Surname	Centre Number	Candidate Number
Other Names		2

GCE A LEVEL – NEW

1420U40-1

S17-1420U40-1

PHYSICS – A2 unit 4
Fields and Options

WEDNESDAY, 21 JUNE 2017 – MORNING

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**20**	
	2.	**12**	
	3.	**17**	
	4.	**19**	
	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 continuation 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 **4*(b)*(ii)**.

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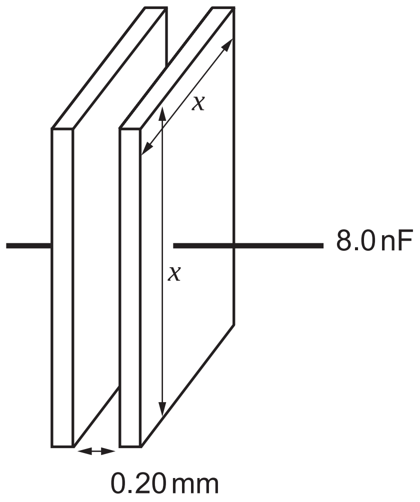
SECTION A

*Answer **all** questions.*

1. *(a)* (i) An 8.0 nF capacitor has square plates separated by 0.20 mm of air. Calculate the length (x) of the sides of the plates. [3]



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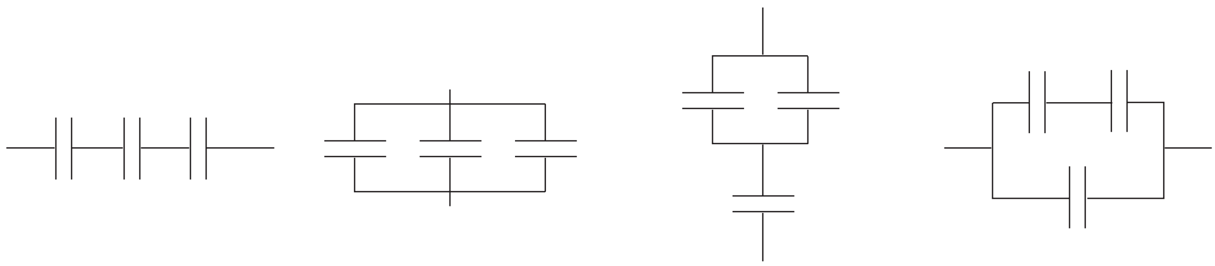
(ii) Which of the following combinations of 8.0 nF capacitors has a capacitance of 12.0 nF? Justify your answer. [4]

All individual capacitors shown are 8.0 nF.



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(iii) State how the capacitance of the capacitor can be increased without changing its dimensions. [1]

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(iv) Calculate the charge on the plates of the 8.0 nF capacitor when it stores an energy of 0.62 μJ. [3]

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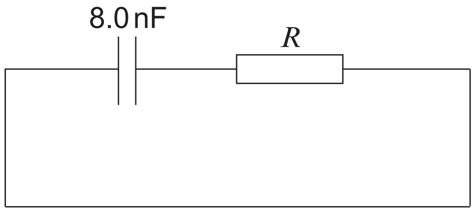
(b) (i) A charged 8.0 nF capacitor is discharged through a large resistor. Calculate the resistance of the resistor if the time constant is 15.5 ms. [2]



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(ii) Calculate the fraction of the initial charge remaining on the capacitor after 31.0 ms. [3]

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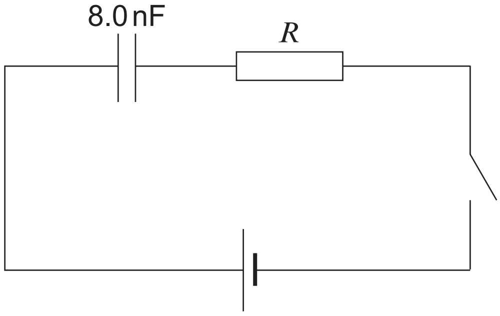
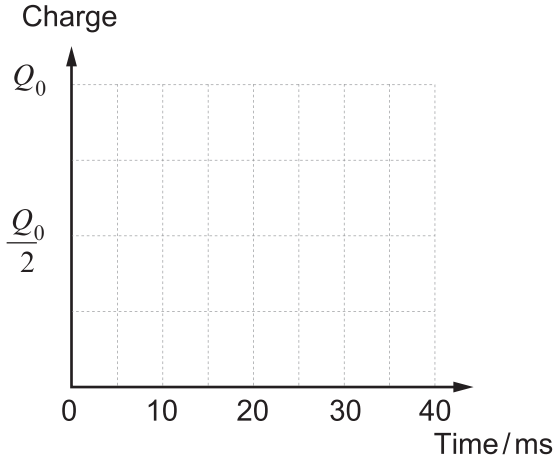
(c) An identical, uncharged 8.0 nF capacitor is **charged** in the following circuit, **using the same large resistor, *R***. The switch is closed and the capacitor is uncharged at time $t = 0$.

