INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

PHYSICS
HIGHER LEVEL
PAPER 2

Tuesday 15 May 2001 (afternoon)

2 hours 15 minutes

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 two questions from Section B in the spaces provided.
- At the end of the examination, indicate the numbers of the Section B questions answered in the boxes below.

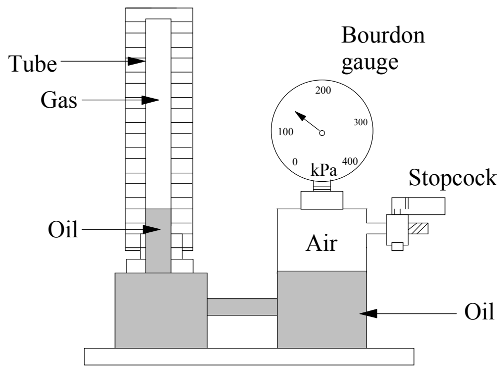
QUESTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
SECTION A	ALL	/35	/35	/35
SECTION B				
QUESTION	. . . .	/30	/30	/30
QUESTION	. . . .	/30	/30	/30
		TOTAL /95	TOTAL /95	TOTAL /95

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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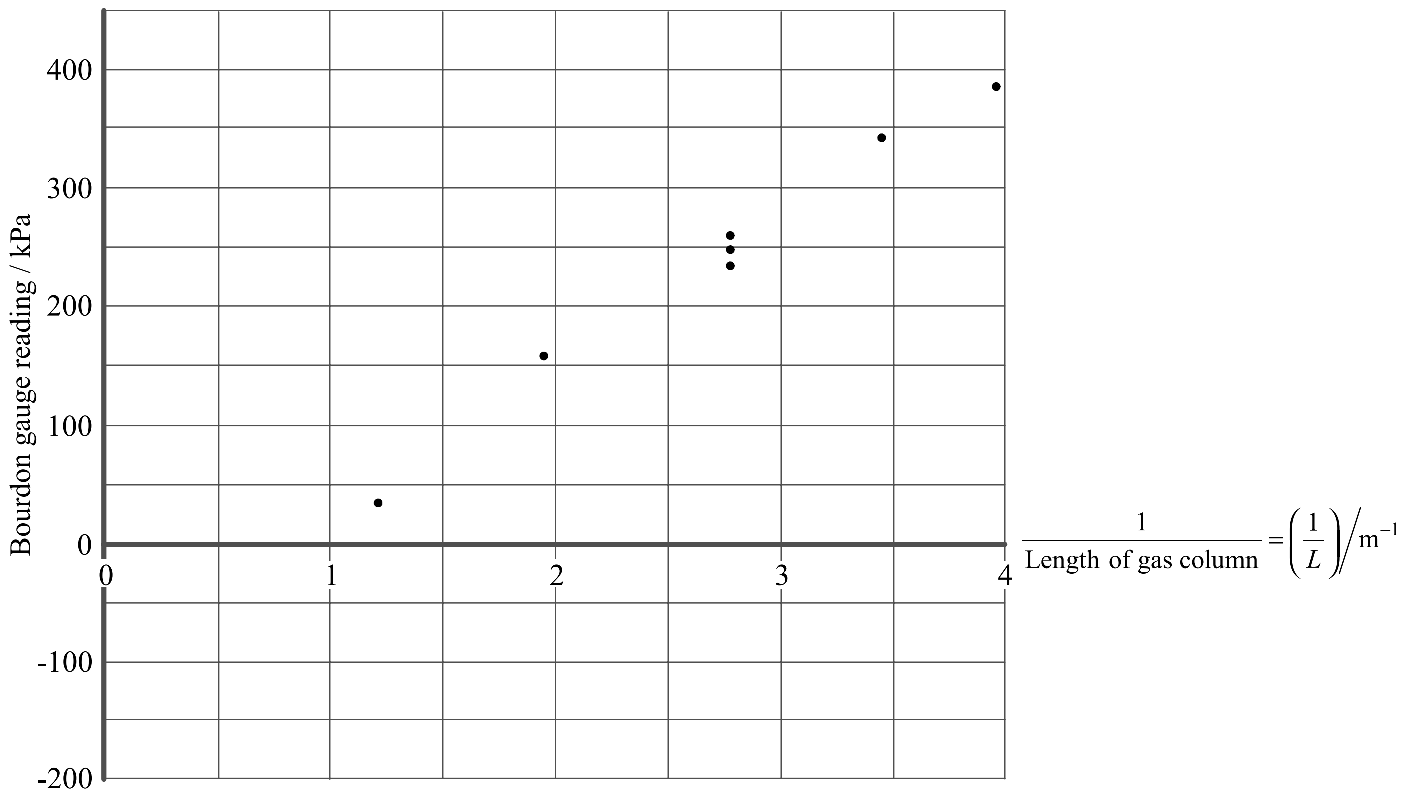
(Question A1 continued)

