22126508

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Baccalauréat International
Bachillerato Internacional

PHYSICS
HIGHER LEVEL
PAPER 2

Thursday 10 May 2012 (afternoon)

2 hours 15 minutes

Candidate session number

0	0							

Examination code

2	2	1	2	–	6	5	0	8

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 questions.
- Section B: answer two questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the ***Physics*** *Data Booklet* is required for this paper.
- The maximum mark for this examination paper is *[95 marks]*.

0136

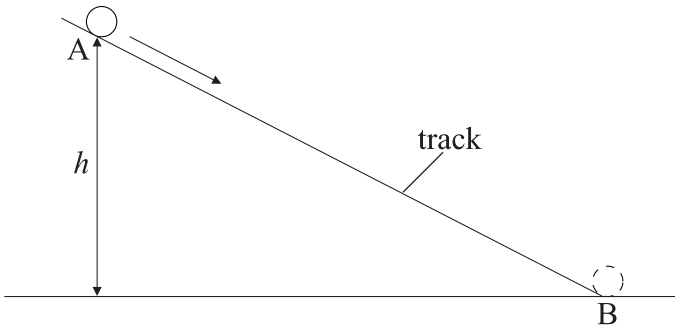
36 pages

SECTION A

*Answer **all** questions. Write your answers in the boxes provided.*

A1. Data analysis question.

A small sphere rolls down a track of constant length AB. The sphere is released from rest at A. The time t that the sphere takes to roll from A to B is measured for different values of height h.



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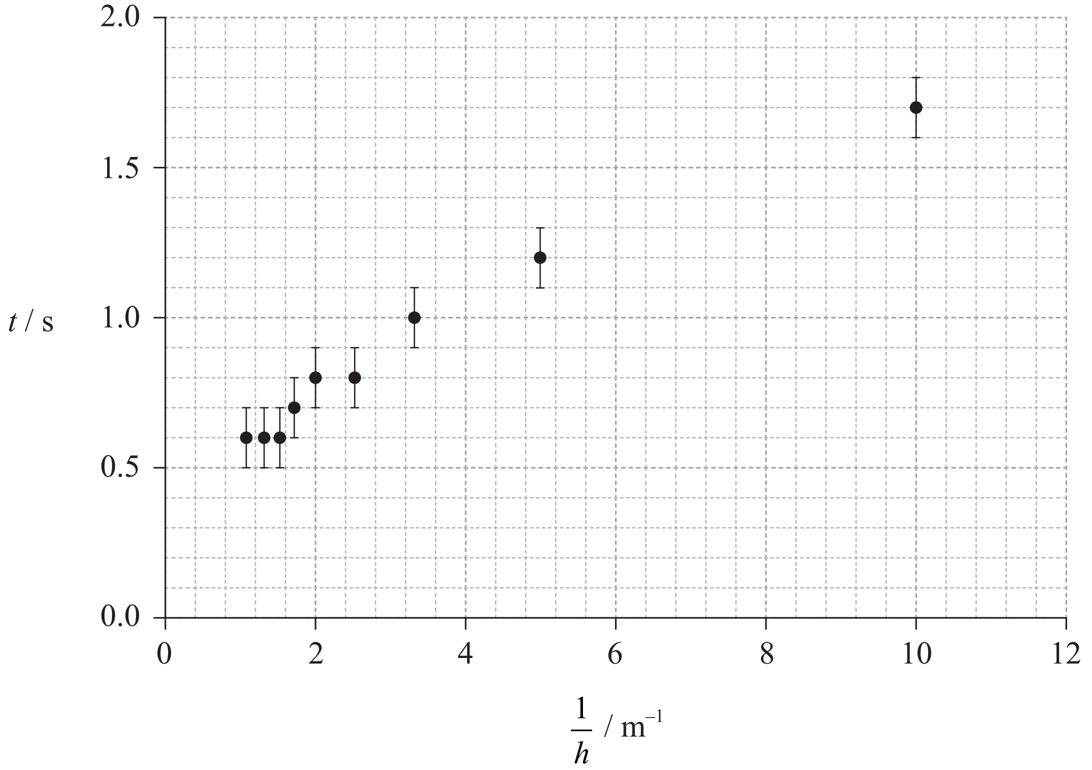
(Question A1 continued)

A student suggests that t is proportional to $\frac{1}{h}$. To test this hypothesis a graph of t against $\frac{1}{h}$ is plotted as shown on the axes below. The uncertainty in t is shown and the uncertainty in $\frac{1}{h}$ is negligible.



