Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A420U30-1

O20-A420U30-1

Part of WJEC

WEDNESDAY, 21 OCTOBER 2020 – MORNING

PHYSICS – A level component 3
Light, Nuclei and Options

2 hours 15 minutes

	For Examiner's use only		
	Question	Maximum Mark	Mark Awarded
Section A	1.	11	
	2.	6	
	3.	11	
	4.	7	
	5.	16	
	6.	6	
	7.	13	
	8.	7	
	9.	8	
	10.	15	
Section B	Option	20	
	Total	120	

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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 or 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(s) 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**: 100 marks. Answer **all** questions. You are advised to spend about 1 hour 50 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 **6**.

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SECTION A

Answer **all** *questions.*

1. *(a)* Bruce throws a lump of coal towards Dani which she catches. Bruce claims that, because chemical energy is being transferred from himself to Dani, the lump of coal is a **wave**. Explain whether or not Bruce is correct. [2]

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(b) The door of a microwave oven has a metal grille and this grille has holes in it of diameter 2 mm so that the food can be seen within the oven.

(i) Explain why the food can be seen through the door while the user is safe from dangerous microwaves of wavelength 12 cm. [3]

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(ii) State or calculate a typical photon energy of visible light. [1]

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(iii) Explain whether or not a microwave photon has a greater or smaller energy than a visible photon. [1]

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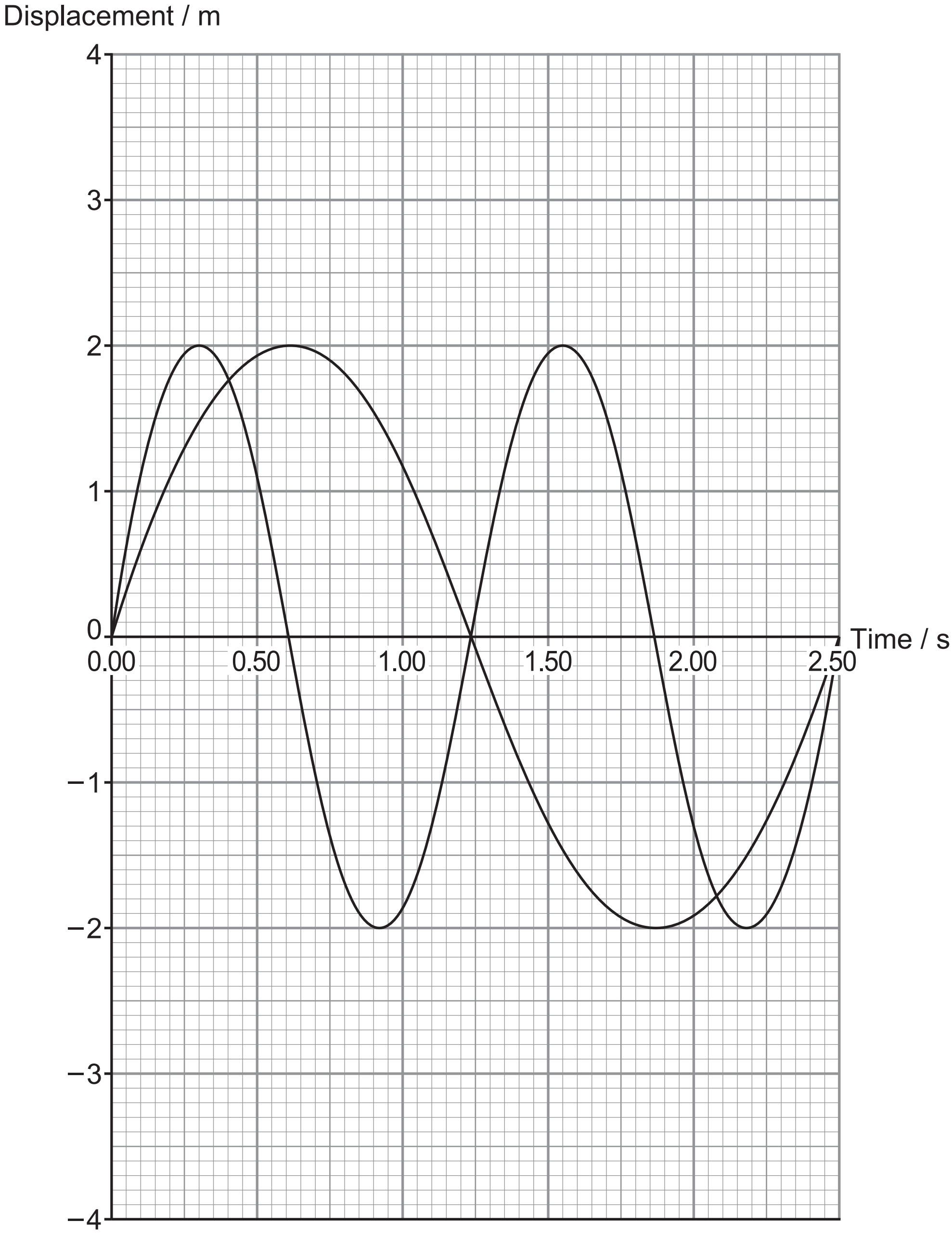
(c) Two water waves of equal amplitude but different frequencies meet. The variation of the displacements of each wave is shown in the graph at the meeting point of the two waves.



