INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

PHYSICS
STANDARD LEVEL
PAPER 2

Friday 10 November 2000 (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.

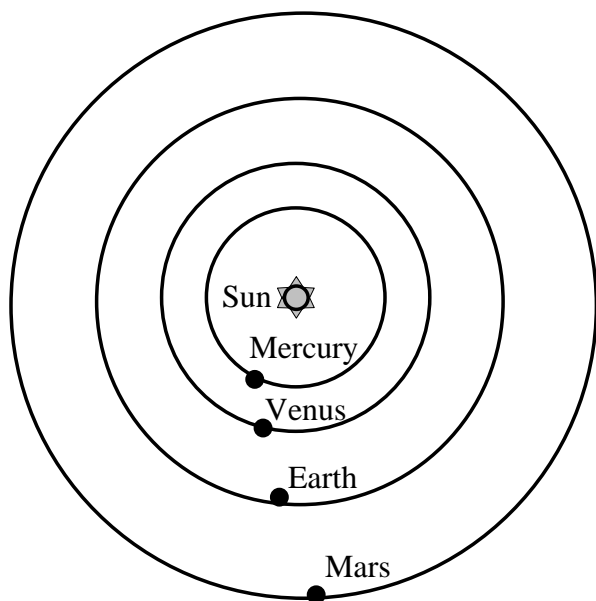| QUESTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
SECTION A	ALL	/25	/25	/25
SECTION B	. . . .	/25	/25	/25
		TOTAL /50	TOTAL /50	TOTAL /50

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SECTION A

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

A1. Planetary orbits: graphical analysis

The figure below shows the orbits of the four innermost planets around the Sun, with the orbit of Jupiter further out.

Orbits of the four innermost planets (not to scale)   Orbit of Jupiter

Kepler worked for many years to find a relation between the motions of the planets, examining possible combinations of factors that might be involved. Finally in 1619 he published his third law, stating that the squares of the orbital periods T are proportional to the cubes of the mean distances R from the Sun. That is, $T^2 = kR^3$, where k is a constant. To check if this relationship is valid we can plot T^2 versus R^3. Data for the four innermost planets is plotted opposite.

(This question continues on the following page)

(Question A1 continued)
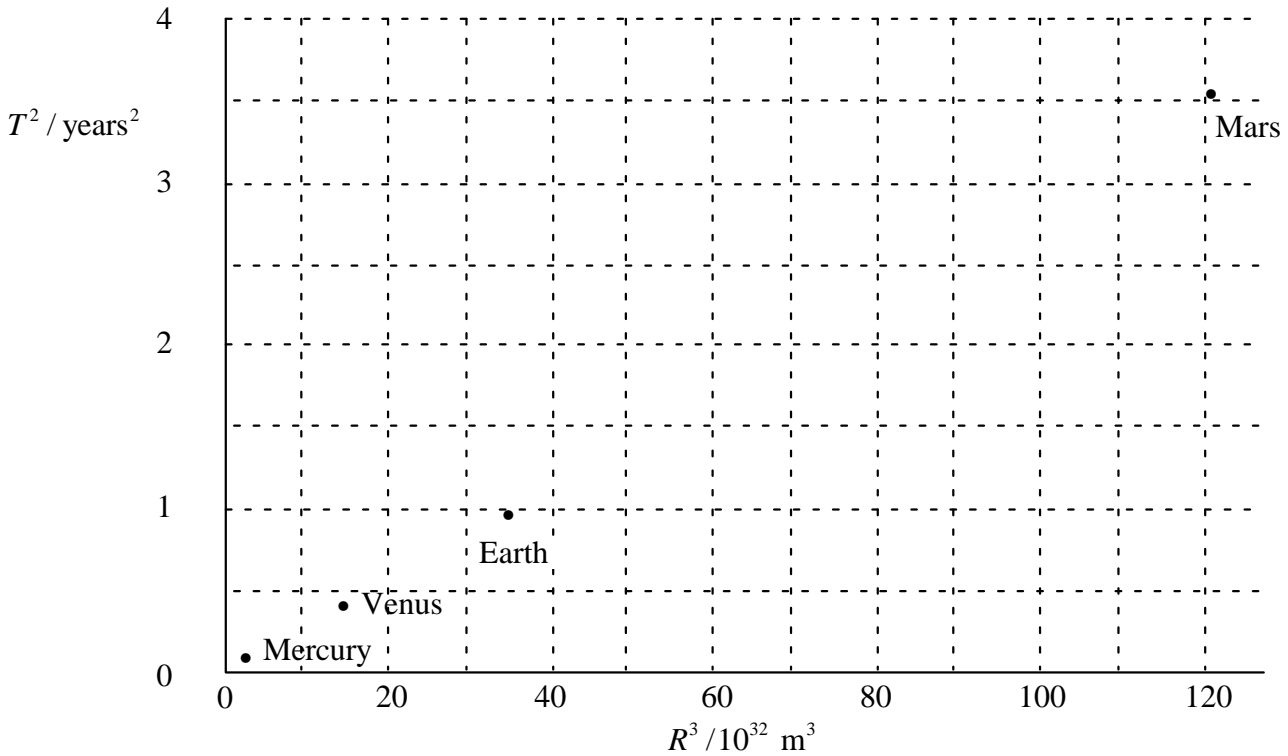
(a) Do the plotted points indicate that the motions of the innermost planets are consistent with the relationship proposed by Kepler?   Explain. *[1]*