The students plot the pressure reading P_B on the Bourdon gauge versus $\frac{1}{L}$, as shown below. In order to estimate the uncertainty in the data, the students have repeated the measurement at $\frac{1}{L} = 2.8\ \text{m}^{-1}$ three times, giving a cluster of three data points.



(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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(f) From the three repeated measurements reflected by the cluster of points,

(i) draw in an error bar on the graph to reflect the experimental uncertainty. *[1]*

(ii) write the pressure value and its uncertainty in the form (value ± uncertainty). *[2]*

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(Question A1 continued)

(g) 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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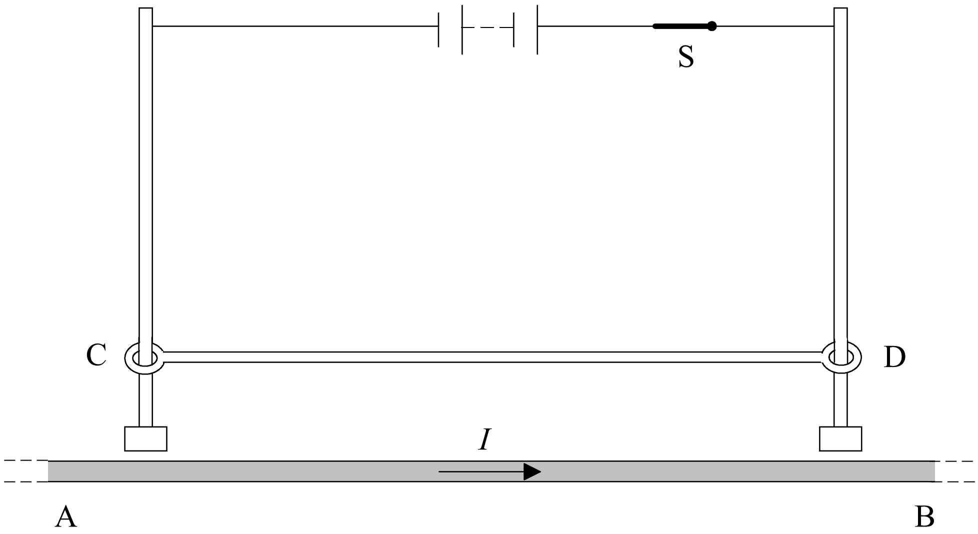
A2. Levitated wire

The diagram shows a section AB of a long conductor carrying a current *I*. Above AB a conducting rod CD can slide up and down on two vertical metal rods while making electrical contact with them as shown. There is a small amount of friction as CD slides.



(a) When switch S is closed, so that current flows in CD, CD moves upwards and eventually comes to rest at a certain height above AB. Explain:

(i) why CD initially starts to move upwards. *[1]*

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(ii) why CD eventually comes to rest at a certain height above AB. *[2]*

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(Question A2 continued)

(b) Given the following data, determine the height *h* to which CD rises. *[5]*

Mass of CD:	10 g
Length of CD:	30 cm
Current in AB:	1000 A
Current in CD:	80 A

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(c) If there were no friction on CD, it would not actually come to rest at this position, but would oscillate up and down about the position.

(i) Explain this behaviour. *[2]*

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(ii) Would this oscillation be simple harmonic in nature? Explain. *[2]*

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(Question A2 continued)

The switch S is opened, so that the current does not flow in CD, and CD falls.

