Introduction to *Mathematica* by David Maslanka.

Mathematica is a computer algebra system designed to do mathematics. Symbolic, numerical and graphical computations can all be done with Mathematica. Mathematica's treatment of the topics of calculus is thorough. The user may compose Mathematica instructions to carry out all of the fundamental operations that are studied in Calculus I - III, Differential Equations and Linear Algebra.

1. Starting *Mathematica*

   When using the Windows version of Mathematica, you may open the program by first clicking on the *Start* button:

   ![Start button](image)

   This button is located on the left end of the *Start bar*. Next select *All Programs* from its menu, Choose *Wolfram Mathematica* from the program list displayed, and finally, choose *Wolfram Mathematica 7* from the drop down menu.

   ![Program selection](image)

   You may now copy the link to this program's location and create a shortcut for it on your desktop which will be easily recognizable by its designation with the Mathematica icon:

   ![Mathematica icon](image)

   Whenever Mathematica 7 is started, a blank *notebook file* will open. It is given the default name: Untitled 1.
2. Adjusting the Magnification

The default size of the characters displayed in a Mathematica notebook is rather small. However, the magnification can easily be adjusted by clicking on Window along top toolbar and selecting a more readable magnification, e.g. 150%.

3. Entering an Instruction in Mathematica

We will call any typed string of symbols to be executed by Mathematica's computational engine (or kernel) an instruction. To execute a typed instruction, hit the [Enter] key at the far right of the keyboard. On a laptop or when using the interior [Enter] key on a desktop keyboard, you must strike the [Enter] key while simultaneously holding down the [Shift] key. Instructions entered in the 7.0 version of Mathematica typically appear in black bold type and in Courrier font by default.

Some of the elementary symbols used frequently in Mathematica commands are described below.

• **Integers**: Use the keys on the top row of your computer's keyboard to enter the desired integer. Use the hyphen character " - " also located along this row to denote a negative number.

• **Fractions**: To enter the fraction in a command, insert the slash symbol " / " between the numbers p and q.

• **Decimals**: Decimals are also entered in the natural way.
4. Special Numbers

<table>
<thead>
<tr>
<th>Handwritten Number</th>
<th>Mathematica Syntax</th>
<th>Basic Math Palette Icon</th>
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<tr>
<td>$\pi$</td>
<td>Pi</td>
<td>$\pi$</td>
</tr>
<tr>
<td>$e$</td>
<td>E</td>
<td>$e$</td>
</tr>
<tr>
<td>$\infty$</td>
<td>Infinity</td>
<td>$\infty$</td>
</tr>
<tr>
<td>$-\infty$</td>
<td>-Infinity</td>
<td>$-\infty$</td>
</tr>
<tr>
<td>$i$</td>
<td>I</td>
<td>$i$</td>
</tr>
</tbody>
</table>

*These icons are found in the Basic Calculator menu.

To view the Basic Math Assistant Palette, click on the Palettes button on the Toolbar and then select Basic Math Assistant from its menu.

Note: Mathematica is case sensitive so to indicate the numbers: $\pi$, $e$, $i$, you must type capitalized first letters or click on the palette icon indicated above.

Almost any letter or string of letters and numbers can be used to name a variable. However, certain letters and strings have preassigned meanings and are therefore "protected" and cannot be reassigned, e.g. D denotes the differential operator and cannot be used to name a variable quantity.
5. Numerical Operations : Operational Mathematica syntax

<table>
<thead>
<tr>
<th>Operation</th>
<th>Mathematica Syntax</th>
<th>Typed Character</th>
<th>Basic Math Palette Icon</th>
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<tbody>
<tr>
<td>Addition</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Subtraction</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Multiplication</td>
<td>*</td>
<td>*</td>
<td>X</td>
</tr>
<tr>
<td>Division</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Exponentiation</td>
<td>^</td>
<td>^</td>
<td></td>
</tr>
<tr>
<td>Factorial</td>
<td>!</td>
<td>!</td>
<td>!</td>
</tr>
</tbody>
</table>

*These icons are also found in the Basic Calculator menu:

Examples

In[1]:= 2 + 3
Out[1]= 5

In[2]:= 2 - 3
Out[2]= -1

In[3]:= 2 * 3
Out[3]= 6

Note: To compute the product of 2 times 3, we may simply enter:

2 3

in an input cell, i.e., 2[space]3, and Mathematica will automatically insert the multiplication operator.

