SECTION A

Answer **all** the questions.

1 This question is about using a thermistor in a temperature sensing circuit.
The graph, Fig. 1.1, shows how the resistance *R* of a thermistor varies with temperature *T*.

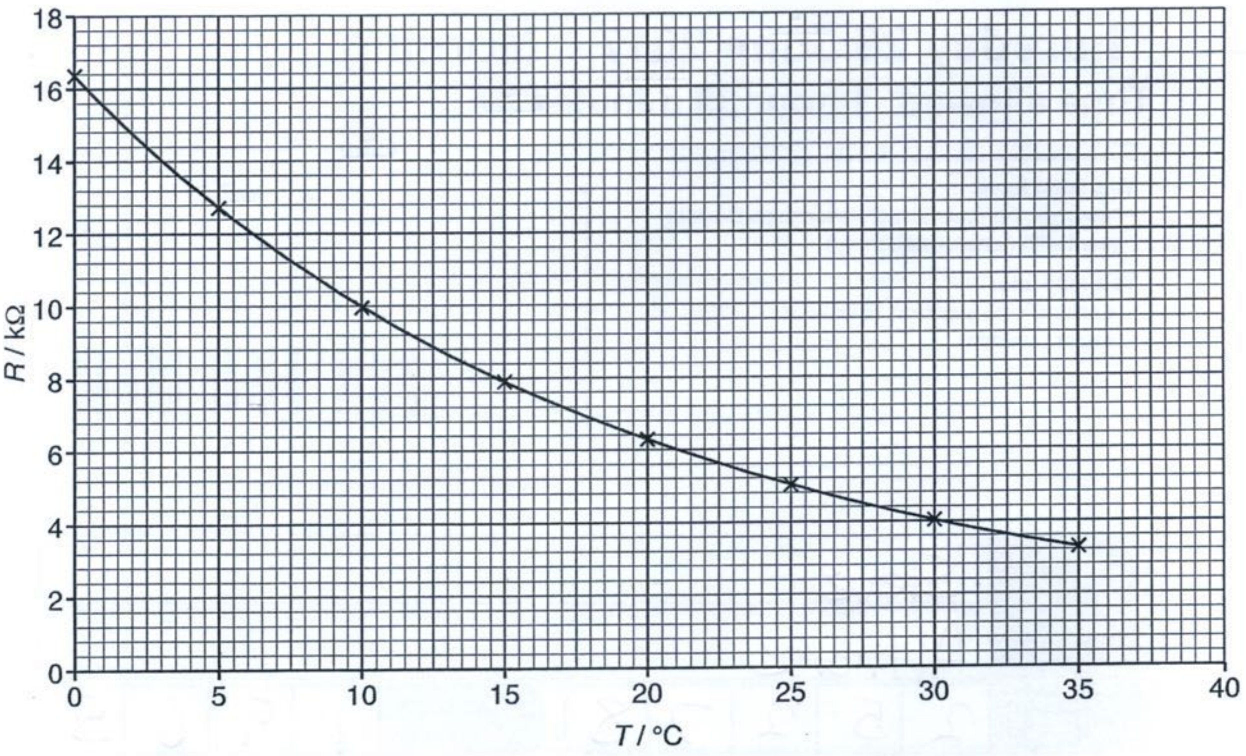


Fig. 1.1

(a) The resistance of the thermistor can be measured with a multimeter on the resistance range. Suggest how you might vary and measure the temperature of the thermistor so that the data, for Fig. 1.1, could be collected.

Place the thermistor, together with a thermometer into a beaker of oil warmed to above 35°C Place into freezer and take temperature and resistance measurements as the oil cools. **[2]**

The thermistor is used in the potential divider shown in Fig. 1.2.

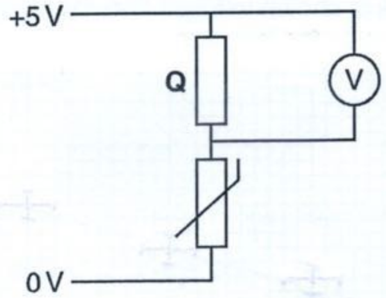


Fig. 1.2

(b) Suggest why the voltmeter is connected across the fixed resistor **Q** rather than the thermistor in this temperature sensing circuit.

So increasing voltage corresponds to increasing temperature.

[1]

(c) Readings of voltage V_{out} against temperature T are recorded using an analogue voltmeter. The uncertainty in the voltmeter readings is ± 0.1 V and the uncertainty in the temperature readings is ± 1 °C. The data is shown in Fig. 1.3 in the form of a graph.

