22106508

International Baccalaureate
Baccalauréat International
Bachillerato Internacional

PHYSICS
HIGHER LEVEL
PAPER 2

Monday 10 May 2010 (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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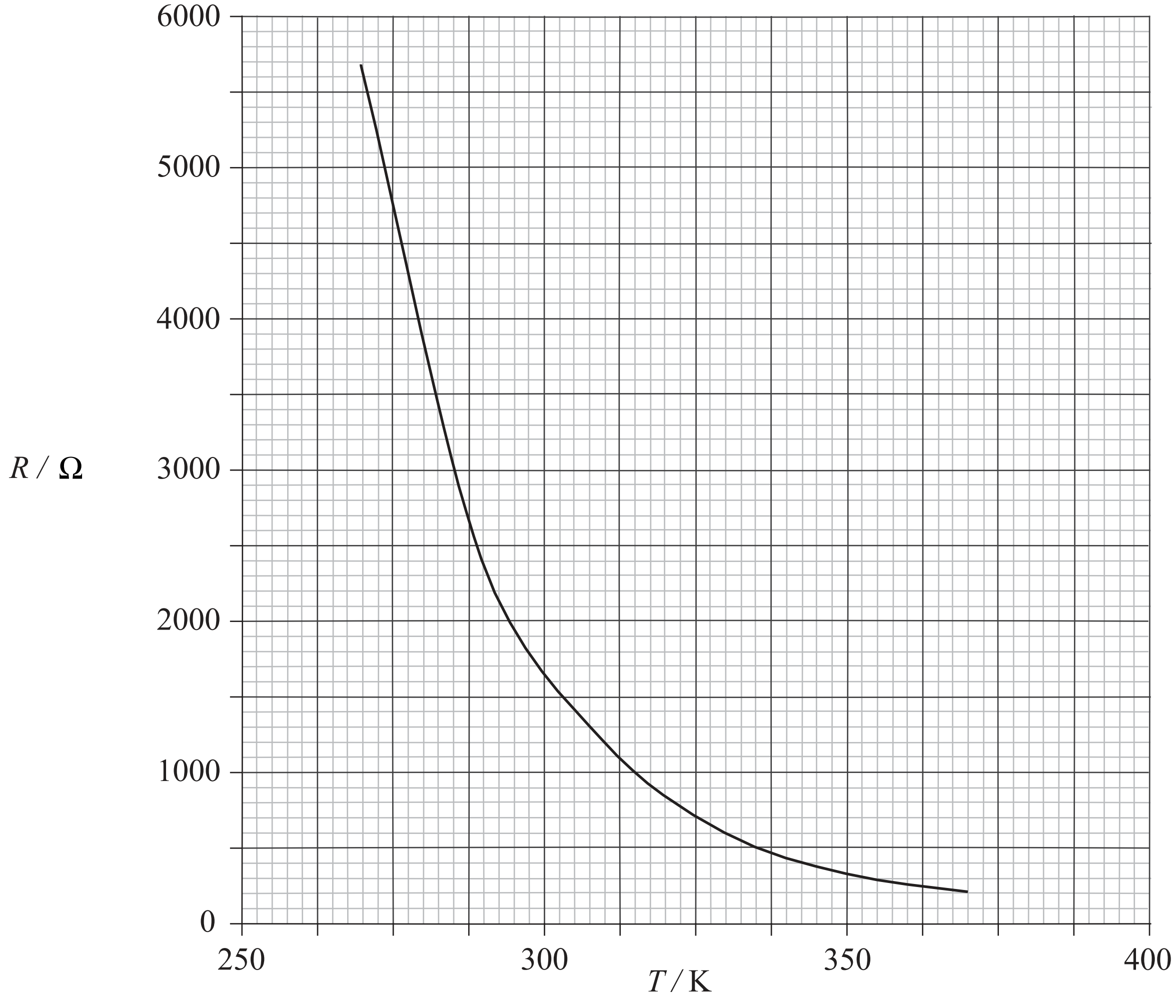
SECTION A

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

A1. This question is about electrical resistance.

The graph shows the variation with temperature T of the resistance R of an electrical component.



