SECTION A

Answer **all** the questions.

1 This question is about estimating small dimensions.

A stack of paper, shown in Fig. 1.1, forms a cube. It was measured, using a standard metre ruler, and found to have a side length of 7.60 ± 0.05 cm.

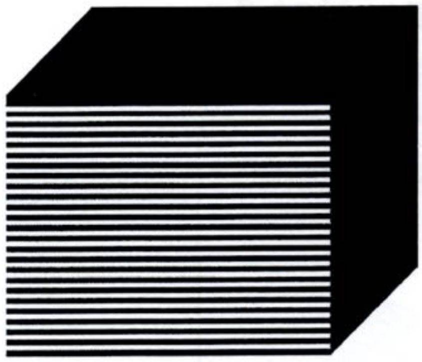


Fig. 1.1

(a) (i) Suggest why an uncertainty value of ± 0.05 cm is reasonable when using a standard metre ruler.

Uncertainty is half smallest scale division of 0.1 cm **[1]**

(ii) Calculate the volume, *V*, of the stack of paper.

$V = l^3 = 7.6^3 =$

V = 439 cm^3 **[1]**

(iii) Show that the percentage uncertainty in the volume of the pad is approximately 2%.

$\%U \text{ in } l = \frac{0.05}{7.6} \times 100 = 0.658$

$\%U \text{ in } l^3 = 3 \times 0.68 = 1.97\%$

[2]

(b) The individual sheets from the pad were laid out, side by side, on a flat surface, to form a square. The length of the side of the resulting square was found to be 152.00 ± 0.05 cm.

(i) Explain why dividing the volume of the pad by the total area of sheets when laid out flat gives the thickness of a single sheet.

Volume remains constant

[1]

(ii) Calculate the thickness, t, of a single sheet of paper using this method and include

$V = A \times t \quad \therefore \quad t = V/A$

$= 439/152^2 = 0.0190$

$\%U_A = 2 \times \frac{0.05}{152} \times 100 = 0.0658\%$

$\%U_t = 0.0658 + 1.97 = 2.04\%$

t = 0.0190 cm ± 2 % **[3]**

(iii) Suggest an alternative method to find the paper thickness that reduces the uncertainty in the result.

Measure total thickness and divide by number of sheets ($7.6/0.019 = 400$)

[1]

(c) An experiment to estimate the size of an oil molecule was first carried out in 1899 by Lord Rayleigh.

The diameter, *d*, of a small drop of oil held on a wire loop is measured using a hand lens and a millimetre scale as shown in Fig. 1.2

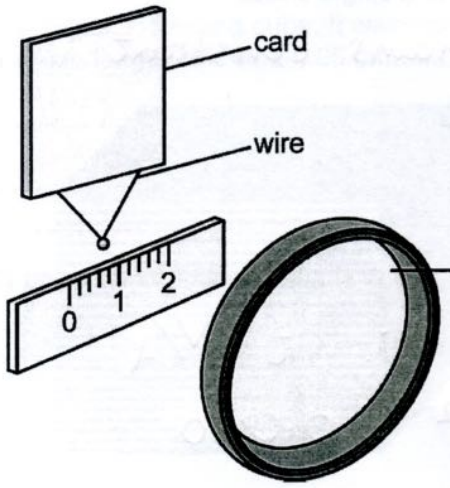


Fig. 1.2

The oil drop is placed on a clean water surface lightly dusted with talcum powder. The drop spreads over the surface, pushing back the talcum powder, producing an almost circular patch, diameter D, on the water surface as shown in Fig. 1.3