Use the principle of superposition to plot the resultant displacement of the two waves at times 0.00 s, 0.40 s, 1.00 s, 1.25 s, 1.50 s, 2.10 s, 2.50 s **on the same grid** and draw a suitable curve. [4]

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2. *(a)* Calculate the de Broglie wavelength of an electron accelerated by a pd of 2200 V. [3]

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(b) Explain how electrons can be used in a laboratory to produce a diffraction pattern and the effect of increasing the pd on the diffraction pattern. [3]

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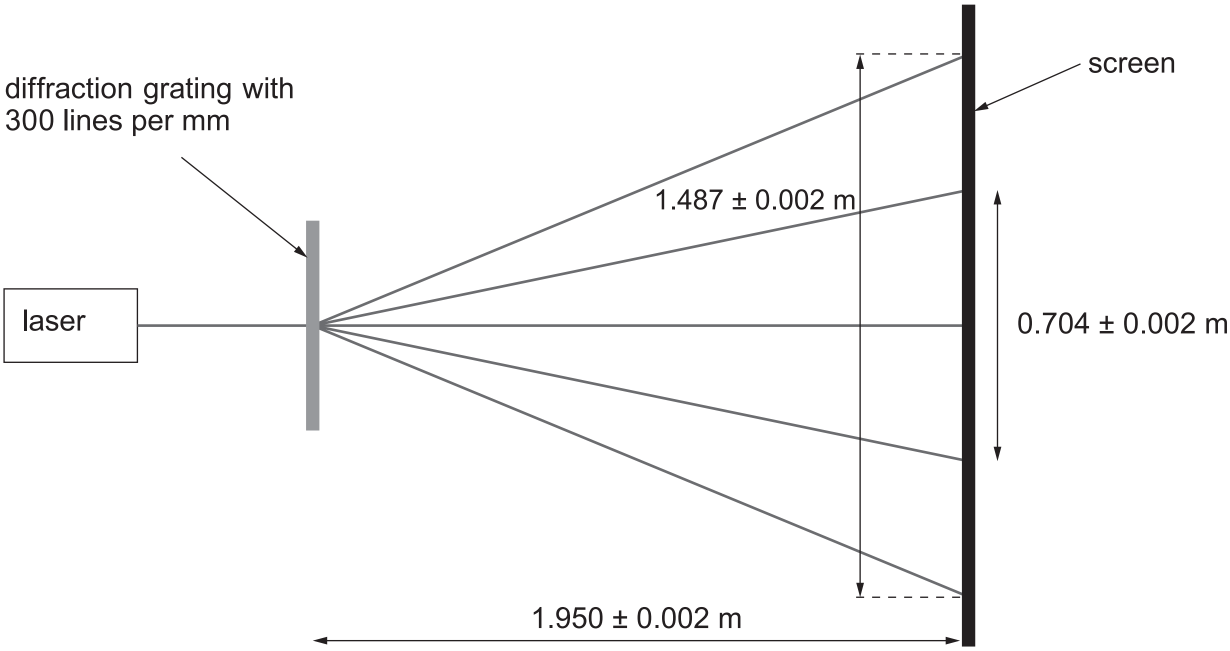
3. Rachel carries out an experiment to measure the wavelength of light emitted by a laser. Her measurements and set-up are shown in the diagram below.



(a) (i) **Show clearly** that the measured wavelength of the laser light is 592 nm using the n = 1 data in the diagram. [3]

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(ii) **Show clearly** that the n = 1 data in the diagram leads to an uncertainty in the wavelength of ±2 nm. You may assume that the manufacturer's labelling of 300 lines per mm for the diffraction grating is exact and that $\tan\theta \approx \sin\theta \approx \theta$. [4]

(b) The manufacturer of the laser states that its wavelength is exactly 593.5 nm. The n = 2 data in the diagram lead to a measured laser wavelength of 594 ± 1 nm. Explain whether or not these values and the value from part *(a)* are all consistent. [2]

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(c) Explain why the n = 1 data (592 ± 2 nm) lead to a larger uncertainty than the n = 2 data (594 ± 1 nm). [2]

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4. *(a)* Explain what is meant by stimulated emission of radiation. [2]

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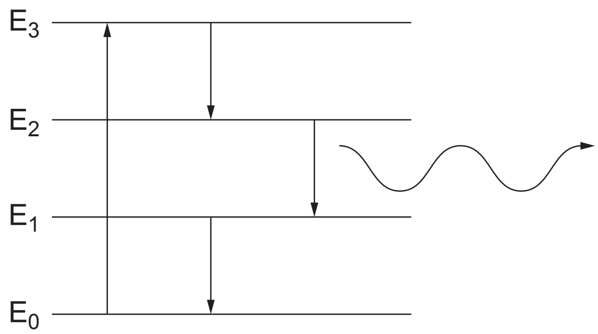
(b) The energy levels of a 4-level laser system are shown.

4-level system



Give **two** reasons why energy level E_1 is always nearly empty. [2]

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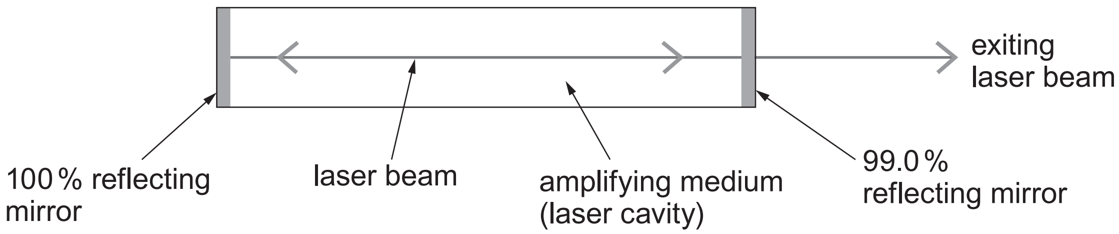
(c) Victoria claims that when the laser system shown below **is in equilibrium**, the amplifying medium provides only a 0.5 % increase in intensity of the beam each time it travels across the cavity. Her research partner, David, insists that the exponential increase in light intensity provided by the amplifying medium means that the beam intensity is increased by a factor of thousands for each pass even when the laser is in equilibrium. Discuss whether Victoria or David is correct. [3]



