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PHYSICS
STANDARD LEVEL
PAPER 2

Candidate session number

Wednesday 7 May 2014 (morning)

1 hour 15 minutes

Examination code

2 2 1 4 – 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.
- A calculator is required for this paper.
- A clean copy of the ***Physics*** *Data Booklet* is required for this paper.
- The maximum mark for this examination paper is *[50 marks]*.

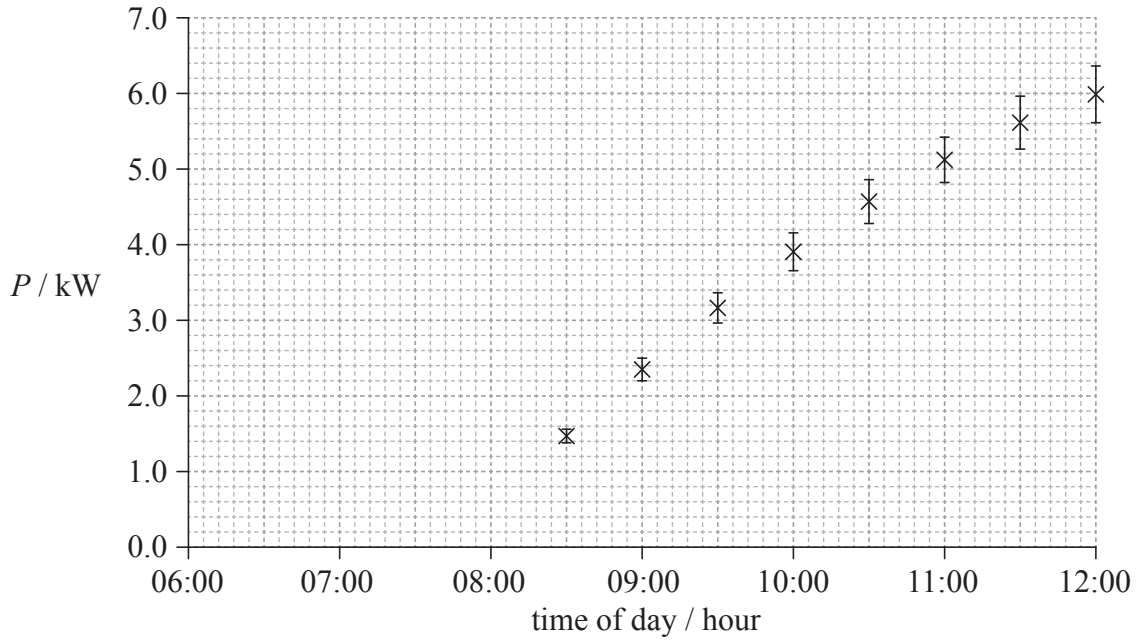
SECTION A

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

1. Data analysis question.

An array of photovoltaic cells is used to provide electrical energy for a house. When the array produces more power than is consumed in the house, the excess power is fed back into the mains electrical supply for use by other consumers.

The graph shows how the power P produced by the array varies with the time of day. The error bars show the uncertainty in the power supplied. The uncertainty in the time is too small to be shown.



(a) Using the graph, estimate the time of day at which the array begins to generate energy. *[2]*

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(Question 1 continued)

(b) The average power consumed in the house between 08:00 and 12:00 is 2.0 kW. Determine the energy supplied by the array to the mains electrical supply between 08:00 and 12:00. *[3]*

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(c) The power P produced by the array is calculated from the generated emf V and the fixed resistance R of the array using the equation $\frac{V^2}{R}$. The uncertainty in the value of R is 2 %. Calculate the percentage uncertainty in V at 12:00. *[3]*

