22086508

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

PHYSICS
HIGHER LEVEL
PAPER 2

Tuesday 20 May 2008 (afternoon)

2 hours 15 minutes

Candidate session number

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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.

0133

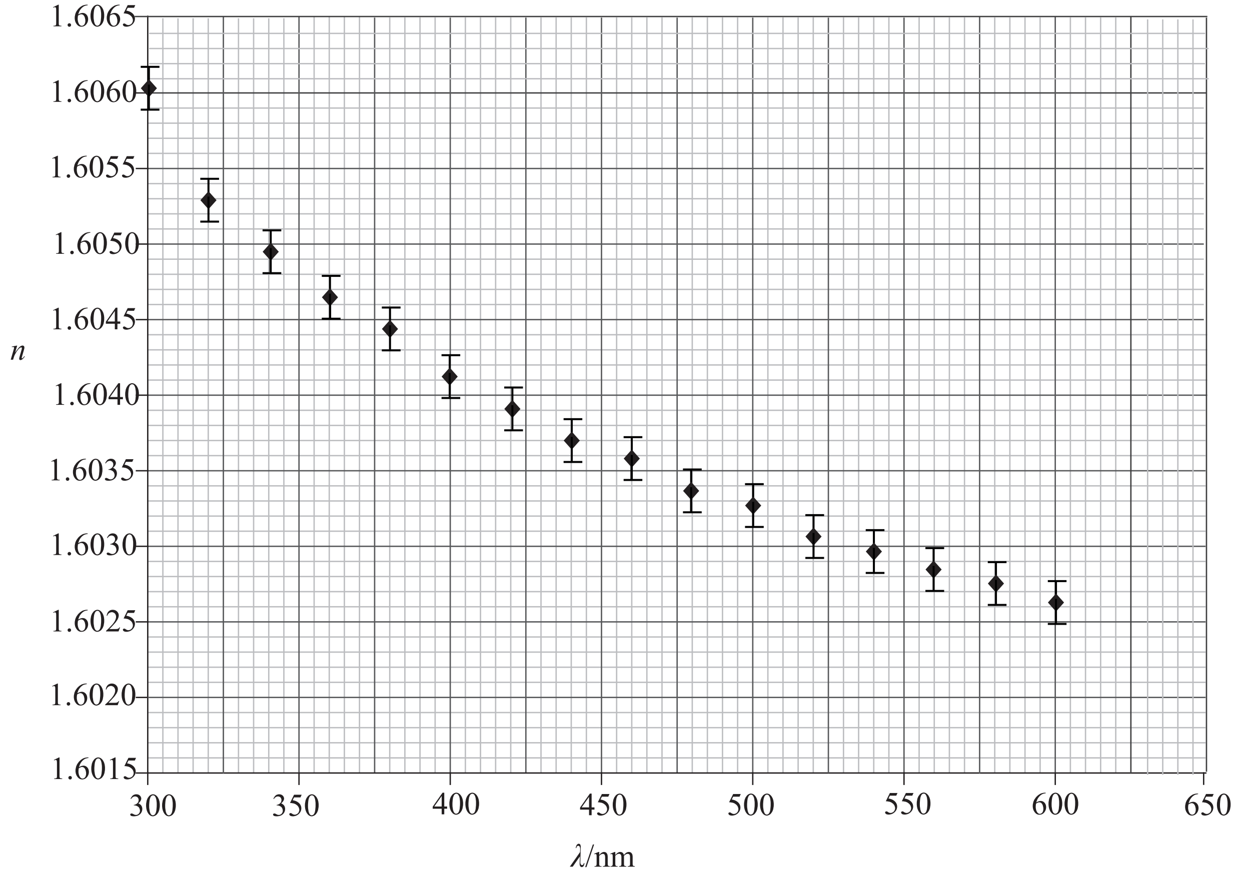
SECTION A

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

A1. This question is about data analysis.

Data for the refractive index n of a type of glass and wavelength λ of the light transmitted through the glass are shown below.

Only the uncertainties in the values of n are significant and these uncertainties are shown by error bars.



(This question continues on the following page)

(Question A1 continued)

(a) State why the data do not support the hypothesis that there is a linear relationship between refractive index and wavelength. *[1]*

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(b) Draw a best-fit line for the data points. *[2]*

(c) The rate of change of refractive index D_λ with wavelength is referred to as the dispersion. At any particular value of wavelength, D_λ is defined by

$$D_\lambda = \frac{\Delta n}{\Delta \lambda}$$

Use the graph to determine the value of D_λ at a wavelength of 380 nm. *[4]*

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(d) It is suggested that the relationship between n and λ is of the form

$$n = k\lambda^p$$

where k and p are constants.

State and explain the graph that you would plot in order to determine the value of p. *[3]*

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(This question continues on the following page)

