INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
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N01/430/H(2)

PHYSICS
HIGHER LEVEL
PAPER 2

Monday 19 November 2001 (afternoon)

2 hours 15 minutes

Name

Number

INSTRUCTIONS TO CANDIDATES

- Write your candidate name and number in the boxes 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 Section B questions answered in the boxes below.

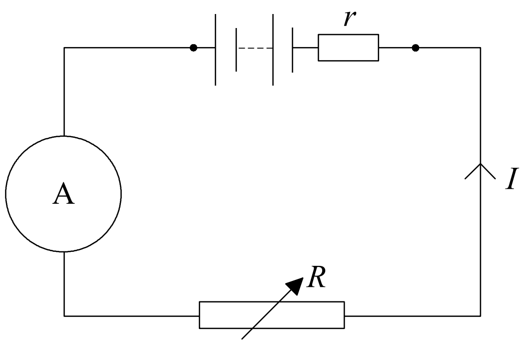
QUESTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
SECTION A	ALL	/35	/35	/35
SECTION B QUESTION QUESTION		 /30 /30	 /30 /30	 /30 /30
		TOTAL /95	TOTAL /95	TOTAL /95

SECTION A

*Candidates must answer **all** questions in the spaces provided.*

A1. This question is about power dissipation in a resistor and the internal resistance of a battery.

In the circuit below the variable resistor can be adjusted to have known values of resistance *R*. The battery has an unknown internal resistance *r*.



The table below shows the recorded value *I* of the current in the circuit for different values of *R*. The last column gives the calculated value of the power *P* dissipated in the resistor.

***R* / Ω**	***I* / A** ±0.01 A	***P* / W**
0	1.50	0
1.0	1.20	1.4
2.0	1.00	2.0
3.0	0.86	2.2
4.0	0.75	2.3
6.0	0.60	2.2
8.0	0.50	2.0
10.0	0.43	

(a) Complete the last line of the table by calculating the power dissipated in the variable resistor when its value is 10.0 Ω. *[2]*

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(This question continues on the following page)

(Question A1 continued)

(b) If each value of R is known to ±10 % determine the **absolute** uncertainty in the value of P when $R = 10.0\ \Omega$. *[3]*

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(c) On the grid below plot a graph of power P against resistance R. **(Do not include error bars)**. *[4]*

(d) It can be shown that the power dissipated in the external resistor is a maximum when the value of its resistance R is equal to the value of the internal resistance r of the battery *i.e.* $R = r$. Use this information and your graph to find the value of r. *[1]*

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(e) The manufacturer of the battery gives the value of its internal resistance as $4.50\ \Omega \pm 0.01\ \Omega$. Is the value of r that you obtained from your graph consistent with the manufacturer's value? Explain. *[2]*

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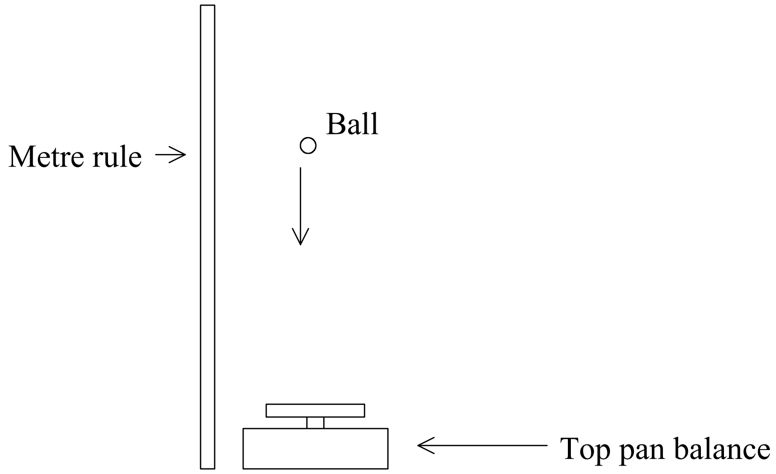
A2. This question is about a bouncing ball and contact time.



Miguel has devised a method to measure how long a bouncing ball is in contact with the surface from which it bounces. The method consists of dropping the ball on to the scale pan of a top pan balance as shown in the diagram above. The balance is calibrated in newtons and Miguel records the maximum reading on the scale, the height from which the ball is dropped and the height to which it bounces.

Miguel obtains the following information.

Height from which the ball is dropped	=	0.80 m
Height to which the ball bounces	=	0.60 m
Maximum reading on the balance scale	=	50.0 N

The mass of the ball is 0.20 kg and the acceleration due to gravity is taken to have a value of $10\ \mathrm{m\,s^{-2}}$.

