1. No mark scheme available

2. The list gives some quantities and units. *Underline* those which are base quantities of the International (SI) System of units.

coulomb force <u>length</u> mole newton <u>temperature interval</u>

(2 marks)

Define the volt.

Volt = Joule/Coulomb or Watt/Ampere

(2 marks)

Use your definition to express the volt in terms of base units.

Volt = J/C

= kg m^2 s^{-2}/A s

= kg m^2 s^{-3} A^{-1}

(3 marks)

Explain the difference between scalar and vector quantities

Vector has magnitude and direction

Scalar has magnitude only

(2 marks)

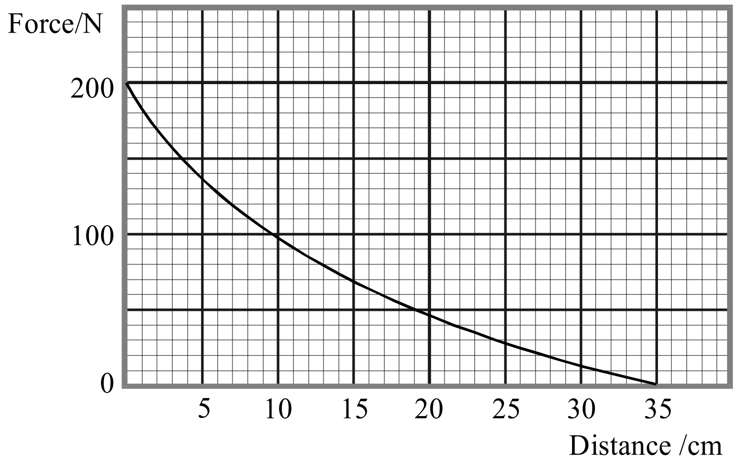
Is potential difference a scalar or vector quantity?

Scalar

(1 mark)

[Total 10 marks]

3. A catapult fires an 80 g stone horizontally. The graph shows how the force on the stone varies with distance through which the stone is being accelerated horizontally from rest.



Use the graph to estimate the work done on the stone by the catapult.

Work done = Area under curve

= 240 × (10 × 0.01)

Work done = 24 J

(4 marks)

Calculate the speed with which the stone leaves the catapult.

$\frac{1}{2} \times 0.08 \times v^2 = 24$

$v = \sqrt{600}$

Speed = 24.5 m s^{-1}

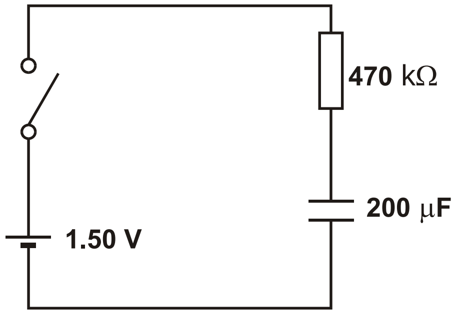
(2 marks)
[Total 6 marks]

4. Define capacitance

Capacitance = Charge / Potential difference.

(2 marks)

An uncharged capacitor of 200 μF is connected in series with a 470 kΩ resistor, a 1.50 V cell and a switch. Draw a circuit diagram of this arrangement.



(1 mark)

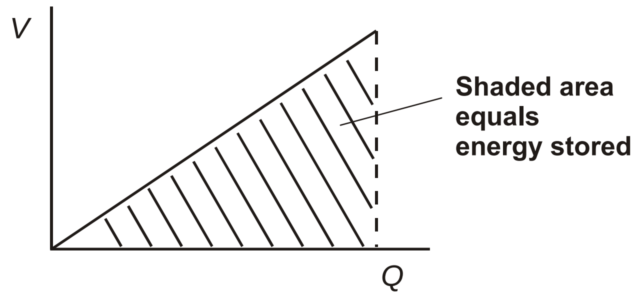
Calculate the maximum current that flows.

Current = 1.5 V/470 kΩ

Current = 3.2 μA

(2 marks)

Sketch a graph of voltage against charge for your capacitor as it charges. Indicate on the graph the energy stored when the capacitor is fully charged.



(4 marks)

Calculate the energy stored in the fully-charged capacitor.

$\frac{1}{2}CV^2 = \frac{1}{2}$ (200 μF) (1.5 V)^2

Energy = 2.25 μJ

(2 marks)
[Total 11 marks]

5. Derive a formula for the equivalent capacitance of two capacitors in series

Starting with $V = V_1 + V_2$ (1)

Justified by diagrams or otherwise (1)

$Q/C = Q/C_1 + Q/C_2$ (1)

$1/C = 1/C_1 + 1/C_1$ (1)

(No marks for unsupported later stages only)

(4 marks)

A 200 μF capacitor is connected in series with a 1000 μF capacitor and a battery of e.m.f. 9 V. Calculate

(i) the total capacitance

$$\frac{1}{C_{\text{Total}}} = \frac{1}{200\ \mu F} + \frac{1}{1000\ \mu F} \quad \textbf{(1)}$$

Capacitance = 167 μF (1)

(2 marks)

(ii) the charge that flows from the battery

$Q = CV = (167 \times 10^{-6}\ \mu\text{F})\ (9\text{V})$ (1)

Charge = 1.5 mC (1)

(2 marks)

(iii) the final potential difference across each capacitor

$V_1 = Q/C_1$ = (1.5 mC)/1000 μF = 1.5 V (2)

$V_2 = Q/C_2$ = (1.5 mC)/200 μF = 7.5 V (1)

P.d. across 1000 μF =1.5 V

P.d. across 200 μF =7.5 V

Either correct (2) Both correct (3)

(3 marks)
[Total 11 marks]

6. A toroid is a conducting wire wound in the shape of a torus (a doughnut). A toroid could be made by bending a slinky spring into a torus. Figure 1 shows such a toroid. Figure 2 shows a plan view of this toroid with one magnetic field line added.

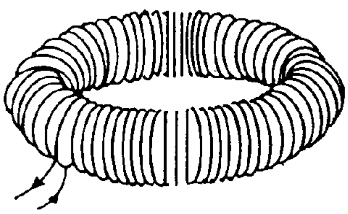


Figure 1

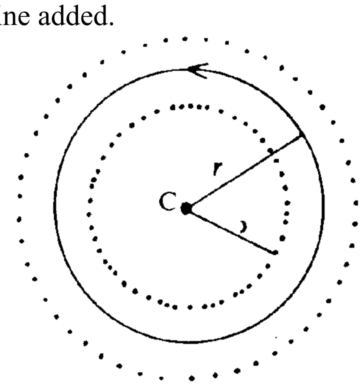


Figure 2

Theory suggests that for a toroid of N turns, the magnetic flux density B within the coils of the toroid at a distance r from the centre C of the toroid is given by

$$B = \frac{\mu_o NI}{2\pi\, r}$$

Describe how you would verify this relationship using a precalibrated Hall probe.

Appreciate that orientation of Hall probe matters (1)

Vary *I* or *r* or *N* while keeping other variable(s) constant and measure B (1)

repeat and average (1)

at different points round the toroid (1)

Plot *B*/*I* or *B*/ $^1/_r$ or *B*/*N* to give straight line through origin (1)

Any 4 points

Choose another variable [Line 2 above] (1)

Plot appropriate graph [Line 5 above] (1)

(6 marks)

For distances $r < r_0$, suggest how B might vary with r. Give a reason for your answer.

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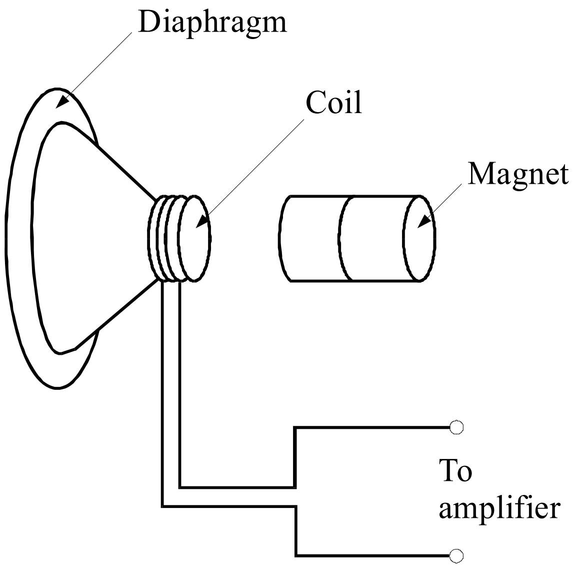
(2 marks)
[Total 8 marks]

7. An induction microphone converts sound waves into electrical signals which can be amplified.



Describe the stages by which the sound waves are converted into electrical signals.
State whether the signals are a.c. or d.c.

Some reference to the movement in the sound wave eg air molecules oscillate/compressions and rarefactions (1)

diaphragm vibrates/equivalent (1)

coil moves (1)

cuts field lines/change in flux linkage (1)

induction occurs (1)

a.c. signals (1)

(6 marks)

If the alternating output from a signal generator were fed into the microphone, describe and explain what would happen to the diaphragm.

diaphragm moves ↔ (1)

changing field in coil or

current in a conductor in a magnetic field (1)

interacts with magnet's field or

experiences a force at right angles/left hand rule/ equivalent (1)

(3 marks)
[Total 9 marks]

8. (a) **Nucleus:** **centre (part), of an atom (1)**
Nucleon: **proton or neutron (1)**

Nuclear Matter: **matter made of nucleons**

or matter found in nucleus (1)

Solid, liquid, gas, plasma (any two) (1)

(4 marks)

(b) **Most stable nucleus is at top of curve (1) (Allow Fe most stable)**
so A = 55 to 70 (Must be integral) (1)

Proton number is about half/just less than half of A (1)

so Z = 22 to 35 (1)

Mass difference = (8.00 to 8.10 MeV) (1) × 180 (1) ×

1.6×10^{-13} J MeV^{-1} (1) ÷ $(3 \times 10^{8}$ m s$^{-1})^2$ (1)

= <u>2.56 to 2.59×10^{-27} kg</u> (Marks are for method)

(Max 7 marks)

(c) **$6^3 = 216$ (1)**

This is approximately 250 (1)

so volumes are in this ratio (1)

Or

volume of sphere = $4\pi r^3/3$ (1)

Multiply by 250 (1)

Equals volume of sphere of radius 6*r* approximately (1)

Approximate as there are spaces between the spheres/ spheres do not pack perfectly (1)

(4 marks)

(d)

	Nuclear matter	Water drops
	Exists as spheres	Exists as spheres
or	Attractive forces hold nucleons together	Attractive forces hold molecules together (1)
	Has density	Has density
or	Density (almost) constant	Density constant
or	Volume $\propto$ nucleon number	Volume $\propto$ mass (1)
	Excess energy is shared	Excess energy is shared
or	Has specific heat	Has specific heat
or	Exhibit thermal agitation	Exhibit thermal agitation (1)
	Nucleons can be emitted	Molecules can evaporate (1)
	Emitted particle carries only small part of energy	Emitted molecule carries only small part of energy (1)

(Max 3 marks)

(e) $F = k\frac{Q_1Q_2}{r^2}$ or $F = \frac{1}{4\pi\epsilon_o}\frac{Q_1Q_2}{r^2}$ **(1)**

$F =$ **[(55 × 1.6 × 10^{-19} C) × (37 × 1.6 × 10^{-9} C)] × (1) for both *Q***

[(9.0 × 10^{9} m F^{-1}) ÷ (3.0 × 10^{-14} m)^2] (1)

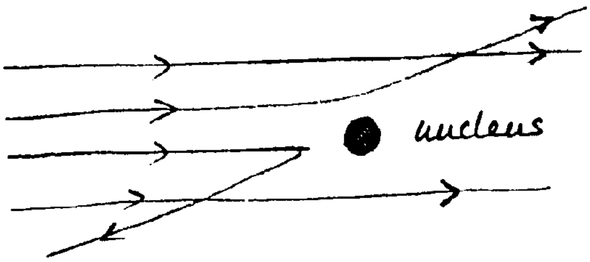
$F =$ **<u>521 N</u> (Allow 520 N) (1)**

(Maximum 2/4 for adding Q_1 and Q_2)

The e.p.e. is very high (1)

(5 marks)

(f)



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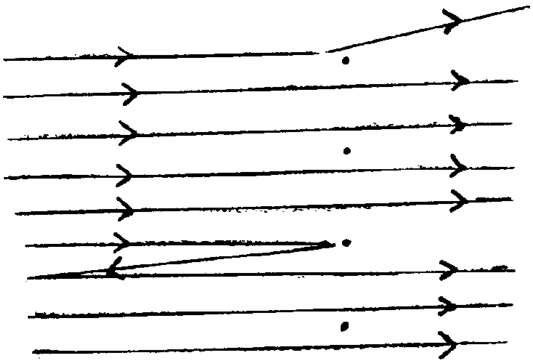


more than one path *straight* (1)

one path bent correctly (or bent > 90° if no nuclei shown) (1)

Nuclei shown and good drawing, e.g. lines straight before and after deflection or a degree of symmetry (1)

(3 marks)

Electrons are attracted to nucleus not repelled by it (1)

Electrons deflected only a bit/can go through nucleus (1)

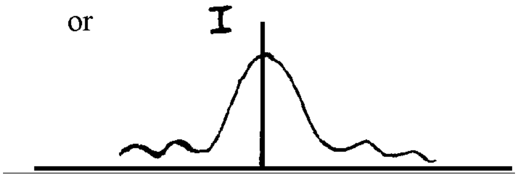
(2 marks)

(g) $\lambda = h/p = \dfrac{6.6 \times 10^{-34}\ \text{J s}}{2.0 \times 10^{-18}\ \text{N s}}$ **(1)**

= <u>3.3×10^{-16} m</u> (Unit) (1)

(2 marks)

or



Circles (1)

Fuzzy Circles (1)

Radial intensity curve (1)

Intensity labelled (1)

(Max 2 marks)
[Total 32 marks]

9. (a) (i) **For 22 10μ*F* capacitor:** $V = Q/C = \dfrac{50 \times 10^{-6}\,\text{C}}{22 \times 10^{-6}\,\text{F}}$ **(1)**

= $\underline{2.27\ \text{V}}$ **(1)**

For 47 μF capacitor: $V = \dfrac{50 \times 10^{-6}\,\text{C}}{47 \times 10^{-6}\,\text{F}}$ **= 1.06 V (1)**

$\therefore V_{AB}$ **= (1.06 + 2.27)** V **(= 1.33 V) (e.c.f.) (1)**

or

Allow calculation via series capacitors

i.e. $1/C = 1/C_1 + 1/C_2 \Rightarrow C = 15.0\ \mu\text{F}$ **hence 3.34 V (2)**

Go on to split this and get 2.27 V/1.06 V (2)

(ii) $C = \dfrac{Q}{V} = \dfrac{50 \times 10^{-6}\,\text{C}}{3.3\ \text{V}} = 15 \times 10^{-6} F$ **(1)**

(accept 15.15/15.12)

(iii) $C = 22\ \mu F + 47\ \mu F = \underline{69\ \mu F}$ **(1)**

(6 marks)

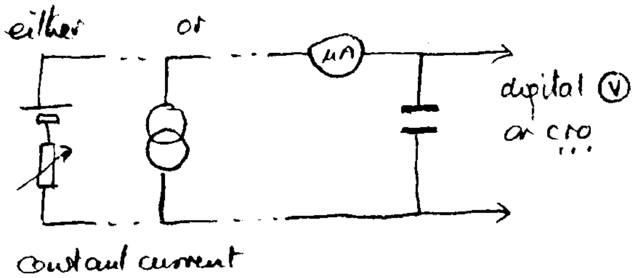
(b) (i) **Larger C:** **use more plates (1)**
use larger plates (1)
more plates closer (1)
fill space with insulator/dielectric medium of $\mu_r > 1$ (1)

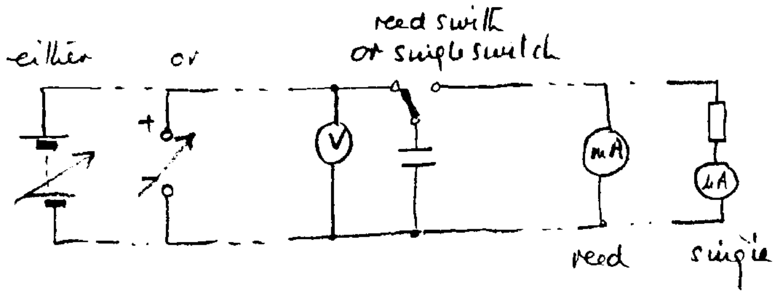
(Max 2 marks)

(ii) **As area of overlap ↓, capacitance C ↓ (1)**
***Q* = *CV* and *Q* is fixed (1)**
***C* ↓ means *V* ↑ (1)**

(3 marks)

(c)





Workable labelled circuit diagram (2)
(if workable but incompletely labelled, 1 mark only)

Explanation of usage (1)

How *Q* established (2)

How *V* established / measured (1)

(Max 5 marks)
[Total 16 marks]

10. (a) (i) **$P = \frac{mgh}{t}$ (Allow *P* = *Fv*) 54.9 N × 2.31 × 10^{-6} m s^{-1} (1)**

$= \frac{5.6\,\text{kg} \times 9.8\,\text{N kg}^{-1} \times 1.4\,\text{m}}{7 \times 24 \times 3600\,\text{s}}$ (1)

= 1.3 × 10^{-4} W (1)

If only *mgh* calculated (77 J), max (1)

(3 marks)

(i) **Use of *mcΔ θ***

A valid expression for *θ*
or answer 0.038 °C/K (0.039 if 10 used) (1)
Assumption: all g.p.e. becomes internal energy/
all heat in the cylinder / no heat loss / no air friction (1)

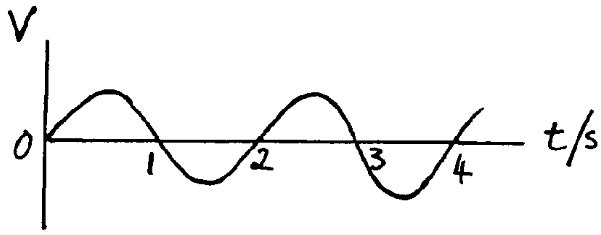
(3 marks)

(b) (i) **Mention of Earth's magnetic field (1)**
[Look for back credit from part (c)]
Pendulum cuts this field/flux (1)

So e.m.f./p.d. is induced (not current) (1)

(3 marks)

(ii)



Any repetitive graph (1)

Sinusoidal in shape (1)

Time scale correct (i.e. period 2 s) (1)

(3 marks)

(c) **Statement that energy conservation is violated/**
perpetual motion machines are impossible/
drawing power would damp oscillation (2)
(Allow not practicable to connect to bottom of pendulum for 1 mark only)
Discussion: induced p.d./e.m.f. could produce a current (1)
which would dissipate/use energy (1)
Switches could attract steel at correct part of swing (1)

(Max 4 marks)
[Total 16 marks]

11. With the aid of an example, explain the statement "The magnitude of a physical quantity is written as the product of a number and a unit".

Both number and unit identified in an example (1)

followed by the idea of multiplication (1)

(2 marks)

Explain why an equation must be homogeneous with respect to the units if it is to be correct.

If the units on one side differ from those on the other, then the two sides of the equation relate to different kinds of physical quantity. They cannot be equal [or similar positive statements] (1)

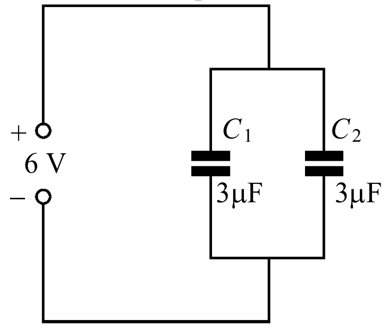
(1 mark)

Write down an equation which is homogeneous, but still incorrect.

Any incorrect but homogeneous algebraic or word equation :
2mgh = ½mv², 2 kg = 3 kg, pressure =stress/strain (2 or 0)

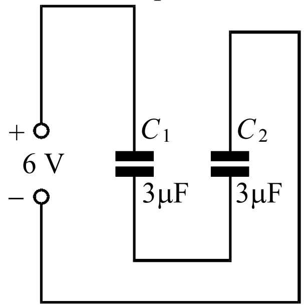
(2 marks)
[Total 5 marks]

12. Complete the circuit below to show the capacitors connected in parallel.



(1 mark)

Complete the circuit below to show the capacitors connected in series.



(1 mark)

Use the information in the diagrams to complete the following table.

Capacitors in parallel	Charge on C_1	*18* μ**C**
	Energy stored in C_1 when fully charge	*54* μ**J**
Capacitors in series	Charge on C_2	*9* μ**C**
	Work done by power supply in charging both capacitors	*27* μ**J** or *54* μ**J**

(4 marks)
[Total 6 marks]

13. State Coulomb's law for the electric force between two charged particles in free space.

Force is proportional to the product of the charges and inversely proportional to the distance between them squared (1) (1)

(OR F = $\frac{kQ_1Q_2}{r^2}$ **with symbols defined (1) (1))**

(2 marks)

What are the base units of ϵ_o (the permittivity of free space)?

ϵ_o → A^2 s^4 kg^{-1} m^{-3} (1) (1)

[Compensation marks, Maximum 1/2: $C^2 = A^2 s^2$

μ_o = kg m s^{-2} A^{-2}

Farad m^{-1} = A s m^{-1}/V
Force × r^2 = kg m^3 s^{-2}]

(2 marks)
[Total 4 marks]

14. (a) Explain how the distance from an observer to a lightning flash may be estimated. Illustrate this for the case where the distance is 1.5 km.

Light travels very fast/instantaneously/at 3 × 10^8 m/s (1)

To travel 1.5 km, sound takes 4.4 s (1)

Measuring time enables distance to be found (1)

(3 marks)

(b) Explain the meaning of the phrase *sheet lightning* (paragraph 2).

Use the passage to explain how thunder is produced.

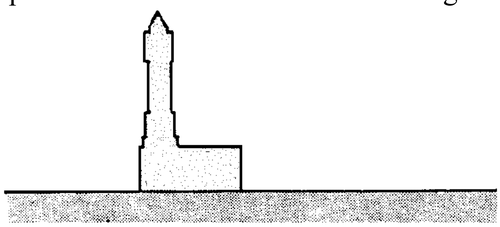
Sheet lightning: flash/ stroke/discharge (1)

within a cloud/from cloud to cloud (1)

Thunder: air heated (1)
rapid expansion (1)
shock wave (1)

(5 marks)

(c) The diagram represents a storm cloud over a building with a high clock tower.



Copy the diagram. Explain, with the aid of additions to your diagram, what is meant by a *negative leader*(paragraph 3).

Charge -ve on cloud (1)
Charge + ve on tower (1)
Jagged line from cloud to tower (1)
Negative leader is column of charged ions (1)
Negative leader marked on diagram (1)

(Max 4 marks)

(d) Describe the process by which a lightning stroke produces visible light.

Explain why, when you see a lightning flash, it may seem to flicker.

Electrical discharge in air (1)

ionises/excites electrons/molecules (1)

which emit light/photons (1)

When they return to ground state (1)

Flicker: a whole series of/several strokes (1)

in a short time/rapidly (1)

(Max 5 marks)

(e) Suppose lightning strikes from a cloud to the Earth along a channel 400 m long.

Calculate

(i) a typical potential difference between cloud and Earth,

Either	Or	
$P = 4 \times 10^{10}$ W	$P = IV \Rightarrow \frac{P}{l} = I\frac{V}{l}$	(1)
$P = IV \rightarrow V = P/I$	$E = \frac{V}{l} = \frac{P/l}{I}$	(1)
$\Rightarrow V = 2 \times 10^6$ V	= 5000 V m^{-1}	(1)

(3 marks)

(ii) the average electric field strength along such a lightning channel.

E = $\frac{V}{d}$ **$E = Vl$ (1)**

= 5000 V m^{-1} = 2×10^6 V 2

(3 marks)

(f) Describe how you would attempt to demonstrate in the laboratory that the electric field strength needed to produce a spark in air is about 3000 V mm^{-1} (3×10^6 V m^{-1}). Suggest why this value differs from that which you calculated in (*e*).

e.h.t/Van der Graaf (1)

with voltmeter (1)

Two metal terminals/spheres/plates (1)

Comment on atmospheric conditions (1)

(4 marks)

(g) Estimate the pressure of the air within a lightning channel immediately after a lightning flash. Take the atmospheric pressure to be 100 kPa. State any assumptions you make.

Air temperature, any value in kelvin (1)

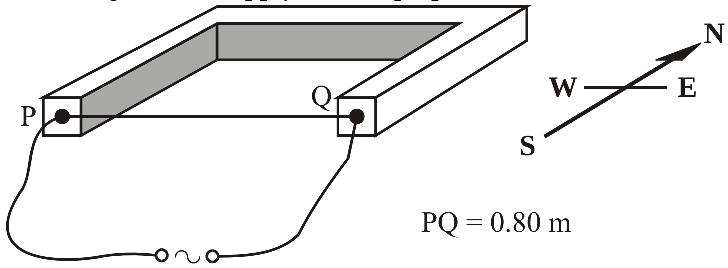
$\frac{p}{T}$ **= constant (1)**

Assume *V* constant (1)

$\Rightarrow$ *p* = around 10 000 kPa (2)

(5 marks)
[Total 32 marks]

15. A thin copper wire PQ, 0.80 m long, is fixed at its ends. It is connected as shown to a variable frequency alternating current supply and set perpendicular to the Earth's magnetic field.



(a) When there is a current from P to Q the wire experiences a force. Draw a diagram showing the resultant magnetic field lines near the wire as viewed from the West. (You should represent the wire PQ as ⊗.)

Explain what is meant by a neutral point.

Circular field round wire (1)

Clockwise (1)

Catapult field (1)

Neutral point: two fields cancel/resultant field zero (1)

(4 marks)

(b) The wire PQ experiences a maximum force of 0.10×10^{-3} N at a place where the Earth's magnetic field is 50×10^{-6} T. Calculate the maximum value of the current and its r.m.s. value.

$F = BIl \Rightarrow I = F/Bl$ (1)

$\Rightarrow I = 2.5$ A (2)

$\therefore I_{rms} = I/\sqrt{2} = 1.77$ A (1)

(4 marks)

(c) A strong U-shaped (horseshoe) magnet is now placed so that the mid-point of the wire PQ lies between its poles. The frequency of the a.c. supply is varied from a low value up to 50 Hz, keeping the current constant in amplitude. The wire PQ is seen to vibrate slightly at all frequencies and to vibrate violently at 40 Hz.

(i) Explain carefully why the wire vibrates and why the amplitude of the vibrations varies as the frequency changes.

Magnetic force/BIl varies (1)

forcing wire to vibrate (1)

At the natural frequency (1)

the amplitude is high/there is resonance (1)

(Max 3 marks)

(ii) Calculate the speed of transverse mechanical waves along the wire PQ.

$PQ = \lambda/2 \Rightarrow \lambda = 1.60$ m (1)

Use of $c = f\lambda$ (1)

$\Rightarrow c = 64$ m/s (1)

(3 marks)

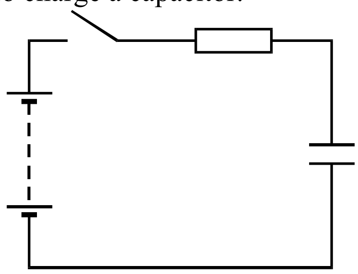
(iii) Describe the effect on the wire of gradually increasing the frequency of the a.c. supply up to 150 Hz.

Wire vibrates slightly at all frequencies (1)

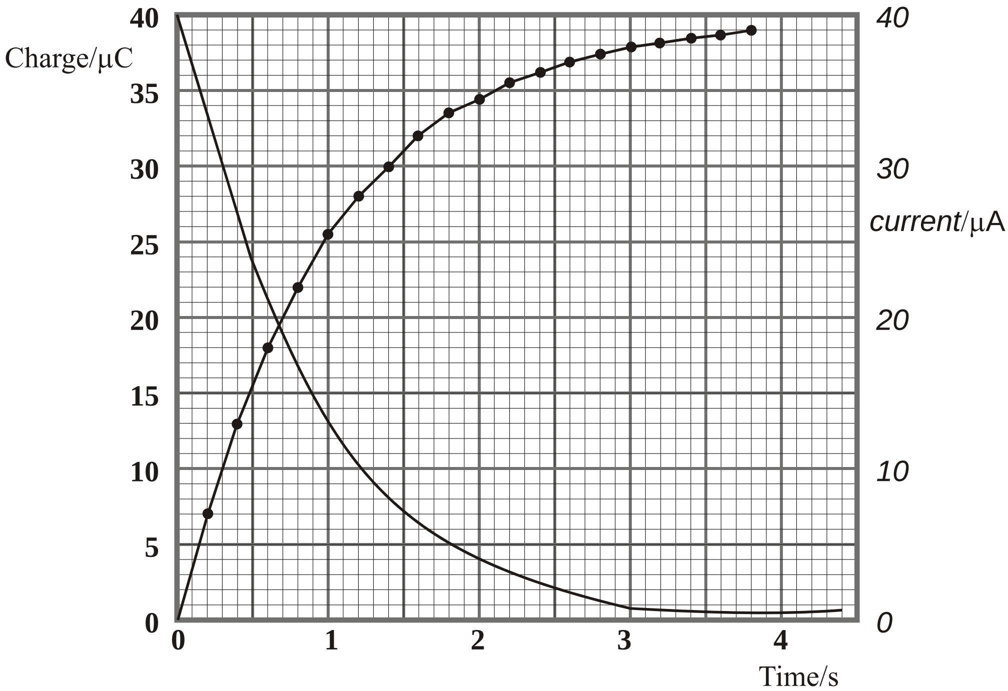
Resonance/max amplitude at 120 Hz/at 80 Hz and at 120 Hz (1)

(2 marks)
[Total 16 marks]

16. The circuit shown is used to charge a capacitor.



The graph shows the charge stored on the capacitor whilst it is being charged.



On the same axes, sketch as accurately as you can a graph of current against time. Label the current axis with an appropriate scale.

Label current axis (1)

Current at *t* = 0 within range 30 – 45 μA (1)

Current graph right shape (1)

Exponential decay (1)

(4 marks)

The power supply is 3 V. Calculate the resistance of the charging circuit.

Resistance = 3 V / 40 μA (1)

= 75 kΩ (1)

Resistance = Allow 66 kΩ →100 kΩ

(2 marks)
[Total 6 marks]

17. Using the usual symbols write down an equation for

(i) Newton's law of gravitation

$$\mathbf{F = G \frac{M_1M_2}{R^2}} \quad \textbf{(1)}$$

(ii) Coulomb's law

$$\mathbf{F = K \frac{Q_1Q_2}{R^2}} \quad \textbf{(1)}$$

(2 marks)

State one difference and one similarity between gravitational and electric fields.

Difference

Gravitational fields are <u>attractive</u> <u>but</u> electric fields can be attractive or repulsive (1)

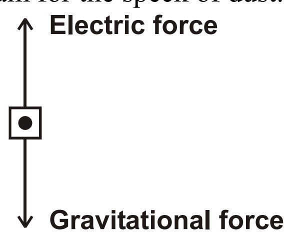
Similarity

Both have an ∝ range (1)

(2 marks)

A speck of dust has a mass of 1.0×10^{-18} kg and carries a charge equal to that of one electron. Near to the Earth's surface it experiences a uniform downward electric field of strength 100 N C^{-1} and a uniform gravitational field of strength 9.8 N kg^{-1}.

Draw a free-body force diagram for the speck of dust. Label the forces clearly.



Calculate the magnitude and direction of the resultant force on the speck of dust.

Electric force $= 100 \text{ N C}^{-1} \times 1.6 \times 10^{-19}$ **C**

$= 1.6 \times 10^{-17}$ **N (1)**

Weight $= 9.8 \times 10^{-18}$ **N (1)**

Net force is <u>upward</u> (1)

Force = 6.2×10^{-18} **N (1)**

(6 marks)
[Total 10 marks]

18. The permittivity of free space ϵ_o has units F m^{-1}. The permeability of free space μ_o has units N A^{-2}

Show that the units of $\frac{1}{\sqrt{\epsilon_o \mu_o}}$ are m s^{-1}

Any two:

N = kg m s^{-2}

F = C/V

V = J/C

Q = A s (1) (1)

Unambiguous manipulation to correct answer (1)

(3 marks)

Calculate the magnitude of $\frac{1}{\sqrt{\epsilon_o \mu_o}}$.

$$\sqrt{\frac{1}{8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}} \times 4\pi \times 10^{-7}\,\mathrm{N\,A^{-2}}}}$$

Magnitude =3.0 × 10^8 (1)

(1 mark)

Comment on your answers.

This is the speed of light (1)

(1 mark)
[Total 5 marks]

19. A child sleeps at an average distance of 30 cm from household wiring. The mains supply is 240 V r.m.s. Calculate the maximum possible magnetic flux density in the region of the child when the wire is transmitting 3.5 kW of power.

P = IV **(1)**

I **= 21.2 A (1)**

Use of B = $\frac{4\pi \times 10^{7}\,\mathrm{N\,A^{-2}} \times 21.2\,\mathrm{A}}{2\pi \times 0.3}$ **(1)**

Magnetic flux density = 1.5 × 10^{-5} T (1)

(4 marks)

Why might the magnetic field due to the current in the wire pose more of a health risk to the child than the Earth's magnetic field, given that they are of similar magnitudes?

Earth's field is constant; wire's field is alternating (1)

Alternating magnetic field can <u>induce</u> an e.m.f. (1)

(2 marks)
[Total 6 marks]

20. (a) Explain the meaning of the following terms as used in the passage:

(i) to ground (paragraph 1),
To the Earth's surface (1)

(ii) leakage current (paragraph 3),

Current produced by fair weather field (1)

Current in opposite/reverse direction to lightning (1)

(iii) horizontally polarised (paragraph 5).

Waves oscillating in one plane (1)

B or E-field horizontal (1)

(5 marks)

(b) What is the electric field strength at the Earth's surface?

100 V m^{-1} OR **100 N C^{-1} (1)**

Calculate the average electric field strength between the Earth's surface and the conducting ionospheric layer.

$$E_{av} = \frac{300 \times 10^3 \text{ V}}{60 \times 10^3 \text{ m}} = 5 \text{ V m}^{-1} \quad (2)$$

(3 marks)

Sketch a graph to show the variation of the Earth's fair-weather electric field with distance above the Earth's surface to a height of 60 km.

Graph:

Axes *E* in V m^{-1} and *h* in km (1)

Scales marked N.B. Error carried forward 100 V m^{-1} (1)

Sloping line (1)

Getting less steep with *h* (1)

Passing through 60,5 or 0,100 (1)

(Max 4 marks)

(c) The power associated with a lightning stroke is extremely large. Explain why *there is no scope for tapping into thunderstorms as an energy' source* (paragraph 3).

Idea of storms spread out in space (1)

Low average current per storm e.g. only 1 A (1)

Idea of storms spread out in time (1)

Strike lasts for a very short time (1)

(Max 3 marks)

(d) Show that a total charge of 5 × 10^5 C spread uniformly over the Earth will produce an electric field of just over 100 V m^{-1} at the Earth's surface. Take the radius of the Earth to be 6400 km.

$$E = \frac{1}{4\pi \epsilon_o} \frac{Q}{r^2} \quad OR \quad k\frac{Q}{r^2} \quad (1)$$

$$= \frac{1}{4\pi(8.9 \times 10^{-12} \text{ F m}^{-1})} \times \frac{5 \times 10^5 \text{ C}}{(6.4 \times 10^6 \text{ m})^2} \quad (1)$$

= 109 V m^{-1} [Accept 110] [No unit required] (1)

(3 marks)

Draw a diagram to show the direction of this fair-weather field.

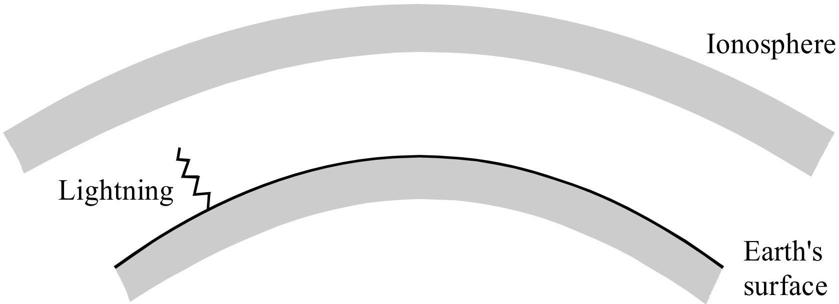
Uniformly spaced radial lines (1)
with downward arrows (1)

Suggest a problem which might arise if the charge on the Earth were very much larger.