(a) (i) Draw the straight line that best fits the data. *[1]*

(ii) State why the data do not support the hypothesis. *[1]*

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(Question A1 continued)

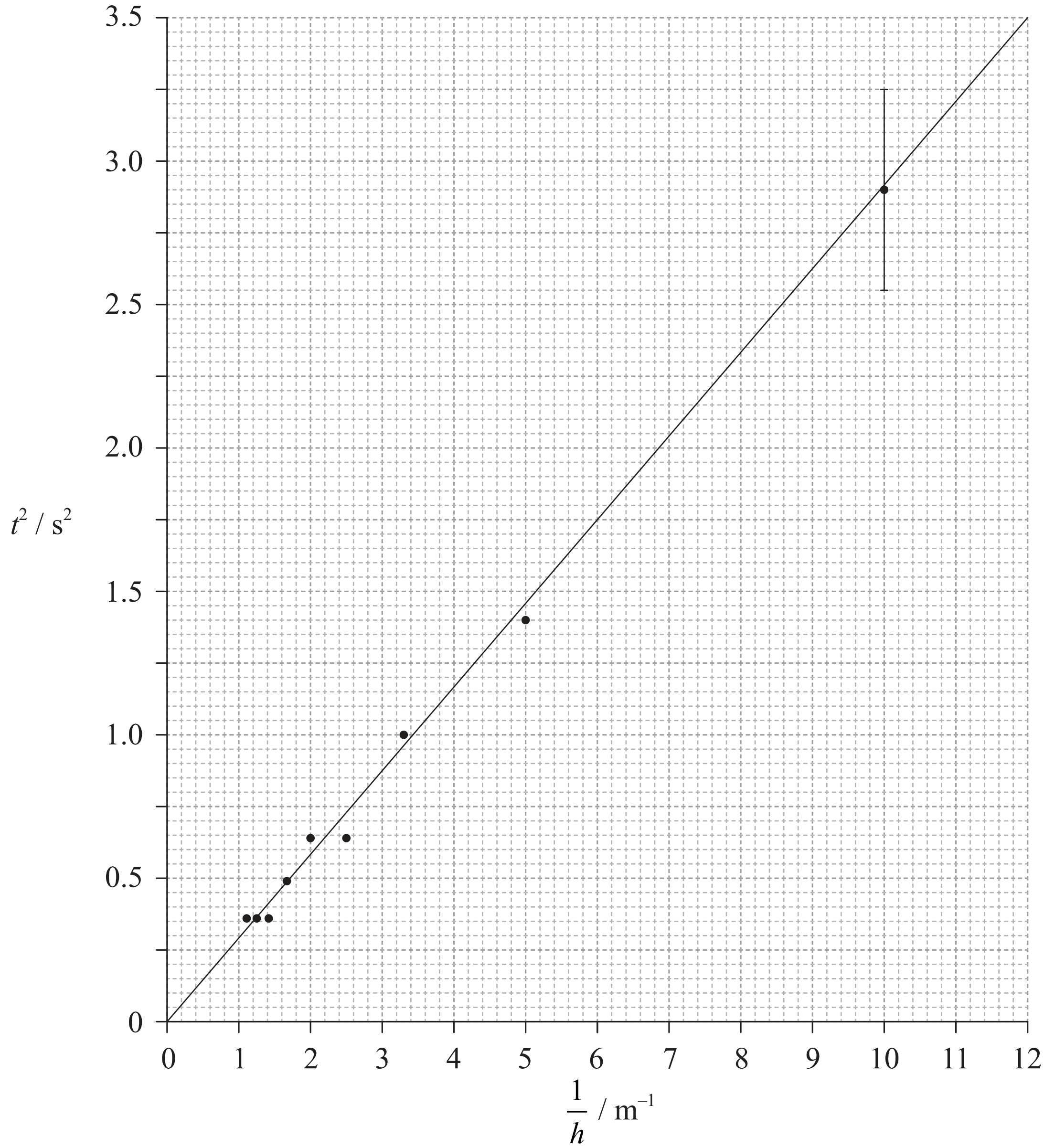
(b) Another student suggests that the relationship between t and h is of the form

$$t = k\sqrt{\frac{1}{h}}$$

where k is a constant.

To test whether or not the data support this relationship, a graph of t^2 against $\frac{1}{h}$ is plotted as shown below.

The best-fit line takes into account the uncertainties for all data points.



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(Question A1 continued)

The uncertainty in t^2 for the data point where $\frac{1}{h} = 10.0\,\text{m}^{-1}$ is shown as an error bar on the graph.

(i) State the value of the uncertainty in t^2 for $\frac{1}{h} = 10.0\,\text{m}^{-1}$. *[1]*

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(ii) Calculate the uncertainty in t^2 when $t = 0.8 \pm 0.1\,\text{s}$. Give your answer to an appropriate number of significant digits. *[4]*

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(iii) Use the graph to determine the value of *k*. Do not calculate its uncertainty. *[3]*

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(iv) State the unit of *k*. *[1]*

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A2. This question is about radioactive decay.

(a) Describe the phenomenon of natural radioactive decay. *[3]*

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(b) A nucleus of americium-241 (Am-241) decays into a nucleus of neptunium-237 (Np-237) in the following reaction.

$$^{241}_{95}\text{Am} \rightarrow {}^{237}_{X}\text{Np} + {}^{4}_{2}\alpha$$

(i) State the value of *X*. *[1]*

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(ii) Explain in terms of mass why energy is released in the reaction in (b). *[2]*

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(Question A2 continued)

(iii) Define *binding energy* of a nucleus. *[1]*

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(iv) The following data are available.

Nuclide	**Binding energy per nucleon / MeV**
americium-241	7.54
neptunium-237	7.58
helium-4	7.07

Determine the energy released in the reaction in (b). *[3]*

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A3. This question is about thermal energy transfer.

A hot piece of iron is placed into a container of cold water. After a time the iron and water reach thermal equilibrium. The heat capacity of the container is negligible.

(a) Define *specific heat capacity*. *[2]*

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(b) The following data are available.

