Rewarding Learning

ADVANCED
General Certificate of Education
2025

Centre Number

Candidate Number

Physics

Assessment Unit A2 2
assessing

Fields, Capacitors and Particle Physics

[APH21]

MONDAY 9 JUNE, MORNING

APH21

TIME

2 hours.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
You must answer the questions in the spaces provided.
Do not write outside the boxed area on each page or on blank pages.
Complete in black ink and use a dark HB pencil for drawings and graphs.
Do not write with a gel pen.
Answer **all nine** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
You may use a scientific calculator.
A Data and Formulae Sheet is included in this question paper.
Quality of written communication will be assessed in Question **7**.

1 A circuit containing two identical capacitors of unknown capacitance is shown in **Fig. 1.1**.

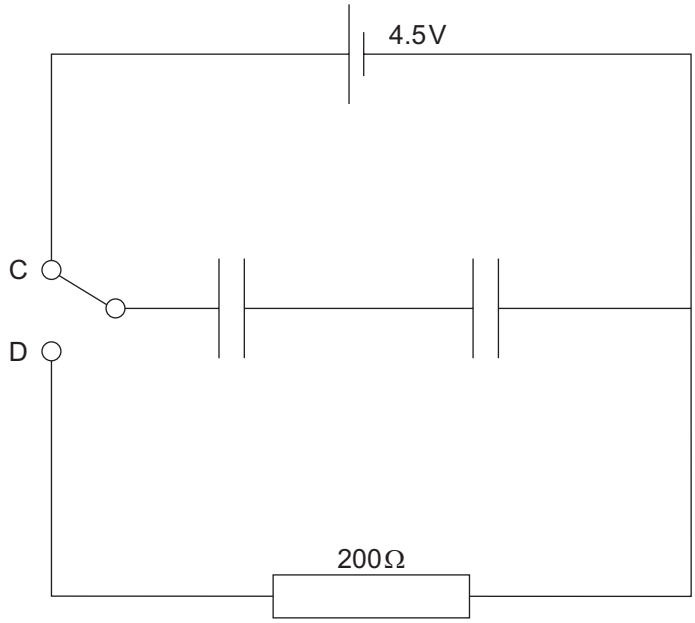

Fig. 1.1

The capacitors are charged by moving a two-way switch to position C, which connects them to a cell of voltage of 4.5 V. The two-way switch is then turned to position D, so the capacitors begin to discharge through the 200 Ω resistor.

(i) Calculate the initial current that will flow through the 200 Ω resistor immediately after the switch has been moved to position D.

Initial current = _____ A [3]

(ii) If after a time of 120 s the current flowing through the resistor is 1.42 mA, calculate the time constant of the circuit.

Time constant = _____ s [5]

(iii) Calculate the capacitance of one of the capacitors.

Capacitance = _____ F [3]

[Turn over

2 **(i)** Explain the concept of a field of force.

[2]

(ii) State one similarity and two differences between gravitational and electric fields.

[3]

(iii) **Fig. 2.1** represents the electric field around an electron. On **Fig. 2.2** sketch the electric field lines around an alpha particle. [3]

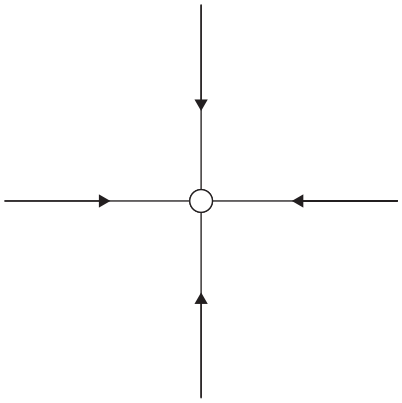

Fig. 2.1

Fig. 2.2

(iv) Explain why electric field lines can never cross.

_____

_____

_____

_____ [2]

[Turn over

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3 Kepler's third law is stated mathematically in **Equation 3.1**.

$$T^2 \propto r^3 \qquad \textbf{Equation 3.1}$$

(a) (i) Express this law in words.

_____

_____

_____

_____ [2]

(ii) Show that Kepler's third law is consistent with Newton's law of universal gravitation.

[5]

[Turn over

(b) The moon orbits Earth at a mean radius of 3.84×10^8 m and takes an average of 27.3 days to orbit the Earth.

The radius of Earth is 6.40×10^3 km.