(a) Calculate

(i) the speed of the ball when it strikes the scale pan. *[1]*

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(ii) the speed of the ball when it leaves the scale pan. *[1]*

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(iii) the total change in momentum of the ball between striking and leaving the scale pan. *[2]*

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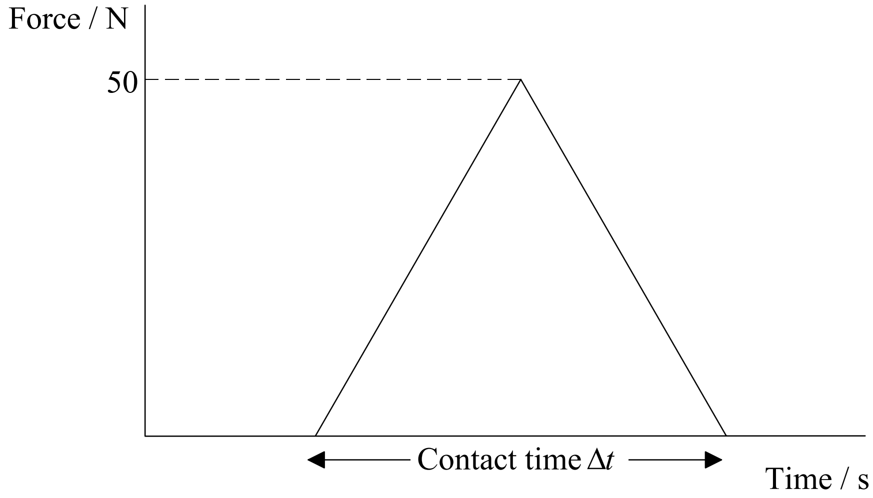
(Question A2 continued)

(b) Miguel assumes that the contact force between the ball and the scale pan varies with time as shown below.



(i) What does the area under the graph represent? *[1]*

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(ii) Calculate the contact time Δt. *[2]*

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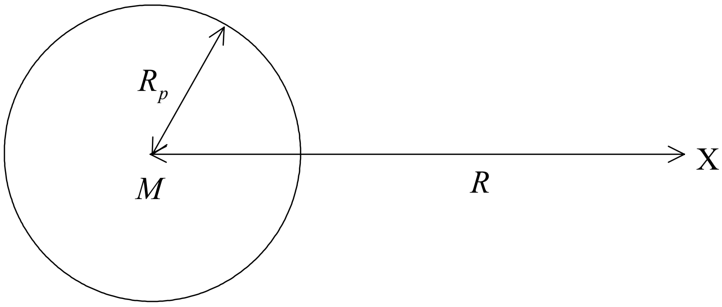
A3. This question is about gravitational potential energy.

(a) The diagram below shows a planet of mass M and radius R_p.



The gravitational potential V due to the planet at point X distance R from the centre of the planet is given by

$$V = -\frac{GM}{R}$$

where G is the universal gravitational constant.

Show that the gravitational potential V can be expressed as

$$V = -\frac{g_0 R_p^{\ 2}}{R}$$

where g_0 is the acceleration of free fall at the surface of the planet. *[3]*

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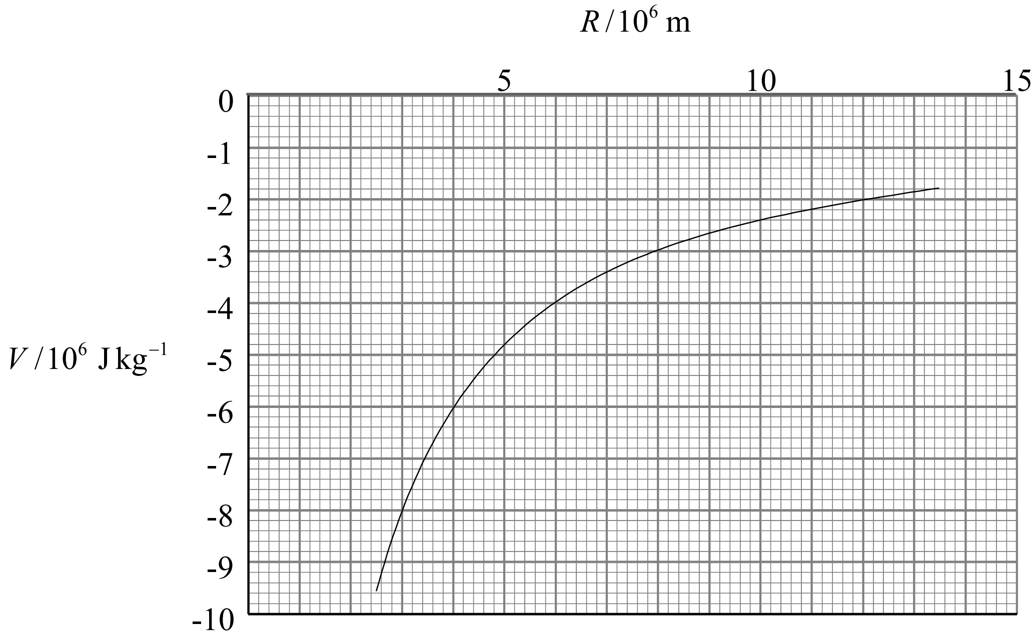
(Question A3 continued)

(b) The graph below shows how the gravitational potential V due to the planet varies with distance R from the centre of the planet for values of R greater than R_p, where $R_p = 2.5\times10^6$ m.