More thunderstorms/lightning strikes
or could upset electrical/electronic equipment (1)

(3 marks)

(e) The diagram shows a lightning stroke close to the surface of the Earth.



Copy the diagram and add rays to it to illustrate the propagation of radio waves in the VLF band.

Straight lines (1)
Reflecting (1)
> 1 bounce (1)

On a second copy of the diagram add wavefronts to illustrate the propagation of radio waves in the ELF band.

Equally spaced wavefronts (1)
to Earth's surface (1)
Curved/diffracting (1)

Explain with the aid of a diagram the meaning of the term *radio horizon* used in paragraph 4 with reference to VHF radio waves.

Waves/ray from above
Earth's surface ⇒ horizon idea (1)
[No diagram, no credit]

(7 marks)

(f) List the frequency ranges of VHF, VLF and ELF radio waves.

VHF 30 – 300 MHZ
VLF 10 – 16 kHz
ELF About 1 kHz All correct (1)

Calculate the wavelength of

(i) a typical VHF signal,

$\lambda = c/f$ (1)

$$\lambda = \frac{3 \times 10^8 \text{ m s}^{-1}}{30 \text{ to } 300 \times 10^6 \text{ Hz}} \quad \textbf{(1)}$$

= 10 m to 1 m (1)

(ii) an ELF signal.

Same calculation, cao 3×10^5 m (1)

(Max 4 marks)
[Total 32 marks]

21. For each of the four concepts listed in the left hand column, place a tick by the correct example of that concept in the appropriate box.

A base quantity	mole		length	✓	kilogram	
A base unit	coulomb		ampere	✓	volt	
A scalar quantity	torque		velocity		kinetic energy	✓
A vector quantity	mass		weight	✓	density	

[Total 4 marks]

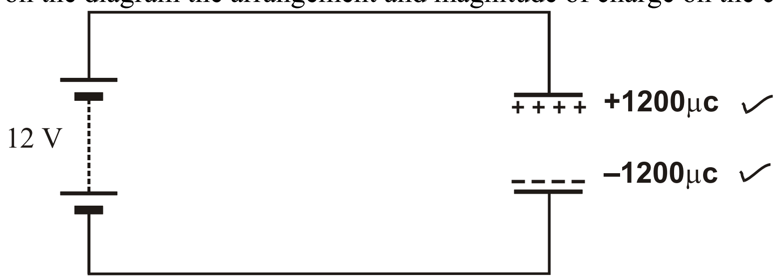
22. A 100 μF capacitor is connected to a 12 V supply. Calculate the charge stored.

Charge stored Q = CV

= $(100 \times 10^{-6}$ F)(12 V)

= 1200 μC (1)

Show on the diagram the arrangement and magnitude of charge on the capacitor.



(2)

(3 marks)

This 100 μF charged capacitor is disconnected from the battery and is then connected across a 300 μF uncharged capacitor. What happens to the charge initially stored on the 100 μF capacitor?

The charge is shared by the two capacitors. (1)

Calculate the new voltage across the pair of capacitors.

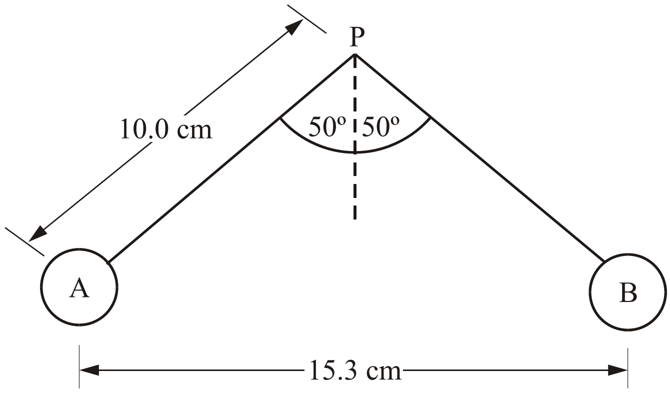
Equivalent capacitance C = 100 μF + 300 μF = 400 μF (1)

New voltage = $\frac{Q}{C} = \frac{1200 \times 10^{-6}\,C}{400 \times 10^{-6}\,F}$ **(1)**

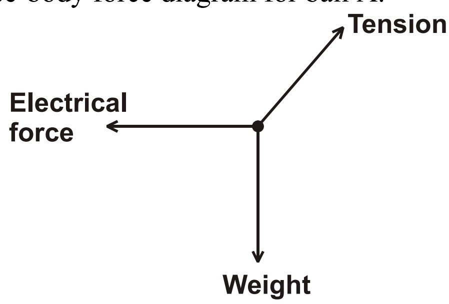
Voltage = 3.0 V (1)

(4 marks)
[Total 7 marks]

23. Two identical table tennis balls, A and B, each of mass 1.5 g are attached to non-conducting threads. The balls are charged to the same positive value. When the threads are fastened to a point P the balls hang as shown in the diagram. The distance from P to the centre of A or B is 10.0 cm.



Draw a labelled free-body force diagram for ball A.



(3 marks)

Calculate the tension in one of the threads.

T cos 50 = *mg* (1)

= $(1.5 \times 10^{-3}$ kg) (9.81 N kg^{-1}) (1)

Tension = 2.3×10^{-2} N (1)

(3 marks)

Show that the electrostatic force between the two balls is 1.8×10^{-2} N.

F_E = $(2.3 \times 10^{-2}$ N) sin 50 = 1.8×10^{-2} N (1)

(1 mark)

Calculate the charge on each ball.

$$F_E = k \frac{q_1 q_2}{d^2}$$ **(1)**

$$1.8 \times 10^{-2}\ \text{N} = \frac{q^2}{4\pi\pi_0 \times (1.53 \times 10^{-2}\ \text{m})^2}$$ **(1)**

Charge = 2.1×10^{-7} C (1)

(3 marks)

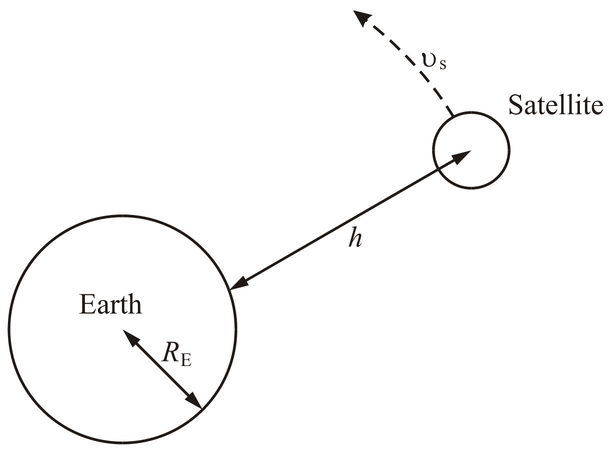
How does the gravitational force between the two balls compare with the electrostatic force given opposite?

It is very much smaller than the electrostatic force or a correctly calculated value. (1)

Gravitational force is attractive. (1)

(2 marks)
[Total 12 marks]

24. The diagram (not to scale) shows a satellite of mass m, in circular orbit at speed v_s around the Earth, *mass* M_E. The satellite is at a height h above the Earth's surface and the radius of the Earth is R_E.



Using the symbols above write down an expression for the centripetal force needed to maintain the satellite in this orbit.

$$F = \frac{m_s v_s^2}{R_E + h}$$ **(2)**

(2 marks)

Write down an expression for the gravitational field strength in the region of the satellite.

$$g = \frac{GM_E}{(R_E + h)^2}$$ **(2)**

State an appropriate unit for this quantity.

N kg $^{-1}$ (1)

(3 marks)

Use your two expressions to show that the greater the height of the satellite above the Earth, the smaller will be its orbital speed.

$$\frac{m_s v_s^2}{R_E + h} = \frac{GM_E m_s}{(R_E + h)^2} \quad \textbf{(1)}$$

$$v_s^2 = \frac{GM_E}{R_E + h} \quad \textbf{(1)}$$

Greater h Þ smaller v_s since G, M_E constant (1)

(3 marks)

Explain why, if a satellite slows down in its orbit, it nevertheless gradually spirals in towards the Earth's surface.

As it slows $\frac{GM_E m_s}{(R_E + h)^2} > \frac{m_s v_s^2}{R_E + h}$ **(1)**

The "spare" gravitational force not needed to provide the centripetal acceleration pulls the satellite nearer to the Earth (1)

(2 marks)
[Total 10 marks]

25. The magnitude of the force on a current-carrying conductor in a magnetic field is directly proportional to the magnitude of the current in the conductor. With the aid of a diagram describe how you could demonstrate this in a school laboratory.

A diagram with a wire perpendicular to a magnetic field with the means to measure the force on the wire. (1)

Method of providing and measuring d.c. (1)

Method of varying and measuring force with details. (1)

For various values of current, measure *F*. (1)

Plot *F* against *I* – straight line through origin. (1)

MAX 3

(4 marks)

At a certain point on the Earth's surface the horizontal component of the Earth's magnetic field is 1.8×10^{-5} T. A straight piece of conducting wire 2.0 m long, of mass 1.5 g lies on a horizontal wooden bench in an East-West direction. When a very large current flows momentarily in the wire it is just sufficient to cause the wire to lift up off the surface of the bench.

State the direction of the current in the wire.

To the East (1)

Calculate the current.

$F = BIl$

$(1.5 \times 10^{-3}$ kg)(9.81 N kg^{-1}) = $(1.8 \times 10^{-5}$ T) × I × (2.0 m)   (1)

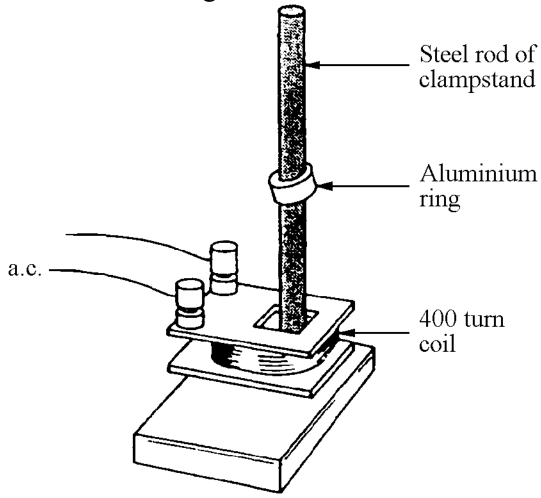
Current = 410 A   (1)

What other noticeable effect will this current produce?

Wire melts   (1)

(4 marks)
[Total 8 marks]

26. Apparatus to demonstrate electromagnetic levitation is shown in the diagram.



When there is an alternating current in the 400-turn coil the aluminium ring rises to a few centimetres above the coil. Changes in the size of the alternating current make the ring rise to different heights.

(a) (i) Explain why. when there is a varying current in the coil, there is an induced current in the aluminium ring. Suggest why the ring then experiences an upward force.

Current in coil produces a magnetic field   (1)

the field varies   (1)

(magnetic) flux through ring changes / field lines are cut by ring   (1)

so induced e.m.f. in ring   (1)

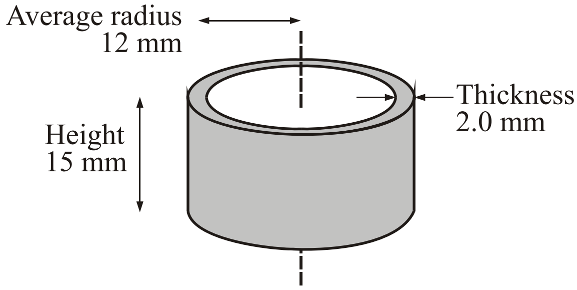
the current feels a *BIl* force / motor effect / Fleming / left hand rule   (1)

because of opposing B-fields / Lenz's law opposing   (1)

(Max 5 marks)

(ii) In one experiment the power transfer to the aluminium ring is 1.6 W. The induced current is then 140 A. Calculate the resistance of the aluminium ring.

The dimensions of the aluminium ring are given on the diagram below. Use your value for its resistance to find a value for the resistivity of aluminium.



$P = I^2R \Rightarrow R = P/I^2$ (1)

$= 1.6$ W $\div$ $(140$ A$)^2$ (1)

$= 8.2 \times 10^{-5}\ \Omega$ (1)

$R = \rho l/A$ (1)

A calculated as $(2.0 \times 10^{-3}$ m$)(15 \times 10^{-3}$ m$)$

OR

l calculated as $2\pi(12 \times 10^{-3}$ m$)$ (1)

$\Rightarrow \rho = 3.3 \times 10^{-8}\ \Omega$ m (1)

(Max 5 marks)

(b) The aluminium ring becomes hot if the alternating current is left on for a few minutes. In order to try to measure its temperature it is removed from the steel rod and then dropped into a small plastic cup containing cold water.

(i) State what measurements you would take and what physical properties of water and aluminium you would need to look up in order to calculate the initial temperature of the hot aluminium ring.

Measure:

Mass of ring and mass of water (1)
Initial and final temperature of water / $\Delta\theta$ water (1)

Look up s.h.c. of aluminium and water (1)

(3 marks)

(ii) Explain whether experimental errors would make your value for the initial temperature of the aluminium ring too big or too small.

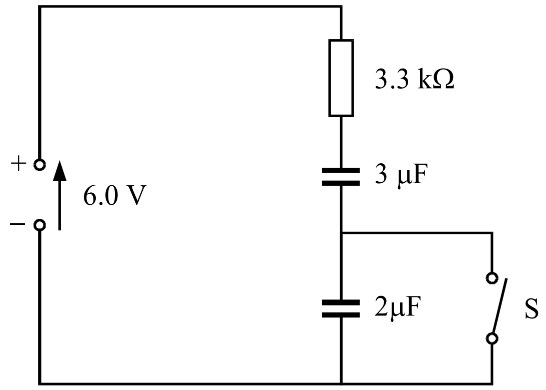
General reference to heat / energy losses (1)

Detail of where / when losses occur (1)

Calculated temperature too small (1)

(3 marks)

27.



Calculate the maximum energy stored in the 3 μ**F** capacitor in the circuit above

(i) with the switch S closed,

$W = \frac{1}{2}cv^2 = \frac{1}{2}(3 \times 10^{-6}\ \mu F)(6.0V)^2$ **(1)**

Maximum energy = 54μJ (1)

(2 marks)

(ii) with the switch S open.

$\mathbf{C'} = \left\{\frac{1}{3} + \frac{1}{2}\right\}^{-1}$ **(1)**

$= {}^{6}/_{5}\ \mu$ **F (1)**

Q = 7.2μC (1)

W = (7.2 × 10⁻⁶)/2 × 3 × 10⁻⁶ (1)

Maximum energy = 8.6 μJ (1)

(4 marks)
[Total 6 marks]

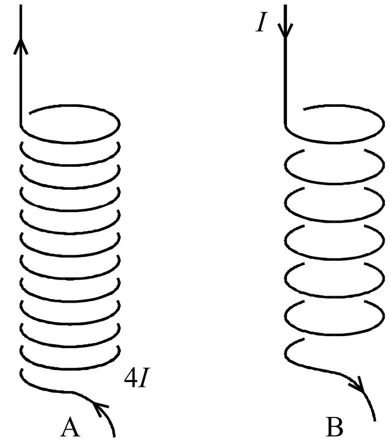
28. Explain what is meant by a neutral point in field.

Where two (or more) fields (1)

Cancel/Produce zero resultant force (1)

(2 marks)

The diagram shows two similar solenoids A and B. Solenoid A has twice the number of turns per metre. Solenoid A carries four times the current as B.



On ONE Solenoid:
Field lines through centre parallel

One complete loop each side

Correct polarity

for other solenoid:
opposite polarity
and different number of field lines

Draw the magnetic field lines in, around and between the two solenoids.

(4 marks)

If the distance between the centres of A and B is 1 m, estimate the position of the neutral point. Ignore the effect of the Earth's magnetic field.

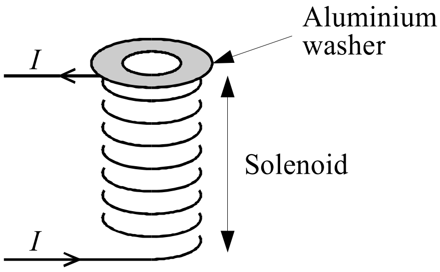
Flux density A = 8 × flux density B (1)

Neutral point 0.89m from A/0.11 m B (2)

(0.875 m / 0.125 m)

(3 marks)
[Total 9 marks]

29. A light aluminium washer rests on the end of a solenoid as shown in the diagram.



A large direct current is switched on in the solenoid. Explain why the washer jumps and immediately falls back.

B field produced by solenoid (1)

Flux lines CUT washer (1)

Induced current/e.m.f. in washer (1)

B field of solenoid opposite to B field washer (1)

Repulsive force lifts washer (1)

Steady current so no changing of flux/no induction (1)

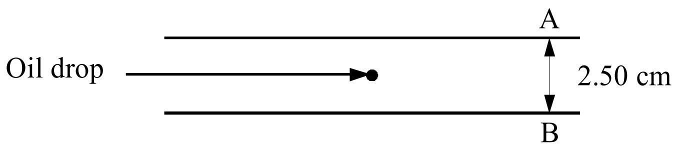
OR explain by force on current carrying conductor in B field (LH rule)

[Total 5 marks]

30. Classify each of the terms in the left-hand column by placing a tick in the relevant box.

[Total 6 marks]

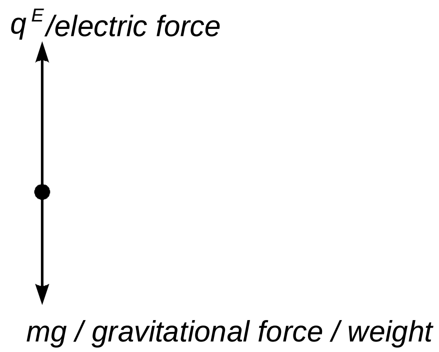
31. The diagram shows a positively charged oil drop held at rest between two parallel conducting plates A and B.



The oil drop has a mass 9.79 x 10^{-15} kg. The potential difference between the plates is 5000 V and plate B is at a potential of 0 V. Is plate A positive or negative?

Negative (1)

Draw a labelled free-body force diagram which shows the forces acting on the oil drop. (You may ignore upthrust).



(2)

(3 marks)

Calculate the electric field strength between the plates.

E = $\frac{\mathbf{5000V}}{\mathbf{2.50} x \mathbf{10^{-2}} m}$ **(1)**

Electric field strength = **2 x 10^5 V m^{-1} [OR N c^{-1}] (1)**

(2 marks)

Calculate the magnitude of the charge Q on the oil drop.

Mg = qE: use of equation (1)

Charge = **4.8 x 10^{-19} C (1)**

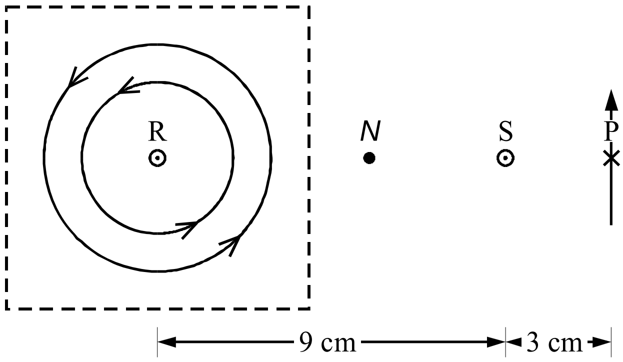
How many electrons would have to be removed from a neutral oil drop for it to acquire this charge?

3 (1)

(3 marks)

[Total 8 marks]

32. Two long parallel wires R and S carry steady currents I_1 and I_2 respectively in the same direction. The diagram is a plan view of this arrangement. The directions of the currents are out of the page.



At least 2 concentric circles both correct direction

N between R and S approximately as shown

Field at P

In the region enclosed by the dotted lines, draw the magnetic field pattern due to the current in wire R alone.

See above (2 marks)

The current I_1 is 4 A and I_2 is 2 A. Mark on the diagram a point N where the magnetic flux density due to the currents in the wires is zero.

See above (2 marks)

Show on the diagram the direction of the magnetic field at P.

See above (1 mark)

(5 marks)

Calculate the magnitude of the magnetic flux density at P due to the currents in the wires.

Use of $B = \frac{\mu_0 I}{2\pi r}$ **with** $\frac{I}{r} = \frac{2A}{0.03m}$ **OR** $\frac{4A}{0.12m}$ **(1)**

Two substitutes involving $\times \frac{4}{12}$ **and** $\times \frac{2}{3}$ **added (1)**

Flux density = 2×10^{-5} **T (1)**

(3 marks)
[Total 8 marks]

33. What is meant by the term *electromagnetic induction*?

The generation of a pd/voltage/emf (1)

by a moving conductor relative to a magnetic field (2)

[Last two points could be interchanged]

(3 marks)

Describe an experiment you could perform in a school laboratory to demonstrate Faraday's law of electromagnetic induction.

A suitable experiment (eg. two coils, one with a.c., magnet and solenoid) (1)

How change of flux linkage is produced (1)

Measurement of induced current or voltage with appropriate device in correct place (1)

How to change the rate of flux cutting (1)

What is observed (1)

(5 marks)

An aircraft has a wing span of 54 m. It is flying horizontally at 860 km h^{-1} in a region where the vertical component of the Earth's magnetic field is 6.0 x 10^{-5} T. Calculate the potential difference induced between one wing tip and the other.

Use of $\mathcal{E}$ = Blv [No mark]

$$\mathcal{E} = 6 \times 10^{-5}\ \text{T} \times 54\ \text{m} \times \frac{860 \times 10^{3} m}{60 \times 60 s} \quad \textbf{(1)}$$

Potential difference = **0.77 V** **(1)**

What extra information is necessary to establish which wing is positive and which negative?

Direction of field / N or S hemisphere **(1)**

(3 marks)
[Total 11 marks]

34. (a) (i) Ion pair:
Charged particles **(1)**
Positive and negative **(1)**

(ii) Space charge:
Region/area containing positively charged **(1)**
massive/slow-moving particles/ions **(1)**

(iii) Dead time:
Period/time when GM tube is insensitive to arrival of further particles **(1)**

(5 marks)

Avalanche:
Electrons accelerate/gain energy **(1)**
causing ionisation **(1)**
idea of a cascade, e.g. chain reaction **(1)**

(3 marks)

(b) $\Delta p = (101 - 11) \times 10^3$ Pa **(1)**
Use of $F = Ap$ OR $A\Delta p$ **(1)**
$= \pi(12 \times 10^{-3}\ \text{m})^2\ (90 \times 10^3\ \text{Pa})$ **(1)**
= 41 N **(1)**

(4 marks)

Difficulty:
α-particles easily stopped/have short range/are least penetrating **(1)**
so thin end windows needed **(1)**
but forces/pressures are high **(1)**

(Max 2 marks)

(c) (i) Thickness of mica = $(2 \times 10^{-2}\ \text{kg m}^{-2}) \div (2800\ \text{kg m}^{-3})$ **(1)**
$= 7.14 \times 10^{-6}$ m **(1)**
Therefore number of molecules
$= 7.14 \times 10^{-6}\ \text{m} \div 8.4 \times 10^{-9}\ \text{m}$ **(1)**
= 850 **(1)**

(Max 3 marks)

(ii) α ionises more densely than β **(1)**
as it has twice the charge/is slower than β **(1)**
Therefore β penetrates more/gets through thicker windows than α **(1)**

(3 marks)

(d) Radial lins/parallel lines **(1)**
with arrows outwards **(1)**
± marked/anode-cathode marked consistent with arrows **(1)**

(3 marks)

Calculation:
$F = qE$ **(1)**
$= 1.92 \times 10^{-14}$ N **(1)**
$ma = F$ **(1)**
$a = 2.1 \times 10^{16}$ m s^{-2} **(1)**

(4 marks)

(e) (i) $\ln(r_a/r_c)$ no units/$r_a \div r_c$ no units/ln is number **(1)**
$\varepsilon_0\, l$ has unit F m^{-1} × m **(1)**
= F which is unit of capacitance **(1)**

(3 marks)

(ii) Time constant = RC
$= (1 \times 10^5\ \Omega)(10 \times 10^{-12}\ \text{F})$ **(1)**
$= 1 \times 10^6$ s **(1)**

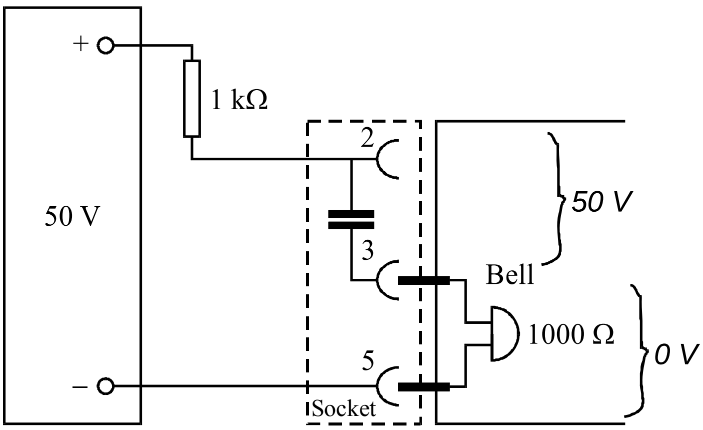
(2 marks)

[Total 32 marks]

35. Define the term *capacitance*.

Capacitance = Charge / Voltage (1)
(Allow C = Q / V if symbols are defined) (1)

The sockets of modern telephones have six pins. A power supply of 50 V in series with a resistance of about 1000 ? is connected to pins 2 and 5.



A capacitor of 2 ?F is connected between pins 2 and 3. In one installation, a bell of resistance 1000 ? is connected to pins 3 and 5.

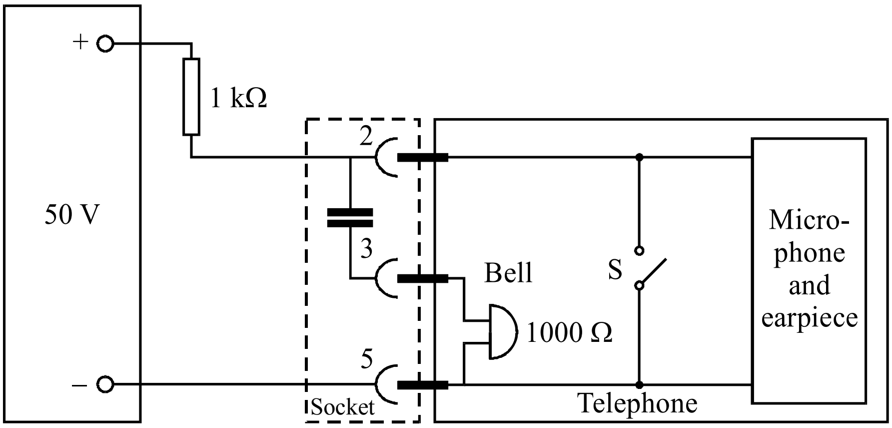
Explain why there is a pulse of current through the bell when the circuit is first connected, but not after the bell has been connected for some time.

Current flows in the bell when the capacitor is charging (1)
but not when the capacitor is fully charged (1)

On the circuit diagram above, label the values of the voltages across the capacitor and across the bell when the circuit has been connected for some time.

(2 marks)

To dial a number, e.g 7, switch S must be closed that number of times.



Explain why the bell sounds softly (tinkles) when the switch is closed and then opened again.

The capacitor discharges (1)
The discharge current flows in the bell (1)

To avoid this tinkling, an "anti-tinkling switch is connected to short-circuit the bell during dialling. Draw this switch on the diagram.

Suitably placed switch (1)

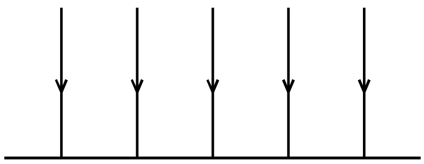
Explain the operation of the anti-tinkling switch.

Action of switch correctly explained (i.e. why no current flows in the bell) (1)

[Total 10 marks]

36. Draw diagrams to represent

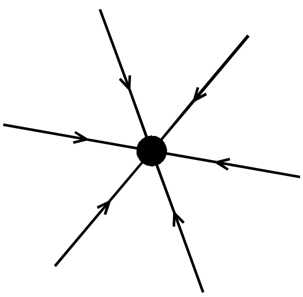
(i) the gravitational field near the surface of the Earth,



Direction

Lines: at least 3 parallel perpendicular equally spaced

(ii) the electric field in the region of an isolated negative. point charge.



Direction

Lines: at least 3 radial equally spaced

(4 marks)

How does the electric field strength *E* vary with distance *r* from the point charge?

$E \propto \frac{1}{r^2}$ (1)

(1 mark)

Give an example of a region in which you would expect to find a uniform electric field.

Between charged parallel plates (1).

(1 mark)
[Total 6 marks]

37. State Lenz's law of electromagnetic induction

Direction of induced emf is such as to oppose the charge producing it (2)

(2 marks)

An exhibit at a science centre consists of three apparently identical vertical tubes, T_1, T_2 and T_3, each about 2 m long. With the tubes are three apparently identical small cylinders, one to each tube.

When the cylinders are dropped down the tubes those in ~T, and ~T2 reach the bottom in less than I second, while that in ~T3 takes a few seconds.

Explain why the cylinder in T_3 takes longer to reach the bottom of the tube than the cylinder in T_1

In T_3 magnetic flux cuts copper tube (1)
induction occurs (1)
current in copper tube (1)
creates magnetic field (1)
opposite to magnet's which repels slows magnet

T_1 is plastic so no induction/no current forms (1)

(5 marks)

Explain why the cylinder in T_2 takes the same time to reach the bottom as the cylinder in T_1

In T_2 falling cylinder unmagnetised so no flux cut or no induction (1)

Both T_1 and T_2 have only force of gravity acting on them (1)

(2 marks)
[Total 9 marks]

38. (a) Upward/electrical force equals/balances weight **(1)**

$EQ = mg$ **(1)**

$$E = \frac{V}{d} = \frac{500\text{V}}{5.8 \times 10^{-3}\,\text{m}}$$ **(1)**

$= 8.62 \times 10\text{-}4 \ \frac{\text{V}}{\text{m}} \Big/ \frac{\text{N}}{\text{C}}$

$= mg = (1.4 \times 10^{-14}\,\text{kg})\,(9.8\ \text{N kg}^{-1})$ **(1)**

$= 1.37 \times 10^{-13}\text{N}$

$$\Rightarrow Q = \frac{1.37 \times 10^{-13}\,\text{N}}{8.62 \times 10^{4}\,\text{NC}^{-1}} = 1.59 \times 10^{-18}\ \text{C}$$ **(1)**

Horizontal: so that two forces/*EQ* and *mg* are parallel **(1)** **6**

(b) β source emits electrons **(1)**

which ionise air (molecules) **(1)**
Positive ions are attracted to sphere **(1)**
Free-body diagram showing upward drag/resistive force **(1)** **Max 3**

(c) Quantised: charge comes in lumps/discrete amounts/packets **(1)**
Other: energy/electro-magnetic wave (energy)/light **(1)**
Situation: photoelectric effect/spectra/energy levels **(1)**
Description of how the situation chosen shows quantisation **(1)** **4**

(d) Spheres are being hit/bombarded **(1)**
by air molecules/particles **(1)**
which are in random motion **(1)**

[Max 1 for simply Brownian motion]

Lower temperature: air molecules' speed/kinetic energy is reduced **(1)** **Max 3**

39. (a) (i) Energy (per s) = NeV **(1)**

(ii) Use of $E = Pt$ **(1)**
$\Rightarrow E = (2.4\ \text{W})\ (20\ \text{s}) = 48\ \text{J}$ **(1)**
Use of $\Delta Q = mc\Delta t$ **(1)**
$\Rightarrow m = 0.77 \times 10^{-3}$ kg **(1)**

Assume:
All energy transferred to heat/no energy transferred to light **(1)**
No heat conducted away from spot/only spot heated **(1)** **7**

(b) Either

Direct electrical method:

Measure Ivt **(1)**
Measure $m\Delta\theta$ for suitable lump of glass **(1)**
Sketch/description of apparatus **(1)**

Or

Method of mextures:

Measure temperature of hot glass **(1)**
Measure $m_w\ c_w\ \Delta_w$ and measure $m_g\ \Delta\theta_g$ **(1)**
Sketch/description of apparatus **(1)**

Difficulty:

Glass poor conductor linked to experiment **(1)**
Difficult to prevent heat loss linked to experiment **(1)** **5**

40. Joule: kg $m^2\ s^{-2}$ **(1)**
Coulomb: Derived unit **(1)**
Time: Scalar quantity **(1)**
Volt: $W \times A^{-1}$ **(1)**

[Total 4 marks]

41. Calculation of energy:

$W = \frac{1}{2} CV^2$ **(1)**

$= \frac{1}{2} (3 \times 10^{-6}\text{ F}) (6\text{ V})^2$ **(1)**

Energy = 54 μJ **(1)** **3**

Calculation of Total energy:

$Q = CV = (3 \times 10^{-6}\text{ F}) (6\text{ V}) = 18\ \mu\text{C}$ **(1)**

$C = C_1 + C_2 = 8\ \mu\text{F}$ **(1)**

$W = Q^2/2C = (18\ \mu\text{C})^2 /2\ (8\ \mu\text{F})$ **(1)**

Total energy = 20 μJ **(1)** **4**

[Correct alternative strategies allowed]

Statement:

Heating of resistor (or wires) **(1)** **1**

[Total 8 marks]

42. Total magnetic flux through the loop when 30 mm from end of magnet:

Flux = $B \times A$

$= 1 \times 10^{-3}\text{ T} \times 16 \times 10^{-4}\text{ m}^2$ **(1)**

[Substitution of 1, 16. Ignore × 10 here]

$= 1.6 \times 10^{-6}$ Wb **(1)**

Total magnetic flux through the loop when 10 mm from end of magnet:

Flux = $30 \times 10^{-3}\text{ T} \times 16 \times 10^{-4}\text{ m}^2$

$= 4.8 \times 10^{-5}$ Wb [Unit penalty once only] **(1)** **3**

Average speed of movement of the loop:

$E = \Delta\phi / \Delta t$

$\Delta t = \dfrac{46.4 \times 10^{-6}\text{ Wb}}{15 \times 10^{-6}\text{ V}}$ **(1)**

= 3.1 s

Use of speed = distance ÷ time = 20 mm ÷ 3.1 s **(1)**

$= 6.5\text{ mm s}^{-1}$ **(1)** **3**

Slow down nearer to the magnet **(1)** **1**

[Total 7 marks]

43. Explanation:

The wire, when carrying a current, feels a force when in a magnetic field **(1)**

The current is at 90° to the magnetic field **(1)**

hence PQ feels an upward force; RS a downward force; they produce a couple which causes rotation **(1)**

Addition to diagram of an arrow ↑ **(1)**

Three factors which would affect the magnitude of force:

(1) Strength/magnitude of B field **(1)**

(2) Size of current **(1)**

(3) Number of turns of coil/length of PQ **(1)** 7

Explanation of observation:
Flux cut → e.m.f. induced **(1)**
e.m.f. opposite to applied p.d. → V_{TOTAL} less, hence I less **(1)** 2

[Total 9 marks]

44. Ohm and farad expressed in terms of SI base units:

Ohm: volt/ampere allow V/A but not V/1 *or* $\Omega \rightarrow \text{V A}^{-1} \rightarrow \text{V C}^{-1}\text{ s}$
$= \text{kg m}^2\text{ A}^{-2}\text{ s}^{-3}$

Farad: coulomb/volt allow C/V but not *Q/V* *or* $\text{F} \rightarrow \text{C V}^{-1}$

$(= \text{A}^2\text{ s}^4\text{ kg}^{-1}\text{ m}^{-2})$

[Give third mark where they seem to work back correctly from $\text{kg m}^2\text{ A}^{-2}\text{ s}^{-3}$] 4

Demonstration that ohm × farad = second *or* $\text{V C}^{-1}\text{ s} \times \text{C V}^{-1} \rightarrow \text{s}$

[No mark if the second comes from multiplying two incorrect expressions]

Calculation of charge at beginning of 10.0 ms discharge period:

(40 000 μF) × (12 V)

= 0.48 C

Calculation of charge at end of the 10.0 ms discharge period:

(40 000 μF) × (10.5 V) = 0.42 C 3

[Allow the third mark if a wrong answer, e.g. 42 C, comes from repeating the same arithmetical error as was made in the earlier calculation.]
[If a wrong equation is used such as $Q = 1/2\, CV^2$, the above three marks are lost but the wrong answers can be carried forward into the following current calculation (67.5 A).]

