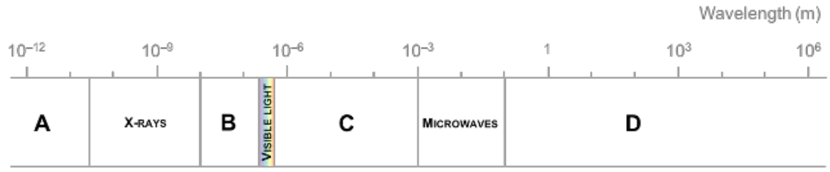
0 1

The electromagnetic spectrum is normally thought of as being made up of seven different types of waves.



0 1 . 1

Identify types A, B, C and D in the above diagram.

A: Gamma rays

C: Infrared

B: Ultraviolet

D: Radio waves

0 1 . 2

State **two** things which all electromagnetic waves have in common.

Any TWO of: all transverse waves, all transfer energy from one place to another can travel through a vacuum, travel at the same speed in vacuum (3×10^8 m/s).

0 1 . 3

Some mobile phone signals in the UK operate at a frequency of 800 MHz. Calculate the wavelength which this corresponds to.

The speed of electromagnetic waves in air is roughly 3×10^8 m/s. (1 MHz = 1 million Hz.)

$f = 800 \times 10^6 = 8 \times 10^8$ Hz
$v = 3 \times 10^8$ m/s
$\lambda = v \div f = (3 \times 10^8) \div (8 \times 10^8) =$ **0.375 m**

0 1 . 4

Visible light ranges in wavelength from 400 to 700 nm (nanometres). Calculate the **maximum** frequency of a visible light wave.

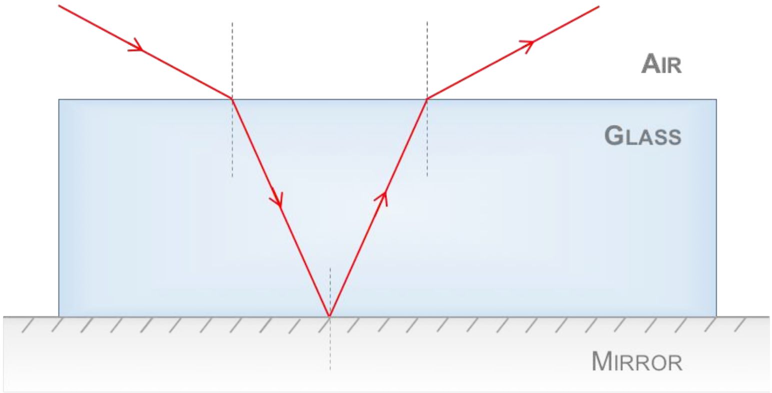
(1 nm = 10^{-9} m)

Maximum frequency at *minimum* wavelength
(f and λ are inversely proportional to one another for waves of constant speed)

$\lambda = 400$ nm $= 400 \times 10^{-9}$ m $= 4 \times 10^{-7}$ m
$f = v \div \lambda = (3 \times 10^8) \div (4 \times 10^{-7}) =$ **7.5×10^{14} Hz**

0 2

A light ray is directed from air into a glass block which is sitting flush with a mirror, as shown in the below diagram.



0 2 . 1

Complete the diagram to show how the path of the ray changes after it strikes the top surface of the glass block.

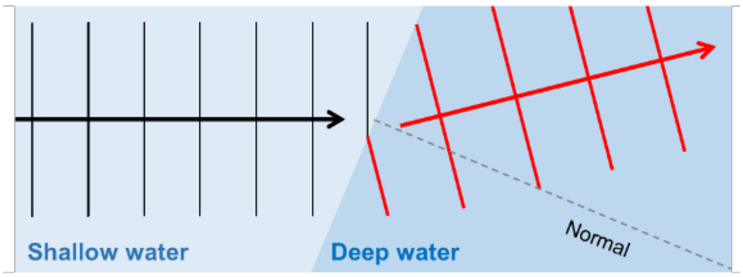
0 2 . 2

Explain why the light ray follows the path shown.

- As the ray travels from air into glass, it bends towards the normal because light travels more slowly in glass than in air [1]
- Inside the glass, the ray reflects from the bottom, mirrored surface, with its angle of incidence equal to the angle of reflection [1] (there is no change of medium here and so no refraction occurs)
- When the ray travels from glass back into air, it bends away from the normal because light travels more quickly in air than in glass [1]

0 3

A water wave is travelling from shallow water into deep water, as shown in the below wavefront diagram.



