MINISTRY OF EDUCATION, SINGAPORE
in collaboration with
UNIVERSITY OF CAMBRIDGE LOCAL EXAMINATIONS SYNDICATE
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME								
CENTRE NUMBER	S					INDEX NUMBER		

PHYSICS

9749/02

Paper 2 Structured Questions

For Examination from 2017

SPECIMEN PAPER

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, candidate number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Singapore Examinations and Assessment Board

CAMBRIDGE
International Examinations

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin\omega t$
velocity of particle in s.h.m.	$v = v_0 \cos\omega t$ $= \pm\,\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 **(a)** A block slides down a frictionless ramp as shown in Fig. 1.1.

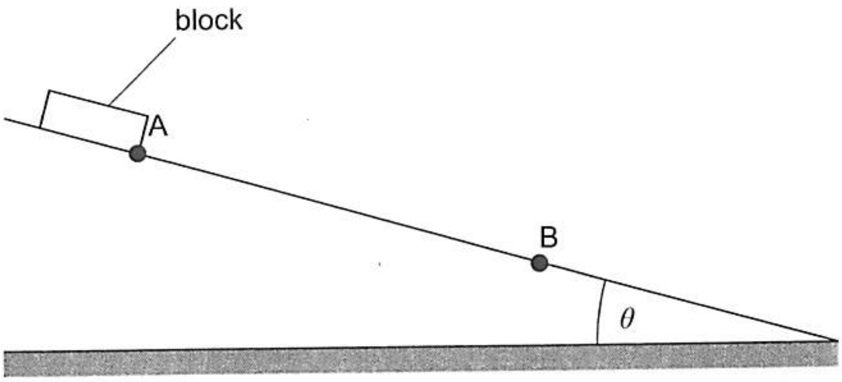

Fig 1.1

The ramp is inclined at an angle of θ to the horizontal. The block starts to move from rest at point A.

Data for the motion of the block as it travels from point A to point B are shown in Table 1.1.

Table 1.1

distance / m	time taken / s
0.80 ± 0.01	0.64 ± 0.02

(i) Calculate the acceleration a of the block down the slope.

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

(ii) Determine the actual uncertainty in the value of a calculated in **(i)**.

Hence state the value of a with its actual uncertainty to an appropriate number of significant figures.

a = ... ± .... $m\,s^{-2}$ [3]

(iii) Show that the speed v of the block at point B is 2.5 ms^{-1}.

[1]

(b) In a second experiment, a barrier is fixed at point B as shown in Fig. 1.2.

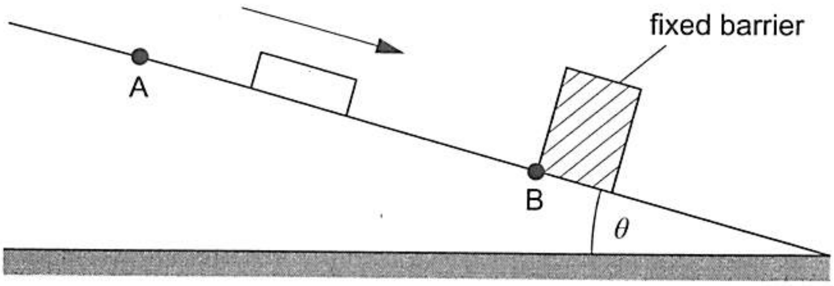

Fig. 1.2

The block slides down the ramp and bounces off the barrier with an initial speed of $1.8\,\text{m}\,\text{s}^{-1}$ up the ramp.

The block of mass 350 g is in contact with the fixed barrier for a time of 0.060 s.

(i) State and explain whether the collision between the block and the barrier is elastic or inelastic.

....

.... [1]

(ii) Calculate the magnitude of the average force F_{av} when the block is in contact with the barrier.

F_{av} = ... N [3]

(iii) During the collision the momentum of the block changes. State and explain whether momentum is conserved in this collision.

....

....

.... [1]

Question 2 starts on the next page.

2 **(a)** State what is meant by the *internal energy* of a system.

....

....

.... [2]

(b) A balloon contains a fixed mass of air that expands on heating, as illustrated in Fig 2.1.

