Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Thursday 4 November 2021 (afternoon)

Candidate session number

2 hours 15 minutes

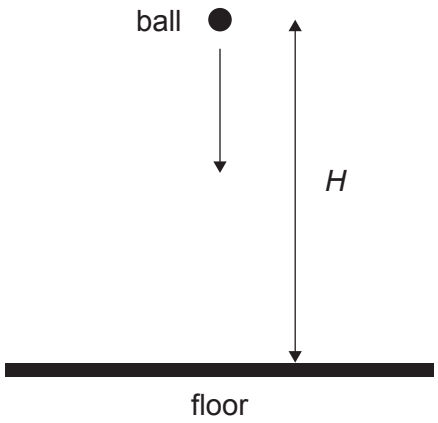
Instructions to candidates

- 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 **[90 marks]**.

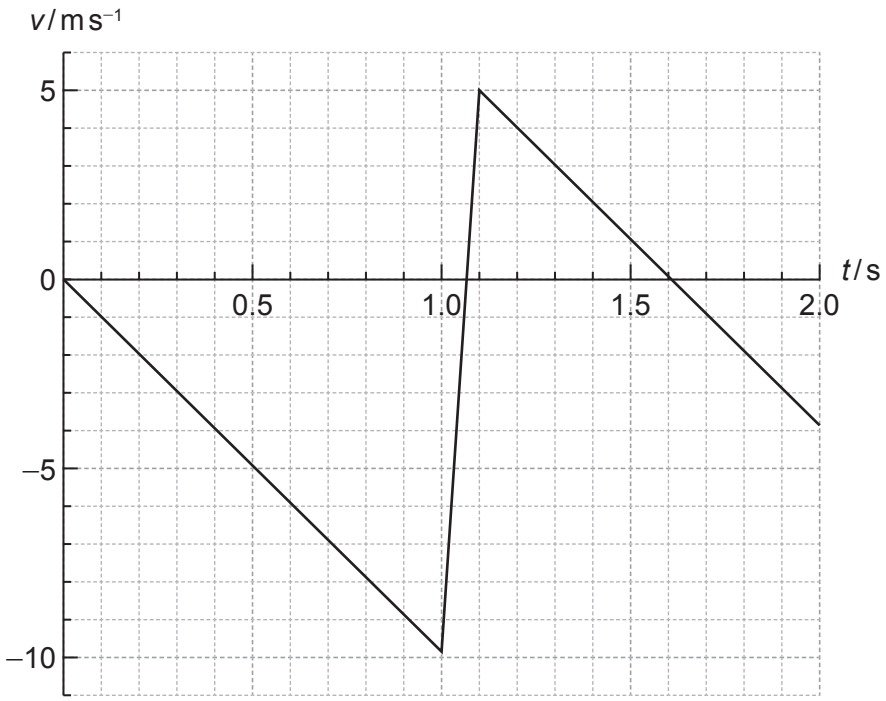
8821 – 6502

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

1. A ball of mass 0.250 kg is released from rest at time $t = 0$, from a height H above a horizontal floor.



The graph shows the variation with time t of the velocity v of the ball. Air resistance is negligible. Take $g = -9.80\,\text{m s}^{-2}$. The ball reaches the floor after 1.0 s.



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(Question 1 continued)

(a) Determine *H*. [1]

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(b) (i) Label the time and velocity graph, using the letter M, the point where the ball reaches the maximum rebound height. [1]

(ii) State the acceleration of the ball at the maximum rebound height. [1]

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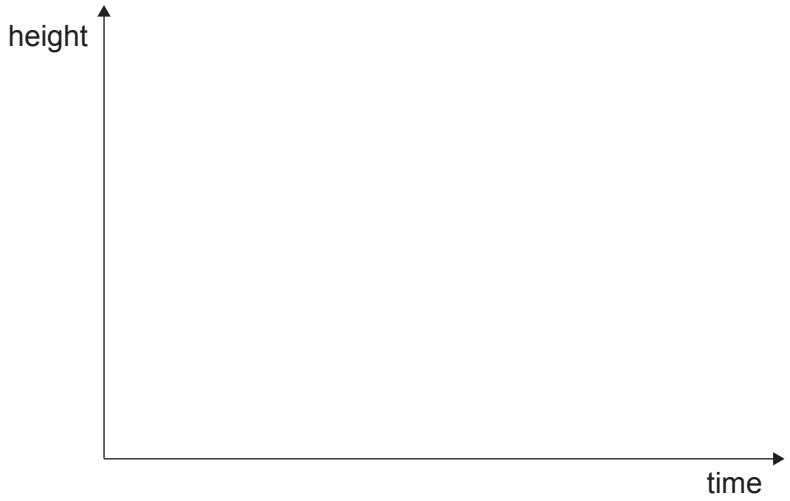
(iii) Draw, on the axes, a graph to show the variation with time of the height of the ball from the instant it rebounds from the floor until the instant it reaches the maximum rebound height. No numbers are required on the axes. [1]



