Diploma Programme
Programme du diplôme
Programa del Diploma

**Physics
Higher level
Paper 2**

Thursday 28 April 2022 (morning)

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]**.

28EP01

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Answers written on this page
will not be marked.

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

1. Airboats are used for transport across a river. To move the boat forward, air is propelled from the back of the boat by a fan blade.

bank   rope   fan blade   river
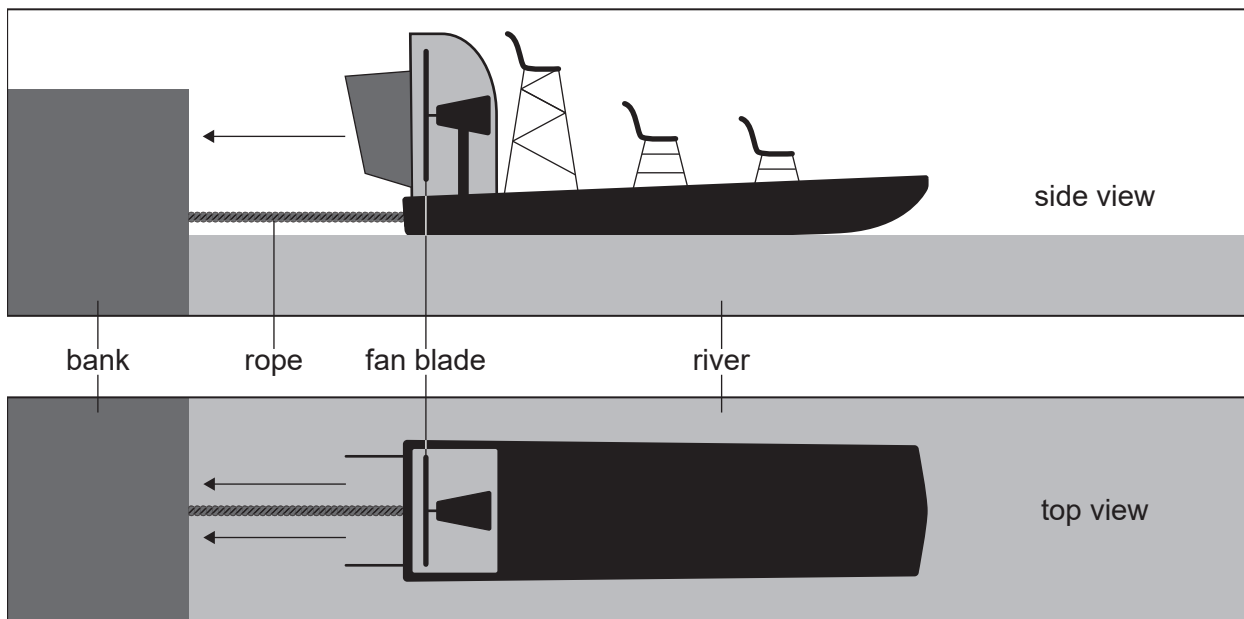
An airboat has a fan blade of radius 1.8 m. This fan can propel air with a maximum speed relative to the boat of $20\,\mathrm{m\,s^{-1}}$. The density of air is $1.2\,\mathrm{kg\,m^{-3}}$.

(a) Outline why a force acts on the airboat due to the fan blade. [3]

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(This question continues on the following page)

(Question 1 continued)

(b)   In a test the airboat is tied to the river bank with a rope normal to the bank. The fan
       propels the air at its maximum speed. There is no wind.

