Diploma Programme
Programme du diplôme
Programa del Diploma

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Physics
Standard level
Paper 2

Monday 3 May 2021 (afternoon)

Candidate session number

1 hour 15 minutes

Instructions to candidates

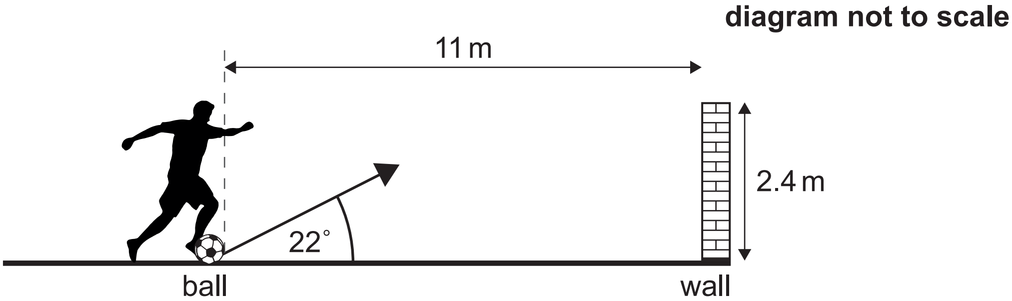
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

2221 – 6517

13 pages

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

1. A football player kicks a stationary ball of mass 0.45 kg towards a wall. The initial speed of the ball after the kick is 19 m s^{-1} and the ball does not rotate. Air resistance is negligible and there is no wind.



(a) The player's foot is in contact with the ball for 55 ms. Calculate the average force that acts on the ball due to the football player. [2]

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(b) (i) The ball leaves the ground at an angle of 22°. The horizontal distance from the initial position of the edge of the ball to the wall is 11 m. Calculate the time taken for the ball to reach the wall. [2]

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(Question 1 continued)

(ii) The top of the wall is 2.4 m above the ground. Deduce whether the ball will hit the wall. [3]

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(c) In practice, air resistance affects the ball. Outline the effect that air resistance has on the vertical acceleration of the ball. Take the direction of the acceleration due to gravity to be positive. [2]

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(d) The player kicks the ball again. It rolls along the ground without sliding with a horizontal velocity of 1.40 m s^{-1}. The radius of the ball is 0.11 m. Calculate the angular velocity of the ball. State an appropriate SI unit for your answer. [1]

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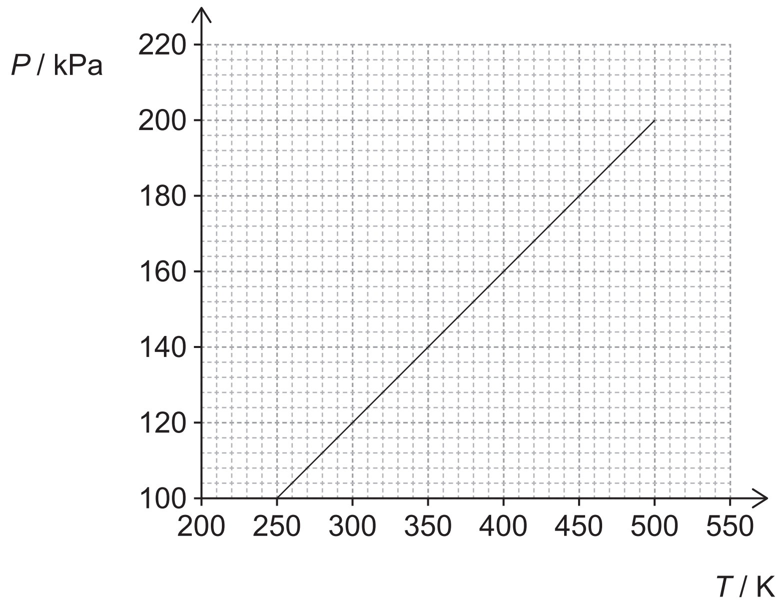
2. The graph shows the variation with temperature T of the pressure P of a fixed mass of helium gas trapped in a container with a fixed volume of $1.0 \times 10^{-3}\,m^3$.