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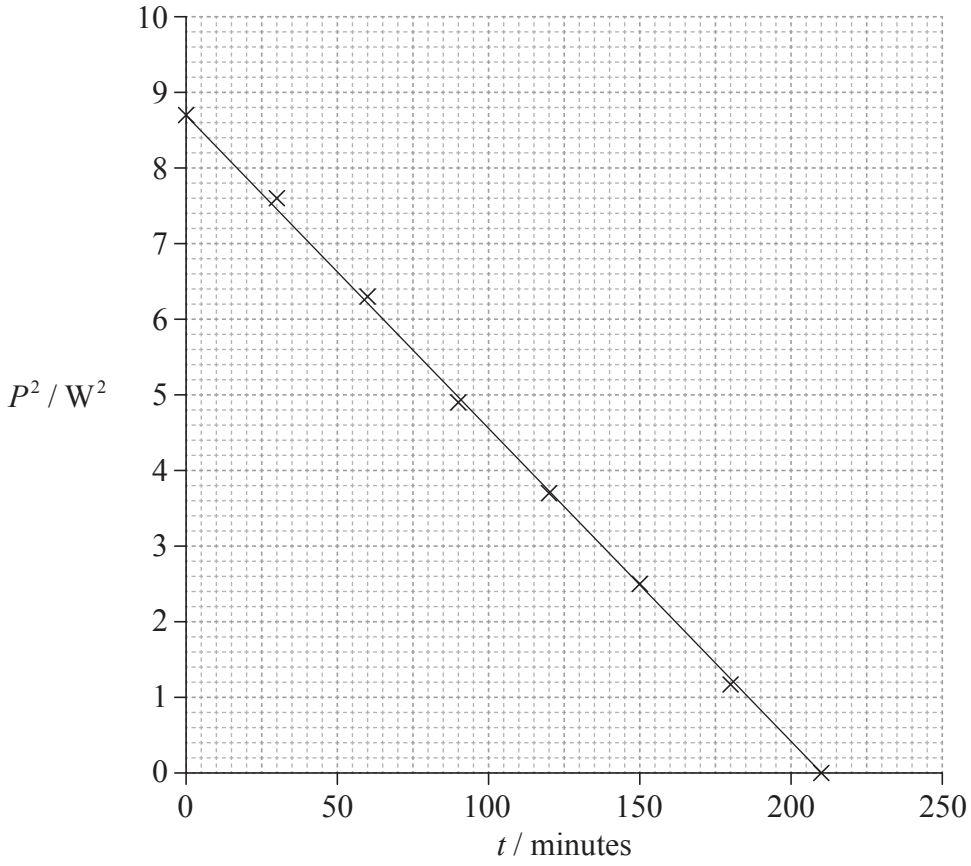
(Question 1 continued)

(d) Later that day a second set of data was collected starting at $t = 0$. The variation of P^2 with time t since the start of this second data collection is shown in the graph.



Using the graph, determine the relationship between P^2 and t. *[3]*

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2. This question is about energy.

At its melting temperature, molten zinc is poured into an iron mould. The molten zinc becomes a solid without changing temperature.

(a) Outline why a given mass of molten zinc has a greater internal energy than the same mass of solid zinc at the same temperature. *[3]*

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(b) The zinc is allowed to cool in the mould. The temperature of the iron mould was 20 °C before the molten zinc, at its melting temperature, was poured into it. The final temperature of the iron mould and the solidified zinc is 89 °C.

The following data are available.

Mass of iron mould	= 12 kg
Mass of zinc	= 1.5 kg
Specific heat capacity of iron	= 440 $J kg^{-1} K^{-1}$
Specific latent heat of fusion of zinc	= 113 $kJ kg^{-1}$
Melting temperature of zinc	= 420 °C

Using the data, determine the specific heat capacity of zinc. *[4]*

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3. This question is about binding energy and mass defect.

(a) State what is meant by mass defect. *[1]*

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(b) (i) Data for this question is given below.

Binding energy per nucleon for deuterium $\left({}_{1}^{2}\mathrm{H}\right)$ is 1.1 MeV.
Binding energy per nucleon for helium-3 $\left({}_{2}^{3}\mathrm{He}\right)$ is 2.6 MeV.

