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PHYSICS
STANDARD LEVEL
PAPER 2

Candidate session number

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Tuesday 13 November 2012 (afternoon)

1 hour 15 minutes

Examination code

8	8	1	2	–	6	5	0	5

INSTRUCTIONS TO CANDIDATES

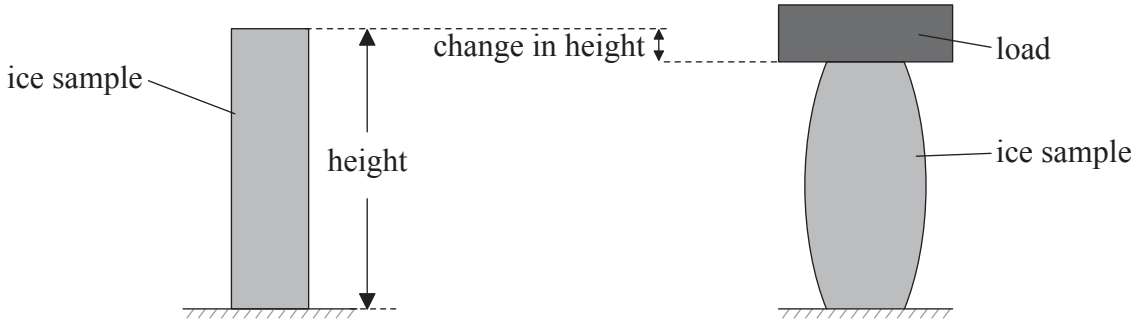
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer one question.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the ***Physics*** *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.*

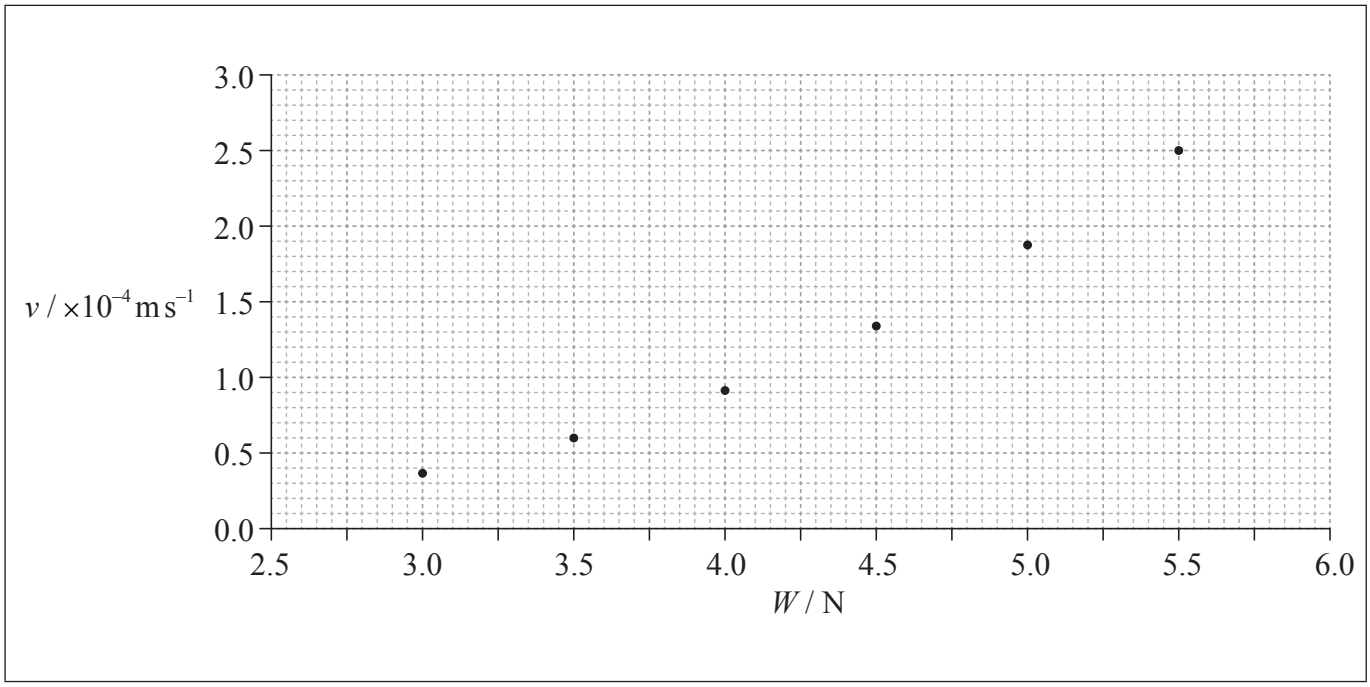
A1. Data analysis question.

