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Physics
Higher level
Paper 2

Friday 17 May 2019 (afternoon)

Candidate session number

2 hours 15 minutes

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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 **[90 marks]**.



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

1. A student strikes a tennis ball that is initially at rest so that it leaves the racquet at a speed of 64 m s^{-1} . The ball has a mass of 0.058 kg and the contact between the ball and the racquet lasts for 25 ms .

(a) Calculate the

(i) average force exerted by the racquet on the ball.

[2]

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(ii) average power delivered to the ball during the impact.

[2]

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(b) The student strikes the tennis ball at point P. The tennis ball is initially directed at an angle of 7.00° to the horizontal.

diagram not to scale



The following data are available.

- Height of P = 2.80 m
- Distance of student from net = 11.9 m
- Height of net = 0.910 m
- Initial speed of tennis ball = 64 m s^{-1}

(This question continues on the following page)



(Question 1 continued)

- (i) Calculate the time it takes the tennis ball to reach the net. [2]

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- (ii) Show that the tennis ball passes over the net. [3]

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- (iii) Determine the speed of the tennis ball as it strikes the ground. [2]

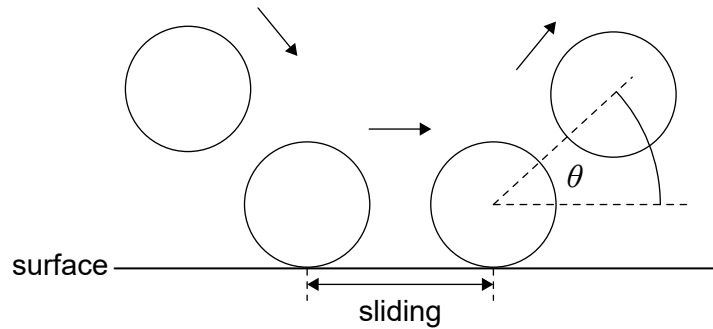
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(Question 1 continued)

- (c) The student models the bounce of the tennis ball to predict the angle θ at which the ball leaves a surface of clay and a surface of grass.



The model assumes

- during contact with the surface the ball slides.
- the sliding time is the same for both surfaces.
- the sliding frictional force is greater for clay than grass.
- the normal reaction force is the same for both surfaces.

Predict for the student's model, without calculation, whether θ is greater for a clay surface or for a grass surface.

[3]

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2. A container of volume $3.2 \times 10^{-6} \text{ m}^3$ is filled with helium gas at a pressure of $5.1 \times 10^5 \text{ Pa}$ and temperature 320 K. Assume that this sample of helium gas behaves as an ideal gas.

(a) The mass of a helium atom is $6.6 \times 10^{-27} \text{ kg}$. Estimate the average speed of the helium atoms in the container.

[2]

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(b) Show that the number of helium atoms in the container is 4×10^{20} .

[2]

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(Question 2 continued)

(c) A helium atom has a volume of $4.9 \times 10^{-31} \text{ m}^3$.

(i) Calculate the ratio $\frac{\text{volume of helium atoms}}{\text{volume of helium gas}}$. [1]

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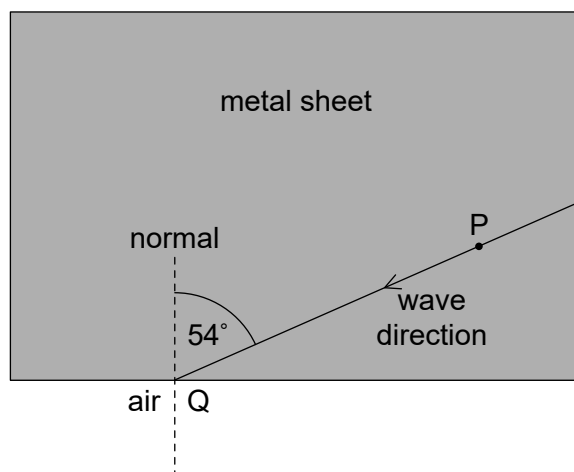
(ii) Discuss, by reference to the kinetic model of an ideal gas and the answer to (c)(i), whether the assumption that helium behaves as an ideal gas is justified. [2]

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3. The diagram shows the direction of a sound wave travelling in a metal sheet.

