INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

M01/430/S(2)

PHYSICS
STANDARD LEVEL
PAPER 2

Tuesday 15 May 2001 (afternoon)

1 hour

Name

Number

INSTRUCTIONS TO CANDIDATES

- Write your candidate name and number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: Answer all of Section A in the spaces provided.
- Section B: Answer one question from Section B in the spaces provided.
- At the end of the examination, indicate the number of the Section B question answered in the box below.

QUESTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
SECTION A	ALL	/25	/25	/25
SECTION B	. . . .	/25	/25	/25
		TOTAL /50	TOTAL /50	TOTAL /50

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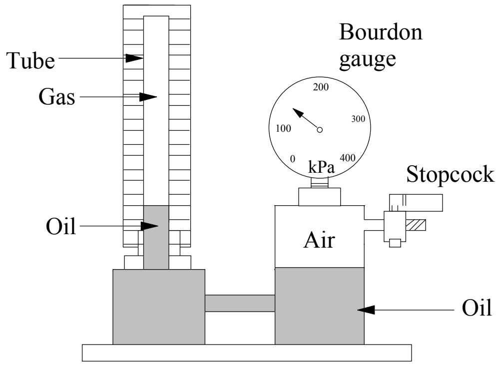
SECTION A

*Candidates must answer **all** questions in the spaces provided.*

A1. Gas law experiment (data based question)

Boyle's law states that for an ideal gas at constant temperature, pressure is inversely proportional to volume. To test whether or not a real gas obeys Boyle's law, three students set up the apparatus shown below.



The gas sample is enclosed in the tube and the length of the gas column can be measured against the scale. The gas pressure in the apparatus can be adjusted by pumping air in or out through the stopcock. The Bourdon gauge indicates 'gauge pressure', *i.e.* the difference in pressure inside and outside the gauge.

(a) After each gas adjustment the students wait a few minutes before reading the column length and the Bourdon gauge. Explain why they should not take the readings immediately and what occurs during waiting. *[2]*

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(b) Boyle's law involves the volume V of the gas, yet the students instead measure the length L of the gas column. Why is this acceptable? *[1]*

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(c) Show algebraically that if Boyle's law holds, a plot of gas pressure P versus the reciprocal of the column length L (*i.e.* P versus $\frac{1}{L}$) should be of straight line form through the origin. *[2]*

