RECOGNISING ACHIEVEMENT

ADVANCED GCE **2864/01**

PHYSICS B (ADVANCING PHYSICS)

Field and Particle Pictures

MONDAY 21 JANUARY 2008 Morning

Time: 1 hour 15 minutes

Candidates answer on the question paper.
Additional materials: Data, Formulae and Relationships Booklet
Electronic calculator

CUP/T28250

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Do **not** write outside the box bordering each page.
- Write your answer to each question in the space provided.
- Show clearly the working in all calculations, and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- The number of marks is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is 70.
- Four marks are available for the quality of written communication in Section B.
- The values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.

FOR EXAMINER'S USE		
Section	**Max.**	**Mark**
A	**20**	
B	**50**	
TOTAL	**70**	

This document consists of **16** printed pages.

Answer **all** the questions.

Section A

1 Here is a list of units.

NC^{-1} JC^{-1} Wb $Wb\,m^{-2}$

(a) Which is an alternative unit for volt, V?

answer .... [1]

(b) Which is an alternative unit for tesla, T?

answer .... [1]

2 Gamma photons with enough energy can make a nucleus of hydrogen-2 disintegrate into a proton and a neutron.

$$^{2}_{1}H + ^{0}_{0}\gamma \rightarrow ^{1}_{1}p + ^{1}_{0}n$$

particle	mass / u
hydrogen-2 nucleus	2.01355
proton	1.00728
neutron	1.00867

(a) Use the table to show that the mass of a hydrogen-2 nucleus is about 4×10^{-30} kg less than the combined mass of a separate neutron and proton.

$u = 1.7 \times 10^{-27}$ kg

[2]

(b) Calculate the minimum energy of a gamma photon for the reaction to take place.

$c = 3.0 \times 10^{8}\,m\,s^{-1}$

photon energy = ... J [1]

3 Fig. 3.1 shows some energy levels for an atom.

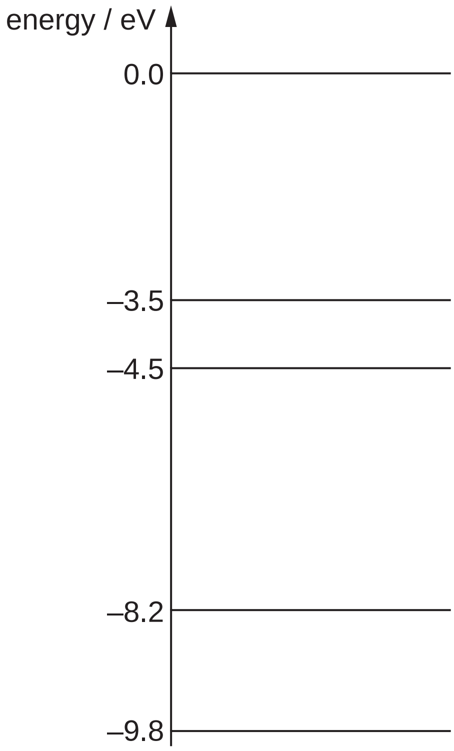

Fig. 3.1

(a) The lowest energy level is –9.8 eV.

Which **one** of these statements, (**A**, **B**, **C** or **D**) explains why the total energy is negative?

A Electrons have negative charge.

B The electron is bound to the atom.

C The kinetic energy of the electron is positive.

D The potential energy of the electron is negative.

answer .... [1]

(b) The atom absorbs photons of energy 5.3 eV. Show the energy levels involved in the absorption by drawing an arrow between them on Fig. 3.1. [1]

(c) Calculate the frequency of the 5.3 eV photons.

$h = 6.6 \times 10^{-34}$ J s
$e = 1.6 \times 10^{-19}$ C

frequency = ... Hz [2]