(a) A student hypothesizes that the resistance is inversely proportional to the temperature. Use data from the graph to show whether the hypothesis is supported. *[3]*

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(This question continues on the following page)

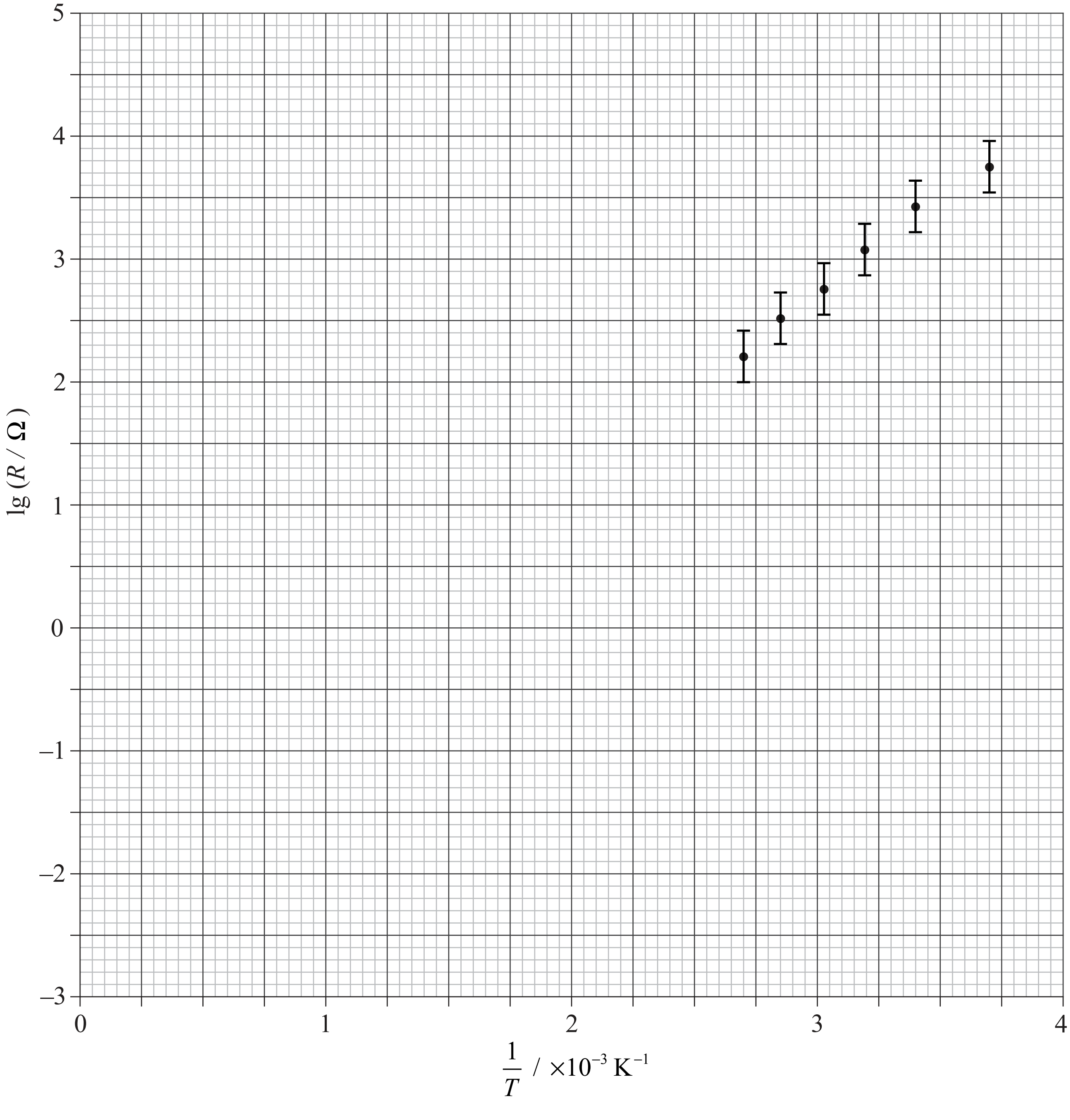
(Question A1 continued)

(b) A second student suggests that the relationship is of the form

$$\lg R = a + \frac{b}{T}$$

where a and b are constants.

The student plots the graph below. Error bars have been included for the sake of clarity.



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(Question A1 continued)

(i) Explain how the graph drawn could be used as evidence to support the student's suggestion. *[2]*

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(ii) Use the graph to determine the constants a and b. *[4]*

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(iii) Using your answers to (b)(ii), determine a value for the resistance of the component at a temperature of 260 K. *[2]*

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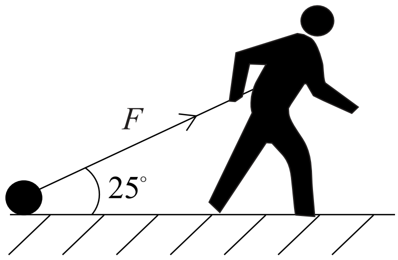
A2. This question is about forces.

An athlete trains by dragging a heavy load across a rough horizontal surface.



The athlete exerts a force of magnitude F on the load at an angle of 25° to the horizontal.

(a) Once the load is moving at a steady speed, the average horizontal frictional force acting on the load is 470 N.