Using the data, calculate the energy change in the following reaction. *[2]*

$$ {}_{1}^{2}\mathrm{H} + {}_{1}^{1}\mathrm{H} \rightarrow {}_{2}^{3}\mathrm{He} + \gamma $$

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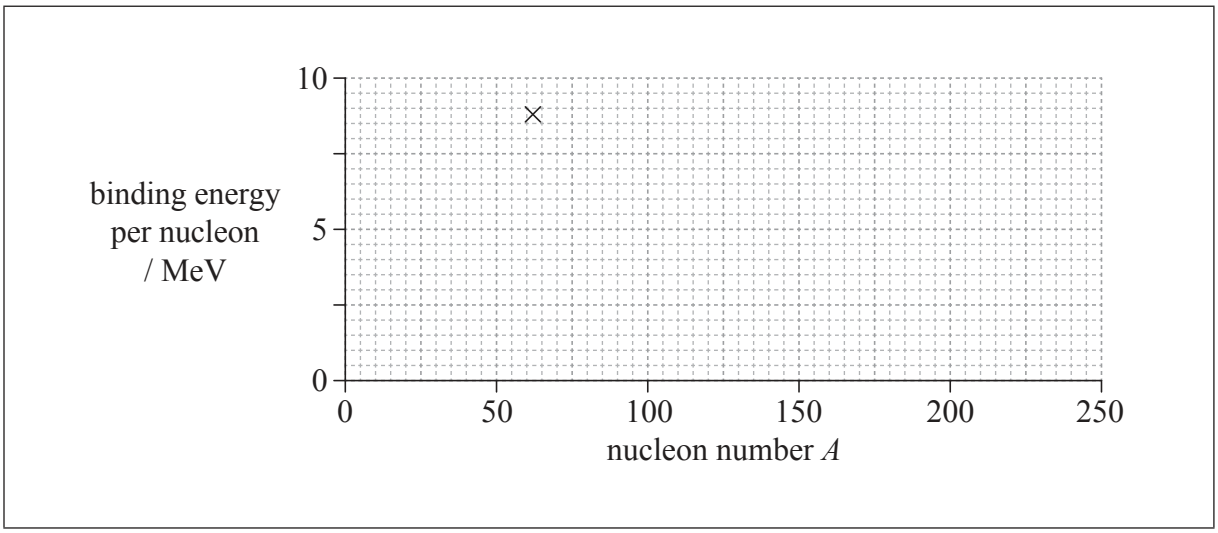
(Question 3 continued)

(ii) The cross on the grid shows the binding energy per nucleon and nucleon number A of the nuclide nickel-62.



On the grid, sketch a graph to show how the average binding energy per nucleon varies with nucleon number A. *[2]*

(iii) State and explain, with reference to your sketch graph, whether energy is released **or** absorbed in the reaction in (b)(i). *[2]*

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SECTION B

*This section consists of three questions: 4, 5 and 6. Answer **one** question. Write your answers in the boxes provided.*

4. This question is about the use of energy resources.

(a) State the difference between renewable and non-renewable energy sources. *[1]*

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(b) Electrical energy is obtained from tidal energy at La Rance in France.

Water flows into a river basin from the sea for six hours and then flows from the basin back to the sea for another six hours. The water flows through turbines and generates energy during both flows.

The following data are available.

Area of river basin	$= 22\,\text{km}^2$
Change in water level of basin over six hours	$= 6.0\,\text{m}$
Density of water	$= 1000\,\text{kg m}^{-3}$

(i) The basin empties over a six hour period. Show that about $6000\,\text{m}^3$ of water flows through the turbines every second. *[2]*

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(Question 4 continued)

(ii) Show that the average power that the water can supply over the six hour period is about 0.2 GW. *[3]*

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(iii) La Rance tidal power station has an energy output of 5.4×10^{8} kW h per year. Calculate the overall efficiency of the power station. Assume that the water can supply 0.2 GW at all times. *[3]*

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will not be marked.

