IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

M04/432/H(2)

PHYSICS
HIGHER LEVEL
PAPER 2

Candidate number

Tuesday 4 May 2004 (afternoon)

2 hours 15 minutes

INSTRUCTIONS TO CANDIDATES

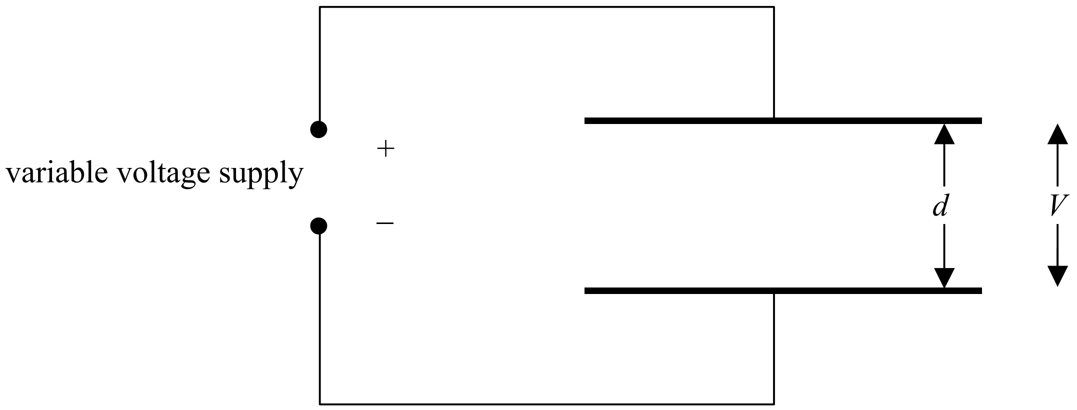
- Write your candidate number in the box above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B in the spaces provided.
- At the end of the examination, indicate the numbers of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

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.



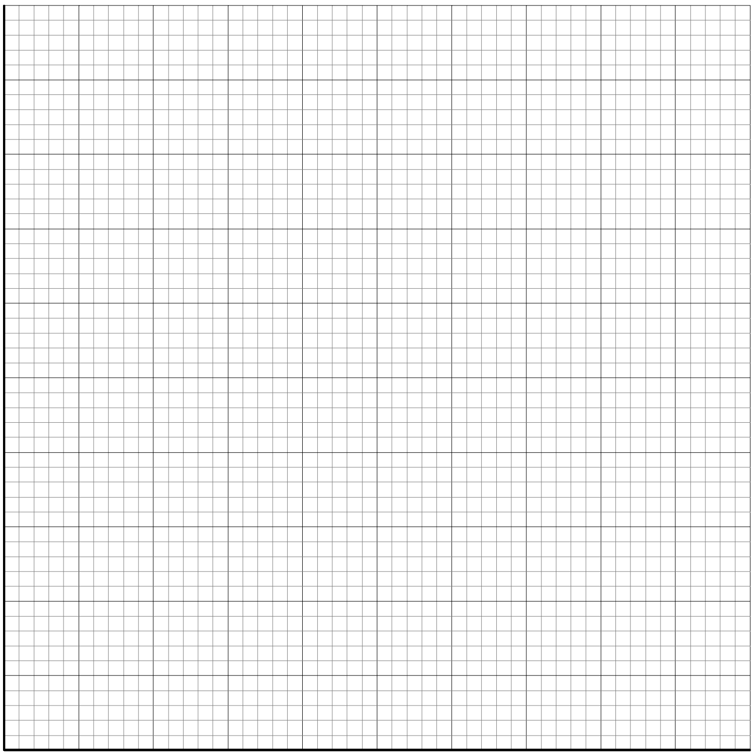
The charge Q on one of the plates is measured for different values of the potential difference V applied between the plates. The values obtained are shown in the table below. The uncertainty in the value of V is not significant but the uncertainty in Q is ±10%.

V / V	Q / nC ±10 %
10.0	30
20.0	80
30.0	100
40.0	160
50.0	180

(This question continues on the following page)

(Question A1 continued)

(a) Plot the data points opposite on a graph of *V* (*x*-axis) against *Q* (*y*-axis). *[4]*



(b) By calculating the relevant uncertainty in *Q*, add error bars to the data points (10.0, 30) and (50.0, 180). *[3]*

(c) On the graph above, draw the line that best fits the data points and has the maximum permissible gradient. Determine the gradient of the line that you have drawn. *[3]*

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

(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 $A = 0.20 \pm 0.05\,\text{m}^2$ and $d = 0.50 \pm 0.01\,\text{mm}$.