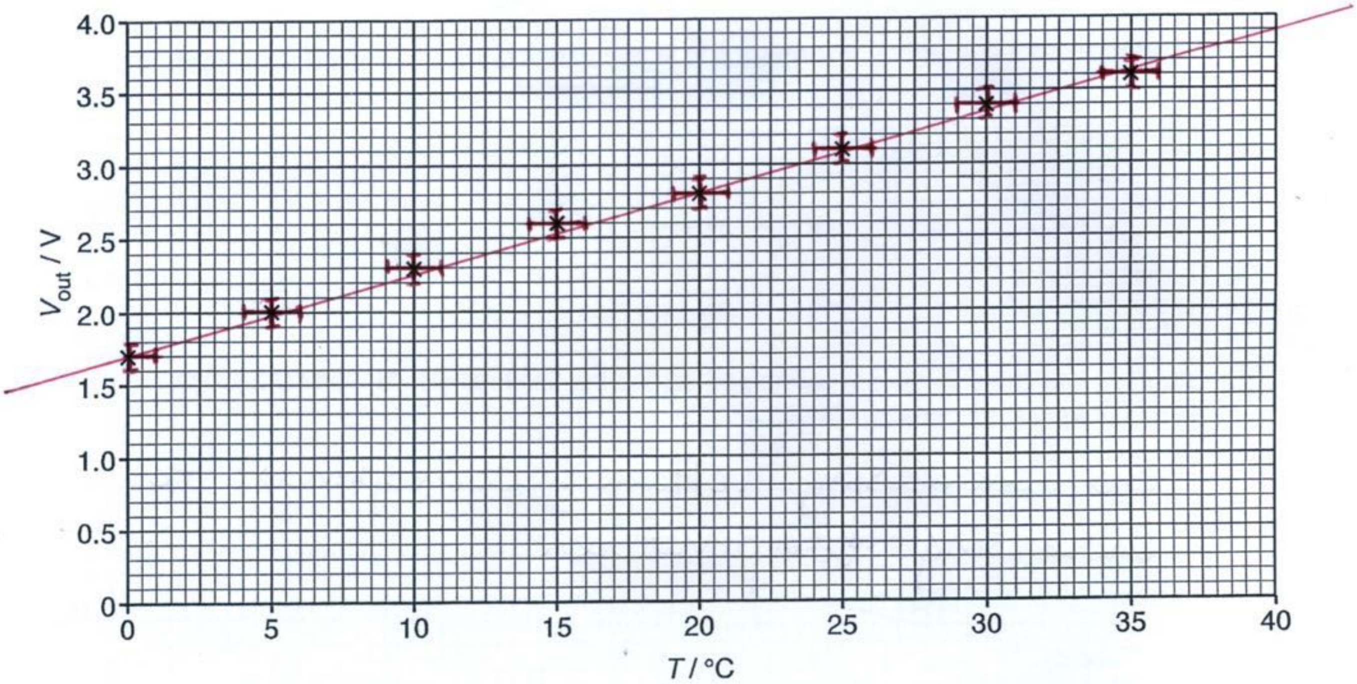


Fig. 1.3

(i) It is suggested that V_{out} varies linearly with T. By adding uncertainty bars to Fig. 1.3 use the graph to show that this is true over the temperature range tested. State your reasoning.

A straight line fits between the uncertainty bars.

[3]

(ii) Explain how you could calibrate the analogue voltmeter scale to read temperature directly.

Replace the voltage scale with a temperature scale. The gradient = $3.9 - 1.7/40$ = 0.055 V/°C and the intercept = 1.7 V $\therefore T = \frac{V_{OUT} - 1.7}{0.055}$

[2]

(d)* Discuss the effect of changing the fixed resistor **Q** to a higher **and** a lower value on the performance of the temperature sensing circuit over the range of temperatures 0 – 35 °C. Use data from Fig. 1.1 and Fig. 1.3 to perform calculations to support your ideas.

At 10°C $V_{OUT} = 2.3V \therefore V_{THER} = 2.7V$
and $R_{THUR} = 10k\Omega$
$Q/R_{THUR} = V_{OUT}/V_{THUR} \therefore Q = \frac{2.3V}{2.7V} \times 10k\Omega$
$\therefore Q = 8.5k\Omega$

		LOWER	HIGHER
	$Q = 8.5k\Omega$	eg $Q = 1k\Omega$	eg $Q = 100k\Omega$
At 0°C $R_{THUR} = 16.4\ k\Omega$	$V_{OUT} = 5 \times \frac{8.5}{24.9}$ $= 1.7V$	$V_{OUT} = 5 \times \frac{1}{17.4}$ $= 0.29V$	$V_{OUT} = 5 \times \frac{100}{116.4}$ $= 4.3V$
At 35°C $R_{THUR} = 3.3\ k\Omega$	$V_{OUT} = 5 \times \frac{8.5}{11.8}$ $= 3.6V$	$V_{OUT} = 5 \times \frac{1}{4.3}$ $= 1.2V$	$V_{OUT} = 5 \times \frac{100}{103.3}$ $= 4.8V$
Output Range	1.9V	0.9V	0.5V
Sensitivity V/°C	1.9/35 = 0.054	0.9/35 = 0.026	0.5/35 = 0.014

The best performance is when $Q \approx R_{THUR}$ as this gives the best sensitivity.