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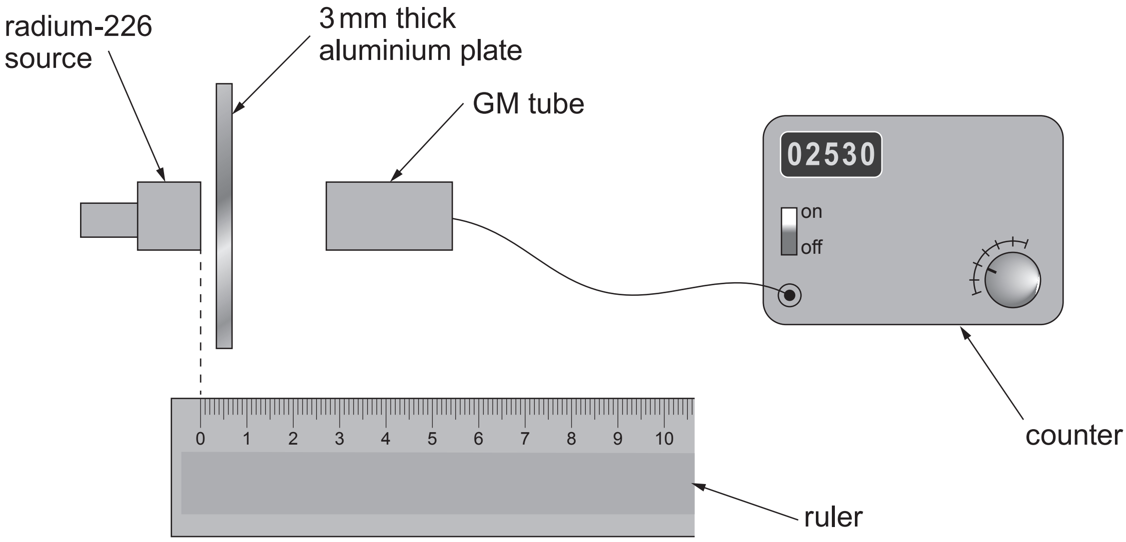
5. Bronwen carries out an experiment to investigate the relationship between count rate and distance from a gamma emitting radioactive source (radium-226).



Her results are shown in the table.

Distance / cm	Total counts in 10 minutes	ln(distance / cm)	ln(corrected total counts in 10 minutes) **{corrected for background radiation}**
2.0	3 466	0.69	8.08
3.0	1 697	1.10	7.28
4.0	1 028	1.39	6.67
5.0	762	....	....
6.0	609	1.79	5.91
7.0	507	1.95	5.59
8.0	447	....	....

(a) (i) The **background radiation is 0.40 counts per second. Complete the table**. [3]
Space for calculations.

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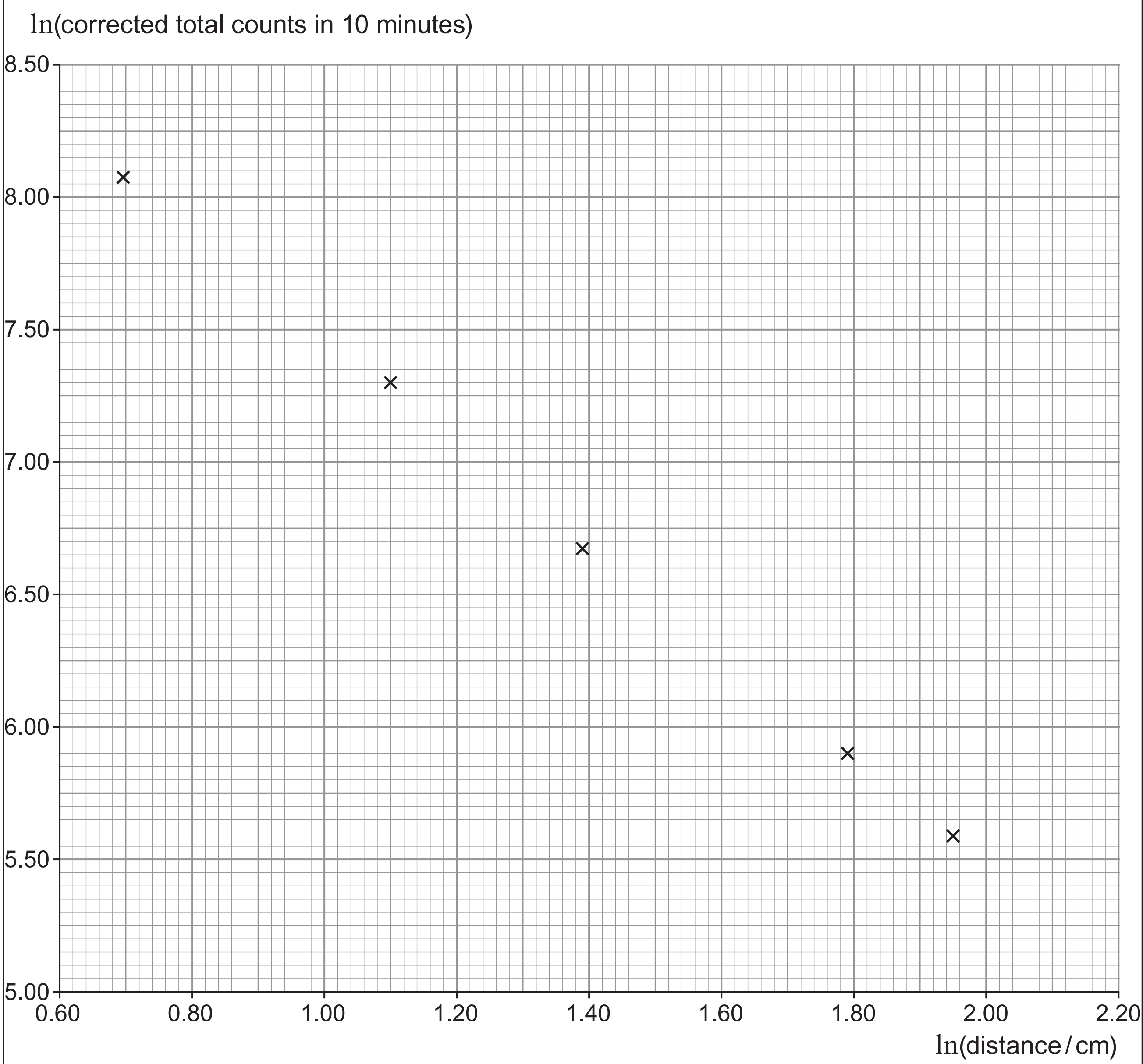
(ii) **Complete the graph** by plotting the two missing data points. [1]