diagram not to scale



(a) Particle P in the metal sheet performs simple harmonic oscillations. When the displacement of P is $3.2\ \mu\text{m}$ the magnitude of its acceleration is $7.9\ \text{ms}^{-2}$. Calculate the magnitude of the acceleration of P when its displacement is $2.3\ \mu\text{m}$. [2]

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(b) The wave is incident at point Q on the metal–air boundary. The wave makes an angle of 54° with the normal at Q. The speed of sound in the metal is $6010\ \text{ms}^{-1}$ and the speed of sound in air is $340\ \text{ms}^{-1}$. Calculate the angle between the normal at Q and the direction of the wave in air. [2]

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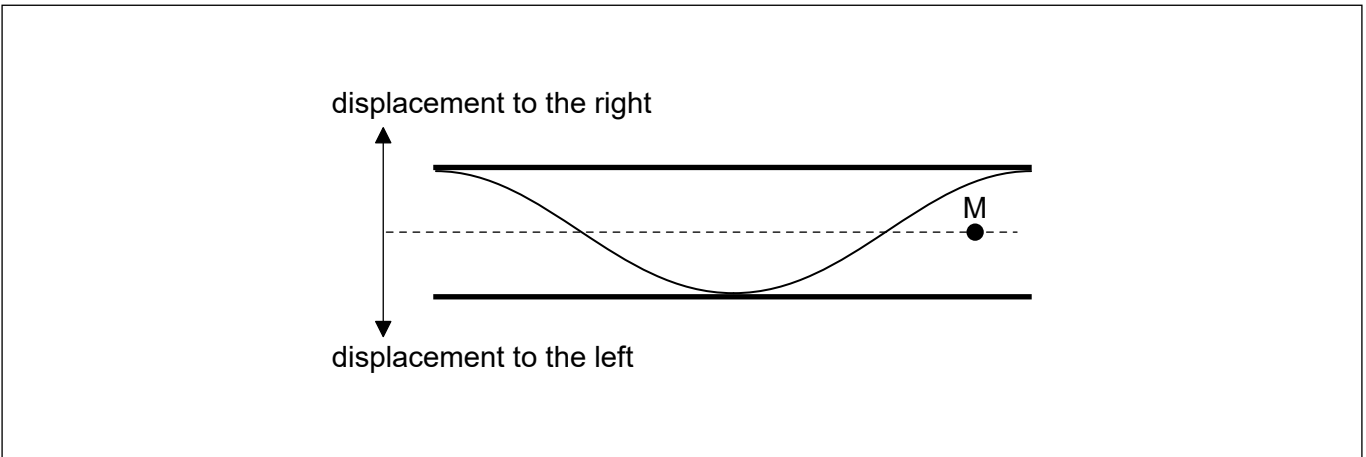
(Question 3 continued)

- (c) The frequency of the sound wave in the metal is 250 Hz. Determine the wavelength of the wave in air. [1]

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- (d) The sound wave in air in (c) enters a pipe that is open at both ends. The diagram shows the displacement, at a particular time T , of the standing wave that is set up in the pipe.



A particular air molecule has its equilibrium position at the point labelled M.

On the diagram, at time T ,

- (i) draw an arrow to indicate the acceleration of this molecule. [1]
- (ii) label with the letter C a point in the pipe that is at the centre of a compression. [1]

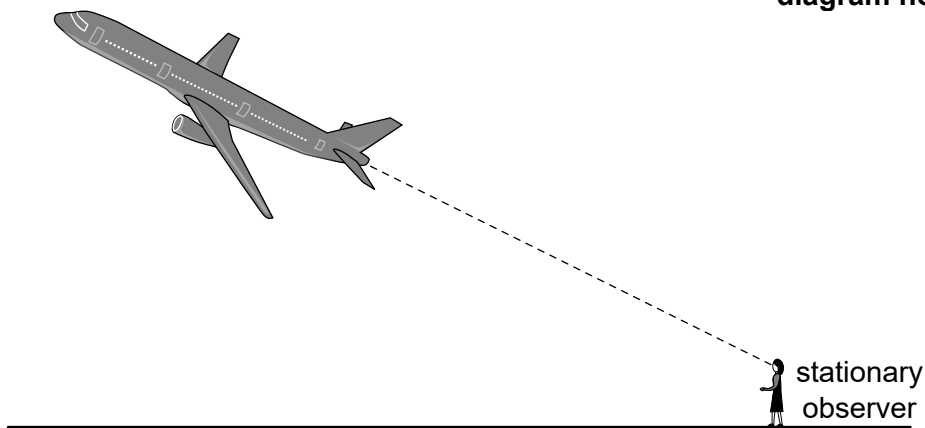
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(Question 3 continued)