(a) Deduce whether helium behaves as an ideal gas over the temperature range 250 K to 500 K. [2]

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(b) Helium has a molar mass of 4.0 g. Calculate the mass of gas in the container. [2]

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(Question 2 continued)

(c) A second container, of the same volume as the original container, contains twice as many helium atoms. The graph of the variation of *P* with *T* is determined for the gas in the second container.

Predict how the graph for the second container will differ from the graph for the first container. [2]

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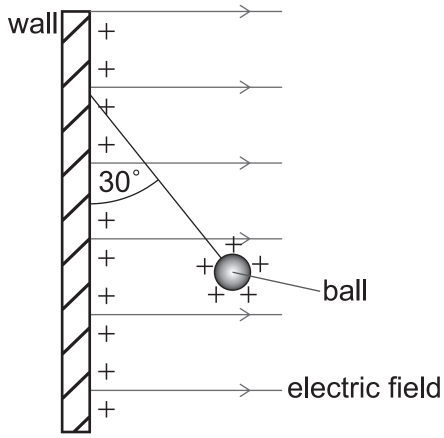
3. A vertical wall carries a uniform positive charge on its surface. This produces a uniform horizontal electric field perpendicular to the wall. A small, positively-charged ball is suspended in equilibrium from the vertical wall by a thread of negligible mass.



(a) The charge per unit area on the surface of the wall is σ. It can be shown that the electric field strength E due to the charge on the wall is given by the equation

$$E = \frac{\sigma}{2\varepsilon_0}.$$

Demonstrate that the units of the quantities in this equation are consistent. [2]

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(b) (i) The thread makes an angle of 30° with the vertical wall. The ball has a mass of 0.025 kg.

Determine the horizontal force that acts on the ball. [3]

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(Question 3 continued)

(ii) The charge on the ball is 1.2×10^{-6} C. Determine σ. [2]

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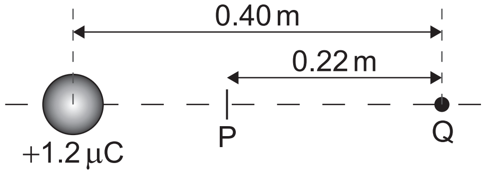
(c) The centre of the ball, still carrying a charge of 1.2×10^{-6} C, is now placed 0.40 m from a point charge Q. The charge on the ball acts as a point charge at the centre of the ball.

P is the point on the line joining the charges where the electric field strength is zero. The distance PQ is 0.22 m.



Calculate the charge on Q. State your answer to an appropriate number of significant figures. [3]

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4. (a) During electron capture, an atomic electron is captured by a proton in the nucleus. The stable nuclide thallium-205 (${}^{205}_{81}\text{Tl}$) can be formed when an unstable lead (Pb) nuclide captures an electron.

Write down the equation to represent this decay. [2]

$${}^{\square}_{\square}\text{Pb} + {}^{\square}_{\square}\text{e} \longrightarrow {}^{205}_{81}\text{Tl} + {}^{\square}_{\square}\upsilon_e$$

(b) The neutron number *N* and the proton number *Z* are not equal for the nuclide ${}^{205}_{81}\text{Tl}$. Explain, with reference to the forces acting within the nucleus, the reason for this. [2]

