Measurement Techniques

Question paper 2

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Measurement Techniques
Sub Topic	
Paper Type	Theory
Booklet	Question paper 2

Time Allowed: **86 minutes**

Score: **/71**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 The volume of fuel in the tank of a car is monitored using a meter as illustrated in Fig. 1.1.

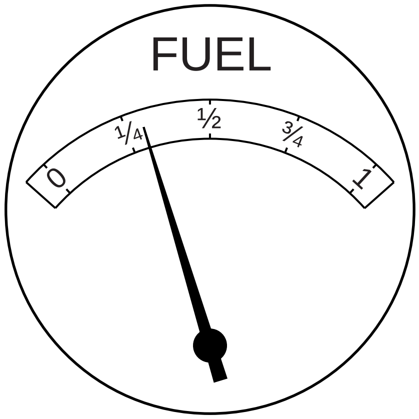

Fig. 1.1

The meter has an analogue scale. The meter reading for different volumes of fuel in the tank is shown in Fig. 1.2.

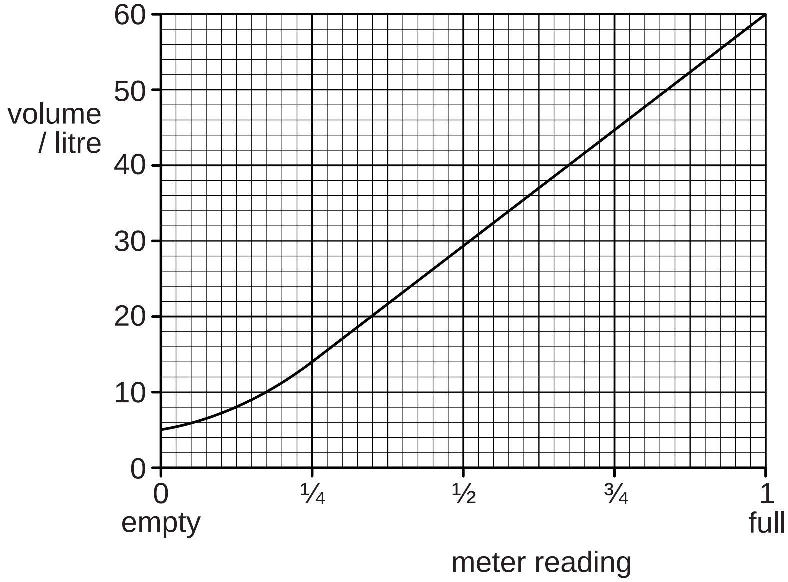

Fig. 1.2

The meter is calibrated in terms of the fraction of the tank that remains filled with fuel.

(a) The car uses 1.0 litre of fuel when travelling 14 km. The car starts a journey with a full tank of fuel.

(i) Calculate the volume of fuel remaining in the tank after a journey of 210 km.

volume = ... litres [2]

(ii) Use your answer to **(i)** and Fig. 1.2 to determine the change in the meter reading during the 210 km journey.

from *full* to .... [1]

(b) There is a systematic error in the meter.

(i) State the feature of Fig. 1.2 that indicates that there is a systematic error.

....

.... [1]

(ii) Suggest why, for this meter, it is an advantage to have this systematic error.

....

.... [1]

2 A simple pendulum may be used to determine a value for the acceleration of free fall *g*. Measurements are made of the length *L* of the pendulum and the period *T* of oscillation.

The values obtained, with their uncertainties, are as shown.

$T = (1.93 \pm 0.03)$ s
$L = (92 \pm 1)$ cm

(a) Calculate the percentage uncertainty in the measurement of

(i) the period *T*,

uncertainty = ... % [1]

(ii) the length *L*.

uncertainty = ... % [1]

(b) The relationship between T, L and g is given by

$$g = \frac{4\pi^2 L}{T^2}.$$

Using your answers in **(a)**, calculate the percentage uncertainty in the value of g.

uncertainty = ... % [1]

(c) The values of L and T are used to calculate a value of g as 9.751 m s^{-2}.

