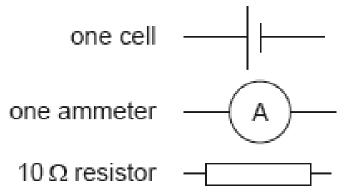
SL Paper 3

An experiment to find the internal resistance of a cell of known emf is to be set. The following equipment is available:

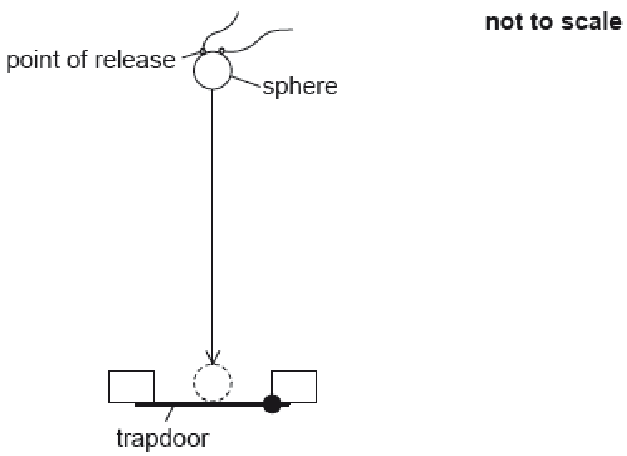


a. Draw a suitable circuit diagram that would enable the internal resistance to be determined. [1]

b. It is noticed that the resistor gets warmer. Explain how this would affect the calculated value of the internal resistance. [3]

c. Outline how using a variable resistance could improve the accuracy of the value found for the internal resistance. [2]

To determine the acceleration due to gravity, a small metal sphere is dropped from rest and the time it takes to fall through a known distance and open a trapdoor is measured.



The following data are available.

$$\begin{array}{ll} \text{Diameter of metal sphere} & = 12.0 \pm 0.1 \text{ mm} \\ \text{Distance between the point of release and the trapdoor} & = 654 \pm 2 \text{ mm} \\ \text{Measured time for fall} & = 0.363 \pm 0.002 \text{ s} \end{array}$$

a. Determine the distance fallen, in m, by the centre of mass of the sphere including an estimate of the absolute uncertainty in your answer. [2]

b. Using the following equation [4]

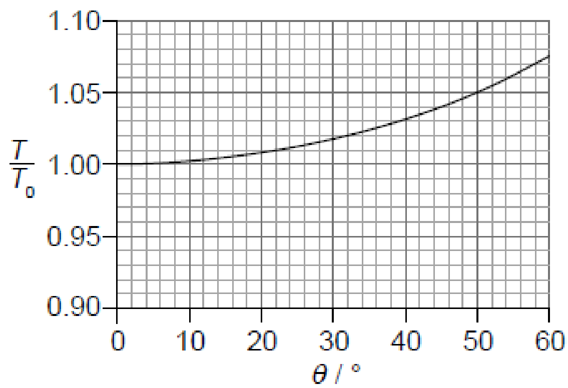
$$\text{acceleration due to gravity} = \frac{2 \times \text{distance fallen by centre of mass of sphere}}{(\text{measured time to fall})^2}$$

calculate, for these data, the acceleration due to gravity including an estimate of the absolute uncertainty in your answer.

a. In a simple pendulum experiment, a student measures the period T of the pendulum many times and obtains an average value T = (2.540 ± 0.005) s. The length L of the pendulum is measured to be L = (1.60 ± 0.01) m. [3]

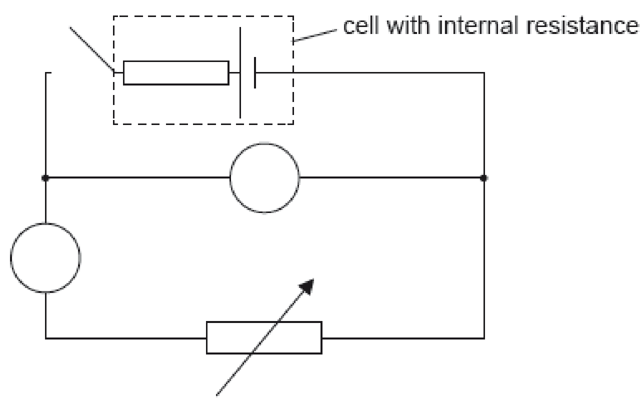
Calculate, using $g = \frac{4\pi^2 L}{T^2}$, the value of the acceleration of free fall, including its uncertainty. State the value of the uncertainty to one significant figure.

b. In a different experiment a student investigates the dependence of the period T of a simple pendulum on the amplitude of oscillations θ. The graph shows the variation of $\frac{T}{T_0}$ with θ, where T_0 is the period for small amplitude oscillations. [2]



The period may be considered to be independent of the amplitude θ as long as $\frac{T-T_0}{T_0} < 0.01$. Determine the maximum value of θ for which the period is independent of the amplitude.

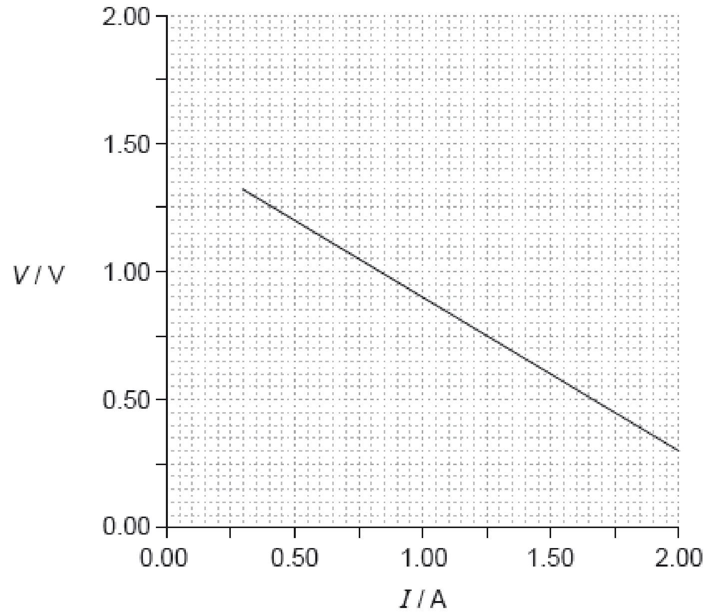
The circuit shown may be used to measure the internal resistance of a cell.