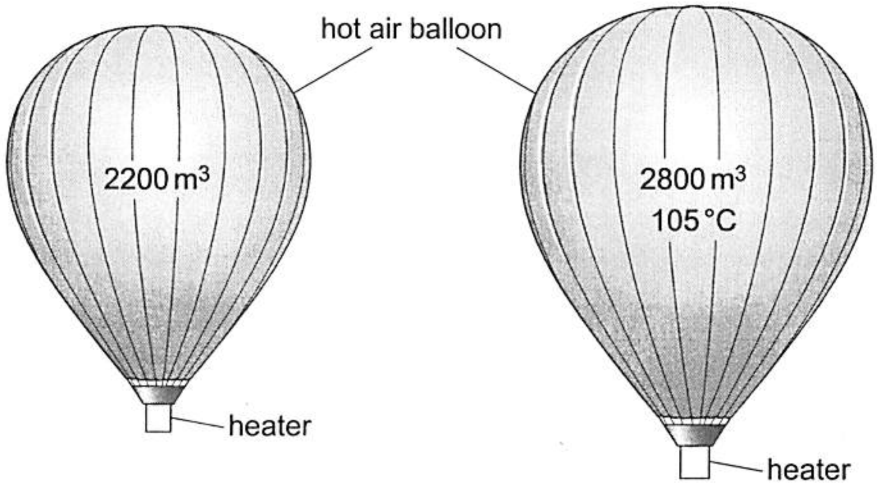

Fig. 2.1

The air is heated to a final temperature of 105 °C and the balloon expands at atmospheric pressure from 2200 m^3 to 2800 m^3, when it is fully inflated.

The air inside the balloon may be assumed to be an ideal gas.

Atmospheric pressure is 1.01×10^5 Pa.

(i) Calculate the work done by the expanding balloon on the atmosphere.

work done = ... J [1]

(ii) Explain why the internal energy of the air inside the balloon increases as the balloon expands.

....

....

....

.... [2]

(iii) The propane used in the heater produces 50 MJ of thermal energy for each kilogram of fuel that is burned. The air inside the balloon gains 116 MJ of internal energy during the expansion.

Calculate the minimum mass of propane which must be burned to fully inflate the balloon.

mass = ... kg [2]

(iv) Calculate the initial temperature, in °C, of the air.

temperature = ...°C [2]

3 **(a)** State three conditions required for the formation of an observable stationary wave.

1 ....

....

2 ....

....

3 ....

.... [3]

(b) The apparatus shown in Fig. 3.1 may be used to demonstrate a stationary wave.

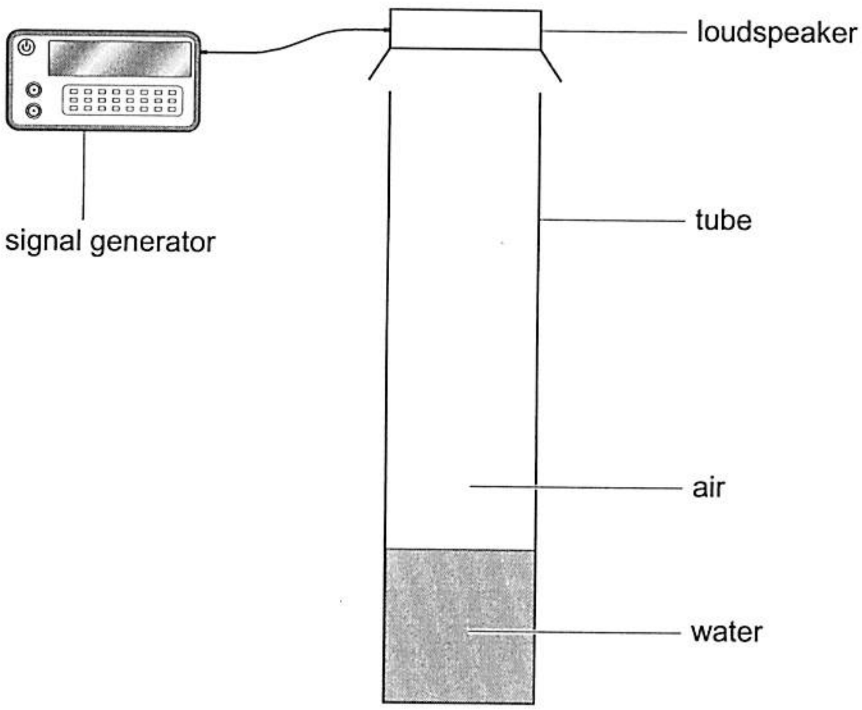

Fig. 3.1

(i) Apart from changing the frequency, state how the apparatus shown in Fig. 3.1 may be adjusted to allow a stationary wave to form.

