

MATLAB
Fundamentals
2017
Parts 7, 8 & 9



These notes are derived from several sources (see below) including MathWorks documentation which can be found at <https://uk.mathworks.com/help/matlab/>

B.C. Lowe, An Introduction to Matlab

David F. Griffiths, Dundee University, An Introduction to Matlab,
<http://www.maths.dundee.ac.uk/software/MatlabNotes.pdf>

David Houcque, Northwestern University, Introduction To Matlab For Engineering Students,
<https://www.mccormick.northwestern.edu/documents/students/undergraduate/introduction-to-matlab.pdf>

Other Matlab Resources:

<https://ocw.mit.edu/resources/res-18-002-introduction-to-matlab-spring-2008/lecture-notes/>

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7. Calculus

MATLAB has commands in its Symbolic Maths Toolbox to perform differentiation, integration and other calculus operations. The engine behind the Symbolic Maths Toolbox is the computer package Maple.

When invoking calculus commands we must define the symbolic variables. For example, to start with a clean sheet of paper and use the variables x , y and t you should type

```
>> clear all
```

```
>> syms x y t % spaces, not commas, between x,y and t
```

7.1 Differentiation

Use the command *diff* to differentiate symbolic expressions once, twice or more.

Example 1

To differentiate x^2 : `>> diff(x^2)`

```
ans =
```

```
2*x
```

so $\frac{d}{dx}(x^2) = 2x$.

Example 2

Differentiate $\sin x$ and $\ln x$.

```
>> diff(sin(x)), diff(log(x))
```

```
ans =  
cos(x)
```

```
ans =  
1/x
```

so $\frac{d}{dx}(\sin x) = \cos x$ and $\frac{d}{dx}(\ln x) = \frac{1}{x}$

Example 3

Find $\frac{dy}{dx}$ given (i) $y = x^3 \cos x$ (ii) $y = \frac{x^2 + 1}{x^2 - 1}$ (iii) $y = (2x + 1)^6$.

Note that, by hand, you would have to use the product rule for (i), the quotient rule for (ii) and the function of a function rule for (iii).

```
>> diff(x^3*cos(x))  
ans =  
3*x^2*cos(x) - x^3*sin(x)  
>> diff((x^2+1)/(x^2-1))  
ans =  
2*x/(x^2-1) - 2*(x^2+1)/(x^2-1)^2*x  
>> diff((2*x+1)^6)  
ans =  
12*(2*x+1)^5
```

We can also find higher derivatives by specifying the order in the *diff* command.

Example 4

Find (i) the second derivative of x^5 (ii) the third derivative of $\tan 2x$ (iii) the fourth derivative of x^n .

(i) `>> diff(x^5,2)`

ans =

$$20*x^3$$

(ii) `>> diff(tan(2*x),3)`

ans =

$$4*(2+2*\tan(2*x)^2)^2+16*\tan(2*x)^2*(2+2*\tan(2*x)^2)$$

(iii) `>> syms n`

`>> diff(x^n,4)`

ans =

$$x^n*n^4/x^4-6*x^n*n^3/x^4+11*x^n*n^2/x^4-6*x^n*n/x^4$$

We can factorize the answer with *factor*.

`>> factor(ans)`

ans =

$$x^n*n*(n-1)*(n-2)*(n-3)/x^4$$

Example 5

Show that $y = \sin 2x$ satisfies the equation $\frac{d^2y}{dx^2} + 4y = 0$.

Here the first and second derivatives of y are called y_1 and y_2 .

```
>> y=sin(2*x);y1=diff(y),y2=diff(y,2)
```

```
y1 =
```

```
2*cos(2*x)
```

```
y2 =
```

```
-4*sin(2*x)
```

```
>> y2+4*y
```

```
ans =
```

```
0
```

Example 6

If $y = e^{ax} \sin bx$ find $\frac{dy}{dx}$ and $\frac{d^2y}{dx^2}$.

Show that y satisfies the equation $\frac{d^2y}{dx^2} - 2a\frac{dy}{dx} + (a^2 + b^2)y = 0$.

Note the use of *simplify* to reduce a complicated result to zero.

```
>> syms x y a b
```

```
>> y=exp(a*x)*sin(b*x),y1=diff(y),y2=diff(y,2)
```

```
y =
```

```
exp(a*x)*sin(b*x)
```

```
y1 =
```

```
a*exp(a*x)*sin(b*x)+exp(a*x)*cos(b*x)*b
```

```
y2 =
```

```
a^2*exp(a*x)*sin(b*x)+2*a*exp(a*x)*cos(b*x)*b
```

```
-exp(a*x)*sin(b*x)*b^2
```

```
>> y2-2*a*y1+(a^2+b^2)*y      % LHS of equation
```

```
ans =
```

```
a^2*exp(a*x)*sin(b*x)+2*a*exp(a*x)*cos(b*x)*b
-exp(a*x)*sin(b*x)*b^2-2*a*(a*exp(a*x)*sin(b*x)+
exp(a*x)*cos(b*x)*b)+(a^2+b^2)*exp(a*x)*sin(b*x)
```

```
>> simplify(ans)
```

```
ans =
```

```
0
```

Exercise 7.1

- Find the first derivatives of x^7 , $x^2 \sin x$, $\frac{2x+1}{4x+1}$ and $\cos x^3$.
- Find the second derivative of $\sin 5x$, the third derivative of $(3x-2)^4$ and the fourth derivative of $\ln(1+e^x)$.
- Show that $y = \cos 4x$ satisfies the equations

$$(i) \frac{dy}{dx} + 4y \tan 4x = 0 \quad (ii) \frac{d^2y}{dx^2} + 16y = 0 \quad (iii) \frac{d^4y}{dx^4} - 256y = 0.$$

- If $y = e^{ax} \cos bx$ find $\frac{dy}{dx}$ and $\frac{d^2y}{dx^2}$.