Use the data from the graph to

(i) determine a value of g_0. *[2]*

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(ii) show that the minimum energy required to raise a satellite of mass 3000 kg to a height 3.0×10^6 m above the **surface** of the planet is about 1.5×10^{10} J . *[3]*

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A4. This question is about using the radioactive decay law to determine the age of an ancient campsite.

(a) The radioactive isotope carbon 14 (C-14) is continually being produced in the upper atmosphere by the interaction of neutrons with nitrogen 14.

Complete the nuclear reaction equation below for the formation of C-14.

$${}^{14}_{7}\mathrm{N} + \mathrm{n} = {}^{14}_{6}\mathrm{C} +$$ *[1]*

(b) Some of the carbon atoms in a living tree consist of the radioactive isotope C-14. Due to the continual taking in of carbon the amount of C-14 in the living tree remains constant throughout the life of the tree. When the tree dies the taking in of carbon ceases and the amount of C-14 in the tree decreases with time.

(i) Explain why the amount of C-14 decreases with time. *[1]*

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(ii) The activity of wood from a living tree is measured as 15.5 disintegrations per minute per unit mass.

A piece of burnt wood (charcoal) found at an ancient settlement has an activity of 13.2 disintegrations per minute per unit mass. If the half-life of C-14 is 5600 years estimate the age of the settlement. *[4]*

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(c) The carbon found in coal also originates from wood. However, it is found that coal shows effectively no radioactivity. Suggest why this might be so. *[2]*

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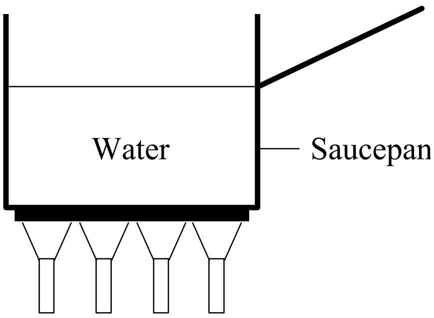
SECTION B

*This section consists of four questions: B1 (parts 1 and 2), B2 (parts 1 and 2), B3 (parts 1 and 2) and B4. Answer any **two** questions in this section.*

B1. This question is in **two** parts. **Part 1** is about change of phase, specific heat capacity and thermal energy transfer and **Part 2** is about a thermodynamic cycle.

Part 1. Change of phase, specific heat capacity and thermal energy transfer.

(a) In an attempt to measure the power supplied by a domestic gas burner a measured mass of water in an aluminium saucepan was heated by the burner until boiling. At this point a stopwatch was started and the water boiled for a measured interval of time. After this time interval the saucepan was removed from the burner and the mass of the saucepan plus water was recorded.



The following data is available:

Mass of empty saucepan	=	250 g
Mass of water **plus** saucepan at start	=	1250 g
Mass of water **plus** saucepan after boiling has taken place	=	850 g
Time for which the water is boiled	=	15 min (900 s)
Latent heat of vaporisation of water	=	2.3×10^{6} J kg^{-1}
Specific heat of water	=	4200 J kg^{-1} K^{-1}

(i) What mass of water is boiled away in 15 min? *[1]*

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(ii) How much energy is required to boil away this mass of water? *[2]*

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(Question B1 part 1 continued)

(iii) Show that thermal energy is supplied to the saucepan and the water at a rate of 1000 W. *[2]*

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(iv) Explain why the rate at which energy is supplied by the burner will actually be greater than 1000 W. *[1]*

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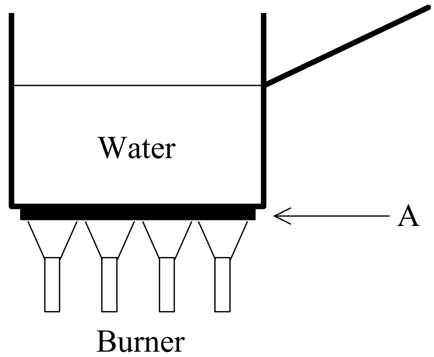
(b) Use the additional data given below to show that the temperature of the lower surface of the base of the saucepan (labelled A in the diagram) is only about $0.6\ ^\circ\mathrm{C}$ higher than that of the temperature of the boiling water.



Data:

Thermal conductivity of aluminium = $200\ \mathrm{W\,m^{-1}\,K^{-1}}$
Area of the saucepan base = $5.0\times10^{-2}\ \mathrm{m^2}$
Thickness of the saucepan base = 6.0 mm *[3]*

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(Question B1 part 1 continued)

(c) The actual temperature of the burner is about $600\ ^{\circ}\mathrm{C}$. Suggest why the lower surface of the base of the saucepan is not at the same temperature as the burner. *[2]*

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(d) Another experiment is now carried out in order to measure the specific heat of aluminium in which a measured mass of cold water is heated in the saucepan to a temperature of $90\ ^{\circ}\mathrm{C}$. Assuming that the burner supplies energy at the rate of 1000 W to the water, use the data below to determine a value for the specific heat of aluminium.

