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PHYSICS
STANDARD LEVEL
PAPER 2

Candidate session number

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Wednesday 11 May 2011 (afternoon)

1 hour 15 minutes

Examination code

2	2	1	1	–	6	5	1	7

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 questions.
- Section B: answer one question.
- Write your answers in the boxes provided.

0128

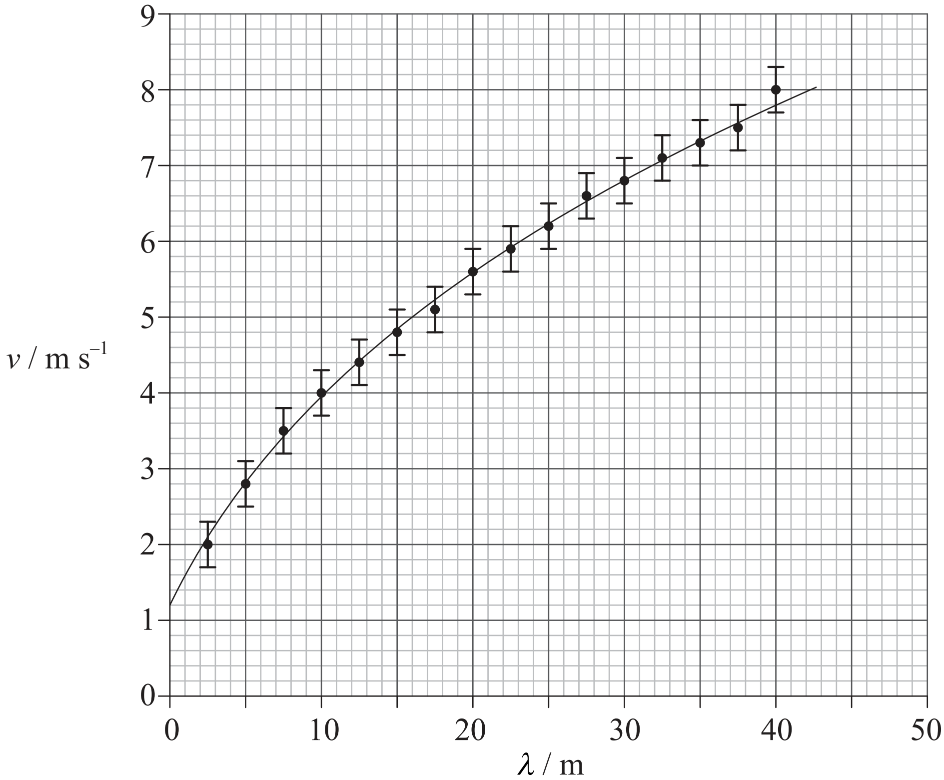
26 pages

SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

A1. Data analysis question.

The speed v of waves on the surface of deep water depends only on the wavelength λ of the waves. The data gathered from a particular region of the Atlantic Ocean are plotted below.



The uncertainty in the speed v is $\pm 0.30\,m\,s^{-1}$ and the uncertainty in λ is too small to be shown on the diagram.

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(Question A1 continued)

(a) State, with reference to the graph,

(i) why v is not directly proportional to λ. *[1]*

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(ii) the value of v for $\lambda = 39\,\text{m}$. *[1]*

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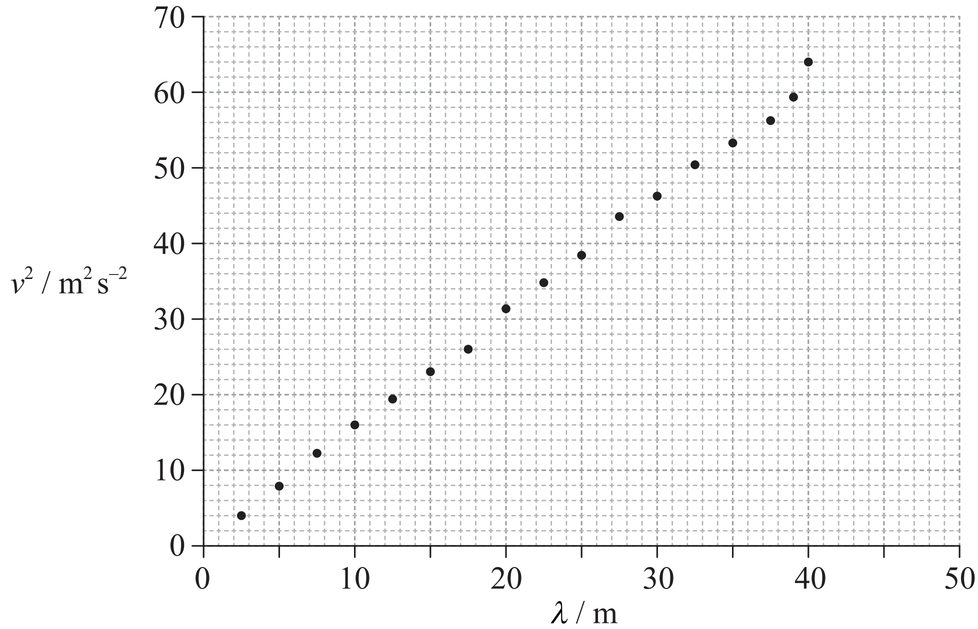
(This question continues on the following page)

