22096514

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

PHYSICS
HIGHER LEVEL
PAPER 2

Tuesday 12 May 2009 (afternoon)

2 hours 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session 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 questions answered in the candidate box on your cover sheet.

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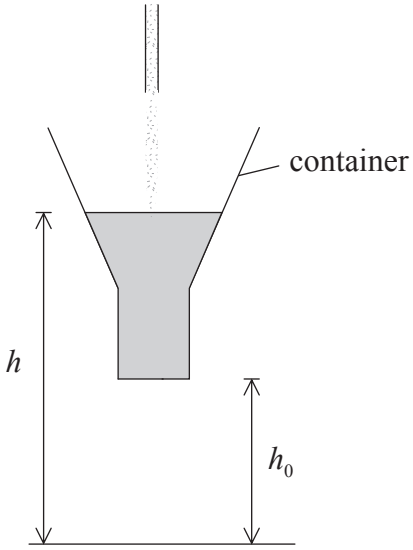
SECTION A

*Answer **all** the questions in the spaces provided.*

A1. This question is about liquid flow.

The diagram shows a storage container for liquids.

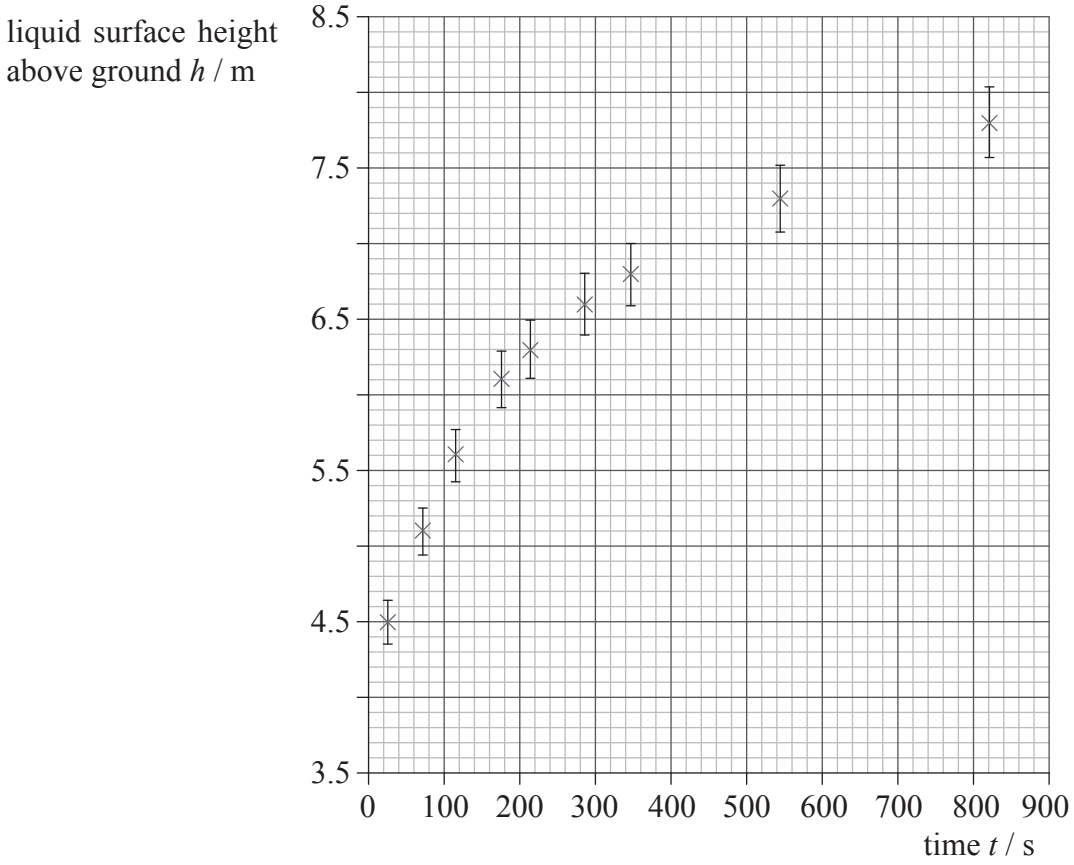


The container is filled from above. The distance between the base of the container and the ground is h_0.

(This question continues on the following page)

(Question A1 continued)

The container, which is initially empty, is then filled at a **constant** rate. The height h of the liquid surface above the ground is measured as a function of time t. The results of the measurements are shown plotted below.



