22106514

International Baccalaureate
Baccalauréat International
Bachillerato Internacional

PHYSICS
HIGHER LEVEL
PAPER 2

Monday 10 May 2010 (afternoon)

2 hours 15 minutes

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

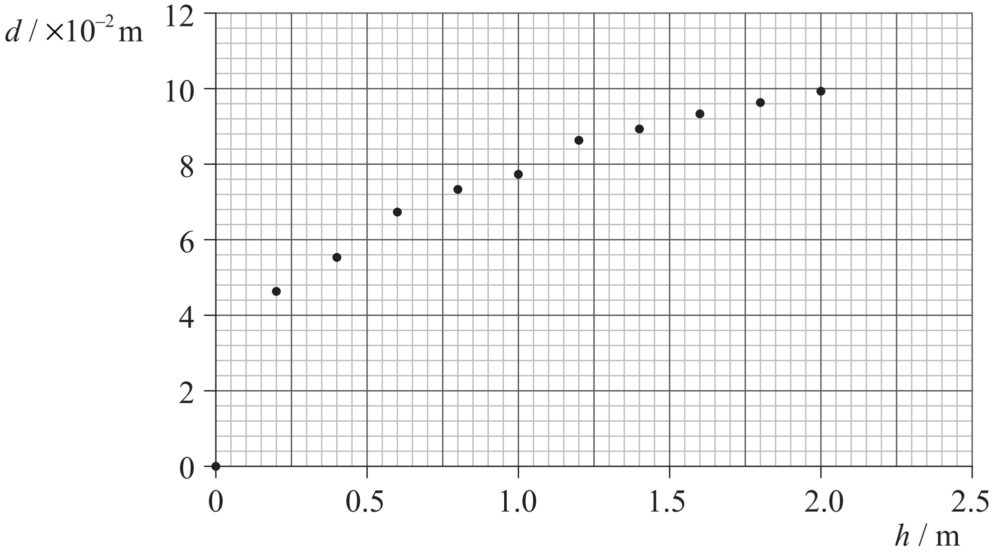
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B in the spaces provided.
- At the end of the examination, indicate the numbers of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

SECTION A

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

A1. Data analysis question.

Gillian carried out an experiment to investigate the craters formed when steel balls are dropped into sand. To try and find the relationship between the diameter of the crater and the energy of impact of steel balls of the same diameter, she dropped a steel ball from different heights h into sand and measured the resulting diameter d of the crater. The data are shown plotted below.



(a) The uncertainty in the measurement of d is ±0.40 cm; the uncertainty in h is too small to be shown. Draw error bars for the data point (0.2, 0.047) and the data point (2.0, 0.10). *[2]*

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

(c) The original hypothesis, made by Gillian, was that the diameter of the crater is directly proportional to the energy of impact of the steel balls. Explain why the data does not support this hypothesis. *[3]*