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(b) From your graph, determine the value of the constant *k* in Kepler's relationship. Include the units. *[2]*

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(c) Jupiter, the first of the *outermost* planets, has an observed period of very nearly 12 years. Determine its mean distance from the Sun. *[3]*

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A2. Hoisting a container

A container of mass 2000 kg is hoisted by an electrically operated crane as shown in **Figure 1**, in order to be loaded onto a ship. Initially the container is accelerated upwards briefly, after which it is hoisted at a constant speed.
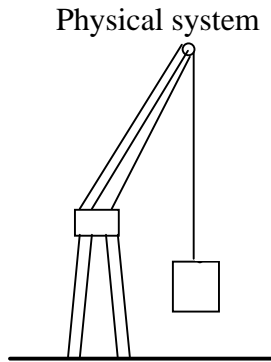
Physical system   Free-body diagram   Free-body diagram

Accelerating upwards

Moving upwards
at constant speed

Figure 1   **Figure 2**   **Figure 3**

(a) On **Figures 2** and **3** above, draw free-body force diagrams showing and labelling the forces acting on the container during the acceleration and constant velocity stages. Use longer vectors for greater forces. State what object exerts each force. *[3]*

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(b) The safety limit for the tension in the cable is 25000 N. Determine the maximum permissible upward acceleration of the container if the limit is not to be exceeded. *[2]*

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    ....

(c) After the initial acceleration, the crane continues hoisting the container at a constant upward speed of $0.5 \ \mathrm{m\,s^{-1}}$.

    (i) Calculate the power output of the crane during this stage. *[2]*

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    (ii) The crane's electric motor operates at 400 V. Assuming no power losses, calculate the current drawn by the motor during hoisting. *[2]*

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    (iii) Eventually the container reaches a height sufficient for loading onto the ship. What has become of the electrical energy supplied to the motor? *[1]*

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Turn over

A3. Electric circuit

This question involves physical reasoning and calculations for electric circuits.

Light bulbs are marked with the rating 10 V; 3 W. Suppose you connect three of the bulbs in series with a switch and a 30 V battery as shown in **Figure 1** below. Switch **S** is initially open.
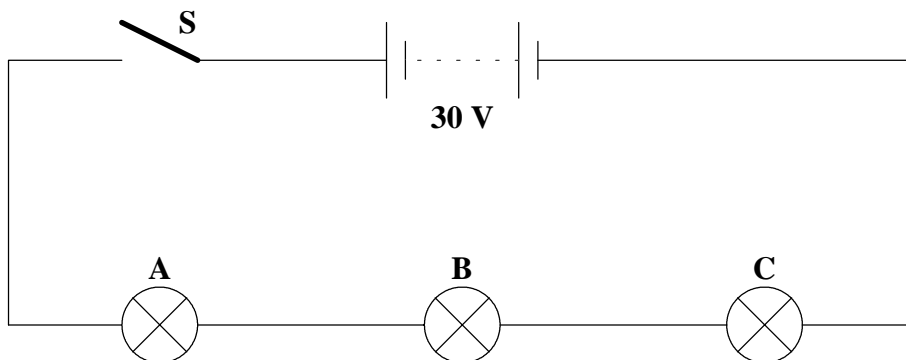

Figure 1

(a) A student tells you that after switch **S** is closed, bulb **C** will light up first, because electrons from the negative terminal of the battery will reach it first, and then go on to light bulbs **B** and **A** in succession. Is this prediction and reasoning correct? How would you reply?   *[2]*

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(b) State how the brightnesses of the three bulbs in the circuit will compare with each other.   *[1]*

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(Question A3 continued)

(c)   The student now connects a fourth bulb **D** across bulb **B** as shown in **Figure 2** below.