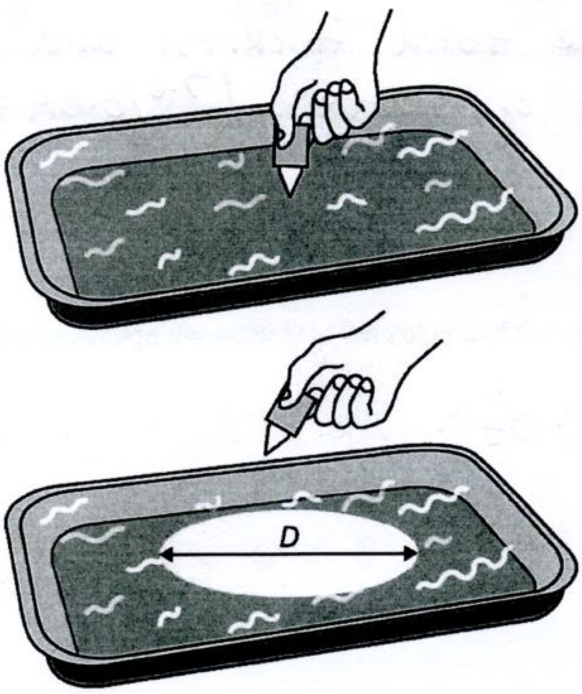


Fig. 1.3

(i) Show that the thickness of the oil film, t, is given by

$$V = \frac{4}{3}\pi r^3 \quad r = \frac{d}{2} \quad \frac{2d^3}{3D^2} \quad V = \pi r^2 t \quad r^2 = \frac{D^2}{4}$$

$$V = \frac{4}{3}\pi\frac{d^3}{8} = \frac{\pi d^3}{6} \quad r^3 = \frac{d^3}{8} \quad V = \frac{\pi D^2}{4}t$$

$$\therefore \frac{\pi d^3}{6} = \frac{\pi D^2}{4}t \quad \therefore t = \frac{4\pi d^3}{6\pi D^2} = \frac{2d^3}{3D^2}$$ **[1]**

(ii) Rayleigh suggested that the oil would spread over the water surface until the patch was one molecule thick. The thickness of the patch is therefore an estimate of the size of an oil molecule.

Suggest how the uncertainty in the values of d and D might be minimized and explain why this is essential if the uncertainty in t is to be reasonably small.

Measure D in several directions and calculate a mean. Uncertainty is ×2 as $V \propto D^2$

Measure d using microscope as uncertainty is ×3 as $V \propto d^3$.

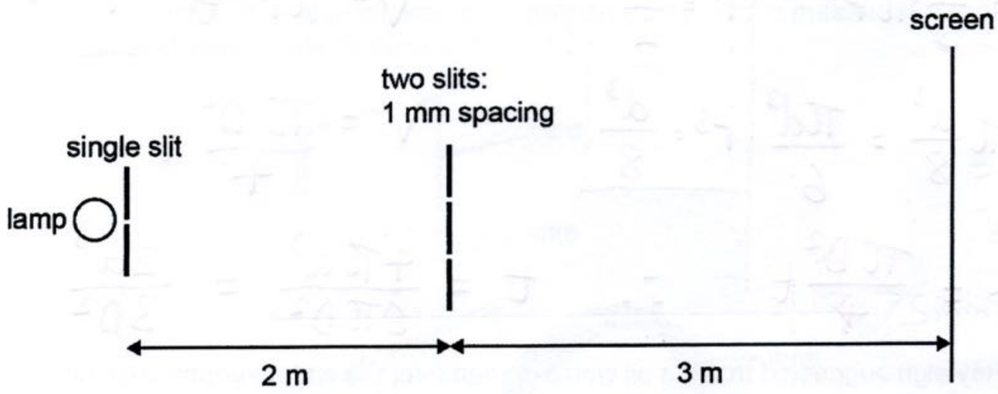
[3]

$$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 = t\,\pi\left(\frac{D}{2}\right)^2$$

$$\frac{d^3}{6} = \frac{tD^2}{4}$$

$$t = \frac{2d^3}{3D^2}$$

2 Fig. 2.1 shows the layout of the apparatus required to observe the superposition of light from two sources.



Not to scale

Fig. 2.1

(a) In a laboratory experiment a vertical filament optics lamp and single slit were used as the light source placed 2 m away from a pair of slits. The slits were produced by painting a glass slide black and then scraping two lines in the paint using a pin.

(i) Suggest how the double slit spacing could be determined.

Microscope with graticule (scale slide)

.... [1]

(ii) Explain why it is necessary to have a small slit spacing.

To get large enough slit spacing

$\lambda = dx/L \therefore x = \frac{\lambda L}{d}$ & λ is small.

.... [2]

(b) Fig. 2.2 shows the arrangement used to create the interference pattern on the screen. The slit separation is *d* and the distance from the slits to the screen is *L*. Point **O** shows the position of the central maximum and the distance to the adjacent maximum at point **P** is *x*.