Show that y satisfies the equation $\frac{d^2y}{dx^2} - 2a \frac{dy}{dx} + (a^2 + b^2)y = 0$.

7.2 Maximum and Minimum

The function $y = f(x)$ has a stationary point where $\frac{dy}{dx} = 0$.

If, at this point, $\frac{d^2y}{dx^2} < 0$ then the point is a local maximum.

If, at this point, $\frac{d^2y}{dx^2} > 0$ then the point is a local minimum.

If, at this point, $\frac{d^2y}{dx^2} = 0$ the test fails and the first derivative test must be used.

We will need the command *subs* to evaluate y at different values of x .

The form of *subs* is *subs(expression, old value, new value)*

For example, if $y = 2x - 1$, then to find y when $x = 3$:

```
>> y=subs(2*x-1,x,3)
```

```
y =
```

```
5
```

Example 1

Find and classify the stationary points for $y = 2x^3 - 3x^2 - 6x + 10$.

```
>> statpts=solve(diff(2*x^3-3*x^2-6*x+10))
```

```
statpts =
```

```
[ 1/2+1/2*5^(1/2)]
```

```
[ 1/2-1/2*5^(1/2)]
```

```
>> % find the decimal form of these values
```

```

>> statpts=double(statpts)

statpts =

    1.6180
   -0.6180

>> % find the corresponding y values
>> y=subs(2*x^3-3*x^2-6*x+10,x,statpts)

y =

    0.9098
   12.0902

```

y has two stationary points, at (1.6180, 0.9098) and (−0.6180, 12.0902).

We will use the second derivative test to see what sort of point each is.

```

>> diff2=diff(2*x^3-3*x^2-6*x+10,2)

diff2 =

12*x-6

>> yd2=subs(diff2,x,statpts)

yd2 =

    13.4164
   -13.4164

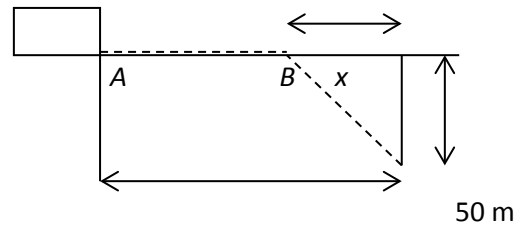
```

At (1.6180, 0.9098) $\frac{d^2y}{dx^2} = 13.4164 > 0$ and so this point is a local minimum.

At (−0.6180, 12.0902) $\frac{d^2y}{dx^2} = -13.4164 < 0$ and so this point is a local maximum.

Example 2

In laying water to a building A the contractor finds he must connect to a point C on the main which lies under a car park.



The total cost, P , of laying the pipe is

$$P = 3600 - 48x + 80\sqrt{x^2 + 2500}$$

Find x so that P is a minimum and hence find the minimum cost of the work to the contractor.

```
>> syms x P
```

```
>> P=3600-48*x+80*sqrt(x^2+2500)
```

```
P =
```

$$3600 - 48x + 80 \cdot (x^2 + 2500)^{(1/2)}$$

```
>> dP=diff(P)
```

```
dP =
```

$$-48 + 80 / (x^2 + 2500)^{(1/2)} \cdot x$$

```
>> solve(dP)
```

```
ans =
```

$$75/2$$

```
>> % stationary point at x=75/2=37.5
```

```
>> d2P=diff(P,2)
```

```
d2P =
```

$$-80 / (x^2 + 2500)^{(3/2)} \cdot x^2 + 80 / (x^2 + 2500)^{(1/2)}$$

```
>> d2Pst=subs(d2P,x,37.5)
```

```
d2Pst =
```

```
0.8192
```

```
>> % 0.8192>0, so P is a min when x=37.5.
```

```
>> Pmin=subs(P,x,37.5)
```

```
Pmin =
```

```
6800
```

So the lowest cost to the contractor is £6800, when $x = 37.5$ metres.

Exercise 7.2

1. Find and classify the stationary points of

(i) $y = x^2 + 4x + 5$

(ii) $y = x^3 - 3x^2 + 4$

(iii) $y = \frac{2x}{x^2 + 1}$

(iv) $y = \frac{2x - 7}{(x - 1)^2}$

(v) $y = x^4 e^x$

(vi) $y = e^{-x} \sin x$

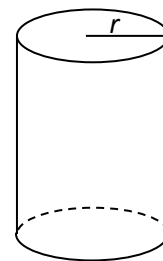
2. A standard drinks can holds 330 ml of liquid.

The total surface area S of the can is given by

$$S = 2\pi r^2 + \frac{660}{r} \text{ and the height } h \text{ by } h = \frac{330}{\pi r^2}.$$

Show that S is a minimum when $r \approx 3.745$

and $h \approx 7.49$ and that $S_{MIN} \approx 266 \text{ cm}^2$.



7.3 Integration

MATLAB can compute definite and indefinite integrals.