4 Fig. 4.1 shows apparatus for measuring the strength of a magnetic field.

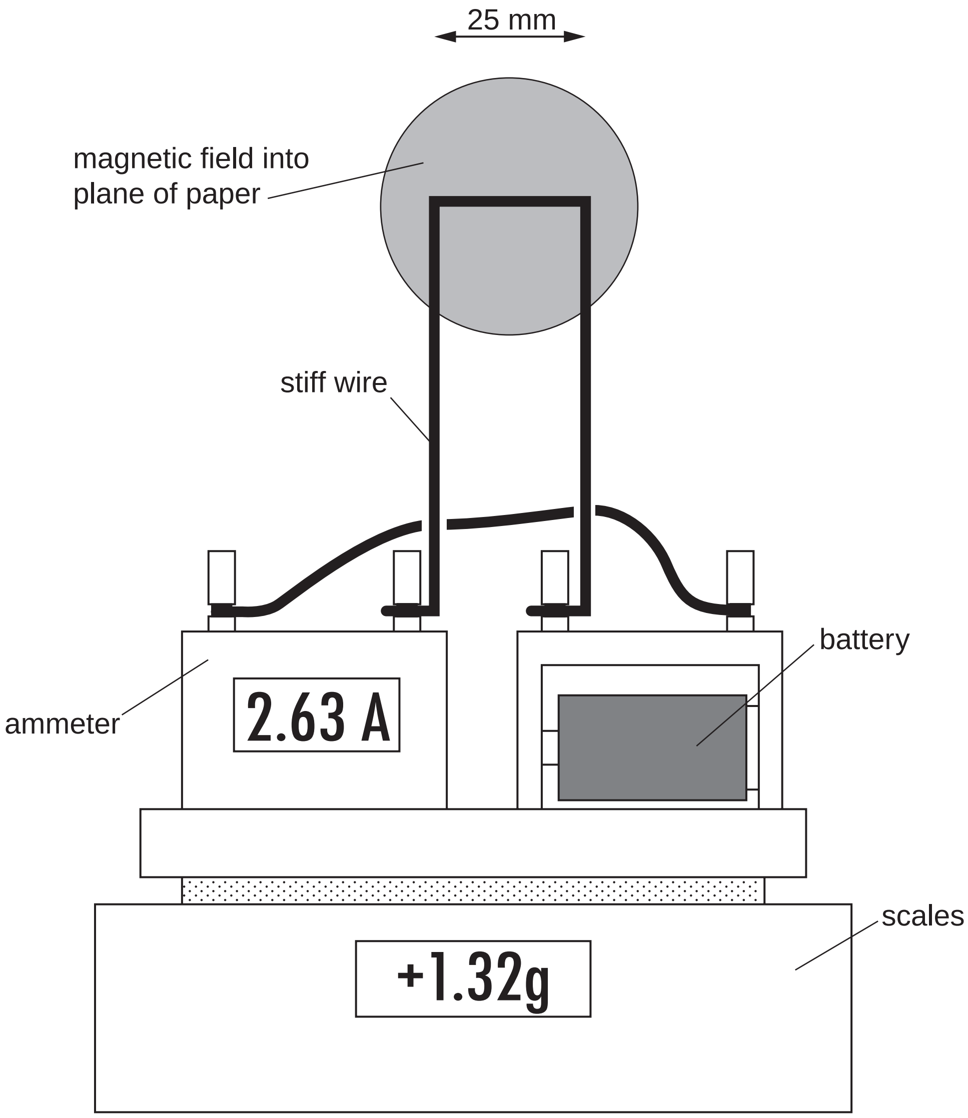

Fig. 4.1

The battery, ammeter and wire are placed on the scales.

The scales are then reset to 00.00 g.

A magnet is then brought up to the 25 mm horizontal length of stiff wire.

Use information in Fig. 4.1 to calculate the strength of the magnetic field.

$g = 9.8\,\mathrm{N\,kg^{-1}}$

magnetic field strength = ... T [2]

5 Salts of sodium-24 can be injected into people to trace the flow of their blood.

(a) Sodium-24 decays with a half-life of 15 hours. It emits gamma photons.

Suggest why these properties make sodium-24 suitable for this application.

[2]

(b) The decay constant of sodium-24 is $1.3 \times 10^{-5}\,s^{-1}$.

Explain the meaning of this statement.

[1]

6 Here are three statements about the scattering of a beam of alpha particles from a thin film of gold.

A All of the alpha particles are scattered out of the beam by nuclei in the film.

B Doubling the thickness of the film halves the number of alpha particles scattered through more than 90°.

C As the angle of scattering increases, the number of scattered alpha particles decreases.