Mass of empty saucepan	= 250 g
Mass of saucepan **plus** water	= 1250 g
Initial temperature of the water	= $20\ ^{\circ}\mathrm{C}$
Final temperature of the water	= $90\ ^{\circ}\mathrm{C}$
Time for the water to reach final temperature	= 315 s
Specific heat of water	= $4200\ \mathrm{J\,kg^{-1}\,K^{-1}}$

[4]

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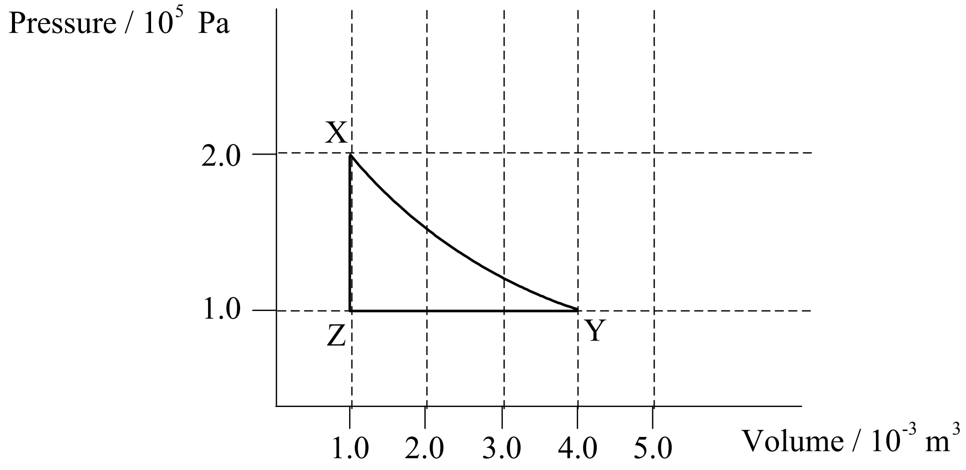
(Question B1 continued)

Part 2. Thermodynamic cycle

A fixed mass of a gas undergoes various changes of temperature, pressure and volume such that it is taken round the P–V cycle shown in the diagram below.



The following sequence of processes take place during the cycle.

$X \rightarrow Y$ the gas expands at constant temperature and the gas absorbs energy from a reservoir and does 450 J of work.

$Y \rightarrow Z$ the gas is compressed and 800 J of thermal energy is transferred from the gas to a reservoir.

$Z \rightarrow X$ the gas returns to its initial state by absorbing energy from a reservoir.

(a) Is there a change in internal energy of the gas during the process $X \rightarrow Y$? Explain. *[2]*

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(b) Is the energy absorbed by the gas during the process $X \rightarrow Y$ less than, equal to or more than 450 J? Explain. *[2]*

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(Question B1 part 2 continued)

(c) Use the graph to determine the work done on the gas during the process $Y \rightarrow Z$. *[3]*

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(d) What is the change in internal energy of the gas during the process $Y \rightarrow Z$? *[2]*

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(e) How much thermal energy is absorbed by the gas during the process $Z \rightarrow X$? Explain your answer. *[2]*

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(f) What quantity is represented by the area enclosed by the graph? Estimate its value. *[2]*

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(g) The overall efficiency of a heat engine is defined as

$$\text{Efficiency} = \frac{\text{net work done by the gas during a cycle}}{\text{total energy absorbed during a cycle}}$$

If this P–V cycle represents the cycle for a particular heat engine determine the efficiency of the heat engine. *[2]*

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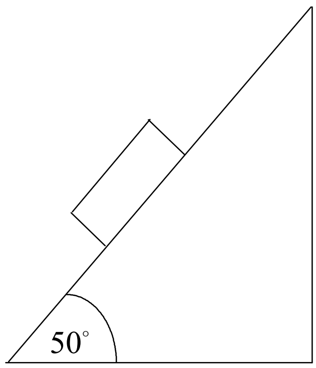
B2. This question is in **two** parts. **Part 1** is about measuring the coefficient of dynamic (kinetic) sliding friction and **Part 2** is about the motion of charged particles in electric and magnetic fields.

Part 1. This question is about measuring the coefficient of dynamic (kinetic) sliding friction.

A student releases a block of mass *M* placed at the top of an inclined plane and measures the time it takes the block to travel a measured distance down the plane. The diagram below shows the block whilst it is still sliding.



(a) On the diagram, draw and name the forces acting on the block. *[3]*

(b) The angle of incline of the plane is 50° and the block takes 1.80 s to travel 4.00 m down the plane. The acceleration due to gravity is $9.81\ \mathrm{m\,s^{-2}}$.