(i)   Show that a mass of about 240 kg of air moves through the fan every second.   [2]

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(ii)   Show that the tension in the rope is about 5 kN.   [1]

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(c)   The rope is untied and the airboat moves away from the bank. The variation with time t
       of the speed v of the airboat is shown for the motion.
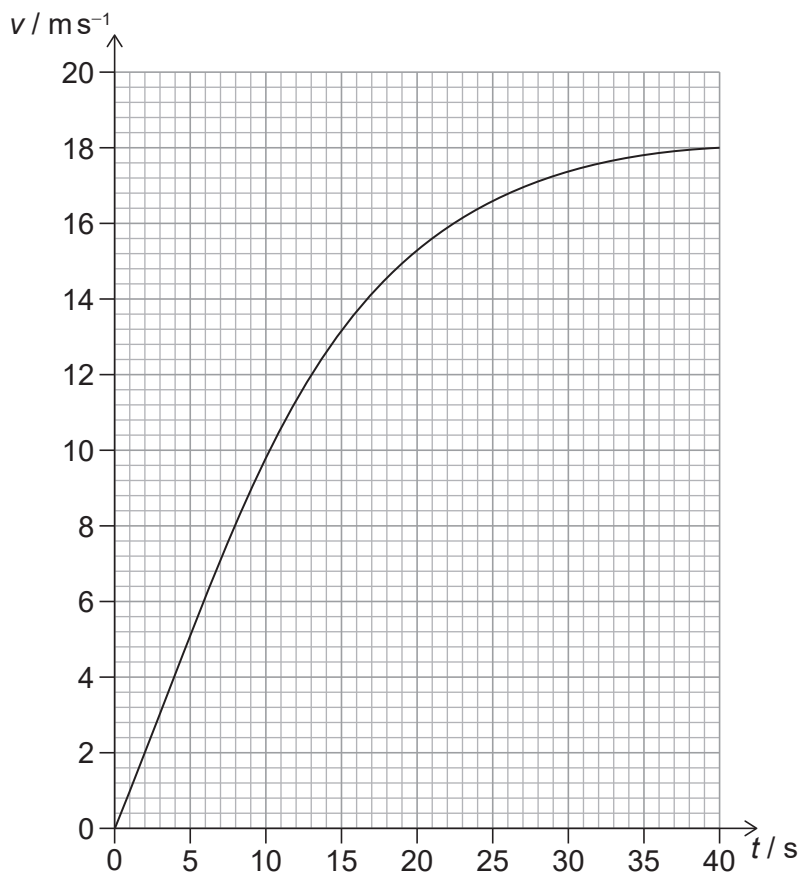
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(Question 1 continued)

(i) Explain why the airboat has a maximum speed under these conditions. [2]

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(ii) Estimate the distance the airboat travels to reach its maximum speed. [2]

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(iii) Deduce the mass of the airboat. [3]

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2. A fixed mass of an ideal gas is contained in a cylinder closed with a frictionless piston. The volume of the gas is $2.5 \times 10^{-3}\,\text{m}^3$ when the temperature of the gas is $37\,°\text{C}$ and the pressure of the gas is $4.0 \times 10^5\,\text{Pa}$.

(a) Calculate the number of gas particles in the cylinder. [2]

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(b) Energy is now supplied to the gas and the piston moves to allow the gas to expand. The temperature is held constant.

Discuss, for this process, the changes that occur in the

(i) density of the gas. [2]

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(ii) internal energy of the gas. [2]

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3. A loudspeaker emits sound waves of frequency f towards a metal plate that reflects the waves. A small microphone is moved along the line from the metal plate to the loudspeaker. The intensity of sound detected at the microphone as it moves varies regularly between maximum and minimum values.

loudspeaker   microphone   metal plate
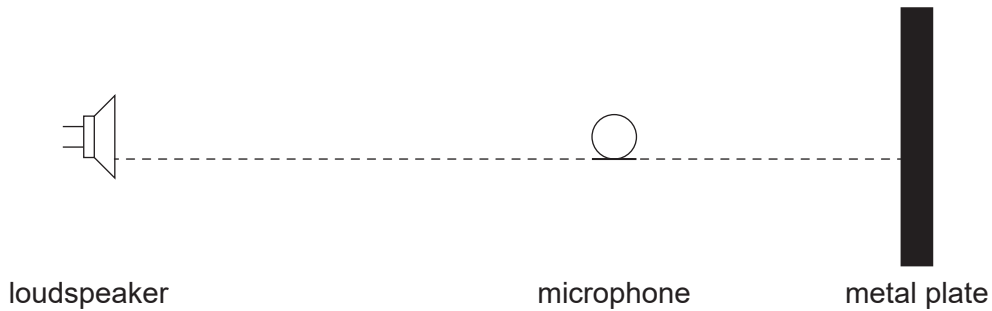
The speed of sound in air is $340\,\text{m s}^{-1}$.

