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

M05/4/PHYSI/HP2/ENG/TZ2/XX+

22056514

PHYSICS
HIGHER LEVEL
PAPER 2

Thursday 19 May 2005 (afternoon)

2 hours 15 minutes

Candidate session number

0	0							

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 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.

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SECTION A

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

A1. The Geiger-Nuttall theory of α-particle emission relates the half-life of the α-particle emitter to the energy E of the α-particle. One form of this relationship is

$$L = \frac{166}{E^{\frac{1}{2}}} - 53.5.$$

L is a number calculated from the half-life of the α-particle emitting nuclide and E is measured in MeV.

Values of E and L for different nuclides are given below. *(Uncertainties in the values are not shown.)*

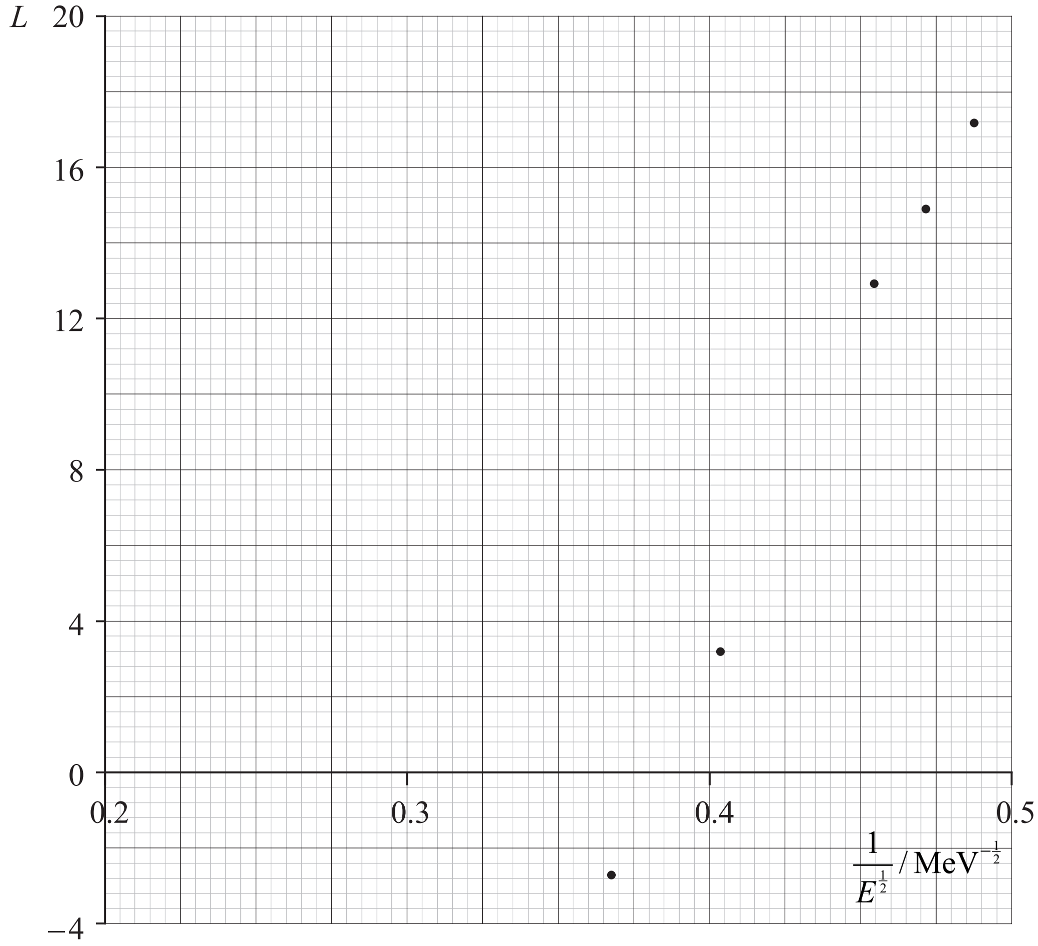
Nuclide	E **/ MeV**	L	$\frac{1}{E^{\frac{1}{2}}}$ **/ MeV**$^{-\frac{1}{2}}$
^{238}U	4.20	17.15	0.488
^{236}U	4.49	14.87	0.472
^{234}U	4.82	12.89	0.455
^{228}Th	5.42	7.78	. . . .
^{208}Rn	6.14	3.16	0.404
^{212}Po	7.39	–2.75	0.368

(a) Complete the table above by calculating, using the value of E provided, the value of $\frac{1}{E^{\frac{1}{2}}}$ for the nuclide ^{228}Th. Give your answer to three significant digits. *[1]*

(This question continues on the following page)

(Question A1 continued)

The graph below shows the variation with $\frac{1}{E^{\frac{1}{2}}}$ of the quantity L. Error bars have not been added.