[6]

2 This question is about the behaviour of a mass on a spring.

(a) The table below shows how the extension *x* of a spring varies as the mass *m* suspended vertically from it alters.

m / g	*x* / cm
100	2.5
200	5.1
300	7.5
400	9.9
500	12.5
600	15.0

Fig. 2.1

(i) Apply a test to the data to see if the extension of the spring is proportional to the applied force. Explain your method and state your conclusion.

If $x \propto F$ and $F = mg$ then $x \propto mg$ (g is constant)

so m/x = constant.

$100/2.5 = 40.0$
$200/5.1 = 39.2$
$300/7.5 = 40.0$
$400/9.9 = 40.4$
$500/12.5 = 40.0$
$600/15 = 40.0$

Yes $\frac{m}{x}$ is constant to 2 sig. fig.

[3]

(ii) Calculate the spring constant *k* of this spring.
$g = 9.8\,\text{N kg}^{-1}$

e.g. $100\text{g} = 0.1\text{ kg}$
$2.5\text{cm} = 0.025\text{m}$

$F = mg = kx$

$\therefore k = \frac{mg}{x} = \frac{0.1 \times 9.8}{0.025}$

$= 39.2\ \text{Nm}^{-1}$

k = ...39...... N m^{-1} **[1]**

(b) In order to investigate the behaviour of an oscillating mass and spring system, the spring is suspended vertically below a vibration generator. A mass is added to the bottom of the spring. The arrangement is suspended above an ultrasound distance sensor as shown in Fig. 2.2.

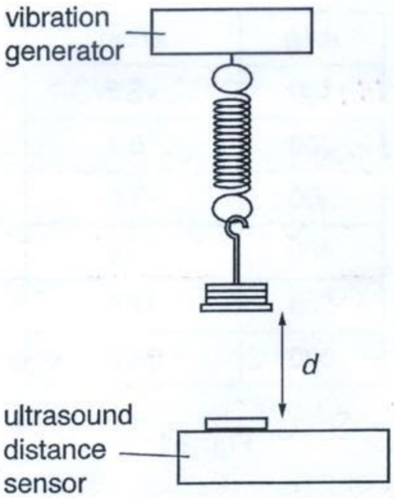


Fig. 2.2

With the vibration generator switched off, the mass is given a small vertical displacement then released. A few oscillations later the ultrasound distance sensor is started and the trace shown in Fig. 2.3 is displayed on a computer.

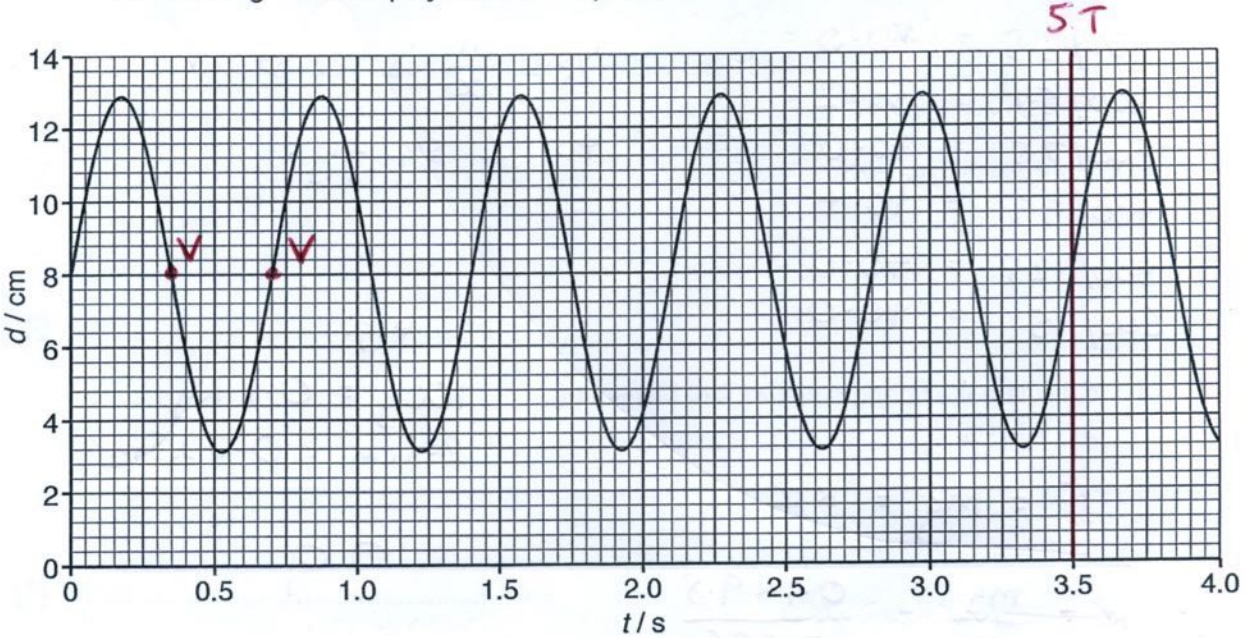


Fig. 2.3

(i) Mark **two** points on the curve shown in Fig. 2.3, to indicate where the speed of the oscillating mass is at its maximum. Label each point with a letter **V**. **[1]**

