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

88046502

PHYSICS
HIGHER LEVEL
PAPER 2

Friday 5 November 2004 (afternoon)

2 hours 15 minutes

School code

Candidate code

INSTRUCTIONS TO CANDIDATES

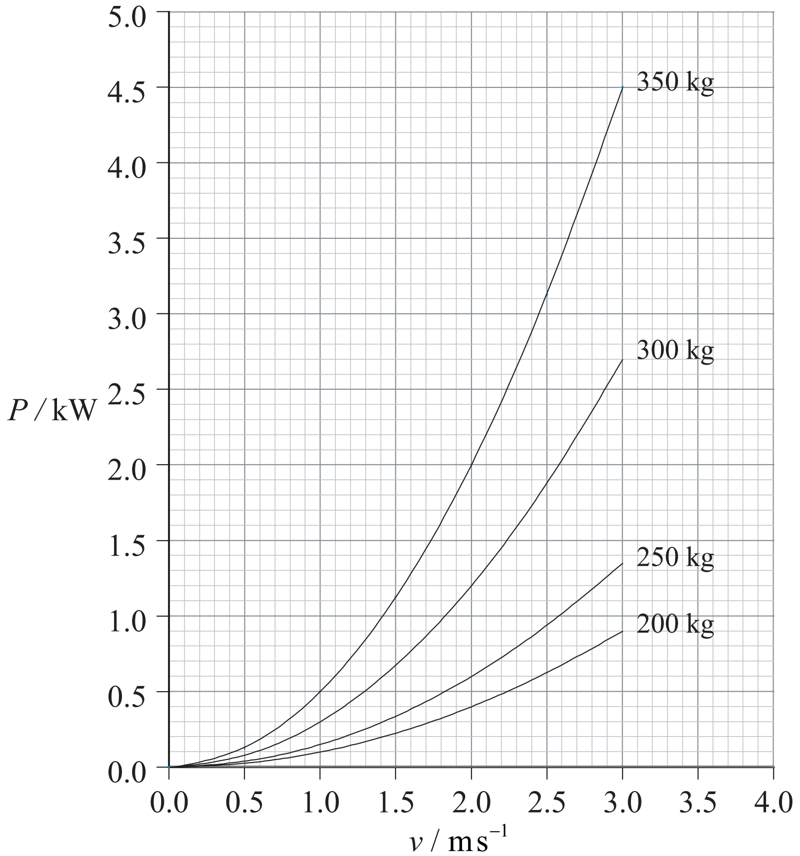
- Write your school code and candidate code in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B in the spaces provided.
- At the end of the examination, indicate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

SECTION A

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

A1. This question is about power output of an outboard motor.

A small boat is powered by an outboard motor of variable power P. The graph below shows the variation with speed v of P when the boat is carrying different loads.



The masses shown are the total mass of the boat plus passengers.

(a) For the boat having a steady speed of $2.0\,\text{m}\,\text{s}^{-1}$ and with a total mass of 350 kg

(i) use the graph to determine the power of the engine. *[1]*

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(ii) calculate the frictional (resistive) force acting on the boat. *[2]*

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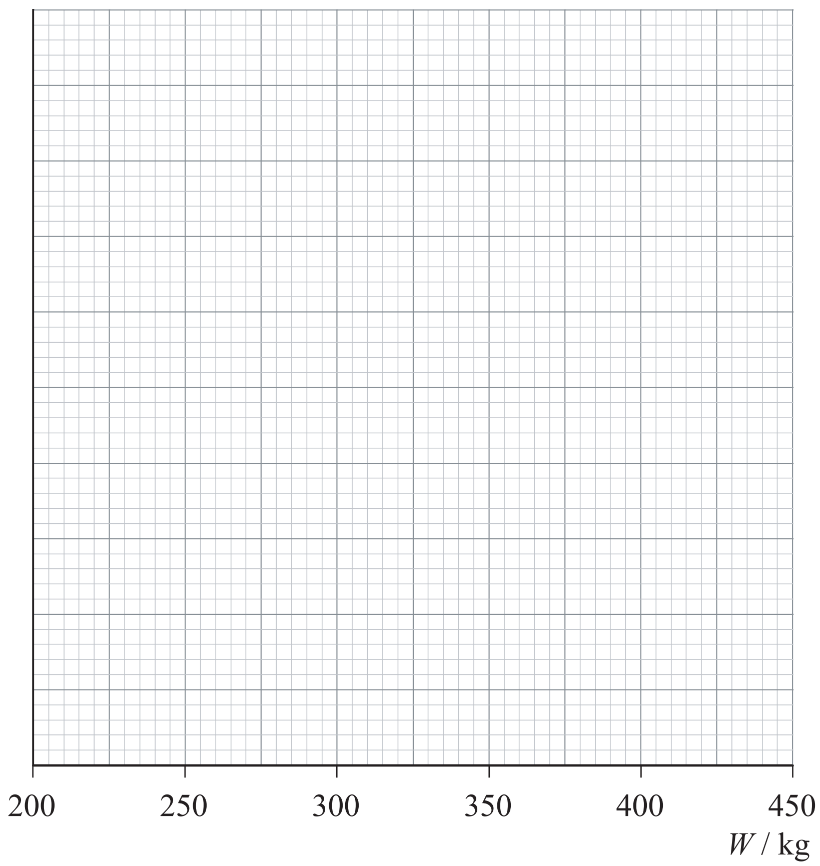
(This question continues on the following page)

(Question A1 continued)

Consider the case of the boat moving with a speed of $2.5\,m\,s^{-1}$.