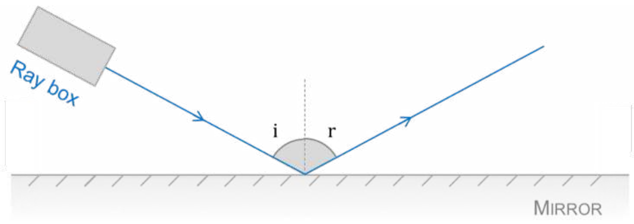
0 3 . 1

Complete the diagram to show how the wavefronts change as they enter and travel through the deep water.

Wavefronts refracted away from normal, as shown [1].
Wavelength longer in deep water than in shallow water (waves travel more quickly in deep water, frequency unchanged, so $\lambda \propto v$) [1].

0 4

A student is using the below experimental setup to investigate the reflection of light from the surface of a plane mirror.



The results which they obtain are as shown in the below table.

Angle of incidence, i (°)	Angle of reflection, r (°)		
	Measurement 1	Measurement 2	Average
10	10	10	10.0
20	20	22	21.0
30	29	32	30.5
40	39	40	39.5
50	50	50	50.0
60	60	62	61.0
70	70	110	70.0
80	79	81	80.0

0 4 . 1

State the independent and dependent variables in this investigation

Independent variable Angle of incidence (*i*)

Dependent variable Angle of reflection (*r*)

0 4 . 2

There are two values of *r* for each value of *i*. Explain why the student decided to repeat the entire experiment once.

To make the results (for each angle of refraction, *r*) more accurate / to reduce the (degree of) random error in the results [1].

0 4 . 3

Complete the final column of the above table to calculate the *average* angle of reflection of each angle of incidence.

Correct averages for first six and final rows [1].
Ignore anomalous value of 110° and correct average in row seven [1].

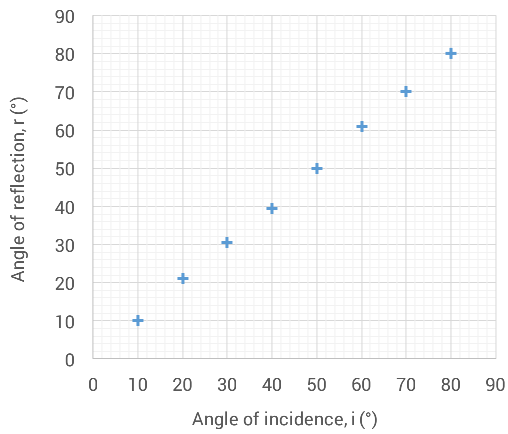
Remember that an *anomalous* value is one which doesn't match the overall trend shown by the data. Here, we expect each angle of reflection to be (roughly) equal to the corresponding angle of incidence. A value of *r* = 110° when *i* = 70° is clearly wrong, and should be ignored in this case when calculating the average value of *r* for this row. The experimenter probably used their protractor incorrectly in this case.

Good news – more on anomalies! In general you should deal with anomalous data in one of two ways:

1. Ideally, you should **repeat the measurement** to double-check the result. Anomalous data is often the result of misreading an instrument or recording a measurement incorrectly. (Note that this is not always the case, and sometimes, anomalous data is a sign that there might be something wrong with the theory on which a trend is based!)
2. If repeating the measurement is not possible, you should **ignore** any anomalous data in calculating averages (as we have done here) and disregard anomalous data points when drawing best-fit lines on graphs (such points are normally *circled* on graphs to mark them out as anomalous).

0 4 . 4

Use the below axes to plot a graph of the results.



0 4 . 5

Describe the trend shown by the above graph.

The angle of incidence is equal to the angle of reflection /
the angle of incidence is directly proportional to the angle of reflection (the constant of proportionality in this case is equal to one) [1].

0 4 . 6

The light which strikes a *smooth* reflective surface (such as the plane mirror which was used in this investigation) is said to undergo a process called *specular reflection*.

Describe and explain how the results would have been different had the light from the ray box been directed onto a *rough* reflective surface.

The angles of reflection would vary randomly / there would be no correlation between the angles of incidence and reflection [1].

The angle of reflection for a light ray which is travelling in a given direction will depend on the point on the surface at which the ray is reflected / on a microscopic level, the fact that the surface is rough will cause light rays to be reflected in an unpredictable way [1].