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**Physics**  
**Standard level**  
**Paper 2**

26 April 2024

**Zone A** morning | **Zone B** morning | **Zone C** morning

Candidate session number

1 hour 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 **[50 marks]**.



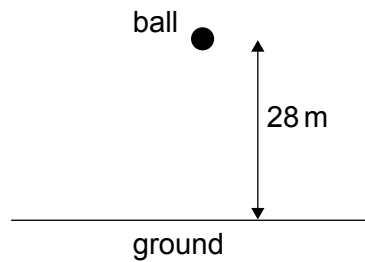
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Answers written on this page  
will not be marked.



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

1. A ball of mass 2.7 g is released from rest from a height of 28 m above horizontal ground.



- (a) Show that in the absence of air resistance the ball impacts the ground with a speed of about  $23 \text{ ms}^{-1}$ . [1]

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- (b) An air resistance force  $F$  acts on the ball.  $F$  can be modeled by  $F = kv^2$  where  $v$  is the speed and  $k$  is a constant.

- (i) Determine the unit of  $k$  in terms of fundamental units. [2]

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- (ii) Describe how the ball reaches terminal speed. [2]

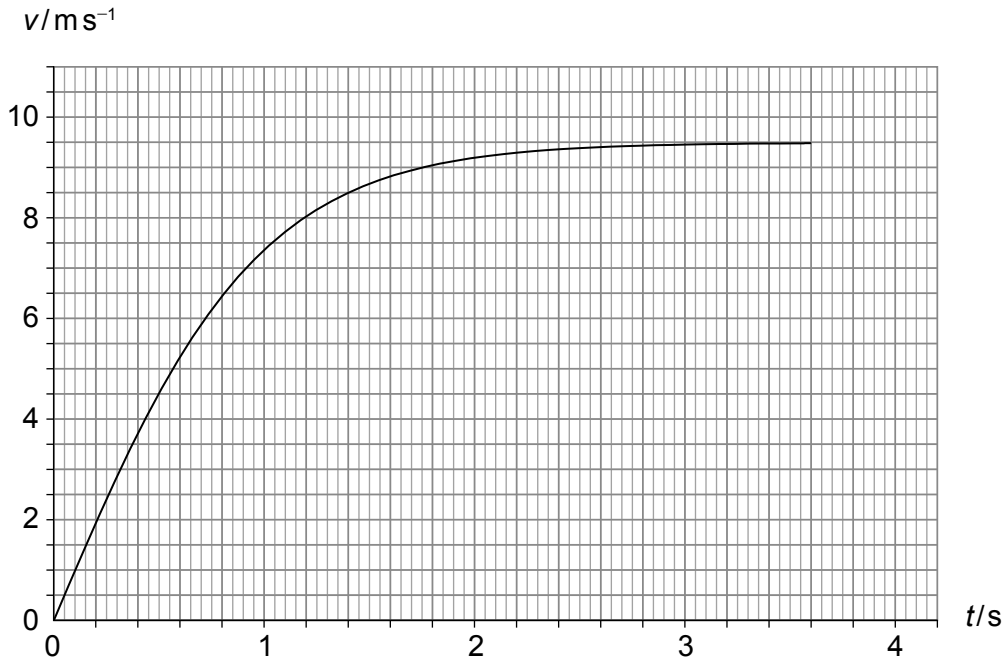
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**(Question 1 continued)**

- (c) The graph shows the variation with time  $t$  of the speed  $v$  of the ball from the instant it is released until it impacts the ground.



- (i) State the value of the area under the curve. [1]

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- (ii) Determine  $k$ . [2]

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**(Question 1 continued)**

- (d) The ball rebounds from the ground with speed  $7.8 \text{ m s}^{-1}$ . The ball is in contact with the ground for a time  $T$ . The average **resultant** force on the ball during this time is  $1.1 \text{ N}$ .

Determine  $T$ .

[2]