Which **one** of the statements is correct?

answer .... [1]

7 The graph of Fig. 7.1 shows the variation with time of the flux in the core of a transformer.

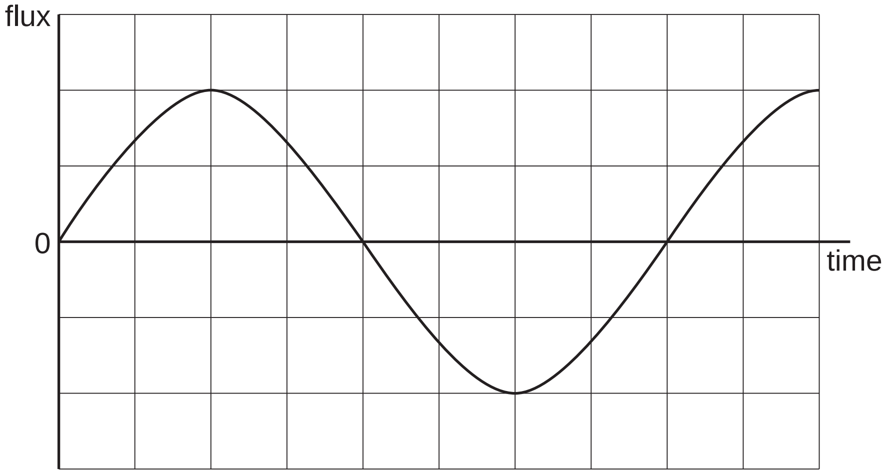

Fig. 7.1

(a) On Fig. 7.1, sketch the variation with time of the emf across the secondary coil of the transformer. [2]

(b) Complete the table. Use only **true** or **false**.

The flux in the primary coil of an ideal transformer ...	**true / false**
... is created by currents in the transformer coils.	
... is always less than the flux in the secondary coil.	
... has to change to generate an emf in the secondary coil.	

[1]

8 State **one** situation for which the electric field strength E is correctly given by the relationship

$$E = \frac{kQ}{r^2}.$$

[1]

9 A proton ^1_1H and an alpha particle ^4_2He are accelerated in a particle accelerator by a potential difference of 500 kV.

Complete the sentence. Choose from

kinetic energy
momentum
rest energy

The alpha particle has twice as much .... as the proton as it leaves the accelerator. [1]

[Section A Total: 20]

Section B

In this section, four marks are available for the quality of written communication.

10 This question is about an experiment to measure the strength of magnetic fields in iron.

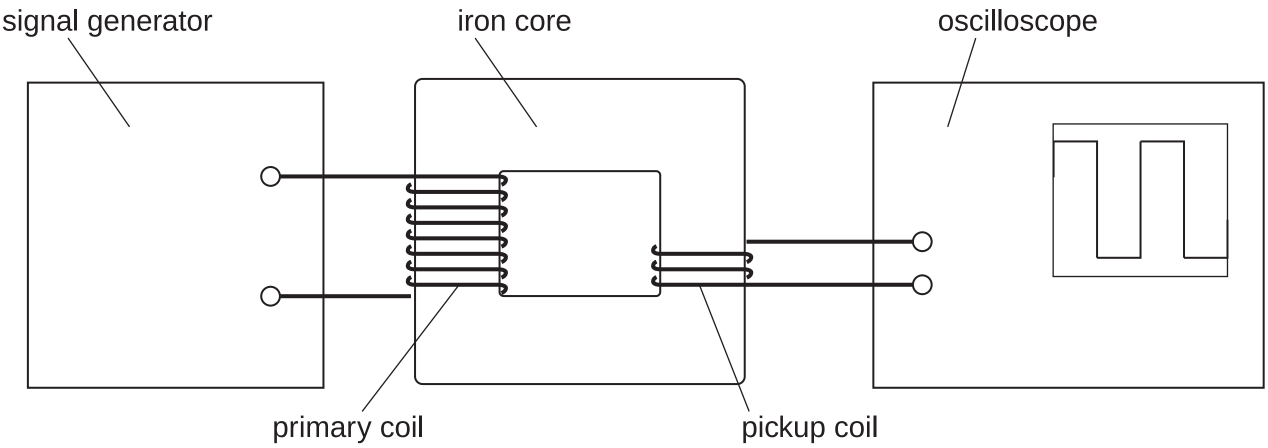

Fig. 10.1

Fig. 10.1 shows a signal generator connected across a coil of wire. Current in this primary coil sets up an alternating magnetic field in the iron core. An oscilloscope displays the emf across a pickup coil wound around the core.

(a) On Fig. 10.1, sketch **two** flux loops in the iron. [1]

(b) The core is constructed from thin iron sheets glued together instead of solid iron.

