Oxford Cambridge and RSA

Friday 23 May 2025 – Morning

A Level Physics B (Advancing Physics)

H557/01 Fundamentals of Physics

Time allowed: 2 hours 15 minutes

You must have:
- the Data, Formulae and Relationships Booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number						Candidate number				

First name(s) ______________________________

Last name ______________________________

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined page at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **110**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **40** pages.

ADVICE
- Read each question carefully before you start your answer.

Section A

You should spend a **maximum** of **40 minutes** on this section.

Write your answer to each question in the box provided.

1 A rectangular digital image measures 1900 pixels by 1100 pixels. Each pixel is represented using 3 bytes.

What is the total amount of information in this image?

A 87.1 kbit

B 697 kbit

C 6.27 Mbit

D 50.2 Mbit

Your answer [ ] **[1]**

2 A student measures the change in temperature of some water when it is heated for 10 seconds. The student's results are:

Starting temperature = $(53.4 \pm 0.2)\,°C$
Final temperature = $(96.1 \pm 0.2)\,°C$

What is the average rate of change in temperature of the water together with its associated uncertainty?

A $(4.27 \pm 0.02)\,°C\,s^{-1}$

B $(4.27 \pm 0.04)\,°C\,s^{-1}$

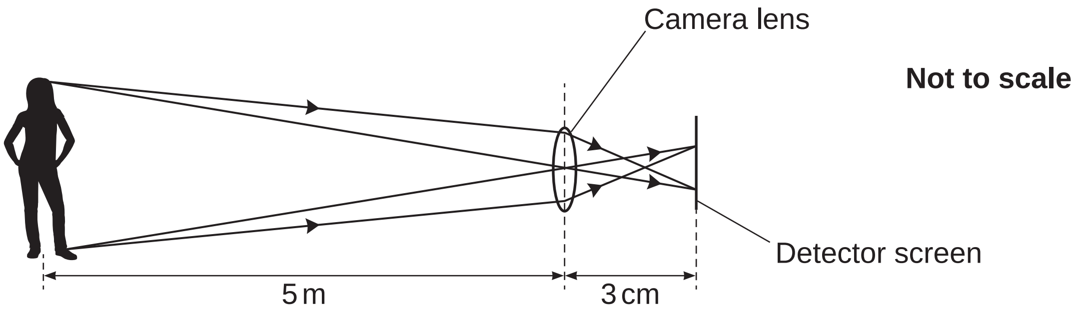
C $(4.27 \pm 0.2)\,°C\,s^{-1}$

D $(4.27 \pm 0.4)\,°C\,s^{-1}$

Your answer [ ] **[1]**

The following information is for use in questions **3** and **4**.

The diagram shows a camera being used to take a picture of a person. The image formed on the camera detector screen is sharp and in focus.



3 What is the magnification of the image?

A –167

B –0.0060

C +0.0060

D +167

Your answer [1]

4 What is the focal length of the lens?

A –3.02 cm

B –2.98 cm

C 2.98 cm

D 3.02 cm

Your answer [1]

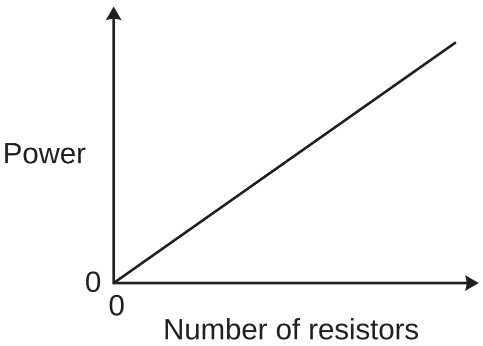
5 Two identical cells are connected in series.
The e.m.f. of each cell is ε and the internal resistance of each cell is r.
Which row shows the combined e.m.f. and the combined resistance of the two cells when they are connected in series?

	E.m.f	**Internal resistance**
A	$-\varepsilon$	r
B	ε	$2r$
C	2ε	r
D	2ε	$2r$

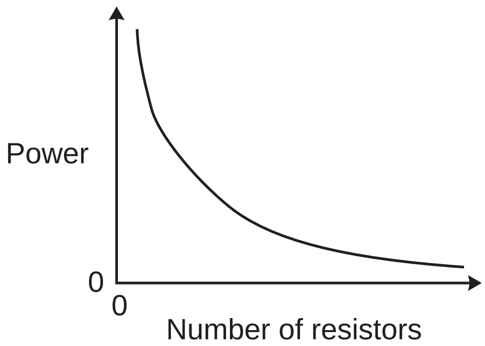
Your answer **[1]**

6 A number of identical resistors are connected in parallel to a cell of negligible internal resistance.
Which graph shows how the power dissipated in the circuit varies with the number of resistors?

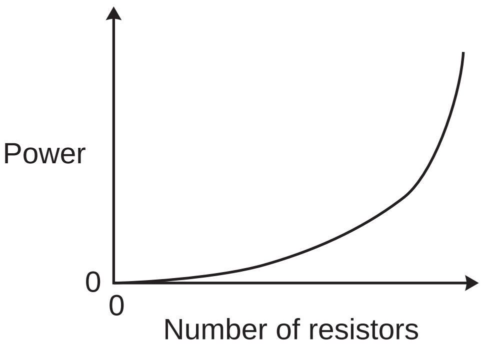
A



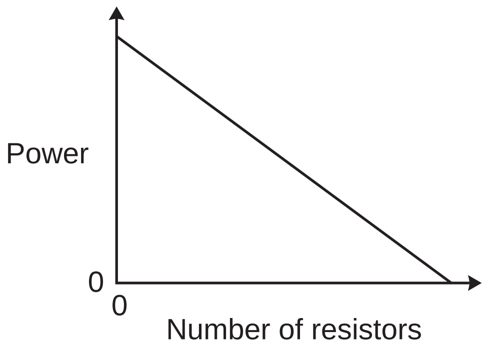
B



C



D



Your answer **[1]**

7 A network of resistors consists of m parallel branches. Each branch contains n identical resistors of resistance R.
What is the total resistance of the network?

A $\frac{mR}{n}$

B $\frac{nR}{m}$

C nmR

D $\frac{R}{nm}$

Your answer ☐ **[1]**

8 Wires P and Q have circular cross sections.

The table gives information about wires P and Q.

Wire	Diameter / mm	Metal	Resistivity / Ω m
P	0.25	constantan	4.9×10^{9}
Q	0.75	nichrome	10×10^{9}

What length of wire P has the same resistance as 1.8 m of wire Q?

A 0.29 m

B 0.41 m

C 1.2 m

D 11 m

Your answer ☐ **[1]**

9 A car registration plate recognition camera is required to recognize 1 185 856 000 alternative values.

How many bits are needed to store 1 185 856 000 alternative values?

A 9

B 21

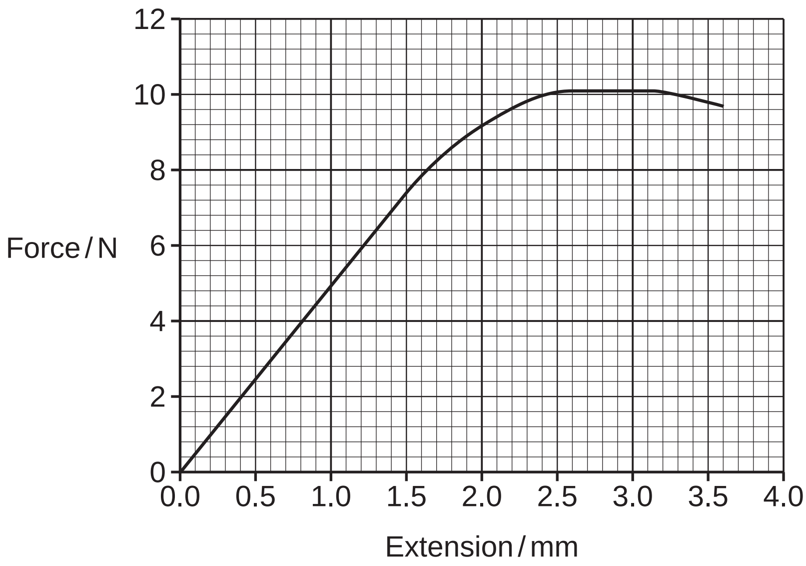
C 31

D 39

Your answer ☐ **[1]**

The following information is for use in questions **10**, **11** and **12**.

