We will go to the computer lab (38-135) to see how Maple can be used to deal with some of the topics in this course. Moreover, you will have access to Maple on exams. Handouts will be provided with explanations and examples illustrating how this application works. Bring them with you to all lab sessions and exams.

**Math Mode vs Text Mode**

When Maple opens you are in Math mode characterized by a slanted input cursor. Maple is waiting for you to make a Math entry. See the following three examples related to Laplace transforms.

\[
\int_0^\infty t \ e^{-st} \ dt \ = \ \lim_{t \to \infty} \left( -\frac{e^{-st} + t \ s \ e^{-st} - 1}{s^2} \right)
\]

\[
\int_0^\infty t \ e^{-st} \ dt \ \text{assuming} \ s > 0 \ = \ \frac{1}{s^2}
\]

\[\text{inttrans[laplace]}(t, t, s) = \frac{1}{s^2}\]

Each of these equations was obtained by typing the left hand side (henceforth referred to as the input), and then pressing the key combination **Command-equals** to get the equals sign and the right hand side (the right hand side is called the output). We explain how to enter a definite integral at the end of this handout.

**Text Mode**

Maple can also be used in Text mode where it serves as a text editor.

To switch from Math mode to Text mode press **Command-T**.

Text mode is characterized by a vertical input cursor.

To switch from Text mode to Math mode press **Command-R**.

Do not mix modes in the same paragraph.

* As a general rule, **once in Text mode stay in Text mode**. If you want to make a Math entry, press the [return] key to move to the next line, and then press Command-R.

* Similarly, as a general rule, **once in Math mode stay in Math mode**. If you want to make a Text entry, press the [return] key and then press Command-T.

**Maple as a Calculator: The evalf Procedure**

Maple can be used as a calculator. However, unlike most calculators, Maple always gives an exact answer when the input contains exact values (i.e. no decimals). The following equation was obtained by typing the left side and then pressing Command-equals.

\[
\frac{234 + \frac{188}{189} - \sqrt{884}}{189} = \frac{44414}{189} - 2\sqrt{221}
\]

To get a decimal approximation to the output apply the **evalf** procedure to the expression or right-click on the output and choose Approximate on the contextual menu that appears.

A 20-digit approximation obtained by right-clicking on the exact output is displayed below.

\[
234 + \frac{188}{189} - \sqrt{884} = \frac{44414}{189} - 2\sqrt{221} \quad \text{at 20 digits} \quad 205.26257150007198366
\]

The next Math entry shows how to use **evalf** to get a 15-digit approximation to the same number.

\[
\text{evalf} \left( 234 + \frac{188}{189} - \sqrt{884}, 15 \right) = 205.262571500072
\]

The default number of digits in an **evalf** approximation is 10. Here is a 10-digit approximation to \(\pi\).

\[
\text{evalf} \left( \pi \right) = 3.141592654
\]

If 200 digits are desired, Maple will supply them, see below.
• The number $\pi$ is entered by typing $\text{pi}$ and pressing the \textit{escape key} followed by the \texttt{[return]} key (the \[enter\] key on a PC). We will refer to this as $\text{esc} \ [\text{return}]$.

The output to the following entry appears on the next line because the [return] key was pressed instead of the key combination Command-equals. Note that the output has a label. This can be used to refer to the output in a subsequent Math entry.

\[
evalf(\pi, 200)
\]

\[
3.1415926535897932384626433832795028841971693993751058209749445922307816406286\backslash \\
2089986280348253421170679821480865132823066470938446095505822317253594081\backslash \\
2848111745028410270193852110555964646229489549303820
\]

Decimal output can also be obtained by using decimals in the input.

\[
234 + \frac{188.0}{189} = 205.2625715
\]

This does not work when an exact number like $\pi$ appears in the expression to be simplified.

\[
\pi + \frac{3.3}{2.2} = \pi + 1.50000000
\]

Apply \texttt{evalf} to get an approximate value. A 4-digit approximation is obtained below.

\[
evalf(\%, 4) = 4.642
\]  
\textbf{(Note. A percent sign in a Math input refers to the output in the last Maple calculation.)}

\section*{The Usual Functions are Entered in the Usual Way}

The standard functions of calculus are typed into a Math entry in the usual way.