(e) Use your answer to (c) to determine the maximum value of ε_0 that this experiment yields. *[4]*

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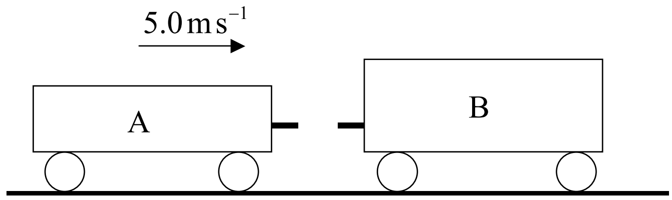
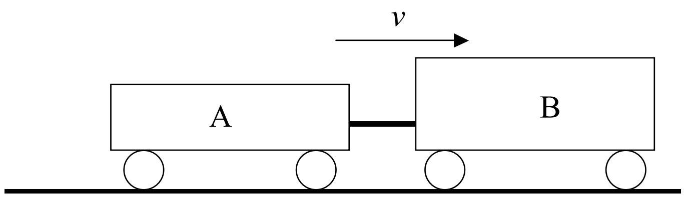
In the diagram below, railway truck A is moving along a horizontal track. It collides with a stationary truck B and on collision, the two join together. Immediately before the collision, truck A is moving with speed $5.0\,\mathrm{m\,s^{-1}}$. Immediately after collision, the speed of the trucks is *v*.



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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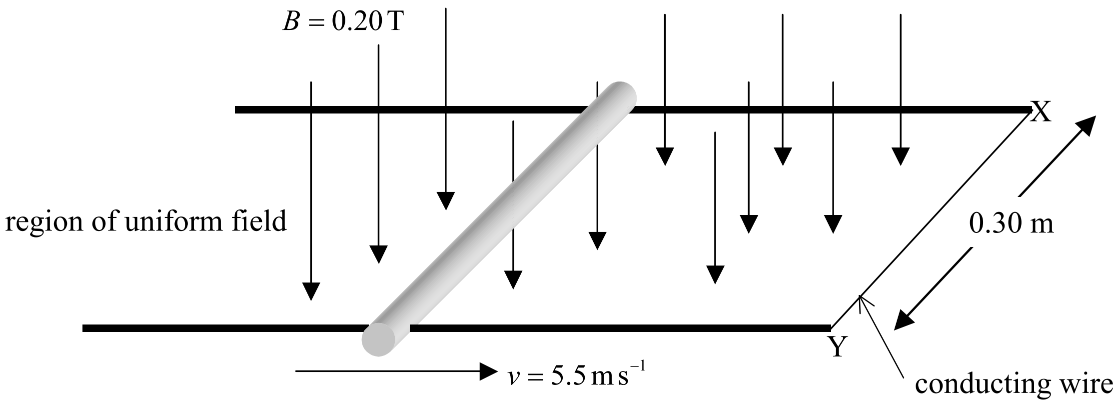
A4. This question is about induced e.m.f.'s.

In the diagram below, a thin rod made of conducting material is moved along the conducting rails X and Y at constant speed. The rails are in a region of uniform magnetic field of strength B that is directed at right angles to the plane of the rails. A conducting wire is connected between the rails as shown.



The distance between the rails, X and Y is 0.30 m, the magnetic field strength is 0.20 T and the speed v of the rod is $5.5\,\text{m}\,\text{s}^{-1}$.

(a) On the diagram above, draw arrows to show the direction of

(i) the force on the electrons in the rod (label this F_E). *[1]*

(ii) the force on the rod due to the induced current (label this F_M). *[1]*

(b) (i) Calculate the e.m.f. induced in the rod. *[1]*

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(ii) Calculate the force required to move the rod at constant speed due to an induced current in the rod of 0.80 A. *[1]*

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(c) Deduce that the mechanical power required to move the rod at the constant speed of $5.5\,\text{m}\,\text{s}^{-1}$ is equal in value to the electrical power dissipated in the rod. *[2]*

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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 the kinematics and dynamics of circular motion. **Part 2** is about the electric potential due to a charged sphere.

