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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	1	4

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]*.

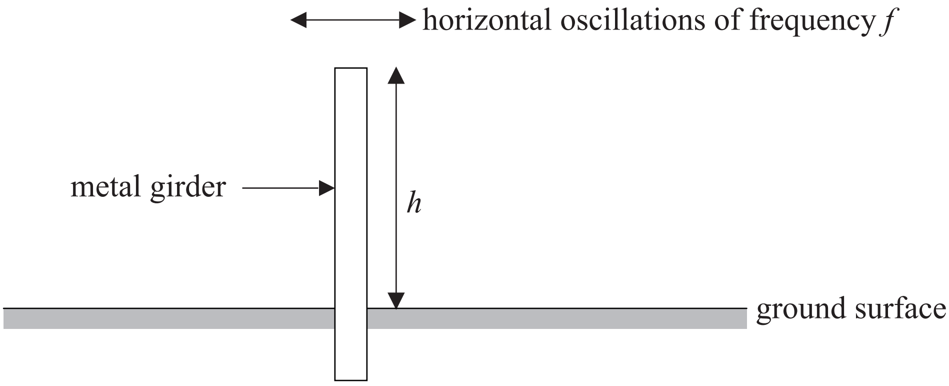
37 pages

SECTION A

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

A1. Data analysis question.

Metal girders are often used in buildings that have been constructed to withstand earthquakes. To aid the design of these buildings, experiments are undertaken to measure how the natural frequency f of horizontal oscillations of metal girders varies with their dimensions. In an experiment, f was measured for vertically supported girders of the same cross-sectional area but with different heights h.



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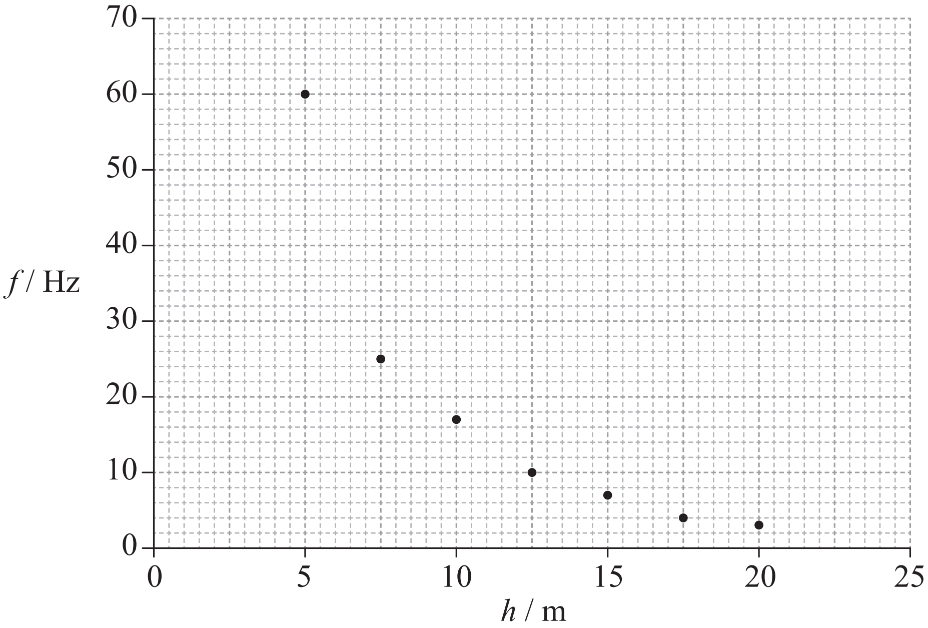
(Question A1 continued)

The graph shows the plotted data for this experiment. Uncertainties in the data are not shown.



(a) Draw a best-fit line for the data. *[1]*

(b) It is hypothesized that the frequency f is inversely proportional to the height h.