Example 1

Find $\int \cos x \, dx$, $\int \frac{1}{x} dx$ and $\int x^2 \, dx$.

```
>> clear all;syms x
>> int(cos(x))
ans =
    sin(x)
>> % note no constant of integration

>> int(1/x)
ans =
    log(x)

>> int(x^2)
ans =
    1/3*x^3
```

Example 2

Find (i) $\int 6x\sqrt{1+x^2} \, dx$ (ii) $\int x^2 \sin x \, dx$

(By hand, (i) would be done by substitution and (ii) by parts.)

```
(i) >> int(6*x*sqrt(1+x^2))
ans =
```

$$2*(1+x^2)^{(3/2)}$$

(ii) `>> int(x^2*sin(x))`

`ans =`

$$-x^2*\cos(x)+2*\cos(x)+2*x*\sin(x)$$

Example 3

Find the definite integrals (i) $\int_0^2 x^3 dx$ (ii) $\int_0^{\pi/2} \sin x dx$ (iii) $\int_1^2 e^x dx$.

The limits of integration are included in the *int* command.

`>> int(x^3,0,2),int(sin(x),0,pi/2),int(exp(x),1,2)`

`ans =`

4

`ans =`

1

`ans =`

$$\exp(2)-\exp(1)$$

`>> double(ans) % to get decimal form of last answer`

`ans =`

4.6708

Example 4

Find (i) $\int_0^1 \frac{x}{1+x^2} dx$ (ii) $\int_0^{\pi/4} x^4 \cos 2x dx$.

```
>> double(int(x/(1+x^2),0,1))
```

```
ans =
```

```
0.3466
```

```
>> double(int(x^4*cos(2*x),0,pi/4))
```

```
ans =
```

```
0.0150
```

Example 5

Consider the curve $y = x^2$ from the point (0, 0) to (2, 4).

Find (i) the area under the curve

(ii) the volume V_1 of the solid formed when the curve is rotated about the x axis

(iii) the volume V_2 of the solid formed when the curve is rotated about the y axis

A , V_1 and V_2 are found from $A = \int_a^b y \, dx$, $V_1 = \pi \int_a^b y^2 \, dx$ and $V_2 = \pi \int_c^d x^2 \, dy$.

```
>> clear all
```

```
>> syms x y
```

```
>> % integrate y=x^2 to find A
```

```
>> A=int(x^2,0,2)
```

```
A =
```

```
8/3
```

```
>> % integrate y=(x^2)^2=x^4 to find V1
```

```
>> V1=pi*int(x^4,0,2)
```

```
V1 =
```

```
32/5*pi
```

```

>> %    integrate x^2=y wrt y to find V2
>> V2=pi*int(y,0,4)
V2 =
      8*pi

>> % to obtain these exact answers in decimal form
>> A=double(A),V1=double(V1),V2=double(V2)
A =
      2.6667
V1 =
     20.1062
V2 =
     25.1327

```

Example 6

Consider $y = \frac{1}{1+x^3}$ from $(0, 1)$ to $(1, 0.5)$. Find A , V_1 and V_2 in decimal form.

(Note that the integrals here cannot be done analytically)

```

>> A=double(int(1/(1+x^3),0,1))
A =
      0.8356
>> V1=double(pi*int(1/(1+x^3)^2,0,1))
V1 =
      2.2738

>> %    rearrange y=1/(1+x^3) for x=..

```

```

>> % limits for y are 1 and 0.5
>> % integrate x^2 =..... wrt y
>> V2=double(pi*int((1/y-1)^(2/3),0.5,1))
Warning: Explicit integral could not be found.
>In C:\MATLAB6p5\toolbox\symbolic\@sym\int.m atline 58
V2 =
    0.7763

```

Exercise 7.3

- Find the following standard integrals

$$(i) \int x^4 dx \quad (ii) \int \tan x dx \quad (iii) \int_0^{\pi/6} \cos x dx \quad (iv) \int_1^2 \frac{1}{x} dx$$

- Find the following integrals which, if done by hand, would need to be done using a substitution.

$$(i) \int 30x^2(x^3+1)^4 dx \quad (ii) \int_0^1 x(1+x)^6 dx \quad (iii) \int \frac{\sqrt{x^2-4}}{x} dx \quad (iv) \int_0^1 \frac{x^3}{\sqrt{9+x^4}} dx$$

- Find the following integrals which, if done by hand, would need to be done using partial fractions.

$$(i) \int \frac{x-8}{(x+1)(x-2)} dx \quad (ii) \int_1^3 \frac{2x^2-1}{x(x+1)^2} dx \quad (iii) \int_0^1 \frac{4x+3}{(x+2)(x^2+1)} dx$$

4. Find the following integrals which, if done by hand, would need to be done using integration by parts.

(i) $\int_0^{\pi/4} x^5 \sin 2x \, dx$

(ii) $\int \sec^3 x \, dx$

(iii) $\int_1^e (\ln x)^2 \, dx$

5. Find the area A under the curve and the volumes of revolution V_1 and V_2 for

(i) $y = \sqrt{x}$ from $x = 0$ to $x = 4$ [5.33, 25.1, 8.34]

(ii) $y = \sqrt{\tan x}$ from $x = 0$ to $x = \frac{\pi}{4}$. [0.4875, 1.0858, 0.9319]

6. A ball is thrown vertically upwards with speed 20 ms^{-1} . It experiences the forces due to gravity and air resistance. The greatest height h reached by the ball and the time t taken are given by $h = \int_0^{20} \frac{v}{10 + 0.01v^2} \, dv$ and $t = \int_0^{20} \frac{1}{10 + 0.01v^2} \, dv$.