The movement of glaciers can be modelled by applying a load to a sample of ice.



After the load has been applied, it is observed to move downwards at a constant speed v as the ice deforms. The constant speed v is measured for different loads. The graph shows the variation of v with load W for a number of identical samples of ice.

The data points are plotted below.



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(Question A1 continued)

The uncertainty in v is $\pm 20\,\mu m\,s^{-1}$ and the uncertainty in W is negligible.

(a) (i) On the graph opposite, draw error bars on the first and last points to show the uncertainty in v. *[1]*

(ii) On the graph opposite, draw the line of best-fit for the data points. *[1]*

(b) Explain whether the data support the hypothesis that v is directly proportional to W. *[1]*

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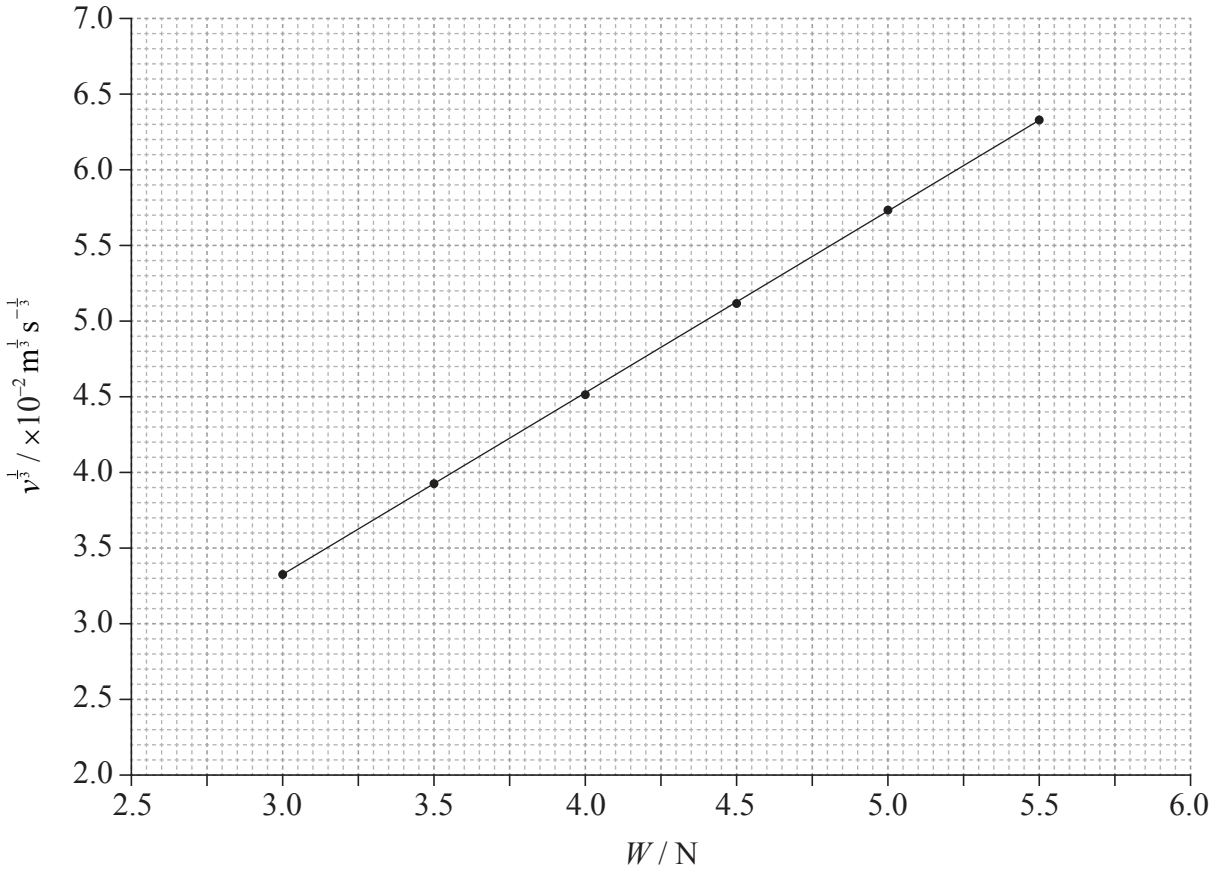
(Question A1 continued)