By choosing **two** well separated points on the best-fit line that you have drawn in (a), show that this hypothesis is incorrect. *[4]*

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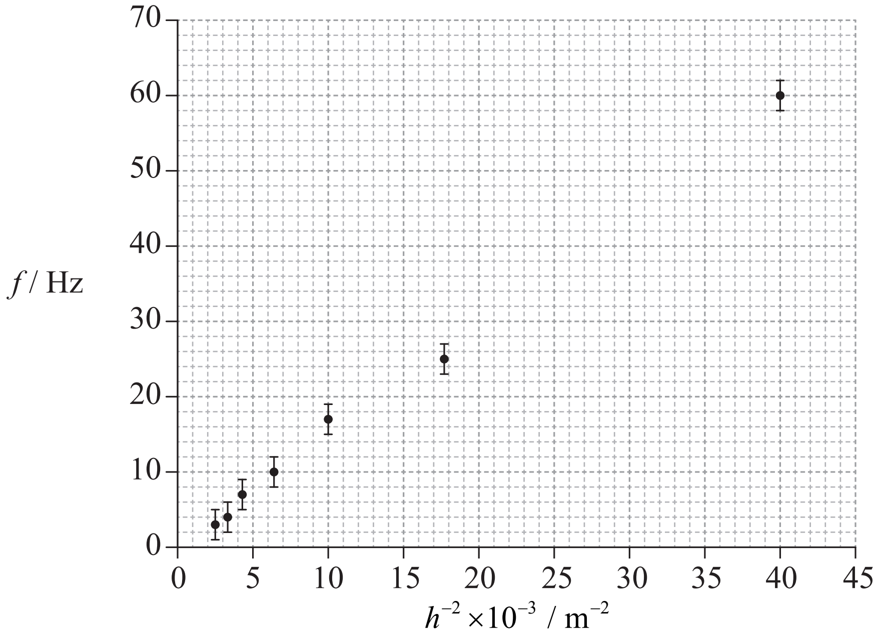
(Question A1 continued)

(c) Another suggestion is that the relationship between f and h is of the form shown below, where k is a constant.

$$f = \frac{k}{h^2}$$

The graph shows a plot of f against h^{-2}.



The uncertainties in h^{-2} are too small to be shown.

(i) Draw a best-fit line for the data that supports the relationship $f = \frac{k}{h^2}$. *[2]*

(ii) Determine, using the graph, the constant k. *[3]*

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(Question A1 continued)

(d) State **one** reason why the results of the experiment could not be used to predict the natural frequency of oscillation for girders of height 50 m. *[1]*

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A2. This question is about kinematics.

(a) State the difference between average speed and instantaneous speed. *[2]*

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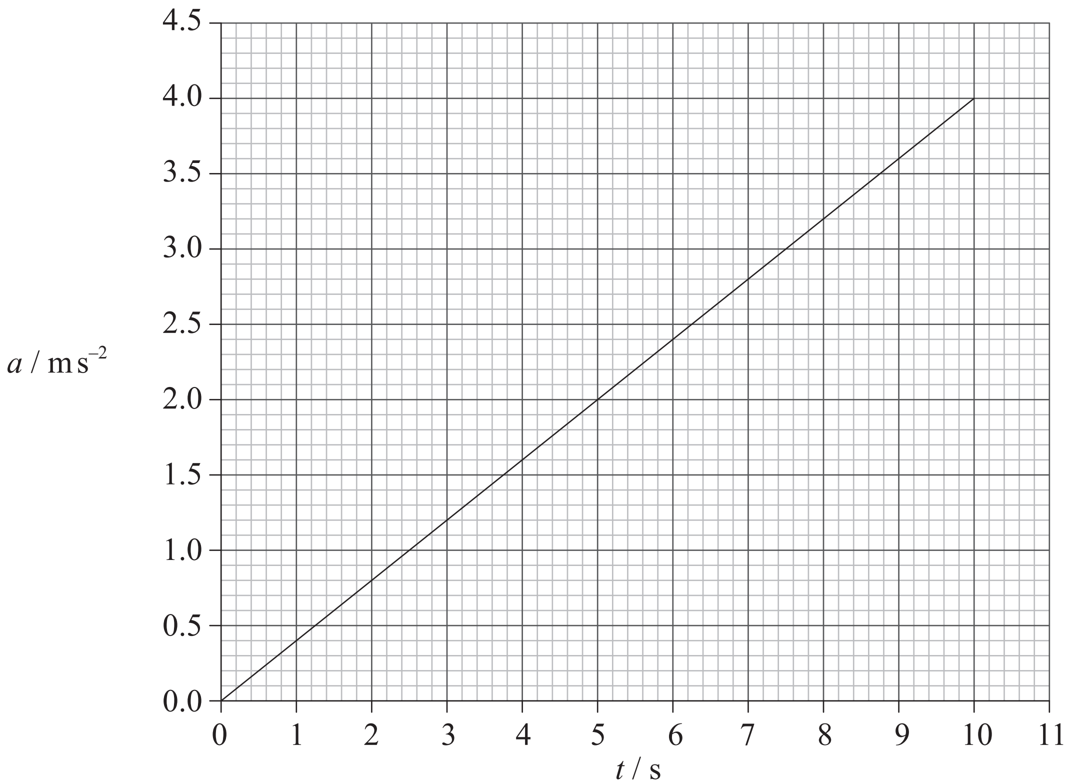
(b) The graph shows how the acceleration a of a particle varies with time t.



