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International Baccalaureate®
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PHYSICS
STANDARD LEVEL
PAPER 2

Tuesday 20 May 2008 (afternoon)

1 hour 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 one question 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.

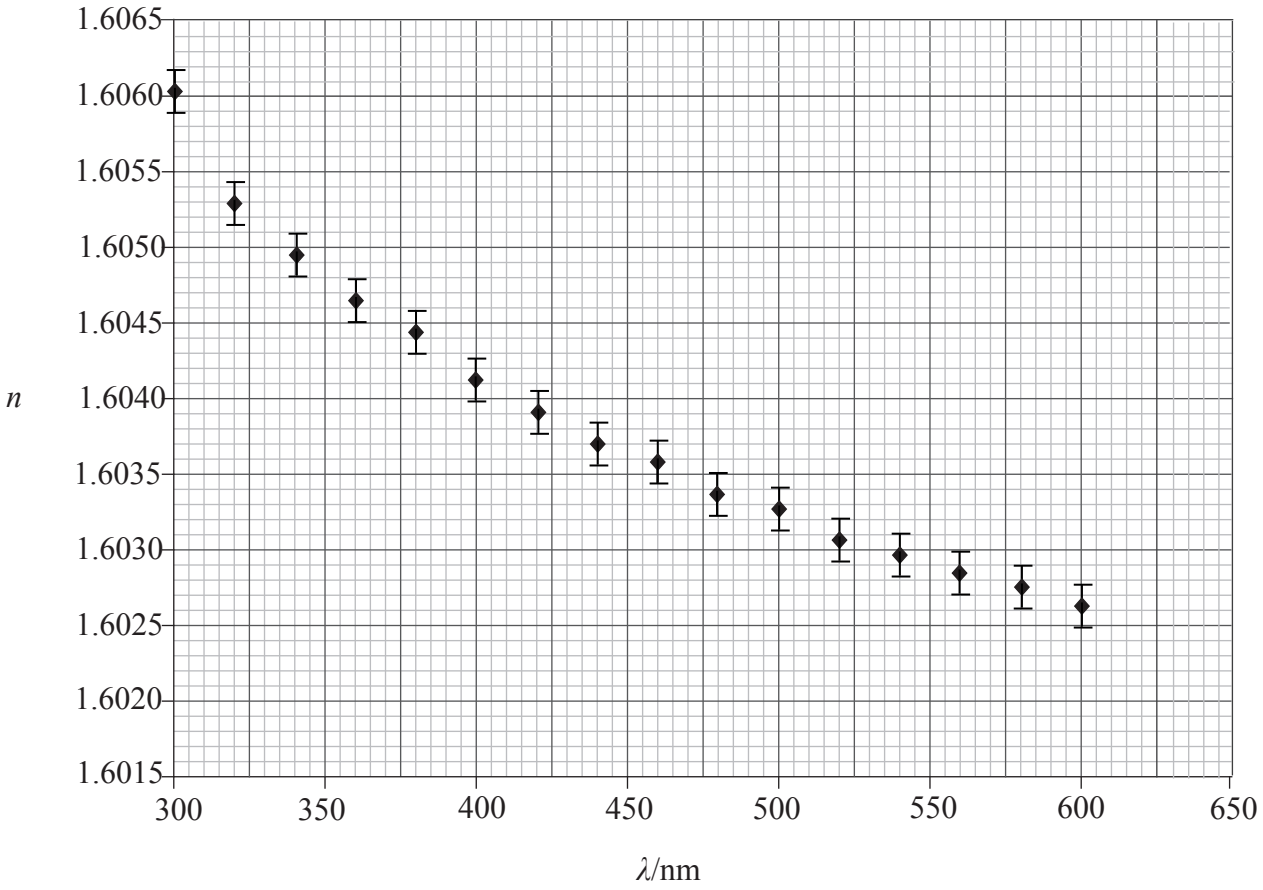
SECTION A

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

A1. This question is about 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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(This question continues on the following page)

