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**Physics**  
**Higher level**  
**Paper 2**

Friday 17 May 2019 (afternoon)

Candidate session number

2 hours 15 minutes

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**Instructions to candidates**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[90 marks]**.



Please **do not** write on this page.

Answers written on this page  
will not be marked.



24EP02

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A girl rides a bicycle that is powered by an electric motor. A battery transfers energy to the electric motor. The emf of the battery is 16 V and it can deliver a charge of 43 kC when discharging completely from a full charge.

(a) The maximum speed of the girl on a horizontal road is  $7.0 \text{ m s}^{-1}$  with energy from the battery alone. The maximum distance that the girl can travel under these conditions is 20 km.

(i) Show that the time taken for the battery to discharge is about  $3 \times 10^3 \text{ s}$ . [1]

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(ii) Deduce that the average power output of the battery is about 240 W. [2]

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(iii) Friction and air resistance act on the bicycle and the girl when they move. Assume that all the energy is transferred from the battery to the electric motor. Determine the total average resistive force that acts on the bicycle and the girl. [2]

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**(Question 1 continued)**

- (b) The bicycle and the girl have a total mass of 66 kg. The girl rides up a slope that is at an angle of  $3.0^\circ$  to the horizontal.



- (i) Calculate the component of weight for the bicycle and girl acting down the slope. [1]

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- (ii) The battery continues to give an output power of 240 W. Assume that the resistive forces are the same as in (a)(iii).

Calculate the maximum speed of the bicycle and the girl up the slope. [2]

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- (c) On another journey up the slope, the girl carries an additional mass. Explain whether carrying this mass will change the maximum distance that the bicycle can travel along the slope. [2]

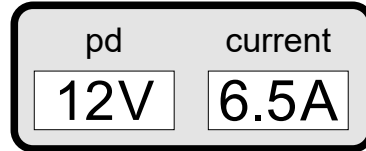
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(Question 1 continued)

- (d) The bicycle has a meter that displays the current and the terminal potential difference (pd) for the battery when the motor is running. The diagram shows the meter readings at one instant. The emf of the cell is 16V.



Determine the internal resistance of the battery.

[2]

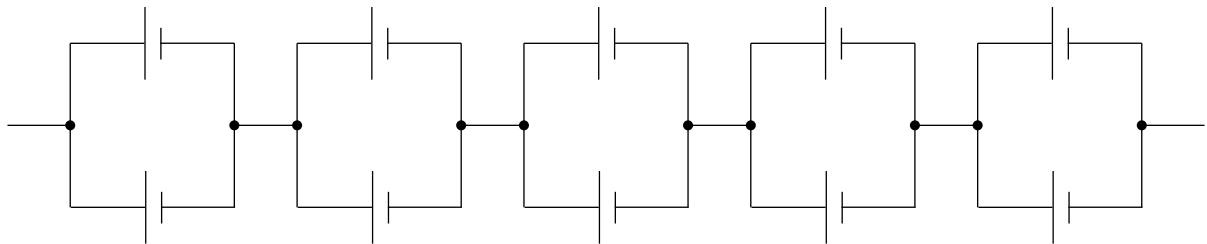
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- (e) The battery is made from an arrangement of 10 identical cells as shown.



Calculate

- (i) the emf of **one** cell.

[1]

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- (ii) the internal resistance of **one** cell.

[2]

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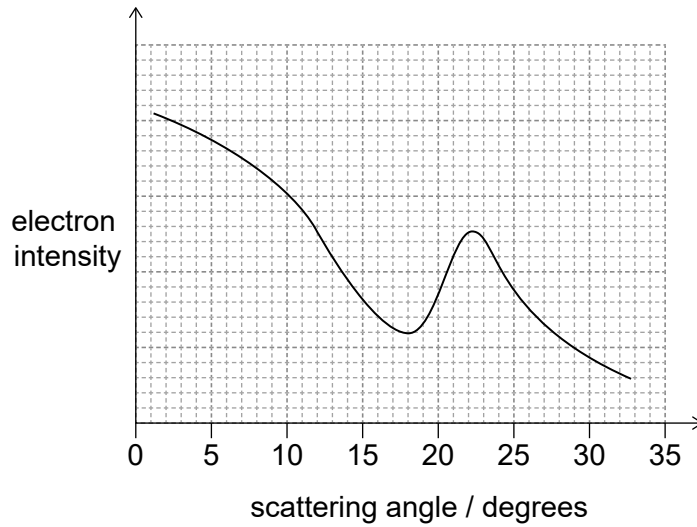
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2. (a) A beam of electrons each of de Broglie wavelength  $2.4 \times 10^{-15}$  m is incident on a thin film of silicon-30 ( $^{30}_{14}\text{Si}$ ). The variation in the electron intensity of the beam with scattering angle is shown.