The ammeter used in the experiment in (b) is an analogue meter. The student takes measurements without checking for a “zero error” on the ammeter.

a. An ammeter and a voltmeter are connected in the circuit. Label the ammeter with the letter A and the voltmeter with the letter V. [1]

b. In one experiment a student obtains the following graph showing the variation with current I of the potential difference V across the cell. [3]

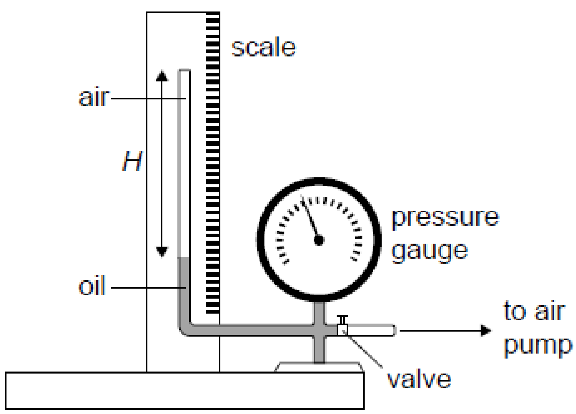


Using the graph, determine the best estimate of the internal resistance of the cell.

c.i. State what is meant by a zero error. [1]

c.ii. After taking measurements the student observes that the ammeter has a positive zero error. Explain what effect, if any, this zero error will have on the calculated value of the internal resistance in (b). [2]

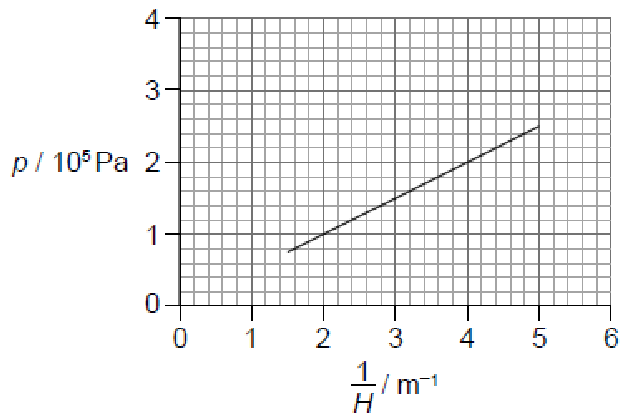
The equipment shown in the diagram was used by a student to investigate the variation with volume, of the pressure *p* of air, at constant temperature. The air was trapped in a tube of constant cross-sectional area above a column of oil.



The pump forces oil to move up the tube decreasing the volume of the trapped air.

a. The student measured the height *H* of the air column and the corresponding air pressure *p*. After each reduction in the volume the student waited for some time before measuring the pressure. Outline why this was necessary. [1]

b. The following graph of *p* versus $\frac{1}{H}$ was obtained. Error bars were negligibly small. [3]



The equation of the line of best fit is $p = a + \frac{b}{H}$.

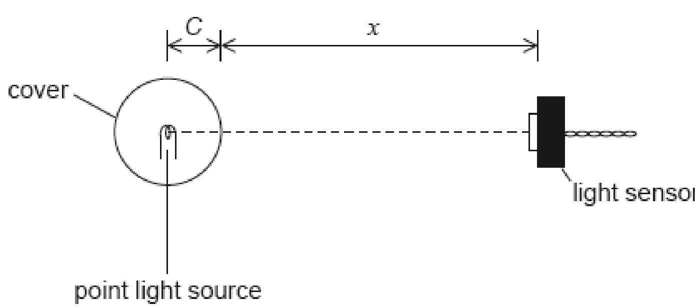
Determine the value of *b* including an appropriate unit.

c. Outline how the results of this experiment are consistent with the ideal gas law at constant temperature. [2]

d. The cross-sectional area of the tube is 1.3×10^{-3} m^2 and the temperature of air is 300 K. Estimate the number of moles of air in the tube. [2]

e. The equation in (b) may be used to predict the pressure of the air at extremely large values of $\frac{1}{H}$. Suggest why this will be an unreliable estimate of the pressure. [2]