(c) Theory suggests that the relation between v and W is

$$v=kW^3$$

where k is a constant.

To test this hypothesis a graph of $v^{\frac{1}{3}}$ against W is plotted.



At $W=5.5\,\text{N}$ the speed is $250\pm20\,\mu\text{m}\,\text{s}^{-1}$.

Calculate the uncertainty in $v^{\frac{1}{3}}$ for a load of 5.5 N. *[3]*

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(Question A1 continued)

(d) (i) Using the graph in (c), determine k without its uncertainty. *[4]*

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(ii) State an appropriate unit for your answer to (d)(i). *[1]*

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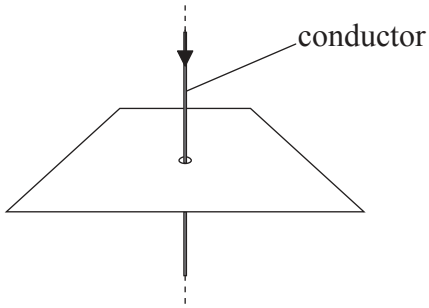
A2. This question is about magnetic fields.

A long straight vertical conductor carries an electric current. The conductor passes through a hole in a horizontal piece of paper.



(a) State how a magnetic field arises. *[1]*

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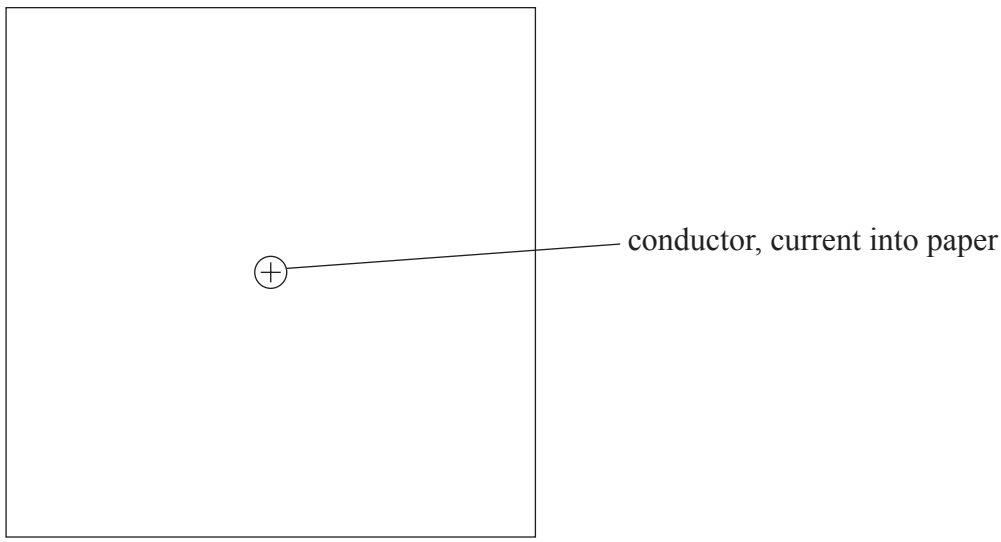
(b) On the diagram below, sketch the magnetic field pattern around the long straight current-carrying conductor. The direction of the current is into the plane of the paper. *[2]*



