IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

PHYSICS
HIGHER LEVEL
PAPER 2

Thursday 2 May 2002 (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 QUESTION		 /30 /30	 /30 /30	 /30 /30
		TOTAL /95	TOTAL /95	TOTAL /95

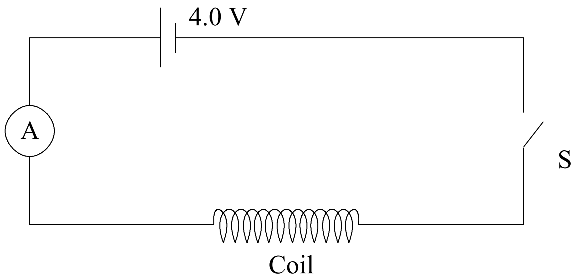
SECTION A

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

A1. This question is about the growth of an electric current in a coil.

When a coil is connected to a d.c. power supply the current in the coil does not change instantaneously but takes a finite time to reach a steady value. For a given supply the final, steady value of the current is determined by the resistance *(R)* of the coil.

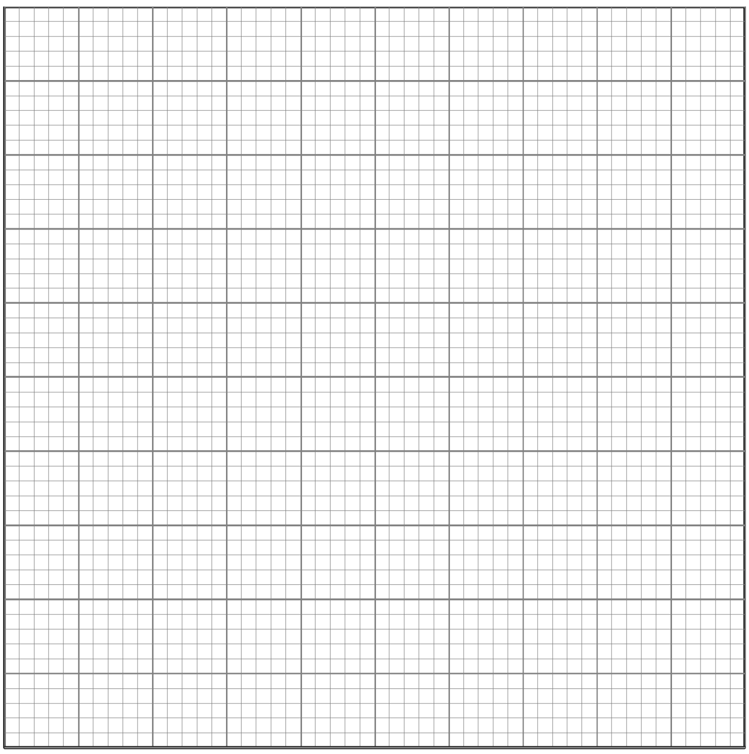
In the diagram below a coil is connected to a d.c. supply of emf 4.0 V.



When the switch S is closed an electronic timer is started and the current I is recorded at different values of the time t. The results are shown in the table below. (Uncertainties in measurement are not shown).

t /s	0	0.2	0.6	1.0	1.4	1.8	2.0
I /A	0	0.8	1.6	1.9	2.0	2.0	2.0

(a) Plot a graph of current against time. *[5]*



(This question continues on the following page)

(Question A1 continued)

(b) What is the steady state value of the current? *[1]*

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(c) Determine the value of the resistance R of the coil. *[1]*

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(d) By drawing a tangent to the curve at the point (0, 0) on your graph, determine the time it would take for the current to reach its steady state value if it were to continue changing at its initial rate. (This time is known as the **time constant** of the coil). *[2]*

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(e) The initial rate at which the current in the coil changes is given by the expression $\frac{V}{L}$ where V is the value of the supply potential and L is a property of the coil known as its **inductance**. Show that the time constant τ for the coil is given by the expression

$$\tau = \frac{L}{R}.$$ *[3]*

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(f) Determine the value of the inductance L of the coil. *[1]*

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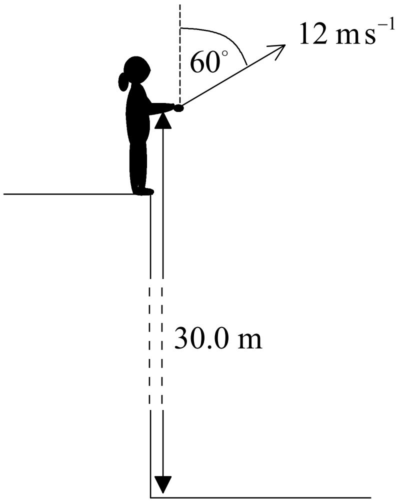
A2. This question is about a projectile.