Calculate

(i) the acceleration of the block down the plane. *[2]*

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(ii) the component of weight down the plane in terms of *M*. *[2]*

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(Question B2 part 1 continued)

(c) If the coefficient of dynamic sliding friction between the plane and the block is μ_k, what is the value of the frictional force expressed in terms of μ_k and *M*? *[2]*

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(d) Calculate the value of μ_k. *[3]*

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(e) If the angle of incline of the plane is changed to 40° the block will only start to slide down the plane if it is given a slight push. Estimate the value of the coefficient of static friction between the block and the plane. *[2]*

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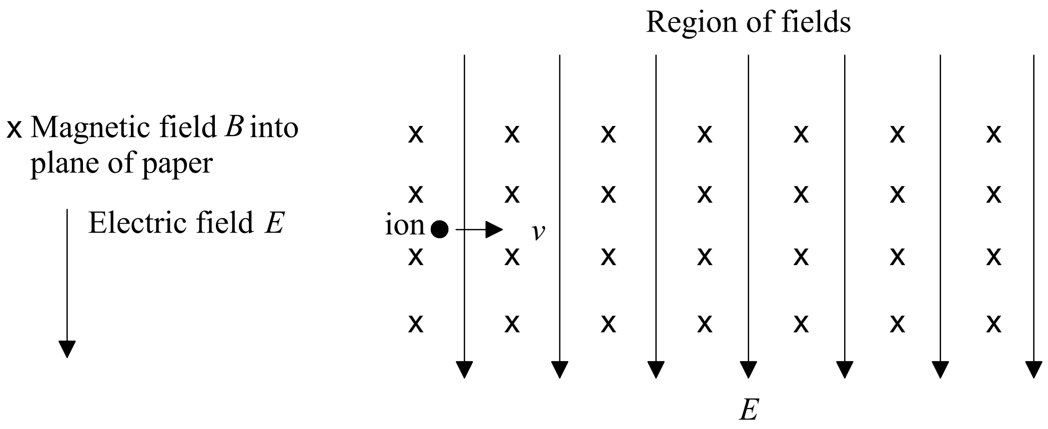
(Question B2 continued)

Part 2. Motion of charged particles in electric and magnetic fields.

In the diagram below a positive ion of mass M and charge $+q$ moving with speed v enters a region in which there is a uniform electric field of strength E and a uniform magnetic field of strength B. The magnetic field is directed into the plane of the paper and the electric field is parallel to the plane of the paper as shown below.



(a) Show on the diagram the directions of the electric force and magnetic force acting on the ion. *[2]*

(b) Write down an expression for

(i) the electric force acting on the particle. *[1]*

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(ii) the magnetic force acting on the particle. *[1]*

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(c) Show that if the particle travels without deflection through the fields then

$$v = \frac{E}{B}$$ *[2]*

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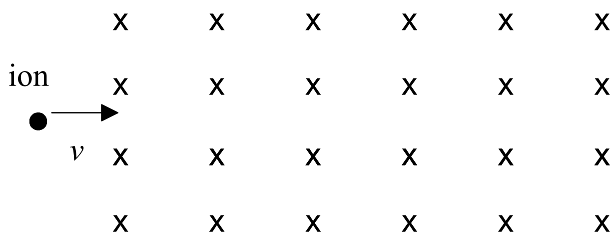
(Question B2 part 2 continued)

(d) The electric field is now switched off and an identical ion travelling with speed v enters the region of magnetic field as shown below.



(i) Explain why the ion will describe a circular path in the region of the magnetic field. *[2]*

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(ii) Deduce an expression for the radius r of the circular path in terms of B, M, q and v. *[2]*

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(Question B2 part 2 continued)

(e) With the aid of your answers to parts (b) and (c) and a labelled diagram, describe the principle of operation of a mass spectrometer and how it can be used to measure isotopic masses. *[6]*

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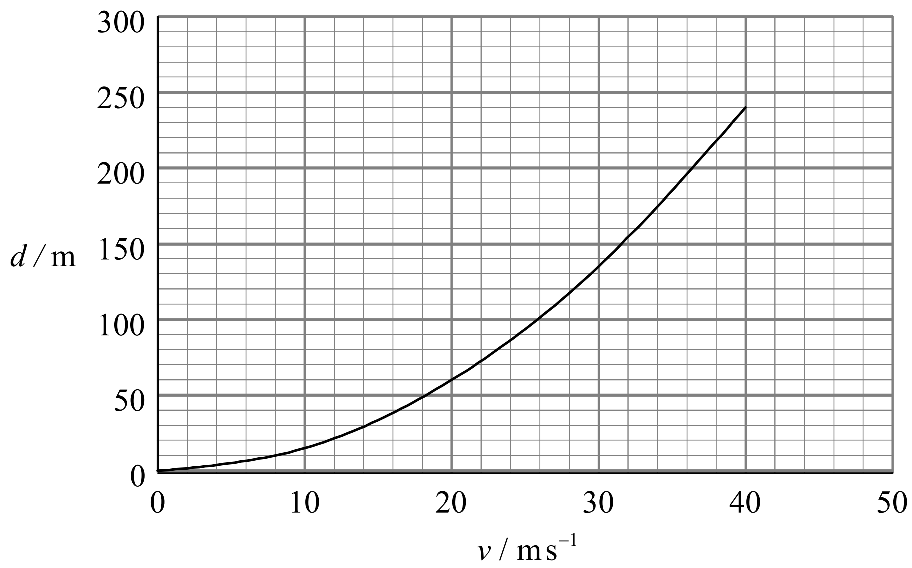
B3. This question is in **two** parts. **Part 1** is about a car braking and coming to rest and **Part 2** is about the photoelectric effect.