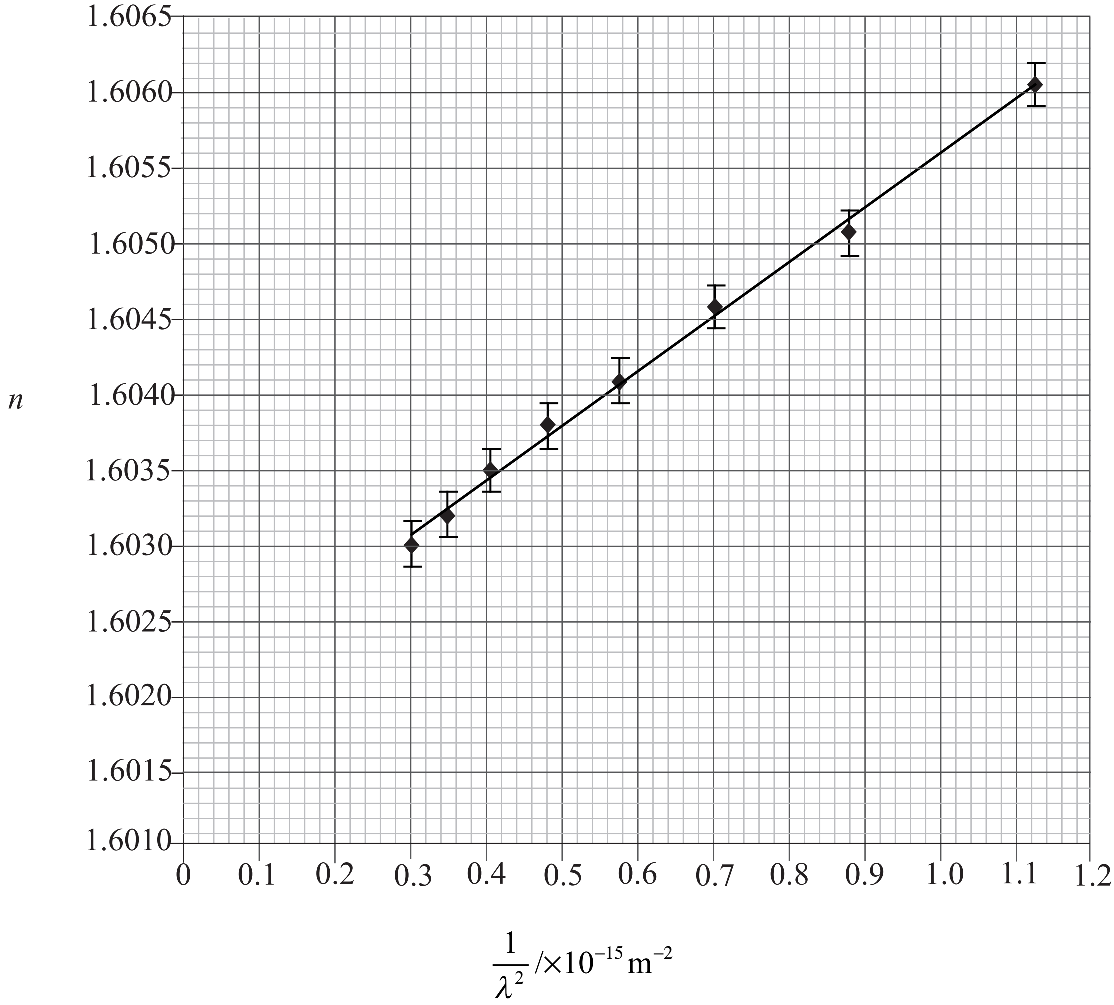
(Question A1 continued)

(e) A second suggestion is that the relationship between n and λ is of the form

$$n = A + \frac{B}{\lambda^2}$$

where A and B are constants.

To test this suggestion, values of n are plotted against values of $\frac{1}{\lambda^2}$. The resulting graph with the line of best fit is shown below.



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(Question A1 continued)

(i) Use the graph to determine the value of the constant *A*. *[3]*

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(ii) State the significance of the constant *A*. *[1]*

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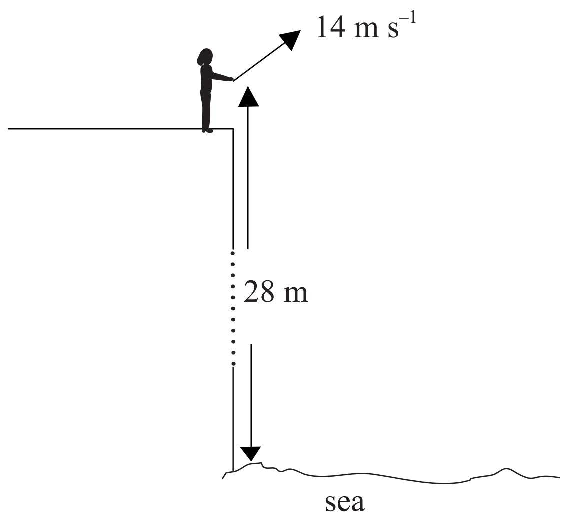
A2. This question is about projectile motion.

A stone is thrown from the top of a cliff of height 28 m above the sea. The stone is thrown at a speed of 14 m s^{-1} at an angle above the horizontal. Air resistance is negligible.



The maximum height reached by the stone measured from the point from which it is thrown is 8.0 m.

(a) By considering the energy of the stone, determine the speed with which the stone hits the sea. *[3]*

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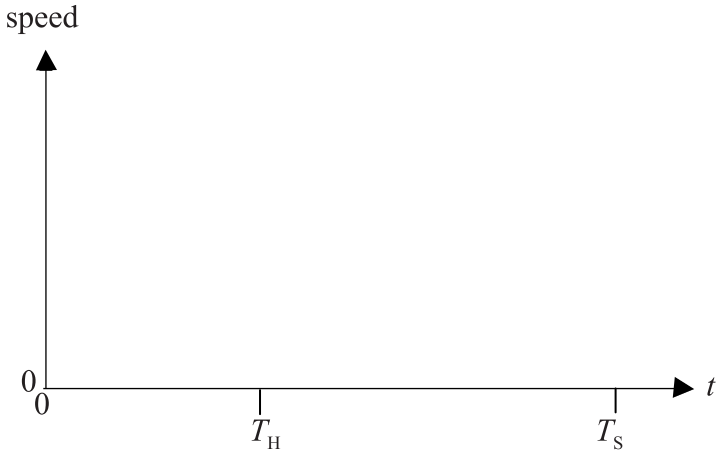
(b) The stone leaves the cliff at time $t=0$. It reaches its maximum height at $t=T_H$. On the axis below, draw a sketch-graph to show the variation with time t of the magnitude of the **vertical** component of velocity of the stone from $t=0$ to $t=T_S$, the time just before the stone strikes the sea. *[4]*



A3. This question is about nuclear reactions.

