

Please write clearly in block capitals.

Centre number

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Surname StemUp Model Solution

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Candidate signature _____

I declare this is my own work.

INTERNATIONAL A-LEVEL PHYSICS

Unit 5 Physics in practice

Tuesday 21 January 2025

07:00 GMT

Time allowed: 2 hours

Materials

For this paper you must have:

- a Data and Formulae Booklet as a loose insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate
- a protractor.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each question or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
TOTAL	



Section A

Answer **all** questions in this section.

0 1

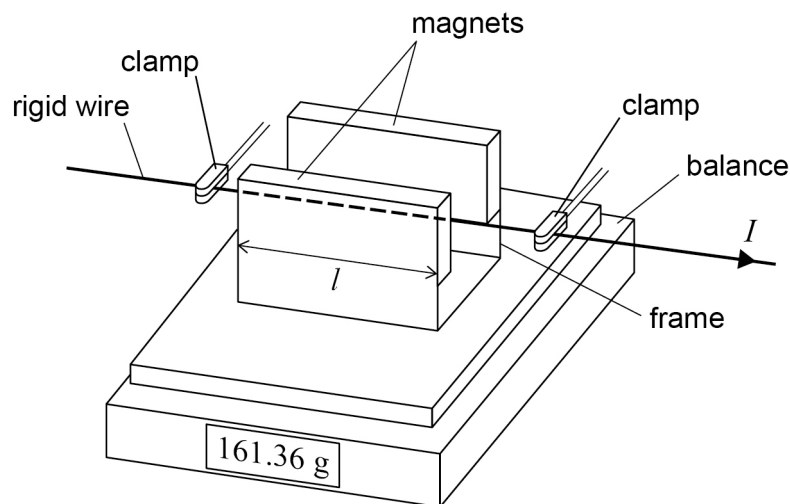
This question is about three methods for measuring the magnetic flux density B between two magnets.

The magnets are mounted on a U-shaped frame. The same frame and pair of magnets are used for all three methods.

Assume that the magnetic field in the space between the two magnets is uniform.

Figure 1 shows the apparatus for **Method 1**. The frame and the magnets are placed on a balance. A rigid wire is clamped midway between the magnets so that it is at 90° to the magnetic field.

Figure 1



When there is a current I in the wire, a force F acts on the wire due to the magnetic field.

I is measured using a digital ammeter.

The length l of the wire in the magnetic field is measured using a millimetre scale.

0 1 . 1

When there is a current I in the wire, the balance reading is 161.36 g.

When the current is zero, the reading on the balance is 164.27 g.

Deduce the magnitude and direction of F .

[2 marks]

$$\Delta m = 164.27 - 161.36 = 2.91 \text{ g} = 2.91 \times 10^{-3} \text{ kg}$$

$$F = \Delta mg = 2.91 \times 10^{-3} \times 9.81 = 0.0285 \text{ N}$$

$$F = \underline{0.0285} \text{ N}$$

direction of $F = \underline{\text{downwards (on the wire)}}$



0 1 . 2

Calculate the value of B obtained using **Method 1**.
State your answer to an appropriate number of significant figures.

$$l = 71 \text{ mm}$$

$$I = 3.62 \text{ A}$$

[2 marks]

$$F = BIl \text{ so } B = F/(Il)$$

$$B = 0.0285 / (3.62 \times 0.071) = 0.111 \text{ T}$$

$$B = \underline{0.11} \text{ T}$$

0 1 . 3

The difference between the balance readings is Δm .

State the absolute uncertainty in Δm and in l .

[2 marks]

$$\text{absolute uncertainty in } \Delta m = \underline{0.01} \text{ g}$$

$$\text{absolute uncertainty in } l = \underline{1} \text{ mm}$$

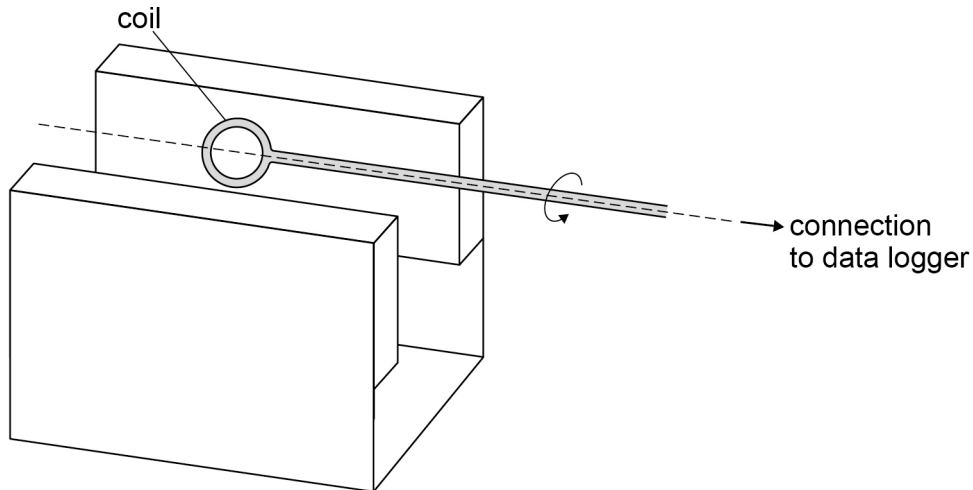
Question 1 continues on the next page

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In **Method 2**, a circular coil with n turns and a cross-sectional area A is held in the magnetic field midway between the magnets as shown in **Figure 2**. The coil is initially stationary with its plane at right angles to the magnetic field.