(ii) Use data from the trace shown in Fig. 2.3 to calculate the natural frequency f of the mass and spring system.

5 oscillations in 3.5 s $\therefore T = 3.5/5 = 0.70\,s$

$$f = \frac{1}{T} = \frac{1}{0.7} =$$

$f =$ ......1.43...... Hz **[2]**

(iii) Show that the mass m supported by the spring is about 500 g.

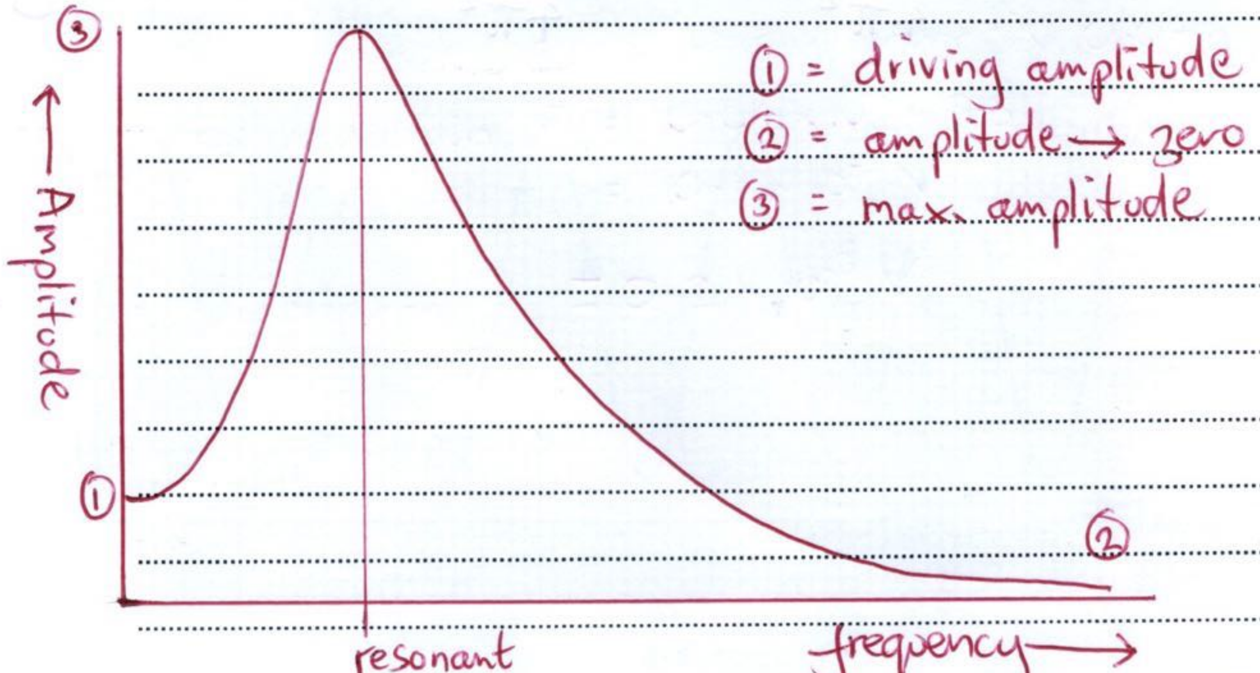
$$T = 2\pi\sqrt{m/k}$$

$$\therefore \quad m = \frac{T^2 k}{4\pi^2} = \frac{0.7^2 \times 39.2}{4\pi^2} = 0.49\,kg$$

[2]

(c)* By connecting the vibration generator to a signal generator it is possible to use this apparatus to investigate forced oscillations of the mass and spring system. Describe in as much detail as possible how you would carry out the investigation, the data that you would record and what you would expect the results to show.

Use a signal generator with a digital frequency display (or connect CRO to output to measure frequency). Start at a low frequency ~0.1 Hz and use the ultrasound distance sensor (or ruler + slow motion video) to measure the amplitude. Increase the frequency a bit and repeat. When close to the resonant frequency go up in very small steps.



[6]

3 This question is about the measurement of the **B**-field between a pair of slab magnets.
Fig. 3.1 shows the arrangement of the apparatus used in the experiment. It consists of a pair of slab magnets, with opposite poles facing one another, fixed onto a piece of U-shaped soft iron. The magnet assembly sits on top of an electronic balance. A rigidly fixed wire is shaped to carry a current I between the magnetic poles. The force created alters the balance reading.