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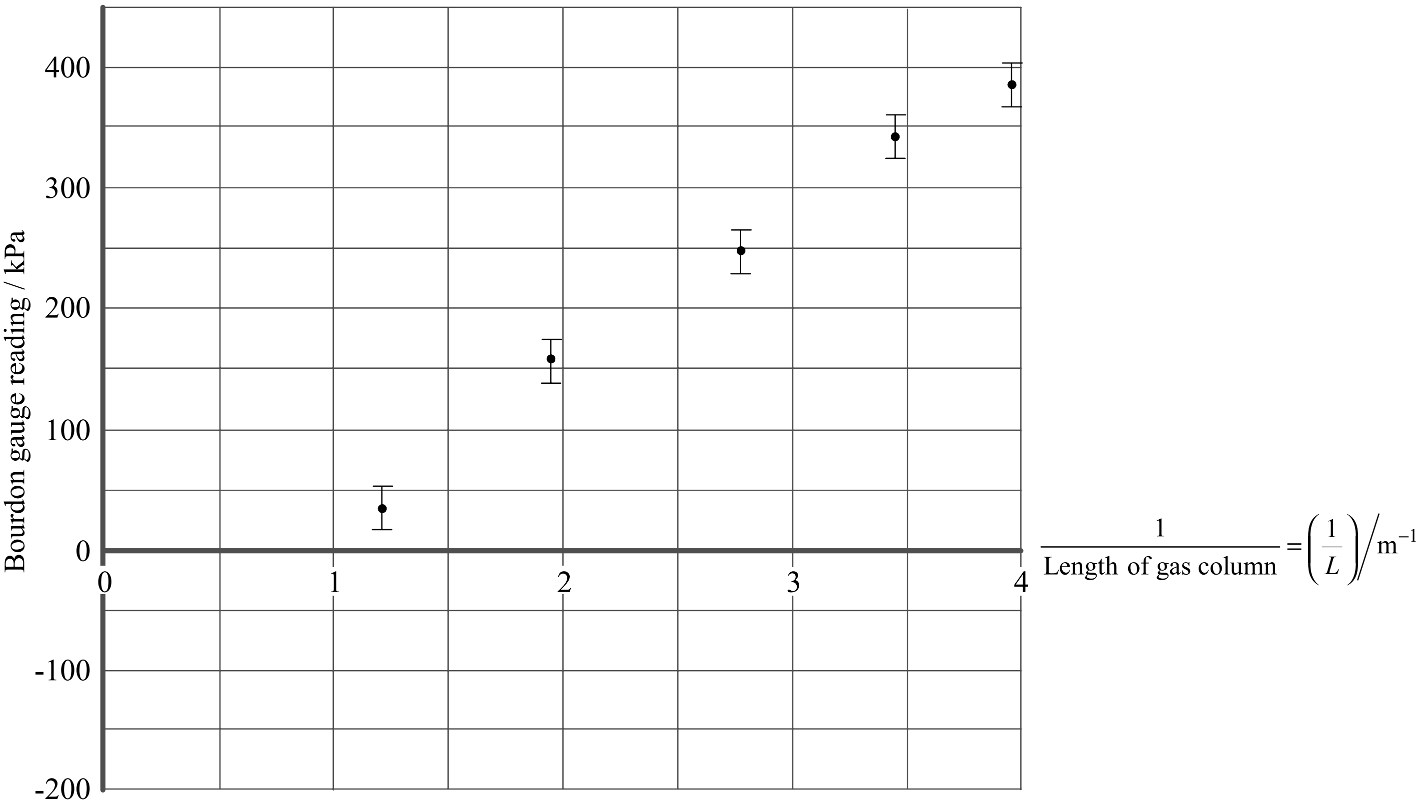
(Question A1 continued)

The students plot the pressure reading P_B on the Bourdon gauge versus $\frac{1}{L}$, as shown below. The error bars indicate the uncertainty in pressure values.



(d) Draw a best-fit straight line for the data points. *[1]*

(e) Determine the intercept value on the Bourdon pressure axis. *[1]*

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(Question A1 continued)

(f) The students note that their graph does not seem to go through the origin (0,0). They each suggest different interpretations of the results of this experiment, as follows:

Student 1 concludes that since the graph does not go through the origin, this gas deviates from Boyle's law behaviour.

Student 2 points out that there are random uncertainties in the data. He suggests that within experimental uncertainty the data may reasonably be fitted by a line drawn through the origin. He concludes that the data shows that the gas obeys Boyle's law within experimental uncertainty.

Student 3 says there could be a systematic error somewhere in the readings or the analysis.

(i) Discuss the reasoning of student 2 in light of the data. *[3]*

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(ii) Suggest the most likely origin of any systematic error suggested by student 3. Explain this with reference to the particular numerical value found in question (e) of the pressure intercept of the graph. *[2]*

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(iii) If specific adjustment is made for such systematic error, are the data consistent with Boyle's law? Explain. *[2]*

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(iv) Which student's interpretation is best, and does the gas obey Boyle's law? *[1]*

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A2. Arriving at the ground floor

Figure 1 shows a 60 kg physics teacher standing on a scale in a lift (elevator) demonstrating dynamics principles to students.

Initially the lift is moving steadily downwards at a speed of 3 m s^{-1}. As the lift approaches the ground floor it slows uniformly, taking 2 seconds to come to rest.

The scale is calibrated in newtons, and you may take gravitational field strength as 10 N kg^{-1} = 10 m s^{-2}.

