Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

26 April 2024

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

Candidate session number

1 hour 15 minutes

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]**.

2224 – 6711

19 pages

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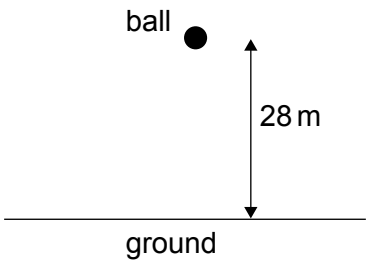
Answers written on this page
will not be marked.

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 m s^{-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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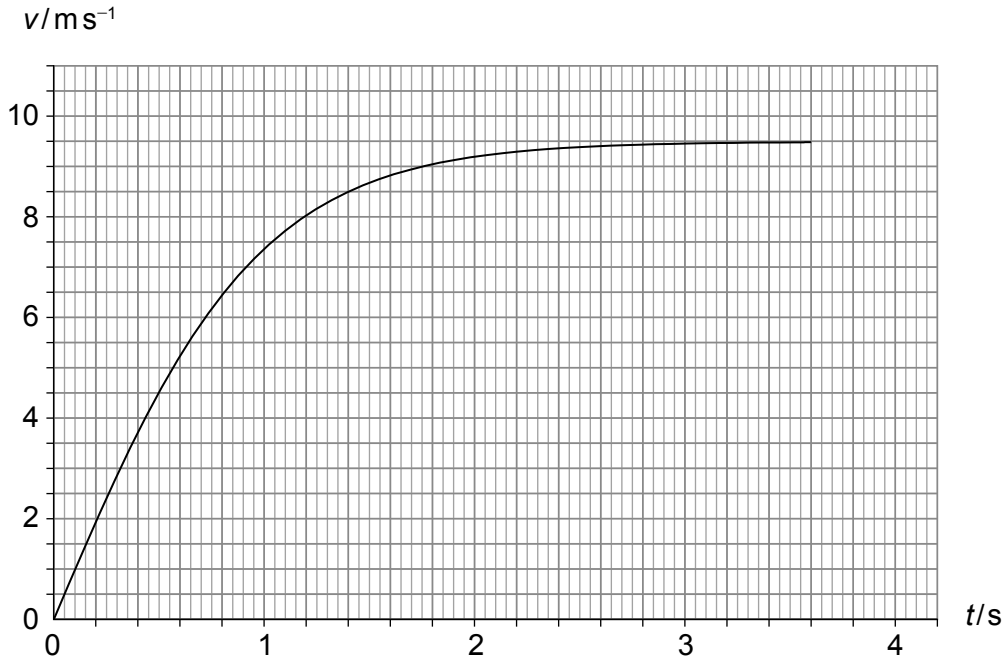
(Question 1 continued)

(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 $7.8\,m\,s^{-1}$. 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 N.

Determine T. [2]

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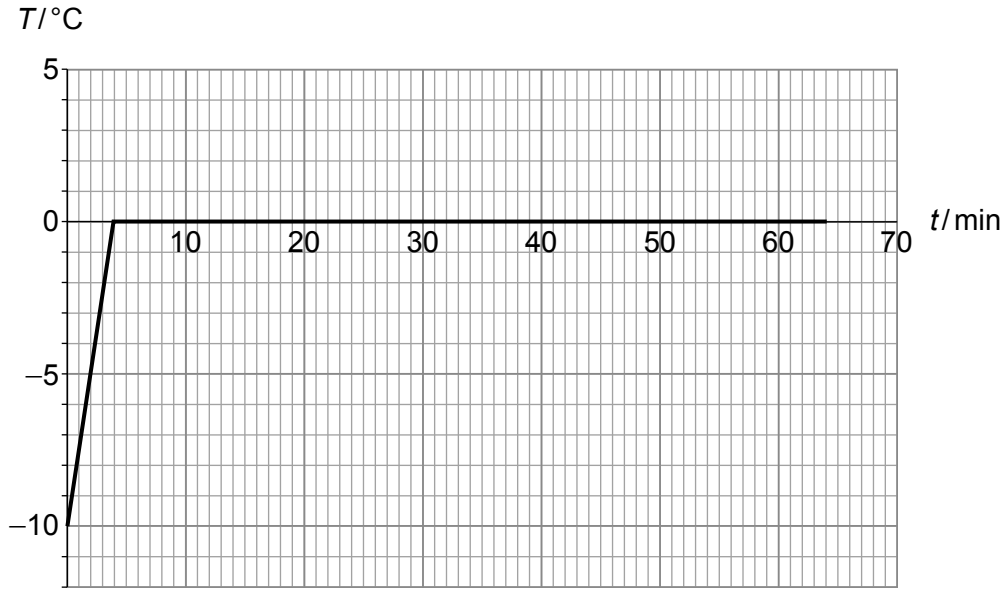
2. Crushed ice of mass 35 g at temperature −10 °C is placed in a warm room. The graph shows the variation of the temperature T of the ice with time t.