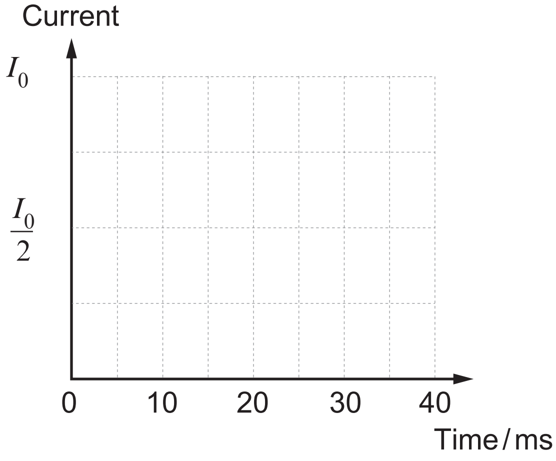


Without further calculations, sketch graphs of:

(i) the charge on the plates of the capacitor against time; [2]



(ii) the current in the circuit against time. [2]



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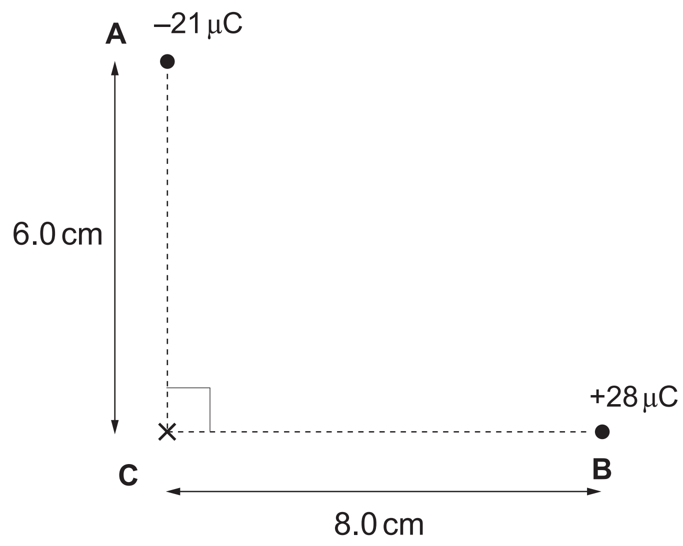
2. Two charges are placed at points **A** and **B** as shown in the diagram.



(a) Draw **two** arrows on the diagram to represent the directions of the electric fields at **C** due to the –21 μC and +28 μC charges. [2]

(b) Calculate the magnitude and direction of the resultant electric field at **C**. [5]

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(c) Show that the electrical potential at point **C** is zero. [2]

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(d) A positron is initially at rest at point **C** and accelerates rapidly due to the electric field. Calculate the potential at the point where the velocity of the positron is $5.4 \times 10^7 \, m\,s^{-1}$. [3]

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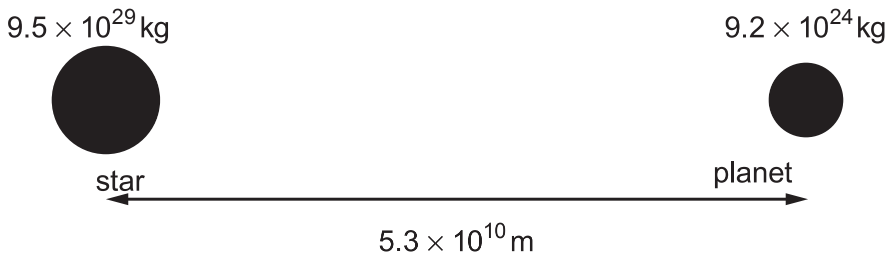
3. The planet (Kepler-186f) orbits the star (Kepler-186) and is considered to be the most Earth-like planet yet discovered. Approximate details of the system are shown in the diagram below.



