OCR
Oxford Cambridge and RSA

Wednesday 21 October 2020 – Morning

A Level Physics A

H556/03 Unified physics

Time allowed: 1 hour 30 minutes

You must have:
- the Data, Formulae and Relationships Booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks might be given for a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

ADVICE
- Read each question carefully before you start your answer.

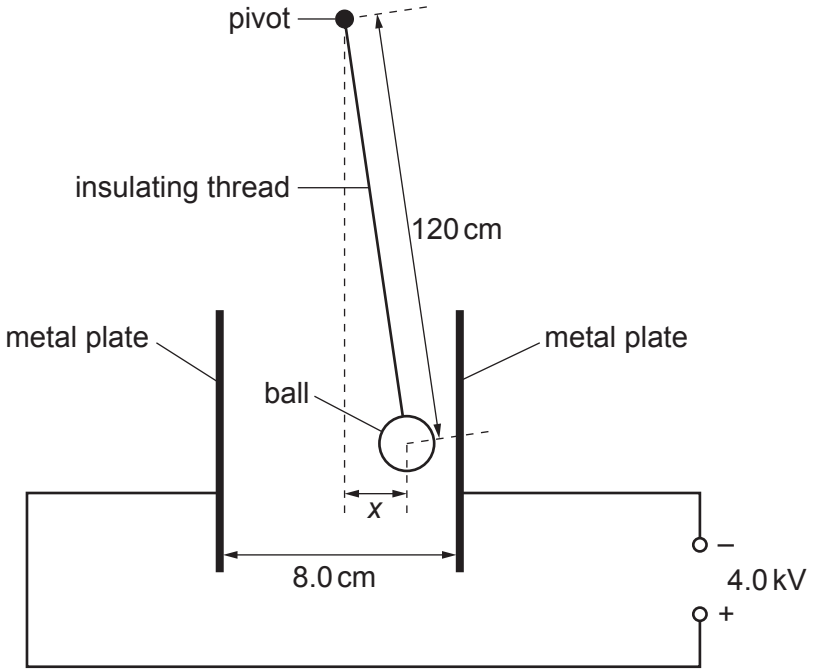
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Answer **all** the questions.

1 A ball coated with conducting paint has weight 0.030 N and radius 1.0 cm. The ball is suspended from an insulating thread. The distance between the pivot and the centre of the ball is 120 cm.

The ball is placed between two vertical metal plates. The separation between the plates is 8.0 cm. The plates are connected to a 4.0 kV power supply.

(a) The ball receives a positive charge of 9.0 nC when it is made to touch the positive plate. It then repels from the positive plate and hangs in equilibrium at a displacement x from the vertical, as shown below. The diagram is **not** drawn to scale.



(i) Show that the electric force acting on the charged ball is 4.5×10^{-4} N.

[2]

(ii) Draw, on the diagram above, arrows which represent the **three** forces acting on the ball. Label each arrow with the name of the force it represents. **[2]**

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(iii) By taking moments about the pivot, or otherwise, show that $x = 1.8\,\text{cm}$.

[2]

(b) The ball is still positively charged.

The plates are now moved slowly towards each other whilst still connected to the 4.0 kV power supply. The plates are stopped when the separation is 5.0 cm.

Explain the effect that this has on the deflection of the ball and explain why the ball eventually starts to oscillate between the plates.

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..... **[4]**

Question 1 continues on page 4

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(c) When the ball oscillates between the plates, the current in the external circuit is 3.2×10^{-8} A.

A charge of 9.0 nC moves across the gap between the plates each time the ball makes one complete oscillation.

