple will assume you are referring to a variable called “`xy`”. Thus, to enter the expression $(2x + y^2)/(x^2 + y) + 1$ into Maple, you type:

```
(2*x +y^2)/(x^2 + 2*y) + 1;
```

Recent versions of Maple allow you to use a **palette** (which is available from the **View** menu) to help build expressions. The project descriptions may use standard mathematical notation that you must translate into **Maple input** in your worksheet.

To help you do algebraic manipulations, Maple has the commands `expand`, `factor`, and `simplify`, which you can learn about by using the **Help** facility. It is often necessary to `expand` an expression before Maple will know what it means to `simplify` it. In particular, Maple considers

```
(2*x +y)*(x + 2*y);
```

to be simple. Likewise, after you `expand` this expression, Maple will consider the expanded form to be simple, but the `factor` command can be used to return the factored form.

Algebraic numbers like the $\sqrt{2}$ are considered to be exact quantities. If you enter

```
a:=(sqrt(2)+1)^10;
```

Maple will appear to simply echo a **prettyprint** version of that statement.

To get an answer in the form $3363 + 2378 * \sqrt{2}$, follow this line with `expand(a);`.

You can also solve algebraic equations using the commands `solve` (for exact answers) or `fsolve` (for numerical answers to the accuracy specified by `Digits`).

The standard functions Note that the exponential function is built into Maple and is referred to as `exp`. The number e , if you ever need it, is `exp(1)`. If you have the fragment `e^x` in a worksheet, it will **look** right, but will usually give **incorrect results** when you try to **use** it. Similarly, the number π has the special name `Pi` — **not** `pi` that looks the same in output lines, but will be treated as an ordinary variable. If you want to, you can say `pi:=3;` but this won’t affect the value of π or anything that depends on it. However, Maple will fuss at you if you try to change the value of `Pi`. Except for `Pi`, that has been part of Maple for a long time, other names that are Greek letters — upper or lower case — are shown as that letter in output. This can be confusing in cases like `Mu` where the Greek letter **looks like** a related Latin letter. Maple also recognizes names like `log`, `ln`, `sin`, `cos`, `tan` as standard functions. Those names are also protected against use as names of variables. Normally, `log` is treated as a synonym for `ln` — to get the

common logarithm of 2 that your calculator uses, you should write `log10(2.);` or `log[10](2.);`. The instruction, `FunctionAdvisor(known_functions);` will give you a list of names of the functions that are available. Many of these have unfamiliar names since they are defined in advanced mathematics, but you should recognize all the **elementary functions** that you learned how to differentiate in Calculus I.

User-defined Functions and Expressions In Maple, $x^2 - 2x + 3$ is an **expression**. You can assign a name to this expression for future use by typing `g:= x^2 - 2*x +3;`. Note that **a colon is required before the equal sign** in an **assignment statement**. Expressions can contain several variables, as in `h:= y*t - sin(y)`. To evaluate an expression at a particular value, use the Maple command `eval`. For example, `eval(g,x=2);` will produce the value 3. In many cases, the Maple command `subs` has a similar effect, although the order of the arguments is different. For example, `subs(x=2,g);` will also produce the value 3.

Maple also has a construct called a **function**, defined by statements like `f:=x -> x^2 - 2*x +3;`. This allows you to recover the expression $x^2 - 2x + 3$ as `f(x);`, and to perform evaluation using the familiar notation `f(2);`. It is also possible to substitute expressions for x — even expressions that contain x — and get the result that you expect. For example, `f(x+1);` returns $(x + 1)^2 - 2x + 1$, which you could **expand** or **simplify** to get $x^2 + 2$.

We won't often use functions, except for pre-defined functions like `exp(x)` or `cos(x)`, since it is easier to work with expressions, but you might see them in examples on **Help** screens. Some *seed files* may also define functions to extend the Maple language on that worksheet. While we don't expect you to **write** functions in the Maple programming language, you should have no difficulty **reading** these definitions.

