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Bachillerato Internacional

PHYSICS
HIGHER LEVEL
PAPER 2

Candidate session number

0	0							

Wednesday 6 November 2013 (morning)

2 hours 15 minutes

Examination code

8	8	1	3	–	6	5	0	2

INSTRUCTIONS TO CANDIDATES

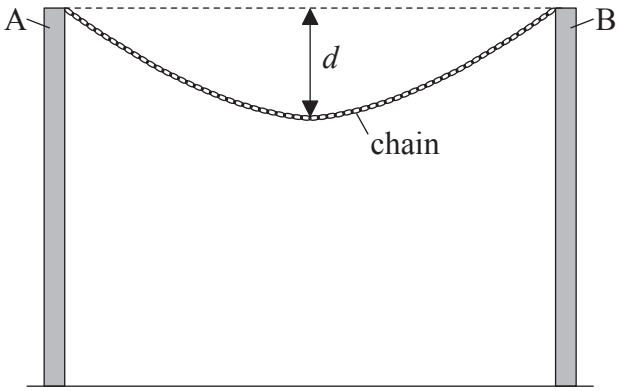
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer two questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the ***Physics*** *Data Booklet* is required for this paper.
- The maximum mark for this examination paper is *[95 marks]*.

SECTION A

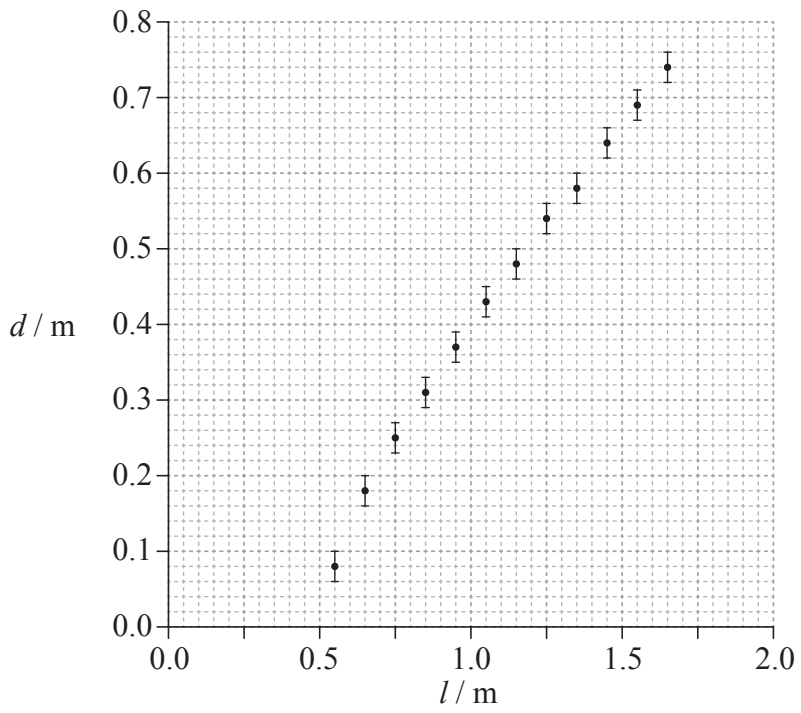
*Answer **all** questions. Write your answers in the boxes provided.*

1. Data analysis question.

A chain is suspended between two vertical supports A and B. The chain is made of a number of identical metal links.



The length l of the chain can be increased by adding extra links. An experiment was undertaken to investigate how the sag d of the midpoint of the chain, measured from the horizontal between A and B, varies with l. The data obtained are shown plotted below. The uncertainties in l are too small to be shown.



(This question continues on the following page)

(Question 1 continued)

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

(b) With reference to your answer to (a),

(i) explain why the relationship between d and l is not linear. *[2]*

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(ii) estimate the horizontal distance between the supports A and B. *[2]*

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(c) Before the experiment was carried out, it was hypothesized that d depends on $\sqrt{l}$. Determine, using your answer to (a), whether this hypothesis is valid. *[4]*

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2. This question is about change of phase.