Explain why this is so.

[2]

(c) Fig. 10.2 shows how the flux in the iron changes with time.

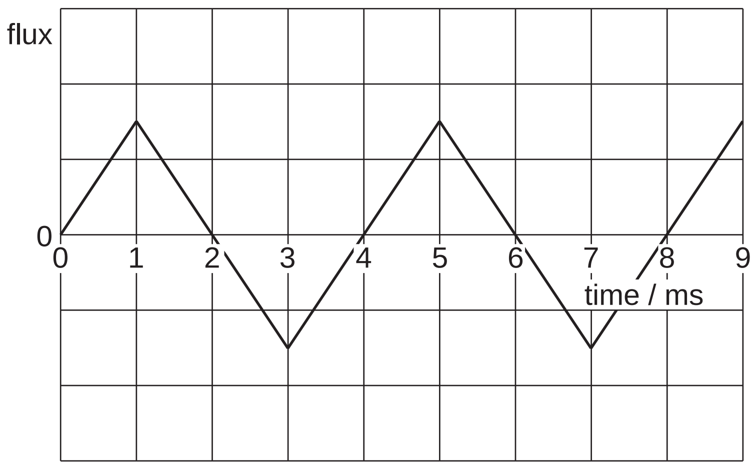

Fig. 10.2

(i) On Fig. 10.2, sketch how the current in the primary coil changes with time. [2]

(ii) Fig. 10.3 shows how the emf across the pickup coil changes with time.

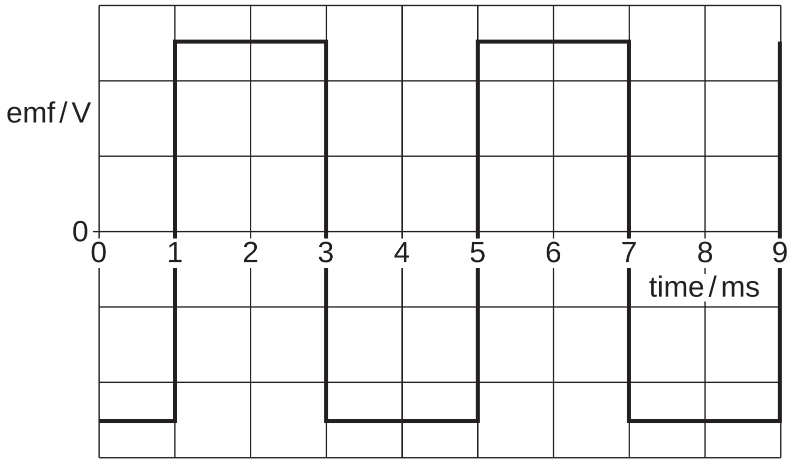

Fig. 10.3

Use Fig. 10.2 to explain the shape of this graph.

[3]

(iii) Use the graph of Fig. 10.2 to calculate the amplitude of the emf across the coil.

The peak magnetic field strength in the iron is 0.55 T.

The cross-sectional area of the iron core is $3.1 \times 10^{-4}\,m^2$.

The pickup coil has three turns of wire.

amplitude of emf = ... V [3]

(d) The signal generator is adjusted so that the frequency of the current in the primary coil is halved. The amplitude of the current remains unchanged.

Explain **two** effects this change will have on the graph of Fig. 10.3.

[3]

[Total: 14]

11 This question is about the motion of charged particles.

(a) Electrons enter an accelerator with negligible speed, and leave with a speed of $1.8 \times 10^{7}\,\mathrm{m\,s^{-1}}$. By calculating the kinetic energy of the electrons, show that they are accelerated by falling through a potential difference of about 900 V.

$e = 1.6 \times 10^{-19}\,\mathrm{C}$
$m_e = 9.1 \times 10^{-31}\,\mathrm{kg}$

[4]

(b) The electrons enter a region of uniform magnetic field, as shown in Fig. 11.1.

The electrons are moving in a vacuum.