(a) (i)   Explain the variation in intensity. [3]

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(ii)   Adjacent minima are separated by a distance of $0.12\,\text{m}$. Calculate f. [2]

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(This question continues on the following page)

(Question 3 continued)

(b) The metal plate is replaced by a wooden plate that reflects a lower intensity sound wave than the metal plate.

State and explain the differences between the sound intensities detected by the same microphone with the metal plate and the wooden plate. [3]

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4. (a) Identify the laws of conservation that are represented by Kirchhoff's circuit laws. [2]

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(b) A cell is connected to an ideal voltmeter, a switch S and a resistor R. The resistance of R is $4.0\,\Omega$.
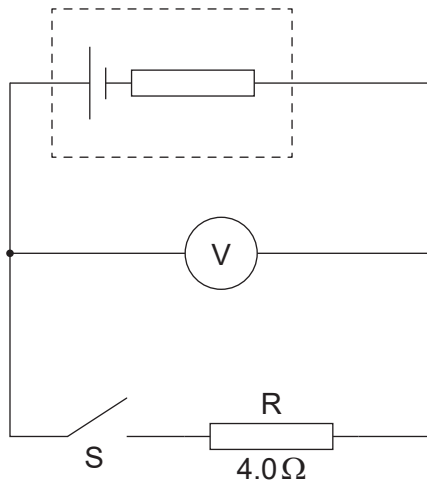
When S is open the reading on the voltmeter is 12 V. When S is closed the voltmeter reads 8.0 V.

(i) State the emf of the cell. [1]

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(ii) Deduce the internal resistance of the cell. [2]

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(This question continues on the following page)

(Question 4 continued)

(c)   The voltmeter is used in another circuit that contains two secondary cells.

cell A

10 V   1.0 Ω

V

cell B

4.0 V   2.0 Ω
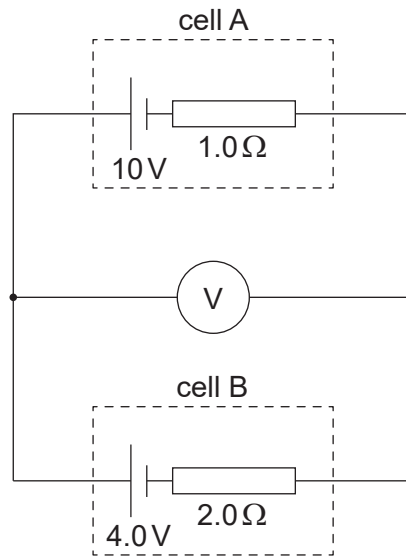
Cell A has an emf of 10 V and an internal resistance of 1.0 Ω. Cell B has an emf of 4.0 V and an internal resistance of 2.0 Ω.

(i)   Calculate the reading on the voltmeter.   [3]

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(ii)   Comment on the implications of your answer to (c)(i) for cell B.   [1]

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(Question 4 continued)

    (d)   Electricity can be generated using renewable resources.

        (i)   Outline why electricity is a secondary energy source.   [1]

        (ii)   Some fuel sources are renewable. Outline what is meant by renewable.   [1]

    (e)   (i)   A fully charged cell of emf 6.0 V delivers a constant current of 5.0 A for a time of 0.25 hour until it is completely discharged.

                The cell is then re-charged by a rectangular solar panel of dimensions $0.40\,\text{m} \times 0.15\,\text{m}$ at a place where the maximum intensity of sunlight is $380\,\text{W m}^{-2}$.

                The overall efficiency of the re-charging process is 18%.