(i) Use Kepler's third law to calculate the time period of a satellite placed in a circular orbit 12.5×10^3 km above Earth's surface.

Time period = _____ s [5]

(ii) Calculate the acceleration of the satellite in this orbit.

Acceleration = _____ m s^{-2} [3]

(iii) Use your answer from **(b)(ii)** to show that the mass of Earth is 6×10^{24} kg.
You are advised to show clearly your working out.

[2]

[Turn over

4 Two electrons are initially stationary 5.2 mm apart at the surface of a metal plate. A potential difference of 450 V is applied between the plate and another plate 0.15 m above, as shown in **Fig. 4.1**.

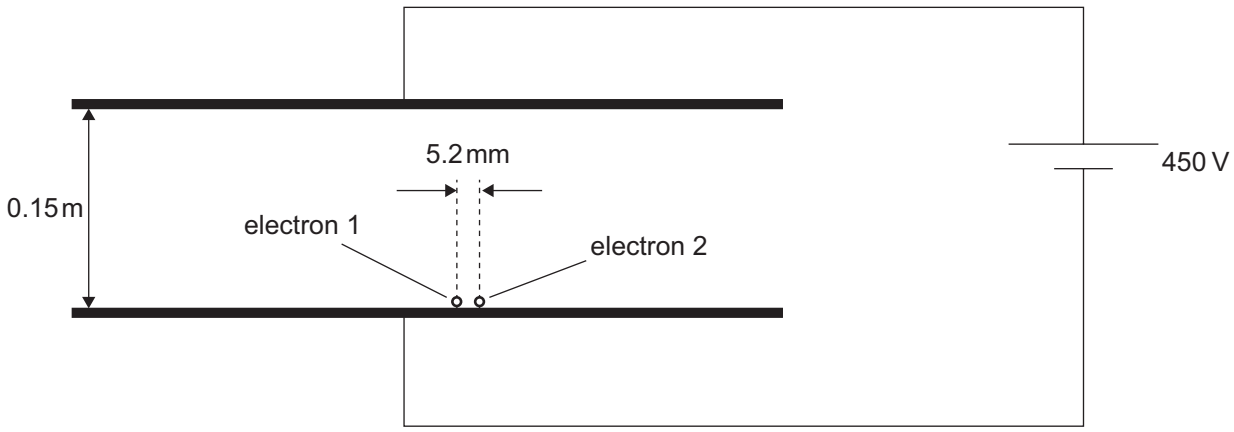

Fig. 4.1

(i) Show that the electric field strength E_e at the position of electron 2 due to electron 1 is negligible when compared to the electric field strength E_p produced by the plates.

[6]

(ii) Calculate the force on one of the electrons due to the electric field between the plates.

Force = _____ N [3]

The electrons accelerate from rest towards the positively charged plate.

(iii) Calculate the velocity of the electrons as they hit the plate.

Velocity = _____ m s $^{-1}$ [5]

[Turn over

5 The graph in **Fig. 5.1** shows how the magnetic flux Φ through a coil changes with time t as the coil of an electric generator rotates.