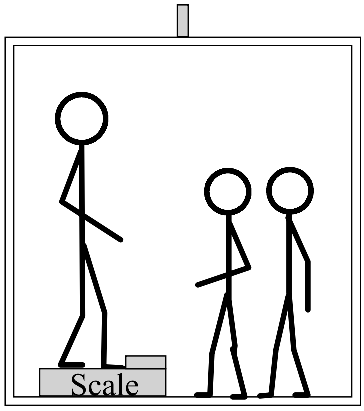

Figure 1

(a) In **Figure 2** and **Figure 3** below the teacher is represented by a block. Draw **two** free-body force diagrams, showing and labelling the forces acting on the teacher during the constant velocity and slowing stages. Arrow lengths should reflect relative magnitudes of forces. State what object exerts each force. *[4]*

FREE BODY DIAGRAM
Moving down at constant speed

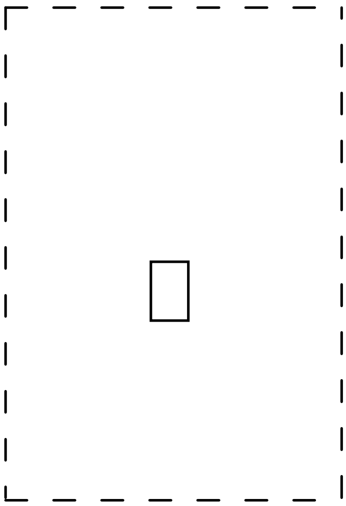

Figure 2

FREE BODY DIAGRAM
Slowing to a stop

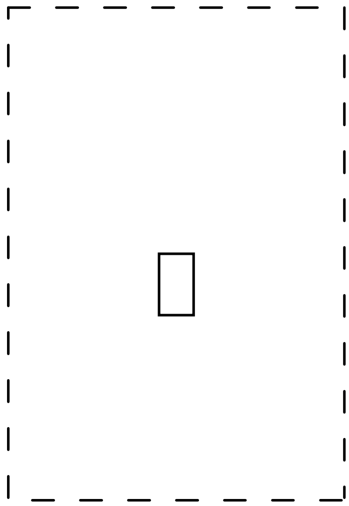

Figure 3

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(Question A2 continued)

(b) Determine the reading on the scale (in newtons) for:

(i) the constant velocity stage. *[2]*

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(ii) the slowing stage. *[4]*

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SECTION B

*This section consists of three questions: B1, B2 and B3. Answer **one** question in this section.*

B1. This question is in **two** parts. **Part 1** is about a charge-measuring device and **Part 2** is about waves in a ripple tank. Answer **both** parts in this question.

Part 1. Charge-measuring device

A light metal-coated pith ball of mass m is suspended between two vertical plates as shown. A potential difference V is applied between the plates, which are a distance d apart. When the ball is charged, the string hangs at an angle to the vertical as shown.