Show that $h = 16.83$ and $t = 1.78$.

8. Statistics

MATLAB can produce different types of visual and numerical summaries of data. The visual summaries include pie charts, bar charts and histograms. The numerical summaries include median, mean, variance and standard deviation.

Note that MATLAB has many more options available than those illustrated in the examples below. See the Help file for details.

8.1 Pie charts

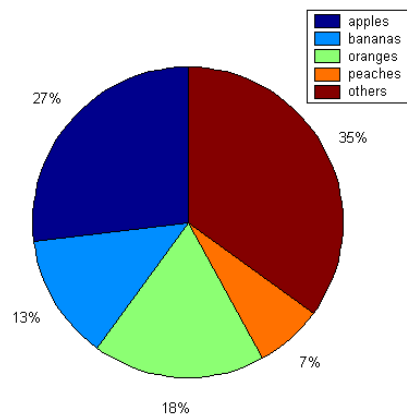
Example 1

The percentages of different types of fruit sold from a greengrocers were:

Apples	Bananas	Oranges	Peaches	Others
27%	13%	18%	7%	35%

To draw a pie chart for this data use the command *pie*,

```
>> % input data as a vector  
>> g=[27 13 18 7 35];  
>> pie(g)
```



>> % use Insert Legend in Figure No.1 window

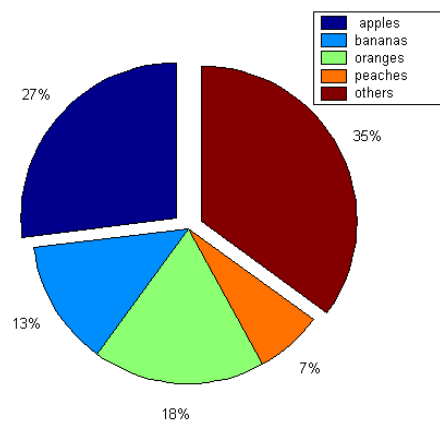
We can make sections of the pie stand out using *explode*. *explode* is a vector of 1's and 0's of the same length as the data. The elements of the data corresponding to the 1's will be *exploded*.

Example 2

Explode the two largest slices of the pie in Example 1.

These are the first and last elements of g and so

```
>> explode=[1 0 0 0 1];
```



```
>> pie(g,explode)
```

8.2 Bar charts

Example 3

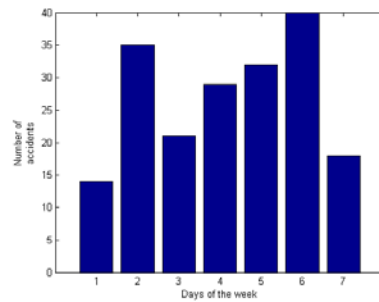
The following frequency distribution shows the number of car accidents on one stretch of road on each day of the week over a year. Sunday = day1, Monday = day 2, . . . , Saturday = day 7.

Day d	1	2	3	4	5	6	7
No. of accidents f	14	35	21	29	32	40	18

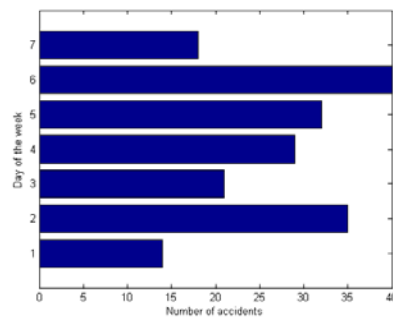
To draw a bar graph use the command *bar*.

```
>> % input days as elements of vector d
```

```
>> d=[1 2 3 4 5 6 7];
>> % input no. of accidents as vector f
>> f=[14 35 21 29 32 40 18];
>> % draw bar graph
>> bar(d,f)
```



We can plot the bar chart horizontally if we wish:



```
>> barh(d,f)
```

8.3 Histograms from data

To draw histograms from data use the command *hist*.

The simplest form is $n = \text{hist}(y)$, where x is a vector of the data elements. *hist*(y) uses 10 class intervals. n is a vector containing the number of elements in each class.

More generally use the form $n = \text{hist}(y, k)$, where k is the number of classes required.

If a frequency distribution is required use $[n, xout] = \text{hist}(y, k)$. The elements of n are the frequencies and those of $xout$ the class mid points.

Example 4

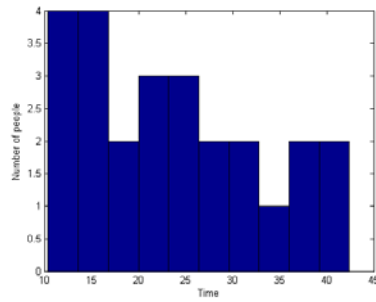
The table gives the time taken by 25 people to perform a particular task.

24.8	20.0	23.4	14.4	15.8	22.4	15.7	28.1	23.2	31.3
33.9	14.1	11.1	20.0	25.0	32.7	10.4	12.5	27.5	42.4
12.6	39.7	20.3	36.1	37.4					

Draw a histogram with (i) 10 (ii) 8 classes. Tabulate the class mid points in (ii).