Figure 2

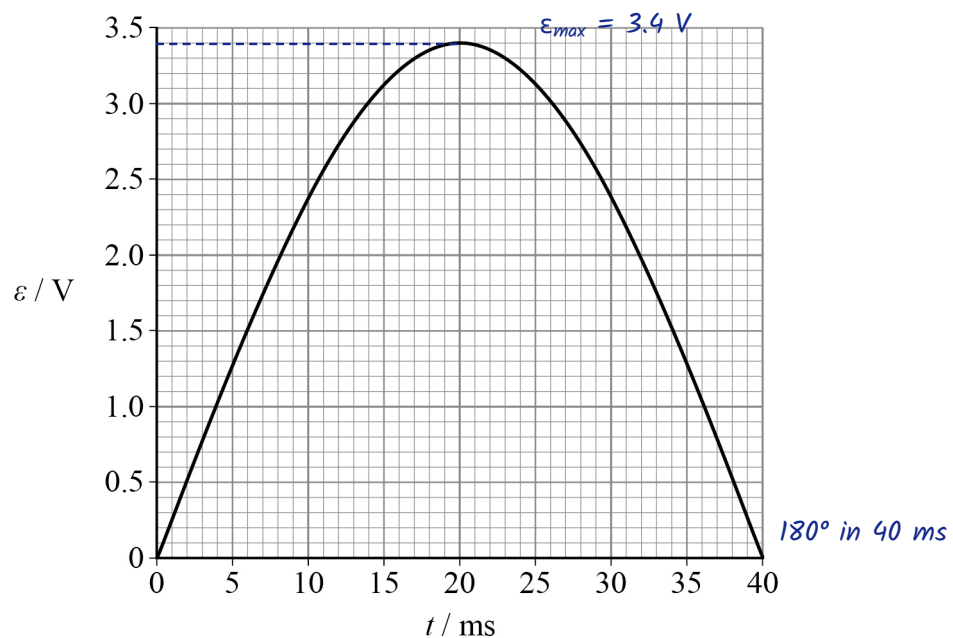


The coil is now rotated at a steady angular speed.

The induced emf ε in the coil is monitored by a data logger.

Figure 3 shows the variation of ε with time t as the coil rotates through 180° .

Figure 3



0 1 . 4

Determine the value of B obtained using **Method 2**.

$$A = 7.8 \times 10^{-5} \text{ m}^2$$

$$n = 5000$$

[3 marks]

from Figure 3: $\epsilon_{\max} = 3.4 \text{ V}$; 180° takes 40 ms so $T = 80 \text{ ms}$

$$\omega = 2\pi/T = 2\pi / 0.080 = 78.5 \text{ rad s}^{-1}$$

$$\epsilon_{\max} = BAN\omega \text{ so } B = \epsilon_{\max}/(AN\omega)$$

$$B = 3.4 / (7.8 \times 10^{-5} \times 5000 \times 78.5)$$

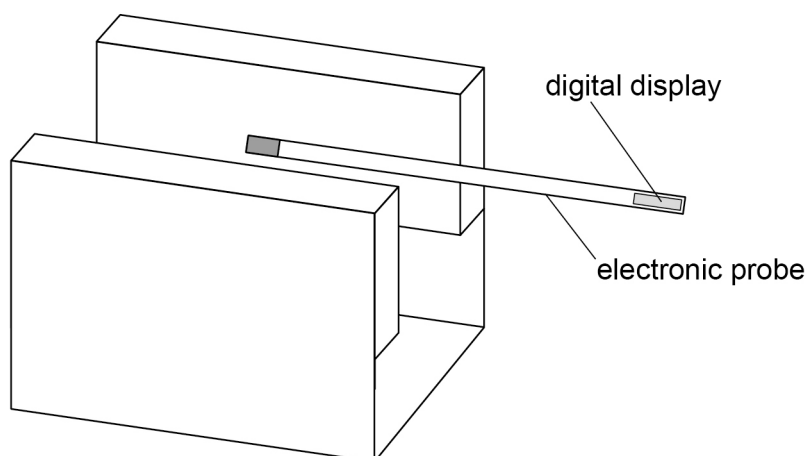
$$B = 3.4 / 30.6 = 0.11 \text{ T}$$

$$B = \underline{0.11} \text{ T}$$

Question 1 continues on the next page**Turn over ►**

In **Method 3**, a digital electronic probe is used to take direct repeated readings of B , as shown in **Figure 4**.

Figure 4



0 1 . 5 Table 1 gives values of B obtained with **Method 3**.

Table 1

B / T	0.118	0.108	0.089	0.113	0.112	0.115
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Determine the value of B for this set of readings.
Go on to state the absolute uncertainty in B .

[2 marks]

0.089 T is anomalous, so ignore it

$$\text{mean} = (0.118 + 0.108 + 0.113 + 0.112 + 0.115)/5 = 0.113 \text{ T}$$

$$\text{uncertainty} = \text{half range} = (0.118 - 0.108)/2 = 0.005 \text{ T}$$

$$B = \underline{0.113} \text{ T}$$

$$\text{absolute uncertainty in } B = \underline{0.005} \text{ T}$$



0 1 . 6

When using **Method 1**, the uncertainty in B is approximately 2%.
When using **Method 2**, the uncertainty in A is 10%.

Deduce whether **Method 1**, **Method 2** or **Method 3** gives the smallest percentage uncertainty in B .

[2 marks]

Method 3: % uncertainty = $0.005/0.113 \times 100 = 4.4\%$

Method 2: A alone has 10 %, so B has more than 10 %.

Method 1 (2 %) < Method 3 (4.4 %) < Method 2 (> 10 %), so

Method 1 gives the smallest % uncertainty.

13

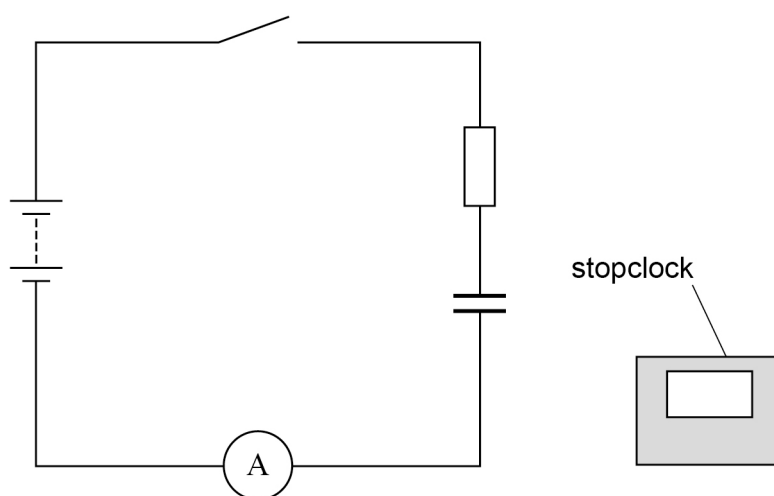
Turn over for the next question

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0 2

A student uses the apparatus shown in **Figure 5** to investigate the charging of a capacitor through a resistor.