(Question 4 continued from page 9)

(c) Energy resources such as La Rance tidal power station could replace the use of fossil fuels. This may result in an increase in the average albedo of Earth.

(i) State **two** reasons why the albedo of Earth must be given as an average value. *[2]*

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(ii) Suggest, with reference to the enhanced greenhouse effect, why the reduction in the use of fossil fuels could lead to an increase in the average albedo of Earth. *[4]*

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(Question 4 continued)

(d) Nuclear reactors are also used to generate energy in France. In a particular nuclear reactor, neutrons collide elastically with carbon-12 nuclei $\left({}^{12}_{6}\mathrm{C}\right)$ that act as the moderator of the reactor. A neutron with an initial speed of $9.8\times10^{6}\,\mathrm{m\,s^{-1}}$ collides head-on with a stationary carbon-12 nucleus. Immediately after the collision the carbon-12 nucleus has a speed of $1.5\times10^{6}\,\mathrm{m\,s^{-1}}$.

(i) State the principle of conservation of momentum. *[2]*

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(ii) Show that the speed of the neutron immediately after the collision is about $8.0\times10^{6}\,\mathrm{m\,s^{-1}}$. *[2]*

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(iii) Show that the fractional change in energy of the neutron as a result of the collision is about 0.3. *[2]*

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(Question 4 continued)

(iv) Estimate the minimum number of collisions required for the neutron to reduce its initial energy by a factor of 10^6. *[2]*

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(v) Outline why the reduction in energy is necessary for this type of reactor to function. *[2]*

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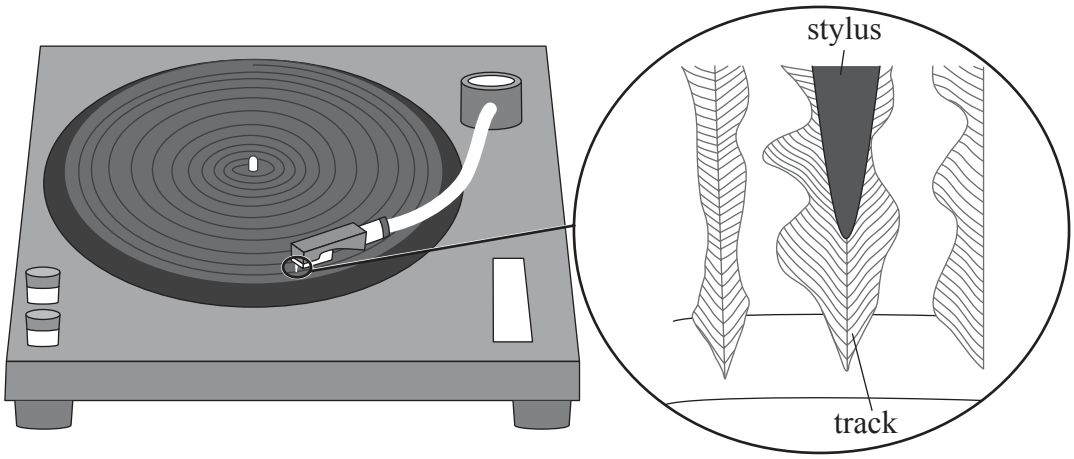
5. This question is in **two** parts. **Part 1** is about simple harmonic motion (SHM) and sound. **Part 2** is about electric and magnetic fields.