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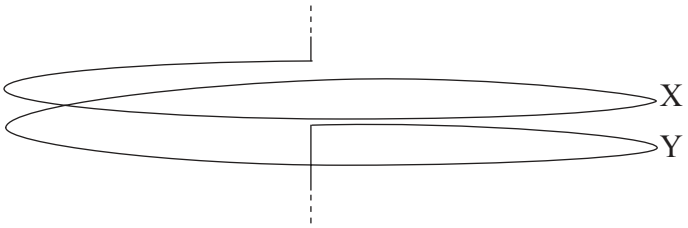
(Question A2 continued)

(c) The long straight conductor is formed into a coil consisting of two separate turns, X and Y. The coil hangs with its axis vertical.



Assume that the turns of the coil each behave as a long straight conductor.

(i) Explain why, when there is a current in the coil, the separation of X and Y decreases. *[2]*

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(ii) The current in the coil is 15 A and the circumference of one turn is 0.48 m. In order to restore X and Y to their original separation, a mass of 2.8×10^{-4} kg is suspended from turn Y. Estimate the magnetic field strength at X due to Y. *[3]*

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A3. This question is about radioactivity.

Caesium-137 $\left({}^{137}_{55}\mathrm{Cs}\right)$ is a radioactive waste product with a half-life of 30 years that is formed during the fission of uranium. Caesium-137 decays by the emission of a beta-minus (β^-) particle to form a nuclide of barium (Ba).

(a) State the nuclear equation for this reaction. *[2]*

$${}^{137}_{55}\mathrm{Cs} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{Ba} + {}^{0}_{-1}\beta^- + \ldots\ldots\ldots$$

(b) Determine the fraction of caesium-137 that will have decayed after 120 years. *[2]*

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(c) Explain, with reference to the biological effects of ionizing radiation, why it is important that humans should be shielded from the radiation emitted by caesium-137. *[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 momentum change. **Part 2** is about an oscillating water column (OWC) energy converter.

Part 1 Momentum change

(a) State the law of conservation of linear momentum. *[2]*

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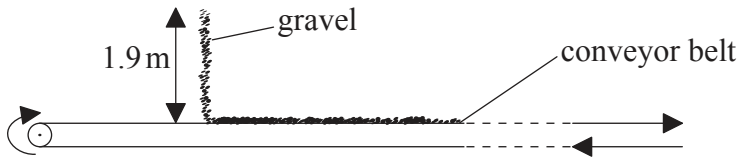
(Question B1, part 1 continued)

(b) Gravel falls vertically onto a moving horizontal conveyor belt.



(i) The gravel falls at a constant rate of $13\,\text{kg}\,\text{s}^{-1}$ through a height of 1.9 m. Show that the vertical speed of the gravel as it lands on the conveyor belt is about $6\,\text{m}\,\text{s}^{-1}$. *[2]*

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(ii) The gravel lands on the conveyor belt without rebounding. Calculate the rate of change of the vertical momentum of the gravel. *[2]*

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(iii) Gravel first reaches the belt at $t = 0.0\,\text{s}$ and continues to fall. Determine the total vertical force that the gravel exerts on the conveyor belt at $t = 5.0\,\text{s}$. *[3]*

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(Question B1, part 1 continued)

(c) The conveyor belt moves with a constant horizontal speed of $1.5\,m\,s^{-1}$. As the gravel lands on the belt, it has no horizontal speed.

(i) Calculate the rate of change of the kinetic energy of the gravel due to its change in horizontal speed. *[1]*

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(ii) Determine the power required to move the conveyor belt at constant speed. *[2]*

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(iii) Outline why the answers to (c)(i) and (ii) are different. *[1]*

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(Question B1 continued)

Part 2 Oscillating water column (OWC) energy converter

(a) Oscillating water column (OWC) energy converters placed in the ocean are suggested for non-fossil fuel power production.

