Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Thursday 10 May 2018 (afternoon)

Candidate session number

2 hours 15 minutes

Instructions to candidates

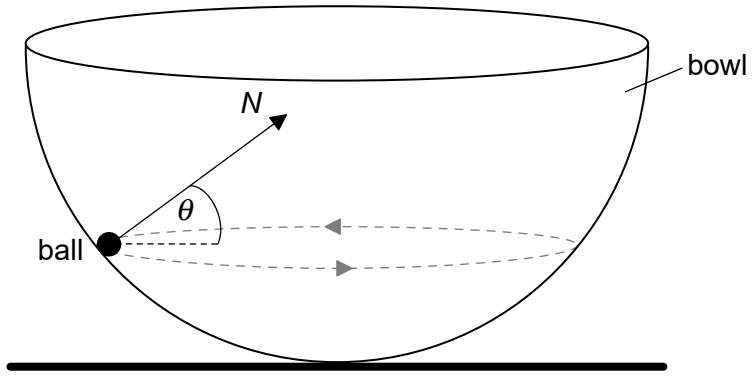
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[95 marks]**.

2218 – 6514

25 pages

Answer **all** questions. Answers must be written within the answer boxes provided.

1. (a) A small ball of mass m is moving in a horizontal circle on the inside surface of a frictionless hemispherical bowl.



The normal reaction force N makes an angle θ to the horizontal.

(i) State the direction of the resultant force on the ball. [1]

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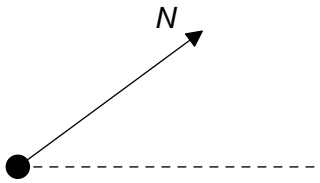
(ii) On the diagram, construct an arrow of the correct length to represent the weight of the ball. [2]



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(Question 1 continued)

(iii) Show that the magnitude of the net force F on the ball is given by the following equation. [3]

$$F = \frac{mg}{\tan\theta}$$

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(b) The radius of the bowl is 8.0 m and $\theta = 22^\circ$. Determine the speed of the ball. [4]

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(c) Outline whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl. [2]

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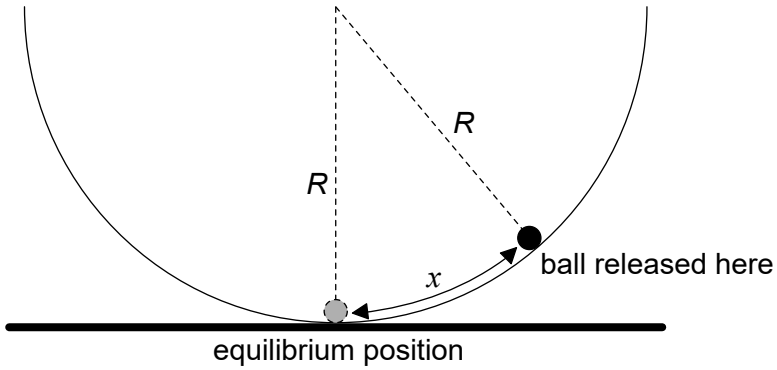
(Question 1 continued)

(d) The ball is now displaced through a small distance x from the bottom of the bowl and is then released from rest.



The magnitude of the force on the ball towards the equilibrium position is given by

$$\frac{mgx}{R}$$

where R is the radius of the bowl.

(i) Outline why the ball will perform simple harmonic oscillations about the equilibrium position. [1]

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(ii) Show that the period of oscillation of the ball is about 6 s. [2]

