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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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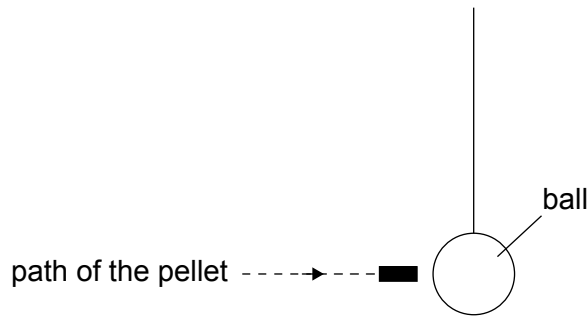
**Instructions to candidates**

- 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]**.



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

1. A stationary ball is hanging from a light string. A pellet from an air rifle is travelling horizontally and becomes embedded in the ball. The velocity of the pellet when it strikes the ball is  $160 \text{ ms}^{-1}$ .



The following data are given.

Mass of the ball = 250 g

Mass of the pellet = 2.0 g

- (a) Calculate the speed of the ball and the pellet immediately after the impact. [2]

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- (b) Suggest why the combined kinetic energy of the ball and the pellet after the impact is less than the initial kinetic energy of the pellet. [2]

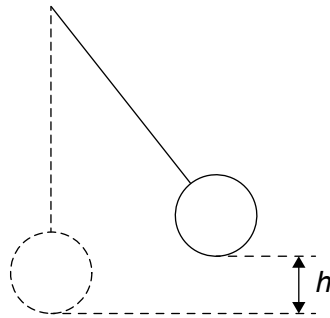
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**(Question 1 continued)**

The ball with the embedded pellet rises to a maximum vertical height  $h$ .



(c) Draw and label the free-body diagram for the ball at height  $h$ .

[2]

A rectangular box containing a free-body diagram. A solid black dot represents the ball and pellet. A dashed line extends from the dot upwards and to the left, labeled "string direction".



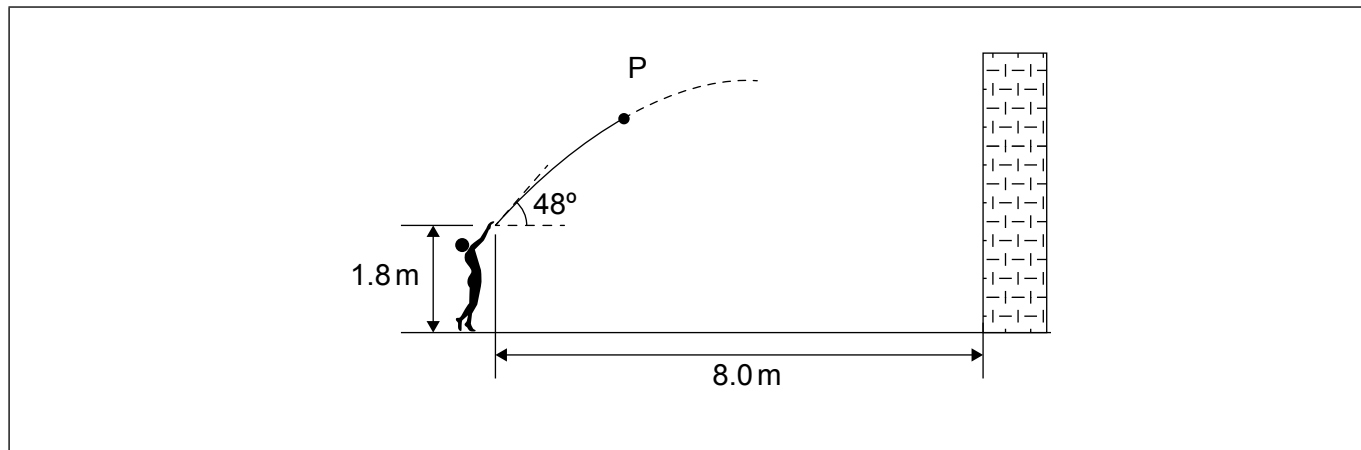
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2. A student throws a ball towards a wall. The ball is released from a point 1.8 m above the ground and 8.0 m from the wall. The initial velocity of the ball makes an angle of  $48^\circ$  with the horizontal. Air resistance is negligible.

The diagram shows the initial path of the ball. P is a point on the path.



- (a) Draw, on the diagram, an arrow to show
- (i) the velocity of the ball at P. Label this arrow  $v$ . [1]
  - (ii) the acceleration of the ball at P. Label this arrow  $a$ . [1]

The ball takes 1.3 s to reach the wall. The initial speed of the ball is  $9.2 \text{ m s}^{-1}$ .