(d) Explain why a potential difference arises between the ends of CD as it falls. *[3]*

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(e) As CD falls lower, the potential difference between its ends increases. Give **two** reasons why it increases. *[2]*

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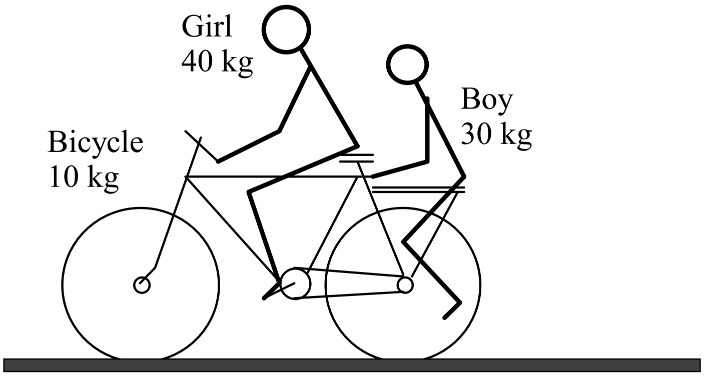
SECTION B

*This section consists of four questions: B1, B2, B3 and B4. Answer any **two** questions in this section.*

B1. This question is in **three** parts. **Part 1** is about children on a bicycle, **Part 2** is about the hydrogen atom and spectrum and **Part 3** is about waves in a ripple tank. Answer **all** the parts in this question.

Part 1. 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 B1 Part 1 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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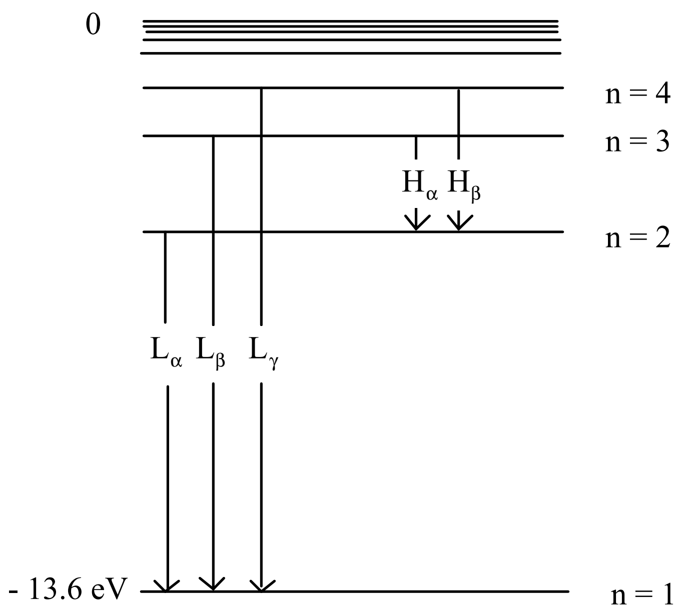
(Question B1 continued)

Part 2. Hydrogen atom and spectrum

Some of the energy levels of the hydrogen atom are shown in the diagram below (not to scale) and some transitions between levels are labelled.



(a) Why are the energy values of the atomic energy levels taken as negative? *[2]*

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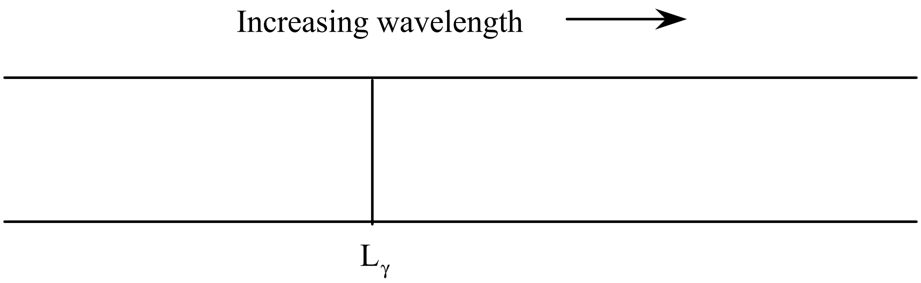
(Question B1 Part 2 continued)

The diagram below shows one line of the emission spectrum of hydrogen, corresponding to the transition labelled L_γ in the energy level diagram.



(b) Draw and label additional lines in the diagram to show qualitatively the relative positions of the spectral lines corresponding to the other transitions L_α, L_β, H_α and H_β. *[2]*

(c) The energy of the *n*th level of the hydrogen atom is given by

$E_n = -\frac{k}{n^2}$ where *k* is a constant and *n* = 1, 2, 3 *etc*.

[5]

Determine the wavelength of the radiation emitted in the transition L_γ.