(b) (i) Use the axes below to construct a graph to show the variation of power P with the total mass W. *[6]*



(ii) Use data from the graph that you have drawn to determine the power of the motor for a total mass of 330 kg. *[1]*

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(This question continues on the following page)

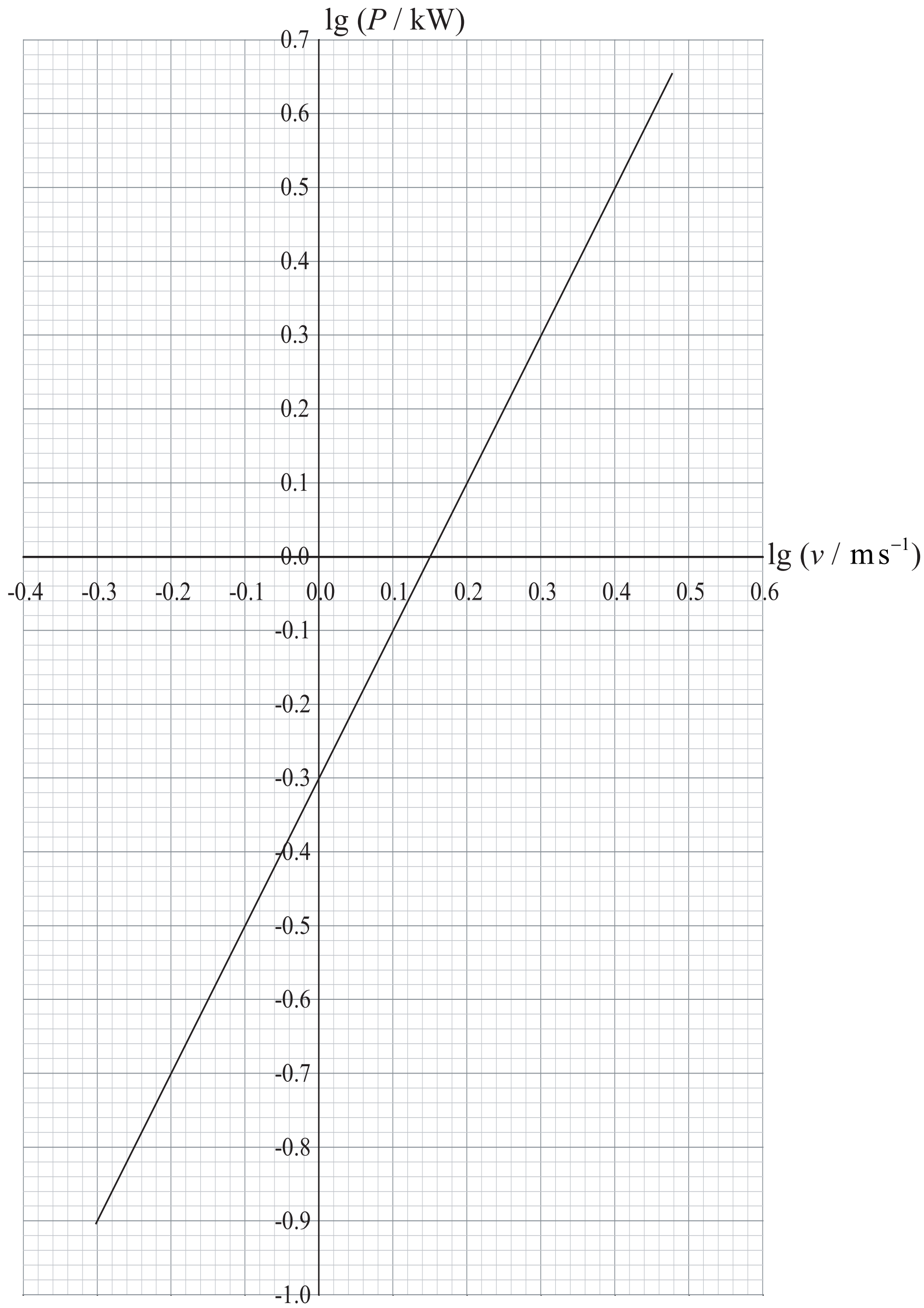
(Question A1 continued)

The relationship between power P and speed v is of the form

$$P = kv^n$$

where n is an integer and k is a constant.

The graph below shows the variation of $\lg v$ ($\log_{10} v$) with $\lg P$ ($\log_{10} P$) for the situation when the total mass is 350 kg. P is measured in kW and v is measured in $\mathrm{m\,s^{-1}}$.