(b) (i) Identify the data point for the nuclide ^{208}Rn. Label this point R. *[1]*

(ii) On the graph, mark the point for the nuclide ^{228}Th. Label this point T. *[1]*

(iii) Draw the best-fit straight-line for all the data points. *[1]*

(This question continues on the following page)

(Question A1 continued)

(c) (i) Determine the gradient of the line you have drawn in (b) (iii). *[2]*

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(ii) Without taking into consideration any uncertainty in the values for the gradient and for the intercept on the x-axis, suggest why the graph does **not** agree with the stated relationship for the Geiger-Nuttall theory. *[2]*

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(d) On the graph opposite, draw the line that would be expected if the relationship for the Geiger-Nuttall theory were correct. No further calculation is required. *[2]*

(e) The uncertainty in the measurement of E for ^{238}U is ±0.03 MeV. Deduce that this uncertainty is consistent with quoting the value of $\frac{1}{E^{\frac{1}{2}}}$ to three significant digits. *[3]*

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A2. This question is about linear motion.

A police car P is stationary by the side of a road. A car S, exceeding the speed limit, passes the police car P at a constant speed of $18\,\text{m}\,\text{s}^{-1}$. The police car P sets off to catch car S just as car S passes the police car P. Car P accelerates at $4.5\,\text{m}\,\text{s}^{-2}$ for a time of 6.0 s and then continues at constant speed. Car P takes a time t seconds to draw level with car S.

(a) (i) State an expression, in terms of t, for the distance car S travels in t seconds. *[1]*

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(ii) Calculate the distance travelled by the police car P during the first 6.0 seconds of its motion. *[1]*

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(iii) Calculate the speed of the police car P after it has completed its acceleration. *[1]*

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(iv) State an expression, in terms of t, for the distance travelled by the police car P during the time that it is travelling at constant speed. *[1]*

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(b) Using your answers to (a), determine the total time t taken for the police car P to draw level with car S. *[2]*

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A3. This question is about nuclear fission and nuclear fusion.

(a) Compare the processes of nuclear fission and nuclear fusion. *[4]*

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(b) A nuclear fusion reaction that is being investigated for the production of power is

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n + (2.8\times10^{-12}\ J)$$

where the energy liberated in each reaction is 2.8×10^{-12} J .

Determine the rate, in $kg\,s^{-1}$, of production of $^{4}_{2}He$ required for a power output of 100 MW. *[2]*

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A4. This question is about the photoelectric effect.

(a) State **three** pieces of evidence provided by the photoelectric effect that support the particle nature of electromagnetic radiation. *[3]*

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2. . . . .

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3. . . . .

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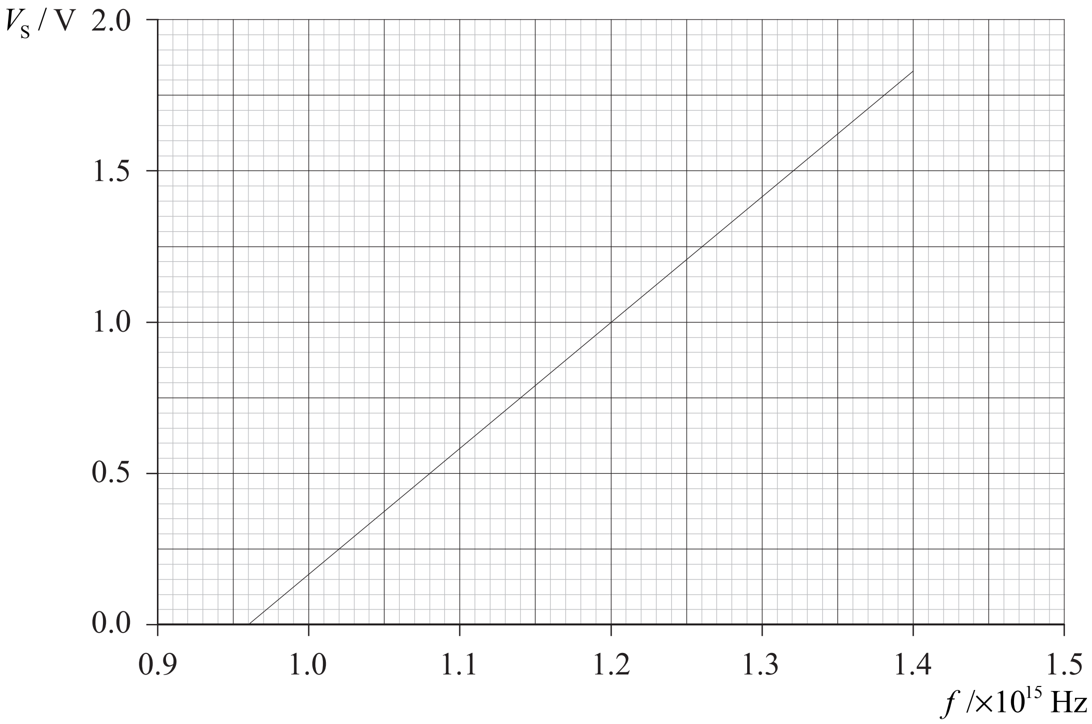
The graph below shows the variation with frequency f of the stopping potential V_S for photoelectrons emitted from a metal surface.