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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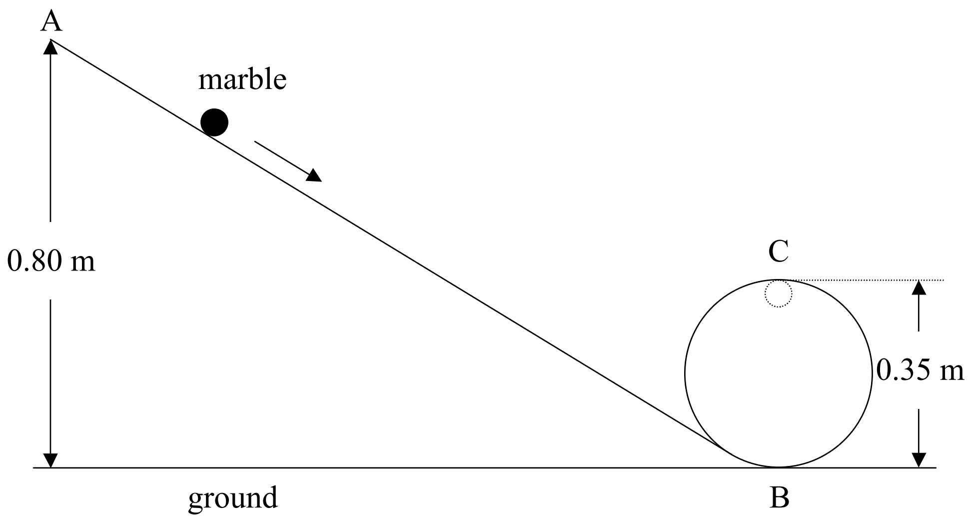
In the diagram below, a marble (small glass sphere) rolls down a track, the bottom part of which has been bent into a loop. The end A of the track, from which the marble is released, is at a height of 0.80 m above the ground. Point B is the lowest point and point C the highest point of the loop. The 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, $g = 10\,\text{m}\,\text{s}^{-2}$.

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 $3.0\,\mathrm{m\,s^{-1}}$. *[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

(a) Define *electric potential* at a point in an electric field. *[3]*

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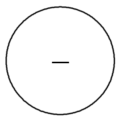
The diagram below shows an isolated, metal sphere in a vacuum that carries a negative electric charge of 9.0 nC.



(b) On the diagram above draw

(i) arrows to represent the electric field pattern in the region outside the charged sphere. *[3]*

(ii) lines to represent three equipotential surfaces in the region outside the sphere. The potential difference between the lines are to be equal in value. *[2]*

(c) Explain how the lines representing the equipotential surfaces that you have sketched indicate that the strength of the electric field is decreasing with distance from the centre of the sphere. *[2]*

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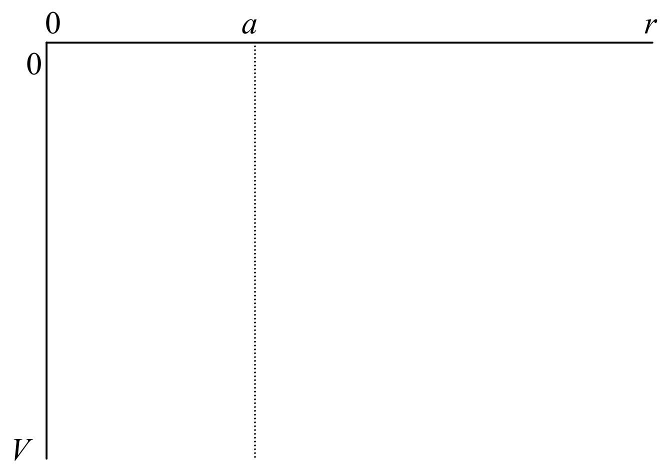
(This question continues on the following page)

(Question B1, part 2 continued)

(d) The electric field strength at all points inside the conductor is zero. On the axes below, draw a graph to show the variation with distance r from the centre of the sphere of the potential V. The dotted line is drawn at $r = a$ where a is the radius of the sphere. *(**Note**: this is a sketch graph; you do not need to add values to the axes.)* *[2]*



(e) The electric field strength at the surface of the sphere and at points outside the sphere may 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 potential at the surface of the sphere is −1800 V. *[1]*

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

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

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(ii) Determine the speed of the electron when it reaches a point a distance 0.30 m from the centre of the sphere. *[4]*

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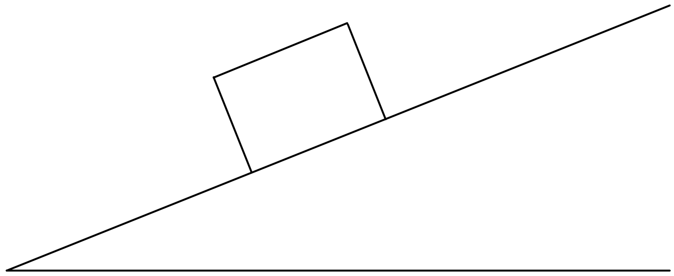
B2. This question is in **two** parts. **Part 1** is about static equilibrium. **Part 2** is about Huygen's principle and refraction.

