PHYSICS
STANDARD LEVEL
PAPER 2

Candidate number

Tuesday 4 May 2004 (afternoon)

1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

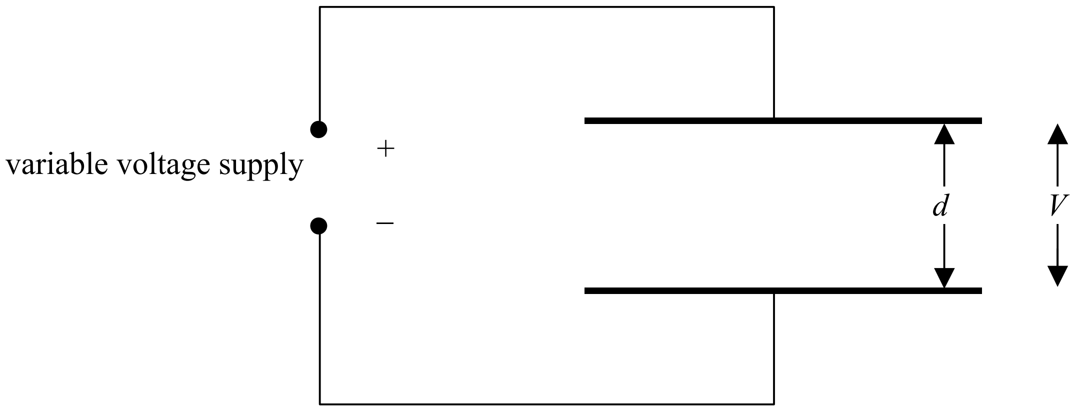
- Write your candidate number in the box above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer one question from Section B in the spaces provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet.

SECTION A

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

A1. This question is about measuring the permittivity of free space ε_0.

The diagram below shows two parallel conducting plates connected to a variable voltage supply. The plates are of equal areas and are a distance d apart.



The charge Q on one of the plates is measured for different values of the potential difference V applied between the plates. The values obtained are shown in the table below. Uncertainties in the data are not included.

V / V	Q / nC
10.0	30
20.0	80
30.0	100
40.0	160
50.0	180

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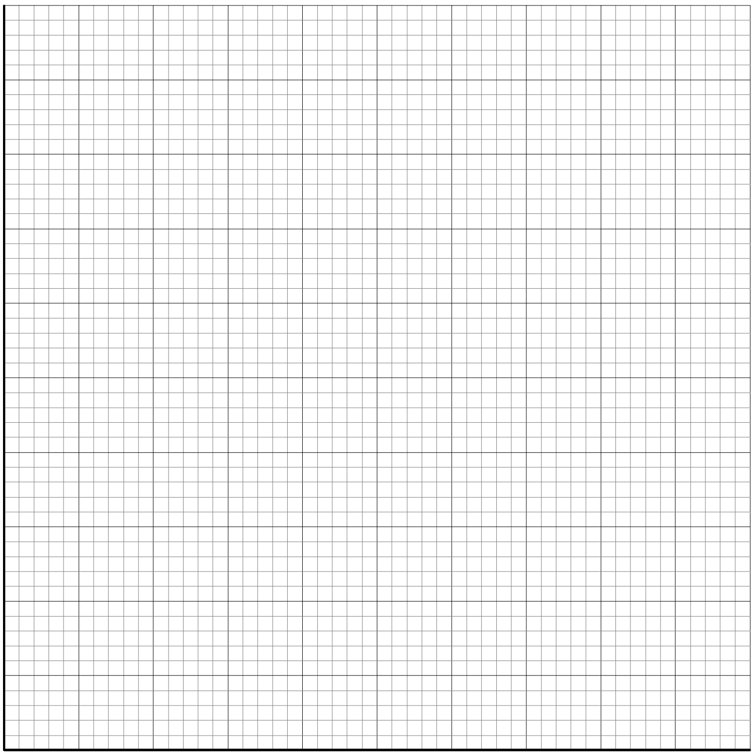
(Question A1 continued)

(a) Plot a graph of V (x-axis) against Q (y-axis). *[4]*



(b) Draw the line of best fit for the data points. *[1]*

(c) Determine the gradient of your best fit line. *[2]*

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(d) The gradient of the graph is a property of the two plates and is known as *capacitance*. Deduce the units of capacitance. *[1]*

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(This question continues on the following page)

(Question A1 continued)

The relationship between Q and V for this arrangement is given by the expression

$$Q = \frac{\varepsilon_0 A}{d} V$$

where A is the area of one of the plates.