- (i) Use the graph to show that the nuclear radius of silicon-30 is about 4 fm. [3]

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- (ii) Estimate, using the result from (a)(i), the nuclear radius of thorium-232 ( $^{232}_{90}\text{Th}$ ). [2]

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**(Question 2 continued)**

- (iii) Suggest **one** reason why a beam of electrons is better for investigating the size of a nucleus than a beam of alpha particles of the same energy. [1]

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- (iv) Outline why deviations from Rutherford scattering are observed when high-energy alpha particles are incident on nuclei. [2]

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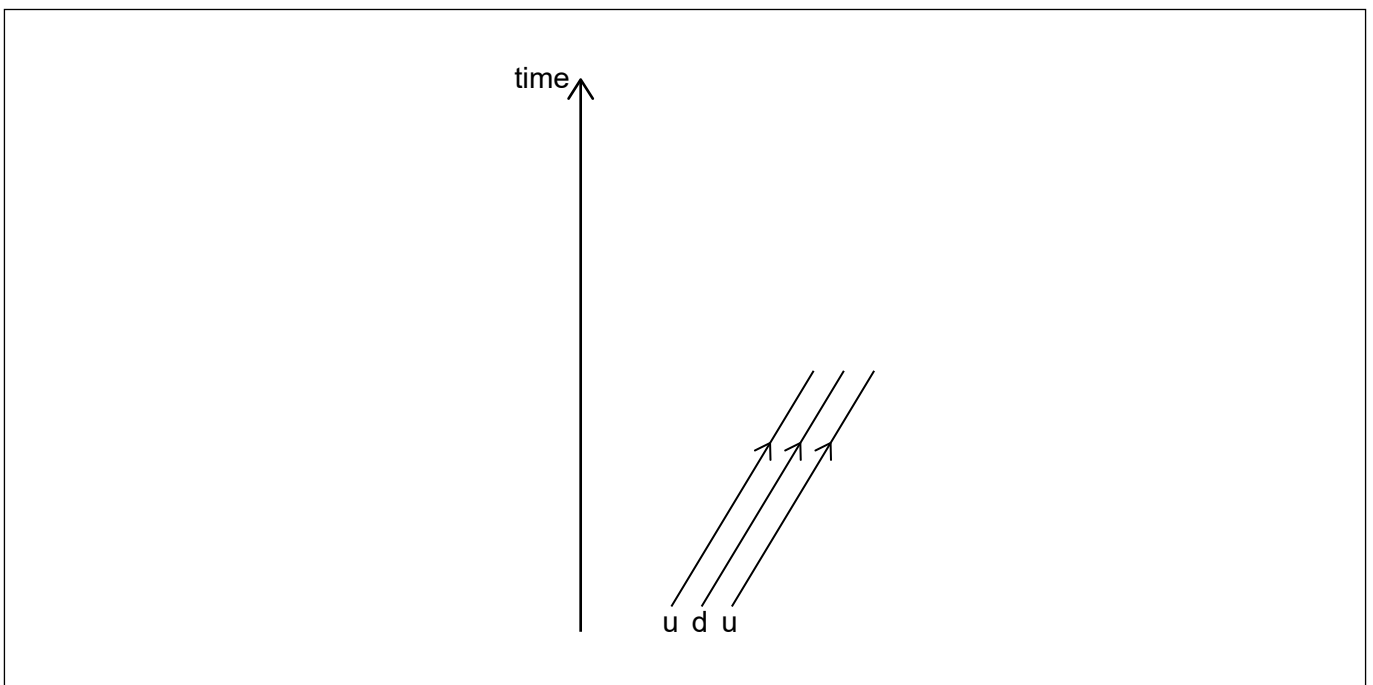
**(Question 2 continued)**

(b) Silicon-30 ( $^{30}_{14}\text{Si}$ ) can be formed from phosphorus-30 ( $^{30}_{15}\text{P}$ ) by a process of beta-plus decay.