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(Question A1 continued)

(c) Use the graph to deduce the value of *n* and explain how you obtained your answer. *[3]*

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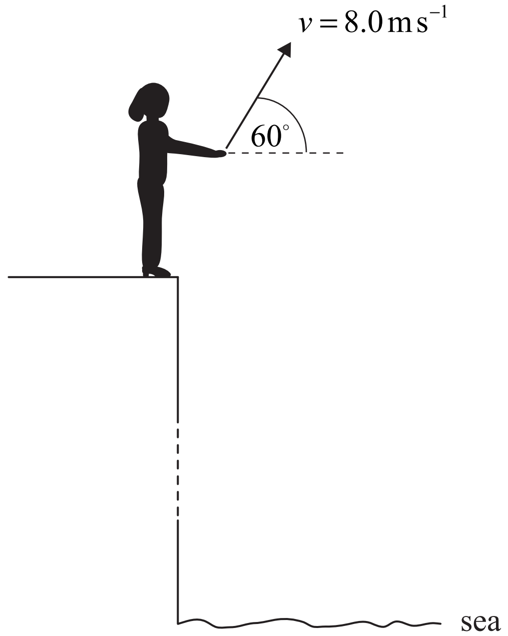
A2. This question is about trajectory motion.

Antonia stands at the edge of a vertical cliff and throws a stone upwards at an angle of 60° to the horizontal.



The stone leaves Antonia's hand with a speed $v = 8.0\,\text{m s}^{-1}$. The time between the stone leaving Antonia's hand and hitting the sea is 3.0 s.

The acceleration of free fall g is $10\,\text{m s}^{-2}$ and all distance measurements are taken from the point where the stone leaves Antonia's hand.

Ignoring air resistance calculate

(a) the maximum height reached by the stone. *[3]*

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(b) the horizontal distance travelled by the stone. *[2]*

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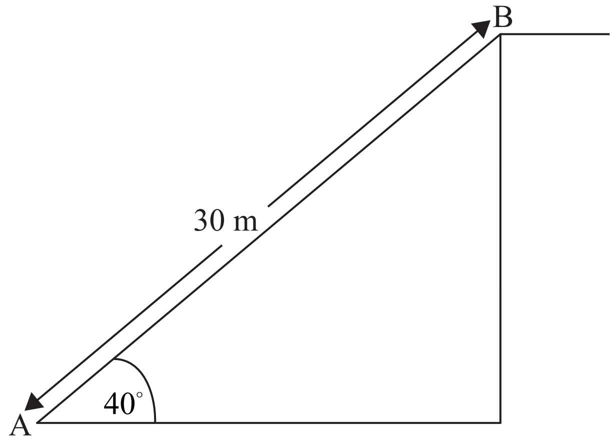
A3. This question is about estimating the energy changes for an escalator (moving staircase).

The diagram below represents an escalator. People step on to it at point A and step off at point B.



(a) The escalator is 30 m long and makes an angle of 40° with the horizontal. At full capacity, 48 people step on at point A and step off at point B every minute.

(i) Calculate the potential energy gained by a person of weight 700 N in moving from A to B. *[2]*

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(ii) Estimate the energy supplied by the escalator motor to the people every minute when the escalator is working at full capacity. *[1]*

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(iii) State **one** assumption that you have made to obtain your answer to (ii). *[1]*

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(Question A3 continued)

The escalator is driven by an electric motor that has an efficiency of 70 %.

(b) (i) Using your answer to (a) (ii), calculate the minimum input power required by the motor to drive the escalator. *[3]*

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(ii) Explain why it is not necessary to take into account the weight of the escalator when calculating the input power. *[1]*

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(c) Explain why in practice, the power of the motor will need to be greater than that calculated in (b) (i). *[1]*

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A4. This question is about the wave nature of matter.

(a) Describe the concept of matter waves and state the de Broglie hypothesis. *[3]*

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(b) An electron is accelerated from rest through a potential difference of 850 V. For this electron

(i) calculate the gain in kinetic energy. *[1]*

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(ii) deduce that the final momentum is 1.6×10^{-23} N s. *[2]*

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(iii) determine the associated de Broglie wavelength. (Electron charge $e = 1.6 \times 10^{-19}$ C, Planck constant $h = 6.6 \times 10^{-34}$ J s) *[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 specific heat capacity and specific latent heat. **Part 2** is about radioactivity and nuclear energy levels.

Part 1 Specific heat capacity and specific latent heat

(a) Define *specific heat capacity*. *[1]*

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(b) Explain briefly why the specific heat capacity of different substances such as aluminium and water are not equal in value. *[2]*