A wire is clamped at one end so that it hangs vertically, and weights are suspended from the lower end. The graph shows how the force on the wire varies with extension.



10 Which statement describes both the deformations and the nature of the wire?

	Deformations	**Nature**
A	elastic followed by plastic	brittle
B	elastic followed by plastic	ductile
C	plastic followed by elastic	brittle
D	plastic followed by elastic	ductile

Your answer ☐ **[1]**

11 The gradient of the graph up to a 1.5 mm extension can be used to determine the Young modulus for the material of the wire.
Which expression gives the Young modulus for this wire?

A gradient × original length of wire × cross sectional area

B gradient × original length of wire ÷ cross sectional area

C gradient × cross sectional area ÷ original length of wire

D gradient ÷ (original length of wire × cross sectional area)

Your answer **[1]**

12 How much work is done in stretching the wire by 1.2 mm?

A 3.6 mJ

B 4.3 mJ

C 7.2 mJ

D 22.6 mJ

Your answer **[1]**

13 An electron travels in a straight line at non-relativistic speed. It has speed v, kinetic energy E, and wavelength λ.

The kinetic energy of the electron is increased to $4E$.

What is the new wavelength?

A $\frac{\lambda}{4}$

B $\frac{\lambda}{2}$

C 2λ

D 4λ

Your answer **[1]**

14 The diagram shows some of the energy levels in a hydrogen atom.

$n = 4$ ———————— $E_4 = -0.85\,\text{eV}$

$n = 3$ ———————— $E_3 = -1.51\,\text{eV}$

$n = 2$ ———————— $E_2 = -3.40\,\text{eV}$

$n = 1$ ———————— $E_1 = -13.6\,\text{eV}$

Which electron transition results in the emission of a photon of frequency $2.46 \times 10^{15}\,\text{Hz}$?

A $n = 4$ to $n = 3$

B $n = 4$ to $n = 2$

C $n = 3$ to $n = 1$

D $n = 2$ to $n = 1$

Your answer ☐ **[1]**

15 A stationary thorium-232 nucleus emits an alpha particle. The velocity of the emitted alpha particle is $1.4 \times 10^4\,\text{m}\,\text{s}^{-1}$. No other particles are emitted with the alpha particle.

What is the recoil speed of the resulting radium-228 nucleus?

A $121\,\text{m}\,\text{s}^{-1}$

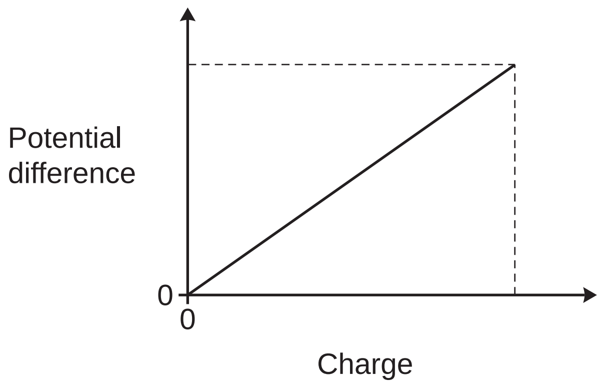
B $123\,\text{m}\,\text{s}^{-1}$

C $241\,\text{m}\,\text{s}^{-1}$

D $246\,\text{m}\,\text{s}^{-1}$

Your answer ☐ **[1]**

16 The graph shows how the potential difference across a capacitor varies with the charge on the capacitor.



What gives the capacitance of the capacitor?

A the area under the graph

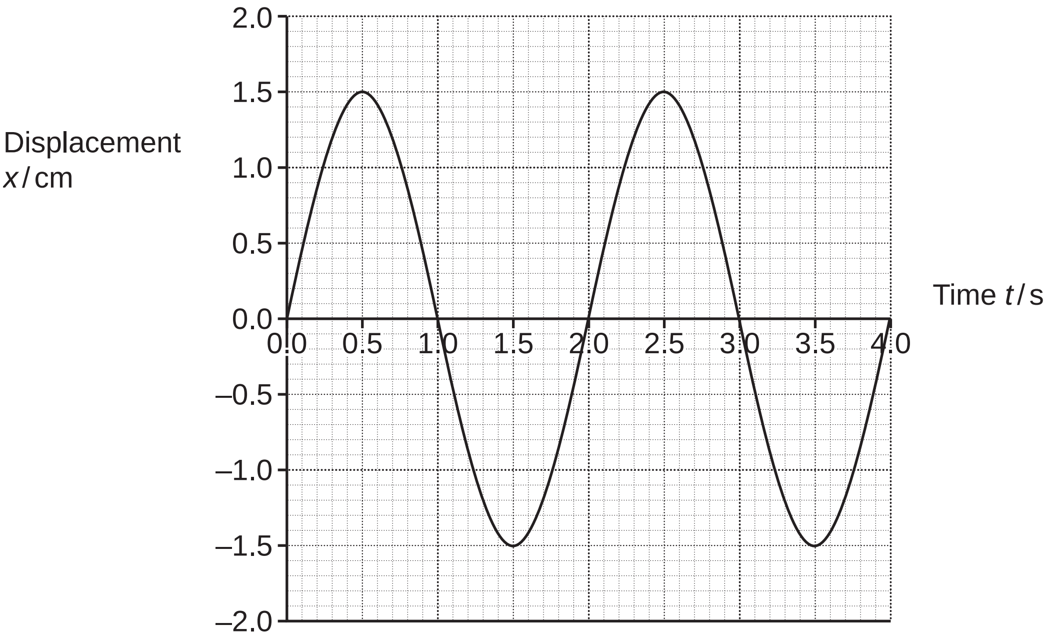
B the gradient of the graph

C $\dfrac{1}{\text{the gradient of the graph}}$

D $\dfrac{1}{\text{the area under the graph}}$

Your answer ☐ **[1]**

17 An object is oscillating with simple harmonic motion. The graph shows how its displacement *x* varies with time *t*.



Which row gives the amplitude and frequency of the motion?

	Amplitude / cm	**Frequency / Hz**
A	1.5	0.5
B	1.5	2.0
C	3.0	0.5
D	3.0	2.0

Your answer ☐ **[1]**

18 Object P collides with another object. A graph of the force experienced by object P during the collision against time is drawn.

What does the area under the graph represent?

A Change in kinetic energy of object P

B Change in velocity of object P

C Impulse of object P

D Work done on object P

Your answer ☐ **[1]**

The following information is for use in questions **19** and **20**.

A fixed amount of gas has volume V, pressure P and absolute temperature T.

The absolute temperature is increased so that the volume increases to $3V$ and the pressure increases to $3P$.

19 What is the new value of the absolute temperature?

A T

B $3T$

C $6T$

D $9T$

Your answer ☐ **[1]**

20 What happens to the root mean square speed of the molecules in the gas when the volume is increased to $3V$ and the pressure is increased to $3P$?

A It stays the same

B It increases by a factor of 3

C It increases by a factor of 6

D It increases by a factor of 9

Your answer ☐ **[1]**

21 The activation energy required to remove a water molecule from a body of water is 6.88×10^{-20} J.

What temperature will produce a Boltzmann factor of 0.200 for this process?