Mass of water	= 0.35 kg
Mass of iron	= 0.58 kg
Specific heat capacity of water	= 4200 $\text{J kg}^{-1}\text{K}^{-1}$
Initial temperature of water	= 20 °C
Final temperature of water	= 44 °C
Initial temperature of iron	= 180 °C

(i) Determine the specific heat capacity of iron. *[3]*

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(ii) Explain why the value calculated in (b)(i) is likely to be different from the accepted value. *[2]*

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A4. This question is about the Doppler effect.

A source emits sound of frequency 100 Hz. The speed of sound in air is $330\,\text{m s}^{-1}$.

(a) Calculate the frequency measured by an observer when

(i) the observer is stationary and the source is moving towards the observer at $120\,\text{m s}^{-1}$. *[2]*

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(ii) the source is stationary and the observer is moving towards the source at $120\,\text{m s}^{-1}$. *[2]*

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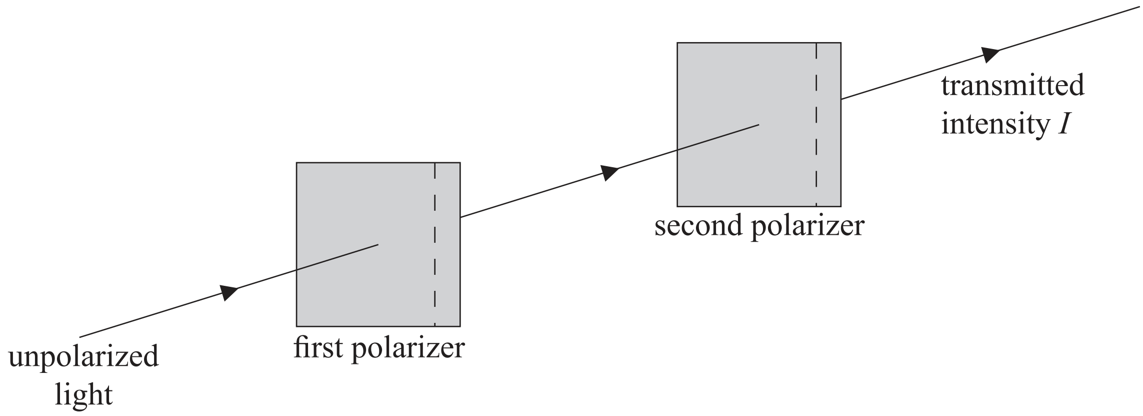
(b) When both source and observer are stationary the wavelength is λ_0 and the wavespeed is v_0.

In the table below, compare the values of measured wavelength and measured wavespeed, as measured by the observer, with respect to λ_0 and v_0. One of the values is given for you. *[3]*

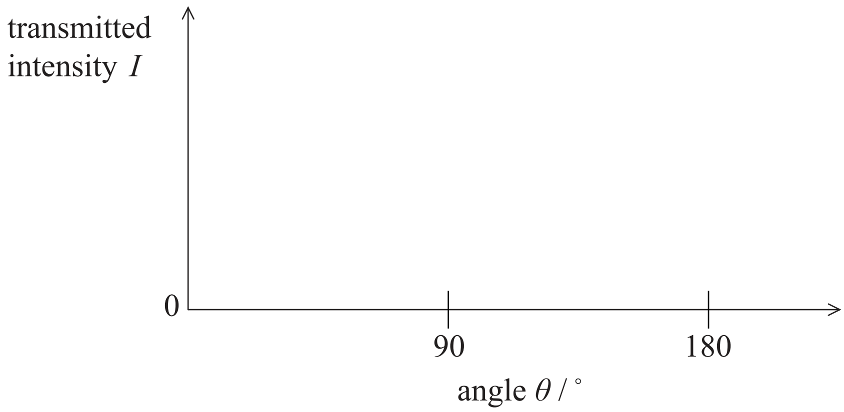
	Measured wavelength	**Measured wavespeed**
Moving source as in (a)(i)	less than λ_0	
Moving observer as in (a)(ii)		

A5. This question is about polarization.

Unpolarized light is directed towards two polarizers. The dashed lines represent the transmission axes of the polarizers. The angle θ between the transmission axes of the polarizers is initially 0°.



(a) On the axes below, sketch a graph to show how the intensity I of the light emerging from the second polarizer varies with θ. *[2]*



(b) Outline how two polarizers can be used to compare the concentrations of different sugar solutions. *[3]*

A6. This question is about electromagnetic induction.

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

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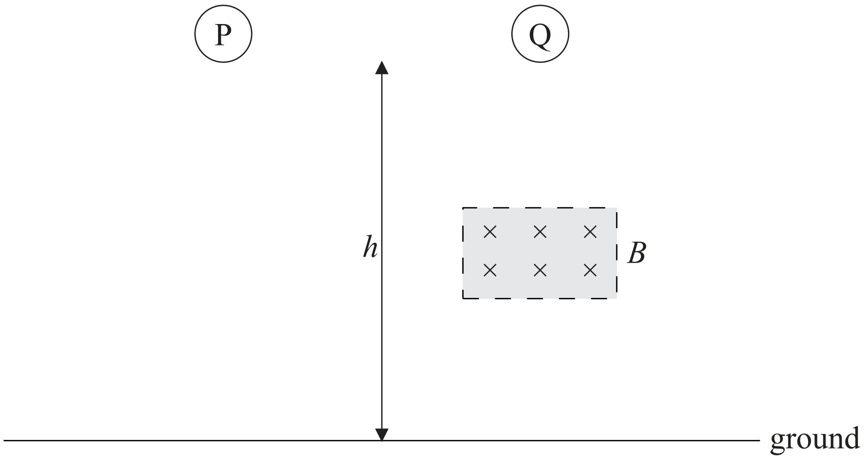
(b) Two identical aluminium balls are dropped simultaneously from the same height. Ball P falls through a region with no magnetic field. Ball Q falls through a region of uniform horizontal magnetic flux density *B*.