(i) State **one** other ocean-based method for power production that does not require the use of fossil fuels. *[1]*

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(ii) Describe the main features of an OWC. *[3]*

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(iii) Outline the energy transformations that take place in an OWC. *[2]*

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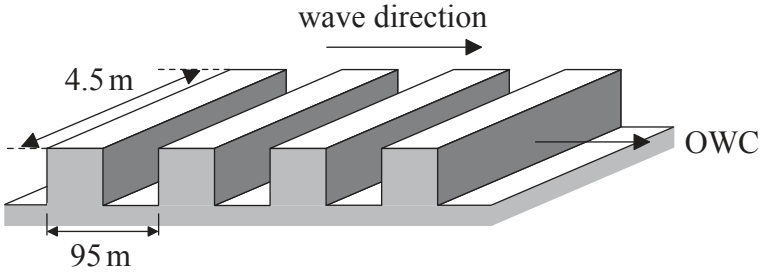
(Question B1, part 2 continued)

(b) (i) An OWC design has an aperture that accepts a wave width of 4.5 m. The waves at the proposed site have an average wavelength of 95 m and wave period of 8.0 s. The overall efficiency of the energy conversion of the OWC is 24 %.



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Assuming that the waves have a rectangular cross-section, determine the minimum wave amplitude that will be required in order for the OWC to produce a power output of 0.10 MW. *[3]*

Density of water=1000 kg m^{-3}

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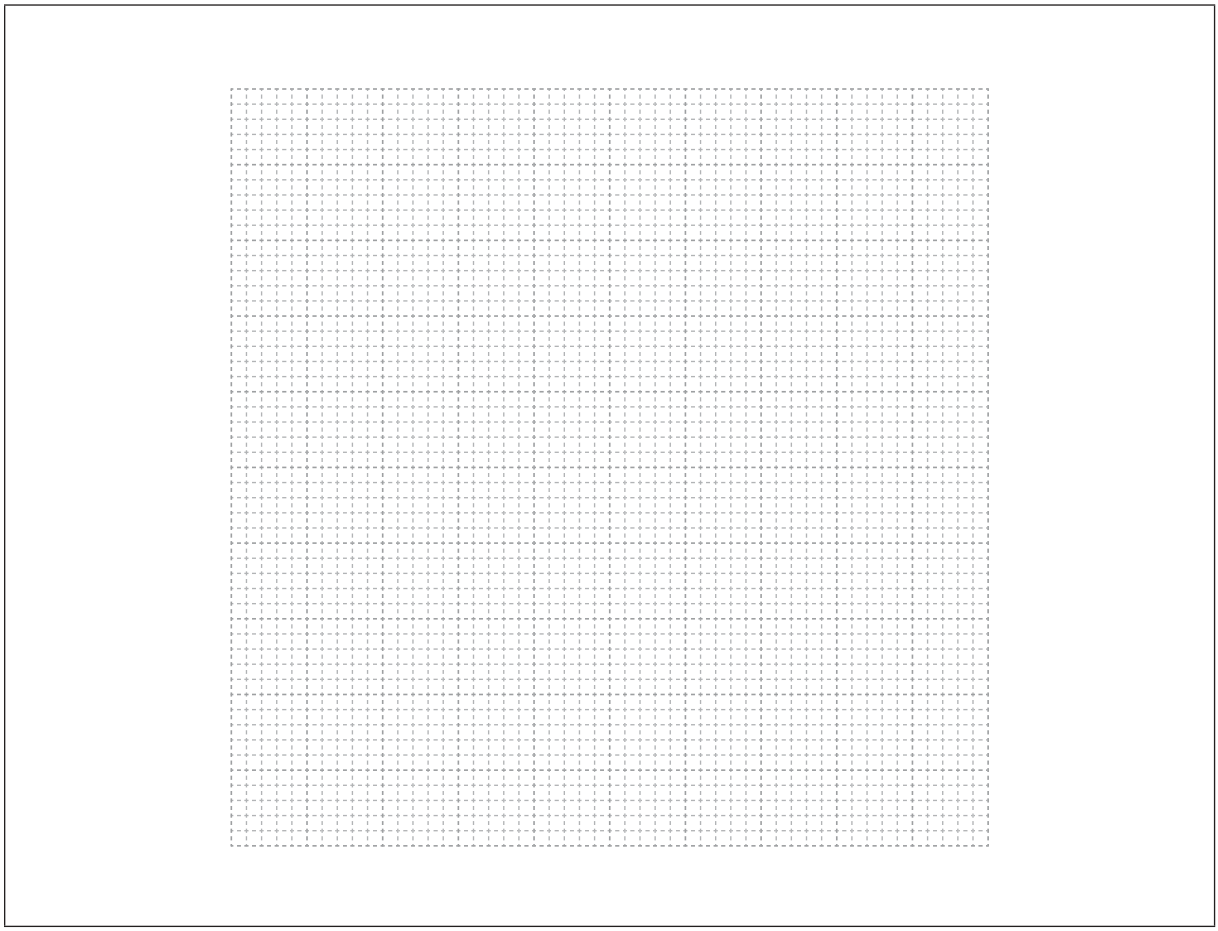
(Question B1, part 2 continued)