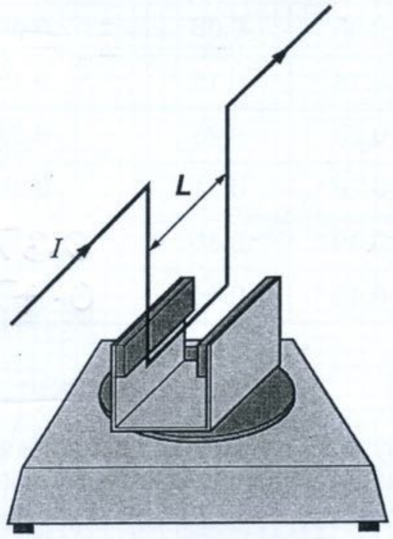


Fig. 3.1

Fig. 3.2 shows a section through the magnet assembly. The dot in the centre represents the wire.

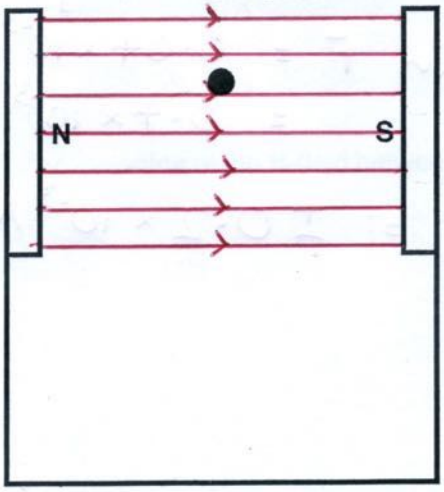


Fig. 3.2

(a) **(i)** Draw, on Fig. 3.2, at least **three** lines to represent the magnetic field in the region between the magnetic poles when the current in the wire is zero. **[2]**

(ii) Explain why the balance reading changes to a new value when the wire carries a current.

Magnetic field from current interacts with permant field to give a force interaction pair (equal & opposite) The force of wire on the magnet give reading on balance. **[2]**

(b) The longest length of wire that could be used is 5.0 cm. The current I is varied and the change in the balance reading is recorded as shown in Fig. 3.3.

	Change in balance reading / g				
I / A	**Trial 1**	**Trial 2**	**Trial 3**	**Mean change / g**	F / $\times 10^{-3}$ N
0.5	0.08	0.05	0.06	0.06	0.59
1.0	0.14	0.16	0.16	0.15	1.5
1.5	0.22	0.20	0.23	0.22	2.2
2.0	0.31	0.29	0.31	0.30	2.9
2.5	0.38	0.39	0.35	0.37	3.6
3.0	0.44	0.48	0.48	0.47	4.6

Fig. 3.3

(i) Complete the table by calculating the mean change in balance reading and the corresponding values of force F for the last two current values.
$g = 9.8\,\text{N kg}^{-1}$ **[2]**

(ii) Use the table to determine the uncertainty in F. Explain your reasoning.

The largest balance reading range is 0.04 g **[2]**

so range in $F = 0.04 \times 10^{-3} \times 9.8$

$= 0.4 \times 10^{-3}$ N

$\therefore$ Uncertainty $= \pm 0.2 \times 10^{-3}$ N

(iii) Plot the last two points from the table, Fig. 3.3, on the graph Fig. 3.4. Draw a line of best fit. **[2]**