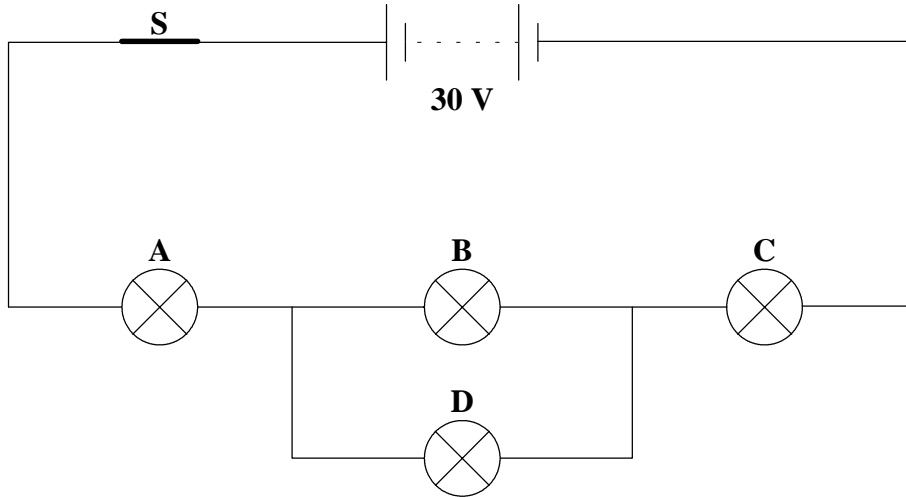**Figure 2**

When she connects **D**, what will happen to the brightnesses of bulbs **A**, **B** and **C**? Explain
your reasoning.   *[3]*

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(d)   Assuming that the resistance of the bulbs remains constant, calculate the power output of
bulb **B** in the modified circuit in **Figure 2**.   *[3]*

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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 collision and **Part 2** is about beats. Answer **both** parts if you choose **B1**.

Part 1. Collision between car and truck

A car and a truck are both travelling at the speed limit of $60 \ km\,h^{-1}$ but in opposite directions as shown. The truck has **twice** the mass of the car.

The vehicles collide head-on and become entangled together.

(a) During the collision, how does the force exerted by the car on the truck compare with the force exerted by the truck on the car? Explain.   *[2]*

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(b) In what direction will the entangled vehicles move after collision or will they be stationary? Support your answer, referring to a physics principle.   *[2]*

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(c) Determine the speed (in $km\,h^{-1}$) of the combined wreck immediately after the collision.   *[3]*

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(Question B1 Part 1 continued)

(d) How does the acceleration of the car compare with the acceleration of the truck during the collision? Explain. *[2]*

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(e) Both the car and truck drivers are wearing seat belts. Which driver is likely to be the more severely jolted in the collision? Explain. *[2]*

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(f) The total kinetic energy of the system decreases as a result of the collision. Is the principle of conservation of energy violated? Explain. *[1]*

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(Question B1 continued)

Part 2. Beats

This question is about the formation of beats in sound waves.