(a) (i) Show that the radius of orbit of the star around the centre of mass of the system is 513 km. [2]

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(ii) The period of orbit of the planet is 130 days. Calculate the orbital velocity of the star. [3]

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(iii) The velocity calculated in part *(a)*(ii) is small. Explain why small velocities are difficult to measure using red shift. [2]

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(b) (i) Calculate the gravitational force between the star and the planet. [2]

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(ii) An historic alternative to Newton's Law of Gravitation involved invisible steel rods connecting stars and planets and providing the force for keeping planets in orbit. A hypothetical cylindrical steel rod of radius 7.0×10^6 m and length 5.3×10^{10} m joins the planet to the star. Determine whether or not this steel rod is strong enough to keep the planet in orbit and explain why this theory is not accepted. (Breaking stress of steel = 4.5×10^8 Pa.) [4]

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(c) (i) Calculate the potential energy of the star-planet system (see diagram in part *(a)*). [2]

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(ii) In fact the planet has a slightly elliptical orbit. Explain how conservation of energy applies to this elliptical orbit. [2]

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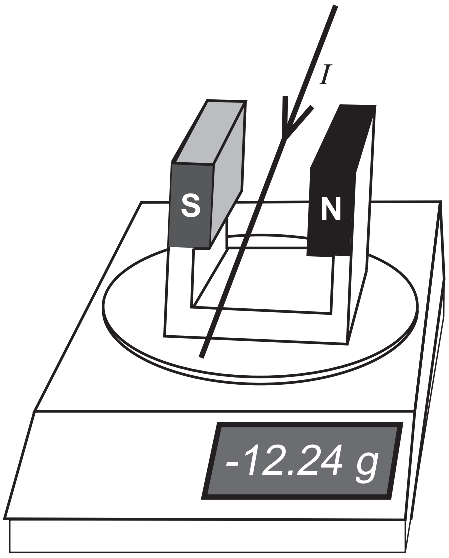
4. A student carries out an investigation. She uses a top pan balance to investigate the relationship $F=BI\ell$ using the set up shown in the diagram. The current-carrying wire is placed perpendicular to the magnetic field, B.

The current in the wire is varied using a variable power supply while the magnetic field, B, and the length of wire in the field, ℓ, are kept constant. Before switching on the current, the balance is set to zero.



(a) (i) Explain why the reading on the balance is negative for the direction of current and magnetic field shown in the diagram. [3]