The specific heat capacity of ice is 2100 J kg^{-1} 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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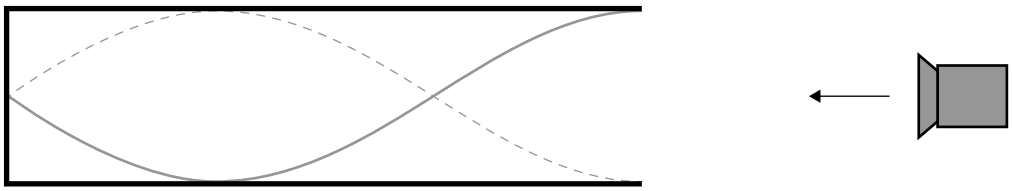
(b) A loudspeaker emits sound of frequency 210 Hz into a pipe with one open and one closed end. The diagram shows a representation of the standing wave established in the pipe.



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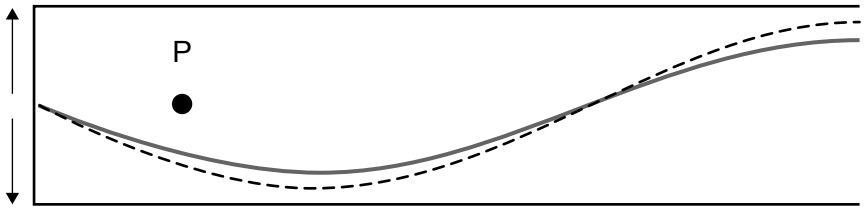
(c) The solid line represents the standing wave at time *t* and the dotted line represents the standing wave at an instant later. The dot is the **equilibrium** position of a particle P in the pipe. The up arrow indicates displacements to the right and the down arrow displacements to the left.



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]

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will not be marked.

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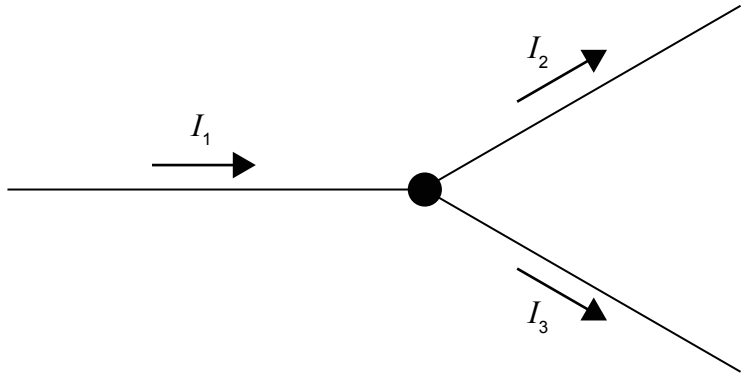
4. (a) The diagram shows a junction in a circuit.



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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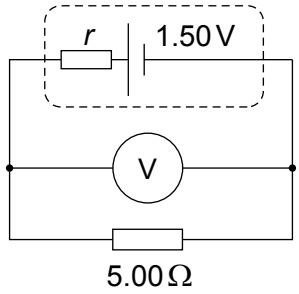
(b) A cell of emf 1.50 V and internal resistance *r* is connected to a resistor of resistance 5.00 Ω and an ideal voltmeter V.



The reading of the voltmeter is 1.20 V.

(i) Determine the internal resistance *r* of the cell. [2]

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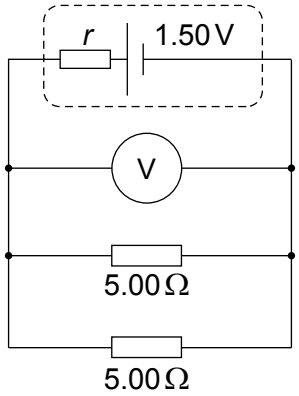
(Question 4 continued)

(ii) A second 5.00 Ω 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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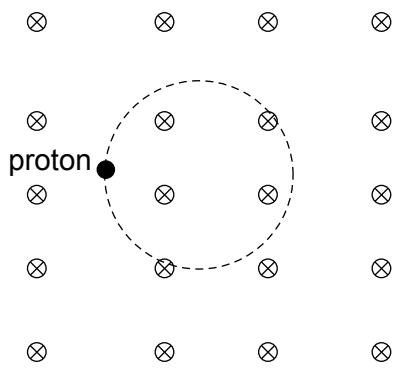
(Question 4 continued)