In this particular experiment $A = 0.20\,\text{m}^2$ and $d = 0.50\,\text{mm}$.

(e) Use your answer to (c) to determine a value for ε_0. *[3]*

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A2. This question is about the collision between two railway trucks (carts).

(a) Define *linear momentum*. *[1]*

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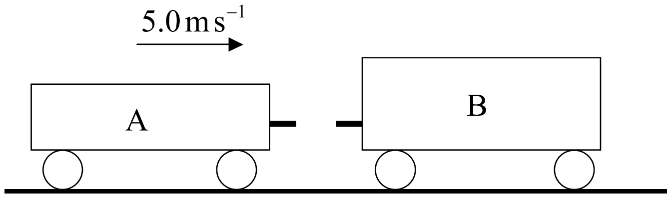
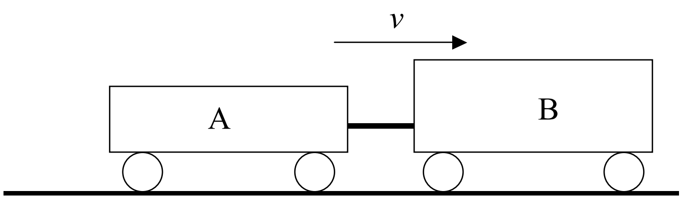
In the diagram below, railway truck A is moving along a horizontal track. It collides with a stationary truck B and on collision, the two join together. Immediately before the collision, truck A is moving with speed $5.0\,\text{m}\,\text{s}^{-1}$. Immediately after collision, the speed of the trucks is v.



Immediately before collision



Immediately after collision

The mass of truck A is 800 kg and the mass of truck B is 1200 kg.

(b) (i) Calculate the speed v immediately after the collision. *[3]*

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(ii) Calculate the total kinetic energy lost during the collision. *[2]*

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(c) Suggest what has happened to the lost kinetic energy. *[2]*

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A3. This question is about a filament lamp.

(a) On the axes below, draw a sketch-graph to show the variation with potential difference V of the current I in a typical filament lamp (the I–V characteristic). *(**Note**: this is a sketch-graph; you do not need to add any values to the axes).* *[1]*

(b) (i) Explain how the resistance of the filament is determined from the graph. *[1]*

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(ii) Explain whether the graph you have sketched indicates ohmic behaviour **or** non-ohmic behaviour. *[1]*

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A filament lamp operates at maximum brightness when connected to a 6.0 V supply. At maximum brightness, the current in the filament is 120 mA.

(c) (i) Calculate the resistance of the filament when it is operating at maximum brightness. *[1]*

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(ii) You have available a 24 V supply and a collection of resistors of a suitable power rating and with different values of resistance. Calculate the resistance of the resistor that is required to be connected in series with the supply such that the voltage across the filament lamp will be 6.0 V. *[2]*

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SECTION B

This section consists of three questions: B1, B2 and B3. Answer ***one*** *question.*

B1. This question is in **two** parts. **Part 1** is about the kinematics and dynamics of circular motion. **Part 2** is about the electric field due to a charged sphere and the motion of electrons in that field.

Part 1 Circular motion

(a) A car goes round a curve in a road at constant speed. Explain why, although its speed is constant, it is accelerating. *[2]*