A 31 K

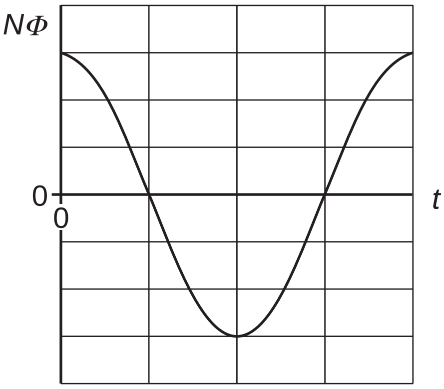
B 310 K

C 3100 K

D 31 000 K

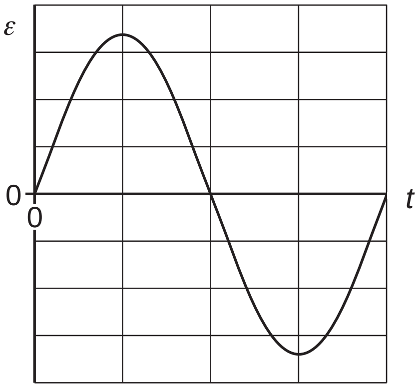
Your answer ☐ **[1]**

22 The graph shows how the flux linkage for a coil rotating in a magnetic field varies with time.

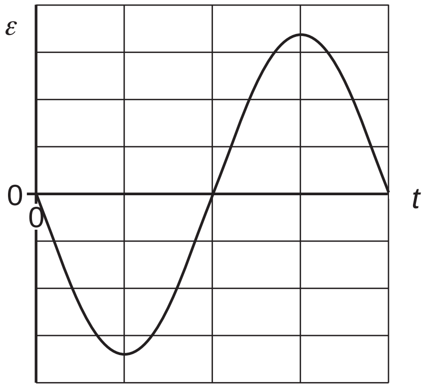


Which graph shows how the induced e.m.f. ε in the coil varies with time?

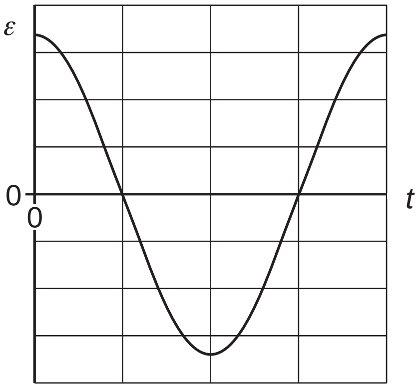
A



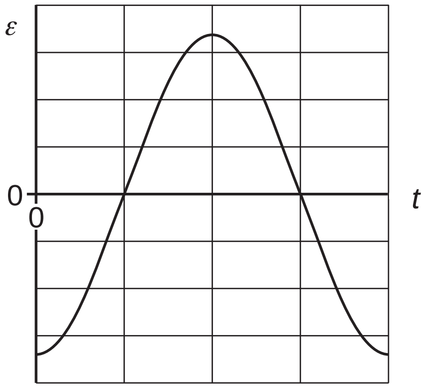
B



C



D



Your answer ☐ **[1]**

23 Which quantity gives the strength of an electric field around an isolated charge?

A The area under a graph of electric field versus distance

B The area under a graph of electric force versus distance

C The gradient of a graph of electric potential energy versus distance

D The gradient of a graph of electrical potential versus distance

Your answer ☐ **[1]**

24 The energy levels in an atom can be modelled as electron standing waves.
An electron jumps from a lower energy level to a higher energy level.

What are the changes to its wavelength and kinetic energy?

	Wavelength	**Kinetic energy**
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

Your answer ☐ **[1]**

25 An alpha particle approaches a large nucleus head-on. It comes to a halt before reaching the nucleus, and it is then deflected backwards.

Which row shows the factors that affect the distance of closest approach?

	The initial kinetic energy of the alpha particle	**The neutron number of the nucleus**	**The proton number of the nucleus**
A	✓	✓	
B	✓		✓
C		✓	✓
D	✓	✓	✓

Your answer ☐ **[1]**

26 Which statement about the binding energy per nucleon in a nucleus is correct?

A It becomes less negative when hydrogen nuclei undergo fusion to produce a helium nucleus.

B It determines the stability of the nucleus.

C It gives the kinetic energy a neutron must have to cause the fission of a nucleus.

D It gives the total energy required to separate all the nucleons in a nucleus.

Your answer [ ] **[1]**

27 What is the total energy of a proton travelling at 50% the speed of light?

A 1.88×10^{-11} J

B 1.51×10^{-10} J

C 1.74×10^{-10} J

D 2.01×10^{-10} J

Your answer [ ] **[1]**

28 An isotope emits alpha particles of energy 9.0×10^{-13} J. All of the alpha particles are absorbed by 0.25 kg tissue. The isotope gives a dose equivalent to 2.0 mSv in 2 hours.

What is the activity of the isotope?

The quality factor for alpha particles is 20.

A 3.9 kBq

B 78 kBq

C 1.5 MBq

D 28 MBq

Your answer [ ] **[1]**

The following information is for use in questions **29** and **30**.

The decay equation of strontium-90 into yttrium-90 is:

$$^{90}_{38}\mathrm{Sr} \longrightarrow {}^{90}_{39}\mathrm{Y} + {}^{\;\,0}_{-1}\mathrm{e} + \text{particle X}$$

0.546 MeV is released in the decay.

29 What is the particle X?

A A gamma photon

B An antineutrino

C A neutrino

D A positron

Your answer ☐ **[1]**

30 What is the difference between the masses of the strontium-90 nucleus and the yttrium-90 nucleus?

Assume that particle X has negligible mass.

A 9.707×10^{-31} kg

B 2.000×10^{-29} kg

C 1.673×10^{-27} kg

D 1.675×10^{-27} kg

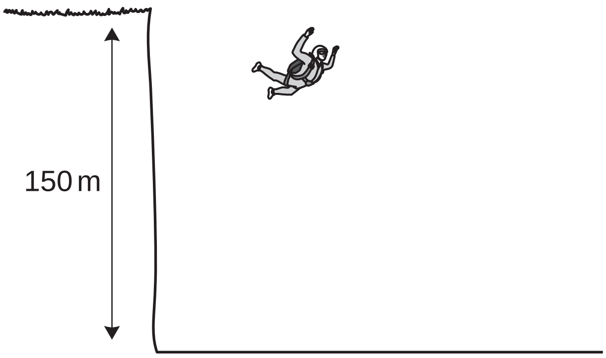
Your answer ☐ **[1]**

Section B

31 Base jumping is a dangerous sport in which participants jump from high cliffs or structures and then open a parachute before reaching the ground.

Fig. 31.1 shows a base jumper just after they have run off the edge of a cliff.
The base jumper's velocity when they leave the top of the cliff is 8 m s^{-1} horizontally.
The cliff is 150 m high.

Fig. 31.1



(a)
(i) Calculate the vertical component of the velocity 1.5 s after the base jumper leaves the edge of the cliff.

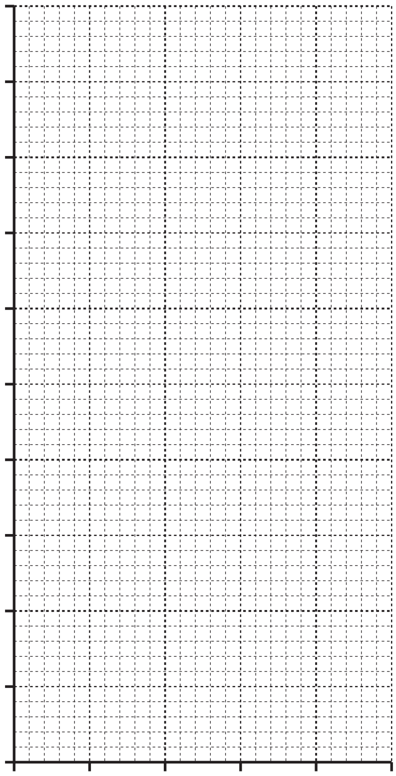
vertical component = ... m s^{-1} **[2]**

(ii) Use the grid in **Fig 31.2** to draw the vectors for the horizontal and vertical components of the base jumper's velocity 1.5 s after they have left the top of the cliff.

Use the scale 1 cm : 2 m s^{-1}.

Use the scale drawing to find the speed of the base jumper at that time.

Fig 31.2



speed = ... $m\,s^{-1}$ **[2]**

(b) To avoid injury, the base jumper must open the parachute when:

- they are at least 20 m from the cliff
- at least 80 m above the ground.

Deduce whether or not the base jumper can avoid injury on this jump.

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.... **[3]**

32 Capacitors can be used as energy storage devices.
A capacitor of capacitance C is charged until the potential difference across it is V.

(a) Show that the energy stored in the capacitor is given by $E = \frac{1}{2}CV^2$.