Explain why ball Q takes longer than ball P to reach the ground. *[4]*

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SECTION B

This section consists of four questions: B1, B2, B3 and B4. Answer ***two*** *questions. Write your answers in the boxes provided.*

B1. This question is in **two** parts. **Part 1** is about wind power. **Part 2** is about projectile motion.

Part 1 Wind power

(a) Outline in terms of energy changes how electrical energy is obtained from the energy of wind. *[2]*

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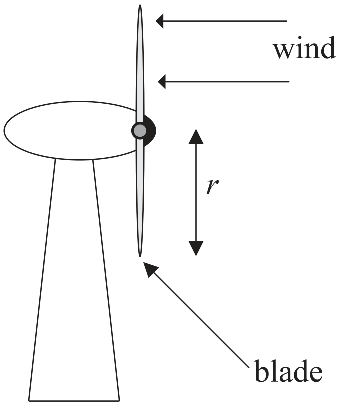
(Question B1, part 1 continued)

(b) Air of density ρ and speed v passes normally through a wind turbine of blade length r as shown below.



(i) Deduce that the kinetic energy per unit time of the air incident on the turbine is

$$\frac{1}{2}\pi\rho r^2 v^3$$ *[3]*

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(ii) State **two** reasons why it is impossible to convert all the available energy of the wind to electrical energy. *[2]*

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2: . . . .

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(This question continues on the following page)

(Question B1, part 1 continued)

(c) Air is incident normally on a wind turbine and passes through the turbine blades without changing direction. The following data are available.

Density of air entering turbine	$= 1.1\,\text{kg}\,\text{m}^{-3}$
Density of air leaving turbine	$= 2.2\,\text{kg}\,\text{m}^{-3}$
Speed of air entering turbine	$= 9.8\,\text{m}\,\text{s}^{-1}$
Speed of air leaving turbine	$= 4.6\,\text{m}\,\text{s}^{-1}$
Blade length	$= 25\,\text{m}$

Determine the power extracted from the air by the turbine. *[3]*

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(This question continues on the following page)

(Question B1, part 1 continued)

(d) A different wind turbine has a mechanical input power of 3.0×10^5 W and generates an electrical power output of 1.0×10^5 W. On the grid below, construct and label a Sankey diagram for this wind turbine. *[3]*

(e) Outline **one** advantage and **one** disadvantage of using wind turbines to generate electrical energy, as compared to using fossil fuels. *[2]*

Advantage: . . . .

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Disadvantage: . . . .

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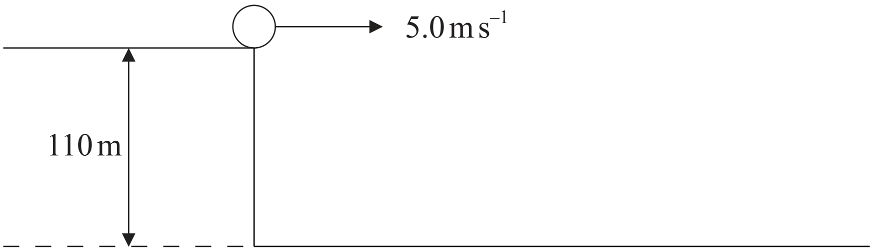
(Question B1 continued)

Part 2 Projectile motion

A ball is projected horizontally at $5.0\,\text{m}\,\text{s}^{-1}$ from a vertical cliff of height 110 m. Assume that air resistance is negligible and use $g = 10\,\text{m}\,\text{s}^{-2}$.



(not to scale)

(a) (i) State the magnitude of the horizontal component of acceleration of the ball after it leaves the cliff. *[1]*

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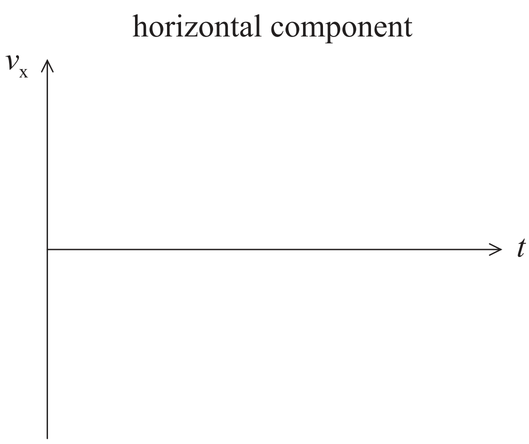
(ii) On the axes below, sketch graphs to show how the horizontal and vertical components of the velocity of the ball, v_x and v_y, change with time t until just before the ball hits the ground. It is not necessary to calculate any values. *[2]*



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(Question B1, part 2 continued)