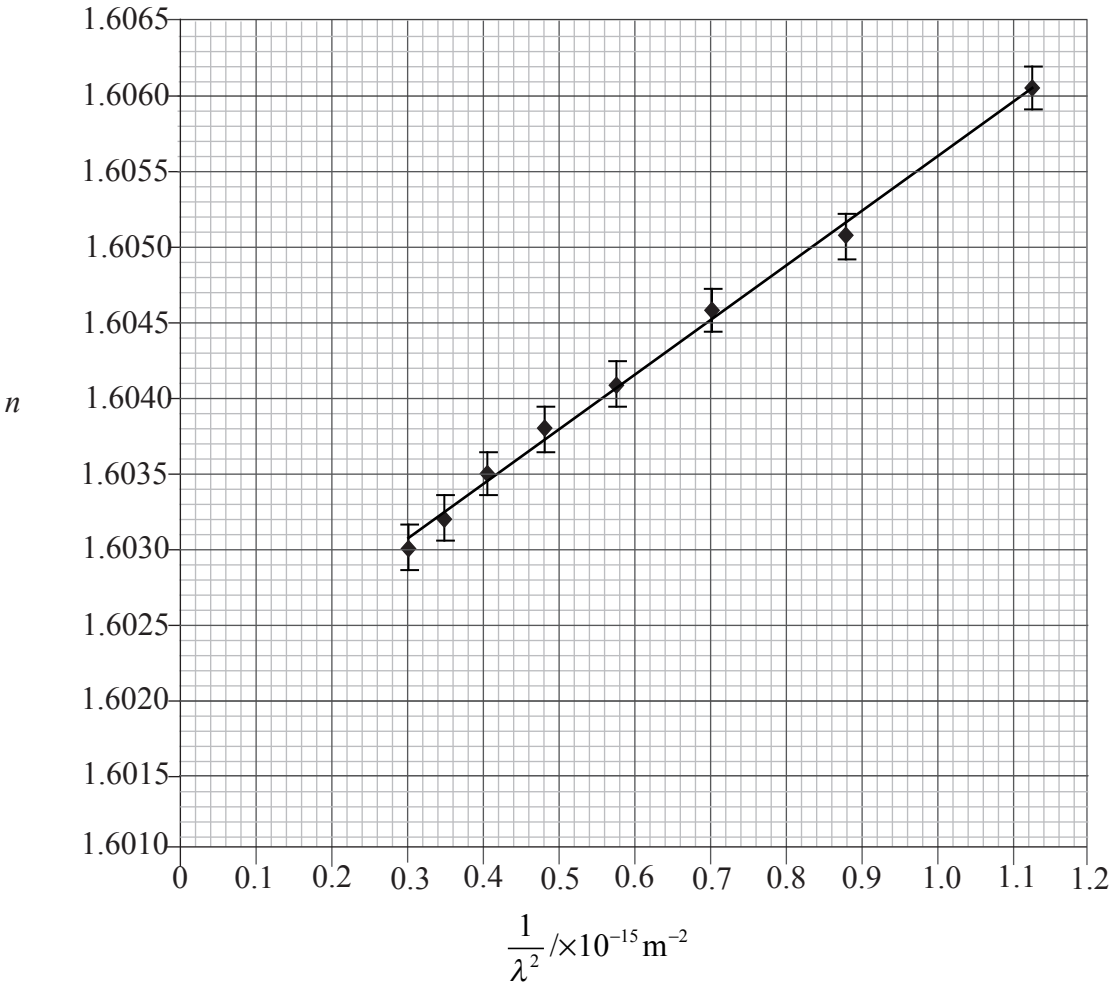
(Question A1 continued)

(d) Based on the plotted data, it is suggested 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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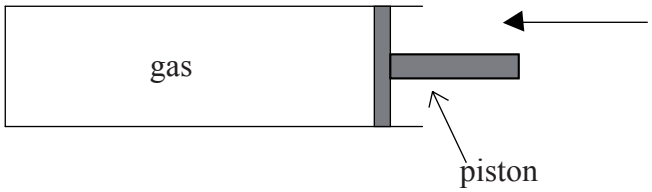
A2. This question is about an ideal gas.