(i) using 10 intervals

```
>> % input the times as the elements of vector t
>> t=[24.8 20.0 23.4 14.4 15.8 22.4 15.7 28.1 23.2
31.3 33.9 14.1 11.1 20.0 25.0 32.7 10.4 12.5 27.5
42.4 12.6 39.7 20.3 36.1 37.4];
>> % find frequencies and draw histogram
>> n=hist(t) % 10 intervals used by default
n =
Columns 1 through 8
     4     4     2     3     3     2     2     1
Columns 9 through 10
     2     2
```



(ii) using 8 intervals

```
>> [n xout]=hist(t,8)
```

>> n, xout are the frequencies, class mid points

n =

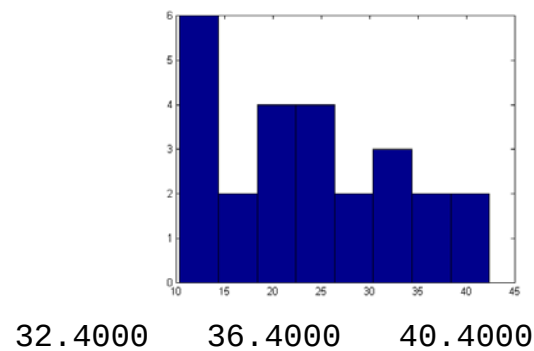
6 2 4 4 2 3 2 2

xout =

Columns 1 through 5

12.4000 16.4000 20.4000 24.4000 28.4000

Columns 6 through 8



Notice how the number of intervals affects the histogram.

8.4 Histograms from frequency distributions

Input the x values as the elements of a vector x , the frequencies as the elements of a vector f and use `bar(x,f)` to draw the histogram.

Example 5

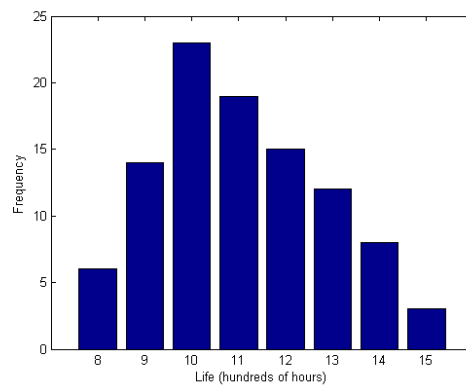
A sample of 100 light bulbs was selected from a large production run and each was tested to failure to find its life time. The results, to the nearest 100 hours were:

Life (hundreds of hours)	8	9	10	11	12	13	14	15
Frequency	6	14	23	19	15	12	8	3

Draw a histogram of the data.

```
>> x=[8 9 10 11 12 13 14 15];
```

```
>> f=[6 14 23 19 15 12 8 3];
```



```
>> bar(x,f)
```

8.5 Numerical summaries

If the data values are the elements of a vector x then

$mean(x)$ finds the mean (average) value

$median(x)$ finds the median

$std(x,1)$ finds the standard deviation from the mean

The variance is the square of the standard deviation.

Example 6

Find the mean, median, standard deviation and variance of the data in Example 4.

```
>> t=[24.8 20.0 23.4 14.4 15.8 22.4 15.7 28.1 23.2
      31.3 33.9 14.1 11.1 20.0 25.0 32.7 10.4 12.5 27.5
      42.4 12.6 39.7 20.3 36.1 37.4];
>> xbar=mean(t),m=median(t),s=std(t,1),var=s^2
xbar =
      23.7920
m =
      23.2000
s =
      9.2882
var =
      86.2703
```

If the data is given in the form of a frequency distribution there is a bit more work to do to find the mean $\bar{x}$, variance σ^2 and standard deviation σ .

The formulae are $\bar{x} = \frac{\sum fx}{\sum f}$, $\sigma^2 = \frac{\sum fx^2}{\sum f} - \bar{x}^2$, $\sigma = \sqrt{\frac{\sum fx^2}{\sum f} - \bar{x}^2}$.

This is illustrated in the following example.

Example 7

A sample of 100 light bulbs was selected from a large production run and each was tested to failure to find its life time. The results, to the nearest 100 hours were:

Life (hundreds of hours)	8	9	10	11	12	13	14	15
Frequency	6	14	23	19	15	12	8	3

Find the mean, variance and standard deviation.

```
>> % input the data as vectors x and f
>> x=[8 9 10 11 12 13 14 15];f=[6 14 23 19 15 12 8 3];
>> % multiply x and f element by element to form fx
>> fx=f.*x
fx =
    48    126    230    209    180    156    112    45

>> % find the sums of vectors f and fx
>> sumf=sum(f),sumfx=sum(fx)
sumf =
    100

sumfx =
    1106

>> % find the mean
>> mean=sumfx/sumf
mean =
    11.0600

>> % find the f x squared by multiplying fx and x
>> fxsq=x.*fx
```

```

fxsq =
Columns 1 through 4
    384    1134    2300    2299
Columns 5 through 8
    2160    2028    1568    675
>> % find the sum of vector fxsq
>> sumfxsq=sum(fxsq)
sumfxsq =
    12548

>> % find the variance
>> var=sumfxsq/sumf-mean^2
var =
    3.1564

>> % find the standard deviation
>> stdev=sqrt(var)
stdev =
    1.7766

```

The mean is 11.06 hundreds of hours, or 1106 hours, with a standard deviation of about

178 hours.

Exercise 8

1. The areas of the continents, to the nearest million square miles, are:

Continent	Africa	America (N+S)	Antarctica	Asia	Australia	Europe
Area	12	16	5	17	3	4

Draw a pie chart for this data. *explode* the two largest continents.