Calculate the average value of F that will enable the load to move at constant speed. *[2]*

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(b) The load is moved a horizontal distance of 2.5 km in 1.2 hours.

Calculate

(i) the work done on the load by the force F. *[2]*

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(ii) the minimum average power required to move the load. *[2]*

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(This question continues on the following page)

(Question A2 continued)

(c) The athlete pulls the load uphill at the same speed as in part (a).

Explain, in terms of energy changes, why the minimum average power required is greater than in (b)(ii). *[2]*

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A3. This question is about solar heating panels.

(a) A village consists of 120 houses. It is proposed that solar panels be used to provide hot water to the houses.

The following data are available.

average power needed per house to heat water = 3.0 kW
average surface solar intensity = 650 W m^{-2}
efficiency of energy conversion of a solar panel = 18 %

Calculate the minimum surface area of the solar panels required to provide the total power for water heating. *[3]*

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(b) Suggest **two** disadvantages of using solar power to provide energy for heating water. *[2]*

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A4. This question is about a generator.

(a) Define *electromotive force*. *[1]*

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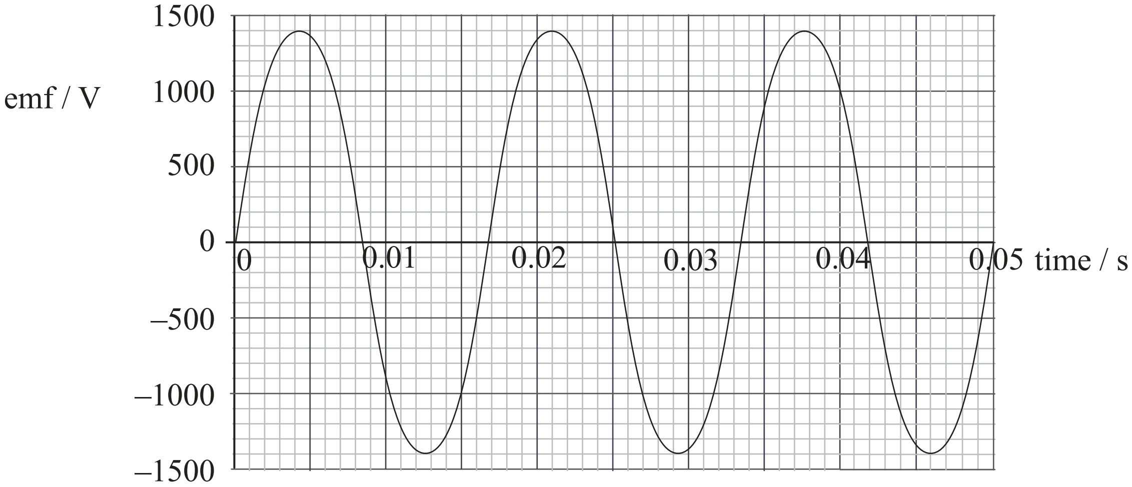
(b) The graph shows the variation with time of electromotive force (emf) for a generator.



(i) Calculate the rms value of the emf of the generator. *[2]*

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(ii) The speed of rotation of the generator is halved with no other changes being made.

On the graph, sketch the variation of emf with time. *[2]*

(iii) Explain why the graph you drew in (ii) is different from the original graph. *[2]*

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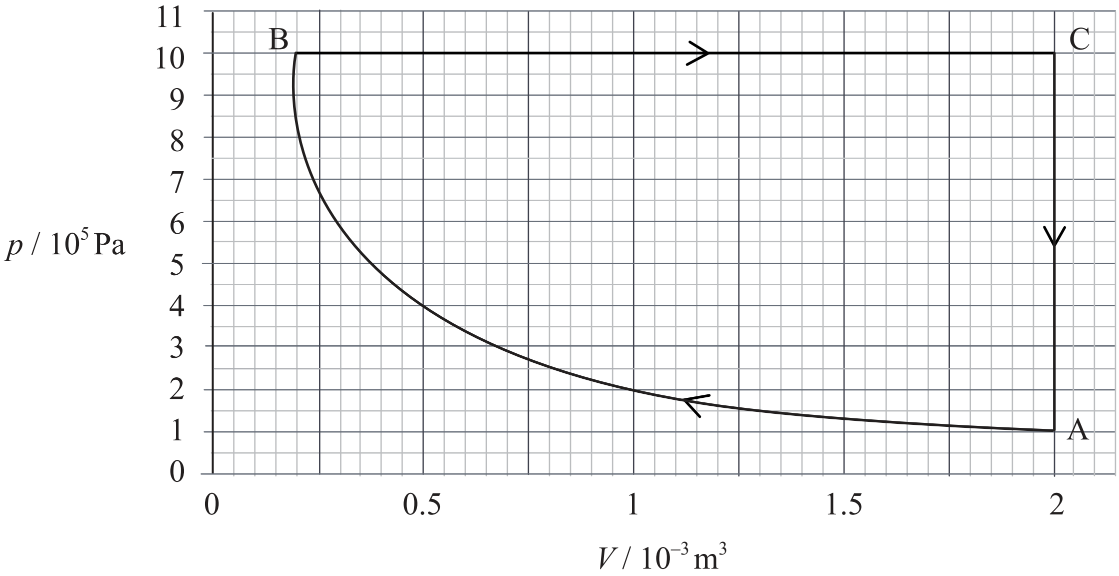
A5. This question is about an ideal gas.

