Introduction to Computer Programming

Week 9.1: Matplotlib - Plotting

Matplotlib is a large and versatile package for visualising data.

It is useful for creating graphs and plots.

We will study the functionality of a submodule of `matlplotlib` called `pyplot` .

A widely-used way to import the matplotlib module is by adding the following line at the start of your code.

Any function belonging to the matplotlib module can then be accessed by writing, for example, {\tt plt.plot()}.

In [2]:

```
import matplotlib.pyplot as plt
```

To display plots created using Matplotlib in Jupyter Notebook, the following line of code must be run in the notebook *before* generating the plot:

In [3]:

```
%matplotlib inline
```

To display plots when running a .py file (e.g. in Spyder), the following line must appear in the programme *after* generating the plot:

In [4]:

```
plt.show()
```

Line and Scatter Graphs

A sample data set: x with corresponding values of f:

In [7]:

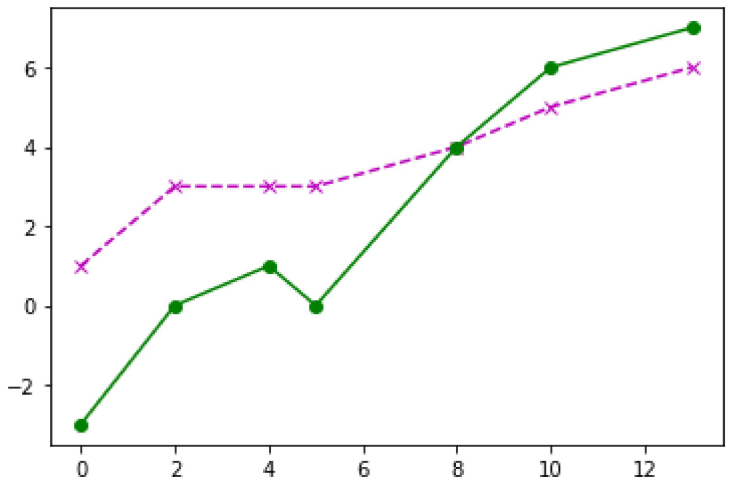
```
x = [-1, 3, 4, 8 , 10]
f = [-1, -2, 7, 13 , 1]
```

In [17]:

```
x = [0,2,4,5,8,10,13]
y = [1,3,3,3,4,5,6]
f = [-3,0,1,0,4,6,7]

plt.plot(x,y, 'xm--')
plt.plot(x,f, 'og-')
```

Out[17]:

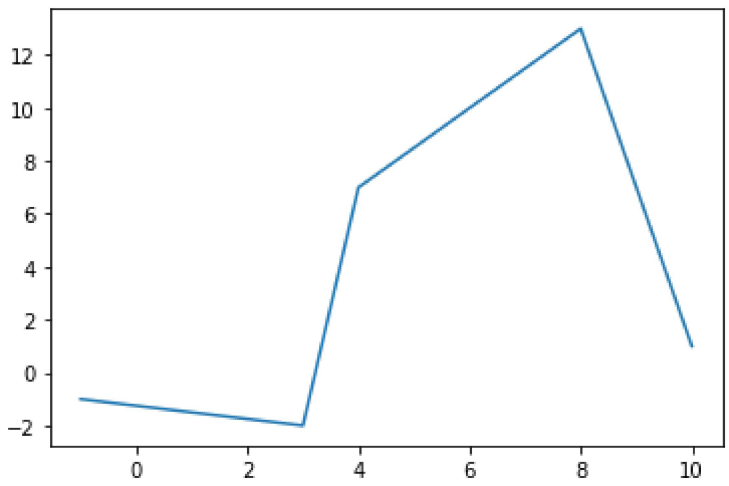
```
[<matplotlib.lines.Line2D at 0x1c402a29880>]
```



Line plot

In [8]:

```
plt.plot(x, f)

plt.show()
```



Printing the statement with format `[<matplotlib.lines.Line2D at 0x30990b0>]` appears each time (the numbers on your computer may look different) can be avoided by including a semicolon after the `plot` function.