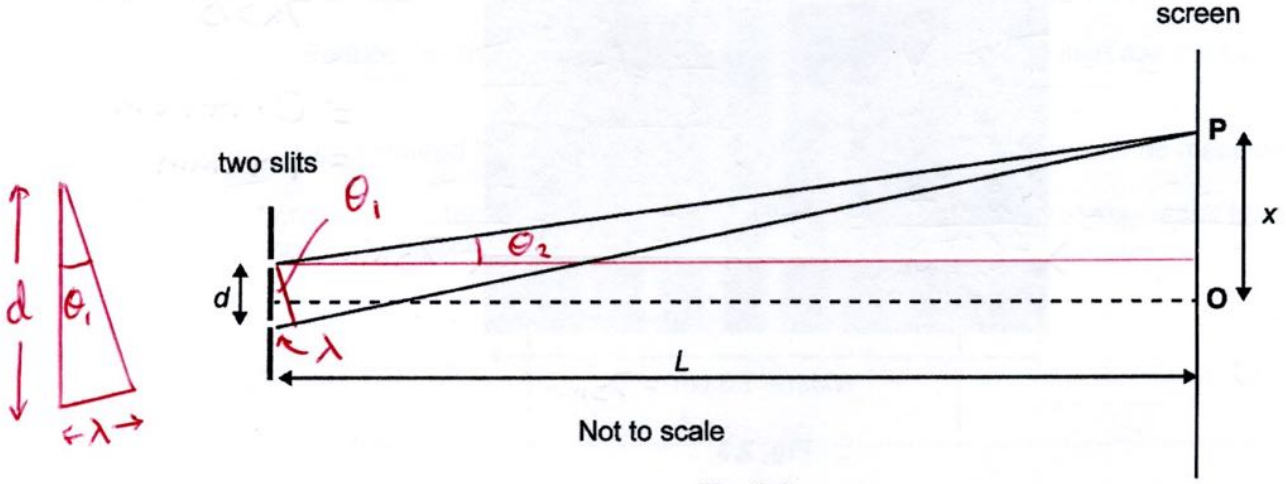


Fig. 2.2

Use the diagram to explain why

$$\lambda \approx \frac{xd}{L}.$$

(For small θ in radians)

$\theta_1 \approx \frac{\lambda}{d}$

$\theta_2 \approx \frac{x}{L}$

$\theta_1 \approx \theta_2$ so

$\frac{\lambda}{d} \approx \frac{x}{L}$

$\lambda \approx \frac{xd}{L}$

OR using trig.

$\sin\theta_1 = \frac{\lambda}{d}$

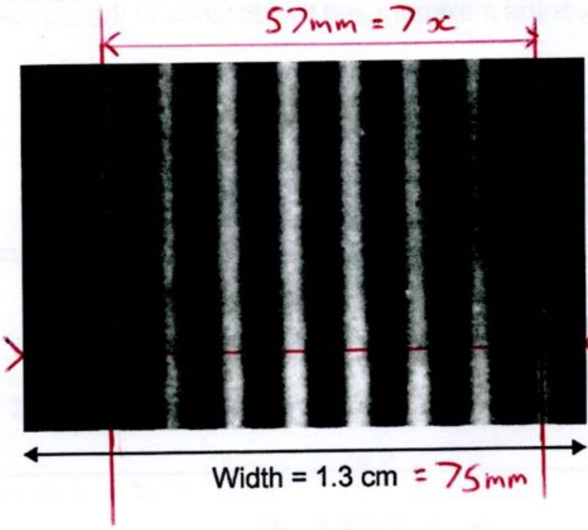
$\tan\theta_2 = \frac{x}{L}$

For Small θ $\sin\theta \approx \tan\theta$ and $\theta_1 = \theta_2$

∴

[2]

(c) Fig. 2.3 shows the pattern of light observed on the screen placed 3 m away from a pair of slits spaced 1 mm apart. The total width of the pattern shown was measured to be 1.3 cm.



$$x = \frac{57}{7 \times 75} \times 1.3 \text{ cm}$$

$$= 0.141 \text{ cm}$$

$$= 1.41 \text{mm}$$

Fig. 2.3

Use data from Fig. 2.3 to estimate the wavelength, λ, of the light used in this experiment.

$$\lambda = \frac{dx}{L} = \frac{1 \times 10^{-3} \times 1.41 \times 10^{-3}}{3} = 4.7 \times 10^{-7}$$

λ = 4.7×10^{-7} m **[3]**

Allow x 0.136 to 0.149 cm

λ 453 – 497 nm

(d)* Some changes were suggested to improve the experiment:

(1) Increase the distance between the slits and the screen to increase the fringe spacing.

