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

Friday 17 May 2019 (afternoon)

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]**.



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

1. A student strikes a tennis ball that is initially at rest so that it leaves the racquet at a speed of  $64 \text{ m s}^{-1}$ . The ball has a mass of  $0.058 \text{ kg}$  and the contact between the ball and the racquet lasts for  $25 \text{ ms}$ .

(a) Calculate the

(i) average force exerted by the racquet on the ball.

[2]

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(ii) average power delivered to the ball during the impact.

[2]

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- (b) The student strikes the tennis ball at point P. The tennis ball is initially directed at an angle of  $7.00^\circ$  to the horizontal.

diagram not to scale



The following data are available.

|                              |                         |
|------------------------------|-------------------------|
| Height of P                  | = $2.80 \text{ m}$      |
| Distance of student from net | = $11.9 \text{ m}$      |
| Height of net                | = $0.910 \text{ m}$     |
| Initial speed of tennis ball | = $64 \text{ m s}^{-1}$ |

(This question continues on the following page)



**(Question 1 continued)**

- (i) Calculate the time it takes the tennis ball to reach the net. [2]

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- (ii) Show that the tennis ball passes over the net. [3]

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- (iii) Determine the speed of the tennis ball as it strikes the ground. [2]

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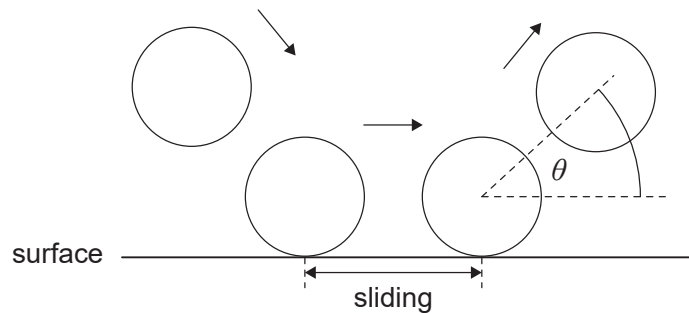
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**(This question continues on the following page)**

(Question 1 continued)

- (c) The student models the bounce of the tennis ball to predict the angle  $\theta$  at which the ball leaves a surface of clay and a surface of grass.



The model assumes

- during contact with the surface the ball slides.
- the sliding time is the same for both surfaces.
- the sliding frictional force is greater for clay than grass.
- the normal reaction force is the same for both surfaces.

Predict for the student's model, without calculation, whether  $\theta$  is greater for a clay surface or for a grass surface.

[3]

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2. A container of volume  $3.2 \times 10^{-6} \text{ m}^3$  is filled with helium gas at a pressure of  $5.1 \times 10^5 \text{ Pa}$  and temperature 320 K. Assume that this sample of helium gas behaves as an ideal gas.

- (a) The molar mass of helium is  $4.0 \text{ g mol}^{-1}$ . Show that the mass of a helium atom is  $6.6 \times 10^{-27} \text{ kg}$ .

[1]

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- (b) Estimate the average speed of the helium atoms in the container.

[2]

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- (c) Show that the number of helium atoms in the container is about  $4 \times 10^{20}$ .

[2]

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- (d) A helium atom has a volume of  $4.9 \times 10^{-31} \text{ m}^3$ .

- (i) Calculate the ratio  $\frac{\text{total volume of helium atoms}}{\text{volume of helium gas}}$ .

[1]

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- (ii) Explain, using your answer to (d)(i) and with reference to the kinetic model, why this sample of helium can be assumed to be an ideal gas.

[2]

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3. The diagram shows the direction of a sound wave travelling in a metal sheet.

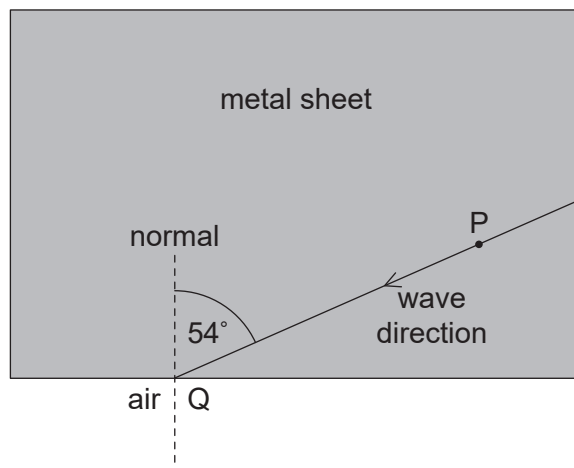


diagram not to scale

- (a) Particle P in the metal sheet performs simple harmonic oscillations. When the displacement of P is  $3.2\mu\text{m}$  the magnitude of its acceleration is  $7.9\text{ms}^{-2}$ . Calculate the magnitude of the acceleration of P when its displacement is  $2.3\mu\text{m}$ . [2]