The photoelectric equation may be written in the form of the word equation

photon energy = work function + maximum kinetic energy of electron.

(b) (i) State this equation in terms of f and V_S, explaining all other symbols you use. *[3]*

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(This question continues on the following page)

(Question A4 continued)

(ii) Use your equation to deduce that the gradient of the graph is $\frac{h}{e}$. *[2]*

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(iii) Given that the Planck constant is 6.6×10^{-34} J s, calculate a value for the work function of the surface. *[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 about collisions and radioactive decay.

(a) (i) Define *linear momentum* and *impulse*. *[2]*

Linear momentum: . . . .

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Impulse: . . . .

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

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(iii) Using your definitions in (a) (i), deduce that linear momentum is constant for an object in equilibrium. *[2]*

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(This question continues on the following page)

(Question B1 continued)

A stationary radon-220 ($^{220}_{86}\text{Rn}$) nucleus undergoes α-decay to form a nucleus of polonium (Po). The α-particle has kinetic energy of 6.29 MeV.

(b) (i) Complete the nuclear equation for this decay. *[2]*

$$^{220}_{86}\text{Rn} \rightarrow \text{Po} + $$

(ii) Calculate the kinetic energy, in joules, of the α-particle. *[2]*

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(iii) Deduce that the speed of the α-particle is $1.74 \times 10^7\ \text{m s}^{-1}$. *[1]*

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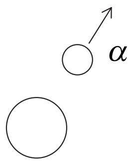
(Question B1 continued)

The diagram below shows the α-particle and the polonium nucleus immediately after the decay. The direction of the velocity of the α-particle is indicated.



(c) (i) On the diagram above, draw an arrow to show the initial direction of motion of the polonium nucleus immediately after the decay. *[1]*

(ii) Determine the speed of the polonium nucleus immediately after the decay. *[3]*

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(iii) In the decay of another radon nucleus, the nucleus is moving before the decay. Without any further calculation, suggest the effect, if any, of this initial speed on the paths shown in (c) (i). *[2]*

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(This question continues on the following page)

(Question B1 continued)

The half-life of the decay of radon-222 is 3.8 days and radon-220 has a half-life of 55 s.

(d) (i) Suggest **three** ways in which nuclei of radon-222 differ from those of radon-220. *[3]*

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2. . . . .

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(ii) Define *half-life*. *[2]*

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(iii) State the expression that relates the activity A_t at time t of a sample of a radioactive material to its initial activity A_0 at time $t=0$ and to the decay constant λ. Use this expression to derive the relationship between the decay constant λ and the half-life $T_{\frac{1}{2}}$. *[3]*

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(iv) Radon-222 emits α-particles. The activity of radon gas in a sample of $1.0\,\text{m}^3$ of air is 4.6 Bq. Given that $1.0\,\text{m}^3$ of the air contains 2.6×10^{25} molecules, determine the ratio

$$\frac{\text{number of radon-222 atoms in } 1.0\,\text{m}^3 \text{ of air}}{\text{number of molecules in } 1.0\,\text{m}^3 \text{ of air}}.$$ *[4]*

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(This question continues on the following page)

(Question B1 continued)

(e) Suggest whether radon-222 or radon-220 presents the greater hazard to people over a long period of time. *[1]*

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B2. This question is about waves and wave properties.

(a) (i) Describe what is meant by a *continuous travelling wave*. *[2]*

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(ii) With reference to your answer in (a) (i), state what is meant by the speed of a travelling wave. *[1]*

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(b) Define, for a wave,

(i) *frequency*. *[1]*

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(ii) *wavelength*. *[1]*

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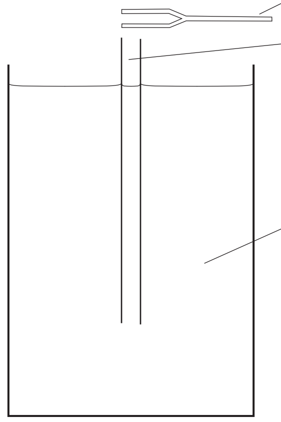
(Question B2 continued)

A tube that is open at both ends is placed in a deep tank of water, as shown below.