(i) By reference to the measurements of L and T, suggest why it would not be correct to quote the value of g as 9.751 m s^{-2}.

....

.... [1]

(ii) Use your answer in **(b)** to determine the absolute uncertainty in g.

Hence state the value of g, with its uncertainty, to an appropriate number of significant figures.

g = ... ± .... m s^{-2} [2]

3 **(a)** State the most appropriate instrument, or instruments, for the measurement of the following.

(i) the diameter of a wire of diameter about 1 mm

.... [1]

(ii) the resistance of a filament lamp

.... [1]

(iii) the peak value of an alternating voltage

.... [1]

(b) The mass of a cube of aluminium is found to be 580 g with an uncertainty in the measurement of 10 g. Each side of the cube has a length of (6.0 ± 0.1) cm.

Calculate the density of aluminium with its uncertainty. Express your answer to an appropriate number of significant figures.

density = ... ± .... $g\,cm^{-3}$ [5]

4 **(a)** Distinguish between systematic errors and random errors.

systematic errors ....

....

random errors ....

.... [2]

(b) A cylinder of length *L* has a circular cross-section of radius *R*, as shown in Fig. 1.1.

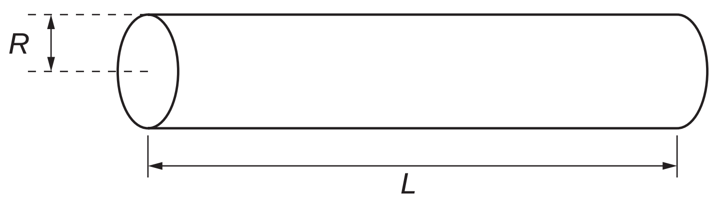

Fig. 1.1

The volume *V* of the cylinder is given by the expression

$$V = \pi R^2 L .$$

The volume and length of the cylinder are measured as

$V = 15.0 \pm 0.5\,\text{cm}^3$
$L = 20.0 \pm 0.1\,\text{cm}.$

Calculate the radius of the cylinder, with its uncertainty.

radius = ... ± .... cm [5]

5 The uncalibrated scale and the pointer of a meter are shown in Fig. 1.1.

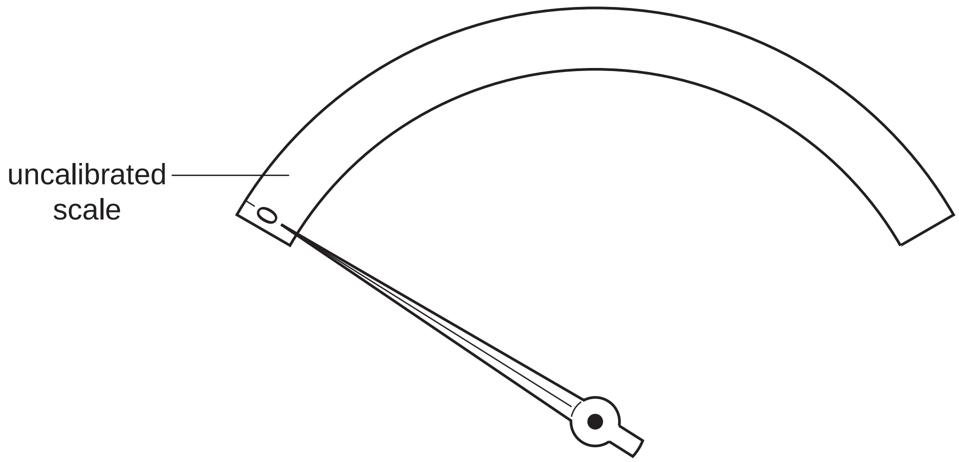

Fig. 1.1

The pointer is shown in the zero position.
The meter is to be used to indicate the volume of fuel in the tank of a car.
A known volume V of fuel is poured into the tank and the deflection θ of the pointer is noted.
Fig. 1.2 shows the variation with θ of V.