(a) State the meaning of the terms

(i) nuclide *[2]*

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(ii) isotope *[1]*

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(b) The isotope sodium-24 undergoes radioactive decay to the stable isotope magnesium-24.

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

$$^{24}_{11}\mathrm{Na} \rightarrow {}^{24}_{12}\mathrm{Mg}$$

(ii) One of the particles emitted in the decay has zero rest-mass. Use the data below to estimate the rest mass, in atomic mass units, of the other particle emitted in the decay of $^{24}_{11}\mathrm{Na}$. *[3]*

$$\text{rest mass of } {}^{24}_{11}\mathrm{Na} = 23.99096u$$
$$\text{rest mass of } {}^{24}_{12}\mathrm{Mg} = 23.98504u$$
$$\text{energy released in decay } = 5.002160\ \mathrm{MeV}$$

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(This question continues on the following page)

(Question A3 continued)

(c) The isotope sodium-24 is radioactive but the isotope sodium-23 is stable. Suggest which of these isotopes has the greater nuclear binding energy. *[2]*

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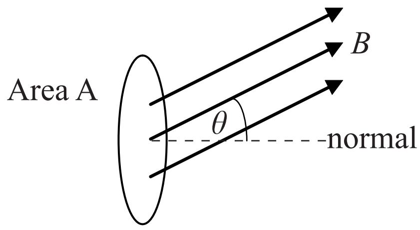
A4. This question is about induced e.m.f.

A small area A is in a region of uniform magnetic field of strength B. The field makes an angle θ to the normal to the area as shown below.



(a) With reference to the diagram, define *magnetic flux* ϕ both in words and in symbols. *[2]*

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(b) A thin copper ring encloses an area of $1.8\times10^{-3}\,\text{m}^2$. The plane of the ring is normal to a uniform magnetic field. The magnetic field strength increases at a constant rate of $5.0\times10^{-2}\,\text{T s}^{-1}$.

Calculate the e.m.f. induced in the ring. *[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 momentum and energy and **Part 2** is about gravitation.

Part 1 Momentum and energy

(a) Define *impulse of a force* and state the relation between impulse and momentum. *[2]*

definition

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(b) By applying Newton's laws of motion to the collision of two particles, deduce that momentum is conserved in the collision. *[5]*

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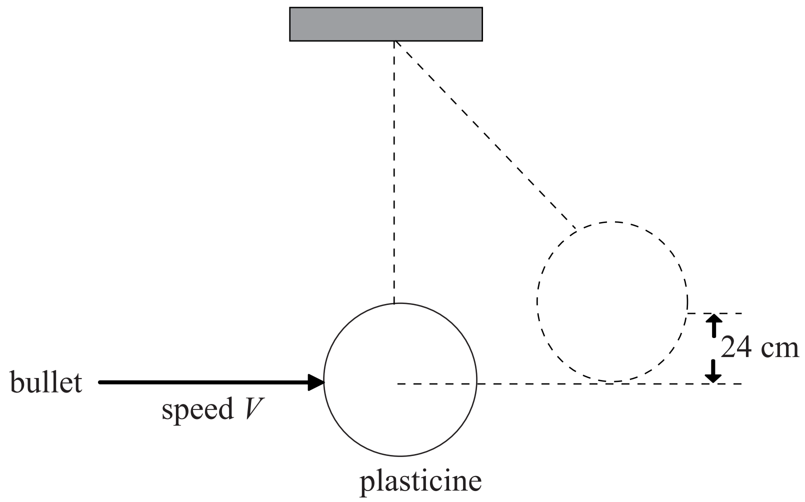
(Question B1 part 1 continued)

(c) In an experiment to measure the speed of a bullet, the bullet is fired into a piece of plasticine suspended from a rigid support by a light thread.



The speed of the bullet on impact with the plasticine is V. As a result of the impact, the bullet embeds itself in the plasticine and the plasticine is displaced vertically through a height of 24 cm. The mass of the bullet is $5.2\times10^{-3}\,\text{kg}$ and the mass of the plasticine is 0.38 kg.

(This question continues on the following page)

(Question B1 part 1 continued)

(i) Ignoring the mass of the bullet, calculate the speed of the plasticine immediately after the impact. *[2]*

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(ii) Deduce that the speed V with which the bullet strikes the plasticine is about $160\ \text{m s}^{-1}$. *[2]*

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(iii) Estimate the kinetic energy lost in the impact. *[3]*

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(This question continues on the following page)

(Question B1 part 1 continued)

(d) Another bullet is fired from a different gun into a large block of wood. The block remains stationary after impact and the bullet melts completely. The temperature rise of the block is negligible. Use the data to estimate the minimum impact speed of the bullet. *[5]*

mass of bullet	$= 5.2 \times 10^{-3}$ kg
specific heat capacity of the material of the bullet	$= 130$ J kg^{-1}K^{-1}
latent heat of fusion of the material of the bullet	$= 870$ J kg^{-1}
melting point of the material of the bullet	$= 330\,^{\circ}$C
initial temperature of bullet	$= 30\,^{\circ}$C

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(This question is continued on the following page)

(Question B1 continued)

Part 2 Gravitation

(a) State Newton's universal law of gravitation. *[3]*

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(b) The average distance of Earth from the Sun is 1.5×10^{11} m. The gravitational field strength due to the Sun at the Earth is 6.0×10^{-3} N kg^{-1}.