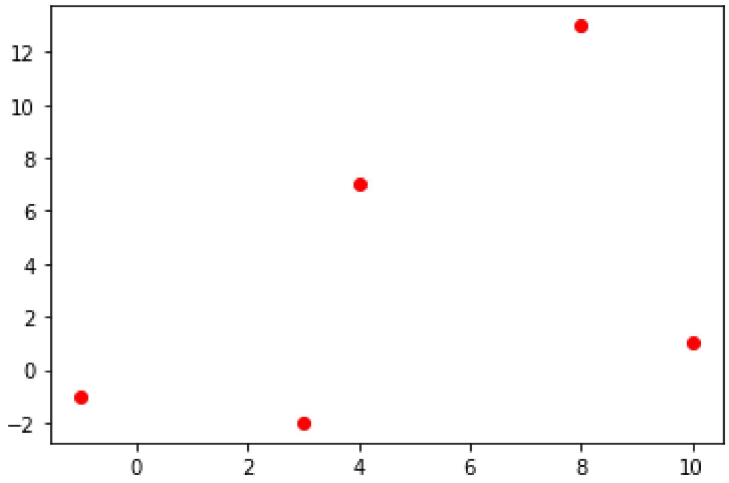
```
`plot(x, y);`
```

Format string: and optional but bonvenient way for defining basic formatting:

- the colour of the plot (e.g. `r` = red, `k` = black)
  https://matplotlib.org/2.0.2/api/colors_api.html (https://matplotlib.org/2.0.2/api/colors_api.html)
- the style of the markers (e.g. `o` = points, `*` = stars)
  https://matplotlib.org/api/markers_api.html (https://matplotlib.org/api/markers_api.html)
- the style of the line (e.g. `--` = dashes, `.` = dots)
  https://matplotlib.org/devdocs/gallery/lines_bars_and_markers/line_styles_reference.html
  (https://matplotlib.org/devdocs/gallery/lines_bars_and_markers/line_styles_reference.html)

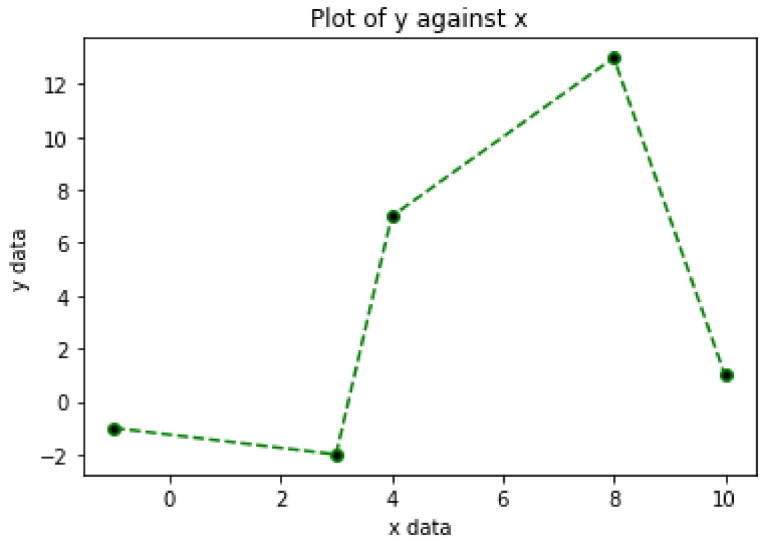
In [9]:

```
plt.plot(x, f, 'or'); # scatter, o markers, red
```



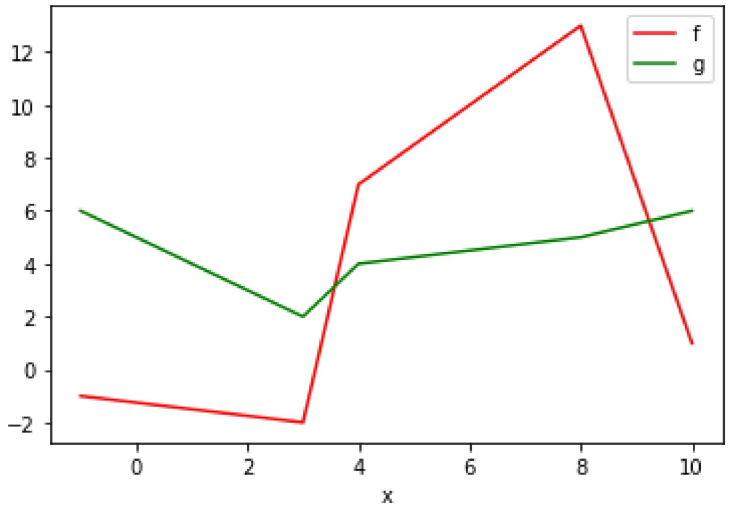
In [10]:

```
#plt.plot(x, f, '--og');
plt.plot(x, f, '--og');
#plt.plot(x, f, 'ro');
plt.plot(x, f, 'k.');

# Axis labels
plt.xlabel('x data');
plt.ylabel('y data');

# title
plt.title('Plot of y against x')

plt.show()
```