(b) (i) Calculate the time taken for the ball to reach the ground. *[2]*

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(ii) Calculate the horizontal distance travelled by the ball until just before it reaches the ground. *[2]*

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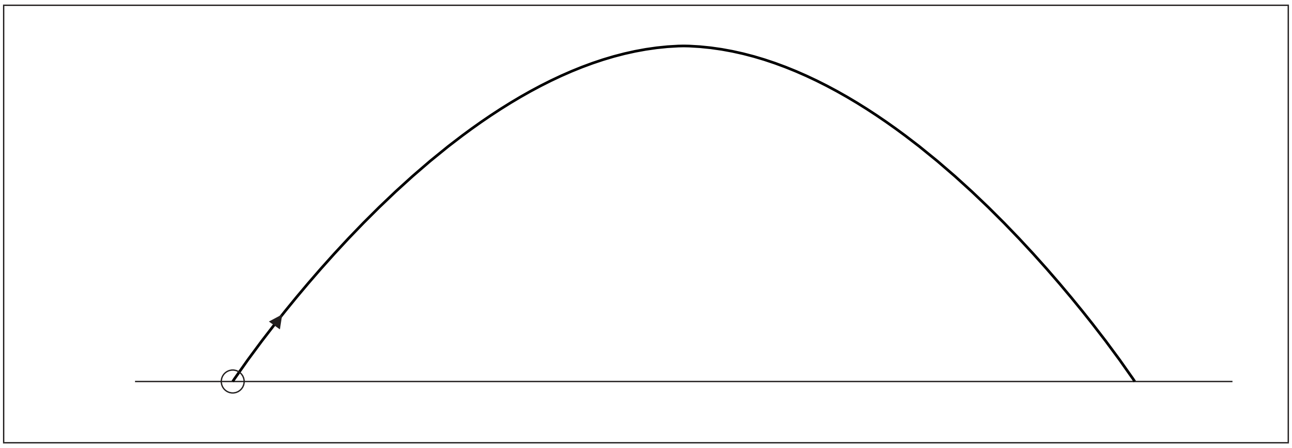
(c) Another projectile is launched at an angle to the ground. In the absence of air resistance it follows the parabolic path shown below.



On the diagram above, sketch the path that the projectile would follow if air resistance were not negligible. *[3]*

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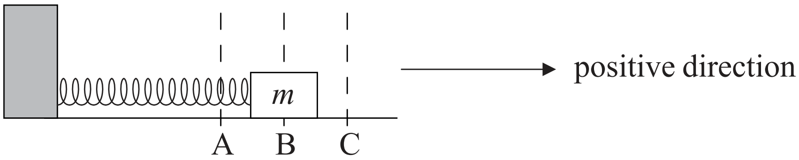
B2. This question is in **two** parts. **Part 1** is about simple harmonic motion and the superposition of waves. **Part 2** is about thermodynamics.

Part 1 Simple harmonic motion and the superposition of waves

An object of mass m is placed on a frictionless surface and attached to a light horizontal spring. The other end of the spring is fixed.



The equilibrium position is at B. The direction B to C is taken to be positive. The object is released from position A and executes simple harmonic motion between positions A and C.

(a) Define *simple harmonic motion*. *[2]*

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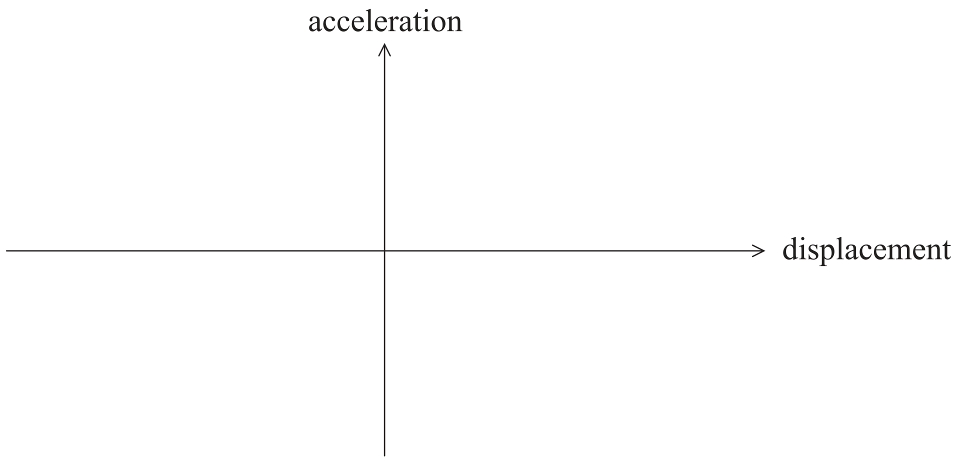
(b) (i) On the axes below, sketch a graph to show how the acceleration of the mass varies with displacement from the equilibrium position B. *[2]*



(ii) On your graph, label the points that correspond to the positions A, B and C. *[1]*

(This question continues on the following page)

(Question B2, part 1 continued)

(c) (i) On the axes below, sketch a graph to show how the velocity of the mass varies with time from the moment of release from A until the mass returns to A for the first time. *[2]*

(ii) On your graph, label the points that correspond to the positions A, B and C. *[1]*

(d) The period of oscillation is 0.20 s and the distance from A to B is 0.040 m. Determine the maximum speed of the mass. *[3]*