(ii) On the grid, sketch a labelled Sankey diagram that represents the energy transformation in this OWC. *[3]*



Please **do not** write on this page.

Answers written on this page
will not be marked.

B2. This question is in **two** parts. **Part 1** is about wave motion. **Part 2** is about the melting of the Pobeda ice island.

Part 1 Wave motion

(a) State what is meant by the terms ray and wavefront and state the relationship between them. *[3]*

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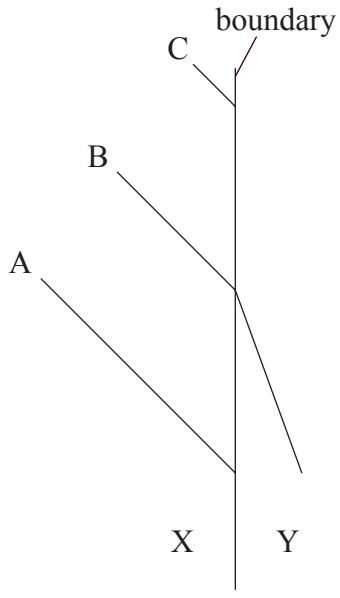
(b) The diagram shows three wavefronts, A, B and C, of a wave at a particular instant in time incident on a boundary between media X and Y. Wavefront B is also shown in medium Y.



(i) Draw a line to show wavefront C in medium Y. *[1]*

(This question continues on the following page)

(Question B2, part 1 continued)

(ii) The refractive index of X is n_X and the refractive index of Y is n_Y. By making appropriate measurements, calculate $\frac{n_X}{n_Y}$. *[3]*

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(c) The wave in (b) is transverse. Describe the difference between transverse waves and longitudinal waves. *[2]*