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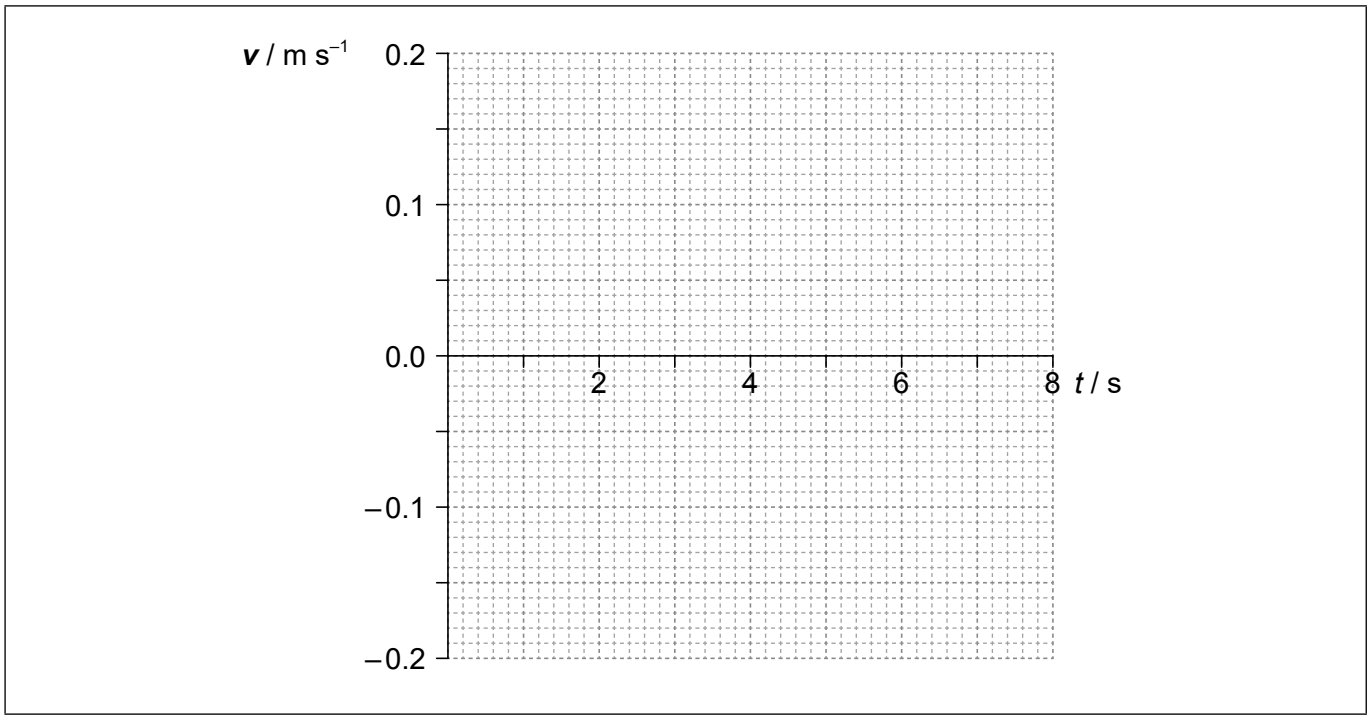
(Question 1 continued)

(iii) The amplitude of oscillation is 0.12 m. On the axes, draw a graph to show the variation with time t of the velocity $\boldsymbol{v}$ of the ball during one period. [3]



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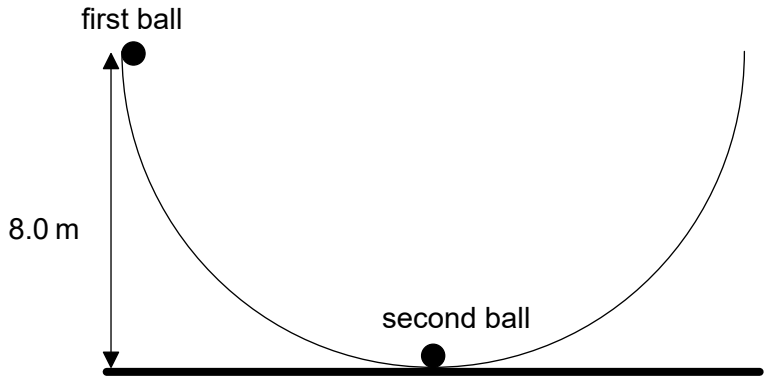
(Question 1 continued)

(e) A second identical ball is placed at the bottom of the bowl and the first ball is displaced so that its height from the horizontal is equal to 8.0 m.