• Enclose the arguments in round parentheses.

• Make sure that there are \textit{no spaces} between the function name and its arguments.

The next entry is a sequence of three trig expressions. The output is on the next line, and labeled, because the [return] key was pressed to process the input. Maple is always in radian mode when it evaluates trig functions.

\[
sin\left(\frac{\pi}{4}\right), \cos(3\pi), \arctan(1)
\]

\[
\frac{1}{2} \sqrt{2}, -1, \frac{1}{4} \pi
\]  
\textbf{(2)}

Since the input is a sequence, the output is also.

The jth term in this output sequence can be obtained by referring to it as \texttt{(2)[j]}. See the next entry where the arcsine function is applied to the second term in sequence \texttt{(2)}.

• The label \texttt{(2)} must be entered by pressing Command-L and typing 2 in the ensuing dialogue.

\[
\text{arcsin}\left(\texttt{(2)[2]}\right) = -\frac{1}{2} \pi
\]

The absolute value function is invoked using vertical slashes, \texttt{ln} denotes to the natural logarithm function.

\[
\ln(|-3.4 + 2|) = 0.3364722366
\]

The exponential function should be entered as \texttt{exp}.

\[
\text{exp}(3.2) = 24.53253020
\]

Type \texttt{exp} [\text{x}] [\text{return}] to obtain a Math input that looks like what you are accustomed to see in math books.

\[
e^{3.2} = 24.53253020
\]

\section*{Two Dimensional (2d) Plots}

Before making a 2d plot we set the default plot color to black and reduce the size of the font for the axes.

\texttt{plots[setoptions](color = black, font = [\textit{times}, roman, 8])}
The plot follows. By pressing Command-equals the output appears on the same line as the input.

\[
p\left(e^{-t}\sin(\pi t), t = 0..4\right) = \]

\[
\begin{array}{c}
\text{0.6} \\
\text{0.4} \\
\text{0.2} \\
\text{0} \\
\text{-0.2}
\end{array}
\]

\[
\begin{array}{c}
\text{1} \\
\text{2} \\
\text{3} \\
\text{4}
\end{array}
\]

The next plot output appears below the plot entry because the input was processed by pressing [return] instead of Command-equals.

\[
p\left([e^{-t}, -e^{-t}, e^{-\sin(\pi t)], t = 0..4, linestyle = [2, 2, 1]}\right)
\]

\[
\begin{array}{c}
\text{0.5} \\
\text{-0.5} \\
\text{t}
\end{array}
\]

\[
\begin{array}{c}
\text{1} \\
\text{2} \\
\text{3} \\
\text{4}
\end{array}
\]

Three curves were drawn, one for each of the expressions appearing in first argument in the \textit{plot} procedure which is a \textit{list} of the expressions to be plotted.

- A list in Maple is a sequence that is enclosed in square brackets: \([\ ]\).

The line style equation assigns the styles numbered 2 (\textit{dot}) and 1 (\textit{solid}, the default line style) to the three curves. There are 7 line styles in all: solid (1), dot (2), dash (3), dashdot (4), and three more.

\textbf{The Number e}

A few more words about the number e are in order. As mentioned above, the exponential function is entered by typing exp, (then pressing [esc] [return] if desired). See the derivative calculation below.

\[
\frac{d}{dt}(e^{-\cos(t)}) = \sin(t) e^{-\cos(t)}
\]

If you just need the number e, type e and then press [esc] [return]. If you do not do this then you will be entering the variable named \textit{e} instead of the number e. See the next Math entry where \textit{evalf} is applied to the list containing the variable \textit{e} and the number e.

\[
evalf([e, e], 6) = [e, 2.71828]
\]

And here are two more integrals. The first one contains an incorrectly entered exponential function.

\[
\int e^{3x} \, dx = \frac{1}{3} \frac{e^{3x}}{\ln(e)} \quad \text{(The integrand was entered incorrectly as e^3xe.)}
\]

\[
\int e^{3x} \, dx = \frac{1}{3} e^{3x} \quad \text{(The integrand was entered correctly as exp [esc] [return] 3x.)}
\]