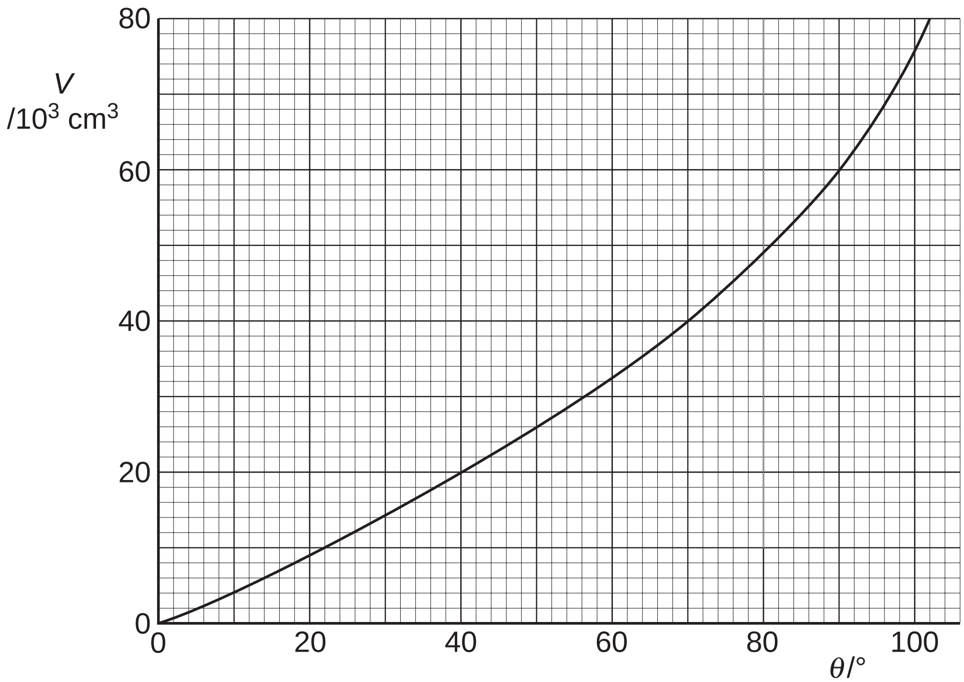

Fig. 1.2

(a) On Fig. 1.1,

(i) calibrate the scale at 20×10^3 cm^3 intervals, [2]

(ii) mark a possible position for a volume of 1.0×10^5 cm^3. [1]

(b) Suggest one advantage of this scale, as compared with a uniform scale, for measuring fuel volumes in the tank of the car.

....

....[1]

6 A student takes readings to measure the mean diameter of a wire using a micrometer screw gauge.

(a) Make suggestions, one in each case, that the student may adopt in order to

(i) reduce a systematic error in the readings,

....

....

(ii) allow for a wire of varying diameter along its length,

....

....

(iii) allow for a non-circular cross-section of the wire.

....

....
[3]

(b) The mean diameter of the wire is found to be 0.50 ± 0.02 mm. Calculate the percentage uncertainty in

(i) the diameter,

uncertainty = ... %

(ii) the area of cross-section of the wire.

uncertainty = ... %
[2]

7 A student has been asked to determine the linear acceleration of a toy car as it moves down a slope. He sets up the apparatus as shown in Fig. 3.1.