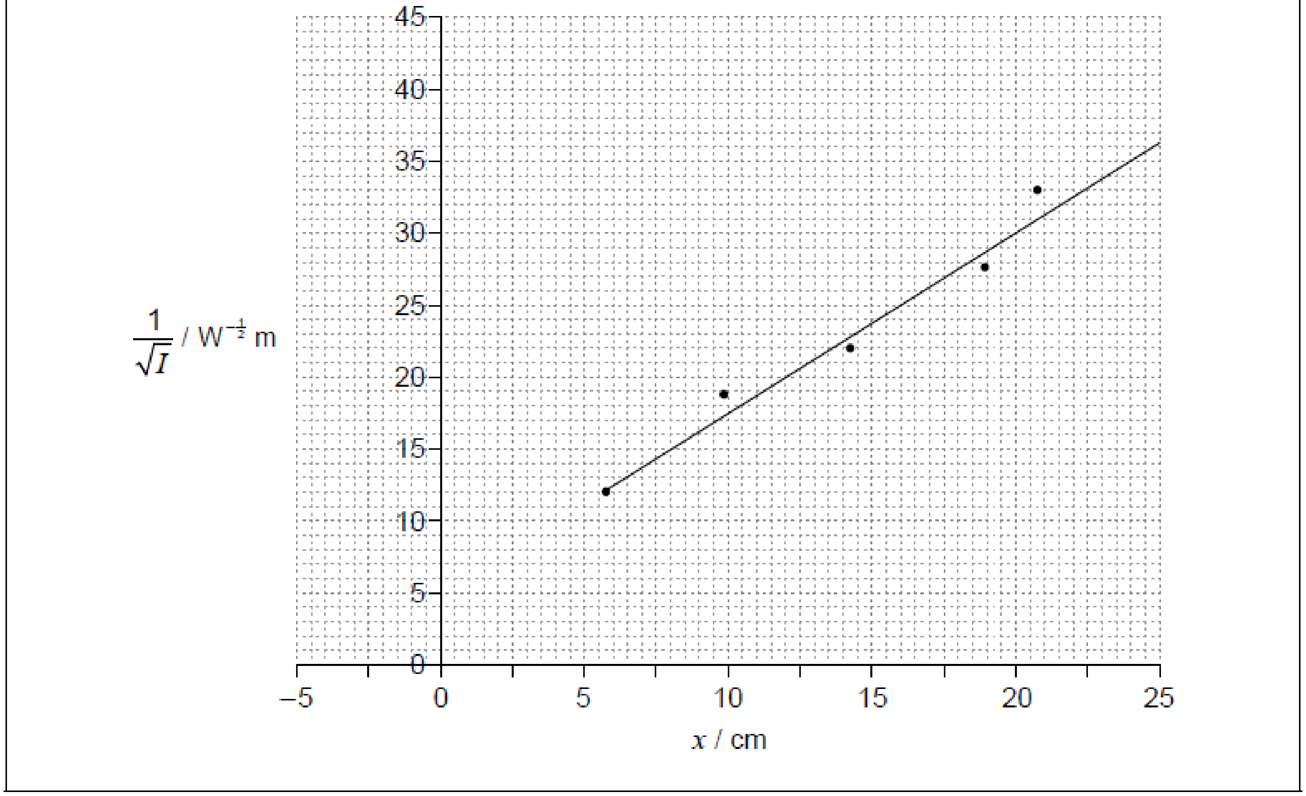
A student carries out an experiment to determine the variation of intensity of the light with distance from a point light source. The light source is at the centre of a transparent spherical cover of radius *C*. The student measures the distance *x* from the surface of the cover to a sensor that measures the intensity *I* of the light.



The light source emits radiation with a constant power *P* and all of this radiation is transmitted through the cover. The relationship between *I* and *x* is given by

$$I = \frac{P}{4\pi(C+x)^2}$$

The student obtains a set of data and uses this to plot a graph of the variation of $\frac{1}{\sqrt{I}}$ with *x*.



a. This relationship can also be written as follows. [1]

$$\frac{1}{\sqrt{I}} = Kx + KC$$

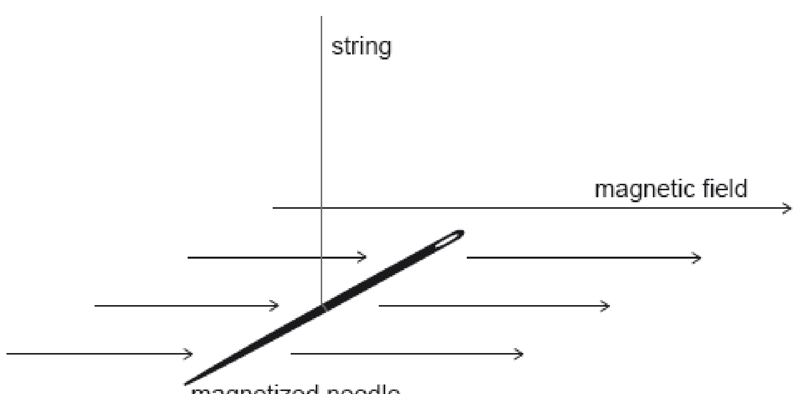
Show that $K = 2\sqrt{\frac{\pi}{P}}$.

b.i. Estimate *C*. [2]

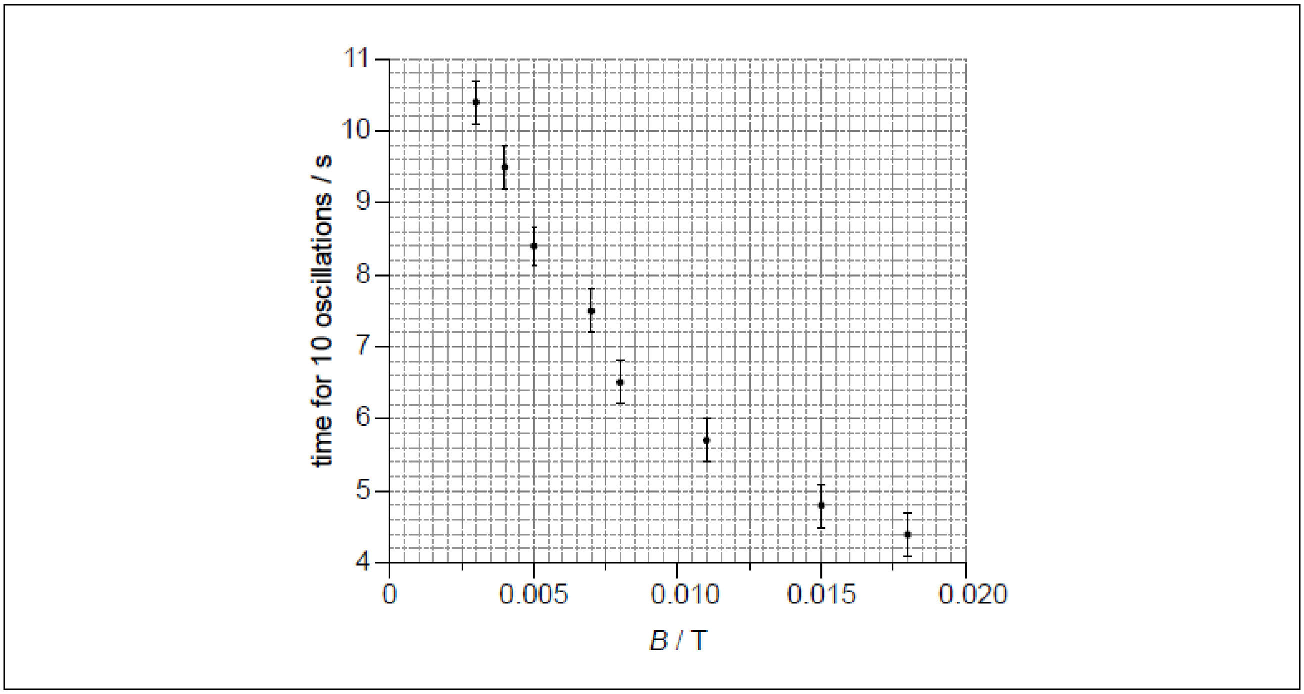
b.ii. Determine *P*, to the correct number of significant figures including its unit. [4]