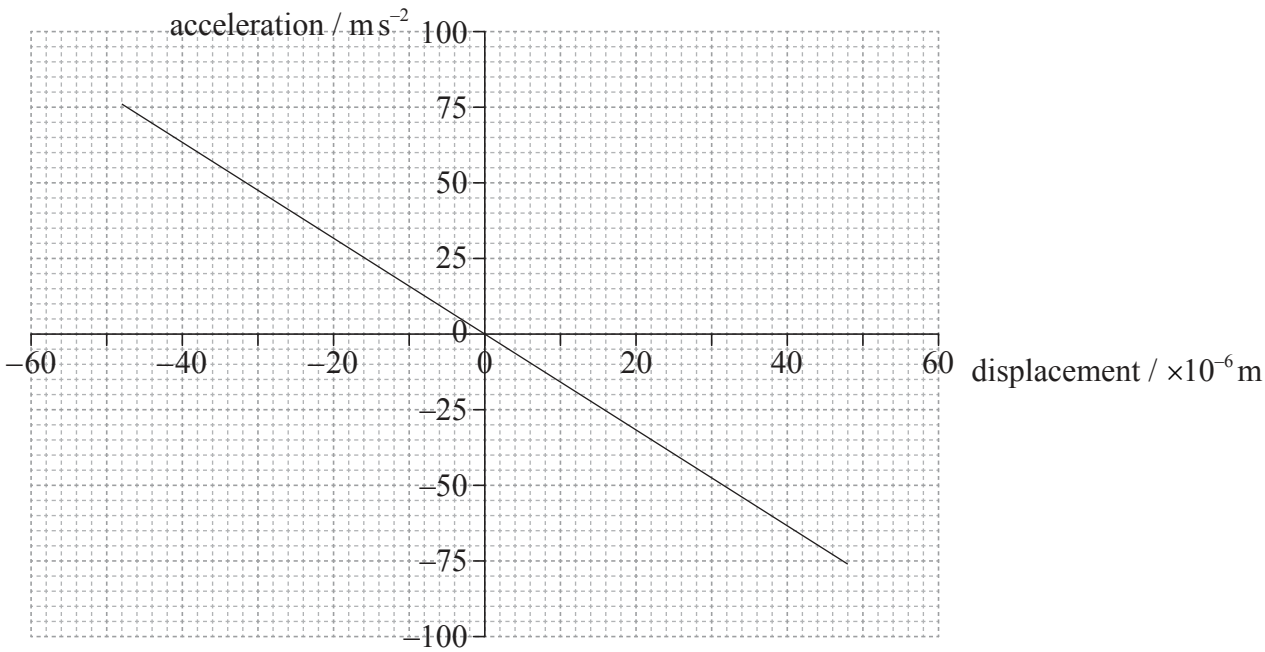
Part 1 Simple harmonic motion (SHM) and sound

The diagram shows a section of continuous track of a long-playing (LP) record. The stylus (needle) is placed in the track of the record.



As the LP record rotates, the stylus moves because of changes in the width and position of the track. These movements are converted into sound waves by an electrical system and a loudspeaker.

A recording of a single-frequency musical note is played. The graph shows the variation in horizontal acceleration of the stylus with horizontal displacement.



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(Question 5, part 1 continued)

(a) Explain why the graph shows that the stylus undergoes simple harmonic motion. *[4]*

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(b) (i) Using the graph on page 14, show that the frequency of the note being played is about 200 Hz. *[4]*