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- (b) The wave is incident at point Q on the metal–air boundary. The wave makes an angle of  $54^\circ$  with the normal at Q. The speed of sound in the metal is  $6010\text{ms}^{-1}$  and the speed of sound in air is  $340\text{ms}^{-1}$ . Calculate the angle between the normal at Q and the direction of the wave in air. [2]

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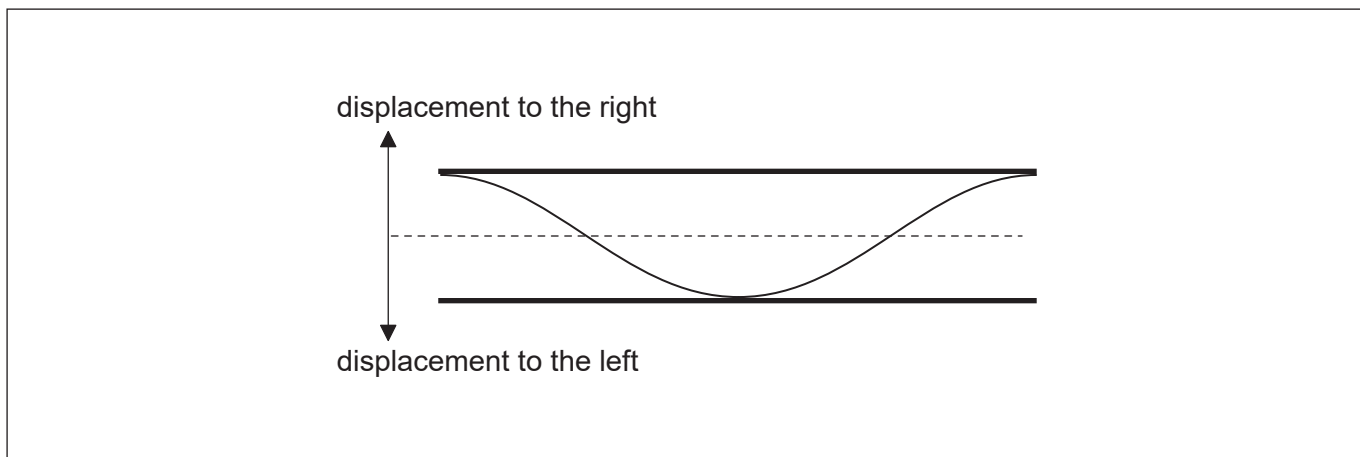
**(Question 3 continued)**

(c) The frequency of the sound wave in the metal is 250 Hz.

(i) State the frequency of the wave in air. [1]

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

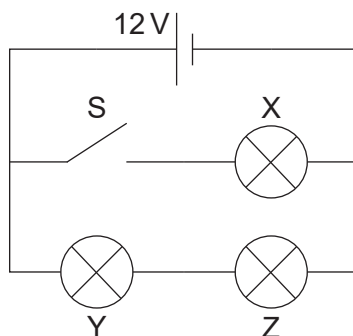
(d) The sound wave in air in (c) enters a pipe that is open at both ends. The diagram shows the displacement, at a particular time  $T$ , of the standing wave that is set up in the pipe.



On the diagram, at time  $T$ , label with the letter C a point in the pipe that is at the centre of a compression. [1]



4. Three identical light bulbs, X, Y and Z, each of resistance  $4.0\Omega$  are connected to a cell of emf 12V. The cell has negligible internal resistance.



- (a) The switch S is initially open. Calculate the total power dissipated in the circuit. [2]

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- (b) The switch is now closed.