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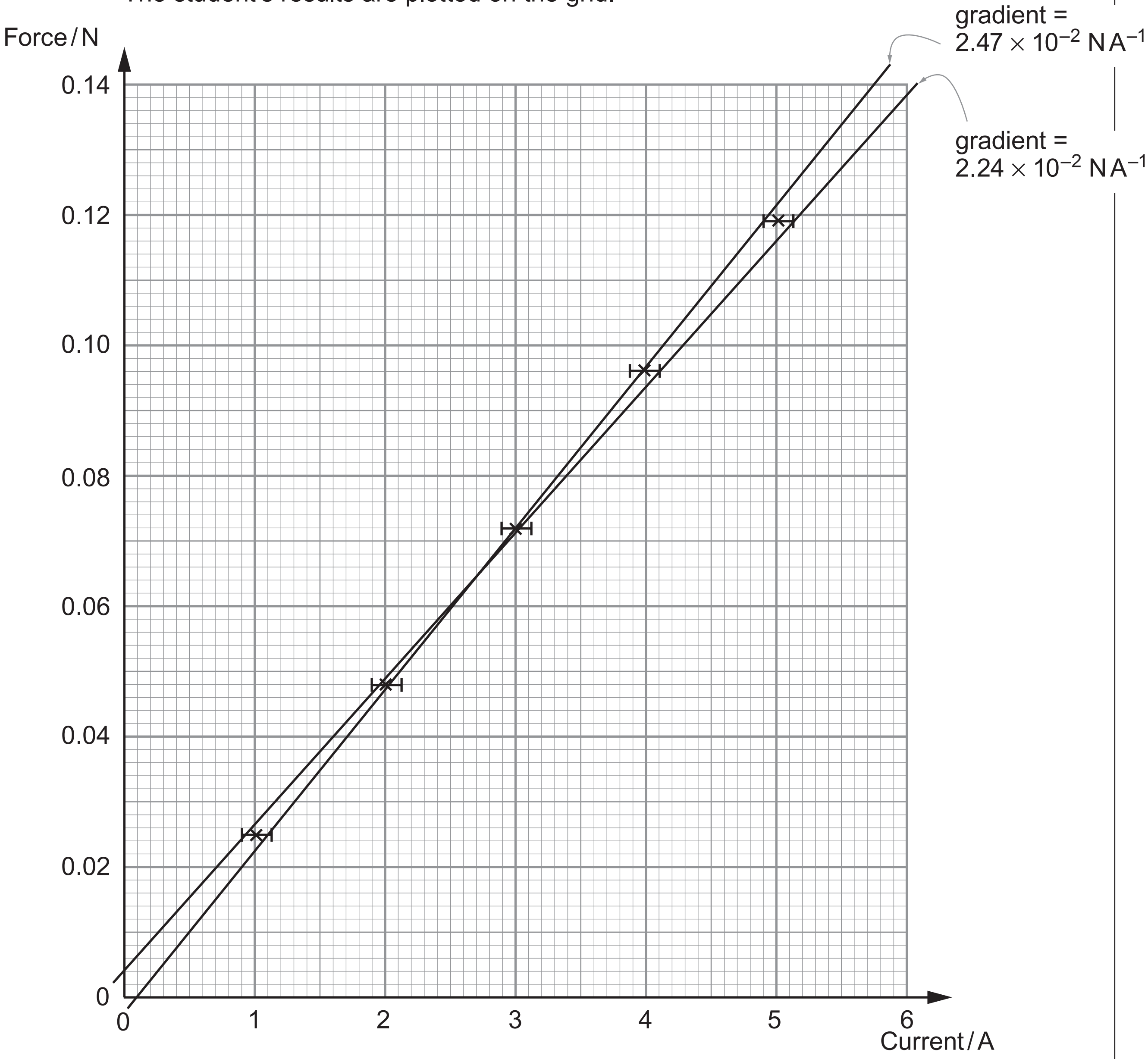
The student's results are plotted on the grid.



(ii) Calculate the mean value of the gradients (2.47×10^{-2} N A^{-1} and 2.24×10^{-2} N A^{-1}) and its **percentage** uncertainty. [3]

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(iii) The length of wire in the uniform magnetic field is (8.0 ± 0.5) cm. Determine a value for the magnetic field strength and its **absolute** uncertainty, stating both to an appropriate number of significant figures. [4]

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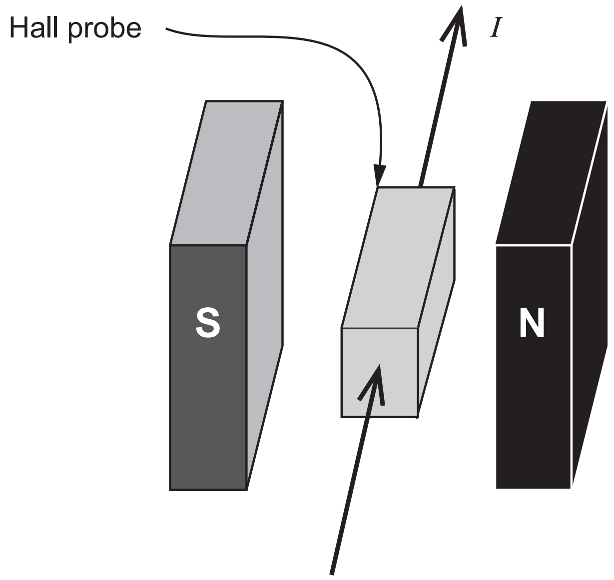
(b) In another experiment a Hall probe is used to confirm the value of the magnetic field strength obtained. The value of B obtained using the Hall probe is (310 ± 8) mT.



(i) Explain how the Hall voltage arises in the Hall probe shown. [3]

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(ii) Discuss the effectiveness of the experiment in part *(a)* for confirming the relationship $F=BI\ell$ and measuring the magnetic field strength, compared with using the Hall probe {see *(a)*(iii) and *(b)*}. [6 QER]

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Turn over.