(Question A1 continued)

(b) It is suggested that the relationship between v and λ is of the form

$$v = a\sqrt{\lambda}$$

where a is a constant. To test the validity of this hypothesis, values of v^2 against λ are plotted below.



(i) Use your answer to (a)(ii) to show that the absolute uncertainty in v^2 for a wavelength of 39 m is ±5 m^2 s^{-2}. *[3]*

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(ii) The absolute uncertainty in v^2 for a wavelength of 2.5 m is ±1 m^2 s^{-2}. Using this value and the value in (b)(i), construct error bars for v^2 at the data points for λ = 2.5 m and 39 m. *[1]*

(This question continues on the following page)

(Question A1 continued)

(iii) State why the plotted data in (b)(ii) suggest that it is likely that v is proportional to $\sqrt{\lambda}$. *[1]*

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(iv) Use the graph opposite to determine the constant a. *[3]*

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(v) Theory shows that $a = \sqrt{\frac{k}{2\pi}}$. Determine a value for k. *[1]*

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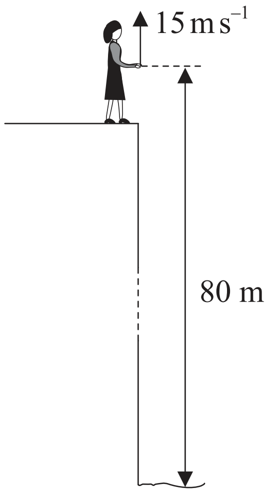
A2. This question is about kinematics.

Lucy stands on the edge of a vertical cliff and throws a stone vertically upwards.



The stone leaves her hand with a speed of $15\,\text{m}\,\text{s}^{-1}$ at the instant her hand is 80 m above the surface of the sea. Air resistance is negligible and the acceleration of free fall is $10\,\text{m}\,\text{s}^{-2}$.

(a) Calculate the maximum height reached by the stone as measured from the point where it is thrown. *[2]*

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(b) Determine the time for the stone to reach the surface of the sea after leaving Lucy's hand. *[3]*

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A3. This question is about internal energy and thermal energy (heat).

(a) Distinguish between internal energy and thermal energy. *[3]*

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(b) Describe, with reference to the energy of the molecules, the difference in internal energy of a piece of iron and the internal energy of an ideal gas. *[2]*

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(Question A3 continued)

(c) A piece of iron is placed in a kiln until it reaches the temperature θ of the kiln. The iron is then quickly transferred to water held in a thermally insulated container. The water is stirred until it reaches a steady temperature. The following data are available.

Thermal capacity of the piece of iron	$= 60\,\text{J K}^{-1}$
Thermal capacity of the water	$= 2.0 \times 10^{3}\,\text{J K}^{-1}$
Initial temperature of the water	$= 16\,^{\circ}\text{C}$
Final temperature of the water	$= 45\,^{\circ}\text{C}$

The thermal capacity of the container and insulation is negligible.

(i) State an expression, in terms of θ and the above data, for the energy transfer of the iron in cooling from the temperature of the kiln to the final temperature of the water. *[1]*

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(ii) Calculate the increase in internal energy of the water as the iron cools in the water. *[1]*

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(iii) Use your answers to (c)(i) and (c)(ii) to determine θ. *[2]*

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SECTION B

This section consists of three questions: B1, B2 and B3. Answer ***one*** *question. Write your answers in the boxes provided.*

B1. This question is in **two** parts. **Part 1** is about simple harmonic motion (SHM) and a wave in a string. **Part 2** is about the unified atomic mass unit and a nuclear reaction.

