Surname	Centre Number	Candidate Number
Other Names		2

GCE A LEVEL

1420U40-1

S19-1420U40-1

PHYSICS – A2 unit 4
Fields and Options

MONDAY, 17 JUNE 2019 – MORNING

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**27**	
	2.	**11**	
	3.	**12**	
	4.	**18**	
	5.	**12**	
Section B	**Option**	**20**	
	Total	**100**	

1420U401 01

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Answer **all** questions.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.

Section **A**: 80 marks. Answer **all** questions. You are advised to spend about 1 hour 35 minutes on this section.

Section **B**: 20 marks. Options. Answer **one option only**. You are advised to spend about 25 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **5*(b)***.

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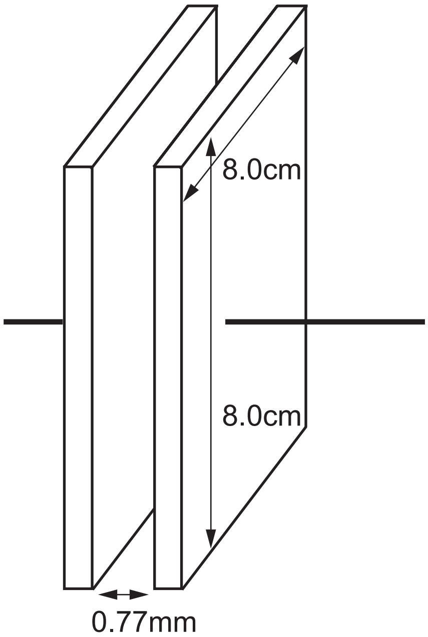
SECTION A

*Answer **all** questions.*

1. *(a)* (i) For the air-spaced parallel plate capacitor shown, calculate the pd applied when it stores 25.5 μJ of energy. [4]



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(ii) Explain why the capacitor stores energy when a pd is applied to the plates. [2]

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(iii) A group of scientists claim that they have developed a new dielectric that enables the above capacitor to store a million times more charge and energy for a given pd. Explain what further steps must be taken by the scientific community and industry before this new dielectric can be used in devices and sold to the public. [3]

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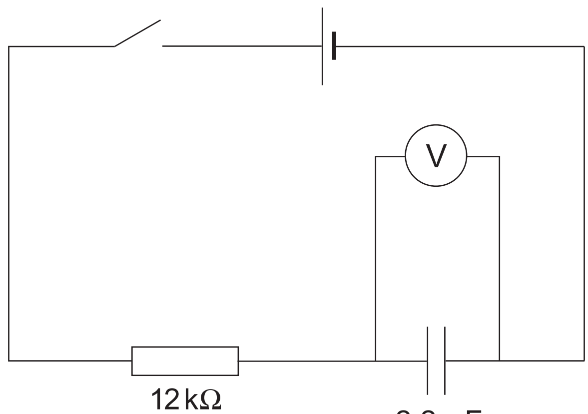
(b) Bethan investigates the charging of a capacitor using the following circuit.



The results she obtains are then tabulated.

Time / s	pd across capacitor / V ± 0.5 V	Charge on capacitor / mC ± 1.1 mC
10.0	6.1	13.4
20.0	10.0	22.0
30.0	12.8	....
40.0	15.1	33.2
50.0	16.2	35.6
60.0	17.1	....
70.0	17.7	38.9
80.0	18.3	40.3

(i) Confirm that the uncertainty in the charge is 1.1 mC (you may assume that the uncertainty in the 2.2 mF capacitor is negligible). [1]

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(ii) **Complete** the table. [2]

