Function inputs may be functions. If *fplot* was not part of Matlab, we could easily create something very similar.

```
function [  ] = DIYfplot( f, range )
%DIYfplot Do it yourself version of fplot. Plots a function over a range.
% Inputs:  f = function to be plotted
%          range = two element vector containing start and end of range
% No Outputs (like a C++ void function)

n = 100; % number of points

x = linspace (range(1), range(2), n); % generate x values

% generate y values
y = zeros ([1 n]); % preallocate for efficiency
for k = 1 : n
   y(k) = f(x(k));
end

plot (x, y);

end
```

The function provided may be a function m-file (see DIYplot.m) (@ required before name);

```
DIYfplot( @PR, [0 7])
>> grid on
>> xlabel ('Mach number');
>> ylabel ('Pressure Ratio');
```

Built in functions are also acceptable (@ required before name):

```
>> DIYfplot( @sin, [0 4*pi])
```

And so are anonymous functions (no @ required – the @ is in the definition).

```
>> f = @(x) x^3 + 2* x^2 + 7;
>> DIYfplot( f, [-5 5])
```

Note: We could also create our own version of *fzero* and will soon be doing exactly this.

Another potentially useful function is shown below. It produces a table of function values (see ftable.m)

```
function [  ] = ftable( f, vector )
%ftable Produces table of function values.
% Inputs:  f = function to be tabulated
%          vector = vector of values for the independent variable
% No Outputs (like a C++ void function)

fprintf ('  Independent      Dependent\n');

for k = 1 : length(vector)
   x = vector(k);
   y = f(x);
   fprintf ('%12f%16f\n', x, y);
end

end
```

Sample usage:

```
>> ftable (@PR, 1:0.5:6)
  Independent       Dependent
    1.000000         1.892929
    1.500000         3.413275
    2.000000         5.640441
    2.500000         8.526136
    3.000000        12.060965
    3.500000        16.242001
    4.000000        21.068081
    4.500000        26.538665
    5.000000        32.653474
    5.500000        39.412352
    6.000000        46.815206
```

Improved Loop:

The loop in the function can be reduced to:

```
for x = vector
   fprintf ('%12f%16f\n', x, f(x));
end
```

The table below shows the situations in which a “dot” must be used to avoid having Matlab assume array arithmetic (e.g. array multiplication) . The “dot” tells Matlab to perform an element by element operation instead. **Note:** there is no “.+” or “.-”

op	Array **op** Scalar	Scalar **op** Array	Array **op** Array
+, -	OK [1 2 3] + 4 = [5 6 7]	OK 9 – [1 2 3] = [8 7 6]	Array operation assumed Sizes must match
*	OK [1 2 3] * 2 = [2 4 6]	OK 2 * [1 2 3] = [2 4 6]	Array operation assumed Sizes must be compatible **Dot required** Sizes must match. [2 3 4].*[1 2 3] = [2 6 12]
/	OK [2 4 6] / 2 = [1 2 3]	Array operation assumed ERROR (as sizes are incompatible) **Dot required** 8 ./ [1 2 4] = [8 4 2]	Array operation assumed Sizes must be compatible. **Dot required** Sizes must match. [2 6 12] ./ [1 2 3] = [2 3 4]
^	Array operation assumed Square array required **Dot required** [1 2 3] .^ 2 = [1 4 9]	Array operation assumed Square array required **Dot required** 2 .^ [1 2 3] = [2 4 8]	ERROR **Dot required** Sizes must match. [2 3 4].^[1 2 3] = [2 9 64]

To evaluate $B(t) = \dfrac{250}{1 + 56.75e^{-0.17t}}$ **for a vector of *t* values:**

```
>> t = [ 0 10 20 ];
>> -0.017 * t
ans =
        0   -0.1700   -0.3400
>> exp(ans)
ans =
   1.0000    0.8437    0.7118
>> 56.75*ans
ans =
  56.7500   47.8780   40.3930
>> 1+ans
ans =
  57.7500   48.8780   41.3930
>> 250/ans    % a scalar divided by a vector is a no-no (see table)
??? Error using ==> mrdivide
Matrix dimensions must agree.
>> 250./ans
ans =
   4.3290    5.1148    6.0397
>> B = @(t) 250./(1 + 56.75*exp(-0,17*t));
```

Problem (text 5.14): You buy a \$25,000 piece of equipment for nothing down at \$5,500 per year for 6 years. What interest rate are you paying?