(a) Water at constant pressure boils at constant temperature. Outline, in terms of the energy of the molecules, the reason for this. *[2]*

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(b) In an experiment to measure the specific latent heat of vaporization of water, steam at 100 °C was passed into water in an insulated container. The following data are available.

Initial mass of water in container	= 0.300 kg
Final mass of water in container	= 0.312 kg
Initial temperature of water in container	= 15.2 °C
Final temperature of water in container	= 34.6 °C
Specific heat capacity of water	= $4.18\times10^{3}\,\text{J kg}^{-1}\,\text{K}^{-1}$

Show that the data give a value of about $1.8\times10^{6}\,\text{J kg}^{-1}$ for the specific latent heat of vaporization L of water. *[4]*

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(Question 2 continued)

(c) Explain why, other than measurement or calculation error, the accepted value of L is greater than that given in (b). *[2]*

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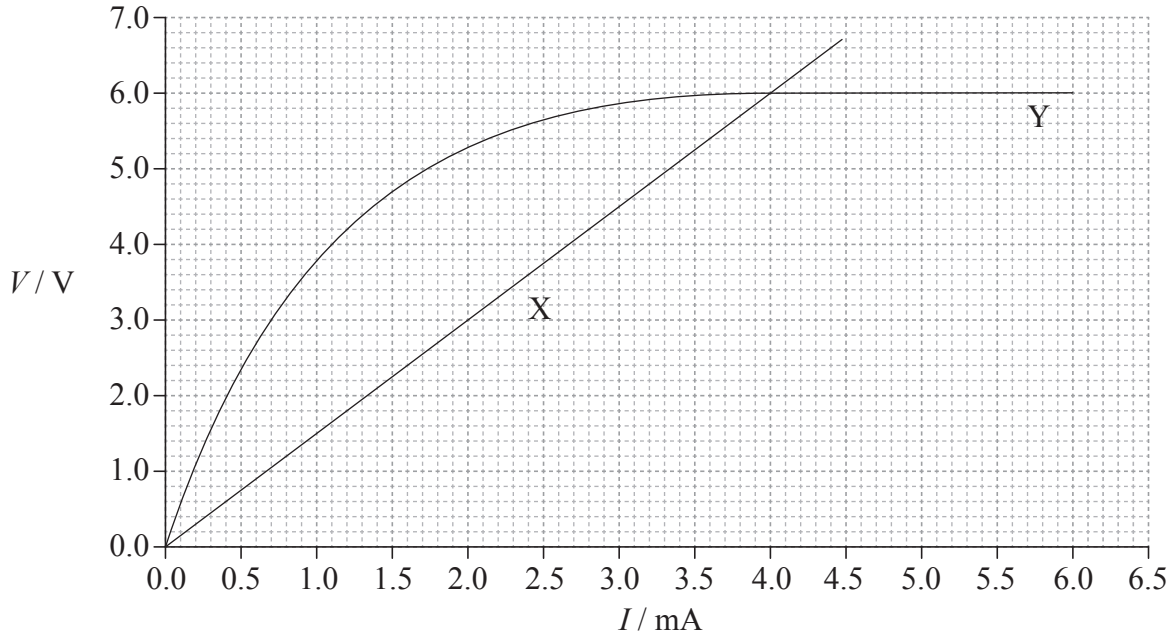
3. This question is about voltage–current (V–I) characteristics.

The graph shows the voltage–current (V–I) characteristics, at constant temperature, of two electrical components X and Y.



(a) Outline, with reference to the graph and to Ohm's law, whether or not each component is ohmic. *[3]*

X: . . . . . .

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Y: . . . . . .