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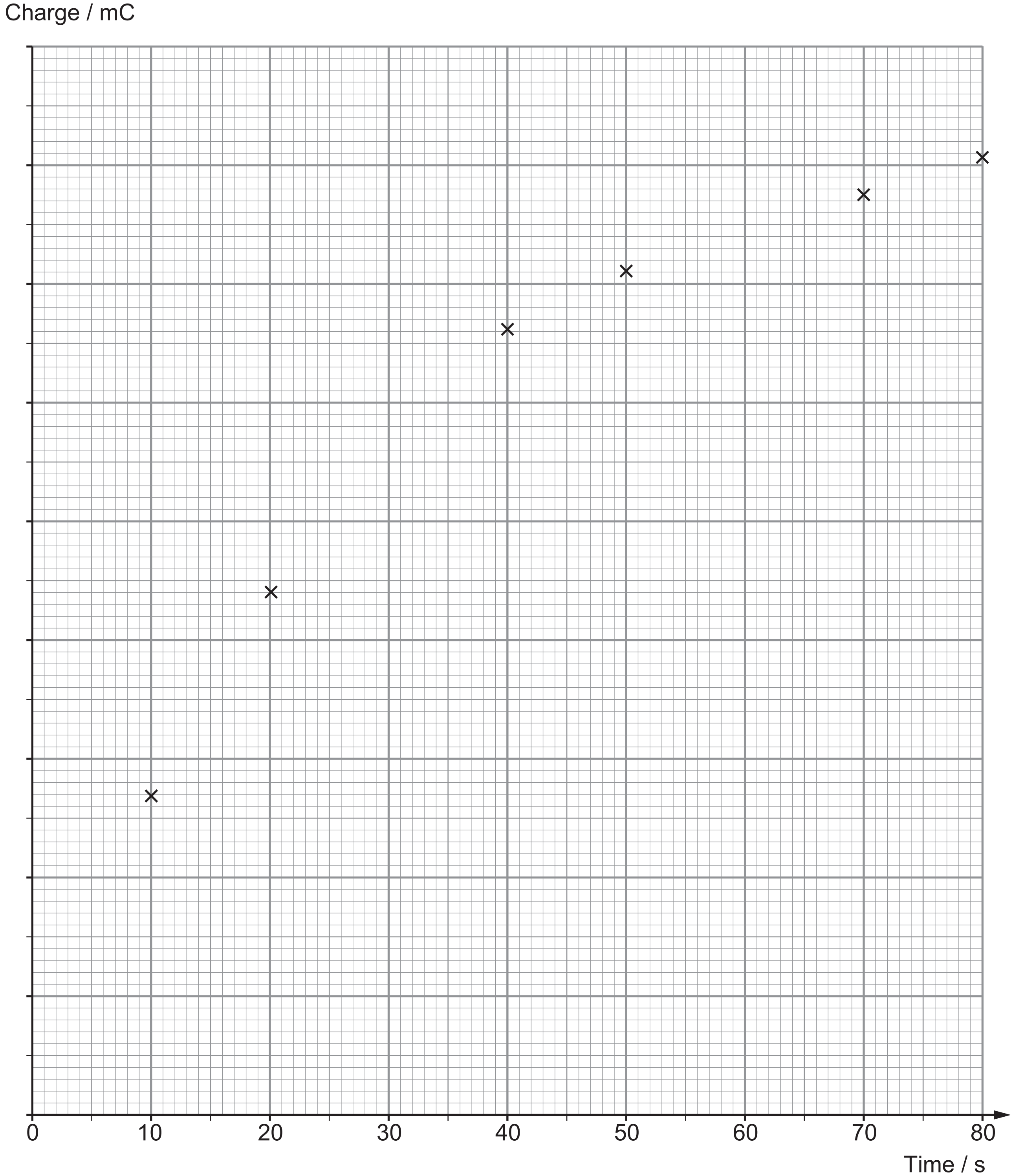
(iii) Complete the graph by labelling the y-axis scale, plotting the remaining two points, adding error bars for charge and drawing a curve of best fit. [5]



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(iv) **Use the curve of best fit** to obtain the time constant of the charging circuit (show your working and do not simply multiply the resistance by the capacitance). [3]

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(v) By drawing a suitable tangent, calculate the current in the circuit at 45 s. [2]

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(c) Use the graph on page 5 and your answers to *(b)*(iv) and *(b)*(v) to evaluate whether or not the data obtained in this experiment are in good agreement with the equations: [5]

$$Q = Q_0\left(1 - e^{-\frac{t}{RC}}\right) \textbf{ and } I = I_0 e^{-\frac{t}{RC}}$$

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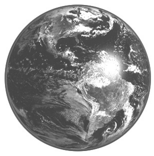
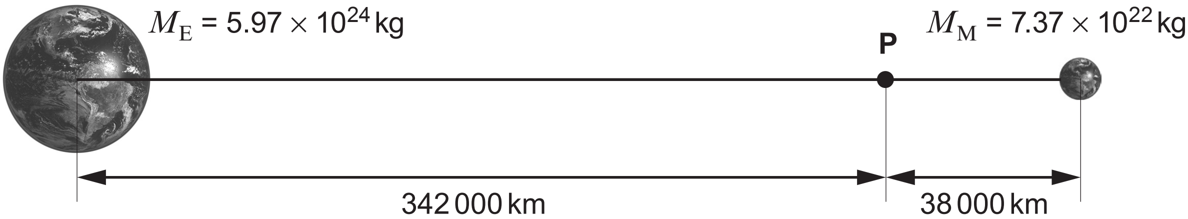
2. *(a)* Assuming that the Earth is an isolated perfect sphere, draw its gravitational field lines and equipotential surfaces. [3]



(b) (i) Use the information in the diagram to calculate the gravitational potential at point **P**. [3]



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(ii) Use the information in the diagram to show that the resultant gravitational field at point **P** is very small. [2]

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(iii) Myfanwy correctly calculates that the force on a 25 tonne spaceship would be negligible at point **P** and that the force would increase by approximately 0.5 N for every 10 km moved away from point **P** towards the Earth. Dafydd then concludes that the spaceship will perform simple harmonic motion about point **P**. Deduce whether or not Dafydd is correct **(no further calculations are required)**. [3]

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3. *(a)* (i) State Kepler's 1st and 2nd laws. [3]

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(ii) Kepler's 3rd law can be derived from Newton's gravitational law and the equation for centripetal motion. Show that, for any object in a circular orbit about the Earth:

$$T^2 = \frac{4\pi^2}{GM_E} r^3$$

where T = the period of orbit, r = the radius of orbit, G = the gravitational constant and M_E = the mass of the Earth. [3]

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(b) The radius of the geostationary orbit above the Earth's equator is 42 000 km and the Earth-Moon distance is 380 000 km. Use Kepler's 3rd law to calculate the period of the Moon's orbit. [3]

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(c) Estimate the minimum possible orbital period for a satellite orbiting the Earth, stating any assumption that you make (the radius of the Earth is 6 370 km). [3]