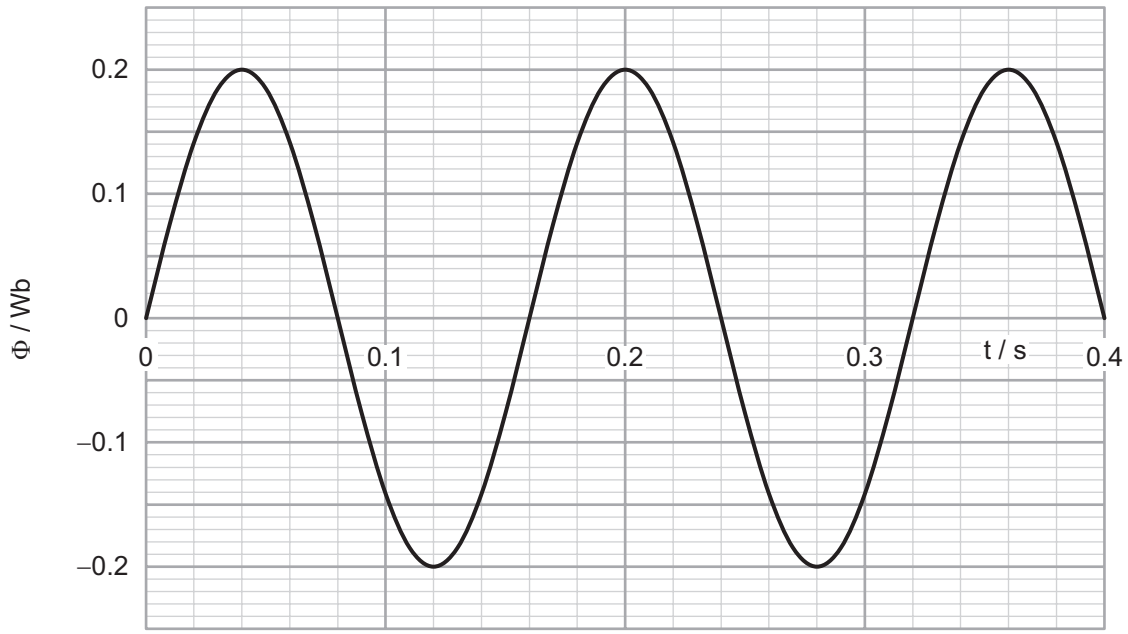

Fig. 5.1

(a) With reference to the graph, describe how an electric generator is able to generate an alternating e.m.f.. State any physical law that may aid your explanation.

[2]

(b) The coil consists of 40 turns.

(i) Using the graph calculate the output voltage of the generator at a time of 0.18 s.

Voltage = _____ V [5]

(ii) Calculate the frequency of the output voltage.

Frequency = _____ Hz [3]

[Turn over

6 The solar wind consists of a stream of charged particles that radiate away from the Sun, and interact with the Earth's magnetic field. **Fig. 6.1** shows Earth from space. A proton is travelling towards Earth at a speed of 5.20×10^5 m s^{-1}. At its location X on **Fig. 6.1** the Earth's magnetic field is acting into the page and has a magnetic flux density of 4.90×10^{-7} T.

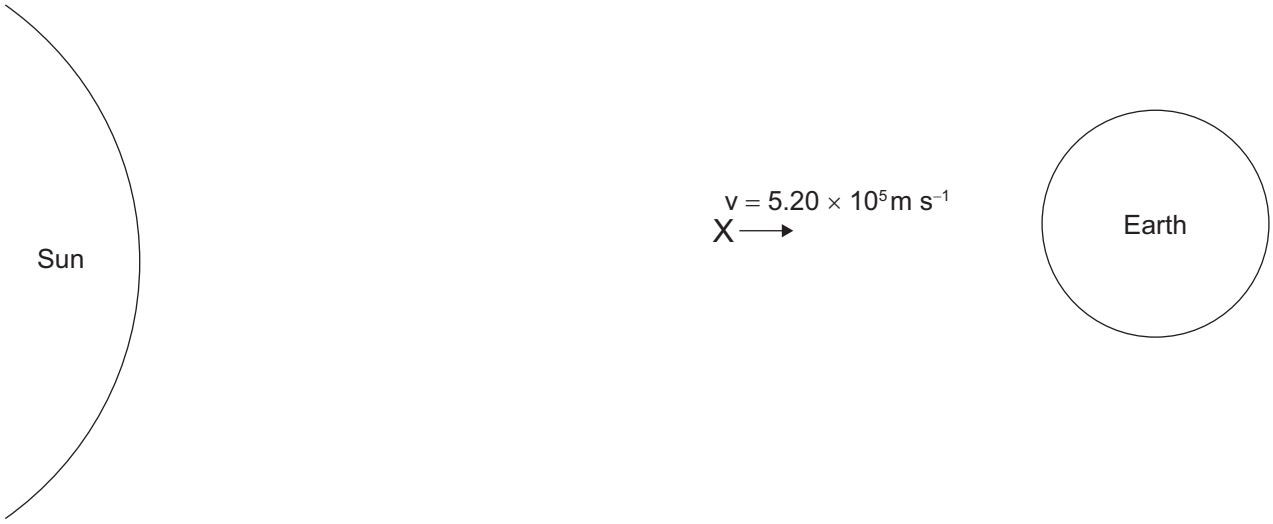

Fig. 6.1

(i) Add an arrow at position X on **Fig. 6.1** to show the direction of the force exerted on the proton by the Earth's magnetic field. [1]

(ii) Calculate the size of the force exerted by the magnetic field on the proton at position X.