An ideal gas is contained in a cylinder by a piston.



The piston is moved rapidly in the direction shown such that it compresses the gas. As a result, the temperature of the gas increases.

(a) Outline how the molecular model of an ideal gas accounts for the rise in temperature. *[3]*

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(b) The initial volume of the gas is $0.20\,m^3$ at a temperature of $27\,^oC$ and a pressure of $1.0\times10^5\,Pa$. After compression, the volume of the gas is $0.070\,m^3$ and the temperature is $57\,^oC$. Determine the final pressure of the gas. *[2]*

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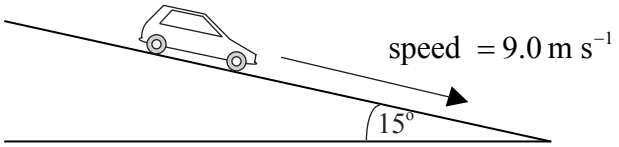
A3. This question is about the breaking distance of a car and specific heat capacity.

(a) A car of mass 960 kg is free-wheeling down an incline at a constant speed of 9.0 m s^{-1}.



The slope makes an angle of 15° with the horizontal.

(i) Deduce that the average resistive force acting on the car is 2.4×10^3 N. *[2]*

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(ii) Calculate the kinetic energy of the car. *[1]*

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(This question continues on the following page)

(Question A3 continued)

(b) The driver now applies the brakes and the car comes to rest in 15 m. Use your answer to (a)(ii) to calculate the average braking force exerted on the car in coming to rest. *[2]*

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(c) The same braking force is applied to each rear wheel of the car. The effective mass of each brake is 5.2 kg with a specific heat capacity of 900 J kg^{-1} K^{-1}. Estimate the rise in temperature of a brake as the car comes to rest. State **one** assumption that you make in your estimation. *[4]*

estimate:

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assumption:

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SECTION B

*This section consists of three questions: B1, B2, and B3. Answer **one** question.*

B1. This question is in **two** parts. **Part 1** is about momentum and energy and **Part 2** is about waves.

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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relation:

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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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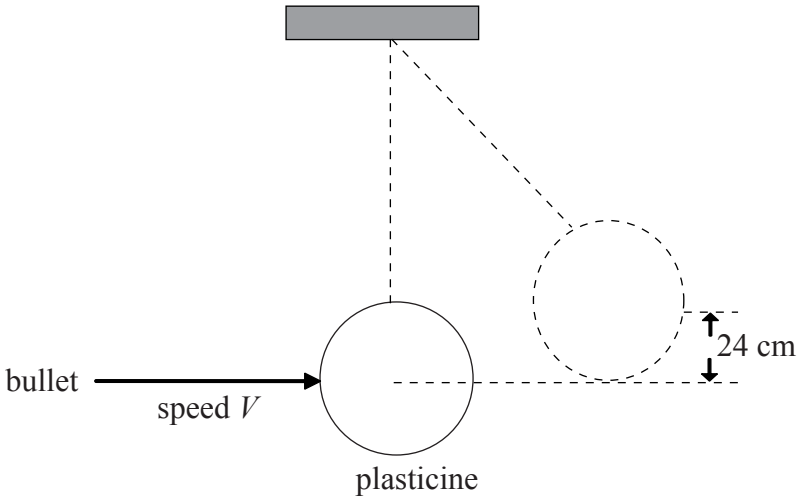
(Question B1 part 1 continued)

(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 5.2×10^{-3} 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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(This question is continued on the following page)

(Question B1 continued)