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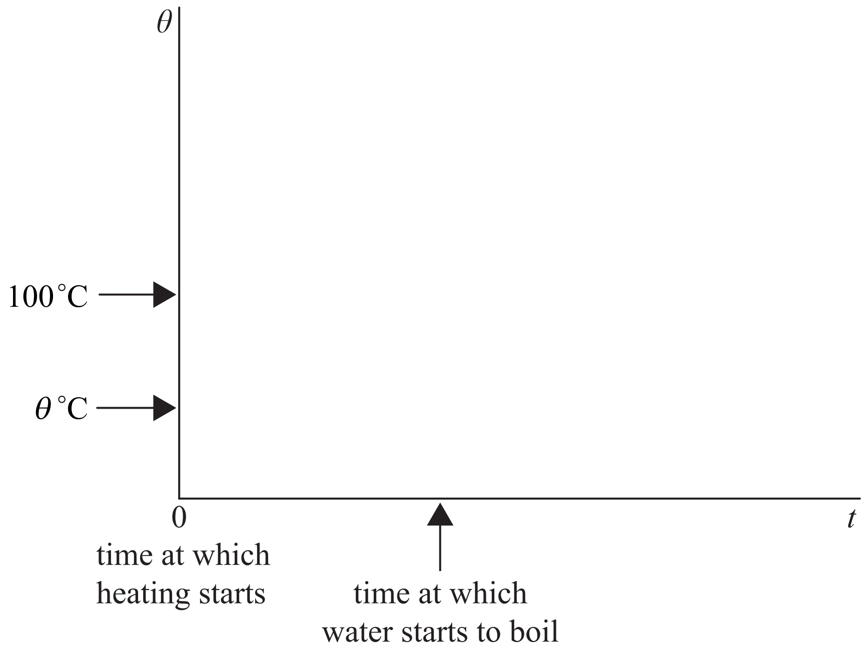
(Question B1, part 1 continued)

A quantity of water at temperature θ is placed in a pan and heated at a constant rate until some of the water has turned into steam. The boiling point of the water is 100˚C.

(c) (i) Using the axes below, draw a sketch-graph to show the variation with time t of the temperature θ of the water. ***(Note**: this is a sketch-graph; you do not need to add any values to the axes.)* *[1]*



(ii) Describe in terms of energy changes, the molecular behaviour of water and steam during the heating process. *[5]*

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(Question B1, part 1 continued)

Thermal energy is supplied to the water in the pan for 10 minutes at a constant rate of 400 W. The thermal capacity of the pan is negligible.

(d) (i) Deduce that the total energy supplied in 10 minutes is 2.4×10^5 J. *[1]*

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(ii) Using the data below, estimate the mass of water turned into steam as a result of this heating process. *[3]*

initial mass of water $= 0.30\,\text{kg}$
initial temperature of the water θ $= 20\,^\circ\text{C}$
specific heat capacity of water $= 4.2\times10^3\,\text{J kg}^{-1}\,\text{K}^{-1}$
specific latent heat of vaporization of water $= 2.3\times10^6\,\text{J kg}^{-1}$

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(iii) Suggest **one** reason why this mass is an estimate. *[1]*

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(Question B1 continued)

Part 2 Radioactivity and nuclear energy levels

(a) Define the following terms.

(i) *Radioactive half-life* ($T_{\frac{1}{2}}$) *[1]*

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(ii) *Decay constant* (λ) *[1]*

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(b) Deduce that the relationship between $T_{\frac{1}{2}}$ and λ is *[2]*

$$\lambda T_{\frac{1}{2}} = \ln 2.$$

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(This question continues on the following page)

(Question B1, part 2 continued)

Thorium-227 (Th-227) undergoes α-decay with a half-life of 18 days to form radium-223 (Ra-223). A sample of Th-227 has an initial activity of 3.2×10^5 Bq.

(c) Determine, the activity of the remaining thorium after 50 days. *[2]*

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In the decay of a Th-227 nucleus, a γ-ray photon is also emitted.

(d) (i) Use the following data to deduce that the energy of the γ-ray photon is 0.667 MeV. *[3]*

mass of Th-227 nucleus	= 227.0278 u
mass of Ra-223 nucleus	= 223.0186 u
mass of helium nucleus	= 4.0026 u
energy of α-particle emitted	= 5.481 MeV
unified atomic mass unit (u)	= 931.5 MeV c^{-2}

You may assume that the Th-227 nucleus is stationary before decay and that the Ra-223 nucleus has negligible kinetic energy.

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(ii) Calculate the frequency of the γ-ray photon. *[3]*

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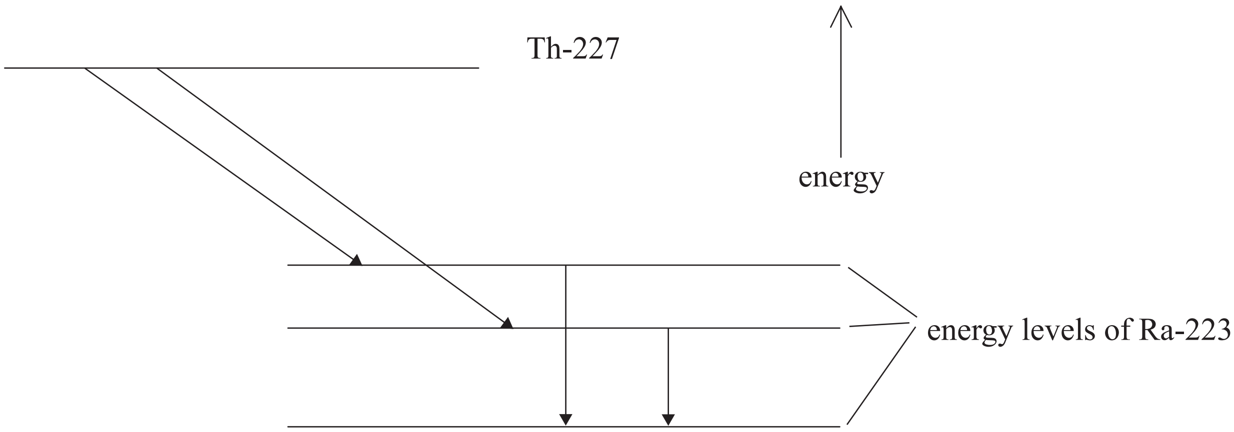
(Question B1, part 2 continued)