....

.... [1]

(ii) On Fig. 3.2, draw a representation of the stationary wave with the longest wavelength that can form in the air column. Label any nodes N and any antinodes AN.

Fig. 3.2 [2]

(iii) Describe the movement of the air particles at the open top of the air column.

....

....

.... [2]

(iv) When the loudspeaker is emitting sound of frequency 480 Hz, the minimum length of the column of air is 18 cm for a stationary wave to be produced. Calculate the speed of sound in the air column.

speed of sound = ... m s^{-1} [2]

(v) The frequency of the sound from the loudspeaker in Fig. 3.1 is increased until the next stationary wave is produced.

Determine the value of this new frequency.

frequency = ... Hz [2]

4 **(a)** Define *electric field strength*.

....

.... [1]

(b) A charged metal sphere of mass 0.025 g is suspended from a light, insulating thread so that it hangs mid-way between two vertical metal plates, as shown in Fig.4.1.

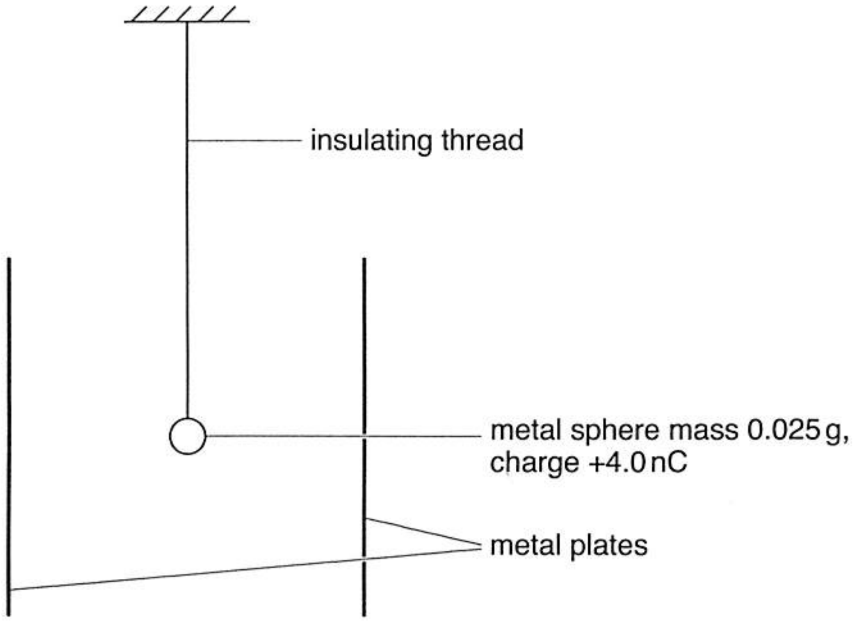

Fig. 4.1

The charge on the sphere is +4.0 nC.

(i) A potential difference is applied to the plates such that the right-hand plate is at a higher positive potential.

On Fig. 4.2, draw the new position of the charged sphere. The sphere does not touch either plate. [1]

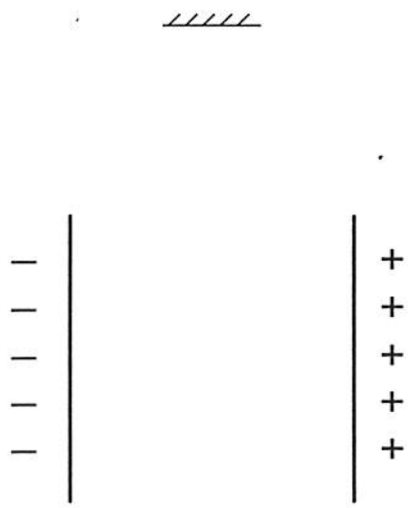

Fig. 4.2

(ii) The potential difference applied between the plates is 5700 V and the distance between the plates is 200 mm. Calculate the electric field strength without the sphere present. Include the unit with your answer.

electric field strength = ... [3]

(iii) Calculate the magnitude of the force the electric field exerts on the sphere.

force = ... N [2]

(iv) Use your answer in **(iii)** to find the angle between the thread and the vertical.

angle = ... ° [2]

(v) When this experiment is performed, the angle of deflection measured is different from the value you have calculated in **(iv)**. State how and why the deflection is different.