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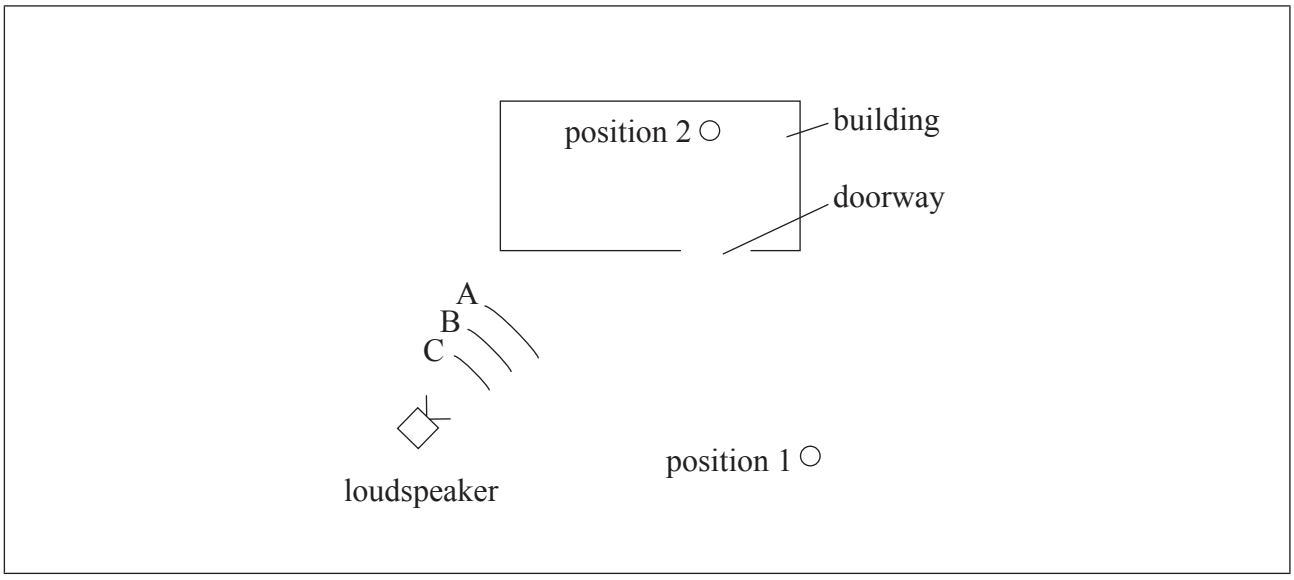
(ii) On the graph on page 14, identify, with the letter P, the position of the stylus at which the kinetic energy is at a maximum. *[1]*

(This question continues on the following page)

(Question 5, part 1 continued)

(c) The sound from the LP record is sent to a loudspeaker which is outside a building. The loudspeaker emits a sound wave that has the same frequency as the recorded note.

A person standing at position 1 outside the building and a person standing at position 2 inside the building both hear the sound emitted by the loudspeaker.



A, B and C are wavefronts emitted by the loudspeaker.

(i) Draw rays to show how the person at **position 1** is able to hear the sound emitted by the loudspeaker. *[1]*

(ii) The speed of sound in the air is $330\,m\,s^{-1}$. Calculate the wavelength of the note. *[1]*

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(Question 5, part 1 continued)

(iii) The walls of the room are designed to absorb sound. Explain how the person at **position 2** is able to hear the sound emitted by the loudspeaker. *[2]*

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(d) The arrangement in (c) is changed and another loudspeaker is added. Both loudspeakers emit the same recorded note in phase with each other.

Outline why there are positions between the loudspeakers where the sound can only be heard faintly. *[3]*

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(Question 5 continued)

Part 2 Electric and magnetic fields

Electrical leads used in physics laboratories consist of a central conductor surrounded by an insulator.

(e) Distinguish between an insulator and a conductor. *[2]*

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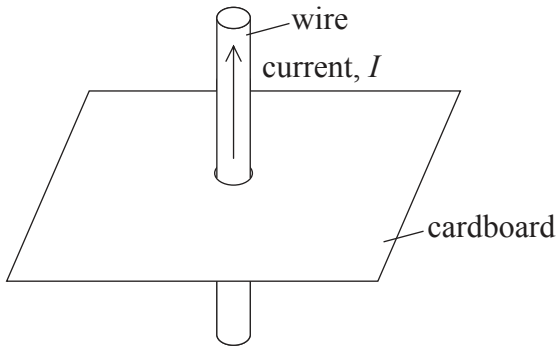
(f) The diagram shows a current I in a vertical wire that passes through a hole in a horizontal piece of cardboard.