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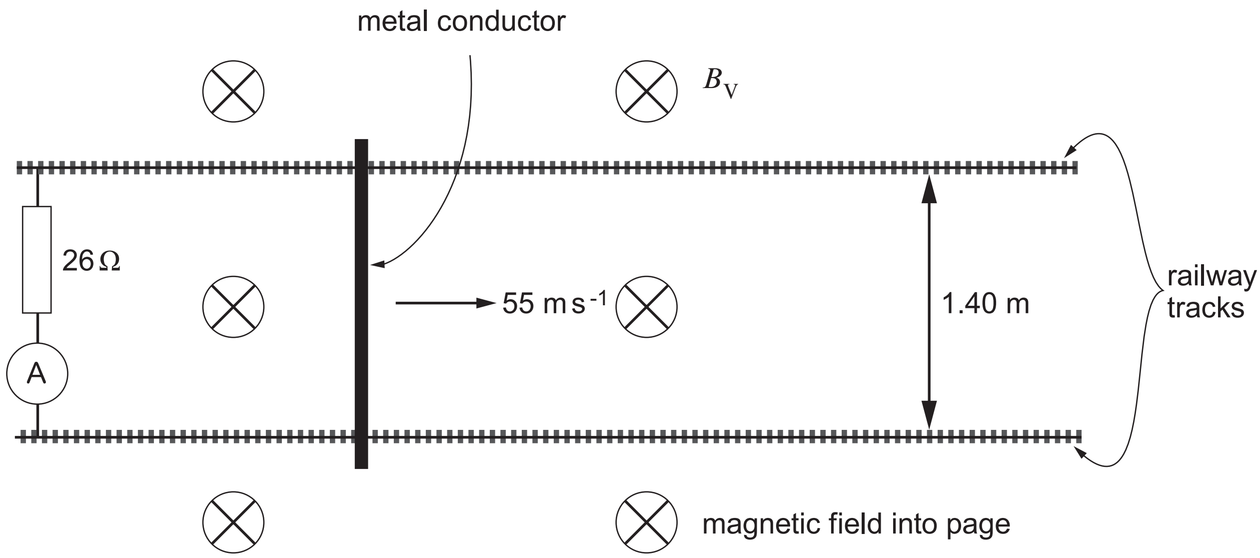
5. A metal conductor is placed across horizontal railway tracks and moved quickly in the direction shown. This set up is designed to measure the vertical component (B_V) of the Earth's magnetic field.



(a) (i) Explain why a current is detected by the ammeter. [2]

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(ii) State why the current is independent of the horizontal component of the Earth's magnetic field. [1]

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(b) Calculate a value for the vertical component of the Earth's magnetic field given that the reading on the ammeter is 184 μA. [3]

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(c) State the direction of the current in the resistor and how you obtained this direction. [2]

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(d) A student suggests that the opposing force due to the magnetic field on the moving conductor is negligible compared with other resistive forces. Is the student correct? Justify your answer with a calculation. [4]

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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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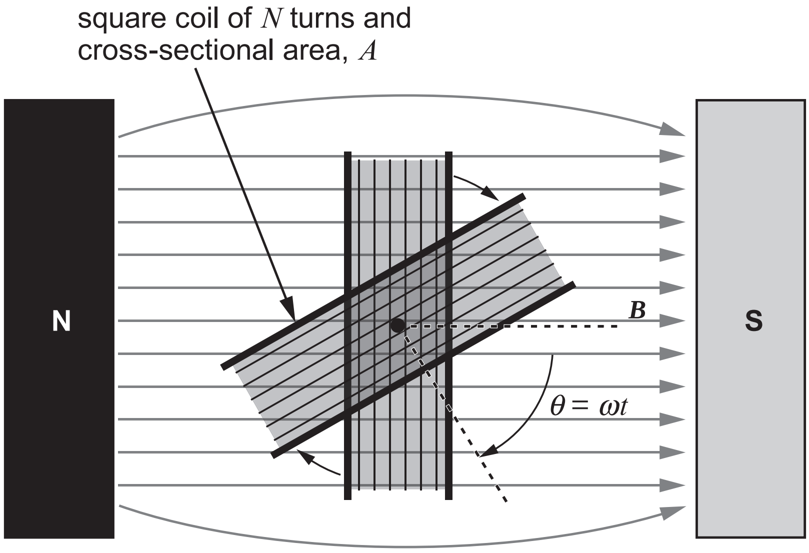
Option A – **Alternating Currents**

6. *(a)* A coil is rotated in a magnetic field.