(i) Write down the nuclear equation that represents this reaction. [2]

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(ii) Sketch the Feynman diagram that represents this reaction. The diagram has been started for you. [3]



(iii) Energy is transferred to a hadron in an attempt to separate its quarks. Describe the implications of quark confinement for this situation. [2]

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**(This question continues on the following page)**



24EP08

**(Question 2 continued)**

- (c) The Standard Model was accepted by many scientists before the observation of the Higgs boson was made.

Outline why it is important to continue research into a topic once a scientific model has been accepted by the scientific community.

[1]

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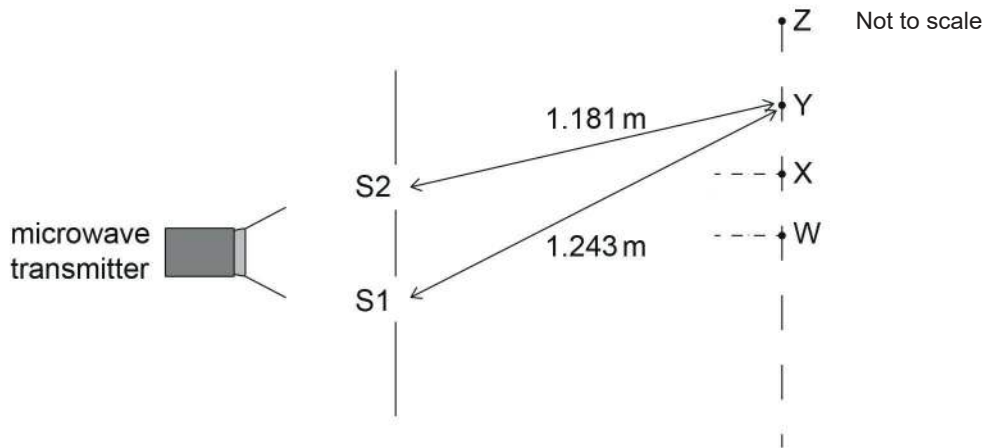
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24EP09

Turn over

3. A beam of microwaves is incident normally on a pair of identical narrow slits S1 and S2.



When a microwave receiver is initially placed at W which is equidistant from the slits, a maximum in intensity is observed. The receiver is then moved towards Z along a line parallel to the slits. Intensity maxima are observed at X and Y with one minimum between them. W, X and Y are consecutive maxima.

(a) Explain why intensity maxima are observed at X and Y. [2]

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The distance from S1 to Y is 1.243m and the distance from S2 to Y is 1.181 m.

(b) Determine the frequency of the microwaves. [3]

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(Question 3 continued)

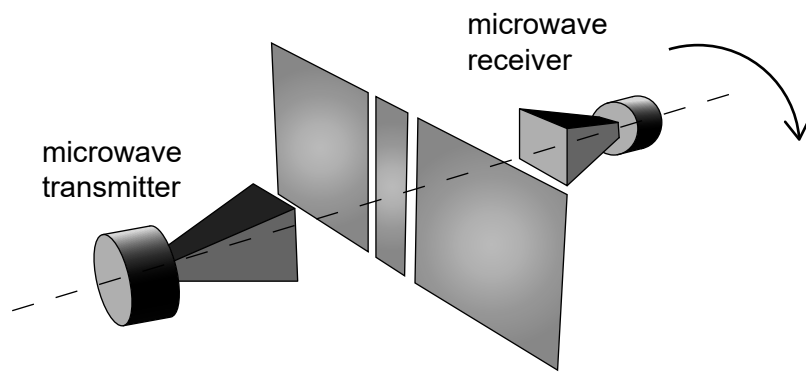
- (c) Outline **one** reason why the maxima observed at W, X and Y will have different intensities from each other.

[1]