(iii) Draw a line of best fit and calculate its gradient. [3]

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(iv) Theory suggests that:

$$\text{count rate} \propto \frac{1}{\text{distance}^2}$$

I. Show that the gradient of the graph should be –2. [2]

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II. Explain to what extent the results obtained in this experiment agree with theory. [3]

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(b) Radium-226 also emits other radiation. Suggest a reason for using a 3 mm aluminium plate between the source and the GM tube. [1]

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(c) In 1896, G. Brandes reported that large intensities of high energy X-rays produced a "blue-grey" glow within the eye. This was later confirmed by Willhelm Röntgen and other scientists. The mechanism for this "blue-grey" glow is still not fully understood. Discuss the ethics of reproducing this experiment to understand it better. [3]

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6. Discuss the make-up and properties of the following particles e^-, e^+, n, $\overline{p}$, π^-. [6 QER]

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7. *(a)* The bismuth isotope ($^{209}_{83}\text{Bi}$) decays by alpha decay to an isotope of thallium (Tl). Fill in the missing numbers for this decay. [2]

$$^{209}_{83}\text{Bi} \longrightarrow \, ^{\cdots\cdots}_{\cdots\cdots}\text{Tl} + \, ^{\cdots\cdots}_{\cdots\cdots}\text{He}$$

(b) Determine whether or not a kinetic energy of 3.6 MeV for the alpha particle in the above reaction is consistent with the data in the table below (you may assume that the kinetic energies of the bismuth and thallium nuclei are negligible). [5]

Nuclear mass of thallium isotope	204.9300 u
Nuclear mass of alpha particle	4.0015 u
Binding energy per nucleon of $^{209}_{83}\text{Bi}$ nucleus	7.87 MeV / nucleon
Mass of proton, m_p	1.0073 u
Mass of neutron, m_n	1.0087 u
Energy equivalent of 1 u	931 MeV

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(c) (i) The half-life of $^{209}_{83}\text{Bi}$ is 1.9×10^{19} year. Calculate the activity of 1.00 gram of $^{209}_{83}\text{Bi}$. [4]

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(ii) Determine the number of nuclei in 1.00 gram of $^{209}_{83}\text{Bi}$ which will decay in 5 years. [2]

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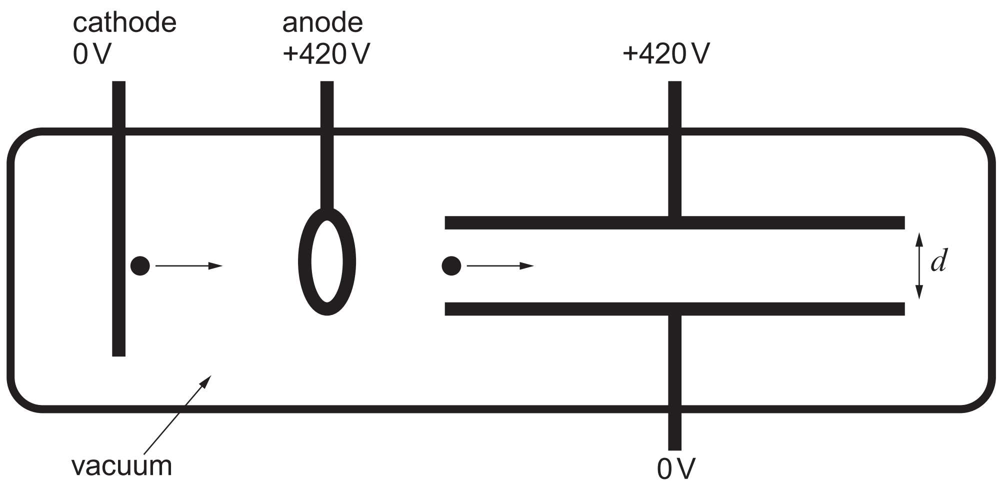
8. An electron is accelerated from rest by a pd of 420 V and then enters the uniform electric field between two parallel plates separated by a distance, d. These parallel plates also have a pd of 420 V across them and the electron enters halfway between the two plates.



(a) Show that, when the electron has travelled a distance, d, horizontally, it will have travelled a distance of $\frac{1}{4}d$ vertically (from the point where it enters the parallel plates). [5]

(b) Explain whether or not an oxygen ion with charge $-2e$ accelerated from rest in the above set-up instead of an electron would pass through the same point. [2]

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Examiner only

9. *(a)* A sphere made of caesium is placed in space and illuminated by ultraviolet radiation of photon energy 10.3 eV. The work function of caesium is 2.1 eV. Explain in clear steps, using Einstein's photoelectric equation (and other physics), why the maximum potential attainable by the caesium sphere is +8.2 V. [5]

(b) Hence, calculate the maximum electric field strength around the caesium sphere given that its radius is 6.5 cm. [3]

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10. *(a)* (i) A long solenoid has 12 000 turns per metre and carries a current of 3.8 A. Calculate the magnetic flux density at its centre. [1]