Plots The basic plotting command in Maple is `plot`. This command has many forms—for example, several functions can be plotted at once—so you should look carefully at the examples given at the end of its **Help** page to get some idea of its flexibility. There are many other plotting commands in Maple; in this course we will use primarily `plot3d` and `implicitplot`. To use all but the most basic the plotting commands you must first issue the command `with(plots);`. For example, this is necessary in order to use the command `implicitplot`. It is frequently useful to change the size of a plot or some of the options used in the plot. To do this, place the mouse pointer in the region occupied by the plot and click the left mouse button. This places a box around the plot and changes the Menu Bar and Control Bar (and context menu) so that new options are offered to manipulate the plot. The plot is resized by placing the mouse pointer at one of the small dots along the edge of the box and dragging the pointer. You can also modify the style of the plot using the Control bar or **context menu** (obtained by clicking the right mouse button near the plot). These changes will lead to a plot with features not shown in the instruction that drew the original plot. Suitable options may be added to the `plot` instruction to assure that the modified plot will be drawn every time the worksheet is executed. When you have finished modifying the plot, move the mouse down to the next prompt `>` and click the left mouse button. When viewing three dimensional plots, it is useful to view the plot from different viewpoints. First, place a box around the plot by moving the mouse pointer in the region occupied by the plot and clicking the left mouse button. Now, place the mouse pointer inside the box and while holding down the left mouse button, move the mouse pointer to different positions. You should also explore the effects of using the **Axes** and other commands.

Vectors As of Maple6, Maple now has two different packages for linear algebra. These packages allow powerful operations to be introduced simple by calling them by name. The original `linalg` package imposed a complicated structure on everything it touched. As a result, simple things became more difficult.

The newer `LinearAlgebra` package is easier to use and is the basis of a `VectorCalculus` package that allows you to communicate to Maple using the terminology introduced in this course.

Calculus In addition to performing basic calculations and evaluating expressions containing standard functions, Maple can also differentiate and integrate. The `diff` command differentiates **expressions**. For example, `diff(x*sin(x), x);` differentiates $x \sin(x)$ with respect to x . If you have named an expression, it is a useful convention to introduce a modification of that name as a name for the derivative (or partial derivatives). That is, if you have `y:=x*sin(x);`, you can write `y1:=diff(y,x);`. A second derivative can then be found, and named, by writing `y2:=diff(y1,x);` to differentiate the first derivative using the name that you introduced. If you need a second derivative without seeing the first derivative, either `diff(x*sin(x), x, x);` or `diff(x*sin(x), x$2);` may be used. If you have typed `g:=x^2*y;`, then `diff(g,x);` gives the first partial derivative of x^2y with respect to x and `diff(g,x,y);` is the mixed second partial derivative. It is also possible to differentiate **functions**, but this uses **totally different** set of conventions.

Note that Maple assumes that everything not involving the variable with which it is differentiating is constant. This means that **no special notation** is required to distinguish partial derivatives of expressions from ordinary derivatives. Note that, although we claim to be differentiating **functions** in Calculus, the techniques are based on examining how **variables** appear in **expressions**, so the way that Maple works with expressions is more familiar.

The command for both definite and indefinite integration is `int`. If Maple cannot evaluate a definite integral exactly, numerical integration may be used. Definite integrals are evaluated using a single instruction written like `int(sin(x), x=0..Pi);` to get

$$\int_0^{\pi} \sin x \, dx.$$

It is not necessary to apply either the `subs` or `eval` instruction to the result of indefinite integration, although that approach gives the same answer. The role of dx in the mathematical notation for integrals is played by **including the name** of the variable x in the second argument of the `int` instruction.

The `VectorCalculus` package includes commands to work with the extend forms of differentiation and integration introduced later in this course.

Maple9 also includes a package named `Student[Calculus1]` that you can use to review basic calculus. There are **interactive** worksheets that allow you to practice the techniques of basic calculus and to step through the solution of problems. The **help pages** will guide you in the use of this package.

Printing your Maple Worksheet. The projects in this course are to be submitted as **printed worksheets**. Usually, two weeks are allowed from the time the project is assigned until the printed worksheet is due. This allows you to explore different approaches to the project and to edit your results.