Average current:

$$\frac{(0.48C - 0.42C)}{10\,\text{ms}}$$

[(1) for correct charge/time, (1) for correct time] 3

= 6 A

Advantage of reduced discharge time: 2

Minimal drop or much reduced drop in voltage value
Reason - insufficient time for larger voltage drop, or similar

[12]

45. Calculation of magnetic flux density:

$B = (4\pi \times 10^{-7}\ \text{N A}^{-2}\ \left(\frac{72}{0.45\text{m}}\right)$ (2.5 A) [Allow × 10 error in 45 only]

5.0×10^{-4} T 2

Observations on voltmeter:

(a) Movement which implies brief or pulsed then V reads zero

(b) Negative reading with respect to direction above

(c) Alternating reading positive to negative and continuous 5

[7]

46. Explanation - Any two from:

Coil carries current at 90° to magnetic field
Force acts at right angles to both *or* reference to left hand rule
AC means current reverses so force and hence movement ↔ Max 2

[Credit two B fields if leads to catapult field]

Drawing of six magnetic field lines on diagram:

Six radii, all N → S

Advantage of unusually shaped magnet:

So the current/coil is always perpendicular to field

or

so that each segment of coil is in same strength field ∴ equal forces

[Not uniform field]

Direction of current shown on diagram:

Current shown clockwise on diagram 3

Force on coil when it carries a current of 20 mA:

$F = BIl$

$= (0.6\ \text{T})\ (20 \times 10^{-3}\ \text{A})\ (2\pi \times 300 \times 20 \times 10^{-3}\ \text{m})$

= 0.45 N (*or* 0.5 N) 3

[8]

47. What is meant by "an equation is homogeneous with respect to its units":
<u>Each side/term</u> has the same units 1

Equation $x = ut + ½ at^2$:

ut - $(\text{m s}^{-1})\ \text{s} = \text{m}$

$at^2/2\ (\text{m s}^{-2})\ \text{s}^2 = \text{m}$

all 3 terms reduce to m 3

[Allow dimensions]

Explanation:

Wrong numerical constant/wrong variables

Units same, numbers wrong/

Units same, magnitudes wrong 1

Example = 1 kg + 2 kg = 5 kg

[5]

48. Slope of graph:

Capacitance

Shaded area of graph:

Energy/work done 2

Energy stored 3.1 J:

$CV^2/2$

$= 100 \times 10^{-6} \times 250^2/2$ [formula + correct substitution]

(= 3.125) = 3.1 J [Must have previous mark] 2

Power from cell, and minimum time for cell to recharge capacitor:

Cell power = 1.5 V × 0.20 A

= 0.30 W [allow 3/10 W here]

Time = 3.1 J/0.30 W(e.c.f.)

= 10 s 3

[7]

49. Demonstration that when current of 0.80 A flows, the magnetic flux density at centre is 0.0018 T:

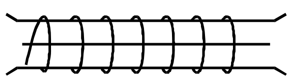
$B = \mu_0 nI$

Substitution of $\frac{250}{0.14}$ 2

Other substitutions
(0.0018 T)
Magnetic flux density at end of solenoid:
Use of $\phi = B \times A$ with ϕ and A identified correctly
$= 9 \times 10^{-4}$ T
Why flux density at end of solenoid is not equal to that at the centre: 2

Because lines of force/field lines spread out at the end
or because lines of force not parallel at end
or because flux leakage through sides near end

or diagram:



1

[5]

50. The joule in base units:

$kg\ m^2\ s^{-2}$ [No dimensions] **(1)** 1

Homogeneity of formula:

ρ $kg\ m^{-3}$ **(1)**

r m, $f = s^{-1}$ **(1)**

(Right hand side units = $(kg\ m^{-3})\ (m)^5\ (s^{-1})^2)$ [Correct algebra]

$= kg\ m^2\ s^{-2}$ [Only if 1st two marks are earned] **(1)** 3

[Ignore numbers; dimensions OK if *clear*]

Why formula might be incorrect:

The ½ could be wrong **(1)** 1

[5]

51. Estimation of charge delivered:

Charge = area under graph **(1)**

= a number of squares × correct calculation for charge of one square i.e. correct attempt at area e.g. single triangle **(1)**

= $(3.5 \text{ to } 4.8) \times 10^{-3}$ C (A s, μA s) **(1)**

[Limit = triangle from 41 μA → 300 s]

OR

Charge = average current × time **(1)**

= (something between 10 and 20 μA) × 300 s **(1)**

= $(3.5 \text{ to } 4.8) \times 10^{-3}$ C **(1)** 3

[But $Q = It$ → 0/3, e.g. 41 μA × 300 s]

Estimation of capacitance

C = calculated charge/9.0V time constant ≈100 s **(1)**

= 390 to 533 μF C = 100 s/220 k.Ω = 450 μF **(1)** 2

[5]

52. Calculation of the magnitude of the electric field strength:

Correct use of $E = kq/r^2$ [all substitutions, any value of q] **(1)**

$q = 92 \times e$ **(1)**

Magnitude = 2.4×10^{21} N C^{-1} OR V m^{-1} **(1)**

Direction of electric field:

Away from nucleus/outwards/on diagram **(1)** 4

Similarity and difference between electric and gravitational field:

Similarity - Both radial/obey inverse square law/ $\propto 1/r^2$ **(1)**

Difference - Magnitude of *g* field << *E*-field

OR G-field direction towards nucleus, E field away from nucleus

OR G-field attractive only, E field attractive OR repulsive **(1)** 2

[6]

53. Calculation of e.m.f. induced across falling rod:

Correct use of $E = Bl\upsilon$ **(1)**

$\upsilon = 25$ m s^{-1} **(1)**

e.m.f. = $7.3 - 7.4 \times 10^{-4}$ V **(1)** 3

Explanation of why magnitude of vertical component is not required:

Earth's field is parallel to direction of fall/body falls vertically **(1)**

Therefore no flux cut **(1)** 2

[5]

54. (a) *Either*

Bunch of threads/hair **(1)**

Connected to top of sphere **(1)**

Fan out repelling each other **(1)**

Or

Light conductor on insulating thread [e.o.p. plastic sphere] **(1)**

Touch to sphere **(1)**

Hold at side repelled **(1)**

[May all be on labelled diagram] Max 2

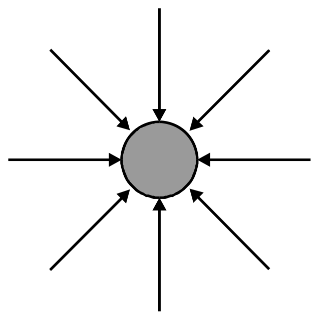
(b) Unit of *I, w* and *v* as A, m and m s^{-1} **(1)**

As A s = C **(1)**

unit of *X* is C m^{-2}

so *X* may be the charge density/per unit area (on belt) **(1)** 3

(c) (i) Radial lines [be generous] **(1)**
> 4 lines **(1)**
Arrows inward [to surface only] **(1)**



(ii) $E = Q/4\pi\varepsilon_0 r^2 \rightarrow Q = 4\pi\varepsilon_0 r^2 E$ **(1)**

$\therefore Q = 4\pi\,(8.85 \times 10^{-12}\ \text{F m}^{-1})\,(0.15\ \text{m})^2\,(3.6 \times 10^5\ \text{N C}^{-1})$

$= 0.90 \times 10^{-6}$ C OR 0.90 μC **(1)**

$V = Q/4\pi\varepsilon_0 r^2$ OR $V = Er$ **(1)**

Substitution [allow e.c.f for *Q*]

$\rightarrow V = 54 \times 10^3$ V OR 54 kV — 6

(d) (i) Leakage current:

(Fast) random movement **(1)**

(Very) slow drift velocity [down] **(1)**

On belt:

Uniform velocity [up] **(1)**

(ii) Axes showing:

V (up) and 120 s/2 min (along) **(1)**

V/2 OR origin OR 60 s [i.e. zero on one axis implied] **(1)**

Exponential curve from (O s, V) not reaching time axis **(1)** — Max 5

[16]

55. Correct quantities on diagram:

Upper ellipse	capacitance	[**not** energy]	[Accept capacitance^{-1}]	**(1)**
Lower ellipse	resistance	[**not** power]	[Accept conductance/resistance^{-1}]	**(1)**

2

Explanation:

Base quantities/units [**Not** fundamental] **(1)**

Not derived from other (physical) quantities **(1)**

OR other (physical) quantities are derived from them

OR cannot be split up/broken down

2

[4]

56. Relationship between current and charge:

Current is the rate of flow of charge/rate of change of charge OR current is charge per second

OR $I = Q/t$ (with or without d or Δ) but with symbols defined **(1)**

1

Explanation:

Since I is constant, Q *o* on capacitor (= It) increases at a steady rate OR charge flows at a constant rate **(1)**

Since $V \propto Q$, V also increases at a steady rate **(1)**

OR

$V = Q/C = It/C$ **(1)**

and $V = (I/C) \times t$ compared with $y = (\text{m}) \times x$

2

Determination of current, using graph:

Use of $Q = CV$	Attempt to get grad	**(1)**
Use of $I = Q/t$	Use of $I = C \times$ grad	**(1)**
= 1.1 mA	1.1 mA	**(1)**

3

Explanation:

Decrease [If increase, 0/3] **(1)**

As capacitor charges, V_R decreases **(1)**

R must decrease because $I = V_R/R$ OR R must decrease to prevent I falling **(1)**

3

Second graph:

Line added to graph showing:

Any curve getting less steep with time [from origin; no maximum] **(1)**

And with same initial gradient as original straight line **(1)**

2

[11]

57. Evenly distributed spray:

The drops repel [i.e. something repels] **(1)**

1

Explanation:

Electrons/negative charge move upwards from Earth on to object **(1)**

as positive/drops <u>induce negative</u> on object **(1)**

negatives attract positive/drops [not "neutralised"] **(1)**

3

Positive builds up on object OR no electrons move upwards from Earth **(1)**

OR negative can no longer flow

Positive repels approaching drops **(1)**

2

[6]

58. Calculation of potential difference:

Use of $E = V/d$ [d in m or cm] **(1)**

$V = 90$ kV **(1)**

Calculation of maximum kinetic energy:

Use of $\times 1.6 \times 10^{-19}$ [in $E = qV$ e.c.f. value of V] 1.4×10^{-14} (J) **(1)**

[e.c.f. their V $\times 1.6 \times 10^{-19}$] **(1)**

4

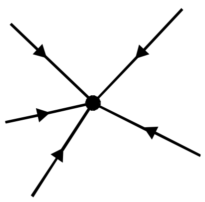
Maximum speed of one of these electrons:

Use of k.e. = ½ $m\upsilon^2$ with m = <u>9.1×10^{-31} kg</u> **(1)**

[Full e.c.f. their k.e. possible; make sure v is speed term]

$= 1.8 \times 10^8$ m s^{-1} [u.e. but only once] **(1)**

Diagram:



2

At least 3 radial lines <u>touching</u> object **(1)**

Direction towards electron **(1)**

2

Expression for electric potential V:

$$V = \frac{1}{4\pi\varepsilon_0} \times \frac{1.6 \times 10^{-19}}{r} \quad \text{OR} \quad \frac{e}{4\pi\varepsilon_0}r \quad \text{OR} \quad \frac{1.44 \times 10^{-9}}{r}$$

[not k unless defined] $\left[Not\ \frac{Q}{4\pi\,\varepsilon_0\, r} \text{ unless } Q \text{ defined} \right]$

[With or without "–" sign] **(1)**

1

[9]

59. Word equation:

Force proportional to product of masses and inversely proportional to (distance / separation) squared **(1)(1)**

2

[No force 0/2]

OR

$$F = \frac{G \times \text{mass}_1 \times \text{mass}_2}{(\text{distance})^2}$$ **(1)**

[or (separation)^2 instead of bottom line]

Calculation of force:

From Newton's law OR idea that force = weight = mg_{planet} **(1)**

$$F = \frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 6.42 \times 10^{23}\ \text{kg} \times 1\ \text{kg}}{(3.40 \times 10^6)^2\ \text{m}^2}$$

[Substitution in correct equation only]

OR

$$g_{\text{mars}} = \frac{\text{G} \times 6.42 \times 10^{23}\ \text{kg}}{(3.4 \times 10^6)^2\ \text{m}^2}$$ **(1)**

= 3.7 N **(1)**

Smaller **(1)**

3

Explanation of reasoning:

g is less, but ρ is similar/same [so R is less] **(1)**

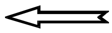
[2nd mark is consequential on first mark]

2

[7]

60. Direction of current: B to A OR North [Not upwards] **(1)**
1

Diagram:



Points to left [anywhere to left] **(1)**

At **(** 45° this way **(1)**
2

Explanation:

Field due to current perpendicular to page at (2) **(1)**

so sets as <u>Earth's field</u>

because:

- cannot pivot up/down **(1)**
- too far from wire
- field due to wire negligible

OR *only* in Earth's field
2

[5]

61. Direction of force, shown on diagram:

Arrow pointing upwards on diagram **(1)**
1

(i) Low frequency:

Wire moves up/vibrates/oscillates, then down, then up, etc
[Not "up and down" – needs implication of repetition]
[Won't move + justification OK] **(1)**
1

(ii) Increased frequency:

Wire vibrates quicker as frequency increases **(1)**

At f = 20 Hz **(1)**

Large amplitude vibrations OR resonance occurs **(1)**

Standing wave set up OR diagram [consequent on 20 Hz] **(1)**

Resonance at 40 Hz OR diagram **(1)**
5

[7]

62. Flux through closed window:

Flux = 20 $\times 10^{-6}$ T $\times$ (1.3 $\times$ 0.7) m^2

[if two equations, must use (1.3 × 0.7) each time] **(1)**

B_H chosen OR area correct **(1)**

= 1.8 $\times 10^{-5}$ Wb/T m^2

2

Average e.m.f. induced:

$E = \dfrac{1.8 \times 10^{-5}\ \text{Wb}}{0.8\ \text{s}}$ [e.c.f.] **(1)**

= 2.3 $\times 10^{-5}$ V [5.6 $\times 10^{-5}$ V if B_v used] **(1)**

2

Effect on induced e.m.f. of converting window: **(1)**

Zero induced e.m.f. [Not "very small"]

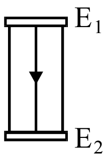
No change in flux linkage OR no flux cut OR e.m.fs. in opposite sides cancel out 2/2
[Consequential] **(1)**

2

[6]

63. (a) (i) Centre line with arrow down **(1)**

More lines on either side **(1)**



Either showing bulges at edges

(ii) E = 6.0 V ÷ 0.15 m **(1)**

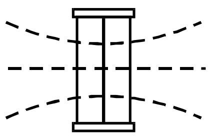
= 40 V m^{-1} [0.40 V cm^{-1}] OR 40 N C^{-1} **(1)**

[e.c.f. ÷ 0.075 m/7.5 cm] **(1)**

(iii) Centre line horizontal **(1)**

Two more lines (accept horizontal) **(1)**

OR showing correct curvature/perpendicular to field lines



(1)

7

(b) (i) V_X = 3.0 V/3 V **(1)**

because potential at Y is 3.0 V/3 V **(1)**

so p.d. across mA is zero OR mA is connected to points at the same potential [an independent mark] **(1)**

(ii) *Either*

Any reference to Y/change the resistors/change one of the resistors/use a rheostat

Or

V for mA move probe over paper **(1)**

Locate points where mA reads zero, add 3 V to V OR move Y to 0 V **(1)**

5

(c) (i) (Use of) R = ρl/A **(1)**

Substitute $l = x$ and $A = xt$ **(1)**

(ii) R = ρ/t $\Rightarrow$ ρ = Rt **(1)**

ρ = (1000 Ω) (0.14 × 10^{-3}m) = 0.14 Ω m [no e.c.f.] **(1)**

4

[16]

64. (a) (i) s.h.m.: acceleration ∝ displacement [Not a « x] **(1)**

and directed to centre [Not a minus sign] **(1)**

(ii) *Either* **(1)(1)**

hump with υ zero at both ends

Or

A and B labelled at axis **(1)(1)**

4

(b) (i) ρ as kg m^{-3} **(1)**

G as N m^2 kg^{-2} **(1)**

[G as kg^{-1} m^{-3} s^{-2} marks 2 and 3]

use of $N \equiv$ kg m s^{-2} [Accept $1/\rho G$ has unit s^2 as 1/3] **(1)**

(ii) $\rho_{MOON} = M_M \div V_M$ and $V = \frac{4}{3}\pi r_M{}^3$ [May be all numbers] **(1)**

Correct substitution in t_{AB} / ρ calculated as 4000/4100 kg/m^3 [e.c.f. $\pi r^3 \rightarrow$ 1300/1400] **(1)**

$\Rightarrow t_{AB}$ = 2980 s OR 49.7 minutes/50 minutes **(1)**

6

(iii) Longer/shorter tunnel has larger/smaller force/acceleration

Reference to component of force (along tunnel) **(1)**

(Hence) high/low speed reached **(1)**

Period is independent of amplitude as it is s.h.m. **(1)**

Max 2

(c) *G:* suspend/pivot mass<u>es</u> /(small) mass on top pan balance **(1)**

attract/make swing by <u>large</u> mass(es)/<u>large</u> mass above balance **(1)**

supported by diagram **(1)**

problem: G forces are very small/ convection currents/ vibrations/ electrostatic forces **(1)**

4

[16]

65. Velocity is a vector quantity and though its magnitude is constant, its direction changes. 1

$$F = \frac{m_s \upsilon_s}{R_E + h}$$

2

$$g = \frac{GM_E}{(R_E + h)^2}$$

N kg^{-1} *or* m s^{-2} 3

Use of expressions:

Equate $m_s g$ with F

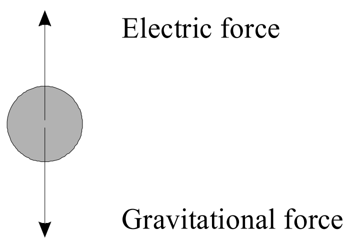
Rearrange to give expression for υ_s

G, M_E , R_E constant so large $h \rightarrow$ smaller υ_s 3

[Not inversely proportional]

[9]

66. Equation: $F = k\frac{Q_1 Q_2}{r^2}$ 2 = [Accept $k = \frac{1}{4\pi\varepsilon_0}$] 1



Electric force = 100 N C^{-1} × 1.6 × 10^{-19}C

1.6 × 10^{-17}N

Weight = 9.8 × 10^{-18}N

Force = 6.2 × 10^{-18}N

Net force is upward 6

[7]

67. Correct circuit 1

Straight line through origin

Q_{MAX} = 900 μC and sensible scale

V_{MAX} = 4.5 V and sensible scale 3

Appropriate formula: ½ CV^2 or ½QV

2×10^{-3} J 2

[6]

68. Diagram:

B perpendicular to current: a workable system **(1)**
d.c. current, variable **(1)**

Measurable force: e.g. riders or weighing **(1)**

Vary *I*; note ammeter **(1)**
Calculate *mg* or Δ scale reading × *g* **(1)**

Plot *F* against *I* -straight line through origin **(1)** Max 5

Quality of written communication 1

$F = BIL$
$(1.5 \times 10^{-3}\text{kg})\ (9.81\ \text{N kg}^{-1}) = (1.8 \times 10^{-5}\ \text{T})\ I\ (2.0\ \text{m})$

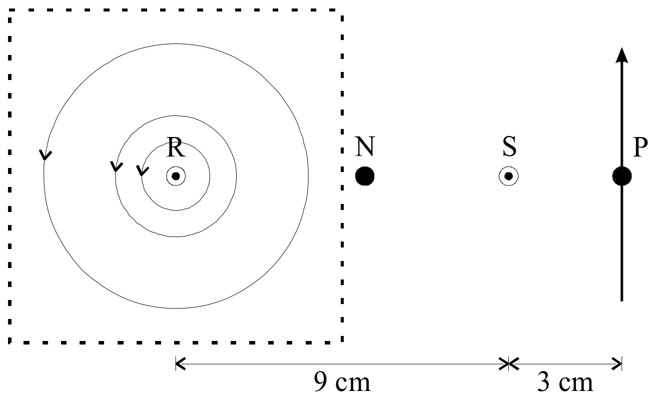
$I = 410$ A 2

[8]

69. Diagram:

At least 3 circles anticlockwise

Circles getting closer together towards the centre 2



Point N on diagram outside dotted box but less than half way from box to S 1

Direction of magnetic field at P as shown above 1

[4]

70. Diagram:

Obviously fewer turns, labelled secondary coil
(Secondary) 132 turns [130] 2

	Induction needs change in flux linkage	1	
	$V_pI_p = V_sI_s$ Algebra	2	
	Resistance heating *or* eddy current heating *or* hysteresis losses	1	
			[6]

71. *Part 1*

Correct series arrangement
Correct polarity of capacitor

Capacitor is electrolytic

Lead connected across capacitor

Correct time measured
Repeats
with different currents/non zero start
Value in range 10 s to 20 s and 2/3 s.f. plus units — 8

Part 2

D, x_R and x_V to the nearest mm
Neatly drawn diagram with filament and spectra
Spectra labelled correctly (violet near filament)
Correct calculation of tan θ
Sin θ in range 0.18 to 0.21
Black band described or drawn between red and violet
Broad absorption band with narrow red and violet bands
Photons with energy corresponding to energy bands of solution are absorbed — 8

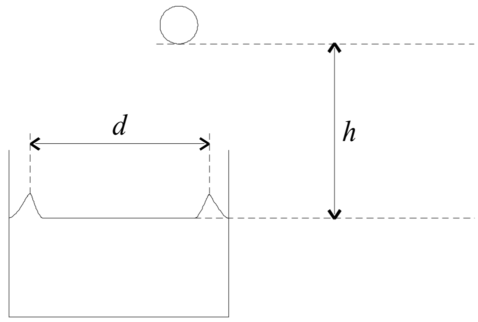
[16]

72.

(a)	Use of horizontal 2nd metre rule Description of how *l* was set.	2	
(b)	ΣnT ≥ 20 Repeat timings T ± 0.02 s of Supervisor	3	
(c)	*b* ± 0.05 cm of Supervisor *d* ± 0.05 mm of Supervisor Repeat *b* and *d* Correct uncertainties Correct calculation of percentages	5	
(d)	Substitution of SI values into expression for E Correct calculation of E with unit	2	
(e)	Larger % uncertainty in *d* % uncertainty multiplied by 3	2	
(f)	Micrometer to measure *d* Measurements 10 times more precise	2	
			[16]

73. (a) (i) Height of the bottom of the sphere above sand

General arrangement correct with h shown correctly



Kinetic energy gained = potential energy lost
$\frac{1}{2}m\upsilon^2 = mgh$
$\upsilon^2 = 2\,gh$
$\upsilon = 2\,gh$ 4

[If candidate uses average velocity of fall = h/t
Impact velocity = 2 h/t , then credit with 1 mark out of 2]

(ii) Air resistance negligible

Use small velocities/heights so that air resistance is minimised. 2

(iii) Vary υ by varying h Measure corresponding d

Plot $\ln(d/m)$ against $\ln(\upsilon/\text{ms}^{-1})$

Expect straight line of gradient n as intercept $\ln(k)$ 3

(b) Correct ln values
Suitable scale for graph
Axes or table column labelled, and units
Plots
Line 5

(c) Large Δ
Correct calculation, 2/3 significant figures, no unit 2

[16]

74. Base units of G: $\text{kg}^{-1}\ \text{m}^3\ \text{s}^{-2}$ **(1)**
Equation homogeneity:

Correct substitution of units of G, r^3 (m^3), M (kg) 1

leading to S^2 and linked to T^2 **(1)**
[Allow e.c.f. of their base unit answer into substitution mark] 3

<u>Use of relationship to find mass of the Earth</u>

Any two from:
Adding 20 000 + 6400 **(1)**
Converting km to m **(1)**
h to s (× 43 200) **(1)** 2
Answer $M = 5.8\ (4) \times 10^{24}$ kg **(1)** 1

[6]

75. Faraday's law of electromagnetic induction
The induced e.m.f. **(1)**
in a conductor is equal to/proportional to
the rate of change of magnetic flux linkage **(1)**

OR

$E = (-)\dfrac{d\varphi}{dt}$ or $E \propto \dfrac{N\Delta\phi}{\Delta t}$ [Accept $\Delta\phi$ or $d\phi$]

E – induced voltage

$d\varphi$ – change of magnetic flux **(1)**
dt – time

[All symbols defined] 2

Conversion of sound waves into electrical signals

Any four from:

- quality of language **(1)**
- sound waves make the diaphragm/coil vibrate/oscillate **(1)**
- coil: change in flux linkage/coil cuts field lines **(1)**
- induced voltage across coil **(1)**
- frequency of sound wave is frequency of induced voltage/current/ electrical wave **(1)** Max 4

[6]

76. Calculation of charge

$6000 \text{ V} \times 20 \times 10^{-6} \text{ F}$ **(1)**
$= 0.12 \text{ C}$ **(1)** 2

Energy stored in capacitor

$\left(\dfrac{CV^2}{2}\right) \dfrac{20 \times 10^{-6} \text{ C} \times (6000 \text{ V})^2}{2}$ **(1)**
$= 360 \text{ J}$ **(1)** 2

Resistance
$\dfrac{6000 \text{ V}}{40 \text{ A}} = 150\ \Omega$ **(1)** 1

Time to discharge capacitor
Time = $\dfrac{0.12 \text{ C}}{40 \text{ A}}$ /their Q **(1)**

$= 0.0030 \text{ s} / 3.0 \times 10^{-3} \text{ s}$ [e.c.f.] **(1)** 2

Reason
Time is longer because the rate of discharge decreases/ current decreases with time **(1)** 1

[8]

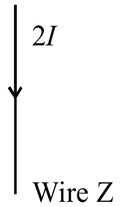
77. Diagram
Reasonably concentric circles [no breaks] **(1)**
Circles become more widely spaced [min 3 circles] **(1)**
Correct direction/anticlockwise **(1)**
[One correctly labelled field line is acceptable. Mark lost if contradictory arrows on diagram] 3

Current in wire

$$B = \left(\frac{\mu_0 I}{2\pi r}\right)$$

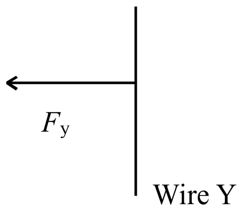
$$1.4 \times 10^{-5}\ \text{T} = \frac{4\pi \times 10^{-7}\ \text{N A}^{-2}}{2\pi} \times \frac{I}{12(\times 10^{-2})\ \text{m}} \quad \textbf{(1)}$$

$I = 8.4$ A **(1)** 2



(1) 1

Must be labelled and originate on line



(1) 1

$F_y : F_z = 1:1$ **(1)** 1

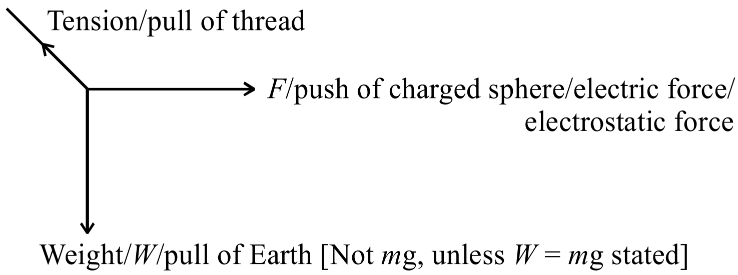
F_y can be reduced by

Reduce *I*/current in Y OR reduce 2*I*/current in *Z* OR reduces currents **(1)**
Increase separation/*r* **(1)**
Reduce length of wire Y **(1)** Max 2

[10]

78. Free-body force diagram

Tension/pull of thread **(1)**
F/push of charged sphere/electric force/electrostatic force **(1)**
Weight/*W*/pull of Earth [Not *mg*, unless *W* = *mg* stated] **(1)** 3



Force equation

$W = T \cos \theta$ (

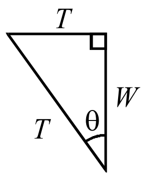
(**(1)**

$F = T \sin \theta$ (

Processing mark, e.g. $F = \dfrac{W}{\cos \theta} \sin \theta$ OR $\tan \theta = \dfrac{\sin \theta}{\cos \theta}$ **(1)**

OR

F, T, W labelled **(1)**
both angles labelled **(1)** 2



Table

Distance $r = 36 \times 10^{-3}$ m
$F = 35.5/36$ [No u.e.] **(1)**
Distance $r = 27 \times 10^{-3}$ m

Using any pair of values **(1)**
Seeing correct constant for their pair of values **(1)**
$\rightarrow F = 63.1$ [n.o u.e.] **(1)**

OR

Valid simple ratio calculation using a pair of values **(1)**
stating produce Q_1Q or kQQ_2 constant **(1)**
$\rightarrow F = 63.1$ [no u.e.] **(1)** 4

Measurements taken quickly because

Leakage/discharge of charge [Allow dissipation or description of process] **(1)** 1

[10]

79. (a) T_1 and T_2 reasonable and T_2 between 0.4 T_1 and 0.6 T_1 from ($20T$ **(2)**
[≥ $10T$ (1)] **(1)**
Repeats of both **(1)**
$\dfrac{T_1}{T_2}$ calculated or *k*s found **(1)**
Quantitative comparison **(1)**
Suitable comment [Not conditional on ratios] 6

(b) (i) Mass of contents = 330 g **(1)**
Hence *m* found correctly with ≥ 2 s.f. and unit **(1)**
Correct calculation of *V* + unit and ≥ 2 s.f. **(2)** 3

(ii) Use of set squares against rule **(2)**
D 63.0 mm to 68.0 mm **(1)**
L 113.0 mm to 117.0 mm **(1)**
Repeats of both **(1)**
Correct substitution [Allow e.c.f.] **(1)**
Correct calculation with unit and 2/3 s.f. **(1)** 7

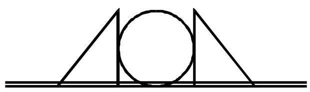
[16]

Sample results:

(a) $10T_1$/s = 32.95, 33.18
$\therefore T_1 = 3.31$ s
$10T_2 = 16.69, 16.67$ s
$\therefore T_2 = 1.67$ s
$\frac{T_1}{T_2} = \frac{3.31}{1.67} = 1.98$
T and l within 1% which acceptable experimental error

(b) (i) $M = 361.3$ g
330 ml = 330 g
$\therefore m = 361.3 - 330$
= 31.3 g
$V = \frac{\text{mass}}{\text{density}}$
$= \frac{31.3}{7.9}$
= 3.96 cm^3

(ii) $D = 65, 65$ mm $\overline{D} = 65$ mm
$L = 115, 115$ mm $\overline{L} = 115$ mm
$t = \frac{3.96}{\pi \times 6.5 \times (11.5 + 6.5)}$
= 0.011 cm



80. (a) Value ± 2 cm of Supervisor's
[±3 cm – (1)] **(2)**

Repeat readings shown/eye level with wire to find resonance/use of card to observe resonance **(1)**
Approach resonance from both directions **(1)**
Correct calculation from sensible Δl_1 **(1)**
[Range, ½ range or precision of rule if only one reading]
l_2 to nearest mm and in range 85.0 cm to 95.0 cm **(1)**
[Or Supervisor's $l_1 \times \sqrt{3}$ ± 5 cm] 6

(b) Both k values calculated using either mass or force **(1)**
≥ 2 s.f. for both with unit seen at least once **(1)**
% difference found with either value or average value as denominator **(1)**
Sensible comment related to l **(1)**
Doubling of % uncertainty in l **(1)** 5

(c) Value 0.21 $\rightarrow$ 0.26 mm [unless alternative wire used] **(1)**
Repeat or zero error check **(1)**
Correct SI substitution **(1)**
Correct calculation ≥ 2 s.f. + unit **(1)**
Value 7500 – 10 000 kg m^{-3} **(1)**
[when rounded to 2 s.f.] 5

[16]

Notes

(i) Repeat mark is consequent on a correct diameter value

(ii) In the substitution either k or the average k may be used

(iii) Use of g = 10 N/kg **(**1

(c) d = 0.23, 0.23 mm
$\bar{d}$ = 0.23 mm

$$\rho = \frac{k}{\pi d^2 f^2}$$

$$= \frac{3.77}{\pi (0.23 \times 10^{-3})^2 \times 50^2}$$

= 9070 kg m^{-3}

81. (a) LDR connected to ohmmeter **(1)**
Light shield around LDR **(1)**
Two polaroid filters between light source and LDR **(1)**
θ shown **(1)**
Measure θ with protractor [shown or stated] **(1)**
A correct technique showing overlapping filters **(1)**
Starting point when maximum (or minimum) LDR resistance **(1)**
$\theta = 90^o$ [or $\theta = 0^o$] **(1)** 8

(b) $I = k (\cos \theta)^n$
$\ln I = n \ln(\cos \theta) + \ln k$ **(1)**
$y = \;\; mx + c$ 1

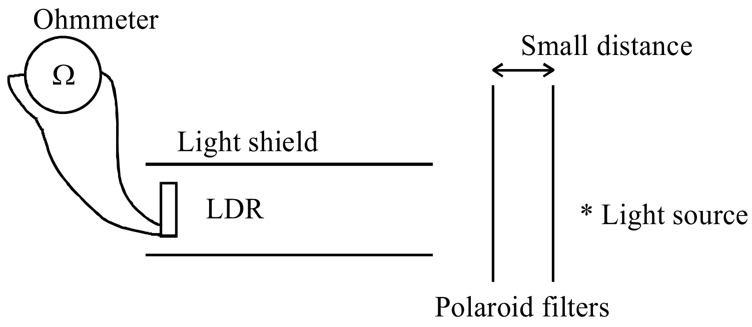
(c) ln values and ≥ 2 decimal places **(1)**
Graph:
Scale **(1)**
Axes labelled with unit **(1)**
Plots **(1)**
Line **(1)**
[Allow reversed negative axis]
[Mark any graph which is plotted using this scheme] 5

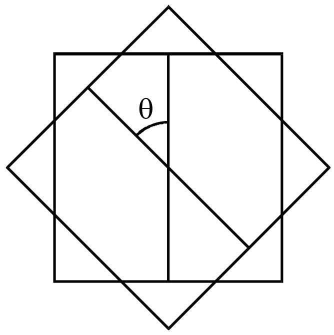
(d) $\Delta x \, \Delta y \geq 64$ cm^2 [or limits of graph] **(1)**
Value 1.45 $\rightarrow$ 1.55 with no unit **(1)** 2

[16]

Sample results

(a)





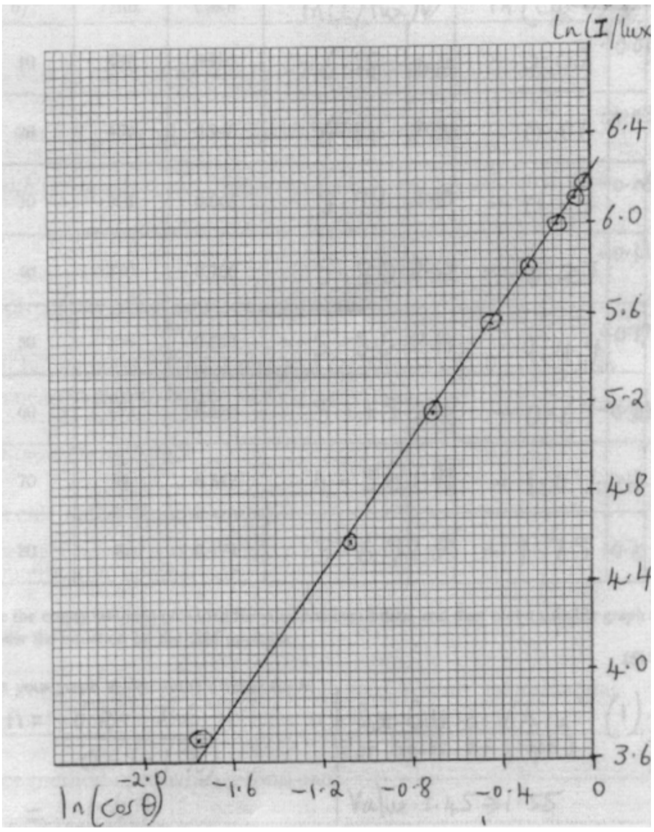
Starting point when maximum (or minimum) LDR resistance.
$\theta = 90^{o}$ (or $\theta = 0^{o}$)

(b) $I = k (\cos \theta)^{n-}$
$\ln I = n \ln (\cos \theta) \quad + \ln k$
$y = mx + c$

(c)

$\theta/^{o}$	I/lux	Cos θ	ln(I/lux)	$\log_{10}$ (I/lux)	ln (cos θ)	$\log_{10}$ (cos θ)
10	481	0.985	6.18	2.68	–0.02	–0.01
20	450	0.940	6.11	2.65	–0.06	–0.03
30	398	0.866	5.99	2.60	–0.14	–0.06
40	330	0.766	5.80	2.52	–0.27	–0.12
50	256	0.643	5.55	2.41	–0.44	–0.19
60	172	0.500	5.15	2.24	–0.69	–0.30
70	98	0.342	4.58	1.99	–1.07	–0.47
80	40	0.174	3.69	1.60	–.75	–0.76

Graph:



(d) $n = \dfrac{6.22 - 3.6}{0 - (-1.76)}$

$= 1.49$

82. (a) (i) T_1 and T_2 reasonable and $T_2 > T_1$ from ≥ 10 oscillations **(2)**

[from ≥ 5 gets (1)]

Both repeated **(1)**

T_2: 4.0 – 6.0 s **(1)** 4

Correct use of set squares against rule **(2)**

D_1 between 63.0 – 68.0 mm and D_2 between 31.0 – 35.0 mm to nearest mm or better **(1)**

D_1 and D_2 repeated **(1)**

*k*s calculated [ignore units] **(1)**

Quantitative comparison **(1)**

OR

Comment that results agree/disagree within experimental error [where nominal 10% for experimental error] 6

(b) Difference method used when filling can **(1)**

Volume 335 – 360 ml with unit **(1)**

L: 113 – 117 mm **(1)**

Correct calculation with unit and 2/3 s.f. [e.c.f.] **(1)**

Suitable suggestion why V differs from volume stated on can **(1)**

Suitable suggestion why V' differs from V **(1)** 6

[16]

Sample results:

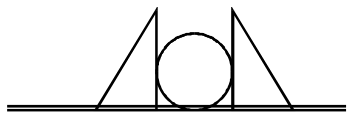
(a) (i) $10T_1$ = 32.95, 33.18 s

$\therefore\ T_1$ = 3.31 s

$5T_2$ = 23.99, 23.56 s

T_2 = 4.76 s

(ii)



D_1 = 65. 65 mm $\overline{D}_1$ = 65 mm

D_2 = 33, 33 mm $\overline{D}_2$ = 33 mm

$k_1 = T_1^2 D_1 = 3.31^2 \times 65$

= 711 s^2 mm

$k_2 = T_2^2 D_2 = 4.76^2 \times 33$

= 746 s^2 mm

% difference = $\frac{35}{729} \times 100$

= 4.8%

which is acceptable experimental error

(b) Measuring cylinder filled and poured into can.
Filled again and poured into can until full

V = 250 + (250 – 160) = 340 ml

L = 115, 115 mm, $\overline{L}$ = 115 mm

$V' = \pi \times 6.5^2 \times \frac{11.5}{4}$

= 382 cm^3

Contents do not usually completely fill can

Can narrows at top and bottom OR V' is external rather than internal volume.