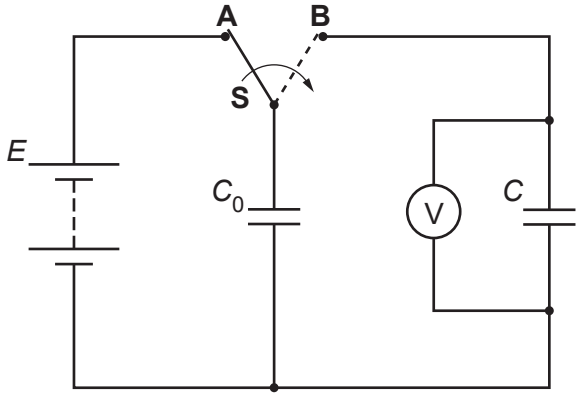
Calculate the frequency f of the oscillations of the ball.

f = ... Hz **[2]**

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2 The diagram below shows a circuit containing two capacitors which are both initially uncharged. The battery has e.m.f. E and negligible internal resistance.

The switch **S** is first moved to position **A** until the capacitor of capacitance C_0 is fully charged.



The switch **S** is then moved to position **B**. The initial charge stored by the capacitor of capacitance C_0 is shared between the two capacitors.
The final reading on the voltmeter is V.

(a) Show that $V = \dfrac{C_0}{C + C_0} E$.

[2]

(b) A student wants to determine the values of E and C_0 by repeating the experiment above and measuring the potential difference (p.d.) V for a selection of capacitors of capacitance C.

The student decides to plot a graph of $\dfrac{1}{V}$ against C.

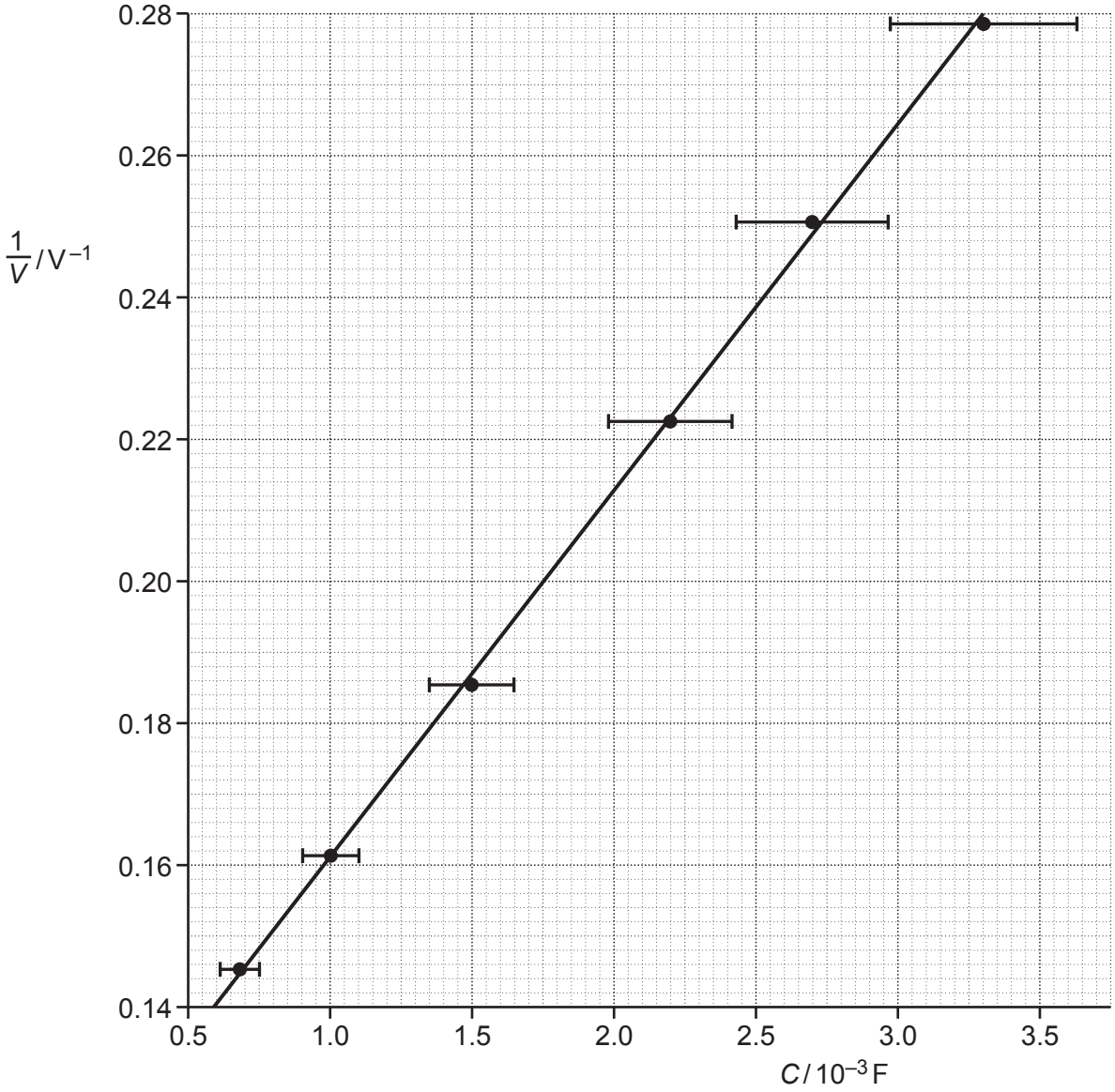
(i) Use the expression in **(a)** to show that the graph should be a straight line of gradient $\dfrac{1}{C_0 E}$ and y-intercept $\dfrac{1}{E}$.