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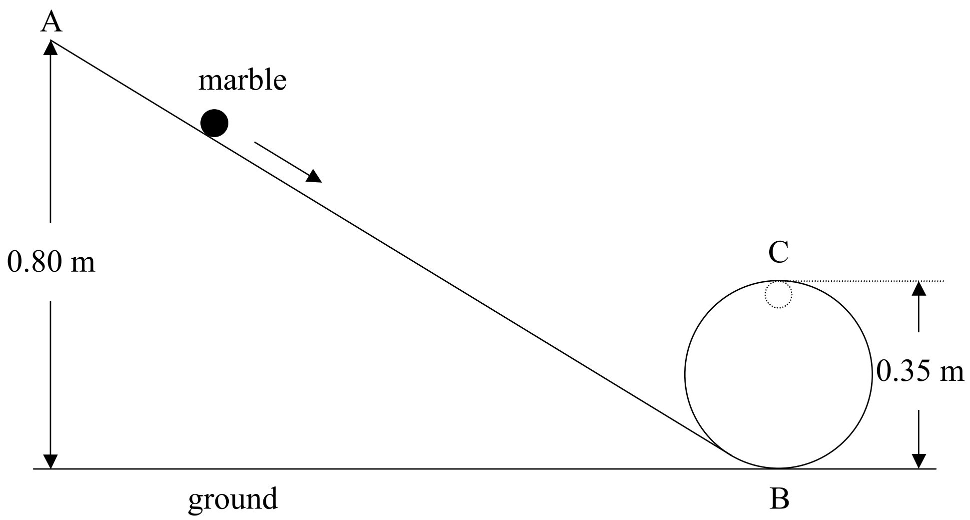
In the diagram below, a marble (small glass sphere) rolls down a track, the bottom part of which has been bent into a loop. The end A of the track, from which the marble is released, is at a height of 0.80 m above the ground. Point B is the lowest point and point C the highest point of the loop. The diameter of the loop is 0.35 m.



The mass of the marble is 0.050 kg. Friction forces and any gain in kinetic energy due to the rotating of the marble can be ignored. The acceleration due to gravity, $g = 10\,\mathrm{m\,s^{-2}}$.

Consider the marble when it is at point C.

(This question continues on the following page)

(Question B1, part 1 continued)

(b) (i) On the diagram opposite, draw an arrow to show the direction of the resultant force acting on the marble. *[1]*

(ii) State the names of the **two** forces acting on the marble. *[2]*

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(iii) Deduce that the speed of the marble is $3.0\,m\,s^{-1}$. *[3]*

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(iv) Determine the resultant force acting on the marble and hence determine the reaction force of the track on the marble. *[4]*

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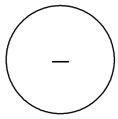
(Question B1 continued)

Part 2 The charged sphere

The diagram below shows an isolated, metal sphere in a vacuum that carries a negative electric charge of 9.0 nC.



(a) On the diagram draw arrows to represent the electric field pattern due to the charged sphere. *[3]*

(b) The electric field strength at the surface of the sphere and at points outside the sphere can be determined by assuming that the sphere acts as though a point charge of magnitude 9.0 nC is situated at its centre. The radius of the sphere is 4.5×10^{-2} m. Deduce that the magnitude of the field strength at the surface of the sphere is 4.0×10^{4} V m^{-1}. *[1]*

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(Question B1, part 2 continued)

An electron is initially at rest on the surface of the sphere.

(c) (i) Describe the path followed by the electron as it leaves the surface of the sphere. *[1]*

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(ii) Calculate the initial acceleration of the electron. *[3]*

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(iii) State and explain whether the acceleration of the electron remains constant, increases or decreases as it moves away from the sphere. *[2]*

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(iv) At a certain point P, the speed of the electron is $6.0 \times 10^{6}\ \mathrm{m\,s^{-1}}$. Determine the potential difference between the point P and the surface of the sphere. *[3]*

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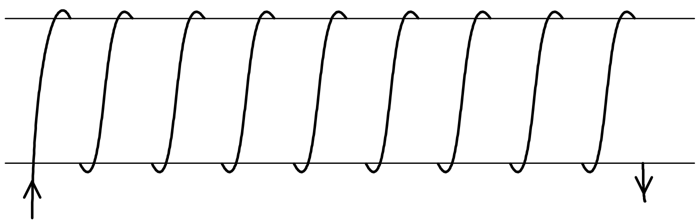
B2. This question is in **two** parts. **Part 1** is about the magnetic field of a solenoid. **Part 2** is about Huygen's principle and refraction.

Part 1 The solenoid.

The diagram below represents a side on view of a solenoid. The current is in the direction shown.



(a) Draw lines to represent the magnetic field due to the current in the solenoid. Your drawing should include both the field inside and outside the solenoid and you should include the direction of the magnetic field. *[4]*

(b) State the name of an object that produces a magnetic field pattern similar to that of a solenoid. *[1]*

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(Question B2, part 1 continued)

A biologist wishes to investigate the effects of magnetic fields on plant seeds. In order to do this, she needs a control experiment in which the seeds are in a region where there is no magnetic field. She decides to arrange a solenoid such that the magnetic field at its centre cancels out the Earth's magnetic field.