The formula below relates the payment amount (*A*) to the present worth of the item (*P*), the number of years (*n*), and the interest rate (*i*, expressed as a fraction, 1% = 0.01)

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1}$$

If we knew *P*, *n*, and *i* we could easily calculate *A*, but this isn't the problem. We know *A*, *P*, and *n* and want to calculate *i*.

Ideally we'd manipulate the equation to obtain an expression for *i* in terms of *A*, *P*, and *n* (remember that analytic solutions are best when we can obtain them).

i = *somefunction* (*A*, *P*, *n*)

Since we can't do this easily we will convert the problem into root finding form

$$P\frac{i(1+i)^n}{(1+i)^n - 1} - A = 0$$

and use numerical methods (e.g. *fzero*) to find the value of *i* that satisfies the equation.

Step 1: Define the basic function.

```
>> P = 25000; n = 6;
>> calcA = @(i) P * (i .* (i + 1).^n) ./ ((i + 1).^n - 1);
```

Step 2: Plot the function to get some idea of its behaviour and the approximate location of the solution.

```
>> fplot (calcA, [0.01 0.20])    % plot for interest rates from 1% to 20%
```

Step 3: Define the function for root finding (the *f* in *f*(*x*) = 0).

```
>> A = 5500;
>> f = @(i) calcA(i) - A;
```

Step 4: Use *fzero* to locate the desired root. In this case the plot tells us that the answer is somewhere between 6% and 10%.

```
>> i = fzero(f, [0.06 0.10])
i =  0.0856
```

```
>> calcA(i)   % check that answer is correct (always a good idea)
ans = 5.5000e+003
```

The basic idea can be used to produce a useful function m-file that calculate the interest rate for any given *P*, *A*, and *n*.

```
function [ i ] = P5_14( P, A, n )
%P5_14 Calculate interest rate.
% NOTE: Assumes that interest rate is >= 0.005.
% Inputs:  P = present value of item
%          A = annual payment
%          n - number of years
% Outputs: i = interest rate (as a fraction)

f = @(i) (P * (i .* (i + 1).^n) ./ ((i + 1).^n - 1)) - A;

maxi = A/P; % if i is very large, eq'n becomes A=Pi, hence i=A/P

i = fzero(f, [ 0.005 maxi ] );

end
```

The search for the root cannot be made to start at zero because *f* is undefined at i = 0 (as the formula for calculating *A* does not work for *i* = 0).

This difficulty can be overcome by producing a *calcA* function that properly deals with the special case of *i* = 0. This function could be implemented in a separate m-file but it is also possible to place it in the same m-file as the basic function as shown below. This makes it a *subfunction* (interested students should read text s.3.1.3/App. A).

```
function [ i ] = P5_14v2( P, A, n )
%P5_14v2 Calculates interest rate.
%  Inputs and outputs as before…

f = @(i) calcA (P, n, i) - A;
maxi = A/P;
 i = fzero(f, [ 0 maxi ] );


 end


function [A] = calcA (P, n, i)
 if i == 0
   A = P / n;
else
   A =  P * (i .* (i + 1).^n) ./ ((i + 1).^n - 1);
end


end
```

Problem: Find all of the points that satisfy both $y = x^2 - 17x + 60$ and $y = 50\sin(x/2)$ (i.e. find all of the intersections of the curves defined by these equations).