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

(b) State and explain whether h is directly proportional to t for the periods

(i) $t = 0$ to $t = 120\,\text{s}$. *[1]*

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(ii) $t > 120\,\text{s}$. *[1]*

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(This question continues on the following page)

(Question A1 continued)

(c) Use data from the graph to determine the value of h_0. *[2]*

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(d) The area of the base of the container is $1.8\,m^2$. Deduce that the volume of liquid entering the storage container each second is approximately $0.02\,m^3\,s^{-1}$. *[3]*

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(e) The container is completely filled after 850 s. Calculate the total volume of the container. *[1]*

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(Question A1 continued)

(f) It is hypothesized that for $t > 400\,\text{s}$ the relation between t and h is of the form

$$h = kt^n$$

where k and n are constants.

(i) Outline how, using a graphical technique, you would verify this hypothesis. *[2]*

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(ii) Explain how you would determine the value of n. *[1]*

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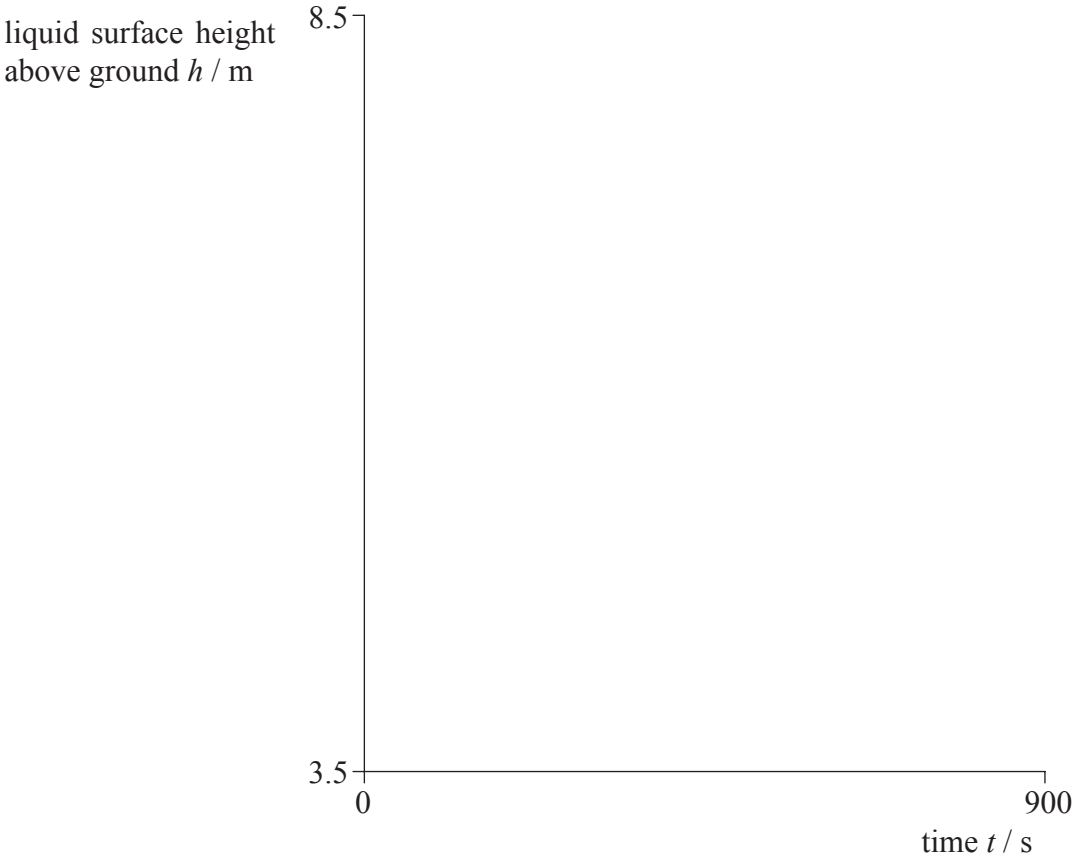
(Question A1 continued)

(g) The empty container is now filled at half the rate in (d). Using the axes, sketch a graph to show the variation of h with t in the range $t = 0$ to $t = 900\,\text{s}$. *[2]*



A2. This question is about electrical resistance.

(a) A heating coil is to be made of wire of diameter 3.5×10^{-4} m. The heater is to dissipate 980 W when connected to a 230 V d.c. supply. The material of the wire has resistivity $1.3 \times 10^{-6}\,\Omega$m at the working temperature of the heater.

