*Tutorials and worked examples for simulation, curve fitting, statistical analysis, and plotting.*
*http://www.simfit.org.uk*

Plotting mathematical equations over a range is often required and the programs and techniques available to do this are as follows.

1. Program **makdat**
   After selecting a model from the compiled library or as a user-defined model, plots can be displayed over a chosen range.

2. Program **deqsol**
   This is similar to the using program **makdat** but is preferred if it is wished to plot systems of nonlinear differential equations, or phase portraits or orbits for autonomous systems.

3. Program **usermod**
   This has similar functionality to program **makdat** except that it allows users to defines a model or set of models interactively. Once a model has been developed it can be archived for future use, so this is the only technique that will be described in this document.

## Defining a mathematical model interactively

From the main SIMFIT menu use the option [A/Z] to open program **usermod** and observe that there is an option to define a model interactively, and when this has been done the mathematical model can be checked for correct syntax, plotted over a chosen range or archived for retrospective use. Some simple examples to illustrate the functionality of program **usermod** will now be given. However note that you will have to be prepared to input the following values.

- The number of equations $NEQN \geq 1$
  The equations will be defined as $f(1), f(2), \ldots, f(NEQN)$.

- The number of variables $NVAR \geq 1$ (or differential equations which assumes $NVAR = 1$)
  The variables will be either $NVAR = 1$ using the symbol $x$ for the independent variable to plot 2 dimensional curves, or $NVAR = 2$ using the symbols $x$ and $y$ for the independent variables to display 3 dimensional surfaces.

- The number of parameters $NPAR \geq 0$
  The parameters will be $p(1), p(2), \ldots, p(NPAR)$ and these can be defined and varied interactively if it is required to study the effect of parameter values on the plots.

## Example 1: A quadratic equation

The mathematical model will be the quadratic

$$f(x) = x^2 - 1.$$

So you have to create a user-defined model with these characteristics:

- One equation $NEQN = 1$
- One variable $NVAR = 1$
- No parameters $NPAR = 0$

then the following unfinished model file will be displayed.

```
%
This is a default template for a user-defined-model file.
%
1 equation
1 variable
0 parameters
%
begin{expression}
f(1) =
end{expression}
%
```

The empty field is then filled in to replace the string `f(1) =` by `f(1) = x^2 - 1` as shown below.

---

```
%
The model y = x^2 - 1 = (x - 1)(x + 1).
%
1 equation
1 variable
0 parameters
%
begin{expression}
f(1) = x^2 - 1
end{expression}
%
```

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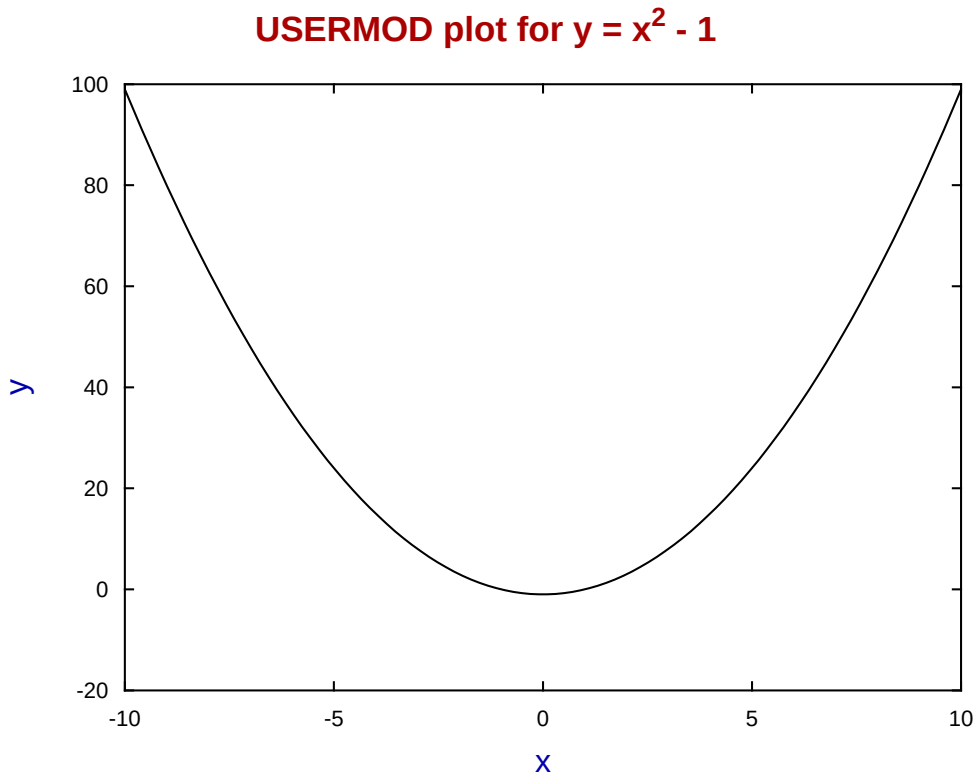
This is then checked for consistency and the option is provided to plot the model as in the next figure.