(a)   State the principle of linear superposition as applied to waves.   *[2]*

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Two tuning forks **A** and **B** of slightly different frequencies are sounded simultaneously, producing two sound waves of the same amplitude. The figure below shows the disturbance at a particular point in the air as a function of time for each of the tuning forks separately, and the resultant disturbance **C**.
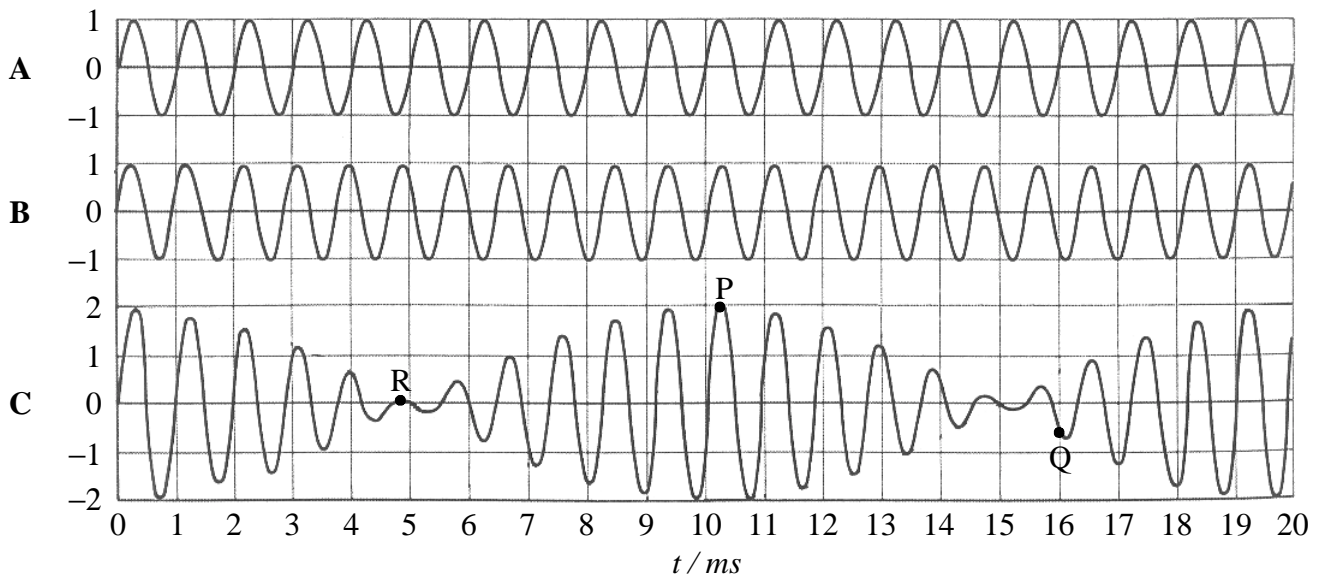
(b)   Three points on the resultant waveform are labelled **P**, **Q** and **R**. For **each** of these points, check whether the resultant waveform **C** as drawn is approximately correct, by referring to the two component waves. Explain in each case.   *[3]*

Point **P**: . . . .

Point **Q**: . . . .

Point **R**: . . . .

(This question continues on the following page)

(Question B1 Part 2 continued)

(c) Use the diagram to determine

(i) the frequencies of **A** and **B**; *[2]*

A: . . . .

B: . . . .

(ii) the beat frequency. *[2]*

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(d) (i) Beats at this frequency could not actually be perceived as beats by human hearing. Explain why. *[1]*

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(ii) In order that the beats become perceived as such by the ear, would the difference in frequency between **A** and **B** have to be greater or smaller than in the case above? *[1]*

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(e) Explain how use could be made of beats to tune a guitar string against a tuning fork. *[2]*

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B2. This question is in **two** parts. **Part 1** is about a stone projected upwards and **Part 2** is about Rutherford scattering. Answer **both** parts if you choose **B2**.

**Part 1.** Stone projected upwards from a cliff

A stone is projected almost vertically upwards at $20 \ \mathrm{m s^{-1}}$ from the edge of a cliff as shown. It finally lands on the ground at the base of the cliff. The sequence diagram below shows the position of the stone at one-second intervals. Image 0 is just after projection, and Image 5 is just before landing. Gravitational acceleration is taken as $10 \ \mathrm{m s^{-2}}$ and air resistance is ignored.
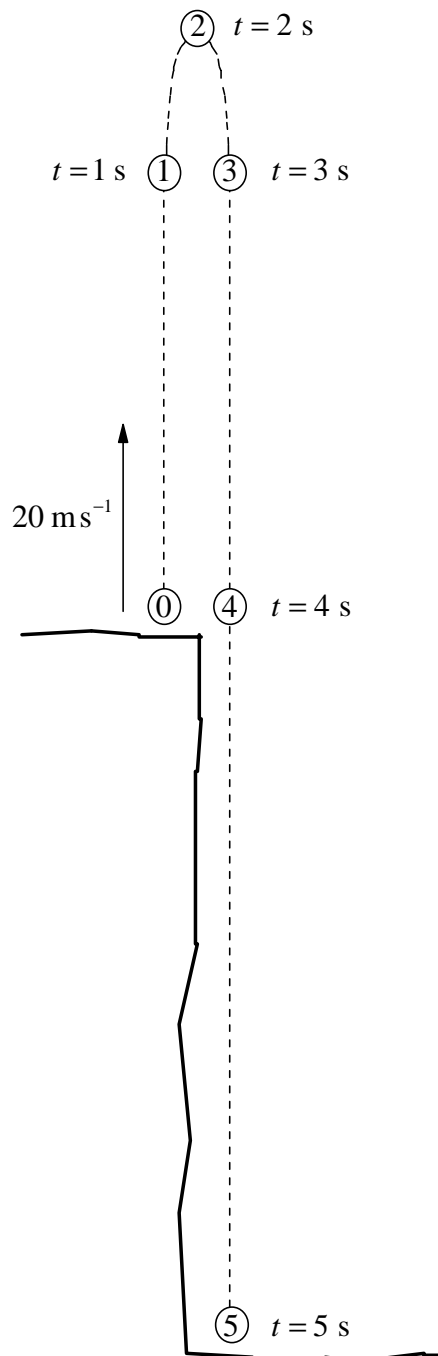
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(Question B2 Part 1 continued)