At time $t = 0$ the instantaneous speed of the particle is zero.

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(Question A2 continued)

(i) Calculate the instantaneous speed of the particle at $t = 7.5$ s. *[2]*

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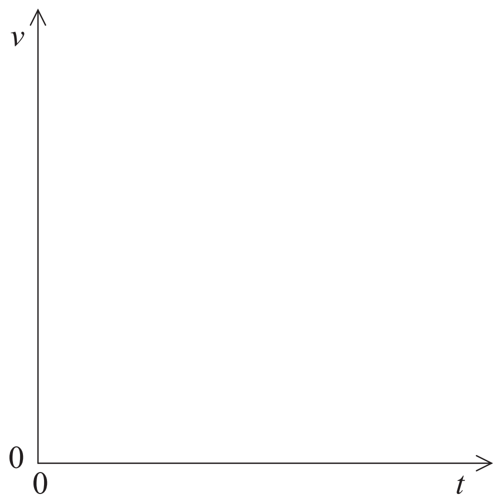
(ii) Using the axes below, sketch a graph to show how the instantaneous speed v of the particle varies with t. *[1]*



A3. This question is about nuclear reactions.

(a) The nuclide U-235 is an isotope of uranium. A nucleus of U-235 undergoes radioactive decay to a nucleus of thorium-231 (Th-231). The proton number of uranium is 92.

(i) State what is meant by the terms nuclide and isotope. *[2]*

Nuclide: . . . .

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Isotope: . . . .

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(ii) One of the particles produced in the decay of a nucleus of U-235 is a gamma photon. State the name of another particle that is also produced. *[1]*

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(b) The daughter nuclei of U-235 undergo radioactive decay until eventually a stable isotope of lead is reached.

Explain why the nuclei of U-235 are unstable whereas the nuclei of the lead are stable. *[3]*

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A4. This question is about ideal gases and specific heat capacity.

(a) State **two** assumptions of the kinetic model of an ideal gas. *[2]*

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(b) Argon behaves as an ideal gas for a large range of temperatures and pressures. One mole of argon is confined in a cylinder by a freely moving piston.

(i) Define what is meant by the term *one mole of argon*. *[1]*

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(ii) The temperature of the argon is 300 K. The piston is fixed and the argon is heated at constant volume such that its internal energy increases by 620 J. The temperature of the argon is now 350 K.

Determine the specific heat capacity of argon in $\text{J kg}^{-1}\,\text{K}^{-1}$ under the condition of constant volume. (The molecular weight of argon is 40) *[3]*

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A5. This question is about electric potential.

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

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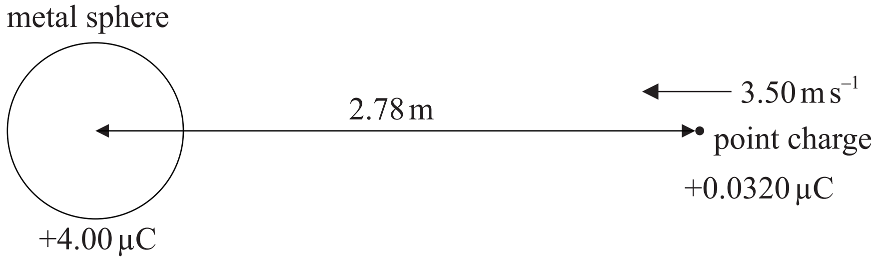
(b) A positive point charge is moving towards a small, charged metal sphere along a radial path.