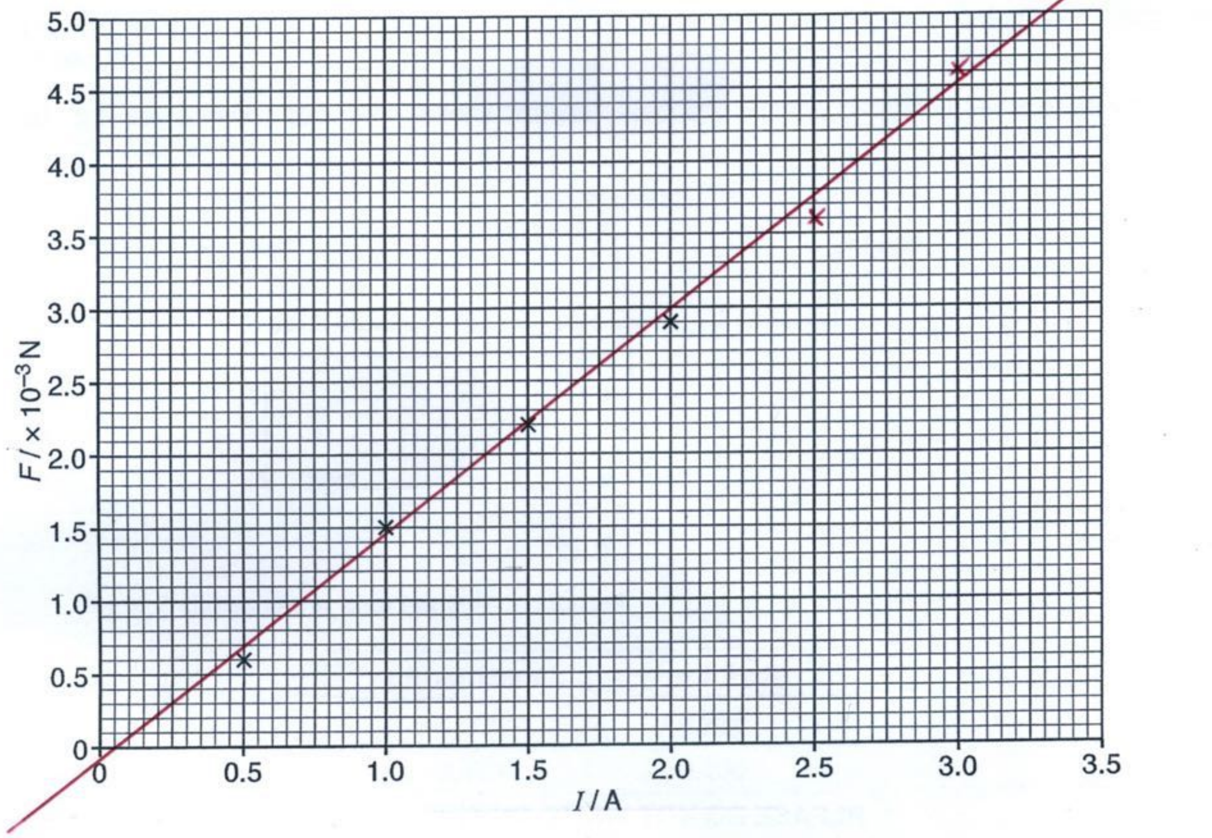


Fig. 3.4

(iv) Use the graph to estimate the value of the **B**-field between the faces of the slab magnets.

$$\text{Gradient} = \frac{5.0\times10^{-3}}{3.3-0.05} = 1.54\times10^{-3}\ \text{NA}^{-1}$$

$F = BlI$
$y = mx$

$B = $ 31 mT **[3]**

$$\therefore B = \frac{\text{gradient}}{l}$$

$$= \frac{1.54\times10^{-3}}{0.05} = 0.0308\ \text{T} = 31\,\text{mT}$$

SECTION B

Answer **all** the questions.

4 This question is about determining the focal length of a converging lens using the apparatus shown in Fig. 4.1.

(a) u is the distance between the lens and the object and v is the distance between the lens and the image.

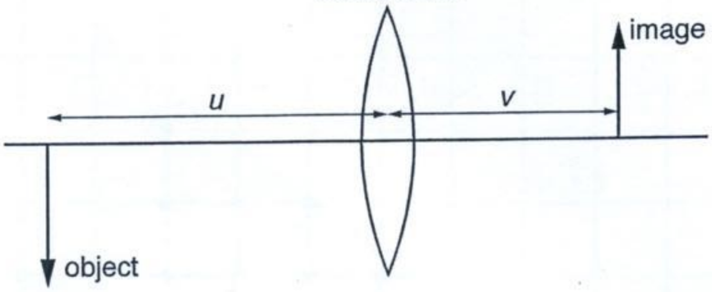


Fig. 4.1

Fig. 4.2 shows some data taken by a student.

u/m ± 1 mm	v/m ± 5 mm
−0.500	0.220
−0.475	0.230
−0.450	0.230
−0.425	0.240
−0.400	0.250
−0.375	0.260
−0.350	0.270
−0.325	0.290
−0.300	0.310
−0.275	0.340
−0.250	0.390
−0.225	0.480
−0.200	0.660

Fig. 4.2

(i) State which measurement, u or v, has the greatest absolute uncertainty and suggest why this is the case.

V has the largest uncertainty as it involves judging when image is in focus.

.... [1]

To assess the reliability of the experiment, the student decided to repeat one measurement (with value of u equal to −0.250) multiple times. These data are shown below in Fig. 4.3 in a dot-plot, the points at 0.330 and 0.430 are potential outliers.