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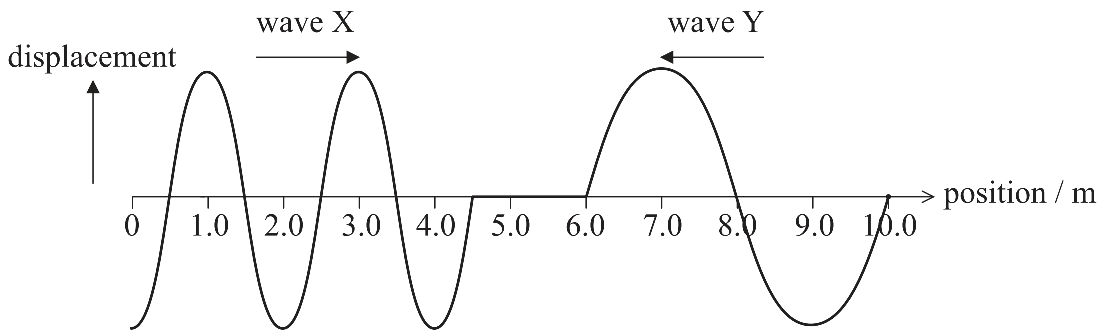
(This question continues on the following page)

(Question B2, part 1 continued)

(e) A long spring is stretched so that it has a length of 10.0 m. Both ends are made to oscillate with simple harmonic motion so that transverse waves of equal amplitude but different frequency are generated.

Wave X, travelling from left to right, has wavelength 2.0 m, and wave Y, travelling from right to left, has wavelength 4.0 m. Both waves move along the spring at speed 10.0 m s^{-1}.

The diagram below shows the waves at an instant in time.



(i) State the principle of superposition as applied to waves. *[2]*

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(ii) By drawing on the diagram or otherwise, calculate the position at which the resultant wave will have maximum displacement 0.20 s later. *[2]*

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(This question continues on page 22)

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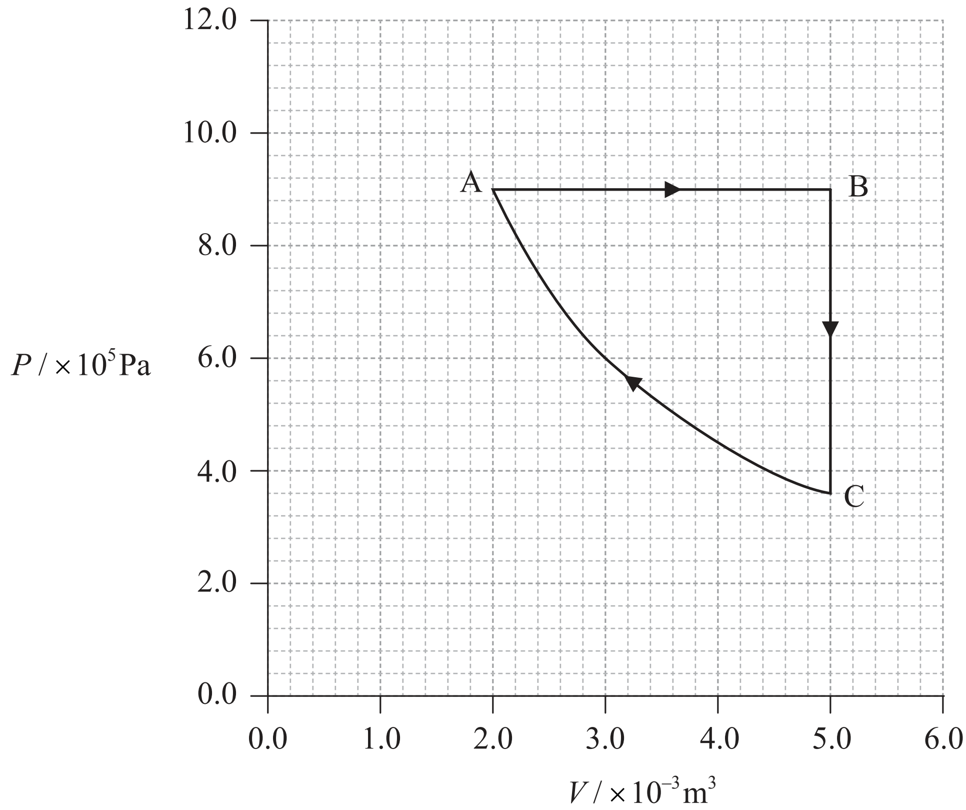
Answers written on this page
will not be marked.

(Question B2 continued from page 20)

Part 2 Thermodynamics

A fixed mass of an ideal gas undergoes the three thermodynamic processes, AB, BC and CA, represented in the *P*–*V* graph below.



(a) State which of the processes is isothermal, isochoric (isovolumetric) or isobaric. *[3]*

Process AB: ....

Process BC: ....

Process CA: ....