83. (a) Value ± 2 cm of Supervisor's value **(2)**

[± 3 cm – (1)]

Repeat readings etc **(1)**

Approach resonance from both directions **(1)**

Correct calculation from sensible Δl **(1)**

[Range, ½ range or 0.1 – 1.0 cm if only one reading] 5

(b) Value 0.21 – 0.26 mm [unless alternative wire used] **(1)**

Repeat measurements or zero error [dependent mark] **(1)**

Correct % from range, ½ range or precision [allow 0.005 mm] **(1)** 3

(c) Correct SI substitution

Correct calculation ≥ 2 s.f. + unit [dependent mark] [–1 if g = 10] **(1)**

Value: 7500 → 10 000 kg m^{-3} [no e.c.f.] [when rounded to 2 s.f.] **(1)** 3

(d) 2 × % uncertainty in d and l **(1)**
Added [Not a dependent mark] **(1)**
Calculation of % difference with 8880 as denominator **(1)**
Compared to % uncertainty **(1)**
Hence sensible conclusion **(1)**
OR
Adds/subtracts their % uncertainty from their value **(1)**
Checks whether in range **(1)**
Hence sensible conclusion **(1)** 5

[16]

Sample results:

(a) l = 71.5, 72.0, 72.5 cm
$\bar{l}$ = 72.0 cm

Repeat readings shown Or eye level with wire/use of care to observe resonance
Approach resonance from both directions

Percentage uncertainty = $\frac{0.5}{72.0} \times 100$
= 0.7%

(b) d = 0.23, 0.23 mm
$\bar{d}$ = 0.23 mm

Percentage uncertainty = $\frac{0.01}{0.23} \times 100$
= 4.3%

(c) $\rho = \frac{0.2 \times 9.81}{\pi \times (0.23 \times 10^{-3})^2 \times 50^2 \times 0.72^2}$
$= 9110 \text{ kg m}^{-3}$

(d) Percentage uncertainty in density
= 2 × 4.3 + 2 × 0.7
= 10.0%

Percentage difference
$= \frac{9110 - 8880}{8880} \times 100\%$
= 2.6%

Much less than total % uncertainty ∴ wire could be made from constantan.

84. (a) Light shield around LDR **(1)**
LDR connected to ohmmeter **(1)**
Lamp connected to power supply **(1)**
[0/2 if all in series circuit]
d measured to front of LDR **(1)**
and filament **(1)**
Appropriate method for measuring d **(1)**
Precautions **(2)** 8

(b) Equation **(1)** 1

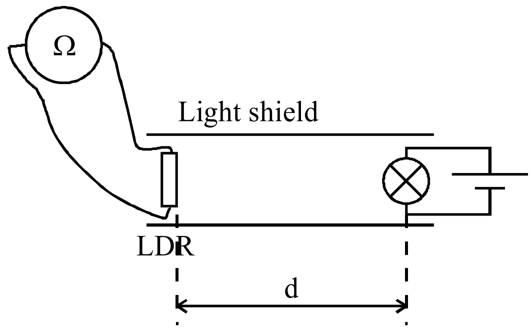
(c) ln values as shown and ≥ 2 decimal places **(1)**
Graph:
Must occupy at least ½ grid, in both directions and avoiding 3s, 7s etc. **(1)**
Scale
Axes labelled and units [Must be in ln(I/lux) etc] **(1)**
Plots [to a precision of 1 mm or better] **(1)**
Line [well drawn line of best fit] **(1)**
[Allow e.c.f. if wrong graph plotted] 5

(d) $\Delta x \Delta y \geq 64\ \text{cm}^2$ [or to limits of axes] **(1)**
Value −2.50 → −2.70 with no unit [must have negative sign] **(1)** 2

[16]

Sample results:

(a) Diagram:



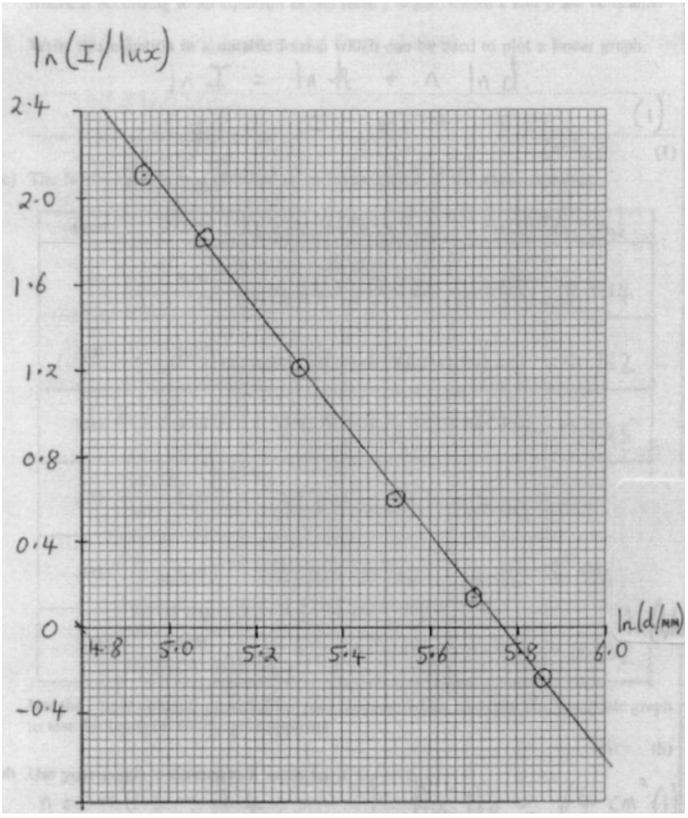
From face of LDR to filament of lamp
Use apparatus in a darkened room
OR
Take a reading of the background light level and subtract it from measured light levels

(b) $\ln I = \ln k + n \ln d$
$y = c + mx$

(c)

d/mm	I/lux	ln(d/mm)	ln(I/lux)	lg(d/mm)	lg(1/lux)
40	8.20	4.94	2.10	2.15	0.91
60	6.05	5.08	1.80	2.20	0.782
200	3.35	5.30	1.21	2.30	0.525
250	1.80	5.52	0.59	2.40	0.255
300	1.15	5.70	0.14	2.48	0.061
350	0.79	5.86	–0.24	2.54	–0.102

Graph:



(d) $n = \dfrac{-0.6 - 2.4}{6.0 - 4.855}$

$= -2.62$

85. <u>Charge and energy table</u>

For first column answers:

Charge = 1.0×10^{-4} C	Value **(1)** Unit **(1)**	
Energy = 2.5×10^{-3} J	Value **(1)** Unit **(1)**	4

[If zero marks are scored, then look to second column to award a **maximum of 2 marks**

Charge= 3.0×10^{-4} C	Value/unit
Energy = 1.5×10^{-2}J	Value/unit]

<u>Equivalent capacitance</u>

Capacitance = 5.0 μF **(1)** 1

Total energy

$W = ½\, Q^2/C$

$$\frac{\frac{1}{2}(4.0\times10^{-4}\,\text{C})^2}{(5.0\times10^{-6}\,\text{F})}$$

= 0.016 J

Use of total charge **(1)**

Use of $W = \dfrac{Q^2 r}{2C_r}$ OR $V = \dfrac{Q_r}{C_r}$ (80 V) **(1)**

Substitution of combined capacitance and answer **(1)** 3

[Accept ecf, their charges and total capacitance]

Energy loss

Gain in internal energy **(1)**
due to electrical work **(1)**

OR

Thermal energy/heating in the wires/wires get hot **(1)**
Dissipated in wires **(1)**

OR

Work done by charges **(1)**

OR

Energy needed to overcome resistance in the wires **(1)** 2

[10]

86. Cathode Ray Tube

Electron emission

- Heating effect (due to current) **(1)**
- (Surface) electrons (break free) because of energy gain **(1)** 2

[Thermionic emission scores both marks]

Electron motion towards anode

The electrons are attracted to/accelerated by the positive anode **(1)** 1

Energy

Electron energy = $(10 \times 10^3\ \text{V})\ (1.6 \times 10^{-19}\ \text{C})$

$= 1.6 \times 10^{-15}$ J

Correct use of 1.6×10^{-19} OR use of 10×10^3 **(1)**
Answer **(1)** 2

Number of electrons per second

Number each second = $\frac{1.5 \times 10^{-3}\text{ A}}{1.6 \times 10^{-19}\text{ J}}$

$9.4 \times 10^{15} s^{-1}$

Correct conversion mA $\rightarrow$A
Answer **(1)** 2

Rate

Energy each second = $(9.4 \times 10^{15}\ s^{-1})\ (1.6 \times 10^{-15}\ J)$ **(1)**

= 15 Js^{-1} (W) / 14.4 Js^{-1} **(1)** 2

[ecf their energy]

[9]

87. Action of transformer

Quality of written communication **(1)** 1

a.c. input/changing current **(1)**

Flux linkage to secondary through core/B field carried through core **(1)**

Induced e.m.f. (in secondary)

Any one from:

Varying magnetic field (in primary)

Changing B field acts over secondary

Flux linkage is greater **(1)** 5

Output voltage of the transformer

$\frac{100}{1200} \times 240\text{V}$ **(1)**

= 20V [Correct answer only] **(1)** 2

[7]

88. Gravitational field strength a vector quantity

(Field) lines have arrows (to Earth) / direction **(1)** 1

Equipotential lines

Three circles drawn **(1)**

Reasonably concentric **(1)**

Getting further apart **(1)** 3

Work done

2.2×10^{7} J kg^{-1} 5500 kg

= 1.2×10^{11} J

Ignore 10^{x}. See 2.2×5500 **(1)**

Answer 1.2×10^{11} J **(1)** 2

Satellite's gpe

Satellite follows an equipotential surface

OR

Satellite's circular orbit is an equipotential line

OR

Satellite's orbit has a fixed radius **(1)** 1

[7]

89. (a) (i) Circular field with arrows **(1)**

Arrows consistent with right hand rule **(1)**

Deflection increases as current increases **(1)**

Plotting compass lies along resultant field [seen or stated] **(1)** Max 3

(ii) Reasonable current with unit from at least two readings to 0.1 A or better **(1)** 2

(iii) Correct SI substitution **(1)**

Correct calculation ≥ 2 significant figures + unit **(1)**

[$N\ A^{-1}m^{-1}$ OR T OR $Wb\ m^{-2}$]

Clear isosceles triangle formed OR international centres close to equator may comment on fields not equal **(1)** 3

(b) (i) Circuit set up correctly **(1) (1)** 2

[Polarity error –1]

(ii) t_1 ± 0.5 s from Supervisor's value from ≥ 2 readings

[± 0.5 s from one – (1) ± 1.0 s from two – (1)]

–1 if no μA

–1 if no seconds

$I_2 \approx 2/3\ I_1$

$t_2 \approx 3/2\ t_1$ **(1)** 3

(iii) Correct calculation + unit **(1)**

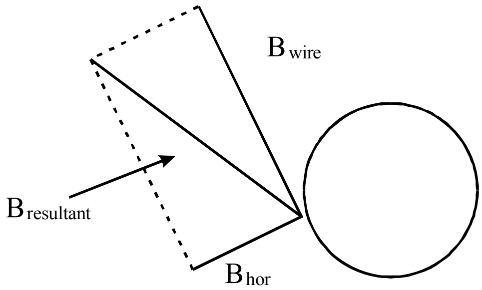
giving $R_2 9 \rightarrow 11k\Omega$ when rounded to nearest kΩ ecf wrong unit **(1)**

Resistance of ammeter or cell is negligible OR other circuit components have negligible resistance compared to R **(1)** 3

[16]

Sample results

(a) (i)



Circular field with arrows
Arrows consistent with right-hand rule
Deflection increases as current increases
Plotting compass lies along resultant field [seen or stated]

(ii) I = 2.50, 2.59, 2.46, 2.45, 2.61, 2.35 A

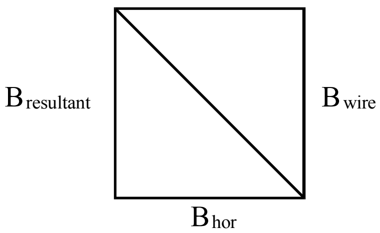
Mean I = 2.49 A

Approached 45° from both directions/tapping compass/4 or more currents

(iii) $B = \dfrac{\mu_0 I}{2\pi r}$

$= \dfrac{4\pi \times 10^{-7} \times 2.49}{2\pi \times 0.03}$

$= 1.7\times10^{-5}$T



Clear isosceles traingle formed

(b) (i) Circuit set up correctly

(ii) I_1 = 64 μA

t_1 = 16.97, 16.91 s

$\bar{t}$ = 16.94 s

I_2 = 44 μA

t_2 = 24.72, 24.69 s

$\bar{t}_2$ = 24.71 s

(iii) $\dfrac{t_1}{t_2} = \dfrac{R_1}{R_1 + R_2}$

$\dfrac{16.94}{24.71} = \dfrac{22K}{22K + R_2}$

$\dfrac{22K + R_2}{22K} = 1.46$

$\therefore R_2 = 10.1\text{k}\Omega$

Resistance of ammeter or cell are negligible OR other circuit components have negligible resistance compared to R.

90. (a) Any four points from:

- B is set into forced oscillations by A
- and its amplitude of oscillation increases
- Energy is transferred from A to B
- Amplitude then reduces
- Energy is transferred back to A
- Process then repeats
- Same natural frequency **(1) (1) (1)**
- A is driver/A and B are coupled **(1)** 4

(b) ±0.03 s of Supervisor from $\geq 40T$ **(1) (1)**

[±0.03 from $\geq 20T$ **(1)**]

± 0.05 from $\geq 40T$ **(1)**]

$T_B > T_A$ **(1)**

from $\geq 40T_B$ **(1)**

[If no units at all –1]

Precautions **(1) (1)** 6

(c) T measured and repeated **(1)**

Correct calculation of $1/r$ and $1/T_A$, $-1/T_B$ to ≥ 3 significant figures **(1)**

[Ignore unit]

Percentage difference found [Either value or average as denominator] **(1)**

≤ 5% **(1) (1)**

Hence sensible comment **(1)**

[10% acceptable experimental error] 6

[16]

Sample results

(a)
- B is set into forced oscillations by A
- and its amplitude of oscillation increases
- Energy is transferred from A to B
- Amplitude then reduces
- Energy is transferred back to A
- Process then repeats
- Same natural frequency

(b) $20T_A = 15.94, 15.87$ s

$T_A = 0.795$ s

$20T_B = 17.32, 17.28$ s

$T_B = 0.865$ *s*

Fiducial marker in centre of oscillation.
Eye level with marker
Repeats shown

(c) $5T = 46.66, 47.54$ s
$T = 9.42$ s

$$\frac{1}{T} = \frac{1}{9.42} = 0.106\,s^{-1}$$

$$\frac{1}{T_A} - \frac{1}{T_B} = \frac{1}{0.795} - \frac{1}{0.865}$$

= 1.258 – 1.156

= 0.102 s^{-1}

Percentage difference = $\frac{0.004}{0.104} \times 100\% = 3.8\%$

Acceptable experimental error therefore supported

91. (a) Potential divider **(1) (1)**

Ammeter in series with lamp **(1)**

Voltmeter in parallel **(1)**

Ammeter: 100 mA, 150 mA, 200 mA **(1)**
Voltmeter: 10 V, 15 V, 20 V **(1)**

[OR
Both values >values for lamp but not standard **(1)**]

Heating effect correctly related to resistance change **(1)**

Sensible argument **(1)** 8

(b) $\ln I = n \ln V + \ln k$

$y = mx + c$ [OR $\log_{10}$] **(1)** 1

(c) Table with correct values to ≥ 2 decimal places **(1)**

Graph:

Suitable scale **(1)**
Axes labelled with units **(1)**
Plots **(1)**
Line **(1)** 5

(d) $\Delta x \Delta y \geq 64$ cm^2 **(1)**

Correct calculation, no unit, 2/3 significant figures and 0.50 and
0.55 [when rounded to 2 significant figures] **(1)** 2

[16]

Sample results

(a) Diagram

Ammeter: 100 mA, 150 mA, 200 mA
Voltmeter: 10 V, 15 V, 20 V

Heating effect correctly related to resistance change

Sensible argument

(b) $\ln I = n\ln V + \ln k$

$y = mx + c$ [OR $\log_{10}$]

(c)

V/V	I/mA	ln(V/V)	$\log_{10}$ (V/V)	ln(I/mA)	$\log_{10}$(I/mA)
0.87	20	–0.14	–0.060	3.00	1.30
1.33	25	0.29	0.124	3.22	1.40
1.81	30	0.59	0.258	3.40	1.48
2.51	35	0.92	0.400	3.56	1.54
3.08	40	1.12	0.489	3.69	1.60
4.02	45	1.39	0.604	3.81	1.65
4.66	50	1.54	0.668	3.91	1.70
5.66	55	1.73	0.753	4.01	1.74
6.79	60	1.92	0.832	4.09	1.78

(d) $n = \text{gradient} = \dfrac{4.16 - 3.0}{2.0 - (-0.2)} = 0.53$

92. <u>Alpha particle: diagram</u>

Curving path between plates 1

Towards 0 V plate 1

Emerging from plates and carrying on straight 1

<u>Calculation</u>

$$\text{Electric field} = \frac{2000\ \text{V}}{10 \times (10^{-3})\ \text{m}}$$

Substitution 1

Force = EQ

$$= \left(\frac{2000}{10 \times 10^{-3}}\right) \text{Vm}^{-1} \times (2) \times 1.6 \times 10^{-19}\ \text{C}$$

Substitution [ecf their E] 1

$= 6.4 \times 10^{-14}$ N

Correct answer 1

[6]

93. <u>Completion of circuit diagrams</u>

1st diagram:

Correctly connected in parallel with supply 1

2nd Diagram:

Correctly connected in series with supply 1

<u>Table with calculations</u>

Capacitors in parallel	Charge on C_1	$Q = VC$ $6\text{ V} \times 12\ \mu\text{F} = 72\ \mu\text{C}$	1 1
	Energy stored on C_1 when fully charged	$\left(\frac{CV^2}{2}\right) = \frac{12\ \mu\text{F} \times (6\text{ V})^2}{2} = 216\mu\text{J}$	1
Capacitors in series	Charge on C_2	Total capacitance = 6 μF OR p.d. across C_2 = 3 V $6\text{ V} \times 6\ \mu\text{F} = 36\ \mu\text{C}$ / $3\text{ V} \times 12\ \mu\text{F} = 36\ \mu\text{C}$	1 1
	Total energy stored on C_1 and C_2 when Fully charged	$\frac{6\mu\text{F} \times (6\text{V})^2}{2} = 108\mu\text{J}$ $2\left(\frac{12\ \mu\text{F} \times (3\text{ V})^2}{2}\right) = 108\ \mu\text{J}$	1

[8]

94. <u>Horizontal component</u>

$4.8 \times 10^{-5}\text{ T} \times \cos 66°$

$= 1.95\ [2.0] \times 10^{-5}\text{ T}$

Use cos 66°/sin 24° 1

Answer 1

<u>Calculation of induced voltage</u>

Speed after 2 seconds = $9.81\text{ m s}^{-2} \times 2\text{ s}$ 1

[ecf their B]

Induced e.m.f. = $1.95 \times 10^{-5}\text{ T} \times 2.5\text{ m} \times [9.81\text{ m s}^{-2} \times 2\text{ s}]$ 1

$= 9.6 \times 10^{-4}\text{V}$ 1

North-south rod

Induced emf = 0 (V) 1

Rod does not cut magnetic field lines/no flux cutting/no change in flux 1

[7]

95. Electrical property of blade

Resistance [Not resistivity] 1

Law of electromagnetic induction

The (magnitude of the) induced emf is equal to/proportional to 1

the rate of change of flux (linkage) 1

[Word equation can score two marks]

Explanation of damping

Quality of written communication 1

E.m.f. induced (in blade) because flux linked (with blade) changes / lines of force are cut (by blade) 1

Large with reference to (induced) current or (induced) magnetic field 1

Any one from:

- The two magnetic fields produce an opposing force (to motion)
- blade has low resistance current is induced
- current produces thermal energy
- kinetic energy/total energy is transferred to thermal energy 1

Blade B

Smaller (eddy) currents (induced) in blade B / weaker field created around blade B 1

[8]

96. Charge distribution on spheres marked on diagram

Left hand sphere marked positive 1

Right hand sphere marked negative 1

Arrow on field line to indicate direction

Direction **on** one field line correctly drawn

Arrow left to right [Any contradictory arrows lose the mark] 1

Work done

(i) 0 1

(ii) –50

One mark for 50 1

One mark for negative sign 1

[6]

97. Forces

(i) $F = GM_Em/R^2$ 1

(ii) $F = GM_Mm/r^2$ 1

Distance R

$$\left.\begin{array}{c}\dfrac{GM_E m}{R^2} = \dfrac{GM_m m}{r^2} \\ \text{OR} \\ \dfrac{M_E}{M_m} = \dfrac{R^2}{r^2} \text{ OR } \left(\dfrac{M_E}{M_m}\right)^{1/2} = \dfrac{R}{r}\end{array}\right\}$$

$$\frac{81}{1} = \frac{R^2}{(3.9 \times 10^7 \text{ m})^2}$$

$R = 3.5 \times 10^8$ m

Evidence that equating forces has occurred 1

Correct substitution 1

Correct answer 1

[5]

98. (a) (i) Circuit set up correctly without help 2

[Polarity of C –1]

Correct calculation of I_0, with unit, from sensible V [V to 3/4 s.f. + unit] 1

(ii) Value between 12- 22 s, to precision of 0.15 or better, with unit 1

Value (3 → 4) × above value 1

Both repeated 1

(iii) Exponential shape 1

Three points plotted approximately in correct positions 1

[OR shown on axes]

(b) (i) From diagram or description

At least 2 orders of spectra observed 1

either side of the centre 1

with blud nearest the centre shown on both sides 1

(ii) Red and violet correct 1

At least orange OR yellow and green 1

(iii) Absorption shown 1

Cut off in green or blue 1

Range stated correctly from diagram [dependent mark] 1

[16]

Sample results

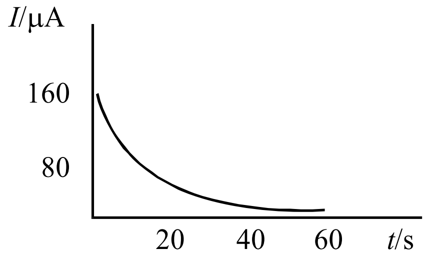
(a) (i) $V = 1.54$ V

$$I_0 = \frac{1.54\ \text{V}}{10\ \text{k}\Omega} = 154\ \mu\text{A}$$

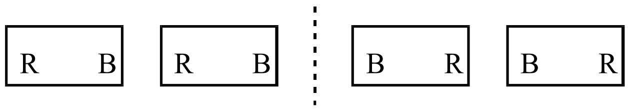
(ii) 154 → 77 μA: 18.6, 19.0, average 18.8 s

154 → 15.4 μA: 63.0, 63.8, average 63.4 s

(iii)

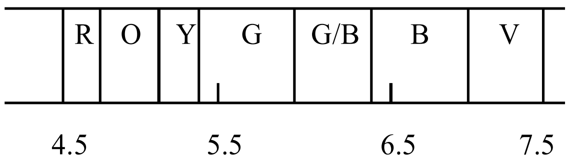


(b) (i)

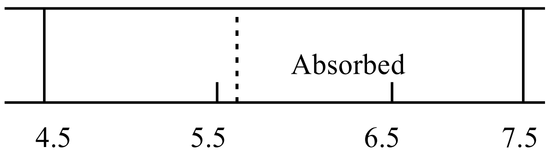


At least two orders of spectra observed either side of the centre with blue nearest the centre shown on both sides

(ii)



(iii)



(4.5 – 5.8) × 10^{14} Hz transmitted

99. (a) Any one from:

Stretched spring
Lined up end of spring where it went above the board
Used pencil to count turns
Mark made on spring 1

Sensible T from $\Sigma nT \geq 40$ [≥ 20 gets (1)] with unit 2

Repeat 1

Used marker at centre of oscillations 1

Correct calculation of percentage from ΔnT 0.05 – 0.1 s or range or ½ range, whichever is the larger 1

Correct calculation to 3 s.f. for both S values with unit 1

[Accept inverse calculation]

(b)	$\Delta N \geq 8$ turns	1
	T sensible and found from at least $2 \times 10T$	1
	s values differ by $\leq$ 0,0001 s when both rounded to 2 s.f.	2
	[$\leq$ 0.002 s gets (1)]	
(c)	Correct calculation from mean as denominator	1
	2 × value found in (a)	1
	Hence sensible deduction, based on candidate's quantitative argument	1
	$m \propto N$) ; $l \propto N$) $\Rightarrow$ $ml \propto N^2$	1
	$\therefore T \propto N$	1

[16]

Sample results

(a) Stretched spring
Lined up end of spring where it went above the board
Used pencil to count turns
Mark made on spring

$20T$: 13.67, 13.75 s [± 0.04 of Supervisor's value]
T = 0.686 s (±.04 from 20 or ± 0.06 from 40 gets (1)]

Used marker at centre of oscillations

Percentage uncertainty = $\frac{0.1}{13.7} \times 100 = 0.7\%$

$T = sN$

$s = \frac{T}{N} = \frac{0.686}{20} = 0.343$ s

(b) N= 30 turns

$20T$: 20.69, 20.68 s

$T = 1.034s$

$s = \frac{1.034}{30}$ =0.0345 s

(c) Percentage difference = $\frac{(0.0345 - 0.0343)}{0.0344} \times 100 = 0.6\%$

Experimental uncertainty = 2 × 0.7= 1.4%

Values of s are constant within the experimental uncertainty

$m \propto N$)
) $ml \propto N^2$
$l \propto N$)

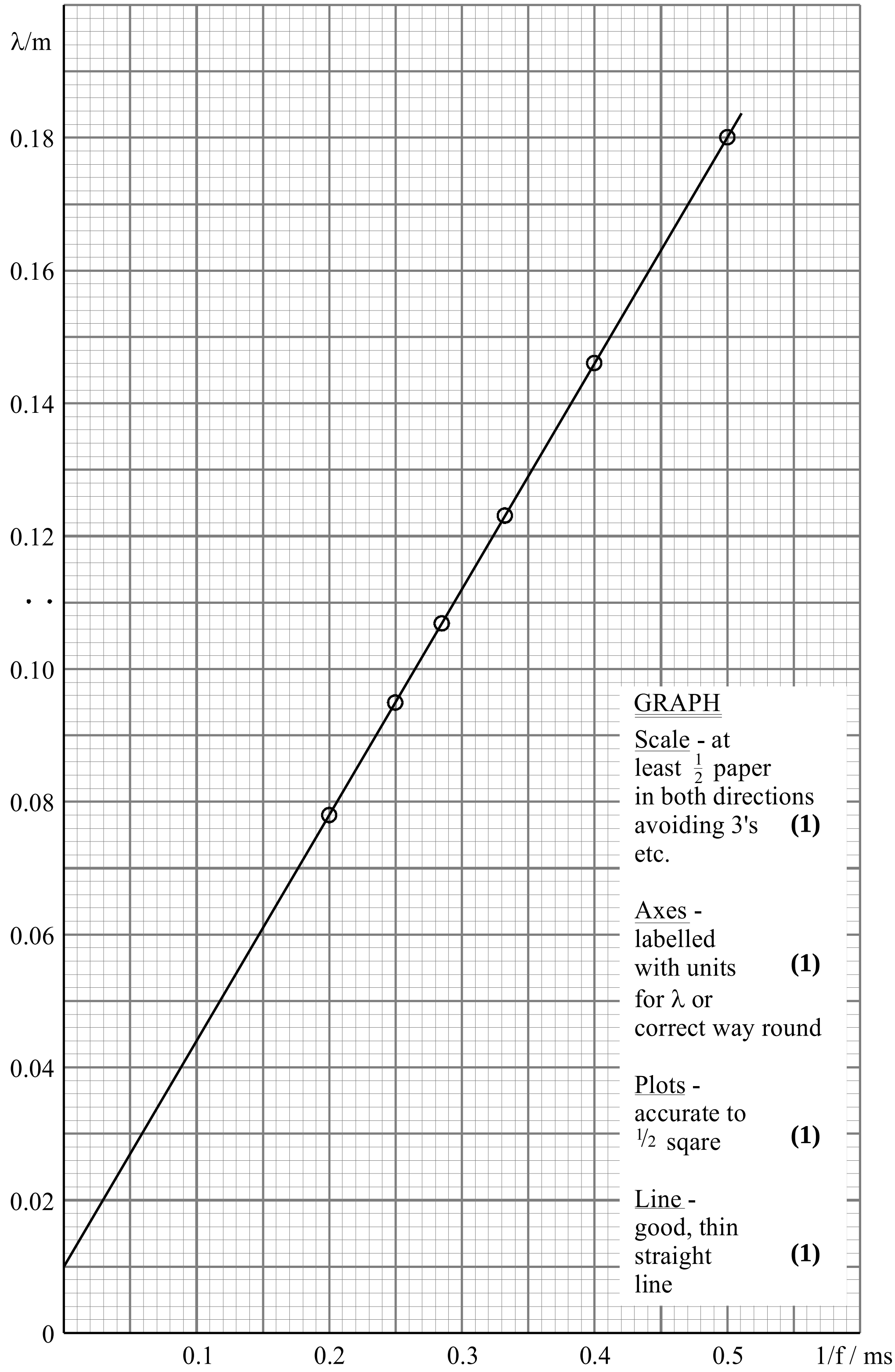
$\therefore T \propto N$

100.	(a)	$T = 0.4$ ms		1
		$f = 2.5$ kHz [e.c.f. from T]		1
	(b)	(i)	Correct set up	2
			[–1 for each error or omission. c.r.o and signal generator must be labelled] [mic between LS and board otherwise –2]	
		(ii)	Distance between (nodes/antinodes/max/min) measured	1
			is $\lambda/2$	1
			Measure across several [implied]	1

(c) 1/*f* values all correct, to 3 s.f. with unit [here or on graph] 1

[Allow kHz^{-1} OR 10^3 Hz^{-1}]

Graph:



GRAPH

Scale - at least ½ paper in both directions avoiding 3's etc. **(1)**

Axes - labelled with units for λ or correct way round **(1)**

Plots - accurate to ½ sqare **(1)**

Line - good, thin straight line **(1)**

(d) $\Delta xy \geq 80\ cm^2$ 1

Gradient calculated correctly and 330 – 350 m S^{-1} 1

= *c,* 2/3 s.f. and unit 1

Eliminates a significant systematic error OR graph averages a number of values 1

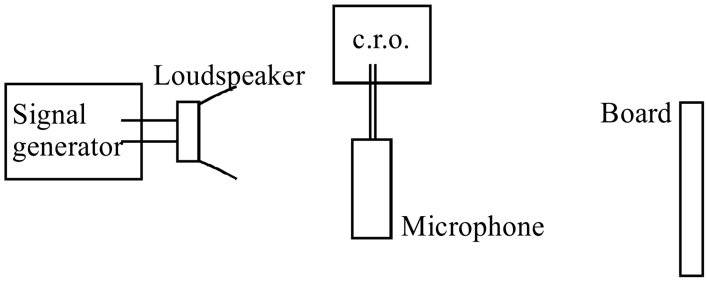
[16]

Sample results

(a) λ = 4 divisions = 4 × 0.1 ms = 0.4 ms

$$f = \frac{1}{T} = \frac{1}{0.4} \times 10^{-3} = 2.5\ \text{kHz}$$

(b) (i)



(ii) Distance between (nodes/antinodes/max/min) measured is λ/2

Measure across several

(c) $\frac{1}{f}$ / ms

0.500
0.400
0.333
0.286
0.250
0.200

(d) c = gradient = $\dfrac{0.180 - 0.010\ \text{m}}{0.500 - 0.000\ \text{ms}}$ = 340 m s^{-1}

Graphical method eliminates a significant *systematic* error OR graph *averages* a number of values

101. (a) (i) Sensible value, with unit to 0.1 cm^3 or better 1

Total volume correct [e.c.f.] with unit

[Penalise unit error once only]

Sensible time, with unit to 0.1 s or better

Correct method clearly explained 4

(ii) Correct calculation with unit and 2/3 s.f.

Correct re-arrangement and substitution

hence correct calculation of value + unit

Value given to 2/3 s.f. [Dependent mark] 4

(b) (i) Sensible T_1 from $\Sigma T \geq 10$ or ≥ 10 s + unit

[Only penalise unit error in Ts once]

Sensible T_2 from $\Sigma t \geq 10$ or ≥ 10 s + unit

T_1 *and* T_2 repeated

D_1 and D_2 sensible and repeated, with unit 4

(ii) $\Delta D \pm 0.5$ mm or 1.0 mm

$\Delta T \pm 0.05 - 0.2$ s [or range/ ½ range if larger and based on their readings] and correct percentages [-1 per error] **(2)**

Ratio of $\frac{T}{D}$ OR $\frac{D_1}{D_2}$ and $\frac{T_1}{T_2}$ found **(1)**

Percentage difference found **(1)**

Compared with 2 × percentage uncertainty above and sensible conclusion **(1)**

[Alternative for last two marks: Range of each ratio found (1), comment related to overlapping ranges (1)] Max 4

[16]

Sample results

(a) (i) Volume = 3.2 ml (cm^3)

Volume = 50.0 + 3.2:= 53.2 ml

$t = 43.8$ s

Take time to run out from 0 mark (53.2 ml) to 26.6 ml mark

(i.e. 53.2 ÷ 2 run out)

(ii) $T = t/\ln 2 = 43.8/0.693 = 63.2$ s

$T = CR \rightarrow R = \frac{T}{C}$

$R = \frac{63.2}{2200 \times 10^{-6}} \Omega = 29 \text{ k}\Omega$

[Would use 33 kΩ, being nearest preferred value]

(b) (i) $10T_1 / s = 14.52, 14.46$

$T_1 = 1.45$ s

$D_1/mm = 59, 59, 57, 57$

Average $D_1 = 58$ mm

$20T_2/s = 17.05, 16.95$

$T_2 = 0.85$s

D_2/mm = 32, 32

Average $D_2 = 32$ mm

(ii) T_2: $\frac{\pm 0.1 \text{ s}}{17.0 \text{ s}} \times 100 = 0.6\%$

$D_2 : \frac{\pm 0.5 \text{ mm}}{32 \text{ mm}} \times 100 = 1.6\%$

$\frac{T_1}{D_2} = 0.0250 \text{ s mm}^{-1}$	$\frac{D_1}{D_2} = 1.81$
$\frac{T_2}{D_2} = 0.0266 \text{ s mm}^{-1}$	$\frac{T_1}{T_2} = 1.71$
$\% \text{ diff} = \frac{0.0016}{0.026} \times 100$	$\% \text{ diff} = \frac{0.10}{1.76} \times 100$
$= 6\%$	$= 6\%$

Experimental uncertainty ~ 2 × 2.2 = 4.4%
Results do not entirely confirm T is proportional to D.