(2) Increase the slit width to increase the intensity of light reaching the screen.

(3) Reduce the distance between the light source and the slits to increase the intensity of the fringes.

(4) Use coloured filters to enable the wavelengths of specific colours to be measured.

Comment on each of the proposals, pointing out any difficulties that may result from the changes mentioned.

(1) Fringes dimmer so fewer visible but x will be larger

(2) Fringes brighter but more spread out - they may overlap making it hard to measure x. + Less diffraction at each slit

(3) Less distance for light to spread out from 1st slit so double slit may not be fully illuminated - Making 1st slit narrower will overcome this but make intensity lower.

(4) Will remove coloured fringes but intensity will be much lower. May not be possible to see them. **[6]**

+ see markscheme.

Level 3 (5-6 marks) ✓✓
Addresses all four points with reasoned comments regarding practicality and disadvantages.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3-4 marks) ✓✓
Addresses each point but may not appreciate the associated difficulty in some cases

There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.

Level 1 (1-2 marks) ✓✓
Comments on at least two points with a least one difficulty described.

The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.

e.g. Increasing the distance between slits and screen will have the desired effect of increasing the fringe spacing but the intensity of the fringes may become so low that fewer if any are clearly visible, making measurement difficult.

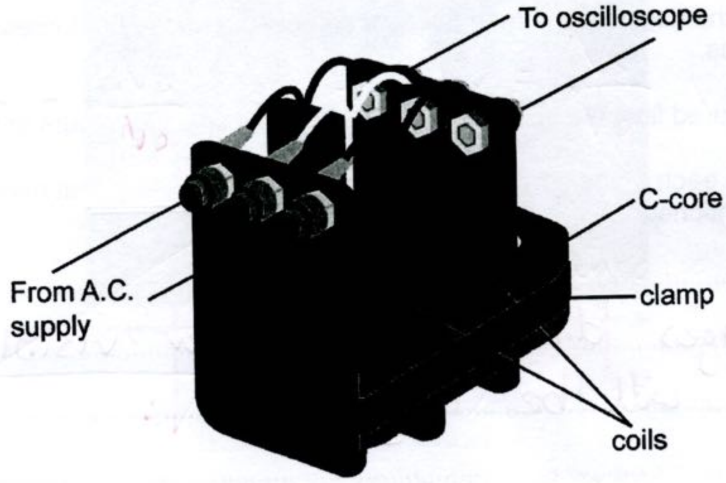
Increasing the slit width to increase the intensity of light reaching the screen will allow more light to reach the screen but the larger slits will allow less diffraction to occur at each slit so the waves from each slit are less likely to superimpose and fringes will not be formed.

Reduce the distance between the light source and the slits to increase the intensity of the fringes. More diffraction at the first slit will be required in order for both the secondary slits to be illuminated. Therefore narrower slit required and lower light intensity will result.

Use coloured filters to enable the wavelengths of specific colours to be measured. A useful improvement but filters will reduce the intensity of light reaching the screen so the fringes may not be visible.

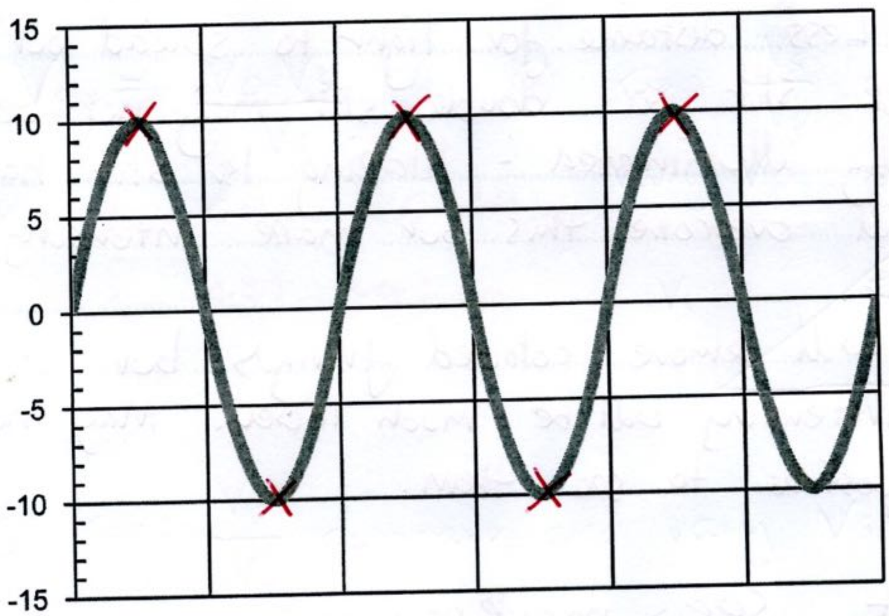
3 This question is about the behaviour of transformers.