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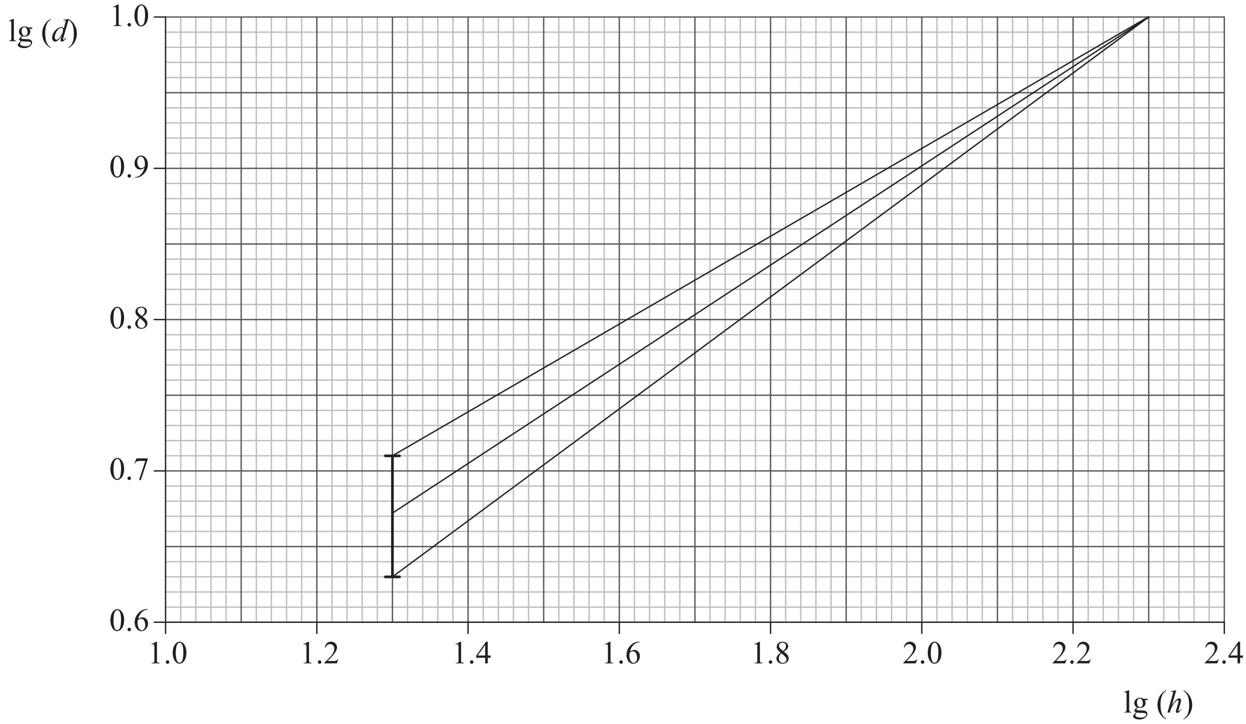
(Question A1 continued)

(d) Since Gillian's data did not support her hypothesis, she researched to find alternative hypotheses. She found that there are two theories used to predict a relationship between d and h.

Theory 1 predicts that $d = const(h)^{\frac{1}{3}}$ and theory 2 predicts that $d = const(h)^{\frac{1}{4}}$.

In order to test which theory her data supports, she plotted a graph of lg(d) against lg(h). The plot produced a straight line that could be drawn through all the error bars.



The graph includes the lines of maximum and minimum gradients based on the first error bar for the first non-zero data point and the last error bar. The last error bar is too small to be shown. State and explain if the original data support theory 1 **or** theory 2. *[4]*

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A2. This question is about radioactive decay and binding energy.

(a) Describe what is meant by radioactive decay. *[2]*

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(b) A nucleus of potassium-40 (K-40) undergoes radioactive decay to a nucleus of argon-40 (Ar-40). In the reaction equation below, identify the proton number *Z* of argon and the particle *x*. *[2]*

$$^{40}_{19}\mathrm{K} \rightarrow {}^{40}_{Z}\mathrm{Ar} + \beta^{+} + x$$

Z: . . . .

x: . . . .

(c) The mass of a K-40 nucleus is 37 216 MeV c^{-2}. Determine the binding energy per nucleon of K-40. *[4]*

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(d) State why the binding energy of Ar-40 is greater than that of K-40. *[1]*

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A3. This question is about change of phase of a liquid and latent heat of vaporization.

(a) State the difference between evaporation and boiling with reference to

(i) temperature. *[1]*

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(ii) surface area of a liquid. *[1]*

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(b) A liquid in a calorimeter is heated at its boiling point for a measured period of time. The following data are available.

Power rating of heater	$= 15\,\text{W}$
Time for which liquid is heated at boiling point	$= 4.5 \times 10^{2}\,\text{s}$
Mass of liquid boiled away	$= 1.8 \times 10^{-2}\,\text{kg}$

Use the data to determine the specific latent heat of vaporization of the liquid. *[3]*

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(c) State and explain **one** reason why the calculation in (b) will give a value of the specific latent heat of vaporization of the liquid that is greater than the true value. *[2]*

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A4. This question is about induced emf and transformers.

(a) One of the coils of a particular transformer is connected in series with a switch and a battery. The coil has low resistance. On closing the switch it is observed that the current takes a certain amount of time to reach its final constant value. Explain this observation with reference to Faraday's law and Lenz's law. *[3]*

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(b) In a particular power station the voltage generated is stepped up by a transformer. The root mean square voltage is increased by a factor of 2×10^{3}. The output power of the transformer is transmitted to a town by cables.