c. Explain the disadvantage that a graph of *I* versus $\frac{1}{x^2}$ has for the analysis in (b)(i) and (b)(ii). [2]

A magnetized needle is oscillating on a string about a vertical axis in a horizontal magneticfield *B*. The time for 10 oscillations is recorded for different values of *B*.



The graph shows the variation with B of the time for 10 oscillations together with the uncertainties in the time measurements. The uncertainty in B is negligible.



a. Draw on the graph the line of best fit for the data. [1]

b.i. Write down the time taken for one oscillation when B = 0.005 T with its absolute uncertainty. [1]

b.ii A student forms a hypothesis that the period of one oscillation P is given by: [3]

$$P = \frac{K}{\sqrt{B}}$$

where K is a constant.

Determine the value of K using the point for which B = 0.005 T.

State the uncertainty in K to an appropriate number of significant figures.

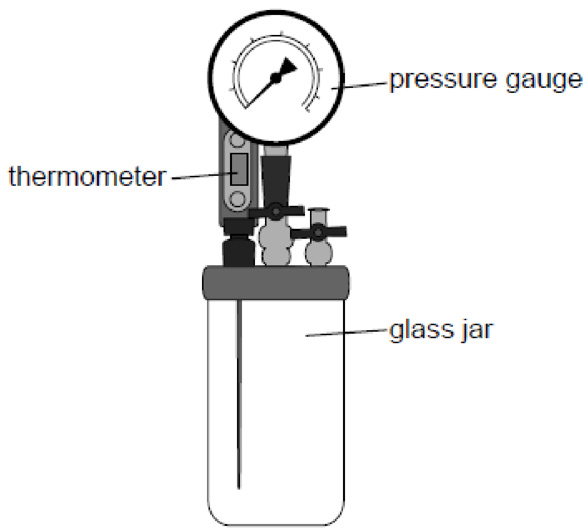
b.iii State the unit of K. [1]

c. The student plots a graph to show how P^2 varies with $\frac{1}{B}$ for the data. [2]

Sketch the shape of the expected line of best fit on the axes below assuming that the relationship $P = \frac{K}{\sqrt{B}}$ is verified. You do **not** have to put numbers on the axes.

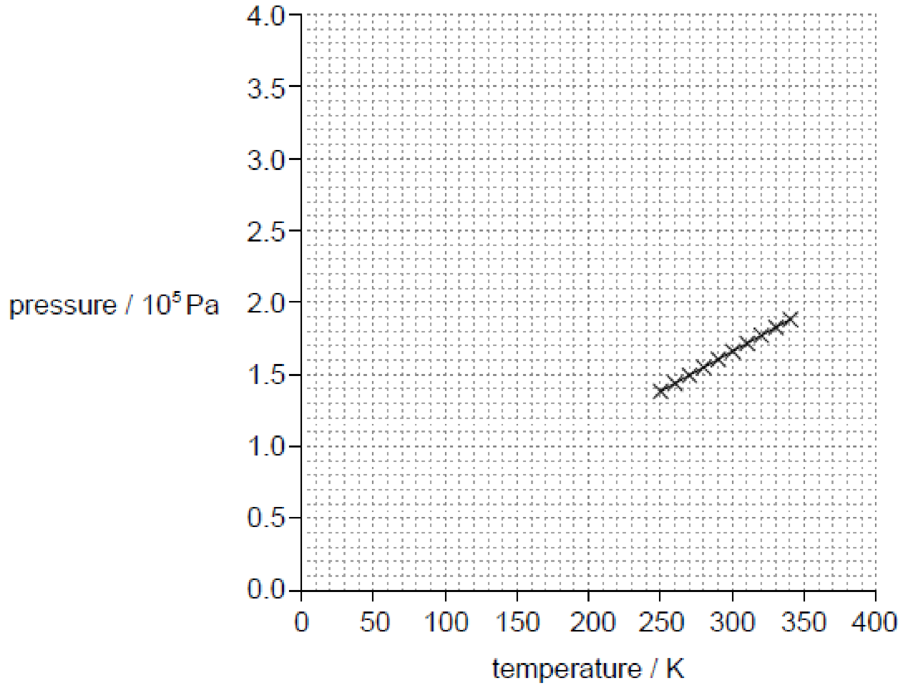
d. State how the value of *K* can be obtained from the graph. [1]

An apparatus is used to verify a gas law. The glass jar contains a fixed volume of air. Measurements can be taken using the thermometer and the pressure gauge.