In[4]:= 2 × 3
Out[4]= 6

In[5]:= 2 / 3
Out[5]= \(\frac{2}{3}\)
6. Numerical Relations: Relation Mathematica syntax

<table>
<thead>
<tr>
<th>Numerical Relation</th>
<th>Mathematica Syntax</th>
<th>Basic Math Palette Icon*</th>
</tr>
</thead>
<tbody>
<tr>
<td>equality</td>
<td>==</td>
<td>=</td>
</tr>
<tr>
<td>inequality</td>
<td>!=</td>
<td>#</td>
</tr>
<tr>
<td>less than</td>
<td>&lt;</td>
<td>NA</td>
</tr>
<tr>
<td>greater than</td>
<td>&gt;</td>
<td>NA</td>
</tr>
<tr>
<td>less than or equal to</td>
<td>&lt;=</td>
<td>≤</td>
</tr>
<tr>
<td>greater than or equal to</td>
<td>&gt;=</td>
<td>≥</td>
</tr>
</tbody>
</table>

*These palette icons are found in the Operators Typesetting menu:

Examples

In[7]: 3 ≠ 4
Out[7]= True

In[8]: Pi ≤ E
Out[8]= False

In[9]: 3 / 4 = 0.75
Out[9]= True
7. Standard Functions : Function Mathematica syntax

<table>
<thead>
<tr>
<th>Standard Function</th>
<th>Typed Characters</th>
<th>Basic Math Palette Icon*</th>
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</thead>
<tbody>
<tr>
<td>absolute value of</td>
<td>Abs[]</td>
<td>Abs</td>
</tr>
<tr>
<td>square root of</td>
<td>Sqrt[]</td>
<td>√</td>
</tr>
<tr>
<td>base e exponential of</td>
<td>Exp[]</td>
<td>e</td>
</tr>
<tr>
<td>base c logarithm of</td>
<td>Log[]</td>
<td>Log</td>
</tr>
<tr>
<td>base b logarithm of</td>
<td>Log[b, ]</td>
<td>Log[b, expr]</td>
</tr>
<tr>
<td>sine of</td>
<td>Sin[]</td>
<td>Sin</td>
</tr>
<tr>
<td>cosine of</td>
<td>Cos[]</td>
<td>Cos</td>
</tr>
<tr>
<td>tangent of</td>
<td>Tan[]</td>
<td>Tan</td>
</tr>
<tr>
<td>cotangent of</td>
<td>Cot[]</td>
<td>Cot</td>
</tr>
<tr>
<td>secant of</td>
<td>Sec[]</td>
<td>Sec[expr]</td>
</tr>
<tr>
<td>cosecant of</td>
<td>Csc[]</td>
<td>Csc[expr]</td>
</tr>
</tbody>
</table>

Examples

In[11]:= Log[E]

In[12]:= Log[E, E^2]
Out[12]= 2

In[13]:= Sin[Pi / 6]
Out[13]= 1/2

In[14]:= Abs[-5] = 5
Out[14]= True

8. Some Commands for Numerical Calculations

We write some more instructions for calculation using the symbols described above.

In[15]:= (3 + 4) * 9
Out[15]= 63
In[16] := (3 + 4) 9
Out[16] = 63

Out[17] = \frac{3 e}{4}

In[18] := (4 / 3) Pi * r^3
Out[18] = \frac{4 \pi r^3}{3}

In[19] := (4 / 3) Pi r^3
Out[19] = \frac{4 \pi r^3}{3}

Note that (3 + 4)*9 = (3 + 4) 9
and
3*Exp[1]/4 = Exp[1]/4
but
(4/3) Pi*r^3 ≠ (4/3) Pi*r^3

Out[20] = 24

In[21] := Sin[Pi / 6]
Out[21] = \frac{1}{2}

In[22] := Tan[Pi / 4]
Out[22] = 1

In[23] := Abs[-17]
Out[23] = 17

Out[24] = \frac{5}{8}
9. Commands for Decimal Representations of Real Numbers

If you would like to obtain a decimal representation for a particular real number, \( x \), then execute the \textit{Mathematica} instruction \( N[ x ] \).