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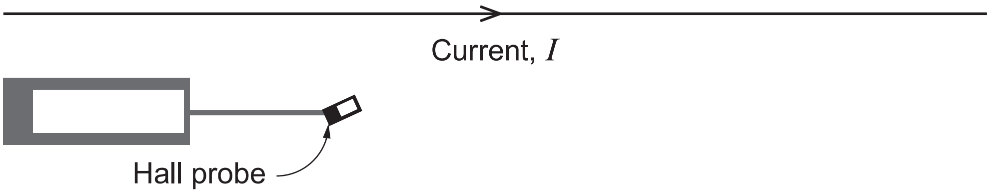
4. *(a)* The current in a long wire is 290 A and is too great to be measured by an ammeter. Explain how you could use a Hall probe, calibrated in tesla (T), to determine this current. [3]



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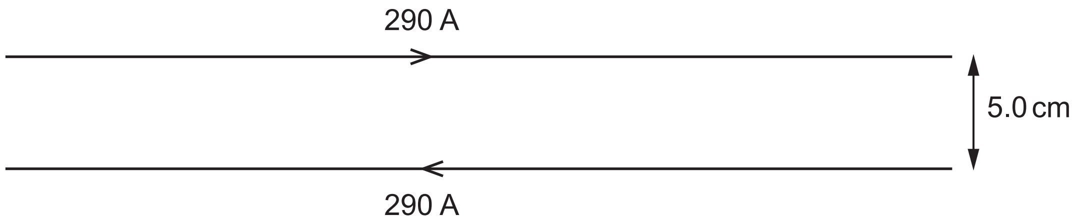
(b) Another long wire carrying the same large current is placed parallel to the original wire as shown. Calculate the force per unit length on each wire also stating the direction of the force on each wire. [4]



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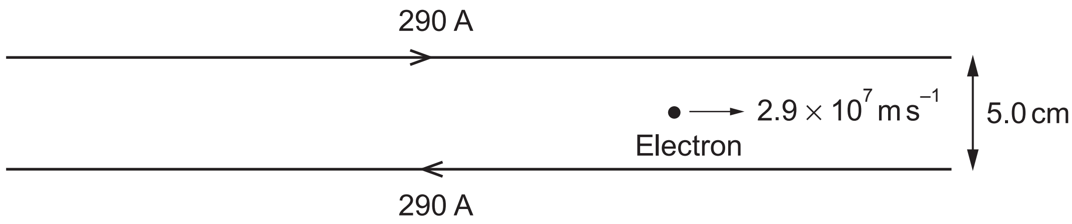
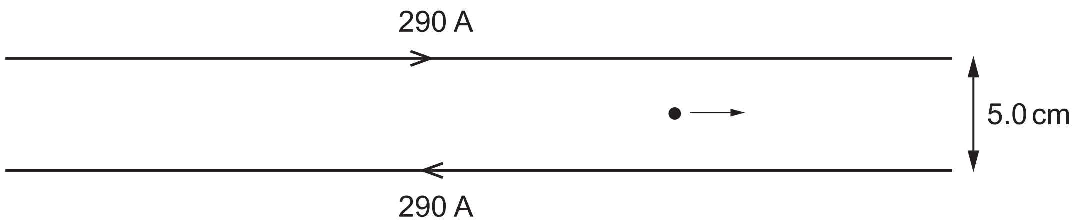
(c) (i) Tirion claims that an electron halfway between the wires, travelling at a speed of $2.9 \times 10^7\,\mathrm{m\,s^{-1}}$ parallel to the wires will perform perfect circular motion between the wires. Determine, using a suitable calculation, whether or not Tirion's claim is correct. The magnetic flux density halfway between the wires is 4.64 mT. [4]



(ii) Sketch the motion of the electron. [2]



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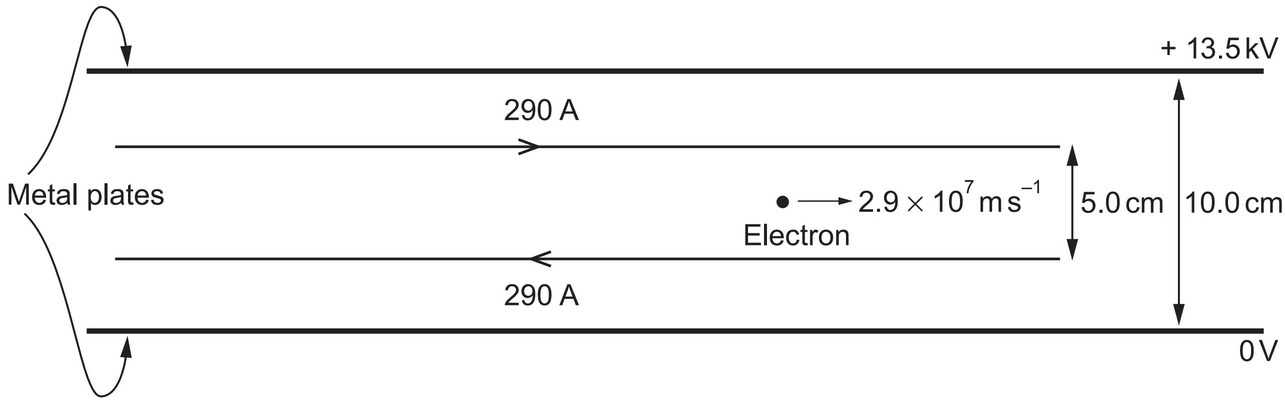
Examiner only