102. (a) Correct circuit without help 2

(b) Table with units [including no units for tan] 1

One $\theta \geq 45°$ 1

One $\theta \leq 20°$ 1

5 or more values plotted 1

Repeat I or θ seen 1

[Obvious systematic error in I -1, incorrect tan θ-l]

Any two from:

- look vertically on compass to avoid parallax/tap the compass/check alignment of coil and compass
- repeat with I increasing and then decreasing
- repeat with I reversed 2

(d) Graph:

Sensible scale [at least half paper in each direction, avoiding 3s etc] and axes labelled or units 1

Plots to accuracy of 1 mm [$\frac{1}{2}$ square] 1

Line -thin, straight line of best fit [*not* forced through origin] 1

[Graph plotted wrong way round, -1]
[Ignore missing θ = 30 if not tabulated]

(e) Large Δ [$\Delta x \Delta y \geq 64 \text{ cm}^2$] 1

Correct calculation of gradient [ignore unit] 1

Correct rearrangement and substitution [i.e. SI units] 1

Correct calculation 2/3 s.f. and unit 1

[16]

Sample results

(a) Circuit set up

(b) I = 0.14 A, 0.14 A, Average 0.14A

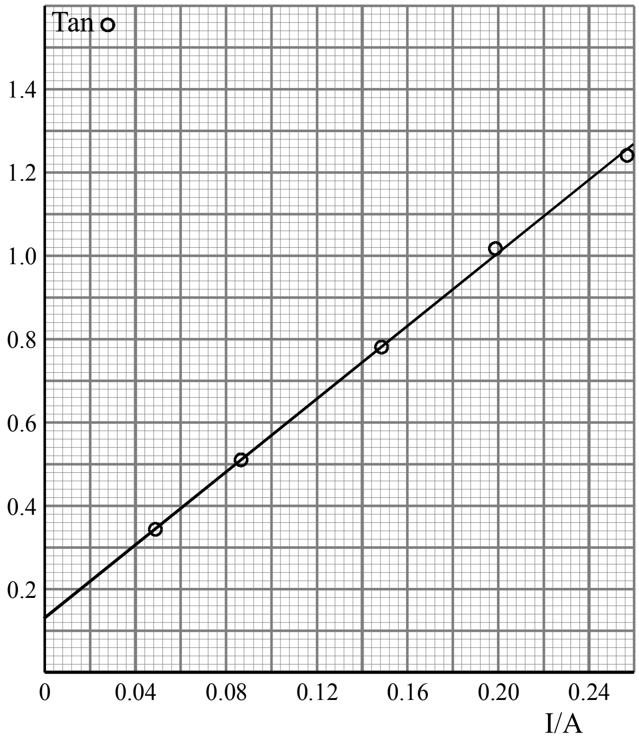
θ = 30°

I/A	θ_1/°	θi_2/°	Mean θ/°	Tan θ
0.05	17	21	19	0.344
0.09	25	29	27	0.510
0.15	34	42	38	0.781
0.20	42	49	45(.5)	1.018
0.26	48	54	51	1.235

(c) Look vertically on compass to avoid parallax/tap the compass/check alignment of coil and compass

Repeat with *I* increasing and then decreasing
OR
Repeat with *I* reversed

(d) Graph:



(e) Gradient = $\frac{1.17 - 0.13}{0.24 - 0.00} = 4.33 \text{ A}^{-1}$

$$\frac{\tan\theta}{I} = \frac{\mu_0 N}{2rB_{hor}}$$

$$B_{hor} = \frac{\mu_0 N}{2r \times \text{gradient}}$$

$$= \frac{4\pi \times 10^{-7} \times 10}{2 \times 0.060 \times 4.33}$$

$=2.4 \times 10^{-5}$T

[Unit T or N A^{-1} m^{-1} or Wb m^{-2}]

103. (a) (i) Correct circuit with ammeter in series with R and C and voltmeter across R and C — 1, 1

[–1 for each error or omission]

87.6 Ω or 88 Ω with unit — 1

[Allow V A^{-1}; do not allow V mA^{-1}]

(ii) Correct substitution — 1

Hence correct calculation [≥ 2 s.f. + unit] — 1

[Do not penalise unit if already penalised in (i)]

(iii) Replace a.c. supply with a signal generator/variable frequency supply — 1

Measure V and I — 1

for different frequencies of f — 1

$Z^2 = \frac{1}{4\pi^2 C^2} \times \frac{1}{f^2} + R^2$ [clearly shown] — 1

$$\underset{y}{Z^2} = \underset{m}{\frac{1}{4\pi^2 C^2}} \times \underset{x}{\frac{1}{f^2}} + \underset{C}{R^2}$$

(b) Z^2 and $1/f^2$ values all correct and — 1

≥ 2 s.f. with units for both — 1

Graph

Scale -at least half paper in each direction avoiding 3s etc and axes labelled [Ignore units] — 1

Plots- all accurate to 1 mm [½ square] — 1

Line -thin, straight line of best fit — 1

(c) Gradient (1.29 – 1.35) 10^7 from large Δ [$\Delta x \Delta y \geq 64$ cm^2] 1

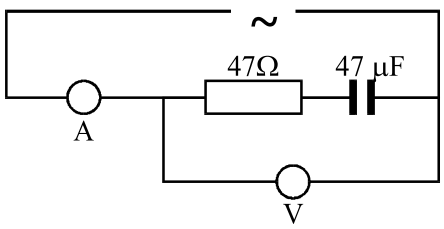
[Ignore units]
[As an alternative to the gradient candidates may use a point on the line and the intercept. This is allowed provided the point is not a data point]

Correct calculation of C with unit [Must be F or μ F] [Ignore s.f.] 1

[16]

Sample results

(a) (i)



$$Z = \frac{1.49\ \text{V}}{17\ \text{mA}} = 87.6\ \Omega$$

(ii) $Z^2 = (4\pi^2 \times (47 \times 10^{-6})^2 \times 50^2)\text{-}1 + 47^2$

$Z^2 = 4587 + 2209 = 6796$

$Z = 82.4\ \Omega$

(iii) Replace a.c. supply with a signal generator/variable frequency supply

Measure V and I for different frequencies of f

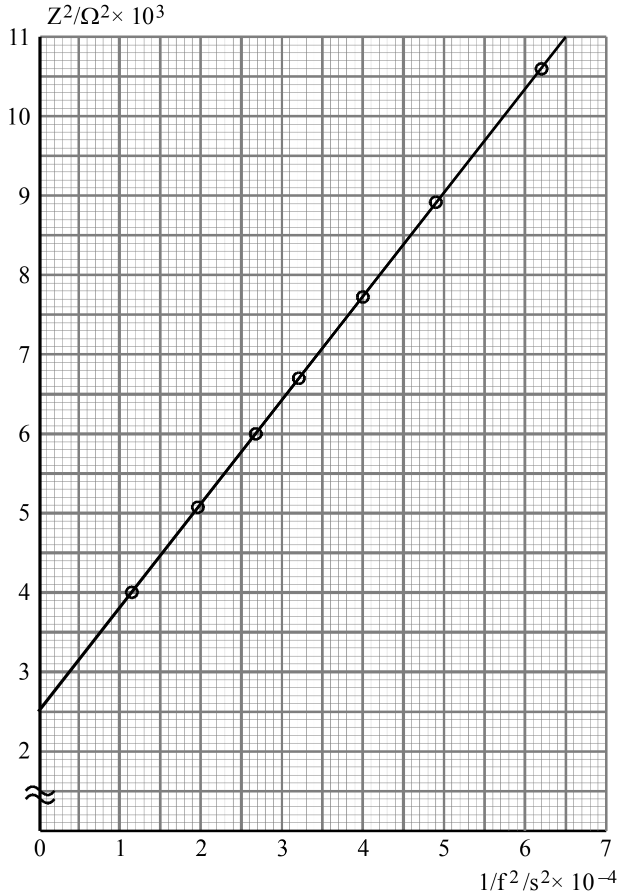
$$Z^2 = \frac{1}{4\pi^2 C^2} \times \frac{1}{f^2} + R^2 \quad \text{[clearly shown]}$$

$$y \ = \quad m \qquad x \ + C$$

(b) Data:

$Z^2/\Omega^2 - \times 10^3$	$1/f^2/s^2 \times 10^{-4}$ (Hz^{-2})
10.6	6.25
8.9	4.94
7.7	4.00
6.7	3.31
6.0	2.78
5.1	2.04
4.0	1.23

Graph:



(c) Gradient = $\dfrac{(10.3-2.4)\times10^3}{(6.0-0.0)\times10^{-4}} = 1.32\times10^7\ \Omega^2\ s^{-2}$

$C^2 = (4\pi^2 \times \text{gradient})^{-1} = (4\pi^2 \times 1.32 \times 10^7)^{-1}$ F

$C = 44\ \mu$F

104. Field definition

A field is a region/space/area/volume **(1)**
where *forces* act **(1)** 2

Two differences between magnetic and electric fields

Any two from:

- E – can be due to single charges; B – cannot be due to single poles
- E – acts on (moving and) stationary charges / all charges; B – only acts on moving charges / does not act on stationary charges
- E – can be radial; B – closed loops
- E – produces a force which is parallel to field; B – produces a force perpendicular to field **(1) (1)** 2

[4]

105. <u>*F* proportional to *I*</u>
Quality of written communication **(1)**
Any two from:
[In words or on diagram]

- Method of producing and measuring a varying direct current
- Wire perpendicular to B field
- Method of measuring/detennining forces, e.g. moments / acceleration **(1) (1)**

Graph of *F* - *I* straight line through origin for *F* = added weight **(1)** 4

[OR correct straight line if *F* is total weight OR $\frac{F}{I}$ constant]

<u>Calculation of Initial acceleration</u>

$F = BIl$
$= 0.20 \text{ T} \times 4.5 \text{ A} \times 5.0 \times 10^{-2} \text{ m}$
$= 4.5 \times 10^{-2} \text{ N}$
$a = F/m$
$= \frac{4.5 \times 10^{-2} \text{ N}}{50 \times 10^{-3} \text{ kg}}$
$= 0.90 \text{ m s}^{-2}$

Recall/state/use $F – ma$ and $F = BIl$ **(1)**
Use $5.0 \times (10^{-2} \text{ m})$ for length **(1)**
Conversion of g to kg 50×10^{-3} **(1)**
$a = 0.90 \text{ m s}^{-2}$ **(1)** 4

[8]

106. <u>E.m.f.</u>
Motion of magnet **(1)**
produces changing magnetic field over the coil **(1)** 2
OR
Field lines (of magnet) cut across coil
OR
Produces changes in flux linkage between coil and magnets
<u>Diagram</u>
X at both ends of path **(1)**
X in middle of path **(1)** 2

Rate of change of flux

$\frac{\Delta\phi}{\Delta t} = \frac{3 \times (10^{-3})(V)}{500}$ **(1)**

$= 6.0 \times 10^{-6}$ wb s^{-1}/V/T m^2 s^{-1} **(1)** 2

Changes to apparatus

Any three from:

- more coils
- stronger magnet [Accept 'more powerful']
- decrease length of suspension) [Not just 'increase'
- larger amplitude) speed of magnet]
- larger cross sectional area of coil
- iron core within coil **(1) (1) (1)** 3

[9]

107. Diagram

Electric pattern:

Straight, parallel, reasonably perpendicular to plates and equispaced [Minimum 3 lines] **(1)**
Correct direction labelled on one line [Downwards arrow] **(1)** 2
Equipotential lines:
Any two correct equipotentials with any labelling to identify potentials (rather than field lines) **(1)** 1
[Arrows on electric field lines – none on equipotential being sufficient labelling]

Force

$E = \frac{3000\,V}{25 \times (10^{-3})\,\text{m}}$ [Correct substitution] **(1)**

Use of $F = Ee$ even if value of "e" is incorrect **(1)**
$F = 120 \times (10^3)$ V $m^{-1} \times 1.6 \times 10^{-19}$ C
$= 1.9\ (2) \times 10^{-14}$ (N) **(1)** 3

Graph

Straight horizontal line [Even if extending beyond 25 mm] **(1)**
Value of F marked [e.c.f. their value] provided graph begins on force axis and is marked at this point **(1)** 2

Speed

Use **(1)**

$eV = ½ mv^2$ $v^2 = 2\ eV/m$	$v^2 = 2\left(\frac{F}{m}\right)s$	$Fd = ½ mv^2$ $v^2 = 2Fd/m$

Substitution **(1)**

$V^2 = \dfrac{2 \times 1.6 \times 10^{-19}(C) \times 3000(V)}{9.11 \times 10^{-31}\,kg}$

$= 2\ \dfrac{(1.92 \times 10^{-14}\,N)}{9.11 \times 10^{-31}\,kg} \times 25\ 10^{-3}\ m$

$= \dfrac{2 \times 1.92 \times 10^{-14}\,N \times 25 \times 10^{-3}\,m}{9.11 \times 10^{-31}\,kg}$

Answer: $V = 3.2 \times 10^7\ ms^{-1}$ **(1)** 3

[If $F = 2 \times 10^{-14}$ N, then $V = 3.3 \times 10^7\ ms^{-1}$]

[11]

108. Expressions for magnitude

(i) Centripetal force = $\dfrac{m_S V_S{}^2}{(R_E + h)} / \dfrac{GM_E m_S}{(R_E + h)^2}$

Correct formula and symbols, ignoring R_E **(1)**

(ii) Gravitational field strength = $\dfrac{GM_E}{(R_E + h)^2}$

Correct formula and symbols, ignoring R_E **(1)**

Use of (R_E+ *h)* in both equations **(1)** 3

Orbital speed

$\dfrac{mv_S{}^2}{(R_E + h)} = \dfrac{GM_E m_S}{(R_E + h)^2}$ [Apply e.c.f. if *h* used above] **(1)**

$V_S{}^2 = \dfrac{GM_E}{(R_E + h)}$

Since G, M_E and R_E are all constant/ $V_S{}^2$, $\propto \dfrac{1}{R_E + h}$, the greater the value of *h*, the smaller the value of *v.* **(1)** 3

Motion of spanner

Path of the spanner is the same as path of spacecraft or mechanic / both moving in same direction / stationary with respect to spacecraft or mechanic **(1)**

They both have the same speed **(1)** 2

[OR the spanner continues to move with the same *velocity* as the spacecraft or mechanic - both marks]

[Same centripetal acceleration as spacecraft or mechanic gets both marks]

[8]

109. (a) (i) *T* found correctly

$\sum NT \geq 20$ for both **(1)**

Any two precautions **(1) (1)**
Ratio of Ts: 1.26 – 1.40 **(1)** 4

(ii) Correct percentage from $\Delta(NT)$ 0.05 – 0.20 s [or range / ½ range if this is $\geq$ 0.05 s] **(1)**
"Constant" or suitable ratios calculation **(1)**
Percentage difference using mean as denominator **(1)**
Sensible comment based on quantitative analysis **(1)** 4
[Or check whether values overlap]

(b) (i) Set up circuit without help **(1) (1)**
[Polarity of C (–1); V (ignore)]
t = 16.5 – 27.5 s with unit **(1)**
Repeated and averaged **(1)** 4

(ii) Resistor combination correct without help **(1)**
[Resistors need not be labelled 10 kΩ]
$t > t$ (i) and 25.0 – 41.0 s **(1) (1)**
[If card given, this can only get 1 mark]
[–1 unit penalty unless already penalised in part (i)]
Correct calculation of average value, with unit and 2 or 3 s.f. **(1)** 4
[e.c.f.] [Do not accept s Ω^{-1}]

[16]

Sample results

(a) (i) $n = 16$
$10T/s$ = 11.53, 11.54, 11.53
So mean $T = 1.15$ s
Precautions:
Nail at centre of oscillations
Repeats shown for both
Careful release to prevent unwanted modes
Start timing when swings have settled
(n = 9) 20T/s: 17.53, 17.49, 17.59
So mean T = 0.877 s

(ii) Percentage uncertainty in $T_{16} = \frac{0.1}{11.5} \times 100 = 0.9\%$

Percentage uncertainty in $T_9 = \frac{0.1}{17.5} \times 100 = 0.6\%$

$$\frac{T_{16}}{T_9} = \frac{1.15}{0.877} = 1.31$$

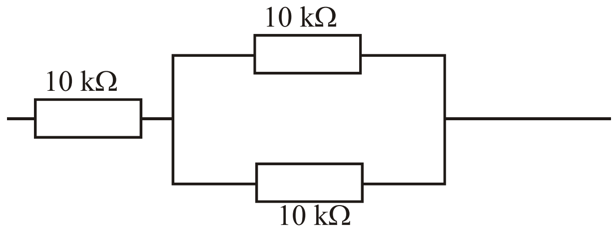
$$\sqrt{\frac{16}{9}} = \frac{4}{3} = 1.33$$

These values differ by $\frac{0.020}{1.32} \times 100 = 1.5\%$. which is comparable with uncertainties in T, thus supporting the suggestion.

(b) (i) t/s: 26.34, 25.86

$\bar{t}$ = 26.1 s

(ii)



t/s:39.51, 38,79

$\bar{t}$ = 39.2 s

$C = t/R = \dfrac{26.1}{10 \times 10^3}$ = 2610 μF

$C = t/R = \dfrac{39.2}{15 \times 10^3}$ = 2610 μF

$\bar{C}$ = 2610 μF

110. (a) Correct circuit without help **(1) (1)** 2

θ 45° – 55° and *I* 0.15 – 0.25 A, recorded to 0.01 A or better, with unit **(1)**

Table with units [Must have tan θ] **(1)**

Δx ≥ 6 cm **(1)**

Clear S shaped curve **(1)**

At least 6 values of tan θ ± 0.02 of examiner's best fit line **(1)**

[Can include 50° point] 5

(c) Any 2 precautions **(1) (1)** 2

(d) Graph:

Scale [at least ½ paper used on each axis, avoiding scales of 3 etc] **(1)**

Plots **(1)**

Smooth curve, of good fit **(1)** 3

(e) *x* read off correctly, to 0.1 cm or better, with unit **(1)**

½*r* found correctly from ≥ 2 values **(1)**

Percentage difference [average or either value as denominator]

[or bracketing] **(1)**

Sensible comment from quantitative argument **(1)** 4

[16]

Sample results

(b) I = 0.19 A
θ = 50°'

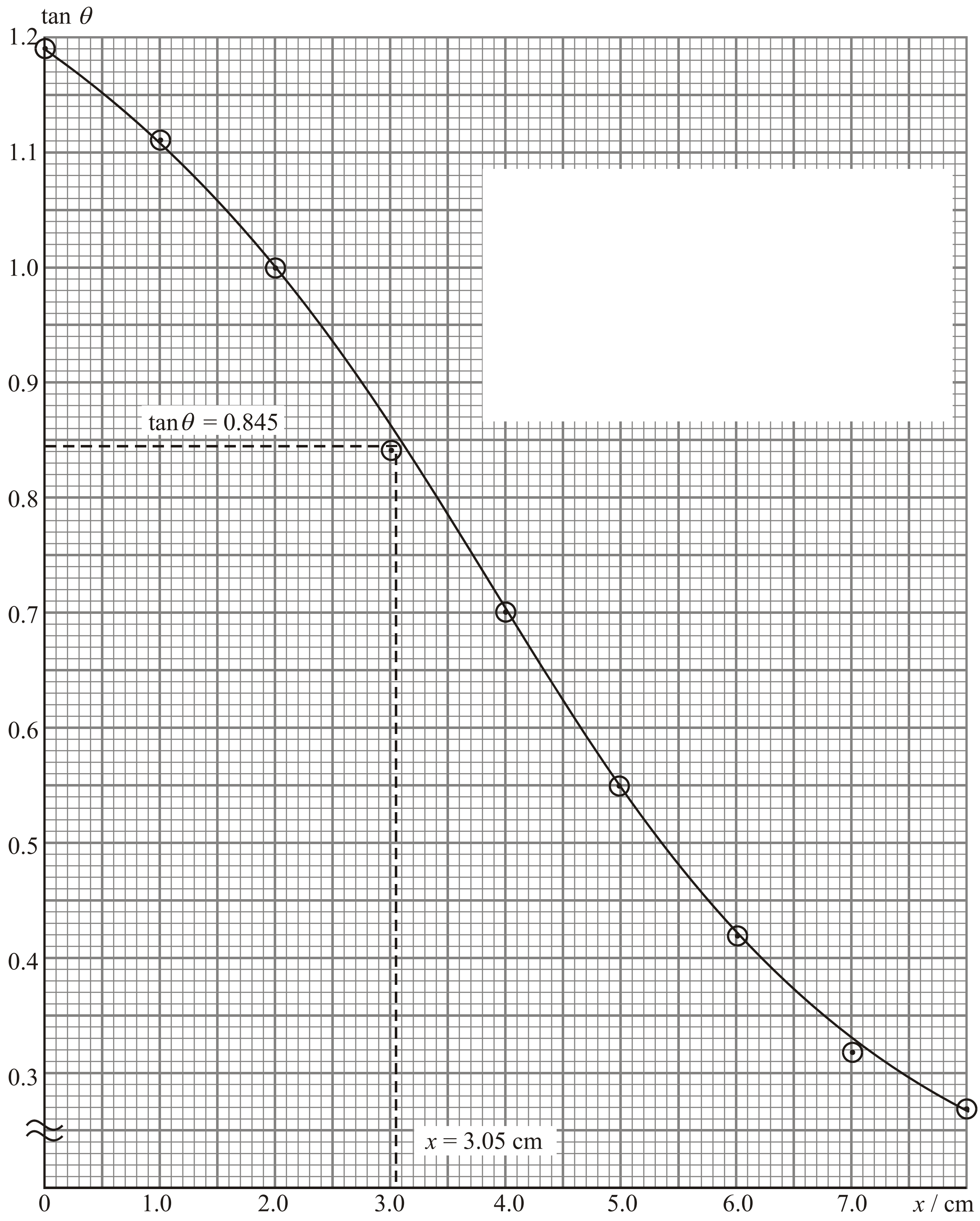
Table:

x/cm	θ°	tanθ
0.0	50	1.19
1.0	48	1.11
2.0	45	1.00
3.0	40	0.84
4.0	35	0.70
5.0	29	0.55
6.0	23	0.42
7.0	18	0.32
8.0	15	0.27

(c) Any two precautions from:

- readings taken on <u>both sides</u> of coil
- averaged [must be <u>shown</u>] and average plotted
- more than 8 readings
- check no iron objects nearby
- tap compass to avoid 'sticking'
- switch off between readings and check alignment of compass

(d) Graph:



(e) $\tan \theta = 0.71 \times 1.19 = 0.845$

$x = 3.05$ cm

Radius of coil = 6.0 cm

½ radius = 3.0 cm

Percentage difference = $\dfrac{0.05}{3.0} \times 100 = 1.7\%$

Acceptable experiment error, particularly as coil not circular and compass difficult to read

111. (a) (i) Pitch (frequency) is higher **(1)** 1
[Accept greater or more]

(ii) Resonance occurs and **(1)**
energy is transferred from the loudspeaker to the vibrating air
OR
amplitude of vibration is a maximum **(1)** 2

(iii) Fill flask with water and find volume (with measuring cylinder) **(1)**

Empty out some water and measure its volume; this is the volume of air **(1)**

Repeat, removing more water each time to increase the volume of air **(1)**

[OR empty out all water to find volume of air initially;
add water to *reduce* volume of air]

Plot Inf against ln V **(1)** 4

[Allow lnf = n lnV + lnK or if correct graph plotted]

(b) Correct ln (or lg) values to 2 or 3 d.p. **(1)** 1
Graph:
Suitable scale (at least ½ paper used for each axis, avoiding scales of 3, etc) **(1)**
Axes labelled with units (or units in table) **(1)**
Plots **(1)**
Line **(1)** 4
[f v V can get all 4 marks]

(c) Large triangle [or maximum] ($\Delta y \Delta x \geq 80$ cm^2) **(1)**
Correct calculation with n in range 0.49 – 0.51, , given to 2/3 s.f.
and no unit **(1)**
Negative sign **(1)**
Negative sign indicates that f increases as V decreases, as was
observed in (a)(i) **(1)** 4

[16]

Sample results

(a) (i) Pitch (frequency) is higher

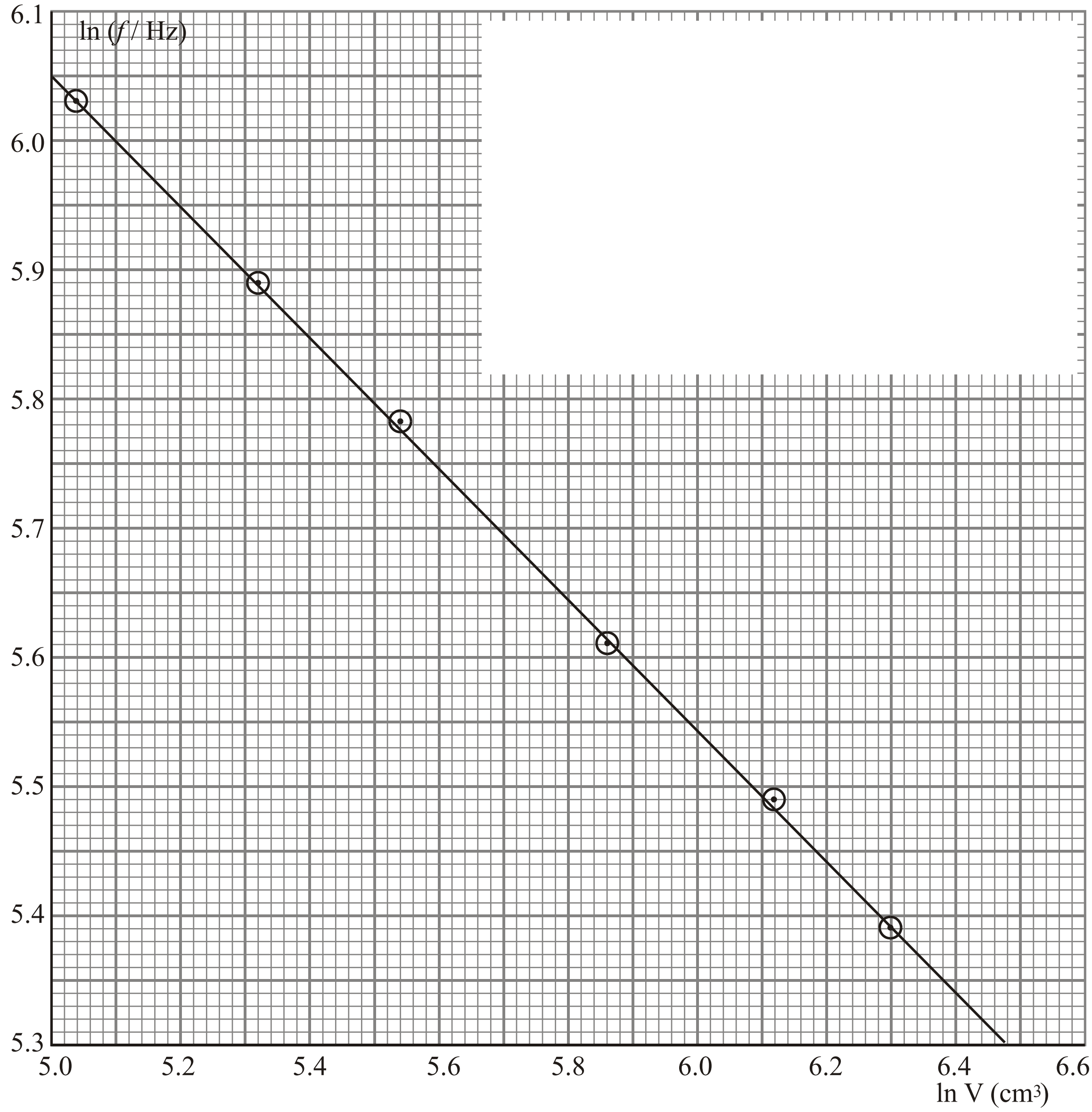
(ii) Resonance occurs and
energy is transferred from the loudspeaker to the vibrating air
OR
amplitude of vibration is a maximum

(iii) Fill flask with water and find volume (with measuring cylinder)
Empty out some water and measure its volume; this is the volume of air
Repeat, removing more water each time to increase the volume of air
[OR empty out *all* water to find volume of air initially; *add* water to *reduce* volume of air]
Plot ln$f$ against ln V

(b) Table:

V/cm^3	f/Hz	ln(V/cm^3)	ln(f/Hz)	log(V/cm^3)	log(f/Hz)
554	219	6.32	5.39	2.74	2.34
454	242	6.12	5.49	2.66	2.38
354	274	5.87	5.61	2.55	2.44
254	324	5.54	5.78	2.40	2.51
204	361	5.32	5.89	2.31	2.56
154	415	5.04	6.03	2.19	2.62

Graph



(c) $n = \text{gradient} = -\dfrac{6.05 - 5.30}{6.50 - 5.00}$

$= -\dfrac{0.75}{1.50} = -0.50$

Negative sign indicates that f increases as V decreases, as was observed in part (a) (i).

112. Explanation

Electrons are transferred from / move from/ rubbed off the rod to the duster **(1)**
Same amount of charge on each/duster becomes negative **(1)** 2

Polystyrene

Polystyrene is an insulator / non conductor [NOT bad or poor conductor] **(1)**
Prevents loss of charge/rod discharging/prevents conduction or charge low from metal plate **(1)** 2

Reading on balance

Quality of written communication **(1)** 1

Any three from:

- Reading increases **(1)**
- There is a (mutual) force of repulsion/like charges repel/rods (they) repel **(1)**
- Because by Coulomb's law/inverse square law/ $\frac{kQ_1Q_2}{r^2}$ / $\frac{1}{r^2}$ as r decreases force must increase **(1)**
- Reading increases at a greater rate/more rapidly [but accept if say "much more"] as distance reduces/when closer **(1)** Max 3

[8]

113. Meaning of uniform magnetic field

Magnetic flux density constant / magnetic field lines parallel / **(1)**
magnetic field strength is constant/ does not vary 1

Sizes and directions of forces on LM and NO

Force on LM: 2.4×10^{-4} N/ 0.24 mN **(1)**
Direction:
Downwards/into (paper) **(1)**

Force on NO:)
2.4×10^{-4} N / 0.24 mN [No unit penalty]) Must have both **(1)** 3
Direction:)
Upwards / out of (paper))

Why no forces on MN and OL

Wires/current and B field directions are parallel [allow 'same direction'] / field due to current and B field of magnet are perpendicular to each other **(1)** 1

The effect on the square

A (turning) moment will be applied / it will (begin) to turn / spin / rotate **(1)** 1

Moving the pole pieces further apart

Reduces the size of the forces, **(1)**
Because the flux density is reduced/ magnetic field (strength) reduced / B (field) reduced **(1)** 2

[8]

114. Charge on capacitor

220 μF × 5 V [use of CV ignore powers of 10] **(1)**
= 1100 μC **(1)** 2

Energy on capacitor

$\frac{220}{2}$ μF × (5 V)^2 / $\frac{1100}{2}$ μC ×5 V / $\frac{1100^2\ \mu C^2}{2 \times 220 \mu F}$ [ignore powers of 10] **(1)**

= 2750 μJ (2.8 × 10^{-3} J) **(1)** 2

Experiment

Method 1 (constant current method):

- Circuit **(1)**
- For a given *V* record time to charge capacitor at a constant rate **(1)**
- for a range of values of *V* **(1)**
- Use $Q = It$ to calculate *Q* **(1)**
- Plot $Q \rightarrow V$– straight line graph through origin / sketch graph / dive *Q/V* and obtain constant value **(1)**

Method 2:

- Circuit **(1)**
- For a given value *V* measure I and t **(1)**
- Plot $I \rightarrow t$ find area under graph *Q* **(1)**
- Repeat for a range of values of *V* **(1)**
- Plot $Q \rightarrow V$ for straight line graph through origin/ sketch graph / dive *Q/V* and obtain constant value **(1)**

Method 3 (joulemeter method):

- Circuit **(1)**
- Record V and energy stored **(1)**
- For range of V **(1)**
- Determine Q from ½ QV or $\frac{Q^2}{2C}$ **(1)**
- Plot $Q \rightarrow V$– straight line graph through origin / sketch graph / divide *Q/V* and obtain constant value **(1)** 5

[Coulombmeter (will not work with this value of capacitor)
circuit **(1)** ; record charge *Q* on colombmeter **(1)**; for a range of values of *V* **(1)**; Plot $Q \rightarrow V$ for straight line through origin **(1)** – Max 3]

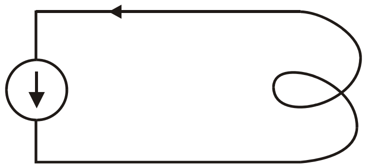
[9]

115. Lenz's law

The direction of an induced current/emf/voltage is such as **(1)**
to oppose the change (in flux) that produces it **(1)** 2

Polarity at top of coil

North **(1)**
Direction of current



Only ONE arrow required **(1)** 2

Graph

Magnet is moving faster / accelerating (under gravity) **(1)**

(Rate of) change/ cutting of flux is greater **(1)**

Induced emf is greater **(1)** Max 2

[6]

116. Gravitational attraction of Earth on Moon

Use $\frac{Gm_1 m_S}{r^2}$, ie $\frac{GMm}{(60R)^2}$ **(1)** 1

Orbital speed of the Moon

$\frac{m\upsilon^2}{r} = \frac{GMm}{r^2}$ **(1)**

Use of $r = 60R$, ie $60 \times 6.4 \times 10^6$ **(1)**

Rearrangement ie $\upsilon = \sqrt{\frac{6.67 \times 10^{-11}\,\text{Nm}^2\text{kg}^{-2} \times 6 \times 10^{24}\,\text{kg}}{60 \times 6.4 \times 10^6\,\text{m}}}$ **(1)**

= 1020 m s^{-1} **(1)** 4

Orbit period

Time = $\frac{2\pi r}{\upsilon}$ /ω = $\frac{2\pi}{T}$ **(1)**

Calculation: $\frac{2 \times \pi \times 60 \times 6.4 \times 10^6}{1020\,\text{m}\,\text{s}^{-1}}$ **(1)**

Divide by 3600 × 24 **(1)**
Using 1020m/s: (27 – 27.4) days
Using 1000m/s: (27.8 – 28) days **(1)** 4

[9]

117. (a) (i) p.d. — No mark

Circuit set up correctly without help **(1) (1)** — 2

[Ignore meter polarity]
[Polarity of capacitors/cell reversed –1
Capacitors interchanged –2
Any one lead incorrect –2]

(ii) Correct calculation of Q with unit and more than 2 sf **(1)**

$\overline{V}$ found from more than 3 readings with unit **(1) (1)** — 3

[from 2 $\rightarrow$ (1)]

[Missing or wrong unit –1. Precision should be to 1 mV or better]

(iii) Correct calculation + unit [ecf] **(1)**

2/3 sf and in range 300 – 600 μF **(1)**

$C > 10$ μF, so most of charge transfers to X **(1)** — 3

[Allow $C > 10$ μF so stores more charge]
[Allow ecf $C < 10$ μF $\therefore$ not valid]

(b) (i) Measurements of d in several different places **(1)**

Correct average of ≥ *3d* **(1)** — 2

[Allow average values rounded to whole millimetre]

(ii) Width — No mark

$\Sigma t \geq 5$ seconds **(1)**

Repeated such that $\Sigma t \geq 10$ seconds **(1)**

υ correctly calculated, with unit and between 0.18 – 0.30 m s^{-1} **(1)** — 3

[Less than or equal to 3 sf]

(iii) Correct calculation of k with unit and value between 7 and 13 m s^{-2} (when rounded) **(1)**

Δd = 0.5 mm or 1.0 mm or range or half range and correct percentage calculation **(1)**