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(Question 1 continued)

(c) Estimate the loss in the mechanical energy of the ball as a result of the collision with the floor. [1]

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(d) (i) Determine the average force exerted on the floor by the ball. [3]

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(ii) Suggest why the momentum of the ball was not conserved during the collision with the floor. [1]

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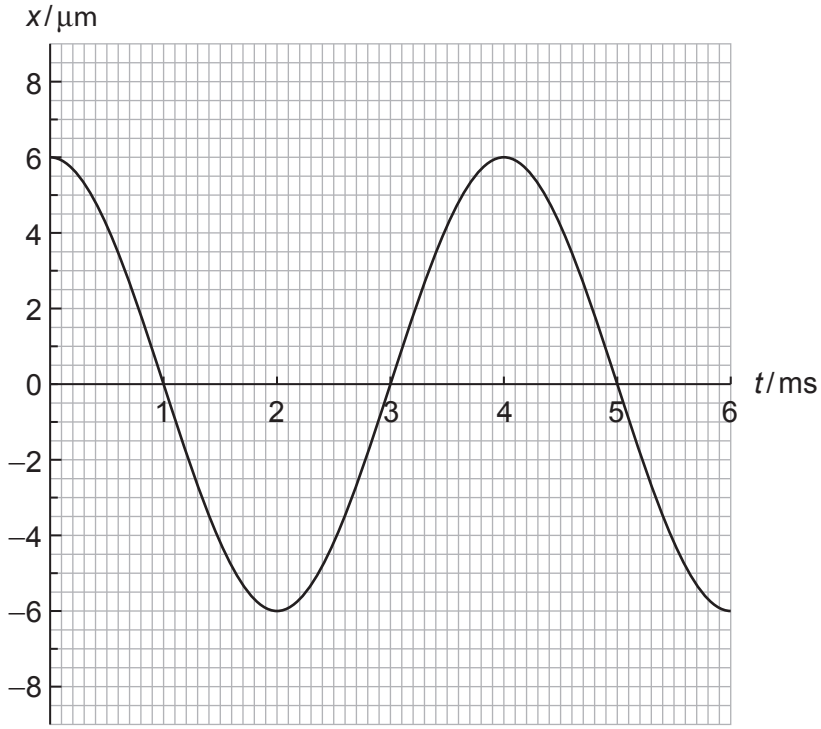
2. A longitudinal wave travels in a medium with speed $340\,\text{m}\,\text{s}^{-1}$. The graph shows the variation with time t of the displacement x of a particle P in the medium. Positive displacements on the graph correspond to displacements to the right for particle P.



(a) Calculate the wavelength of the wave. [2]

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(b) Determine, for particle P, the magnitude and direction of the acceleration at $t = 2.0\,\text{m}\,\text{s}$ [3]