Estimate the mass of the Sun. *[3]*

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(c) Deduce that the orbital period T of a planet about the Sun is given by the expression

$$T^2 = KR^3$$

where R is the radius of the orbit and K is a constant. *[5]*

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B2. This question is in **two** parts. **Part 1** is about waves and **Part 2** is about magnetic fields.

Part 1 Waves

(a) With reference to the direction of energy transfer through a medium, distinguish between a transverse wave and a longitudinal wave. *[3]*

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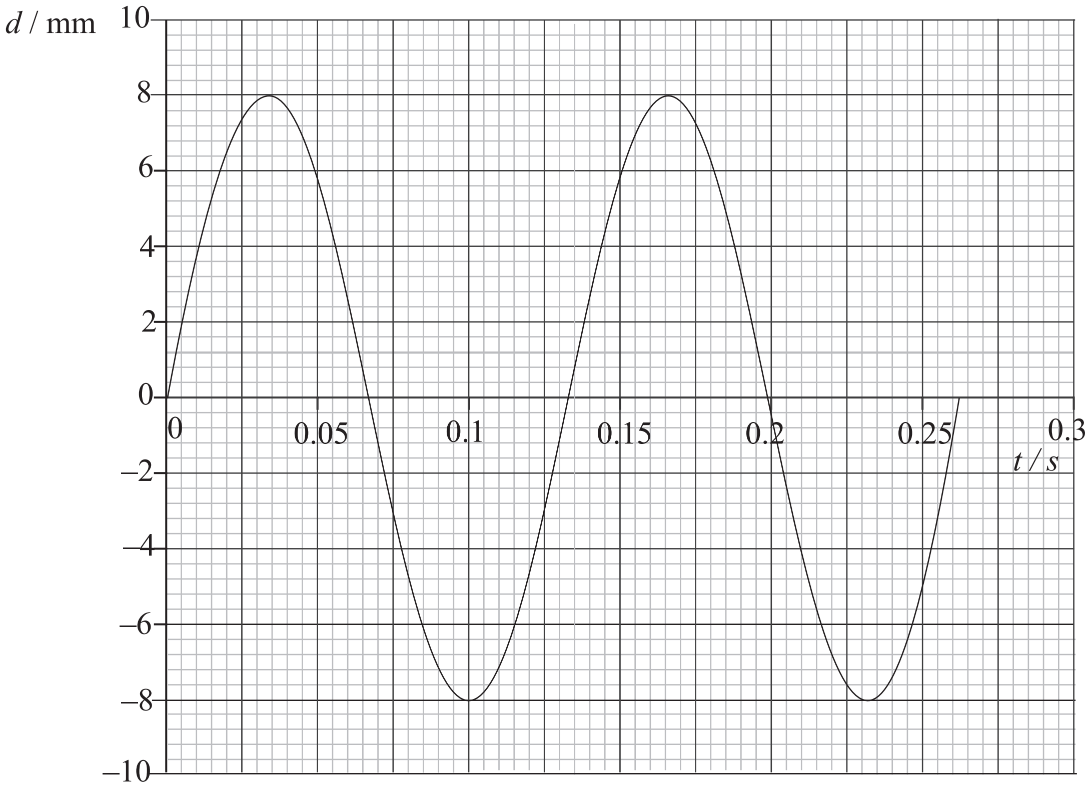
(b) A wave is travelling along the surface of some shallow water in the x-direction. The graph shows the variation with time t of the displacement d of a particle of water.



Use the graph to determine for the wave

(i) the frequency, *[2]*

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(ii) the amplitude. *[1]*

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(Question B2, part 1 continued)

(c) The speed of the wave in (b) is 15 cm s^{-1}. Deduce that the wavelength of this wave is 2.0 cm. *[2]*

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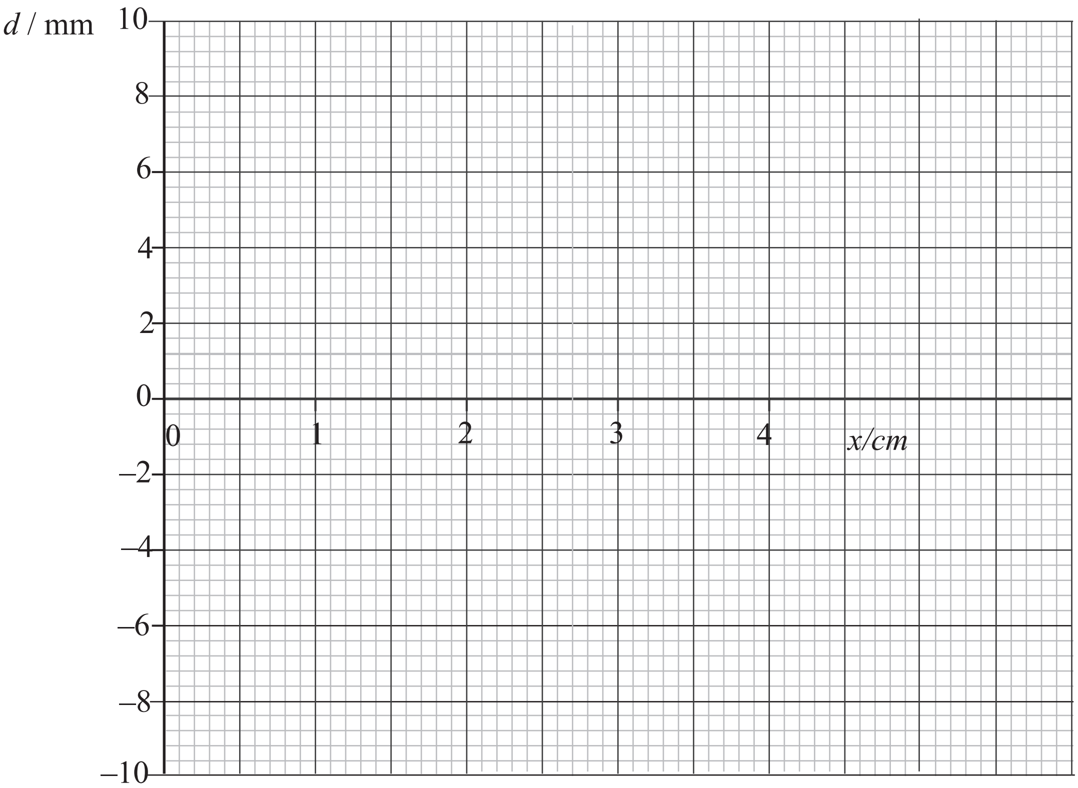
(d) The graph in (b) shows the displacement of a particle at the position $x = 0$.