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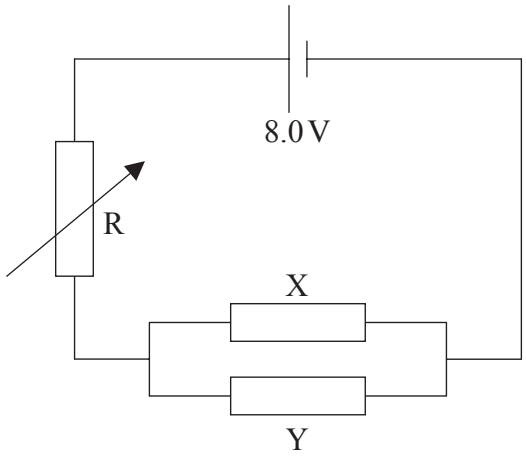
(Question 3 continued)

(b) Components X and Y are connected in parallel. The parallel combination is then connected in series with a variable resistor R and a cell of emf 8.0 V and negligible internal resistance.



The resistance of R is adjusted until the currents in X and Y are equal.

(i) Using the graph, calculate the resistance of the parallel combination of X and Y. *[3]*

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(ii) Using your answer to (b)(i), determine the resistance of R. *[2]*

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4. This question is about an ideal gas.

(a) Describe how the ideal gas constant R is defined. *[2]*

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(b) Calculate the temperature of 0.100 mol of an ideal gas kept in a cylinder of volume $1.40\times10^{-3}\,m^3$ at a pressure of $2.32\times10^{5}\,Pa$. *[1]*

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(c) The gas in (b) is kept in the cylinder by a freely moving piston. The gas is now heated at constant pressure until the volume occupied by the gas is $3.60\times10^{-3}\,m^3$. The increase in internal energy of the gas is 760 J. Determine the thermal energy given to the gas. *[2]*

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(Question 4 continued)

(d) After heating, the gas is compressed rapidly to its original volume in (b). Outline why this compression approximates to an adiabatic change of state of the gas. *[2]*

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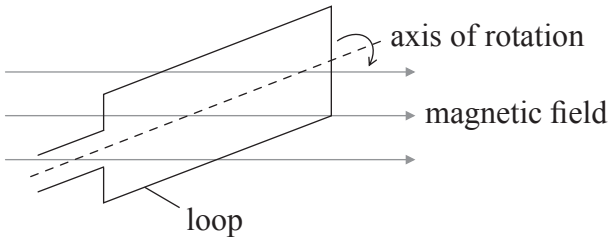
5. This question is about induced electromotive force (emf).

(a) A loop of copper wire in a region of uniform magnetic field is rotated about a horizontal axis.



The magnitude of the magnetic field strength is B and the area of the loop is A.

(i) State the minimum value and the maximum value of the magnetic flux linking the loop. *[1]*

Minimum value: . . . . . .

Maximum value: . . . . . .

(ii) Outline with reference to Faraday's law why, if the speed of rotation of the loop is increased, the maximum emf induced in the loop is increased. *[3]*

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(Question 5 continued)

(b) The loop in (a) is connected in series with a resistor of resistance 15 Ω. The root mean squared (rms) value of the sinusoidal current in the resistor is 2.3 mA.

(i) Explain what is meant by the rms value of a sinusoidal current. *[2]*

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(ii) Determine the maximum power dissipated in the resistor. *[2]*

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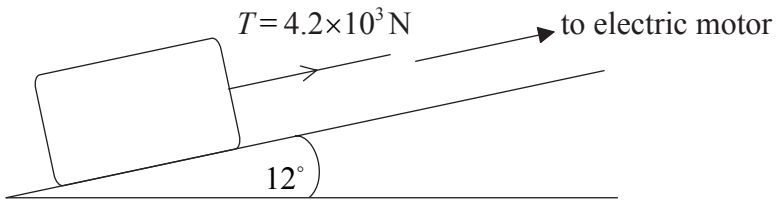
6. This question is about forces.