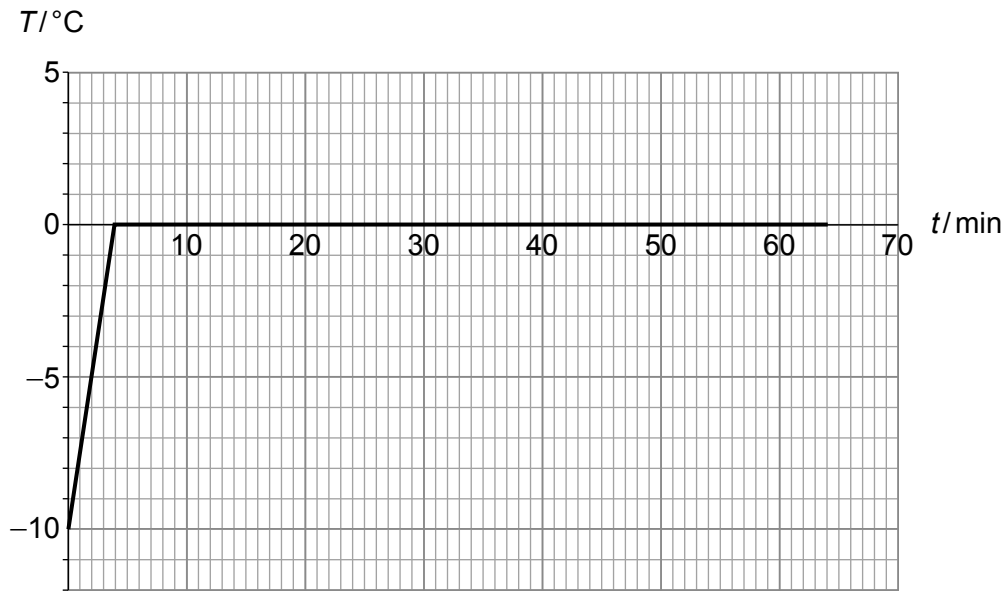
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2. Crushed ice of mass 35 g at temperature  $-10^{\circ}\text{C}$  is placed in a warm room. The graph shows the variation of the temperature  $T$  of the ice with time  $t$ .



The specific heat capacity of ice is  $2100\text{ J kg}^{-1}\text{ K}^{-1}$ .

- (a) (i) Show that the average rate at which thermal energy is being transferred into the ice is about 3 W. [2]

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- (ii) Estimate the specific latent heat of fusion of ice. [2]

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**(Question 2 continued)**

- (b) Between 4 minutes and 64 minutes solid ice and liquid water coexist at 0 °C. Compare and contrast, during this time, the internal energy of solid ice to that of an equal mass of liquid water.

[2]

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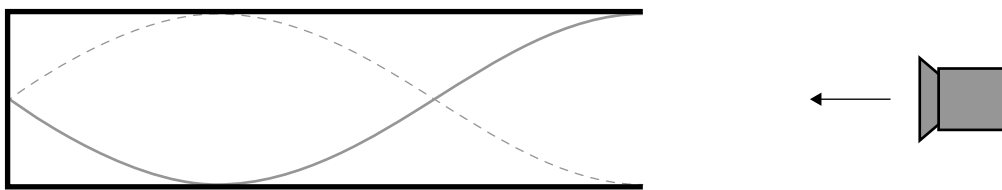




3. (a) Outline what is meant by a travelling wave. [2]

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- (b) A loudspeaker emits sound of frequency 210 Hz into a pipe with one open and one closed end. The diagram shows a representation of the standing wave established in the pipe.



The length of the pipe is 1.20 m.

- (i) Outline how the standing wave is formed in the pipe. [2]

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- (ii) Determine the wavelength of the wave. [1]

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**(Question 3 continued)**

- (iii) Calculate the speed of sound in the pipe stating the answer to an appropriate number of significant figures. [2]

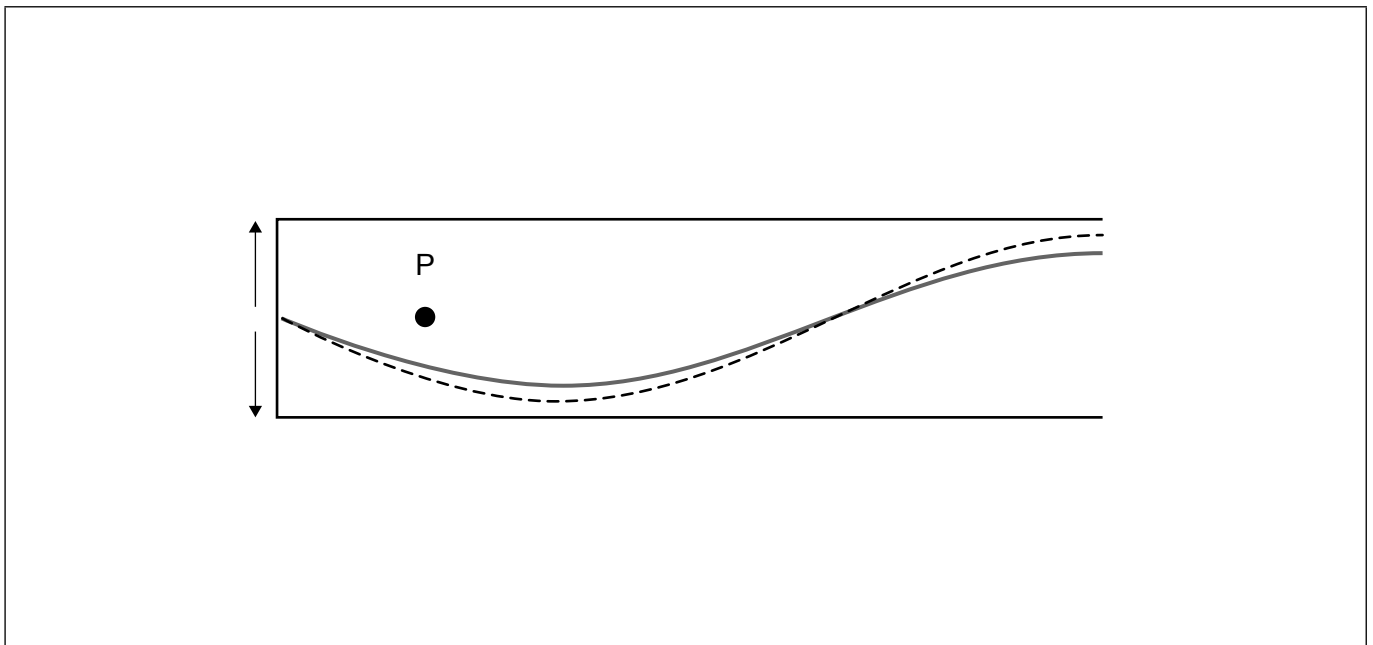
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- (c) The solid line represents the standing wave at time  $t$  and the dotted line represents the standing wave at an instant later. The dot is the **equilibrium** position of a particle P in the pipe. The up arrow indicates displacements to the right and the down arrow indicates displacements to the left.