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(d) In which region of the electromagnetic spectrum does this radiation lie? *[1]*

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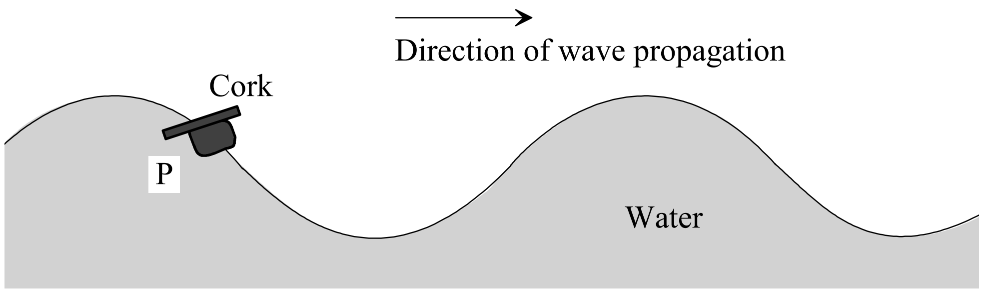
(Question B1 continued)

Part 3. 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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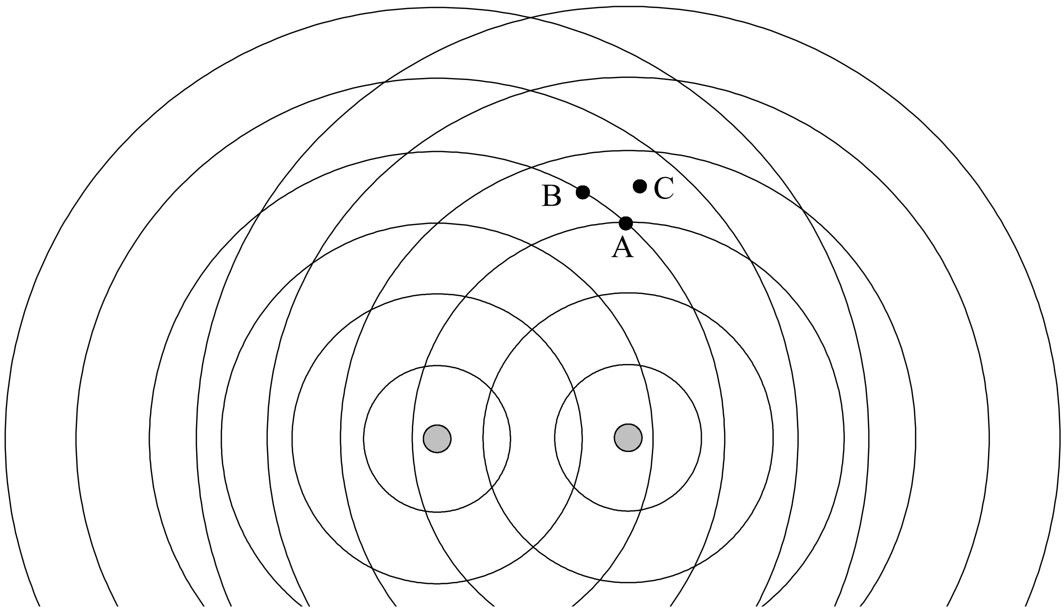
(Question B1 Part 3 continued)

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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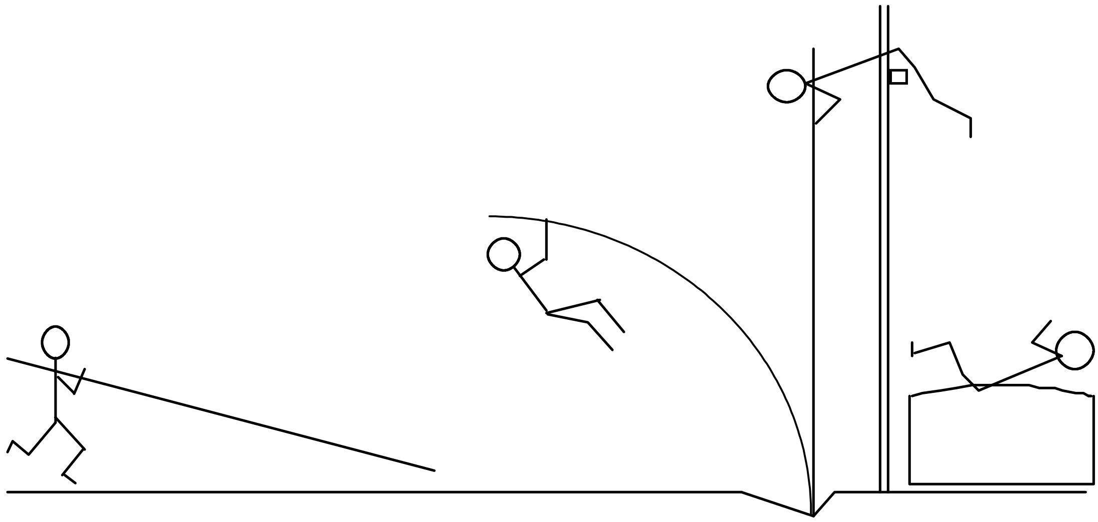
(d) On the diagram, draw in a section of any nodal line of your choice. *[2]*