Part 1 Simple harmonic motion and a wave in a string

(a) By reference to simple harmonic motion, state what is meant by amplitude. *[1]*

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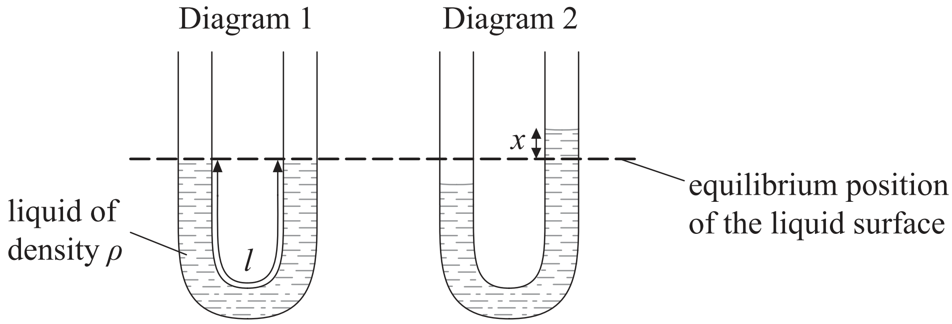
(Question B1, part 1 continued)

(b) A liquid is contained in a U-tube.



The pressure on the liquid in one side of the tube is increased so that the liquid is displaced as shown in diagram 2. When the pressure is suddenly released the liquid oscillates. The damping of the oscillations is small.

(i) Describe what is meant by damping. *[2]*

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(Question B1, part 1 continued)

(ii) The displacement of the liquid surface from its equilibrium position is x. The acceleration a of the liquid in the tube is given by the expression

$$a = -\frac{2g}{l}x$$

where g is the acceleration of free fall and l is the total length of the liquid column. The total length of the liquid column in the tube is 0.32 m. Determine the period of oscillation. *[3]*

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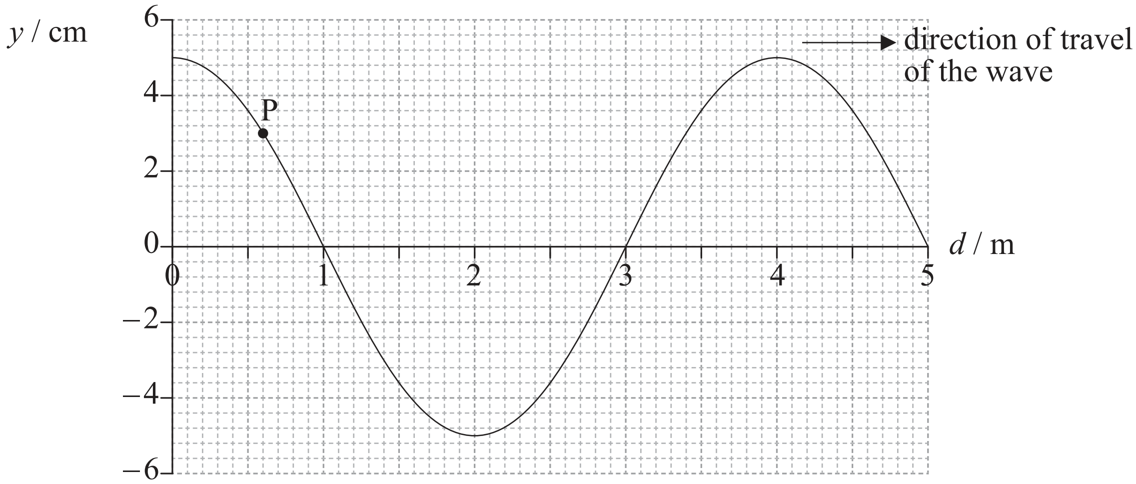
(Question B1, part 1 continued)

(c) A wave is travelling along a string. The string can be modelled as a single line of particles and each particle executes simple harmonic motion. The period of oscillation of the particles is 0.80 s.

The graph shows the displacement y of part of the string at time $t = 0$. The distance along the string is d.