(i) Define *electrical resistance*. *[1]*

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(ii) Calculate the resistance of the heating coil at its normal working temperature. *[2]*

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(iii) Show that the length of wire needed to make the heating coil is approximately 4 m. *[2]*

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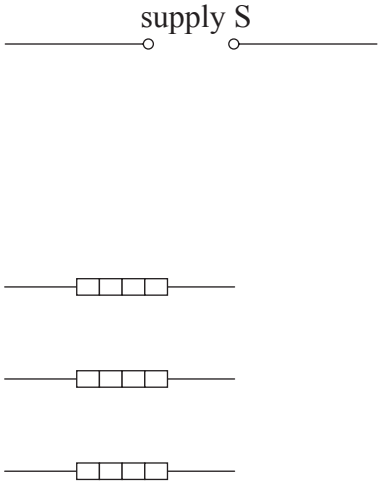
(This question continues on the following page)

(Question A2 continued)

(b) Three identical electrical heaters each provide power P when connected separately to a supply S which has zero internal resistance. On the diagram below, complete the circuit by drawing **two** switches so that the power provided by the heaters may be **either** P **or** $2P$ **or** $3P$. *[2]*



A3. This question is about force fields.

(a) Outline what is meant by a field of force. *[2]*

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(b) Three particles A, B, and C are each placed in a different type of field. Complete the table to identify the nature of the field in which each particle is situated. *[3]*

Particle	Charge on particle	Initial direction of motion of particle	Direction of force on particle	Type of field
A	uncharged	stationary	in direction of field	. . . . .
B	negative	along direction of field	opposite to direction of field	. . . . .
C	positive	normal to direction of field	normal to direction of field	. . . . .

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A4. This question is about wave power.

(a) Outline how the energy of a wave can be converted to electrical energy. *[2]*

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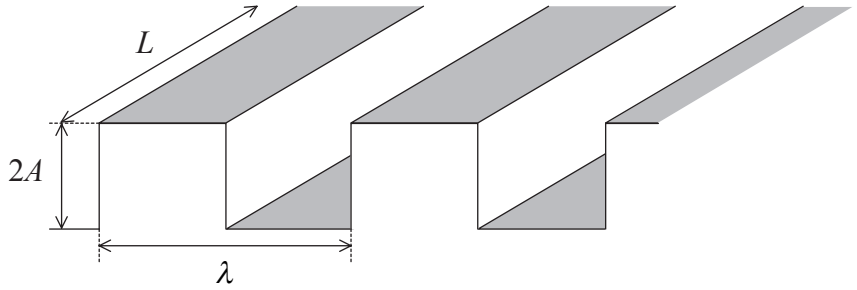
(b) A wave on the surface of water is assumed to be a square-wave of height $2A$, as shown.



The wave has wavelength λ, speed v and has a wavefront of length L. For this wave,

(i) show that the gravitational potential energy E_P stored in one wavelength of the wave is given by

$$E_P = \tfrac{1}{2} A^2 \lambda g \rho L$$

where ρ is the density of the water and g is the acceleration of free fall. *[3]*

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(ii) deduce that the gravitational wave power P per unit length of the wavefront is given by

$$P = \tfrac{1}{2} A^2 v g \rho$$ *[2]*

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(This question continues on the following page)

(Question A4 continued)

(c) The density of sea-water is $1.2 \times 10^3\,\text{kg}\,\text{m}^{-3}$. Using the expression in (b)(ii), estimate the gravitational power per metre length available in a wave of height 0.60 m. *[2]*

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(d) In practice a water wave is approximately sinusoidal in cross-section. Outline whether a sine wave of the same height as in (b) transfers a greater **or** a smaller amount of power than that derived in (b)(ii). *[2]*

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A5. This question is about charge-coupled devices (CCD).

(a) With reference to a CCD, state what is meant by a pixel. *[2]*

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(b) Outline how light falling on a CCD leads to an electrical signal being produced by a pixel. *[3]*

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(c) State **one** other piece of information that needs to be collected, in addition to the electrical signal in (b), in order that an image may be formed. *[1]*

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(d) Suggest **two** advantages of a CCD in comparison with a photographic film for image production. *[2]*