A tuning fork of frequency 256 Hz is sounded continuously above the tube. The tube is slowly raised out of the water and, at one position of the tube, a maximum loudness of sound is heard.

(c) (i) Explain the formation of a standing wave in the tube. *[2]*

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(ii) The tube is raised a further small distance. Explain, by reference to resonance, why the loudness of the sound changes. *[4]*

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(This question continues on the following page)

(Question B2 continued)

(iii) The tube is gradually raised from a position of maximum loudness until the next position of maximum loudness is reached. The length of the tube above the water surface is increased by 65.0 cm. Calculate the speed of sound in the tube. *[2]*

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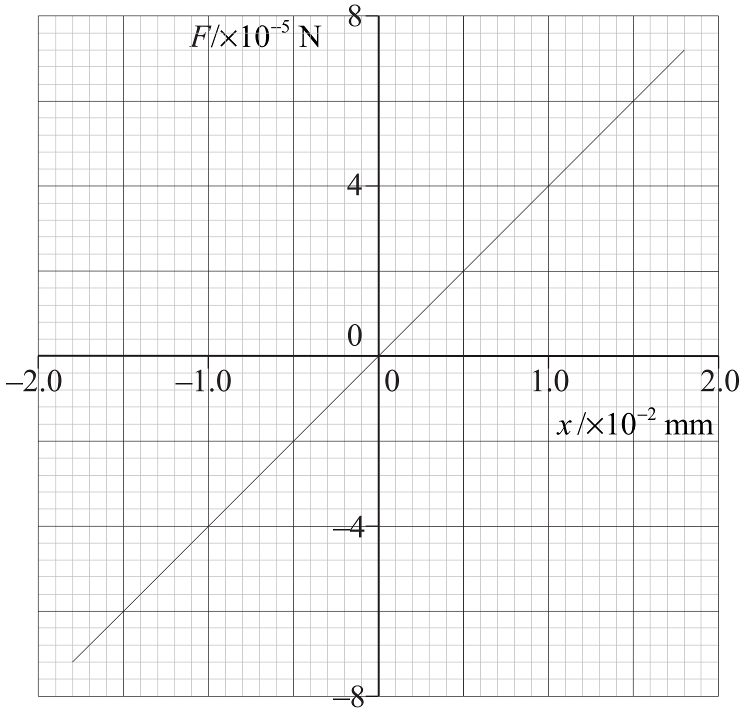
(This question continues on the following page)

(Question B2 continued)

A sound wave is incident on the ear of a person. The pressure variation of the sound wave causes a force F to be exerted on a moveable part of the ear called the eardrum. The variation of the displacement x of the eardrum caused by the force F is shown below.



(d) The eardrum has an area of $30\,mm^2$. Calculate the pressure, in pascal, exerted on the eardrum for a displacement x of 1.0×10^{-2} mm. *[2]*

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(This question continues on the following page)

(Question B2 continued)

(e) (i) Calculate the energy required to cause the displacement to change from $x = 0$ to $x = +1.5\times10^{-2}$ mm. *[3]*

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The sound wave causing a maximum displacement of the eardrum of 1.5×10^{-2} mm has frequency 1000 Hz.

(ii) Deduce that the energy causing the displacement in (e) (i) is delivered in a time of 0.25 ms. Also, determine the mean power of the sound wave to cause this displacement. *[4]*

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(iii) Suggest the form of energy into which the energy of the sound wave has been transformed at the eardrum. *[1]*

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(Question B2 continued)

In an experiment to measure the speed of sound, two coherent sources S_1 and S_2 produce sound waves of frequency 1700 Hz. A sound detector is moved along a line AB, parallel to S_1S_2 as shown below.

When the detector is at P, such that $S_1P = S_2P$, maximum loudness of sound is detected. As the detector is moved along AB, regions of minimum and maximum loudness are detected. Point X is the *third* position of minimum loudness from P. The distance $(S_2X - S_1X)$ is 0.50 m.

(f) (i) Determine the speed of the sound. *[3]*

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(ii) At X, no sound is detected. The loudness of the sound produced by S_1 alone is then reduced. State and explain the effect of this change on the loudness of sound heard at X and at P. *[4]*

at X: . . . .

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at P: . . . .