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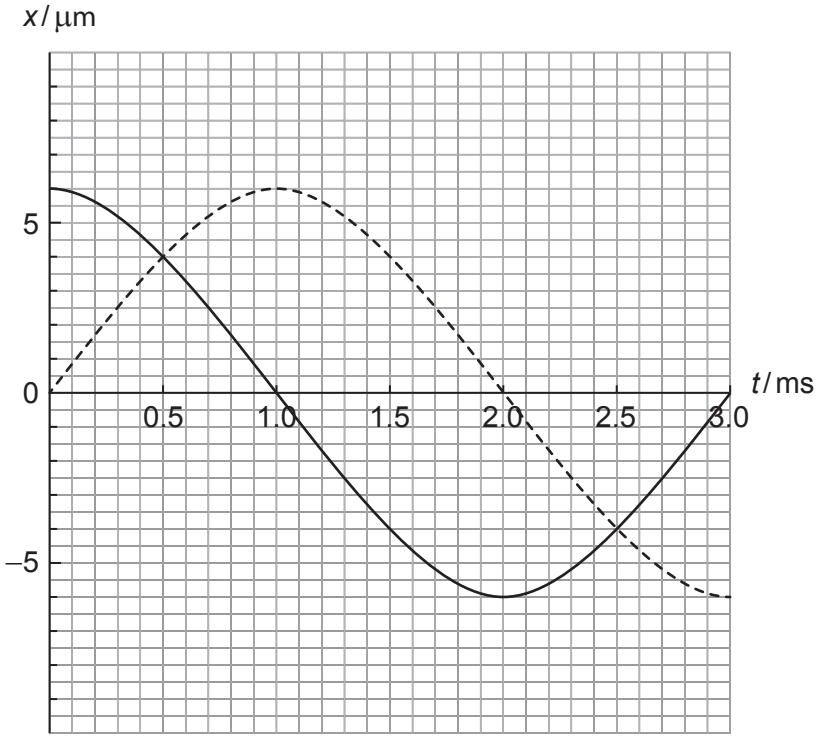
(Question 2 continued)

(c) Another wave travels in the medium. The graph shows the variation with time t of the displacement of each wave at the position of P.



(i) State the phase difference between the two waves. [1]

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(ii) Identify a time at which the displacement of P is zero. [1]

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(iii) Estimate the amplitude of the resultant wave. [1]

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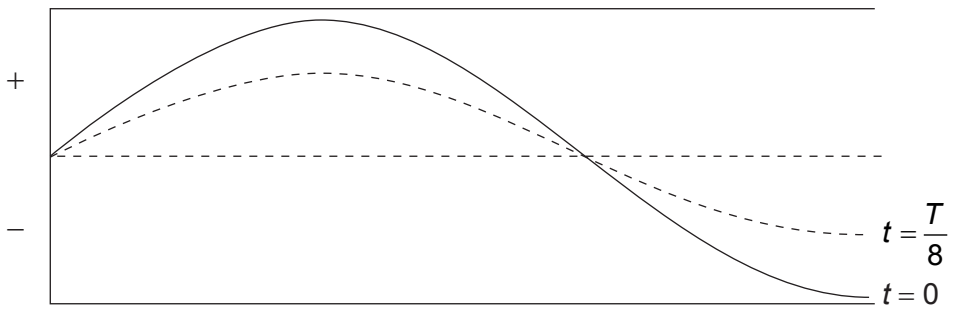
(Question 2 continued)

(d) A standing sound wave is established in a tube that is closed at one end and open at the other end. The period of the wave is T. The diagram represents the standing wave at $t = 0$ and at $t = \frac{T}{8}$. The wavelength of the wave is 1.20 m. Positive displacements mean displacements to the right.



(i) Calculate the length of the tube. [1]

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(ii) A particle in the tube has its equilibrium position at the open end of the tube. State and explain the direction of the velocity of this particle at time $t = \frac{T}{8}$ [2]

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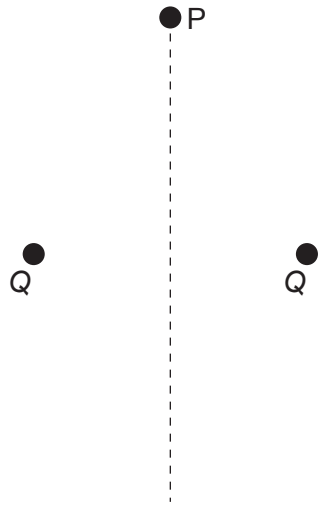
(iii) Draw on the diagram the standing wave at time $t = \frac{T}{4}$ [1]

3. Two equal positive fixed point charges $Q = +44\,\mu C$ and point P are at the vertices of an equilateral triangle of side 0.48 m.