(a)   State whether the stone's acceleration is upward, downward or zero in each of the following cases:

   (i)   when the stone is on its way **up** . . . .

   (ii)   when the stone is on its way **down** . . . .

   (iii) when the stone is at the **top** of its path . . . .   *[3]*

(b)   Next to each of the six images draw in a vector to represent the **instantaneous velocity** at that stage of the motion. The vector at image 0 has been drawn in for you. Pay attention to the direction and relative lengths of the vectors, and label them with their magnitudes in ms^{-1}.   *[3]*

(c)   Draw a velocity–time graph to represent the motion of the stone. On the graph label the stages representing **upwards motion** and **downwards motion**, and label the **topmost point** of the motion.   *[3]*

$v/\mathrm{m\,s}^{-1}$
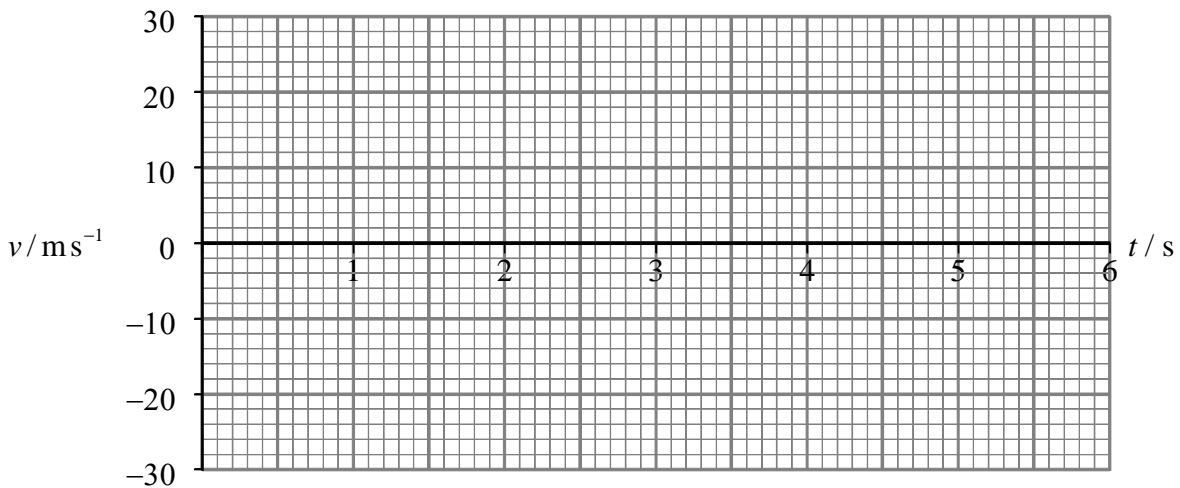
(d)   What does the gradient of the graph represent?   *[1]*

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(e)   Determine the height of the cliff.   *[3]*

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(Question B2 continued)

Part 2. Rutherford scattering and a nuclear reaction

In 1911 Geiger and Marsden bombarded a thin gold foil with alpha particles from a radioactive source.

