Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

3 May 2023

Zone A morning | **Zone B** afternoon | **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]**.

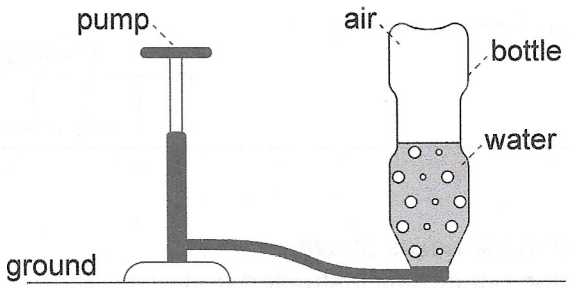
2223–6517

12 pages

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

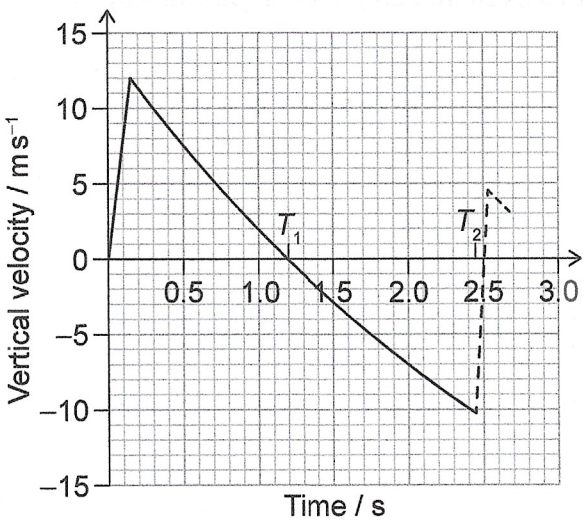
1. A toy rocket is made from a plastic bottle that contains some water.

Air is pumped into the vertical bottle until the pressure inside forces water and air out of the bottle. The bottle then travels vertically upwards.



The air–water mixture is called the propellant.

The variation with time of the vertical velocity of the bottle is shown.



The bottle reaches its highest point at time T_1 on the graph and returns to the ground at time T_2. The bottle then bounces. The motion of the bottle after the bounce is shown as a dashed line.

(a) Estimate, using the graph, the maximum height of the bottle. [3]

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(This question continues on the following page)

(Question 1 continued)

(b) Estimate the acceleration of the bottle when it is at its maximum height. [2]

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(c) The bottle bounces when it returns to the ground.

(i) Calculate the fraction of the kinetic energy of the bottle that remains after the bounce. [2]

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(ii) The mass of the bottle is 27 g and it is in contact with the ground for 85 ms.

Determine the average force exerted by the ground on the bottle. Give your answer to an appropriate number of significant figures. [3]

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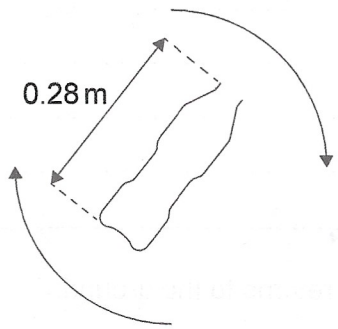
(Question 1 continued)

(d) After a second bounce, the bottle rotates about its centre of mass. The bottle rotates at 0.35 revolutions per second.



The centre of mass of the bottle is halfway between the base and the top of the bottle. Assume that the velocity of the centre of mass is zero.

Calculate the linear speed of the top of the bottle. [3]

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(e) The maximum height reached by the bottle is greater with an air–water mixture than with only high-pressure air in the bottle.

Assume that the speed at which the propellant leaves the bottle is the same in both cases.

Explain why the bottle reaches a greater maximum height with an air–water mixture. [2]

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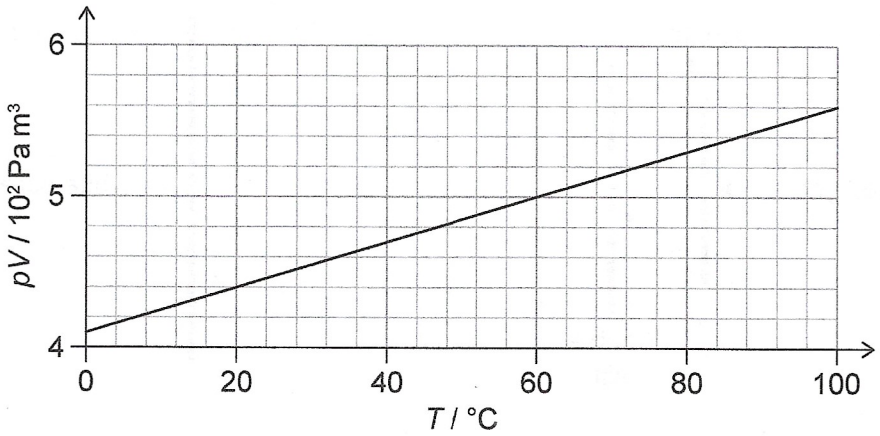
2. Pressure p, volume V and temperature T are measured for a fixed mass of gas. T is measured in degrees Celsius.