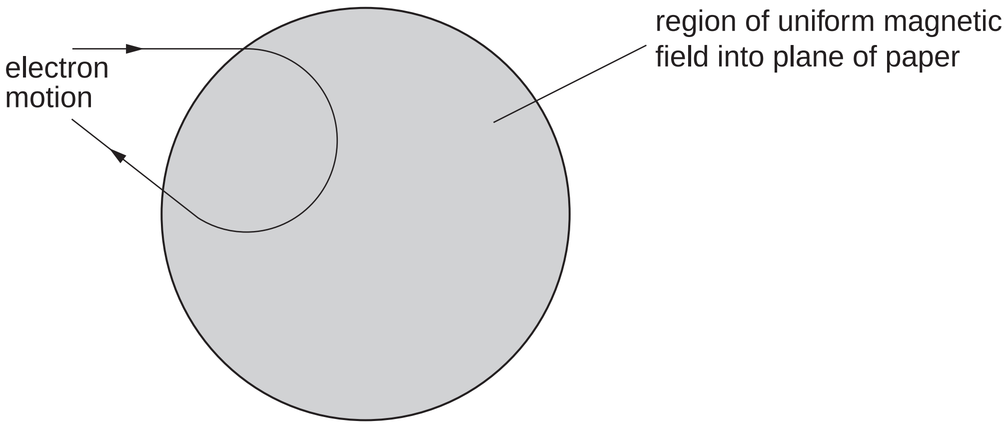

Fig. 11.1

The magnetic field of strength B causes each electron of mass m, velocity v and charge e to move in a circle of radius r. By considering the centripetal force on each electron of kinetic energy E_k, show that

(i) $r = \dfrac{mv}{Be}$

[1]

(ii) $r = \dfrac{\sqrt{2E_k m}}{Be}$.

[2]

(c) The electrons are replaced with protons of the same energy. Use $r = \dfrac{\sqrt{2E_k m}}{Be}$ to sketch on Fig. 11.2 the path you would expect for the protons as they pass through the field and out the other side. You are not required to do any calculations.

$m_p = 1.7 \times 10^{-27}$ kg

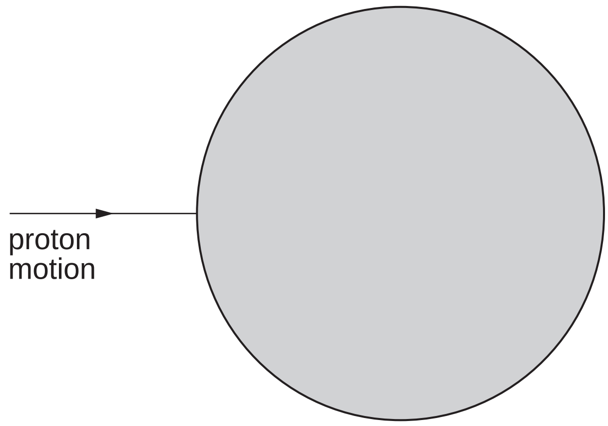

Fig. 11.2

[3]

[Total: 10]

12 This question is about neutrons from a nuclear reactor in a power station.

Fig. 12.1 shows the construction of a detector of neutrons from the reactor.