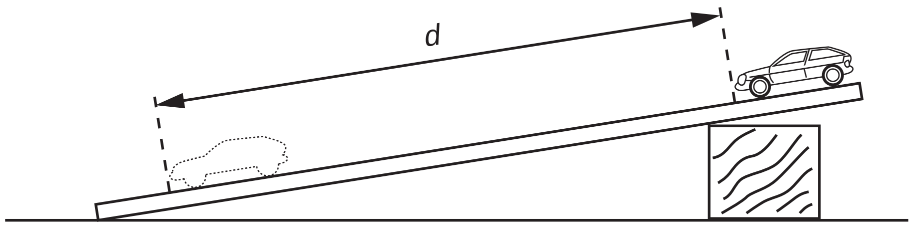

Fig. 3.1

The time t to move from rest through a distance d is found for different values of d. A graph of d (y-axis) is plotted against t^2 (x-axis) as shown in Fig. 3.2.

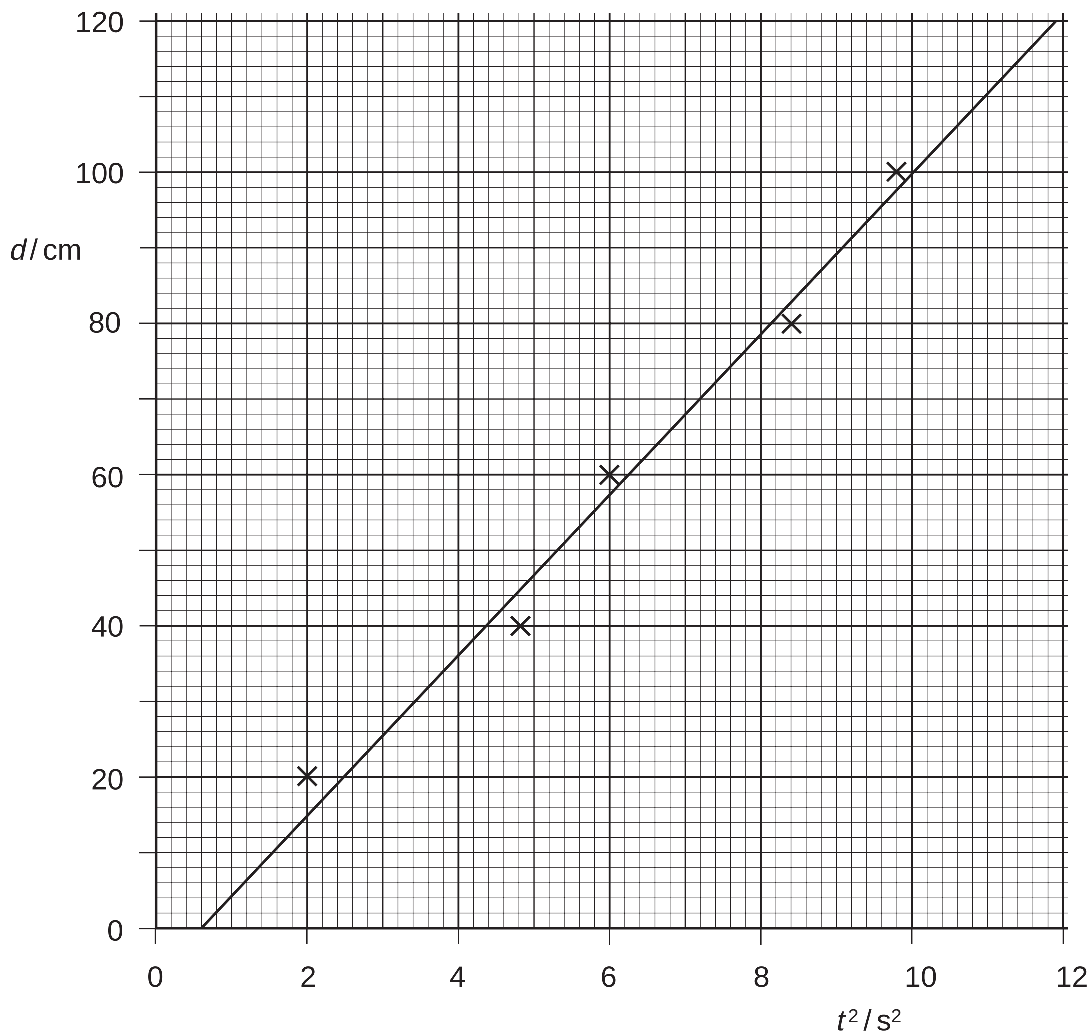

Fig. 3.2

(a) Theory suggests that the graph is a straight line through the origin.
Name the feature on Fig. 3.2 that indicates the presence of

(i) random error,

....