B2. This question is in **two** parts. **Part 1** is about the pole vault event and **Part 2** is about an electric kettle and the specific heat capacity of water. Answer **both** parts in this question.

Part 1. Pole vault

In the pole vault event an athlete runs as fast as possible towards the bar, holding a flexible fibreglass pole. He sticks the end of the pole into a slot in the ground, swings up on the pole and over the bar as shown (not to scale).



(a) Describe the energy transformations that occur for the athlete and the pole during the event. *[4]*

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(Question B2 Part 1 continued)

(b) A good athlete can reach a maximum running speed of about 9 m s^{-1} carrying the pole. Estimate the maximum bar height over which a pole vaulter can vault. Assume that the athlete's mass can be taken as concentrated at his 'centre of mass' roughly at the centre of his body. Omit any work done as the vaulter pulls or pushes on the pole during the vault. State any other assumptions or simplifications you make. *[5]*

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(c) The vaulter will in fact pull on the pole during ascent, and push down on it when nearing the top. Suggest what approximate additional height might be gained in this way, with reasoning. *[2]*

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(d) Hence predict what the world record for the pole vault might be, based on your calculations and estimates. *[1]*

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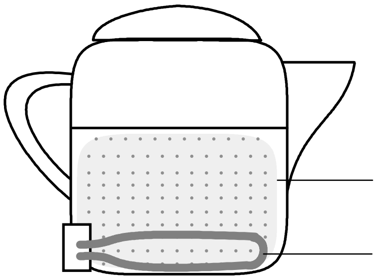
(Question B2 continued)

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 B2 Part 2 continued)

Electrical characteristics

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

(c) The kettle is in an AC circuit, so that 220 V is the *rms* value of the mains voltage. Determine the peak value of the voltage across the element. *[1]*

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

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

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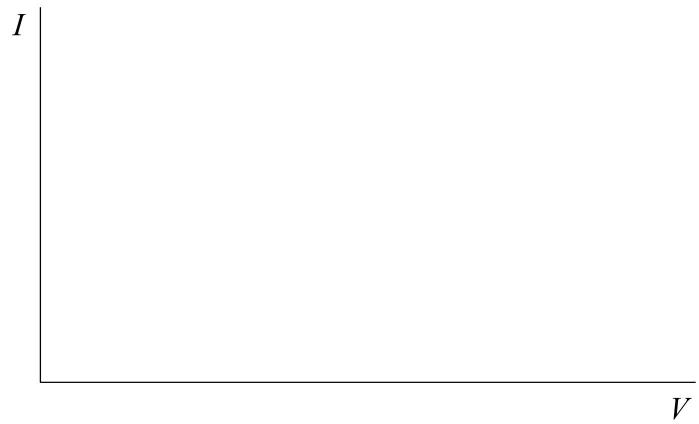
(f) The electrical characteristics of the kettle element can be investigated by applying various voltages V to it, from very small up to 220 V, and measuring the current I in each case. Sketch a graph which shows the shape of the I-V characteristic expected for the element. Explain the shape of your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



Explanation and assumptions:

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(Question B2 Part 2 continued)

(g) Explain whether or not the power drawn will be equal to 1100 W in the first few seconds after the kettle is switched on. *[1]*

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Measuring the specific heat capacity of water using the kettle

(h) 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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(i) In the light of your assumptions, is your calculated value of specific heat capacity likely to be higher or lower than the true value? Explain. *[2]*

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B3. This question is in **two** parts. **Part 1** is about a charge-measuring device and **Part 2** is about a nuclear reaction. Answer **both** parts.