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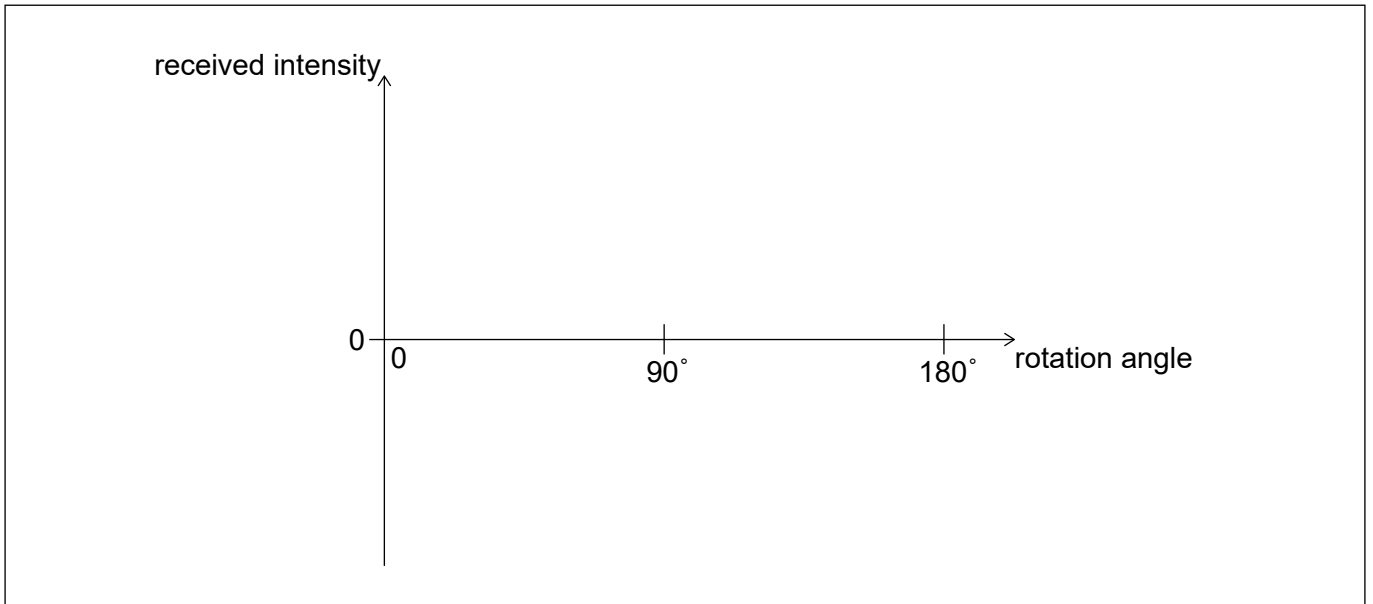
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- (d) The microwaves emitted by the transmitter are horizontally polarized. The microwave receiver contains a polarizing filter. When the receiver is at position W it detects a maximum intensity.



The receiver is then rotated through  $180^\circ$  about the horizontal dotted line passing through the microwave transmitter. Sketch a graph on the axes provided to show the variation of received intensity with rotation angle.

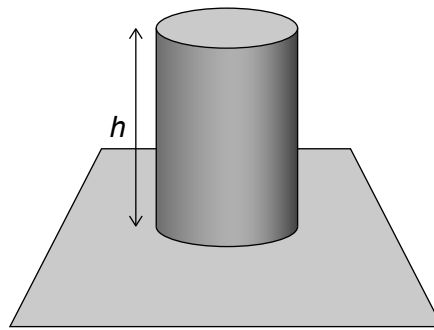
[2]



24EP11

Turn over

4. A solid cylinder of height  $h$  and density  $\rho$  rests on a flat surface.



(a) Show that the pressure  $p_c$  exerted by the cylinder on the surface is given by  $p_c = \rho gh$ . [2]

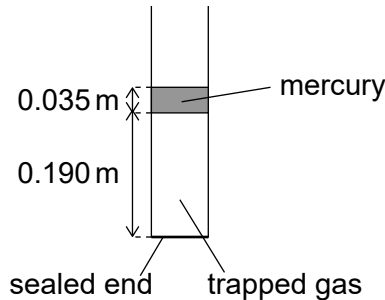
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(b) A tube of constant circular cross-section, sealed at one end, contains an ideal gas trapped by a cylinder of mercury of length 0.035 m. The whole arrangement is in the Earth's atmosphere. The density of mercury is  $1.36 \times 10^4 \text{ kg m}^{-3}$ .



When the mercury is above the gas column the length of the gas column is 0.190 m.

(i) Show that  $(p_o + p_m) \times 0.190 = \frac{nRT}{A}$  where

$p_o$  = atmospheric pressure

$p_m$  = pressure due to the mercury column

$T$  = temperature of the trapped gas

$n$  = number of moles of the trapped gas

$A$  = cross-sectional area of the tube. [2]

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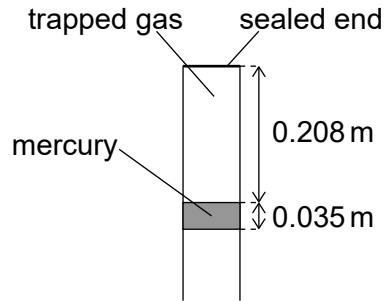


24EP12

**(Question 4 continued)**

(ii) The tube is slowly rotated until the gas column is above the mercury.