The first ball is released and eventually strikes the second ball. The two balls remain in contact. Calculate, in m, the maximum height reached by the two balls. [3]

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2. (a) An ideal monatomic gas is kept in a container of volume $2.1 \times 10^{-4}\ m^3$, temperature 310 K and pressure 5.3×10^5 Pa.

(i) State what is meant by an ideal gas. [1]

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(ii) Calculate the number of atoms in the gas. [1]

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(iii) Calculate, in J, the internal energy of the gas. [2]

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(b) The volume of the gas in (a) is increased to $6.8 \times 10^{-4}\ m^3$ at constant temperature.

(i) Calculate, in Pa, the new pressure of the gas. [1]

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(ii) Explain, in terms of molecular motion, this change in pressure. [2]

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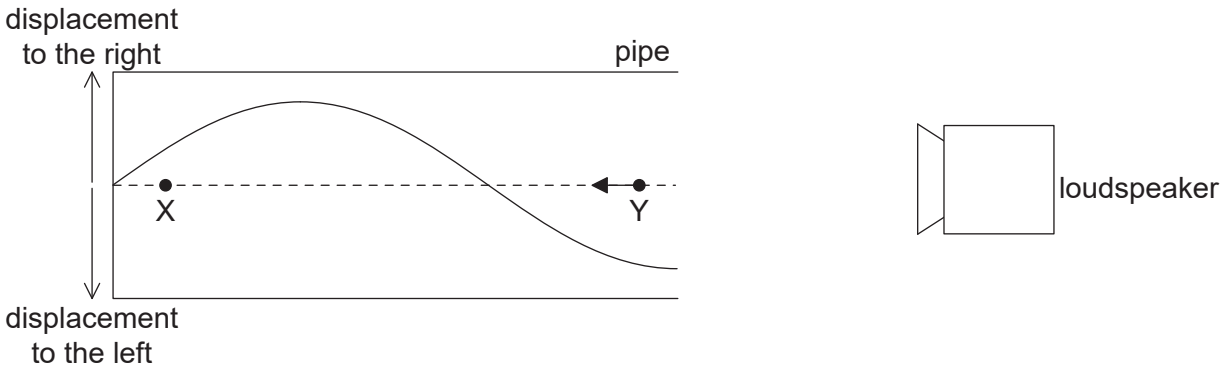
3. (a) A loudspeaker emits sound towards the open end of a pipe. The other end is closed. A standing wave is formed in the pipe. The diagram represents the displacement of molecules of air in the pipe at an instant of time.



(i) Outline how the standing wave is formed. [1]

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X and Y represent the equilibrium positions of two air molecules in the pipe. The arrow represents the velocity of the molecule at Y.

(ii) Draw an arrow on the diagram to represent the direction of motion of the molecule at X. [1]

(iii) Label a position N that is a node of the standing wave. [1]

(iv) The speed of sound is 340 m s^{-1} and the length of the pipe is 0.30 m. Calculate, in Hz, the frequency of the sound. [2]

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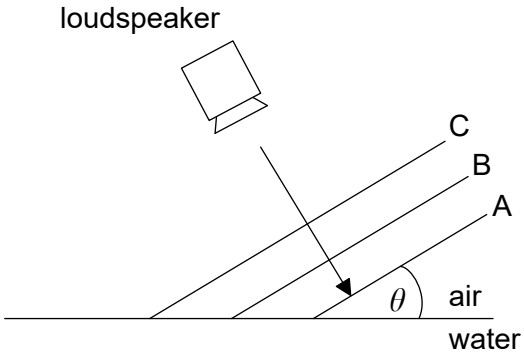
(Question 3 continued)

(b) The loudspeaker in (a) now emits sound towards an air–water boundary. A, B and C are parallel wavefronts emitted by the loudspeaker. The parts of wavefronts A and B in water are not shown. Wavefront C has not yet entered the water.