Although in the decay of a Th-227 nucleus, an α-particle and a γ-ray photon are emitted, they may have different energies to those in (d) (i). However, all the α-particles emitted in the decay of Th-227 have discrete energies as do the associated γ-ray photons. This provides evidence for the existence of nuclear energy levels. The diagram below represents some of the energy levels of a nucleus of Ra-223 relative to Th-227.



(e) On the diagram above label

(i) the arrows associated with α-particles (with the letter A). *[1]*

(ii) the arrows associated with γ-ray photons (with the letter G). *[1]*

(iii) the ground state energy level of Ra-223 (with the letter R). *[1]*

(f) Use data from (d), to suggest a value for the energy difference between the ground states of a nucleus of Th-227 and the ground state of a nucleus of Ra-223. *[1]*

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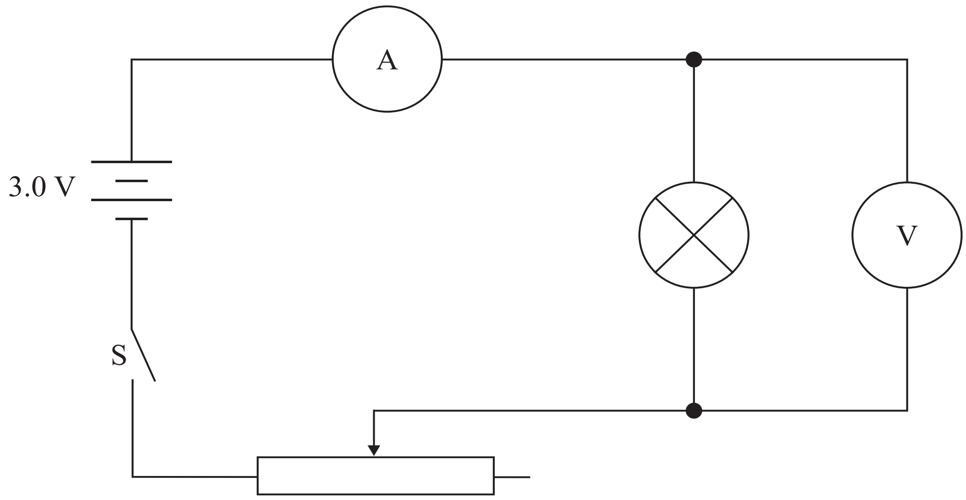
B2. This question is in **two** parts. **Part 1** is about electric circuits and **Part 2** is about an orbiting satellite.

Part 1 Electric circuits

Susan sets up the circuit below in order to measure the current-voltage (I-V) characteristic of a small filament lamp.



The supply is a battery that has an e.m.f. of 3.0 V and the ammeter and voltmeter are considered to be ideal. The lamp is labelled by the manufacturer as "3 Volts, 0.6 Watts".

(a) (i) Explain what information this labelling provides about the normal operation of the lamp. *[2]*

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(ii) Calculate the current in the filament of the lamp when it is operating at normal brightness. *[2]*

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(Question B2, part 1 continued)

Susan sets the variable resistor to its maximum value of resistance. She then closes the switch S and records the following readings.

Ammeter reading = 0.18 A	Voltmeter reading = 0.60 V

She then sets the variable resistor to its zero value of resistance and records the following readings.

Ammeter reading = 0.20 A	Voltmeter reading = 2.6 V

(b) (i) Explain why, by changing the value of the resistance of the variable resistance, the potential difference across the lamp cannot be reduced to zero or be increased to 3.0 V. *[2]*

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(ii) Determine the internal resistance of the battery. *[3]*

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(Question B2, part 1 continued)

(c) Calculate the resistance of the filament when the reading on the voltmeter is

(i) 0.60 V. *[1]*

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(ii) 2.6 V. *[1]*

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(d) Explain why there is a difference between your answers to (c) (i) and (c) (ii). *[2]*