**diagram not to scale**



The length of the gas column is now 0.208 m. The temperature of the trapped gas does not change during the process.

Determine the atmospheric pressure. Give a suitable unit for your answer.

[4]

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(iii) Outline why the gas particles in the tube hit the mercury surface less often after the tube has been rotated.

[1]

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24EP13

Turn over

5. (a) The moon Phobos moves around the planet Mars in a circular orbit.

(i) Outline the origin of the force that acts on Phobos. [1]

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(ii) Outline why this force does no work on Phobos. [1]

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(b) The orbital period  $T$  of a moon orbiting a planet of mass  $M$  is given by

$$\frac{R^3}{T^2} = kM$$

where  $R$  is the average distance between the centre of the planet and the centre of the moon.

(i) Show that  $k = \frac{G}{4\pi^2}$  [3]

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(Question 5 continued)

- (ii) The following data for the Mars–Phobos system and the Earth–Moon system are available:

Mass of Earth =  $5.97 \times 10^{24}$  kg

The Earth–Moon distance is 41 times the Mars–Phobos distance.

The orbital period of the Moon is 86 times the orbital period of Phobos.

Calculate, in kg, the mass of Mars.

[2]

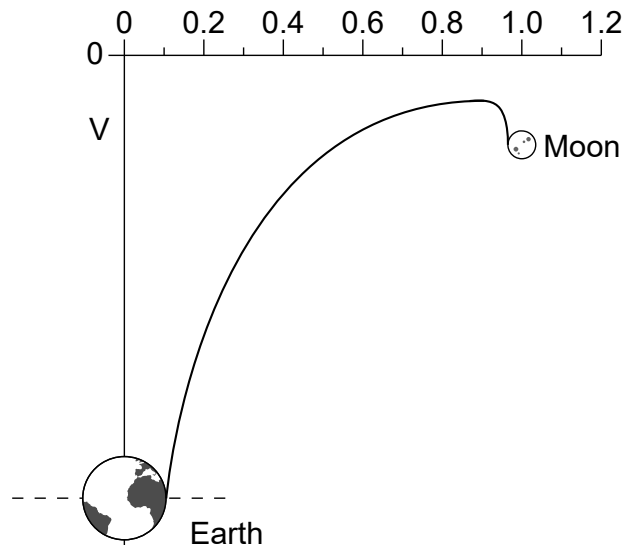
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- (c) The graph shows the variation of the gravitational potential between the Earth and Moon with distance from the centre of the Earth. The distance from the Earth is expressed as a fraction of the total distance between the centre of the Earth and the centre of the Moon.



Determine, using the graph, the mass of the Moon.

[3]