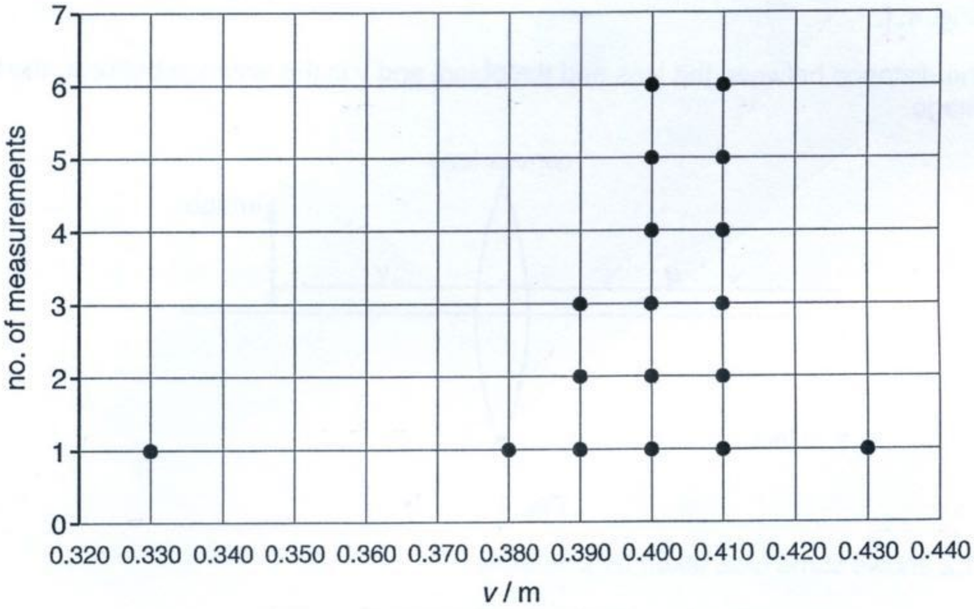


Fig. 4.3

(ii) Ignoring the two potential outliers, calculate the range of the typical values on the dot-plot.

$0.410 - 0.380 =$

range = 0.03 m **[1]**

(iii) Calculate the mean of the values within the range calculated in **(a)(ii)**. Mark this on the dot-plot above.

$$\frac{0.38 + 0.39 \times 3 + 0.4 \times 6 + 0.41 \times 6}{16}$$

mean = 0.401 m **[2]**

(iv) The spread of data is given by; *spread* = ± ½ *range*. A measurement can be considered to be an outlier if it is more than twice the spread from the mean. State whether you consider either of the points; 0.330 or 0.430 to be outliers and explain your reasoning.

2 × spread = ± 0.03

Range of values that are NOT outliers

= 0.401 − 0.03 to 0.401 + 0.03

= 0.371 to 0.431

So 0.330 is an outlier but 0.430 is not.

[2]

(b) Fig. 4.4 shows a plot of magnification m against v for the data from Fig. 4.2. The last two points are missing from the graph. The uncertainties are too small to be shown on this graph.

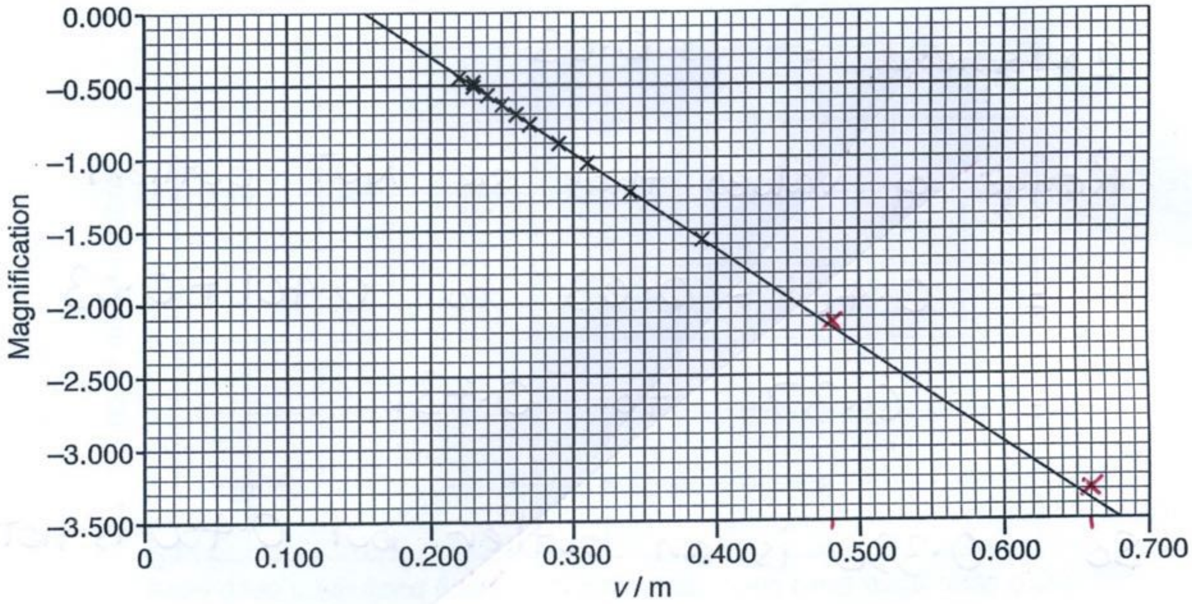


Fig. 4.4

(i) The last two points from Fig. 4.2 have not been plotted. Complete Fig. 4.5 below, adding the last two magnification values.