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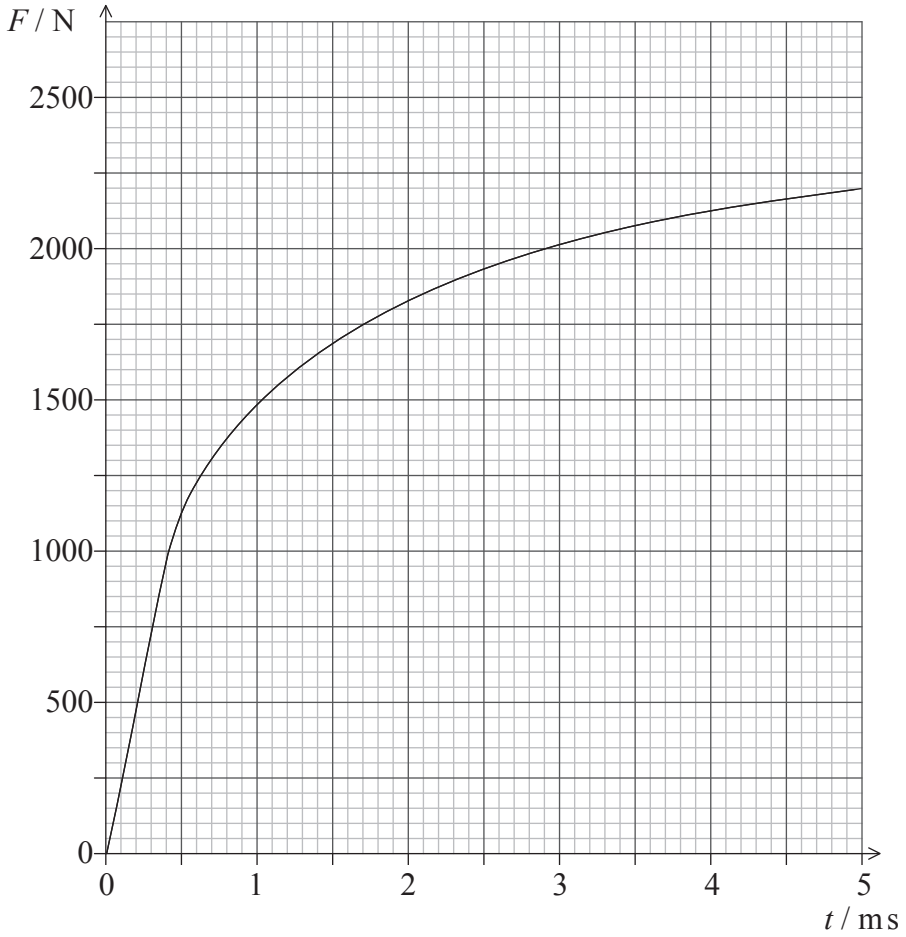
SECTION B

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

B1. This question is in **two** parts. **Part 1** is about dynamics and energy. **Part 2** is about the motion of a charged particle in an electric field.

Part 1 Dynamics and energy

A bullet of mass 32 g is fired from a gun. The graph shows the variation of the force F on the bullet with time t as it travels along the barrel of the gun.



The bullet is fired at time $t = 0$ and the length of the barrel is 0.70 m.

(This question continues on the following page)

(Question B1, part 1 continued)

(a) State and explain why it is inappropriate to use the equation $s = ut + \frac{1}{2}at^2$ to calculate the acceleration of the bullet. *[2]*

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(b) Use the graph to

(i) determine the average acceleration of the bullet during the final 2.0 ms of the graph. *[2]*

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(ii) show that the change in momentum of the bullet, as the bullet travels along the length of the barrel, is approximately 9 N s. *[3]*

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(Question B1, part 1 continued)

(c) Use the answer in (b)(ii) to calculate the

(i) speed of the bullet as it leaves the barrel. *[2]*

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(ii) average power delivered to the bullet. *[3]*

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(d) Use Newton's third law to explain why a gun will recoil when a bullet is fired. *[3]*

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(Question B1 continued)

Part 2 Motion of a charged particle in an electric field

(a) An α-particle of mass $4u$ and charge $+2e$ is accelerated from rest in a vacuum through a potential difference of 2.4 kV. Show that the final speed of the α-particle is $4.8 \times 10^5 \text{ m s}^{-1}$. *[2]*

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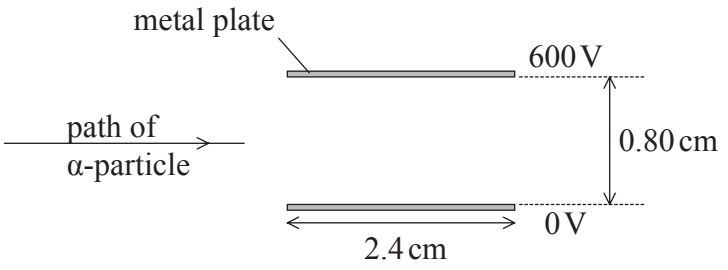
(b) The α-particle is travelling in a direction parallel to and mid-way between two parallel metal plates.



(not to scale)

The metal plates are of length 2.4 cm and their separation is 0.80 cm. The potential difference between the plates is 600 V. The electric field is uniform in the region between the plates and is zero outside this region.

(i) Calculate the magnitude of the electric field between the plates. *[2]*

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(ii) Show that the magnitude of the acceleration of the α-particle by the electric field is $3.6 \times 10^{12} \text{ m s}^{-2}$. *[2]*

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(Question B1, part 2 continued)

(c) (i) Calculate the time taken for the α-particle to travel a horizontal distance of 2.4 cm parallel to the plates. *[1]*

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(ii) Use your answers in (b)(ii) and (c)(i) to deduce whether, as the α-particle passes between the plates, it will hit one of the plates. *[3]*

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B2. This question is in **two** parts. **Part 1** is about ideal gases. **Part 2** is about the use of fossil fuels.