(a) The graph shows a pressure-volume (*P*–*V*) relationship for a fixed mass of an ideal gas.



The gas undergoes a three-stage cycle AB, BC and CA.

(i) Identify the isochoric (isovolumetric) change of state. *[1]*

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(ii) Use data from the graph to show that the change AB is isothermal. *[3]*

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(iii) State the **two** changes for which thermal energy is transferred from the gas. *[1]*

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(This question continues on the following page)

(Question A5 continued)

(iv) Calculate the work done by the gas in the change BC. *[2]*

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(b) The amount of gas in part (a) is 0.74 mol.

Calculate the maximum temperature of the gas during the cycle in part (a). *[4]*

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(c) The fixed mass of gas is heated from temperature T_1 to T_2 at constant volume. Explain why, if this fixed mass of gas is heated from T_1 to T_2 at constant pressure, the amount of energy required is different. *[3]*

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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 solar radiation. **Part 2** is about charge-coupled devices (CCDs).

Part 1 Solar radiation

(a) State the Stefan–Boltzmann law for a black body. *[2]*

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(b) The following data relate to the Earth and the Sun.

Earth-Sun distance	$=1.5\times10^{11}\,\text{m}$
radius of Earth	$=6.4\times10^{6}\,\text{m}$
radius of Sun	$=7.0\times10^{8}\,\text{m}$
surface temperature of Sun	$=5800\,\text{K}$

(i) Use data from the table to show that the power radiated by the Sun is about $4\times10^{26}\,\text{W}$. *[1]*

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(ii) Calculate the solar power incident per unit area at a distance from the Sun equal to the Earth's distance from the Sun. *[2]*

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(This question continues on the following page)

(Question B1, part 1 continued)

(iii) The average power absorbed per unit area at the Earth's surface is $240\,\text{W m}^{-2}$. State **two** reasons why the value calculated in (b)(ii) differs from this value. *[2]*

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2: . . . .

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(iv) Show that the value for power absorbed per unit area of $240\,\text{W m}^{-2}$ is consistent with an average equilibrium temperature for Earth of about 255 K. *[2]*

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(c) Explain, by reference to the greenhouse effect, why the average temperature of the surface of the Earth is greater than 255 K. *[3]*

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(d) Suggest why the burning of fossil fuels may lead to an increase in the temperature of the surface of the Earth. *[3]*

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(This question continues on the following page)

(Question B1 continued)

Part 2 Charge-coupled devices (CCDs)

(a) List **two** advantages of using CCDs as compared to using film for image capture. *[2]*

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(b) A CCD used to capture X-ray images consists of a square $26\,000 \times 26\,000$ arrangement of pixels. Each pixel produces 16 levels of information. Images captured by the CCD are stored on a disk which can store a maximum of 4.0×10^{11} bits of data.

Determine the number of images that may be stored on one disk. *[3]*

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(c) Outline

(i) how X-rays incident on a pixel in a CCD produce a voltage signal. *[2]*

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(ii) how voltage signals such as that in (c)(i) are used to store the X-ray information. *[3]*

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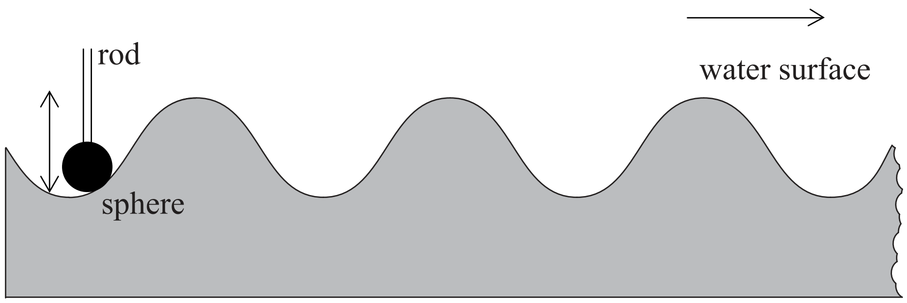
B2. This question is in **two** parts. **Part 1** is about water waves. **Part 2** is about projectile motion.