At the position shown in the diagram, the point charge has a speed of $3.50\,\text{m}\,\text{s}^{-1}$ and is at a distance of 2.78 m from the centre of the metal sphere. The charge on the sphere is +4.00 μC.

(i) State the direction of the velocity of the point charge with respect to an equipotential surface due to the metal sphere. *[1]*

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(This question continues on the following page)

(Question A5 continued)

(ii) Show that the electric potential V due to the charged sphere at a distance of 2.78 m from its centre is 1.29×10^{4} V. *[1]*

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(iii) The electric potential at the surface of the sphere is 7.20×10^{4} V. The point charge has a charge of +0.0320 μC and its mass is 1.20×10^{-4} kg. Determine if the point charge will collide with the metal sphere. *[4]*

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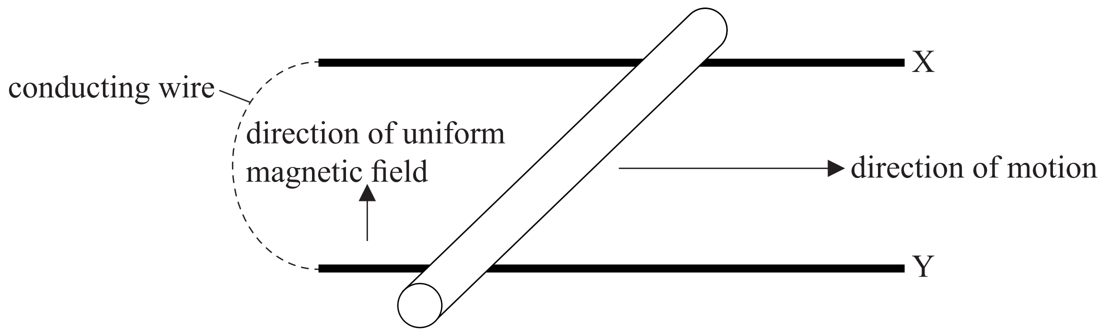
A6. This question is about induced electromotive force (emf).

(a) A rod made of conducting material is in a region of uniform magnetic field. It is moved horizontally along two parallel conducting rails X and Y. The other ends of the rails are connected by a thin conducting wire.



The speed of the rod is constant and is also at right angles to the direction of the uniform magnetic field.

(i) Describe, with reference to the forces acting on the conduction electrons in the rod, how an emf is induced in the rod. *[3]*

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(ii) An induced emf is produced by a rate of change of flux. State what is meant by a rate of change of flux in this situation. *[1]*

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(Question A6 continued)

(b) The length of the rod in (a) is 1.2 m and its speed is $6.2\,m\,s^{-1}$. The induced emf is 15 mV.

(i) Determine the magnitude of the magnetic field strength through which the rod is moving. *[2]*

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(ii) Explain how Lenz's law relates to the situation described in (a). *[2]*

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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 fields, electric potential difference and electric circuits. **Part 2** is about thermodynamic cycles.

Part 1 Fields, electric potential difference and electric circuits

(a) The magnitude of gravitational field strength g is defined from the equation shown below.

$$g = \frac{F_{\mathrm{g}}}{m}$$

The magnitude of electric field strength E is defined from the equation shown below.

$$E = \frac{F_{\mathrm{E}}}{q}$$

For each of these defining equations, state the meaning of the symbols

(i) F_{g}. *[1]*

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(ii) F_{E}. *[1]*

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(This question continues on the following page)

(Question B1, part 1 continued)

(iii) *m*. *[1]*

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(iv) *q*. *[1]*

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(b) In a simple model of the hydrogen atom, the electron is regarded as being in a circular orbit about the proton. The magnitude of the electric field strength at the electron due to the proton is E_p. The magnitude of the gravitational field strength at the electron due to the proton is g_p.