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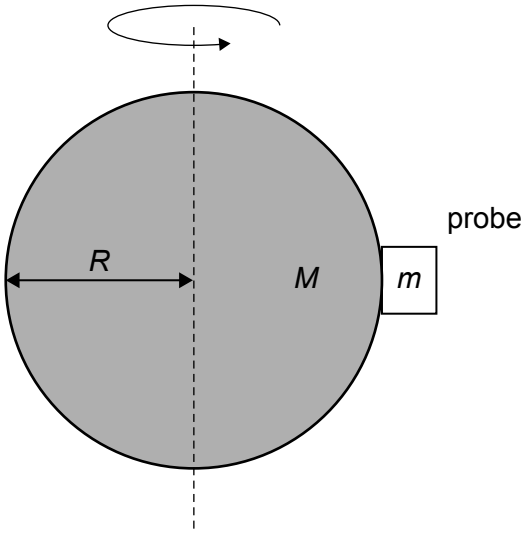
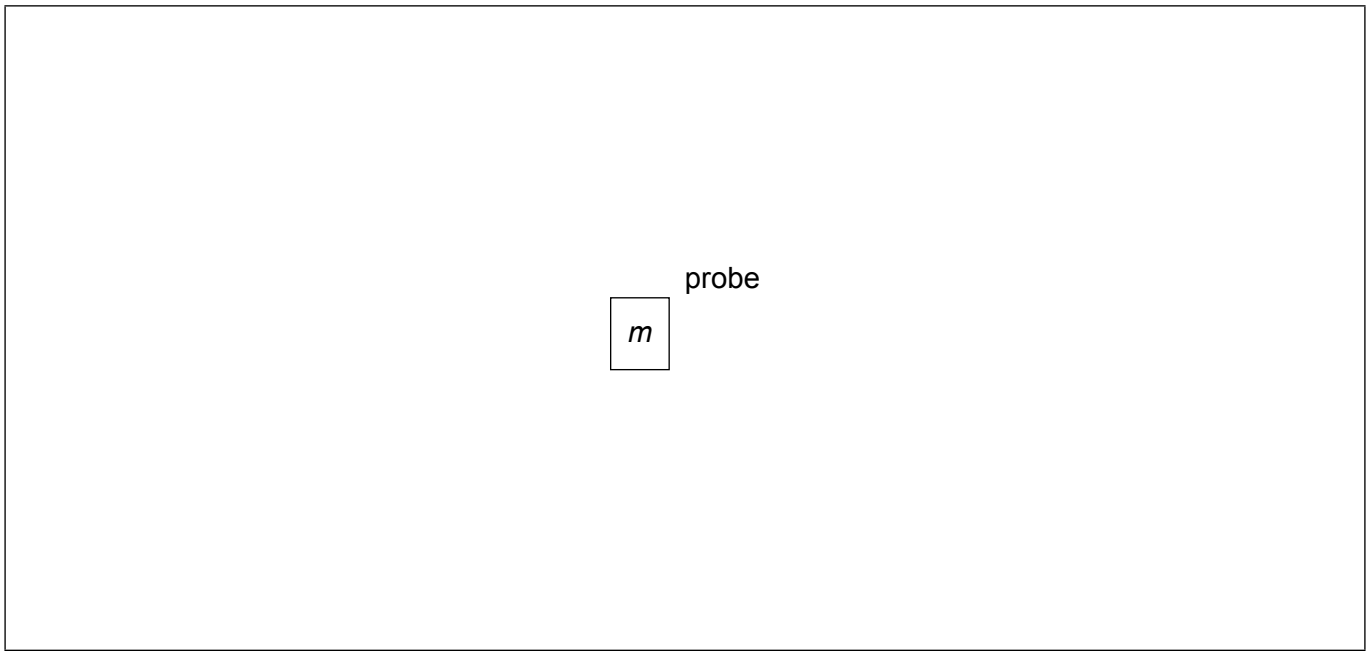
5. A probe of mass m has landed on the equator of a rotating asteroid of mass M and radius R.

diagram not to scale



The asteroid rotates with angular speed ω.

(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 $N = m(\frac{GM}{R^2} - \omega^2 R)$. [2]



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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 $85\,W\,m^{-2}$. [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 (Λ^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 ${}^{228}_{90}\mathrm{Th} \rightarrow {}^{224}_{88}\mathrm{Ra} + {}^{4}_{2}\mathrm{He}$. [2]

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