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B3. This question is in **three** parts. **Part 1** is about electrical components. **Part 2** is about magnetic forces and **Part 3** is about electromagnetic induction.

Part 1 Electrical components

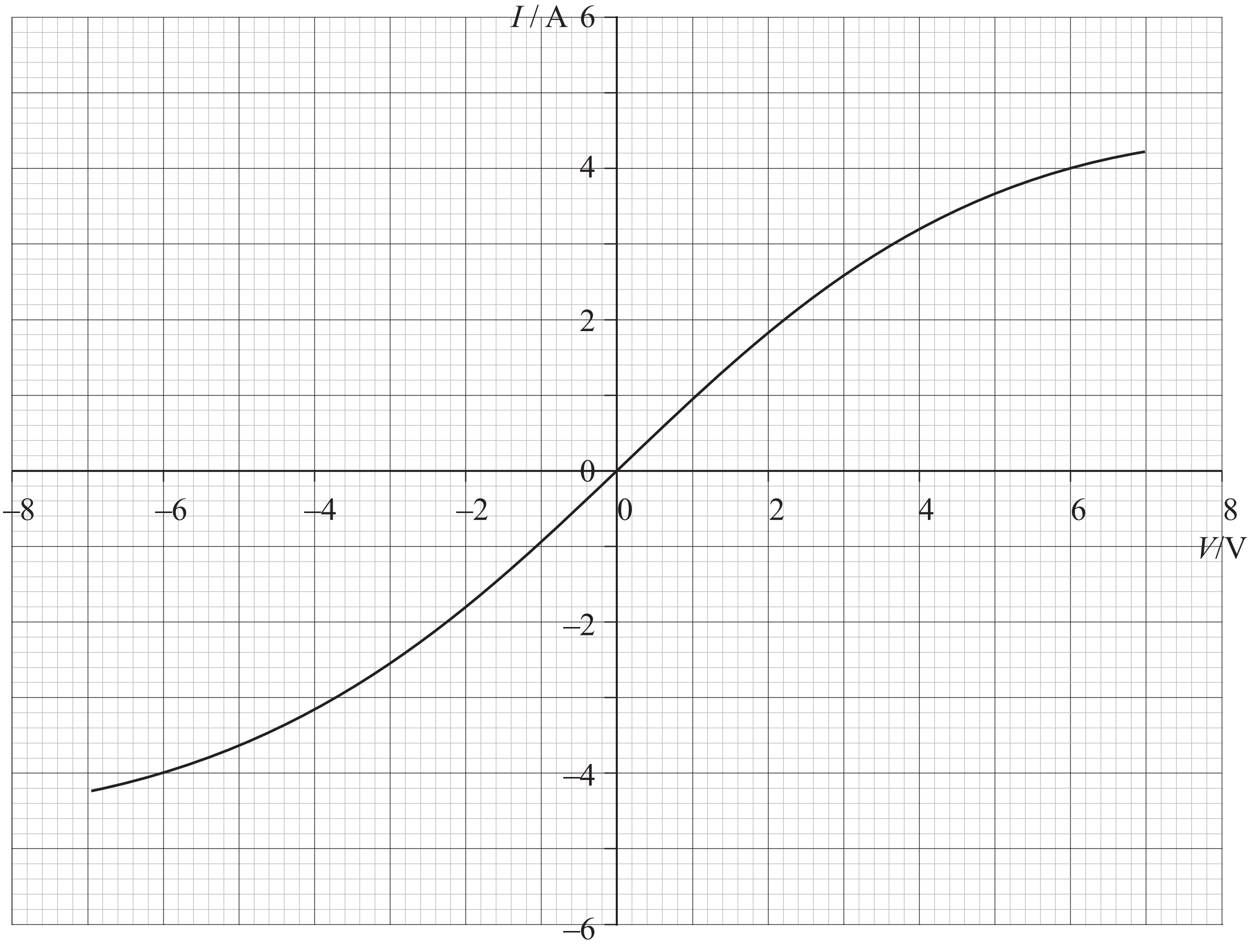
(a) In the space below, draw a circuit diagram that could be used to determine the current-voltage *(I-V)* characteristics of an electrical component X. *[2]*

component X

(This question continues on the following page)

(Question B3, part 1 continued)

The graph below shows the *I-V* characteristics for the component X.



The component X is now connected across the terminals of a battery of e.m.f. 6.0 V and negligible internal resistance.