(a) A girl stands on the edge of a vertical cliff and throws a stone upwards at an angle of 60° to the vertical such that the stone eventually lands in the sea below. The stone leaves her hand with a speed of 12 m s^{-1} at a height of 30.0 m above the sea.



Taking the acceleration due to gravity to be 10 m s^{-2} and ignoring air resistance determine

(i) the maximum height, measured from sea-level, reached by the stone. *[4]*

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(ii) the **speed** with which the stone hits the sea. *[5]*

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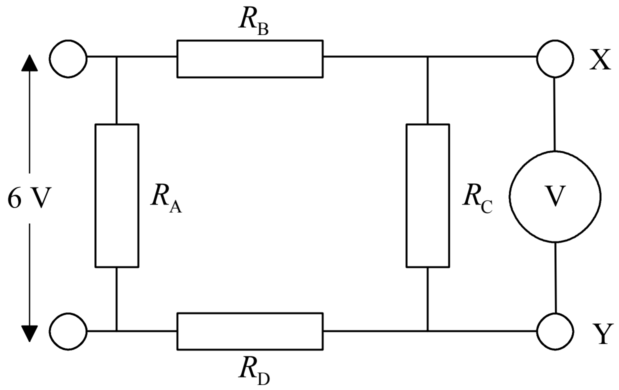
(This question continues on the following page)

(Question A2 continued)

(b) In the space provided below sketch, using the same axes, graphs to show how the horizontal and the vertical components of velocity of the stone vary with **time** from the moment it leaves her hand to just before it hits the sea. *(Note that this is a sketch graph; you do not need to add values to the axes.)* *[2]*

A3. This question is about testing an electrical circuit.

The diagram below shows an electrical circuit consisting of four identical resistors R_A, R_B, R_C, and R_D. The resistance of each resistor is 10 kΩ.



(a) Commercial resistors sometimes fail in one of two ways. They can go "open-circuit" in which the resistance of the resistor becomes infinite **or** they can go "short-circuit" in which the resistance becomes zero.

In order to test the circuit a technician connects a high resistance voltmeter between the terminals X and Y and applies a potential difference of 6 V across the resistor R_A.

(i) What voltage will the voltmeter read if all the resistors are functioning normally? *[2]*

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(ii) What would the voltmeter read if **either** resistor R_B **or** R_D were to short-circuit? *[1]*

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(iii) If the electrician were to note a reading on the voltmeter that suggested **either** R_B **or** R_D had short-circuited how could he test which **one** of these had in fact short-circuited using only the voltmeter? *[2]*

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(b) Identify **two** possible faults with the circuit that would produce a reading of 6 V on the voltmeter when it is connected between X and Y. *[2]*

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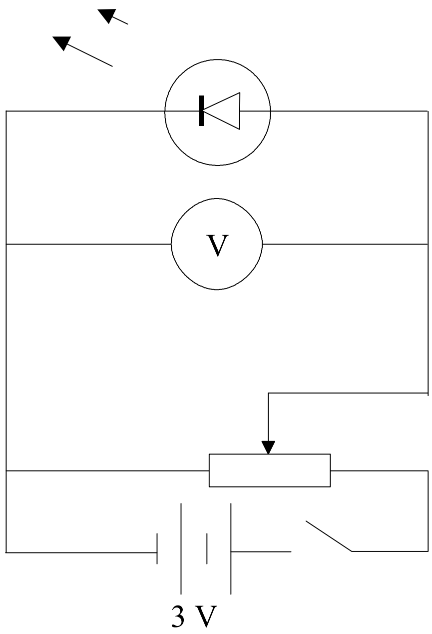
A4. This question is about measuring a value of Planck's constant using a light emitting diode (LED).

An LED is a device that emits light of a particular frequency when the voltage applied across the LED reaches a certain value. This effect can be used to measure Planck's constant.