Part 1. Braking distance

The **minimum braking distance** is the shortest distance a car travels without skidding from the moment the brakes are applied until the moment the car comes to rest.

The graph below shows how the minimum braking distance *d* varies with the initial speed *v* of a car travelling along a straight, horizontal road.



(a) By choosing **two** data points show that the graph suggests that the minimum braking distance depends on the square of the initial speed. *[4]*

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(b) Explain why, if the braking force is constant, you would expect theoretically the braking distance to depend on the square of the speed. *[3]*

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(This question continues on the following page)

(Question B3 part 1 continued)

(c) The car has a mass of 1500 kg and is moving with an initial speed of $20\,\mathrm{m\,s^{-1}}$ when the brakes are applied. Calculate

(i) the time that it takes the car to come to rest. *[3]*

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(ii) the average braking force acting on the car. *[3]*

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(d) The **stopping distance** of a car is the distance that the car travels in coming to rest from the moment that the driver decides to apply the brakes. The **stopping distance** is greater than the **minimum braking distance**. Explain why you think that this is so. *[2]*

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(e) Using the same axes as for the graph given at the start of the question sketch a graph to show how the stopping distance varies with initial speed. Explain the shape of the graph that you have drawn. *[3]*

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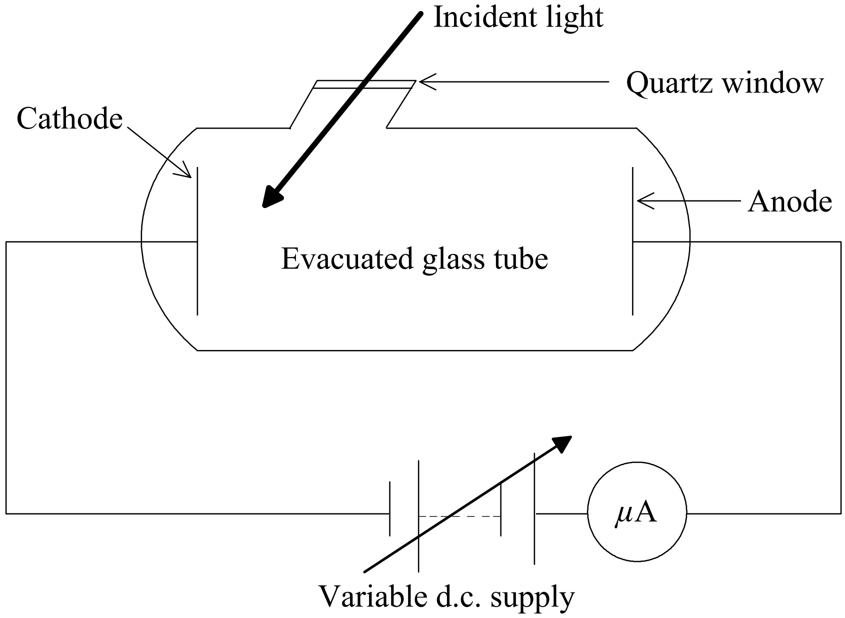
(Question B3 continued)

Part 2. This question is about the photoelectric effect.

Light of different frequencies is shone on to a metal cathode in an evacuated tube. The light enters through a quartz window and a potential difference is applied between the cathode and anode as shown in the diagram below. Initially the supply potential is set to a maximum.



When ultraviolet light is shone on to the cathode the microammeter registers a current but when red light is used no current is registered.