(ii) systematic error.

.... [2]

(b) **(i)** Determine the gradient of the line of the graph in Fig. 3.2.

gradient = ... [2]

(ii) Use your answer to **(i)** to calculate the acceleration of the toy down the slope.
Explain your working.

acceleration = ... $m\,s^{-2}$ [3]

8 **(a)** One of the equations of motion may be written as

$$v^2 = u^2 + 2as.$$

(i) Name the quantity represented by the symbol *a*.

....

(ii) The quantity represented by the symbol *a* may be either positive or negative. State the significance of a negative value.

....

[2]

(b) A student investigates the motion of a small polystyrene sphere as it falls from rest alongside a vertical scale marked in centimetres. To do this, a number of flash photographs of the sphere are taken at 0.1 s intervals, as shown in Fig. 1.1.

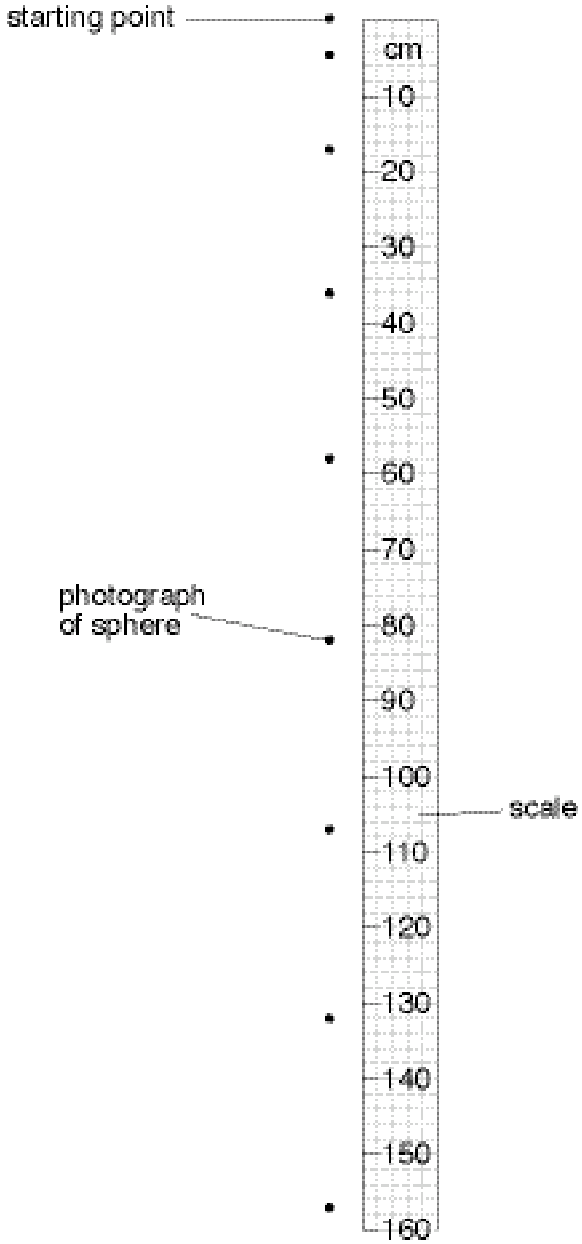

Fig. 1.1

The first photograph is taken at time $t = 0$.

By reference to Fig. 1.1,

(i) briefly explain how it can be deduced that the sphere reaches a constant speed,

....

....