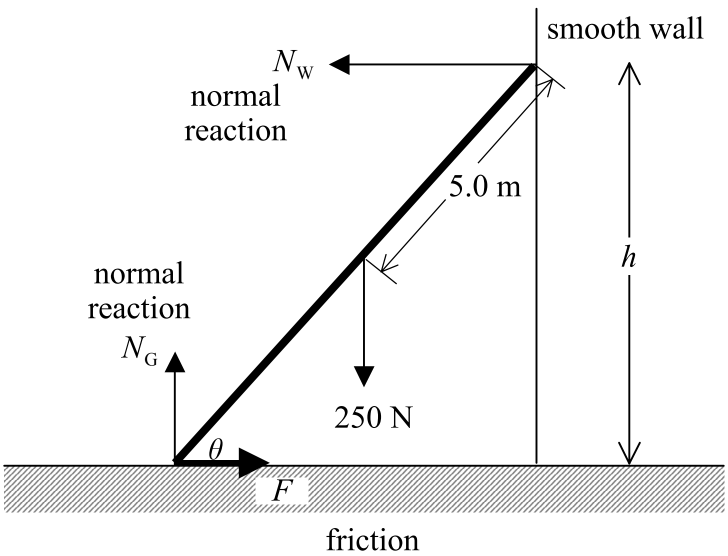
Part 1 Static equilibrium

The diagram below shows a wooden block that is at rest on an inclined plane.



(a) On the diagram above, draw arrows to represent the forces acting on the block. Label each arrow with the name of the force that it represents. *[3]*

A uniform ladder of weight 250 N and length 10 m rests against a smooth wall. The forces acting on the ladder are shown in the diagram below.



In the position shown, the foot of the ladder makes an angle θ with the ground and the ladder is just about to slip.

(b) (i) The coefficient of static friction between the ladder and the ground is 0.40. State the relation between the friction force F and the normal reaction N_G. *[1]*

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(This question continues on the following page)

(Question B2, part 1 continued)

(ii) By taking moments about the point where the ladder rests on the ground, deduce that

$$N_W = 125\cot\theta.$$ *[2]*

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(iii) Hence determine the height *h* of the top of the ladder above the ground. *[6]*

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(iv) Explain whether the height *h* should be decreased **or** increased in order to prevent the ladder slipping. *[4]*

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(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.

Diagram 1

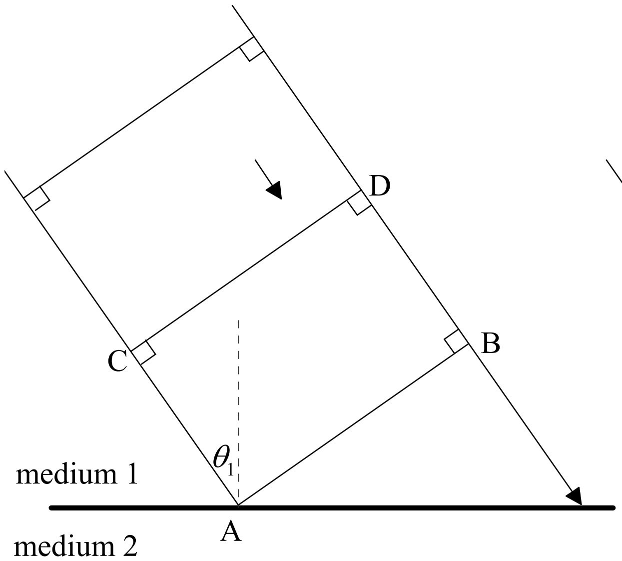
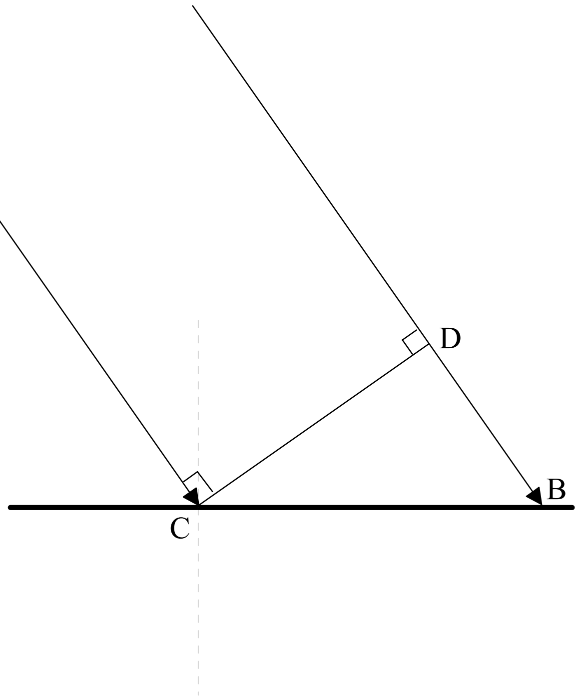


Diagram 2



(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 $8.0\ \mathrm{cm\,s^{-1}}$. 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 nucleons and nuclear binding energy. **Part 2** is about the interference of waves.