(i) The speed of sound in air is 340 m s^{-1} and in water it is 1500 m s^{-1}. The wavefronts make an angle θ with the surface of the water. Determine the maximum angle, θ_{max}, at which the sound can enter water. Give your answer to the correct number of significant figures. [2]

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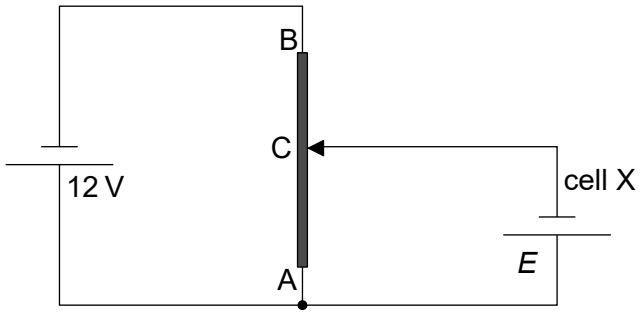
(ii) Draw lines on the diagram to complete wavefronts A and B in water for $\theta < \theta_{max}$. [2]

4. The diagram shows a potential divider circuit used to measure the emf *E* of a cell X. Both cells have negligible internal resistance.



(a) State what is meant by the emf of a cell. [2]

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(b) AB is a wire of uniform cross-section and length 1.0 m. The resistance of wire AB is 80 Ω. When the length of AC is 0.35 m the current in cell X is zero.

(i) Show that the resistance of the wire AC is 28 Ω. [2]

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(ii) Determine *E*. [2]

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(Question 4 continued)

(c) Cell X is replaced by a second cell of identical emf E but with internal resistance 2.0 Ω. Comment on the length of AC for which the current in the second cell is zero. [2]

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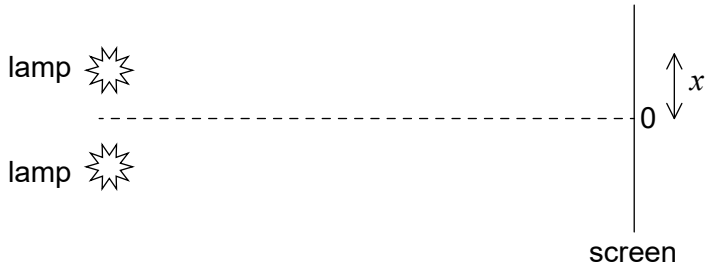
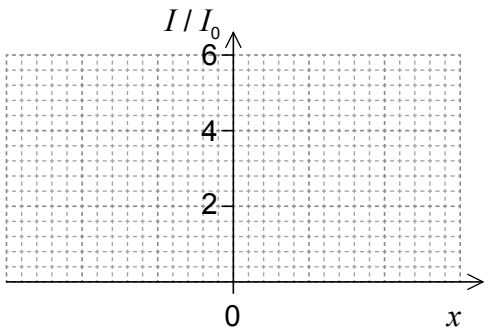
5. (a) Monochromatic light from two identical lamps arrives on a screen.



The intensity of light on the screen from each lamp separately is I_0.

On the axes, sketch a graph to show the variation with distance x on the screen of the intensity I of light on the screen. [1]



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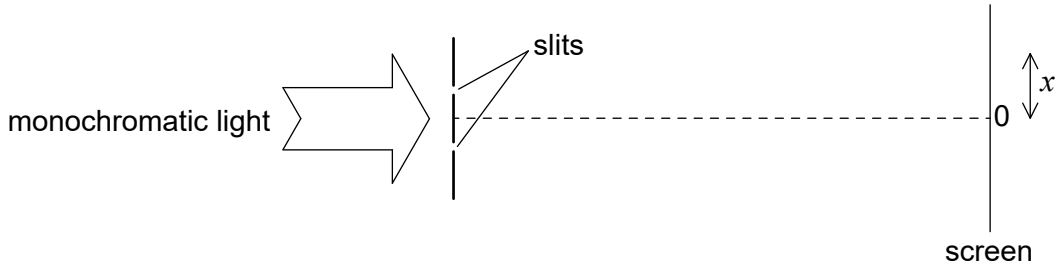
(Question 5 continued)