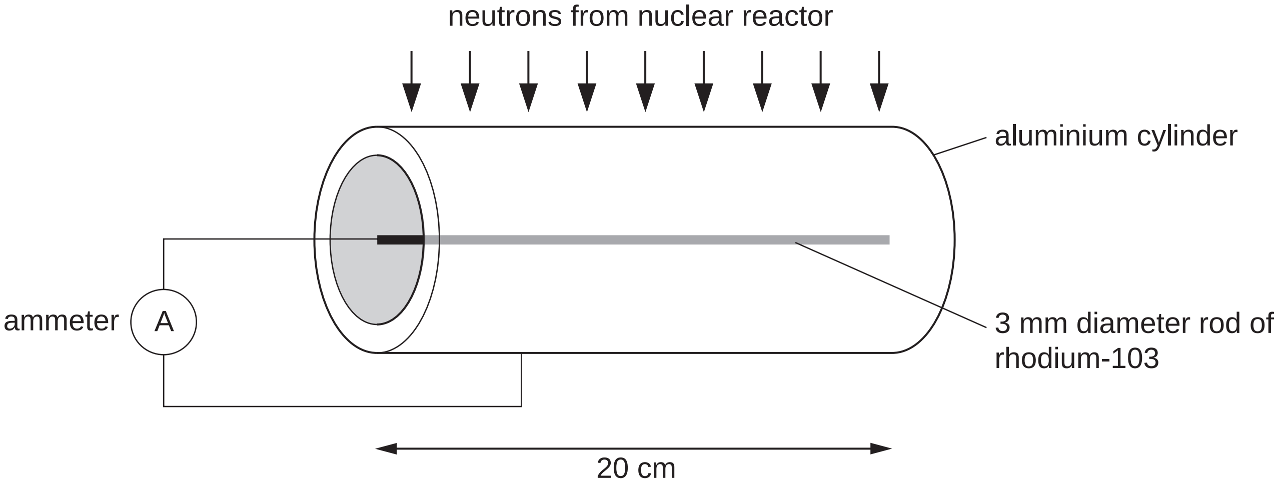

Fig. 12.1

A rod of rhodium-103 at the centre of a metal cylinder absorbs neutrons to become rhodium-104. The rhodium-104 decays with a half-life of 43 s, emitting 2.44 MeV beta particles. These are absorbed by the cylinder giving a current in the ammeter.

(a) **(i)** Complete the nuclear equation to represent the process of neutron absorption and beta emission.

$$^{103}_{45}\text{Rh} + {}^{1}_{0}\text{n} \rightarrow {}^{104}_{45}\text{Rh} \rightarrow {}^{\dots\dots}_{\dots\dots}\text{Pd} + {}^{0}_{-1}\text{e} + {}^{0}_{0}\bar{\nu}$$

[1]

(ii) Suggest why most of the neutrons pass through the aluminium cylinder but all of the beta particles are absorbed by it.

[1]

(b) The detector produces one beta particle for every 6 neutrons which arrive at the rod of rhodium-103. Calculate the rate at which neutrons are arriving at the rod when the ammeter reads 42 nA.

$e = 1.6 \times 10^{-19}$ C

neutron rate = ... s^{-1} [2]

(c) The reactor is shielded by 48 cm of concrete. Half of the neutrons from the reactor are absorbed by 8.0 cm of concrete. Calculate the percentage of the neutrons transmitted through 48 cm of concrete.

percentage transmitted = ... % [2]

(d) The maximum permitted dose equivalent for people who work with radiation is 20 mSv per year over five years.

(i) The risk of developing cancer due to exposure to radiation is 3% per Sv.

Estimate the risk to a worker who receives the maximum permitted dose equivalent for five years.

risk = ... % [1]

(ii) Calculate the average rate at which a 65 kg person must absorb 0.025 eV neutrons from the reactor over a year to reach the maximum permitted dose equivalent.

Neutrons have quality factor of 10.

1 year = 3.2×10^{7} s
1 eV = 1.6×10^{-19} J

neutron absorption rate = ... Bq [3]

[Total: 10]

13 This question is about the electric field around the charged conducting sphere of Fig. 13.1.

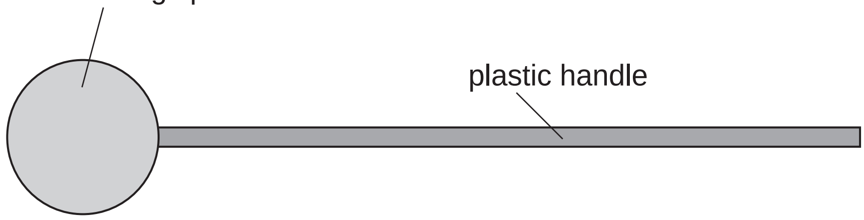

Fig. 13.1

(a) The conducting sphere is charged by placing it in contact with an electrostatic generator. This raises the potential of the sphere sufficiently high for the electric field at its surface to be $3.0 \times 10^6\,\mathrm{V\,m^{-1}}$. This is the highest field strength at which air is still an insulator.

(i) Show that the charge on the sphere is about $1 \times 10^{-7}\,\mathrm{C}$.

radius of sphere = 2.0 cm
$k = 9.0 \times 10^9\,\mathrm{N\,m^2\,C^{-2}}$

[3]

(ii) Calculate the potential of the charged sphere.

potential = ... V [2]

(b) The centre of the charged sphere is held a distance *h* above a metal plate as shown in Fig. 13.2. The metal plate has a potential of 0V.