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.

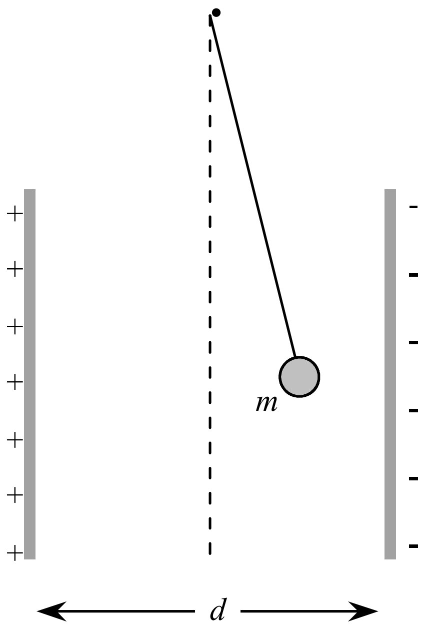

Figure 1: Physical situation

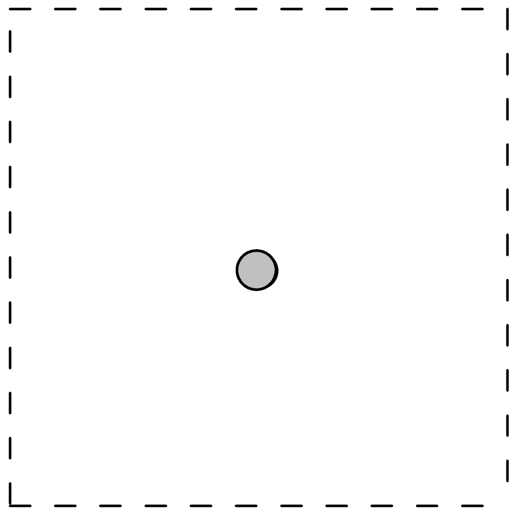

Figure 2: Free-body diagram

(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 B3 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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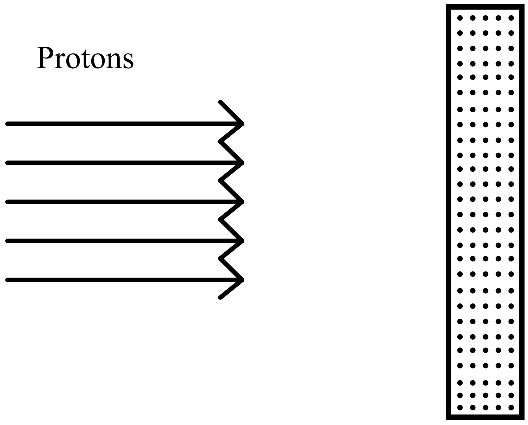
(Question B3 continued)

Part 2. Nuclear reaction

Protons are accelerated in a particle accelerator and strike a lithium foil target. The dots in the diagram below are an exaggerated representation of the lithium nuclei in the target.



A proton of sufficient energy may induce a nuclear reaction with a lithium nucleus, producing two alpha particles and the release of energy *Q*.

(a) Complete the reaction equation below, inserting the mass numbers and atomic numbers. *[2]*

$$\mathrm{H} + \mathrm{Li} \rightarrow \mathrm{He} + \mathrm{He} + Q$$

(b) What does the fact that energy is released in the reaction tell us about the sum of the rest masses of the particles before and after the reaction? *[1]*

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(c) Why must an incident proton have a certain minimum or 'threshold' energy in approaching a lithium nucleus in order for this nuclear reaction to occur? Describe what happens to the proton if its energy is less than this. *[2]*

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(Question B3 Part 2 continued)

(d) Estimate the threshold energy, given that the radius of the Li nucleus is about 2.5 fm. *[6]*

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(e) Suppose the protons in the beam have energy greater than the threshold value for the reaction. Explain why some but not all of the protons will cause a nuclear reaction. *[2]*

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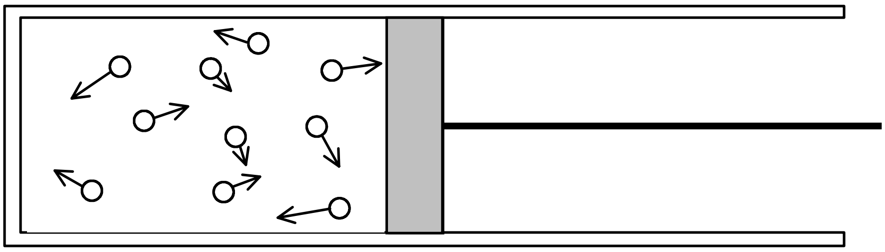
B4. This question is in **two** parts. **Part 1** is about gas expansion and **Part 2** about a puck on a spring. Answer **both** parts.