Determine the order of magnitude of the ratio shown below. *[3]*

$$\frac{E_p}{g_p}$$

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(Question B1, part 1 continued)

(c) Ionized hydrogen atoms are accelerated from rest in the vacuum between two vertical parallel conducting plates. The potential difference between the plates is V. As a result of the acceleration each ion gains an energy of 1.9×10^{-18} J.

Calculate the value of V. *[2]*

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(d) The plates in (c) are replaced by a cell that has an emf of 12.0 V and internal resistance 5.00 Ω. A resistor of resistance R is connected in series with the cell. The energy transferred by the cell to an electron as it moves through the resistor is 1.44×10^{-18} J.

(i) Define *resistance* of a resistor. *[1]*

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(Question B1, part 1 continued)

(ii) Show that the value of R is $15.0\,\Omega$. *[4]*

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(iii) Calculate the total power supplied by the cell. *[1]*

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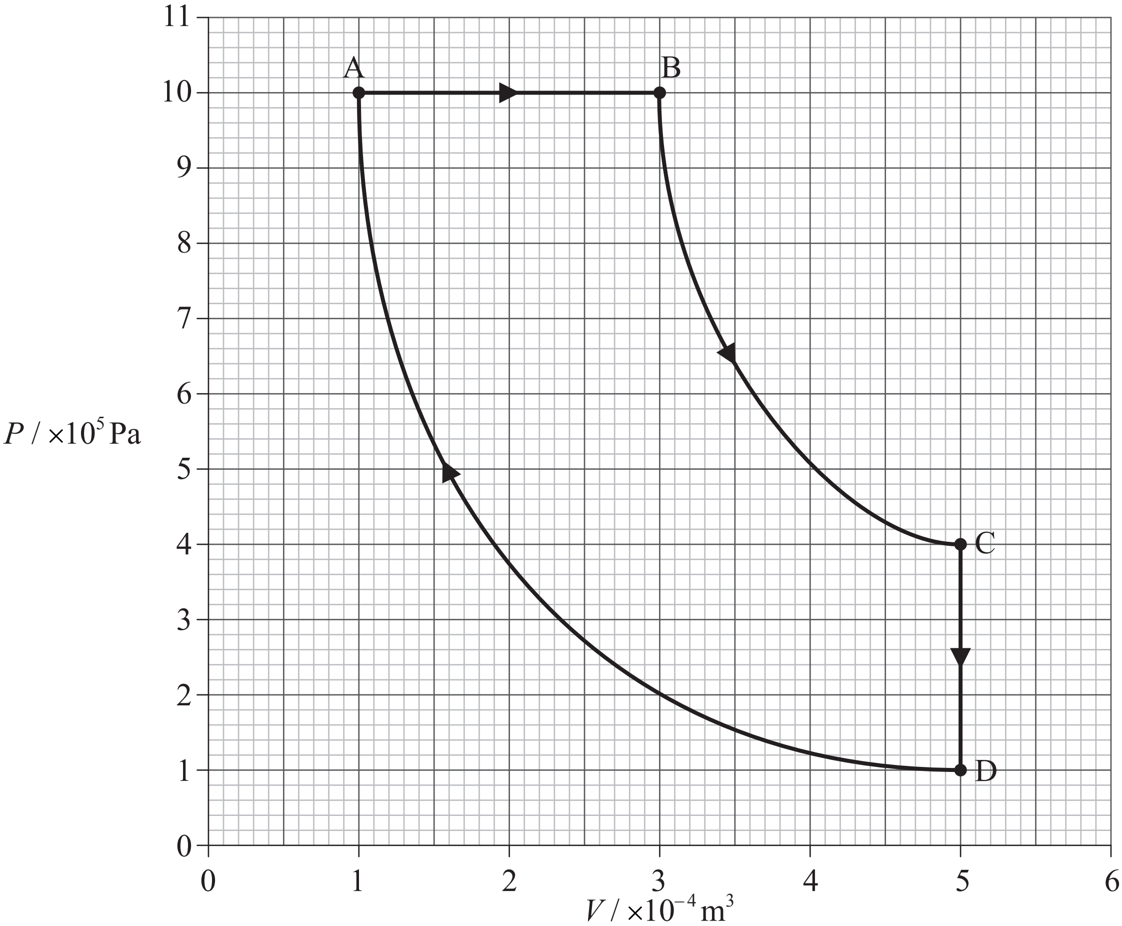
(Question B1 continued)

Part 2 Thermodynamic cycles

(a) A gas undergoes a thermodynamic cycle. The P–V diagram for the cycle is shown below.