Force = _____ N [3]

(iii) Calculate the radius of the path that the proton will start to follow at position X.

Radius = _____ m [2]

(iv) The solar wind consists mainly of protons and electrons. Describe how, and explain why, the path of an electron will differ from the path of a proton travelling at the same speed.

_____

_____

_____

_____

_____ [3]

[Turn over

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In this question you will be assessed on the quality of your written communication skills, including the use of specialist scientific terms.

7 A synchrotron is a type of particle accelerator. State the two main components in the ring of a synchrotron and describe their purpose.

As the particles gain energy, the current supplied to one of the components stated above must be increased. Explain why this increase in current is required.

[8]

8 **(i)** With reference to its structure, explain why a neutron is not considered a fundamental particle.

[2]

(ii) Neutrons can undergo β^- decay. A student incorrectly states **Equation 8.1** as the equation for β^- decay. With reference to all three conservation rules, explain why β^- cannot occur in this manner.

$$n \rightarrow \beta^- + \bar{p} + \upsilon_e$$ **Equation 8.1**

[6]

(iii) State the correct equation for β^- decay below.

[1]

(iv) Describe what happens to the structure of a neutron in β^- decay.

_____

_____

_____ [1]

[Turn over

9 A power station produces a power of 320 MW at 22 000 V. The voltage is stepped up by a transformer to 110 000 V before transmission across power lines. The transformer used is 95% efficient.

(i) State two possible causes of the power loss across the transformer.

_____

_____

_____ [2]

(ii) Calculate the current in the power lines.

Current = _____ A [4]

(iii) The power lines have a resistance of $0.008\,\Omega$ per kilometre and are 200 km long.

Calculate the total power loss across the transformer and in the power lines.

Power loss = _____ MW [5]

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For Examiner's use only	
Question Number	**Marks**
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Total Marks	

Examiner Number

Rewarding Learning

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General Certificate of Education

Physics

Assessment Units A2 1 and A2 2

[APH11/APH21]

DATA AND FORMULAE SHEET

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1} $\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
(unified) atomic mass unit	1 u $= 1.66 \times 10^{-27}$ kg
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall on the Earth's surface	$g = 9.81$ m s^{-2}
electron volt	1 e$V = 1.60 \times 10^{-19}$ J
the Hubble constant	$H_0 \approx 2.4 \times 10^{-18}$ s^{-1}

Useful formulae

The following equations may be useful in answering some of the questions in the examination:

Mechanics

conservation of energy	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force
Hooke's Law	$F = kx$ (spring constant k)
strain energy	$E = \frac{1}{2}Fx = \frac{1}{2}kx^2$

Uniform circular motion

centripetal Force	$F = \frac{mv^2}{r}$

Simple harmonic motion

displacement	$x = A\cos\omega t$
simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$
loaded spiral spring	$T = 2\pi\sqrt{\frac{m}{k}}$

Waves

two-source interference	$\lambda = \frac{ay}{d}$
diffraction grating	$d\sin\theta = n\lambda$

Thermal physics

average kinetic energy of a molecule	$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$
kinetic theory	$pV = \frac{1}{3} Nm \langle c^2 \rangle$
thermal energy	$Q = mc\Delta\theta$

Capacitors

capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
capacitors in parallel	$C = C_1 + C_2 + C_3$
time constant	$\tau = RC$
capacitor discharge	$Q = Q_0 e^{\frac{-t}{CR}}$ or $V = V_0 e^{\frac{-t}{CR}}$ or $I = I_0 e^{\frac{-t}{CR}}$

Light

lens formula	$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Electricity

terminal potential difference	$V = E - Ir$ (e.m.f., E; Internal Resistance, r)
potential divider	$V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$
a.c. generator	$E = BAN\omega \sin\omega t$

Nuclear Physics

nuclear radius	$r = r_0 A^{\frac{1}{3}}$
radioactive decay	$A = -\lambda N, \quad A = A_0 e^{-\lambda t}$
half-life	$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

Particles and photons

Einstein's equation	$\frac{1}{2} m v_{max}^2 = hf - hf_0$
de Broglie equation	$\lambda = \frac{h}{p}$

Astronomy

red shift	$z = \frac{\Delta\lambda}{\lambda}$
recession speed	$z = \frac{v}{c}$
Hubble's law	$v = H_0 d$