In the circuit shown below the switch is closed and the potentiometer is adjusted until the LED just emits light. When this occurs the voltmeter reads 2.5 V.



(a) How much energy is transferred by the battery to each electron in the LED? *[1]*

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(b) The LED operates in such a way that the electrons can give up the energy that they gain from the battery by emitting a photon. Assuming that all the energy gained by an electron is transferred to a photon and that the LED used in this experiment emits light of wavelength 480 nm calculate a value for Planck's constant. *[3]*

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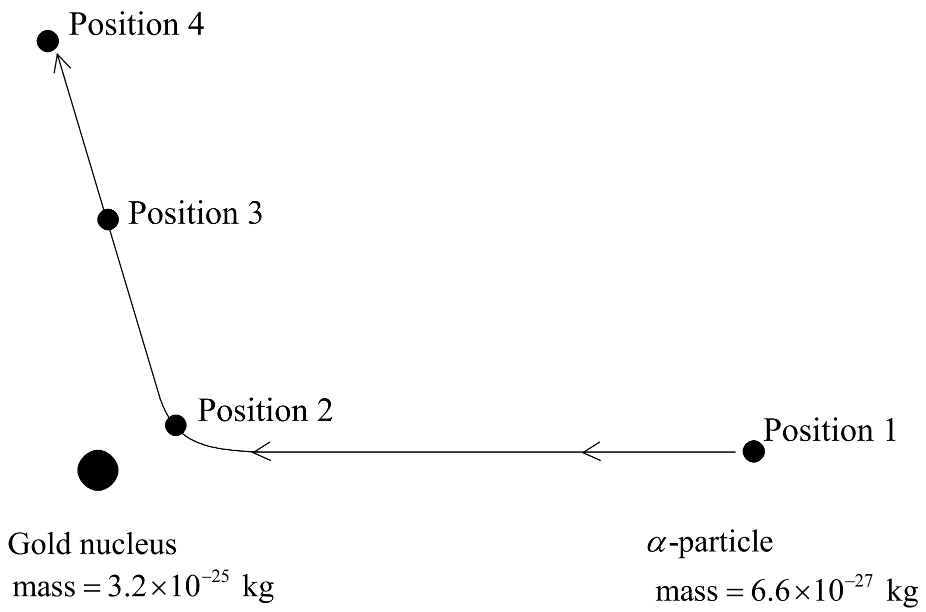
SECTION B

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

B1. This question is about the momentum and energy changes involved in the scattering of α-particles by gold nuclei.

The diagram below shows the path followed by a particular α-particle that is scattered by the nucleus of a gold atom. When the α-particle is at positions 1 and 4 it is far from the gold nucleus. The respective masses of the α-particles and gold nucleus are given on the diagram below.



(a) Indicate on the diagram above the direction of the force acting on the α-particle when it is at positions 1, 2 and 3. *[3]*

Geiger and Marsden performed an experiment in which α-particles were scattered by gold nuclei. In order to predict the angles through which α-particles would be scattered, they assumed the energy transferred to the gold nuclei by the α-particles was negligible. Parts (c) to (f) of this question address the validity of this assumption.

(b) The kinetic energy of the α-particle when it is at position 1 in the diagram is 4.2 MeV. Show that

(i) an energy of 4.2 MeV is equivalent to 6.7×10^{-13} J. *[2]*

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(This question continues on the following page)

(Question B1 (b) continued)

(ii) the magnitude of the momentum of the α-particle is 9.4×10^{-20} N s when it is at position 1. *[3]*