(ii) determine the distance that the sphere has fallen from rest during a time of

1. 0.7 s,

distance = ………………………………… cm

2. 1.1 s.

distance = ………………………………… cm
[4]

(c) The student repeats the experiment with a lead sphere that falls with constant acceleration and does not reach a constant speed.

Determine the number of flash photographs that will be observed against the 160 cm scale.

Include in your answer the photograph obtained at time $t = 0$.

number = ………………………………… [3]

9 A student uses a metre rule to measure the length of an elastic band before and after stretching it.

The lengths are recorded as

length of band before stretching, $L_0 = 50.0 \pm 0.1$ cm

length of band after stretching, $L_S = 51.6 \pm 0.1$ cm.

Determine

(a) the change in length $(L_S - L_0)$, quoting your answer with its uncertainty,

$(L_S - L_0)$ = ... cm [1]

(b) the fractional change in length, $\frac{(L_S - L_0)}{L_0}$,

fractional change = ... [1]

(c) the uncertainty in your answer in **(b)**.

uncertainty = ... [3]

10 A solenoid is connected in series with a battery and a switch. A Hall probe is placed close to one end of the solenoid, as illustrated in Fig. 7.1.

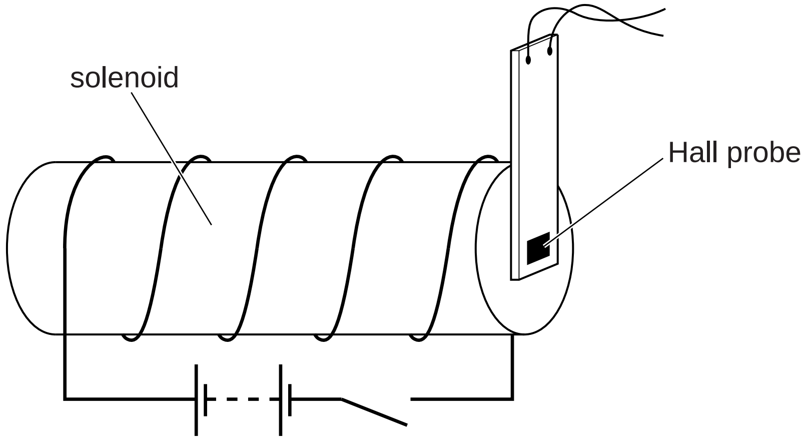

Fig. 7.1

The current in the solenoid is switched on. The Hall probe is adjusted in position to give the maximum reading. The current is then switched off.

(a) The current in the solenoid is now switched on again. Several seconds later, it is switched off. The Hall probe is not moved.

On the axes of Fig. 7.2, sketch a graph to show the variation with time t of the Hall voltage V_H.

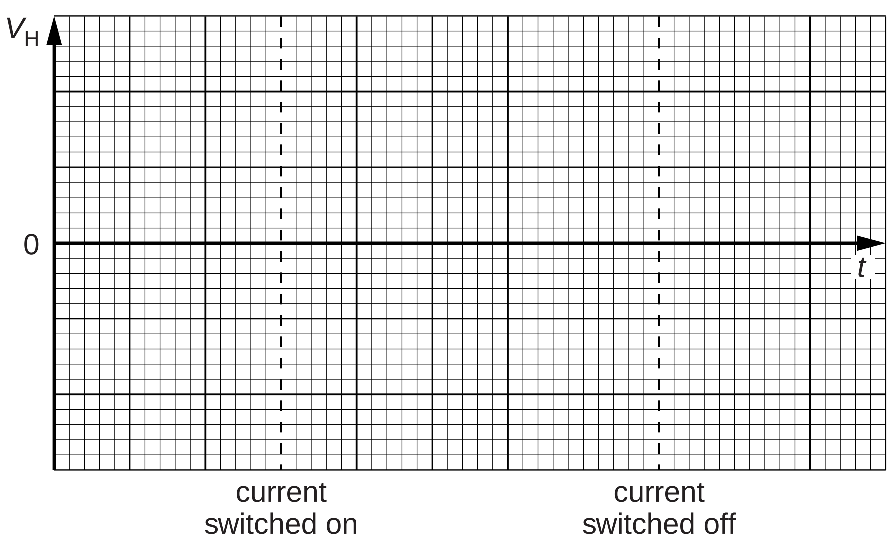

Fig. 7.2

[3]

(b) The Hall probe is now replaced by a small coil. The plane of the coil is parallel to the end of the solenoid.