(i) Outline what is meant by the root mean square value of a time-varying voltage. *[2]*

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(ii) State the best estimate for the factor by which the power loss in the cables is reduced as a result of stepping up the voltage. *[1]*

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A5. This question is about standing waves.

(a) State **two** properties of a standing (stationary) wave. *[2]*

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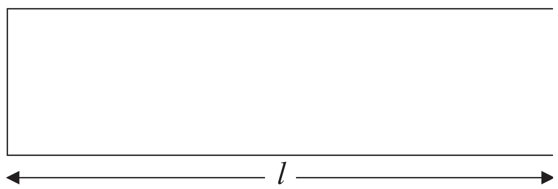
(b) The diagram shows an organ pipe that is open at one end.



The length of the pipe is l. The frequency of the fundamental (first harmonic) note emitted by the pipe is 16 Hz.

(i) On the diagram, label with the letter P the position along the pipe where the amplitude of oscillation of the air molecules is the largest. *[1]*

(ii) The speed of sound in the air in the pipe is $330\,\text{m}\,\text{s}^{-1}$. Calculate the length l. *[3]*

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(c) Use your answer to (b)(ii) to suggest why it is better to use organ pipes that are closed at one end for producing low frequency notes rather than pipes that are open at both ends. *[2]*

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A6. This question is about polarized light.

(a) Distinguish between polarized and unpolarized light. *[2]*

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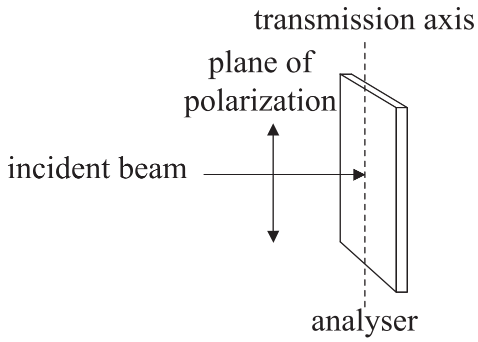
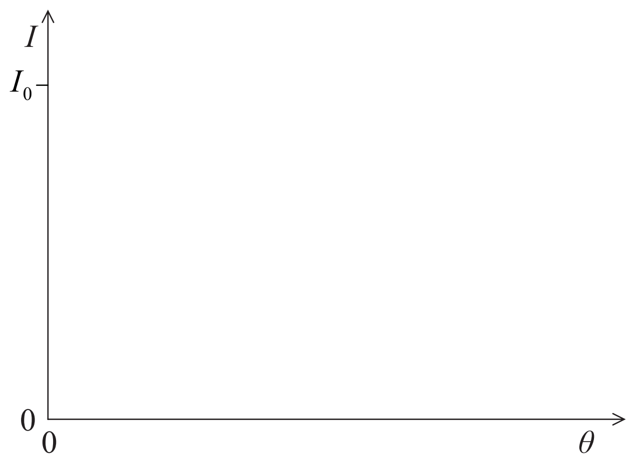
(b) A beam of plane polarized light of intensity I_0 is incident on an analyser. The direction of the beam is at right angles to the plane of the analyser.



The angle between the transmission axis of the analyser and the plane of polarization of the light is θ. In the position shown the transmission axis of the analyser is parallel to the plane of polarization of the light ($\theta = 0$).

On the axes, sketch a graph to show how the intensity I of the transmitted light varies with θ as the analyser is rotated through 180°. *[2]*



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 electric fields and electrical resistance. **Part 2** is about radioactive decay.