Figure 5

The capacitor is initially uncharged. The student closes the switch and starts the stopclock.

The student records values of time t and current I as the capacitor charges.

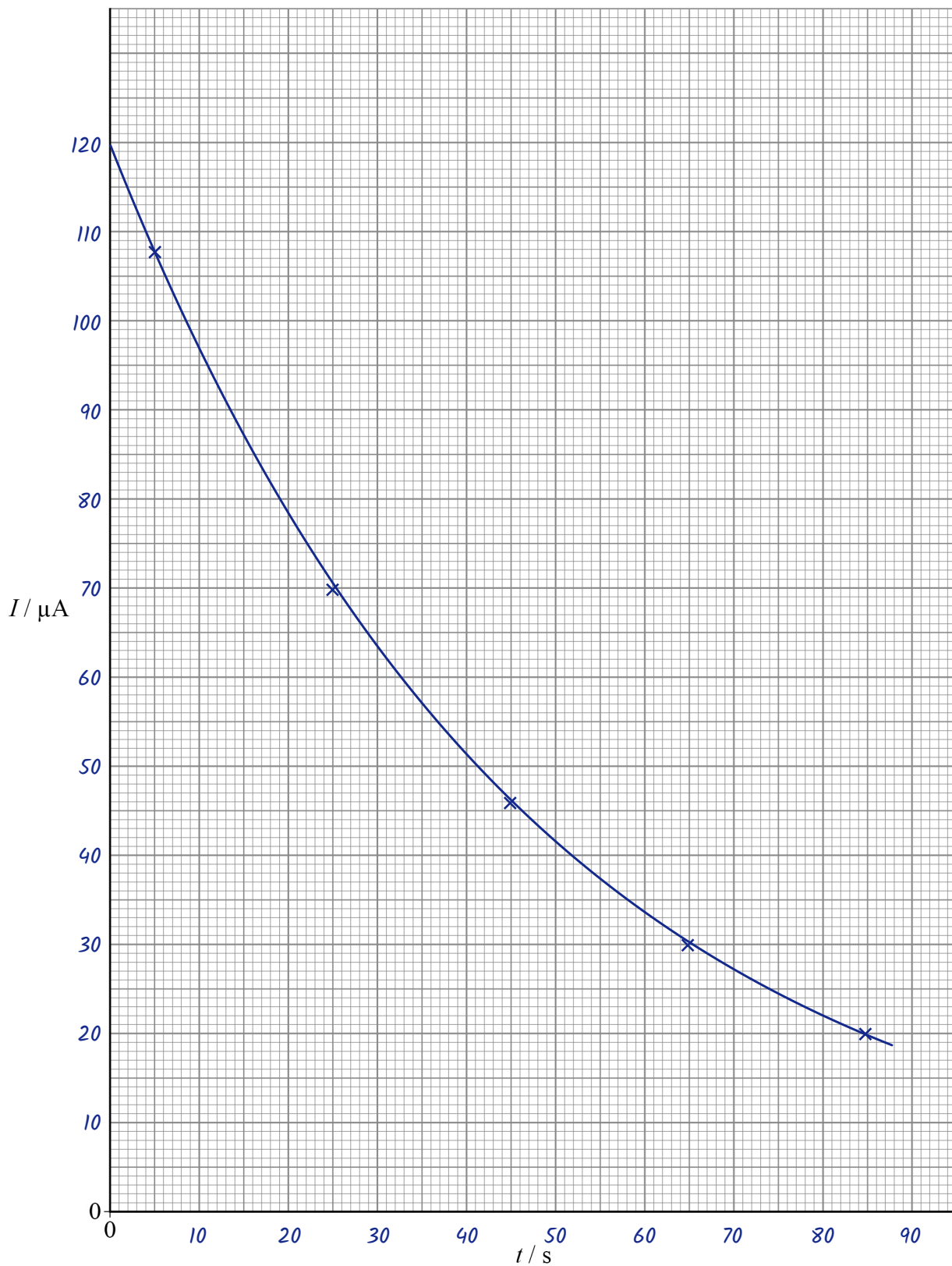
Table 2 shows the student's values.

Table 2

t / s	$I / \mu\text{A}$
5.0	108
25.0	70
45.0	46
65.0	30
85.0	20



0 2 . 1

Draw, on **Figure 6**, a graph to show the variation of I with t .**[4 marks]**Do not write
outside the
box**Figure 6**

Turn over ►



0 2 . 2

The student knows the resistance R of the resistor.
She uses the same data to draw a graph of $\ln I$ against t .

Explain how she can use the graph of $\ln I$ against t to determine the capacitance C of the capacitor.

[3 marks]

$I = I_0 e^{-t/RC}$, so taking logs: $\ln I = \ln I_0 - t/RC$.

So the graph of $\ln I$ against t is a straight line with gradient $= -1/RC$.

She finds the gradient using a large triangle, then $C = -1/(R \times$
gradient).

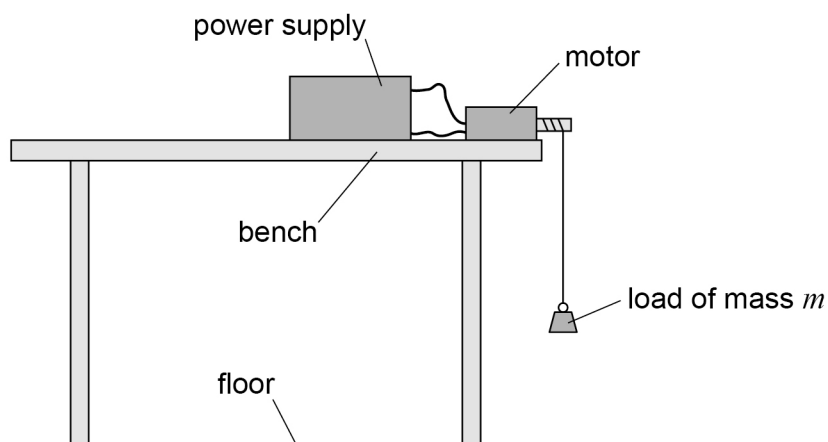
7



0 3

Figure 7 shows an electric motor being used to raise a load of mass m .