(i) State Faraday's law of electromagnetic induction.

....

....

.... [2]

(ii) On the axes of Fig. 7.3, sketch a graph to show the variation with time *t* of the e.m.f. *E* induced in the coil when the current in the solenoid is switched on and then switched off.

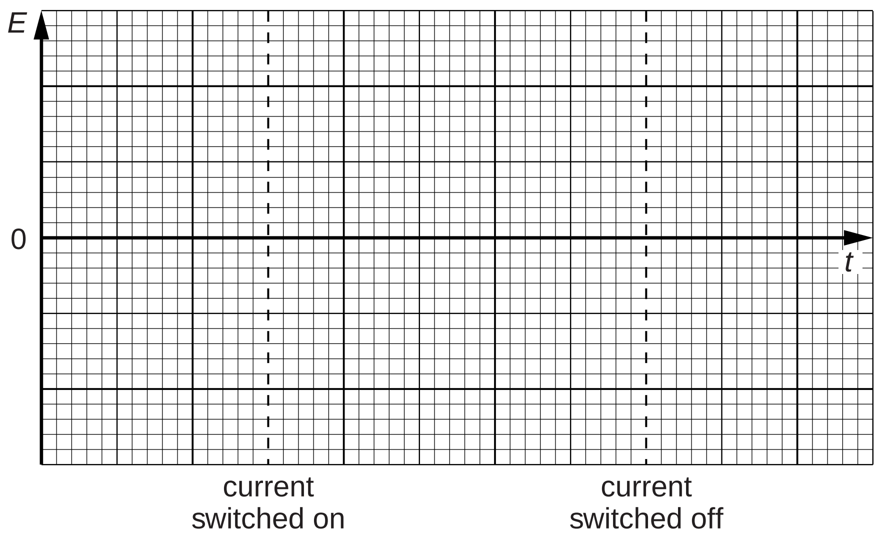

Fig. 7.3

[3]

11 A Hall probe is placed a distance *d* from a long straight current-carrying wire, as illustrated in Fig. 5.1.

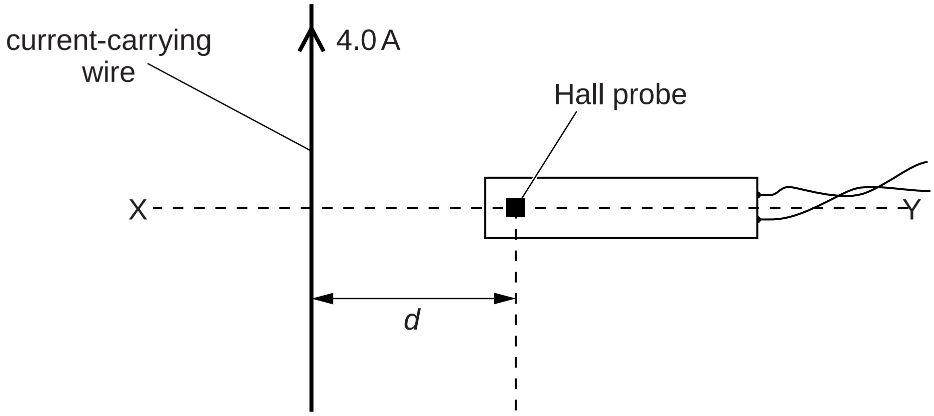

Fig. 5.1

The direct current in the wire is 4.0 A. Line XY is normal to the wire.

