Rewarding Learning

ADVANCED
General Certificate of Education
2019

Centre Number

Candidate Number

Physics

Assessment Unit A2 2

assessing

Fields, Capacitors and Particle Physics

[APH21]

APH21

FRIDAY 24 MAY, MORNING

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 only. **Do not write with a gel pen.**
Answer **all nine** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100.
Quality of written communication will be assessed in Question **4(c)**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.

11996

1 **(a)** Define the farad, the unit of capacitance.

____

____

____ [2]

(b) Two uncharged capacitors of 330 μF and 660 μF are connected in series with a resistor R and a 12 V d.c. supply. A voltmeter is connected across one of the capacitors. The arrangement is shown in **Fig. 1.1**.

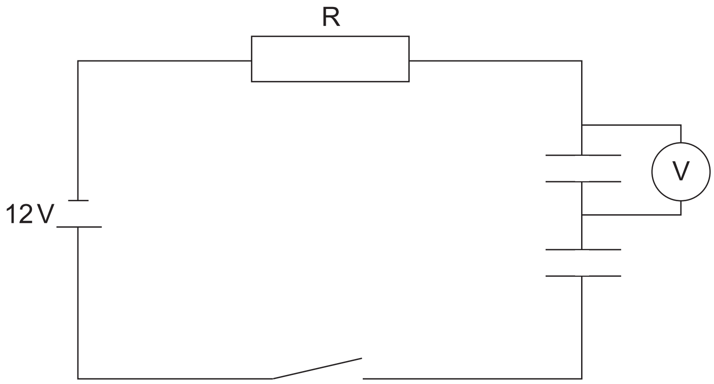

Fig. 1.1

(i) The switch is closed and the reading on the voltmeter increases to a maximum value of 8 V. Across which capacitor is the voltmeter connected? **You must show clearly how you obtain your answer to obtain maximum marks.**

Capacitor of ____________________ μF [3]

(ii) Calculate the total energy stored by the two capacitors in series.

Energy = ____________________ J [4]

2 **(a)** Explain what is meant by a field of force.

____

____

____ [2]

(b) **(i)** **Fig. 2.1** and **Fig. 2.2** below are diagrams drawn to represent the fields of force around two of the three point objects listed below:

- –6 μC charge
- +2 μC charge
- 4 kg mass

Identify, in the space provided, which point object could produce each of the fields drawn.

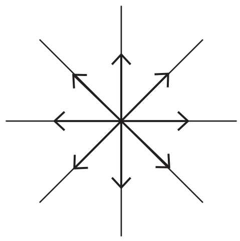

Fig. 2.1

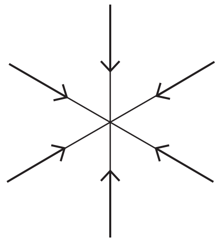

Fig. 2.2

______________________ ______________________ [2]

(ii) Compare and contrast the fields around point charges and point masses.

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____

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____ [3]

3 Two point charges –2 μC and +8 μC are placed 3.0 mm apart in a vacuum, as shown in **Fig. 3.1**.

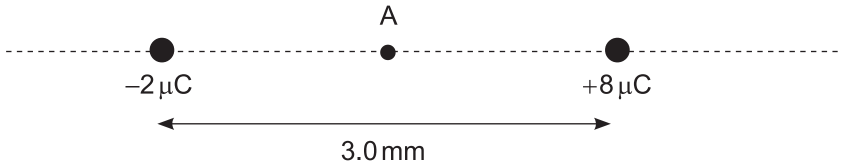

Fig. 3.1

(a) Calculate the resultant force exerted on a –4 μC point charge placed at the point A halfway between the charges and state its direction.

Force = ____________________ N Direction ____________________ [5]

(b) At a certain point, the resultant field strength due to the two point charges –2 μC and +8 μC is zero. Will this point be found to the left of the –2 μC charge, between the charges or to the right of the +8 μC charge? Explain how you decided on this position.