Part 1 Electric fields and electrical resistance

(a) State, in terms of electrons, the difference between a conductor and an insulator. *[1]*

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(b) Suggest why there must be an electric field inside a current-carrying conductor. *[3]*

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(c) The magnitude of the electric field strength inside a conductor is $55\,\text{N}\,\text{C}^{-1}$. Calculate the force on a free electron in the conductor. *[1]*

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(d) Define *resistance*. *[1]*

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(e) A resistor made from a metal oxide has a resistance of $1.5\,\Omega$. The resistor is in the form of a cylinder of length $2.2\times10^{-2}\,\text{m}$ and radius $1.2\times10^{-3}\,\text{m}$. Calculate the resistivity of the metal oxide. *[2]*

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(This question continues on the following page)

(Question B1, part 1 continued)

(f) The manufacturer of the resistor in (e) guarantees its resistance to be within ±10% of 1.5 Ω provided the power dissipation in the resistor does not exceed 1.0 W. Calculate the maximum current in the resistor for the power dissipation to be equal to 1.0 W. *[2]*

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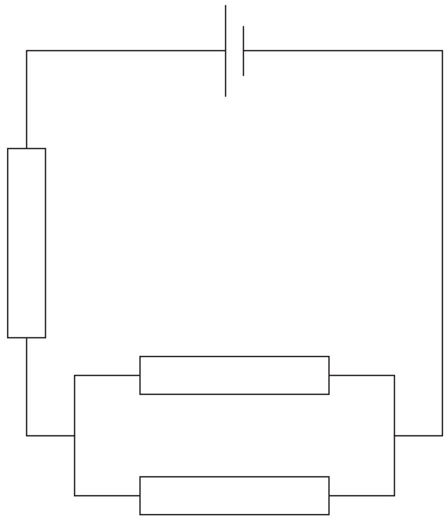
(g) Three of the resistors in (f) are connected in the circuit below.



The cell has an emf of 2.0 V and negligible internal resistance.

(i) Define *emf*. *[1]*

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(ii) Determine the minimum and the maximum power that could be dissipated in this circuit. *[3]*

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(Question B1 continued)

Part 2 Radioactive decay

(a) The alpha particles produced in alpha decay have discrete energies. Suggest how this observation provides evidence for the existence of nuclear energy levels. *[2]*

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(b) A nucleus of the isotope fluorine-18 decays into a nucleus of oxygen-18 by the emission of a positron and neutrino. Outline how the nature of the β-decay energy spectrum of fluorine-18 suggests the existence of the neutrino involved in the decay. *[3]*

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(c) A freshly prepared sample of fluorine-18 has an activity of 1.12 MBq. Its activity four hours later is 0.246 MBq.

(i) Show that the decay constant for fluorine-18 is $0.379\,\text{hr}^{-1}$. *[3]*

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(ii) Calculate the half-life of fluorine-18. *[1]*

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(d) The energy of a beta particle in the decay of the sample in (c) is $8.4\times10^{-15}\,\text{J}$. Show that the de Broglie wavelength of this particle is $5.3\times10^{-12}\,\text{m}$. *[2]*

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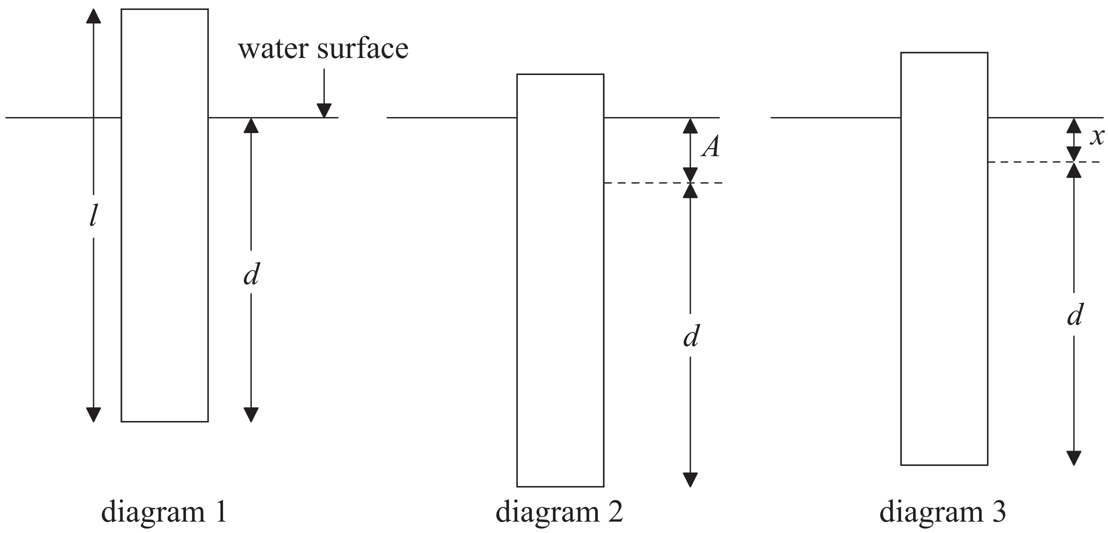
B2. This question is in **two** parts. **Part 1** is about oscillations and waves. **Part 2** is about gases and thermodynamic processes.