(a) (i) Show that the magnitude of the resultant electric field at P is $3\,MN\,C^{-1}$ [2]

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(ii) State the direction of the resultant electric field at P. [1]

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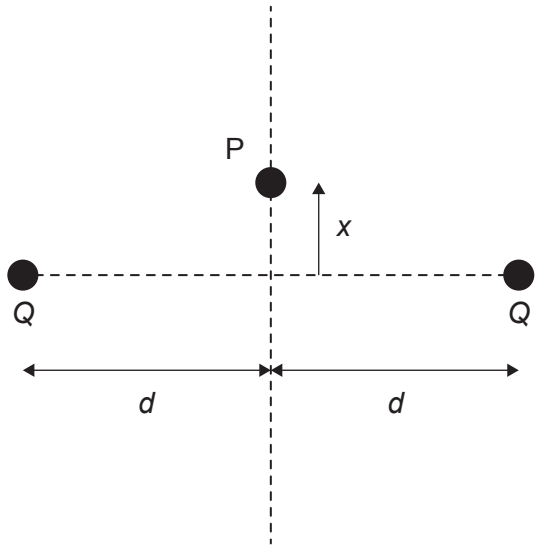
(Question 3 continued)

(b) Point P is now moved closer to the charges.



A point charge $q = -2.0\,\mu C$ and mass 0.25 kg is placed at P. When x is small compared to d, the magnitude of the net force on q is $F \approx 115x$.

(i) Explain why q will perform simple harmonic oscillations when it is released. [2]

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(ii) Calculate the period of oscillations of q. [2]

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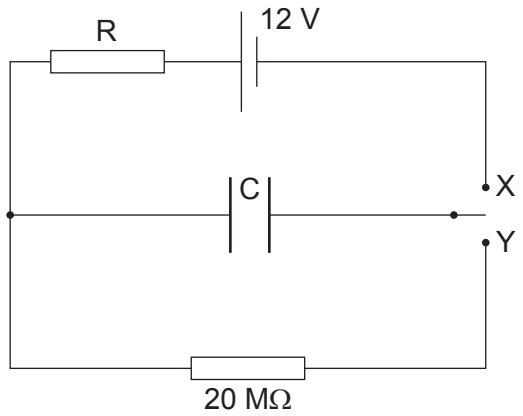
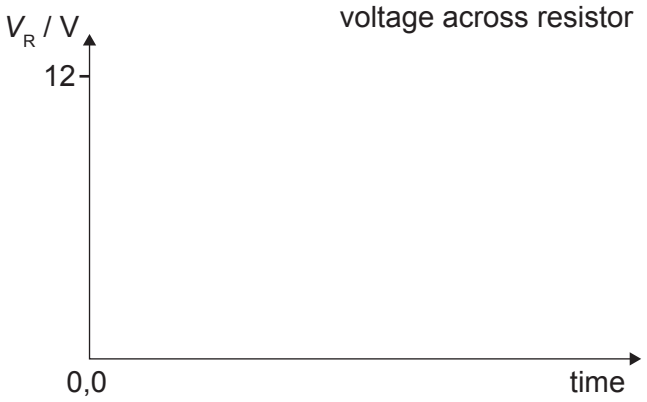
(Question 3 continued)

(c) An uncharged parallel plate capacitor C is connected to a cell of emf 12 V, a resistor R and another resistor of resistance 20 MΩ.



(i) At $t = 0$, the switch is connected to X. On the axes, draw a sketch graph to show the variation with time of the voltage V_R across R. [2]



(ii) The switch is then connected to Y and C discharges through the 20 MΩ resistor. The voltage V_C drops to 50 % of its initial value in 5.0 s. Determine the capacitance of C. [2]

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4. (a) (i) State what is meant by the binding energy of a nucleus. [1]

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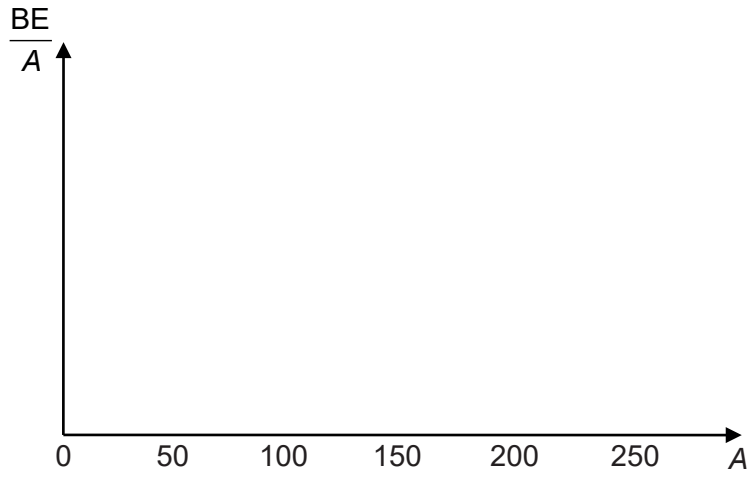
(ii) Draw, on the axes, a graph to show the variation with nucleon number A of the binding energy per nucleon, $\frac{BE}{A}$. Numbers are not required on the vertical axis. [2]