Part 1 Ideal gases

(a) The atoms or molecules of an ideal gas are assumed to be identical hard elastic spheres that have negligible volume compared with the volume of the containing vessel.

(i) State **two** further assumptions of the kinetic theory of an ideal gas. *[2]*

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2. . . . . .
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(ii) Suggest why only the average kinetic energy of the molecules of an ideal gas is related to the internal energy of the gas. *[3]*

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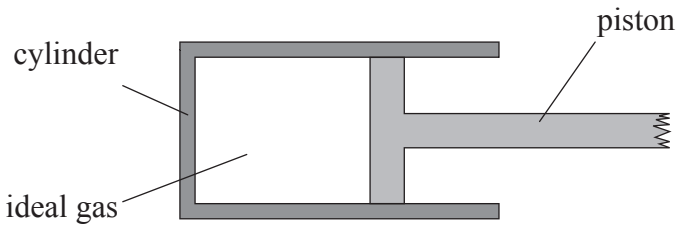
(Question B2, part 1 continued)

(b) An ideal gas is contained in a cylinder by means of a frictionless piston.



At temperature 290 K and pressure 4.8×10^5 Pa, the gas has volume 9.2×10^{-4} m^3.

(i) Calculate the number of moles of the gas. *[2]*

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(ii) The gas is compressed isothermally to a volume of 2.3×10^{-4} m^3. Determine the pressure p of the gas. *[2]*

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(iii) The gas is now heated at constant volume to a temperature of 420 K. Show that the pressure of the gas is now 2.8×10^6 Pa. *[1]*

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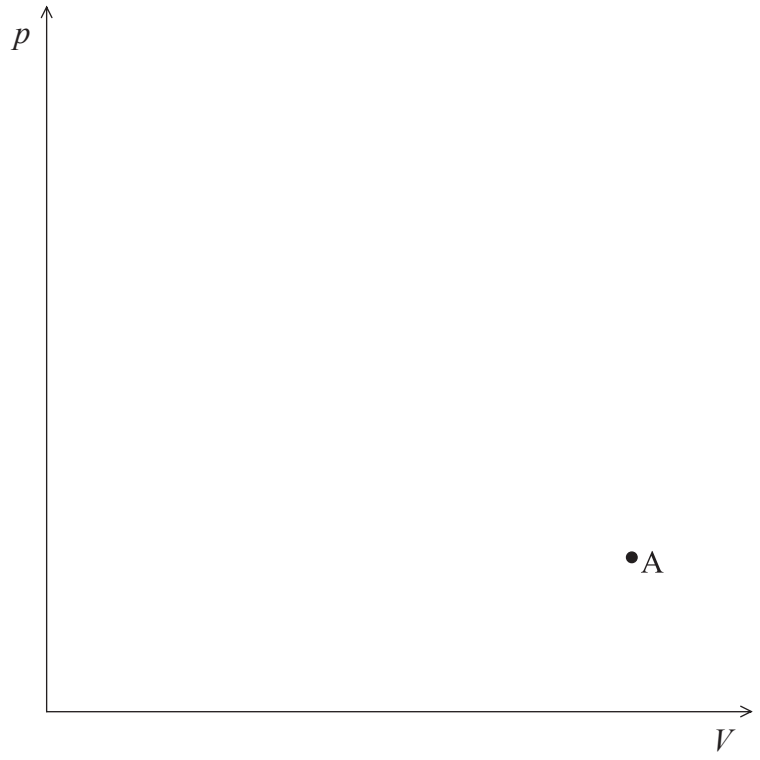
(This question continues on the following page)

(Question B2, part 1 continued)

(c) The gas in (b)(iii) is now expanded adiabatically so that its temperature and pressure return to 290 K and 4.8×10^5 Pa respectively. This state is shown below as point A.



(i) Using the axes above sketch a pressure-volume (p-V) diagram for the changes in (b)(ii), (b)(iii) and (c). *[3]*

(ii) On your diagram in (c)(i), identify with the letter H any change **or** changes where the gas does external work on its surroundings. *[1]*

(iii) Describe how a p-V diagram may be used to estimate a value for the useful work done in one cycle of operation of an engine. *[2]*

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(This question continues on the following page)

(Question B2 continued)

Part 2 Fossil fuels

(a) State **two** examples of fossil fuels. *[2]*

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2. . . . . .