(d) Suppose that an electron travels in a region with a magnetic field and an electric field due to two parallel metal plates as shown below. Deduce whether or not the electron continues with constant velocity (B = 4.64 mT). [5]



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5. *(a)* State the laws of Faraday and Lenz for electromagnetic induction. [2]

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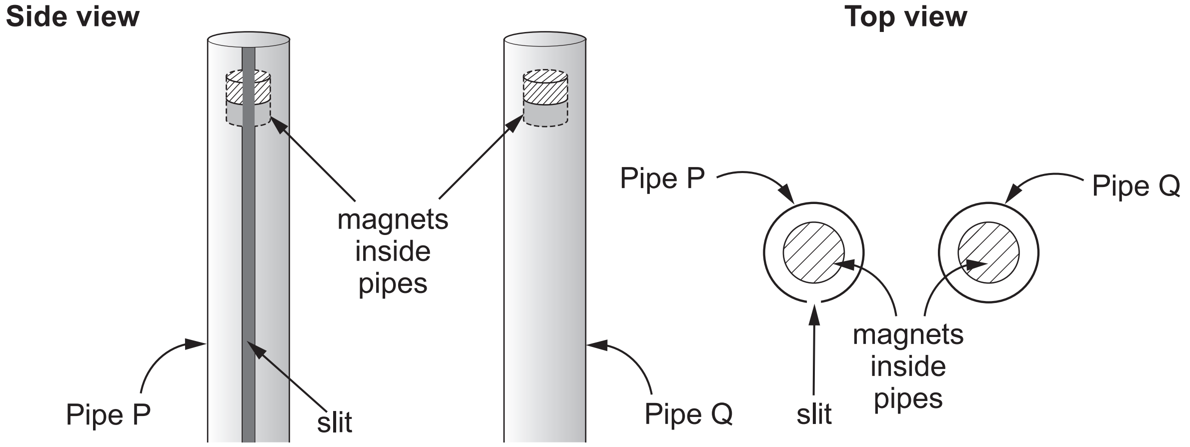
(b) Two strong bar magnets are dropped through two copper pipes (P and Q). Pipe P has a slit running along its length but Q is complete. When the magnet is dropped through pipe P it accelerates almost uniformly but the magnet dropped through pipe Q quickly reaches a very low terminal velocity. Explain these observations. [6 QER]



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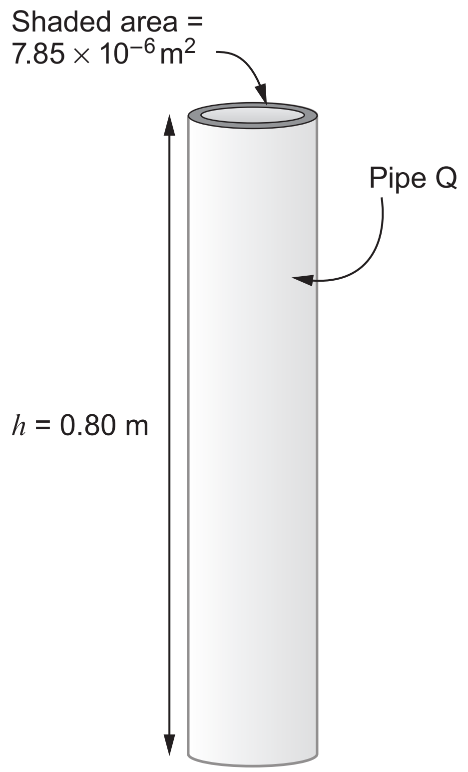
(c) By applying the principle of conservation of energy, calculate the temperature increase of pipe Q after the magnet has fallen at constant speed. [4]

Data:

- mass of magnet = 0.300 kg,
- cross-sectional area of the copper walls of pipe Q = $7.85 \times 10^{-6}\,m^2$ (see diagram)
- density of copper = $8\,960\,kg\,m^{-3}$
- specific heat capacity of copper = $385\,J\,K^{-1}\,kg^{-1}$.



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SECTION B: OPTIONAL TOPICS

Option A – **Alternating Currents** ☐

Option B – **Medical Physics** ☐

Option C – **The Physics of Sports** ☐

Option D – **Energy and the Environment** ☐

Answer the question on **one topic only.**

Place a tick (✓) in **one** of the boxes above, to show which topic you are answering.

You are advised to spend about 25 minutes on this section.

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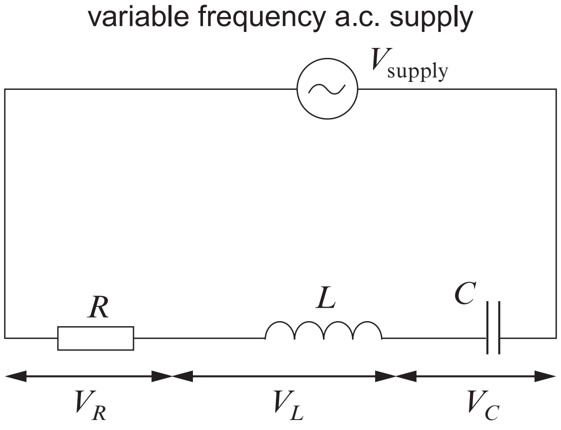
Option A – **Alternating Currents**

6. *(a)* The following RCL circuit is constructed.



For this RCL circuit, describe the relationships between the rms pds V_{supply}, V_R, V_L and V_C:

(i) when the circuit is not in resonance; [3]
Space for diagram.