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24EP15

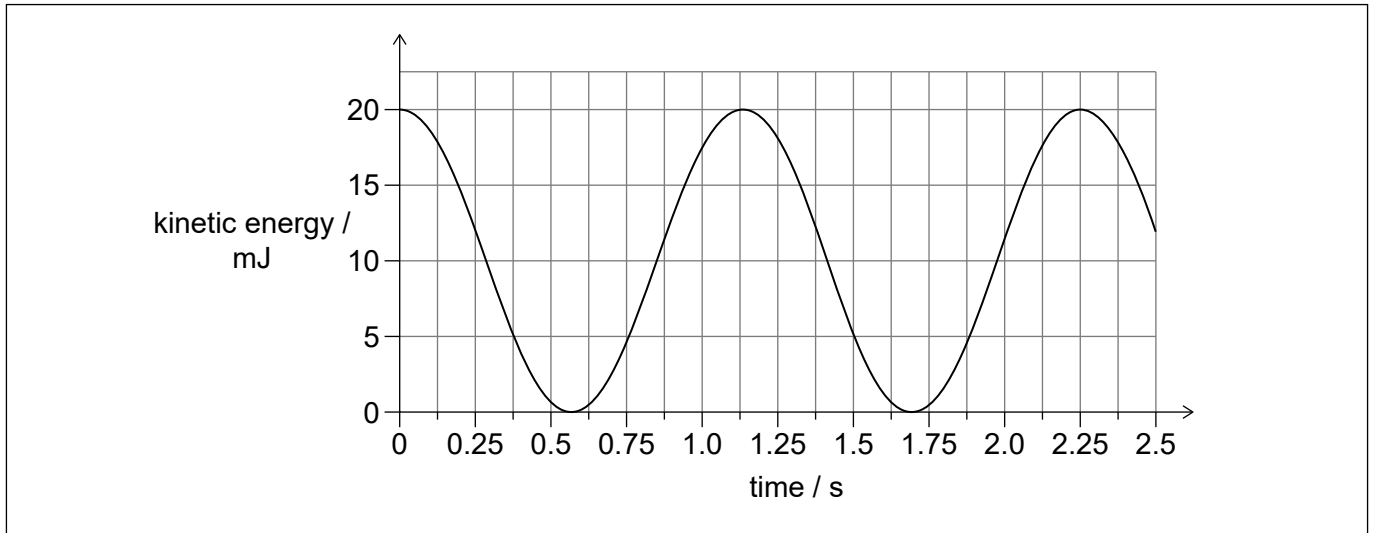
Turn over



6. A small metal pendulum bob is suspended at rest from a fixed point with a length of thread of negligible mass. Air resistance is negligible.

The pendulum begins to oscillate. Assume that the motion of the system is simple harmonic, and in one vertical plane.

The graph shows the variation of kinetic energy of the pendulum bob with time.



(a) (i) Calculate, in m, the length of the thread. State your answer to an appropriate number of significant figures. [3]

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(ii) Label on the graph with the letter X a point where the speed of the pendulum is half that of its initial speed. [1]

(iii) The mass of the pendulum bob is 75 g. Show that the maximum speed of the bob is about  $0.7 \text{ m s}^{-1}$ . [2]

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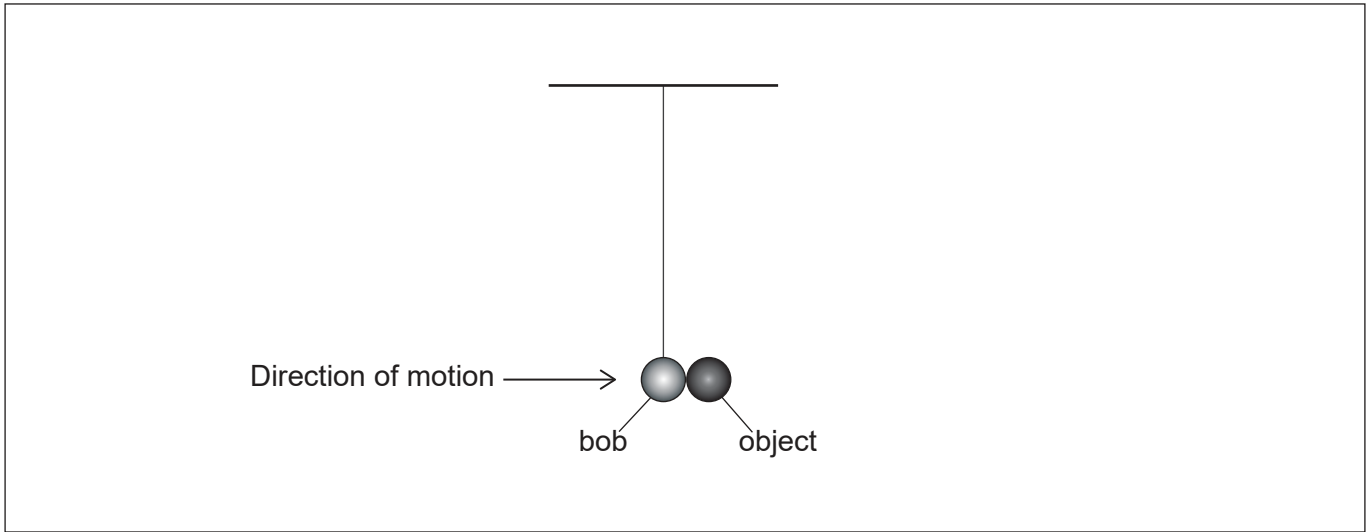
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24EP16

**(Question 6 continued)**

- (b) When the 75 g bob is moving horizontally at  $0.80 \text{ m s}^{-1}$ , it collides with a small stationary object also of mass 75 g. The object and the bob stick together.



