Dr. Straight's Maple Examples
Example V: Plane Plots
Functions Covered: @ (composition of functions), densityplot, implicitplot, plot, polarplot

One of the most useful functions in Maple is the plot function. It comes with many options; for details, use the "Help" feature and search for "plot/details" or "plot/options." Here are some examples.

\[
> f := x \rightarrow \exp(-x) \cdot \sin(x);
\]

\[
> plot(f(x), x = 0..2\pi);
\]

To gain more control over the "window" Maple employs, use the "view" option:

\[
> plot(f(x), x = 0..2\pi, view = [-1..7, -0.1..0.4]);
\]
To place a caption on the graph, use the "caption" option:

\[ \text{plot}(f(x), x = 0 .. 2 \cdot \pi, \text{view} = [-1 .. 7, -0.1 .. 0.4], \text{caption} = 'The graph of } y = f(x) \text{ on } [0, 2 \cdot \pi]' \];
The graph of \( y = f(x) \) on \([0, 2\pi]\)

To specify the color of the graph, use the "color" option:

\[
plot(f(x), x = 0 .. 2\pi, \text{view} = [-1 .. 7, -0.1 .. 0.4], \text{color} = \text{blue});
\]
Sometimes, it is useful to see the "gridlines" when plotting a function. To do so, set the option "gridlines" to true (the default value is false):

\[
\text{plot}(f(x), x = 0 .. 2 \pi, \text{view} = [-1 .. 7, -0.1 .. 0.4, \text{gridlines} = \text{true}]);
\]
Use the "label" option to label the axes:

\[ \text{plot}(f(x), \ x = 0 \ .. \ 2 \ \pi, \ \text{view} = [-1 \ .. \ 7, \ -0.1 \ .. \ 0.4], \ \text{labels} = [\text{time}, \ \text{displacement}]); \]
Let's plot the top half of the ellipse $x^2 + 4y^2 = 25$:

```latex
> plot\left(\frac{\sqrt{25-x^2}}{2}, x=-5..5, view=[-6..6,-1..3]\right);
```

\textit{displacement}
Maple's plot makes it look like the major axis of the ellipse is the y axis when, in fact, the major axis is the x axis. To remedy the situation, we use the "scaling" option, set to be "constrained" (the default value for this option is "unconstrained"):

\[ \text{plot}\left( \frac{\sqrt{25-x^2}}{2}, x=-5..5, \text{view}=[-6..6,-1..3], \text{scaling=constrained} \right); \]
That's better! Note that "scaling = constrained" tells Maple to make 1 unit on the $x$ axis the same length as 1 unit on the $y$ axis.

If you have several functions you wish to plot, put them in a list.

```maple
> plot([f(x), x/10], x = 0 .. Pi);
```
Again, you can specify, using a list, the colors to use:

$> \text{plot}\left(\left[f(x), \frac{x}{10}\right], x = 0 .. \pi, \text{color} = [\text{black, blue}]\right);$
If you are going to be printing your plot in black and white, then you may wish to distinguish the two graphs by using different line styles. For this, use the "linestyle" option; among the choices for the line style are: solid (the default), dot, and dash.

```octave
> plot([f(x), x/10], x = 0 .. pi, color = [black, black], linestyle = [dot, dash]);
```
Next, we investigate the `implicitplot` function. This is used to plot curves defined by equations in two variables. It is contained in the "plots" package; thus, before using the `implicitplot` command, we need to open the plots package.

```text
> with(plots) :
> implicitplot(x^2 + 4 \cdot y^2 = 25, x = -5 ..5, y = -2.5 ..2.5, view = [ -6 ..6, -3 ..3], scaling = constrained);
```
Again, if you have several functions you wish to implicit plot, put them in a list.

> `implicitplot([x^2 + 4*sqrt(5), y = x - 5], x=-6..6, y=-6..6, view=[-6..6, -6..3], scaling = constrained);`
I like to see the gridlines. Also, let's add some color:

```maple
> implicitplot([x^2 + 4*y^2 = 25, y = x - 5], x = -6 .. 6, y = -6 .. 6, view = [-6 .. 6, -6 .. 3], color = [blue, green], scaling = constrained, gridlines = true);
```
From this plot, it is natural to conjecture that the ellipse and the line intersect at (3,-2) and at (5,0). This conjecture can then be verified algebraically.

> \[ g := x \rightarrow x^2; \]  

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> \[ h := x \rightarrow \sin(x); \]  

> \[ h := x \rightarrow \sin(x) \]  

The @ symbol is used to denote composition.

> \[ plot( (g @ h)(x), x = -\pi..\pi); \]
> plot((h @ g)(x), x = -π..π);
Here's another example of plot. Note how Maple adds the vertical asymptotes.

> \[ f := x \mapsto \frac{\sqrt{4 - x^2}}{x^2 - 1} ; \]

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> \text{plot}(f(x), x = -3..3, \text{view} = [-3..3, -10..10], \text{color} = \text{blue});
Let's move on to parametric plots. To plot the curve defined parametrically by \((x(t), y(t))\), for \(t\) between \(a\) and \(b\), use \(\text{plot}([x(t), y(t), t=a..b])\). The usual options are available.

> \(\text{plot}([t - \sin(t), 1 - \cos(t), t = 0 .. \pi], \text{view} = [-1 .. 7, -0.5 .. 2.5], \text{gridlines} = \text{true}, \text{scaling} = \text{constrained});\)
To plot the curve $r = f(\theta)$ in polar coordinates, use the `polarplot` command from the `plots` package.

```maple
> with(plots):
> polarplot(1 + 2*sin(\theta), \theta = 0 .. 2*\pi);
```
Again, several curves may be plotted together by using a list.

> \texttt{polarplot([3 - 3 \cdot \sin(\theta), \theta], \theta = 0..2 \cdot \pi, color = \texttt{[black, blue]})};
Finally, we look at the `densityplot` command. This command is also contained in the `plots` package. The simplest form is

```
densityplot(f(x,y),x = a..b, y = c..d)
```

It produces an "image," where the value $f(x,y)$ is interpreted as a shade of gray. For example:

```
> with(plots):
> densityplot(100 - x*y, x = 1..10, y = 1..10);
```
We illustrate a few of the options; for details, use “Help.”

> densityplot(100 - x*y, x = 1..10, y = 1..10, colorstyle = RGB);
I don't like this one, because the image should be symmetric with respect to the line $y = x$. Let's try a different option.

> `densityplot(100 - x*y, x = 1..10, y = 1..10, colorstyle = HUE);`
To get more “pixels,” use the grid option:

\[
\text{densityplot}(100 - x \cdot y, x = 1..10, y = 1..10, \text{grid} = [50, 50], \text{colorstyle} = \text{HUE});
\]
There is another version of the *densityplot* command that is used in conjunction with a Maple procedure. In a later example, we'll see how this can be used to graph the Mandelbrot set and Julia sets.