- (b) Determine the height above the ground at which the ball hits the wall. [3]

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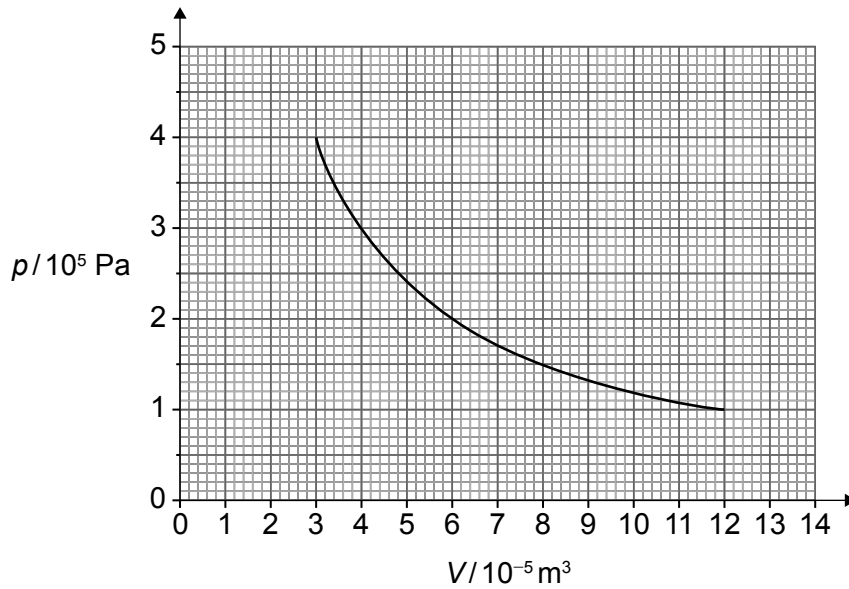
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3. A fixed quantity of  $4.5 \times 10^{-3}$  mol of air is compressed at a constant temperature. The graph shows the variation of pressure  $p$  with volume  $V$  of the air.



- (a) Suggest whether the air behaves as an ideal gas during this change. [2]

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- (b) Calculate the temperature of the air. [2]

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**(Question 3 continued)**

- (c) Outline how the kinetic theory of gases relates observable properties of a gas to the motion of the molecules.

[2]

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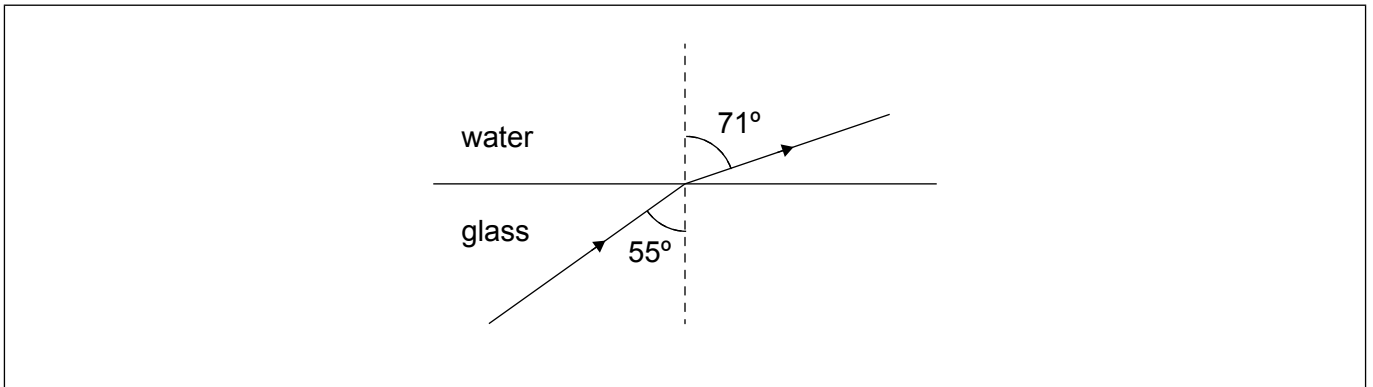
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4. A solid block of glass is covered with water. The diagram shows the path of a monochromatic light ray entering the water from the glass block.



The speed of light in the glass is  $2.0 \times 10^8 \text{ ms}^{-1}$ .

- (a) Calculate the speed of light in the water. State the answer to an appropriate number of significant figures. [3]

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- (b) Explain the change in the wavelength of the light at the glass–water boundary. [2]

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**(Question 4 continued)**

The light ray is partly reflected from the glass–water boundary.

- (c) Draw, on the diagram, the path of the reflected ray. [1]

The water is removed and replaced with air. The refractive index of air is 1.0. The direction of the incident light ray in the glass is unchanged.

- (d) Determine whether light emerges from the glass block into the air. [3]

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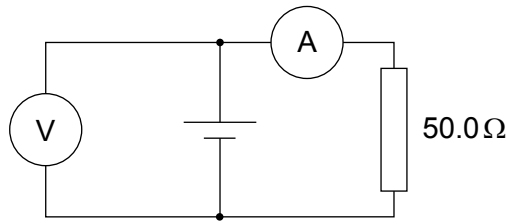
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5. A  $50.0\ \Omega$  resistor is connected to a cell of emf  $3.00\ \text{V}$ . The voltmeter and the ammeter in the circuit are ideal.