For example, consider

\begin{verbatim}
In[26]:= N[e]
Out[26]= 2.71828
\end{verbatim}

By default, \textit{Mathematica} will calculate the decimal number to six significant digits. However, this can be changed by adding a digits option to the decimal converter operator.

\begin{verbatim}
In[27]:= N[e, 20]
Out[27]= 2.7182818284590452354
In[28]:= N[Sqrt[2], 25]
Out[28]= 1.772453850905516027298167
\end{verbatim}

Note: An alternative way of obtaining the decimal representation for \( x \) is by entering: \( x \, \text{\texttt{\hspace{1pt}#\hspace{1pt}}} \, N \).

\begin{verbatim}
In[29]:= Sqrt[2] \, \text{\texttt{\hspace{1pt}#\hspace{1pt}}} \, N
Out[29]= 1.77245
\end{verbatim}

10. Commands involving Symbolic Calculations

We will apply some commands to polynomial and rational expressions to simplify, expand or collect like terms. First, we construct a polynomial expression:

\begin{verbatim}
In[30]:= 8 \, x \, ^\, 2 + \, 16 \, x + \, 6
Out[30]= 6 + \, 16 \, x + \, 8 \, x \, ^\, 2
\end{verbatim}

Observe that when \textit{Mathematica} prints a polynomial it always does so in \textit{increasing} powers of the variable.
The percentage symbol \texttt{"\%"} stands for "the last output", so the result of the above instruction is a rational expression in \(x\).

One way to simplify the above rational expression is to use the instruction \texttt{Simplify[expr]} which performs a sequence of algebraic and other transformations on \(expr\), and returns the simplest form it finds.

Another way of simplifying the expression is to invoke the instruction \texttt{Apart[expr]}. This instruction writes the rational expression \(expr\) in terms of its partial fractions decomposition.

Yet another way to fully simplify the rational expression is to invoke the instruction \texttt{Factor[poly]}.

Note that \texttt{Factor[poly]} factors the polynomial \(poly\) over the integers.

The instruction \texttt{Expand[expr]} is used to write the expression \(expr\) as a sum of simple terms. For example, consider

\begin{align*}
\text{In}[35]:= & \quad \texttt{Expand[(2 \, x + 3) \, (4 \, x + 2)]} \\
\text{Out}[35]= & \quad 6 + 16 \, x + 8 \, x^2
\end{align*}

In order to display the polynomial in decreasing powers of \(x\) we may invoke the \texttt{TraditionalForm} instruction:

\begin{align*}
\text{In}[36]:= & \quad \texttt{TraditionalForm[\%]} \\
\text{Out}[36]/\text{TraditionalForm}= & \quad 8 \, x^2 + 16 \, x + 6
\end{align*}

In the above instruction, \texttt{Mathematica} expanded the product of the two linear expressions in \(x\). Of course, this instruction may be applied to more complicated polynomial expressions.
11. Commands to Assign Names or Values to Expressions

It is often useful to assign names to mathematical expressions. This can always be accomplished with an instruction of the form

\[ \text{name} = \text{expr} \]

which assigns to the variable called \text{name} the value \text{expr}. Here, \text{expr} may denote any mathematical expression.

For example, consider the following calculations involving assigned variables:

\[ \text{In[38]} := y = 8x^2 + 16x + 6 \]
\[ \text{Out[38]} = 6 + 16x + 8x^2 \]
\[ \text{In[39]} := Y = y / (2x + 1) \]
\[ \text{Out[39]} = \frac{6 + 16x + 8x^2}{1 + 2x} \]
\[ \text{In[40]} := \text{Simplify}[Y] \]
\[ \text{Out[40]} = 6 + 4x \]
\[ \text{In[41]} := Z = y * Y \]
\[ \text{Out[41]} = \frac{(6 + 16x + 8x^2)^2}{1 + 2x} \]
\[ \text{In[42]} := Z1 = \text{Simplify}[Z] \]
\[ \text{Out[42]} = 4(1 + 2x)(3 + 2x)^2 \]
\[ \text{In[43]} := Z2 = \text{Expand}[Z1] \]
\[ \text{Out[43]} = 36 + 120x + 112x^2 + 32x^3 \]

An instruction of the form \[ \text{expr} /. \text{var} \rightarrow a \] will replace the variable \text{var} with the value of \text{a} in the expression \text{expr}. For example consider the following instructions:

\[ \text{In[44]} := Z1 /. x \rightarrow 2 \]
\[ \text{Out[44]} = 980 \]
The simplest way to define a function \( f \) in Mathematica is with a mapping instruction of the form:

\[
  f\left[ x_\_ \right] := expr
\]

which assigns the name of \( f \) to the mapping of the variable \( x \) into the expression \( expr \) (where, of course, \( expr \) involves \( x \) in the case the function \( f \) is to be nonconstant).