To print a Maple worksheet, choose **Print** from the **File** menu or click on the print button in the **Tool Bar** (its position varies, but it is with the other file tools at the left and its icon looks like a printer). A panel will appear with the options “Output to File” and “Print Command” at the top. Clicking on “Print Command” will direct your output to the printer if the command has been correctly entered, while clicking on “Output to File” places your output in a file, whose name and location will be chosen in another dialog box (the default is `out.ps`). If you wish to change the file name or the print command, click in the box and type your changes. Since the file will be a postscript file, the file name should have the form *something.ps*. When you have finished making your choices, click on the “Print” button.

You should also use the following tools to improve the appearance of your printed worksheet.

- (1) **Print Preview** to see how your worksheet will appear before you commit it to paper.
- (2) The **page break** item in the **Insert** Menu to force extra page breaks as needed to improve readability. In Maple 9 the location of the break is shown in the worksheet on your screen.

Saving your Maple Worksheet. If your work is interrupted, you can save your work so that you can resume later where you left off. There is a tool on the toolbar that saves a worksheet under its current name if it has one, or prompts you for a place to save a newly created worksheet. In addition, the **File** menu contains the usual **Save** and **Save As** options. The **mw** extension will be added to the name that you give.

It is also possible to save the file in the older **mws** format, but this may lose features introduced after Maple8. **Don't do this unless absolutely necessary**, and inform your instructor if you will not be able to complete the worksheet in Maple9 (or newer).

Ending your Maple Session To end your Maple session, choose **Exit** from the **File** menu. When you close a worksheet, or exit the program, Maple will prompt you to save worksheets that have changed since the last save. This may only save the worksheet of the PC in the lab. That file will then need to be copied to your directory on eden to have it available for later editing.

Useful Commands and Techniques. If Maple gets hung up in a calculation or is taking too long, click the mouse on the **stop** button in the **Tool Bar** menu. This usually means that the command that Maple was working on was incorrect. An **alternative approach** to the calculation may give the desired result. Computational efficiency is usually not an issue on modern computers, so you shouldn't try to find the best way to compute something. However, you should check that reasonable results are obtained fairly quickly.

Any Maple command previously entered in your worksheet can be re-executed without retyping it in a new location. Simply move the mouse to the position of the command you wish to execute and hit the **Enter** (or **Return**) key. However, this works **only for the current session**. If you need the instruction at some point in the worksheet, it should be copied there.

It is often useful to be able to refer later to the result of a computation—the output of some command—in a simple way. To make this possible, simply assign the output of the command to a variable. For example, if you enter `a := evalf(2*Pi);` then you can later square the result of `evalf(2*Pi);` by typing `a*a;`. If you find that you need a recent result that was not named, the special names `%`, `%%`, etc. may be used to refer to the previous result, the one before that, etc. (the instructions are not clear about how much of the history can be retrieved in this way). A better solution might be to add a name the line that computed the expression and re-execute that line.

You can assign a name to a plot just as described above for assigning a name to an expression, but an instruction creating a **named plot** should always end with a colon instead of a semicolon — you **don't want to see** that output. Several previously named plots can then be displayed on the same graph by using the command `display`. This is part of the `plots` library. Looking in the documentation for that library may be the easiest way to find the help page for this function.

Only the most recent assignment to a name is remembered. You can unassign `a` by typing `a := 'a';`. To clear all the assigned variables in a Maple session, you can type `restart;` as indicated earlier. If you are unsure of what value has been assigned to the name `a`, you can type `a;` at the current prompt. Such working notes should be edited out of the worksheet before you submit it.

Getting Help From Other Students

The course includes some **laboratory projects** that form a small portion of your grade. Just as with other homework assignments, it is permissible and helpful to discuss these Maple labs with other students. However, the Maple lab reports that you turn in are being graded and will be part of your final course grade. As with all such work, the printed form of the worksheet is expected to be the work of the student who submits it. In particular, the projects include questions that involve your interpretation of results of Maple's computation. The grader will concentrate on the text comments that contain your answers to these questions, that are expected to reflect your **individual understanding** of the topic.

End of Maple instructions document