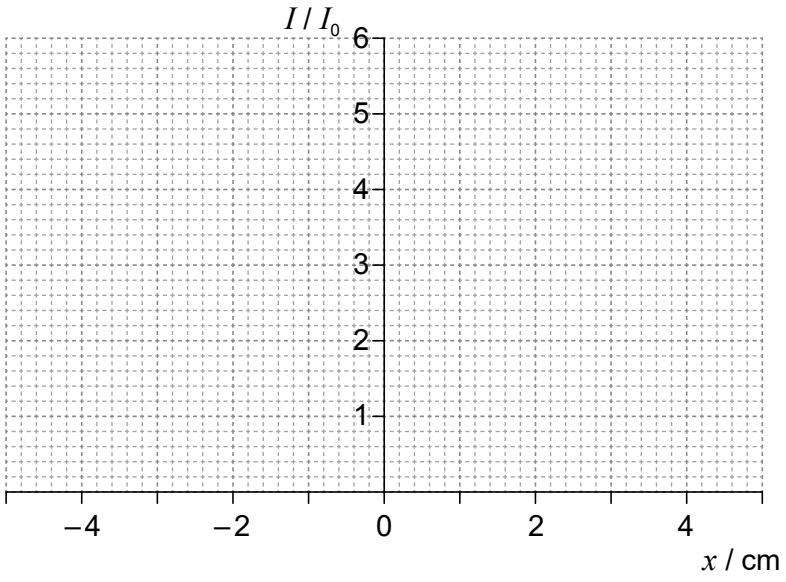
(b) Monochromatic light from a single source is incident on two thin, parallel slits.



The following data are available.

Slit separation = 0.12 mm
Wavelength = 680 nm
Distance to screen = 3.5 m

The intensity I of light at the screen from each slit separately is I_0. Sketch, on the axes, a graph to show the variation with distance x on the screen of the intensity of light on the screen for this arrangement. [3]



(c) The slit separation is increased. Outline **one** change observed on the screen. [1]

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6. (a) A planet has radius R. At a distance h above the surface of the planet the gravitational field strength is g and the gravitational potential is V.

(i) State what is meant by gravitational field strength. [1]

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(ii) Show that $V = -g(R + h)$. [2]

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(iii) Draw a graph, on the axes, to show the variation of the gravitational potential V of the planet with height h above the surface of the planet. [2]

(This question continues on the following page)

(Question 6 continued)

(b) A planet has a radius of 3.1×10^6 m. At a point P a distance 2.4×10^7 m above the surface of the planet the gravitational field strength is 2.2 N kg^{-1}. Calculate the gravitational potential at point P, include an appropriate unit for your answer. [1]

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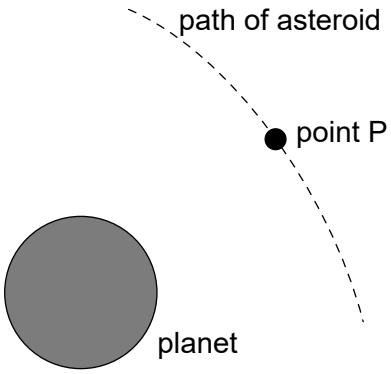
(c) The diagram shows the path of an asteroid as it moves past the planet.



When the asteroid was far away from the planet it had negligible speed. Estimate the speed of the asteroid at point P as defined in (b). [3]

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(Question 6 continued)

(d) The mass of the asteroid is 6.2×10^{12} kg. Calculate the gravitational force experienced by the **planet** when the asteroid is at point P. [2]