(This question continues on the following page)

(Question B2, part 2 continued)

(b) The temperature of the gas at A is 300 K. Calculate the temperature of the gas at B. *[2]*

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(c) The increase in internal energy of the gas during process AB is 4100 J. Determine the heat transferred to the gas from the surroundings during the process AB. *[2]*

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(Question B2, part 2 continued)

(d) The gas is compressed at constant temperature. Explain what changes, if any, occur to the entropy of

(i) the gas. *[1]*

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(ii) the surroundings. *[1]*

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(iii) the universe. *[1]*

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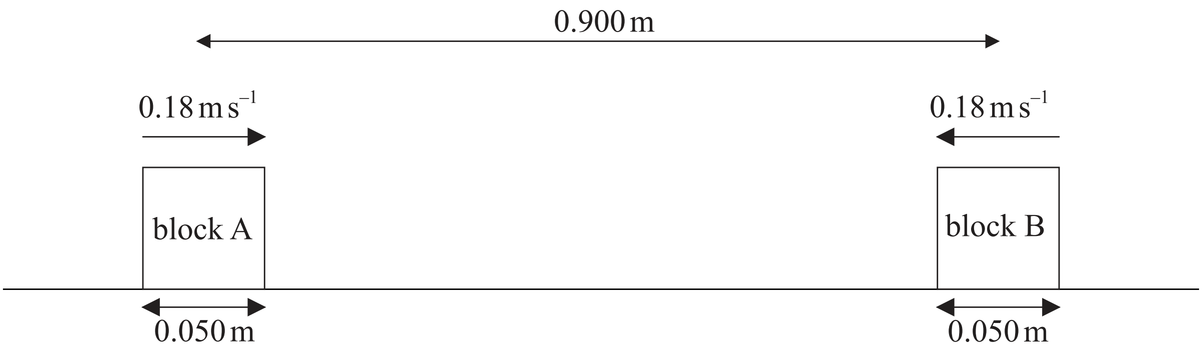
B3. This question is in **two** parts. **Part 1** is about a collision. **Part 2** is about digital data storage.

Part 1 A collision

Two identical blocks of mass 0.17 kg and length 0.050 m are travelling towards each other along a straight line through their centres as shown below. Assume that the surface is frictionless.



The initial distance between the centres of the blocks is 0.900 m and both blocks are moving at a speed of 0.18 m s^{-1} relative to the surface.

(a) Determine the time taken for the blocks to come into contact with each other. *[3]*

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(Question B3, part 1 continued)

(b) As a result of the collision, the blocks reverse their direction of motion and travel at the same speed as each other. During the collision, 20% of the kinetic energy of the blocks is given off as thermal energy to the surroundings.

(i) State and explain whether the collision is elastic or inelastic. *[2]*

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(ii) Show that the final speed of the blocks relative to the surface is $0.16\,m\,s^{-1}$. *[3]*

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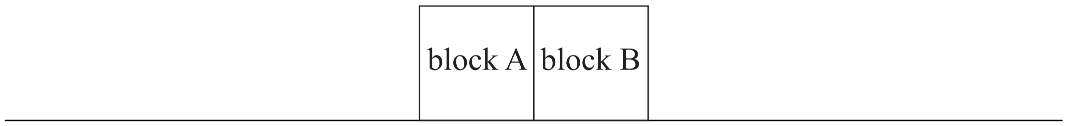
(Question B3, part 1 continued)

(c) (i) State Newton's third law of motion. *[1]*

(ii) During the collision of the blocks, the magnitude of the force that block A exerts on block B is F_{AB} and the magnitude of the force that block B exerts on block A is F_{BA}. On the diagram below, draw labelled arrows to represent the magnitude and direction of the forces F_{AB} and F_{BA}. *[3]*



(iii) The duration of the collision between the blocks is 0.070 s. Determine the average force one block exerted on the other. *[3]*

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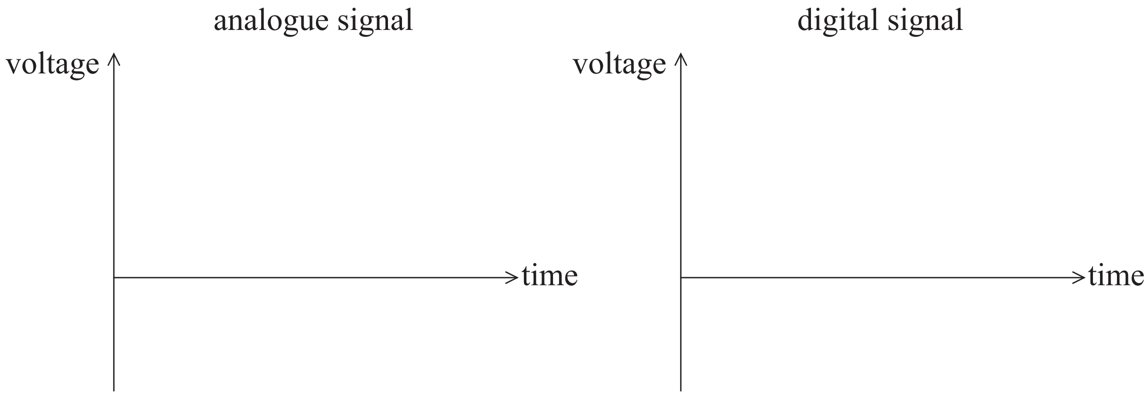
(Question B3 continued)

Part 2 Digital data storage

(a) On the axes below, draw an example of an analogue signal and a digital signal. *[2]*



(b) The binary number 00101 contains five bits. Explain what is meant by the most-significant bit of a binary number. *[2]*

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(Question B3, part 2 continued)

(c) (i) Outline how digital information is stored on a CD. *[2]*

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(ii) Outline why a DVD can store more information than a CD even though they are the same physical size. *[2]*

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(iii) The laser of a DVD player has a wavelength in air of 630 nm. The coating of the DVD has a refractive index of 1.53. Calculate a suitable pit depth for this DVD. *[2]*

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B4. This question is in **three** parts. **Part 1** is about gravitational fields. **Part 2** is about electric current and resistance. **Part 3** is about atomic energy levels.