(iii) Identify, with a cross, on the graph in (a)(ii), the region of greatest stability. [1]

(iv) Some unstable nuclei have many more neutrons than protons. Suggest the likely decay for these nuclei. [1]

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(This question continues on the following page)

(Question 4 continued)

(b) Plutonium-238 (Pu) decays by alpha (α) decay into uranium (U).

The following data are available for binding energies per nucleon:

plutonium	7.568 MeV
uranium	7.600 MeV
alpha particle	7.074 MeV

(i) Show that the energy released in this decay is about 6 MeV. [3]

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(ii) The plutonium nucleus is at rest when it decays.

Calculate the ratio $\frac{\text{kinetic energy of alpha particle}}{\text{kinetic energy of uranium}}$ [2]

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(Question 4 continued)

(c) The energy in b(i) can be transferred into electrical energy to run the instruments of a spacecraft. A spacecraft carries 33 kg of pure plutonium-238 at launch. The decay constant of plutonium is $2.50 \times 10^{-10}\,s^{-1}$

(i) Estimate the power, in kW, that is available from the plutonium at launch. [3]

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(ii) The spacecraft will take 7.2 years (2.3×10^{8} s) to reach a planet in the solar system. Estimate the power available to the spacecraft when it gets to the planet. [2]

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(Question 4 continued)

(d) Solar radiation falls onto a metallic surface carried by the spacecraft causing the emission of photoelectrons. The radiation has passed through a filter so it is monochromatic. The spacecraft is moving away from the Sun. State and explain what happens to

(i) the kinetic energy of an emitted photoelectron. [2]

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(ii) the rate at which charge leaves the metallic surface. [2]

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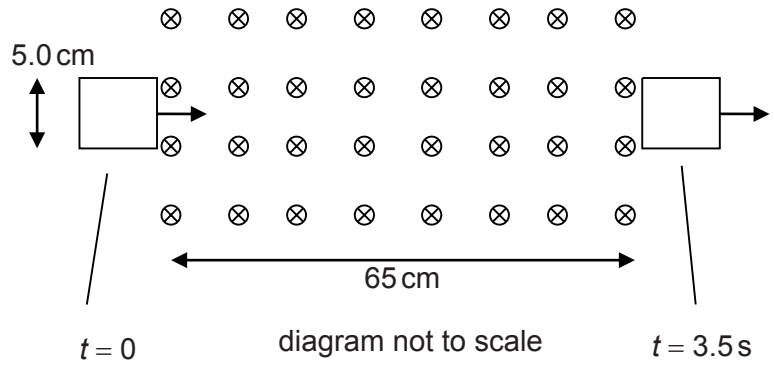
5. A square loop of side 5.0 cm enters a region of uniform magnetic field at $t = 0$. The loop exits the region of magnetic field at $t = 3.5$ s. The magnetic field strength is 0.94 T and is directed into the plane of the paper. The magnetic field extends over a length 65 cm. The speed of the loop is constant.



(a) Show that the speed of the loop is 20 cm s^{-1} [1]

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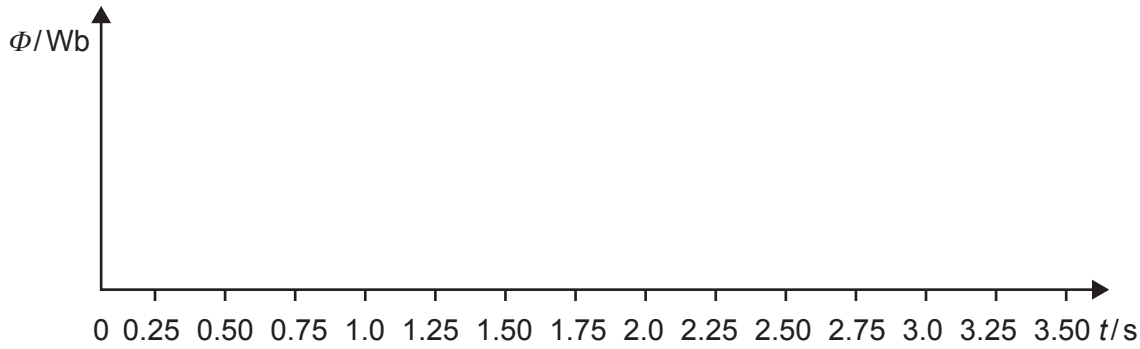
(b) Sketch graphs, on the axes, to show the variation with time of