The apparatus is cooled in a freezer and then placed in a water bath so that the temperature of the gas increases slowly. The pressure and temperature of the gas are recorded.

a. The graph shows the data recorded. [1]



Identify the fundamental SI unit for the gradient of the pressure–temperature graph.

b. The experiment is repeated using a different gas in the glass jar. The pressure for both experiments is low and both gases can be considered to be ideal. [3]

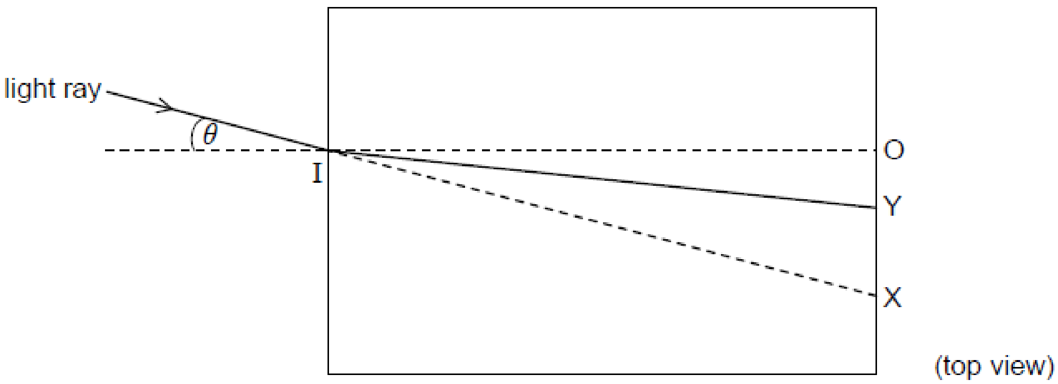
(i) Using the axes provided in (a), draw the expected graph for this second experiment.

(ii) Explain the shape and intercept of the graph you drew in (b)(i).

A student measures the refractive index of water by shining a light ray into a transparent container.

IO shows the direction of the normal at the point where the light is incident on the container. IX shows the direction of the light ray when the container is empty. IY shows the direction of the deviated light ray when the container is filled with water.

The angle of incidence θ is varied and the student determines the position of O, X and Y for each angle of incidence.



The table shows the data collected by the student. The uncertainty in each measurement of length is ±0.1 cm.

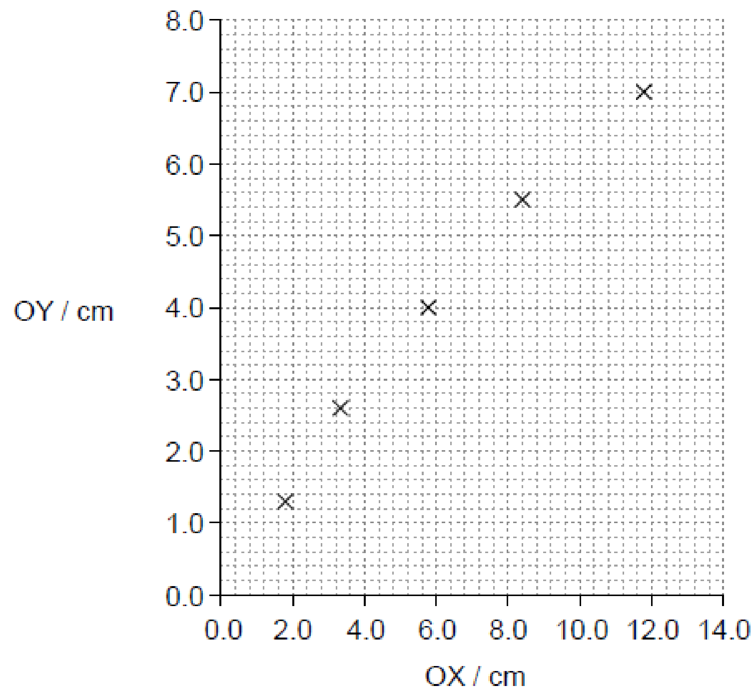
OX / cm	OY / cm
1.8	1.3
3.6	2.6
5.8	4.0
8.4	5.5
11.9	7.3
17.3	9.5
27.4	12.2

a. (i) Outline why OY has a greater percentage uncertainty than OX for each pair of data points. [3]

(ii) The refractive index of the water is given by $\frac{\mathrm{OX}}{\mathrm{OY}}$ when OX is small.

Calculate the fractional uncertainty in the value of the refractive index of water for OX = 1.8 cm.

b. A graph of the variation of OY with OX is plotted. [5]



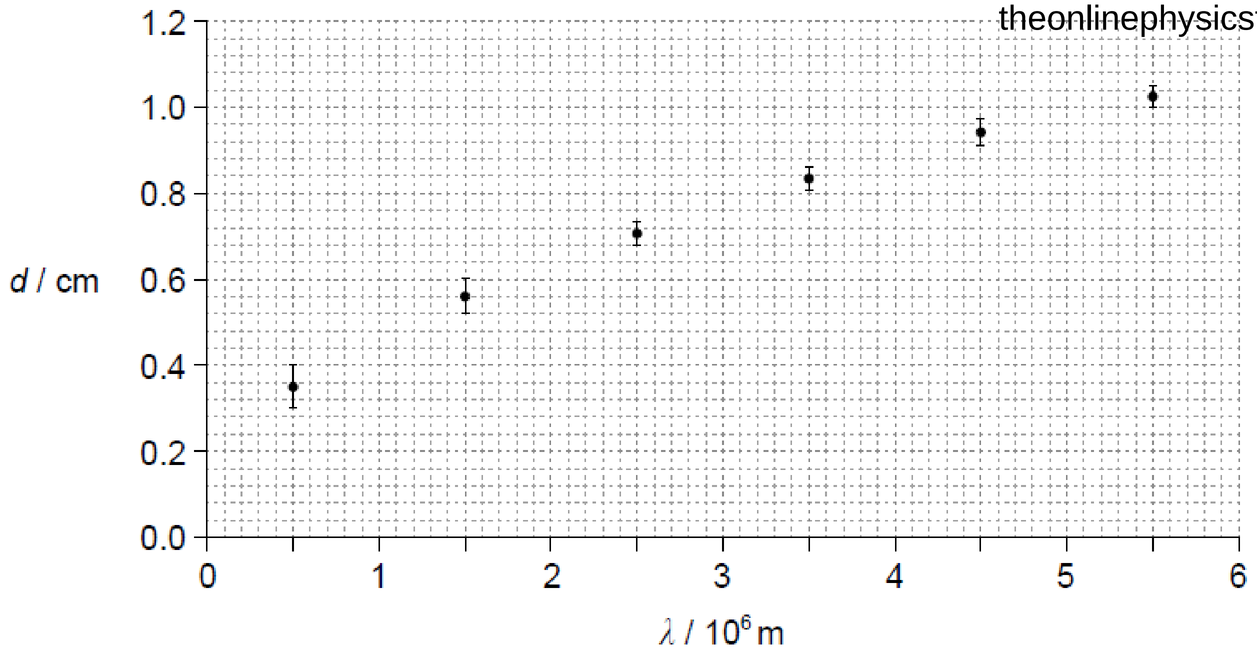
(i) Draw, on the graph, the error bars for OY when OX = 1.8 cm **and** when OY = 5.8 cm.