Part 1 Nuclear binding energy

(a) Define *nucleon* and state to what class of observed particle a nucleon belongs. *[2]*

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(b) Outline the structure of nucleons in terms of quarks. *[2]*

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(c) Define *nuclear binding energy*. *[1]*

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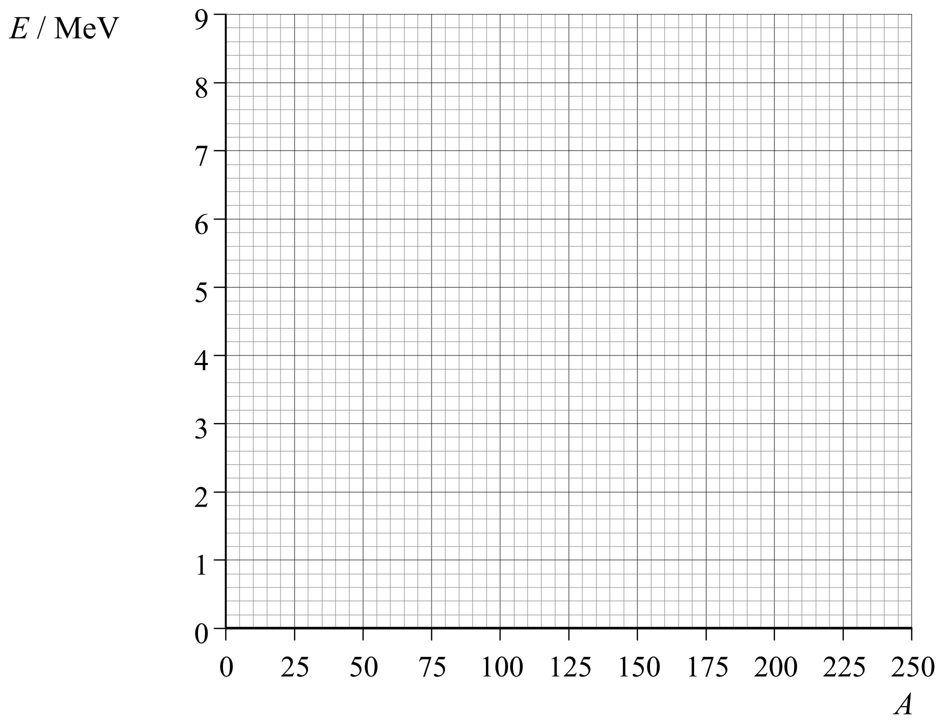
The axes below show values of nucleon number A (horizontal axis) and average binding energy per nucleon E (vertical axis). (Binding energy is taken to be a positive quantity).



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(Question B3, part 1 continued)

(d) Mark on the E axis opposite, the approximate position of

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

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

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

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

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

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

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

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

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

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(Question B3 continued)

Part 2 Wave interference

(a) State the principle of superposition. *[2]*

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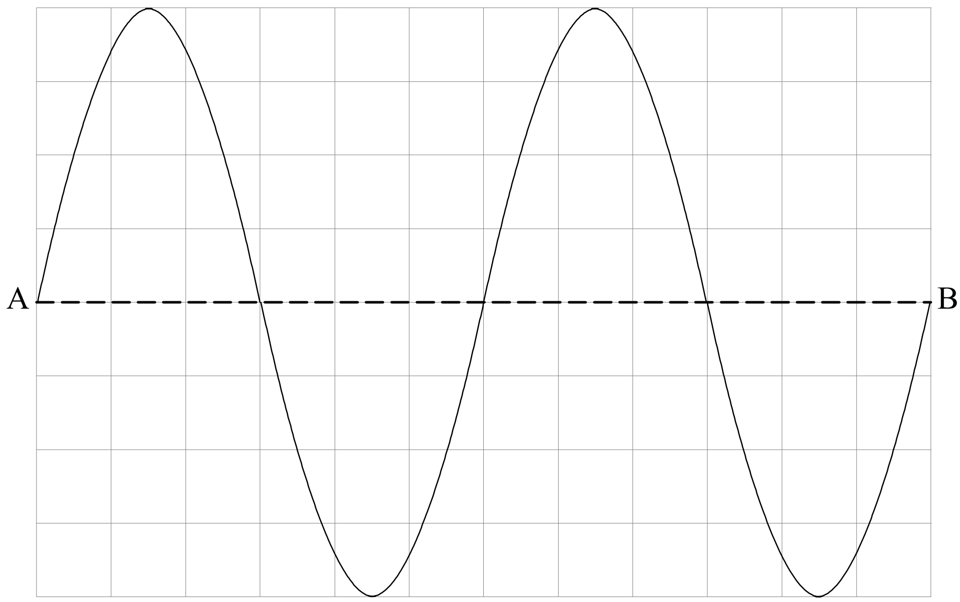
A wire is stretched between two points A and B.