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(ii) when the circuit is in resonance. [2]

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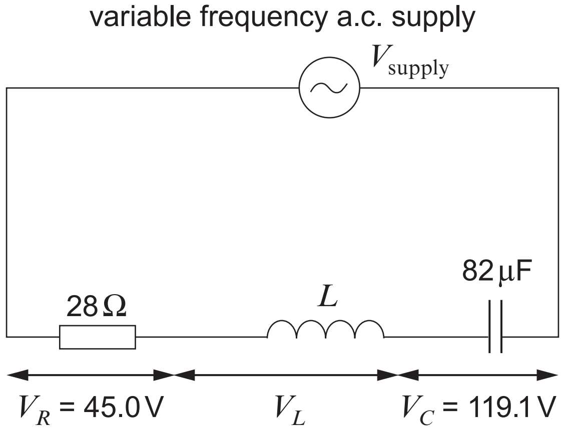
(b) The following RCL circuit is **at resonance**. The values of R and C are provided along with their rms pd values.



Calculate:

(i) the Q factor of the circuit; [1]

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(ii) the rms current; [1]

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(iii) the frequency of the power supply; [2]

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(iv) the inductance of the inductor. [2]

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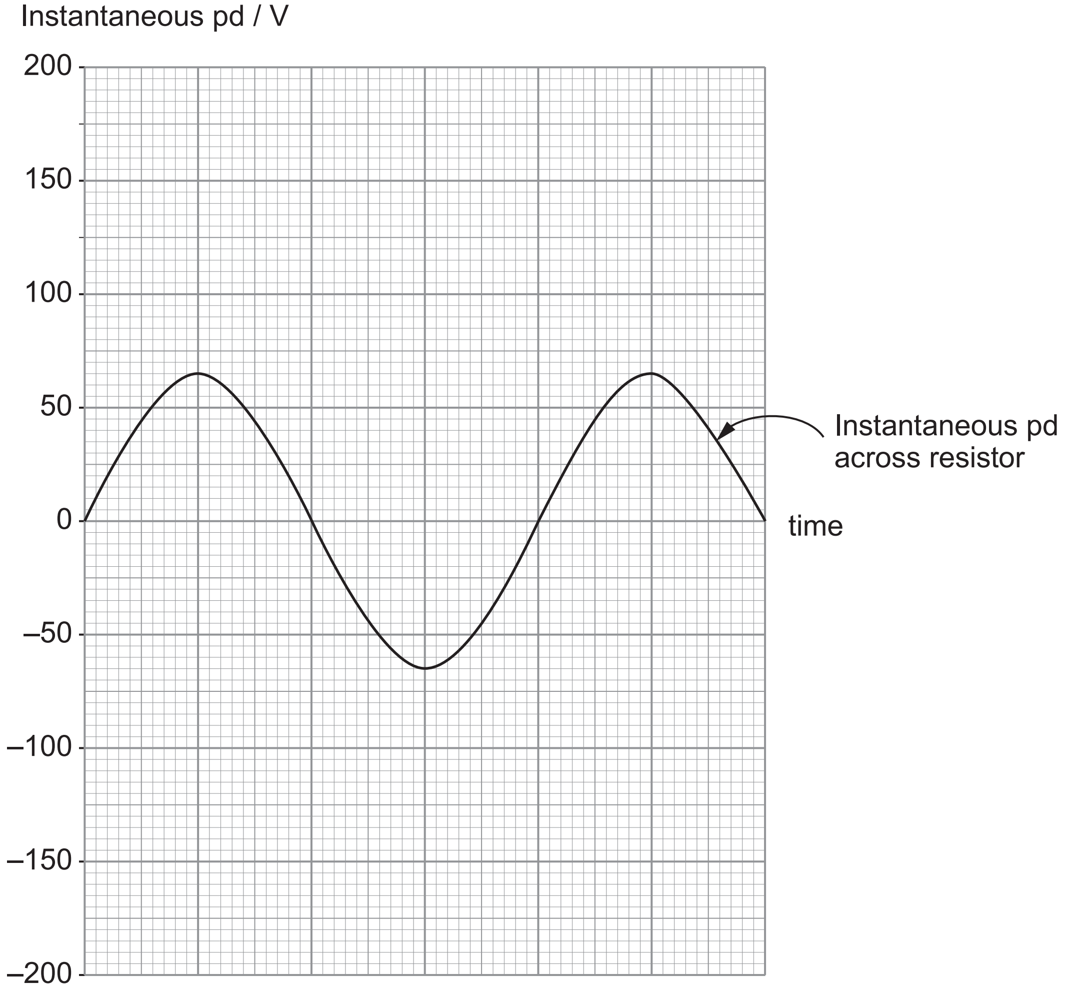
Examiner only

(v) Sketch a graph of the instantaneous pd across the capacitor on the grid provided. (The instantaneous pd across the resistor is shown.) [2]



(vi) Without further calculation, explain why the current decreases when the frequency of the power supply is increased. [2]