(b) Use the graph to determine

(i) the current in component X. *[1]*

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(ii) the resistance of component X. *[2]*

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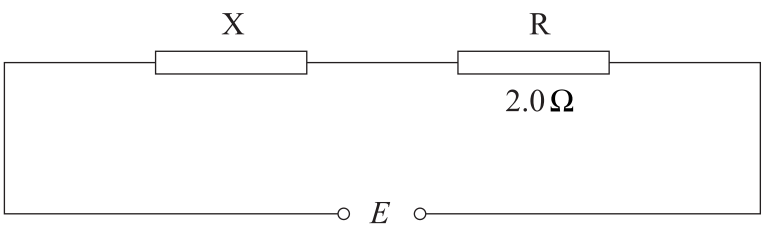
(Question B3, part 1 continued)

A resistor R of constant resistance 2.0 Ω is now connected in series with component X as shown below.



(c) (i) On the graph opposite, draw the *I-V* characteristics for the resistor R. *[2]*

(ii) Determine the total potential difference *E* that must be applied across component X and across resistor R such that the current through X and R is 3.0 A. *[2]*

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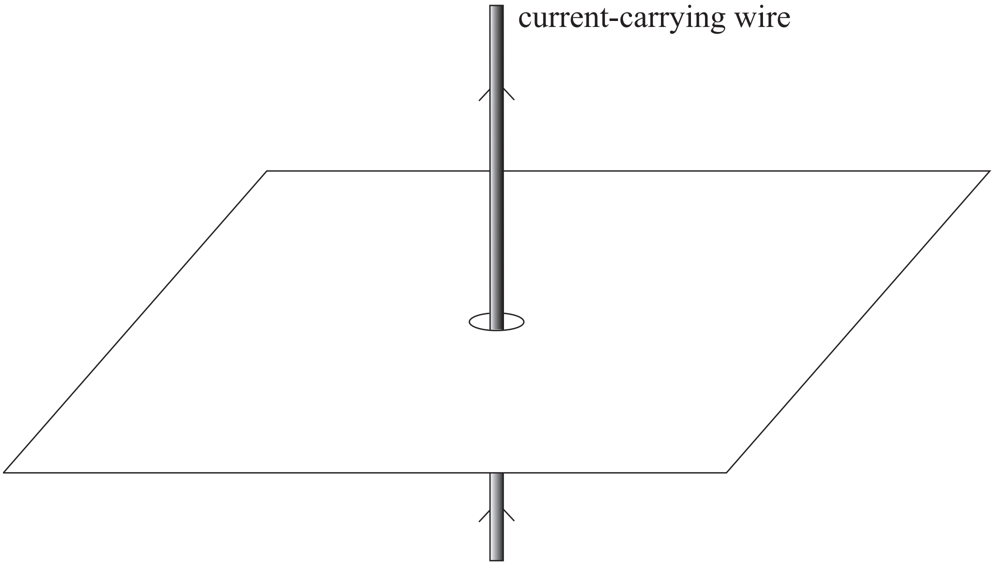
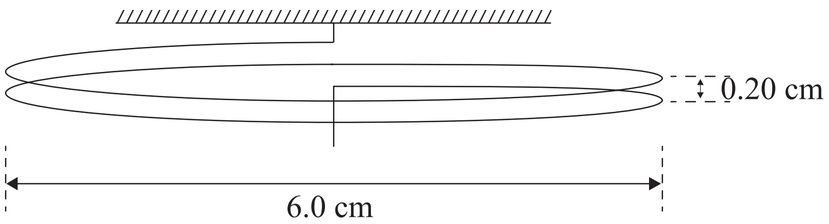
(Question B3 continued)

Part 2 Magnetic forces

(a) On the diagram below, draw the magnetic field pattern around a long straight current-carrying conductor. *[3]*



The diagram below shows a coil consisting of two loops of wire. The coil is suspended vertically.



Each loop has a diameter of 6.0 cm and the separation of the loops is 0.20 cm. The coil forms part of an electrical circuit so that a current may be passed through the coil.

(b) (i) State and explain why, when the current is switched on in the coil, the distance between the two loops changes. *[3]*

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(This question continues on the following page)

(Question B3 continued)

When there is a current I in the coil, a mass of 0.10 g hung from the free end of the coil returns the separation of the loops to the original value of 0.20 cm.