2. Draw vertical and horizontal bar charts for the data in question 1.

3. The times taken by 35 people to perform a certain calculation were as follows (to the nearest second)

41	33	58	50	58	31	51
53	58	55	36	68	46	62
46	44	52	56	47	54	37
60	64	48	55	49	51	50
51	43	60	40	37	41	45

Draw a histogram with 10 intervals and tabulate the number of people in each interval.

4. The breaking strengths in N/m^2 of 50 metal specimens are given in the following table, with a class interval of 0.2 N/m^2 .

Centre of Interval x	32.0	32.2	32.4	32.6	32.8	33.0	33.2	33.4
No. of specimens f	1	4	7	12	13	9	3	1

Input the the centres of the intervals and the frequencies as the elements of vectors x and f and draw a histogram of the data.

5. Find the median, mean, standard deviation and variance of the data in question 3.

6. Find the mean, standard deviation and variance of the data in question 4.

9. m-files

Up to now MATLAB has been used in an interactive manner only. That is, you issue a command, see the result, issue a second command, see the result, and so on. This is often inconvenient for longer or more complex problems. With m-files we can store MATLAB commands in a separate file which can be executed any number of times. It can also be edited.

There are two types of m-files, called script m-files and function m-files; these are discussed below.

9.1 Script m-files

Two examples illustrate how script m-files are created and used.

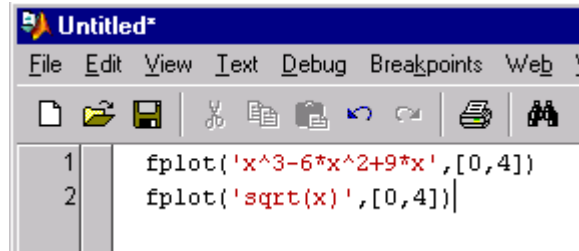
Example 1

We will create a script m-file to draw the graphs of $y = x^3 - 6x^2 + 9x$ and $y = \sqrt{x}$ from $x = 0$ to $x = 4$. (These graphs were also produced in Section 2.2)

1. open a new m-file by clicking on the white file icon at the top left of the MATLAB



window and then type in the commands, to produce



2. Save the file with a name of your choice.

Click on File, Save As. The filename will be Untitled.m. Change this to file1.m (you can choose any name you like rather than file1, but you must include the .m) and then Save.

(You can also save on your own floppy disk in A drive if you wish. In Save in scroll to $3\frac{1}{2}$ Floppy (A:) and click to select.)

3. To execute the file go to the Command Window. It is a good idea to start off with *clear all* and *close all* so that your work is not affected by anything you did previously.

```
>> clear all
```

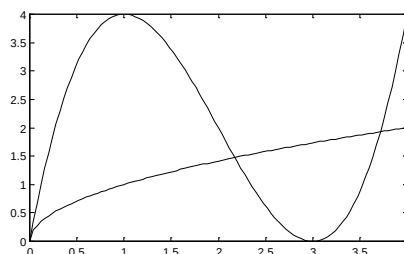
```
>> close all
```

```
>> hold % so that both graphs are shown
```

Current plot held

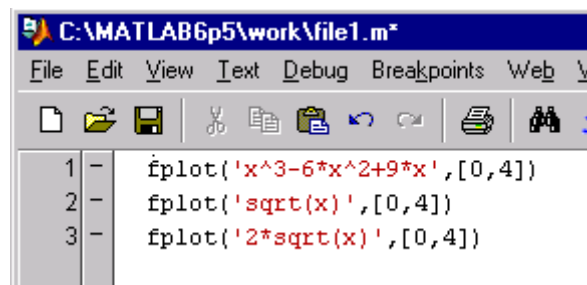
```
>> file1
```

The graphs appear as before.



4. an m-file can be edited if required. Suppose we wanted to plot $y = 2\sqrt{x}$ as well as the other two. To do this click on File Open and then file1.m.

Add an extra line and click on Save.

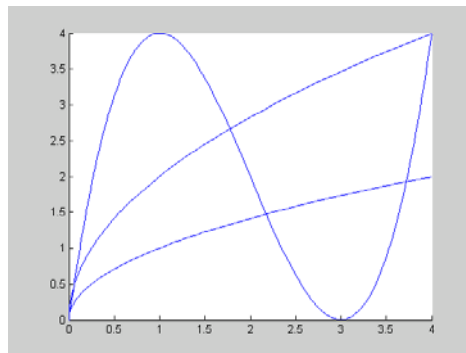


```
C:\MATLAB6p5\work\file1.m
File Edit View Text Debug Breakpoints Web V
1 - fplot('x^3-6*x^2+9*x',[0,4])
2 - fplot('sqrt(x)', [0,4])
3 - fplot('2*sqrt(x)', [0,4])
```

In the Command Window

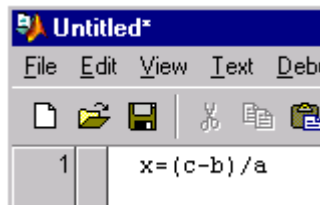
>> file1

This produces



Example 2

We will create an m-file to solve a linear equation of the form $ax + b = c$, the solution of which is $x = \frac{c - b}{a}$.



