Rewarding Learning

ADVANCED
General Certificate of Education
2024

Centre Number

Candidate Number

Physics

Assessment Unit A2 2
assessing

Fields, Capacitors and Particle Physics

APH21

[APH21]

THURSDAY 6 JUNE, AFTERNOON

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 seven** 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 **3(a)**.

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1 **Fig. 1.1** shows a diagram of a step-up transformer.

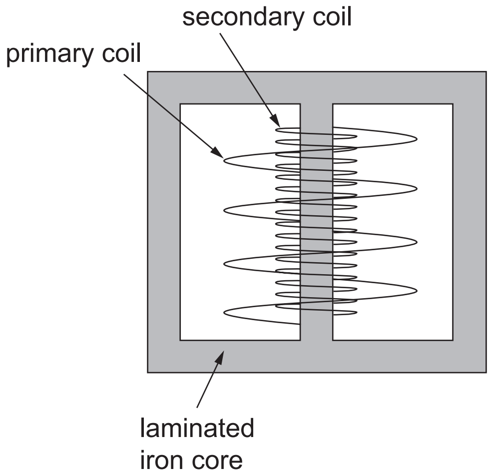

Fig. 1.1

(a) State how you can determine from the diagram that the transformer is a step-up transformer.

____

____ [1]

(b) The coils are wound on a common core that is laminated to reduce energy loss and improve efficiency.

(i) State a reason for winding the primary and secondary coils on a common core as shown in **Fig. 1.1**.

____

____ [1]

(ii) Explain the reason for laminating the core and state the advantage of doing this.

____

____ [2]

(c) The primary coil of a transformer is connected to an a.c. supply with a 40 V peak value. This induces an e.m.f. across the secondary coil as shown in **Fig. 1.2**.

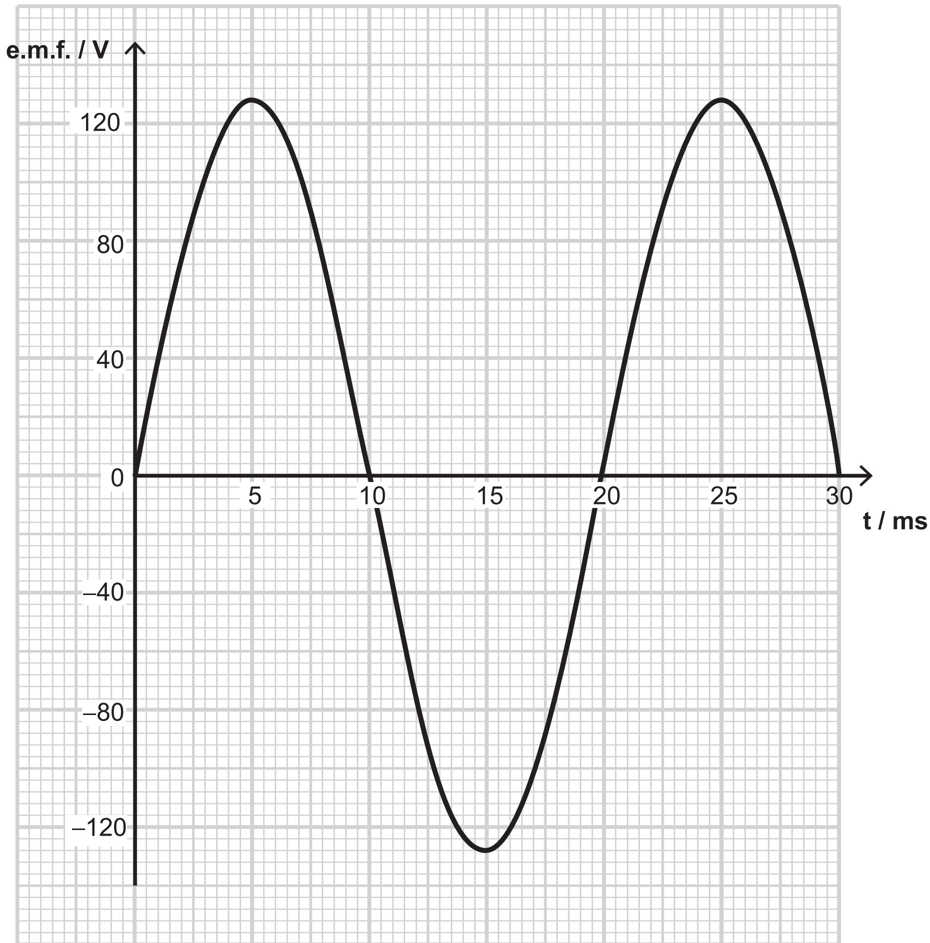

Fig. 1.2

(i) Calculate the number of turns on the primary coil if the secondary coil has 800 turns.

Number of turns on primary coil = ____________________ [4]

(ii) Calculate the current drawn from the 40 V a.c. supply if the current in the secondary coil is 0.75 A. Assume that the transformer is 100% efficient.

Current = ____________________ A [3]

2 **(a)** Define capacitance.