## Example 2: Four trigonometric functions

Selecting four functions of one variables with four parameters and then choosing

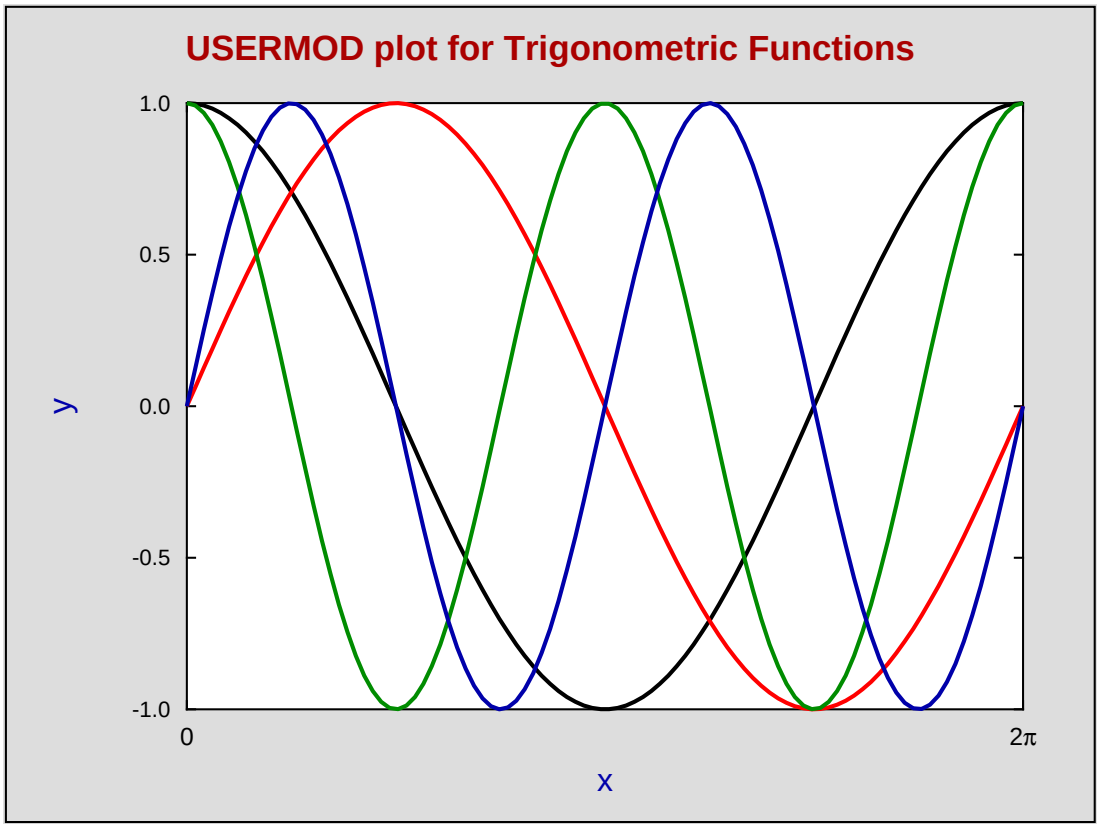
$$f_1(x) = p_1 \cos x,\ f_2(x) = p_2 \sin x,\ f_3(x) = p_3 \cos 2x,\ f_4(x) = p_4 \sin 2x$$

leads to the following model.

```
 %
f(1)=p(1)cos(x), f(2)=p(2)sin(x), f(3)=p(3)cos(2x), f(4)=p(4)sin(2x)
 %
 4 equations
 1 variable
 4 parameters
 %
 begin{expression}
 f(1) = p(1)cos(x)
 f(2) = p(2)sin(x)
 f(3) = p(3)cos(2x)
 f(4) = p(4)sin(2x)
 end{expression}
 %
```

---

This is then checked for consistency and the option is provided to plot the model as in the next figure using the default values of 1 for all the parameters.




The border, colors, line thicknesses, and title were added using the Advanced Graphics option and the $x$ labels were plotted as characters instead of numbers and edited to show the range ($0 \le x \le 2\pi$).