The graph shows the variation of pV with T.

The mass of a molecule of the gas is 4.7×10^{-26} kg.



(a) State the unit for pV in fundamental SI units. [1]

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(b) Deduce, using the graph, whether the gas acts as an ideal gas. [3]

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(c) Calculate, in g, the mass of the gas. [3]

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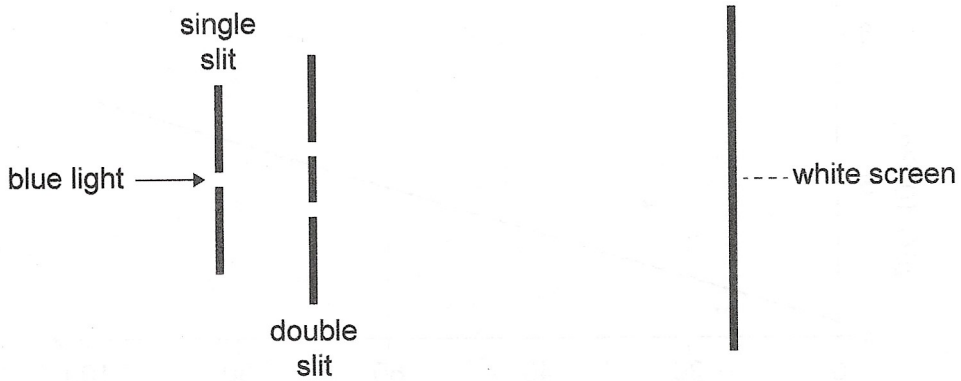
3. Blue light of wavelength λ is incident on a double slit. Light from the double slit falls on a screen. A student measures the distance between nine successive fringes on the screen to be 15 cm.

The separation of the double slit is 60 μm; the double slit is 2.5 m from the screen.



(a) Explain the pattern seen on the screen. [3]

(b) Calculate, in nm, λ. [3]

(This question continues on the following page)

(Question 3 continued)

(c) The student changes the light source to one that emits two colours:
- blue light of wavelength λ, and
- red light of wavelength 1.5λ.

Predict the pattern that the student will see on the screen. [3]

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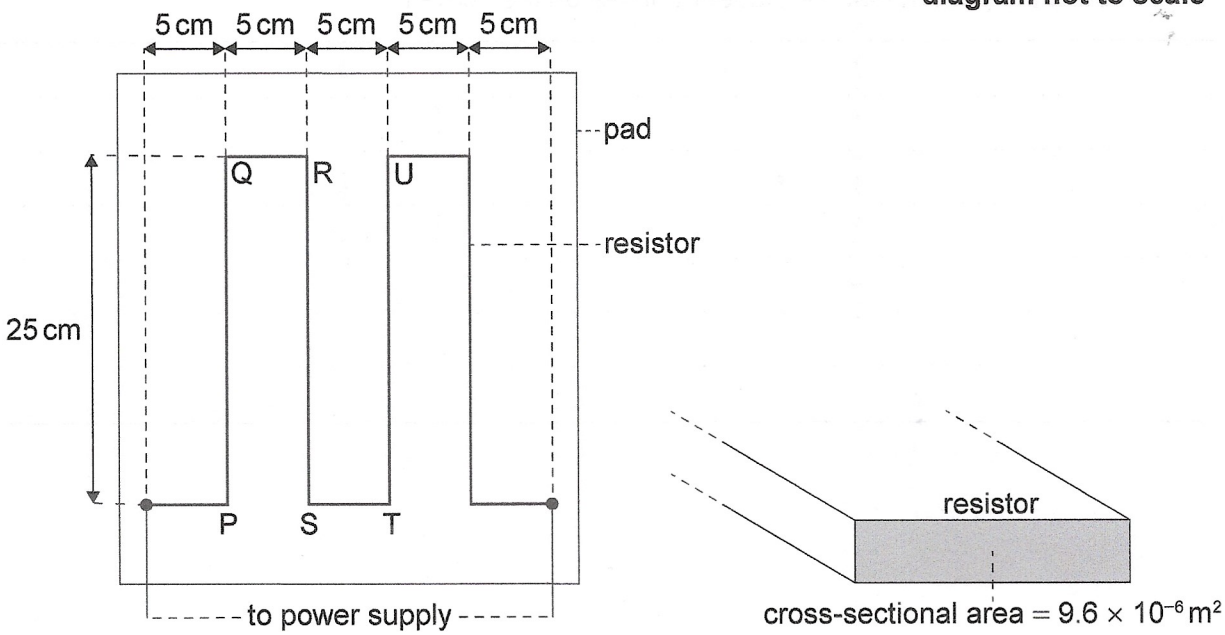
4. An electrically heated pad is designed to keep a pet warm.