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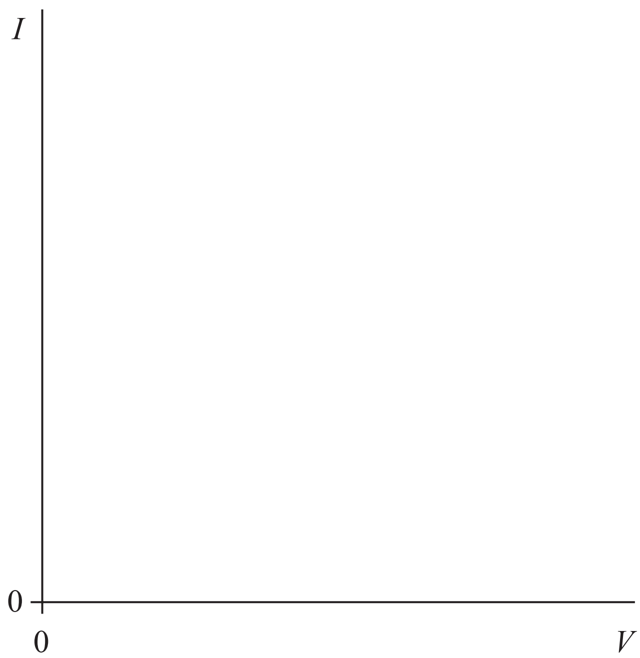
(e) Using the axes below, draw a sketch-graph of the *I*-*V* characteristic of the filament of the lamp. *(**Note**: this is a sketch-graph; you do not need to add any values to the axis.)* *[1]*



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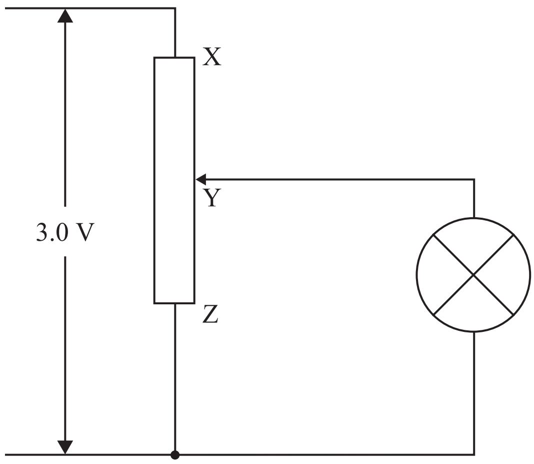
(Question B2, part 1 continued)

The diagram below shows an alternative circuit for varying the potential difference across the lamp.



The potential divider XZ has a potential of 3.0 V across it. When the contact is at the position Y, the resistance of XY equals the resistance of YZ which equals 12 Ω. The resistance of the lamp is 4.0 Ω.

(f) Calculate the potential difference across the lamp. *[4]*

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(Question B2 continued)

Part 2 Orbiting satellite

(a) Define *gravitational field strength* at a point in a gravitational field. *[2]*

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A satellite of mass m is in orbit around the Earth. The orbital radius of the satellite is r. The gravitational potential V at distance r from the centre of the Earth is given by the expression

$$V = -G\frac{M}{r}$$

where M is the mass of the Earth.

The gravitational field strength g_0 at the surface of the Earth is given by the expression

$$g_0 = G\frac{M}{R^2}$$

where R is the radius of the Earth.

(b) (i) Use the above expressions to deduce that the potential energy E_P of the satellite is given by the expression *[2]*

$$E_P = -\frac{mg_0R^2}{r}.$$

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(ii) By considering the centripetal force acting on the satellite, deduce that the kinetic energy E_K of the satellite is numerically equal to half the potential energy of the satellite. *[3]*

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(Question B2, part 2 continued)

The potential energy of a satellite at the surface of the Earth is -9.6×10^{10} J.

(c) (i) Deduce that the potential energy of the satellite in an orbit of radius 4.3×10^{7} m is 1.4×10^{10} J. ($g_0 = 10\,\text{N kg}^{-1}$, $R = 6.4\times10^{6}$ m) *[2]*

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(ii) Assuming that the satellite is launched close to one of the poles of the Earth, estimate the minimum energy required to put the satellite into an orbit of radius 4.3×10^{7} m. *[3]*

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B3. This question is in **two** parts. **Part 1** is about conservation of momentum and conservation of energy. **Part 2** is about electromagnetic induction.

Part 1 Conservation of momentum and energy

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

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

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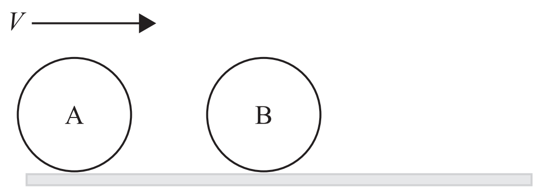
The diagram below shows two identical balls A and B on a horizontal surface. Ball B is at rest and ball A is moving with speed V along a line joining the centres of the balls. The mass of each ball is M.

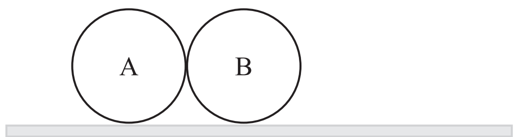
Before collision



During the collision of the balls, the magnitude of the force that ball A exerts on ball B is F_{AB} and the magnitude of the force that ball B exerts on ball A is F_{BA}.

(c) On the diagram below, add labelled arrows to represent the magnitude and direction of the forces F_{AB} and F_{BA}. *[3]*

During the collision



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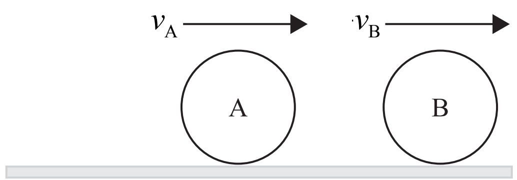
(Question B3, part 1 continued)

The balls are in contact for a time Δt. After the collision, the speed of ball A is $+v_A$ and the speed of ball B is $+v_B$ in the directions shown.