[1]

Question 2 continues on page 6

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(ii) The data points, error bars and the line of best fit drawn by the student are shown in the graph below.



The gradient of the line of best fit is 51 V^{-1} F^{-1}. The value of E is 9.1 V.

Determine the value of C_0 in millifarads (mF). Write your answer to 2 significant figures.

C_0 = ... mF **[2]**

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(iii) Draw on the graph a straight line of worst fit.

Use this line to determine the absolute uncertainty in your value of C_0. Write your answer to an appropriate number of significant figures.

absolute uncertainty = ... mF **[4]**

(c) The experiment is repeated with a resistor of resistance 10 kΩ placed in series between **S** and the capacitor of capacitance C_0.

State with a reason what effect, if any, this would have on the experiment.

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..... **[1]**

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3 This question is about the Sun and its radiation.

(a) (i) Use the data below to show that the luminosity of the Sun is about 4×10^{26} W.

- radius of Sun = 7.0×10^{8} m
- surface temperature of Sun = 5800 K

[1]

(ii) Sirius, the brightest star in the night sky, has a luminosity 25 times greater than that of the Sun. It has diameter 1.7 times greater than that of the Sun.

Calculate the surface temperature T of Sirius.

T = ... K **[3]**

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***(b)** A student attends a lecture about the Sun and makes the following notes.

1. The Sun loses more than 4×10^9 kg of its mass every second to maintain its luminosity.
2. Treating hydrogen nuclei (protons) as an ideal gas, a temperature of 10^{10} K provides a kinetic energy of about 1 MeV, which is necessary for fusion.
3. However, the Sun's core temperature is only 10^7 K, so the chance of protons fusing on collision is very small. This explains why the Sun has such a long lifetime.

Explain the principles of physics which are involved in each of the three points.
You should include relevant formulae, but no numbers or calculations are required.

[6]

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4 The International Space Station (ISS) orbits the Earth at a height of 4.1×10^5 m **above** the Earth's surface.

The radius of the Earth is 6.37×10^6 m. The gravitational field strength g_0 at the Earth's surface is $9.81\,\text{N kg}^{-1}$.

(a) Both the ISS and the astronauts inside it are in free fall.

Explain why this makes the astronauts feel **weightless**.

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..... **[1]**

(b) **(i)** Calculate the value of the gravitational field strength g at the height of the ISS above the Earth.

g = ...N kg^{-1} **[3]**

(ii) The speed of the ISS in its orbit is $7.7\,\text{km s}^{-1}$. Show that the period of the ISS in its orbit is about 90 minutes.