[Allow ecf wrong *d*]

Quantitative (%) comparison of k with g, hence conclusion **(1)** — 3

[Allow ecf] [Either g as denominator or range of k compared to g]

[16]

Sample results

(a) (i) Vo = 1.60 V

(ii) $Q = CV$ = 10 μF × 1.60 V
= 16.0 μC
V = 0.034 V, 0.034 V, 0.035 V
$\overline{V}$ = 0.034 (3) V

(iii) $C = \frac{Q}{V} = \frac{16.0\mu\text{C}}{0.034(3)\text{ V}} = 470\ \mu\text{F}$

As X is 47 times larger than the 10 μF capacitor it will take 47 ÷ 48 of the charge, ie 98%

(b) (i) Measure d in several different places

d/mm: 5.0, 6.0, 6.0, 5.0

$\bar{d}$ = 5.5 mm

(ii) Width = 0.285 m

$4t$ = 4.81 s, 4.81 s

$3t$ = 3.78 s, 3.68 s

$\bar{t}$ = 17.08/14 = 1.22 s

$\upsilon = \frac{0.285\text{m}}{1.22\text{s}}$

= 0.234 m s^{-1}

(iii) $k = \frac{\upsilon^2}{d} = \frac{(0.234)^2}{5.5 \times 10^{-3}} = 9.9\text{ms}^{-2}$

% uncertainty in $d = \frac{0.5\text{mm}}{5.5\text{ mm}} \times 100 = 9.1\%$

k differs from g by $\frac{9.9 - 9.8}{9.8} \times 100 = 1.0\%$

So k could be equal to g

118. (a) Correct use of vertical rule **(1)**

Difference method indicated on diagram)

Correct use of set square for h; or vertical rule close to horizontal rule and eye level) **(1) (1)**

Set square used to ensure rule is vertical)

h_1 and h_2 recorded with unit **(1)**

Sensible scale [can include origin], correct plots and good line **(1)**

m read off correctly with unit and ± 8 g of Supervisor's value [–1 per error] 7

(b) (i) $\Sigma nT \geq 30$ for T_1 and T_2 **(1)**

Repeats for T_1 and T_2 **(1)**

Correct T_1^2 and T_2^2, correctly plotted and good line **(1)** 3

[Ignore units and sf in section (b)(i)]

[Allow graph to start at origin]

(ii) T_b^2 read off correctly **(1)**) [Allow ecf]

T_b calculated, with unit **(1)**)

± 0.05 s of Supervisor's value **(1)** 3

(c) Δy ± 1 or 2 mm and correct percentage **(1)**

[OR range/ ½ range if greater for Δy OR ΔT]

ΔnT ± 0.05 – 0.2 s and correct percentage for T **(1)**

Doubled for T^2 [Allow ecf] **(1)** 3

[16]

Sample results

(a) Diagram:

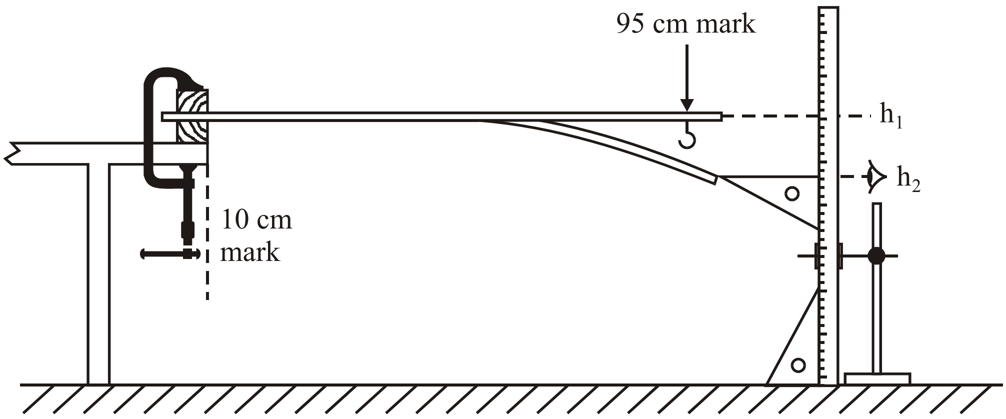
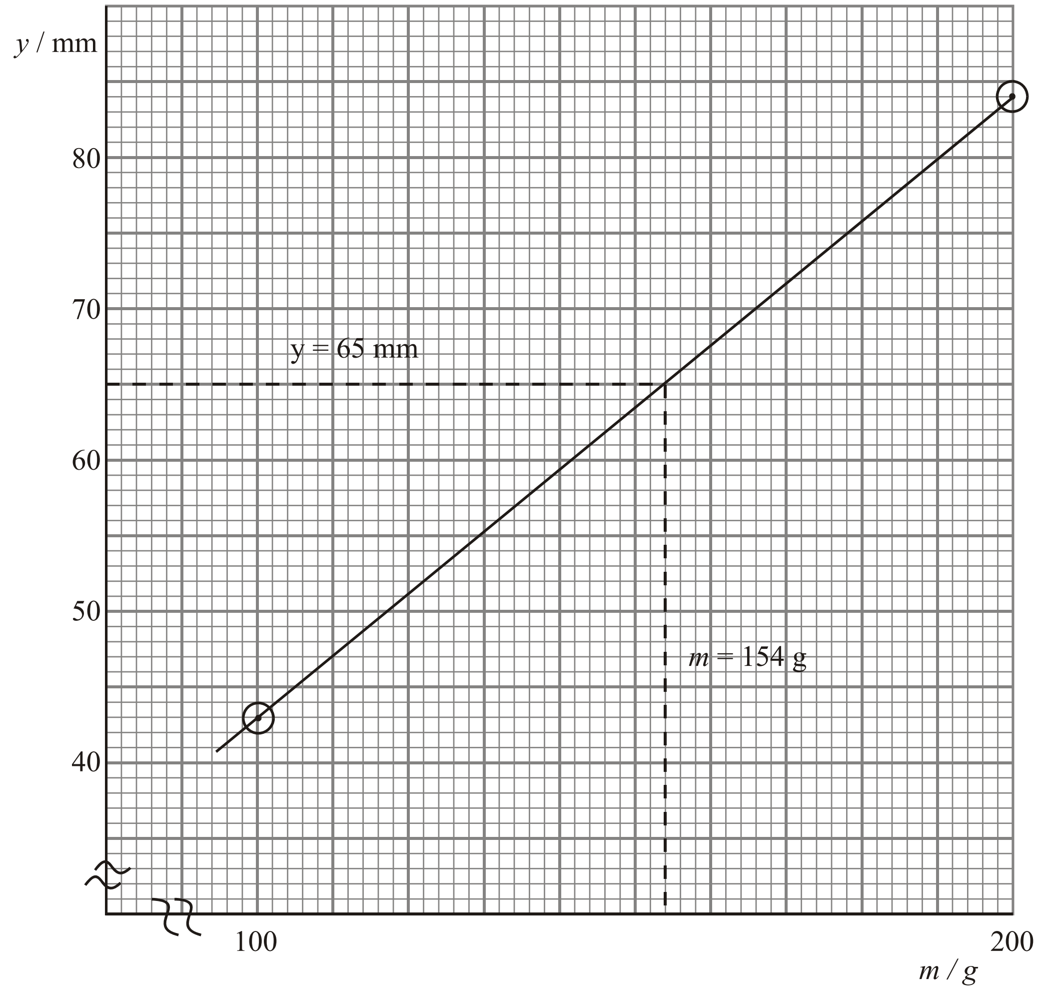


Table:

	h_1/mm	h_2/mm	y/mm
100 g	135	178	43
200 g	135	219	84
Block	135	200	65

m = 154 g

Graph:



(b) (i) $20T_1$/s: 8.81, 8.87

$\overline{T} = 0.442$ s

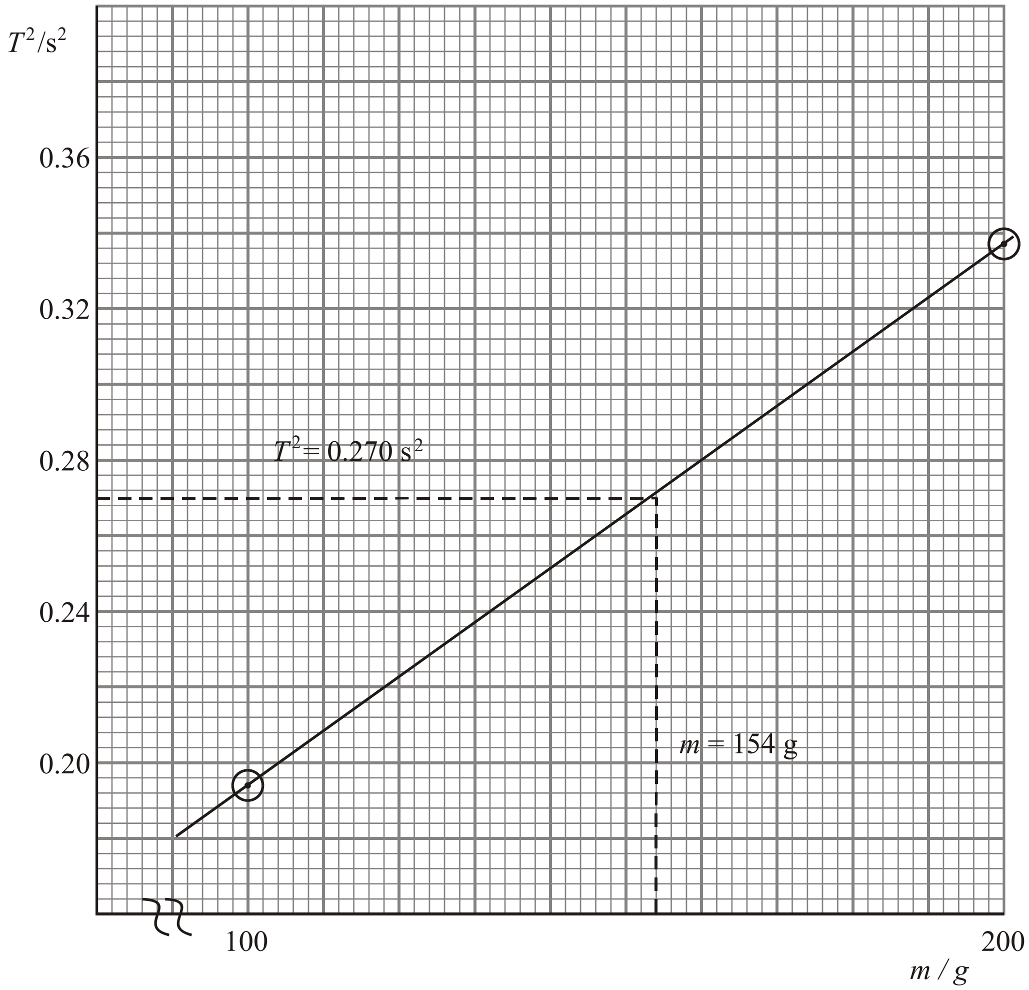
$20T_2$/s: 11.65, 11.61

$\overline{T_2} = 0.582$ s

$T_1^2 = 0.195$ s^2

$T_2^2 = 0.338$ s^2

Graph:



(ii) $T_b^2 = 0.270$ (s^2)
$T_b = 0.520$ s

(c) % uncertainty in $y_b = \dfrac{\pm 2\text{mm}}{65\text{mm}} \times 100 = 3.1\%$

% uncertainty in $T_2^2 = 2 \times \dfrac{\pm 0.1\text{s}}{11.63\,s} \times 100 = 1.7\%$

119. (a) (i) Straight wire, power supply, resistor and ammeter in series **(1)**
Flat face of probe in same plane as wire/statement that probe is perpendicular to field line **(1)**
Distance *r* shown correctly to centre of sensor **(1)**
Probe alongside wire and approximately at mid-point **(1)**
Meter connected to probe in some way **(1)**
Half-metre rule perpendicular to wire **(1)** Max 4

(ii) Resistor limits current (prevents short circuit) **(1)**
[Not reduces current]
and so prevents damage/overheating **(1)** 2

(iii) Between 5 A and 20 A **(1)** 1

(iv) Several parallel wires (or long length of wire wound into a large rectangular coil, with the probe near vertical side of coil) **(1)** 1

[NOT coils or solenoids unless clear that only one limb is used and the other limbs are far enough away not to have an effect.]

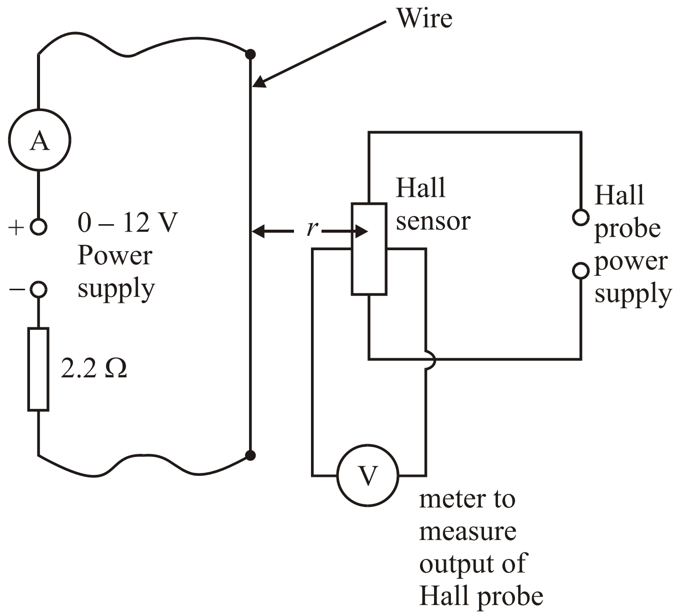
(b) Correct $1/r$ values to 2/3 sf and unit [here or on graph] **(1)**
[Only penalise wrong or no unit for $1/r$ once]
Graph:
Scale: at least half paper in each direction, avoiding awkward scales, e.g. 3s **(1)**
Axes: labelled with units **(1)**
Plots: accurate to ½ square **(1)**
Line: thin, straight, best fit **(1)** 5

(c) Large Δ ($\Delta x \Delta y \geq 100\ \text{cm}^2$) **(1)**
Correct calculation of gradient to ≥ 2 sf [ignore unit] **(1)**
Correct calculation of I to 2/3 sf + unit **(1)** 3

[16]

Sample results

(a) (i)



(ii) Resistor limits current (prevents short circuit) and so prevents damage/overheating

(iii) Between 5 A and 20 A

(iv) Several parallel wires [or long length of wire wound into a large rectangular coil, with the probe near vertical side of coil]

(b) Plot B against $1/r$

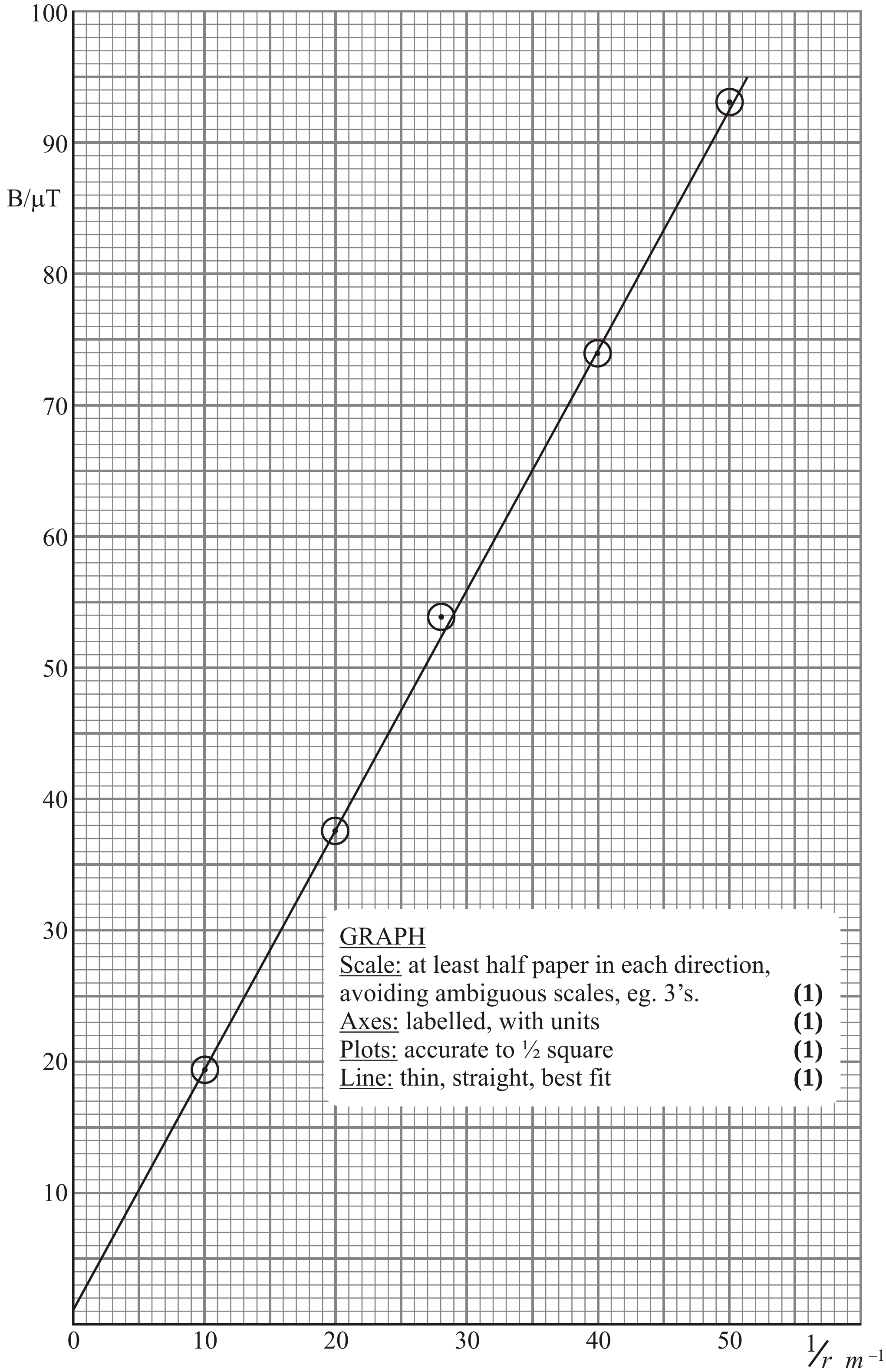
B/μT	r/m	$\frac{1}{r}$ /m^{-1}
93	0.020	50.0
74	0.025	40.0
54	0.035	28.6
38	0.050	20.0
19	0.100	10.0

(c) Gradient = $\dfrac{92.5 - 1.0}{50.0 - 0.0}$ = 1.83 μT m

Gradient = $\dfrac{\mu_0 I}{2\pi} \rightarrow I = \dfrac{2\pi \times \text{gradient}}{\mu_0}$

$I = \dfrac{2\pi \times 1.83 \times 10^{-6}}{4\pi \times 10^{-7}}$ = 9.2 A

Graph:



GRAPH
Scale: at least half paper in each direction, avoiding ambiguous scales, eg. 3's. **(1)**
Axes: labelled, with units **(1)**
Plots: accurate to ½ square **(1)**
Line: thin, straight, best fit **(1)**

120. (a) (i) 800 ± 20 mm, recorded to mm or better, with unit **(1)** 1
[OR Supervisor's value instead of 800]
[670± 20 mm if 60 Hz]

(ii) Value 0.19 ± 0.02 mm. Recorded to 0.01 mm or better **(1)**
[OR Supervisor's value ± 0.02 mm]
From more than 3 readings in different places **(1)**
Different directions **(1)** 3

(iii) Value 150 - 180 g with unit **(1)** 1
[± 20 g of Supervisor's value]

(iv) Correct substitution in SI units [Allow *m* in grams *if* final unit is given as $m^3\ g^{-1}$] **(1)**
Correct calculation with unit and 2 sf [unless *d* is 3 sf] **(1)**
Value between $(3.4 – 3.8) \times 10^{-5}\ m^3\ kg^{-1}$ **(1)** 3

(b) (i) Sensible value to 0.01 V or better with unit **(1)**
Correct calculation with unit and more than 2 sf **(1)** 2

(ii) Circuit set up correctly without help **(1) (1)** 2
[(–1) polarity on capacitor or cell; (–2) if help with flying lead]

(iii) *V* sensible, to mV or better, with unit **(1)**
Correct calculation with unit and more than 2 sf [ecf from *V*] **(1)** 2

(iv) Correct percentage transfer **(1)**
Less than expected [allow 100%] because of leakage
[no data needed] **(1)** 2

[16]

Sample results

(a) (i) $l = 807$ mm

(ii) d/mm: 0. 19, 0.19. 0.19, 0.19
$\bar{d} = 0.19$ mm
Repeated at different positions along the wire and in perpendicular (different) directions

(iii) $m = 170$ g

(iv) $$k = \frac{50^2 \times (0.19 \times 10^{-3})^2 \times (0.807)^2}{0.170 \times 9.81}$$
$= 3.5 \times 10^{-5}\ m^3\ kg^{-1}$

(b) (i) $E = 1.52$ V
$Q = CV = 1\ \mu F \times 1.52\ V$
$= 1.52\ \mu C$

(ii) Circuit set up correctly

(iii) $V = 25.9$ mV
$Q = CV = 47\ \mu F \times 25.9 \times 10^{-3}\ V$
$= 1.22\ \mu C$

(iv) Percentage transferred = $\frac{1.22}{1.52} \times 100\%$
= 80%
[Would expect 47/48 = 98%]

121. (a) Correct use of vertical rule **(1)**
Difference method indicated **(1)**
Correct use of set-square for h; or rule close and at eye level **(1)**
Set-square used to ensure rule is vertical **(1)** Max 3
h_1 and h_2 recorded **(1)**
Sensible scale, good plots and line **(1)**
m read off correctly with unit **(1)**
± 8 g of Supervisor's value **(1)** 4

(b) (i) $\Sigma\, nT \geq 30$ for T_1, T_2 and T_b **(1)**
Repeats for T_1, T_2 and T_b **(1)**
Correct T_1 and T_2^2, correctly plotted with good line **(1)**
[Penalise $(10\ T)^2$,f^2 etc in the above]
$T_b^{\ 2}$ correct, plotted correctly and m read off correctly, with unit **(1)**

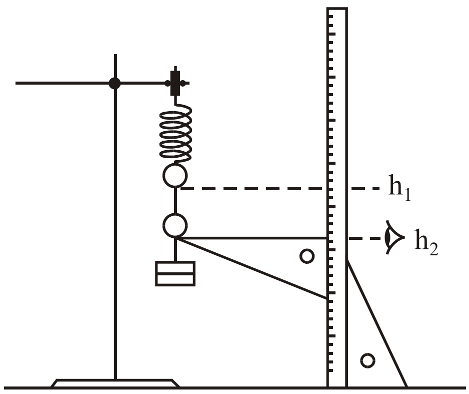
(ii) ± 8 g of Supervisor **(1)** 5

(c) Δx_b ± 1 or 2 mm and correct percentage **(1)**
[or range/ ½ range if greater]
ΔnT_b ± 0.05 - 0.1 s and correct percentage for T_b **(1)**
[OR range / ½ range if greater]
Doubled for T_b^2 **(1)**
[Allow ecf]
Percentage difference correctly calculated using mean as denominator, hence sensible comment comparing with above percentage **(1)** 4

[16]

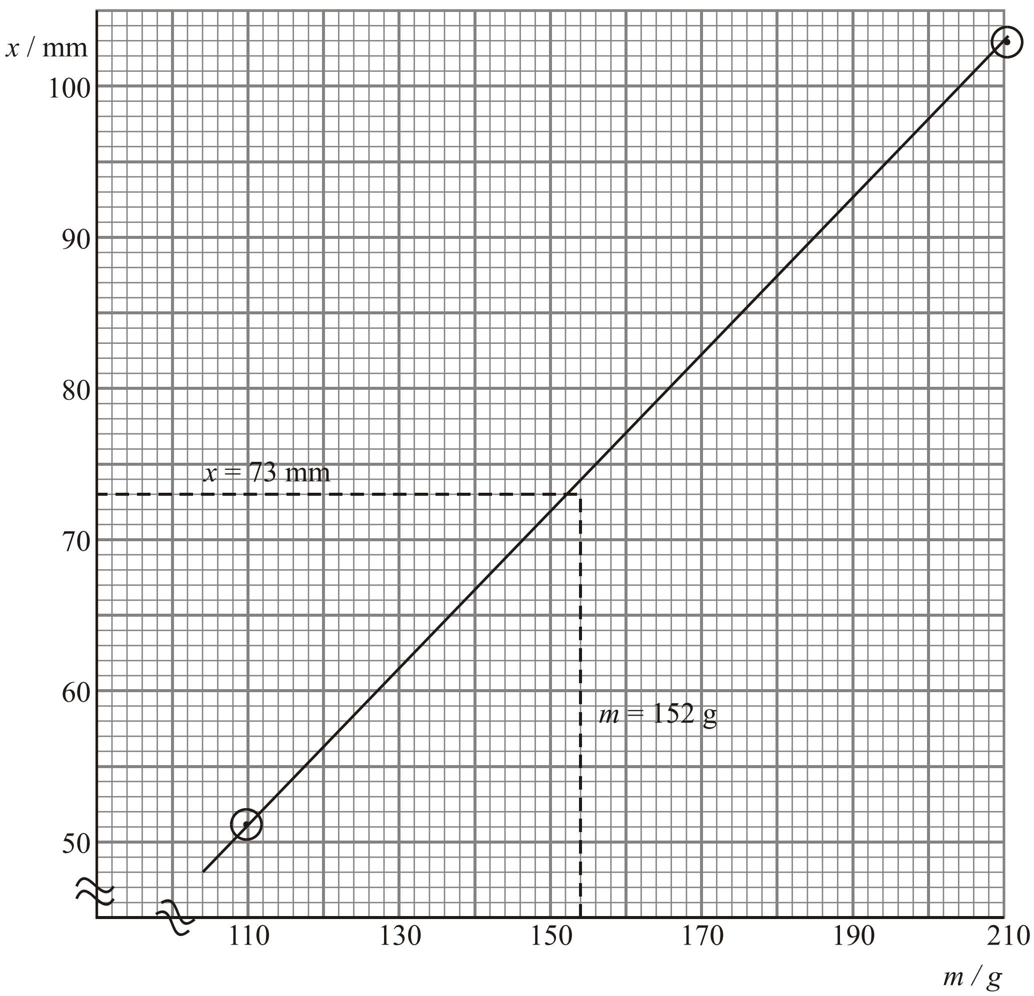
Sample results

(a) Diagram:



	h_1/mm	h_2/mm	x/mm
110 g	340	391	51
210 g	340	443	103
Block	340	413	73

Graph



m = 152 g

(b) (i) 20 T_1 /s: 9.18, 9.21

$\overline{T_1} = 0.460$ s

20 T_2 /s: 12.98, 12.96

$\overline{T_2} = 0.649$ s

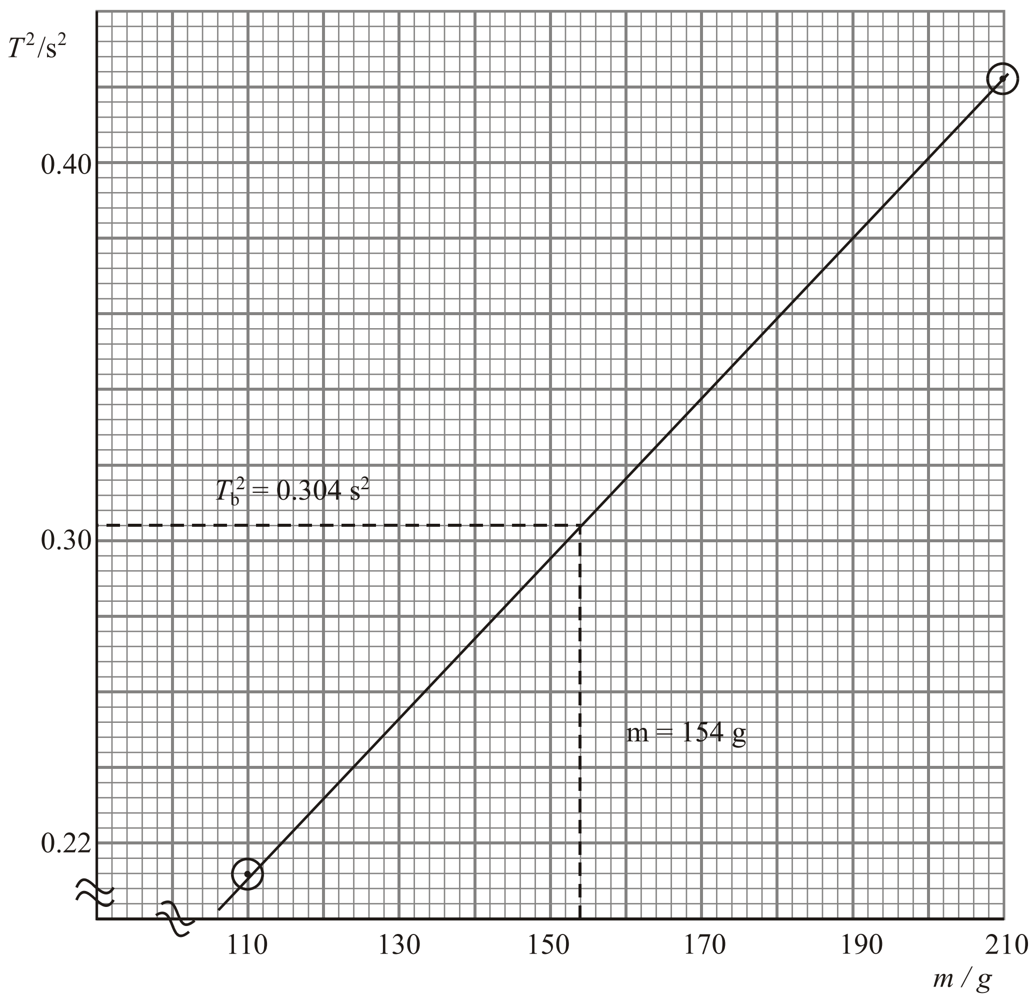
20 T_b /s: 11.01, 11.05

$\overline{T_b} = 0.551$ s

$T_1^2 = 0.211$ s^2

$T_2^2 = 0.421$ s^2

$T_b^2 = 0.304$ s^2



(ii) $m = 154$ g

(c) Percentage uncertainty in x_b $= \frac{\pm 2mm}{73mm} \times 100\%$

$= 2.7\ \%$

Percentage uncertainty in T_b^2 $= 2 \times \frac{0.1s}{11.03s} \times 100\%$

$= 1.8\%$

Percentage difference $= \frac{(154-152)g}{153g}$

$= 1.3\%$

Difference in two values for mass of block easily accounted for in terms of uncertainties in x_b and T_b^2

122. (a) (i) Solenoid, power supply and ammeter in series **(1)**
Hall probe sensor shown at centre of solenoid **(1)**
Flat face of probe perpendicular to axis of solenoid **(1)**
[Details of Hall probe circuit are not required]
Length of solenoid **(1)**
Number of turns **(1)** 5

(ii) Sensor shown near mid-axis of magnet **(1)**
Correct orientation of flat face of sensor [ecf] **(1)**
d shown correctly from axis of magnet to centre of sensor **(1)** 3

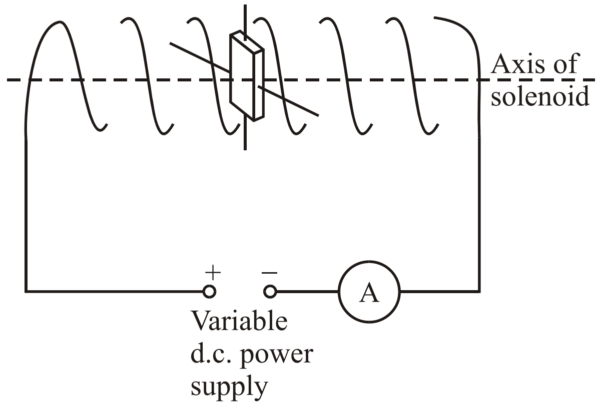
(b) Correct expansion [Need not be related to $y = mx + c$] **(1)**
Correct ln values to 2 or 3 decimal places **(1)**
Units [here OR on graph] **(1)**
Graph:
Scale – at least ½ paper in each direction, avoiding awkward scales, e.g. 3s, **AND** axes – labelled [ignore units here] **(1)**
Plots – accurate to ½ square **(1)**
Line – thin, straight, best fit **(1)** 6

(c) Large Δ ($\Delta x \Delta y \geq 80$ cm^2) [Allow if a tangent drawn to a curve] **(1)**
Correct calculation giving *n* in range –2.05 to –2.11 **(1)** 2

[16]

Sample results

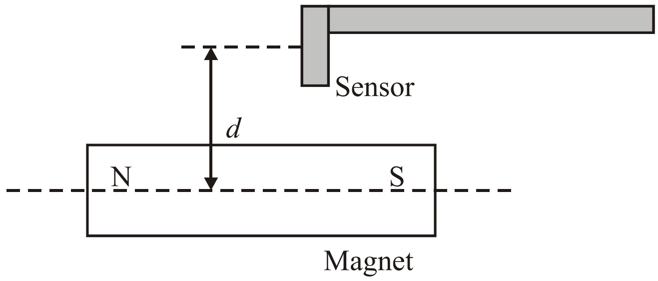
(a) (i)



Length of solenoid

Number of turns

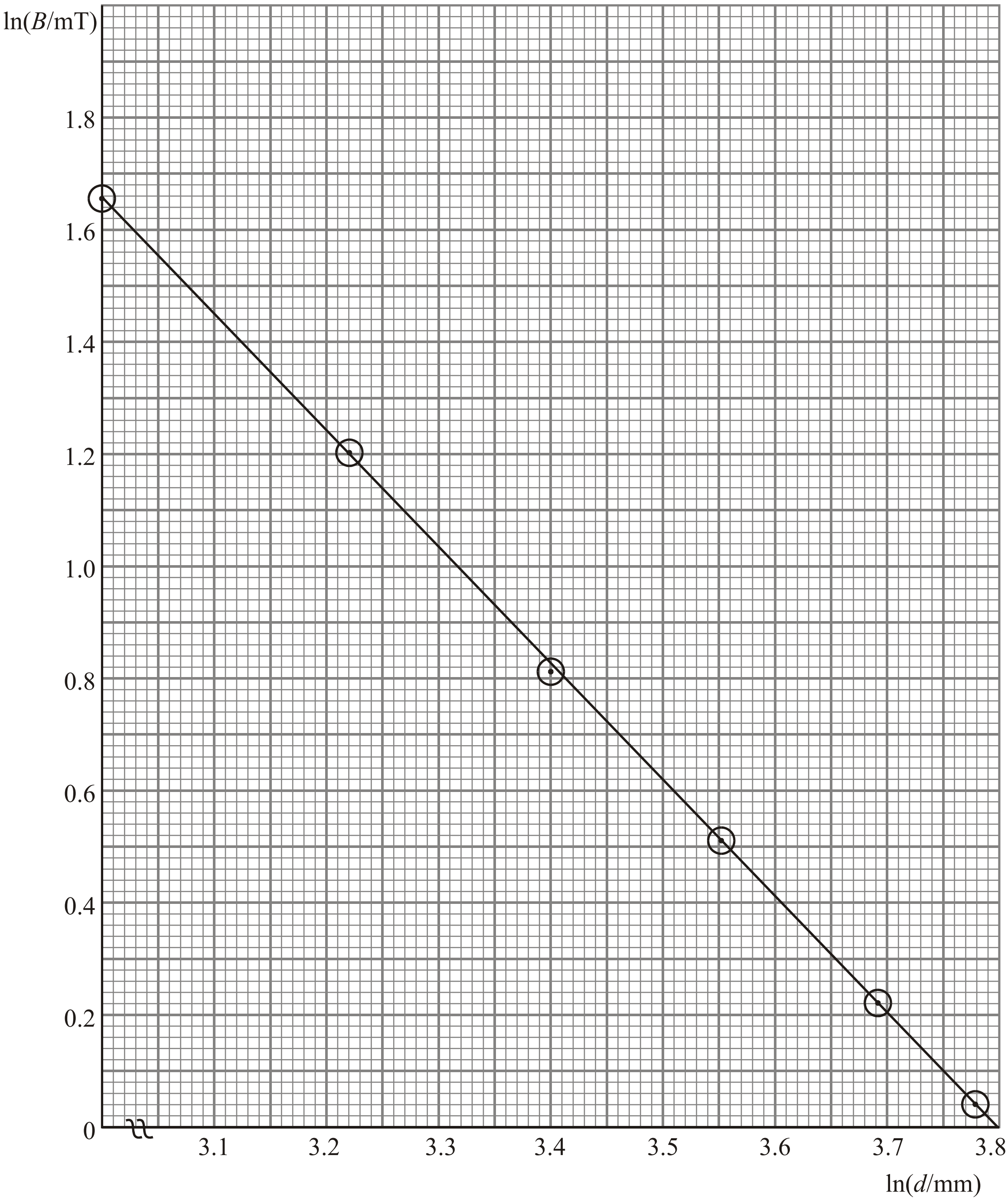
(ii)



(b) $\ln B = n \ln d + \ln k$
$y = mx + c$

B/mT	d/mm	ln(b/mT)		ln(d/mm)	
5.26	20	1.66	0.721	3.00	1.30
3.31	25	1.20	0.520	3.22	1.40
2.27	30	0.82	0.356	3.40	1.48
1.67	35	0.51	0.223	3.56	1.54
1.24	40	0.22	0.093	3.69	1.60
1.04	44	0.04	0.017	3.78	1.64

Graph:



(c) Gradient $= -\dfrac{1.67 - 0.00}{3.80 - 3.00}$

$n = -2.08$

123. (i) Calculation of equivalent capacitance

Use of $C_1 + C_2$ OR 4 μF **(1)**

(ii) Charge stored

EITHER	OR	
• Hence same voltage across 4 μF and parallel combination/12 V	• Combined capacitance $\frac{1}{C_1} + \frac{1}{C_2}$ / 2μF **(1)**	
• Use of $Q = VC$ (12 V × 4 μF)	• Use of $Q = VC$ (24 V × 2 μF) **(1)**	
• = 48 μC	• = 48 μC **(1)**	4

124. (a) (i) Definition of law

EITHER
Equation given and all symbols defined **(1)** **(1)**
[For each symbol incorrectly defined −1 mark; 3 incorrect get zero, not −1]
OR
Force proportional to product of masses **(1)**
Force inversely proportional to square of distance between the masses **(1)** — 2

(ii) Derivation

Set $mg = \frac{GMm}{r^2}$ hence $g = \frac{GM}{r^2}$ **(1)** — 1

(iii) Graph

Starting point [R, g] **(1)**

(R, g) and ($2R$, $\frac{g}{4}$) plotted **(1)**

($3R$, $\frac{g}{9}$) and ($4R$, $\frac{g}{16}$) ~ plotted **(1)** — 3

[Ignore the line joining origin to (R, g)]

(b) (i) Equipotential surface

Surface containing all points at the same (gravitational) potential (energy) **(1)** — 1

(b) (ii) Drawing of equipotential surfaces
Three concentric circles drawn **(1)**
Increasing separation **(1)** — 2

(c) Explanation
The weight / g must remain constant OR uniform gravitational field **(1)**
(For this to be true) changes in height must be small **(1)** — 2

[11]

125. (a) Direction of field lines

Downwards **(1)** 1

(b) (i) Calculation of force

Use of V/d i.e. 250 V/0.05 m [if 5 used mark still awarded] **(1)**

Use of $\frac{V}{d}$ e [Mark is for correct use of 1.6×10^{-19} C] **(1)**

$= 8.0 \times 10^{-16}$ N **(1)** 3

(ii) Direction and explanation

(Vertically) upwards / towards AB **(1)**

No (component of) force in the horizontal direction OR because **(1)** 2
(the force) does no work in the horizontal direction

(c) Calculation of p.d.