The magnetic field of the Earth has a horizontal component B_H and a vertical component B_V. At the place where the biologist carries out the experiment, $B_H = 60\,\mu\text{T}$ and $B_V = 150\,\mu\text{T}$.

(c) By means of a scale diagram **or** by calculation, determine the magnitude and direction of the resultant magnetic field strength. *[4]*

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(d) The solenoid that the biologist chooses is 0.75 m long and consists of 500 turns. Determine the current in the solenoid that will produce a magnetic strength at its centre equal in magnitude to that calculated in (c). *[2]*

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(This question continues on the following page)

(Question B2 continued)

Part 2 Refraction

(a) State Huygen's principle. *[1]*

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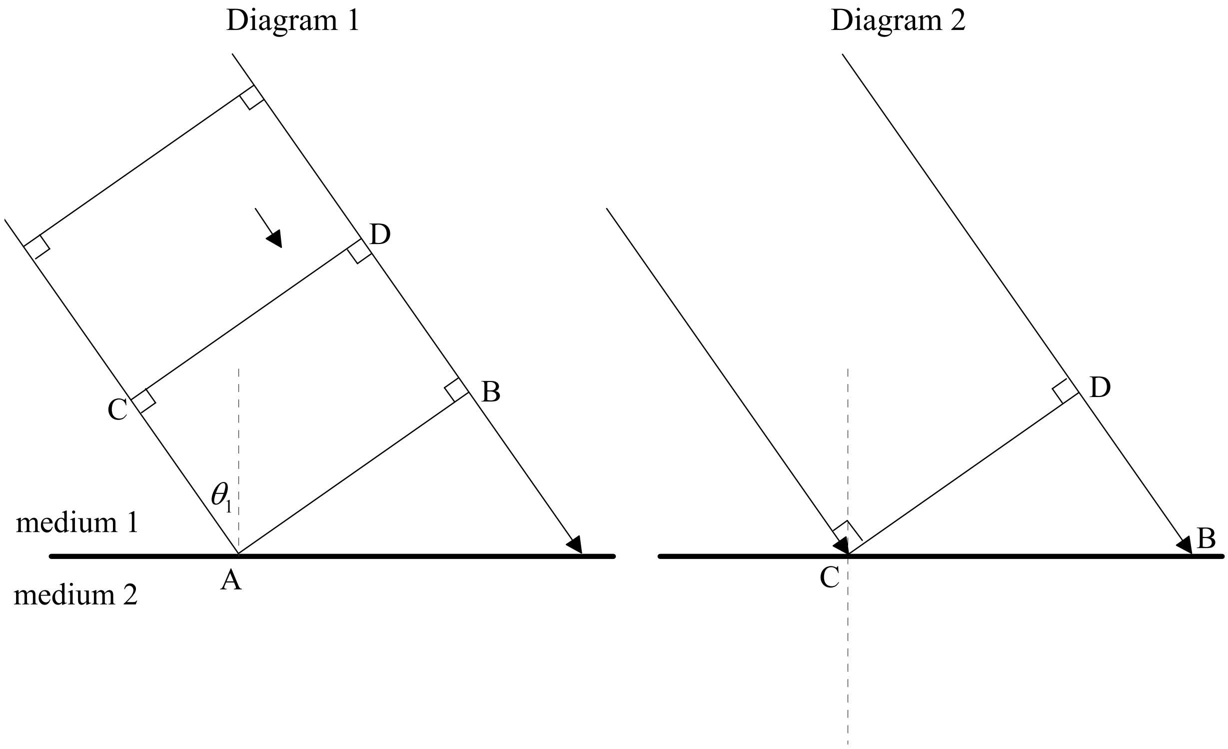
Diagram 1 below shows a wave that approaches the boundary between medium 1 and medium 2. AB and CD are two wavefronts of the wave.

Diagram 2 shows the situation a time later when point C of the wavefront CD has just reached the boundary. The speed of the wave in medium 1 is v_1 and the speed in medium 2 is v_2. v_1 is greater than v_2.