In [11]:

```
x = [-1, 3, 4, 8 , 10]
f = [-1, -2, 7, 13 , 1]
y = [6, 2, 4, 5, 6]

plt.plot(x, f, '-r', label='f');
plt.plot(x, y, '-g', label='g');

plt.xlabel('x');
plt.legend()

plt.show()
```



Bar Charts

Steps to create a bar chart:

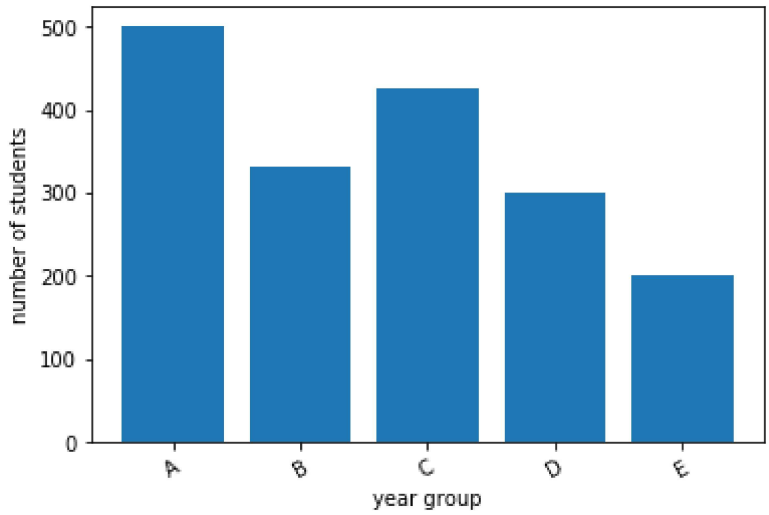
1. Create a numpy array with the same number of positions as bars
2. Generate bar chart
3. Replace x ticks with field name
4. Add axis labels

In [14]:

```
#sample data
groups = ('A', 'B', 'C', 'D', 'E')
num_students = (500, 332, 425, 300, 200)
```

In [15]:

```
# 1. Create a numpy array with the same number of positions as bars
x_pos = np.arange(len(groups))

# 2. Generate bar chart
plt.bar(x_pos, num_students);

# 3. Replace x ticks with field name
# (Rotate labels 30 degrees)
plt.xticks(x_pos, groups, rotation=30);

# 4. Add axis labels
plt.xlabel('year group');
plt.ylabel('number of students');

plt.show()
```



Histograms

We can visualise the distribution values using a histogram.

In a histogram, data is sorted into intervals (bins) along one axis.

The number of values that fall within a 'bin' is then displayed on the perpendicular axis.

Example data set generated using `numpy.random.randint`

In [16]:

```
import numpy as np
x = np.random.randint(low=0, high=100, size=25)
```

We can visualise how `x` is distributed by determining a set of bins to hold different ranges of values.

Bins are defined by their edge values:

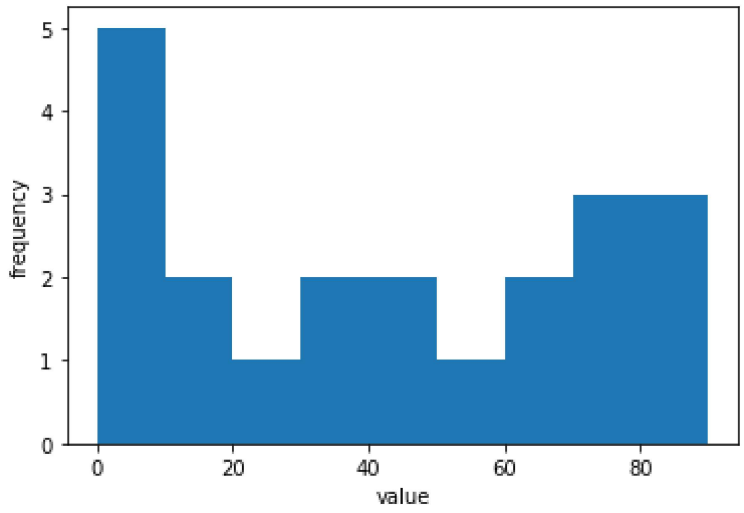
- If bins is an integer, it defines the number of equal-width bins in the range.
- If bins is a sequence, it defines the bin edges, including the left edge of the first bin and the right edge of the last bin.