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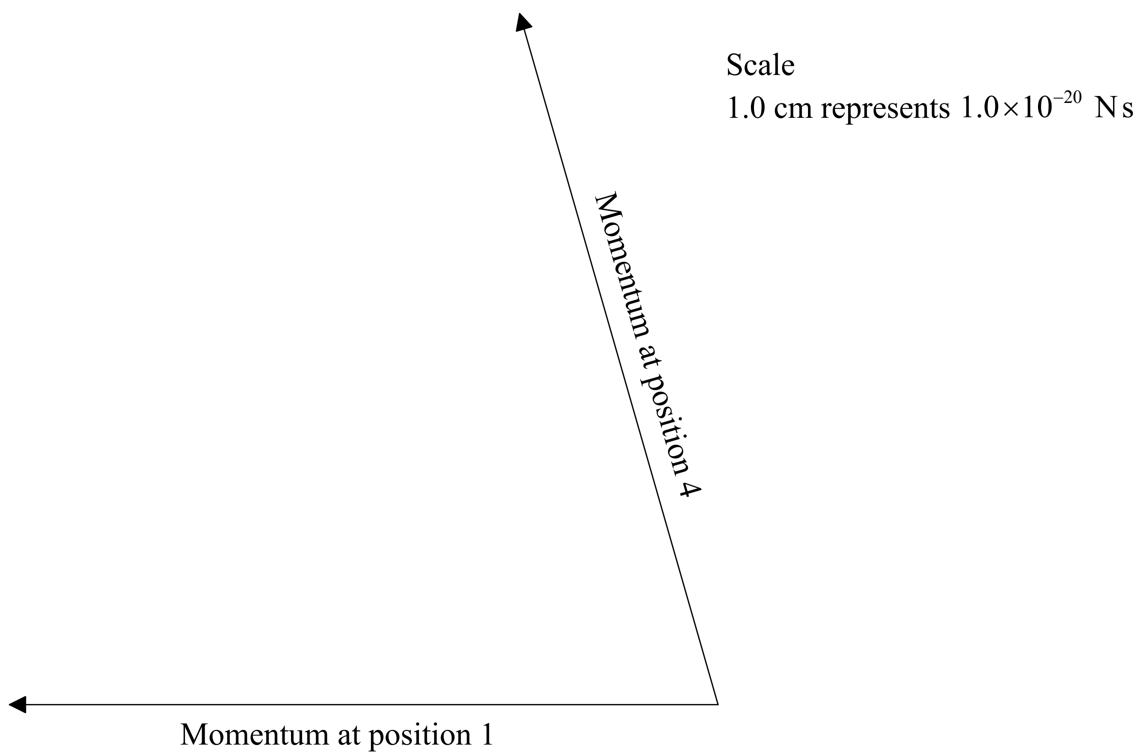
(c) The α-particle is assumed to have the same speed at position 4 as it has at position 1. On the vector diagram below construct the vector representing the **change** in momentum of the α-particle between positions 1 and 4 and show that the magnitude of this change is 11.6×10^{-20} N s. *[3]*



(d) Draw, in the space at the side of the above diagram, a vector representing the momentum change of the gold nucleus when the α-particle moves between positions 1 and 4. *[2]*

(This question continues on the following page)

(Question B1 continued)

(e) For the scattering event shown in the diagram on page 8 calculate the recoil kinetic energy of the gold nucleus. *[4]*

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(f) From your answer to part (d) show that Geiger and Marsden were justified in making the assumption that the α-particle loses negligible energy during the scattering process. *[3]*

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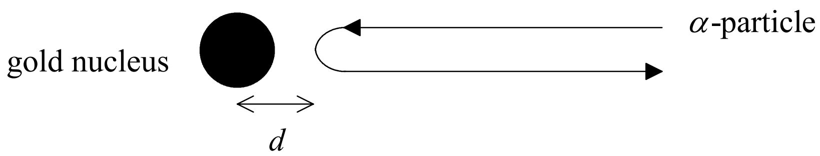
The next section of this question deals with determining a value for distance of closest approach to a gold nucleus.

(g) The diagram below shows the path followed by an α-particle that is incident "head-on" to a gold nucleus.



The kinetic energy of this α-particle when it is far from the gold nucleus is 4.2 MeV. The distance d on the diagram represents the closest distance of approach of the α-particle to the gold nucleus as measured from the "centre" of the gold nucleus.

(i) Explain what has happened to the kinetic energy of the α-particle when it is at a distance d from the centre of the gold nucleus. *[3]*

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(This question continues on the following page)

(Question B1 (g) continued)

(ii) Determine the distance *d* of closest approach. (The atomic number of gold is 79). *[7]*

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B2. This question is in **two** parts. **Part 1** is about the behaviour of an ideal gas and **Part 2** is about magnetic forces.