[1]

(b) A 680 μF capacitor is charged until it stores 12 mJ energy. It is then discharged through a 1.2 kΩ resistor.

Calculate the time taken for the capacitor to transfer 8 mJ energy when discharging through the 1.2 kΩ resistor.

time = ... s **[4]**

33 A spacecraft approaches a planet. It uses radar to measure its distance from the planet and its average velocity towards the planet. Radar pulses are sent at intervals of exactly 900.000 s. The time intervals for the signal to travel from spacecraft to the planet and back (journey time) are given in the table.

Time pulse sent / s	**Journey time / s**
00.00	12.000014
900.00	12.000

Explain how this data can be used to determine the average velocity of the spacecraft.

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.... **[2]**

34 A car is supported by four springs in its suspension. A student models the oscillation of the car on the springs iteratively. They assume that, when the car is oscillating vertically on the springs:

- the oscillation is simple harmonic
- the acceleration is uniform over time intervals of 0.02 s.
- the acceleration a, is given by

$$a = \frac{100\,000x - 240}{1200}$$

where x is the vertical displacement of the car from its equilibrium position.

(a) The car is lifted 0.050 m above its equilibrium position and then released.

(i) Show that the initial downward acceleration of the car is approximately 4.0 m s^{-2}.

[1]

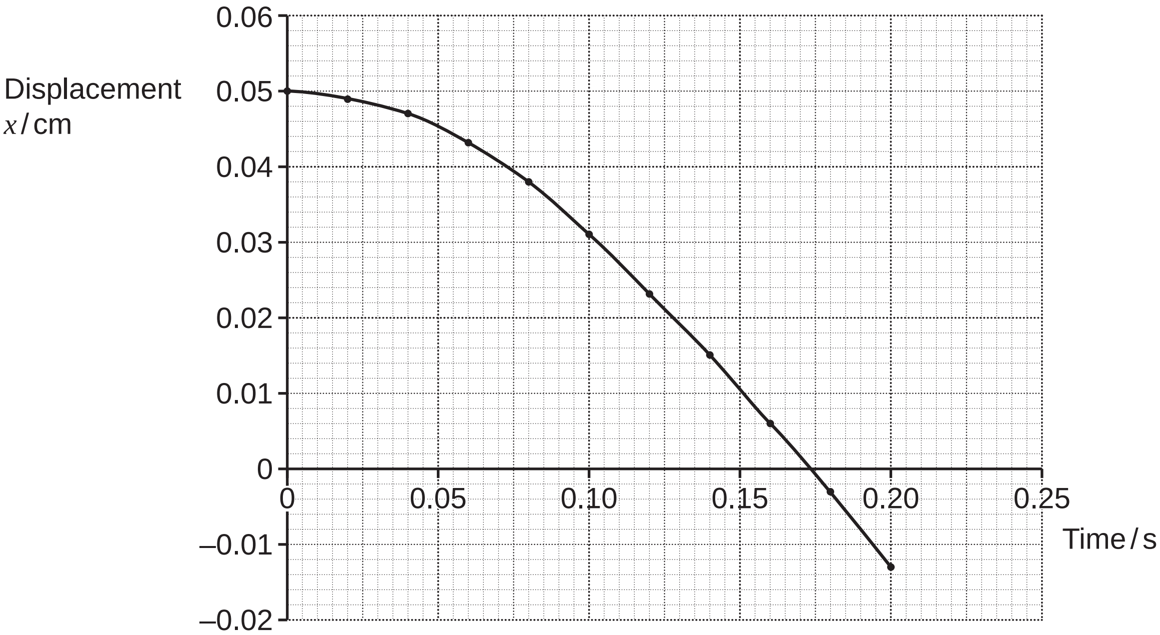
(ii) Show that the change of displacement over the initial 0.02 s is approximately 0.0008 m.

[2]

(iii) Hence calculate the displacement of the car from its equilibrium position after the first 0.02 s.

displacement = ... m **[1]**

(b) Further iterations of the model produce the graph shown below.



(i) Use data from the graph to estimate the period of the oscillation.

period = ... s **[2]**

(ii) Calculate a value for the time period of the oscillation.

Use the equation $a = 4\pi^2 f^2 x$ where f = frequency of oscillation.

Use data from **(a)(i)**

period calculated from equation = ... s **[2]**

(iii) Explain how the iterative model can be improved.

....

.... **[1]**

35 A neutrino detector uses germanium crystals cooled to a temperature of a few mK to detect neutrinos. When a neutrino interacts with a germanium crystal its energy is transferred as thermal energy in the crystal and results in a small but detectable temperature rise.

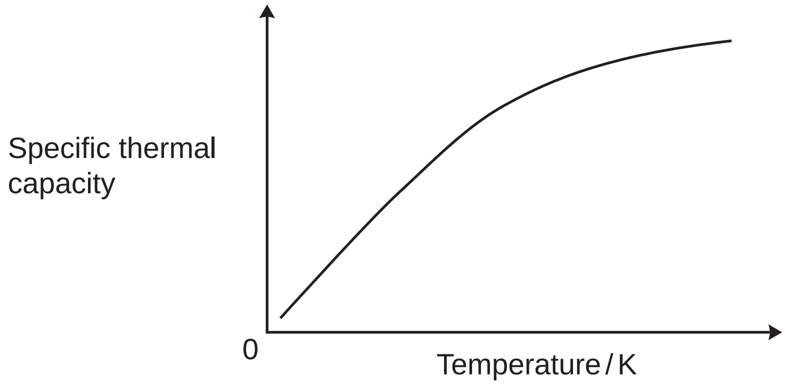
Germanium crystals, each of mass 0.5 g, are used.

The specific thermal capacity of germanium close to absolute zero is 0.10 $J\,kg^{-1}\,K^{-1}$.

(a) Calculate the maximum temperature increase in one of the germanium crystals caused by a 1200 MeV neutrino.

temperature increase = ... K **[3]**

(b) The graph shows how the specific thermal capacity of germanium varies with temperature.



Suggest a reason for operating the neutrino detector at a very low temperature.

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Section C

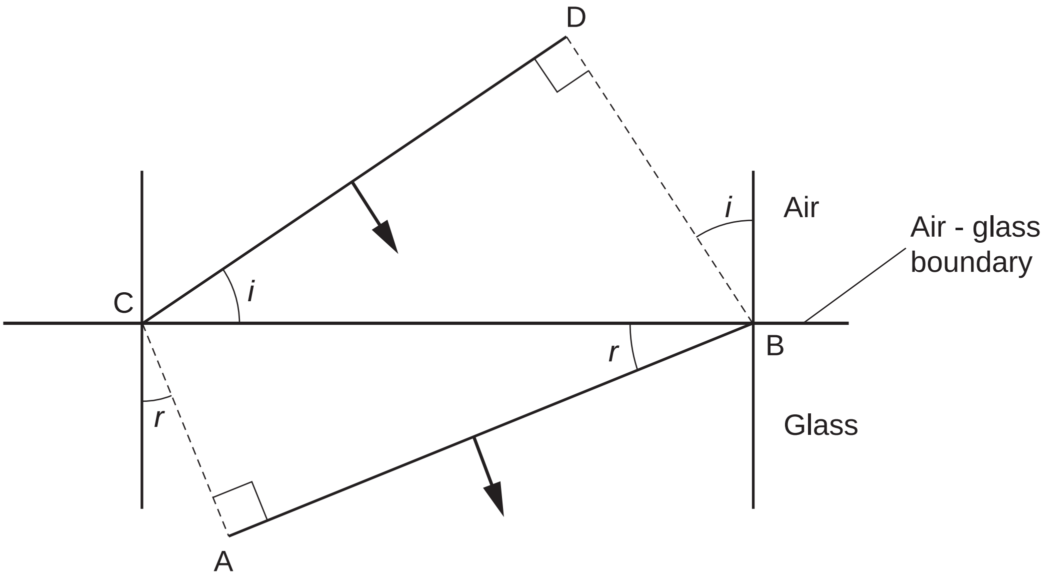
36

(a) A student studies the refraction of light as it passes from air to glass using the wave model of light.