Position ____

Explanation ____

____

____

____ [3]

[Turn over

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

4 **(a)** A cathode ray tube is an example of a basic particle accelerator. In the tube electrons are accelerated from rest across a potential difference of 2.5 kV.

By considering the conversion from electrical potential energy to kinetic energy in the cathode ray tube, show that the electrons reach a velocity of $3.0 \times 10^7\,\mathrm{m\,s^{-1}}$.

[3]

(b) The value of electron mass on your data sheet is the mass of an electron at rest, called its rest mass m_e. When moving at a velocity v the mass of the electron increases to a value m given by **Equation 4.1**.

$$m = \frac{m_e}{\sqrt{1-\left(\frac{v^2}{c^2}\right)}} \qquad \textbf{Equation 4.1}$$

Calculate the percentage increase from rest mass m_e of electrons travelling at a velocity of $6.20 \times 10^7\,\mathrm{m\,s^{-1}}$.

Percentage increase = ______________ % [4]

(c) In a synchrotron, charged particles are accelerated to velocities approaching the speed of light.

Explain how a synchrotron operates to:

- accelerate the charged particles
- keep the particles in circular paths of fixed radius
- maintain synchronicity as the velocity of the particle beam increases
- focus the beam.

[6]

5 **(a)** Certain subatomic particles are classified as leptons, others as hadrons. Complete **Table 5.1** below with an example from each class of particle and two differences between the particles.

Table 5.1

	Lepton	Hadron
Example		
Difference 1		
Difference 2		

[4]

(b) In the 1930s the work of particle physicists such as Pauli and Dirac predicted a new particle called a neutrino. In order to prove its existence, an experiment was devised in which an 'inverse beta decay' reaction would occur.
An incomplete equation for this reaction is shown in **Equation 5.1**.

$$\bar{\upsilon}_e + p \longrightarrow n + X \qquad \textbf{Equation 5.1}$$

By applying the laws of conservation, deduce the charge, lepton number and baryon number of the unidentified particle X and hence identify what particle it is.

Charge ____

____

Lepton number ____

____

Baryon number ____

____

Particle X is ______________ [4]

(c) When β^- decay occurs an unstable nucleus will become more stable.

(i) Write the full equation for β^- decay.

[1]

(ii) Name the force responsible for β^- decay.

____ [1]

6 A mass spectrometer is an instrument used to analyse the atoms present in a sample of gas. The atoms are ionised in order to produce positive ions and then passed through a velocity selector, as shown in **Fig. 6.1**.

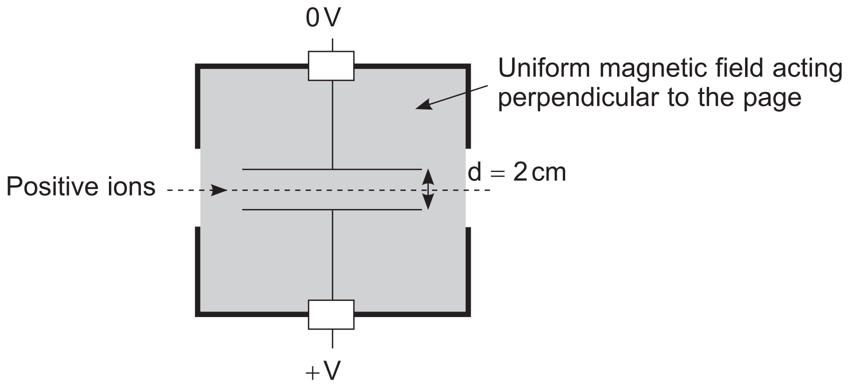

Fig. 6.1

The electric field is produced by a pair of parallel plates of separation d with a high potential difference V across them as shown in **Fig. 6.1**.

The velocity selector consists of electric and magnetic fields acting at right angles to each other, so that each ion is acted on by vertical forces in opposite directions. When these forces are equal, only the ions with velocity v pass through in a straight line as indicated.