- (e) Sound of frequency $f = 2500\text{ Hz}$ is emitted from an aircraft that moves with speed $v = 280\text{ ms}^{-1}$ away from a stationary observer. The speed of sound in still air is $c = 340\text{ ms}^{-1}$.

diagram not to scale



Calculate the

- (i) frequency heard by the observer. [2]

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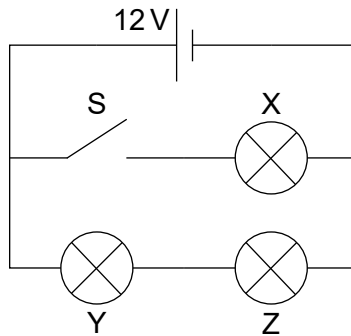
- (ii) wavelength measured by the observer. [1]

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4. Three identical light bulbs, X, Y and Z, each of resistance 4.0Ω are connected to a cell of emf 12V. The cell has negligible internal resistance.



- (a) The switch S is initially open. Calculate the total power dissipated in the circuit. [2]

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- (b) The switch is now closed.

- (i) State, without calculation, why the current in the cell will increase. [1]

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- (ii) Deduce the ratio $\frac{\text{power dissipated in Y with S open}}{\text{power dissipated in Y with S closed}}$. [2]

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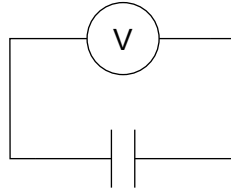
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(Question 4 continued)

- (c) The cell is used to charge a parallel-plate capacitor in a vacuum. The fully charged capacitor is then connected to an ideal voltmeter.



The capacitance of the capacitor is $6.0 \mu\text{F}$ and the reading of the voltmeter is 12V .

Calculate the energy stored in the capacitor.

[1]

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- (d) When fully charged the space between the plates of the capacitor is filled with a dielectric with double the permittivity of a vacuum.

(i) Calculate the change in the energy stored in the capacitor.

[3]

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(ii) Suggest, in terms of conservation of energy, the cause for the above change.

[1]

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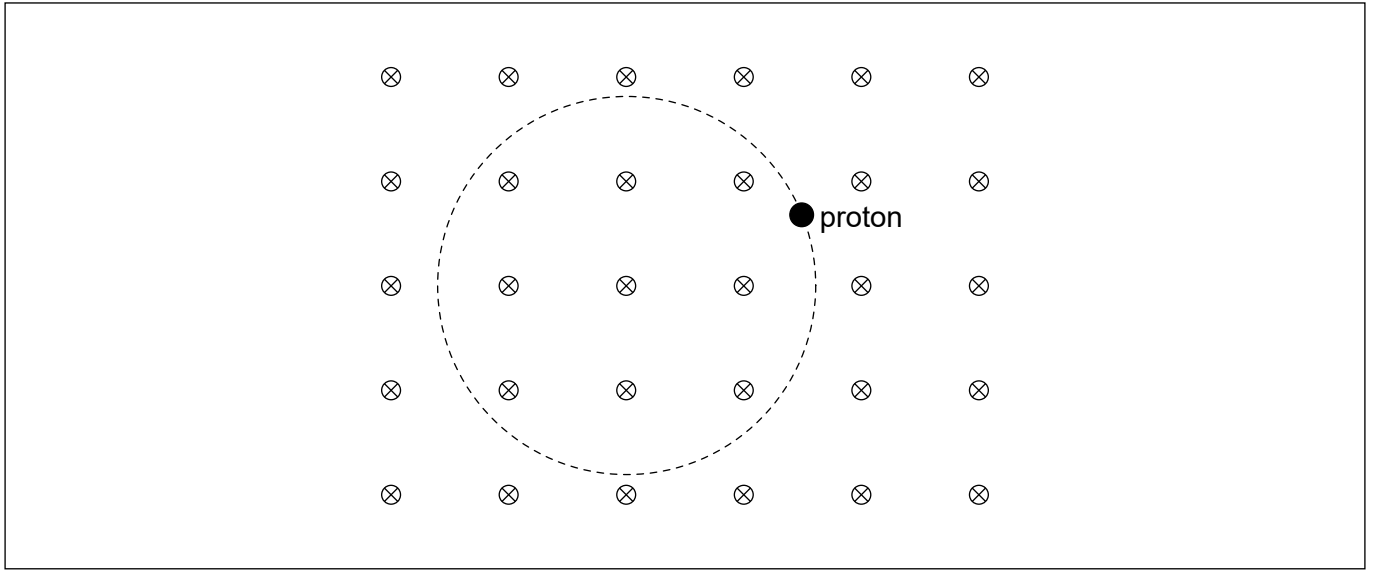