Note the underscore after the variable \( x \) in the definition. It must be inserted in order for the kernel to recognize that \( x \) denotes the independent variable in this definition of the function \( f \).

Consider the following examples:

\[
\text{In}[46]:= f[x_] := x^3 - 2 x + 1
\]

\[
\text{In}[47]:= f[x]
\]

\[
\text{Out}[47]= 1 - 2 x + x^3
\]

\[
\text{In}[48]:= f[5]
\]

\[
\text{Out}[48]= 116
\]

\[
\text{In}[49]:= g[x_] := \cos[3 x]
\]

\[
\text{In}[50]:= g[\pi]
\]

\[
\text{Out}[50]= -1
\]

\[
\text{In}[51]:= f[g[x]]
\]

\[
\text{Out}[51]= 1 - 2 \cos[3 x] + \cos[3 x]^3
\]

Note the difference between the functions \( f \) and \( g \) defined above and the expression \( y \) defined in Mathematica by:

\[
\text{In}[52]:= y = x + \operatorname{Abs}[x]
\]

\[
\text{Out}[52]= x + \operatorname{Abs}[x]
\]

To evaluate this expression \( y \) when \( x = 5 \), we must use the more complicated command:

\[
\text{In}[53]:= y /. x \rightarrow 5
\]

\[
\text{Out}[53]= 10
\]

However, we can convert this expression into a function, \( k \), with an instruction of the form:

\[
 k[x_] = y /. x \rightarrow x
\]

which assigns the name \( k \) to the mapping of the variable \( x \) into the expression \( y \).
In[54]:= \(k[x_] = y /. x \rightarrow x\)
Out[54]= \[x + \text{Abs}[x]\]

In[55]:= \(k[5]\)
Out[55]= 10

Sometimes, we may need to define a piecewise function in Mathematica. To illustrate one way of doing this, consider the following example. Suppose that
\[
f(x) = \begin{cases} 
x^2 & \text{if } x \leq -1 \\
-2 + x & \text{if } -1 < x < 1 \\
x^3 & \text{otherwise}
\end{cases}
\]

To define this function, we may enter the instruction:

In[56]:= \(f[x_] := \text{Piecewise}[[\{(x^2, x <= -1), (x - 2, -1 < x < 1)\}, x^3]]\)

In[57]:= \(f[x]\)
Out[57]= \[
\begin{align*}
x^2 & \quad \text{if } x \leq -1 \\
-2 + x & \quad -1 < x < 1 \\
x^3 & \quad \text{otherwise}
\end{align*}
\]

In general, the instruction
\[
f[x_] = \text{Piecewise}[[\{\text{val}_1, \text{cond}_1\}, \{\text{val}_2, \text{cond}_2\}, \ldots, \{\text{val}_n, \text{cond}_n\}], \text{val}]
\]
assigns the value \(\text{val}_i\) to the function \(f\) at \(x\) in case the condition \(\text{cond}_i\) is TRUE. It assigns the value \(\text{val}\) to \(x\) whenever none of the conditions \(\text{cond}_i\), \(i = 1, 2, \ldots, n\) are TRUE.

Examples

In[58]:= \(p[x_] := \text{Piecewise}[[\{(x^2, x <= 1), (2 - x, 1 <= x <= 2), (2*x - 2, x > 2)\}]\)

In[59]:= \(p[x]\)
Out[59]= \[
\begin{align*}
x^2 & \quad x < 1 \\
2 - x & \quad 1 \leq x \leq 2 \\
-2 + 2x & \quad x > 2 \\
0 & \quad \text{True}
\end{align*}
\]

In[60]:= \(q[x_] := \text{Piecewise}[[\{(x, x < 3)\}], 3]\)

In[61]:= \(q[x]\)
Out[61]= \[
\begin{align*}
x & \quad x < 3 \\
3 & \quad \text{True}
\end{align*}
\]

In[62]:= \(p[4]\)
Out[62]= 6

In[63]:= \(p[2]\)
Out[63]= 0
In[64]:= q[5]