Figure 7



A student plans to investigate how the efficiency η of the motor varies with the mass m of the load at a constant supply voltage.

The student plans to vary m from 0.10 kg to 0.60 kg in increments of 0.10 kg.

0 3 . 1

Describe how the student should perform the investigation using the apparatus shown in **Figure 7** and any other necessary equipment.

In your answer, describe how to:

- make the necessary measurements
- perform the investigation accurately
- process the results in order to plot a graph of η against m .

You may draw a diagram to help your description.

[6 marks]

Measurements: connect an ammeter in series with the motor and a voltmeter across the motor (or use a joulemeter). Measure each load mass on a top-pan balance, starting with $m = 0.10$ kg.

Clamp a metre ruler vertically beside the path of the load (check it is

Question 3 continues on the next page

Turn over ►



vertical with a set square or plumb line). Mark a lower and an upper point with fiducial markers (tape) a large height h apart, e.g. 1.00 m, measured from above the floor, not from the floor itself.

Switch on. When the load is rising at a steady speed, start a stopwatch as it passes the lower marker and stop it at the upper marker, viewing at eye level to avoid parallax. Record the time t and the readings V and I while the load rises.

Accuracy: keep the supply voltage constant for every load (check it on the voltmeter). Repeat each run three times, remove any anomalies and average t , V and I . Using a light gate and data logger (or a video in slow motion) removes the human reaction time error in t .

Repeat for $m = 0.20, 0.30, 0.40, 0.50$ and 0.60 kg.

Processing: useful output power $P_{out} = mgh/t$, input power $P_{in} = VI$, so efficiency $\eta = P_{out}/P_{in} = mgh/(VIt)$.

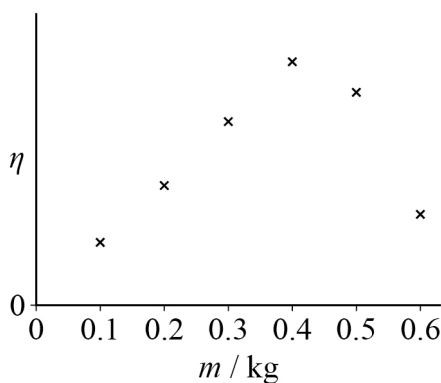
Calculate η for each mass and plot η on the y-axis against m on the x-axis.



0 3 . 2

Figure 8 shows the student's plot of η against m .

Figure 8



The student wants to determine the maximum efficiency $\eta_{\max}$ of the motor.

Suggest how the student can improve the data collection to find an accurate value for $\eta_{\max}$.

[2 marks]

*Use smaller increments of mass, e.g. every 0.02 kg to 0.05 kg,
with more readings close to the maximum of the graph (between about
0.3 kg and 0.5 kg), so the peak and $\eta_{\max}$ can be located precisely.*

0 3 . 3

The current in the motor increases as m increases.

Suggest why η is smaller for large values of m .

[1 mark]

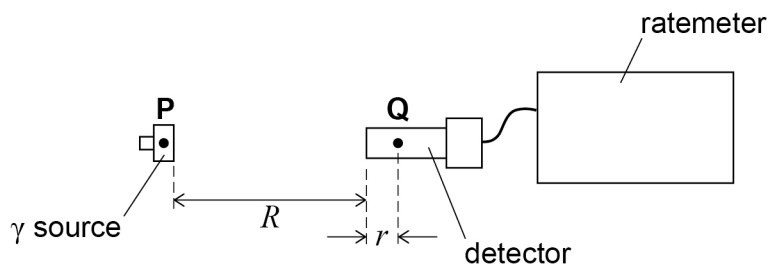
*A larger current is needed (greater torque), so the heating (I^2R) losses
in the motor coils are much greater, so a smaller fraction of the input
is useful.*



0 4

Figure 9 shows apparatus used to verify the inverse-square law for γ radiation.

Figure 9



The γ rays are emitted from point **P** inside the γ source. **P** acts as a point source. The average position where γ rays are detected is at point **Q**, a distance r from the front face of the detector.

The count rate is measured for a distance R between the source and the detector. The corrected count rate C is determined. C is determined for a range of values of R .

Figure 10 is a plot of R against $\frac{1}{\sqrt{C}}$.

Error bars indicate the uncertainties in the data for $\frac{1}{\sqrt{C}}$.

The uncertainty in measurements of R is negligible.