On the axes below, draw a graph to show the variation with distance x along the water surface of the displacement d of the water surface at time $t = 0.070$ s. *[3]*



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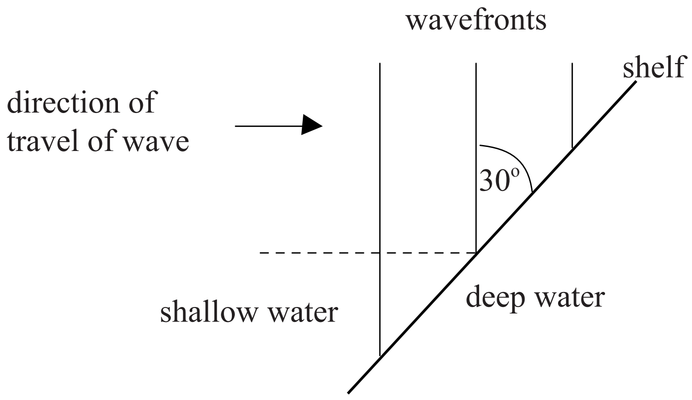
(Question B2, part 1 continued)

(e) The wave encounters a shelf that divides the water into two separate depths. The water to the right of the shelf is deeper than that to the left of the shelf.



The angle between the wavefronts in the shallow water and the shelf is 30°. The speed of the wave in the shallow water is 15 cm s^{-1} and in the deeper water is 20 cm s^{-1}. For the wave in the deeper water, determine the angle between the normal to the wavefronts and the shelf. *[3]*

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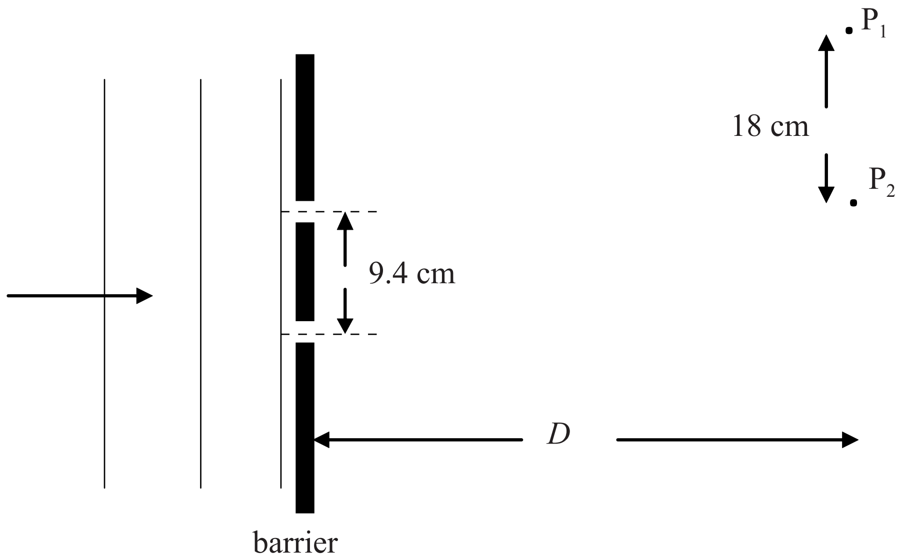
(Question B2 part 1 continued)

(f) The shelf is removed so that the water is of constant depth. A barrier containing two narrow slits is placed parallel to the wavefronts.



The separation of the two slits is 9.4 cm.
P_1 and P_2 are adjacent nodal points that lie on a line parallel to, and distance D from, the barrier. The separation of P_1 and P_2 is 18 cm.

(i) Explain why, as a result of the waves passing through the slits, there are points such as P_1 and P_2 where the displacement of the water is a minimum. *[4]*

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(ii) The wavelength of the waves is 2.0 cm. Estimate the distance *D*. *[3]*

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(Question B2 part 1 continued)

(g) A similar effect to that described in (f) can be demonstrated using light waves. The slits in this case are very narrow and their separation is large compared to their width. A screen is placed beyond the narrow slits. The distance between the narrow slits and the screen is about 1 m. The light waves emerging from the slits are coherent.