Part 1 Water waves

A small sphere, mounted at the end of a vertical rod, dips below the surface of shallow water in a tray. The sphere is driven vertically up and down by a motor attached to the rod. The oscillations of the sphere produce travelling waves on the surface of the water.



(a) State what is meant by a travelling (progressive) wave. *[1]*

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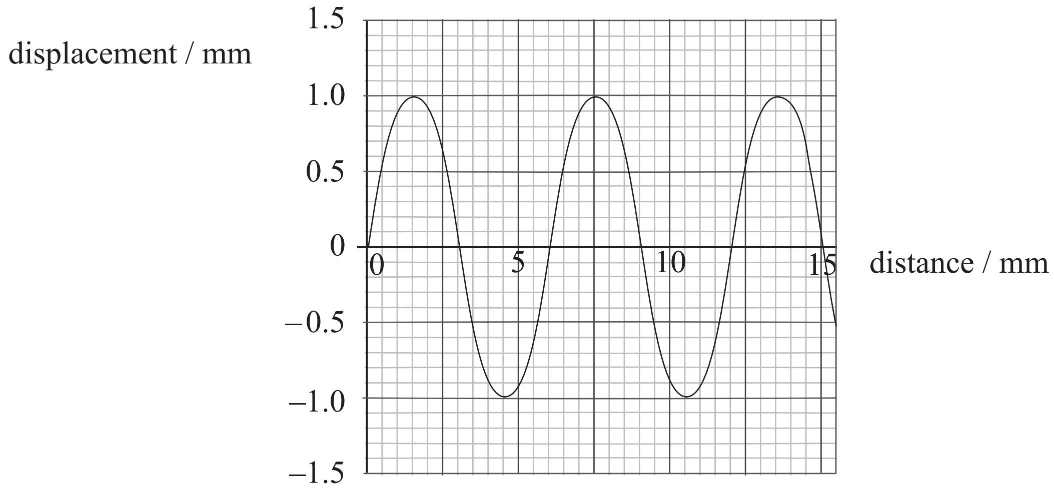
(Question B2, part 1 continued)

(b) The diagram shows how the displacement of the water surface at a particular instant in time varies with distance from the sphere. The period of oscillation of the sphere is 0.027 s.



Use the diagram to calculate, for the wave,

(i) the amplitude. *[1]*

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(ii) the wavelength. *[1]*

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(iii) the frequency. *[1]*

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(iv) the speed. *[1]*

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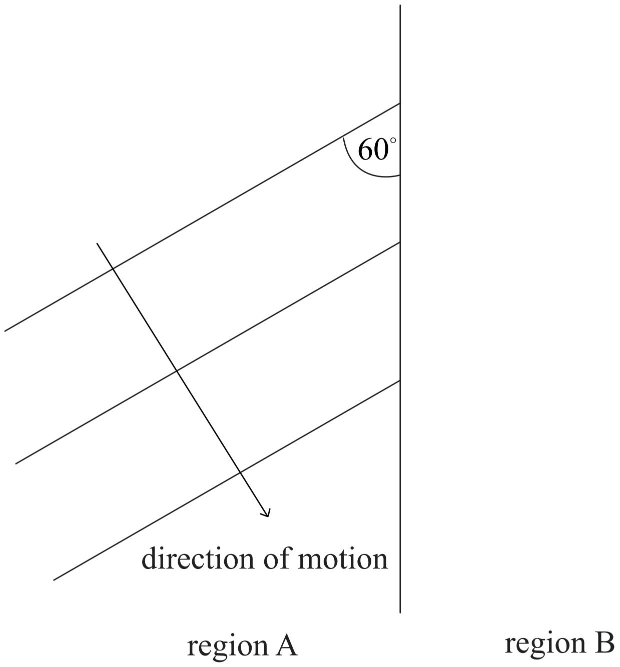
(Question B2, part 1 continued)

(c) The wave moves from region A into a region B of shallower water. The waves move more slowly in region B. The diagram (not to scale) shows some of the wavefronts in region A.



(i) On the diagram, draw **three** lines to complete the wavefronts in region B. *[2]*

(ii) Theory suggests that the wave speed c is related to the water depth d by

$$c = \sqrt{gd}$$

where g is a constant.

The refractive index for waves travelling from region A to region B is 1.4.