On the diagram, draw

- (i) a dot to indicate the approximate position of P at time  $t$ , [1]
- (ii) an arrow to indicate the velocity of P at time  $t$ . [1]

**(This question continues on page 11)**



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**(Question 3 continued)**

- (d) The frequency of sound is reduced to 140 Hz. Explain why a standing wave will not be formed in the pipe. [2]

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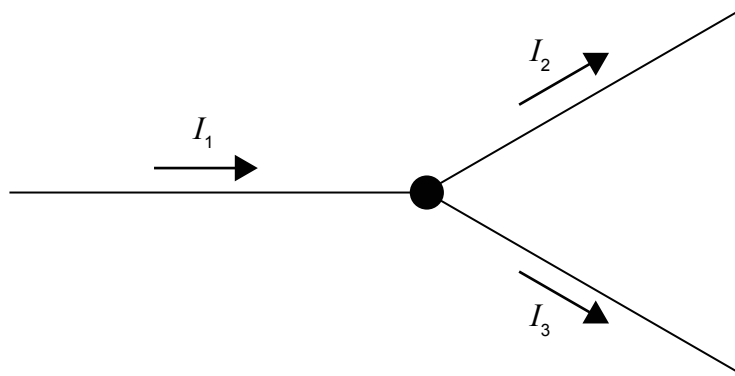
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4. (a) The diagram shows a junction in a circuit.



The currents in the three wires are related by  $I_1 = I_2 + I_3$ .

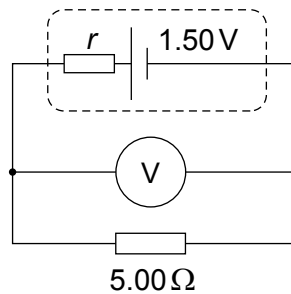
State the fundamental law of Physics from which this relation is derived.

[1]

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- (b) A cell of emf 1.50 V and internal resistance  $r$  is connected to a resistor of resistance  $5.00 \Omega$  and an ideal voltmeter V.



The reading of the voltmeter is 1.20 V.

- (i) Determine the internal resistance  $r$  of the cell.

[2]

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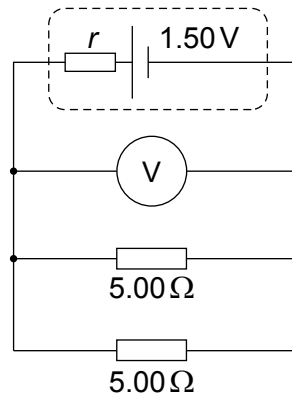
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**(Question 4 continued)**

(ii) A second  $5.00\ \Omega$  resistor is connected in parallel to the first resistor.



State and explain the change, if any, in the voltmeter reading without further calculation.