- (i) State, without calculation, why the current in the cell will increase. [1]

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- (ii) Deduce the ratio  $\frac{\text{power dissipated in Y with S open}}{\text{power dissipated in Y with S closed}}$ . [2]

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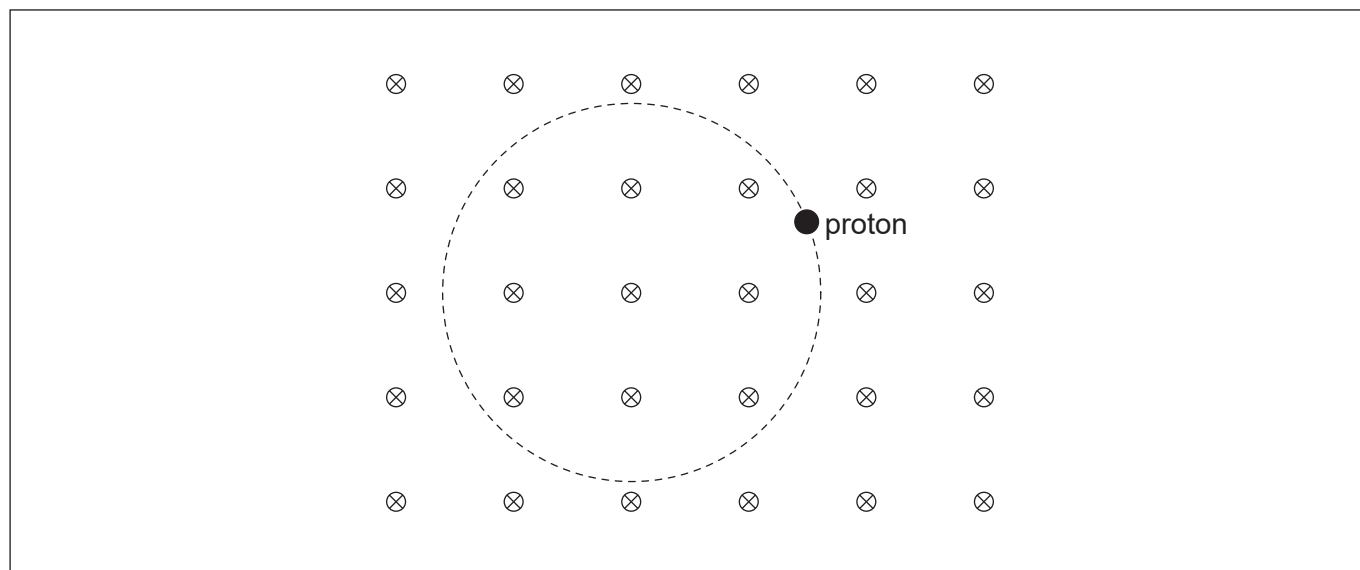
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5. A proton moves along a circular path in a region of a uniform magnetic field. The magnetic field is directed into the plane of the page.



- (a) Label with arrows on the diagram the
- magnetic force  $F$  on the proton. [1]
  - velocity vector  $v$  of the proton. [1]
- (b) The speed of the proton is  $2.16 \times 10^6 \text{ m s}^{-1}$  and the magnetic field strength is  $0.042 \text{ T}$ . For this proton, determine, in  $\text{m}$ , the radius of the circular path. Give your answer to an appropriate number of significant figures. [3]

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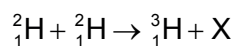
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6. Deuterium,  ${}^2_1\text{H}$ , undergoes fusion according to the following reaction.



- (a) Identify particle X.

[1]

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- (b) The following data are available for binding energies per nucleon.

$${}^2_1\text{H} = 1.12\text{MeV}$$

$${}^3_1\text{H} = 2.78\text{MeV}$$

- (i) Determine, in MeV, the energy released.

[2]

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- (ii) Suggest why, for the fusion reaction above to take place, the temperature of deuterium must be very high.

[2]

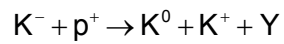
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**(Question 6 continued)**

- (c) Particle Y is produced in the collision of a proton with a  $K^-$  in the following reaction.



The quark content of some of the particles involved are

$$K^- = \bar{u}s \quad K^0 = d\bar{s}$$

Identify, for particle Y, the

- (i) charge.

[1]

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- (ii) strangeness.

[1]

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7. The average temperature of ocean surface water is 289K. Oceans behave as black bodies.

(a) Show that the intensity radiated by the oceans is about  $400 \text{ W m}^{-2}$ . [1]

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(b) Explain why some of this radiation is returned to the oceans from the atmosphere. [3]

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