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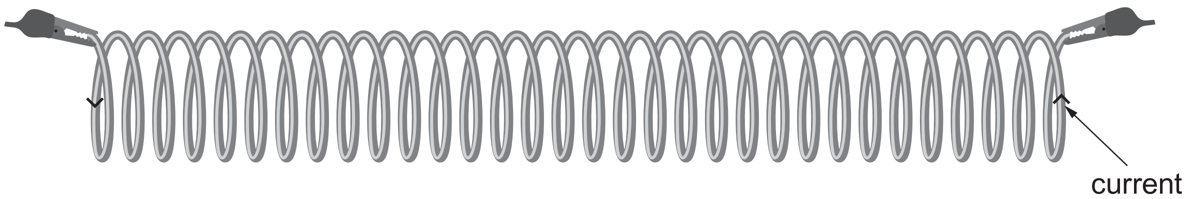
(ii) **Sketch the magnetic field lines** due to this long solenoid. [2]



(iii) State how the strength of the magnetic field produced by **this solenoid** can be increased greatly without increasing the current or changing the dimensions of the solenoid. [1]

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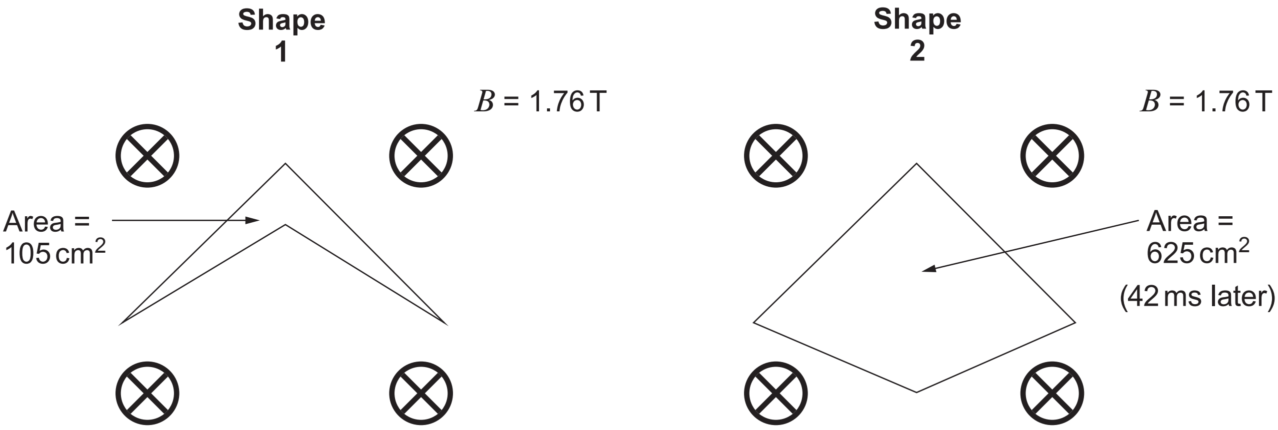
(b) Maria carries out an experiment inside an extremely large magnetic field of uniform density 1.76 T. She uses a copper wire and deforms it from shape 1 to shape 2 in a time of 42 ms.



(i) Explain why a large current flows in the copper wire during this deformation. [3]

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(ii) Explain how you can deduce that this current flows anticlockwise. [2]

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(iii) Calculate the mean current flowing in the copper wire given that its resistance is $6.75 \times 10^{-3}\,\Omega$. [3]

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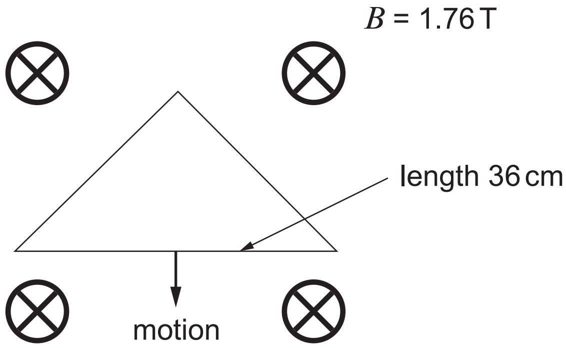
(iv) Halfway through the deformation of the copper wire it is in the position shown below. Maria claims that in this position, a "motor effect" force of approximately 200 N will act upwards on the length of copper wire shown. Determine whether or not Maria is correct. [3]



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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

11. *(a)* With the aid of a phasor diagram, explain why the impedance of an RCL circuit is given by: [3]

$$Z = \sqrt{\left(X_L - X_C\right)^2 + R^2}$$

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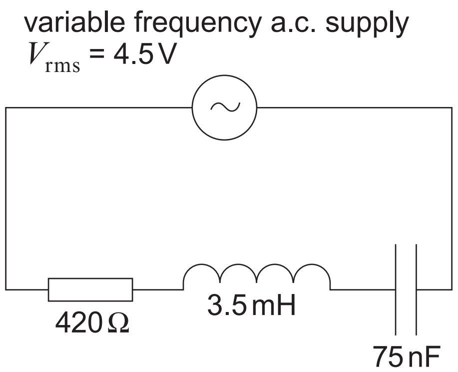
(b) Consider the following RCL circuit.



(i) Show that the combined magnitude of the reactance of the inductor and capacitor is the same (to 3 s.f.) as the resistance of the resistor when the frequency is 4 150 Hz. [3]

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(ii) Hence, calculate the rms current in the circuit when the frequency is 4 150 Hz. [3]

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(iii) Calculate (or state) the phase angle between the applied pd and the current when the frequency is 4 150 Hz. [1]