(a) Explain how Einstein's photoelectric theory accounts for this. *[4]*

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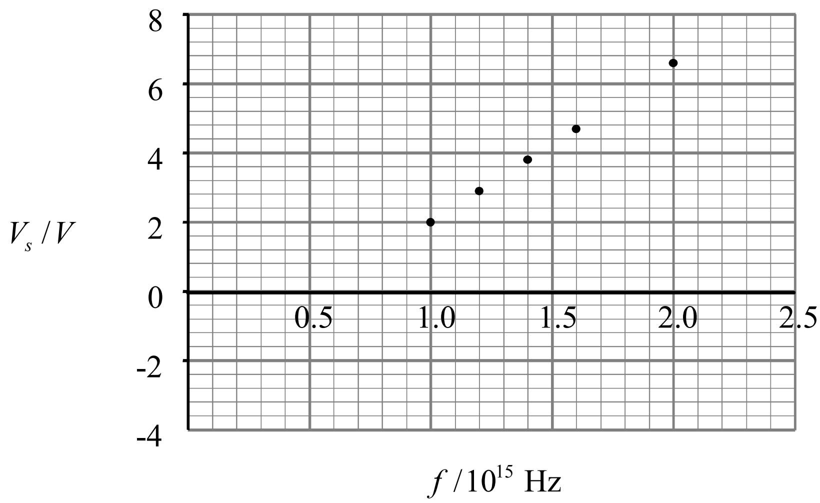
(Question B3 part 2 continued)

(b) The applied potential difference is now reversed and ultraviolet light of different frequencies is shone onto the cathode. For each frequency of the incident light the potential of the supply is adjusted until the microammeter does not register a current. The value of this potential, the **stopping potential** V_s is recorded.

Values of the stopping potential V_s and frequency f of the light incident on the cathode are shown plotted below.



Complete the graph of V_s against f. *[1]*

(c) Use the graph you have drawn to find the following values,

(i) the threshold frequency for the metal from which the cathode is made. *[2]*

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(ii) Planck’s constant. *[3]*

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(Question B3 part 2 continued)

(iii) the work function of the metal in units of electron-volts. *[2]*

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B4. This question is about waves and their various properties.

Diagram 1 below represents a snapshot of some of the wavefronts of a continuous plane wave travelling in the direction shown.

Diagram 2 is a sketch-graph that shows how the displacement of the medium through which the wave is travelling varies with distance along the medium.

Diagram 1

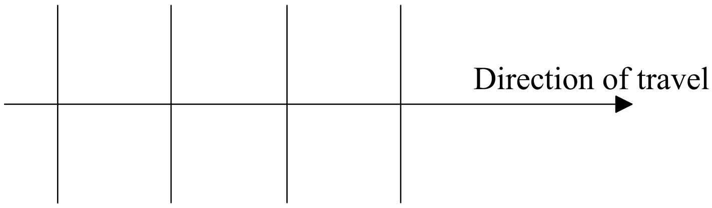
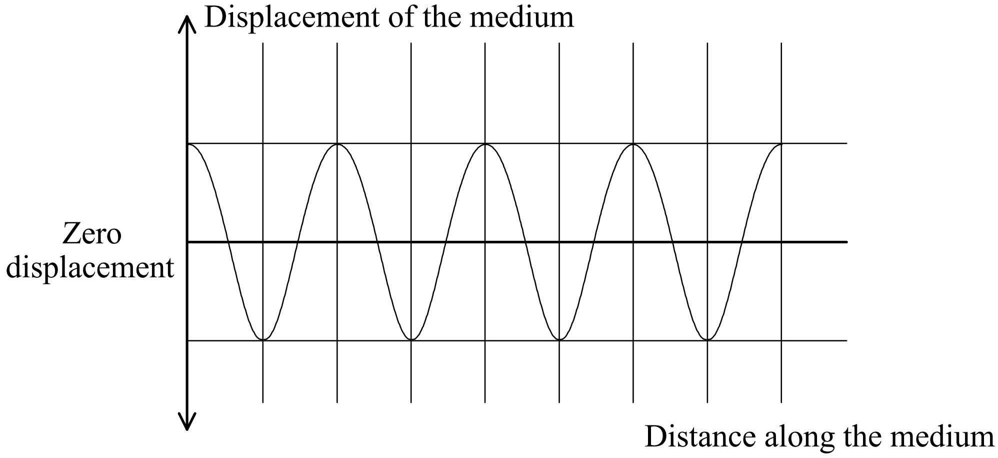


Diagram 2



The frequency of the source producing the waves is 10 Hz and the speed of the waves is 30 cm s^{-1}.

(a) On Diagram 1 mark the wavelength of the waves. *[1]*

(b) Calculate the value of the wavelength of the waves. *[1]*

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(c) Another snapshot of the wave is taken 0.05 s later.

(i) Determine how far the wavefronts have moved in this time. *[2]*

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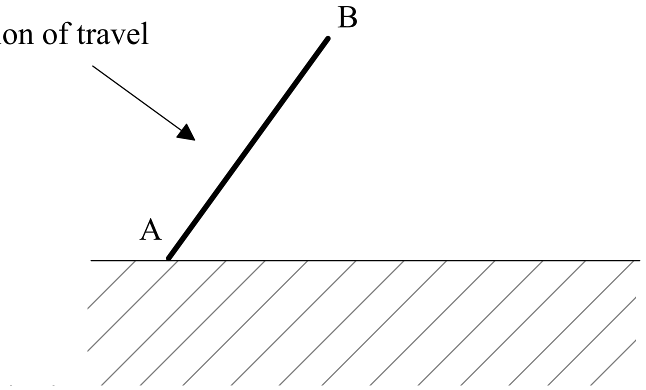
(ii) On Diagram 2 sketch another graph to show how the displacement of the medium now varies with distance along the medium. *[1]*

(This question continues on the following page)

(Question B4 continued)

Part (d) deals with the reflection of waves.