A standing wave is set up in the wire. This wave can be thought of as being made up from the superposition of two waves, a wave X travelling from A to B and a wave Y travelling from B to A. At one particular instant in time, the displacement of the wire is as shown. A background grid is given for reference and the equilibrium position of the wire is shown as a dotted line.



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(Question B3, part 2 continued)

(b) On the grids below, draw the displacement of the wire due to wave X and wave Y. *[4]*

Wave X

Wave Y

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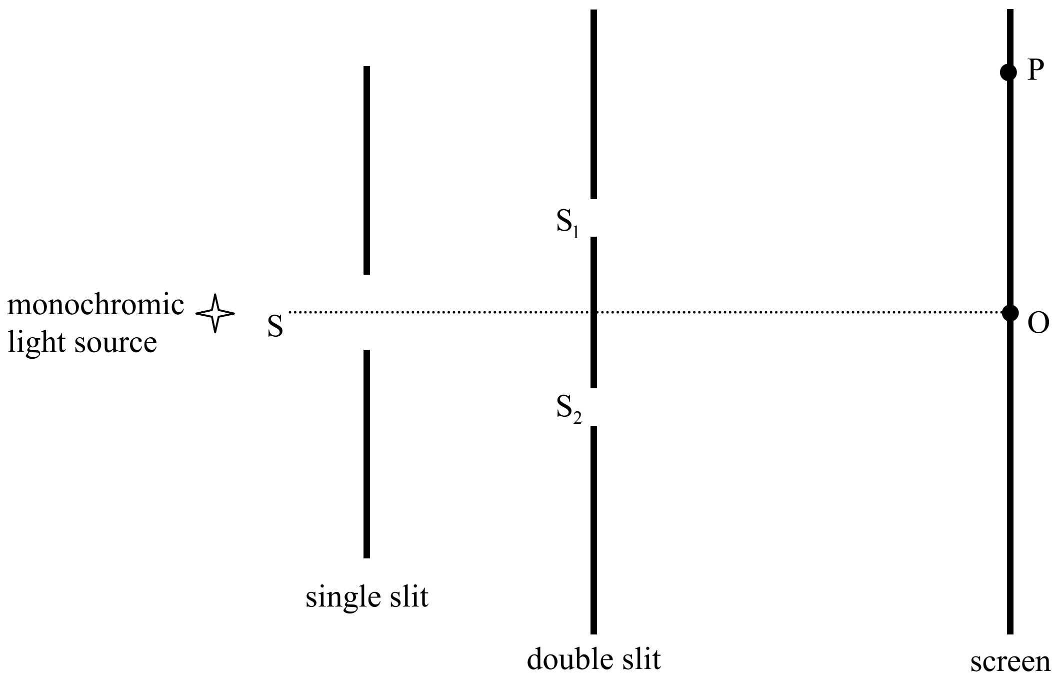
(Question B3, part 2 continued)

The diagram below shows an arrangement (not to scale) for observing the interference pattern produced by the superposition of two light waves.



S_1 and S_2 are two very narrow slits. The single slit S ensures that the light leaving the slits S_1 and S_2 is coherent.

(c) (i) Define *coherent*. *[1]*

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(ii) Explain why the slits S_1 and S_2 need to be very narrow. *[2]*

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(Question B3, part 2 continued)

The point O on the diagram is equidistant from S_1 and S_2 and there is maximum constructive interference at point P on the screen. There are no other points of maximum interference between O and P.

(d) (i) State the condition necessary for there to be maximum constructive interference at the point P. *[1]*

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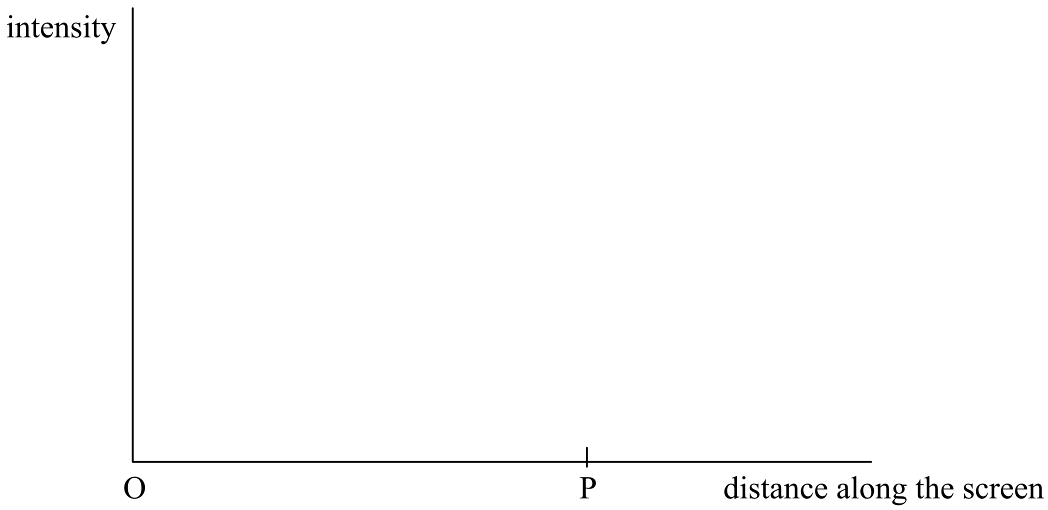
(ii) On the axes below, draw a graph to show the variation of intensity of light on the screen between the points O and P. *[2]*