(b) Explain why fossil fuels are said to be non-renewable. *[2]*

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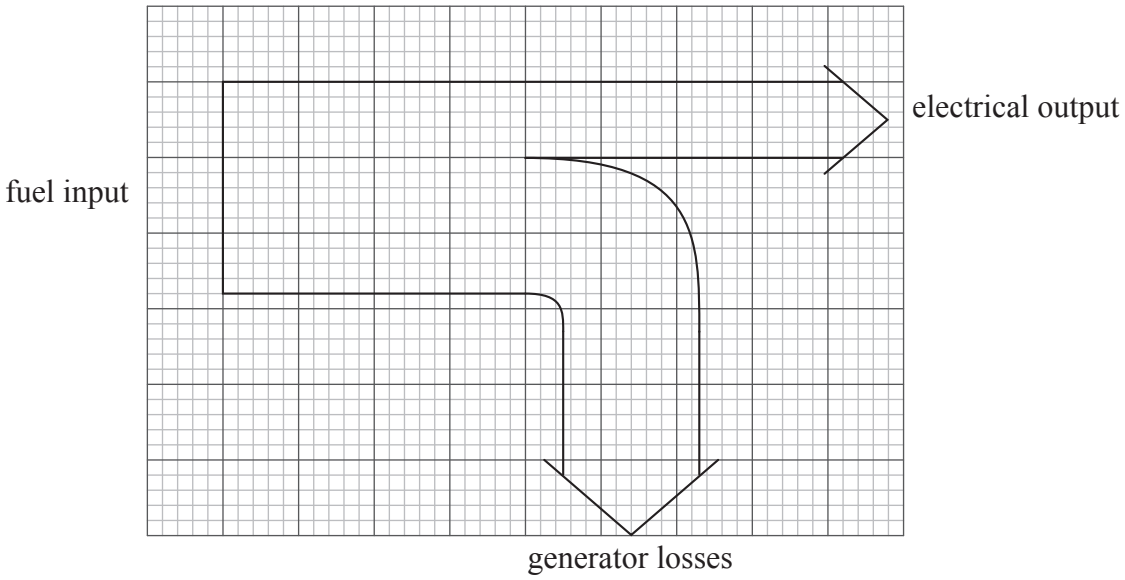
(c) A Sankey diagram for the generation of electrical energy using fossil fuel as the primary energy source is shown.



Use the Sankey diagram to estimate the efficiency of production of electrical energy and explain your answer. *[2]*

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(This question continues on the following page)

(Question B2, part 2 continued)

(d) Despite the fact that fossil fuels are non-renewable and contribute to atmospheric pollution there is widespread use of such fuels. Suggest **three** reasons for this widespread use. *[3]*

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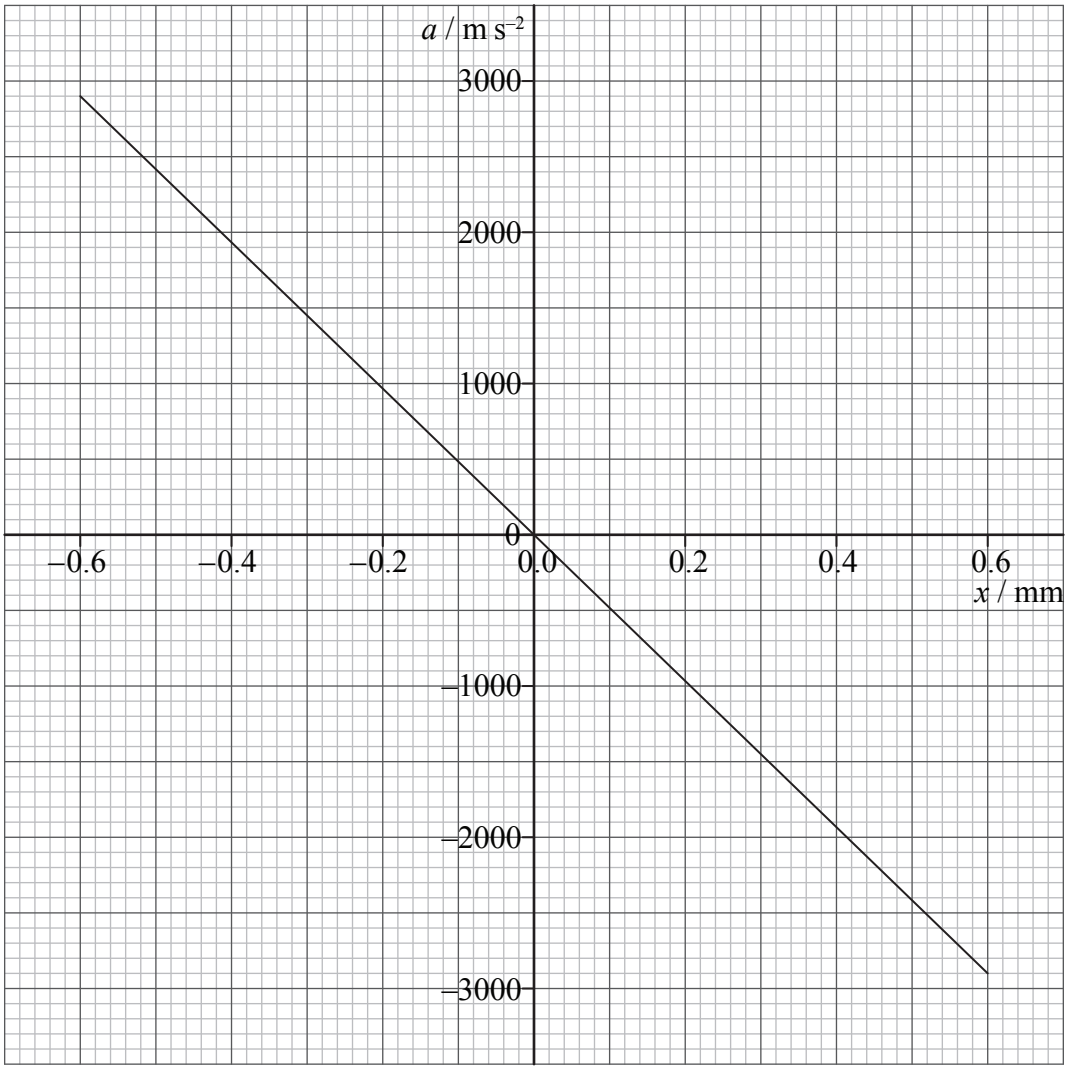
B3. This question is in **two** parts. **Part 1** is about simple harmonic motion and waves. **Part 2** is about the diffraction of light.