(d) The same wavefronts as in Diagram 1 are now incident at an angle on a reflective boundary. The diagram below shows one of the wavefronts, labelled AB.



(i) State Huygens' principle. *[2]*

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(ii) With aid of the above diagram explain how Huygens' principle accounts for the fact that the angle of incidence is equal to the angle of reflection when wavefronts are reflected at a boundary. *[8]*

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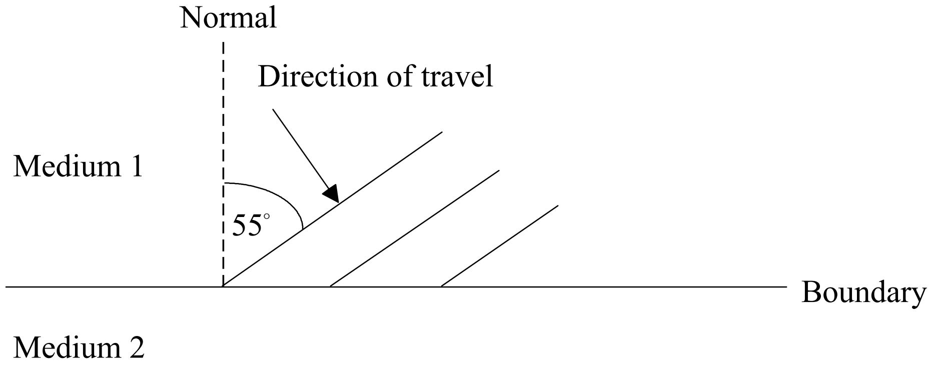
(Question B4 continued)

Part (e) deals with the refraction of waves.

(e) The same waves now travel across a boundary between two different media. The diagram below shows wavefronts incident on this boundary such that they make an angle of 55° with the normal. The speed of the waves in medium 1 is $30\,\text{cm}\,\text{s}^{-1}$ and in medium 2 is $45\,\text{cm}\,\text{s}^{-1}$.

(iii)



(i) Calculate the value of the angle that the wavefronts in medium 2 make with the normal. *[4]*

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(ii) Explain what will happen to waves in medium 1 that are incident at an angle of 45° to the normal and justify your explanation by means of a calculation. *[4]*

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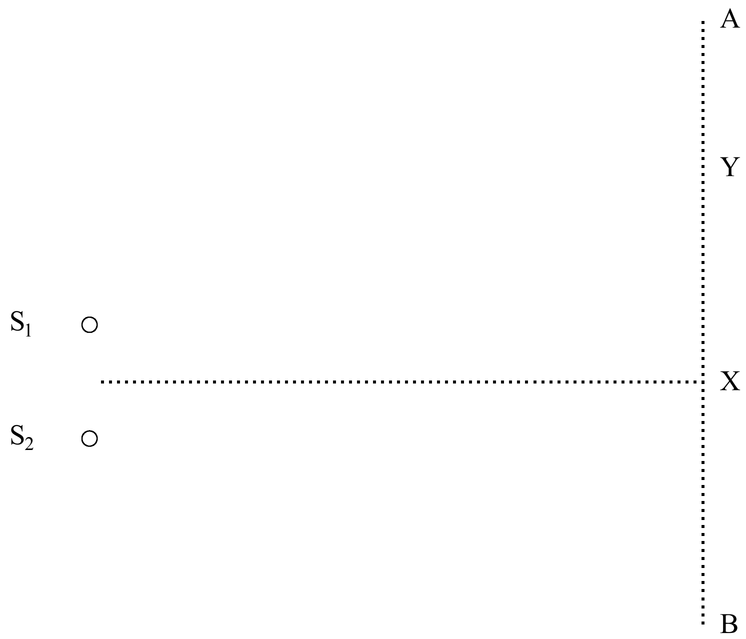
(Question B4 continued)

Part (f) deals with interference of waves.

(f) In the diagram below S_1 and S_2 are two continuous harmonic sound sources each of which emit sound of wavelength 0.70 m. As an instrument that detects sound intensity is moved along the line AB it registers a series of maximum sound intensities and minimum sound intensities. The first maximum registered is at X and the first minimum at Y. The distance $S_1X = S_2X$.



(i) If the distance S_1Y is 3.0 m what is the distance S_2Y equal to? Explain your answer. *[2]*

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(ii) Describe and explain what will happen to the distance between the first maximum and the first minimum if the frequency of the sound from the two sources is increased. *[3]*

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(iii) If the frequency of S_1 is 440 Hz and the frequency of S_2 is altered to 444 Hz describe quantitatively the nature of the sound detected at X. *[2]*

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