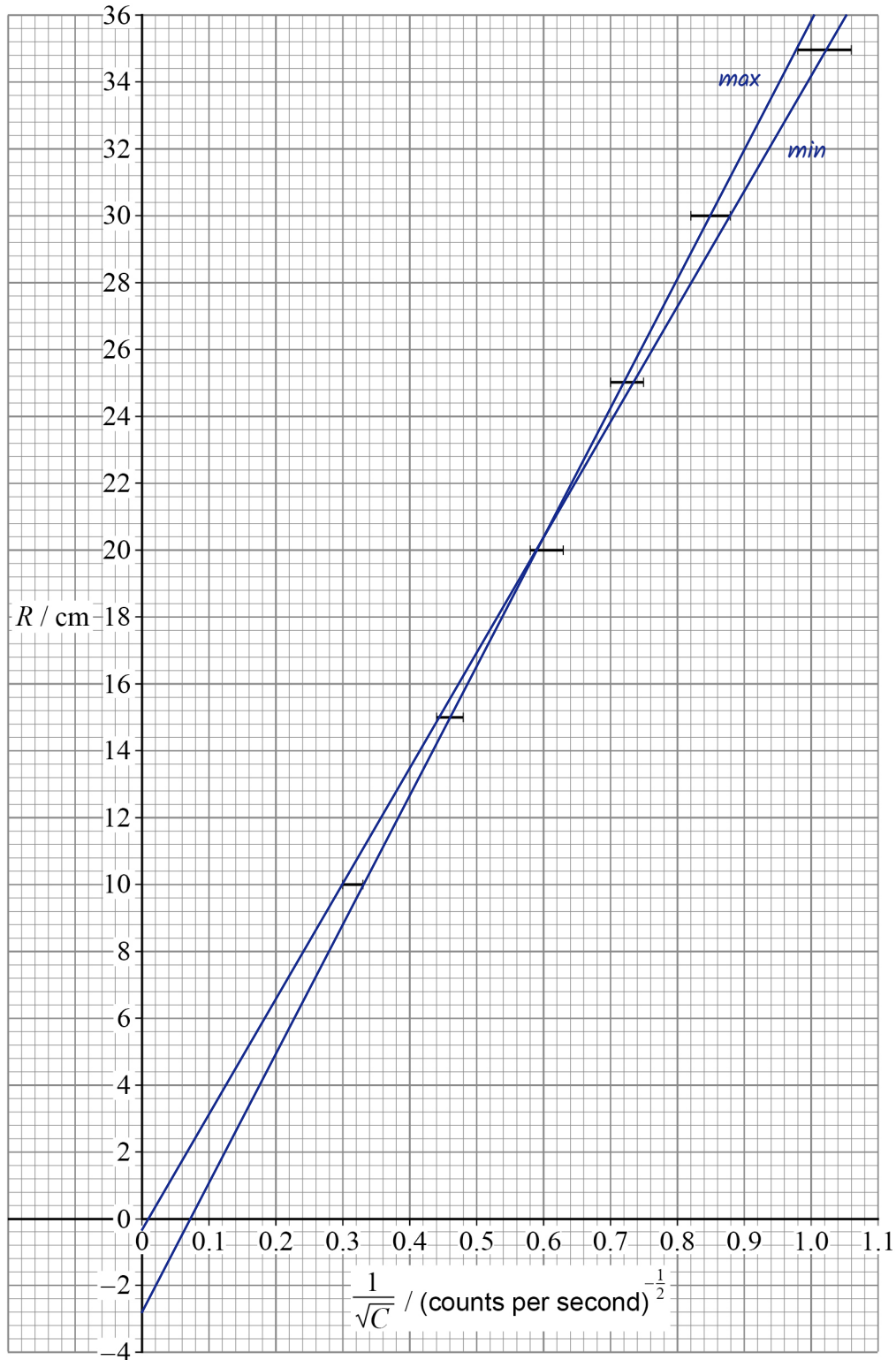


0 4 . 1

Draw, on **Figure 10**, lines with the minimum and maximum gradients consistent with the data.

[2 marks]

Figure 10



Question 4 continues on the next page

Turn over ►



The equation of the graph is $R = \frac{k}{\sqrt{C}} - r$

0 4 . 2

Determine a mean value for r and a value for the absolute uncertainty in r .

[3 marks]

R-intercept = $-r$ for each line:

min gradient line: intercept = -0.3 cm so $r = 0.3$ cm

max gradient line: intercept = -2.8 cm so $r = 2.8$ cm

mean $r = (0.3 + 2.8)/2 = 1.6$ cm (1.55 cm)

uncertainty = half the range = $(2.8 - 0.3)/2 = 1.2$ cm

$r =$ 1.6 cm

uncertainty in $r =$ 1.2 cm

0 4 . 3

Explain how the data in **Figure 10** support the inverse-square law for γ radiation.

[2 marks]

$$R = k/\sqrt{C} - r \text{ so } \sqrt{C} = k/(R + r) \text{ so } C = k^2/(R + r)^2$$

so $C \propto 1/(\text{distance})^2$: the inverse-square law

Straight line ($y = mx + c$, not through origin), so the data fit the equation.

$C \propto 1/(R + r)^2$, where $R + r = \text{distance } P \text{ to } Q$.

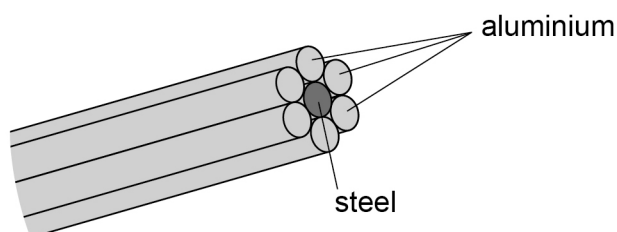
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END OF SECTION A



Section BAnswer **all** questions in this section.**0 5**

A power cable has a central steel wire fixed to six aluminium wires.
Figure 11 shows the structure of the power cable.

Figure 11

For this cable:

length = 68 m

cross-sectional area of each wire = $1.05 \times 10^{-5} \text{ m}^2$

total mass of steel in the cable = 5.62 kg

total mass of aluminium in the cable = 11.6 kg.

Table 3 shows properties of the steel and the aluminium.**Table 3**

	Resistivity / $\Omega \text{ m}$	Young modulus / Pa	Specific heat capacity / $\text{J kg}^{-1} \text{ K}^{-1}$
steel	6.9×10^{-7}	2.1×10^{11}	502
aluminium	2.8×10^{-8}	7.0×10^{10}	921

The initial resistance of the central steel wire is 4.47Ω .**0 5 . 1**

Calculate the initial total resistance of the cable.

[3 marks]

$$\text{one Al wire: } R = \rho l / A = 2.8 \times 10^{-8} \times 68 / 1.05 \times 10^{-5} = 0.181 \Omega$$

$$\text{six Al wires in parallel: } R = 0.181 / 6 = 0.0302 \Omega$$

$$1/R_T = 1/4.47 + 1/0.0302 = 0.224 + 33.1 = 33.3 \Omega^{-1}$$

$$R_T = 0.030 \Omega$$

resistance = 0.030 Ω **Question 5 continues on the next page****Turn over ►**

When a current is turned on in the cable, the initial power generated in the cable only heats the cable.

The initial potential difference across the length of the cable is 0.91 V.

0 5 . 2

Calculate the initial power generated in the **central steel wire** of the cable.