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5. A proton moves along a circular path in a region of a uniform magnetic field. The magnetic field is directed into the plane of the page.



- (a) Label with arrows on the diagram the
 - (i) magnetic force F on the proton. [1]
 - (ii) velocity vector v of the proton. [1]
- (b) The speed of the proton is $2.16 \times 10^6 \text{ m s}^{-1}$ and the magnetic field strength is 0.042 T . For this proton,
 - (i) determine, in m, the radius of the circular path. Give your answer to an appropriate number of significant figures. [3]

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- (ii) calculate, in s, the time for one full revolution. [2]

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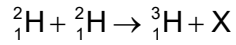
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6. Deuterium, ${}^2_1\text{H}$, undergoes fusion according to the following reaction.



(a) Identify particle X. [1]

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(b) The following data are available for binding energies per nucleon.

$${}^2_1\text{H} = 1.12\text{MeV}$$

$${}^3_1\text{H} = 2.78\text{MeV}$$

(i) Determine, in MeV, the energy released. [2]

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(ii) Suggest why, for the fusion reaction above to take place, the temperature of deuterium must be very high. [2]

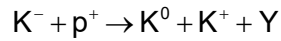
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(Question 6 continued)

(c) Particle Y is produced in the collision of a proton with a K^- in the following reaction.



The quark content of some of the particles involved are

$$K^- = \bar{u}s \quad K^0 = d\bar{s}$$

Identify, for particle Y, the

(i) charge.

[1]

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(ii) strangeness.

[1]

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7. The average temperature of ocean surface water is 289K. Oceans behave as black bodies.

(a) Show that the intensity radiated by the oceans is about 400 W m^{-2} . [1]

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(b) Explain why some of this radiation is returned to the oceans from the atmosphere. [3]

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(c) The intensity in (b) returned to the oceans is 330 W m^{-2} . The intensity of the solar radiation incident on the oceans is 170 W m^{-2} .

(i) Calculate the additional intensity that must be lost by the oceans so that the water temperature remains constant. [2]

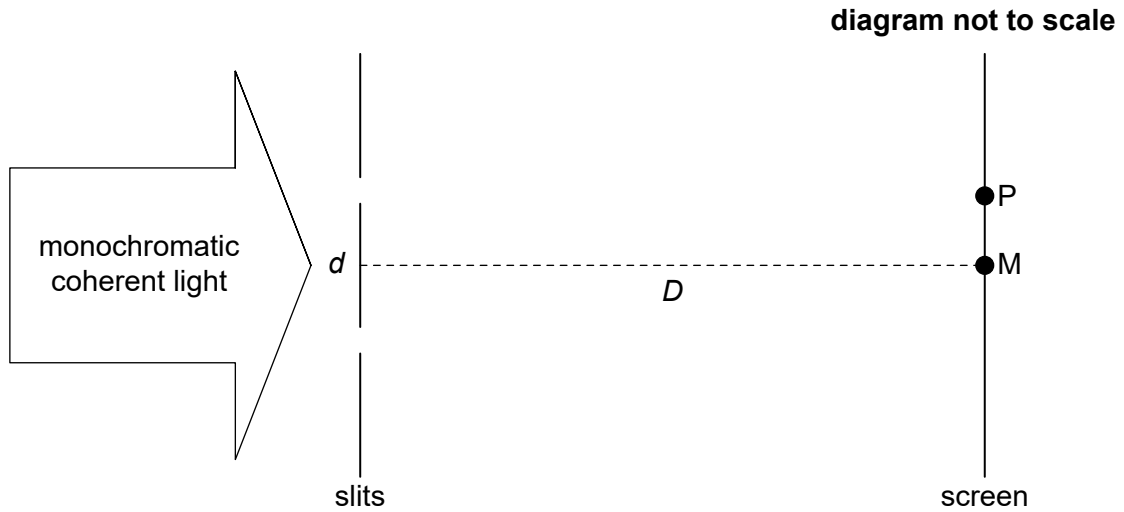
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(ii) Suggest a mechanism by which the additional intensity can be lost. [1]

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8. Monochromatic coherent light is incident on two parallel slits of negligible width a distance d apart. A screen is placed a distance D from the slits. Point M is directly opposite the midpoint of the slits.