Part 1. Ideal gas behaviour

(a) Explain in terms of the microscopic (kinetic) model of an ideal gas the difference between the temperature of an ideal gas and its internal energy. *[4]*

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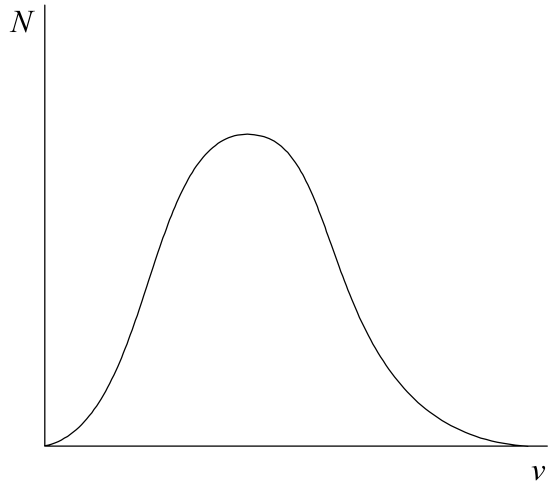
(b) An ideal gas is contained in a cylinder fitted with a moveable piston. The mass of the gas is 4.0×10^{-3} kg and the specific heat of the gas at constant volume is $3.1\times10^{3}\ \mathrm{J\,kg^{-1}\,K^{-1}}$. The gas is initially at a temperature of $27\ ^{\circ}\mathrm{C}$ and pressure 1.0×10^{5} Pa.

The diagram below shows a sketch graph of the distribution of the molecule speeds of the gas. *N* is the number of molecules per unit speed interval and *v* is the speed.



The gas is now heated at a constant volume until its pressure becomes 2.0×10^{5} Pa.

(i) Sketch on the diagram above the molecular speed distribution after the gas has been heated. *(Note that this is only a sketch graph; you do not need to add any values.)* *[1]*

(This question continues on the following page)

(Question B2 part 1 (b) continued)

(ii) Calculate the temperature of the gas and its change in internal energy. *[5]*

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(c) The gas is now compressed at constant temperature until its volume is half its original volume.

(i) What is the change in internal energy of the gas resulting from this compression? *[1]*

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(ii) Calculate the pressure of the gas. *[3]*

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(d) During this heating at constant volume and compression at constant temperature, 3500 J of work is done on the gas. How much energy does the gas lose to the surroundings during this change? *[1]*

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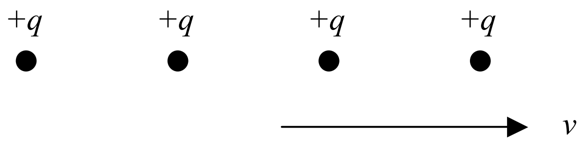
(This question continues on the following page)

(Question B2 continued)

Part 2. Magnetic forces

The diagram below shows a beam of charged particles moving in a straight line with speed v. Each particle has a charge $+q$ and there are N particles in length L of the beam.



(a) How far do the particles travel in time Δt? *[1]*

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(b) How many particles pass a given point in a time Δt? *[2]*

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(c) Using your answers to (a) and (b) above show that the current I carried by the beam is given by the expression

$$I = \frac{Nvq}{L}.$$ *[2]*

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(d) When a uniform magnetic field of strength B is applied at right angles to the direction of motion of the particles each particle experiences a force of magnitude Bqv.

If the direction of the field is into the plane of the paper show, on the above diagram, the direction of the magnetic force on **one** of the charges. *[1]*

(This question continues on the following page)

(Question B2 part 2 continued)

(e) Show that a force Bqv on each particle is equivalent to a length L of the beam experiencing a force of magnitude BIL. *[3]*

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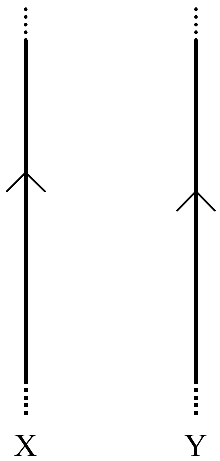
(f) The diagram below shows two long parallel wires X and Y, carrying equal currents in the same direction.