Part 1 Oscillations and waves

(a) A rectangular piece of wood of length l floats in water with its axis vertical as shown in diagram 1.



The length of wood below the surface is d. The wood is pushed vertically downwards a distance A such that a length of wood is still above the water surface as shown in diagram 2. The wood is then released and oscillates vertically. At the instant shown in diagram 3, the wood is moving downwards and the length of wood beneath the surface is $d+x$.

(i) On diagram 3, draw an arrow to show the direction of the acceleration of the wood. *[1]*

(ii) The acceleration a of the wood (in m s^{-2}) is related to x (in m) by the following equation.

$$a = -\frac{14}{l}x$$

Explain why this equation shows that the wood is executing simple harmonic motion. *[2]*

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(This question continues on the following page)

(Question B2, part 1 continued)

(iii) The period of oscillation of the wood is 1.4 s. Show that the length l of the wood is 0.70 m. *[3]*

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(b) The wood in (a), as shown in diagram 2, is released at time $t=0$. On the axes below, sketch a graph to show how the velocity v of the wood varies with time over one period of oscillation. *[1]*

(c) The distance A that the wood is initially pushed down is 0.12 m.

(i) Calculate the magnitude of the maximum acceleration of the wood. *[2]*

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(ii) On your sketch graph in (b) label with the letter P one point where the magnitude of the acceleration is a maximum. *[1]*

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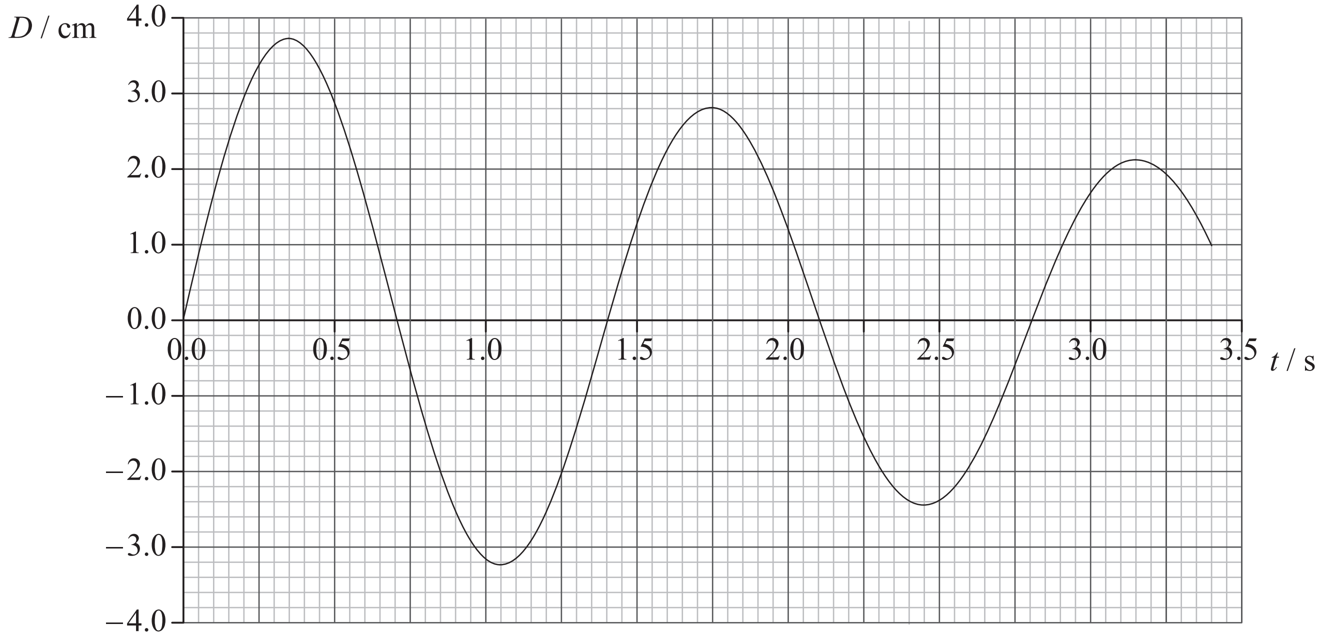
(Question B2, part 1 continued)