A stone block is pulled at constant speed up an incline by a cable attached to an electric motor.



The incline makes an angle of 12° with the horizontal. The weight of the block is 1.5×10^4 N and the tension T in the cable is 4.2×10^3 N.

(a) On the diagram draw and label arrows that represent the forces acting on the block. *[2]*

(b) Calculate the magnitude of the friction force acting on the block. *[3]*

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SECTION B

*This section consists of four questions: 7, 8, 9 and 10. Answer **two** questions. Write your answers in the boxes provided.*

7. This question is in **two** parts. **Part 1** is about electric fields and radioactive decay. **Part 2** is about the Doppler effect and optical resolution.

Part 1 Electric fields and radioactive decay

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

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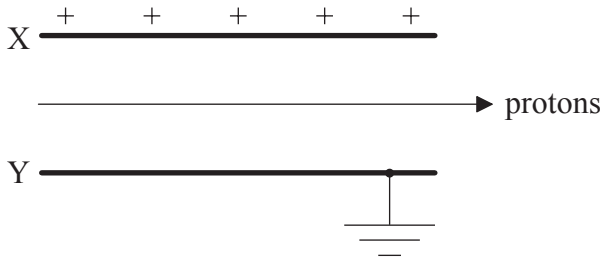
(This question continues on the following page)

(Question 7, part 1 continued)

(b) Protons travelling with a speed of $3.9\times10^{6}\,\text{m}\,\text{s}^{-1}$ enter the region between two charged parallel plates X and Y. Plate X is positively charged and plate Y is connected to earth.



A uniform magnetic field also exists in the region between the plates. The direction of the field is such that the protons pass between the plates without deflection.

(i) State the direction of the magnetic field. *[1]*

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(ii) The magnitude of the magnetic field strength is $2.3\times10^{-4}\,\text{T}$. Determine the magnitude of the electric field strength between the plates, stating an appropriate unit for your answer. *[3]*

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(Question 7, part 1 continued)

(c) Protons can be produced by the bombardment of nitrogen-14 nuclei with alpha particles. The nuclear reaction equation for this process is given below.

$$^{14}_{7}\mathrm{N} + ^{4}_{2}\mathrm{He} \rightarrow \mathrm{X} + ^{1}_{1}\mathrm{H}$$

Identify the proton number and nucleon number for the nucleus X. *[1]*

Proton number: . . . . . .

Nucleon number: . . . . . .

(d) The following data are available for the reaction in (c).

Rest mass of nitrogen-14 nucleus	= 14.0031 u
Rest mass of alpha particle	= 4.0026 u
Rest mass of X nucleus	= 16.9991 u
Rest mass of proton	= 1.0073 u

Show that the minimum kinetic energy that the alpha particle must have in order for the reaction to take place is about 0.7 MeV. *[3]*

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(Question 7, part 1 continued)

(e) A nucleus of another isotope of the element X in (c) decays with a half-life $T_{\frac{1}{2}}$ to a nucleus of an isotope of fluorine-19 (F-19).