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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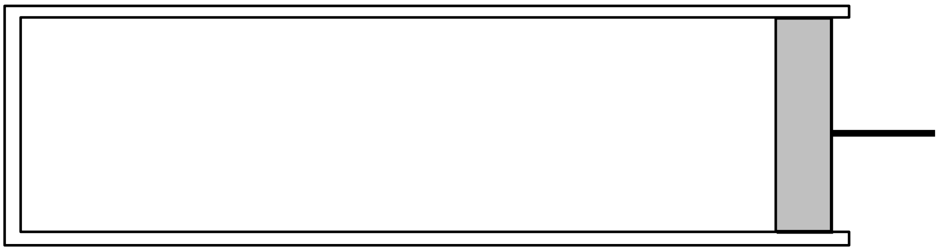
(Question B4 Part 1 continued)

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, 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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(Question B4 Part 1 continued)

(g) Is work done as the piston moves outwards? If so, is it done on the gas or by the gas? *[2]*

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(h) Is there a flow of heat as the piston moves outwards? If so, does it flow into or out of the cylinder? Explain. *[2]*

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(i) Is heat completely converted to work in this expansion? If so, could this process be used in a device to continuously convert heat into work, in apparent contravention of the second law of thermodynamics? Discuss. *[3]*

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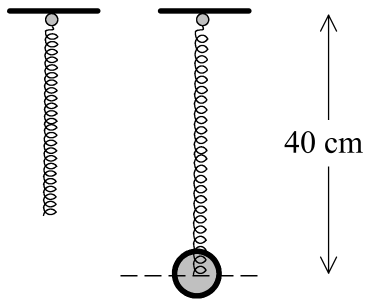
(Question B4 continued)

Part 2. Puck on a spring

For this question take g = 10 N kg^{-1} = 10 m s^{-2}.

When a puck (flat disk) of mass *m* is hung from a spring, the spring extends to a length of 40 cm as shown.



(a) The spring with the puck hanging from it is set swinging as a pendulum, with small oscillations. Calculate the period. *[2]*

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(b) If the oscillations were large, explain why the length of this ‘spring pendulum’ could not be taken as 40 cm. *[2]*

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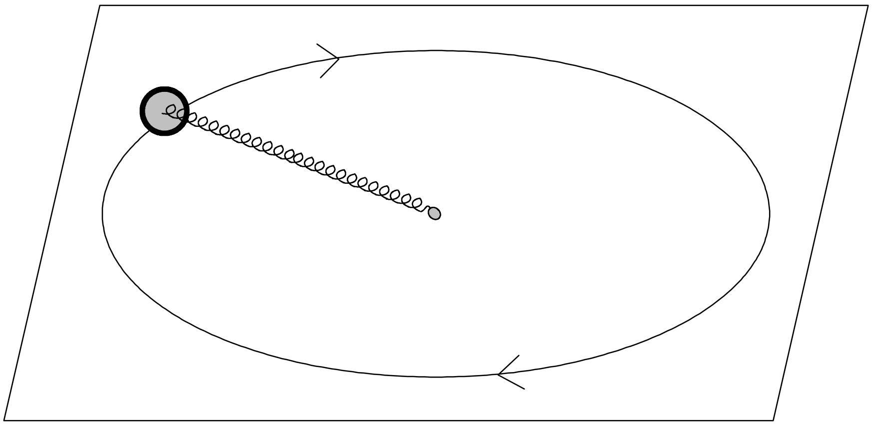
(Question B4 Part 2 continued)

The puck is now set in circular motion at the end of the spring, on a frictionless horizontal surface. The other end of the spring is fixed.



(c) If the circular motion is set up in such a way that the spring extends to the same length as when the puck hung from it, determine the period of revolution. Show all steps. *[5]*

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(d) Is it possible for the puck to move in a circle with the spring at its original (unextended) length? Explain. *[2]*

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