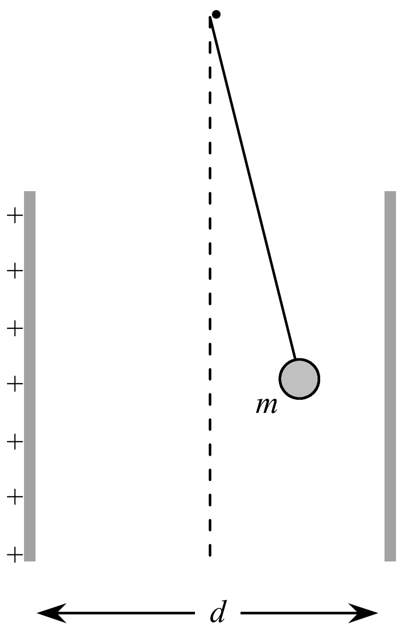

Figure 1: Physical situation

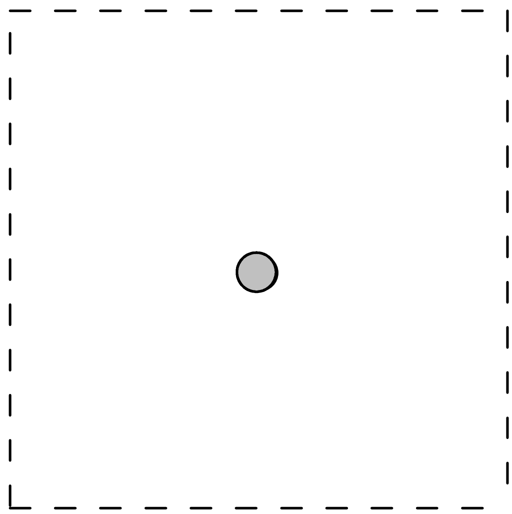

Figure 2: Free-body diagram

(a) Sketch the electric field lines due to the plates alone in **Figure 1**. *[1]*

(b) What is the sign of the charge on the ball? *[1]*

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(c) Draw a free-body force diagram in **Figure 2**, for the pith ball hanging at an angle. Label each force. *[3]*

(d) By considering the work done in moving a charge between the plates, show that the electric field E between the plates is given by $E = \frac{V}{d}$. Show all steps. *[4]*

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(Question B1 Part 1 continued)

(e) The mass of the ball is 40 milligrams, the applied potential difference is 480 V and the plate separation is 6 cm. If the string hangs at an angle of 20° to the vertical, determine the charge on the pith ball. *[6]*

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(f) An arrangement like this can serve as a charge-measuring device. How would you make the device more sensitive, to measure smaller charges than that above? State **two** changes you could make to the set up. *[2]*

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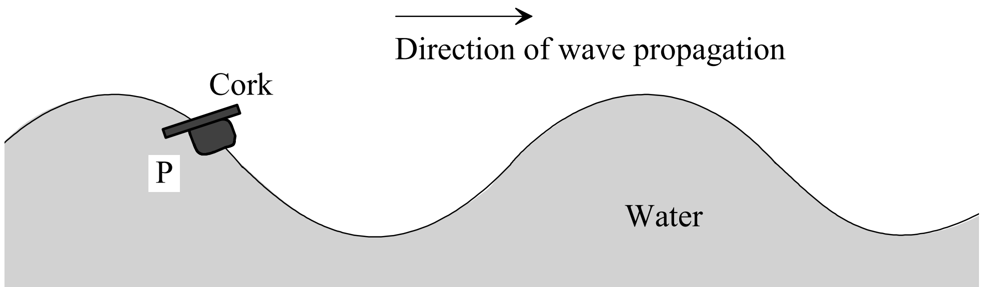
(Question B1 continued)

Part 2. Waves in a ripple tank

Wave characteristics

Water waves are produced in a glass-sided ripple tank. Viewed from the side at a particular instant, the waves appear as shown below. A small cork floats on the water at point P.



(a) On the diagram indicate and label:

(i) a *crest* and a *trough* of the wave. *[1]*

(ii) one *wavelength* of the wave. *[1]*

(iii) the *amplitude* of the wave. *[1]*

(b) Draw in the position of the wave half a period later, and mark the position of the cork. *[2]*