Out[64]= 3

In[65]:= q[a + b]

Out[65]= a + b < 3

3 True

In[66]:= PiecewiseExpand[Abs[x], x ∈ Reals]

Out[66]= Abs[x]

13. Commands for Solving Equations

An instruction of the form

Solve [equa, vars ]

asks Mathematica to solve the equation equa in terms of the variables vars. For example, consider

In[67]:= y = Solve[x^5 + 12 x^3 - 4 x == 0, x]

Out[67]= {x -> 0}, {x -> -\sqrt{2 (3 + \sqrt{10})}}, {x -> \sqrt{2 (3 + \sqrt{10})}},

{x -> -i \sqrt{2 (3 + \sqrt{10})}}, {x -> i \sqrt{2 (3 + \sqrt{10})}}

Each of the five solutions listed above has a unique name. To pick out the second solution, we enter:

In[68]:= x /. y[[2]]

Out[68]= -\sqrt{2 (3 + \sqrt{10})}

Similarly, the fourth solution is designated by:

In[69]:= x /. y[[4]]

Out[69]= -i \sqrt{2 (3 + \sqrt{10})}

Mathematica can often solve equations which have an infinite number of solutions with the Reduce instruction. Reduce[ expr, vars, dom ] executes the reduction over the domain dom. Common choices of dom are Reals, Integers and Complexes.

Recall how the function

k (x) = x + |x| which was defined above and consider the command:

In[70]:= k[x]

Out[70]= x + Abs[x]
However, sometimes it may be too complicated for Mathematica to express all of the solution to an equation in terms of the usual operations of algebra.

For a nonpolynomial equation the Solve and Reduce instructions may still be invoked to find its solutions.

In order to plot the expression \( expr \) involving the single variable \( var \) over the interval \([a, b]\), we use an instruction of the form:

\[
\text{Plot}\left[ expr, \{var, a, b\}\right] 
\]

For example, suppose
In[77]:= \[ y = 3x^4 - 4x^3 \]

Out[77]= \[ -4x^3 + 3x^4 \]

In[78]:= \[ Plot[y, \{x, -2, 2\}] \]

Note that the general shape of this graph is not easily recognized due to the large values that \( y \) attains when \( x \) lies in the interval \([-2, -1]\). We can restrict the range of the plotted curve to the interval \([c, d]\) by entering:

\[ Plot[expr, \{var, a, b\}, PlotRange \rightarrow \{c, d\}] \]

In[79]:= \[ Plot[y, \{x, -2, 2\}, PlotRange \rightarrow \{-1, 4\}] \]

Now consider the following function described in terms of the absolute value and the signum functions:

In[80]:= \[ h[t_] := Abs[t]^{1/2} \times Sign[t] \]
The signum function is denoted `Sign` in Mathematica, is defined by:

\[
\text{Sign}(x) = \begin{cases} 
-1 & \text{if } x < 0 \\
0 & \text{if } x = 0 \\
1 & \text{if } x > 0
\end{cases}
\]

Therefore, we can express the function \( h \) more simply as:

\[
h(t) = t^{1/3}
\]

In order to plot \( h \) over the interval \( x \in [-10, 10] \) we input:

\[
\text{In[82] = \text{Plot}[h[t], \{t, -10, 10\}]}
\]

As before, we may restrict the plot of the range of this function to the interval \( [c, d] \) by utilizing the `Plot` option:

\[
\text{PlotRange} \rightarrow \{c, d\}
\]
The option `PlotStyle -> {Thickness[n]}` may be inserted in a plot command to control the width of the plot of the curve. The value of \(n\) denotes the thickness of lines as a fraction of the total width of the graphic.

The color of the curve can also be specified using the `PlotStyle` option in a `Plot` instruction.
II . Plotting Functions of One Variable Possessing Jump Discontinuities.

Recall the piecewise defined function $f$ from the example in  Section 11 :

In[87]:= Clear[f]

In[88]:= f[x_] := Piecewise[{{x^2, x <= -1}, {x - 2, -1 < x < 1}}, x^3]

In[89]:= f[x]

Out[89]= \[
\begin{cases}
  x^2 & x \leq -1 \\
  -2 + x & -1 < x < 1 \\
  x^3 & \text{True}
\end{cases}
\]

III . Plotting Several Functions or Expressions Together.