(i) the magnetic flux linkage Φ in the loop. [1]



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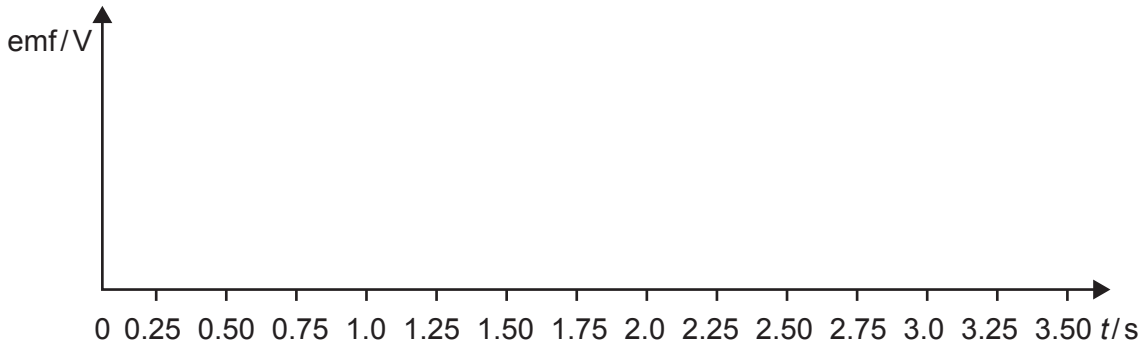
(Question 5 continued)

(ii) the magnitude of the emf induced in the loop. [1]



(c) (i) There are 85 turns of wire in the loop. Calculate the maximum induced emf in the loop. [2]

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(ii) The resistance of the loop is 2.4 Ω. Calculate the magnitude of the magnetic force on the loop as it enters the region of magnetic field. [2]

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(Question 5 continued)

(d) (i) Show that the energy dissipated in the loop from $t = 0$ to $t = 3.5\,s$ is $0.13\,J$. [2]

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(ii) The mass of the wire is $18\,g$. The specific heat capacity of copper is $385\,J\,kg^{-1}\,K^{-1}$. Estimate the increase in temperature of the wire. [2]

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6. (a) Titan is a moon of Saturn. The Titan-Sun distance is 9.3 times greater than the Earth-Sun distance.

(i) Show that the intensity of the solar radiation at the location of Titan is $16\,W\,m^{-2}$ [1]

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(ii) Titan has an atmosphere of nitrogen. The albedo of the atmosphere is 0.22. The surface of Titan may be assumed to be a black body. Explain why the **average** intensity of solar radiation **absorbed** by the whole surface of Titan is $3.1\,W\,m^{-2}$ [3]

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(iii) Show that the equilibrium surface temperature of Titan is about 90 K. [1]

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(This question continues on the following page)

(Question 6 continued)

(b) The mass of Titan is 0.025 times the mass of the Earth and its radius is 0.404 times the radius of the Earth. The escape speed from Earth is $11.2\,\text{km}\,\text{s}^{-1}$. Show that the escape speed from Titan is $2.8\,\text{km}\,\text{s}^{-1}$ [1]

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(c) (i) The orbital radius of Titan around Saturn is R and the period of revolution is T. Show that $T^2 = \dfrac{4\pi^2 R^3}{GM}$ where M is the mass of Saturn. [2]

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(ii) The orbital radius of Titan around Saturn is $1.2 \times 10^9\,\text{m}$ and the orbital period is 15.9 days. Estimate the mass of Saturn. [2]

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(Question 6 continued)

(d) The molar mass of nitrogen is $28\,g\,mol^{-1}$

(i) Show that the mass of a nitrogen molecule is 4.7×10^{-26} kg. [1]

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(ii) Estimate the root mean square speed of nitrogen molecules in the Titan atmosphere. Assume an atmosphere temperature of 90 K. [2]

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(e) Discuss, by reference to the answer in (b), whether it is likely that Titan will lose its atmosphere of nitrogen. [1]

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7. A conducting sphere has radius 48 cm. The electric potential on the surface of the sphere is 3.4×10^5 V.