$m = v/u$

u/m	v/m	m
−0.225	0.480	−2.13
−0.200	0.660	−3.30

Fig. 4.5 **[2]**

(ii) Add the remaining points to the graph. **[1]**

(iii) Use $\frac{1}{v}=\frac{1}{u}+\frac{1}{f}$ to show that $m=-\frac{v}{f}+1$.

$$\frac{1}{v}=\frac{1}{u}+\frac{1}{f} \xrightarrow{\times v} \frac{v}{v}=\frac{v}{u}+\frac{v}{f} \rightarrow 1=m+\frac{v}{f}$$

$$\therefore\ m = 1-\frac{v}{f} = -\frac{v}{f}+1$$

[2]

(iv) Use data from the graph to calculate the focal length f of the lens.

$$m = -\frac{1}{f}v+1 \qquad \therefore \text{ gradient of line} = -1/f$$

$$y = mx + c \qquad \therefore\ f = -1/\text{gradient} = -1/-6.667$$

$$= 0.15\text{m}$$

$$\text{gradient} = \frac{-3.5}{0.68-0.155}$$

$$= -6.667$$

$f =$ 0.15 m **[2]**

(c) A second converging lens of different focal length is used to form an image. Data for the second lens is displayed in Fig. 4.6.

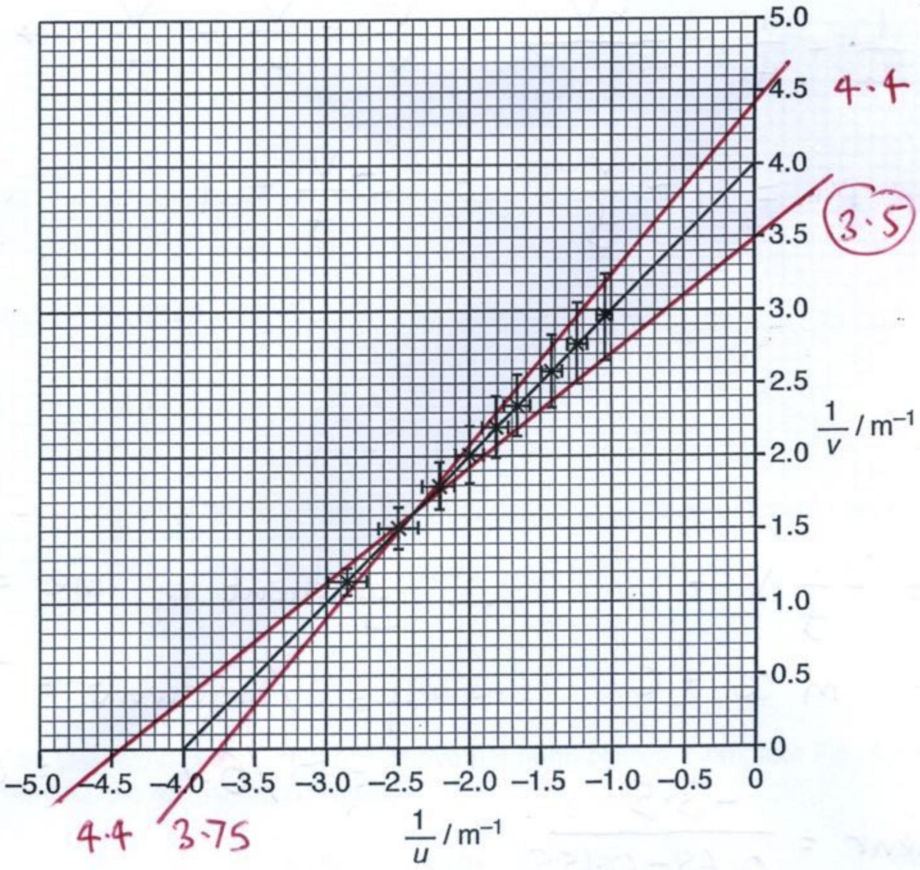


Fig. 4.6

(i) Use Fig. 4.6 to determine the power of this lens.

Power = ...4........ dioptre **[1]**

(ii) Use the uncertainty bars on Fig. 4.6 to determine the maximum and minimum values for the power of the lens. Use these values to determine the percentage uncertainty in the power of the lens.

max = 4.4 D
min = 3.5 D

range = 0.9 D
$P = 4 \pm 0.5$ D
1 s.f.

$U = \frac{0.5}{4} \times 100 = 13\%$

Maximum power value = 4.4 dioptre

Minimum power value = 3.5 dioptre

Percentage uncertainty = 13 %

[4]

END OF QUESTION PAPER