(i) On the diagram above show the direction of the force acting on each wire. *[1]*

(ii) The current in each wire is 2.0 A and the wires are 0.50 m apart. Calculate the magnitude of the force exerted per unit length on each wire. *[2]*

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(iii) Suppose that wire Y is free to move. Describe and explain the subsequent motion of wire Y in terms of its velocity and acceleration. *[3]*

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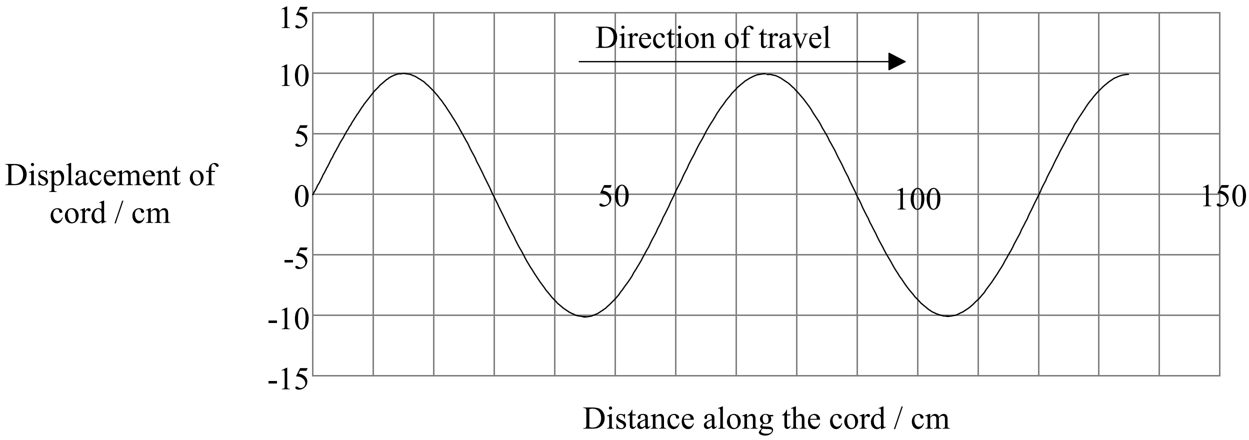
B3. This question is in **two** parts. **Part 1** is about waves in a rubber cord and **Part 2** is about radioactive decay.

Part 1. Waves in a rubber cord

The diagram below shows part of a rubber cord along which a wave is travelling.



(a) For this wave determine

(i) its amplitude. *[1]*

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(ii) its wavelength. *[1]*

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(b) The period of the wave is 0.2 s. What is the speed of the wave? *[2]*

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(c) If the above diagram shows the displacement of the cord at time $t = 0$, sketch on the same diagram the displacement of the rubber cord at time 0.1 s later. Explain your sketch. *[3]*

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(This question continues on the following page)

(Question B3 part 1 continued)

(d) The rubber cord is now stretched between two fixed points 2.5 m apart such that the tension in the cord is 50 N.

(i) On the diagram below sketch the shape of the standing (stationary) wave pattern produced when the cord is set to vibrate at its fundamental frequency. *[1]*

Undisturbed cord

(ii) The mass of the cord is 1.25 kg. Show that the fundamental frequency of vibration of the stretched cord is 2.0 Hz. *[5]*

(iii) What is the frequency of vibration of the first harmonic of the stretched cord? *[1]*

(This question continues on the following page)

(Question B3 continued)

Part 2. Radioactive decay

(a) Explain the term *half-life* as applied to radioactive decay. *[1]*

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(b) The isotope $^{220}_{86}\text{Rn}$ (radon) decays by α emission to an isotope of polonium. For this isotope of **polonium** determine

(i) the atomic number. *[1]*

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(ii) the number of neutrons in the nucleus. *[2]*

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(c) If the initial number of atoms in a sample of a radioactive isotope is N_0 then the number N remaining after a time t is given by the expression

$$N = N_0\,\mathrm{e}^{-\lambda t} \quad \text{where } \lambda \text{ is the decay constant.}$$

Show that the relation between the half-life $t_{½}$ and the decay constant is

$$t_{½} = \frac{\ln 2}{\lambda}.$$ *[4]*

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(d) Alpha radiation is an ionising radiation. Explain what is meant by the term *ionising radiation*. *[2]*