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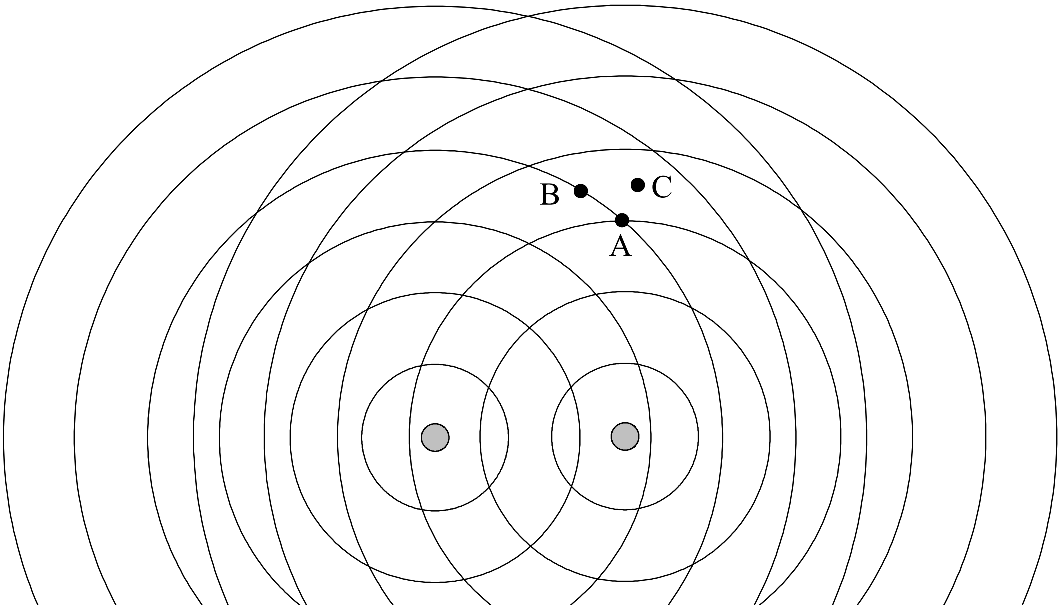
(Question B1 Part 2 continued)

Waves from two sources

The diagram below represents wavefronts spreading out from two sources in the ripple tank. The dark circles indicate crests of waves.



(c) Small floating corks are placed in the water at positions A, B and C. Describe the motion of each cork. *[3]*

(i) Cork at A:

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(ii) Cork at B:

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(iii) Cork at C:

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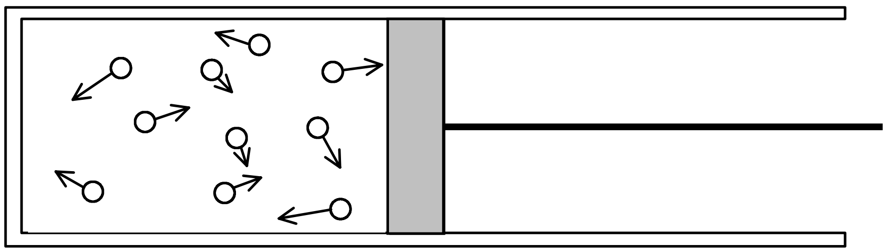
B2. This question is in **two** parts. **Part 1** is about gas expansion and **Part 2** is about children on a bicycle. Answer **both** parts in this question.

Part 1. Gas expansion

A quantity of gas is enclosed in a metal cylinder fitted with a piston. There are very many gas molecules, but they are represented in the diagram by the ten molecules shown, with velocities indicated. The cylinder walls are thermally conducting.



(a) Explain in terms of molecular motions how pressure arises on the face of the piston. *[2]*

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(b) If gravity acts on the molecules, why do they not all fall down and accumulate stationary at the lower surface? Explain. *[2]*

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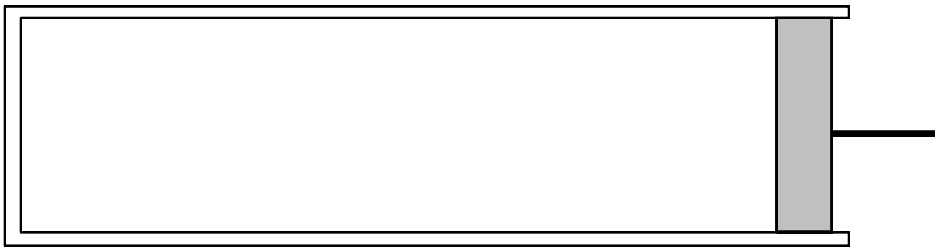
(Question B2 Part 1 continued)

Suppose the piston is moved outwards, with sufficient time allowed so that the gas temperature is the same afterwards. The diagram below shows the piston position where the gas volume has doubled.