## Example 3: A quadratic surface with contours

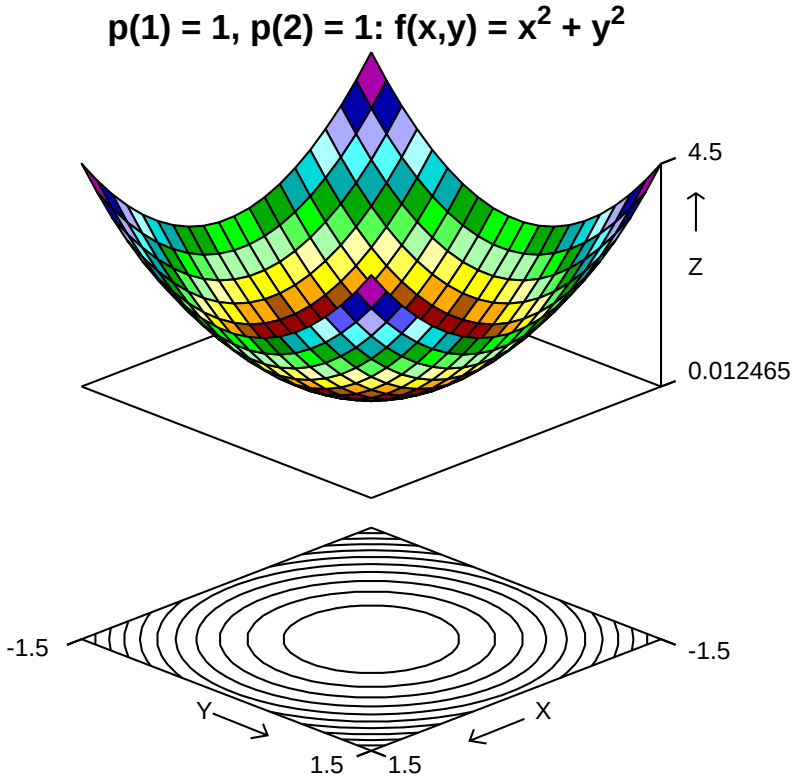
Select one function of two variables with two parameters then create the following model.

```
%
A function of two variables.
%
1 equation
2 variables
2 parameters
%
begin{expression}
f(1) = p(1)x^2 + p(2)y^2
end{expression}
%
```

Note that the default parameters are

$$p_1 = 1, p_2 = 1$$

which defines the following convex paraboloid.




However it is possible to edit the parameters using the same model to create a hyperboloid by setting

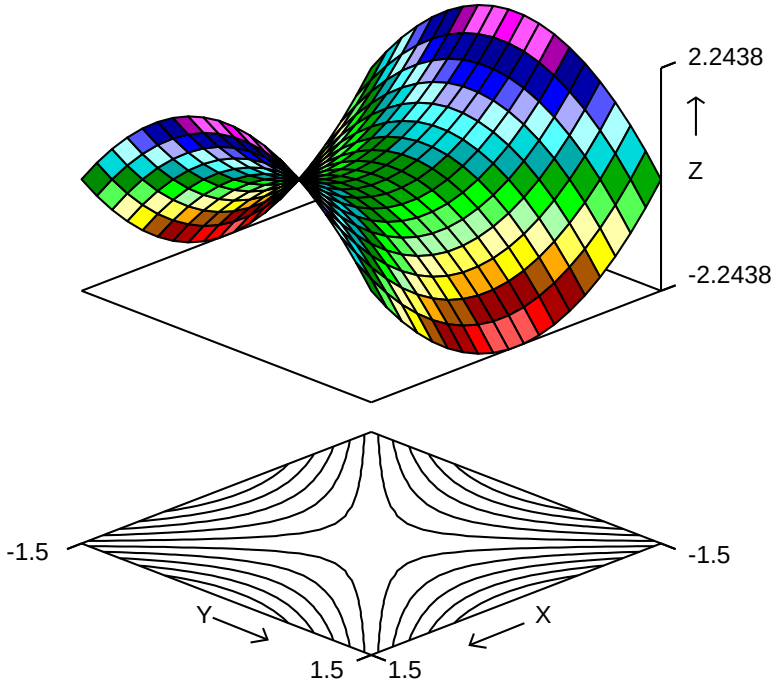
$$p_1 = 1, p_2 = -1$$

or a concave paraboloid by using

$$p_1 = -1, p_2 = -1$$

as demonstrated in the next two plots.

**p(1) = 1, p(2) = -1: f(x,y) = $x^2 - y^2$**

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**p(1) = -1, p(2) = -1: f(x,y) = - ($x^2 + y^2$)**