All but the last (right-most) bin *includes* the (left-most) value, but *excludes* the (right-most) value.
e.g. `bins = [1,2,3,4]`

- first bin [1, 2) (includes 1, excludes~ 2)
- second bin [2, 3)
- third bin [3, 4] (includes 4)

In [17]:

```
edges = np.arange(0, 100, 10) # start, stop, step

plt.hist(x, bins=edges);

# Add label
plt.xlabel('value')
plt.ylabel('frequency')

plt.show()
```



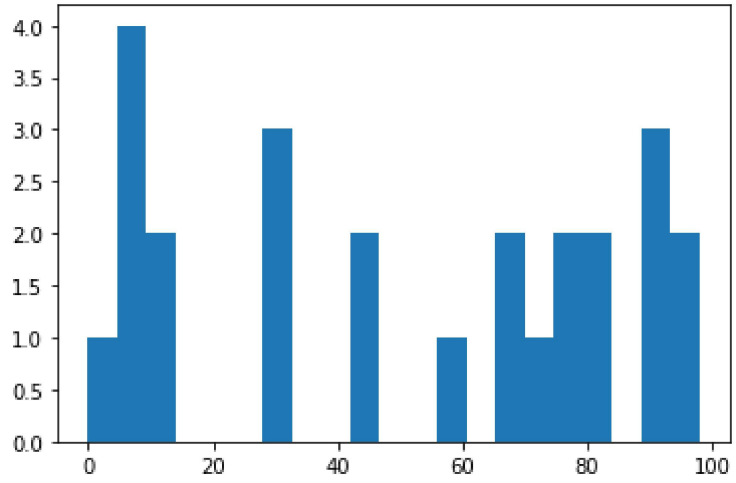
Generating the histogram returns 3 values:

- value of bins
- edges of bins
- graphical data for constructing histogram

In [18]:

```
n, edges, patches = plt.hist(x, 21);

print(n)
```

```
[1. 4. 2. 0. 0. 0. 3. 0. 0. 2. 0. 0. 1. 0. 2. 1. 2. 2. 0. 3. 2.]
```



Subplots

Multiple plots can be included in the same figure using `sublplot` .

`subplot(nrows, ncols, index)`

In [19]:

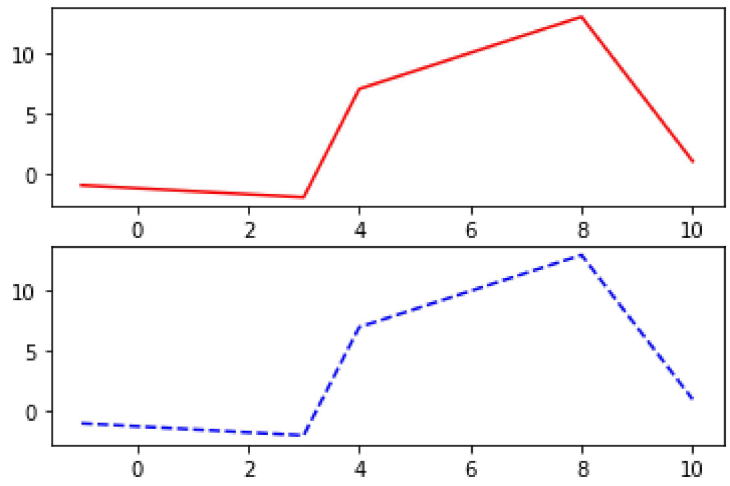
```
x = [-1, 3, 4, 8 , 10]
f = [-1, -2, 7, 13 , 1]
```

In [20]:

```
plt.subplot(211)    # 2 rows, 1 column, index 1
plt.plot(x, f, 'r')

plt.subplot(212)    # 2 rows, 1 column, index 2
plt.plot(x, f, 'b--')
```