(i) State what is meant by coherent. *[1]*

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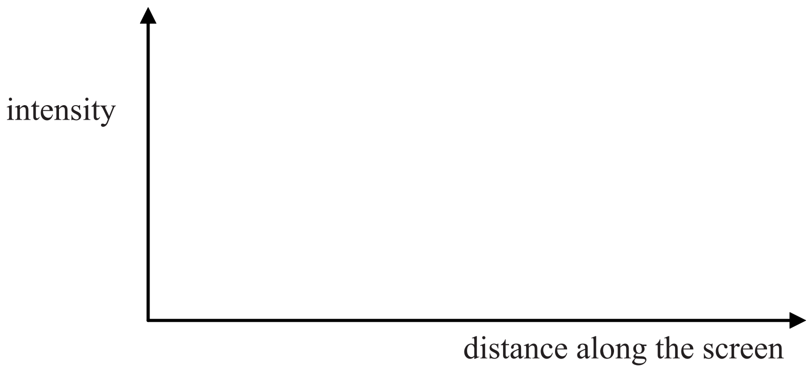
(ii) Using the axes below, draw a sketch of the intensity distribution of the light on the screen. *[2]*



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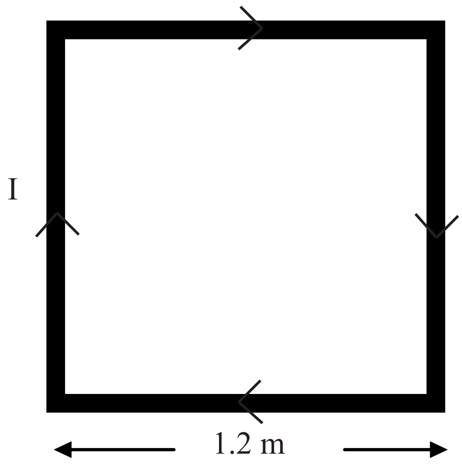
(Question B2 continued)

Part 2	Magnetic fields

In a certain experiment it is necessary to create a small region in which the effect of the horizontal component of the Earth's magnetic field is eliminated. In order to achieve this, a square coil of side 1.2 m consisting of 20 turns of copper wire is constructed.



The current I in the coil is in the direction shown. The strength of the horizontal component of the Earth's magnetic field is 7.0×10^{-5} T.

(a)	Assuming each side of the coil behaves as an infinitely long wire, deduce that, for a current of 2.6 A, the horizontal magnetic field strength at the centre of the coil is 7.0×10^{-5} T. *[4]*

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(Question B2, part 2 continued)

(b) The horizontal component of the Earth's magnetic field strength is 7.0×10^{-5} T. Draw a labelled sketch to show how the coil must be arranged with respect to the Earth's magnetic field so that the resultant field at the centre of the coil could be zero. *[2]*

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B3. This question is in **two** parts. **Part 1** is about aspects of electric fields and electric charge and **Part 2** is about thermodynamics.

Part 1 Fields and electric charge associated with atoms

(a) A proton may be considered to be a point charge. For such a proton

(i) sketch the electric field pattern. *[2]*

(ii) calculate the magnitude of the electric field strength at a distance of 5.0×10^{-11} m from the proton. *[2]*

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(Question B3, part 1 continued)

(b) In a simple model of the hydrogen atom, an electron orbits the proton. Both electron and proton are regarded as point charges. The orbital radius of the electron is 5.0×10^{-11} m.

(i) Using your answer to (a)(ii) deduce that the magnitude of the electric force between the electron and the proton is 9.3×10^{-8} N. *[1]*

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(ii) Deduce that the kinetic energy of the electron is 2.3×10^{-18} J. *[3]*

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(c) The electron in (b) also has electrostatic potential energy.

(i) Define *electrostatic potential* at a point. *[2]*

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(ii) Calculate the electrostatic potential energy of this electron. *[2]*

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(Question B3 part 1 continued)

(d) Using your answers in (b)(ii) and (c)(ii) determine the energy required, in electron volt, to completely remove the electron from the influence of the proton. *[2]*

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Fields and electric charge in conductors

(e) Define *electromotive force* (e.m.f.). *[1]*

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(f) A filament lamp is operating at normal brightness.

The potential difference across the lamp is 6.0 V. The current in the filament is 0.20 A. For the filament of this lamp, calculate

(i) the resistance. *[1]*

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(ii) the power dissipated. *[1]*

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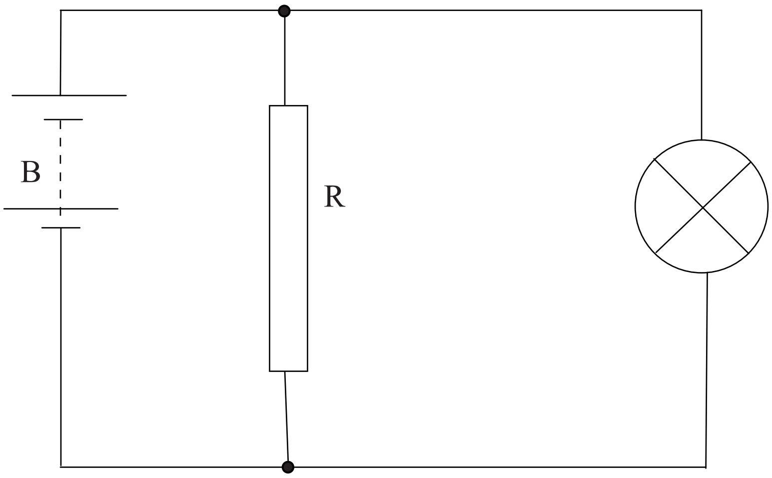
(Question B3 part 1 continued)

(g) The lamp in (f) is connected in the circuit below. The lamp is still operating at normal brightness.



The battery B has an internal resistance of 5.0 Ω and the resistance R of the resistor is 15 Ω.