The forms of the commands for plotting several functions or expressions together are analogous to those described above in section I. However, the set of functions/expressions to be plotted must be enclosed by curly braces " { } " within the Plot instruction.

Consider the following examples:

(a) Plotting two or more expressions together
\textbf{In[91]}: \quad w = 3x^4 - 4x^3 - 12x^2 + 5

\textbf{Out[91]}: \quad 5 - 12x^2 - 4x^3 + 3x^4

\textbf{In[92]}: \quad v = 10x^3 - 43x

\textbf{Out[92]}: \quad -43x + 10x^3

\textbf{In[93]}: \quad \text{Plot}\{\{w, v\}, \{x, -2, 2\}, \text{PlotStyle} \rightarrow \{\text{Red, Green, Thick}\}\}

\textbf{Out[93]}: \quad \text{(b) Plotting two or more functions together}

\textbf{In[94]}: \quad \text{Plot}\{\{w, v\}, \{x, -2, 2\}, \text{PlotStyle} \rightarrow \{\text{Green, Red, Thick}\}\}

\textbf{Out[94]}: \quad \text{(b) Plotting two or more functions together}

\textbf{In[95]}: \quad g[x_] := x^2

\textbf{In[96]}: \quad h[x_] := x^3
In[97] := Plot[{g[x], h[x]}, {x, -2, 2}, PlotStyle -> {Blue, Magenta, Thick}]

Out[97]=

(c) Plotting functions and expressions together

In[98] := Plot[{g[x], h[x], w, v}, {x, -2, 2},
PlotStyle -> {Orange, Green, Blue, Magenta, Thickness[0.05]}]

Out[98]=

IV. Plotting curves together with different linestyles for distinction.
V. Plotting Equations in Two Variables.

The instruction:

\[
\text{ContourPlot[equ, \{x, x_{\text{min}}, x_{\text{max}}\}, \{y, y_{\text{min}}, y_{\text{max}}\}}]
\]

plots the equation \(\text{equ}\) in the variables \(x\) and \(y\) over the ranges \([x_{\text{min}}, x_{\text{max}}]\) and \([y_{\text{min}}, y_{\text{max}}]\) for the variables \(x\) and \(y\) respectively. Consider the following example.
In order to use the same scale for a unit length along both the $x$ and $y$ axes, we include the option \texttt{AspectRatio$\to$Automatic} in the \texttt{Plot} instruction.

To make the $x$ and $y$ axes appear in the graph of the cardioid, and to eliminate the box circumscribing it, we include the option \texttt{Axes$\to$True, Frame$\to$False} in the \texttt{Plot} instruction.
In[103]:= ContourPlot[x^4 + (-4 + y) y^3 + 2 x^2 (-2 - 2 y + y^2) = 0, {x, -4.7, 4.7}, {y, -3, 5}, AspectRatio -> Automatic, Axes -> True, Frame -> False]

Out[103]=

To adjust the color and thickness of the graph, we use the option

ContourStyle -> {Color, Thickness[.003]} in the ContourPlot instruction.

In[104]:= M = ContourPlot[x^4 + (-4 + y) y^3 + 2 x^2 (-2 - 2 y + y^2) = 0, {x, -4.7, 4.7}, {y, -3, 5}, AspectRatio -> Automatic, Axes -> True, Frame -> False, ContourStyle -> {Magenta, Thickness[.003]}, ContourShading -> {Purple}]

Out[104]=
15. Instructions for Adding Labels to Graphs

In order to add text to a plot, we must

(i) assign a name to the plot, e.g. \texttt{name1=Plot[...]} or \texttt{name1 = ContourPlot[...]}text

(ii) construct a text instruction of the form:

\texttt{name2 = Graphics[Text["expr",{xo, yo}], TextStyle \rightarrow \{Fontsize \rightarrow nmbr, clr\}];}

in order to add the text \texttt{expr} centered at the point \texttt{(xo, yo)} with font size \texttt{nmbr} and in the color \texttt{clr}.

(iii) Execute the instruction:

\texttt{Show[ name1, name2 ]}

in order to display both the plot and the text in a single coordinate plane.

For instance, we may add a text description to the graph of the cardioid plotted above.