Out[20]:

```
[<matplotlib.lines.Line2D at 0x1130a56d0>]
```

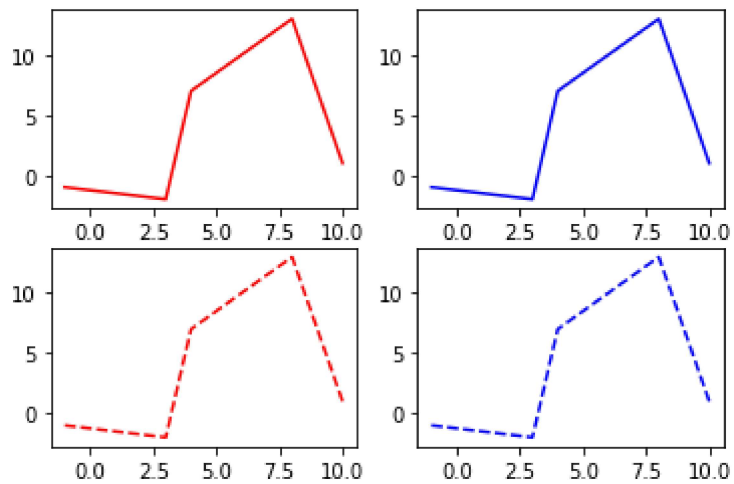


In [21]:

```
plt.subplot(221)    # 2 rows, 2 columns, index 1
plt.plot(x, f, 'r')

plt.subplot(222)    # 2 rows, 2 columns, index 2
plt.plot(x, f, 'b')

plt.subplot(223)    # 2 rows, 2 columns, index 3
plt.plot(x, f, 'r--')

plt.subplot(224)    # 2 rows, 2 columns, index 4
plt.plot(x, f, 'b--')
```

Out[21]:

```
[<matplotlib.lines.Line2D at 0x11323ee10>]
```



Saving plots

Plots can be saved in widely used formats (.png, .pdf etc) specified using the file name extension.

Must appear before `matplotlib.pyplot.show()` (or `plt.show()`) in a Python programme.

In [23]:

```
plt.savefig('img/four_plots.png');
```

```
<Figure size 432x288 with 0 Axes>
```

In [ ]:

```

```

Importing Data with Numpy

`numpy.loadtxt` can be used to import data form delimited text files.
The user can specify paramters including:

- **delimiter** (default = whitespace)
- **data type** (default = float) :
  If data contains items that cannot be expressed as a float, importing will cause an error unless the data-type is specified.
  Mixed data types can be imported as `string` values.

Example: Import data from `sample_data/data.dat`

- **delimiter** : whitespace
- **data type** : float

```
 0.000 1.053 2.105 3.158 4.211
74.452 48.348 68.733 59.796 54.123
```

In [5]:

```
import numpy as np
A = np.loadtxt('sample_data/sample_data.dat')

print(A)       # stored as numpy array

print(A[0][1]) # individual elements can be addressed
```

```
[[ 1.053  2.105  3.158  4.211  6.065]
 [48.348 68.733 59.796 54.123 74.452]]
2.105
```

Regions can be selected, for example to select only numerical data.

`skiprows` skips the first n lines.

`usecols` specifies which columns to read (numbering starts at 0)

- `usecols = (1, 4, 5)` : extracts the 2nd, 5th and 6th columns.
- `usecols = (3, 4)` : extracts the 4th and 5th columns

In [28]:

```
import numpy as np
A = np.loadtxt('sample_data/sample_data.dat',
               skiprows=1,
               usecols=(2,3,4))

print(A)       # stored as numpy array

print(A[0]) # individual elements can be addressed
```

```
[59.796 54.123 74.452]
59.796
```

Summary

- Simple line and scatter plots can be customised using a `formatstring`
- Features such as a figure legend and axis labels can be added after generating the plot.
- Steps to generate a bar chart:
  1. Create a numpy array with the same number of positions as bars
  2. Generate bar chart
  3. Replace x ticks with field name
- Plots can be saved in images formats e.g. .png, p.df with `matplotlib.pyplot.savefig`

Further reading

- Matplotilib has built-in tools for many more types of plot (scatter, box and whisker, 3D surface, animation etc)
- Matplotlib Gallery (http://matplotlib.org/gallery.html (http://matplotlib.org/gallery.html))
- Github (http://gree2.github.io/python/2015/04/10/python-matplotlib-plotting-examples-and-exercises (http://gree2.github.io/python/2015/04/10/python-matplotlib-plotting-examples-and-exercises))