Use of $\Delta E_K = ½ mv^2$ / ½ 9.11×10^{-31} (kg) × $(1.3 \times 10^7)^2$ **(1)**

Use of Ve / $V \times 1.6 \times 10^{-19}$ (C) **(1)**

= 480 V **(1)** 3

(d) Beam of electrons

Diagram showing:

Spreading out from one point **(1)**
fastest electrons labelled **(1)**

2

[11]

126. (a) Investigation

Name or describe apparatus for measuring B, eg Hall probe/search coil (with pre–calibrated meter) **(1)**
Probe positioned so the B field is perpendicular to the Hall **(1)** slice/probe
Appropriate method for measuring r **perpendicular** to wire described or shown on diagram OR repeat readings for each r **(1)** OR keep current constant
Vary distance r and measure B (and r) each time OR reference to **(1)** graph plotting 4

(b) (i) Relationship shown by graph

(B) inversely proportional (to *r*) / *B* proportional to $^1/_r$ /Br = **(1)** constant 1

(ii) Finding *I*

Gradient measured / corresponding values of *B* and $^1/_r$ read from graph / 2.95 − 3.00 (10^{-7}) (T m) [Ignore incorrect powers of 10] **(1)**

Use of $B = \left(\frac{\mu I}{2\pi}\right)\frac{1}{r}$ ie $3 \times (10^{-7})\text{Tm} = \frac{\mu I}{2\pi}$ **(1)**

[Ignore incorrect powers of 10]
= I = 1.48 − 1.50 A **(1)** 3

[8]

127. Explanation

AC/changing current in the primary **(1)**

Produces a changing *B* field **(1)**

B field carried through core (to secondary) **(1)**

Changing *B* field over secondary induces emf **(1)**

Rate of change of flux linkage is less through secondary OR emf induced across sec. is less because it has less turns than primary OR explanation in terms of the turns ratio formula **(1)**

Quality of written communication **(1)** 6

[6]

128. (a) Sensible use of rule in contact with block or clamp **(1)**
and set square or pin **(1)**
Readings on both sides of mass or b + ½ diameter or uses slot **(1)**

Sensible l to 1 mm i.e. ‹ 880 mm or centre value **(1)**
± 0.02 s of Supervisor's from ≥ 30 T **(1) (1)**

$$\begin{pmatrix} \pm 0.02\text{s from} \geq 10T\,\mathbf{(1)} \\ \pm 0.03\text{s from} \geq 30T\,\mathbf{(1)} \end{pmatrix}$$

Repeat readings shown **(1)**
Fiducial marker (pin) at centre of oscillations [must be at centre] **(1)** 8
[Do not allow "eye level"]

(b) $w \pm 0.03$ cm of Supervisor's from ≥ 2 readings **(1) (1)**

$\begin{pmatrix} \pm 0.03 \text{ cm from 1 reading } \mathbf{(1)} \\ \pm 0.05 \text{ cm from} \geq 2 \text{ readings } \mathbf{(1)} \end{pmatrix}$

$t \pm 0.03$ cm of Supervisor's from ≥ 2 readings **(1) (1)**

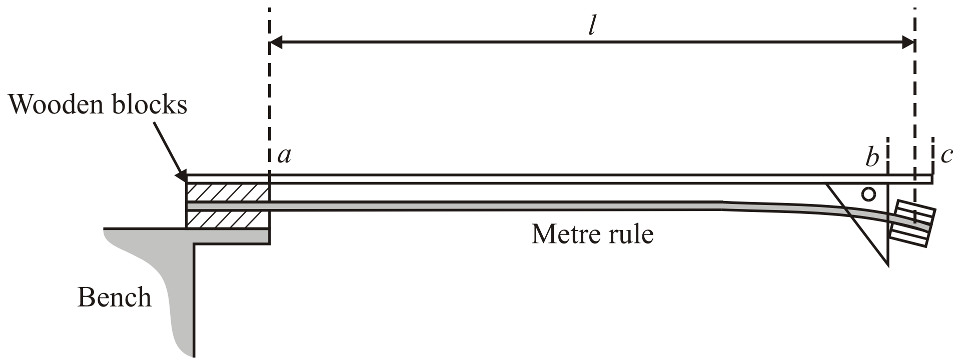
$\begin{pmatrix} \pm 0.03 \text{ cm from 1 reading } \mathbf{(1)} \\ \pm 0.05 \text{ cm from} \geq 2 \text{ readings } \mathbf{(1)} \end{pmatrix}$

[Readings to 0.1 mm, otherwise max 2/4]

(c) Consistent (for *l*, *w, t*) substitution [allow ecf] **(1)**
Correct calculation [dependent mark] **(1)**
Unit consistent with substitution **(1)**
Value in range $(0.5 \rightarrow 2.5) \times 10^{10}$ kg $m^{-1}s^{-2}$and 2 / 3 **(1)**
significant figures [No ue] 4

[16]

Sample results



Second metre rule and set square used as shown
$a = 90.0$ cm
$b = 5.5$ cm
$c = 0.2$ cm

$$l = 90.0 - \left(\frac{5.5 + 0.2}{2}\right) \text{ cm}$$

= 87.2 cm
20 T / s = 13.13, 13.00, 13.16
average $T = 0.655$ s
Repeat readings
Fiducial marker (pin) at centre of oscillations

(b) w / cm = 2.78, 2.82, 2.86
average $w = 2.82$ cm
t / cm = 0.64, 0.67, 0.66
average $t = 0.66$ cm

(c) $$E = \frac{16\pi^2 Ml^3}{T^2 wt^3}$$

$$= \frac{16\pi^2 \times 0.600 \times (0.872)^3}{(0.655)^2 \times 2.82 \times 10^{-2} \times \left(0.66 \times 10^{-2}\right)^3}$$

$= 1.8 \times 10^{10}$ kg m^{-1} s^{-2} [Pa]

129. (a) Table with units (allow x to whole cm), precision of V to **(1)**
0.1 V,

One value ‹ 2 cm **(1)**

Linear region in middle **(1)**

Steep fall detected by 14 cm or one value › 14 cm **(1)**

9 good points, [if *x* from wrong end –2 then ecf]

$\begin{pmatrix} \text{7 good points } \mathbf{(1)(1)} \\ \text{5 good points } \mathbf{(1)} \end{pmatrix}$ **(1) (1) (1)**

"Good" = ± 0.1 V from best fit curve 7

(b) Plots accurate to ½ square **(1)**
Good smooth curve **(1)** 2

(c) Sensible range [no extrapolation] from limits of linear **(1)**
region, with unit [based on examiner's line]

Base of triangle ≥ 10 cm **(1)**

Correct calculation [allow ecf wrong *x*] **(1)**

2 / 3 significant figures + unit [allow N C^{-1} if *x* in metres] **(1)** 4

(d) Correct pattern with no lines crossing. Must be some **(1)**
curved lines beyond each charge and ≥ 5 "parallel" lines,
allow lines not reaching charges

Arrows in correct direction and on virtually all lines **(1)**

Regions where lines are approximately parallel marked and
equi-spaced [can get this mark if draw equipotentials] **(1)** 3

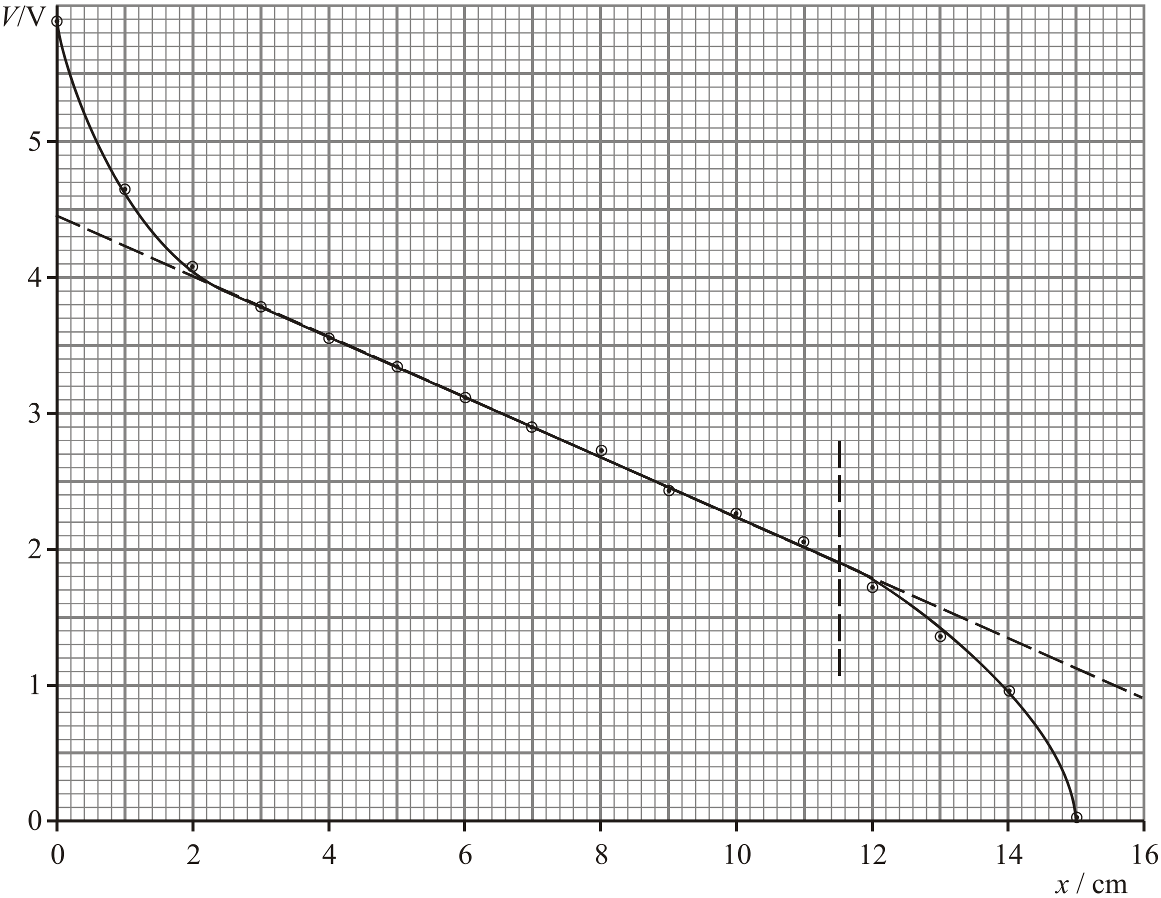
[16]

Sample results

(a) *V* = 2.74 V

x / cm	*V* / V	*x* / cm	*V* / V
0.0	5.88	8.0	2.74
1.0	4.64	9.0	2.43
2.0	4.07	10.0	2.26
3.0	3.75	11.0	2.06
4.0	3.56	12.0	1.68
5.0	3.34	13.0	1.34
6.0	3.13	14.0	0.93
7.0	2.88	15.0	0.00

(b) Graph

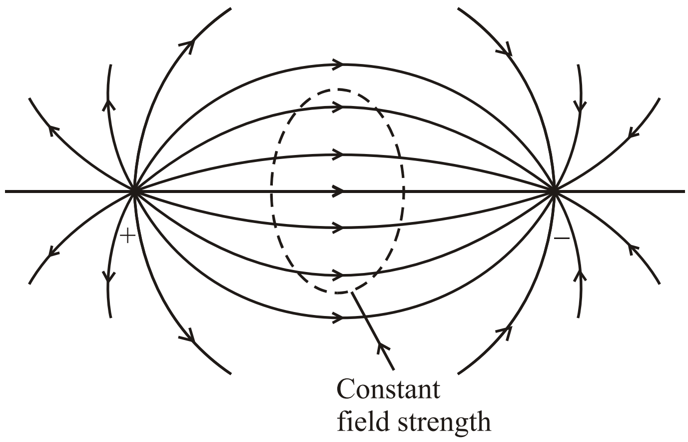


(c) Range of x 3.0 – 11.5 cm

$$E = -\left(\frac{4.43 - 0.90}{0.16 - 0.00}\right)$$

$$= -22 \text{ V m}^{-1} \ (-0.22 \text{ V cm}^{-1})$$

(d)



130. (a) (i) T = 2 ms **(1)**
f = 500 Hz + unit **(1)**
[ecf on T]

(ii) (6.5 → 7.0) V + unit [allow 1 significant figure] **(1)** 3

(b) Correct series circuit **(1)**
CRO across coil or resistor **(1)**
[CRO in series 0 / 2]
Vary frequency f **(1)**)
Find f <u>from</u> CRO or scale of signal generator **(1)**)
Measure V across coil [stated or seen] with CRO between)
A and B **(1)**)
Determine current by finding V across 10 Ω resistor with) Max 5
CRO between BC and using $I = V / 10\ \Omega$ **(1)**)
Calculate Z from V_c / I_c [accept V_c / I] **(1)**)
Plot Z^2 against f^2 **(1)**) 7

(c) (i) f^2 and Z^2 values correct to 2 to 4 significant figures (ignore units) **(1)**

Graph

Scale: at least ½ grid in both directions, avoiding awkward scales, e.g. 3's etc **(1)**
Axes: labelled with correct units **(1)**
Plots & line: Plots accurate to ½ square and thin, straight line **(1)** 4
[Allow ecf for incorrect graphs]

(ii) Intercept read off correctly [ecf incorrect graph] **(1)**
$R = 5.5 \rightarrow 5.8\ \Omega$ to 2 significant figures + unit [from correct graph] **(1)** 2

[16]

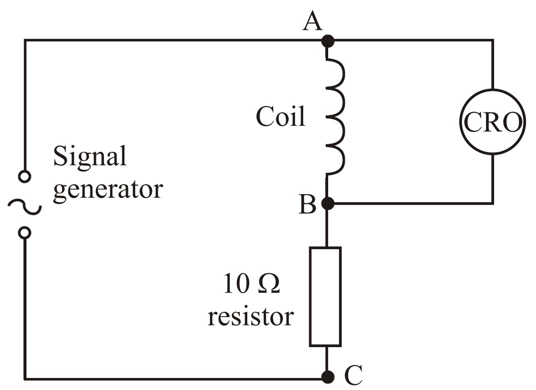
Sample results

(a) (i) $1\lambda = 4$ div $= 4 \times 0.5 = 2.0$ ms

$$f = \frac{1}{2 \times 10^{-3}}$$
$$= 500 \text{ Hz}$$

(ii) Peak = 1.4 div × 5 V/div
$V_0 = 7.0$ V

(b)

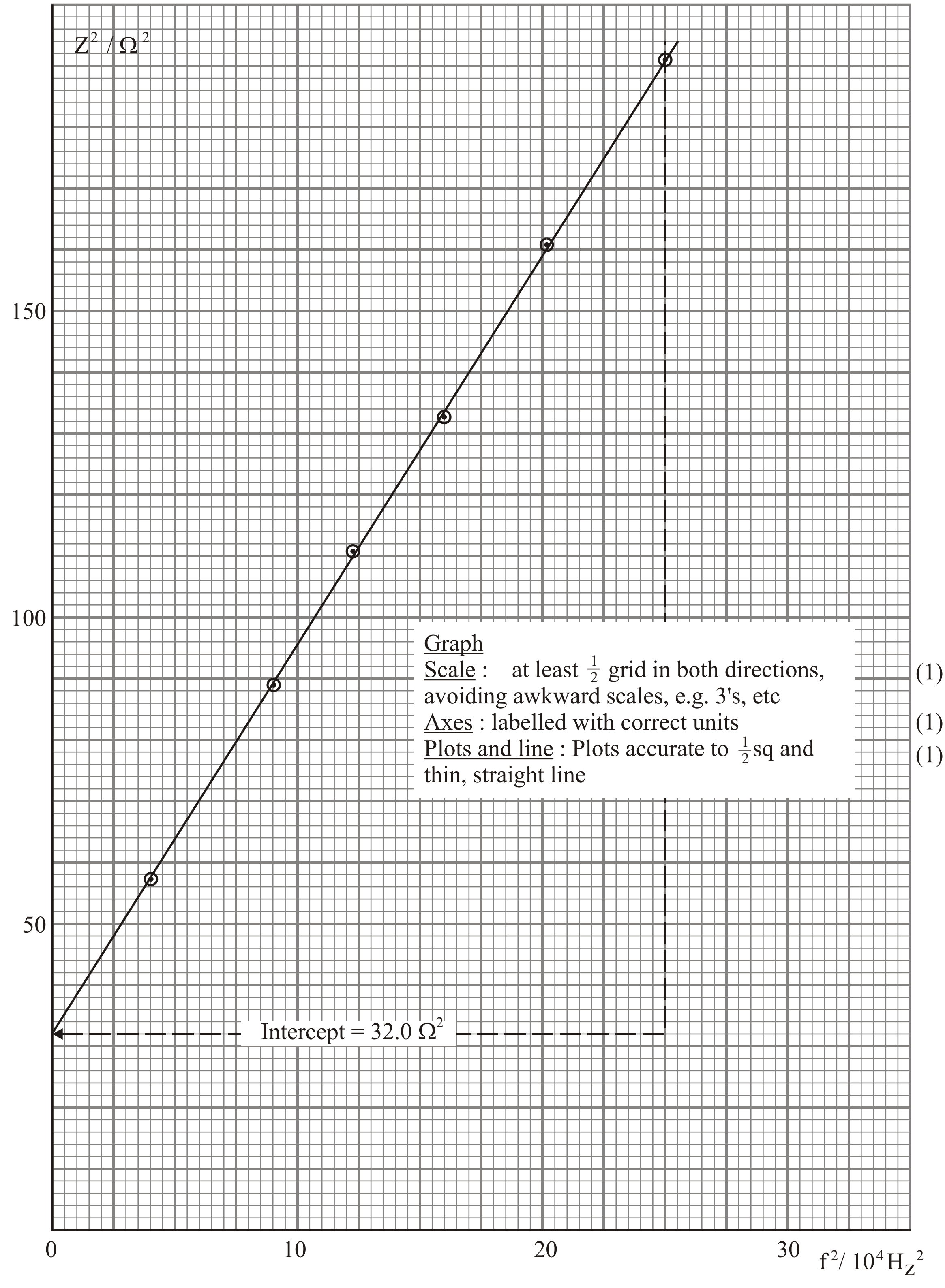


Vary frequency f
Find f from CRO or scale of signal generator
Measure V across coil with CRO between A and B
Determine current by finding V across 10 Ω resistor with
CRO between BC and using $I = V / 10\ \Omega$
Calculate Z
Plot Z^2 against f^2

(c) (i)

f^2 / 10^4 Hz^2	Z^2 / Ω^2
4.00	56.3
9.00	88.4
12.25	110.3
16.00	132.3
20.25	161.3
25.00	190.4

Graph



(ii) Intercept on $Z^2 = 32\ \Omega^2$

$R = \sqrt{32} = 5.7\ \Omega$

131. (a) l correctly found to mm or better from average of l_1 and l_2 [shown] **(1)**
Checked that separation of threads at top was also 40.0 cm **(1)**
± 0.03 s of Supervisor's value from ≥ 30T **(1) (1)**

$$\begin{pmatrix} \pm 0.03\text{s from} \geq 10T\textbf{(1)} \\ \pm 0.05\text{s from} \geq 30T\textbf{(1)} \end{pmatrix}$$

[0/2 if T to nearest second]
[0/2 if T not shown i.e. 20T]

Repeat readings [shown] **(1)**
Use of fiducial mark (pin) at centre of oscillations [must be at centre] **(1)** 6

(b) Correct diagram of arrangement **(1)**
Distances shown clearly to centres of mass **(1)**
All positions recorded to mm or better from diagram or below **(1)**
Long lengths used (both › 8 cm) or repeats shown **(1)**
Any good technique for centre of 50 g mass **(1)**
Correct calculation 2 / 3 significant figures + unit **(1)** [Max 5]
Value ± 2 g of Supervisor's value **(1) (1)**
[± 4 g → **(1)**] 7

(c) Correct S.I. substitution **(1)**
Correct calculation **(1)**
Unit **(1)** 3

[16]

Sample results

(a) l_1 = 49.0 cm, l_2 = 49.0 cm ⇒ l = 49.0 cm

Checked that separation of threads at top was also 40.0 cm

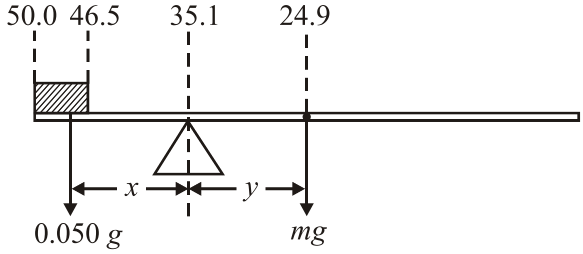
20T / s: 20.03, 20.13, 19.96

average T = 1.00 s

Repeat readings

Use of a fiducial mark (pin) at centre of oscillations

(b) Scale readings at centre of mass = 24.9 cm



$$x = \left[\frac{50.0 + 46.5}{2}\right] - 35.1 \text{ cm}$$

$= 13.15$ cm

$y = 35.1 - 24.9 = 10.2$ cm

$mgy = 0.050gx$

$$m = \frac{0.050 \times 13.15}{10.2}$$

$= 0.0645$ kg (64.5 g)

(c) $$I = \frac{0.0645 \times 9.81 \times (0.400)^2 \times (1.00)^2}{16\pi^2 \times 0.490}$$

$= 1.31 \times 10^{-3}$ kg m^2

132. (a) Table with units **(1)**
One value ‹ 1.0 cm **(1)**
Gently sloping curve **(1)**
One value › 7.0 cm **(1)**
9 good values **(1) (1) (1)**

$\left(\begin{array}{l}\text{7 good values} \rightarrow \textbf{(1)(1)} \\ \text{5 good values} \rightarrow \textbf{(1)}\end{array}\right)$

"Good" = ± 0.1 V from best fit curve 7

(b) Plots (accurate to ½ square) **(1)**
Good, smooth curve **(1)** 2

(c) Good tangents at correct points **(1)**
Base of triangle's at least 6 cm **(1)**
Correct calculations **(1)**
2 / 3 significant figures + unit **(1)** 4

(d) $E = k / d$
Correct ratio expected (2.00 or 0.50) Or correct k values calculated **(1)**
Percentage difference correctly calculated with 2.00 (or 0.50) as denominator Or percentage difference for k with mean as denominator **(1)**
Sensible comment based on any one source of error Or reference to 10% experimental error **(1)** 3

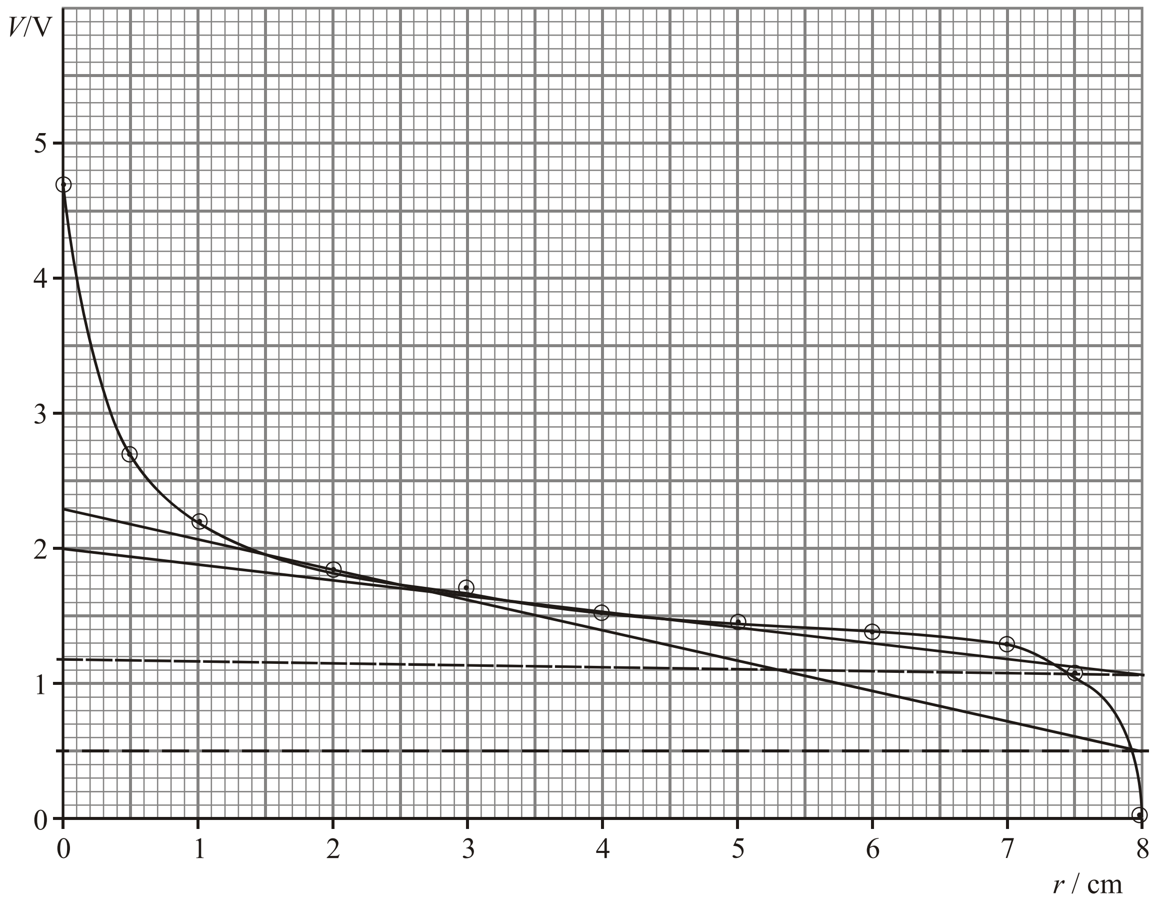
[16]

Sample results

(a) V = 1.52 V

r / cm	V / V	r / cm	V / V
0.0	4.65	6.0	1.37
1.0	2.20	7.0	1.27
2.0	1.88	8.0	0.00
3.0	1.68	Supplementary	
4.0	1.52	0.5	2.7
5.0	1.44	7.5	1.1

(b) Graph



(c) $E_2 = -\dfrac{2.30 - 0.50}{0.08}$

$= \underline{-22.5\ \text{V m}^{-1}}\ (-0.225\ \text{V cm}^{-1})$

$E_4 = -\dfrac{2.00 - 1.16}{0.08}$

$= \underline{-10.5\ \text{V m}^{-1}}\ (-0.105\ \text{V cm}^{-1})$

(d) If $E \propto 1 / d$

would expect $\frac{E_2}{E_4} = 2.00$

Experimentally $\frac{E_2}{E_4} = \frac{-22.5}{-10.5} = 2.14$

Percentage difference = $\frac{2.14 - 2.00}{2.00} \times 100$

= 7%

This is probably in the order of experimental error from size of electrode, *r*, measurements and difficulty in drawing tangents, so suggestion is supported.

133. (a) (i) $T = 4$ ms **(1)**
$f = 250$ Hz + unit [ecf on T] **(1)**

(ii) (2.6 → 2.8) V + unit **(1)** — 3

(b) Correct series circuit **(1)**
CRO across capacitor <u>or</u> resistor **(1)**
[CRO in series 0 / 2]

Vary frequency f **(1)**)
Find f from scale of signal generator or CRO **(1)**)
Measure V across capacitor with CRO connected between A and B **(1)**)
Determine current by finding V across 100 Ω resistor with CRO between B and C using $I = \frac{V}{100\Omega}$ **(1)**) Max 5
Calculate X from V_c / I_c **(1)**)
Plot X against $1/f$ **(1)**)
[or $1/X$ against f; ln X against ln f] — 7

(c) (i) $1 / f$ values (or $1/X$; ln) correct to 2 to 4 significant figures (ignore units) **(1)**
<u>Graph</u>
Scale: at least ½ grid in both directions, avoiding awkward **(1)** scales, eg 3's etc.
Axes: labelled with correct units **(1)**
Plots & line: plots accurate to ½ square and thin, straight line **(1)** — 4

(ii) Comment on origin and straight line **(1)**
Suitable deduction **(1)**
<u>Or</u>
For log log graph straight line of slope = − 1 **(1)**
Slope value found **(1)** — 2

[16]

Sample results

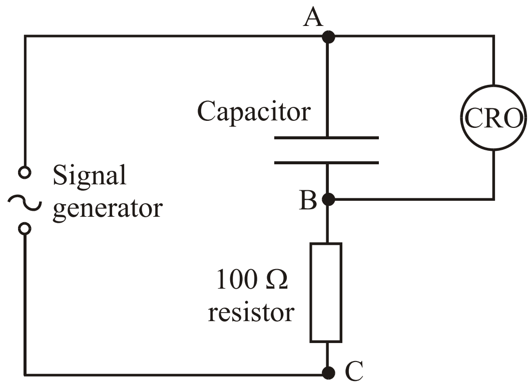
(a) (i) $1\lambda = 4$ div $= 4 \times 1$ ms $= 4$ ms

$f = \frac{1}{4 \times 10^{-3}}$

= <u>250 Hz</u>

(ii) $V_0 = 1.4$ div × 2 V/div = <u>2.8 V</u>

(b)



Vary frequency f
Find f from scale of signal generator or CRO
Measure V across capacitor with CRO connected between A and B

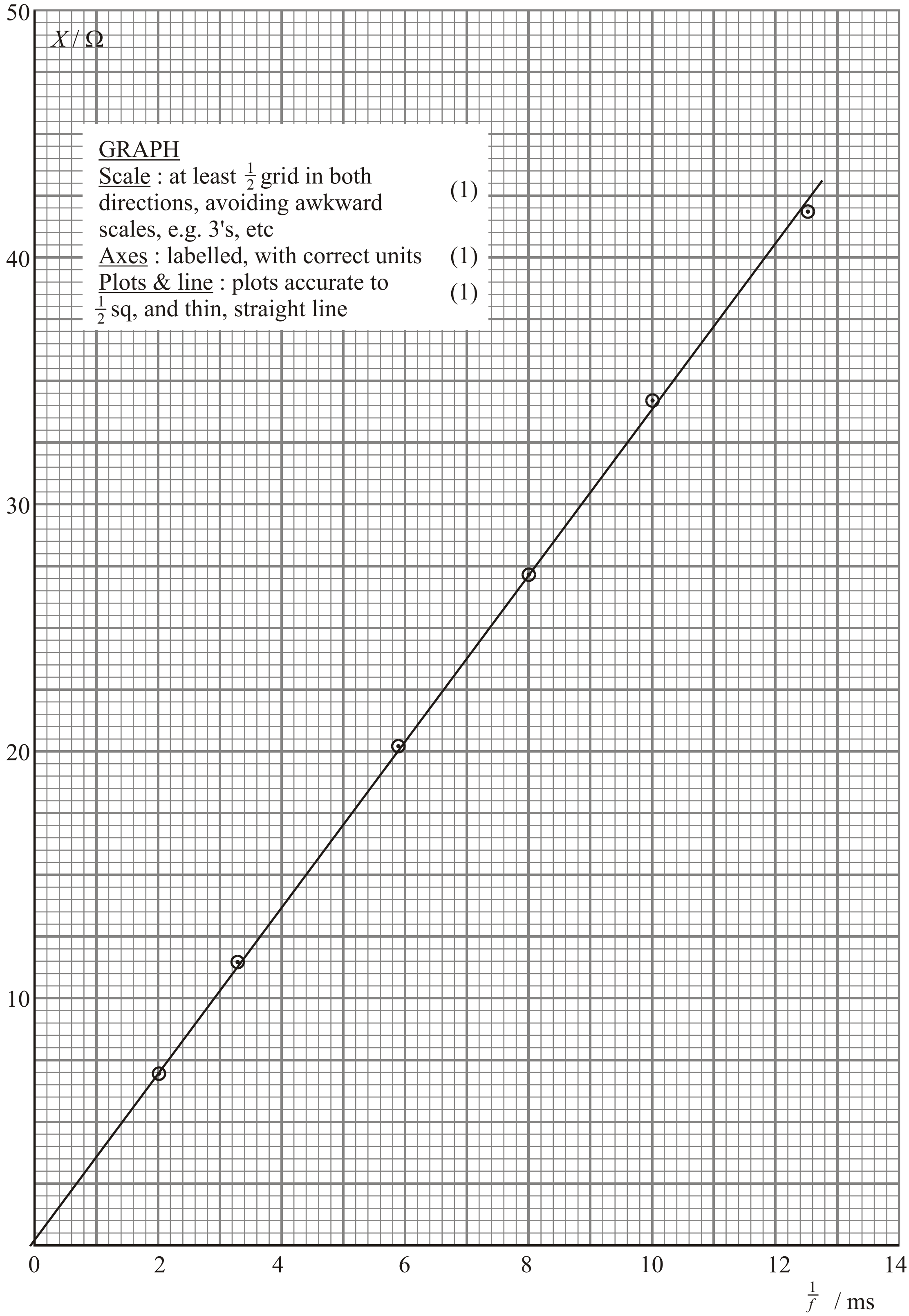
Determine current by finding V across 100 Ω resistor with CRO between B and C and using $I = \dfrac{V}{100\Omega}$

Calculate X
Plot X against $1/f$
[or $1/X$ against f ; $\ln X$ against $\ln f$]

(c) (i)

$1/X$ / kΩ^{-1}	$1/f$ / ms
23.9	12.5
29.1	10.0
36.9	8.0
49.8	5.9
87.7	3.3
147.1	2.0

(ii) The graph is a straight line with a very small intercept which could easily be a small systematic error, suggesting the relationship is confirmed.