                Calculate the minimum time required to re-charge the cell fully.   [3]

        (ii)   Outline why research into solar cell technology is important to society.   [1]

5. An experiment is carried out to determine the count rate, corrected for background radiation, when different thicknesses of copper are placed between a radioactive source and a detector. The graph shows the variation of corrected count rate with copper thickness.
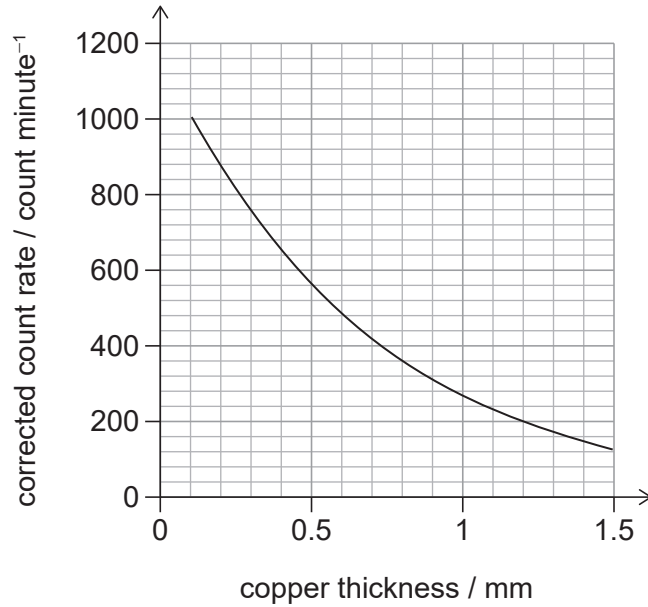
(a)   Outline how the count rate was corrected for background radiation. [1]

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(b)   When a single piece of thin copper foil is placed between the source and detector, the count rate is 810 count minute^{-1}. The foil is replaced with one that has three times the thickness. Estimate the new count rate. [2]

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(This question continues on the following page)

(Question 5 continued)

(c)   Further results were obtained in this experiment with copper and lead absorbers.

Absorber	Thickness / mm	Corrected count rate / count minute^{-1}
copper	3.5	32
lead	3.5	10

Comment on the radiation detected from this radioactive source.   [4]

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(d)   Another radioactive source consists of a nuclide of caesium ($^{137}_{55}$Cs) that decays to barium ($^{137}_{56}$Ba).

Write down the reaction for this decay.   [2]

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6. An experiment to investigate simple harmonic motion consists of a mass oscillating at the end of a vertical spring.
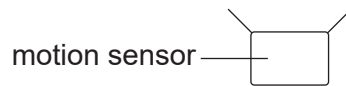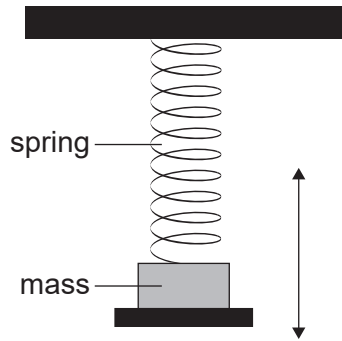
The mass oscillates vertically above a motion sensor that measures the speed of the mass. Test 1 is carried out with a 1.0 kg mass and spring of spring constant k_1. Test 2 is a repeat of the experiment with a 4.0 kg mass and spring of spring constant k_2.