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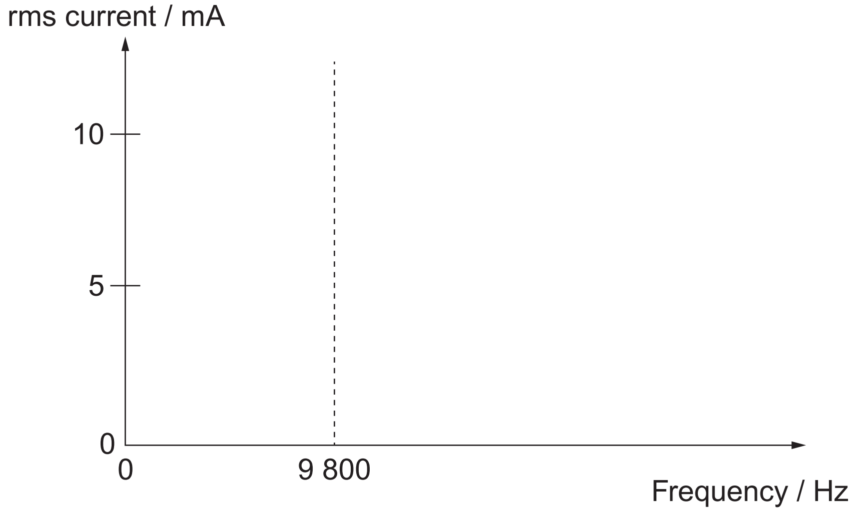
(iv) The resonance frequency of the RCL circuit is approximately 9 800 Hz. **By sketching** a graph of rms current against frequency, explain why there is a second higher frequency that provides the same rms current as your answer to *(b)*(ii). [3]



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(v) This second frequency occurs when the magnitude of the reactances of the inductor and capacitor are reversed from those in part *(b)*(i). Use this information to calculate this second frequency. [2]

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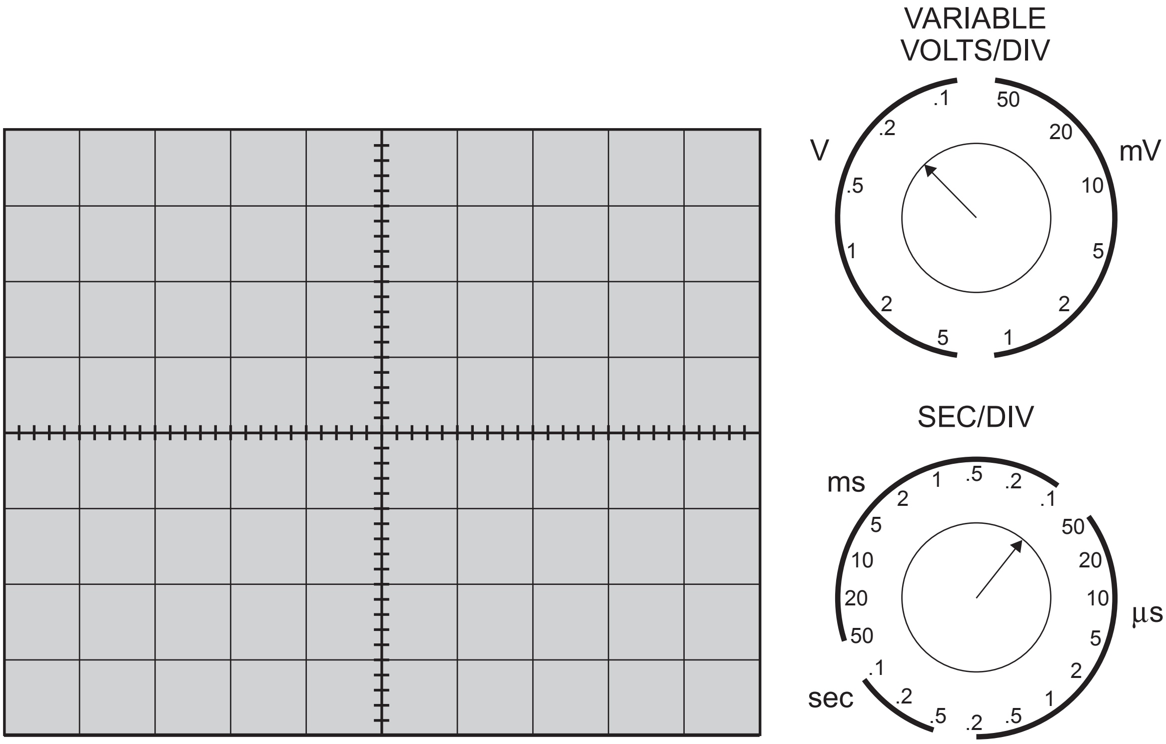
(c) Robyn is required to produce a wave trace on an oscilloscope for an a.c. power supply of frequency 3.0 kHz and rms pd 0.60 V. Deduce whether or not the settings of the oscilloscope shown below are appropriate. [5]



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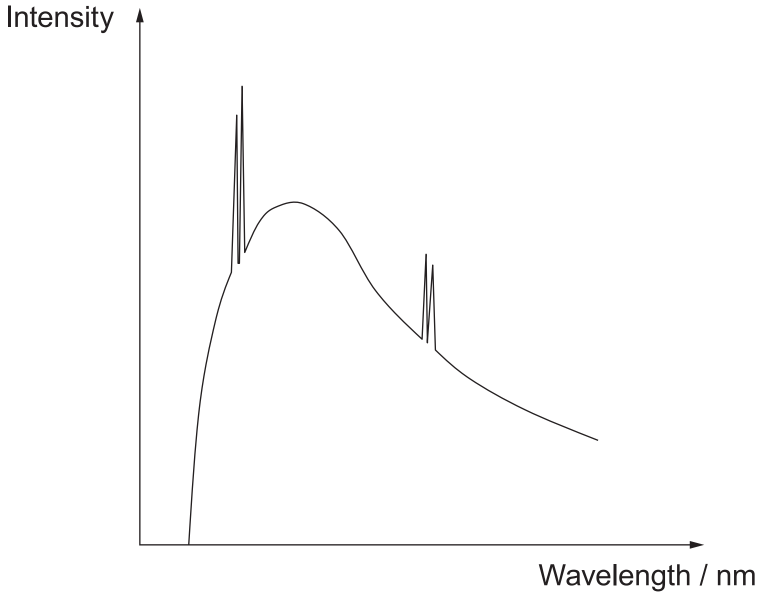
Option B – Medical Physics

12. *(a)* The graph below shows the intensity spectrum for an X-ray tube.