Determine the following ratio.

$$\frac{\text{water depth in A}}{\text{water depth in B}}$$ *[3]*

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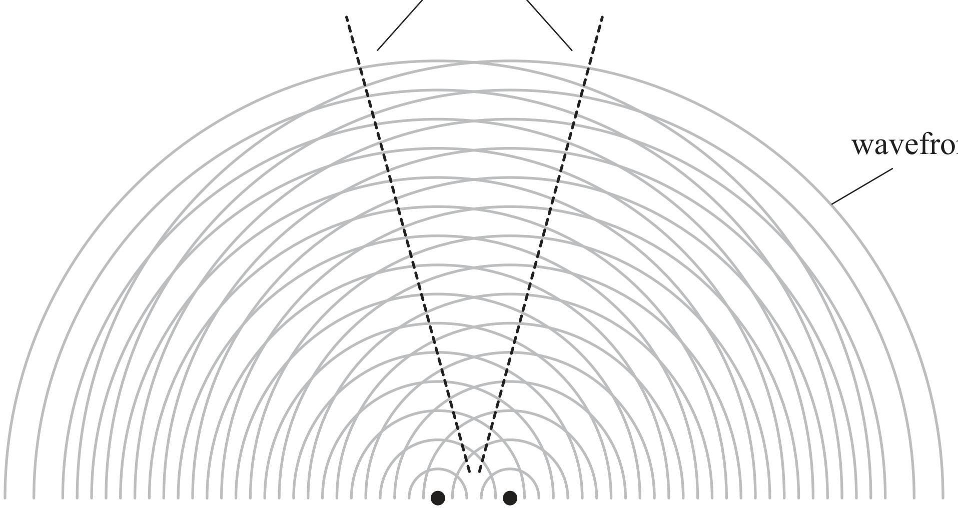
(Question B2, part 1 continued)

(d) Another sphere is dipped into the water. The spheres oscillate in phase. The diagram shows some lines in region A along which the disturbance of the water surface is a minimum.



(i) Outline how the regions of minimum disturbance occur on the surface. *[3]*

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(ii) The frequency of oscillation of the spheres is increased.

State **and** explain how this will affect the positions of minimum disturbance. *[2]*

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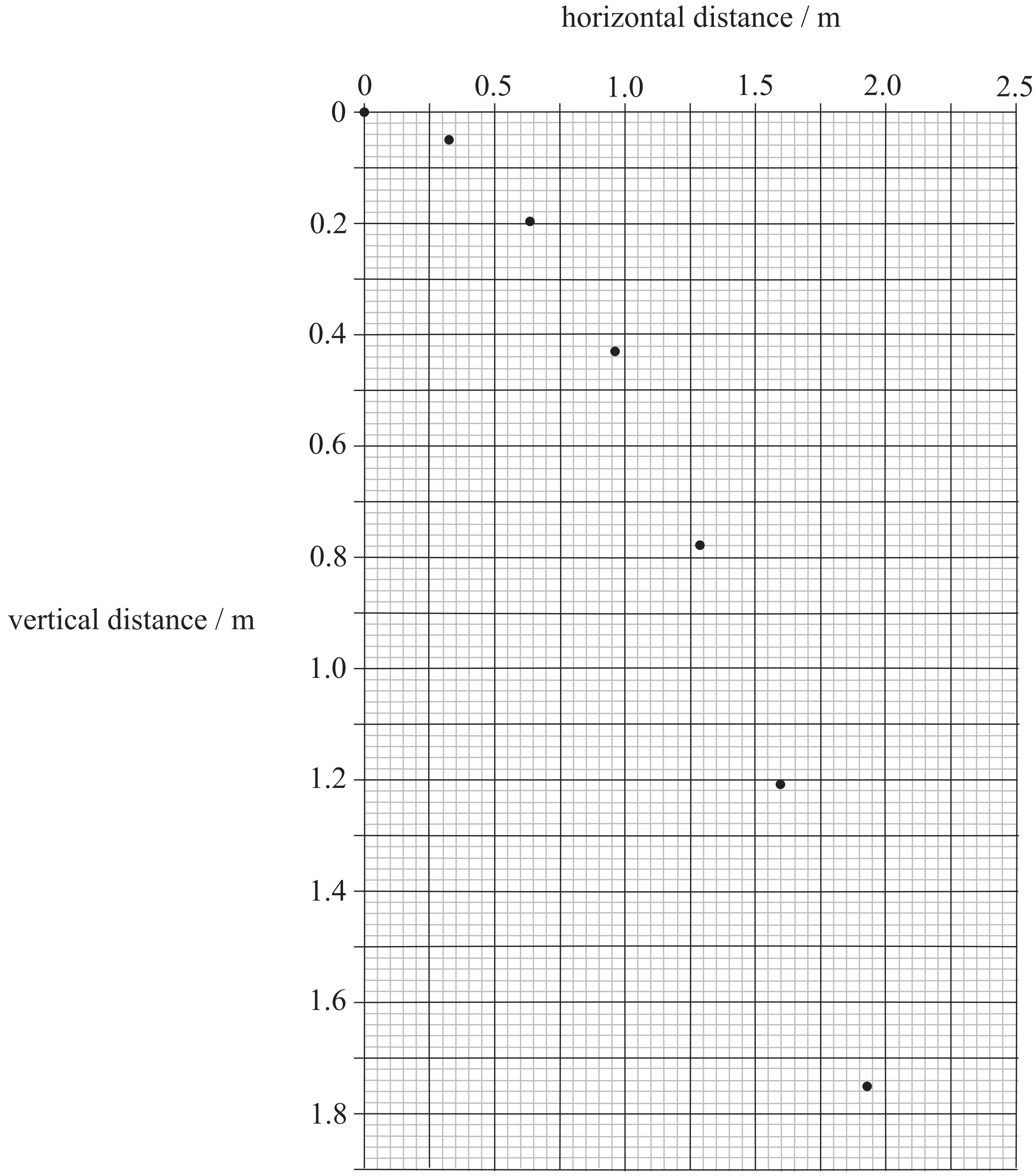
(Question B2 continued)