Part 2 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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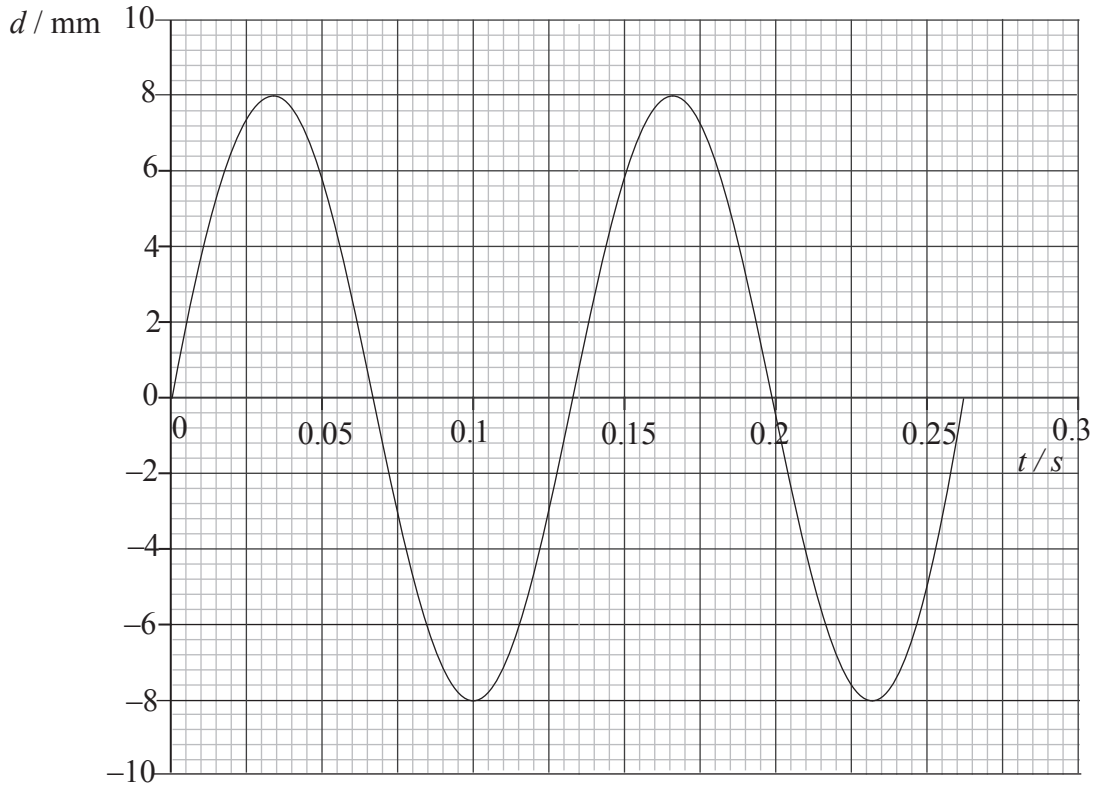
(b) A wave is travelling along the surface of some shallow water in the *x*-direction. The graph shows the variation with time *t* of the displacement *d* of a particle of water.



Use the graph to determine for the wave

(i) the frequency, *[2]*

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(ii) the amplitude. *[1]*

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(This question continues on the following page)