In an experiment to verify the relationship between the primary and secondary voltage and the number of turns on the primary and secondary windings, some pre-wound coils were assembled onto a laminated iron C-core as shown below.



(a) The voltages were measured using an oscilloscope. The y axis was set to 5 volts per division and the x axis to 10 milliseconds per division. The voltage gain and time base settings remained constant throughout the experiment.

The trace shown below was obtained with a secondary coil of 300 turns.



(i) Mark with an **X** three points on the trace where the flux in the transformer core is zero.

[1]

(ii) Show that the maximum rate of change of flux in the core is about 3 x 10^{-2} Wb s^{-1}.

$$\varepsilon = \frac{N d\Phi}{dt} \therefore \frac{d\Phi}{dt} = \frac{\varepsilon}{N} = \frac{10V}{300} = 0.033 \text{ Wbs}^{-1}$$

[1]

(iii) Explain why the peak flux in the core is unlikely to exceed 0.17 mWb.

Flux cannot exceed max $d\Phi/dt$ times time flux rises = 10ms/2

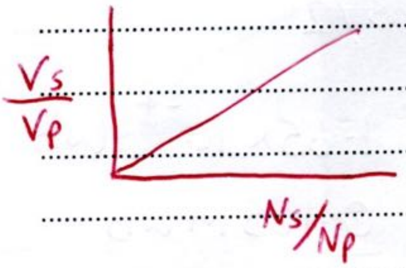
$$0.033 \times \frac{10 \times 10^{-3}}{2} = 1.65 \times 10^{-4} \text{ Wb}$$

[2]

$$= 0.165 \text{ mWb}$$

(b)* Describe the experiments, using the same apparatus, which would need to be performed in order to verify the equation that links the primary and secondary voltages with the numbers of turns on the primary and secondary coils for an ideal transformer. Include how the data gathered would be analysed in order to see if it was consistent with the equation.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

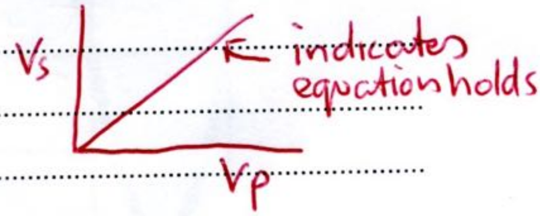


For range of N_s/N_p and V_s/V_p plot V_s/V_p vs N_s/N_p. a straight line indicates that the equation holds.

OR better ...

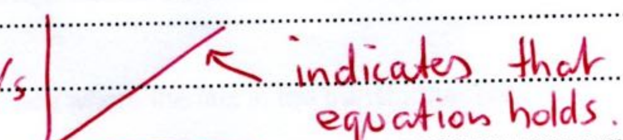
$$V_s = \frac{V_p N_s}{N_p}$$

① Keep $\frac{N_s}{N_p}$ constant and vary V_p plot



② Keep $\frac{V_p}{N_p}$ constant and vary N_s

plot graph of



[6]

+ see markscheme

Level 3 (5-6 marks) ✓✓ Experiments V_s against V_p and V_s against N_p both described in detail, including graphs expected and the interpretation of them leading to the expression $V_s/V_p = N_s/N_p$ *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** ✓✓ Experiments V_s against V_p and V_s against N_p both described or one in detail, including graphs expected and some interpretation of them leading to the expression $V_s/V_p = N_s/N_p$ *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1-2 marks)** ✓✓ Either experiments V_s against V_p or V_s against N_p described with some interpretation of results leading to an appreciation of the relationship, $V_s/V_p = N_s/N_p$ *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**6**	**Indicative points include:** V_s against V_p identified as additional experiment. V_s against N_p identified as additional experiment. Statement of variables held constant for each experiment. Details of graphs plotted : e.g. V_s against V_p showing direct proportion V_s against $1/N_p$ indicating inverse proportion between V_s and N_p Clear link to $V_s/V_p = N_s/N_p$

SECTION B

Answer **all** the questions.