(i) Define *half-life*. *[1]*

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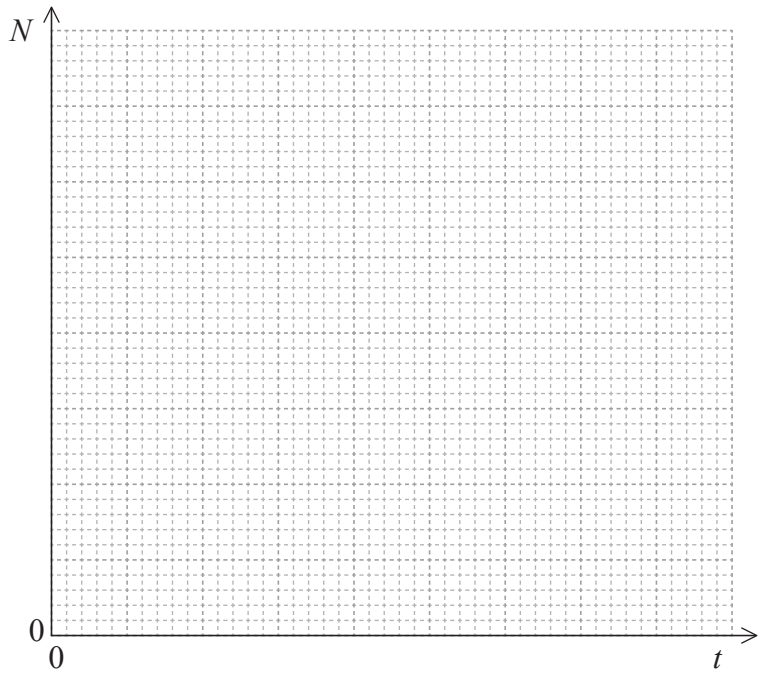
(ii) Using the axes below, sketch a graph to show how the number of atoms N in a sample of X varies with time t, from $t = 0$ to $t = 3T_{\frac{1}{2}}$. There are N_0 atoms in the sample at t=0. *[3]*



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(Question 7 continued)

Part 2 The Doppler effect and optical resolution

The Doppler effect can be used to deduce that a particular star X is moving towards Earth.

(f) Describe what is meant by the Doppler effect. *[2]*

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(Question 7, part 2 continued)

(g) One of the lines in the spectrum of atomic hydrogen has a frequency of 4.6×10^{16} Hz as measured in the laboratory. The same line in the spectrum of star X is observed on Earth to be shifted by 1.3×10^{12} Hz.

(i) State the direction of the observed frequency shift. *[1]*

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(ii) Determine the speed at which X is moving towards Earth stating any assumption that you have made. *[3]*

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Assumption:

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(Question 7, part 2 continued)

(h) The star X has a companion star Y. The distance from Earth to the stars is 1.0×10^{18} m. The images of X and Y are just resolved according to the Rayleigh criterion by a telescope on Earth with a circular eyepiece lens of diameter 5.0×10^{-2} m.

(i) State what is meant by the statement "just resolved according to the Rayleigh criterion". *[2]*

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(ii) The average wavelength of the light emitted by the stars is 4.8×10^{-7} m. Determine the separation of X and Y. *[3]*

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8. This question is in **two** parts. **Part 1** is about energy sources and the greenhouse effect. **Part 2** is about gravitational potential.

Part 1 Energy sources and the greenhouse effect

(a) Nuclear fuels, unlike fossil fuels, produce no greenhouse gases.

(i) Identify **two** greenhouse gases. *[1]*

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(ii) Discuss, with reference to the mechanism of infrared absorption, why the temperature of the Earth's surface would be lower if there were no greenhouse gases present in the atmosphere. *[4]*

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(Question 8, part 1 continued)

(iii) State **one** advantage of power production using fossil fuels compared to using nuclear fuels. *[1]*

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(b) Outline the reason why fuel enrichment is necessary for the fuel used in a commercial nuclear reactor. *[3]*

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(Question 8, part 1 continued)

(c) A domestic water tank contains 620 kg of water. You are asked to compare raising the temperature of the water by 25 K using the energy available from nuclear fission and the energy available from the Sun. The following data are available.