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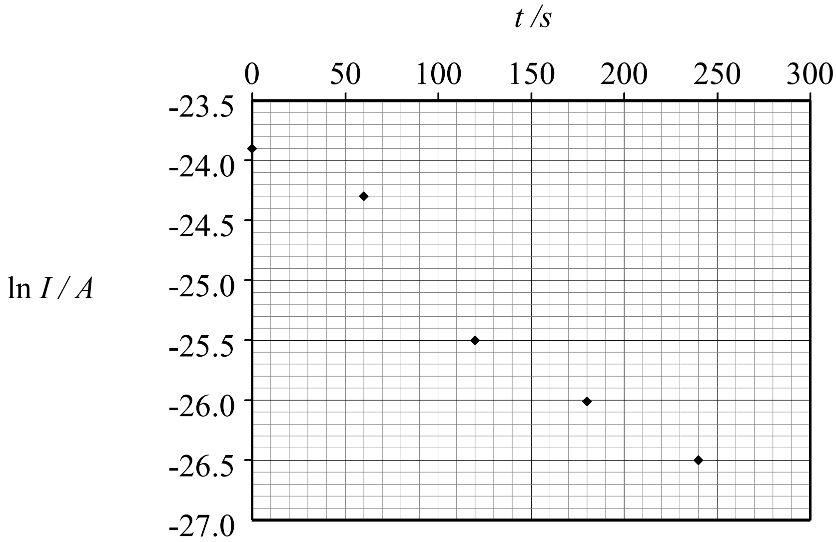
(This question continues on the following page)

(Question B3 part 2 continued)

(e) An experiment is set up to measure how the ionisation current I produced by the α-particles in the decay of radon gas varies with time t. The data obtained from the experiment is shown below plotted as a graph of ln (I) against t.



(i) On the above graph draw a best fit straight line for the data points. *[1]*

(ii) Determine the decay constant of radon from the graph. *[3]*

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(iii) Determine the half-life of radon. *[2]*

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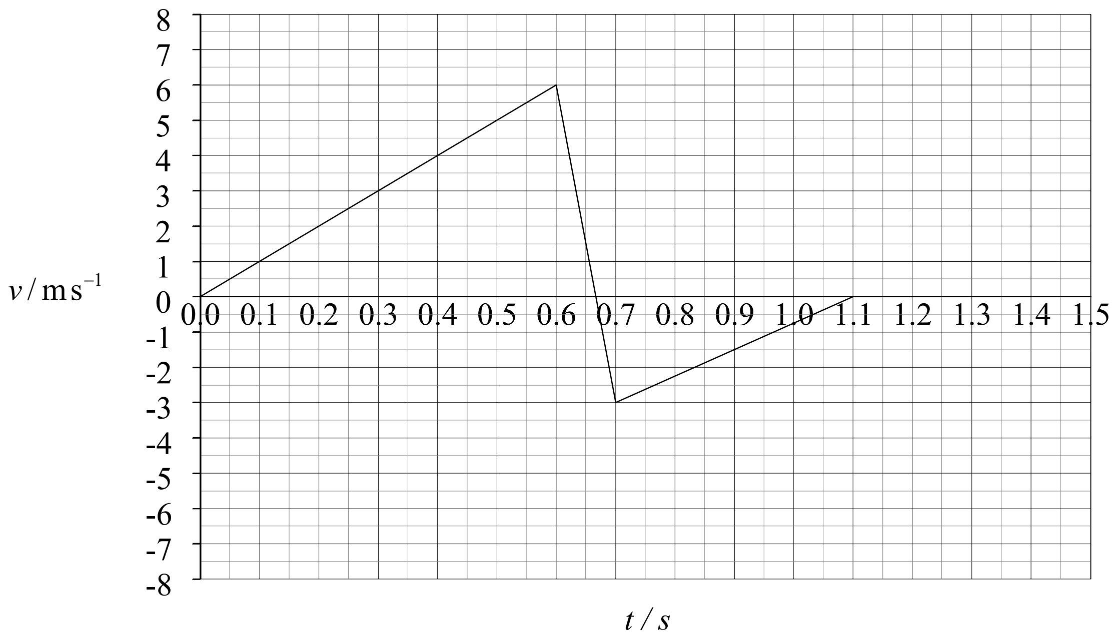
B4 . This question is in **two** parts. **Part 1** is about a bouncing ball and **Part 2** is about the thermodynamics of a refrigerator.

Part 1. The bouncing ball

A soft rubber ball of mass 0.20 kg is dropped from rest on to a flat horizontal surface and it is caught at its maximum height of rebound. A sonic data logger is used to record the velocity of the ball as a function of time. The graph below shows how the velocity of the ball varies with time t from the instant it is released to the instant that it is caught.