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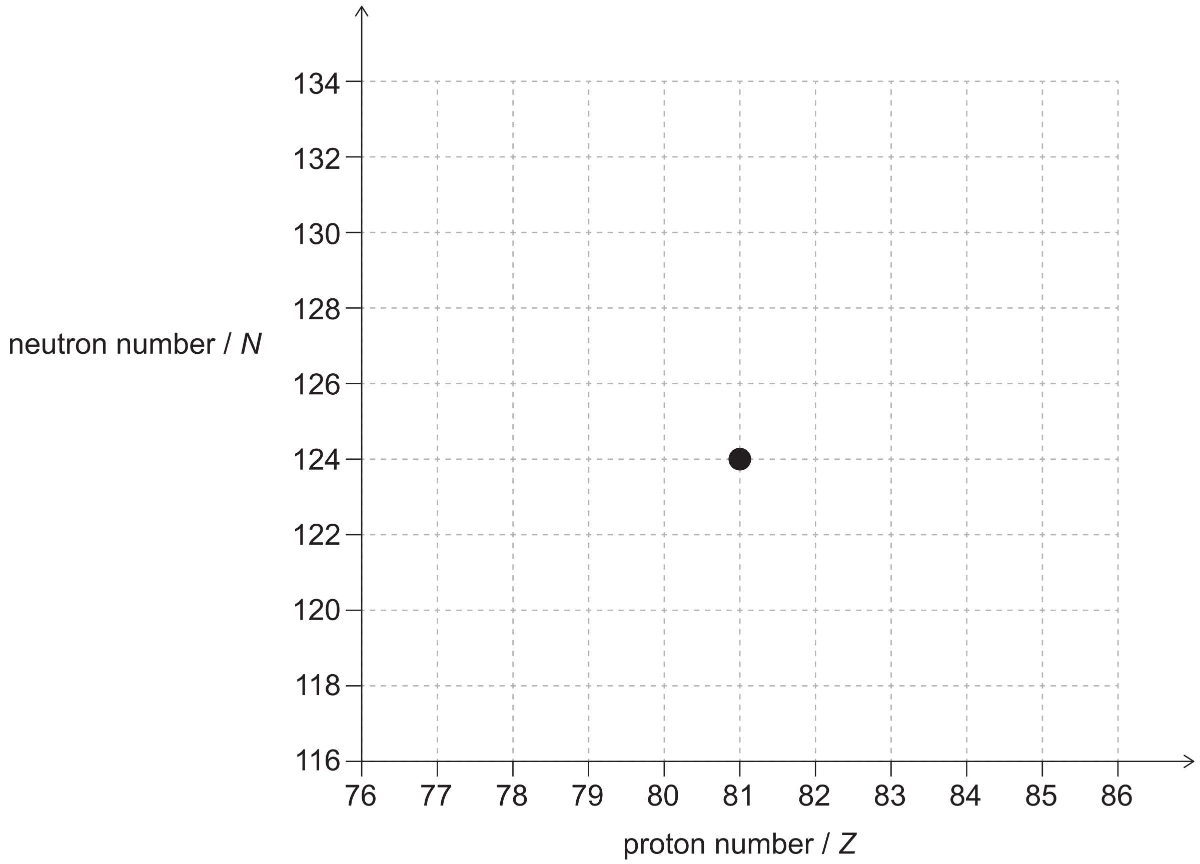
(Question 4 continued)

(c) Thallium-205 ($^{205}_{81}Tl$) can also form from successive alpha (α) and beta-minus (β^-) decays of an unstable nuclide. The decays follow the sequence $\alpha\ \beta^-\ \beta^-\ \alpha$. The diagram shows the position of $^{205}_{81}Tl$ on a chart of neutron number against proton number.



Draw **four** arrows to show the sequence of changes to *N* and *Z* that occur as the $^{205}_{81}Tl$ forms from the unstable nuclide. [3]

5. (a) Describe **two** ways in which standing waves differ from travelling waves. [2]