After the collision



As a result of the collision there is a change in momentum of ball A and of ball B.

(d) Use Newton's second law of motion to deduce an expression relating the forces acting during the collision to the change in momentum of

(i) ball B. *[2]*

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(ii) ball A. *[2]*

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(e) Apply Newton's third law and your answers to (d), to deduce that the change in momentum of the system (ball A and ball B) as a result of this collision, is zero. *[4]*

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(f) Deduce, that if kinetic energy is conserved in the collision, then after the collison, ball A will come to rest and ball B will move with speed V. *[3]*

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(Question B3 continued)

Part 2 Electromagnetic induction

In 1831 Michael Faraday demonstrated three ways of inducing an electric current in a ring of copper. One way is to move a bar magnet through the stationary copper ring.

(a) Describe briefly a way that a current may be induced in the copper ring using a **stationary** bar magnet. *[1]*

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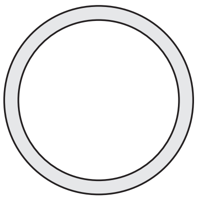
You are given the following apparatus: copper ring, battery, variable resistor, lengths of insulated copper wire with connecting terminals at each end.

(b) Describe, how you would use all of this apparatus to induce a current in the copper ring. *[4]*



copper ring

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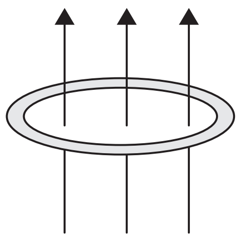
(Question B3, part 2 continued)

In the diagram below, a magnetic field links a circular copper ring. The field is uniform over the area of the ring and its strength is increasing in magnitude at a steady rate.



(c) (i) State Faraday's law of electromagnetic induction as it applies to this situation. *[2]*

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(ii) Draw on the diagram, an arrow to show the direction of the induced current in the copper ring. Explain how you determined the direction of the induced current. *[3]*

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(iii) The radius of the copper ring is 0.12 m and its resistance is $1.5 \times 10^{-2}\,\Omega$. The field strength is increasing at rate of $1.8 \times 10^{-3}\,\text{T s}^{-1}$. Calculate the value of the induced current in the copper ring. *[3]*

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B4. This question is in **two** parts. **Part 1** is about wave properties and interference. **Part 2** is about thermodynamic processes.

Part 1 Wave properties and interference

Wave properties

The diagram below represents the direction of oscillation of a disturbance that gives rise to a wave.

(a) By redrawing the diagram in the spaces below, add arrows to show the direction of wave energy transfer to illustrate the difference between

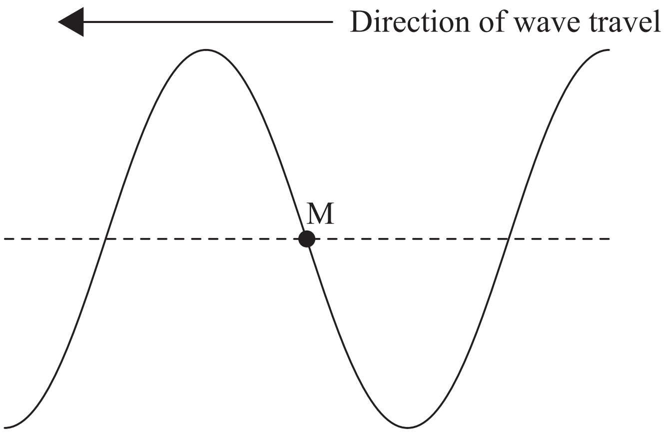
(i) a transverse wave and *[1]*

(ii) a longitudinal wave. *[1]*

(This question continues on the following page)

(Question B4, part 1 continued)

A wave travels along a stretched string. The diagram below shows the variation with distance along the string of the displacement of the string at a particular instant in time. A small marker is attached to the string at the point labelled M. The undisturbed position of the string is shown as a dotted line.



(b) On the diagram above

(i) draw an arrow to indicate the direction in which the marker is moving. *[1]*

(ii) indicate, with the letter A, the amplitude of the wave. *[1]*

(iii) indicate, with the letter λ, the wavelength of the wave. *[1]*

(iv) draw the displacement of the string a time $\frac{T}{4}$ later, where T is the period of oscillation of the wave. Indicate, with the letter N, the new position of the marker. *[2]*

The wavelength of the wave is 5.0 cm and its speed is $10\,\text{cm}\,\text{s}^{-1}$.