Energy density of uranium-235	$=2.0\times10^{13}\,\text{J kg}^{-1}$
Area of solar panels used	$=23\,\text{m}^2$
Average solar power during daylight	$=0.74\,\text{kW m}^{-2}$
Specific heat capacity of water	$=4.2\times10^{3}\,\text{J kg}^{-1}\,\text{K}^{-1}$

Determine the

(i) mass of uranium-235 that is needed to raise the temperature of the water by 25 K. *[2]*

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(ii) time in hours required to raise the temperature of the water by 25 K using the solar panels. *[2]*

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(This question continues on the following page)

(Question 8, part 1 continued)

(d) The solar energy in (c) is used to heat the water directly, whereas the nuclear energy must first be converted into electrical energy in the nuclear power station. Outline the energy transformations that take place within the nuclear power station in the production of electrical power. *[2]*

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(Question 8 continued)

Part 2 Gravitational potential

(e) Define *gravitational potential* at a point in a gravitational field. *[3]*

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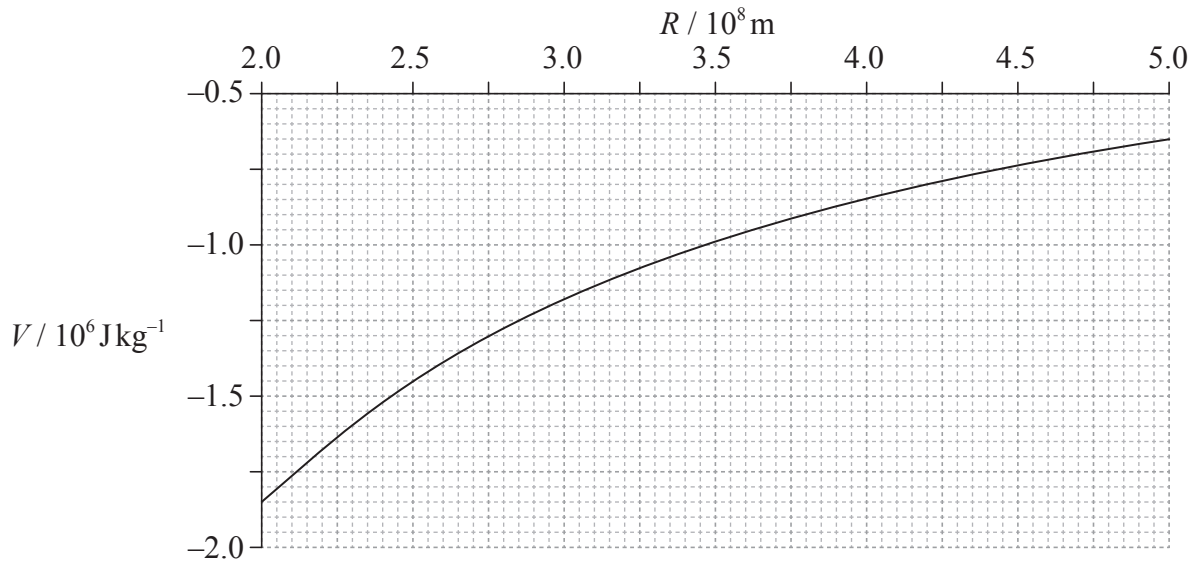
(f) The graph shows how the gravitational potential V of Earth varies with distance R from the centre of Earth in the range $R = 2.0\times10^8$ m to $R = 5.0\times10^8$ m.



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(Question 8, part 2 continued)

The Moon is at a distance of 4.0×10^{8} m from the centre of Earth. At some time in the past it was at a distance of 2.7×10^{8} m from the centre of Earth.

Use the graph opposite to determine

(i) the present day magnitude of the acceleration of the Moon. *[4]*

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(ii) by how much the potential energy of the Moon has changed as a result of moving from $R=2.7\times10^{8}$ m to $R=4.0\times10^{8}$ m. The mass of the Moon is 7.4×10^{22} kg. *[2]*

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(g) State why the change of potential energy in (f)(ii) is an increase. *[1]*

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9. This question is in **two** parts. **Part 1** is about Newton's laws and momentum. **Part 2** is about data storage.

Part 1 Newton's laws and momentum

(a) State the condition for the momentum of a system to be conserved. *[1]*

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(b) A person standing on a frozen pond throws a ball. Air resistance and friction can be considered to be negligible.