(i) On the graph, draw an arrow to show the direction of motion of particle P at the point marked on the string. *[1]*

(ii) Determine the magnitude of the velocity of particle P. *[4]*

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(Question B1, part 1 continued)

(iii) Show that the speed of the wave is $5.0\,\text{m}\,\text{s}^{-1}$. *[3]*

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(iv) On the graph opposite, label with the letter X the position of particle P at $t = 0.40\,\text{s}$. *[1]*

(This question continues on the following page)

(Question B1 continued)

Part 2 Unified atomic mass unit and a nuclear reaction

(a) Define the term *unified atomic mass unit*. *[1]*

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(b) The mass of a nucleus of rutherfordium-254 is 254.1001 u. Calculate the mass in $\text{GeV}\,c^{-2}$. *[1]*

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(c) In 1919, Rutherford produced the first artificial nuclear transmutation by bombarding nitrogen with α-particles. The reaction is represented by the following equation.

$$\alpha + {}^{14}_{7}\text{N} \rightarrow {}^{17}_{8}\text{O} + \mathbf{X}$$

(i) Identify **X**. *[1]*

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(Question B1, part 2 continued)

(ii) The following data are available for the reaction.

Rest mass of α $= 3.7428\,\text{GeV}\,c^{-2}$
Rest mass of ${}^{14}_{7}\text{N}$ $= 13.0942\,\text{GeV}\,c^{-2}$
Rest mass of ${}^{17}_{8}\text{O} + \mathbf{X}$ $= 16.8383\,\text{GeV}\,c^{-2}$

The initial kinetic energy of the α-particle is 7.68 MeV. Determine the sum of the kinetic energies of the oxygen nucleus and **X**. (Assume that the nitrogen nucleus is stationary.) *[3]*

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(d) The reaction in (c) produces oxygen (O-17). Other isotopes of oxygen include O-19 which is radioactive with a half-life of 30 s.

(i) State what is meant by the term isotopes. *[1]*

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(ii) Define the term *radioactive half-life*. *[1]*

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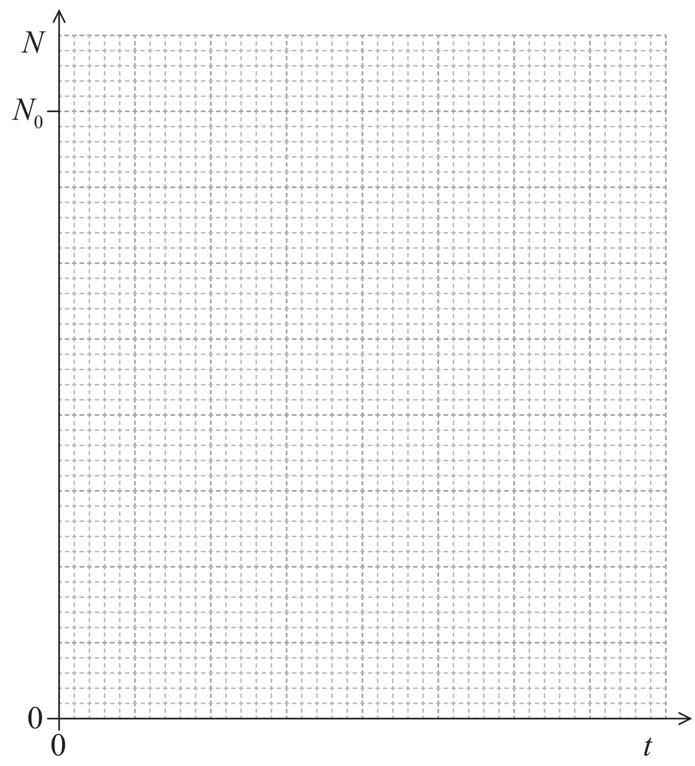
(Question B1, part 2 continued)

(e) A nucleus of the isotope O-19 decays to a stable nucleus of fluorine. The half-life of O-19 is 30 s. At time $t = 0$, a sample of O-19 contains a large number N_0 nuclei of O-19.

On the grid below, draw a graph to show the variation with time t of the number N of O-19 nuclei remaining in the sample. You should consider a time of $t = 0$ to $t = 120$ s. *[2]*



B2. This question is in **two** parts. **Part 1** is about power production and global warming. **Part 2** is about electric charge.

