

## MATH.2720 Introduction to Programming with MATLAB

### User-Defined Functions (aka Custom Functions)

#### A. User-Defined Functions

A MATLAB function file is similar to a script file in that it contains MATLAB code. Most function files, however, require input and produce output, like a mathematical function. The first word on the first line of a function file must be `function`. This is followed by the name(s) of the output variables, an = sign, the name of the function, and the name(s) of the input variables in parentheses.

Here is an example, taken from *Programming in MATLAB* by Knoesen, Amirtharajah, Vahid, and Lysecky.

In the File menu on the MATLAB toolbar, click on *New*, then click on *Function*. A box will open in the Editor window with the skeleton of a function file.

Edit the file so it contains the following lines.

```
function distance = LightningDistance( seconds )
% LightningDistance: Estimates distance of lightning strike based on
% seconds between observer seeing lightning strike and hearing thunder.
% Input: seconds -- Measured time between lightning strike and thunder.
% Output: distance -- Distance to lightning strike, in kilometers.
speedOfSound = 340.29; % Speed of sound in meters/sec at sea level
distance = (speedOfSound * seconds) / 1000; % / 1000 yields km
end
```

Save the file using the file name *LightningDistance*. In the command window, type the command

```
>>help LightningDistance
```

Now type the command

```
distKm = LightningDistance(10)
```

**Please keep these rules in mind:**

1. Never use the input command in a function file. Input should be passed in the function call.
2. (Almost) never display output in a function file. Let the user who called the function decide how to display the output.

#### B. Scope of Variables within Function Files

Variables used within a function file are known only within the function, not in other files or in the command window. Similarly, variables defined in a script file or in the command window are not known by any functions. One way to make a variable known everywhere is to use the `global` command. Here is a simple example.

Create a function file containing the following lines

```
function yMax = max_height(v0)
%max_height calculates how high a ball rises given its initial velocity
%Input: v0 -- initial velocity of ball in m/s
%Output: yMax -- maximum height of ball
global g
yMax = v0.^2/(2*g);
end
```

In the command window, type the commands

```
>>global g
>>g = 9.81
>>ymax = max_height(40)
```

### C. Anonymous Functions

It is possible to define a function within a script file, a function file, or the command window *without* creating a separate function file. Functions defined in this way are called *anonymous functions*. Here is an example of a script file in which an anonymous function is defined.

```
circleArea = @(r) pi*r^2;
r = input('Enter the radius of a circle: ');
area = circleArea(r);
fprintf('The area of your circle is %6.2f\n',area)
```

The first line of the script file defines a function named `circleArea` which has one input argument (`r`) and one output (the area of a circle of radius `r`.) If you save this script file, **do not save it with the file name `circleArea`**.

The command defining an anonymous function has the form

```
function_name = @ (list of input arguments) function_formula.
```

### D. Function Functions

Some MATLAB functions require the name of another function as an input argument. For example, the built-in MATLAB function `fzero` finds a root of a function, but you have to tell `fzero` what function you want a root of. Try this example. First create the function file `f.m` defining the function given by  $f(x) = x - \cos(x)$ :

```
function y = f(x)
y = x - cos(x);
end
```

In the command window, type the command

```
fzero(@f, 1)
```

This will calculate a root of the function `f` near  $x = 1$ . Notice that the first input argument to `fzero` is the `@` symbol followed directly by the function file name. (Exception to the rule: If your function has been defined as an anonymous function, you don't need the `@` symbol before the function name.)

## E. Subfunctions (aka Local Functions)

It is possible to define more than one function within a single function file. If you do this, the first function defined in the file is called the *primary function* and the others are called *subfunctions*. Here is an example of a file containing multiple function definitions.

```
function [circ, area] = CircleMeasurements(radius)
%CircleMeasurements calculates the circumference and area of a circle of
%given radius
%Input: radius -- radius of circle
%Outputs: circ = circumference of circle
%         area = area of circle
circ = Circumf(radius);
area = CircleArea(radius);

    function perim = Circumf(r)
        perim = 2*pi*r;
    end

    function area_of_circle = CircleArea(r)
        area_of_circle = pi*r^2;
    end

end
```

Try executing this command in the command window:

```
[c, a] = CircleMeasurements(1)
```

## Practice Problems

1. Write a function file that takes the height of a person in inches as input and produces the corresponding height in centimeters as output. (1 inch = 2.54 centimeters.) Test your function with the input 65 inches.
2. Write a function file that takes the length and width of a rectangle as inputs and produces the area and perimeter of the rectangle as outputs. Test your function using dimensions of 3 and 2.
3. Modify the script file example in the section on anonymous functions to calculate both circumference and area.
4. Use `fzero` to find a root of the function given by  $f(x) = \tan(x) - x$  near  $x = 4$ .
5. Write a function file that calculates the volume and surface area of a sphere given the radius of the sphere. Use subfunctions to calculate volume and surface area.

## Answers to Practice Problems

1. 165.1
2. 6
4. 4.4934