(i) Calculate the current in the resistor R. *[1]*

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(ii) Determine the e.m.f. of the battery. *[4]*

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(Question B3 continued)

Part 2 Thermodynamics

(a) State, by reference to energy exchanges, the difference between a heat pump and a heat engine. *[2]*

Heat pump: . . . .

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Heat engine: . . . .

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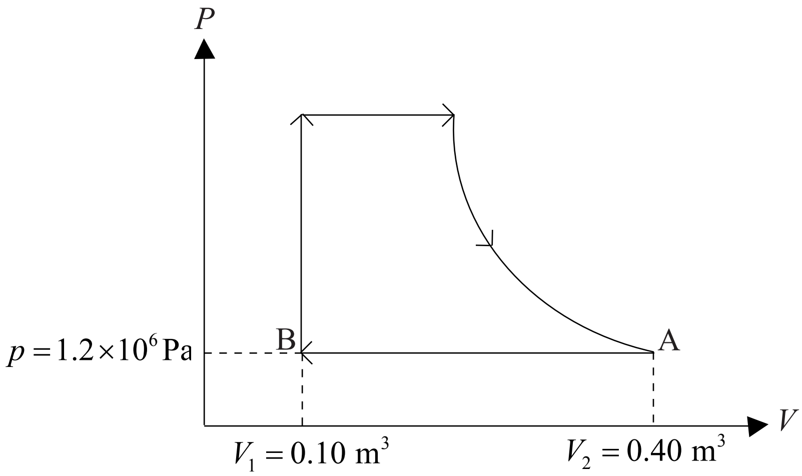
(b) The diagram shows the ideal shape of a pressure-volume relationship (*P*-*V*) for the working substance during one cycle of a steam engine.



The part of the cycle labelled AB is an isobaric isothermal change of phase.

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(Question B3 part 2 continued)

(i) The only part of the cycle in which energy is transferred to the surroundings is $A \rightarrow B$. Assuming that there is no change in the internal energy of the working substance, use data from the diagram to deduce that the energy transferred to the surroundings is 3.6×10^5 J . *[2]*

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(ii) The efficiency of the engine is 32 %. Determine the energy transferred **from** the surroundings during one cycle. *[3]*

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(iii) Calculate the work done by the engine in one cycle. *[1]*

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B4. This question is in **two** parts. **Part 1** is about power and an ideal gas and **Part 2** is about photoelectric effect.

Part 1 Power and an ideal gas

(a) Define *power*. *[1]*

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(b) A constant force of magnitude F moves an object at constant speed v in the direction of the force. Deduce that the power P required to maintain constant speed is given by the expression *[2]*

$$P = Fv$$

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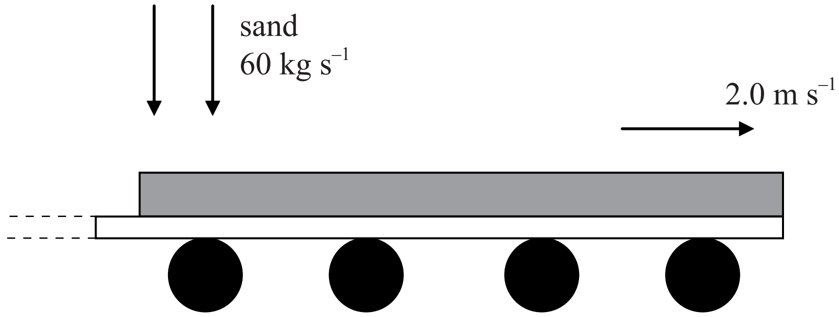
(Question B4 part 1 continued)

(c) Sand falls vertically on to a horizontal conveyor belt at a rate of 60 kg s^{-1}.



The conveyor belt that is driven by an engine, moves with speed 2.0 m s^{-1}.

When the sand hits the conveyor belt, its horizontal speed is zero.

(i) Identify the force F that accelerates the sand to the speed of the conveyor belt. *[1]*

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(ii) Determine the magnitude of the force F. *[2]*

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(iii) Calculate the power P required to move the conveyor belt at constant speed. *[1]*

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(iv) Determine the rate of change of kinetic energy K of the sand. *[2]*

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(v) Explain why P and K are not equal. *[2]*

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(Question B4, part 1 continued)

(d) The engine that drives the conveyor belt in (c) operates in a cycle. In part of this cycle, air is compressed in a cylinder of the engine such that the pressure and the temperature of the air increases. Assuming that the air in the cylinder behaves as an ideal gas, outline how the kinetic model of an ideal gas accounts for this increase in temperature and pressure. *[7]*

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pressure:

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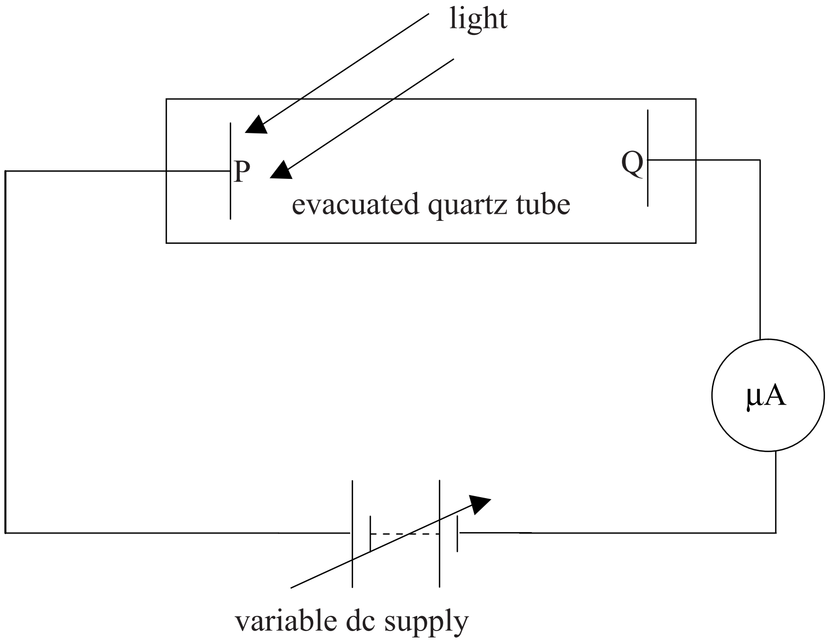
(Question B4 continued)