(b) On diagram 2 above

(i) draw the wavefront AB. *[1]*

(ii) draw a line to represent the distance travelled by point A. *[1]*

(iii) label the distance travelled by point B with the letter "s". *[1]*

(This question continues on the following page)

(Question B2, part 2 continued)

(c) Use your completed diagram 2 to derive the relation *[6]*

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$$

where θ_1 is the angle of incidence and θ_2 is the angle of refraction.

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(d) In medium 1 the wave has a wavelength of 4.0 cm and travels at a speed of $8.0\ \text{cm s}^{-1}$. Determine the frequency of the wave in **medium 2**. *[2]*

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(e) The angle of incidence is 60° and the angle of refraction is 35°. Calculate the speed of the wave in **medium 2**. *[2]*

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B3. This question is in **two** parts. **Part 1** is about nuclear binding energy. **Part 2** is about the change of phase (state) of ice.

Part 1 Nuclear binding energy

(a) (i) Define *nucleon*. *[1]*

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(ii) Define *nuclear binding energy of a nucleus.* *[1]*

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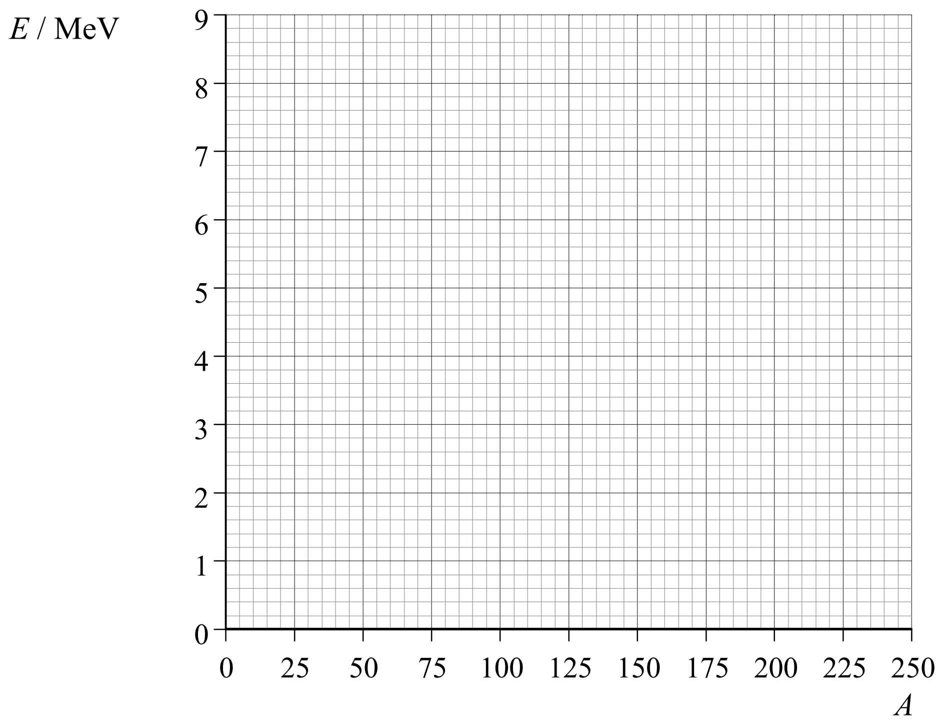
The axes below show values of nucleon number A (horizontal axis) and average binding energy per nucleon E (vertical axis). (Binding energy is taken to be a positive quantity).



(b) Mark on the E axis above, the approximate position of

(i) the isotope ${}^{56}_{26}Fe$ (label this F). *[1]*

(ii) the isotope ${}^{2}_{1}H$ (label this H). *[1]*

(iii) the isotope ${}^{238}_{92}U$ (label this U). *[1]*

(This question continues on the following page)

(Question B3, part 1 continued)

(c) Using the grid opposite, draw a graph to show the variation with nucleon number A of the average binding energy per nucleon E. *[2]*

(d) Use the following data to deduce that the binding energy per nucleon of the isotope ${}^{3}_{2}He$ is 2.2 MeV. *[3]*

nuclear mass of ${}^{3}_{2}He$ = 3.01603 u
mass of proton = 1.00728 u
mass of neutron = 1.00867 u

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In the nuclear reaction ${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n$ energy is released.