- (i) Calculate the speed of the combined masses immediately after the collision. [1]

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- (ii) Show that the collision is inelastic. [3]

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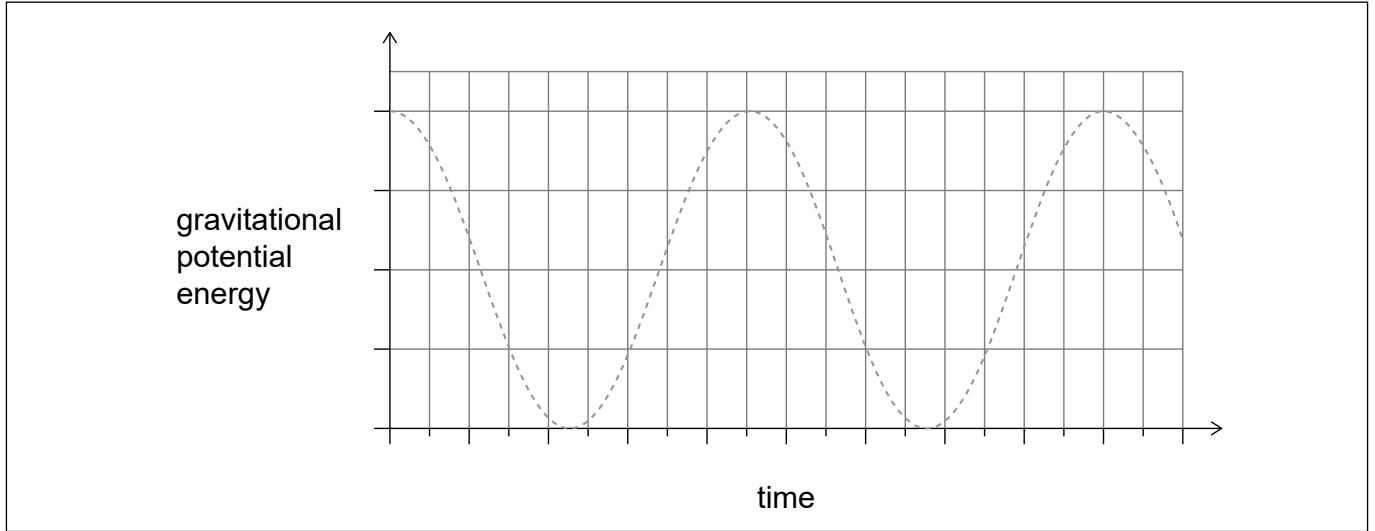


24EP17

Turn over

(Question 6 continued)

- (iii) Sketch, on the axes, a graph to show the variation of gravitational potential energy with time for the bob and the object after the collision. The data from the graph used in (a) is shown as a dashed line for reference. [2]



- (iv) The speed after the collision of the bob and the object was measured using a sensor. This sensor emits a sound of frequency  $f$  and this sound is reflected from the moving bob. The sound is then detected by the sensor as frequency  $f'$ .

Explain why  $f$  and  $f'$  are different.

[3]

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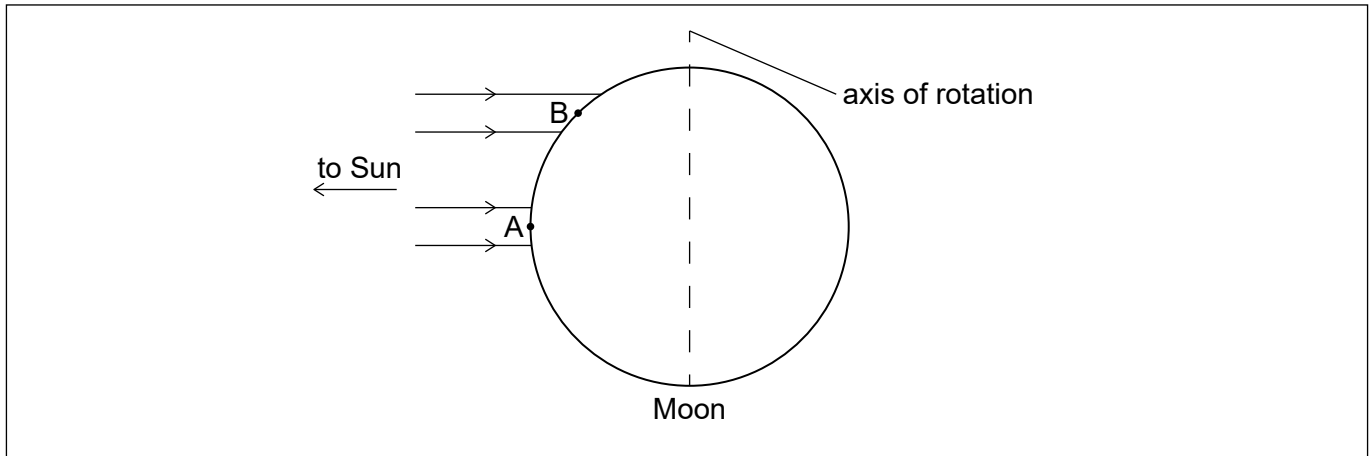
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7. The Moon has no atmosphere and orbits the Earth. The diagram shows the Moon with rays of light from the Sun that are incident at  $90^\circ$  to the axis of rotation of the Moon.