\texttt{T = Graphics[Text["The cardioid: $x^4 + (y-4)y^3 + 2x^2(y^2-2y-2) = 0$", {0, 4.5}, TextStyle \rightarrow \{Fontsize \rightarrow 12, Bold, Orange\}];}
The cardioid: $x^4 + (y-4)y^3 + 2x^2(y^2-2y-2) = 0$

Observe that the cardioid passes has the intercepts: $(0, 0), (+2, 0), (0, 4)$.

We may highlight these points by adding blue circular disks at each of these intercepts in the figure using the instruction:

```
Disk[{x, y}, r].
```

```
In[108]= D1 = Graphics[{Blue, Disk[{0, 0}, 0.075]}];
D2 = Graphics[{Blue, Disk[{2, 0}, 0.075]}];
D3 = Graphics[{Blue, Disk[{-2, 0}, 0.075]}];
D4 = Graphics[{Blue, Disk[{0, 4}, 0.075]}];
```
In[112]:= Show[M, T, D1, D2, D3, D4]

Out[112]=

The cardioid: $x^4+(y-4)y^3+2x^2(y^2-2y-2)=0$

16. Commands for Differentiation and Integration

Enter the instruction  \textbf{D} \ [ \textit{expr} , \var ]

to differentiate the expression \textit{expr} with respect to the variable \var

\texttt{In[113]= S = t^4 - t^3 + t^2}
\texttt{Out[113]= t^3 - t^3 + t^4}
\texttt{In[114]= D[S, t]}
\texttt{Out[114]= 2 t - 3 t^2 + 4 t^3}
\texttt{In[115]= F[x_] = Cos[x] - Sin[x]}
\texttt{Out[115]= Cos[x] - Sin[x]}
\texttt{In[116]= D[F[x], x]}
\texttt{Out[116]= -Cos[x] - Sin[x]}

The derivative of a function, \textit{F}, may also be found using the instruction  \textbf{F}'[ \textit{x} ].

\texttt{In[117]= F'[x]}
\texttt{Out[117]= -Cos[x] - Sin[x]}

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Enter the instruction:

\textbf{Integrate} [ \textit{expr}, \textit{var} ]

to obtain an antiderivative, (no constant of integration appears), of the given expression \textit{expr} with respect to the variable \textit{var}. Alternatively, you may use the integral operator located in the Calculus section of the Basic Commands palette.

To obtain the definite integral of an expression, we use a command of the form

\textbf{Integrate} [ \textit{expr}, \textit{var}, \{a, b\} ] .

Alternatively, you may also use the Basic Commands Pallette to enter the definite integral.
In[130]:= \textbf{Integrate}[S, \{t, 0, 2\}]

Out[130]= \frac{76}{15}

In[131]:= \int_{0}^{2} S \, dt

Out[131]= \frac{76}{15}

In[132]:= \textbf{Integrate}[S, \{t, 0, 2\}]

Out[132]= \frac{76}{15}

In[133]:= \textbf{Integrate}[F[x], \{x, 1, 5\}]

17. Inserting a New Input Cell Between Two Existing Instructions

In order to insert a new line of input between two existing Mathematica instructions, just slide the mouse vertically in the notebook window to the desired location. The vertical bar "|" tracing the mouse's position will change to a horizontal one " -- " when positioned between two adjacent input cells. When the horizontal bar is attained, right click the mouse. Then a pop-up menu and a vertical line across the page should appear. Now select **Insert New Cell → Input** from this menu. A new input cell now will appear between the two existing instructions.

18. Instructions for Adding Text to Mathematica Notebooks

Mathematica may be used as a word processor to add text to a notebook file. Once an instruction is executed, the program is expecting a new instruction. In order to enter text to the document instead, simply click on **[Create Text Cell]** from the **Basic Calculator** portion of the **Basic Math assistant Palette**.

All characters entered now will appear in Times Roman font by default. This type further indicates that these symbols are in text format. Mathematica instructions cannot be entered while in text mode.

After you have completed typing all your comments in the section you may return to executing Mathematica instructions by clicking **[Create Input Cell]** on the **Basic Calculator** portion of the **Basic Math assistant Palette**.

To insert mathematical symbols or expressions while in text mode, you may use the features of the **Typesetting** portion of the Basic Math Assistant Palette. The palette works much like the Equation Editor does in MS Word.

You may also copy **TraditionalForm** output from a Mathematica instruction into a text cell.

You may also insert a new text cell between two existing cells using a procedure analogous to that described in section 17 for inserting a new input cell between two existing cells.