On the cardboard, draw the magnetic field pattern due to the current. *[3]*

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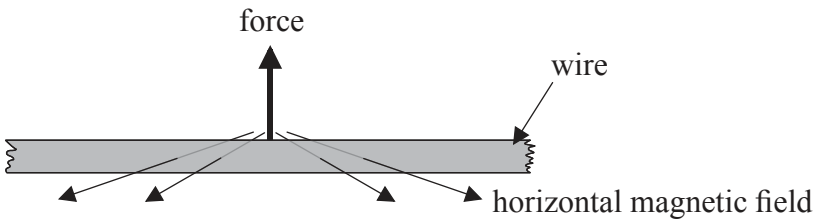
(Question 5, part 2 continued)

(g) (i) The diagram shows a length of copper wire that is horizontal in the magnetic field of the Earth.



The wire carries an electric current and the force on the wire is as shown. Identify, with an arrow, the direction of electron flow in the wire. *[1]*

(ii) The horizontal component of the magnetic field of the Earth at the position of the wire is $40\,\mu T$. The mass per unit length of the wire is $1.41\times10^{-4}\,kg\,m^{-1}$. The net force on the wire is zero. Determine the current in the wire. *[3]*

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6. This question is in **two** parts. **Part 1** is about the motion of a car. **Part 2** is about electricity.

Part 1 Motion of a car

(a) A car accelerates uniformly along a straight horizontal road from an initial speed of $12\,m\,s^{-1}$ to a final speed of $28\,m\,s^{-1}$ in a distance of 250 m. The mass of the car is 1200 kg. Determine the rate at which the engine is supplying kinetic energy to the car as it accelerates. *[4]*

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(b) Later, the car is travelling along the straight horizontal road at its maximum speed of $56\,m\,s^{-1}$. The power output required at the wheels is 0.13 MW.

(i) Calculate the total resistive force acting on the car when it is travelling at a constant speed of $56\,m\,s^{-1}$. *[2]*

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(Question 6, part 1 continued)

(ii) The mass of the car is 1200 kg. The resistive force F is related to the speed v by $F \propto v^2$. Using your answer to (b)(i), determine the maximum theoretical acceleration of the car at a speed of $28\,m\,s^{-1}$. *[3]*

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(c) A driver moves the car in a horizontal circular path of radius 200 m. Each of the four tyres will not grip the road if the frictional force between a tyre and the road becomes less than 1500 N.

(i) Calculate the maximum speed of the car at which it can continue to move in the circular path. Assume that the radius of the path is the same for each tyre. *[3]*

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(Question 6, part 1 continued)

(ii) While the car is travelling around the circle, the people in the car have the sensation that they are being thrown outwards. Outline how Newton's first law of motion accounts for this sensation. *[3]*

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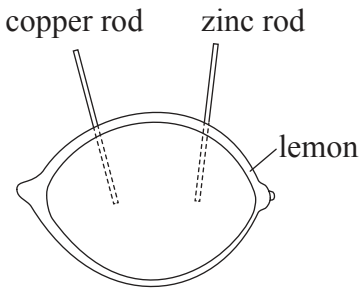
Part 2 Electricity

(d) A lemon can be used to make an electric cell by pushing a copper rod and a zinc rod into the lemon.



A student constructs a lemon cell and connects it in an electrical circuit with a variable resistor. The student measures the potential difference V across the lemon and the current I in the lemon.