....

....

....

....

.... [2]

5 A current I in a wire causes the charge carriers to have a drift velocity v, as shown in Fig. 5.1.

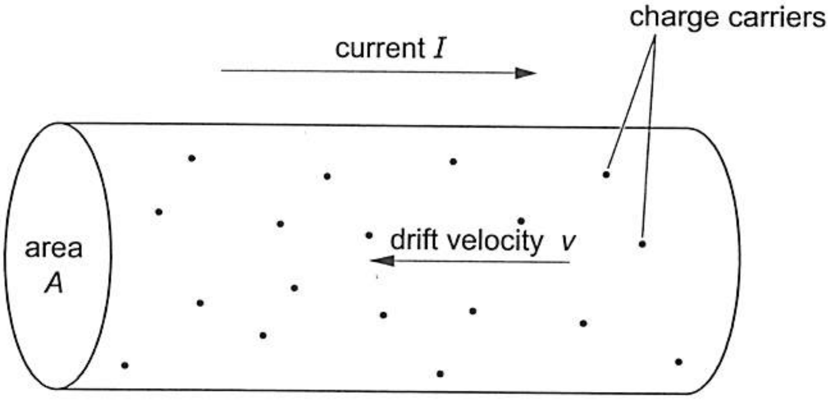

Fig. 5.1

The wire has an area of cross-section A. The number density of charge carriers in the wire is n. Each charge carrier has charge of magnitude q.

(a) Derive an equation relating current I to n, A, v and q.

[3]

(b) (i) A copper wire has diameter 0.38 mm and the number density n of charge carriers is $8.5 \times 10^{28}\,\text{m}^{-3}$. The current in the wire is 0.24 A. Calculate the drift velocity v of the charge carriers.

v = ... m s^{-1} [2]

(ii) The drift velocity of the charge carriers in the wire is much lower than the maximum velocity that the charge carriers could achieve from the potential difference applied to the wire.

Explain why.

....

....

....

....[2]

(iii) The potential difference applied across the wire is doubled. State and explain the effect on the drift velocity of the charge carriers.

....

....

....

.... [2]

(c) When a domestic lighting circuit is switched on the lights come on almost immediately.

Explain this in the context of your answer to **(b)(i)**.

....

....

.... [1]

6 (a) Two parallel wires A and B have a separation of 0.12 m, as shown in Fig. 6.1.

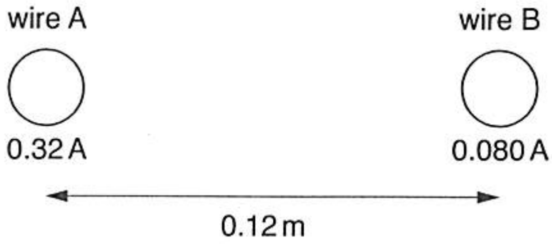

Fig. 6.1

The current in wire A is 0.32A and the current in wire B is 0.080A. In both wires the current is in the same direction.

Calculate the resultant magnetic flux density at the mid-point between the two wires.

magnetic flux density = ... T [3]

(b) A thick wire is clamped in a fixed horizontal position between the poles of a horseshoe magnet. The horseshoe magnet rests on a digital balance as shown in Fig 6.2.

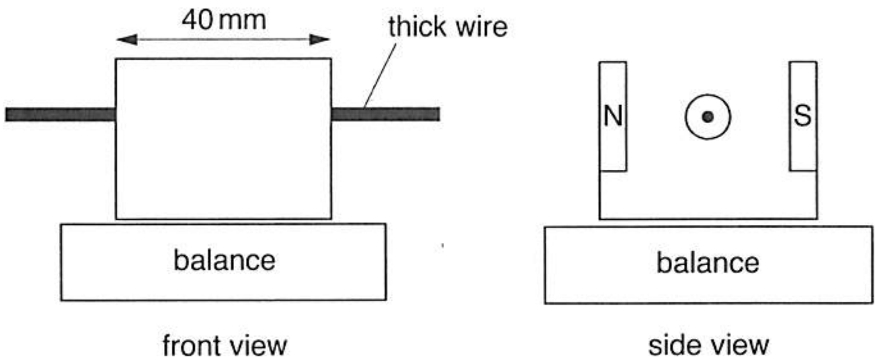

Fig. 6.2

The magnetic flux density between the poles of the magnet is 65 mT.