(a) (i) A black body is on the Moon's surface at point A. Show that the maximum temperature that this body can reach is 400 K. Assume that the Earth and the Moon are the same distance from the Sun.

[2]

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(ii) Another black body is on the Moon's surface at point B.

Outline, without calculation, why the maximum temperature of the black body at point B is less than at point A.

[2]

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(b) The albedo of the Earth's atmosphere is 0.28. Outline why the maximum temperature of a black body on the Earth when the Sun is overhead is less than that at point A on the Moon.

[1]

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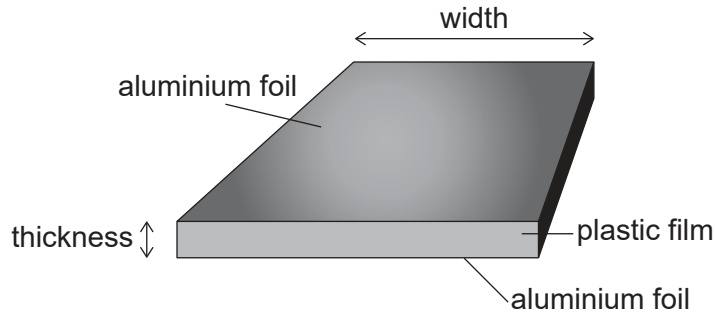
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24EP20

8. A student makes a parallel-plate capacitor of capacitance 68 nF from aluminium foil and plastic film by inserting one sheet of plastic film between two sheets of aluminium foil.

diagram not to scale



The aluminium foil and the plastic film are 450 mm wide.

The plastic film has a thickness of 55  $\mu\text{m}$  and a permittivity of  $2.5 \times 10^{-11} \text{C}^2 \text{N}^{-1} \text{m}^{-2}$ .

- (a) (i) Calculate the total length of aluminium foil that the student will require. [3]

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- (ii) The plastic film begins to conduct when the electric field strength in it exceeds  $1.5 \text{MN C}^{-1}$ . Calculate the maximum charge that can be stored on the capacitor. [2]

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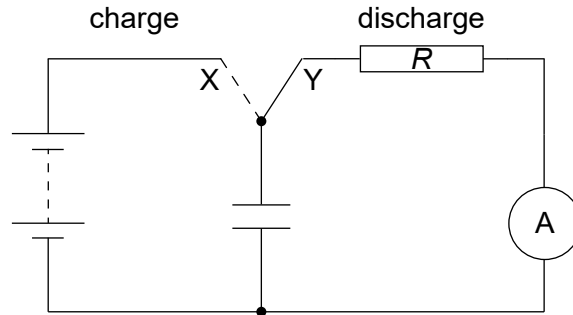
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**(Question 8 continued)**

- (b) The student uses a switch to charge and discharge the capacitor using the circuit shown. The ammeter is ideal.



The emf of the battery is 12V.

- (i) The resistor  $R$  in the circuit has a resistance of  $1.2\text{ k}\Omega$ . Calculate the time taken for the charge on the capacitor to fall to 50% of its fully charged value. [3]

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- (ii) The ammeter is replaced by a coil. Explain why there will be an induced emf in the coil while the capacitor is discharging. [2]

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**(Question 8 continued)**

- (iii) Suggest **one** change to the discharge circuit, apart from changes to the coil, that will increase the maximum induced emf in the coil.

[2]

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24EP24