(ii) Determine, using the graph, the refractive index of the water in the container for values of OX less than 6.0 cm.

(iii) The refractive index for a material is also given by $\frac{\sin i}{\sin r}$ where *i* is the angle of incidence and *r* is the angle of refraction.

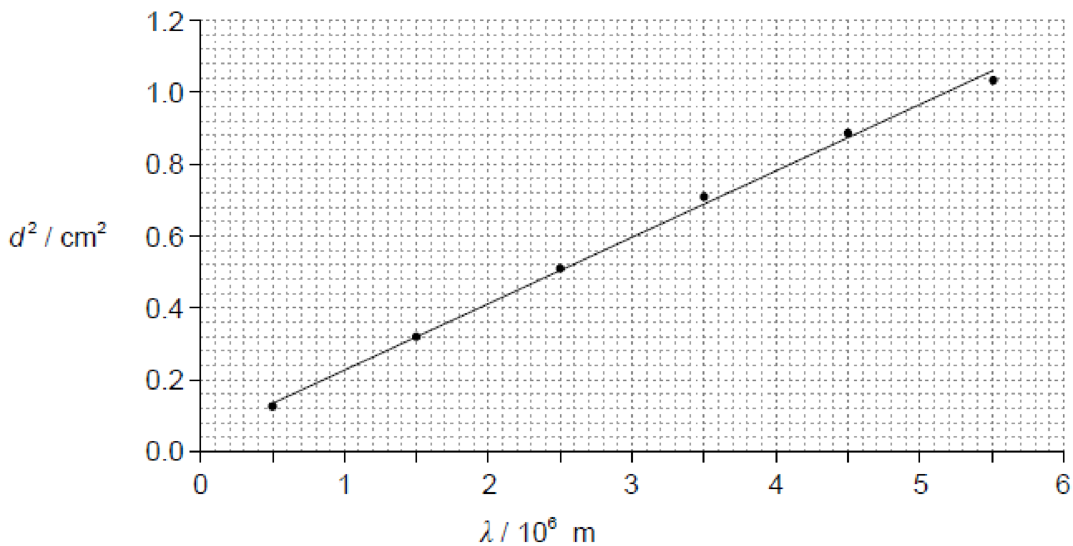
Outline why the graph deviates from a straight line for large values of OX.

A radio wave of wavelength λ is incident on a conductor. The graph shows the variation with wavelength λ of the maximum distance *d* travelled inside the conductor.



For $\lambda = 5.0 \times 10^5$ m, calculate the

The graph shows the variation with wavelength λ of d^2. Error bars are not shown and the line of best-fit has been drawn.



A student states that the equation of the line of best-fit is $d^2 = a + b\lambda$. When d^2 and λ are expressed in terms of fundamental SI units, the student finds that $a = 0.040 \times 10^{-4}$ and $b = 1.8 \times 10^{-11}$.

a. Suggest why it is unlikely that the relation between d and λ is linear. [1]

b.i. fractional uncertainty in d. [2]

b.ii. percentage uncertainty in d^2. [1]

c.i. State the fundamental SI unit of the constant a and of the constant b. [2]

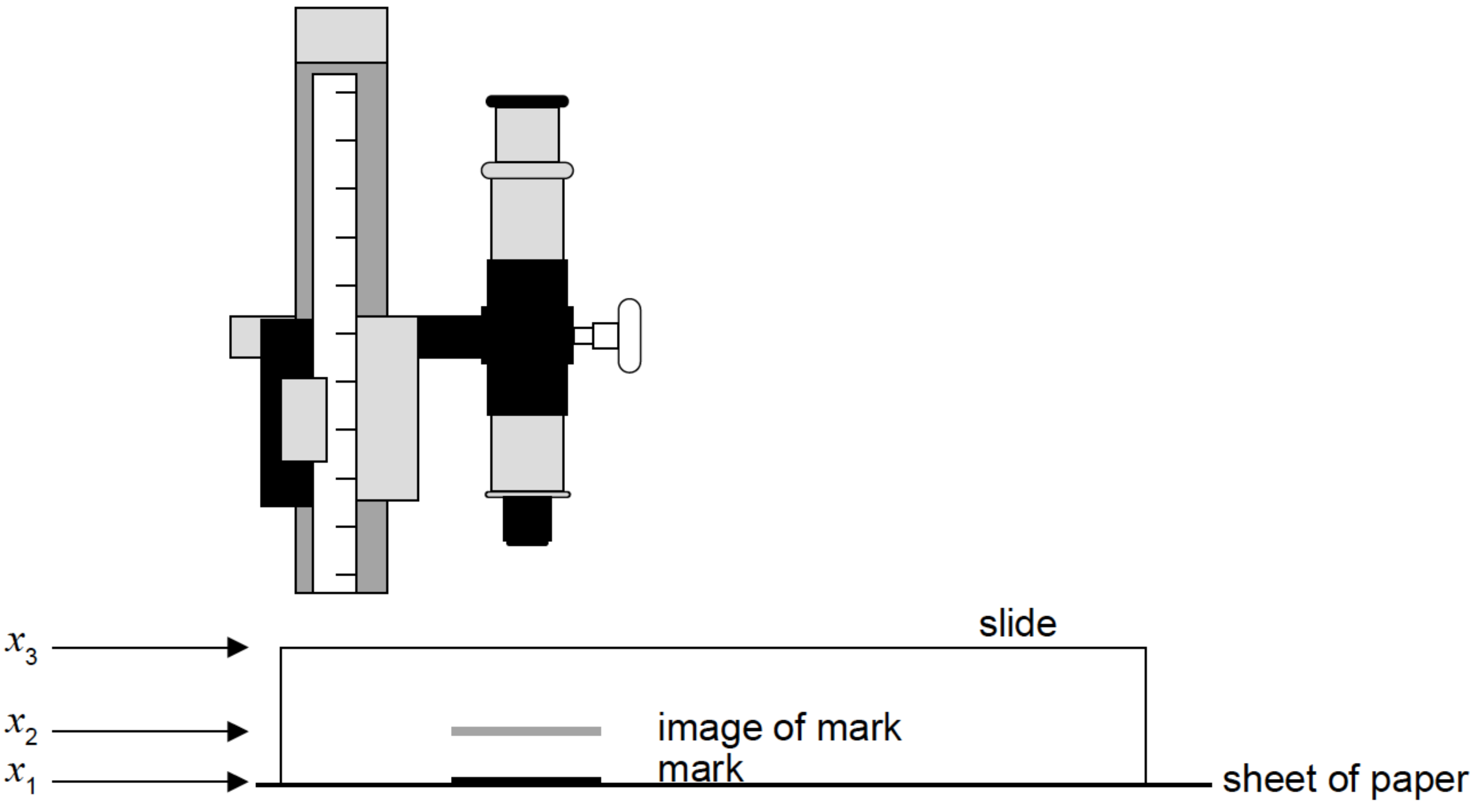
a: ....