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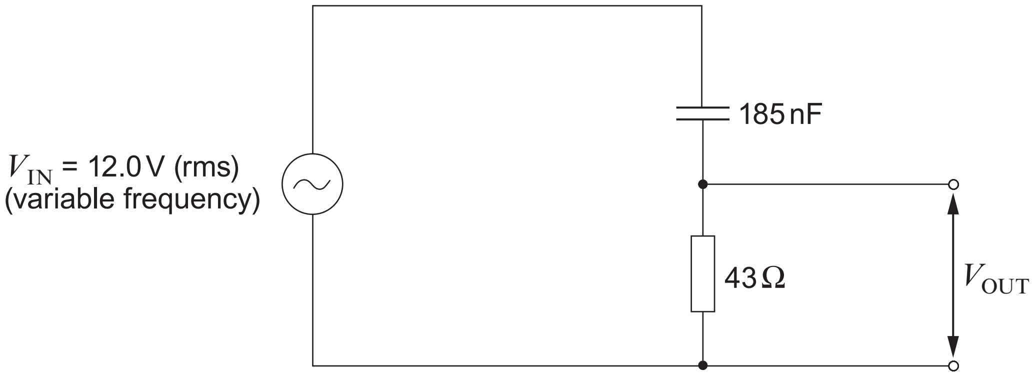
Examiner only

(c) Sam claims that the output pd (V_{OUT}) in the following circuit is greater than 6.0 V when the frequency is greater than 20 kHz, but less than 6.0 V when below 20 kHz. Investigate whether or not Sam is correct. [5]



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Option B – **Medical Physics**

7. *(a)* (i) Discuss how the properties of X-rays make them suitable for medical imaging. [3]

(ii) An X-ray machine has an operating pd of 18 kV and a current of 12 mA. If only 0.5% of the power is converted into X-rays find:

I. the velocity with which the electrons strike the target; [2]

II. the power of the emitted X-rays. [2]

Examiner only

(b) (i) The intensity, I, of an ultrasound beam decreases with the thickness, x, of a material according to the equation:

$$I = I_0 e^{-\mu x}$$

The half-value thickness, $x_{\frac{1}{2}}$ is the thickness of the material that reduces the intensity of an incident beam by 50 %. Show that:

$$\mu x_{\frac{1}{2}} = \ln 2$$ [2]

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(ii) The half-value thickness of muscle for ultrasound of frequency 1.0 MHz is 2.7 cm. Determine the thickness of muscle required to reduce the intensity to 70 % of its original value. [3]

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(c) A patient has a suspected heart murmur possibly caused by a problem with their aortic valve. You have the choice of the following forms of medical imaging available:

MRI scan **ultrasound B-scan** **fluoroscopy** **CT scan** **X-ray**

Evaluate the effectiveness of each type of imaging in confirming the diagnosis. [5]

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Examiner only

(d) (i) When discussing radiation exposure, medical scientists will mention the *absorbed dose*, D, and the *equivalent dose*, H. Explain the difference between these two terms. [2]

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(ii) During treatment for a cancerous tumour using gamma radiation, a patient's lungs received an equivalent dose of 4 mSv. If the weighting factor of lung tissue is 0.12 calculate the effective dose. [1]

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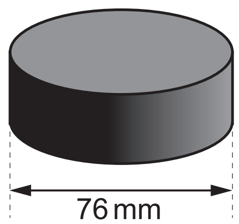
Option C – **The Physics of Sports**

8. This question is about the physics of the motion of an ice hockey puck which is a hard rubber disc of mass 0.17 kg and diameter 76 mm.



(a) When the disc is at room temperature, the coefficient of restitution between the puck and ice is 0.55.

(i) Explain what is meant by the statement *"the coefficient of restitution is 0.55"*. [2]

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(ii) When a puck is cooled from room temperature to 0 °C its coefficient of restitution is reduced by 30%. Calculate the bounce height of a puck at 0 °C when it is dropped from an initial height of 0.50 m on to ice. [4]

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(b) The image shows an ice hockey player taking a shot at goal.

(i) When striking the puck, the player changes its speed from $3\,\mathrm{m\,s^{-1}}$ to $34\,\mathrm{m\,s^{-1}}$ without changing its direction. The puck remains in contact with the hockey stick for 25 ms. Calculate the mean force exerted by the hockey stick on the puck. [2]

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(ii) The player aims for the top corner of the goal, which is at a height of 1.2 m. The initial angle of the puck's motion is 8° to the horizontal and its speed is $34\,\mathrm{m\,s^{-1}}$. Determine whether or not the puck ever exceeds the height of the goal.
Ignore the effect of air resistance. [3]

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(iii) The spin rate of the puck at its maximum height is 14 revolutions per second. Calculate its **rotational** kinetic energy.
The moment of inertia of the puck is given by $I = \dfrac{mr^2}{2}$. [3]

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(iv) Wayne thinks that the answer to part *(b)*(iii) is actually the **total** kinetic energy of the puck at the maximum height. Determine whether Wayne is correct. [2]

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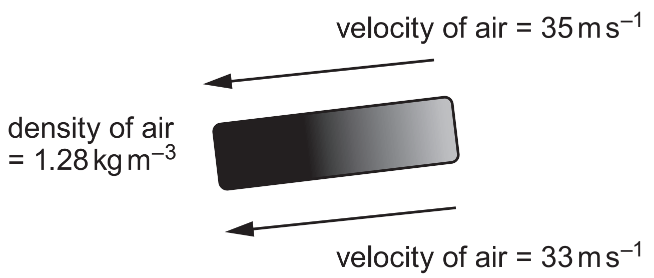
(v) During the shot at goal, the puck is moving to the right. The diagram below shows the velocity of the air relative to the puck. During its flight, the velocity of the air above the puck is greater than that below it creating lift.