(Question B1 part 2 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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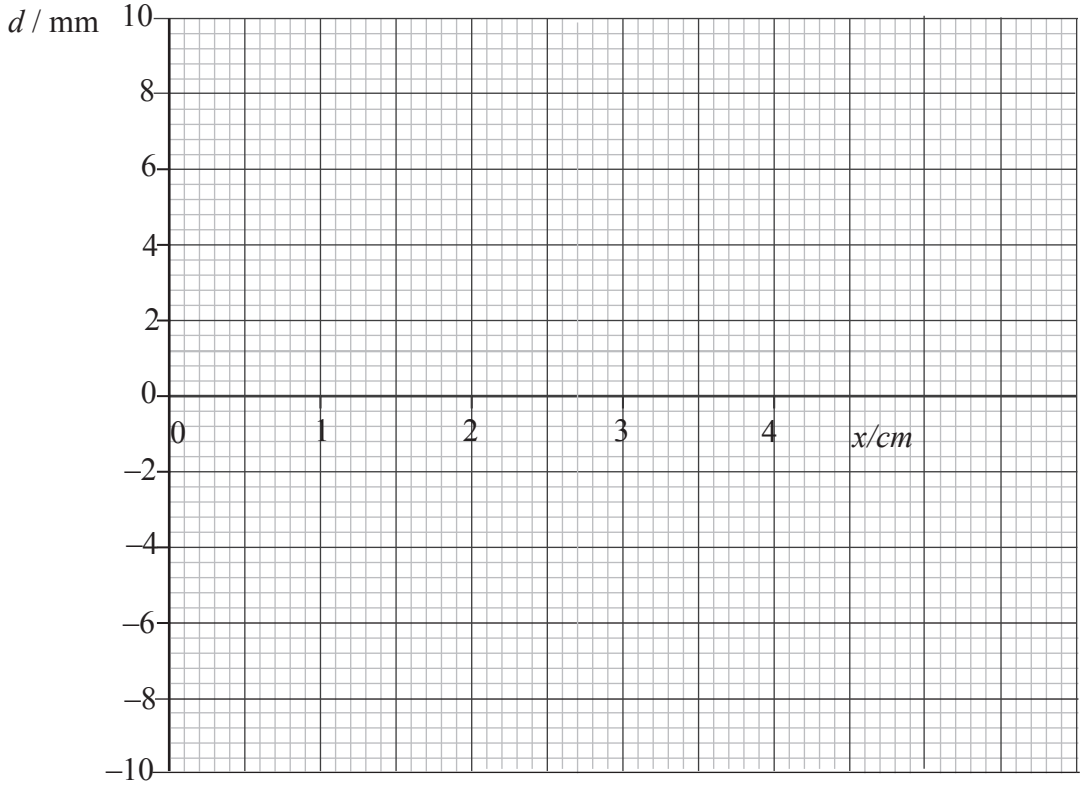
(d) The graph in (b) shows the displacement of a particle at the position $x = 0$.

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 $t = 0.070\,\text{s}$. *[3]*



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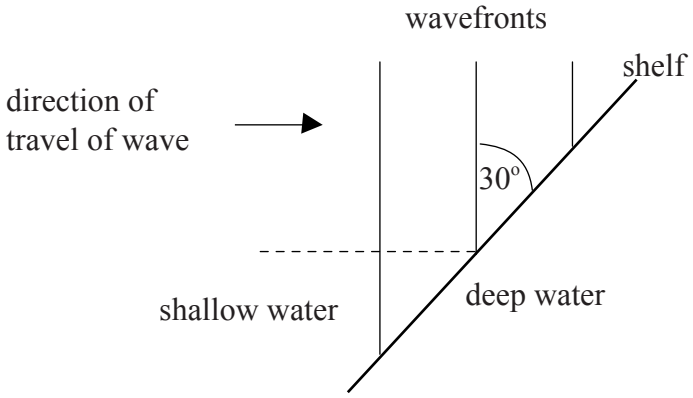
(Question B1, part 2 continued)

(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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B2. This question is in **two** parts. **Part 1** is about power and **Part 2** is about nuclear reactions.

Part 1 Power

(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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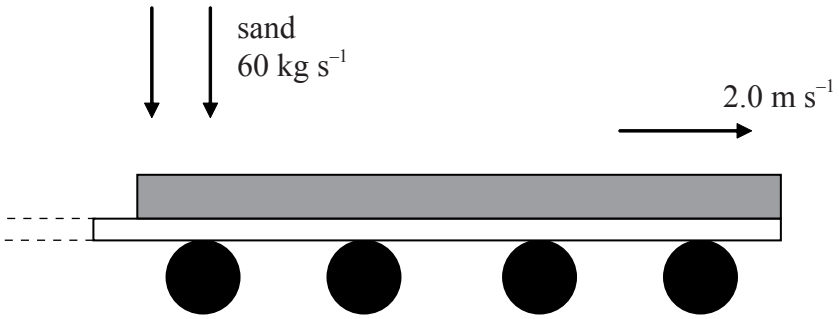
(Question B2 part 1 continued)

(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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(This question continues on the following page)

(Question B2, part 1 continued)

(d) The engine that drives the conveyor belt has an efficiency of 40 %. Calculate the input power to the engine. *[2]*

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Part 2 Nuclear reaction

(a) State the meaning of the terms

(i) nuclide *[2]*

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(ii) isotope *[1]*

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(b) A nucleus of $^{24}_{11}\text{Na}$ undergoes radioactive decay to the stable nucleus $^{24}_{12}\text{Mg}$.