(e) In this particular arrangement, the distance between the double slit and the screen is 1.50 m and the separation of S_1 and S_2 is 3.00×10^{-3} m.

The distance OP is 0.25 mm. Determine the wavelength of the light. *[2]*

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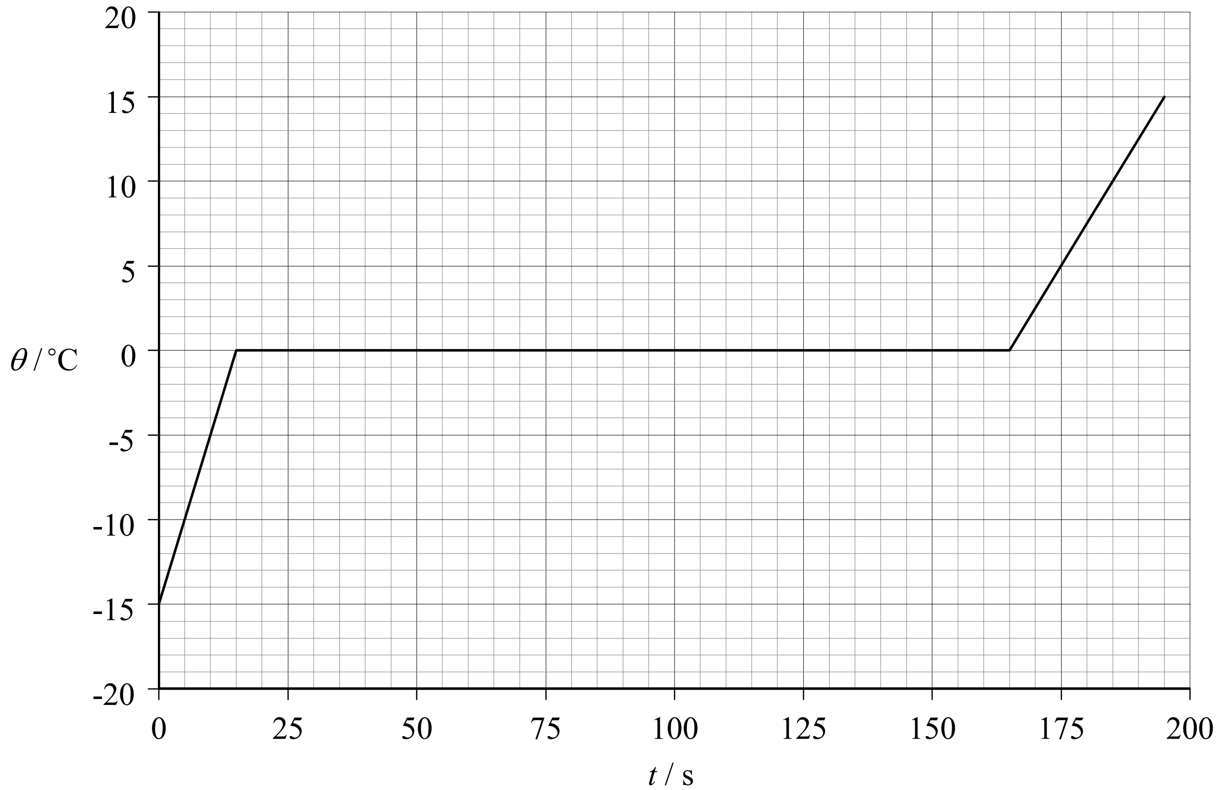
B4. This question is in **two** parts. **Part 1** is about is about the change of phase (state) of ice. **Part 2** is about the nuclear structure of the atom and atomic energy levels.

Part 1 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 B4, part 1 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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(d) State what property of the molecules of the ice is measured by a change in entropy. *[1]*

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(e) State, in terms of entropy change, the second law of thermodynamics. *[1]*

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(Question B4, part 1 continued)

(f) State what happens to the entropy of water as it freezes. Outline how this change in entropy is consistent with the second law of thermodynamics. *[4]*

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(Question B4 continued)

Part 2 The atom

When the electron was first discovered it led to the idea that an atom consists of a lump of positive charge in which the electrons are embedded.