(i) **Draw on the above diagram** an intensity spectrum for the same X-ray tube with a **higher** operating voltage. [1]

(ii) If the operating voltage of the tube is 30 000 V, determine the minimum wavelength of the X-rays produced. [2]

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(iii) If the anode current is 120 mA and the X-ray tube has an efficiency of 0.450 % calculate the rate of production of heat at the anode. [2]

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(iv) Explain whether it would be possible to reduce the minimum wavelength to zero. [1]

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(b) (i) An ultrasound probe (A scan) can be used to determine the thickness of a lens in the human eye. Explain how a piezoelectric transducer can be used to produce ultrasound. [2]

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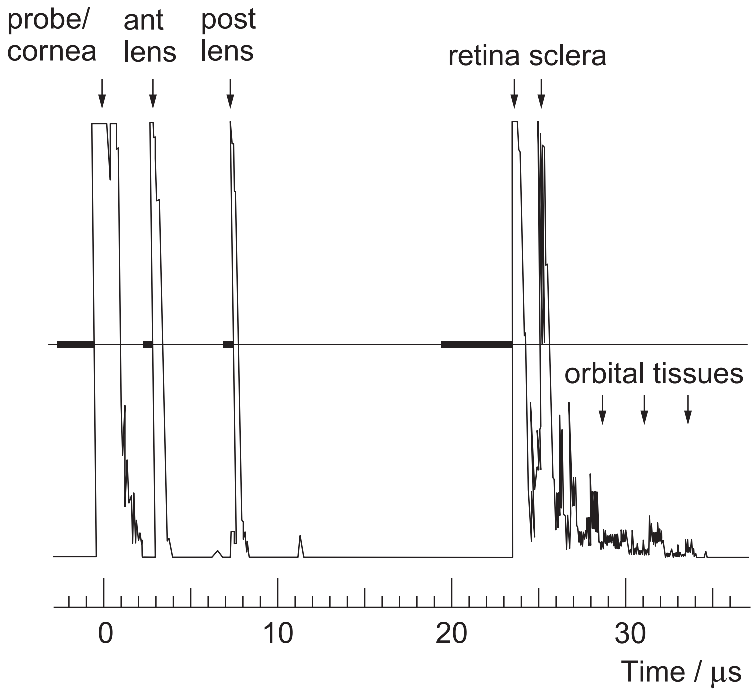
(ii) A typical ultrasound A scan used to determine the thickness of a lens is given in the diagram below. The spike labelled ‘ant lens’ corresponds to the front of the lens and the spike labelled ‘post lens’ corresponds to the back of the lens.



Use the information in the diagram to calculate the lens thickness. The speed of ultrasound in the lens is $1640\,m\,s^{-1}$. [3]

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(c) You have the choice of the following forms of medical imaging:

X-ray **ultrasound A scan** **radioactive tracer** **CT scan**

Justifying the reasons for your answer, state which of the above you would use to detect the following:

(i) A cerebral haemorrhage (bleed in the brain). [3]

(ii) An underactive thyroid gland. [2]

(d) An MRI (magnetic resonance imaging) scanner has a magnetic field that varies from 0.80 T to 1.40 T along its length. Calculate the wavelength of electromagnetic waves required to scan a slice halfway along its length **and** state which part of the electromagnetic spectrum they belong to. [4]

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Option C – Physics of Sports

13. *(a)* (i) Explain what is meant by the term *moment of inertia* of an object. [2]

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(ii) Calculate the moment of inertia of a cricket ball which has a rotational kinetic energy of 1.47 J if it is spinning at a rate of 30 revolutions per second. [3]

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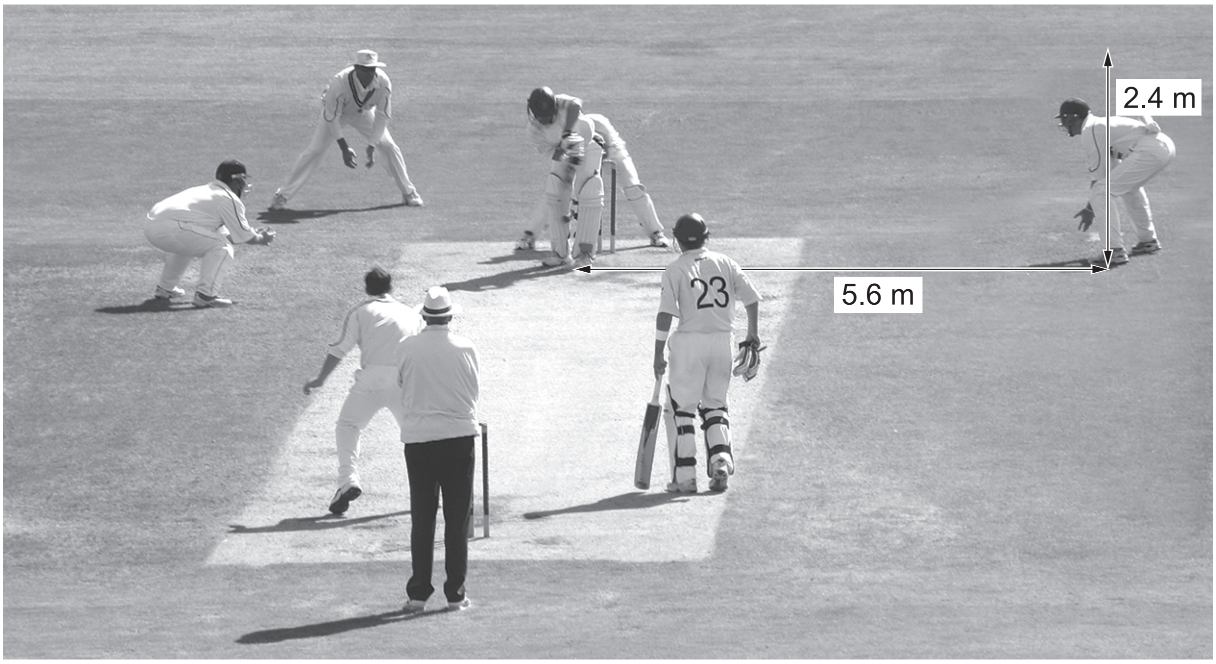
(b) (i) The batsman hits the ball with an initial velocity of 25 m s^{-1} at an angle of 30° to the horizontal. A fielder standing 5.6 m away from the batsman can catch a ball 2.4 m above the ground. Evaluate whether the ball can be caught by the fielder. Assume that air resistance can be ignored and that the ball is hit from ground level. [5]