1. open a new m-file and type
2. Save file as file2.m (or your choice of name)
3. In the Command Window give a , b and c values and then find x by running file2,

```
>> a=2;b=5;c=9;
```

```
>> file2
```

```
x =
```

```
2
```

(Check: $x = \frac{c - b}{a} = \frac{9 - 5}{2} = \frac{4}{2} = 2$.)

4. Run it again with different values of a , b and c .

```
>> a=3;b=-4;c=17;
```

```
>> file2
```

```
x =
```

```
7
```

Note.

1. To see all the m-files you have created

```
>> what
```

2. To see the contents of a file use *type*

```
>> type file1
```

3. The lines of the m-file are not printed when it is executed. If you do want them shown use the *echo* command.

```
>> echo on
```

```
>> file2
```

```
x=(c-b)/a
```

```
x =
```

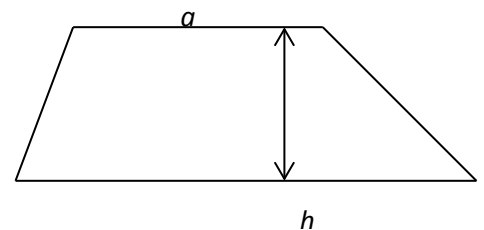
```
7
```

echo off reverts to the original situation.

4. To delete an m-file click on File Open, highlight the file to be deleted, click right mouse and then delete.

Exercise 9.1

1. Write and save a script m-file called *trap* to find the area of the trapezium shown.



The formula is $area = \frac{1}{2}h(a + b)$.

In the Command Window define $a = 6$, $b = 10$ and $h = 2$.

Execute *trap* and obtain $area = 16$.

Execute *trap* again with your own values of a , b and h ,

2. A car travelling with initial speed $u \text{ ms}^{-1}$ accelerates at $a \text{ ms}^{-2}$ for t seconds. It has then traveled a distance $s = ut + \frac{1}{2}at^2$ (1)

The speed v is related to t by $v = u + at$ (2)

and to s by $v^2 = u^2 + 2as$ (3)

Write a script m-file called *car* to find s from (1) and v from (2) and (3).

(Use $v_1 = u + at$ and $v_2 = \sqrt{u^2 + 2as}$)

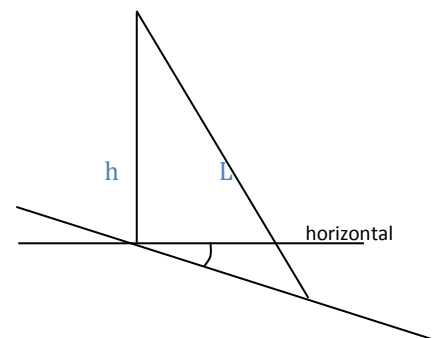
In the Command Window define $u = 5$, $a = 2$, $t = 6$, execute *car* and obtain $s = 66$, $v_1 = v_2 = 17$.

Execute *car* again with your own values.

3. The length L of a guy rope to a pole of height h is given by

$$L = \sqrt{h^2 + d^2 + 2hd \sin \alpha}.$$

Write a script m-file *guy* to find L .



Define $h = 10$, $d = 5$, $\alpha = 10^\circ$ and execute *guy* and obtain $L = 11.9317$.

If $h = 15$, $d = 6$, $\alpha = 15^\circ$ show that $L = 17.5382$.

(Hint: use *alpha* for α and convert the angle to radians)

9.2 Function m-files

As we saw in Section 1.5, MATLAB has a number of built in functions such as $\sin(x)$ and $\sqrt{x}$. A function m-file allows us to write our own functions for complicated or frequently used groups of expressions.

Two examples illustrate how function m-files are created and used.

Example 1

We will create a function m-file to calculate the function $y = \frac{\sqrt{x}}{x+1}$.

1. open a new m-file by clicking on the white file icon at the top left of the MATLAB window
2. type in the lines of the function
 - (i) decide on a name for your function – say *fred*
 - (ii) the first line of the file must have the format

function[list of outputs]=name(list of inputs)

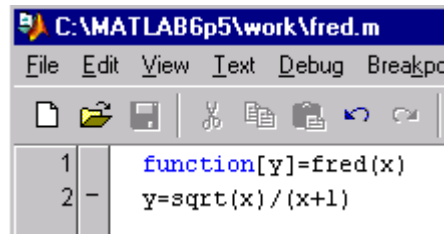
In this example there is only one output, y , and one input, x so type

function[y]=fred(x)

(iii) enter the code that defines the function. In this example this is

$$y = \sqrt{x} / (x + 1)$$

(iv) for larger files explain what the function is doing using comment lines starting with %.



You should obtain

3. Save the file with File Save (or click on the save icon). The file will be given the name you chose in the first line (*fred*).
4. To execute a file go to the Command Window. Type the function name together with the value of x in brackets (no .m here). If $x = 4$ then $y = \frac{\sqrt{4}}{4 + 1} = 0.4$.