____

____ [1]

(b) Most smart phones, tablets and computers use capacitive touchscreens. These touch sensitive screens use the touch of a human finger or stylus for input and control.

(i) A capacitor within a touchscreen is connected to a 6 V supply. A finger touches the screen and the capacitance increases by 50 nF. This causes charge to flow onto the capacitor. Calculate the amount of charge that flows onto the capacitor.

Charge = ____________________ C [4]

(ii) Calculate the increase in energy stored when the charge has moved onto the capacitor.

Energy = ____________________ J [3]

(c) **(i)** Many touchscreens incorporate polarising filters to plane-polarise the light emitted which reduces reflections and improves contrast. Explain what is meant by plane-polarised light.

____

____ [1]

(ii) Most modern touchscreens emit blue light. Calculate the energy of a photon of blue light of wavelength 4.50×10^{-7} m.

Energy = ____________________ J [3]

Quality of written communication will be assessed in part (a) of this question.

3 The Standard Model of particle physics is a theory concerning the four fundamental forces in nature and is used to classify all subatomic particles that are known to exist. One of the four fundamental forces, the weak nuclear force, acts on leptons and quarks. Its associated exchange particles are the W^+, W^- and Z^0.

(a) Write a brief account of the **other three** fundamental forces. In your answer include:

- the name of each force;
- the type of particle that each force acts on;
- its associated exchange particle.

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(b) Hadrons (which are made up of quarks) can be classified as either baryons or mesons.

Complete **Table 3.1** for the two hadrons that are named by indicating whether each is a baryon or meson and stating the quark structure and baryon number of each hadron.

Table 3.1

hadron	baryon or meson	quark structure	baryon number
antiproton			
neutron			

[3]

4 (a) What is a gravitational field?

____

____

____ [3]

(b) The position on Earth of the receiver of a Global Positioning System (GPS) can be accurately determined when it receives radio wave signals from GPS satellites orbiting the Earth. Each GPS satellite orbits the Earth twice every day.

(i) Calculate the height of a GPS satellite above the Earth's surface.
The mass of the Earth is 5.98×10^{24} kg.
The radius of Earth is 6.37×10^{6} m.

Height above Earth's surface = ____________________ m [7]

(ii) Determine the linear speed of the GPS satellite at this height above the Earth's surface.

Linear speed = ________________ m s^{-1} [3]

5 (a) (i) The equation representing Coulomb's law contains the term ε_0, the permittivity of a vacuum. Write down this equation and identify any other terms used.

____

____

____ [3]

(ii) Determine the base units of ε_0.

Base units = ____________________ [4]

(b) **Fig. 5.1** shows two parallel plates separated by a distance of 35 mm. A potential difference of 500 V is applied across the plates.

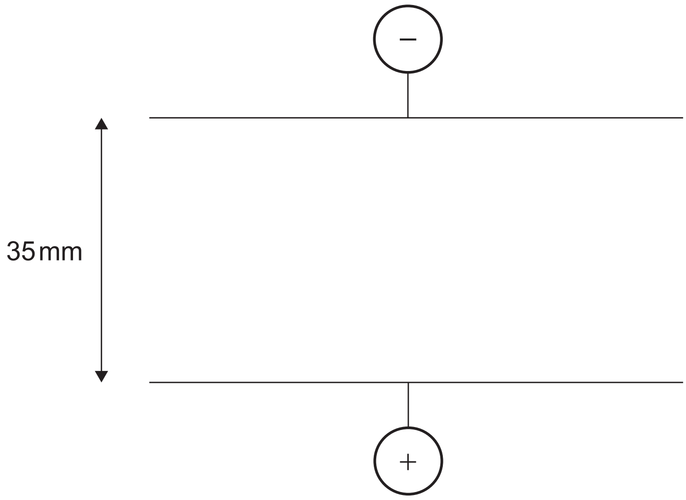

Fig. 5.1

(i) On **Fig. 5.1**, sketch the electric field lines between the two plates and show the direction of the electric field with appropriate arrows. [3]

(ii) Calculate the magnitude of the electric field strength between the plates.

Electric field strength = ____________________ $V\,m^{-1}$ [4]

[Turn over

(c) A beam of electrons enters the electric field between the two plates. It enters horizontally with a speed of 4.35×10^7 m s^{-1}. The plates are of length L metres. The electron beam is deflected through a vertical distance of 5.72 mm on exiting the electric field. **Fig. 5.2** illustrates the situation.