Use the Bernoulli equation to calculate the lift force on the puck and show that this is small compared with its weight. [4]

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Option D – **Energy and the Environment**

9. *(a)* (i) State Archimedes' principle. [1]

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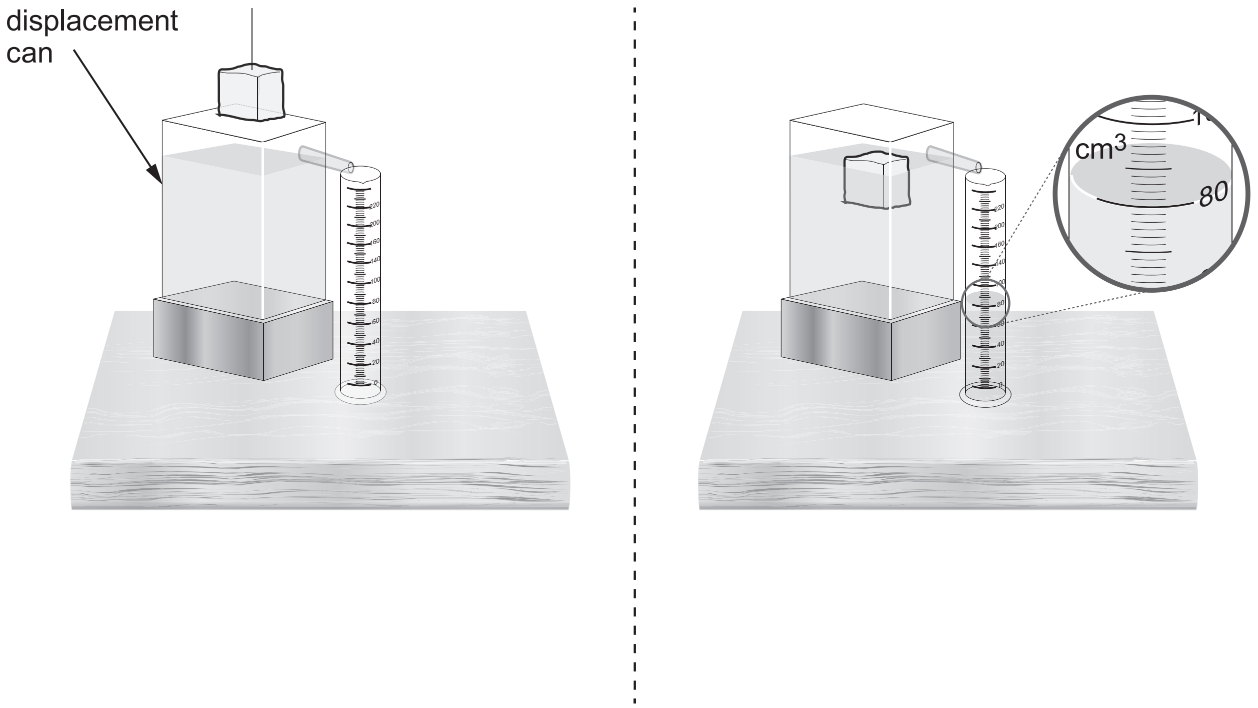
(ii) A student lowers a block of ice into a displacement can containing salt water. As shown in the diagram, 80 cm^3 of displaced salt water is collected in the measuring cylinder.



Calculate the mass of salt water displaced taking the density of salt water, $\rho_{\text{salt water}}$, to be 1 030 $kg\,m^{-3}$. [1 cm^3 = 1 × 10^{-6} m^3] [2]

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(iii) The density of ice, ρ_{ice}, is 920 kg m^{-3}. Use this and the Archimedes' principle to determine the volume of the block of ice above the surface. [3]

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(iv) The Greenland ice sheet is a vast body of ice covering roughly 80 % of the surface of Greenland. It is estimated that Greenland's melting ice is releasing 2.2×10^{11} m^3 of water into the surrounding ocean every year.

I. If the surface area of oceans on Earth is 3.6×10^{14} m^2 calculate the rise in water levels per year from Greenland ice melting. [1]

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II. Explain why the melting of the ice sheet would have a greater effect on global sea levels than the melting of the same mass of icebergs. [2]

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III. It is believed that melting ice sheets may lead to further increases in global temperatures. Suggest a reason for this. [1]

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(b) (i) Use an appropriate equation to show that the unit of the coefficient of thermal conductivity, K, is $\text{W}\,\text{m}^{-1}\,\text{K}^{-1}$. [2]

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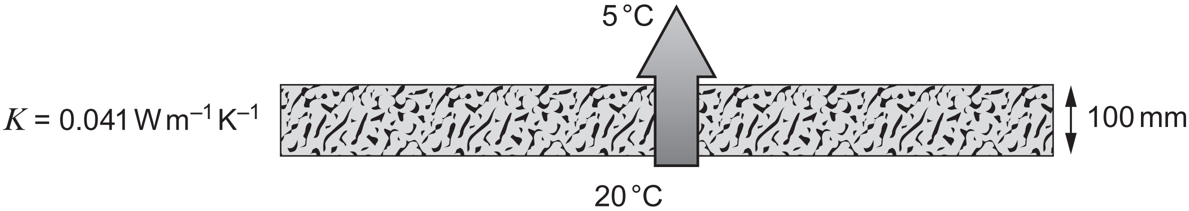
(ii) The recommended thickness of loft insulation has changed over time. In 1985, a 100 mm layer of fibre glass loft insulation ($K = 0.041\,\text{W}\,\text{m}^{-1}\,\text{K}^{-1}$) was used to cover an area of $72\,\text{m}^2$ in the roof space of a house. During winter, the air temperature just above the insulation was 5 °C and the temperature of the surface supporting the insulation was 20 °C. Calculate the rate of heat flow through the insulation. [2]