Part 1 Power production and global warming

(a) In any cyclical process designed to continuously convert thermal energy to work, some energy is always degraded. Explain what is meant by degraded energy. *[2]*

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(b) A nuclear power station uses uranium-235 (U-235) as fuel. Outline the

(i) processes and energy changes that occur through which thermal energy is produced. *[4]*

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(Question B2, part 1 continued)

(ii) role of the heat exchanger of the reactor and the turbine in the generation of electrical energy. *[3]*

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(c) Identify **one** process in the power station where energy is degraded. *[1]*

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(d) The maximum power output of the Drax coal-fired power station in the UK is 4.0 GW. Determine the minimum mass of pure U-235 that would be required by a nuclear power station to provide the same maximum annual energy output as the Drax power station. *[2]*

Energy density of U-235 $= 82\ \text{TJ kg}^{-1}$
1 year $= 3.2 \times 10^{7}\ \text{s}$

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(Question B2, part 1 continued)

(e) The Drax power station produces an enormous amount of carbon dioxide, a gas classified as a greenhouse gas. Outline, with reference to the vibrational behaviour of molecules of carbon dioxide, what is meant by a greenhouse gas. *[3]*

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(f) It has been suggested that the production of greenhouse gases by coal-fired power stations has increased global warming. One piece of evidence to support this suggestion is the increase in sea-level due to an increase in temperature of the oceans. Over the past 100 years it is suggested that sea-levels have risen by 6.4×10^{-2} m due to volume expansion.

Using the following data, determine the average rise in temperature in the top levels of the oceans in the last 100 years. *[3]*

Mean depth of oceans that is affected by global warming $= 4.0\times10^{2}$ m
Coefficient of volume expansion of sea water $= 5.1\times10^{-5}\ K^{-1}$

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(Question B2 continued)

Part 2 Electric charge

(a) A plastic rod XY is held at end X. The end Y is rubbed with a piece of cloth and, as a result, the end Y becomes electrically charged.

The procedure is now repeated using a copper rod and it is found that the copper rod remains electrically neutral. Explain these observations in terms of the properties of conductors and insulators. *[5]*

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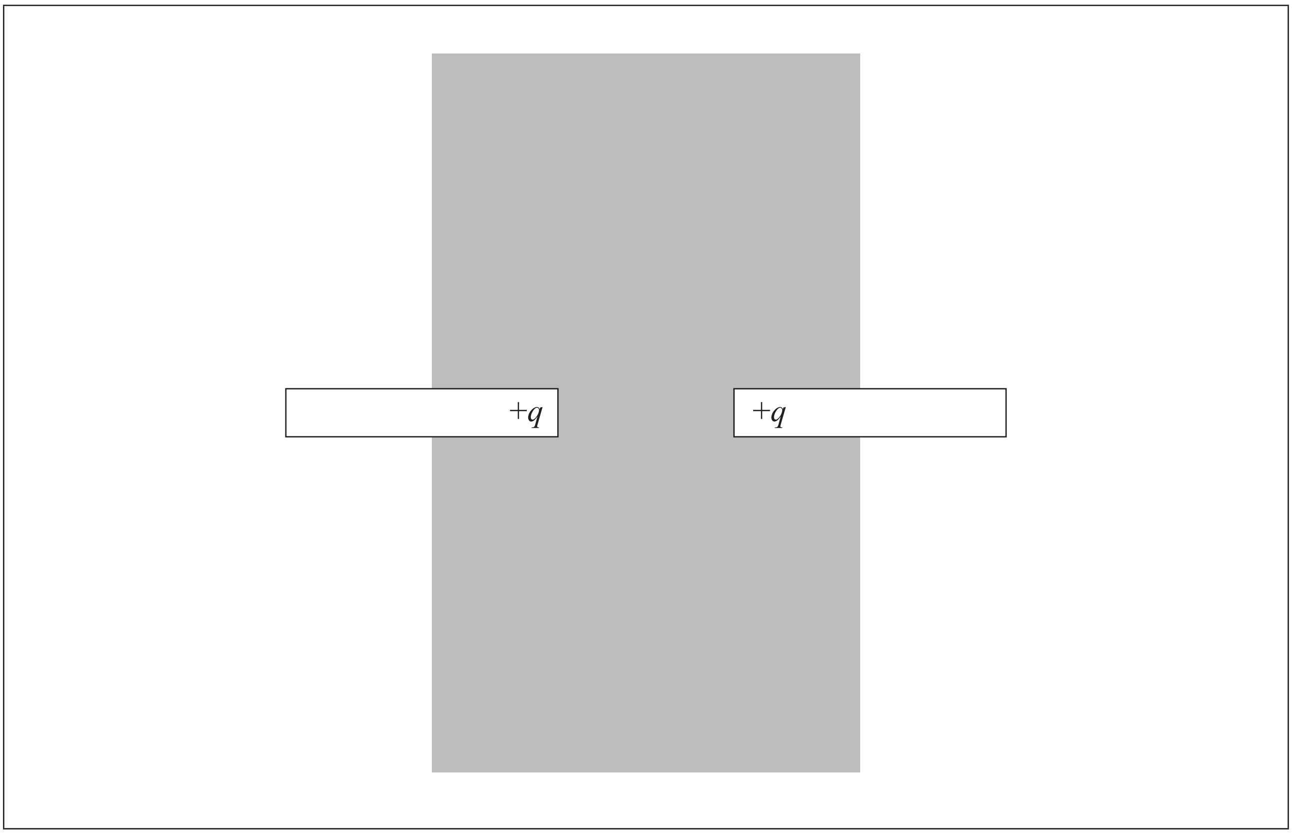
(Question B2, part 2 continued)