(a) **(i)** Write equations for the force acting vertically upwards and the force acting vertically downwards on a positive ion passing through the fields.

Upwards force = ________________

Downwards force = ________________ [3]

(ii) Calculate the velocity of each ion passing straight through the selector when the magnetic field strength B = 240 mT, the potential difference V = 1100 V and plate separation d = 2 cm.

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

(b) A mixture of ionised lithium isotopes of velocity $4.8 \times 10^4\,m\,s^{-1}$ leaves the velocity selector and enters the shaded region of uniform magnetic field as shown in **Fig. 6.2**. The isotopes experience a force due to this field which results in them striking the detector.

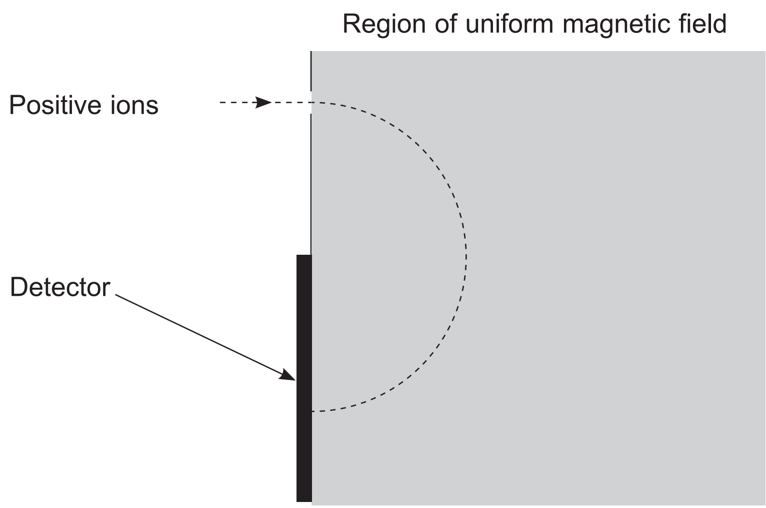

Fig. 6.2

(i) In what direction does the magnetic field act to make the particles follow such a path?

____ [1]

(ii) How is information about the relative masses of the ions deduced from the detector?

____

____ [2]

(iii) The mixture of lithium ions contains the isotopes ^{6}Li and ^{7}Li with masses of 6 u and 7 u respectively. The upper edge of the detector is 40 mm from the point at which the ions enter the field. Calculate the maximum magnetic field strength that can be applied in order for both ions to be detected. Each ion has a charge of $+1.6 \times 10^{-19}$ C.

Maximum magnetic field strength = ________________ T [5]

[Turn over

7 **(a)** Scientists wish to position a satellite in a 'jovi-stationary' orbit around the planet Jupiter. This is an orbit equivalent to a geostationary orbit around Earth.

(i) Give **three** characteristics of the path such a satellite would take around the planet Jupiter.

____

____

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____

____

____ [3]

(ii) At what height above Jupiter must the satellite be situated in order to travel in a jovi-stationary orbit? Take the mass of Jupiter as 1.9×10^{27} kg, the radius of Jupiter as 7.2×10^{7} m and Jupiter's day length as 10 hours.

Height above Jupiter = ____________________ m [6]

(iii) Calculate the linear speed of the satellite in this orbit.

Linear speed = ____________________________ $m\ s^{-1}$ [2]

(b) The jovi-stationary satellite has a mass of 300 kg. Calculate the weight of the satellite at this position above Jupiter.

Weight = __________________ N [3]

8 **(a)** In the space below, sketch and label a diagram of a step-up transformer.

[3]

(b) Step-up transformers are an important part of the national electricity supply grid. One such transformer changes the voltage at the generating station before the electric current is transmitted over long distances through the power lines. It has a turns ratio of 20. A current of 0.045 A is required in the power lines.

(i) Calculate the current that enters the transformer on the primary side.