Initially the lower slit is covered and the intensity of light at M due to the upper slit alone is 22Wm^{-2} . The lower slit is now uncovered.

- (a) Deduce, in Wm^{-2} , the intensity at M. [3]

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- (b) P is the first maximum of intensity on **one** side of M. The following data are available.

$$d = 0.12\text{ mm}$$
$$D = 1.5\text{ m}$$
$$\text{Distance MP} = 7.0\text{ mm}$$

Calculate, in nm, the wavelength λ of the light. [2]

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(Question 8 continued)

(c) The width of each slit is increased to 0.030 mm. D , d and λ remain the same.

(i) Suggest why, after this change, the intensity at P will be less than that at M. [1]

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(ii) Show that, due to single slit diffraction, the intensity at a point on the screen a distance of 28 mm from M is zero. [2]

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9. (a) A planet of mass m is in a circular orbit around a star. The gravitational potential due to the star at the position of the planet is V .

(i) Show that the total energy of the planet is given by the equation shown. [2]

$$E = \frac{1}{2}mV$$

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(ii) Suppose the star could contract to half its original radius without any loss of mass. Discuss the effect, if any, this has on the total energy of the planet. [2]

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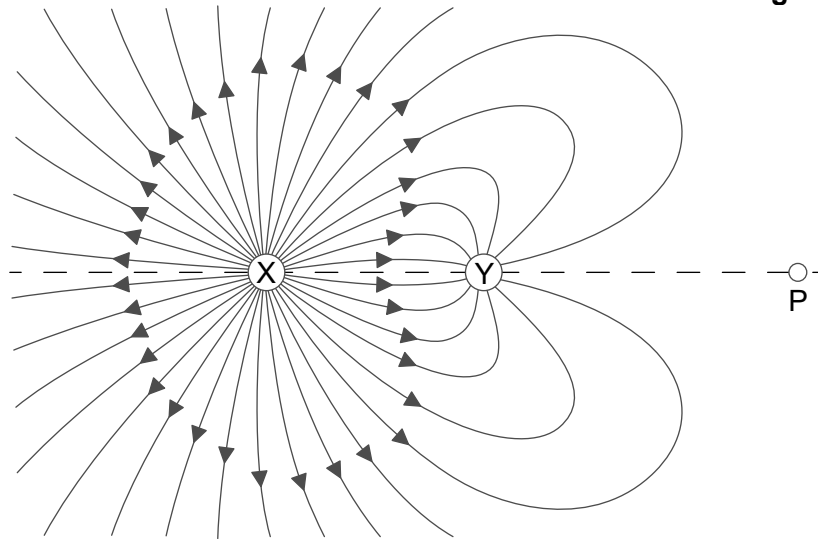
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(Question 9 continued)

(b) The diagram shows some of the electric field lines for two fixed, charged particles X and Y.

diagram not to scale



The magnitude of the charge on X is Q and that on Y is q . The distance between X and Y is 0.600 m. The distance between P and Y is 0.820 m.

At P the electric field is zero. Determine, to **one** significant figure, the ratio $\frac{Q}{q}$. [2]