(e) (i) State the name of this type of reaction. *[1]*

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(ii) Use your graph in (c) to explain why energy is released in this reaction. *[2]*

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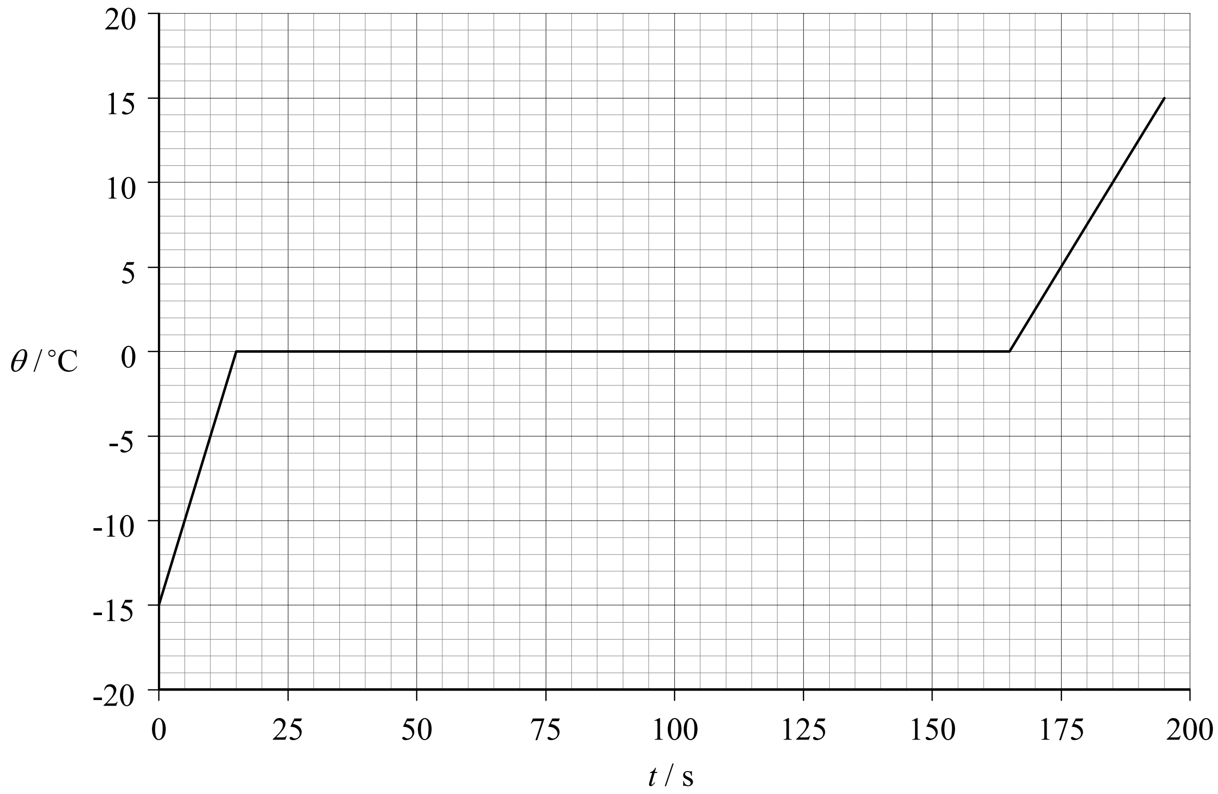
(Question B3 continued)

Part 2 Melting ice

A quantity of crushed ice is removed from a freezer and placed in a calorimeter. Thermal energy is supplied to the ice at a constant rate. To ensure that all the ice is at the same temperature, it is continually stirred. The temperature of the contents of the calorimeter is recorded every 15 seconds.

The graph below shows the variation with time t of the temperature θ of the contents of the calorimeter. *(Uncertainties in the measured quantities are not shown.)*



(a) On the graph above, mark with an X, the data point on the graph at which all the ice has just melted. *[1]*

(b) Explain, with reference to the energy of the molecules, the constant temperature region of the graph. *[3]*

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(Question B3, part 2 continued)

The mass of the ice is 0.25 kg and the specific heat capacity of water is $4200\,J\,kg^{-1}\,K^{-1}$.

(c) Use these data and data from the graph to

(i) deduce that energy is supplied to the ice at the rate of about 530 W. *[3]*

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(ii) determine the specific heat capacity of ice. *[3]*

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(iii) determine the specific latent heat of fusion of ice. *[2]*

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