(a) Mark on the graph above the time t_1 where the ball hits the surface and the time t_2 where it just loses contact with the surface. *[2]*

(b) Use data from the graph above to find the change in momentum of the ball between t_1 and t_2. *[3]*

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(Question B4 part 1 continued)

(c) Determine the magnitude of the average force that the ball exerts on the surface. *[4]*

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(d) Explain how the collision between the ball and the surface is consistent with the principle of momentum conservation. *[2]*

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(e) A hard rubber ball of the same mass as the soft rubber ball is dropped from the same height as that from which the soft rubber ball was dropped.

Given that the hard rubber ball exerts a greater force on the surface than the soft rubber ball, sketch on the graph opposite how you think the velocity of the hard rubber ball will vary with time. *(Note that this is a sketch graph; you do not need to add any values.)* *[5]*

(This question continues on the following page)

(Question B4 continued)

Part 2. The refrigerator

The function of a refrigerator is to extract as much energy as possible from a cold reservoir with the least possible amount of work. To accomplish this the refrigerator operates in a cycle and during the cycle an amount of energy Q_c is extracted from a cold reservoir, an amount of energy Q_h is ejected into a hot reservoir and an amount of work W is done. This process is represented schematically in Diagram 1 below.

Diagram 2 shows an idealised relation between the pressure and volume of the working substance (*the refrigerant*) of the refrigerator as it is taken through one cycle. The isothermal and adiabatic processes of the cycle are indicated on the diagram.

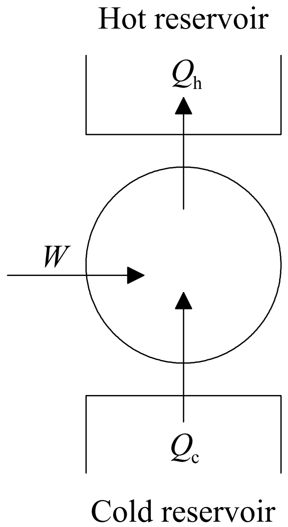

Diagram 1

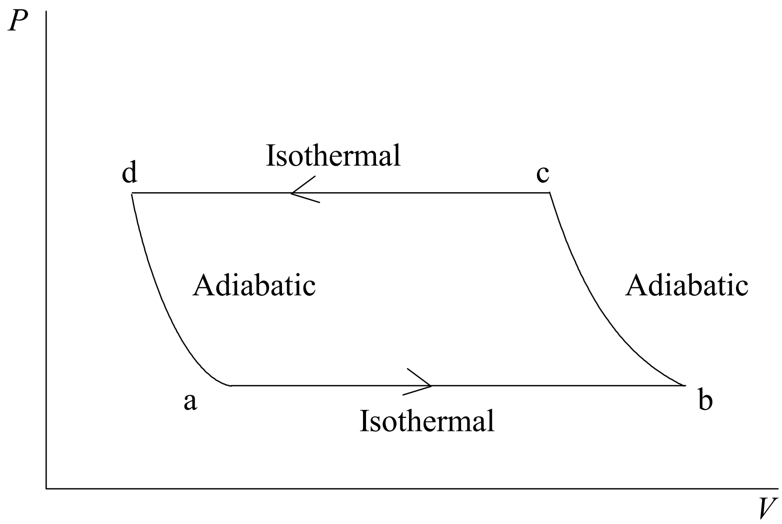

Diagram 2

(a) On Diagram 2 indicate during which stage(s) Q_c is absorbed from the cold reservoir and during which stage(s) Q_h is ejected to the hot reservoir. Explain your answers. *[6]*

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(Question B4 part 2 continued)

(b) The coefficient of performance of a refrigerator *(cop)* is defined as

$$cop = \frac{Q_c}{W}.$$

A particular refrigerator that uses an electric motor has a *cop* equal to five. Show that for every unit of energy used by the electric motor six units of energy will be ejected from the refrigerator to the surroundings. *[4]*

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(c) A refrigerator can in fact be adapted as a heat pump to heat the inside of a house.

(i) What in practice would be the cold reservoir of such a heat pump? *[1]*

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(ii) Explain with reference to the coefficient of performance of a heat pump why heating the inside of a house using a heat pump is likely to be cheaper than using conventional electrical heating elements. *[3]*

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