Part 1 Gravitational fields

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

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(b) Deduce that the gravitational field strength g at the surface of a spherical planet of uniform density is given by

$$g = \frac{GM}{R^2}$$

where M is the mass of the planet, R is its radius and G is the gravitational constant. You can assume that spherical objects of uniform density act as point masses. *[2]*

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(This question continues on the following page)

(Question B4, part 1 continued)

(c) The gravitational field strength at the surface of Mars g_M is related to the gravitational field strength at the surface of the Earth g_E by

$$g_M = 0.38 \times g_E.$$

The radius of Mars R_M is related to the radius of the Earth R_E by

$$R_M = 0.53 \times R_E.$$

Determine the mass of Mars M_M in terms of the mass of the Earth M_E. *[2]*

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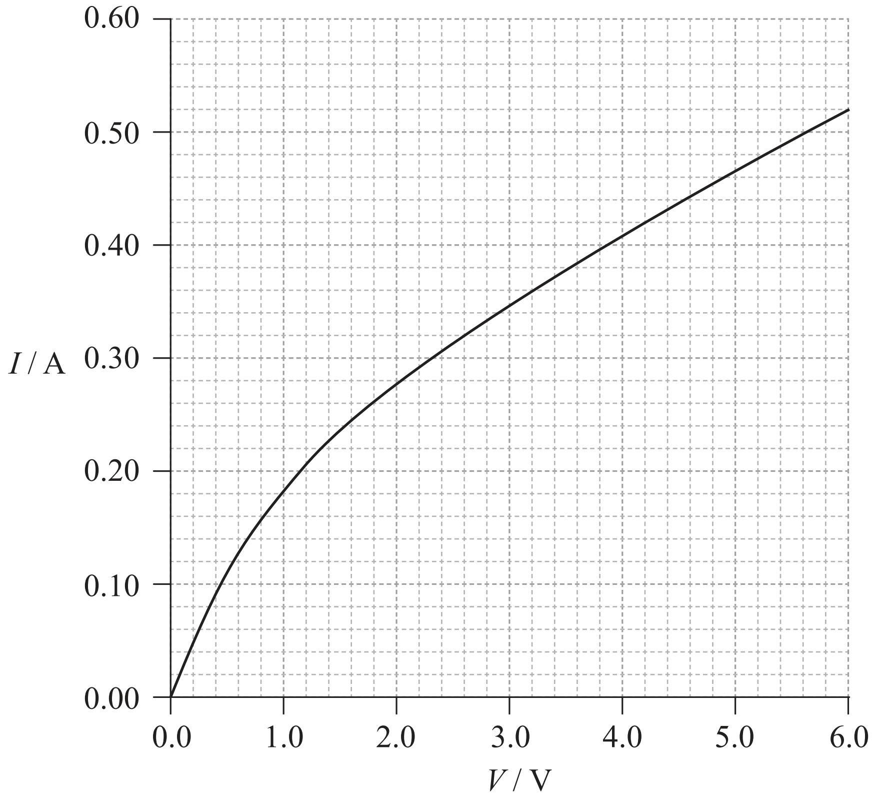
(Question B4 continued)

Part 2	Electric current and resistance

The graph below shows how the current I in a tungsten filament lamp varies with potential difference V across the lamp.



(a)	(i)	Define the electrical *resistance* of a component.	*[1]*

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(Question B4, part 2 continued)

(ii) Explain whether or not the filament obeys Ohm's law. *[2]*

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(b) Calculate the resistance of the filament lamp when the potential difference across it is 2.8 V. *[2]*

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(c) Two identical filament lamps are connected in series with a cell of emf 6.0 V and negligible internal resistance. Using the graph opposite, calculate the total power dissipated in the circuit. *[2]*

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(Question B4 continued)

Part 3 Atomic energy levels

(a) Describe the de Broglie hypothesis. *[2]*

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(b) Outline how atomic emission spectra provide evidence for the quantization of energy in atoms. *[2]*

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(Question B4, part 3 continued)

(c) Consider an electron confined in a one-dimensional "box" of length L. The de Broglie waves associated with the electron are standing waves with wavelengths given by $\frac{2L}{n}$, where $n = 1, 2, 3, \ldots$

Show that the energy E_n of the electron is given by

$$E_n = \frac{n^2 h^2}{8 m_e L^2}$$

where h is Planck's constant and m_e is the mass of the electron. *[3]*

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(This question continues on the following page)

(Question B4, part 3 continued)

(d) An electron is confined in a "box" of length $L = 1.0 \times 10^{-10}$ m in the $n = 1$ energy level. Its position as measured from one end of the box is $(0.5 \pm 0.5) \times 10^{-10}$ m. Determine

(i) the momentum of the electron. *[2]*

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(ii) the uncertainty in the momentum. *[2]*

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