Before reaching the air-glass boundary the wavefronts AB and CD are parallel to each other.

Fig. 36.1 shows the wavefronts after AB has entered the glass.

Fig. 36.1



In the diagram:

- CD strikes the surface a time Δt after AB has entered the glass
- i is the angle of incidence and r is the angle of refraction.

(i) Explain why the length DB is greater than the length CA in **Fig. 36.1**.

....

.... **[1]**

(ii) The student measures the distances DB and CA on a scale drawing.

DB = 4.5 cm

CA = 3.0 cm

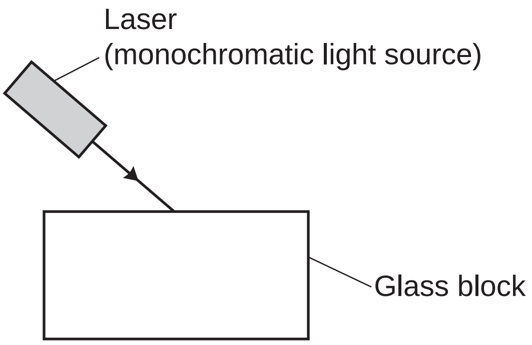
Use this data to calculate the refractive index of the glass.

refractive index = ... **[2]**

Turn over

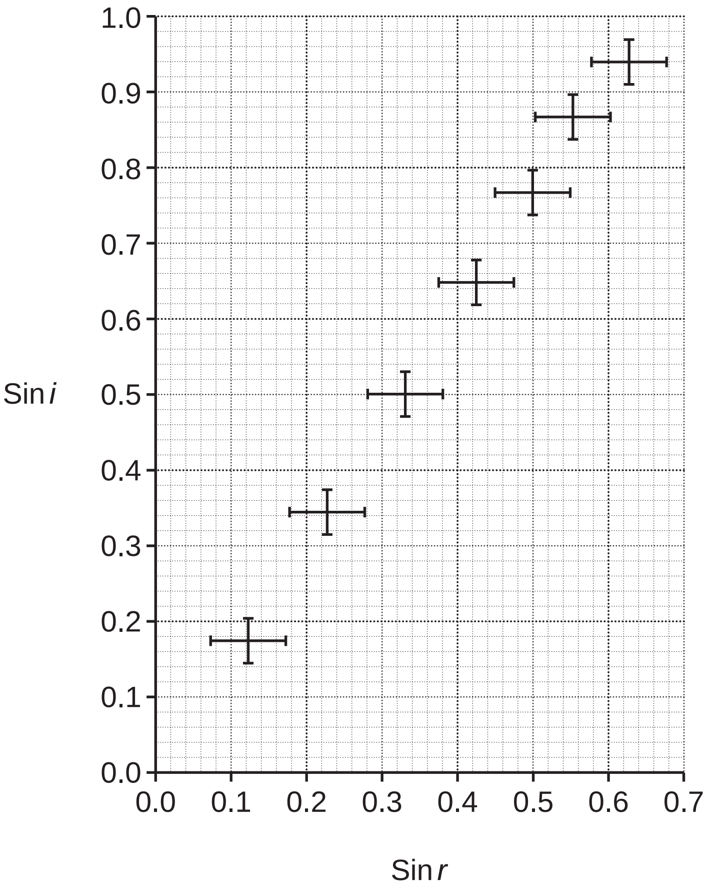
(b)* A student carries out an experiment to determine the refractive index of a glass block using the apparatus shown in **Fig. 36.2**.

Fig. 36.2



The graph in **Fig. 36.3** shows the results of the experiment.

Fig. 36.3



The student believes that the block is made from either crown glass or flint glass.
The table gives information about these two types of glass.

Type of glass	Refractive index
crown glass	1.50–1.54
flint glass	1.60–1.62

Using data from **Fig. 36.3** and the table, determine whether the block is made from crown glass or flint glass.

Include calculations of the uncertainty in your value.

Comment on the validity of your conclusion.

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.... **[6]**

Extra answer space if required.

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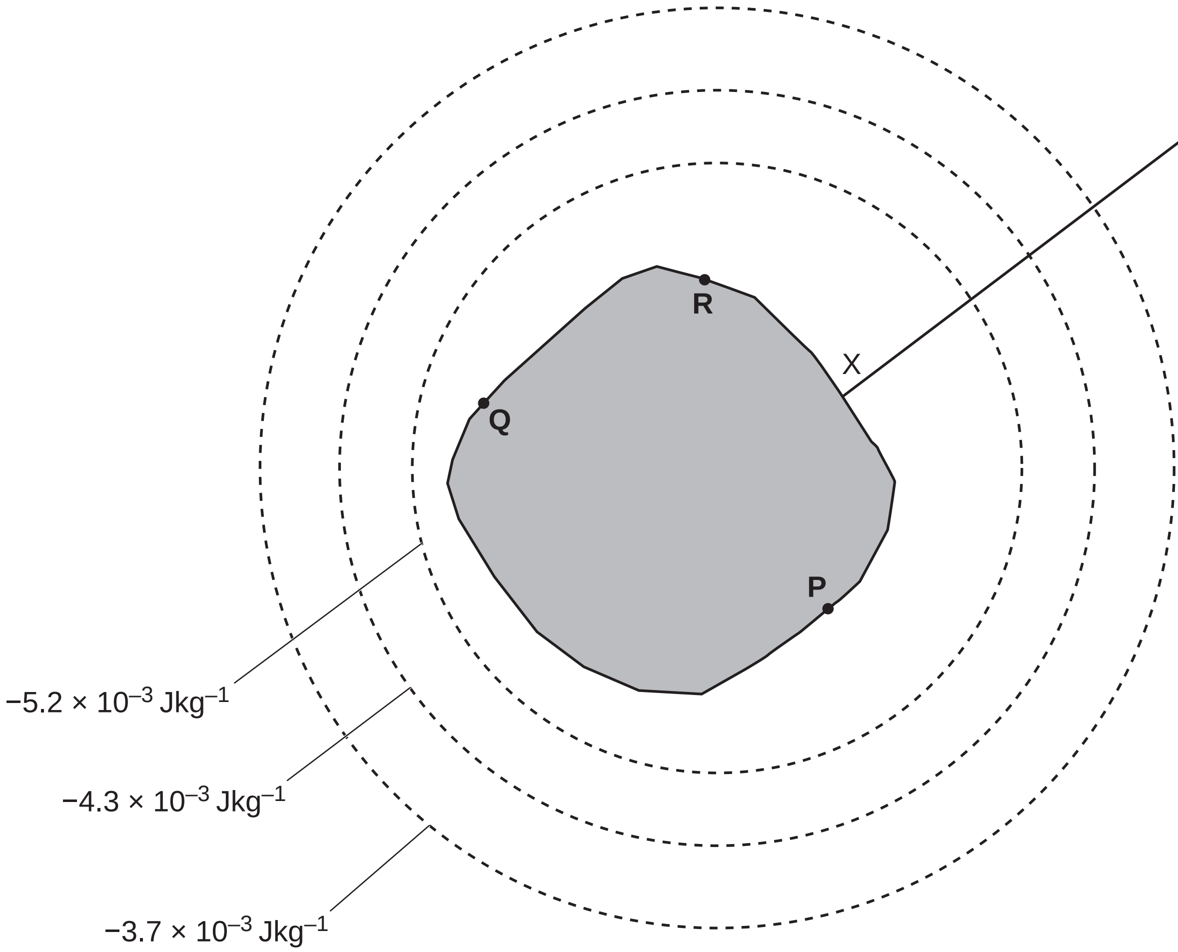
37 In September 2016 NASA sent the Osiris-Rex spacecraft to intercept and study the comet Bennu. To prepare for the mission, scientists developed models of Bennu.

Fig. 37.1 illustrates one simple model, in which a number of gravitational equipotential surfaces are shown, centred on the centre of mass of the comet.

Fig. 37.1



(a)

(i) On **Fig. 37.1 draw one** gravitational field line that starts from the point **P** on the surface of Bennu. **[2]**

(ii) For the spacecraft to travel at a constant height above Bennu from **R** to **Q**, requires a thrust from its engines.