In the changes of state B to C and D to A, the gas behaves as an ideal gas and the changes in state are adiabatic.

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(Question B1, part 2 continued)

(i) State the circumstances in which the behaviour of a gas approximates to ideal gas behaviour. *[2]*

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

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(b) With reference to the first law of thermodynamics, explain for the change of state A to B, why energy is transferred from the surroundings to the gas. *[4]*

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(Question B1, part 2 continued)

(c) Estimate the total work done in the cycle. *[3]*

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B2. This question is in **two** parts. **Part 1** is about solar power and climate models. **Part 2** is about digital storage of data.

Part 1 Solar power and climate models

(a) Distinguish, in terms of the energy changes involved, between a solar heating panel and a photovoltaic cell. *[2]*

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(b) State an appropriate domestic use for a

(i) solar heating panel. *[1]*

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(ii) photovoltaic cell. *[1]*

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(Question B2, part 1 continued)

(c) The radiant power of the Sun is 3.90×10^{26} W. The average radius of the Earth's orbit about the Sun is 1.50×10^{11} m. The albedo of the atmosphere is 0.300 and it may be assumed that no energy is absorbed by the atmosphere.

Show that the intensity incident on a solar heating panel at the Earth's surface when the Sun is directly overhead is 966 W m^{-2}. *[3]*

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(d) Show, using your answer to (c), that the average intensity incident on the Earth's surface is 242 W m^{-2}. *[3]*

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(Question B2, part 1 continued)

(e) Assuming that the Earth's surface behaves as a black-body and that no energy is absorbed by the atmosphere, use your answer to (d) to show that the average temperature of the Earth's surface is predicted to be 256 K. *[2]*

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(f) Outline, with reference to the greenhouse effect, why the average surface temperature of the Earth is higher than 256 K. *[4]*

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(Question B2 continued)

Part 2 Digital storage of data

(a) State **two** social implications of the ever increasing ability to store data. *[2]*

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(b) A charge-coupled device (CCD) enables large amounts of photographic data to be captured and stored.

(i) Describe what is meant by a pixel. *[1]*

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(ii) Outline how the image on a CCD is digitized. *[2]*

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(Question B2, part 2 continued)

(c) The CCD used in a particular camera has an area of $7.4\times10^{-5}\,m^2$ and contains 10 megapixels. The magnification of the CCD is 7.0×10^{-3}. Two small dots on an object that is photographed by the camera are separated by $2.0\times10^{-4}\,m$. Determine if the images of the dots on the CCD are resolved. *[4]*

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B3. This question is in **two** parts. **Part 1** is about kinematics and mechanics. **Part 2** is about resolution and the Doppler effect.

Part 1 Kinematics and mechanics

(a) Define *linear momentum*. *[1]*

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(b) State, in terms of momentum, Newton's second law of motion. *[1]*

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(c) Show, using your answer to (b), how the impulse of a force F is related to the change in momentum Δp that it produces. *[1]*

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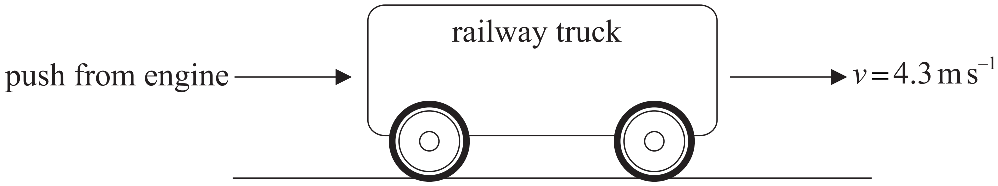
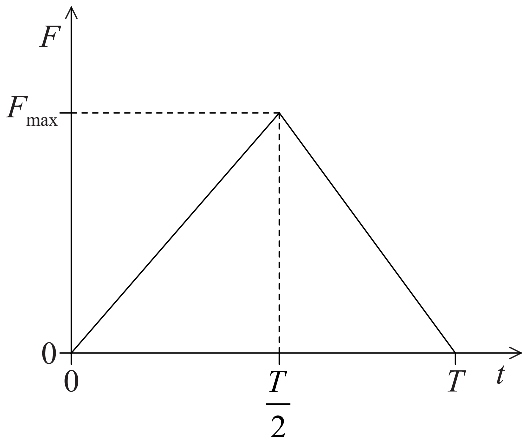
(Question B3, part 1 continued)

(d) A railway truck on a level, straight track is initially at rest. The truck is given a quick, horizontal push by an engine so that it now rolls along the track.