[2]

Question 4 continues on page 12

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(c) Use the information in **(b)(ii)** and the data below to show that the root mean square (r.m.s.) speed of the air molecules inside the ISS is approximately 15 times smaller than the orbital speed of the ISS.

- molar mass of air = $2.9 \times 10^{-2}\,\text{kg mol}^{-1}$
- temperature of air inside the ISS = 20 °C

[3]

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(d) The ISS has arrays of solar cells on its wings. These solar cells charge batteries which power the ISS. The wings always face the Sun.

Use the data below and your answer to **(b)(ii)** to calculate the **average** power delivered to the batteries.

- The total area of the cells facing the solar radiation is 2500 m^2.
- 7% of the energy of the sunlight incident on the cells is stored in the batteries.
- The intensity of solar radiation at the orbit of the ISS is 1.4 $kW\,m^{-2}$ outside of the Earth's shadow and zero inside it.
- The ISS passes through the Earth's shadow for 35 minutes during each orbit.

average power = ... W **[4]**

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5 This question is about investigations involving an electromagnetic wave.

A vertical transmitter aerial emits a **vertically polarised** electromagnetic wave which travels towards a vertical receiver aerial. The wavelength of the wave is 0.60 m.

Fig. 5.1 shows a short section of the oscillating electric field of the electromagnetic wave.

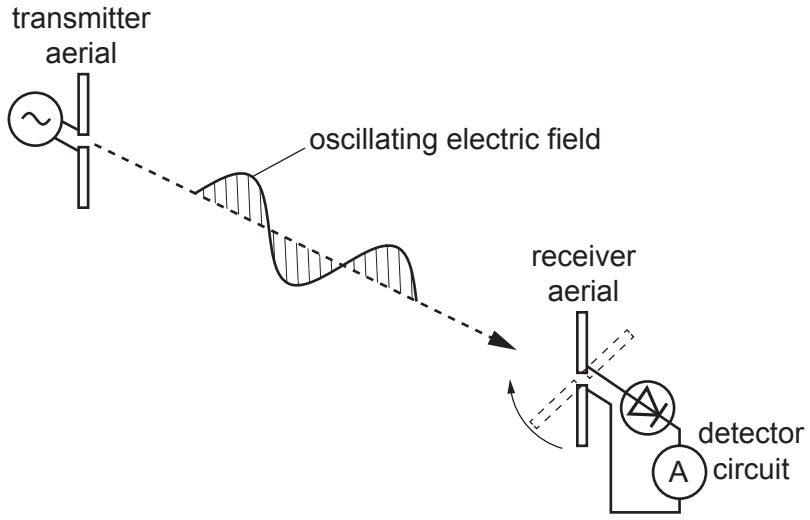


Fig. 5.1

(a) Calculate the frequency f of the transmitted wave.

f = ... Hz **[2]**

(b) The electromagnetic wave is caused by electrons oscillating in the transmitter aerial. Each electron oscillates with simple harmonic motion.

Calculate the maximum acceleration a_{max} of an electron which oscillates with an amplitude of 4.0×10^{-6} m.

a_{max} = ... $m\,s^{-2}$ **[3]**

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(c) Suggest why the diode in **Fig. 5.1** is necessary for an ammeter to detect a signal at the receiver aerial.

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***(d)** A student carries out two investigations with these electromagnetic waves.

In **investigation 1**, the student rotates the receiver aerial about the horizontal axis joining the two aerials, as shown in **Fig. 5.1**.

In **investigation 2**, the student places a metal sheet behind the receiver aerial. The student moves the sheet backwards and forwards along the horizontal axis joining the two aerials, as shown in **Fig. 5.2**.