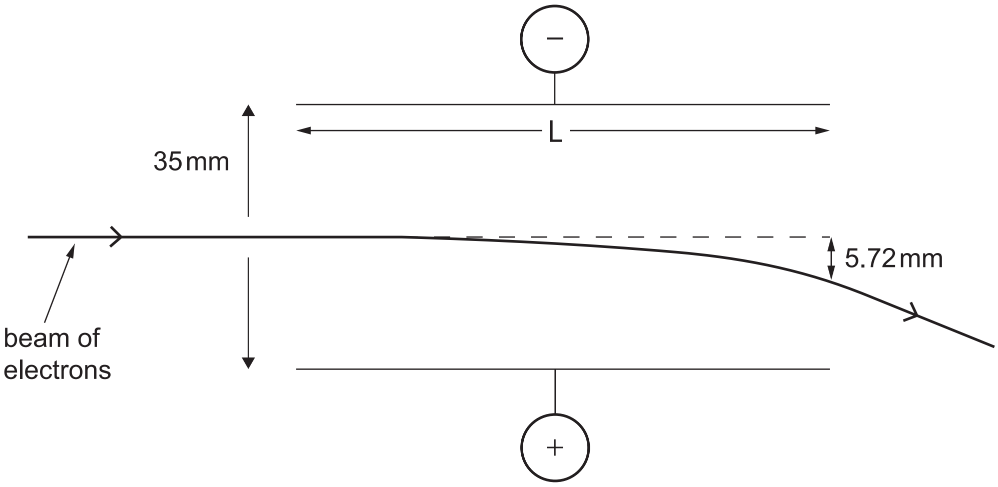

Fig. 5.2

(i) Calculate the force on an electron in the beam due to the electric field.

Force = ____________________ N [3]

(ii) Calculate the acceleration of an electron in the beam due to the electric field.

Acceleration = ____________________ $m\ s^{-2}$ [3]

(iii) Calculate the length L of the plates.

L = ____________________ m [5]

6 **(a)** **(i)** State Faraday's law of electromagnetic induction.

____

____

____ [1]

(ii) State Lenz's law of electromagnetic induction.

____

____

____ [1]

(b) A circular coil of wire with 180 turns is placed perpendicular to a uniform magnetic field of flux density 0.40 T. The radius of the coil is 0.12 m and it has a resistance of 25 Ω.

(i) Calculate the flux linkage through the coil and state the unit of flux linkage.

Flux linkage = ___________________

Unit of flux linkage = ___________________ [5]

(ii) The coil is turned through 90° in 0.65 s. Calculate the average induced current in the coil.

Induced current = ___________________ A [3]

[Turn over

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7 (a) **Fig. 7.1** shows the basic structure of a synchrotron. A synchrotron accelerates charged particles, in a circular path of fixed radius, to velocities approaching the speed of light.

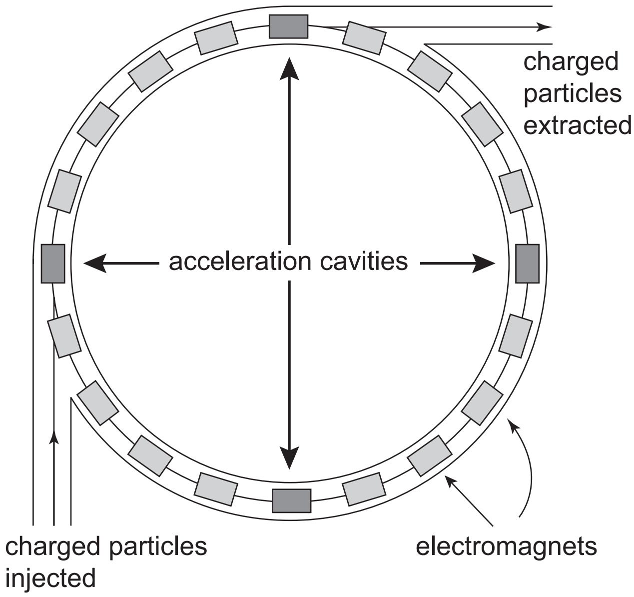

Fig. 7.1

(i) Describe how the circular path of fixed radius is achieved.

____

____ [2]

(ii) Explain why there must be a vacuum in the pipes through which the particles travel.

____

____ [2]

(b) In 2020, the European Synchrotron Radiation Facility opened a synchrotron called the Extremely Brilliant Source. Here, electrons are first accelerated to 2.99×10^8 m s^{-1} in a booster ring and then transferred to a storage ring until required. When moving at this speed, electrons have an effective mass that is 12 times larger than their rest mass.

(i) The storage ring has a circumference of 844 metres. Calculate how many orbits the electrons make every second. Assume that the speed of 2.99×10^8 m s^{-1} is maintained during each orbit. Give your answer to 3 significant figures.

Number of orbits every second = __________________ [3]

(ii) Calculate the magnitude of the centripetal force acting on the electrons in the storage ring.

Centripetal force = __________________ N [5]

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(iii) Calculate the magnetic flux density produced by the electromagnets.

Magnetic flux density = ________________ T [4]

(iv) As the electrons orbit the storage ring they emit synchrotron radiation in the form of high frequency intense X-rays. The energy of each X-ray photon emitted from the synchrotron is 12440 eV.

If the energy delivered to each square millimetre every second is 2.67×10^5 J, calculate the number of photons falling onto an area of 35 mm^2 each second.

Number of photons per second = ________________ [4]

[Turn over

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For Examiner's use only	
Question Number	Marks
1	
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Total Marks	

Examiner Number

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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}
	$\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
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	$t_{\frac{1}{2}} = \dfrac{0.693}{\lambda}$

Particles and photons

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

Astronomy

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