(i) Outline how Newton's third law and the conservation of momentum apply as the ball is thrown. *[3]*

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(ii) Explain, with reference to Newton's second law, why the horizontal momentum of the ball remains constant whilst the ball is in flight. *[2]*

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(Question 9, part 1 continued)

(c) The maximum useful power output of a locomotive engine is 0.75 MW. The maximum speed of the locomotive as it travels along a straight horizontal track is $44\,m\,s^{-1}$. Calculate the frictional force acting on the locomotive at this speed. *[2]*

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(Question 9, part 1 continued)

(d) The locomotive engine in (c) gives a truck X a sharp push such that X moves along a horizontal track and collides with a stationary truck Y. As a result of the collision the two trucks stick together and move off with speed v. The following data are available.

Mass of truck X $= 3.7 \times 10^3\,\text{kg}$
Mass of truck Y $= 6.3 \times 10^3\,\text{kg}$
Speed of X just before collision $= 4.0\,\text{m s}^{-1}$

(i) Calculate v. *[2]*

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(ii) Determine the kinetic energy lost as a result of the collision. *[2]*

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(e) The trucks X and Y come to rest after travelling a distance of 40 m along the horizontal track. Determine the average frictional force acting on X and Y. *[3]*

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(This question continues on the following page)

(Question 9 continued)

Part 2 Data storage

(f) State **one** advantage of storing information in a digital form rather than analogue form. *[1]*

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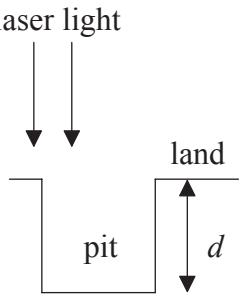
(g) Digital data are encoded on a DVD as a series of lands and pits. The wavelength of the laser light used is 640 nm.



Explain, with reference to the diagram, why the depth d of a pit needs to be 160 nm. *[3]*

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(Question 9, part 2 continued)

(h) A charge-coupled device (CCD) is a device that enables data to be stored for retrieval as a digital image.

(i) Outline the structure and operation of a CCD. *[3]*

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(ii) A certain digital camera has a CCD that has an area of 25 mm×25 mm. There are 8.0×10^{6} pixels on the CCD. The magnification of the CCD is 4.8×10^{-3}. The camera is used to photograph a leaf which has two black spots 5.0×10^{-4} m apart. Determine whether the image of the spots formed by the CCD will be resolved. *[3]*

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10. This question is in **two** parts. **Part 1** is about simple harmonic motion (SHM) and waves. **Part 2** is about atomic and nuclear energy levels.

Part 1 Simple harmonic motion (SHM) and waves

(a) A particle P moves with simple harmonic motion.

(i) State, with reference to the motion of P, what is meant by simple harmonic motion. *[2]*

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(ii) State the phase difference between the displacement and the velocity of P. *[1]*