In 1912 Geiger and Marsden carried out an experiment to test the validity of this idea. The results of their experiment in fact suggested that the atom is mostly empty space with an electrically charged nucleus of relatively large mass occupying only a small amount of space. (This is the so-called *nuclear model* of the atom). Their experiment involved "firing" alpha particles at a thin sheet of gold foil.

(a) State the nature of an alpha particle. *[1]*

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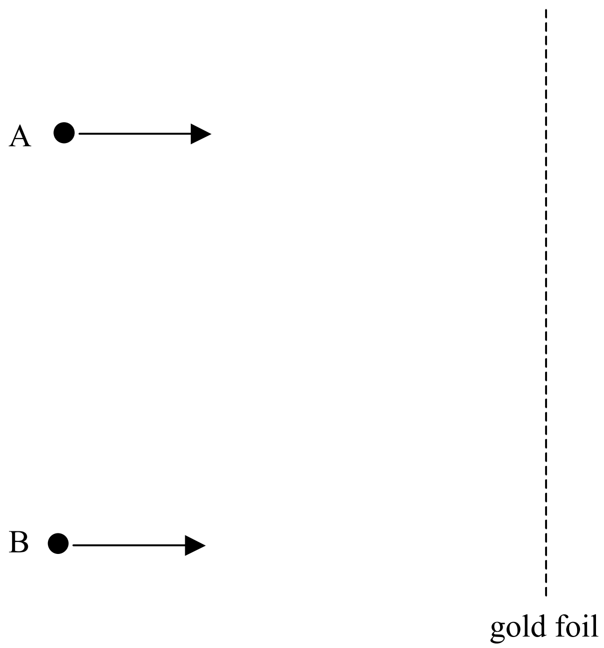
The diagram below shows a small part of the gold foil with two alpha particles A and B approaching the foil.



(b) (i) Some alpha particle trajectories lead to the idea that most of the atom is empty space. On the diagram, draw such a trajectory for the alpha particle A. *[1]*

(ii) Some other alpha particle trajectories lead to the idea that the atom has an electrically charged, relatively massive nucleus. On the diagram, draw such a trajectory for the alpha particle B. *[1]*

(This question continues on the following page)

(Question B4, part 2 continued)

(iii) Describe briefly how these trajectories lead to the idea of the nuclear model of the atom. *[4]*

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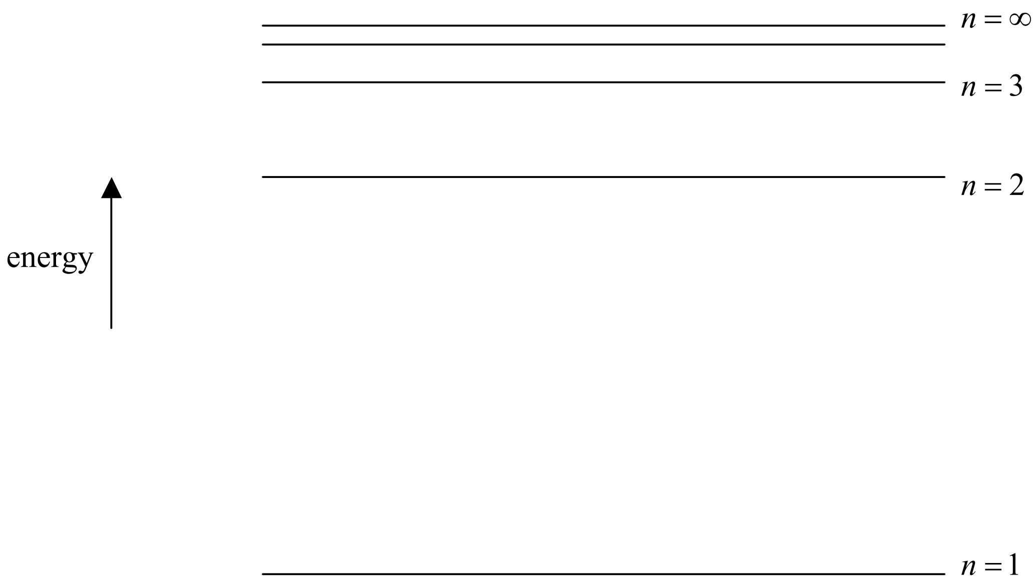
(Question B4, part 2 continued)

In 1914 Neils Bohr suggested that the electrons in an hydrogen atom occupy discrete energy levels. The diagram below shows some of the principal energy levels.



(c) (i) Label with the letter X, the energy level in which an electron will have zero potential energy. *[1]*

(ii) Explain how the line spectra of atomic hydrogen supports the idea of discrete energy levels. You may use the diagram above to support your answer. *[4]*

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