The engine is in contact with the truck for a time $T = 0.54\,\text{s}$ and the initial speed of the truck after the push is $4.3\,\text{m s}^{-1}$. The mass of the truck is $2.2 \times 10^3\,\text{kg}$.

Due to the push, a force of magnitude F is exerted by the engine on the truck. The sketch shows how F varies with contact time t.



(i) Determine the magnitude of the maximum force F_{max} exerted by the engine on the truck. *[4]*

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(Question B3, part 1 continued)

(ii) After contact with the engine ($t = 0.54$ s) the truck moves a distance 15 m along the track. After travelling this distance the speed of the truck is $2.8\,\text{m s}^{-1}$. Assuming a uniform acceleration, calculate the time it takes the truck to travel 15 m. *[2]*

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(iii) Calculate the average rate at which the kinetic energy of the truck is dissipated as it moves along the track. *[2]*

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(iv) When the speed of the truck is $2.8\,\text{m s}^{-1}$ it collides with a stationary truck of mass 3.0×10^{3} kg. The two trucks move off together with a speed V. Show that the speed $V = 1.2\,\text{m s}^{-1}$. *[2]*

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(Question B3, part 1 continued)

(v) Outline the energy transformations that take place during the collision of the two trucks. *[2]*

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(Question B3 continued)

Part 2 Resolution and the Doppler effect

(a) Radio telescopes can be used to locate distant galaxies. The ability of such telescopes to resolve the images of galaxies is increased by using two telescopes separated by a large distance *D*. The telescopes behave as a single radio telescope with a dish diameter equal to *D*.

The images of two distant galaxies G_1 and G_2 are just resolved by the two telescopes.

(i) State the phenomenon that limits the ability of radio telescopes to resolve images. *[1]*

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(ii) State the Rayleigh criterion for the images of G_1 and G_2 to be just resolved. *[1]*

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(iii) Determine, using the following data, the separation *d* of G_1 and G_2. *[3]*

Effective distance of G_1 and G_2 from Earth	$= 2.2 \times 10^{25}$ m
Separation *D*	$= 4.0 \times 10^{3}$ m
Wavelength of radio waves received from G_1 and G_2	$= 0.14$ m

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(Question B3, part 2 continued)

(b) Due to the Doppler effect, light from distant galaxies is often red-shifted.

(i) Describe, with reference to the Doppler effect, what is meant by red-shift. *[3]*

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(ii) The frequency of a particular spectral line as measured in the laboratory is 4.57×10^{14} Hz. The same line in the spectrum of a distant galaxy has a frequency that is lower than the laboratory value by 6.40×10^{11} Hz. Determine the speed with which the galaxy is receding from Earth. *[2]*

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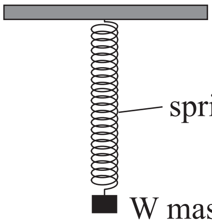
B4. This question is in **two** parts. **Part 1** is about simple harmonic motion and waves. **Part 2** is about the energy levels of the hydrogen atom.

Part 1 Simple harmonic motion and waves

(a) One end of a light spring is attached to a rigid horizontal support.



An object W of mass 0.15 kg is suspended from the other end of the spring. The extension *x* of the spring is proportional to the force *F* causing the extension. The force per unit extension of the spring *k* is 18 N m^{-1}.

A student pulls W down such that the extension of the spring increases by 0.040 m. The student releases W and as a result W performs simple harmonic motion (SHM).