(c) How does the average kinetic energy of the gas molecules compare before and after this expansion? Explain. *[2]*

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(d) Draw in ten representative gas molecules on the diagram above, including representative velocity vectors, to illustrate the situation after expansion. Explain your diagram briefly. *[2]*

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(e) Explain, in terms of molecular motion and the diagrams above, why the pressure exerted by the gas on the piston is less in the expanded situation you have drawn. *[2]*

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(f) If the gas pressure was 300 kPa before expansion, calculate the pressure after expansion, when the volume has doubled. *[2]*

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(g) Suppose one wishes to bring the pressure back to the original 300 kPa by increasing the temperature of the gas (at the fixed new volume). If the current temperature is 20 $^{\circ}$C, what new temperature is required? *[3]*

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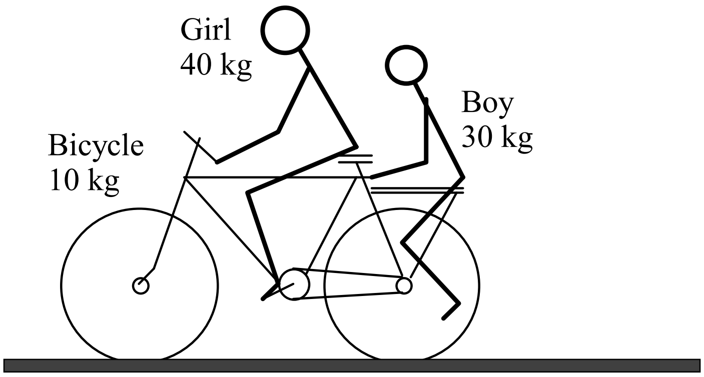
(Question B2 continued)

Part 2. Children and bicycle

A boy of mass 30 kg is being given a lift on the back of a 10 kg bicycle by a girl of mass 40 kg. They are travelling at a steady speed of 2.5 m s^{-1}.



The boy wishes to get off the back of the bicycle while it is still moving.

(a) He knows that if he just puts his feet on the ground and stands up he is likely to fall over. Explain why this is so. *[2]*

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So instead he pushes himself off the back of the bicycle by pushing forward on the bicycle frame with his hands, so that he lands on the ground with zero horizontal velocity.

(b) Calculate the velocity of the bicycle and the girl immediately after the boy has left the bicycle. *[4]*

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(Question B2 Part 2 continued)

(c) Calculate the total kinetic energy of the system (bicycle and both children) before and after the boy gets off. Explain the reason for any difference. *[4]*

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B3. This question is in **two** parts. **Part 1** is about radioactive decay and **Part 2** is about an electric kettle and the specific heat capacity of water. Answer **both** parts in this question.

Part 1. Radioactive decay

Nuclide X is radioactive, decaying with a half-life of 4.0 days to a daughter nuclide Y, which is stable.

(a) Explain what is meant by ‘decaying with a half-life of 4.0 days’. *[2]*

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(b) A student suggests that the alternative concept of a ‘whole-life’ might be simpler, being the time required for all the radioactive nuclei in the sample to decay. Why would this suggestion not work? *[2]*