(d) The oscillations of the wood generate waves in the water of wavelength 0.45 m. The graph shows how the displacement D, of the water surface at a particular distance from the wood varies with time t.



Using the graph, calculate the

(i) speed of the waves. *[2]*

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(ii) ratio of the displacement at $t = 1.75$ s to the displacement at $t = 0.35$ s. *[2]*

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(iii) ratio of the energy of the wave at $t = 1.75$ s to the energy at $t = 0.35$ s *[1]*

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(Question B2 continued)

Part 2 Gases and thermodynamic processes

(a) State **one** way in which a real gas differs from an ideal gas. *[1]*

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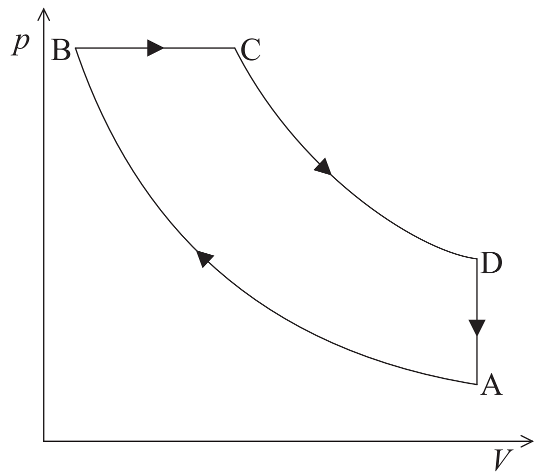
(b) The diagram shows how the pressure p varies with volume V of an ideal gas that undergoes a cyclic change of state.



AB and CD are adiabatic changes of state. The pressure at point B is 1.8×10^{5} Pa and the change in volume of the gas between B and C is $4.8\times10^{-4}\,m^{3}$.

(i) State what is meant by an adiabatic change of state. *[1]*

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(ii) The change in volume of the gas between B and C takes 0.020 s. Determine the power developed during this change of state. *[2]*

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(iii) State during which part of the cycle thermal energy is transferred from the gas to the surroundings. *[1]*

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(Question B2, part 2 continued)

(c) The energy transferred is degraded. Explain what is meant by degraded energy. *[2]*

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(d) Discuss how your answer to (c) relates to the second law of thermodynamics. *[3]*

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B3. This question is in **two** parts. **Part 1** is about fossil fuels and the greenhouse effect. **Part 2** is about electric potential.

Part 1 Fossil fuels and the greenhouse effect

(a) State **two** reasons why most of the world's energy consumption is provided by fossil fuels. *[2]*

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(b) A power station has an output power of 500 MW and an overall efficiency of 27 %. It uses natural gas as a fuel that has an energy density of 56 MJ kg^{-1}.

(i) Define *energy density*. *[1]*

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(ii) Determine the rate of consumption of natural gas in the power station. *[3]*

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(c) Outline why the enhanced greenhouse effect may result in an increase in the temperature of the Earth's surface. *[3]*

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(Question B3, part 1 continued)

(d) (i) The solar intensity at the position of the Earth is $1380\,\text{W m}^{-2}$. The average albedo of Earth is 0.300. State why an average value of albedo is quoted. *[1]*

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(ii) Show that the average reflected intensity from the Earth is about $100\,\text{W m}^{-2}$. *[4]*

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(e) One of the expected results of global warming is an increased sea level. The increase in volume ΔV for a temperature increase ΔT is given by $\Delta V = \gamma V \Delta T$. Show, using the following data, that the resulting rise in sea level is about 0.5 m. *[2]*

Temperature increase $= 2.0\,^{\circ}\text{C}$
Surface area of oceans on Earth $= 3.6 \times 10^{8}\,\text{km}^{2}$
Average ocean depth $= 3.0\,\text{km}$
$\gamma = 8.8 \times 10^{-5}\,\text{K}^{-1}$

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(Question B3 continued)

Part 2 Electric potential

(a) Define *electric potential* at a point in an electric field. *[3]*

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(b) The electric field inside a charged conducting sphere is zero. State and explain why the value of the potential inside the sphere is constant. *[2]*

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(c) In 1914 Niels Bohr proposed a simple model of the hydrogen atom in which the electron is assumed to be in an orbit of radius r about the proton. Both the electron and the proton are regarded to be point charges.