In-class Demos

Example 1:
Import height and weight data from `sample_data/sample_student_data.txt` and plot a scatter plot of the data.

```
Subject    Sex    DOB        Height    Weight    BP
(ID)       M/F    dd/mm/yy   m         kg        mmHg
JW-1       M      19/12/1995 1.82      92.4      119/76
JW-2       M      11/01/1996 1.77      80.9      114/73
JW-3       F      02/10/1995 1.68      69.7      124/79
JW-6       M      06/07/1995 1.72      75.5      110/60
JW-7       F      28/03/1996 1.66      72.4      -
JW-9       F      11/12/1995 1.78      82.1      115/75
...
```

In [44]:

```
import matplotlib.pyplot as plt
import numpy as np

students = np.loadtxt('sample_data/sample_student_data.txt',
                      skiprows=15,
                      usecols=(3,4))
print(students)
```

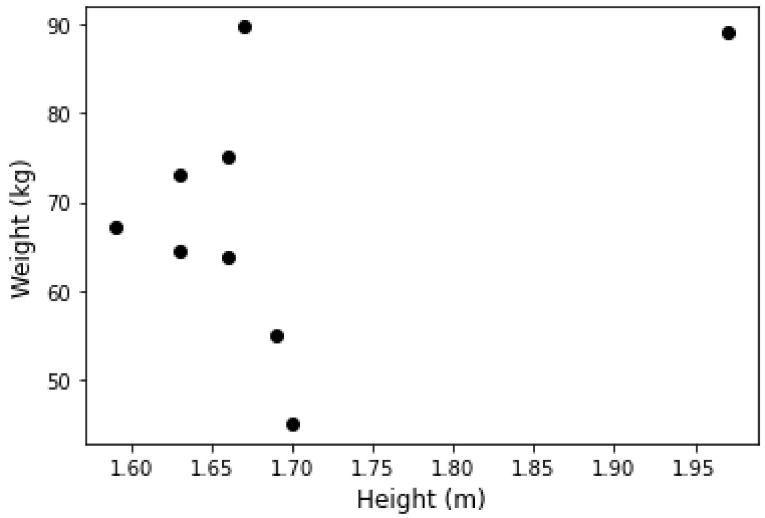
```
[[ 1.63 73.  ]
 [ 1.67 89.8 ]
 [ 1.66 75.1 ]
 [ 1.59 67.3 ]
 [ 1.7  45.  ]
 [ 1.97 89.2 ]
 [ 1.66 63.8 ]
 [ 1.63 64.4 ]
 [ 1.69 55.  ]]
```

In [46]:

```
# Plot column 1 against column 0
plt.plot(students[:, 0], students[:, 1], 'ko')

# Axes labels
plt.xlabel('Height (m)', fontsize=12)
plt.ylabel('Weight (kg)', fontsize=12)
```

Out[46]:

```
Text(0, 0.5, 'Weight (kg)')
```



Example 2:

Import data from `sample_data/sample_student_data.txt` and plot a histogram of the height of female students.

In [49]:

```
students = np.loadtxt('sample_data/sample_student_data.txt', dtype=str) # mixed data types

# all rows, where element 1 == F
female = students[students[:,1]=='F']

print(female)
```

```
[['JW-3' 'F' '02/10/1995' '1.68' '69.7' '124/79']
 ['JW-5' 'F' '02/10/1995' '1.68' '69.7' '124/79']
 ['JW-7' 'F' '28/03/1996' '1.66' '72.4' '-']
 ['JW-9' 'F' '11/12/1995' '1.78' '82.1' '115/75']
 ['JW-10' 'F' '07/04/1996' '1.6' '45' '-/-']
 ['JW-14' 'F' '12/01/1996' '1.56' '56.3' '108/72']
 ['JW-15' 'F' '01/06/1996' '1.64' '65' '99/67']
 ['JW-19' 'F' '30/10/1995' '1.59' '67.3' '103/69']
 ['JW-22' 'F' '09/03/1996' '1.7' '45' '119/80']
 ['JW-24' 'F' '01/12/1995' '1.66' '63.8' '100/78']
 ['JW-25' 'F' '25/10/1995' '1.63' '64.4' '-/-']]
```

In [87]:

```
weight = female[:, 3]           # select hieght data

weight = weight.astype(float)   # convert to float

# histogram
plt.hist(weight, 10); # equally spaced bins between minimum and maximum values can be auto-

# add label
plt.xlabel('height')
plt.ylabel('frequency')
```

Out[87]:

```
Text(0, 0.5, 'frequency')
```