The variation with time of the vertical speed of the masses, for one cycle of the oscillation, is shown for each test.
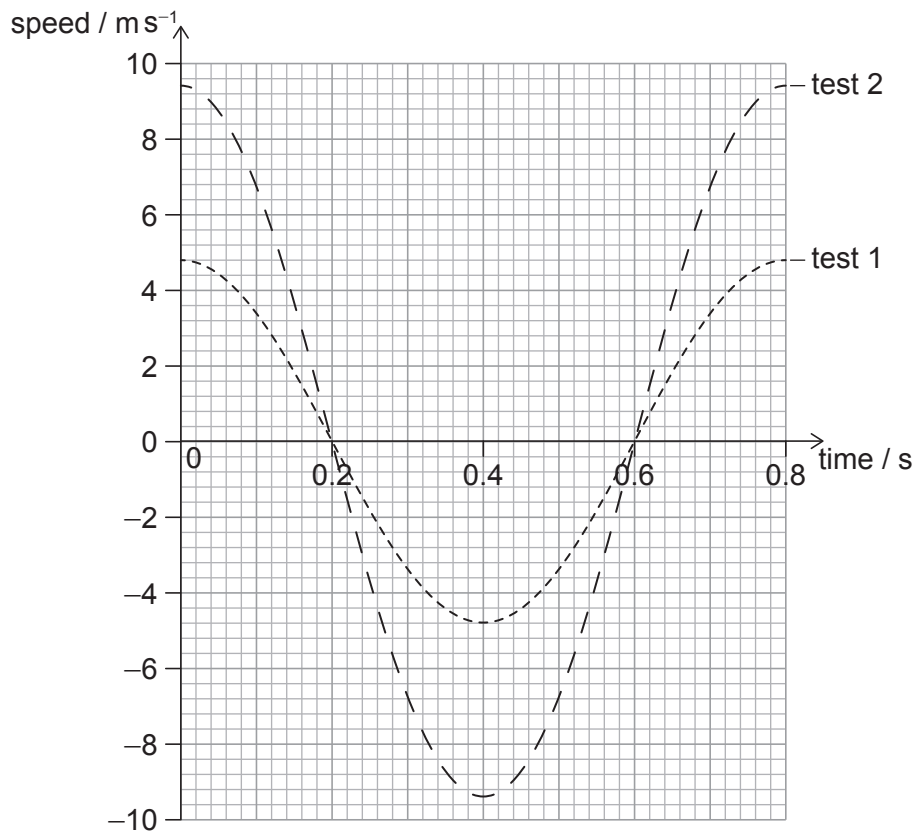
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(Question 6 continued)

    (a)   (i)   Calculate the frequency of the oscillation for both tests. [1]

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          (ii)   Deduce $\dfrac{k_1}{k_2}$. [2]

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          (iii)   Determine the amplitude of oscillation for test 1. [2]

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(Question 6 continued)

(iv) In test 2, the maximum elastic potential energy E_p stored in the spring is 44 J.

When $t = 0$ the value of E_p for test 2 is zero.

Sketch, on the axes, the variation with time of E_p for test 2.   [2]