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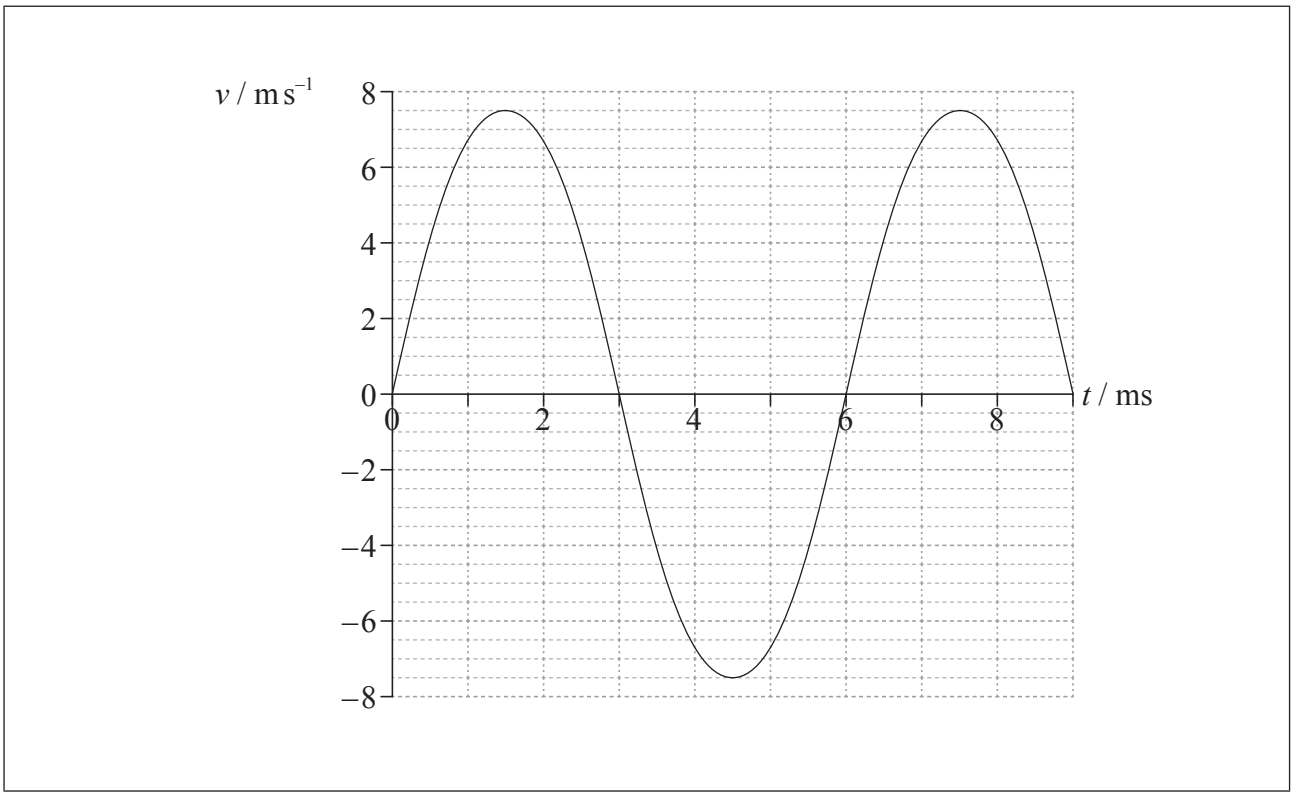
(Question B2, part 1 continued)

(d) The graph below shows the variation of the velocity v with time t for one oscillating particle of medium Y.



(i) Calculate the frequency of oscillation of the particle. *[2]*

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(ii) Identify on the graph, with the letter M, a time at which the displacement of the particle is a maximum. *[1]*

(This question continues on the following page)

(Question B2, part 1 continued)

(iii) Using the graph, determine the approximate amplitude of the oscillation of the particle. *[3]*

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(Question B2 continued)

Part 2 Melting of the Pobeda ice island

(a) The Pobeda ice island forms regularly when icebergs run aground near the Antarctic ice shelf. The "island", which consists of a slab of pure ice, breaks apart and melts over a period of decades. The following data are available.

Typical dimensions of surface of island	$= 70\,\text{km} \times 35\,\text{km}$
Typical height of island	$= 240\,\text{m}$
Average temperature of the island	$= -35\,^{\circ}\text{C}$
Density of sea ice	$= 920\,\text{kg}\,\text{m}^{-3}$
Specific latent heat of fusion of ice	$= 3.3 \times 10^{5}\,\text{J}\,\text{kg}^{-1}$
Specific heat capacity of ice	$= 2.1 \times 10^{3}\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$

(i) Distinguish, with reference to molecular motion and energy, between solid ice and liquid water. *[2]*

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(ii) Show that the energy required to melt the island to form water at $0\,^{\circ}\text{C}$ is about $2 \times 10^{20}\,\text{J}$. Assume that the top and bottom surfaces of the island are flat and that it has vertical sides. *[3]*

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(Question B2, part 2 continued)

(iii) The Sun supplies thermal energy at an average rate of $450\,W\,m^{-2}$ to the surface of the island. The albedo of melting ice is 0.80. Determine an estimate of the time taken to melt the island assuming that the melted water is removed immediately and that no heat is lost to the surroundings. *[3]*

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(b) Suggest the likely effect on the average albedo of the region in which the island was floating as a result of the melting of the Pobeda ice island. *[2]*

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B3. This question is in **two** parts. **Part 1** is about a lighting system. **Part 2** is about a satellite.