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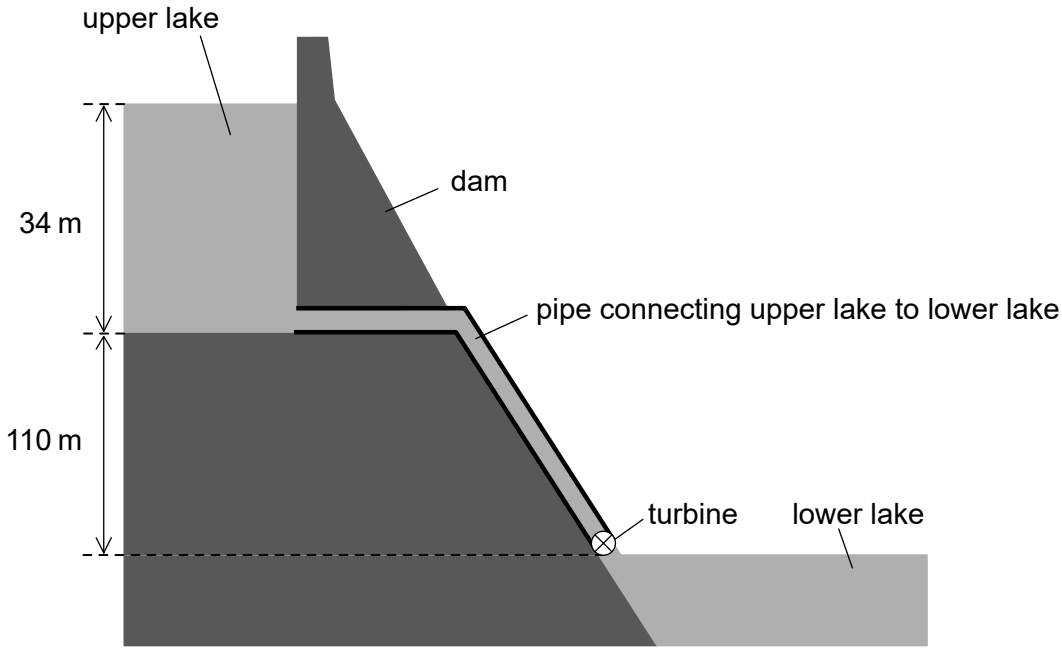
7. In a pumped storage hydroelectric system, water is stored in a dam of depth 34 m.



The water leaving the upper lake descends a vertical distance of 110 m and turns the turbine of a generator before exiting into the lower lake.

(a) Water flows out of the upper lake at a rate of 1.2×10^5 m^3 per minute. The density of water is 1.0×10^3 kg m^{-3}.

(i) Estimate the specific energy of water in this storage system, giving an appropriate unit for your answer. [2]

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(Question 7 continued)

(ii) Show that the average rate at which the gravitational potential energy of the water decreases is 2.5 GW. [3]

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(iii) The storage system produces 1.8 GW of electrical power. Determine the overall efficiency of the storage system. [1]

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(b) After the upper lake is emptied it must be refilled with water from the lower lake and this requires energy. Suggest how the operators of this storage system can still make a profit. [1]

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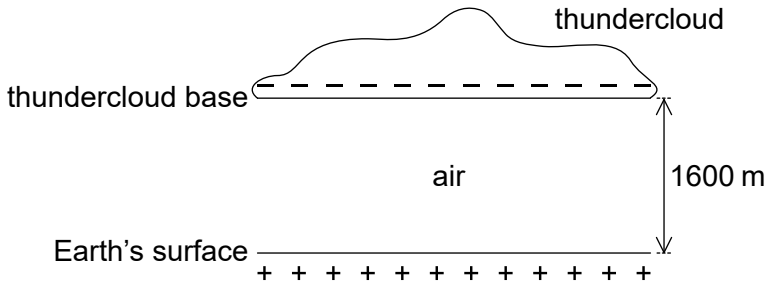
8. A negatively charged thundercloud above the Earth's surface may be modelled by a parallel plate capacitor.



The lower plate of the capacitor is the Earth's surface and the upper plate is the base of the thundercloud.

The following data are available.

$$\text{Area of thundercloud base} = 1.2 \times 10^{8}\ \text{m}^2$$
$$\text{Charge on thundercloud base} = -25\ \text{C}$$
$$\text{Distance of thundercloud base from Earth's surface} = 1600\ \text{m}$$
$$\text{Permittivity of air} = 8.8 \times 10^{-12}\ \text{F m}^{-1}$$

(a) Show that the capacitance of this arrangement is $C = 6.6 \times 10^{-7}$ F. [1]

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(Question 8 continued)

(b) Calculate

(i) in V, the potential difference between the thundercloud and the Earth's surface. [2]

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(ii) in J, the energy stored in the system. [2]

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(c) Lightning takes place when the capacitor discharges through the air between the thundercloud and the Earth's surface. The time constant of the system is 32 ms. A lightning strike lasts for 18 ms.