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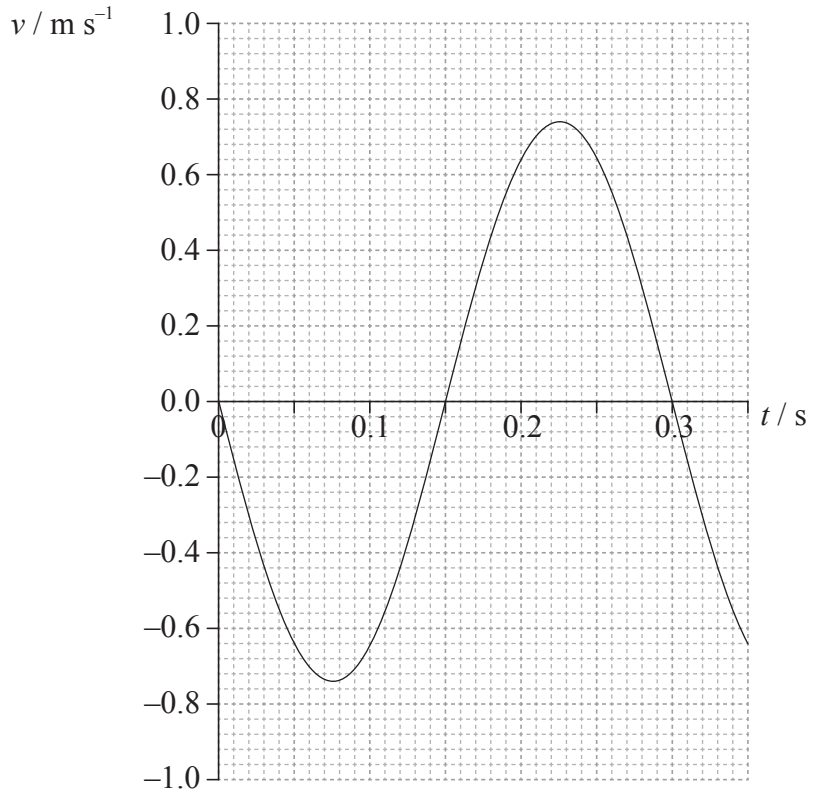
(Question 10, part 1 continued)

(b) The graph shows how the velocity v of particle P varies with time t.



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(Question 10, part 1 continued)

Use the graph opposite to determine for the motion of P the

(i) period. *[1]*

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(ii) amplitude. *[4]*

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(iii) displacement of P from equilibrium at $t = 0.2\,\text{s}$. *[2]*

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(Question 10, part 1 continued)

(c) The particle P in (b) is a particle in the medium through which a transverse wave is travelling.

(i) Describe, in terms of energy propagation, what is meant by a transverse wave. *[1]*

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(ii) The speed of the wave through the medium is $0.40\,m\,s^{-1}$. Calculate, using your answer to (b)(i), the wavelength of the wave. *[2]*

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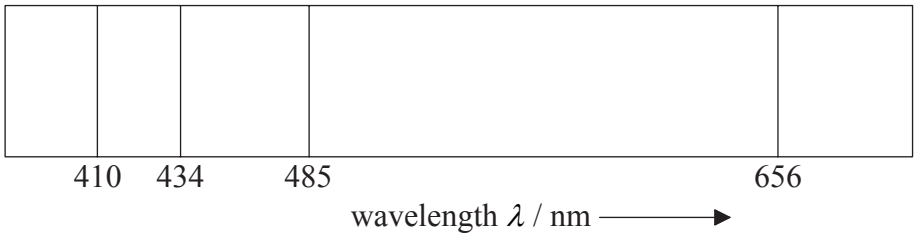
(Question 10 continued)

Part 2 Atomic and nuclear energy levels

(d) The diagram shows four spectral lines in the visible line emission spectrum of atomic hydrogen.



(not to scale)

(i) Outline how such a spectrum may be obtained in the laboratory. *[3]*

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(Question 10, part 2 continued)

(ii) Explain how such spectra give evidence for the existence of discrete atomic energy levels. *[3]*

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(e) The energies of the principal energy levels in atomic hydrogen measured in eV are given by the expression

$$E_n = -\frac{13.6}{n^2} \text{ where } n = 1, 2, 3 \ldots\ldots\ldots$$

The visible lines in the spectrum correspond to electron transitions that end at $n=2$.

(i) Calculate the energy of the level corresponding to $n=2$. *[1]*

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(ii) Show that the spectral line of wavelength $\lambda = 485\,\text{nm}$ is the result of an electron transition from $n=4$. *[3]*

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(Question 10, part 2 continued)

(f) The alpha particles and gamma rays produced in radioactive decay have discrete energy spectra. This suggests that nuclei also possess discrete energy levels. However, beta particles produced in radioactive decay have continuous energy spectra. Describe how the existence of the antineutrino accounts for the continuous nature of beta spectra. *[2]*

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