Radioactive source ○ ===⟶ Gold foil
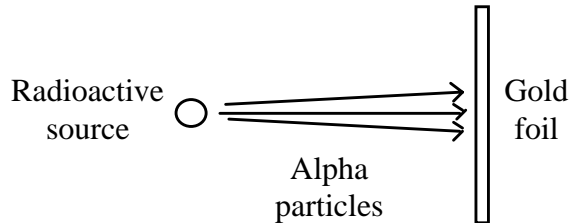
Alpha particles

(a) Based on ideas about atoms at the time, physicists had expected that the alpha particles would go through the atoms in the foil with very little deflection. They were astonished that some alpha particles were scattered almost completely backward. What did Rutherford conclude from this about the structure of the atom? Explain. *[2]*

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The diagram below shows four alpha particles approaching a gold nucleus. The deflected path of one of them (α_2) is shown. Assume that any recoil of the gold nucleus can be neglected.

Alpha particles   Gold nucleus

α_4 ⟶● ⟶ – – – – – – – – ● – – – – – – – – –

α_3 ⟶● ⟶

k

α_2 ⟶● ⟶ ● l

α_1 ⟶● ⟶

m
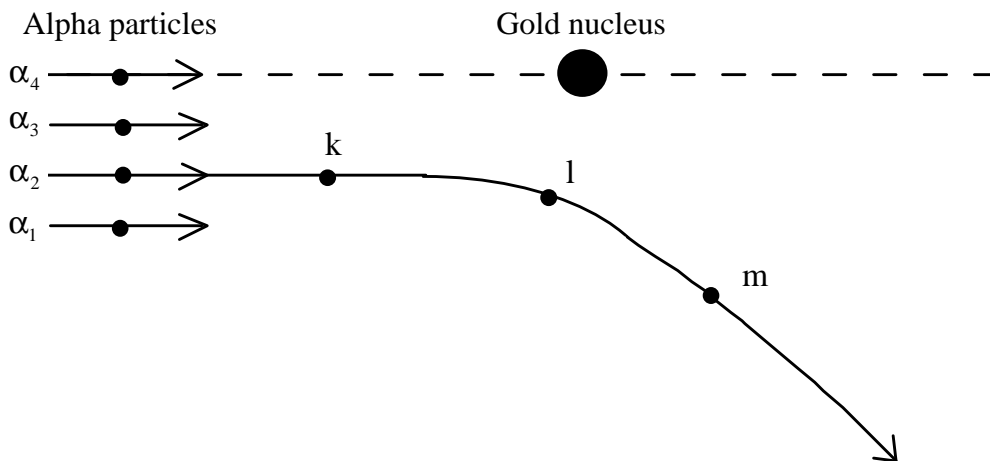
(b) Draw in the force(s) acting on alpha particle α_2 when it is at the positions labelled k, l and m. Your force vectors should be of the right relative lengths, given that points k and m are **twice** as far from the nucleus as l is. State the source of any forces you show. *[2]*

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(Question B2 Part 2 continued)

(c) As α_2 travels the path shown, describe what happens to its electric potential energy, kinetic energy and total energy. The recoil energy of the gold nucleus is negligible. *[2]*

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(d) On the diagram, sketch the approximate paths of the three other alpha particles labelled α_1, α_3 and α_4. Explain the paths you have drawn. *[4]*

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(e) For target nuclei of lower atomic number, alpha particles may reach the nucleus and a nuclear reaction may occur. Thus when alpha particles bombard the light element beryllium, neutrons are produced.
Complete the equation for the reaction of beryllium with an alpha particle. Include all the atomic and mass numbers. *[2]*

$$^{9}_{4}\text{Be} \quad + \quad \text{He} = \quad \text{n} \quad +$$

Turn over

B3. This question is in **three** parts. **Part 1** is about mixing ice and water, **Part 2** is about charging processes and **Part 3** is about electromagnetic induction. Answer **all three** parts if you choose **B3**.

Part 1. Mixing ice and water

2 kg of ice from a freezer at $-15\,^{\circ}$C is mixed with 10 kg of water at $30\,^{\circ}$C.

(a) Determine the final temperature of the mixture after equilibrium is reached. Energy losses to the environment are negligible. *[4]*

Data:

Specific heat capacity of ice: 2.1×10^3 J kg^{-1} $^{\circ}$C^{-1}
Specific heat capacity of water: 4.2×10^3 J kg^{-1} $^{\circ}$C^{-1}
Specific latent heat of melting of ice: 3.4×10^5 J kg^{-1}

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(b) In the stage of the process while the ice is melting, it absorbs energy but its temperature does not increase. Explain, from the molecular point of view, how this can be consistent with the principle of conservation of energy. State what becomes of the energy absorbed. *[3]*

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(Question B3 continued)

Part 2. Charging processes

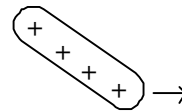This question is about two electrostatic charging processes.