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(ii) Explain why a fielder will move his hands in the direction of motion of the cricket ball when catching. [2]

(iii) The coefficient of restitution between the pitch and the ball is 0.37. Determine the bounce height if the ball falls from a height of 2.35 m. [2]

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(c) For this part of the question, the interactions between the ball and the air need to be taken into account.

(i) Explain why a spinning cricket ball will change direction when moving through the air. Your answer should include the forces acting on the ball during the flight and a diagram may be included. [3]

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(ii) Determine the drag force acting on a cricket ball of radius 3.6 cm during flight if the speed of the ball is 24.3 $m\,s^{-1}$ and its drag coefficient is 0.76.
Density of air = 1.3 $kg\,m^{-3}$. [3]

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Option D – Energy and the Environment

14. *(a)* (i) The total power emitted by the Sun is 3.8×10^{26} W. Calculate the intensity of radiation received at the upper atmosphere of planet Earth and state the name given to this value. The distance between the Earth and the Sun is 1.5×10^{11} m. [2]

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(ii) A student models the energy balance of planet Earth without its atmosphere. He calculates the theoretical power absorbed by the Earth to be 1.2×10^{17} W. Assuming the Earth to be in thermal equilibrium and to behave as a black body, show that the temperature of the Earth for this model is approximately 250 K. The radius of the Earth is 6.4×10^{6} m. [3]

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(iii) The actual mean surface temperature of the Earth is 287 K. Without calculation, account for this difference in temperature and explain how human activity has further contributed to this. [3]

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(b) (i) State and explain the three conditions that are simultaneously required to produce a sustainable fusion reaction. [3]

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(ii) A fusion test reactor requires a triple product greater than 3.5×10^{28} s K m^{-3}. The plasma has a volume of 70 m^3 and contains 2.4×10^{22} particles. If a confinement time of 0.9 seconds is achieved, determine the minimum temperature necessary for this reaction. [2]

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(c) (i) A company manufactures thermal plasterboards using a composite of two different materials. One of the materials is known to have a *thermal conductivity value of 0.030 W m^{-1} °C^{-1}*. Explain what the statement in italics means. [2]

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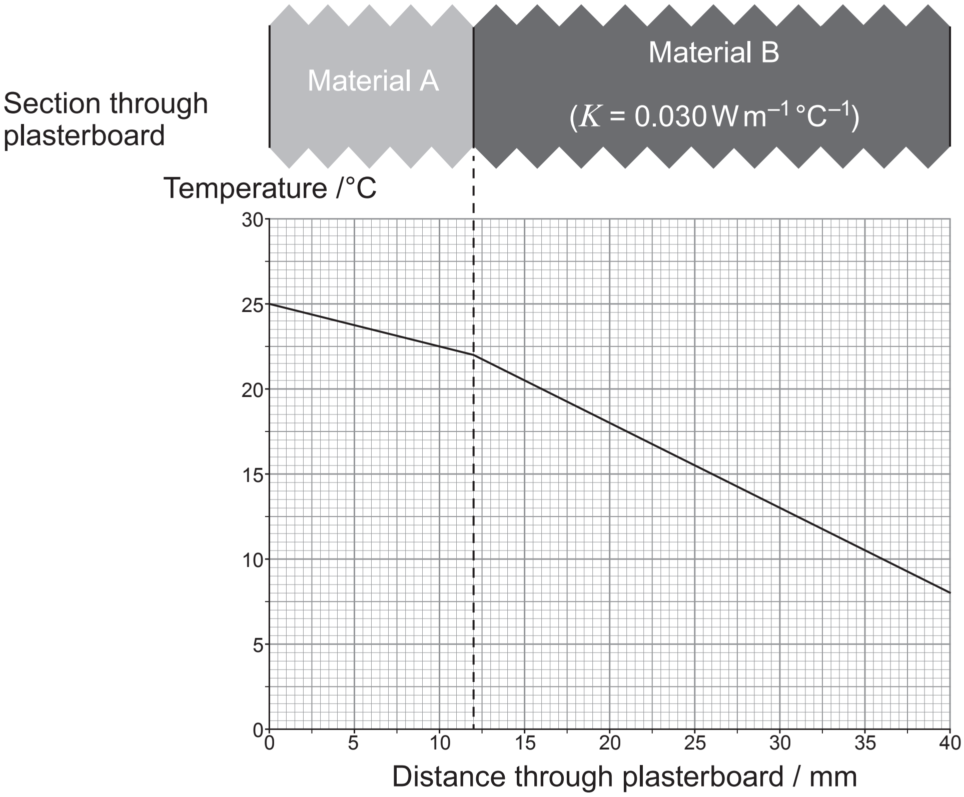
(ii) Jack investigates the thermal properties of a sample of thermal plasterboard. He produces a graph of temperature against distance as shown below.



Jack suggests that material **B** has twice the thermal conductivity value of material **A** and that the U-value of the plasterboard is approximately 0.90 W m^{-2} °C^{-1}. Evaluate whether or not Jack's suggestions are correct. [5]

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END OF PAPER

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

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