The circumference C of a circle of radius r is given by the expression

$$C = 2\pi r.$$

(ii) Calculate the current I in the coil. You may assume that each loop behaves as a long straight current-carrying wire. *[5]*

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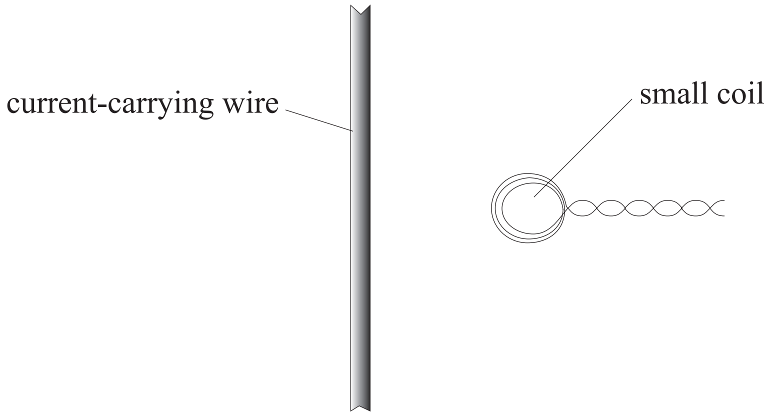
(Question B3 continued)

Part 3 Electromagnetic induction

A small coil is placed with its plane parallel to a long straight current-carrying wire, as shown below.



(a) (i) State Faraday's law of electromagnetic induction. *[2]*

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(ii) Use the law to explain why, when the current in the wire changes, an e.m.f. is induced in the coil. *[1]*

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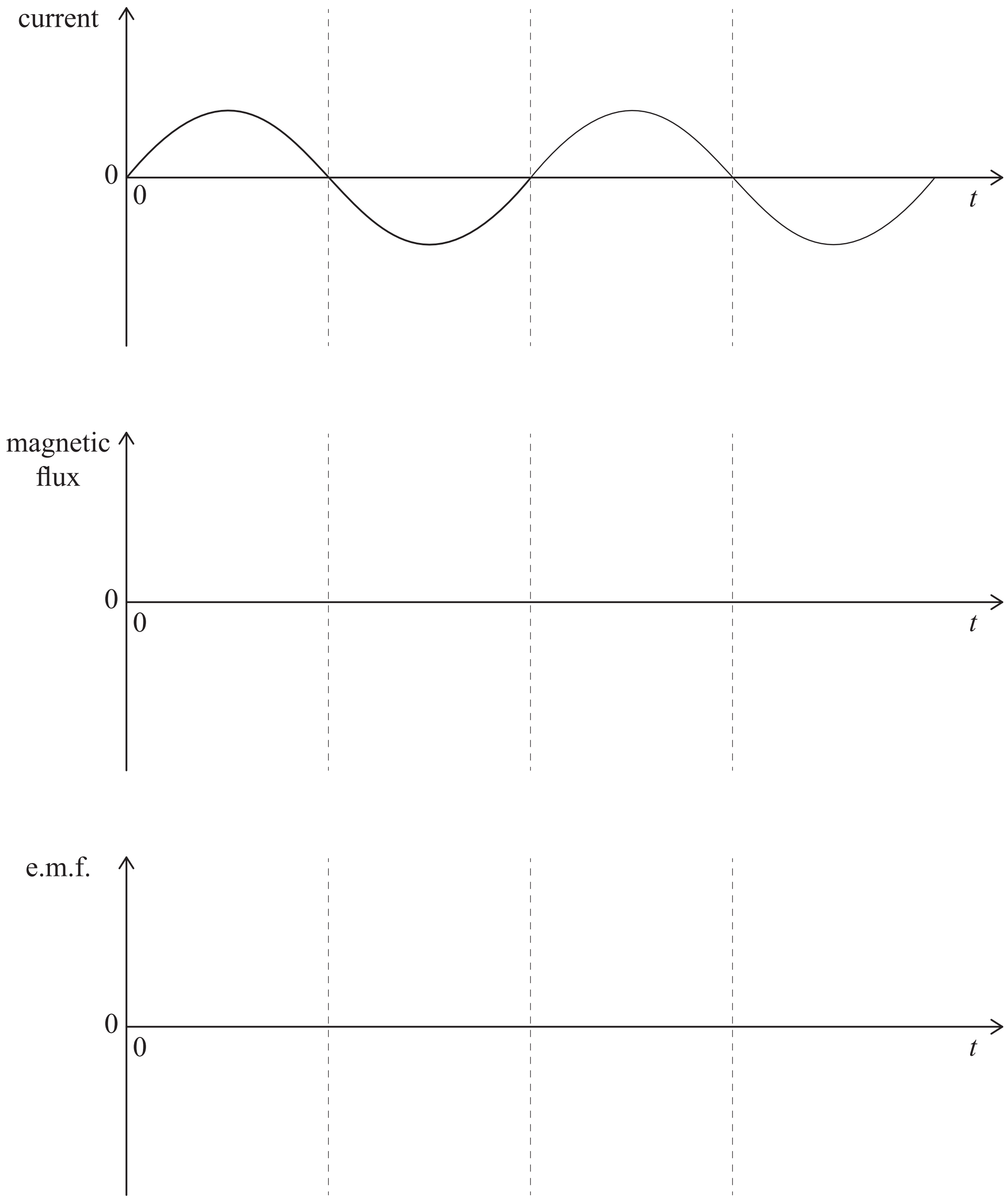
(Question B3, part 3 continued)

The diagram below shows the variation with time *t* of the current in the wire.