>> fred(4)

y =

0.4000

Run it again:

```
>> a=fred(1),b=fred(10),c=fred(100)
```

```
y =
```

```
0.5000
```

```
a =
```

```
0.5000
```

```
y =
```

```
0.2875
```

```
b =
```

```
0.2875
```

```
y =
```

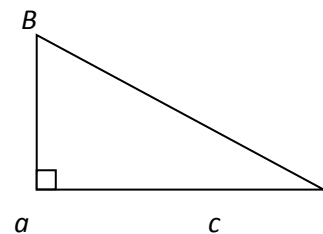
```
0.0990
```

```
c =
```

```
0.0990
```

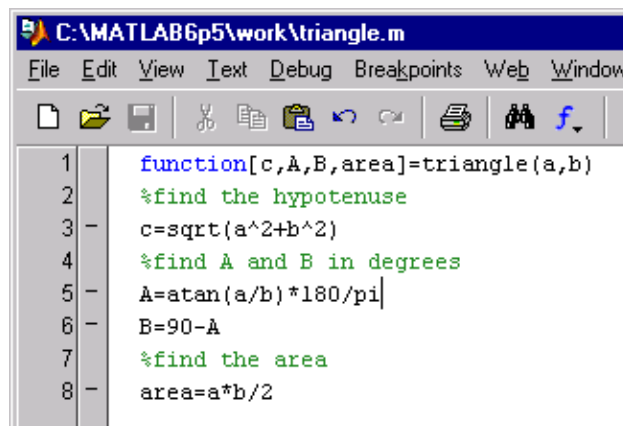
Example 2

We will write a function m-file to input two sides a and b of a right angled triangle and calculate the hypotenuse c , the angles A and B and the area of the triangle.



We will call the function *triangle*.

1. open a new m-file, type the following commands and Save.



```
C:\MATLAB6p5\work\triangle.m
File Edit View Text Debug Breakpoints Web Window
1 function[c,A,B,area]=triangle(a,b)
2 %find the hypotenuse
3 c=sqrt(a^2+b^2)
4 %find A and B in degrees
5 A=atan(a/b)*180/pi
6 B=90-A
7 %find the area
8 area=a*b/2
```

The inputs are a and b and the outputs are c , A , B and $area$.

2. In the command window run the function with $a = 3$ and $b = 4$

```
>> triangle(3,4)
```

```
c =
```

```
5
```

```
A =
```

```
36.8699
```

```
B =
```

```
53.1301
```

```
area =
```

```
6
```

Check these answers and run the function again with your own values of a and b .

3. Suppose that we wish to find the circumference of the triangle as well

($circ = a + b + c$).

Edit the function to do this, save the edited file and run it again. Make sure that it does what you expect!

9.3 A comparison of script and function m-files

Script m-files

Do not accept input arguments
or return output arguments.

A file is executed by typing its
name (for example, *file2*). The
values used must have already
been defined in the Command
Window. (*a*, *b*, *c* in *file2*)

Function m-files

Can accept input arguments
(*a* and *b* in Example 2)

Can return output arguments
(*c*, *A*, *B*, *area*)

Executed by typing its name
with the values of the input
arguments in brackets.
(for example *triangle*(3,4))

The variables used in a function
are local to the function (that is,
we could use *a* to represent
something entirely different in
the Command Window)

Exercise 9.2

1. The quadratic equation $ax^2 + bx + c = 0$ has roots

$$x_1 = \frac{-b + \sqrt{b^2 - 4ac}}{2a} \quad \text{and} \quad x_2 = \frac{-b - \sqrt{b^2 - 4ac}}{2a}.$$

- (i) Write a function m-file called *quadratic* to accept values of *a*, *b* and *c* and output the roots x_1 and x_2 .
- (ii) In the Command Window type

quadratic(1,-6,5) to get $x_1 = 1$, $x_2 = 5$ and

quadratic(3,10,2) to get $x_1 = -3.1196$, $x_2 = -0.2137$.

Solve your own quadratic equations.

2. £ P invested for n years at r % grows to

$$S = P \left(1 + \frac{nr}{100} \right) \text{ with simple interest}$$

$$C = P \left(1 + \frac{r}{100} \right)^n \text{ if interest is added annually}$$

$$C_k = P \left(1 + \frac{r}{100k} \right)^{nk} \text{ if interest is added } k \text{ times per year.}$$

- (i) Write a function m-file called *interest* to accept values of P , n , r and k , and output

S , C and C_k to the nearest penny.

- (ii) Execute *interest* for $P = 1000$, $n = 7$, $r = 5$ and $k = 12$ (monthly) and obtain

$S = 1350.00$, $C = 1407.10$ and $C_k = 1418.04$.

Execute *interest* for your own values of S , C and C_k .

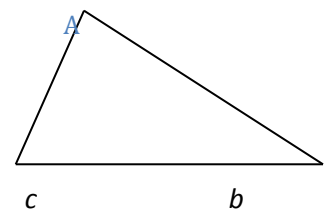
3. The angles A , B , C and area S of a triangle can be found, given the sides a , b and c , from

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}, \quad \cos B = \frac{a^2 + c^2 - b^2}{2ac},$$

$$C = 180^\circ - A - B, \quad S = \frac{1}{2}ab \sin C$$

- (i) Write a function m-file *triangle2* that accepts a , b and c and finds A , B , C and S .

- (ii) Execute *triangle2* for the following values of a , b and c .



$$a = 11, b = 10, c = 8$$

the equilateral triangle with $a = b = c = 2$.

the isosceles right angled triangle with $a = b = 1, c = \sqrt{2}$.

the right angled triangle with $a = 3, b = 4$ and $c = 5$.

the isosceles triangle with $a = b = 1, c = \sqrt{3}$.

You should get the following results.

a	b	c	A	B	C	S
2	2	2	60	60	60	1.7321
1	1	$\sqrt{2}$	45	45	90	0.5
3	4	5	37	53	90	6
1	1	3	30	30	120	0.4330