[2]

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**(This question continues on page 15)**



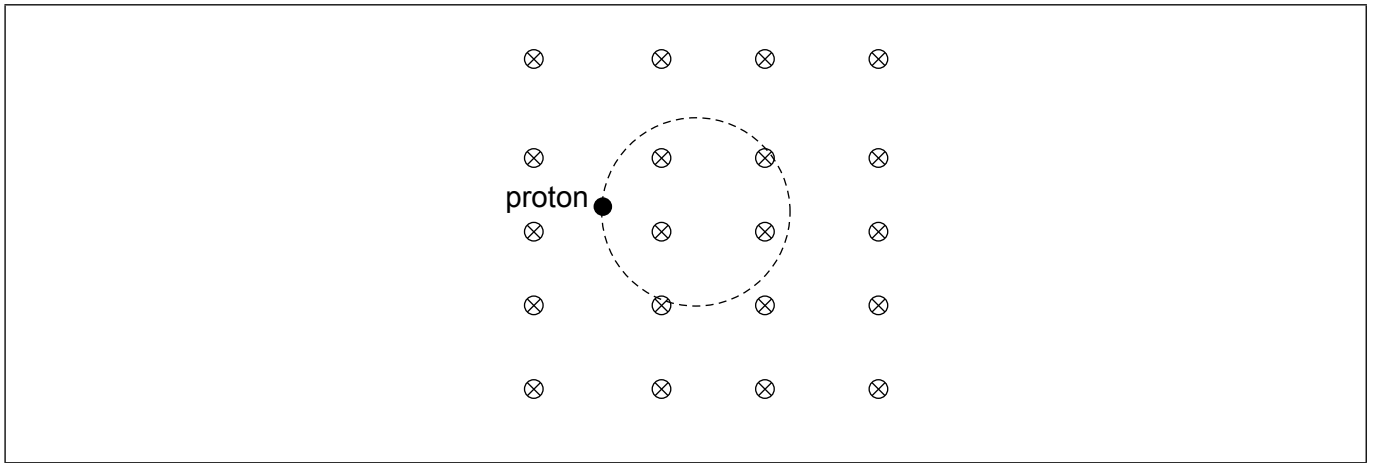
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(Question 4 continued)

- (c) A proton moves on a circular path in a region of uniform magnetic field of magnetic flux density  $B$  that is directed into the plane of the page.



- (i) On the diagram, draw an arrow to indicate the velocity of the proton at the position shown. [1]

- (ii) Show that the frequency of revolution of the proton is given by  $f = \frac{eB}{2\pi m_p}$ . [3]

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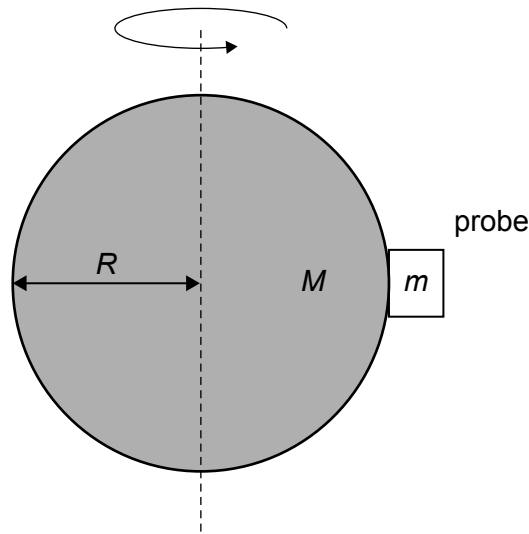
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5. A probe of mass  $m$  has landed on the equator of a rotating asteroid of mass  $M$  and radius  $R$ .

diagram not to scale



The asteroid rotates with angular speed  $\omega$ .

- (a) By drawing a free-body diagram for the probe, show that the normal force,  $N$ , on the probe from the asteroid is given by  $N = m\left(\frac{GM}{R^2} - \omega^2 R\right)$ . [2]

probe

$m$

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**(Question 5 continued)**

(b) Another probe orbits the Sun.

(i) The distance between the probe and the Sun is 4 times the distance between the Earth and the Sun. Show that the intensity of the solar radiation at the surface of the probe is  $85\text{Wm}^{-2}$ . [2]

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(ii) Estimate the equilibrium temperature of the probe assuming it behaves as a black body. [2]

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6. (a) Quarks are elementary particles.

(i) State what is meant by an elementary particle. [1]

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(ii) List the fundamental forces that act on quarks. [1]

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(iii) The lambda baryon ( $\Lambda^0$ ) has quark content  $uds$ . It decays according to the reaction  $\Lambda^0 \rightarrow p + \pi^-$ . The quark content of the pion is  $\bar{u}d$ .

State and explain which fundamental interaction is responsible for this decay. [2]

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**(Question 6 continued)**

- (b) (i) By reference to the concept of binding energy, explain why the combined mass of the nucleons of a nucleus is greater than the mass of the nucleus. [2]

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- (ii) The following binding energies per nucleon are available:

Th: 7.645074 MeV  
Ra: 7.679917 MeV  
He: 7.073915 MeV

Determine the energy released in the decay  ${}_{90}^{228}\text{Th} \rightarrow {}_{88}^{224}\text{Ra} + {}_2^4\text{He}$ . [2]

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