Part 2 The photoelectric effect

In the photoelectric effect, electrons are emitted from a metal surface when light of a suitable frequency is incident on the surface. The diagram below shows an arrangement for investigating some aspects of the photoelectric effect.



P and Q are metal plates. Monochromatic light of frequency f is incident on plate P.
In the situation shown, the microammeter (μA) registers a current. The intensity of the light is kept constant throughout the experiment.

(This question continues on the following page)

(Question B4 part 2 continued)

(a) As the potential difference between P and Q is increased, the current in the circuit decreases until it is zero. State and explain the polarity of the metal plate Q. *[4]*

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(b) The potential difference in the circuit is increased until the current in the circuit just becomes zero. The potential difference is then kept constant. The frequency f of the light is increased to a new value and the intensity is kept constant. The microammeter again registers a current. Outline how Einstein's theory of the photoelectric effect accounts for this observation. *[3]*

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(c) Explain why in (b) as f is increased at constant intensity, the current registered by the microammeter decreases. *[2]*

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(Question B4 part 2 continued)

(d) At a frequency f of 3.0×10^{15} Hz, the potential difference between P and Q at which the current just becomes zero is 8.0 V. The work function of the metal surface of P is 4.4 eV.

Determine a value for the Planck constant. *[3]*

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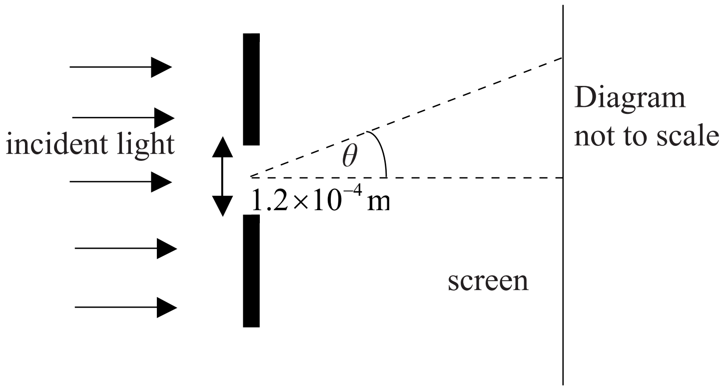
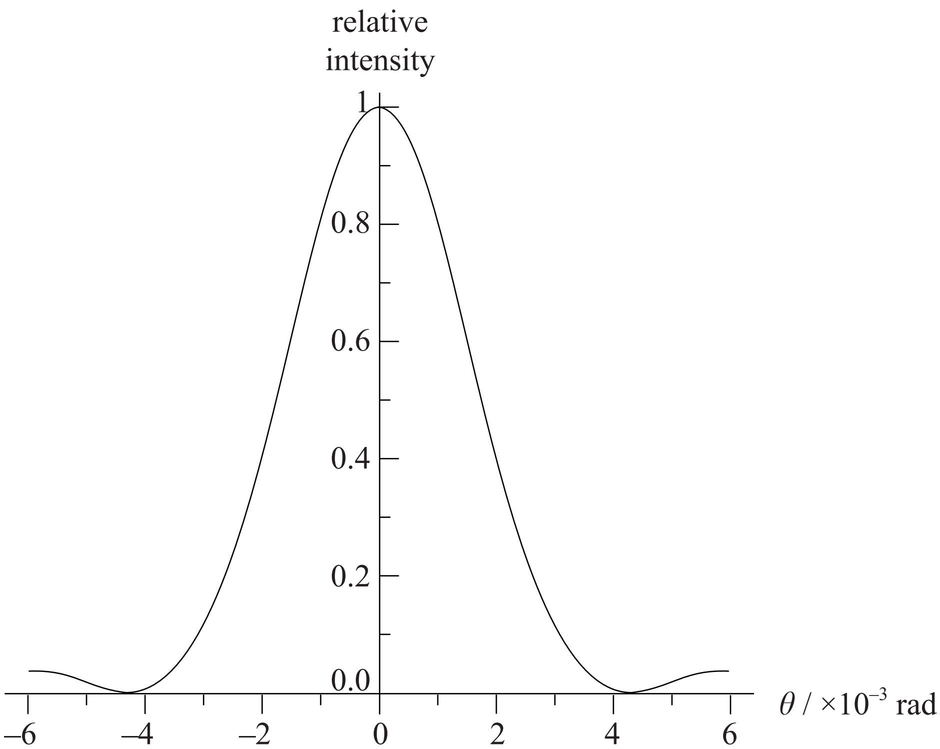
H4. This question is about diffraction.

Monochromatic light is incident on a single slit of width 1.2×10^{-4} m.



The graph shows the variation with angle θ of the intensity of the light on the screen.



(a) Use the graph to estimate the wavelength of the light. *[1]*

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(b) Monochromatic light is incident on two parallel slits. After passing through the slits, the light is incident on a screen. The separation of the slits is approximately twice the slit width. On the axes above draw a graph to show the intensity distribution of the light on the screen. *[2]*