(c) Determine

(i) the frequency of the wave. *[1]*

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(ii) how far the wave has moved in $\frac{T}{4}$ s. *[2]*

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(Question B4, part 1 continued)

Interference of waves

(d) By reference to the principle of superposition, explain what is meant by constructive interference. *[4]*

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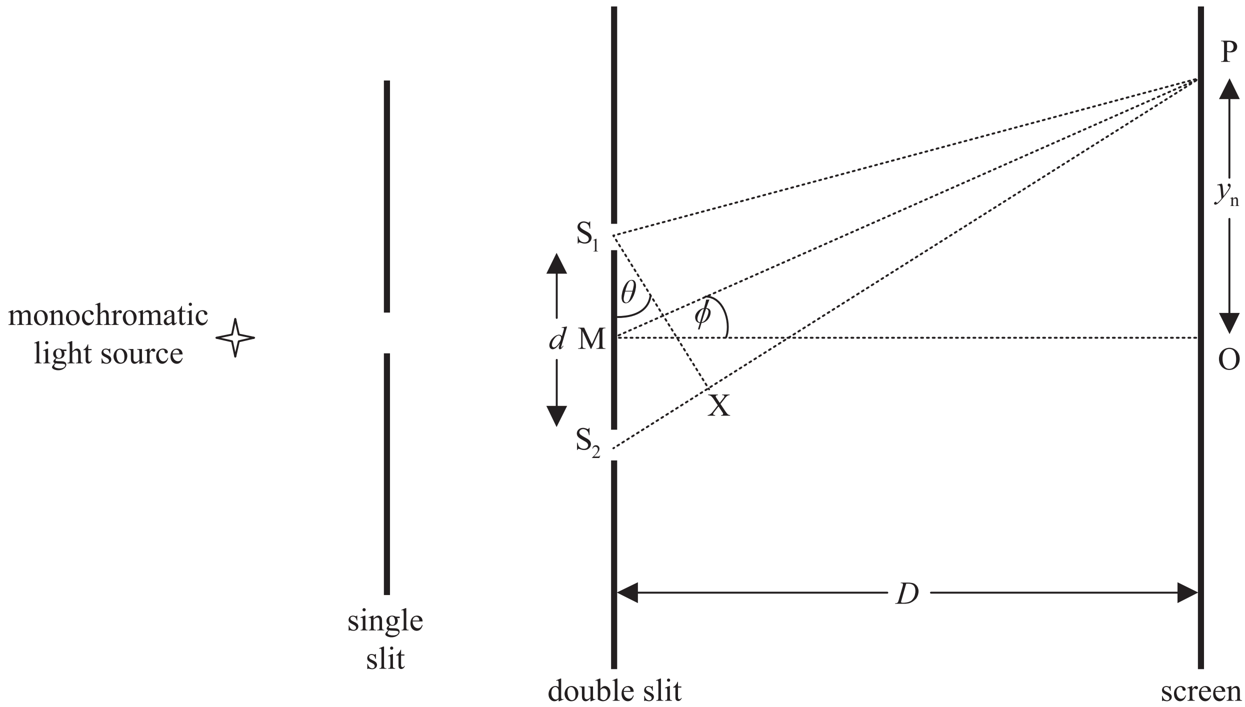
(Question B4, part 1 continued)

The diagram below (not drawn to scale) shows an arrangement for observing the interference pattern produced by the light from two narrow slits S_1 and S_2.



The distance S_1S_2 is d, the distance between the double slit and screen is D and $D \gg d$ such that the angles θ and ϕ shown on the diagram are small. M is the mid-point of S_1S_2 and it is observed that there is a bright fringe at point P on the screen, a distance y_n from point O on the screen. Light from S_2 travels a distance S_2X further to point P than light from S_1.

(e) (i) State the condition in terms of the distance S_2X and the wavelength of the light λ, for there to be a bright fringe at P. *[2]*

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(ii) Deduce an expression for θ in terms of S_2X and d. *[2]*

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(iii) Deduce an expression for ϕ in terms of D and y_n. *[1]*

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(Question B4, part 1 continued)

For a particular arrangement, the separation of the slits is 1.40 mm and the distance from the slits to the screen is 1.50 m. The distance y_n is the distance of the eighth bright fringe from O and the angle $\theta = 2.70 \times 10^{-3}$ rad.

(f) Using your answers to (e) to determine

(i) the wavelength of the light. *[2]*

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(ii) the separation of the fringes on the screen. *[3]*

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(Question B4 continued)

Part 2 Thermodynamic processes

(a) Distinguish between an *isothermal* process and an *adiabatic* process as applied to an ideal gas. *[2]*

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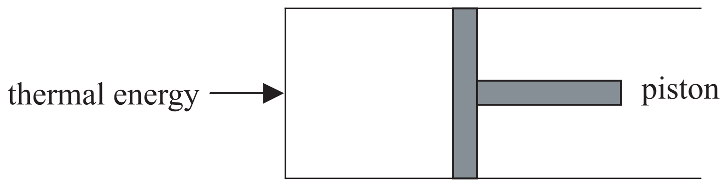
An ideal gas is held in a container by a moveable piston and thermal energy is supplied to the gas such that it expands at a constant pressure of 1.2×10^5 Pa.



The initial volume of the container is $0.050\,m^3$ and after expansion the volume is $0.10\,m^3$. The total energy supplied to the gas during the process is 8.0×10^3 J.

(b) (i) State whether this process is **either** isothermal **or** adiabatic **or** neither. *[1]*

. . . .

(ii) Determine the work done by the gas. *[1]*

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(iii) Hence calculate the change in internal energy of the gas. *[2]*

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