Part 2 Projectile motion

A sphere is projected horizontally. The sphere is photographed at intervals of 0.10 s. The images of the sphere are shown against a grid on the diagram. Air resistance is negligible.



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(Question B2, part 2 continued)

(a) Use data from the diagram to determine the acceleration of free fall. *[3]*

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(b) Determine the speed of the sphere 1.2 s after release. *[5]*

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(c) On the grid, draw the path of the sphere assuming air resistance is not negligible. *[2]*

B3. This question is in **two** parts. **Part 1** is about nuclear decay and ionization. **Part 2** is about radio waves.

Part 1 Nuclear decay and ionization

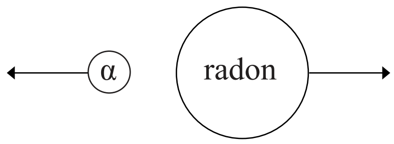
(a) A nucleus of radium-91 $\left({}^{226}_{91}\text{Ra}\right)$ undergoes alpha particle decay to form a nucleus of radon (Rn).

Identify the proton number and nucleon number of the nucleus of Rn. *[2]*

Proton number: . . . .

Nucleon number: . . . .

(b) Immediately after the decay of a stationary radium nucleus, the alpha particle and the radon nucleus move off in opposite directions and at different speeds.



(i) Outline the reasons for these observations. *[3]*

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(ii) Show that the ratio

$$\frac{\text{initial kinetic energy of alpha particle}}{\text{initial kinetic energy of radon atom}}$$

is about 56. *[3]*

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(Question B3, part 1 continued)

(c) The initial kinetic energy of the alpha particle is 4.9 MeV. As the alpha particle passes through air, it loses all its kinetic energy by causing the ionization of 1.7×10^{5} air molecules.

(i) State what is meant by ionization. *[1]*

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(ii) Estimate, in joules, the average energy needed to ionize an air molecule. *[2]*

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(d) Outline why a beta particle has a longer range in air than an alpha particle of the same energy. *[3]*

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(Question B3 continued)

Part 2 Radio waves

A satellite is travelling directly away from a space shuttle with a speed of $7.9\,\text{km s}^{-1}$. The satellite is transmitting radio waves of frequency 150.000 000 MHz.

(a) (i) Calculate the frequency to which an astronaut on the shuttle will need to set a receiver in order to receive the signal from the satellite. *[2]*

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(ii) The satellite now passes close to a second space shuttle. Describe the changes that will need to be made to the setting of the receiver as the satellite approaches and moves away from the second shuttle. *[3]*

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(iii) Suggest why the formula used in the calculation in (a)(i) would **not** be suitable for radiation from a distant galaxy moving away from the Earth at 90% of the speed of light. *[1]*

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(Question B3, part 2 continued)

(b) A space shuttle orbits at a height of 300 km above the surface of the Earth. It carries two panels separated by a distance of 24 m. The panels reflect light of wavelength 500 nm towards an observer on the Earth's surface.

The observer views the panels with a telescope of aperture diameter 85 mm. The panels act as point sources of light for the observer.

(i) Describe what is meant by the Rayleigh criterion. *[2]*

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(ii) Determine whether the images of the panels formed by the telescope will be resolved. *[3]*

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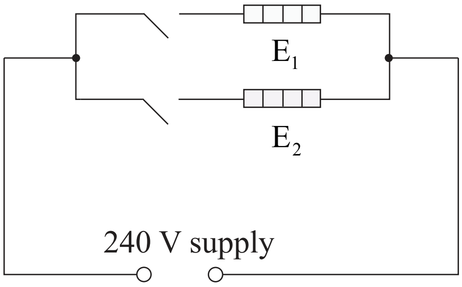
B4. This question is in **two** parts. **Part 1** is about an electrical heater. **Part 2** is about the hydrogen atom.