E_p / J

50 ⊣

40 ⊣

30 ⊣

20 ⊣

10 ⊣

0

0   0.1   0.2   0.3   0.4   0.5   0.6   0.7   0.8 t / s

−10 ⊣

−20 ⊣

−30 ⊣

−40 ⊣

−50 ⊣
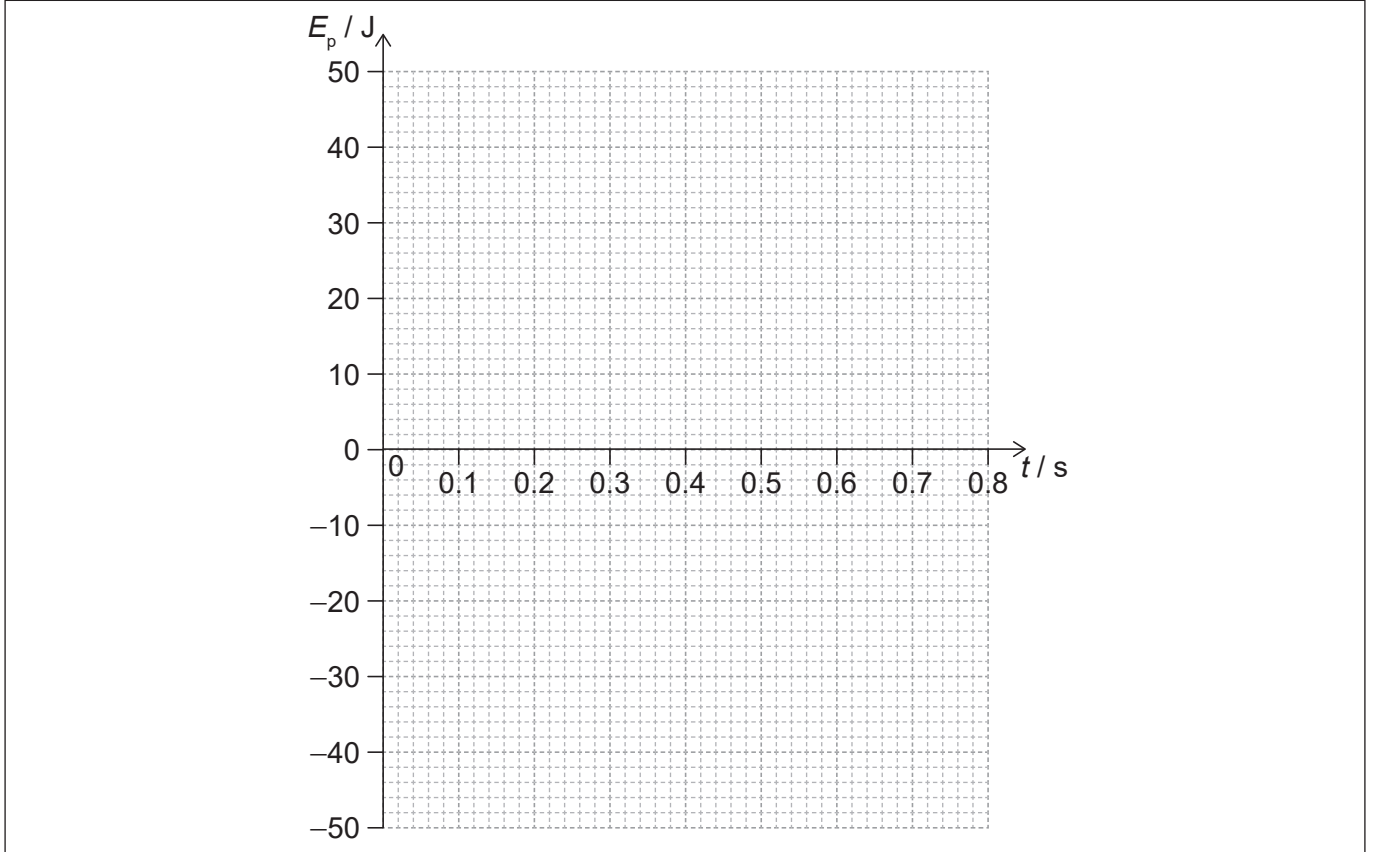
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(Question 6 continued)

(b)   The motion sensor operates by detecting the sound waves reflected from the base of the mass. The sensor compares the frequency detected with the frequency emitted when the signal returns.

The sound frequency emitted by the sensor is 35 kHz. The speed of sound is $340\,m\,s^{-1}$.

Determine the maximum frequency change detected by the sensor for test 2.   [4]

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Turn over

7. A metal sphere is charged positively and placed far away from other charged objects. The electric potential at a point on the surface of the sphere is 53.9 kV.

(a) Outline what is meant by electric potential at a point. [2]

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(b) The electric potential at a point a distance 2.8 m from the centre of the sphere is 7.71 kV. Determine the radius of the sphere. [2]

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(Question 7 continued)

(c) A small positively charged object moves towards the centre of the metal sphere.
When the object is 2.8 m from the centre of the sphere, its speed is $3.1\,m\,s^{-1}$.
The mass of the object is 0.14 g and its charge is $2.4 \times 10^{-8}\,C$.