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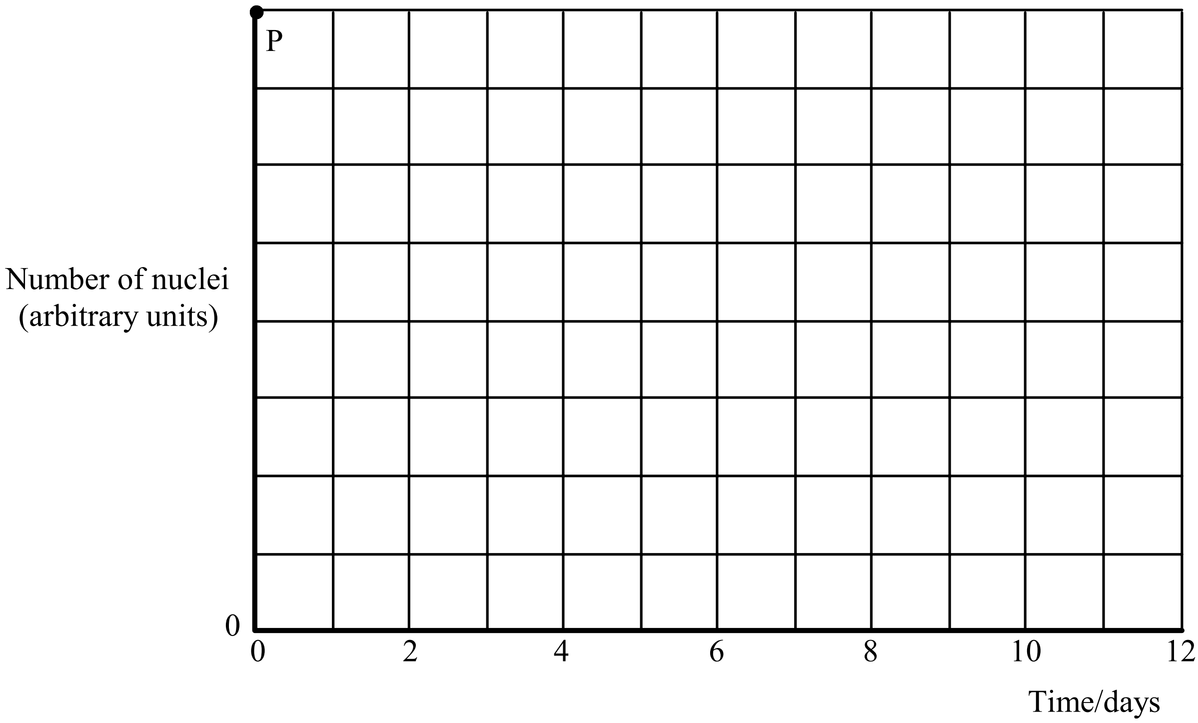
(Question B3 Part 1 continued)

(c) A sample originally consists entirely of nuclide X. Construct a graph on the axes below showing the number of undecayed X nuclei in the sample as a function of time. The initial number is shown at point P.



[3]

(d) On the same axes construct another graph showing the number of daughter (Y) nuclei as a function of time. Label this graph Y. *[2]*

(e) Determine the ratio of Y to X nuclei after 12 days. *[2]*

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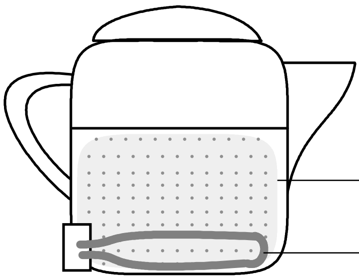
(Question B3 continued)

Part 2. Electric kettle and specific heat capacity of water

This question is about the properties of an electric kettle and its use to measure the specific heat capacity of water.

Kettle construction

The diagram shows an electric kettle, with its resistive heating element at the bottom.



(a) Why is the element mounted at the bottom rather than higher up? Give **two** reasons. *[2]*

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(b) Plastic kettles are now replacing metal ones. State any **two** advantages that plastic kettles might have over metal ones. *[2]*

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(Question B3 Part 2 continued)

Electrical characteristics

The rating written on the electric kettle reads as follows: 1100 W : 220 V

(c) Calculate the current through the heating element when in normal use. *[1]*

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(d) Calculate the resistance of the element when in normal use. *[1]*

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(e) The electrical characteristics of the kettle element can be investigated by applying various voltages V to it, from very small up to 220 V, and measuring the current I in each case. Sketch a graph which shows the shape of the I-V characteristic expected for the element. Explain the shape of your graph, stating and justifying any assumptions you have made. *[3]*

Explanation and assumptions:

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(This question continues on the following page)

(Question B3 Part 2 continued)

Measuring the specific heat capacity of water using the kettle

(f) A student measures the specific heat capacity of water by heating it in the kettle. She finds that it takes 170 seconds to bring 0.50 kg of water to the boil, starting at 20 °C. Calculate a value for the specific heat capacity of water, stating any assumptions you make. *[5]*

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