(a) Show that the charge on the surface of the sphere is $+18\,\mu$C. [1]

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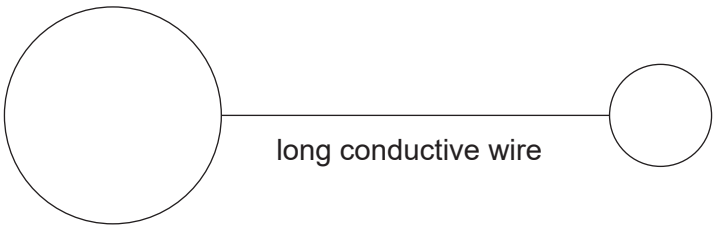
(b) The sphere is connected by a long conducting wire to a second conducting sphere of radius 24 cm. The second sphere is initially uncharged.



(i) Describe, in terms of electron flow, how the smaller sphere becomes charged. [1]

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(ii) Predict the charge on each sphere. [3]

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8. (a) State what is meant by the Doppler effect. [2]

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(b) A plate performs simple harmonic oscillations with a frequency of 39 Hz and an amplitude of 8.0 cm.

Show that the maximum speed of the oscillating plate is about 20 m s^{-1} [2]

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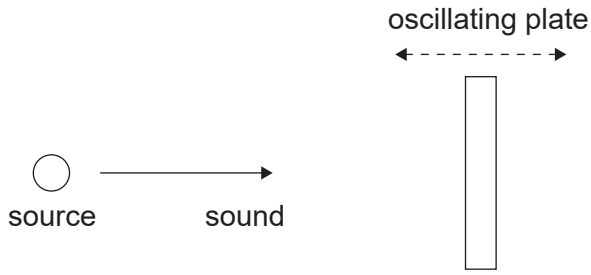
(c) Sound of frequency 2400 Hz is emitted from a stationary source towards the oscillating plate in (b). The speed of sound is 340 m s^{-1}



Determine the maximum frequency of the sound that is received back at the source after reflection at the plate. [2]

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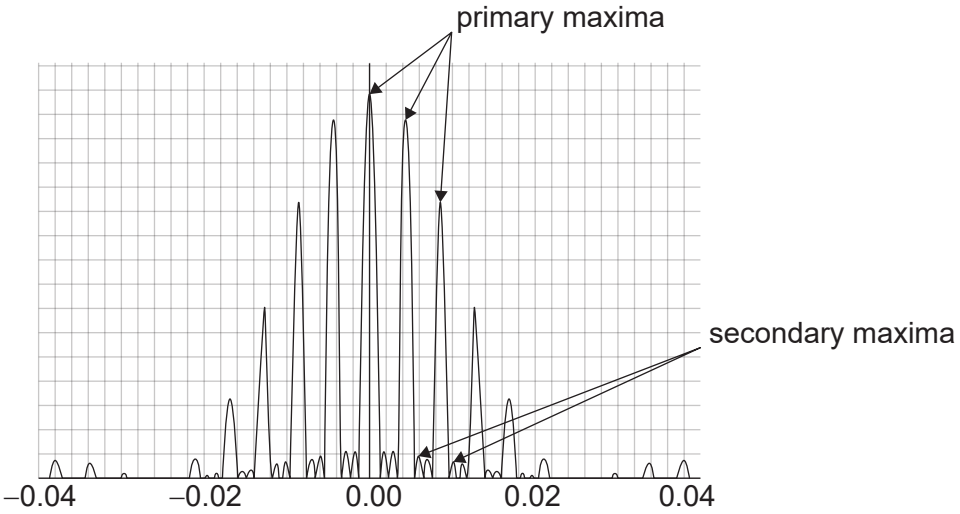
(Question 8 continued)

(d) The graph shows the variation with diffraction angle of the intensity of light after it has passed through four parallel slits.



The number of slits is increased but their separation and width stay the same. All slits are illuminated. State what will happen to

(i) the angular position of the primary maxima [1]

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(ii) the width of the primary maxima [1]

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(iii) the intensity of the secondary maxima. [1]

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References:

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