Part 1 Simple harmonic motion and waves

An object is vibrating in air. The variation with displacement x of the acceleration a of the object is shown below.



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(Question B3, part 1 continued)

(a) State and explain **two** reasons why the graph opposite indicates that the object is executing simple harmonic motion. *[4]*

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(b) Use data from the graph to show that the frequency of oscillation is 350 Hz. *[4]*

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(c) The motion of the object gives rise to a longitudinal progressive (travelling) sound wave.

(i) State what is meant by a longitudinal progressive wave. *[2]*

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(ii) The speed of the wave is $330\,m\,s^{-1}$. Using the answer in (b), calculate the wavelength of the wave. *[2]*

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(This question continues on the following page)

(Question B3 continued)

Part 2 Diffraction of light

(a) (i) Describe what is meant by the diffraction of light. *[2]*

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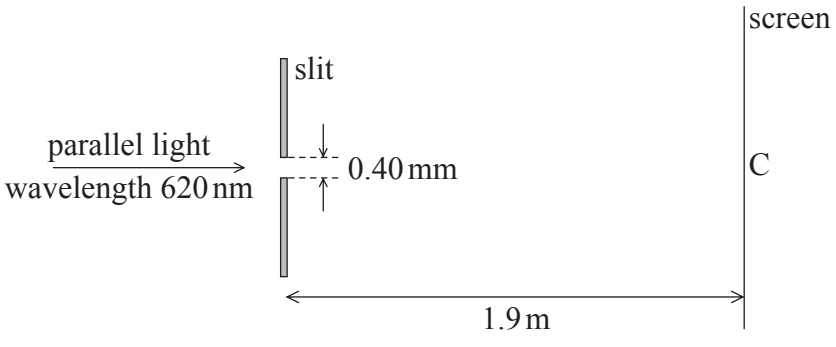
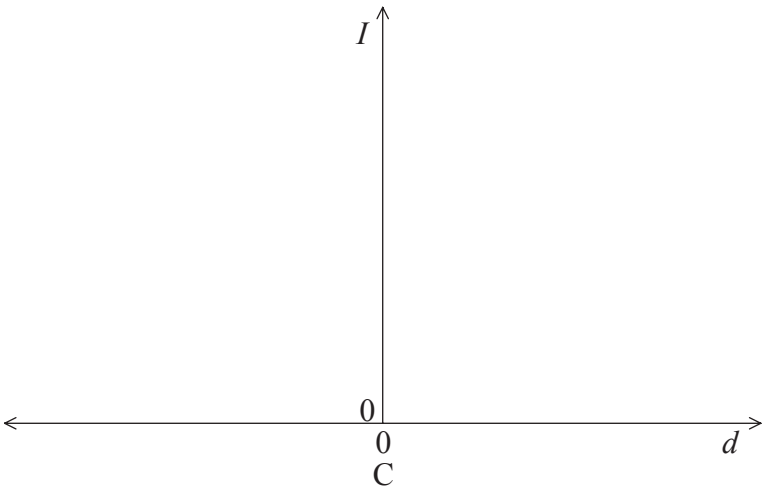
(ii) A parallel beam of monochromatic light from a laser is incident on a narrow slit. The diffracted light emerging from the slit is incident on a screen.