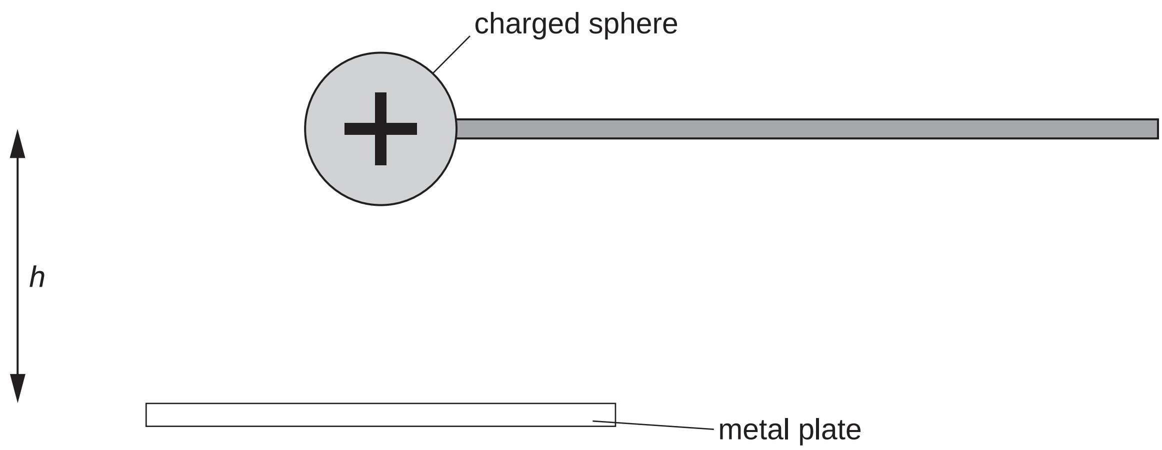

Fig. 13.2

(i) On Fig. 13.2, draw **five** solid lines to represent the electric field between the charged sphere and the metal plate. Use arrows to show the direction of the field. [2]

(ii) On Fig. 13.2, sketch a dotted line to show an equipotential between the sphere and the plate. [1]

Turn over for question 13(c)

(c)

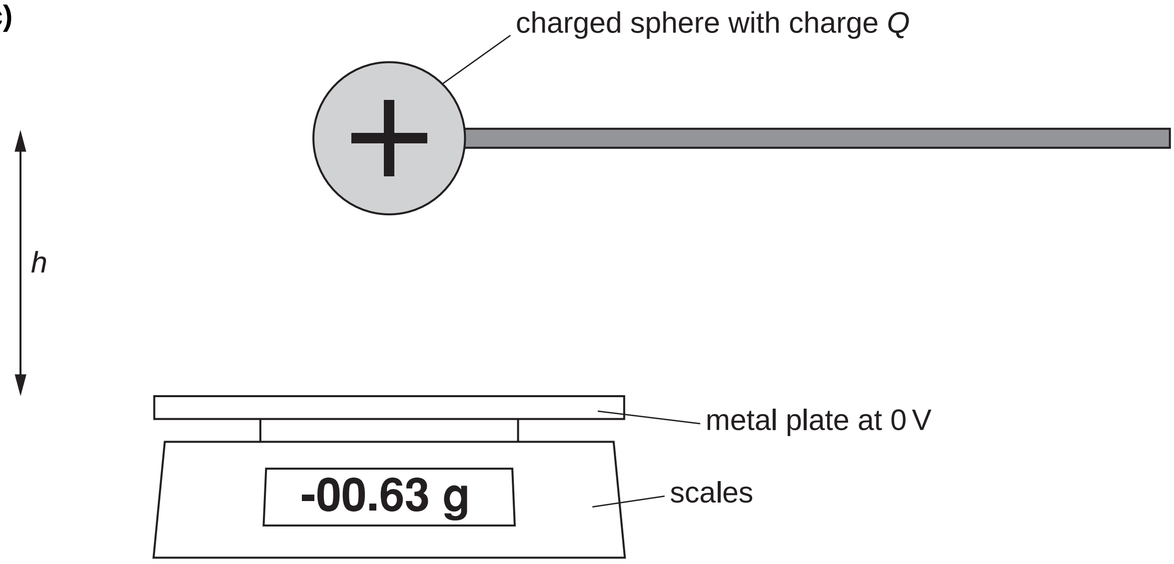

Fig. 13.3

The charged sphere exerts an upwards force *F* on the metal plate given by

$$F = \frac{kQ^2}{4h^2}$$

where *Q* is the charge of the sphere and *h* is the distance from the metal plate to the centre of the charged sphere.

Describe how this relationship could be checked by making a series of measurements with the apparatus of Fig. 13.3.

[4]

[Total: 12]

Quality of Written Communication [4]

[Section B Total: 50]

END OF QUESTION PAPER