(a)   A rubber rod R is originally uncharged. When rubbed with fur, the rod becomes positively charged. Explain **briefly** how the net positive charge arises on the rod. *[1]*
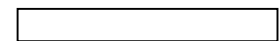
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(b)   We now wish to use the positively charged rubber rod to charge a metal rod by **electrostatic induction**. The diagrams below show the steps in the process. For each step, state what happens and draw the charge distribution in the metal rod. *[4]*

Metal rod

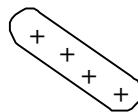(i)   The charged rubber rod is brought close to the metal rod.

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(ii)   The metal rod is connected to earth.

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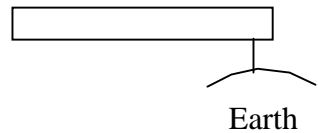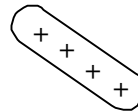
Earth

(iii)   The earth connection is removed.

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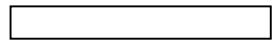
(iv)   The rubber rod is removed.

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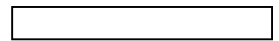
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(Question B3 Part 2 continued)

(c)   The charged rubber rod can continue to be used to charge additional metal rods by induction. How is this consistent with the principle of charge conservation? Explain, accounting for all charge before and after the process. *[2]*
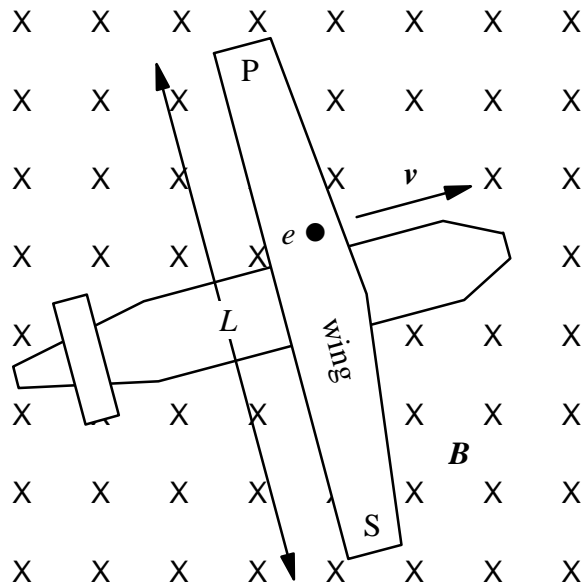
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(Question B3 continued)

Part 3. Electromagnetic induction

A jet aeroplane is flying with velocity *v* at right angles to the Earth's magnetic field *B* near the North pole of the Earth, as shown in the plan view below. The plane's wingspan (distance between wingtips) is *L*. The wingtips are labelled P (port) and S (starboard).

(a) Consider an electron of charge magnitude *e* in the metal wing of the plane at the point shown by a dot in the figure.

   (i) In what direction will this electron experience a magnetic force due to its motion in the magnetic field? Draw a vector on the diagram to represent the force. *[1]*

   (ii) State an expression for the magnitude of the force on the electron in this situation. *[1]*

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(This question continues on the following page)

Turn over

(Question B3 Part 3 continued)

(b) While the plane is flying steadily in the magnetic field, the electrons in the wing experience this magnetic force but do not move along the wing; such motion is opposed by an *electric* field arising in the wing.

    (i) Explain how this electric field originates, and draw a vector in the diagram to show its direction. *[2]*

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    (ii) Explain why the electric force on the electron is **exactly** equal to the magnetic force, in this situation. (Hint: imagine this were not the case and consider what would happen next.) *[2]*

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(c) Show that the magnitude of the electric field produced in the wing is given by $E = vB$. *[1]*

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(d) Calculate the magnitude of the electric field when the plane flies at $200 \ \mathrm{m\,s^{-1}}$ ($720 \ \mathrm{km\,hr^{-1}}$) in the Earth's field of 8×10^{-5} T near the pole. *[1]*

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(e) Would the effect still arise if the plane were flying near the Equator? Explain. *[1]*

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(f) Will there also be a potential difference between the *nose* and the *tail* of the plane? Explain why or why not. *[2]*

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