Part 1 Electrical heater

An electrical heater consists of two heating elements E_1 and E_2. The elements are connected in parallel. Each element has a switch and is connected to a supply of emf 240 V. The supply has negligible internal resistance.



Element E_1 is made from wire that has a cross-sectional area of $6.8\times10^{-8}\,m^2$. The resistivity of the wire at the operating temperature of the element is $1.1\times10^{-6}\,\Omega\,m$.

(a) (i) The total length of wire is 4.5 m. Show that the resistance of E_1 is 73 Ω. *[1]*

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(ii) Calculate the power output of E_1 with only this element connected to the supply. *[2]*

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(iii) Element E_2 is made of wire of the same cross-section and material as E_1. The length of wire used to make E_2 is 1.5 m. Determine the total power output when both E_1 and E_2 are connected to the supply. *[3]*

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(Question B4, part 1 continued)

(iv) With reference to the power output, explain why it would be inappropriate to connect the heating elements in series. *[3]*

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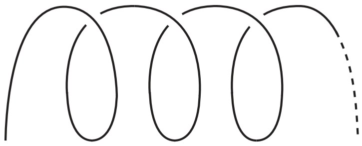
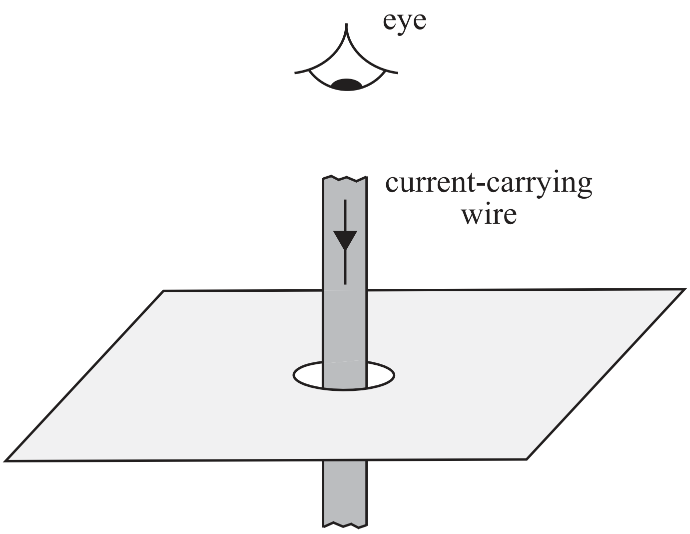
(b) Each element in the electrical heater is wound as a coil as shown.



Each turn of the coil may be considered to act as a current-carrying long straight wire.

(i) On the diagram, draw the magnetic field around a current-carrying long straight wire. The arrow shows the direction of the current. *[3]*



(ii) State **and** explain whether the turns of wire will attract or repel one another. *[3]*

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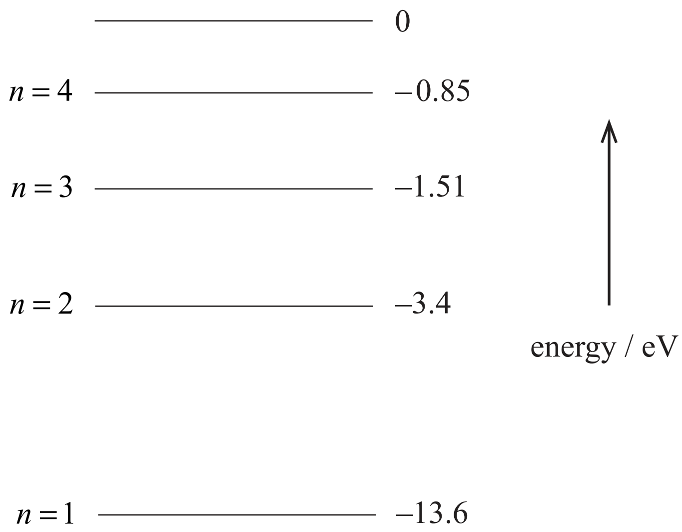
(Question B4 continued)

Part 2 The hydrogen atom

(a) A parallel beam of visible light is shone through monatomic hydrogen gas.

The radiation emerging from the gas is analysed by comparing the incident and emerging intensities at various wavelengths. It is found that at a wavelength of 490 nm the intensity of the emergent beam is greatly reduced.

The diagram shows some of the electron energy states of the hydrogen atom where *n* is the quantum number of the energy level.



(i) Calculate the energy, in eV, of a photon of light of wavelength 490 nm. *[2]*

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(Question B4, part 2 continued)

(ii) Use your answer in (a)(i) and the energy level diagram to explain the reduction in intensity of the emergent beam. *[4]*

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(b) Outline how the Schrödinger model of the hydrogen atom leads to the idea of discrete electron energy states. *[4]*

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