The length of the wire in the magnetic field is 40 mm.

When there is no current in the wire, the reading on the balance is 1.1772 N.

A current of 2.2 A now flows through the wire. The side view of Fig 6.2 shows the current in the wire directed perpendicularly out of the page.

Calculate the reading on the balance for the current of 2.2 A in the wire.

Explain your working.

reading = ... N [4]

7 The article below is based on an article on the Internet.

Read the article and then answer the questions that follow.

Photovoltaic (PV) Efficiency: The Temperature Effect

A photovoltaic (PV) cell absorbs light energy and converts this into electrical energy. A PV panel consists of a large number of photovoltaic cells. A PV system consists of a PV panel and the rest of the circuit to which it is connected.

Temperature generally affects current in an electrical circuit by changing the speed at which the electrons travel. In metals, this is due to an increase in resistance of the circuit that results from an increase in temperature. The opposite effect is seen in semiconductor materials where an increased temperature results in a decrease in resistance due to a change in the number density of charge carriers.

It is important that the equipment associated with a PV panel is appropriate for the context in which it will be used. The current and voltage output of a PV cell is affected by changing weather conditions. A PV system at a higher temperature will have a lower maximum voltage, lower efficiency and lower power output than the same system at a lower temperature.

Engineers must carefully choose the PV system for different temperature environments to ensure that the output voltage is not too high, which could damage the equipment. It is also important to consider the average operating voltage and current of a PV system for safety concerns, equipment capabilities and choices, and to minimise the amount of wire required for construction.

Since PV panels are more efficient at lower temperatures, engineers design systems with active and passive cooling. An example of active cooling is to pump water behind the panels to remove the heat. An example of passive cooling is to let the system be cooled by convection currents in the air.

While it is important to know the temperature of a solar PV panel to predict its power output, it is also important to know the PV panel materials because the efficiencies of different materials have varied levels of dependence on temperature. Therefore, a PV system must be engineered not only according to the maximum, minimum and average environmental temperatures at each location, but also with an understanding of the materials used.

The temperature dependence of a material is described with a temperature coefficient. For monocrystalline PV panels, if the temperature decreases by 1 °C, the voltage increases by 0.48 V, so the temperature coefficient is $0.48\,\text{V}\,^{\circ}\text{C}^{-1}$. The general equation for estimating the open circuit voltage V of a material at the temperature T of the panel is

$$V = \mu\,(T_R - T) + V_R \quad .$$

where μ is the temperature coefficient, T_R is a reference temperature and V_R is the open circuit voltage at the reference temperature. The temperatures are in degrees Celsius.

The variation with voltage of current at two different temperatures for one cell of the panel is shown in Fig. 7.1.