[1 mark]

$$P = V^2/R = 0.91^2 / 4.47 = 0.19 \text{ W}$$

initial power generated = 0.19 W

0 5 . 3

The central steel wire of the cable has an initial rate of temperature increase of $\frac{\Delta\theta}{\Delta t}$.

Calculate $\frac{\Delta\theta}{\Delta t}$.

[2 marks]

$$P = mc\Delta\theta/\Delta t \text{ so } \Delta\theta/\Delta t = P/(mc)$$

$$\Delta\theta/\Delta t = 0.185 / (5.62 \times 502)$$

$$\Delta\theta/\Delta t = 6.6 \times 10^{-5} \text{ K s}^{-1}$$

$$\frac{\Delta\theta}{\Delta t} = \underline{6.6 \times 10^{-5}} \text{ K s}^{-1}$$



0 5 . 4

The initial rate of temperature increase for the aluminium is very much greater than the initial rate of temperature increase for the steel.

Explain this using data from page 17.

[3 marks]

$$P = V^2/R: P_{Al} = 0.91^2/0.0302 = 27.4 \text{ W}, P_{steel} = 0.185 \text{ W}, \text{ ratio} \approx 148$$

$$\text{thermal capacity } mc: Al \ 11.6 \times 921 = 1.07 \times 10^4 \text{ J K}^{-1}$$

$$\text{steel } 5.62 \times 502 = 2.82 \times 10^3 \text{ J K}^{-1}, \text{ ratio} \approx 3.8$$

$$Al: \Delta\theta/\Delta t = 27.4 / 1.07 \times 10^4 = 2.6 \times 10^{-3} \text{ K s}^{-1} \text{ (about } 39 \times \text{ steel)}$$

The wires are in parallel, so the pd across the aluminium is the same as across the steel.

The aluminium has a much lower resistance, so its power is about 148 times greater, but its thermal capacity is only 3.8 times greater.

So its rate of temperature rise is about 39 times that of the steel.

0 5 . 5

Eventually, the current in the cable reaches a constant value.

Explain why the cable eventually reaches a steady temperature.

[1 mark]

The rate of heating by the current becomes equal to the rate of heat transfer from the cable to the surroundings.

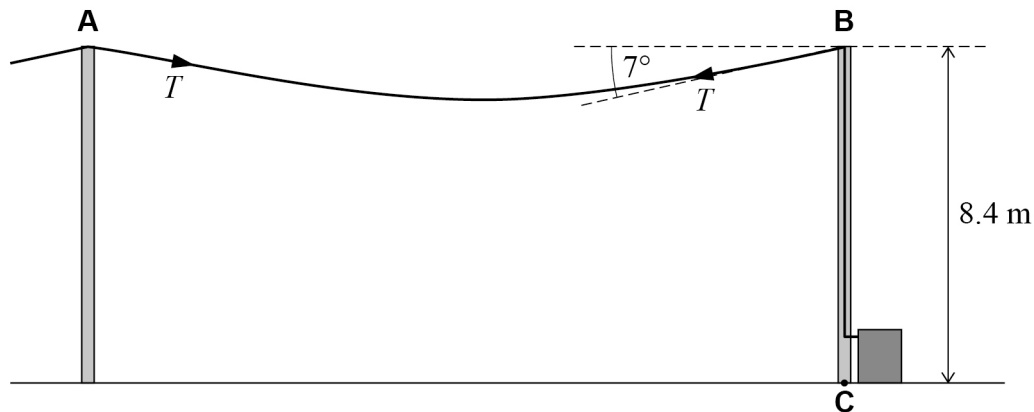
Question 5 continues on the next page

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Figure 12 shows the cable attached to posts A and B.

Figure 12



The magnitude of the tension T in the cable is 693 N.

Assume that T is constant everywhere along the cable between A and B.

The strain in the aluminium wires is the same as the strain in the steel wire.

0 5 . 6

Explain why all the wires have the same strain.

[1 mark]

*The wires are fixed together so they all extend by the same amount,
and they all have the same original length.*

0 5 . 7

Show that the tension in the steel part of the cable is 50% of the total tension in the aluminium part of the cable.

[2 marks]

$E = FL/(A\Delta L)$ so $F = EA \times \text{strain}$, with the same strain for all wires

$$F_{\text{steel}} / F_{\text{Al}} = (E_{\text{steel}} \times A) / (E_{\text{Al}} \times 6A)$$

$$F_{\text{steel}} / F_{\text{Al}} = 2.1 \times 10^{11} / (7.0 \times 10^{10} \times 6)$$

$$F_{\text{steel}} / F_{\text{Al}} = 3/6 = 0.5, \text{ so the steel tension is 50 \%}$$

of the total aluminium tension



0 5 . 8

Calculate the extension of the cable due to T .

[3 marks]

$$T_{\text{steel}} + T_{\text{Al}} = 693 \text{ and } T_{\text{steel}} = 0.5 T_{\text{Al}} \text{ so } T_{\text{Al}} = 462 \text{ N}, T_{\text{steel}} = 231 \text{ N}$$

$$\Delta L = FL/(EA) = 231 \times 68 / (2.1 \times 10^{11} \times 1.05 \times 10^{-5})$$

$$\Delta L = 7.1 \times 10^{-3} \text{ m}$$

$$\text{extension} = \underline{7.1 \times 10^{-3}} \text{ m}$$

0 5 . 9

The cable makes an angle of 7° to the horizontal at **B** as shown in **Figure 12**.Determine the moment of T about point **C** shown on **Figure 12**.

[2 marks]

$$\text{horizontal component of } T = T \cos 7^\circ, \text{ at } 8.4 \text{ m above C}$$

(the vertical component acts through C)

$$\text{moment} = 693 \times \cos 7^\circ \times 8.4 = 5780 \text{ N m}$$

$$\text{moment} = \underline{5780} \text{ N m}$$

0 5 . 1 0

The moment exerted by the cable on **B** changes when weather conditions change.State and explain, for **one** weather condition, how this change in moment occurs.

[1 mark]

Hot weather: the cable expands and sags more, so the angle at B increases, the horizontal component $T \cos \theta$ falls and the moment about C decreases.