(b) (i) Draw, on the axes provided, a sketch-graph to show the variation with time *t* of the magnetic flux in the coil. *[1]*

(ii) Construct, on the axes provided, a sketch-graph to show the variation with time *t* of the e.m.f. induced in the coil. *[2]*

(This question continues on the following page)

(Question B3, part 3 continued)

(iii) State and explain the effect on the maximum e.m.f. induced in the coil when the coil is further away from the wire. *[2]*

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(c) Such a coil may be used to measure large alternating currents in a high-voltage cable. Identify **one** advantage and **one** disadvantage of this method. *[2]*

Advantage: . . . .

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Disadvantage: . . . .

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B4. This question is in **two** parts. **Part 1** is about ideal gases and specific heat capacity. **Part 2** is about satellite motion.

Part 1 Ideal gases and specific heat capacity

(a) (i) State, in terms of kinetic theory, what is meant by an *ideal gas*. *[3]*

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(ii) Explain why the internal energy of an ideal gas is kinetic energy only. *[2]*

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A fixed mass of an ideal gas has a volume of $870\,cm^3$ at a pressure of 1.00×10^5 Pa and a temperature of 20.0 °C. The gas is heated at constant pressure to a temperature of 21.0 °C.

(b) (i) Calculate the change in volume of the gas. *[3]*

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(ii) Determine the external work done during this process. *[2]*

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(This question continues on the following page)

(Question B4, part 1 continued)

(c) (i) Define *specific heat capacity*. *[2]*

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(ii) Explain what happens to the molecules of an ideal gas when the temperature of the gas is increased at constant volume. *[2]*

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(iii) Apply the first law of thermodynamics to show that, if the temperature of a gas is raised at constant pressure, the specific heat capacity of the gas is different from that when the temperature is raised at constant volume. *[3]*

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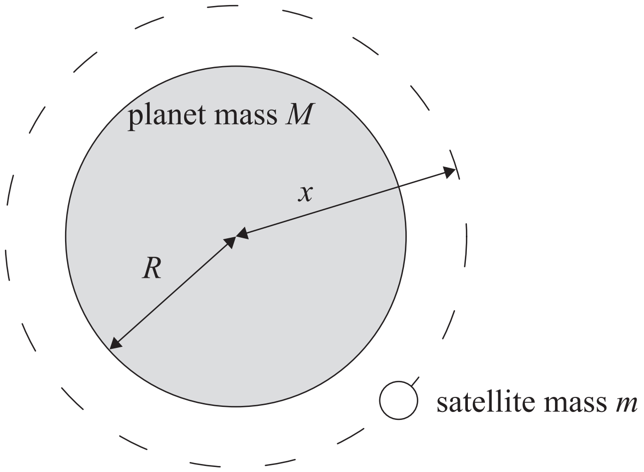
(Question B4 continued)

Part 2 Satellite motion

A satellite of mass m orbits a planet of mass M and radius R as shown below. *(The diagram is not to scale.)*



The radius of the circular orbit of the satellite is x. The planet may be assumed to behave as a point mass with its mass concentrated at its centre.

(a) Deduce that the linear speed v of the satellite in its orbit is given by the expression

$$v = \sqrt{\frac{GM}{x}},$$

where G is the gravitational constant. *[2]*

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(b) (i) Derive expressions, in terms of m, G, M and x, for the kinetic energy of the satellite and for the gravitational potential energy of the satellite. *[2]*

Kinetic energy:

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Gravitational potential energy:

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(Question B4, part 2 continued)

(ii) Deduce an expression for the total energy of the satellite. *[2]*

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The satellite is moved into an orbit closer to the planet where there is friction with the planet's atmosphere.

(c) (i) State the effect of these frictional forces on the total energy of the satellite. *[1]*

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(ii) Apply your equation in (b) (ii) to deduce that, as a result of this friction, the radius of the orbit will change continuously. *[2]*

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(iii) Describe the effect of this change in orbital radius on the speed of the satellite. *[1]*

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(iv) The frictional forces will change as the orbit of the satellite changes. Suggest and explain the effect on the motion of the satellite of these changing frictional forces. *[3]*

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