Explain why a thrust is needed.

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.... **[2]**

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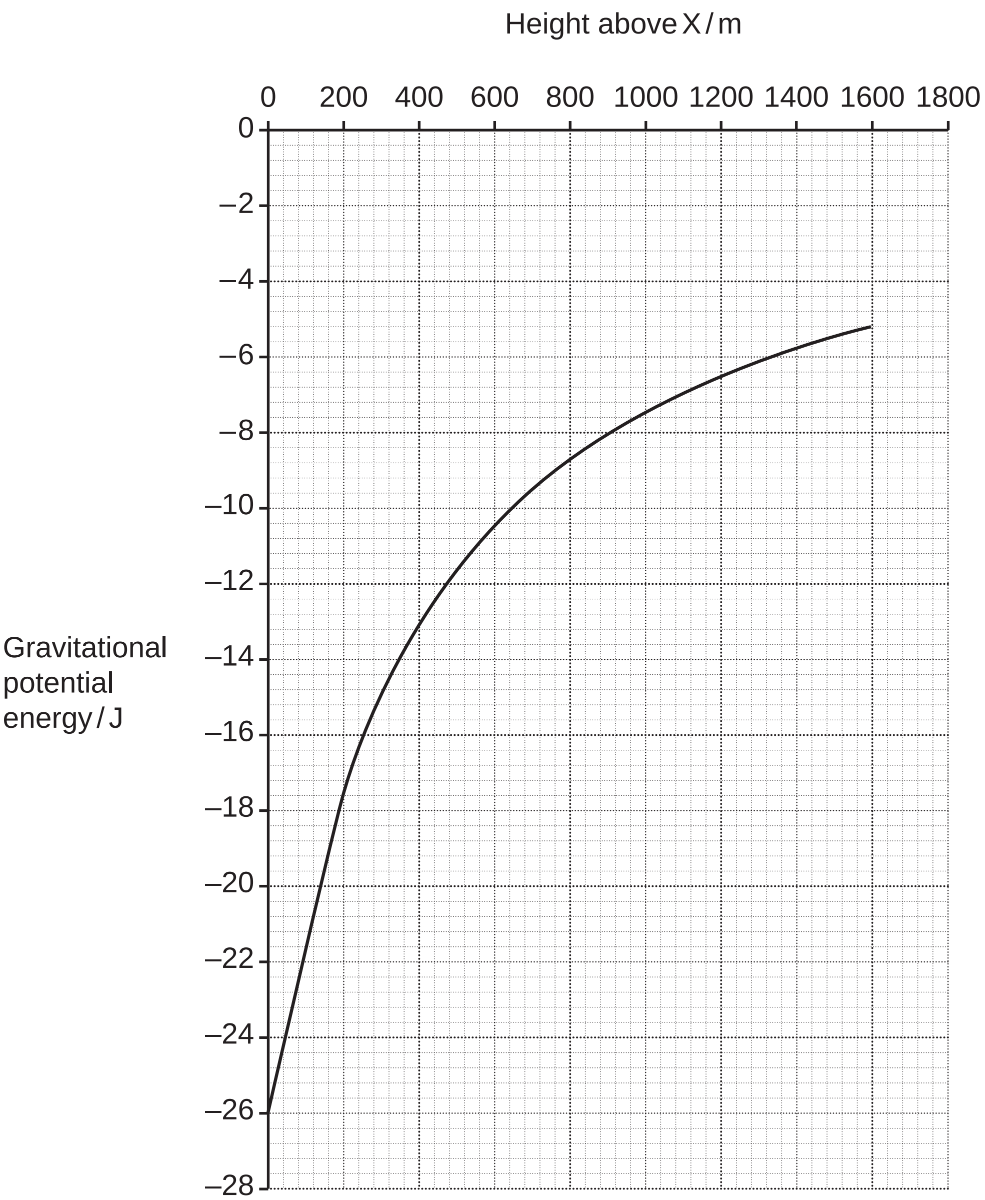
Question 37 continues on page 28

(b) The graph in **Fig. 37.2** shows how the gravitational potential energy of the Osiris-Rex spacecraft varies with height above point X on the surface of Bennu along the line XY.

Fig. 37.2



(i) Use the graph in **Fig. 37.2** to calculate the gravitational force on the spacecraft when it is 600 m above the surface.

force = ... N **[4]**

(ii) At the time of its departure from Bennu the Osiris-Rex spacecraft is orbiting 400 m above Bennu.

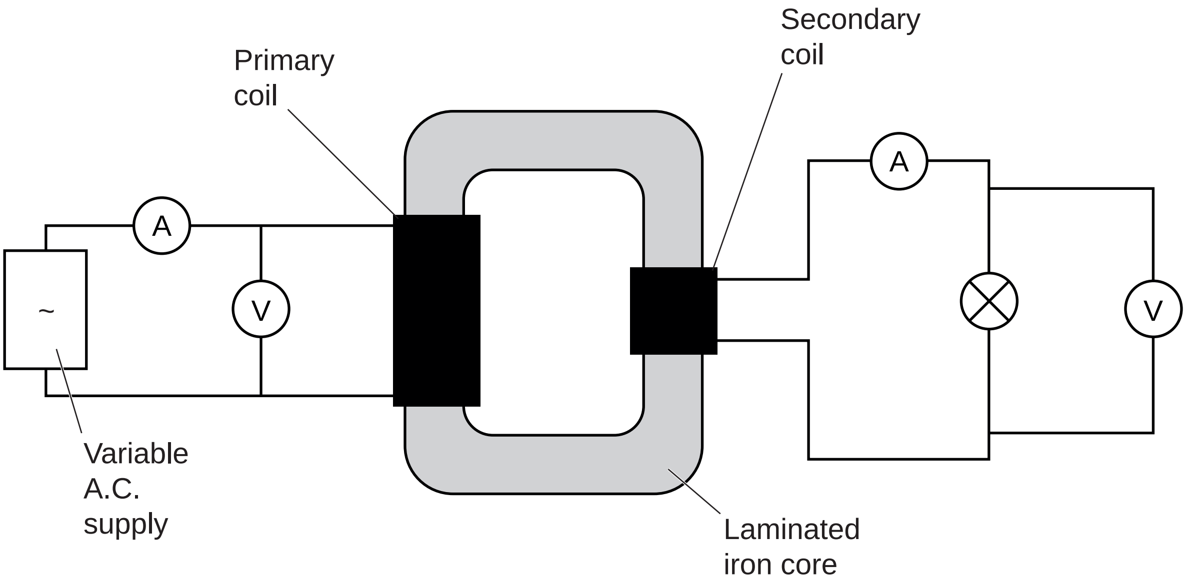
Calculate the velocity required to escape the gravitational field of Bennu from this height.

Mass of the spacecraft = 2000 kg.

velocity = ... $m\,s^{-1}$ **[3]**

38 Students investigate the action of a transformer. **Fig. 38.1** shows the apparatus used in the investigation.

Fig. 38.1



The students keep the secondary coil the same and change the number of turns on the primary coil. They then adjust the variable A.C. supply to make the filament lamp operate at normal brightness.

(a) The filament lamp connected to the secondary coil is rated at 3 V, 0.6 W.

In one experiment the number of turns on the primary coil is 400 and the number of turns on the secondary coil is 50.

Calculate the potential difference across the primary coil and the current through it when the filament lamp is operating normally.

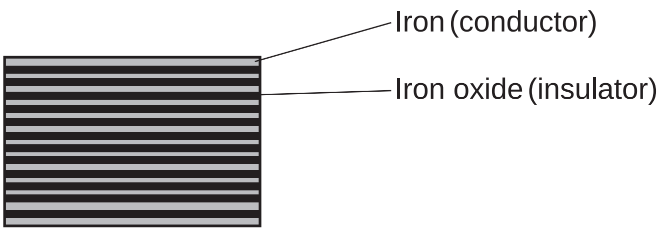
Assume the transformer is ideal.

potential difference = ... V

current = ... A
[5]

(b) **Fig. 38.2** shows an enlarged top view of the top section of the laminated core.

Fig. 38.2



Explain how the laminations make the transformer more efficient.