Part 1 Lighting system

(a) State Ohm's law. *[1]*

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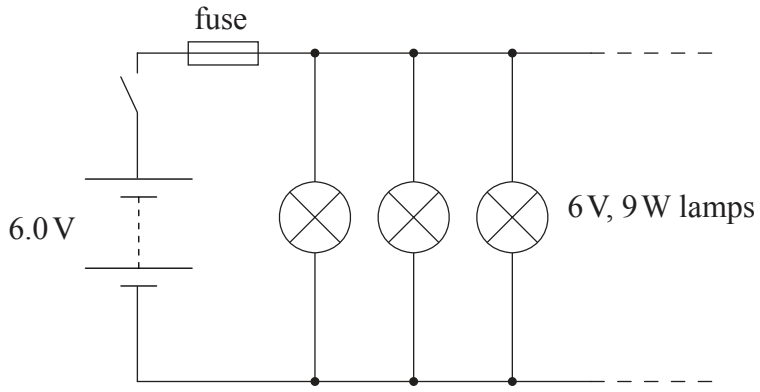
(b) A lighting system is designed so that additional lamps can be added in parallel.



The diagram shows three 6 V, 9 W lamps connected in parallel to a supply of emf 6.0 V and negligible internal resistance. A fuse in the circuit melts if the current in the circuit exceeds 13 A.

(i) Determine the maximum number of lamps that can be connected in parallel in the circuit without melting the fuse. *[3]*

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(Question B3, part 1 continued)

(ii) Calculate the resistance of a lamp when operating at its normal brightness. *[1]*

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(iii) By mistake, a lamp rated at 12 V, 9 W is connected in parallel with three lamps rated at 6 V, 9 W. Estimate the resistance of the circuit stating any assumption that you make. *[4]*

Estimate:

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Assumption:

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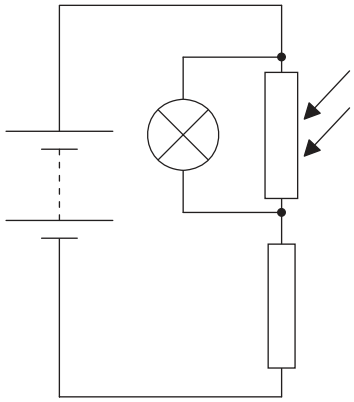
(Question B3, part 1 continued)

(c) The diagram shows a lighting circuit which includes a light-dependent resistor (LDR).



The LDR is shielded from the lamp. Explain why the intensity of the lamp increases when darkness falls. *[3]*

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(Question B3 continued)

Part 2 Satellite

(a) State, in words, Newton's universal law of gravitation. *[2]*

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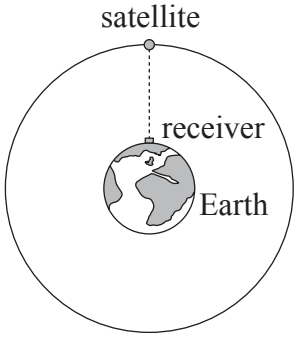
(Question B3, part 2 continued)

(b) The diagram shows a satellite orbiting the Earth. The satellite is part of the network of global-positioning satellites (GPS) that transmit radio signals used to locate the position of receivers that are located on the Earth.



(not to scale)

When the satellite is directly overhead, the microwave signal reaches the receiver 67 ms after it leaves the satellite.

(i) State the order of magnitude of the wavelength of microwaves. *[1]*

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(ii) Calculate the height of the satellite above the surface of the Earth. *[2]*

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(Question B3, part 2 continued)

(c) (i) Explain why the satellite is accelerating towards the centre of the Earth even though its orbital speed is constant. *[2]*

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(ii) Calculate the gravitational field strength due to the Earth at the position of the satellite. *[2]*

Mass of Earth $= 6.0 \times 10^{24}$ kg
Radius of Earth $= 6.4 \times 10^{6}$ m

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(iii) Determine the orbital speed of the satellite. *[2]*

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(Question B3, part 2 continued)

(iv) Determine, in hours, the orbital period of the satellite. *[2]*

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