(i) Use Faraday's law to explain why the emf is proportional to the angular velocity of the coil. [2]

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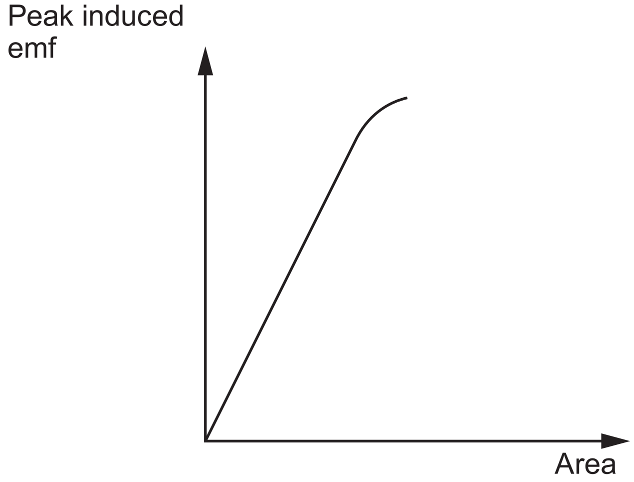
The peak emf induced in a rotating coil is given by:

$$E = \omega BAN$$

An experiment is carried out to investigate the variation in the peak emf with area, A, by using coils with different cross-sectional areas. The following graph is obtained.



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(ii) Discuss the agreement of the graph with the equation for the peak emf and suggest a reason for any disagreement (see diagram of coil opposite). [3]

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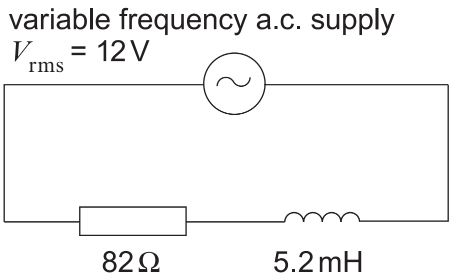
(b) (i) The minimum impedance of the circuit below occurs when the frequency of the a.c. supply is zero. Explain why this is so. [2]



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(ii) Calculate the rms current when the rms pd across the resistor and inductor are equal. [3]

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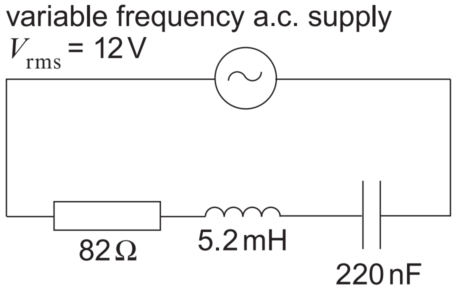
(c) (i) Explain how resonance arises in the *LCR* circuit shown. [3]



(ii) Calculate the power dissipated in the circuit at resonance. [2]

(iii) Calculate the rms current when the frequency of the supply is 9.40 kHz. [3]

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Examiner only

(iv) Discuss briefly the effectiveness of the given LCR circuit for providing a sharp resonance curve. [2]

(It may be useful to note that $\frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$.)

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Option B – **Medical Physics**

7. *(a)* An X–ray machine is designed to fire enormous numbers of electrons per second at very high speeds into a metal target. To do this it typically operates with a current of 100 mA. The electrons are accelerated from rest through a distance of about 3 cm hitting the target at half the speed of light.

(i) State how fast moving electrons can produce X-rays. [1]

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(ii) Determine the number of electrons arriving at the target every second. [2]

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(iii) Calculate the acceleration of an electron in the X-ray tube as it travels towards the target. [3]

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(iv) Explain how the photon energy and the intensity of the X-ray output can be increased. [2]

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Examiner only

(b) Give **one** advantage and **one** disadvantage of using CT scans compared with conventional X-ray imaging. [2]

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(c) The following table provides information relating to ultrasound in fat and muscle.