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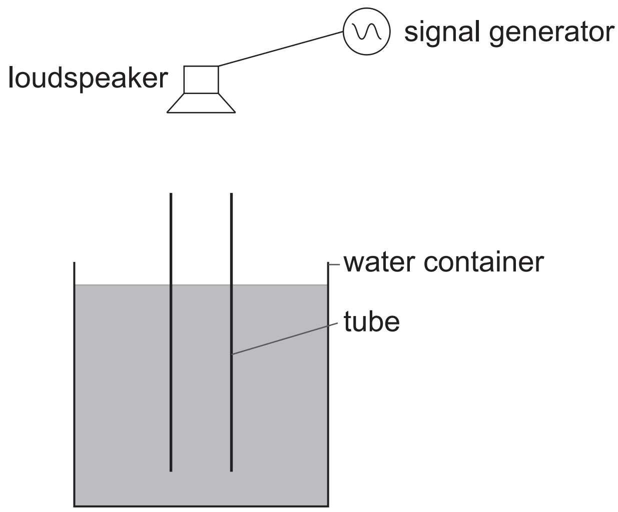
(b) A vertical tube, open at both ends, is completely immersed in a container of water. A loudspeaker above the container connected to a signal generator emits sound. As the tube is raised the loudness of the sound heard reaches a maximum because a standing wave has formed in the tube.



(i) Outline how a standing wave forms in the tube. [2]

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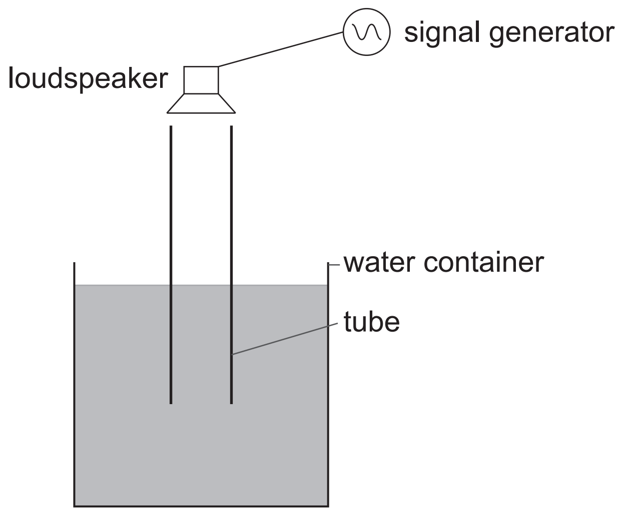
(Question 5 continued)

(ii) The tube is raised until the loudness of the sound reaches a maximum for a **second time**.

Draw, on the following diagram, the position of the nodes in the tube when the second maximum is heard. [1]



(iii) Between the first and second positions of maximum loudness, the tube is raised through 0.37 m. The speed of sound in the air in the tube is $320\,m\,s^{-1}$. Determine the frequency of the sound emitted by the loudspeaker. [2]

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6. A photovoltaic cell is supplying energy to an external circuit. The photovoltaic cell can be modelled as a practical electrical cell with internal resistance.

The intensity of solar radiation incident on the photovoltaic cell at a particular time is at a maximum for the place where the cell is positioned.

The following data are available for this particular time:

Operating current = 0.90 A
Output potential difference to external circuit = 14.5 V
Output emf of photovoltaic cell = 21.0 V
Area of panel = 350 mm × 450 mm

(a) Explain why the output potential difference to the external circuit and the output emf of the photovoltaic cell are different. [2]

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(b) Calculate the internal resistance of the photovoltaic cell for the maximum intensity condition using the model for the cell. [3]

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(Question 6 continued)

(c) The maximum intensity of sunlight incident on the photovoltaic cell at the place on the Earth's surface is 680 W m^{-2}.

A measure of the efficiency of a photovoltaic cell is the ratio

$$\frac{\text{energy available every second to the external circuit}}{\text{energy arriving every second at the photovoltaic cell surface}}.$$

Determine the efficiency of this photovoltaic cell when the intensity incident upon it is at a maximum. [3]

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(d) State **two** reasons why future energy demands will be increasingly reliant on sources such as photovoltaic cells. [2]

Reason 1: . . . .

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Reason 2: . . . .

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References:

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