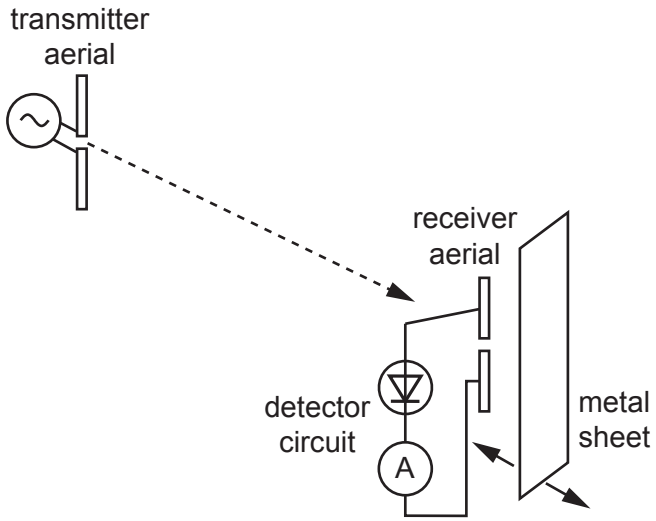


Fig. 5.2

For each of these two investigations:

- Explain why the ammeter sometimes gives a maximum reading and sometimes a zero (or near zero) reading.
- State the orientations of the receiver aerial in **investigation 1**, and the positions of the metal sheet in **investigation 2**, where these maximum and zero readings would occur.

[6]

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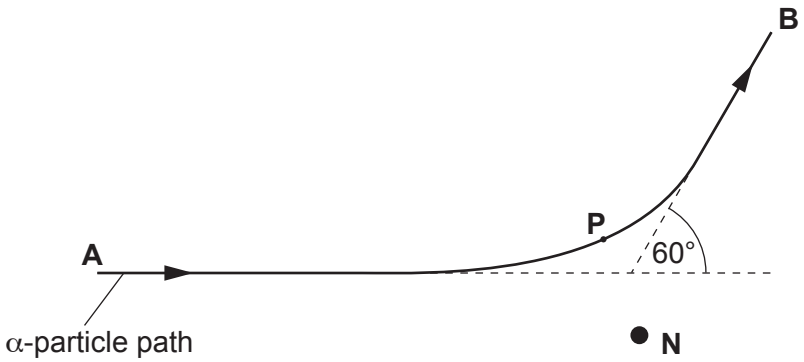
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6 A beam of α-particles is incident on a thin gold foil. Most α-particles pass straight through the foil. A few are deflected by gold nuclei.

The diagram shows the path of one α-particle which passes close to a gold nucleus **N** in the foil. The α-particle is deflected through an angle of 60° as it travels from **A** to **B**.

P marks its position of closest approach to the gold nucleus.



(a) Another α-particle in the beam is deflected by the same gold nucleus **N** through an angle of 30°.

Sketch its path onto the diagram above. **[2]**

(b) The distance between **P** and **N** is 6.8×10^{-14} m.

Calculate the magnitude of the electrostatic force F between the α-particle ($^{4}_{2}\text{He}$) and the gold nucleus ($^{197}_{79}\text{Au}$) when the α-particle is at **P**.

F = ... N **[4]**

Question 6 continues on page 18

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(c) The initial kinetic energy of each α-particle is 5.0 MeV.

Show that the magnitude of the initial momentum of each α-particle is about 10^{-19} kg m s^{-1}. Take the mass of the α-particle to be 6.6×10^{-27} kg.

[3]

(d) The **magnitude** of the final momentum of the α-particle at **B** is equal to its initial value at **A**.

The gold nucleus **N** is initially at rest. During the passage of the α-particle from **A** to **B**, no other forces act on the two particles.

In the following questions label any relevant angles.

(i) Draw two vectors in the spaces below to represent the initial momentum and the final momentum of the α-particle.

initial momentum at **A**

final momentum at **B**

[2]

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(ii) Draw a vector in the space below to represent the momentum of the nucleus **N** when the α-particle reaches **B**.

Explain how you determined this momentum.

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..... **[2]**

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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