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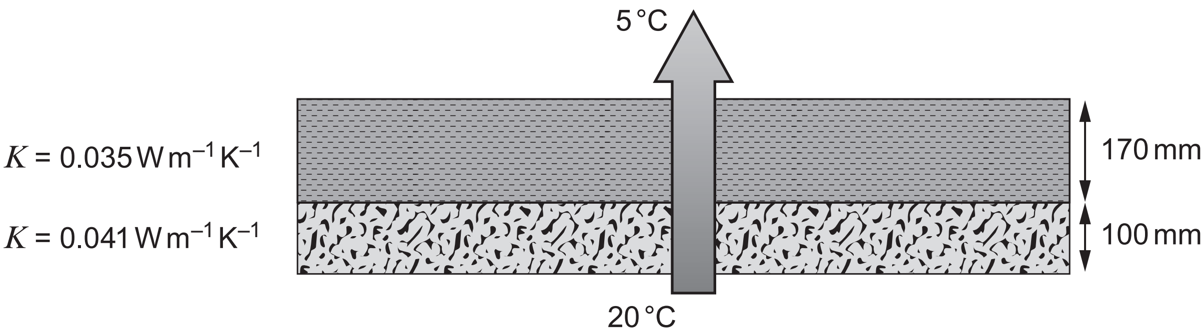
(iii) A present day loft insulation manufacturer recommends a loft insulation thickness of 270 mm. They suggest the house could achieve this modern standard by adding 170 mm of cellulose loft insulation ($K = 0.035\,\text{W}\,\text{m}^{-1}\,\text{K}^{-1}$) and that it would reduce the rate at which energy is transferred by more than 60 %.



Again, taking the air temperature just above the insulation to be 5 °C and the temperature of the surface supporting the insulation as 20 °C, investigate whether their recommendation is correct. [4]

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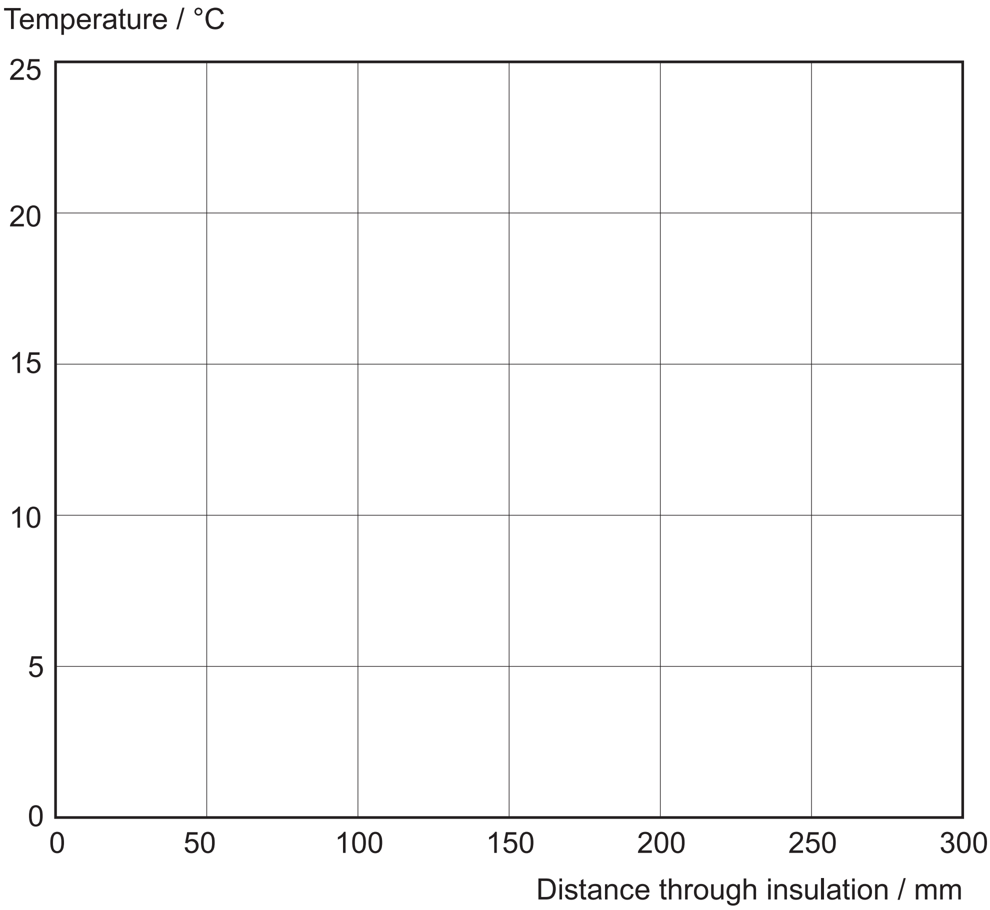
(iv) Starting from the lower surface at 20 °C, sketch a graph of temperature against distance through the loft insulation on the axis provided. [2]



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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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