(i) Comment on the angle at which the object meets equipotential surfaces around the sphere. [1]

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(ii) Show that the kinetic energy of the object is about 0.7 mJ. [1]

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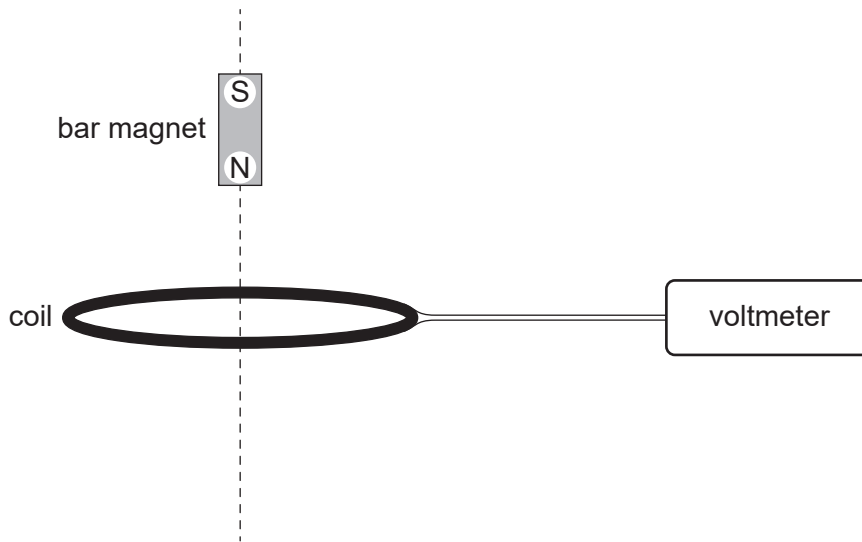...

(iii) Determine whether the object will reach the surface of the sphere. [3]

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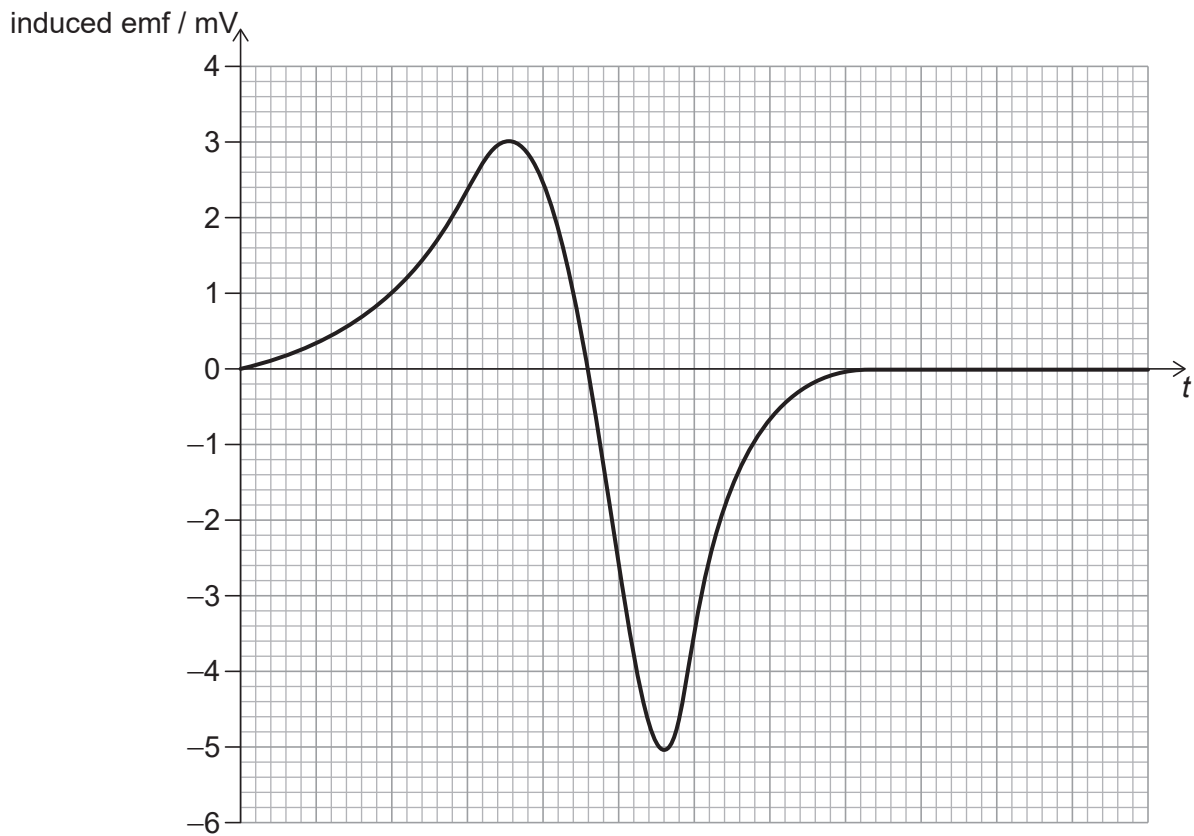...