(i) Identify this type of radioactive decay. *[1]*

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(ii) Use the data below to determine the rest mass in atomic mass unit of the particle emitted in the decay of $^{24}_{11}\text{Na}$. *[3]*

rest mass of $^{24}_{11}\text{Na} = 23.99096u$

rest mass of $^{24}_{12}\text{Mg} = 23.98504u$

energy released in decay $= 5.002160\ \text{MeV}$

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(This question continues on the following page)

(Question B2 part 2 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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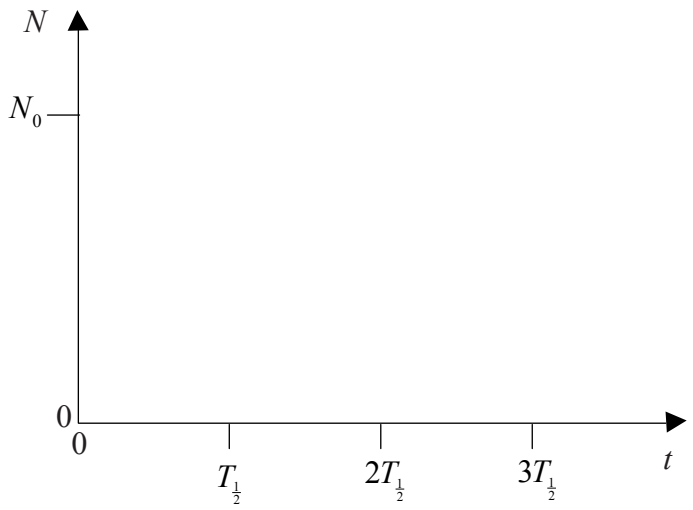
(d) At time $t = 0$, a sample of sodium-24 contains N_0 atoms of sodium-24. The half-life of sodium-24 is $T_{\frac{1}{2}}$.

(i) Using the axes below, draw a sketch graph to show the variation with time t of the number N of sodium-24 atoms in the sample. *[2]*



(ii) State how the rate at which the sample is decaying at any time t can be found from your sketch graph. *[1]*

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B3. This question is about aspects of electric fields and electric charge.

Fields and electric charge associated with atoms

(a) Define *electric field strength.* *[2]*

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

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

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(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 continued)

(c) 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 (b)(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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(iii) The total energy of the electron is –14 eV. Determine the potential energy of the electron in electron volt. *[3]*

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(Question B3 continued)

Fields and electric charge in conductors

(d) Describe the concept of drift velocity as applied to the conduction electrons in a conductor. *[4]*

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(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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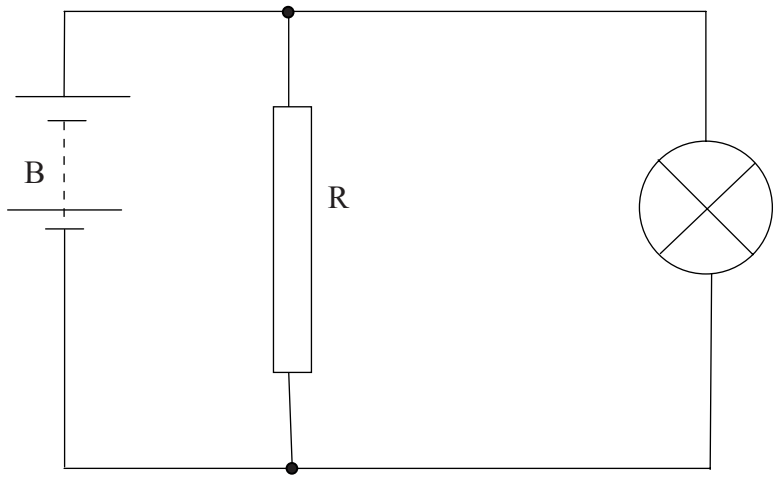
(Question B3 continued)

(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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