The pad is heated using a resistor that is placed inside the pad. The dimensions of the resistor are shown on the diagram. The resistor has a resistance of 4.2 Ω and a total length of 1.25 m.

diagram not to scale



When there is a current in the resistor, the temperature in the pad changes from a room temperature of 20 °C to its operating temperature at 35 °C.

(a) The designers state that the energy transferred by the resistor every second is 15 J.

Calculate the current in the resistor. [1]

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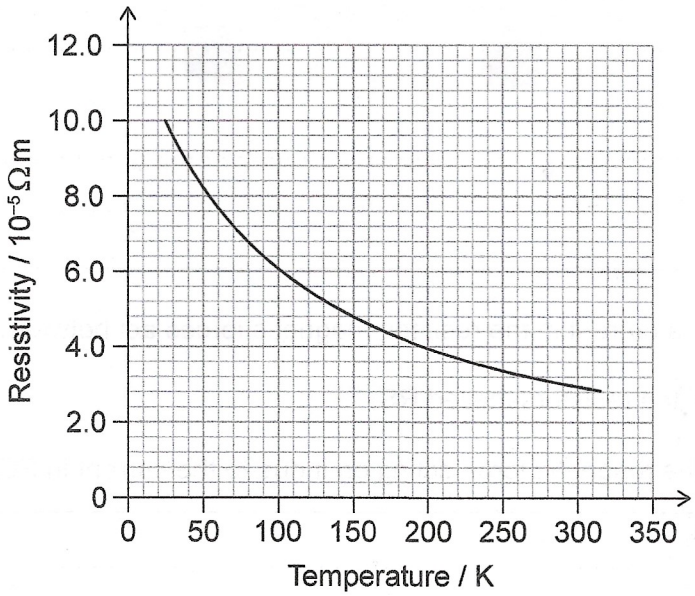
(Question 4 continued)

(b) The designers wish to make the resistor from carbon fibre.

The graph shows the variation with temperature, in Kelvin, of the resistivity of carbon fibre.



(i) The resistor has a cross-sectional area of $9.6 \times 10^{-6}\,m^2$.

Show that a resistor made from carbon fibre will be suitable for the pad. [3]

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(Question 4 continued)

(ii) The power supply to the pad has a negligible internal resistance.

State and explain the variation in current in the resistor as the temperature of the pad increases. [2]

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(c) When there is a current in the resistor, magnetic forces act between the resistor strips.

For the part of the resistor labelled RS,

(i) outline the magnetic force acting on it due to the current in PQ. [1]

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(ii) state and explain the net magnetic force acting on it due to the currents in PQ and TU. [2]

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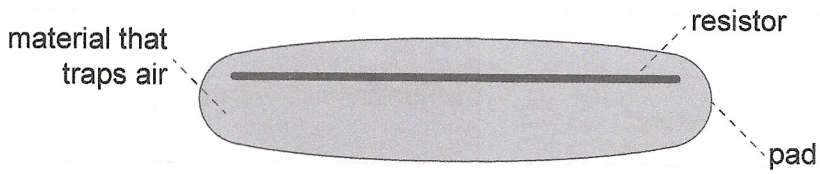
(Question 4 continued)

(d) The design of the pad encloses the resistor in a material that traps air. The design also places the resistor close to the top surface of the pad.



Explain, with reference to thermal energy transfer, why the pad is designed in this way. [3]

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5. The magnesium nuclide $^{27}_{12}Mg$ decays by beta-minus (β^-) decay to form a nuclide of aluminium (Al).

(a) Write down the equation for this decay. [2]

$^{27}_{12}Mg \rightarrow$

(b) Describe this decay in terms of the hadrons and quarks involved. [2]

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(c) The aluminium nuclide is stable.

State and explain the properties of the strong nuclear force and of the electromagnetic force that allow stable nuclei to exist. [3]

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