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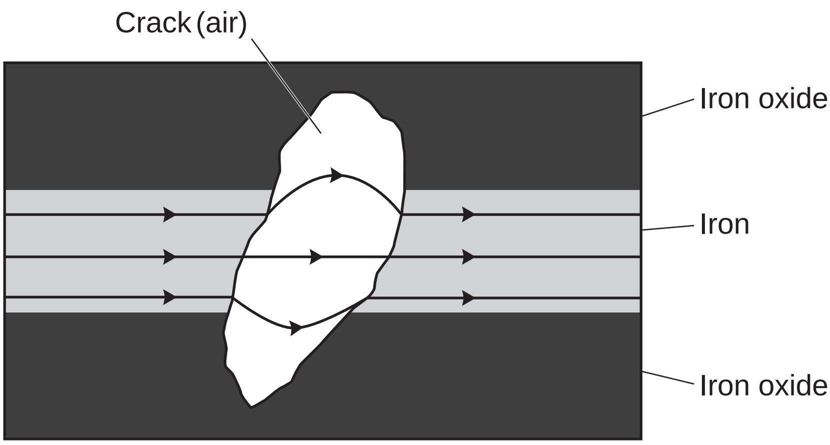
.... **[3]**

(c) In practice the transformer is not ideal and the students find that the values of the potential difference across the primary coil and the current in it are significantly higher than those calculated in part **(a)**.
The students think that this may be caused by small cracks in the core. **Fig. 38.3** shows one such crack and the effect it has on the magnetic field in the core.

Fig. 38.3



Explain how a large number of such cracks reduces the efficiency of the transformer.

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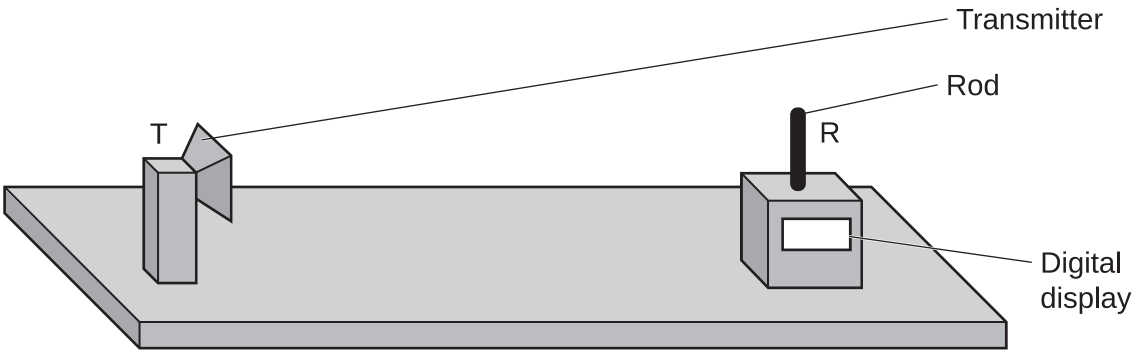
.... **[3]**

39 **Fig. 39.1** shows the apparatus used by a student to investigate the properties of microwaves. The microwaves from transmitter T are detected by the vertical metal rod R and their intensity is shown on the digital display.

Fig 39.1



(a) Explain how the apparatus can be used to test if the microwaves from T are polarised vertically or horizontally.

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.... **[2]**

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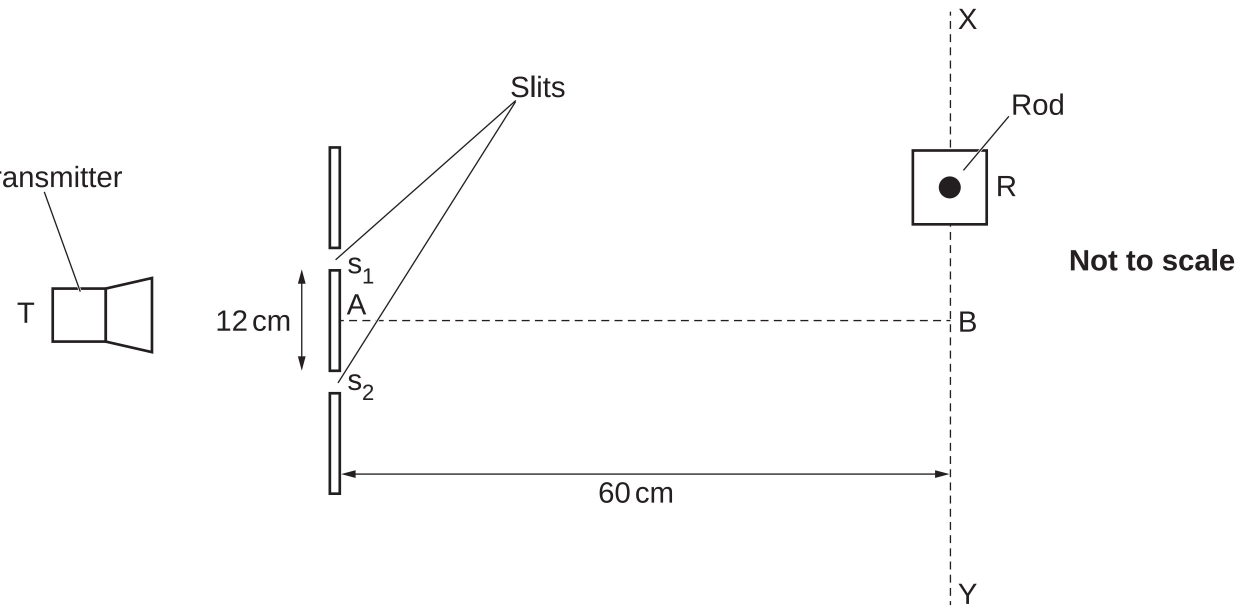
Question 39 continues on page 34

(b) The student then investigates the interference of microwaves. **Fig. 39.2** shows the experiment viewed from above.

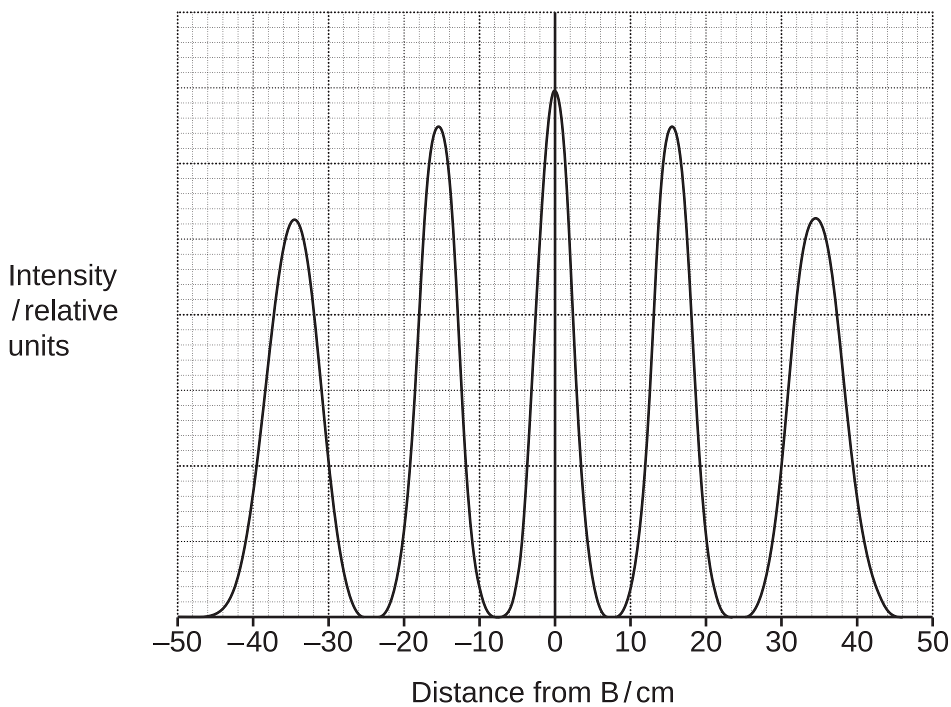
Fig. 39.2



- The microwaves emitted from T are incident on two slits, s_1 and s_2, which then act as coherent sources.
- The slits are 12 cm apart and point A is mid-way between them.
- R is initially placed at point B, directly opposite point A, and 60 cm from point A.
- The receiver and rod R are then moved along the straight line XY at 90° to the line AB.