(i) Show that about –11 C of charge is delivered to the Earth's surface. [3]

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(ii) Calculate, in A, the average current during the discharge. [1]

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(Question 8 continued)

(d) State **one** assumption that needs to be made so that the Earth-thundercloud system may be modelled by a parallel plate capacitor. [1]

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9. (a) Rutherford constructed a model of the atom based on the results of the alpha particle scattering experiment. Describe this model. [2]

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(b) Bohr modified the Rutherford model by introducing the condition $mvr = n\frac{h}{2\pi}$. Outline the reason for this modification. [3]

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(Question 9 continued)

(c) (i) Show that the speed v of an electron in the hydrogen atom is related to the radius r of the orbit by the expression

$$v = \sqrt{\frac{ke^2}{m_e r}}$$

where k is the Coulomb constant. [1]

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(ii) Using the answer in (b) and (c)(i), deduce that the radius r of the electron's orbit in the ground state of hydrogen is given by the following expression. [2]

$$r = \frac{h^2}{4\pi^2 k m_e e^2}$$

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(iii) Calculate the electron's orbital radius in (c)(ii). [1]

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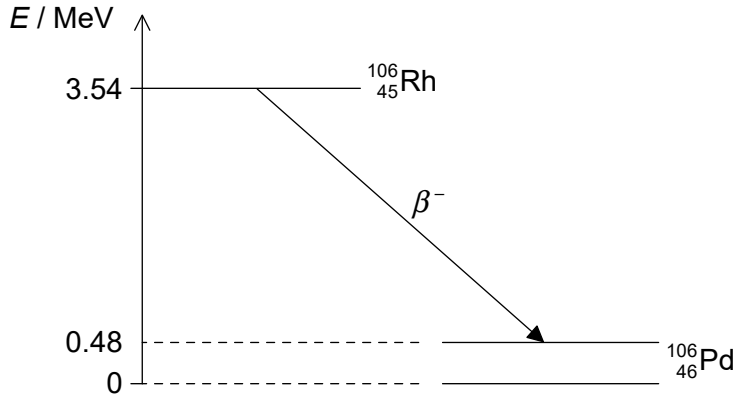
(Question 9 continued)

(d) Rhodium-106 $\left({}^{106}_{45}\text{Rh}\right)$ decays into palladium-106 $\left({}^{106}_{46}\text{Pd}\right)$ by beta minus (β^-) decay. The diagram shows some of the nuclear energy levels of rhodium-106 and palladium-106. The arrow represents the β^- decay.



(i) Explain what may be deduced about the energy of the electron in the β^- decay. [3]

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(ii) Suggest why the β^- decay is followed by the emission of a gamma ray photon. [1]

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(iii) Calculate the wavelength of the gamma ray photon in (d)(ii). [2]

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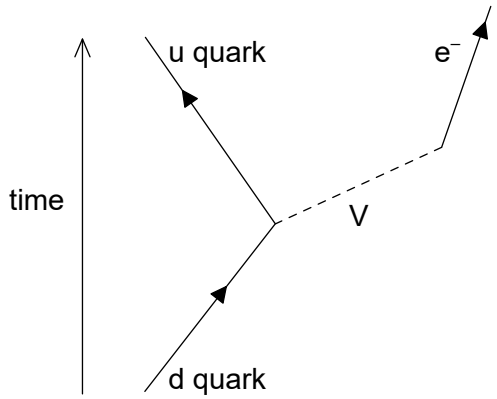
(Question 9 continued)

(e) β^- decay is described by the following incomplete Feynman diagram.



(i) Draw a labelled arrow to complete the Feynman diagram. [1]

(ii) Identify particle V. [1]

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