(b) Two plastic rods each have a positive charge $+q$ situated at one end. The rods are arranged as shown.

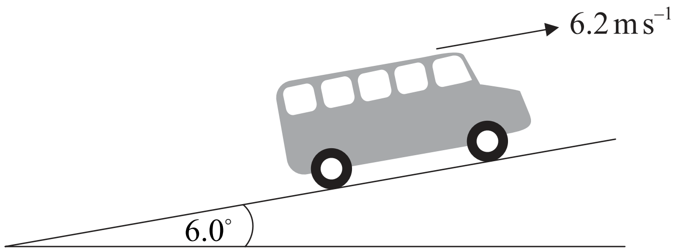


Assume that the charge at the end of each rod behaves as a point charge. Draw, in the shaded area on the diagram, the electric field pattern due to the two charges. *[2]*

B3. This question is in **two** parts. **Part 1** is about power and efficiency. **Part 2** is about electrical resistance.

Part 1 Power and efficiency

A bus is travelling at a constant speed of $6.2\,\text{m}\,\text{s}^{-1}$ along a section of road that is inclined at an angle of 6.0° to the horizontal.



(a) (i) The bus is represented by the black dot shown below. Draw a labelled sketch to represent the forces acting on the bus. *[4]*

(ii) State the value of the rate of change of momentum of the bus. *[1]*

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(This question continues on the following page)

(Question B3, part 1 continued)

(b) The total output power of the engine of the bus is 70 kW and the efficiency of the engine is 35 %. Calculate the input power to the engine. *[2]*

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(c) The mass of the bus is 8.5×10^3 kg. Determine the rate of increase of gravitational potential energy of the bus. *[3]*

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(d) Using your answer to (c) and the data in (b), estimate the magnitude of the resistive forces acting on the bus. *[3]*

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(Question B3, part 1 continued)

(e) The engine of the bus suddenly stops working.

(i) Determine the magnitude of the net force opposing the motion of the bus at the instant at which the engine stops. *[2]*

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(ii) Discuss, with reference to the air resistance, the change in the net force as the bus slows down. *[2]*

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(Question B3 continued)

Part 2 Electrical resistance

(a) A resistor of resistance 1.5 Ω is made from copper wire of radius 0.18 mm. The resistivity of copper is $1.7\times10^{-8}\,\Omega\,\text{m}$. Determine the length of copper wire used to make the resistor. *[2]*

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(b) The manufacturer of the resistor in (a) guarantees that the resistance is within 10% of 1.5 Ω, provided that the power dissipation in the resistor does not exceed 1.0 W.

(i) Suggest why the resistance of the resistor might be greater than 1.65 Ω if the power dissipation in the resistor is greater than 1.0 W. *[2]*

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(ii) Show that, for a power dissipation of 1.0 W, the current in a resistor of resistance 1.5 Ω is 0.82 A. *[1]*

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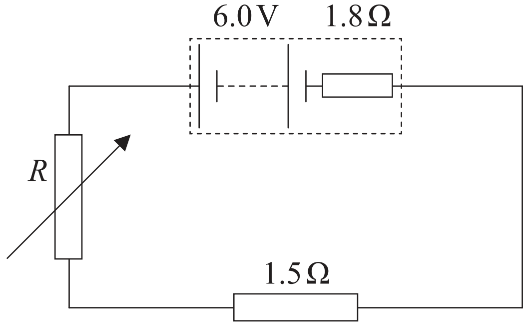
(Question B3, part 2 continued)

(iii) The 1.5 Ω resistor is connected in series with a variable resistor and battery of emf 6.0 V and internal resistance 1.8 Ω.



Estimate the resistance *R* of the variable resistor that will limit the current to 0.82 A. *[3]*

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