4 This question is about an experiment investigating the relationship between volume of a gas, V, and temperature, T, at constant pressure. Fig 4.1 shows measurements taken by a student.

T / °C ±1 °C	**V / mm^3 ±5 mm^3**
1	115
6	117
10	119
15	122
20	124
25	127
30	130

Fig 4.1

Fig. 4.2 shows the graph for five of the data points.

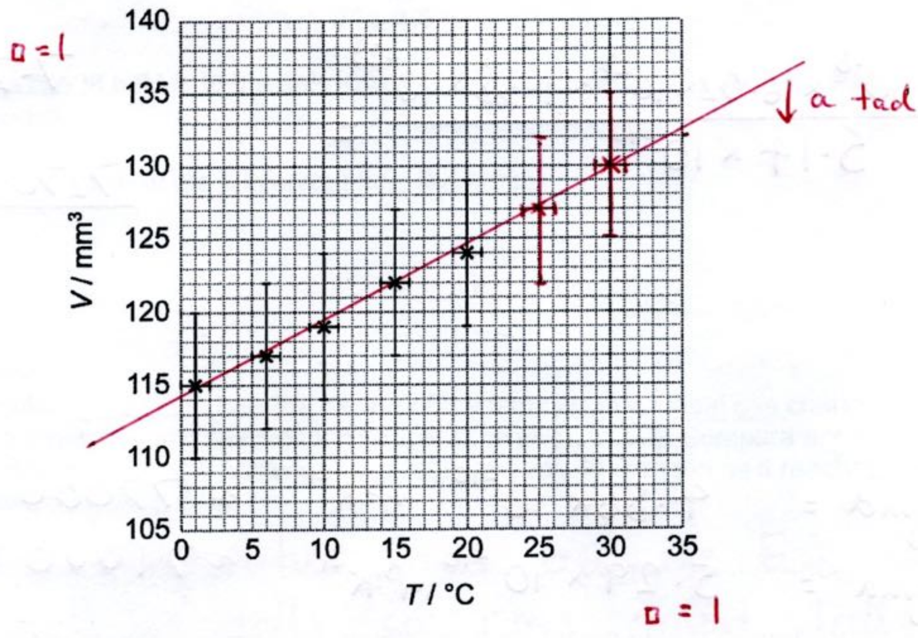


Fig. 4.2

(a) (i) Add the **two** remaining data points to the graph. Include uncertainty bars for the points and an appropriate line of best fit.

[4]

$\left(x \text{ intercept} = \frac{-c}{m} = \frac{-114}{18/35} = -221 \text{ K} \right)$

(ii) Calculate the percentage uncertainty for the values of V and T at point (30, 130).

$T \quad 1/30 \times 100 = 3.3\%$

$V \quad 5/130 \times 100 = 3.8\%$

Percentage uncertainty in V = 3.8 %

Percentage uncertainty in T = 3.3 %

[2]

(iii) The sample contains 4.5 μmol of particles. Use data from the graph to calculate the pressure of the gas, P.

$\frac{V}{T}$ = Gradient $= (132-114)\times 10^{-9}\,m^3/35\,K = 5.14\times 10^{-10}\,m^3K^{-1}$

$pV = NkT \therefore p = \frac{NkT}{V} = \frac{Nk}{grad}$

$p = \frac{4.5\times 10^{-6}\times 6.02\times 10^{23}\times 1.38\times 10^{-23}}{5.14\times 10^{-10}}$

P = 7.27×10^4 Pa

[4]

72700 Pa

min grad = $4.86\times 10^{-10}\,m^3K^{-1}$ ~ 77000 Pa

max grad = $5.29\times 10^{-10}\,m^3K^{-1}$ ~ 71000 Pa

(b) Fig. 4.3 shows the same data set plotted on different axes. The uncertainties in T and V are too small to be shown on this graph.