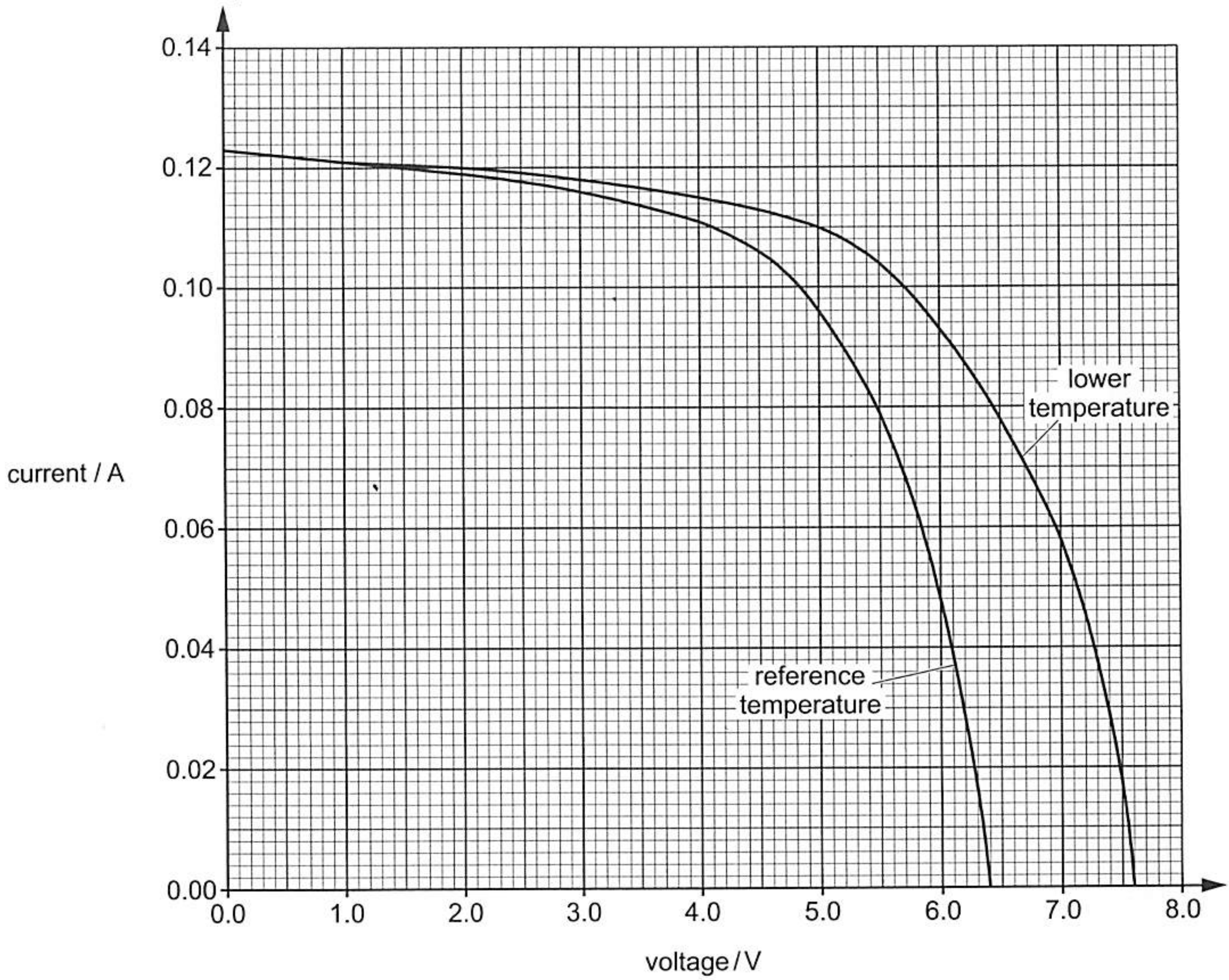

Fig. 7.1

(a) State and explain why the resistance of metals increases with temperature.

....

....

.... [2]

(b) The panel produces a much larger voltage or current than an individual cell. State how the cells are connected in a panel so that

(i) the voltage is increased,

.... [1]

(ii) the current is increased.

.... [1]

(c) (i) Suggest what is meant by *passive cooling*.

....

....

.... [1]

(ii) Suggest why engineers do not design systems with active cooling alone.

....

....

.... [1]

(d) Suggest how passive air cooling may be enhanced for a PV panel.

....

....

.... [1]

(e) (i) Use Fig. 7.1 to state the open circuit voltage (e.m.f.) of the PV cell at both the reference temperature and the lower temperature.

V_R = ... V

V = ... V

[1]

(ii) Use Fig. 7.1 to describe qualitatively the variation with temperature of the current in the cell.

....

....

....

....

....[2]

Question 7 continues on the next page.