(This question continues on the following page)

(Question 6, part 2 continued)

(i) Draw a circuit diagram of the experimental arrangement that will enable the student to collect the data for the graph. *[2]*

(ii) Show that the potential difference V across the lemon is given by

$$V = E - Ir$$

where E is the emf of the lemon cell and r is the internal resistance of the lemon cell. *[2]*

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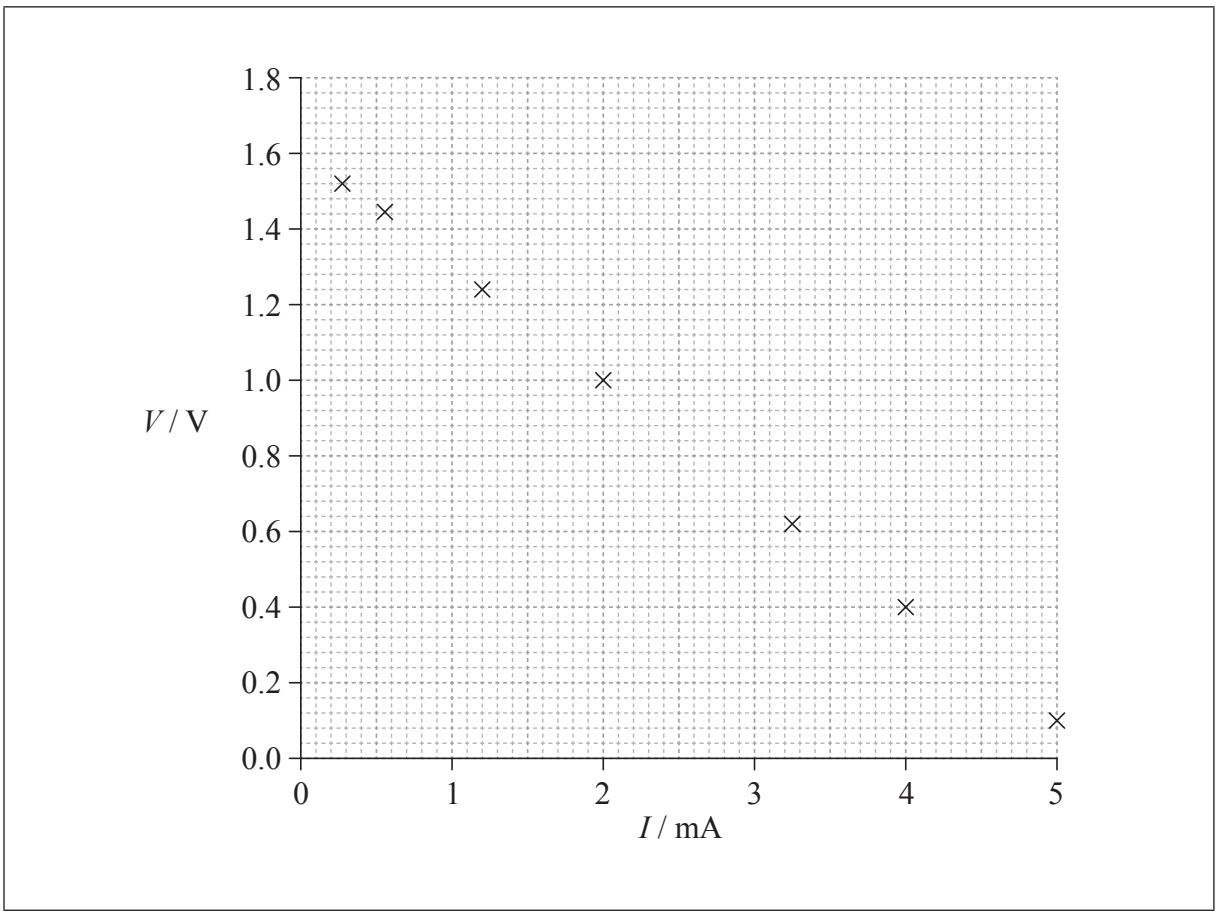
(Question 6, part 2 continued)

(iii) The graph shows how V varies with I.



Using the graph, estimate the emf of the lemon cell. *[2]*

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(Question 6, part 2 continued)

(iv) Determine the internal resistance of the lemon cell. *[3]*

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(v) The lemon cell is used to supply energy to a digital clock that requires a current of 6.0 μA. The clock runs for 16 hours. Calculate the charge that flows through the clock in this time. *[1]*

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