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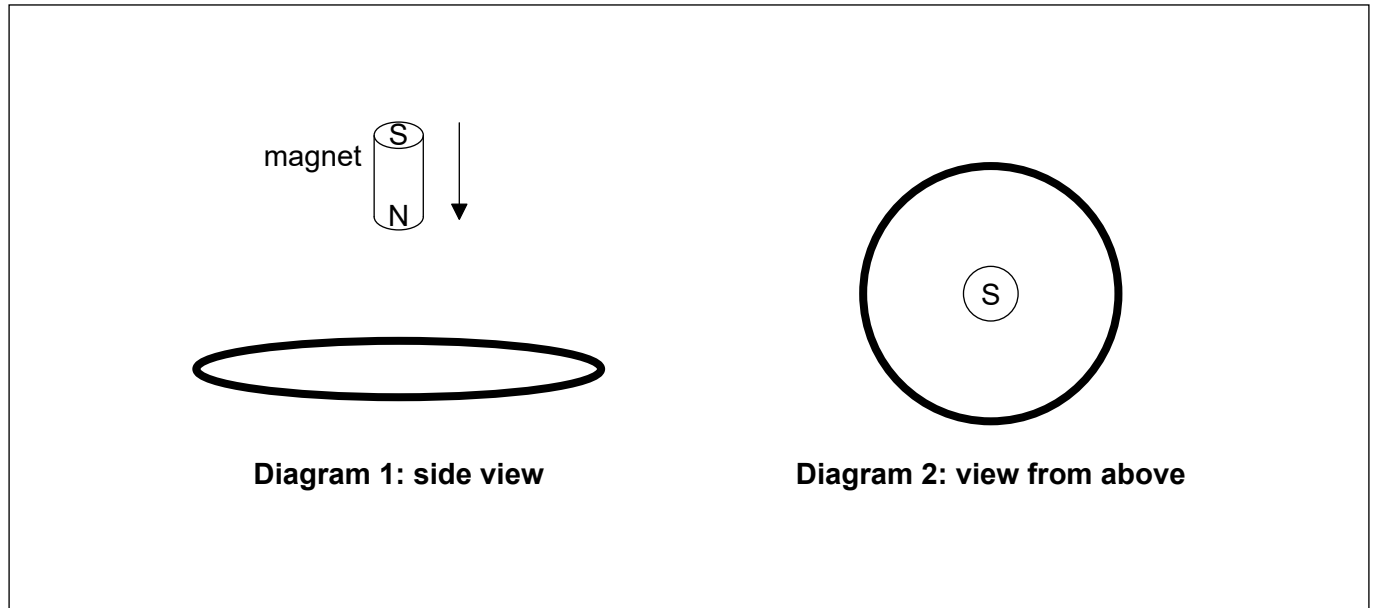


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10. A small magnet is dropped from rest above a stationary horizontal conducting ring. The south (S) pole of the magnet is upwards.



While the magnet is moving towards the ring,

- (a) state why the magnetic flux in the ring is increasing. [1]

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- (b) sketch, using an arrow on **Diagram 2**, the direction of the induced current in the ring. [1]

- (c) deduce the direction of the magnetic force on the magnet. [2]

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11. (a) Suggest why de Broglie's hypothesis is **not** consistent with Bohr's conclusion that the electron's orbit in the hydrogen atom has a well defined radius. [2]

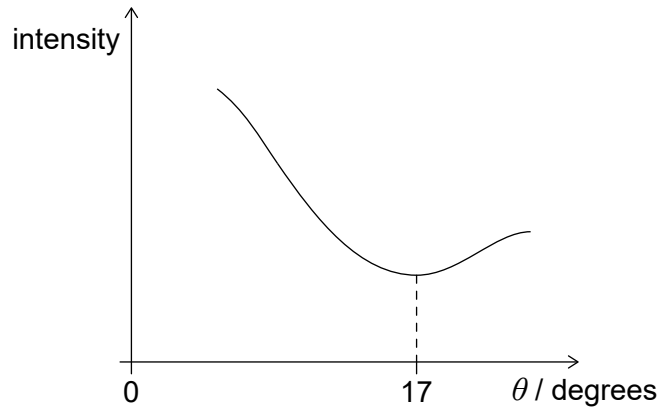
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- (b) In an experiment to determine the radius of a carbon-12 nucleus, a beam of neutrons is scattered by a thin film of carbon-12. The graph shows the variation of intensity of the scattered neutrons with scattering angle. The de Broglie wavelength of the neutrons is 1.6×10^{-15} m.



- (i) Estimate, using the graph, the radius of a carbon-12 nucleus. [2]

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- (ii) The ratio $\frac{\text{volume of a nucleus of mass number } A}{\text{volume of a nucleon}}$ is approximately A .

Comment on this observation by reference to the strong nuclear force. [2]

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(Question 11 continued)

(c) A pure sample of copper-64 has a mass of 28 mg. The decay constant of copper-64 is $5.5 \times 10^{-2} \text{ hour}^{-1}$.

(i) Estimate, in Bq, the initial activity of the sample. [2]

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(ii) Calculate, in hours, the time at which the activity of the sample has decreased to one-third of the initial activity. [2]

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