(iii) Fig 7.2 shows the variation with temperature T of the open circuit voltage V. Draw the line of best fit. [1]

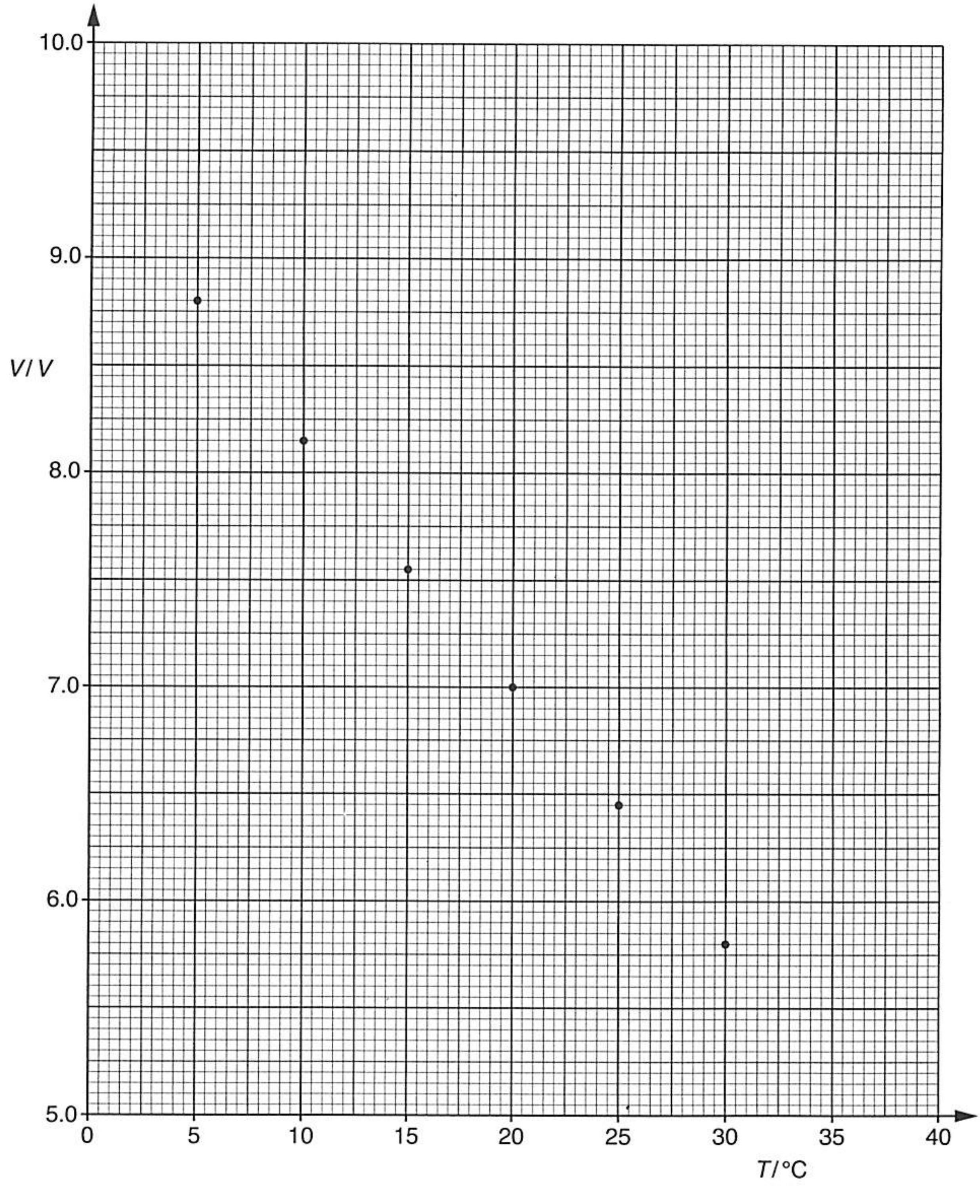

Fig. 7.2

(iv) Use Fig. 7.2 to determine the constants μ and T_R.

μ = ... V °C^{-1}

T_R = ... °C
[3]

(v) Use your answers to **(e)(i)** and **(e)(iv)** to determine the lower temperature used to obtain the data for Fig. 7.1.

lower temperature = ... °C [1]

(vi) The PV cell is producing 6.0 V at the reference temperature.

On Fig. 7.1, indicate the area which represents the output power of the cell. [2]

(vii) Use Fig 7.1 to estimate the maximum power output of the PV cell at the reference temperature.

maximum power output = ... W [2]

(f) (i) A PV cell may have multiple layers of different semi-conducting materials. As the number of layers increases, the efficiency of conversion of light energy to electrical energy increases.

Suggest a reason why the efficiency increases.

....

....

.... [1]

(ii) Suggest how the angle between the PV panel and the incident sunlight affects the power output of the PV panel.

....

.... [1]