Tissue	Density / $kg\,m^{-3}$	Speed / $m\,s^{-1}$
Muscle	1.1×10^3	1.6×10^3
Fat	0.8×10^3	1.5×10^3

By considering acoustic impedance, explain whether or not you would expect to receive an ultrasound echo from a muscle-fat boundary. [4]

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(d) (i) Explain briefly the role played by the absorbed radio waves in the resonance process of MRI scans. [2]

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(ii) In an MRI scanner radio waves of frequency 64 MHz are absorbed and cause hydrogen atoms to resonate in a magnetic field of 1.5 T. Determine the frequency of absorbed radio waves that would be needed if the field was reduced to 1.2 T. [2]

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(e) (i) Alpha particles have a radiation weighting factor of 20. If a patient receives an absorbed dose of 55 mGy determine the dose equivalent received. [1]

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(ii) State whether or not beta particles would have a weighting factor of 20, greater than 20 or less than 20. Justify your answer. [1]

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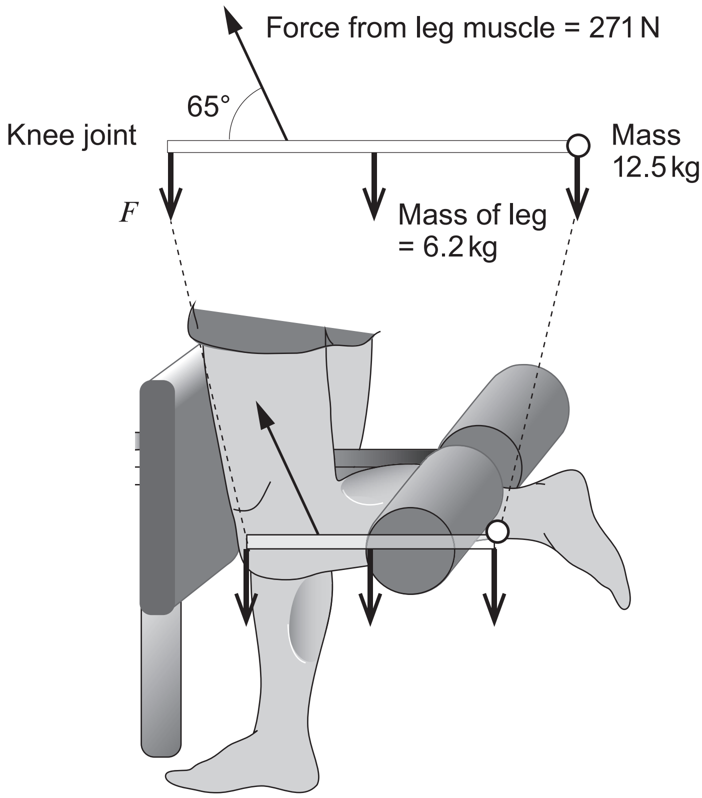
Option C **– The Physics of Sports**

8. The following simplified diagram is of the lower leg of an athlete holding a mass of 12.5 kg in equilibrium. The leg pivots around the knee joint and the effective mass of the lower leg is 6.2 kg. The force, F, shown is the vertical component of the force exerted on the lower leg by the knee.



(a) Calculate the force, F. [3]

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(b) (i) A football player must kick a football a distance of 43.6 m for it to be a successful kick. Determine whether or not the kick will be successful if it is kicked with a speed of 18 m s^{-1} at an angle of 50 ° to the horizontal. *Ignore the effects of air resistance.* [4]

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(ii) The football has a mass of 0.45 kg and spins at a rate of 8.8 Hz. It has a moment of inertia of 0.0041 kg m^2.

I. Explain what is meant by the moment of inertia. [2]

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II. Calculate the angular momentum of the football. [2]

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III. Determine the **total** kinetic energy of the ball **at its greatest height** *(remember to ignore the effects of air resistance)*. [4]

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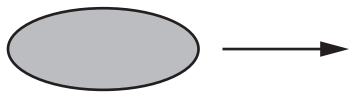
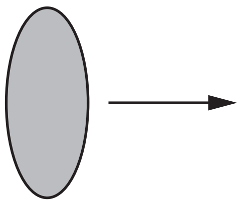
(c) Due to the shape of a rugby ball, its cross-sectional area can be varied depending on its orientation and motion. The minimum and maximum cross-sectional areas are 43.2 cm^2 and 217.7 cm^2 respectively and are shown below.