Fig. 39.3 shows how the intensity of the microwaves detected by R varies with the distance of R from the point B.

Fig. 39.3



(i) Use information from **Fig. 39.2** and **Fig. 39.3** to show that the wavelength of the microwaves is about 3 cm.

[3]

(ii)* The graph has peaks of decreasing amplitude either side of the central peak.

Explain these features using **either** the wave model **or** the particle model.

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.... **[6]**

Extra answer space if required.

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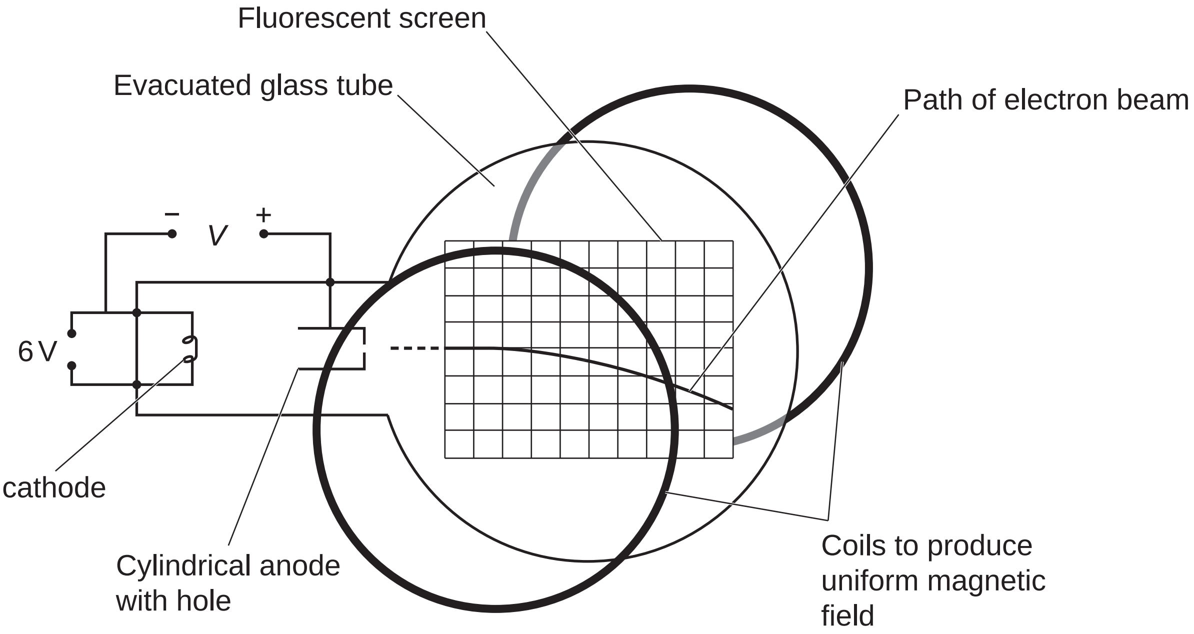
40

(a) **Fig. 40.1** shows apparatus that can be used to determine the charge to mass ratio of the electron $\frac{e}{m_e}$.

Fig. 40.1



- Electrons are emitted by the cathode and then accelerated through the hole in the anode by a large potential difference V to form an electron beam.
- The fluorescent screen shows the path of the beam.
- A uniform magnetic field is applied perpendicular to the beam by the two coils.
- The deflection of the electron beam is observed on the screen.

(i) The electrons in the beam are accelerated through a potential difference V. When they enter the magnetic field of flux density B they follow a circular path of radius r.

Show that the charge to mass ratio of the electron is given by:

$$\frac{e}{m_e} = \frac{2V}{B^2r^2}$$

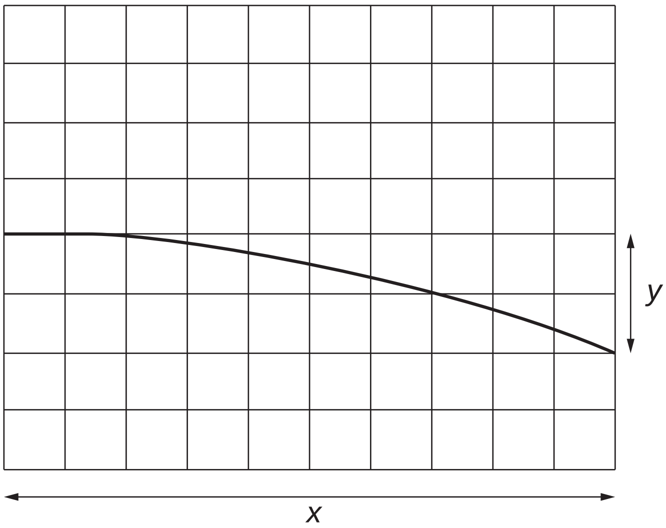
Consider:

- the kinetic energy of the electrons
- the force due to the magnetic field which deflects them in a circular path.

[2]

(ii) **Fig. 40.2** shows the path of the electron beam on the fluorescent screen when the magnetic field is produced by the coils.

Fig. 40.2



The radius of the circular path of the electron beam is given by

$r = \dfrac{x^2 + y^2}{2y}$.

The measurements made in this experiment are:

$V = 2.0\,\text{kV}$
$B = 5.8 \times 10^{-4}\ \text{T}$

$x = 10.0\,\text{cm}$
$y = 2.0\,\text{cm}$

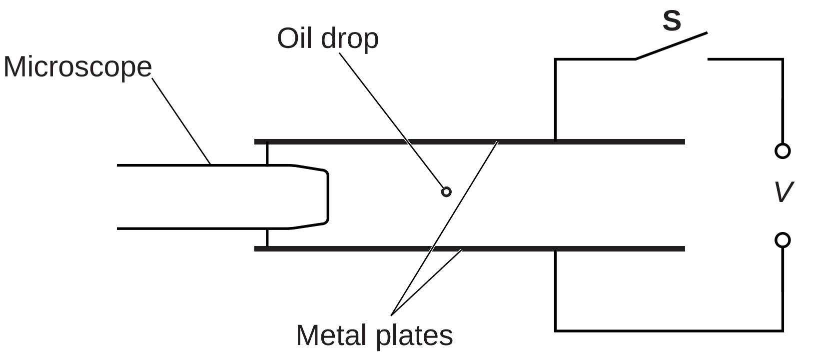
Use these measurements to calculate $\dfrac{e}{m_e}$.

$\dfrac{e}{m_e}$ = ... C kg^{-1} **[3]**

(b) The charge on the electron was first determined by spraying tiny drops of oil between two metal plates connected to a high voltage power supply and observing their motion through a microscope.

Fig. 40.3 shows the equipment used.

Fig. 40.3



- Oil is forced through a spray nozzle and forms negatively charged oil drops.
- Switch S is closed and the voltage supply is adjusted until one drop becomes stationary.
- Switch S is then opened, and the oil drop falls at constant velocity through the air.
- The constant velocity of the oil drop is given by the equation:

$$v = \frac{2\rho g r^2}{9\eta}$$

where ρ is the density of the oil, g is the acceleration due to gravity, r is the radius of the drop, and η is the viscosity of air.

The following data are recorded in one experiment:

potential difference $V = 1.60 \times 10^4$ V
distance between the plates $d = 10$ mm
constant velocity of falling oil drop $v = 8.3 \times 10^{-4}\ \text{m s}^{-1}$
viscosity of air $\eta = 1.8 \times 10^{-5}\ \text{kg m}^{-1}\text{s}^{-1}$
density of oil $\rho = 920\ \text{kg m}^{-3}$

(i) Show that the mass of the oil drop is 7.8×10^{-14} kg.

Use data for the oil drop when it is falling.

[3]

(ii) Calculate the charge on the oil drop.

Use data for the oil drop when it is stationary.

charge = ... C **[3]**

END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use this lined page. You must write the question numbers clearly in the margin.