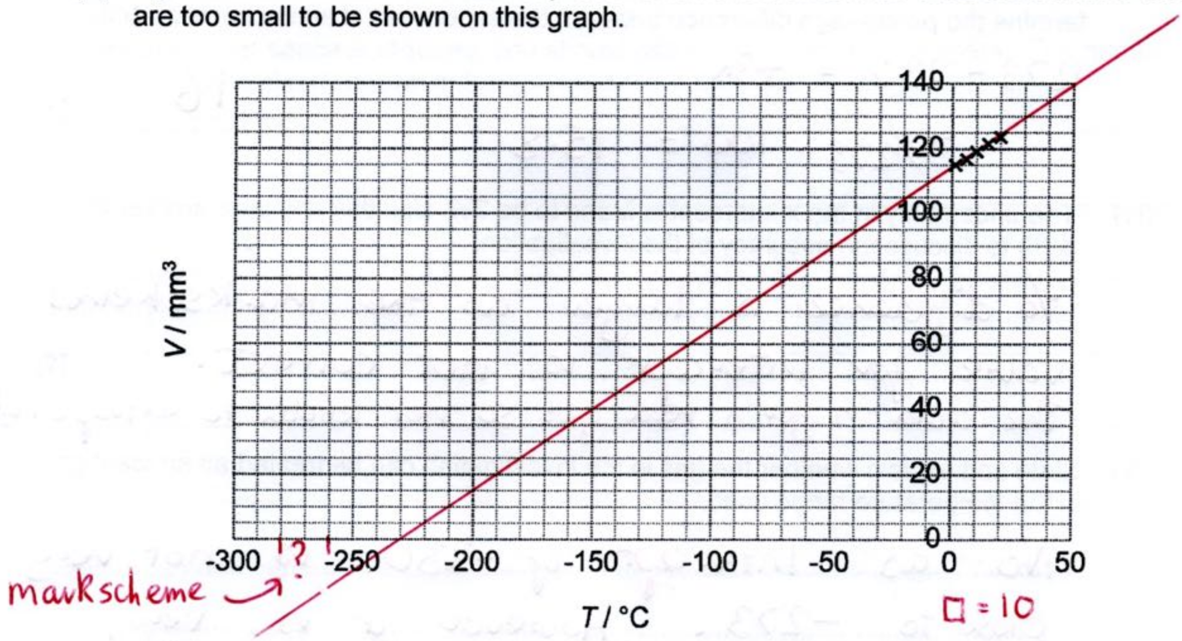


Fig. 4.3

(i) Add a line of best fit to the data points and extrapolate the line so that it intercepts the x-axis.

State the value of the x-intercept from the graph.

x-intercept = -230 **[1]**

(ii) Describe and explain how the motion of the particles in an ideal gas changes as the gas approaches and reaches the temperature given in **b(i)**. Compare and explain any differences in the behaviour of a real gas such as nitrogen as it reaches the temperature given **b(i)**.

As temperature falls average E_K of ideal gas particles falls so rms speed falls until at 0K E_K and V = 0

A real gas will condense and then freeze as bonds between the molecules form. **[4]**

(iii) The accepted value of the *x*-intercept is – 273 °C. Use your answer from **b(i)** to determine the percentage difference between the experimental and accepted value.

273 − 230 = 43K

43/273 × 100 = 15.8

16 % **[1]**

(iv) The uncertainty in the *x*-intercept is found to be 7%. Use this and your answer to **b(iii)** to discuss the accuracy of the investigation.

% difference is larger as the markschemes value for intercept is not correct. **[2]**
The data is for a real gas so not reliable to extrapolate...

...to OK

(v) State and explain whether the gas in the investigation can be treated as an ideal gas in the temperature range used.

No as intercept of −230 is not very close to −273. However it is very close to a straight line as graph. **[1]**

(vi) The molar mass of N_2 is 28 g mol^{-1}.

Treating nitrogen as an ideal gas, calculate the ratio of the r.m.s speed of the gas molecules between *T*= 20 °C and *T*= -196 °C.

Number of particles in one mole = 6.0 x 10^{23} mol^{-1}

$pV = \frac{1}{3}Nm\overline{c^2} = NkT \quad \therefore \quad \overline{c^2} = \frac{3kT}{m}$

$\therefore \sqrt{\overline{c^2}} = \sqrt{\frac{3kT}{m}} \qquad \text{ratio} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{293}{77}}$

[4]

= 1.95 : 1

END OF QUESTION PAPER