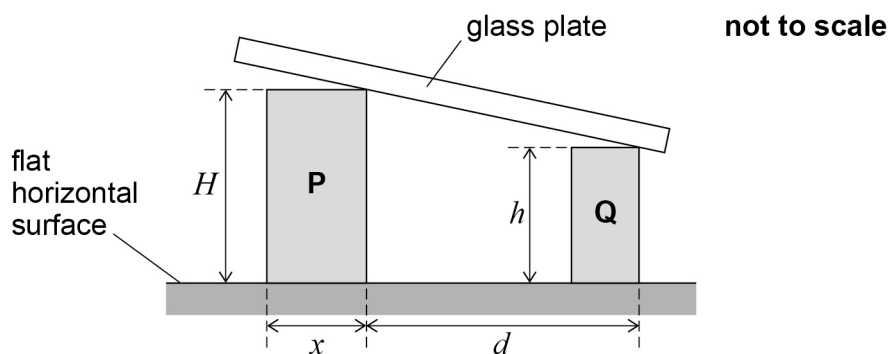
0 6

Figure 13 shows an arrangement to find the height h of a block **Q**.

Two blocks **P** and **Q** are placed on a flat horizontal surface. A glass plate rests on **P** and **Q**.

The width x of **P** and the distance d between the right-hand edges of **P** and **Q** are accurately known. The height of **P** is known to be H .

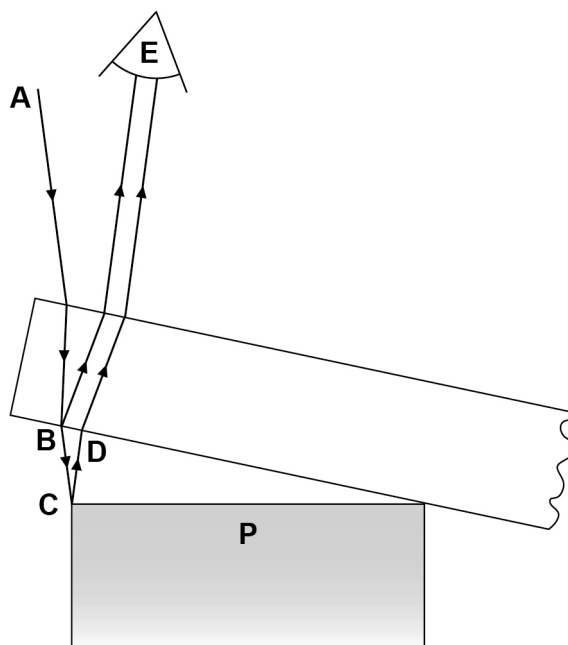
Figure 13



A ray of light from a monochromatic source is incident on the top of the glass plate, as shown in **Figure 14**. At **B** this ray splits into two rays, **ABE** and **ABCDE**.

Figure 14 shows an enlarged view of the top of **P** and the two rays. Horizontal distances are exaggerated to make the paths of the rays clear.

Figure 14



ABE is reflected from the lower surface of the glass plate at **B**.

ABCDE is transmitted at **B** and reflected from the top of **P** at **C**.

t is the mean of the distances **BC** and **CD**.

ABCDE travels a distance $2t$ more than ray **ABE**.

ABE and **ABCDE** meet and superpose in an observer's eye **E**.

0 6 . 1

State what is meant by coherence.

[2 marks]

*Coherent waves have the same (constant) frequency and wavelength,
and a constant phase difference between them.*

0 6 . 2

Explain why **ABE** and **ABCDE** are coherent.

[1 mark]

Both rays come from the same original ray, split at the same point B.

0 6 . 3

Light travelling along **ABCDE** has a phase change of π rad when it reflects at **C**.

Deduce whether a dark fringe or a bright fringe is observed by the eye when $t = 24\lambda$.

[2 marks]

*Path difference = $2t = 48\lambda$, a whole number of wavelengths, which on
its own would give reinforcement (a bright fringe).*

*But the π rad phase change at C makes the total path difference
 48.5λ , so the rays arrive in antiphase and a dark fringe is seen.*

Question 6 continues on the next page

Turn over ►



The interference of the light is used to compare h with H .

0 6 . 4

There are 48 complete sets of interference fringes across the width of **P**.

Show, using similar triangles, that $h = H - \frac{24\lambda d}{x}$

[2 marks]

each complete fringe means $2t$ increases by λ , so t increases by $\lambda/2$

48 fringes across P: $t = 48 \times \lambda/2 = 24\lambda$ (gap at the left edge of P)

similar triangles (plate rises t over x , and $H - h$ over d):

$$t/x = (H - h)/d \text{ so } H - h = td/x = 24\lambda d/x$$

$$h = H - 24\lambda d/x$$

0 6 . 5

The light has a frequency of 462.000 THz.

Calculate h .

$$H = 150.000 \text{ mm}$$

$$x = 50.0000 \text{ mm}$$

$$d = 147.200 \text{ mm}$$

$$c_{\text{air}} = 2.99705 \times 10^8 \text{ m s}^{-1}$$

[2 marks]

$$\lambda = c/f = 2.99705 \times 10^8 / 4.62000 \times 10^{14} = 6.48712 \times 10^{-7} \text{ m}$$

$$24\lambda d/x = 24 \times 6.48712 \times 10^{-7} \times 0.147200 / 0.0500000 = 4.5835 \times 10^{-5} \text{ m}$$

$$h = 0.150000 - 0.0000458 = 0.149954 \text{ m}$$

$$h = \underline{0.149954} \text{ m}$$

0 6 . 6

The light source is replaced with one that emits light with a higher frequency.

Deduce how the number of observable fringes across the width of **P** changes.

[2 marks]

Higher frequency means a shorter wavelength. The gap (t) is unchanged,

so $2t$ now equals more wavelengths and the fringe spacing decreases.

So more fringes (more than 48) fit across the width of P.



0 7

This question is about aspects of global warming and the greenhouse effect.

Oceans cover an area of $3.6 \times 10^8 \text{ km}^2$ of the Earth's surface and have a volume of $1.3 \times 10^9 \text{ km}^3$. Assume that the surface area of the oceans remains constant.