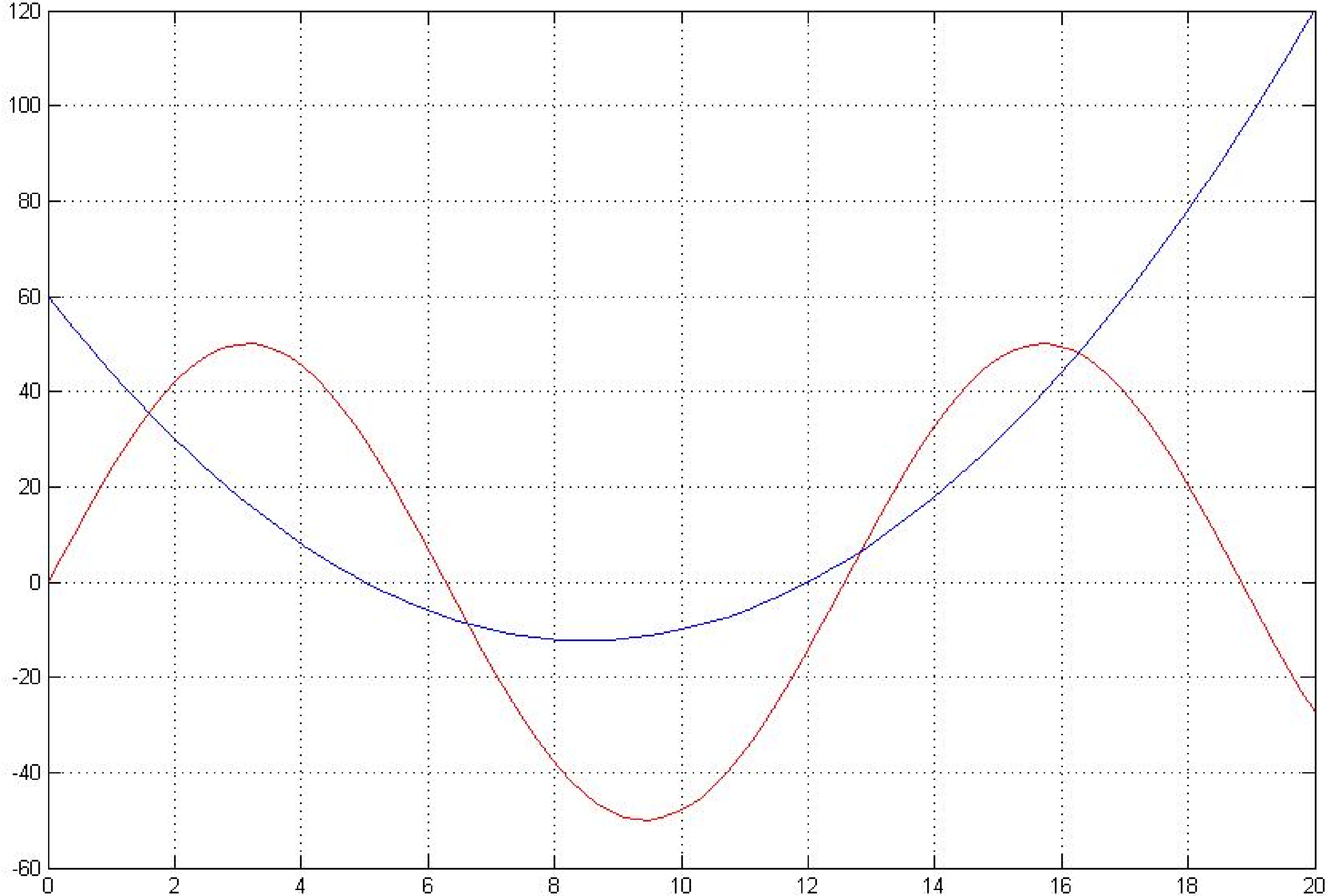
Step 1: Plot the two curves.

```
>> f1 = @(x) 50 * sin(0.5 * x);
>> f2 = @(x) x.^2 - 17 * x + 60;

>> x = linspace (0, 20, 100);
>> y1 = f1(x); y2 = f2(x);

>> plot (x, y1, 'r', x, y2, 'b')
>> grid on
```

The plot function will accept more than one pair of *x* and *y* vectors. This allows multiple plots to be placed on the same graph. Each pair of vectors may be followed by a string containing plotting options. Some of the permitted characters are:

colour: ‘r’ = red, ‘b’ = blue, ‘k’ = black, ‘g’ = green
line style: ‘-’ = solid, ‘:’ = dotted, ‘--’ = dashed, ‘-.’ = dash dot
data point markers: ‘x’ = crosses, ‘o’ = circles

Options may be combined (e.g. ‘r:x’ gives a dotted red plot with a crosses)



120
100
80
60
40
20
0
-20
-40
-60
0
2
4
6
8
10
12
14
16
18
20

Note: The hold command is another way of placing multiple plots on the same graph.

```
>> plot (x, y1, 'r‘)
>> hold on
>> plot (x, y2, 'b')
>> hold off           % be careful - hold for a figure stays in effect until it is turned off
>> grid on
```

Step 2: Define the function for root finding (and perhaps plot it)

```
>> f = @(x) f1(x) - f2(x);

>> figure (2)
>> fplot (f, [0 20])
>> grid on;
```

Step 3: Find the roots:

```
>> x1 = fzero(f, [0 2]);
>> x2 = fzero(f, [6 8]);
>> x3 = fzero(f, [12 14]);
>> x4 = fzero(f, [16 18]);
```