Current = ____________________ A [2]

(ii) The electrical power entering the primary side of the transformer is 22.5 kW and the transformer is 95.5% efficient. Calculate the voltage at which the electricity is transmitted across the power lines.

Voltage = ____________________ V [3]

(iii) Outline three causes of energy loss in transformers and state how the loss is minimised in each case.

1. ____

____

____

2. ____

____

____

3. ____

____

____ [6]

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

____

____

____ [1]

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

____

____

____ [1]

(b) A bar magnet was dropped through a multiturn coil as shown in **Fig. 9.1a**. The coil is connected to a data-logger which records the e.m.f. The e.m.f. induced in the coil varies with time as shown in **Fig. 9.1b**.

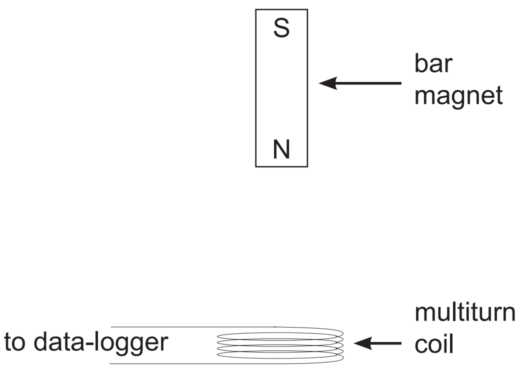

Fig. 9.1a

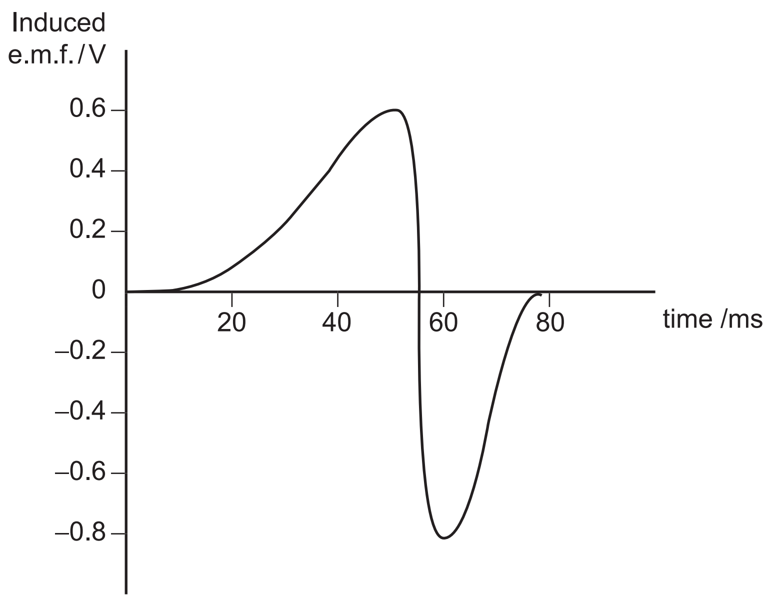

Fig. 9.1b

(i) Explain why a data-logger is used to record the e.m.f. in this experiment.

[1]

(ii) Explain, with reference to Faraday's and Lenz's laws, the difference in the peak values of 0.6 V and –0.8 V when the magnet is dropped through the coil.

[5]

(iii) Describe the difference in the graph if:

1. the magnet is dropped from a position further above the coil of wire.

2. the magnet is dropped from the same height as in **(b)** but through a coil with a greater number of turns.

[3]

DO NOT WRITE ON THIS PAGE

For Examiner's use only	
Question Number	Marks
1	
2	
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9	
Total Marks	

Examiner Number

New Specification

Rewarding Learning

ADVANCED
General Certificate of Education

Physics

Assessment Units A2 1 and A2 2

[APH11/APH21]

DATA AND FORMULAE SHEET

FOR USE FROM 2018 ONWARDS

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	$E = \frac{1}{2}\text{Fx} = \frac{1}{2}kx^2$

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	$v = H_0 d$