Minimum cross-sectional area = 43.2 cm^2



Maximum cross-sectional area = 217.7 cm^2

(i) Explain clearly by what factor the drag force changes for these two cross-sectional areas. [3]

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(ii) If the rugby ball had been kicked in a region where the density of the air is lower, explain how your answer to part *(c)*(i) would change, if at all. [2]

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Option D – **Energy and the Environment**

9. *(a)* (i) The total power emitted by the Sun is 4.0×10^{26} W. Given that the Earth is 1.5×10^{11} m from the Sun show that the intensity of the radiation reaching the Earth's outer atmosphere is approximately 1 400 W m^{-2}. [2]

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(ii) The mean annual power available at the Earth's surface in the UK is only about 20% of the answer to part *(a)*(i). By the middle of 2015 solar photovoltaic (PV) installations accounted for approximately 8 GW of the UK's electricity production. Given that solar panels are only 15% efficient at converting solar radiation into electricity, estimate the total area of solar panels in the UK in 2015. [2]

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(iii) Give a reason why the amount of electrical energy produced by a solar farm in Portugal is likely to be greater than that from a solar farm of the same size in the UK per year. [1]

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(b) (i) State Wien's law. [1]

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(ii) Assuming a mean temperature of 290 K for the Earth and that it emits radiation from its surface as a black body, show that the peak wavelength of the radiation emitted by the Earth is in the infra-red region of the electromagnetic spectrum. [2]

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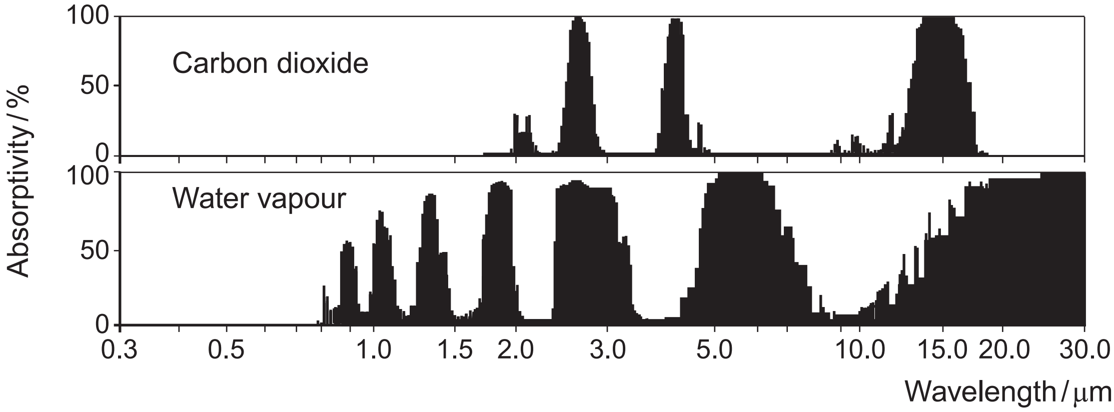
(iii) The graphs below show greenhouse gas absorption spectra for water vapour and carbon dioxide as a function of the wavelength of the radiation incident on the gas. An absorptivity of zero % means no radiation is absorbed, whilst an absorptivity of 100% means that all the incident radiation is absorbed.



www.worldclimatereport.com

I. Use the graphs to explain how increased levels of water vapour and carbon dioxide in the atmosphere can account for the greenhouse effect. [4]

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II. The term *'positive feedback'* is used to describe a system's output influencing the system so as to increase the output even further. The Earth's surface and atmosphere may be regarded as a system, and temperature as the system's output. Explain how the greenhouse effect is part of a positive feedback. [2]

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Examiner only

(c) (i) Define the term U-value and state **one** factor which affects the U-value of a material. [2]

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(ii) A room in a large office block is maintained at a constant temperature of 21 °C. The room has one of its walls, measuring 5.0 m × 3.0 m, exposed to the outside. This wall is double glazed (made of two layers of glass with a small air filled gap between them). Negligible heat is lost through the other walls of the room.
Calculate the energy per second transmitted through the outside wall if the outside temperature is 9 °C. [U-value of double glazing glass = 1.8 W m^{-2} K^{-1}] [2]

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(iii) The heating system in the room can provide a maximum output of 1 kW. Determine the lowest outside temperature for which the double glazing can maintain an internal temperature of 21 °C. [2]

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END OF PAPER

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

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