134. (a) <u>Formula in words</u>

(The force between two charged particles is directly) proportional to the **product** of their charges [plural] and **(1)**

inversely proportional to the square of their separation [not just 'radius']. **(1)**

<u>OR</u> Either equation for F*, with valid word replacements for Q_1, Q_2 **(1)**
and r or r^2 symbols. One mark for numerator, one for denominator. **(1)**

$$\left[\text{* i.e. words in F} = \frac{kQ_1Q_2}{r^2} \text{ or in } \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2} \right]$$

[If equation given in symbol form, followed by a key to the symbol meanings, then 1/2.] 2

(b) <u>Base units of constant</u>

[Either k or $(4\pi)\varepsilon_0$, be sure which]
[ecf from part a if power of Q or r wrong]

$F = \frac{kQ_1Q_2}{r^2}$ **or** $F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$ [OR using k units N m^2 C^{-2}]

Q_1Q_2 (*or* C^2) → A^2s^2 **(1)**

F (*or* N) → kg m s^{-2} **(1)**
→ (units of) k = kg m^3 A^{-2} s^{-4} OR (units of) ε_0 = kg^{-1} m^{-3} A^2 s^4 **(1)**

OR using ε_0 units F m^{-1}:

C = As **and** either F = CV^{-1} or V = JC^{-1} **(1)**
J = kg m^2 s^{-2} or N = kg m s^{-2} **(1)**

→ (units of) ε_0 = kg^{-1} m^{-3} A^2 s^4 **(1)** 3

[5]

135. (a) (i) <u>Direction of current</u>
Into (paper) [not just 'down'] **(1)** 1

(ii) <u>Feature</u>

(Field lines are) circular / circles / rings / constant radius idea / no distortion **(1)** 1

[Accept circles are uniform – the no distortion idea – but **not** uniform field or 'uniform spacing']

(b) Explanation of observation

At the point concerned [stated or implied], the two fields are:

Equal (in magnitude / size / strength) [not simply ‘same’] **(1)**

Opposite (in direction) [not simply ‘opposing’.
Accept field directions cancel out] **(1)**

[For **just** saying it is a neutral point, 1 mark only of these 2.]

Current in second wire is in the same direction as that in L **(1)** 3
OR the point (in question) is mid-way between / equidistant
from the two wires OR the field around the second wire is clockwise

[5]

136. (a) Electron speed

Substitution of electronic charge and 5000V in eV **(1)**
Substitution of electron mass in $\frac{1}{2} mv^2$ **(1)**

Correct answer [4.2 (4.19) × 10^7 (m s^{-1}), no ue] to at least 2 sf **(1)** 3
[Bald answer scores zero, reverse working can score 2/3 only]

Example of answer:
$v^2 = (2 \times 1.6 \times 10^{-19}\text{C} \times 5000\text{ V})/(9.11 \times 10^{-31}\text{ kg}) = 1.76 \times 10^{15}$
$v = 4.19 \times 10^7\text{ m s}^{-1}$

(b) (i) Value of E

Correct answer [2.80×10^4 V m^{-1}/N C^{-1} or 2.80×10^2 V cm^{-1}] **(1)** 1

Example of answer:
$E = V/d = 1400\text{ V} / 5.0 \times 10^{-2}$
$= 28\,000\text{ V m}^{-1}$

(ii) Value of force F
Correct answer [4.5×10^{-15} N, ecf for their E] **(1)** 1

Example of answer:
$F = Ee = 2.80 \times 10^4\text{ V m}^{-1} \times 1.6 \times 10^{-19}\text{ C}$
$= 4.48 \times 10^{-15}\text{N}$

(c) Calculation *of h* 4

See a = their F / 9.11 × 10^{-31} kg **(1)**
[→ $a = 4.9 \times 10^{15}$ m s^{-2}]

See t = 12 (× 10^{-2}) m / 4 × 10^7 m s^{-1} (or use 4.2 × 10^7 m s^{-1}) **(1)**
[$t = d/v$, with d = plate length; 12 cm]
[→ $t = 3.0 \times 10^{-9}$ s, or 2.86 × 10^{-9} s]

See substitution of a and t values [**arrived at by above methods**] into ½ at^2 **(1)**

Correct answer [h = 0.020 m – 0.022 m] **(1)**

[Full ecf for their value of F **if** methods for a and t correct **and** their $h \leq 5.0$cm]

Example of answer:
$h = ½\, a\, t^2$
$= ½ \times 4.9 \times 10^{15}$ m $s^{-2} \times (2.86 \times 10^{-9}$ s$)^2$
$= 2.0 \times 10^{-2}$ m

(d) (i) Path A of electron beam
Less curved than original **(1)** 1

(ii) Path B of electron beam
More curved than original, curve starting as beam enters field [started by H of the Horizontal plate label] **(1)** 1

[For **both** curves:
- ignore any curvature beyond plates after exit
- new path must be same as original up to plates]

[No marks if lines not identified, OK if either one is labelled]

[11]

137. (a) Newton's law

Equation route:

$$F = \frac{GM_1M_2}{R^2} \quad \textbf{(1)}$$

M_1, M_2, R defined correctly, G defined correctly or not defined **(1)**
[Both marks can be awarded for word equation]

OR Proportion route:
(force is directly) proportional to the **product** of the masses [plural] and

inversely proportional to the square of their separation [not just 'radius', unless related to orbital motion] **(1)** 2

(b) (i) Graph

Take two pairs of values off graph **(1)**

A). Find gR^2 for one pair [$\approx 400\ (\times 10^{12})$]

Attempt to show $gR^2 \approx$ same for second pair **(1)**
(within uncertainty limits of data read from graph) **(1)**

OR B). Compare pairs of values to show that as *R* changes by a factor n, *g* changes by a factor $1/n^2$. **(1) (1)**

OR C). Substitute into formula with one pair to give a value of M or some other constant. **(1)**

Repeat with second pair to give same value OR substitute back to confirm agreement of second pair of values. **(1)** 3

(ii) Gravitational field strength
Valid approach via routes A, B or C above. **(1)**
$g = 0.0027 – 0.0031\ \text{N kg}^{-1}$ **(1)** 2

Example of answer:
$g \times 380^2 = 400 \rightarrow g = 400/\ 380^2 = 0.00277\ \text{N kg}^{-1}$

(c) Effect
Maintains the Moon in orbit around the Earth / keeps Moon **(1)** rotating around the Earth / provides (**all** the) centripetal **(1)** force/acceleration for its circular motion / pulls Moon towards Earth. [**not** just exerts force on the Moon] 1

[8]

138. (a) (i) Additional force
Correct answer [3.9×10^{-3} N] **(1)** 1
Example of answer:
$0.4 \times 10^{-3}\ \text{kg} \times 9.81\ \text{N kg}^{-1} = 4 \times 10^{-3}\ \text{N}$

(ii) Explanation
Quality of written communication **(1)**
(Current produces) a magnetic field around the **rod (1)**
[Do not accept in the rod]

There is an interaction between the two magnetic fields / fields combine to give catapult field **(1)**

Fleming's Left Hand Rule/ Fleming's Motor Rule **(1)**
The rod experiences an upward force **(1)**

Using Newton 3 → downward force on magnet Max 4

(b) (i) Diagram
Lower pole labelled North/N and upper pole labelled South/S **(1)** 1

(ii) Calculation of current in rod
Use of $F = BIl$. (Ignore 10^x. *F* is their force and *l* is 5cm) **(1)**
See conversions; mT to T and cm to m **(1)**
Correct answer [2.6/2.7 A] **(1)** 3

Example of answer:
$I = 3.9 \times 10^{-3}\ \text{N} / (30 \times 10^{-3}\ \text{T} \times 5 \times 10^{-2}\ \text{m}) = 2.6\ \text{A}$

(iii) New reading on the balance
Value < 85g [not a negative value] **(1)**
84.6 g **(1)** 2

[11]

139. (a) (i) ± 1 mm from accepted values & to mm precision (or better) **(1)**
Repeats of both **(1)**
Correct calculation 2/3 s.f. + unit [Allow ecf] **(1)** 3

(ii) Folded thickness ≥ 8t **(1)**
Repeat or zero error **(1)**
Value 0.090 – 0.110 mm to 0.01 mm precision or better **(1)**
Correct calculation 2/3 s.f. + unit [ecf] **(1)** 4

(b) (i) (1.5 s → 2.5 s) sensible value from ≥ 15T + unit **(1)** **(1)**
[from ≥ 10T only **(1)**]

$$\left[\begin{array}{l}\text{If} \neq T \rightarrow 0\\ \underline{\text{Or}}\\ \text{Counting oscillations in fixed time} \rightarrow 0\\ \text{If time not recorded to 0.1 s or better} \rightarrow (\text{-}1)\\ (\text{but no s.f. penalty for } T)\end{array}\right]$$

(ii) $T_2 > T_1$ from > 15T + unit **(1)** 3
[from > 10T only **(1)**] [ecf if ≠ T] **(1)** **(1)** 2
[only penalise units once in (i) and (ii)]

(iii) Both values recorded to mm precision, ± 2 mm of stated values + unit **(1)**
Both calculated correctly to 2/3 s.f. [ecf] **(1)**
Valid comparison (i.e. 10% in T_2/T_1) **(1)**
Sensible comment **(1)**
Or
Percentage difference using 1.63 as denominator **(1)**
Compared with 10% for T_2/T_1 **(1)** 4

[16]

Sample results

(a) (i) l = 297mm, 297mm Av. = 297 mm
w = 210 mm, 210 mm Av. = 210 mm
mass = 80 × 0.297 × 0.210 g
= 5.0 g

16t/mm: 1.57, 1.58, 1.57
$\overline{t}$ = 0.098 mm (9.8 × 10^{-5} m)

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{5.0 \times 10^{-3}\,\text{kg}}{9.8 \times 10^{-5} \times 0.297 \times 0.210\ \text{m}^3}$$

= 8.2×10^2 kg m^{-3}) $\left[\dfrac{80 \times 10^{-3}\,\text{kg m}^{-2}}{9.8 \times 10^{-5}\,\text{m}}\right]$

(b) (i) 10 T_1/s: 20.53, 20.61

$\overline{T_1}$ = 2.06 s

Pin was placed at <u>centre</u> of oscillations

$10T_2$/s: 38.86, 38.79

$\overline{T_2}$ = 3.88 s

(iii) l_1 = 480 mm

l_2 = 780 mm

T_2 / T_1 = 3.88 / 2.06 = 1.88

l_2 / l_1 = 780/480 = 1.63

Smallest feasible T_2 / T_1 = 0.90 × 1.88 = 1.69

As this is still more than 1.63, the data suggests the relationship is not valid.
<u>Or</u>
Percentage difference = $\frac{1.88 - 1.63}{1.63} \times 100\%$ = 15.3%
which is > 10% in T_2/T_1

140. (a) Circuit set up correctly without help **(2)** 2

(b) (i) Units for X and V [seen anywhere] **(1)**

5 good values (± 0.01 V of examiner's best line) **(1)**
[4 good values + units only **(1)**]

(ii) <u>Graph</u>
Plots – accurate to ½ square **(1)**
Lines – both thin, straight and best fit **(1)**

(iii) 5 good values (± 0.01 V of examiner's best line) **(2)**
[4 good values only **(1)**]
[Allow point(s) off end of voltage scale]

(iv) Read off correctly, 0.66 – 0.71 m + unit **(1)** 7

(c) Both triangle's large [m_X base ≥ 6 cm, m_Y base ≥ 4 cm] **(1)**
m_X correctly calculated to > 2 s.f. **(1)**
m_Y correctly calculated to > 2 s.f. [No units required] **(1)** 3

(d) Ratio correctly calculated to > 2s.f. [ecf] **(1)**
Correct percentage difference with 0.360 as denominator **(1)**
Sensible comment based on percentage difference **(1)**

With reference to experimental error <u>or</u> sensible estimate of experimental error e.g. error in V or gradient **(1)** 4

[16]

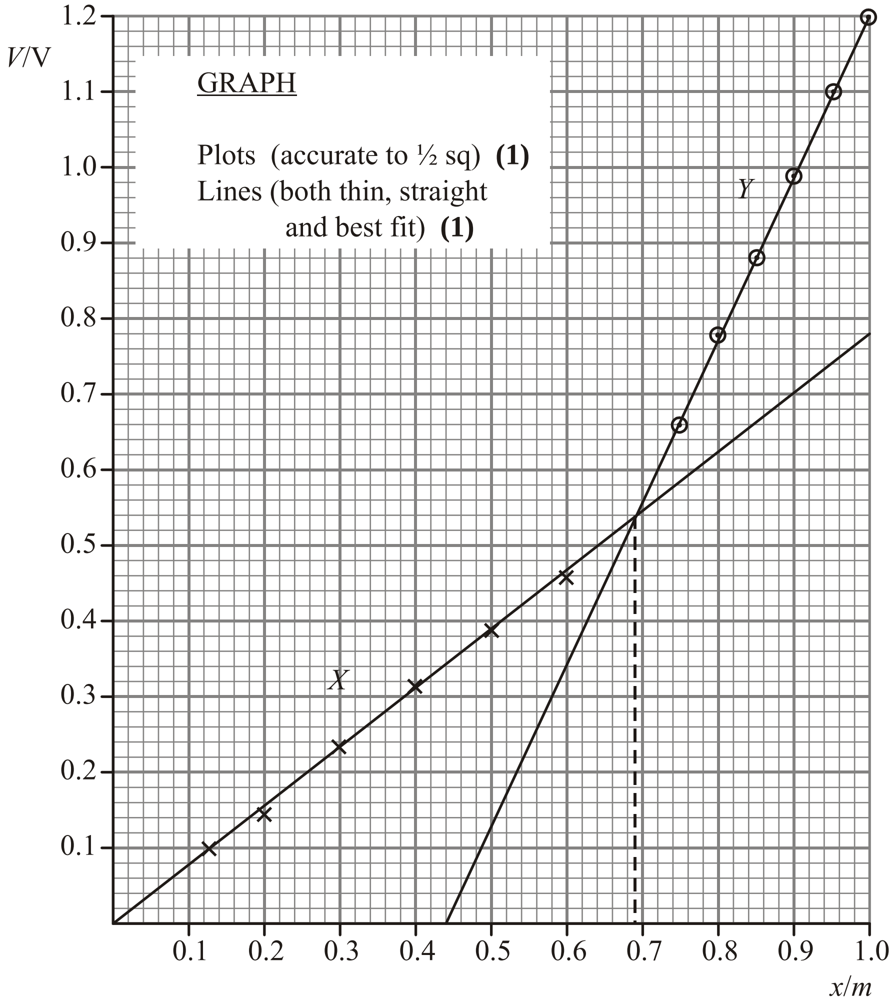
Sample results

(a) x = 0.500 m
V = 0.39 V

(b) (i)

AB	x/m	**V/V**
	0.100	0.08
	0.200	0.15
	0.300	0.23
	0.400	0.31
	0.500	0.39
	0.600	0.46
	0.680	0.52

(ii)



(iii)

BC	*x*/m	**V/V**
	0.750	0.66
	0.800	0.78
	0.850	0.88
	0.900	0.99
	0.950	1.10
	1.000	1.20

(iv) $x = 0.68(5)$ m

$$m_X = \frac{0.78 - 0.00}{1.00 - 0.44} = 0.78 \text{ V m}^{-1}$$

$$m_Y = \frac{1.20 - 0.00}{1.00 - 0.44} = 2.14 \text{ V m}^{-1}$$

(d) $\frac{m_X}{m_Y} = \frac{0.78}{2.14} = 0.36(4)$

$$\text{Percentage difference} = \frac{0.364 - 0.360}{0.360} \times 100$$

= <u>1%</u>

This is acceptable experimental error, suggesting the results support the suggestion.

141. (a) (i) Geiger-Muller tube <u>must be labelled</u> **(1)**

Level and ≤ 1 cm away [between ‘g’ and ‘e’ of ‘arrangement’] **(1)**

Counter, ratemeter or scaler <u>must be labelled</u>

[<u>Or</u> G-M tube **(1)**, Close **(1)** and Interface + computer (or datalogger) **(1)**] 3

(ii) Well-away from other sources/sample and <u>NOT</u> in several places **(1)**

Record for at least 3 minutes **(1)b** 2

(iii) Suitable time interval (5 s → 20 s) for ≥ 2 minutes **(1)** 2

(iv) Correct arrangement into y = mx + c [need not relate to **(1)** y = mx + c] 1

(b) Corrected count rate & ln*A* to ≥ 3 s.f. **(1) (1)**

<u>Graph</u>
Scale at least ½ graph paper in each direction, avoiding awkward scales such as 3’s **(1)**

Axes: labelled with units, must have $\ln(A/\text{min}^{-1})$ **(1)**

Plots: accurate to ½ square **(1)**

Line: straight thin & best fit **(1)** 5

(c) Large triangle [base ≥ 8 cm] **(1)**

Correct calculation of $\lambda \geq 2$ s.f. [ignore unit] **(1)**

69 – 73 s with unit and 2 s.f. [No ecf] **(1)** 3

<u>If A v t plotted</u>

$3 \times \frac{1}{2}$ lives read off correctly (69 – 73 s), with unit **(1) (1)**

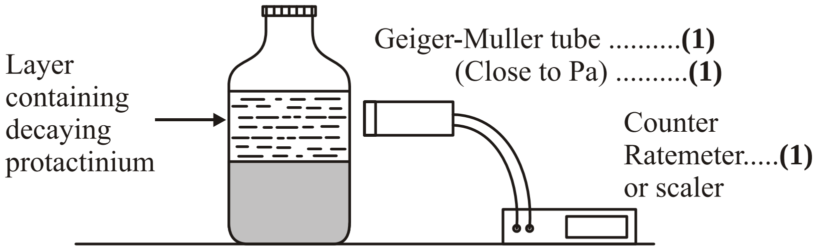
[$2 \times \frac{1}{2}$ lives only **(1)**

Hence λ calculated [ignore unit] to 2 s.f. **(1)**

[16]

Sample results

(a) (i)



(ii) Keep G-M tube well away from all radioactive sources (or Pa sample) and record count for 5 minutes to determine the average count rate. Subtract this from subsequent count rates.

(iii) Record readings from ratemeter every 15 s for about 5 mins
<u>Or</u>
Diagram interface to integrate for 3 s and find count rate for a duration of 5 minutes.

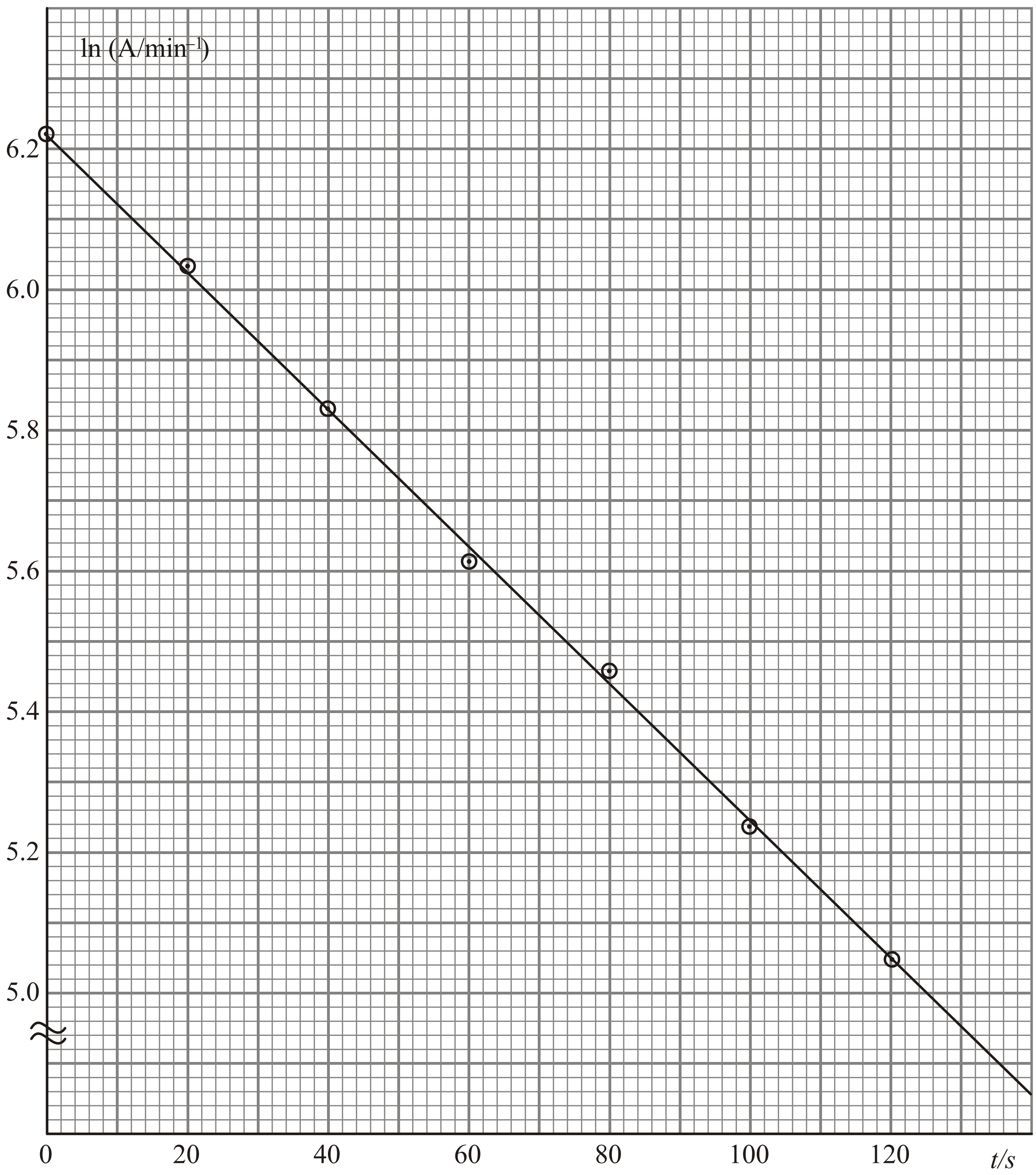
(iv) $A = A_0 e^{-\lambda t}$

$\ln A = -\lambda t + \ln A_0$

y = mx + c

(b)

Corrected count rate / min^{-1}	$\ln(A/\text{min}^{-1})$
500	6.21
420	6.04
340	5.83
273	5.61
235	5.46
189	5.24
156	5.05



(c) $\lambda = -\text{ gradient} = \dfrac{6.22 - 5.00}{126 - 0}\ \text{s}^{-1}$

$= 9.68 \times 10^{-3}\ \text{s}^{-1}$

$t_{½} = \dfrac{0.69}{9.68 \times 10^{-3}}\ \text{s}$

$=$ <u>71 s</u>

142. (a) (i) ± 1 mm from accepted values & to mm precision (or better) **(1)**
Repeats of both **(1)**
Correct calculation to give value in g m^{-2} [Allow ecf] **(1)**
2/3 s.f. **(1)** 4

(ii) Use a micrometer screw gauge **(1)**
Fold the paper to measure
several thicknesses/ use several sheets **(1)**

Exclude air
Measure in <u>several places</u> } **Any one** 3
Check zero error

(b) (i) Sensible value with unit from ≥ 15T **(1) (1)**
[from > 10Tonly **(1)**] [No s.f. penalty on T]
[Counts no. of oscillations in fixed time 0/2]

Placed pin at <u>centre</u> of oscillations **(1)** 3

(ii) $T_2 < T_1$ from > 15T **(1) (1)**
[from ≥ 10T only **(1)**] 2

(iii) Calculated as a decimal or percentage to 2/3 s.f. & NO unit **(1)**

Sensible ΔnT rangeM range <u>or</u> 0.50 – 0.10 s human error
[whichever is larger] **(1)**

Correct percentages **(1)**

<u>Add</u> to get percentage of ratio [Allow ecf] **(1)** 4

[16]

Sample results

(a) (i) l = 297mm, 297 mm Av. = 297 mm
w = 210 mm, 210 mm Av. = 210 mm
m = 5.02 g

$$\frac{\text{mass}}{\text{area}} = \frac{5.02\text{ g}}{0.297\text{ m} \times 0.210\text{ m}} = \underline{80.5\text{ g m}^{-2}}$$

(b) (i) $10T_1$/s: 40.42, 40.89
$\overline{T_1} = 4.07$ s

(ii) $5T_2$/s: 12.01, 12.14, 12.18, 12.17
$\overline{T_2} = 2.43$ s

(iii) $T_2 / T_1 =$ 2.43 / 4.07 = 0.60

Percentage uncertainty in $10T_1 = \frac{0.24}{40.7} \times 100\%$

$= 0.6\%$

Percentage uncertainty in $5T_2 = \frac{0.09}{12.1} \times 100\%$

$= 0.8\%$

Percentage uncertainty in ratio = 0.6% + 0.8%

= <u>1.4%</u>

143. (a) 0.25 – 0.29 mm with 0.01 mm precision + unit <u>or</u> centre value **(1)** ± 0.02 mm

Repeat **(1)** 2

(b) (i) Circuit set up without help **(2)** 2

(ii) *V* & *I* to 3 s.f. or better and correct values in table **(1)**
R and *R*/*x* correctly calculated ≥ 2 d.p. **(1)**
6 good values (± 1½ squares in *R*/*x*) **(1) (1) (1) (1)**
[4 good values only **(1) (1)**] 6
[If these 6 include $x < 0.300$ m, allow best fit line as curve then –2 rubric error]

(c) <u>Graph</u>
Plots: to ½ square accuracy **(1)**
Line: thin, straight and of best fit **(1)** 2

(d) Large triangle [base ≥ 6 cm] **(1)**
Correct calculation ≥ 2 s.f. [Ignore unit] [Ignore sign] **(1)** 2

(e) Correct calculation [Allow ecf] **(1)**

2/3 s.f. + unit **(1)** 2

[16]

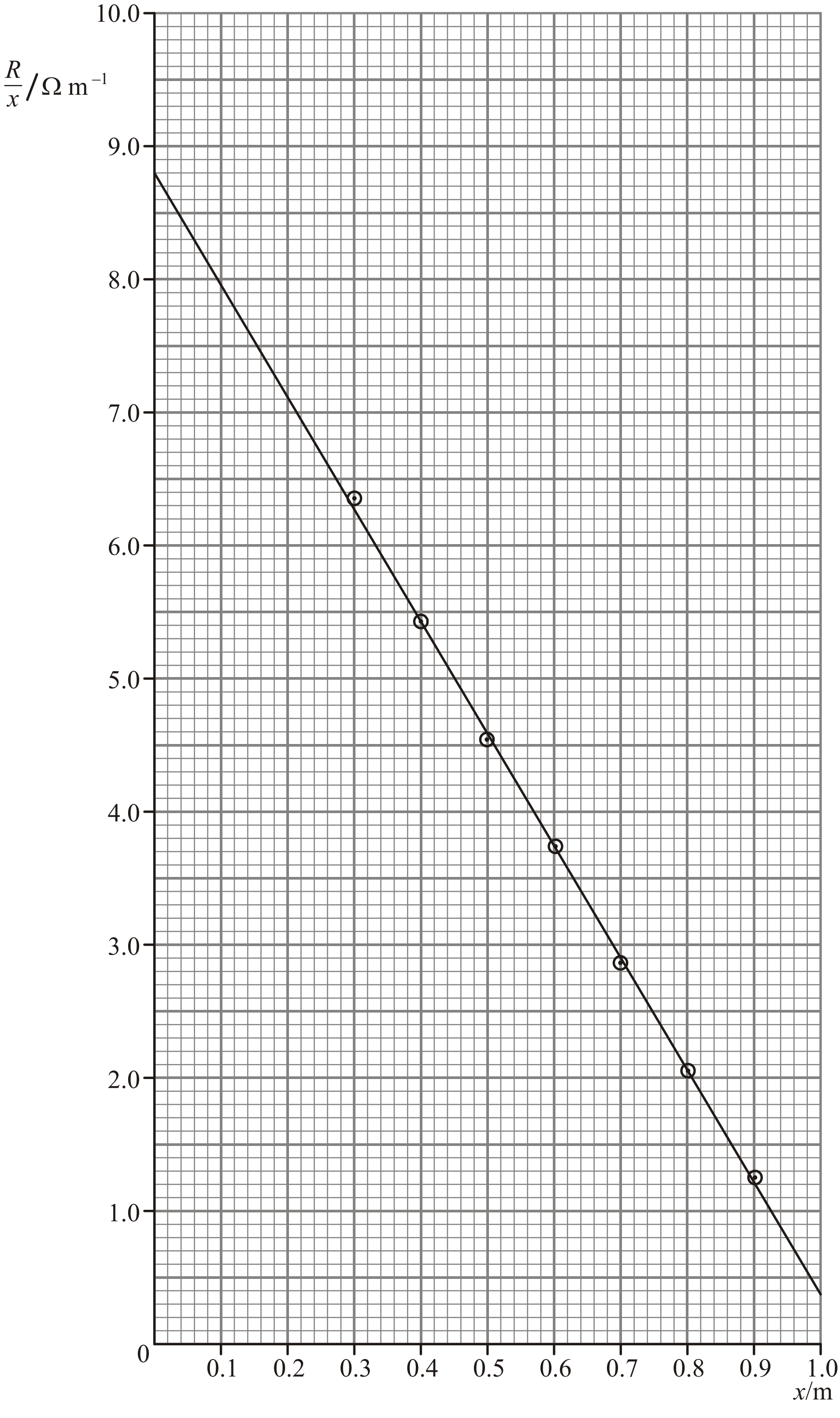
Sample results

(a) d = 0.27 mm, 0.27 mm
Av. = 0.27 mm

(b) (ii) V = 0.292 V I = 0.138 A
R = 2.12 Ω

x/m	V/V	I/A	R/Ω	(R/x)/ Ω m^{-1}
0.300	0.242	0.127	1.90	6.34
0.400	0.268	0.124	2.17	5.42
0.500	0.292	0.129	2.26	4.53
0.600	0.306	0.138	2.22	3.70
0.700	0.277	0.138	2.01	2.87
0.800	0.234	0.143	1.64	2.05
0.900	0.164	0.145	1.13	1.26

(c)



(d) $s = \frac{8.81 - 0.36}{1.00 - 0.00}$

$= \underline{8.45}$

(e) $\rho = \dfrac{\pi(0.27 \times 10^{-3})^2 \times 8.45 \times 1.00}{4}$

$= 4.8 \times 10^{-7}\ \Omega\ \text{m}$

144. (a) (i) Correct circuit [–1 per error or omission] **(1) (1) (1)** 3

(ii) Connect capacitor to P to charge it **(1)**
Switch to Q and start stopwatch **(1)**
Record current I at regular time intervals t **(1)** 3

(iii) Correct arrangement into y = mx + c form
[need not relate to $y = mx + c$] **(1)**
Correct calculation <u>shown</u> + unit **(1)** 2

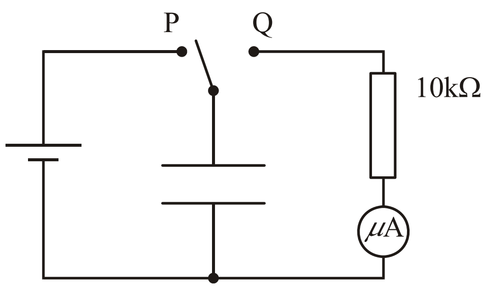
(b) Correct values of ln(I/uA) to 3/4 s.f. **(1)**
Scale: at least ½ paper in each direction, avoiding awkward **(1)**
scales, eg 3’s
Axes: labelled + unit, must be of form ln (I/uA) **(1)**
Plots: accurate to *V*2 square **(1)** 5

(c) Large triangle [base ≥ 8 cm] **(1)**
Correct value [ignore units] [Ignore signs] **(1)**
4.5 mF < C < 4.7 mF from correct calculation 2/3 s.f. + unit **(1)** 3
[must be F, mF or μF]

[16]

Sample results

(a) (i)



(iii) $I = I_0 e^{-at}$

$1\text{n}I = -at + 1\text{n}I_0$

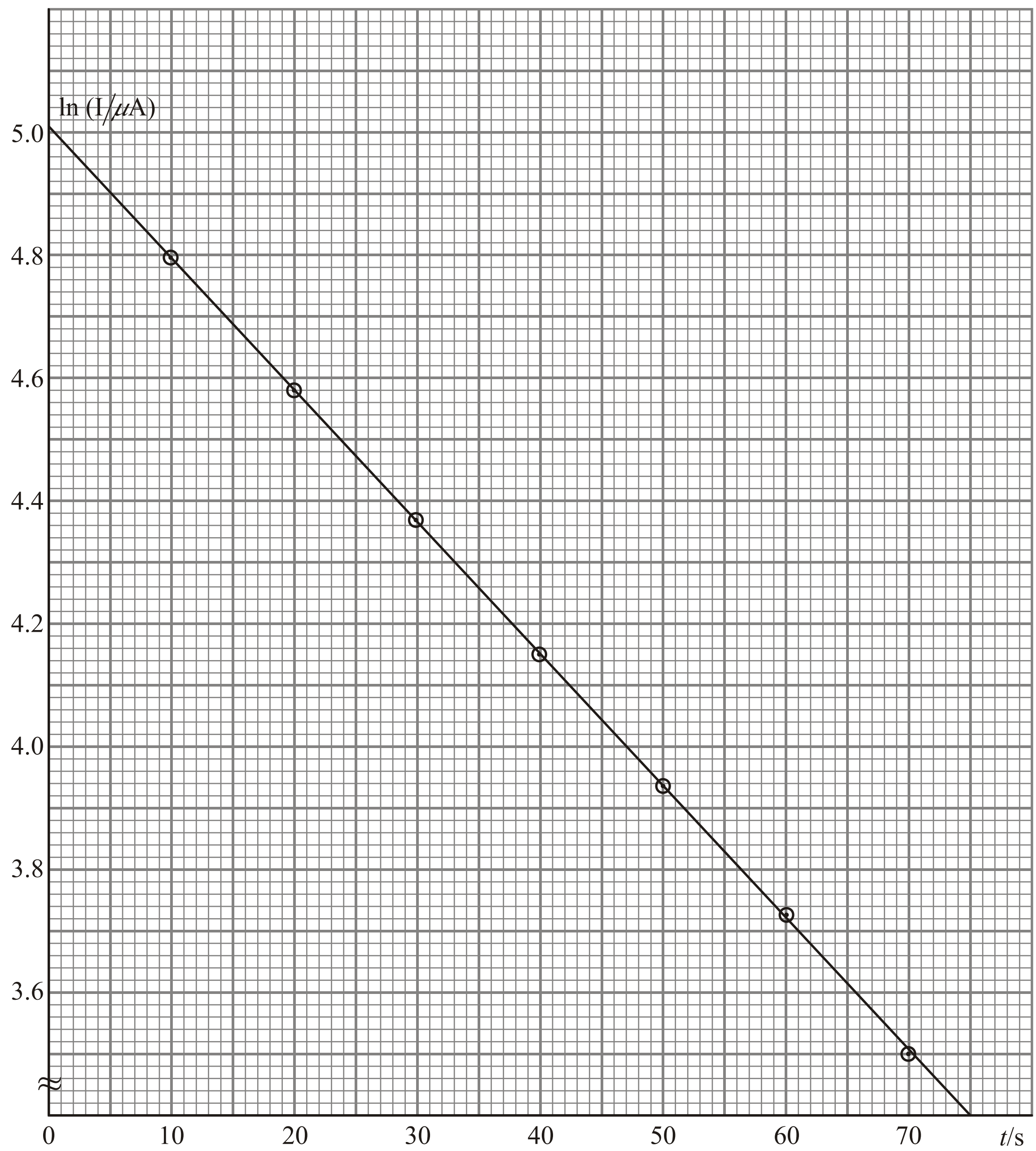
y = mx + c

At $t = 0$, $I = \dfrac{V}{R} \approx \dfrac{1.5\ \text{V}}{10\ \text{k}\Omega}$

≈ 0.15 mA (150 μA)

(b)

$\ln(I\ /\ \mu A)$
4.80
4.58
4.37
4.15
3.94
3.73
3.50



(c) $a = -\text{gradient} = \dfrac{5.02 - 3.68}{62 - 0}$

$= 0.0216\ \text{s}^{-1}$

$C = \dfrac{1}{aR} = \dfrac{1}{0.0216 \times 10 \times 10^3} = 4.6 \times 10^{-3}\ \text{F}$

= <u>46000 μF</u> (to 2 s.f)