The Hall probe is rotated about the line XY to the position where the reading V_H of the Hall probe is maximum.

(a) The Hall probe is now moved away from the wire, along the line XY.
On the axes of Fig. 5.2, sketch a graph to show the variation of the Hall voltage V_H with distance *x* of the probe from the wire. Numerical values are not required on your sketch.

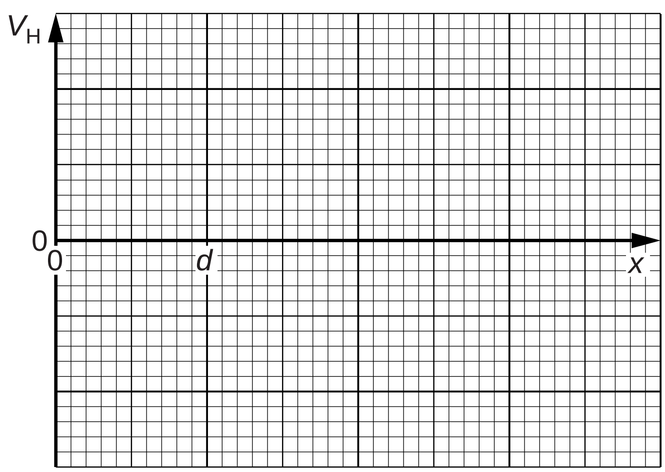

Fig. 5.2

[2]

(b) The Hall probe is now returned to its original position, a distance *d* from the wire. At this point, the magnetic flux density due to the current in the wire is proportional to the current.

For a direct current of 4.0 A in the wire, the reading of the Hall probe is 3.5 mV. The direct current is now replaced by an alternating current of root-mean-square (r.m.s.) value 4.0 A. The period of this alternating current is *T*.

On the axes of Fig. 5.3, sketch the variation with time *t* of the reading of the Hall voltage V_H for two cycles of the alternating current. Give numerical values for V_H, where appropriate.

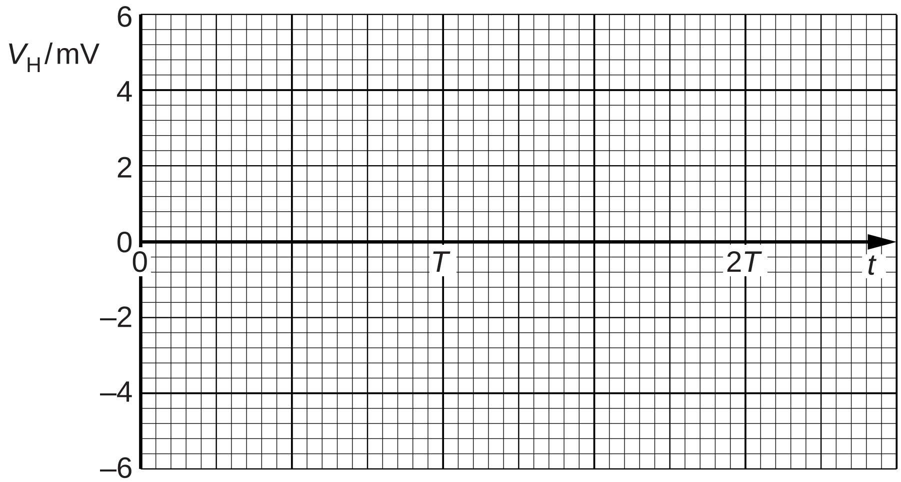

Fig. 5.3

[3]

(c) A student suggests that the Hall probe in **(a)** is replaced with a small coil connected in series with a millivoltmeter. The constant current in the wire is 4.0 A.
In order to obtain data to plot a graph showing the variation with distance *x* of the magnetic flux density, the student suggests that readings of the millivoltmeter are taken when the coil is held in position at different values of *x*.

Comment on this suggestion.

....

....

....

.... [2]