b: ....

c.ii.Determine the distance travelled inside the conductor by very high frequency electromagnetic waves. [2]

A student measures the refractive index of the glass of a microscope slide.

He uses a travelling microscope to determine the position x_1 of a mark on a sheet of paper. He then places the slide over the mark and finds the position x_2 of the image of the mark when viewed through the slide. Finally, he uses the microscope to determine the position x_3 of the top of the slide.



The table shows the average results of a large number of repeated measurements.

	Average position of mark / mm
x_1	0.20 ±0.02
x_2	0.59 ±0.02
x_3	1.35 ±0.02

a. The refractive index of the glass from which the slide is made is given by [4]

$$\frac{x_3 - x_1}{x_3 - x_2}$$

.

Determine

(i) the refractive index of the glass to the correct number of significant figures, ignoring any uncertainty.

(ii) the uncertainty of the value calculated in (a)(i).

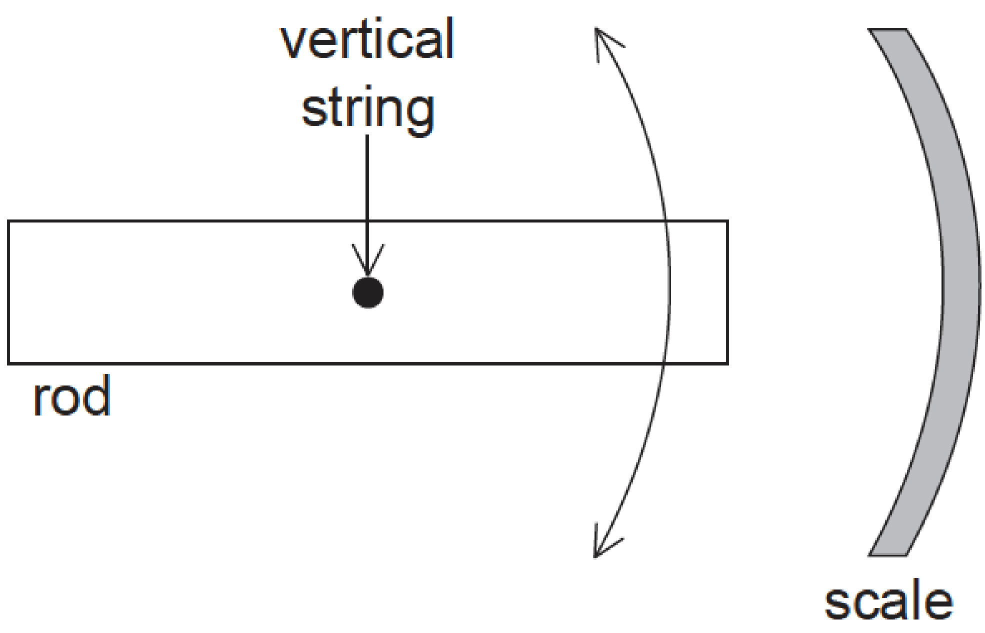
b. After the experiment, the student finds that the travelling microscope is badly adjusted so that the measurement of each position is too large by 0.05mm. [3]

(i) State the name of this type of error.

(ii) Outline the effect that the error in (b)(i) will have on the calculated value of the refractive index of the glass.