8. A fixed horizontal coil is connected to an ideal voltmeter. A bar magnet is released from rest so that it falls vertically through the coil along the central axis of the coil.

The variation with time *t* of the emf induced in the coil is shown.

induced emf / mV

(This question continues on the following page)

(Question 8 continued)

(a) (i) Write down the maximum magnitude of the rate of change of flux linked with the coil. [1]

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(ii) State the fundamental SI unit for your answer to (a)(i). [1]

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(b) (i) Explain why the graph becomes negative. [3]

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(ii) Part of the graph is above the *t*-axis and part is below. Outline why the areas between the *t*-axis and the curve for these two parts are likely to be the same. [2]

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(Question 8 continued)

(c) Predict the changes to the graph when the magnet is dropped from a lower height above the coil. [3]
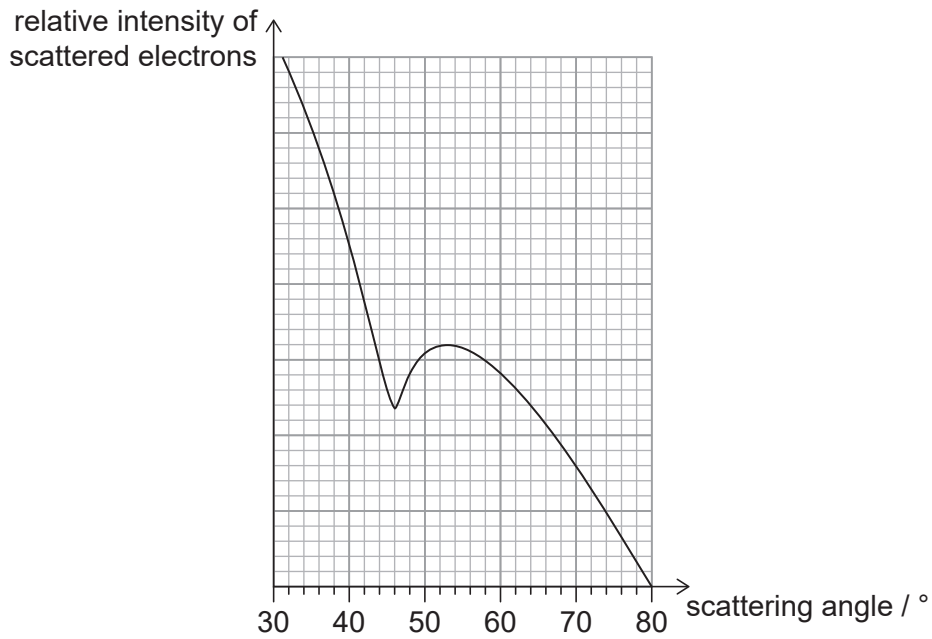
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9. In an experiment a beam of electrons with energy 440 MeV are incident on oxygen-16 ($^{16}_{8}O$) nuclei. The variation with scattering angle of the relative intensity of the scattered electrons is shown.

(a) (i) Identify a property of electrons demonstrated by this experiment.   [1]

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(ii) Show that the energy E of each electron in the beam is about 7×10^{-11} J.   [1]

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(This question continues on the following page)

(Question 9 continued)

    (iii)   The de Broglie wavelength for an electron is given by $\dfrac{hc}{E}$. Show that the diameter of an oxygen-16 nucleus is about 4 fm.   [3]

    (b)   Estimate, using the result in (a)(iii), the volume of a tin-118 ($^{118}_{50}$Sn) nucleus. State your answer to an appropriate number of significant figures.   [4]

References:

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