(i) It can be shown that the kinetic energy E_K of the electron is given by the equation

$$E_K = \frac{ke^2}{2r}$$

where k is the Coulomb constant and e is the electron charge. Deduce an equation for the total energy E of the electron. *[2]*

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(ii) In the Bohr model, the magnitude of the minimum energy of the electron is 2.2×10^{-18} J. Estimate the radius of the orbit, in which the electron has minimum energy. *[2]*

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B4. This question is in **two** parts. **Part 1** is about momentum, energy and power. **Part 2** is about CCDs and digital data storage.

Part 1 Momentum, energy and power

(a) In his *Principia Mathematica* Newton expressed his third law of motion as "to every action there is always opposed an equal reaction". State what Newton meant by this law. *[1]*

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(b) A book is released from rest and falls towards the surface of Earth. Discuss how the conservation of momentum applies to the Earth-book system. *[3]*

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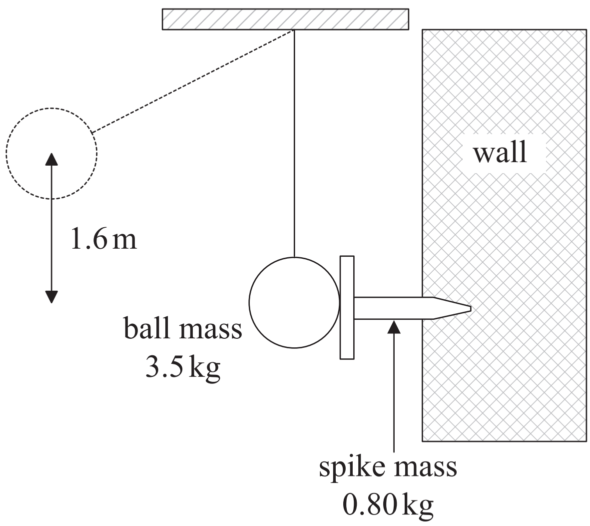
(c) A large swinging ball is used to drive a horizontal iron spike into a vertical wall. The centre of the ball falls through a vertical height of 1.6 m before striking the spike in the position shown.



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(Question B4, part 1 continued)

The mass of the ball is 3.5 kg and the mass of the spike is 0.80 kg. Immediately after striking the spike, the ball and spike move together. Show that the

(i) speed of the ball on striking the spike is $5.6\,\text{m}\,\text{s}^{-1}$. *[1]*

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(ii) energy dissipated as a result of the collision is about 10 J. *[4]*

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(d) As a result of the ball striking the spike, the spike is driven a distance $7.3\times10^{-2}\,\text{m}$ into the wall. Calculate, assuming it to be constant, the friction force F between the spike and wall. *[3]*

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(e) The machine that is used to raise the ball has a useful power output of 18 W. Calculate how long it takes for the machine to raise the ball through a height of 1.6 m. *[3]*

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(This question continues on the following page)

(Question B4 continued)

Part 2 CCDs and digital data storage

(a) An object is to be photographed using a digital camera.

(i) State the name of the phenomenon in which light causes electrons to be emitted from a pixel of a CCD. *[1]*

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(ii) Outline how the image of the object on the CCD is formed. *[2]*

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(b) Photons are incident on one of the pixels of the CCD at a rate of $3.6\times10^{6}\,\mathrm{s}^{-1}$. The pixel has capacitance 34 pF and quantum efficiency of 80 %. Determine the potential difference across the pixel after an exposure time of 15 ms. *[4]*

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(c) Outline, with reference to the retrieval of stored data, why it is better to store data in digital form rather than analogue form. *[3]*

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