(not to scale)

The centre of the diffraction pattern produced on the screen is at C. On the axes sketch a graph to show how the intensity I of the light on the screen varies with the distance d from C. *[3]*



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(Question B3, part 2 continued)

(iii) The slit width is 0.40 mm and it is 1.9 m from the screen. The wavelength of the light is 620 nm. Determine the width of the central maximum on the screen. *[3]*

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(b) (i) When two separate lasers are used as sources, the images of the slit formed by the light from each laser are resolved. State what is meant by the term resolved in this context. *[1]*

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(ii) A car, with its two headlights switched on, is approaching an observer who has good eyesight. Outline why, at a long distance from the observer, the images of the headlights of the car are not resolved by the observer. *[4]*

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B4. This question is in **two** parts. **Part 1** is about α-particle scattering and nuclear processes. **Part 2** is about the albedo of the Earth.

Part 1 α-particle scattering and nuclear processes

Radium-226 decays with the emission of α-particles to radon (Rn).

(a) Complete the nuclear reaction equation. *[2]*

$$^{226}_{88}\text{Ra} \rightarrow \qquad \text{Rn} \quad +$$

(b) The decay constant of radium-226 is $1.4 \times 10^{-11}\,\text{s}^{-1}$ and each emitted α-particle has an energy of $7.6 \times 10^{-13}\,\text{J}$.

(i) Calculate the half-life of radium-226. *[1]*

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(ii) Determine the rate, in watts, of emission of energy from 1.0 g of radium-226. *[4]*

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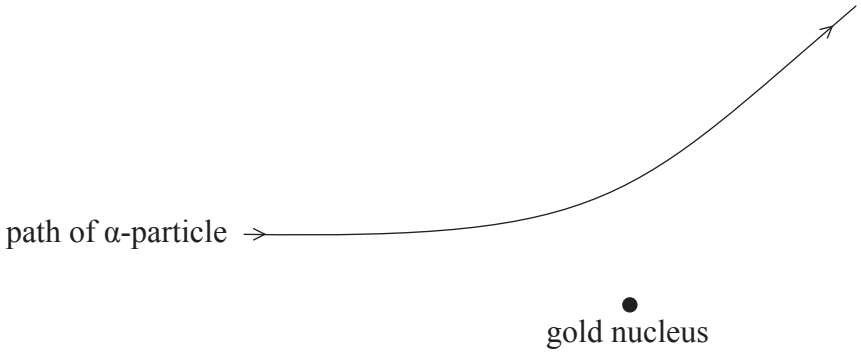
(Question B4, part 1 continued)

(c) Experimental evidence that supports a nuclear model of the atom was provided by α-particle scattering. The diagram represents the path of an α-particle as it approaches and then recedes from a stationary gold nucleus.



(i) On the diagram, draw lines to show the angle of deviation of the α-particle. Label this angle *D*. *[1]*

(ii) The gold nucleus is replaced by another gold nucleus that has a larger nucleon number. Suggest and explain the change, if any, in the angle *D* of an α-particle with the same energy and following the same initial path as in (c)(i). *[2]*

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(d) Estimate the distance of closest approach to a gold nucleus ($Z = 79$) of an α-particle with an initial kinetic energy of 4.0 MeV. *[3]*

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(This question continues on the following page)

(Question B4 continued)

Part 2 Albedo of the Earth

(a) Outline the mechanism by which a gas, such as carbon dioxide, absorbs infra-red radiation. *[2]*

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(b) State, with reference to your answer in (a), why carbon dioxide is known as a greenhouse gas. *[1]*

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(c) State the **name** of another greenhouse gas. *[1]*

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(d) In the last fifty years the amount of carbon dioxide in the Earth's atmosphere has increased significantly. Explain

(i) why this increase could account for global warming. *[1]*

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(ii) what effect this has had on the average albedo of the Earth. *[3]*

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(This question continues on the following page)

(Question B4, part 2 continued)

(e) It has been estimated that doubling the amount of carbon dioxide in the Earth's atmosphere changes the albedo of the Earth by 0.01. Use the data to show that this doubling will lead to a change of about $3\,\text{W}\,\text{m}^{-2}$ in the intensity being reflected by the Earth into space. *[3]*

Average intensity received at Earth from the Sun $= 340\,\text{W}\,\text{m}^{-2}$
Average albedo $= 0.30$

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(f) State **one** reason why the answer to (e) is an estimate. *[1]*

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