(i) State what is meant by the expression "W performs SHM". *[2]*

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(ii) Determine the maximum acceleration of W. *[2]*

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(Question B4, part 1 continued)

(iii) Determine the period of oscillation of the spring. *[3]*

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(b) W in (a) is immersed in a beaker of oil. As a result of this immersion the oscillations of W are critically damped. Describe what is meant by critically damped. *[2]*

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(Question B4, part 1 continued)

(c) A spring, such as that in (a), is stretched horizontally and a longitudinal travelling wave is set up in the spring, travelling to the right.

(i) Describe, in terms of the propagation of energy, what is meant by a longitudinal travelling wave. *[2]*

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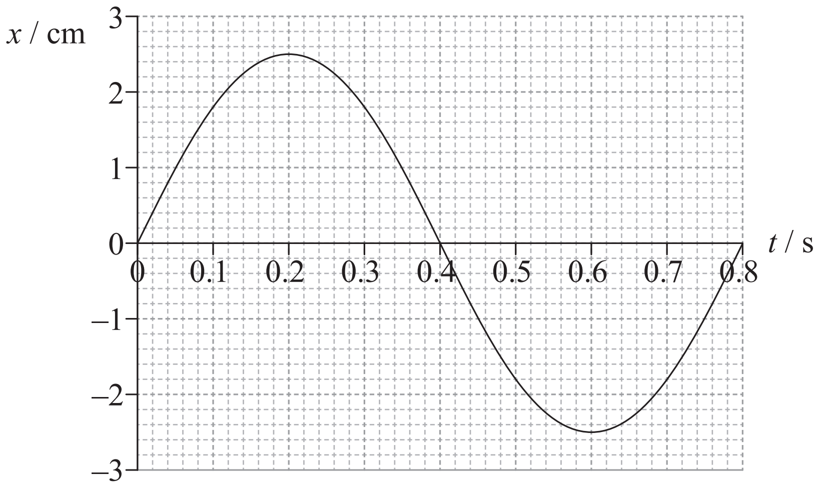
(Question B4, part 1 continued)

(ii) The graph shows how the displacement x of one coil C of the spring varies with time t.



The speed of the wave is $3.0\,\text{cm}\,\text{s}^{-1}$. Determine the wavelength of the wave. *[2]*

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(iii) Draw, on the graph in (c)(ii), the displacement of a coil of the spring that is 1.8 cm away from C in the direction of travel of the wave, explaining your answer. *[2]*

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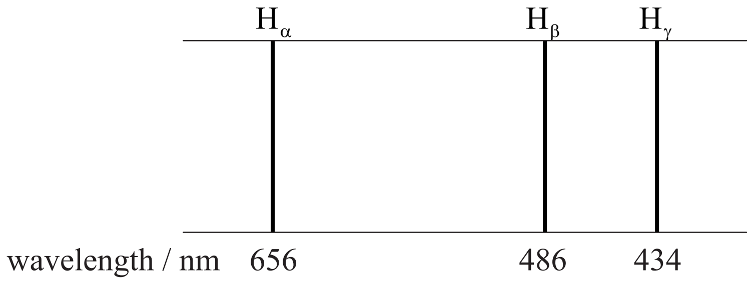
(Question B4 continued)

Part 2 Energy levels of the hydrogen atom

(a) The diagram represents the three principal spectral lines in the visible region of the spectrum of atomic hydrogen.



The electron in the hydrogen atom can only occupy certain allowed energy levels.

(i) Outline how the spectral lines provide evidence for the existence of these energy levels. *[3]*

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(ii) Determine the difference in energy between the **two** levels from which electron transitions give rise to the H_α and H_γ spectral lines respectively. *[2]*

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(Question B4, part 2 continued)

(b) The existence of atomic energy levels can be understood by applying the de Broglie hypothesis to an electron confined to move in one dimension in a box of length L.

(i) State the de Broglie hypothesis as it applies to an electron. *[1]*

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(ii) Show that the energy E_n of the electron in the box is given by

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

where $n = 1, 2, 3 \ldots$, h is the Planck constant and m_e is the mass of the electron. *[3]*

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(c) The magnitude of the least energy that an electron in the hydrogen atom can have is 2.2×10^{-18} J. Estimate, using the equation in (b)(ii), the radius of the hydrogen atom. *[1]*

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