0 7 . 1

Estimate, in m, the mean depth of the Earth's oceans.

[1 mark]

$$\text{depth} = \text{volume/area} = 1.3 \times 10^9 \text{ m}^3 / 3.6 \times 10^8 \text{ m}^2 = 3611 \text{ m}$$

mean depth = 3611 m

0 7 . 2

During the last 100 years, the mean depth of the oceans has increased by approximately 6 cm due to the melting of ice on land.

Estimate the energy required to melt sufficient ice at 0°C to cause this increase in depth.

Ignore thermal expansion in this part of the question.

$$\begin{aligned} \text{mean density of water from land ice} &= 1.0 \times 10^3 \text{ kg m}^{-3} \\ \text{specific latent heat of ice} &= 3.34 \times 10^5 \text{ J kg}^{-1} \end{aligned}$$

[3 marks]

$$\text{volume} = 0.06 \times 3.6 \times 10^8 = 2.16 \times 10^{13} \text{ m}^3$$

$$\text{mass } m = \rho V = 1.0 \times 10^3 \times 2.16 \times 10^{13} = 2.16 \times 10^{16} \text{ kg}$$

$$Q = mL = 2.16 \times 10^{16} \times 3.34 \times 10^5 = 7.2 \times 10^{21} \text{ J}$$

energy = 7.2×10^{21} J

Question 7 continues on the next page

Turn over ►



0 7 . 3

The mean depth of the oceans has increased by approximately 12 cm because water expands as its temperature increases.

This thermal expansion only happens in the top layer of the oceans. The top layer has a thickness of 1000 m.

During the last 100 years, the water in this top layer has expanded by an average of 0.0020% for every 0.100 K increase in temperature.

Estimate the increase in temperature of the top layer during this time period.

[2 marks]

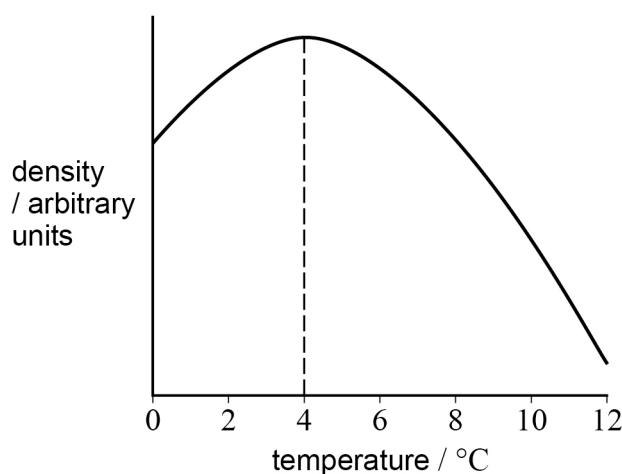
$$\text{fractional expansion} = 0.12/1000 = 1.2 \times 10^{-4} = 0.012 \%$$

$$\Delta T = (0.012 / 0.0020) \times 0.100 = 0.60 \text{ K}$$

increase in temperature = 0.6 K

Figure 15 shows the variation of the density of seawater with temperature between 0 °C and 12 °C.

Figure 15



0 7 . 4

The surface of the oceans is heated by solar radiation.

Only the top layer of the oceans changes significantly in volume due to thermal expansion.

Suggest **one** reason why this is true.

[1 mark]

*Warm water is less dense than cold water, so the heated water floats
and stays in the top layer (water is also a poor thermal conductor).*



The atmosphere is transparent to most of the solar radiation that is incident on the Earth.

As a result, the surface of the Earth warms up and energy is emitted upwards from the surface through the atmosphere.

For this emitted radiation, the peak intensity occurs at a wavelength of λ_{peak} .
 λ_{peak} is given by:

$$\lambda_{\text{peak}} = \frac{C}{T}$$

where

λ_{peak} for the Earth's surface is approximately 10^4 nm

T is the average absolute temperature of the Earth's surface

C is a constant.

0 7 . 5

Estimate C .

Give an appropriate unit for your answer.

[2 marks]

$$\text{take } T \approx 15^\circ\text{C} = 288\text{ K and } \lambda_{\text{peak}} = 10^4\text{ nm} = 1.0 \times 10^{-5}\text{ m}$$

$$C = \lambda_{\text{peak}} T = 1.0 \times 10^{-5} \times 288 = 2.9 \times 10^{-3}\text{ m K}$$

$$C = \underline{2.9 \times 10^{-3}}$$

$$\text{unit} = \underline{\text{m K}}$$

Question 7 continues on the next page

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Radiation of wavelength λ_{peak} is absorbed by carbon dioxide molecules in the atmosphere. The molecules gain energy as a result.

0 7 . 6

The carbon dioxide in the atmosphere is at a temperature of -40°C .
A carbon dioxide molecule in the gas absorbs a photon of wavelength $1.00 \times 10^4 \text{ nm}$.

Compare the energy absorbed by the molecule with the initial average molecular kinetic energy of the gas.

Assume that carbon dioxide behaves as an ideal gas.

[3 marks]

$$\text{photon: } E = hc/\lambda = 6.63 \times 10^{-34} \times 3.00 \times 10^8 / 1.00 \times 10^{-5} = 1.99 \times 10^{-20} \text{ J}$$

$$T = -40 + 273 = 233 \text{ K}$$

$$\text{mean KE} = 3/2 kT = 1.5 \times 1.38 \times 10^{-23} \times 233 = 4.82 \times 10^{-21} \text{ J}$$

The photon energy is about 4.1 times (410 % of) the mean molecular kinetic energy.

0 7 . 7

Carbon dioxide molecules can lose this energy by the emission of one or more photons of radiation.

One cause of the greenhouse effect is that the energy of these photons is trapped in the atmosphere.

Suggest **two** reasons why this energy can become trapped in the atmosphere.

[2 marks]

1 *The photons are re-emitted in all directions, so some go back to the Earth.*

2 *Photons travelling towards space are likely to be absorbed again by other CO_2 or greenhouse gas molecules higher up.*

END OF QUESTIONS



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