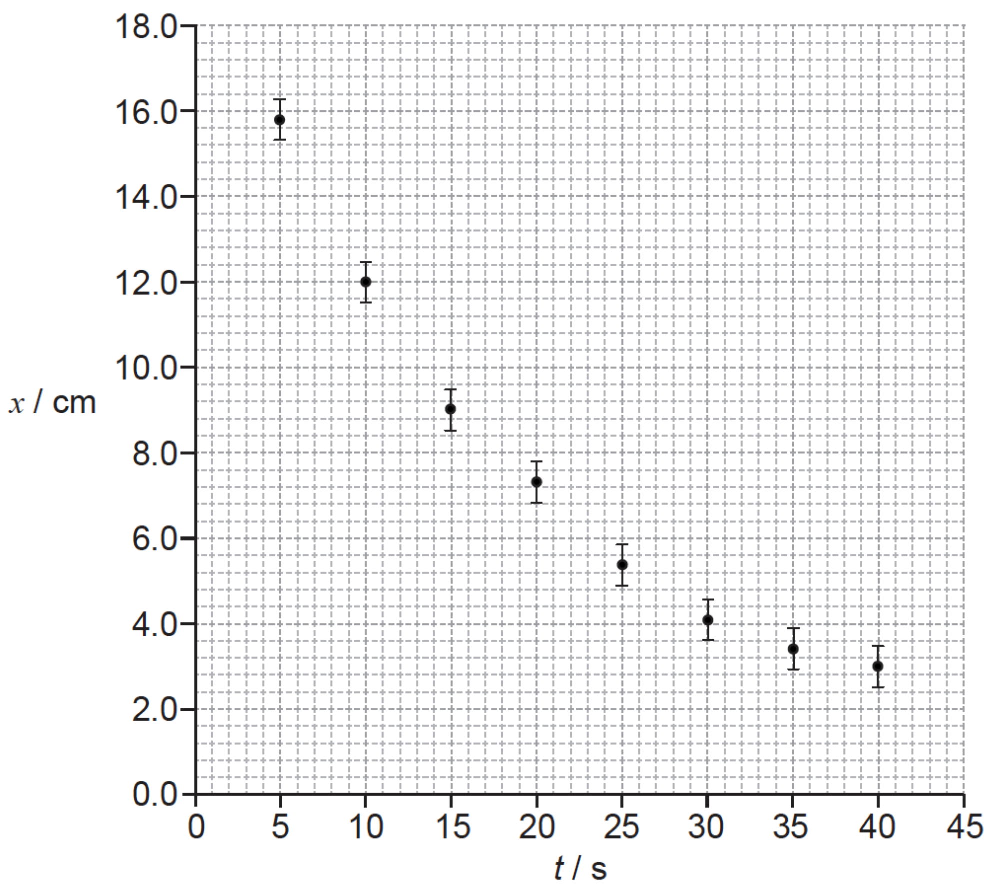
c. After correcting the adjustment of the travelling microscope, the student repeats the experiment using a glass block 10 times thicker than the original microscope slide. Explain the change, if any, to the calculated result for the refractive index and its uncertainty. [2]

A student investigates the oscillation of a horizontal rod hanging at the end of a vertical string. The diagram shows the view from above.



The student starts the rod oscillating and measures the largest displacement for each cycle of the oscillation on the scale and the time at which it occurs. The student begins to take measurements a few seconds after releasing the rod.

The graph shows the variation of displacement *x* with time *t* since the release of the rod. The uncertainty for *t* is negligible.

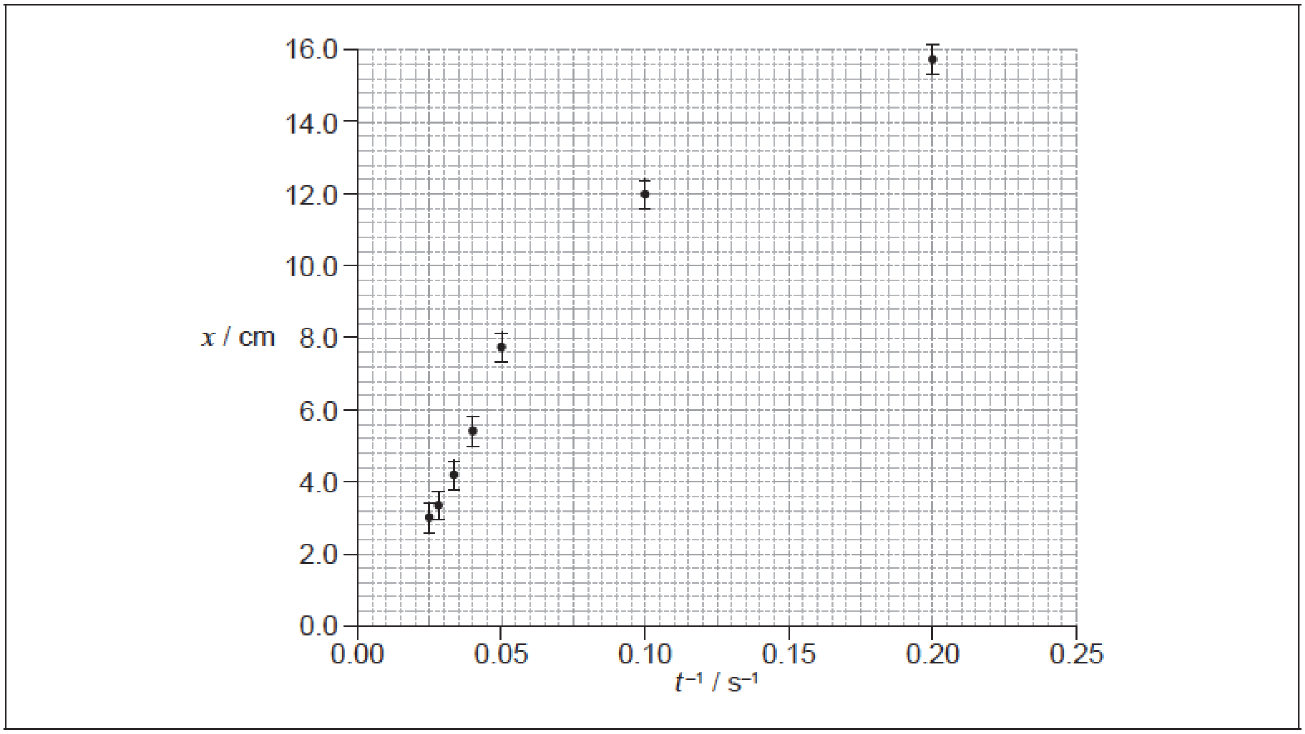


a. On the graph above, draw the line of best fit for the data. [1]

b. Calculate the percentage uncertainty for the displacement when t=40s. [2]

c. The student hypothesizes that the relationship between x and t is $x = \frac{a}{t}$ where a is a constant. [3]

To test the hypothesis x is plotted against $\frac{1}{t}$ as shown in the graph.



(i) The data point corresponding to t=15s has not been plotted. Plot this point on the graph above.

(ii) Suggest the range of values of t for which the hypothesis may be assumed to be correct.