- (a) The current in the ammeter is  $59.0\ \text{mA}$ .

Calculate the internal resistance of the cell.

[2]

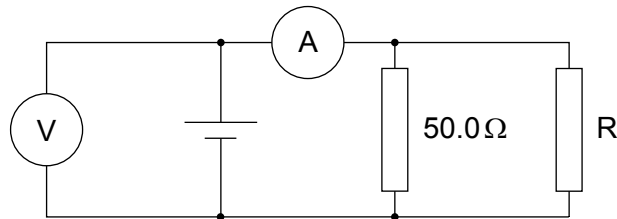
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The circuit is changed by connecting another resistor  $R$  in parallel to the  $50.0\ \Omega$  resistor.



- (b) Explain the effect of this change on

(i) the reading of the ammeter.

[2]

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**(Question 5 continued)**

(ii) the reading of the voltmeter.

[2]

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R is made of a resistive wire of uniform cross-sectional area  $3.1 \times 10^{-8} \text{ m}^2$ , resistivity  $4.9 \times 10^{-7} \Omega \text{ m}$  and length  $L$ . The resistance of R is given by the equation

$$R = kL$$

where  $k$  is a constant.

(c) Calculate  $k$ . State an appropriate unit for your answer.

[3]

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6. (a) State what is meant by the half-life of a radioactive nuclide. [1]

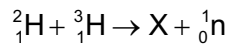
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Tritium,  ${}^3_1\text{H}$ , is a radioactive isotope of hydrogen. The activity of a sample of tritium decreases to  $\frac{A_0}{8}$  after a time of 37.0 years where  $A_0$  is the initial activity.

- (b) Calculate the half-life of tritium. [2]

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Deuterium,  ${}^2_1\text{H}$ , and tritium undergo nuclear fusion according to:



- (c) Identify nuclide X. [1]

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**(Question 6 continued)**

The following data are given for binding energies per nucleon.

Nuclide	Binding energy per nucleon/MeV
${}^2_1\text{H}$	1.112
${}^3_1\text{H}$	2.827
X	7.074

(d) (i) Show that the energy released in this reaction is about 18 MeV. [2]

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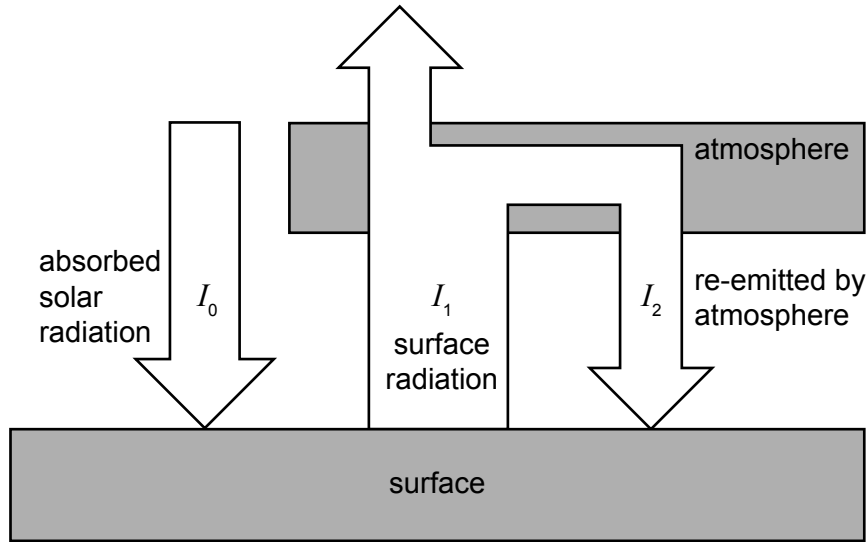
(ii) Outline why mass is not conserved in this reaction. [1]

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7. In a simplified model of energy balance of the Earth:

- the surface of the Earth absorbs incoming solar radiation of average global intensity  $I_0$
- the surface emits thermal radiation of average intensity  $I_1$
- some of the radiation emitted by the surface is absorbed by the atmosphere and re-emitted towards the surface. The average intensity of this radiation is  $I_2$ .



(a) Explain the effect of an increase in the concentration of greenhouse gases in the atmosphere on  $I_2$ .

[2]

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The following data are given.

$$I_0 = 240 \text{ W m}^{-2}$$
$$I_2 = 150 \text{ W m}^{-2}$$

(b) Determine the average temperature of the surface of the Earth according to this model.

[2]

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8. A satellite orbits the Earth in a circular orbit of radius  $1.0 \times 10^7$  m. At the orbital radius of the satellite, the gravitational field strength due to the Earth is  $4.0 \text{ ms}^{-2}$ .

(a) Show that the orbital speed of the satellite is about  $6 \times 10^3 \text{ ms}^{-1}$ . [2]

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(b) Calculate the orbital period of the satellite. [2]

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