\textbf{The Number \pi}

The number \pi can be entered by typing pi [esc] [return]. It can also be entered by typing Pi.

\[
evalf([\pi, Pi], 6) = [3.14159, 3.14159]
\]

If you simply enter \textit{pi} without using [esc] [return] then Maple interprets it as the Greek letter \pi.

\[
evalf(pi, 6) = \pi
\]

\textbf{Roots}

A square root can be entered, for example, as sqrt(144). Type sqrt [esc] [return] to obtain \sqrt{.}

\[
sqrt(144), \sqrt{144} = 12, 12
\]

To enter a cube root use a fractional exponent.
\[
8^{1/3} = 8^{1/3} \quad \text{at 5 digits} \quad \rightarrow 2.0000 \quad \text{(Note that Maple did not automatically simplify the output.)}
\]

**Integrals**

An *indefinite* integral can be entered as follows.

\[
\text{int}(4 \cdot x \cdot \sin(2 \cdot x), x) = \sin(2 \cdot x) - 2 \cdot x \cdot \cos(2 \cdot x)
\]

To enter the integral using an integral symbol type int [esc] [return] and choose the appropriate template on the contextual menu.

\[
\int 4 \cdot x \cdot \sin(2 \cdot x) \, dx = \sin(2 \cdot x) - 2 \cdot x \cdot \cos(2 \cdot x)
\]

A *definite* integral can be entered like this.

\[
\text{int}(4 \cdot x \cdot \sin(2 \cdot x), x = 0 \ldots 3) = \sin(6) - 6 \cdot \cos(6)
\]

Or, an integral template can be used. Type int [esc] [return] and choose the definite integral template. Tab from position to position in the template.

\[
\int_{0}^{3} 4 \cdot x \cdot \sin(2 \cdot x) \, dx = \sin(6) - 6 \cdot \cos(6)
\]

If one of the limits of integration is in *decimal* form then Maple will evaluate the integral numerically and return an approximate value.

\[
\int_{0}^{2.0} x^4 \, dx = 2.833876745
\]

Compare the output above to what is obtained below when both limits are in exact form.

\[
\int_{0}^{2} x^4 \, dx = \int_{0}^{2} x^4 \, dx \quad \text{(If Maple cannot evaluate an integral exactly, it returns the unevaluated integral.)}
\]

**Derivatives**

A prime (apostrophe) on an expression denotes differentiation with respect to \( x \).

\[
(x \ln(x) - x)' = \ln(x)
\]

If a prime is attached to a variable, then Maple assumes that the variable represents a function of \( x \).

\[
y' = \frac{d}{dx} y(x)
\]

To differentiate with respect to some other variable type diff [esc] [return] and choose the appropriate derivative template.

\[
\frac{d}{dz} (z + \tan(z)) = 2 + \tan(z)^2 \quad \text{(Maple differentiates \( \tan(z) \) as \( 1 + \tan^2(z) \).)}
\]

An initial value problem is solved below. The solution equation is assigned the name \texttt{soln} (output suppressed), the solution and driver are plotted, and the solution is displayed (three-digit accuracy).

\[
\text{soln} := \text{dsolve}(\{ y'' + 0.2 \cdot y' + 9.01 \cdot y = \cos(3 \cdot x), y(0) = 1, y'(0) = -1 \}) : \\
\text{plot}(\{ \text{rhs(soln)}, \cos(3 \cdot x) \}, x = 0 .. 16, \text{linestyle} = [1, 2], \text{caption} = "The driver is the dotted curve"); \\
\text{evalf(soln, 3)}
\]

\[
y(x) = -1.97 \cdot e^{-0.100 \cdot x} \cdot \sin(3 \cdot x) + 0.972 \cdot e^{-0.100 \cdot x} \cdot \cos(3 \cdot x) + 1.67 \cdot \sin(3 \cdot x) + 0.0278 \cdot \cos(3 \cdot x)
\]