



ADVANCED GCE
PHYSICS B (ADVANCING PHYSICS)
 Field and Particle Pictures

2864/01

Candidates answer on the Question Paper

OCR Supplied Materials:

- Data, Formulae and Relationships Booklet

Other Materials Required:

- Electronic calculator

Friday 18 June 2010
Morning

Duration: 1 hour 15 minutes



Candidate Forename		Candidate Surname	
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Centre Number							Candidate Number			
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INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use 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.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.
- 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.
- This document consists of **16** pages. Any blank pages are indicated.

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

Answer **all** the questions.

Section A

- 1 Here is a list of units.

A T V W Wb

State the correct unit from the list for

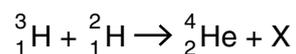
- (a) magnetic flux density

..... [1]

- (b) rate of change of magnetic flux linkage.

..... [1]

- 2 The equation shows the fusion of tritium and deuterium to form helium.



Particle X is one of the following:

electron neutron proton quark

X is [1]

- 3 A nitrogen-14 nucleus has a charge of $1.12 \times 10^{-18}\text{C}$.
Calculate the electric field strength at a distance of $9.0 \times 10^{-10}\text{m}$ from the centre of the nucleus.

$$k = 9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

electric field strength = N C^{-1} [2]

- 4 Fig. 4.1 shows a number of equipotentials around a charged conductor.

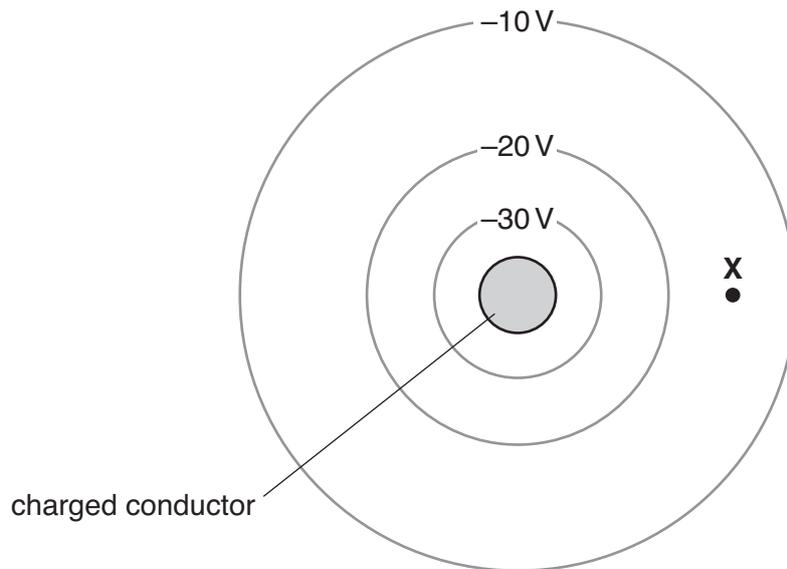


Fig. 4.1

- (a) Draw an arrow through point **X** to show the direction of the electric field at that point. [1]
- (b) The strength of the electric field around the charged conductor decreases with increasing distance from the conductor.

Describe the feature of Fig. 4.1 which shows this.

[1]

- 5 The iron rod of Fig. 5.1 has 420 turns of wire coiled around it. A current of 0.48 A in the coil gives it a flux linkage of 6.3×10^{-4} Wb turns. The rod has a cross-sectional area of $2.6 \times 10^{-5} \text{ m}^2$.

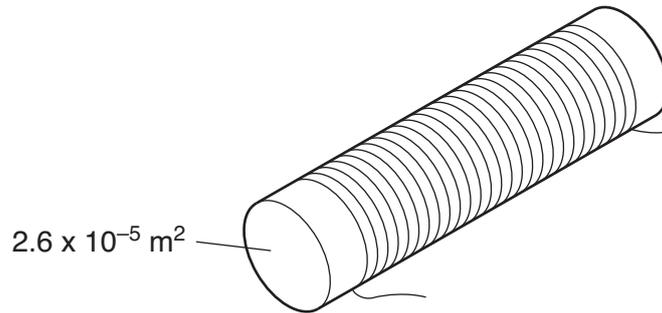


Fig. 5.1

- (a) Calculate the magnetic flux density in the iron.

flux density = Wb m^{-2} [2]

- (b) The current in the coil is increased steadily from 0 A to 0.48 A in 5.0 ms. Calculate the p.d. required across the coil during the 5.0 ms. Assume the coil has no resistance.

p.d. = V [1]

- 6 The primary coil of a transformer has 1200 turns and the secondary coil has 240 turns. The primary coil is connected to a 110V, 50Hz supply. Calculate the voltage across the secondary coil and state its frequency.

voltage = V

frequency = Hz [3]

- 7 Fig. 7.1 shows the initial path **P** of an alpha particle as it approaches close to a nucleus.

nucleus •



Fig. 7.1

- (a) Draw the path of the alpha particle on Fig. 7.1 when it is scattered through 90° by the nucleus. [1]
- (b) A beam of 5 MeV alpha particles is fired at a thin metal target. A small number of alpha particles in the beam is scattered through more than 90° . Which one of the following changes (**A**, **B** or **C**) would result in a **decrease** in this number?
- A** Increasing the thickness of the metal target.
B Increasing the atomic number of the metal target.
C Increasing the energy of the alpha particles in the beam.

answer [1]

8 Here is a list of numbers.

10^{-6}

10^{-10}

10^{-14}

10^{-18}

For a nucleus of ${}_{11}^{23}\text{Na}$, which value is the best order of magnitude estimate for

(a) the charge in coulombs

charge = C [1]

(b) the radius in metres?

radius = m [1]

9 Palladium-101 is an emitter of positrons.

(a) The activity of any radioactive source can be calculated using the relationship

$$\frac{\Delta N}{\Delta t} = -\lambda N.$$

Use the relationship to show that the decay constant λ has units of s^{-1} .

[1]

(b) Palladium-101 has a half-life of 8.4 hours.
Show that its decay constant is about $2 \times 10^{-5} \text{ s}^{-1}$.

[1]

(c) Calculate the number of palladium-101 atoms required to make a source of activity $3.7 \times 10^4 \text{ Bq}$.

number of atoms = [1]

[Section A Total: 20]

Section B

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

10 This question is about the electric motor shown below.

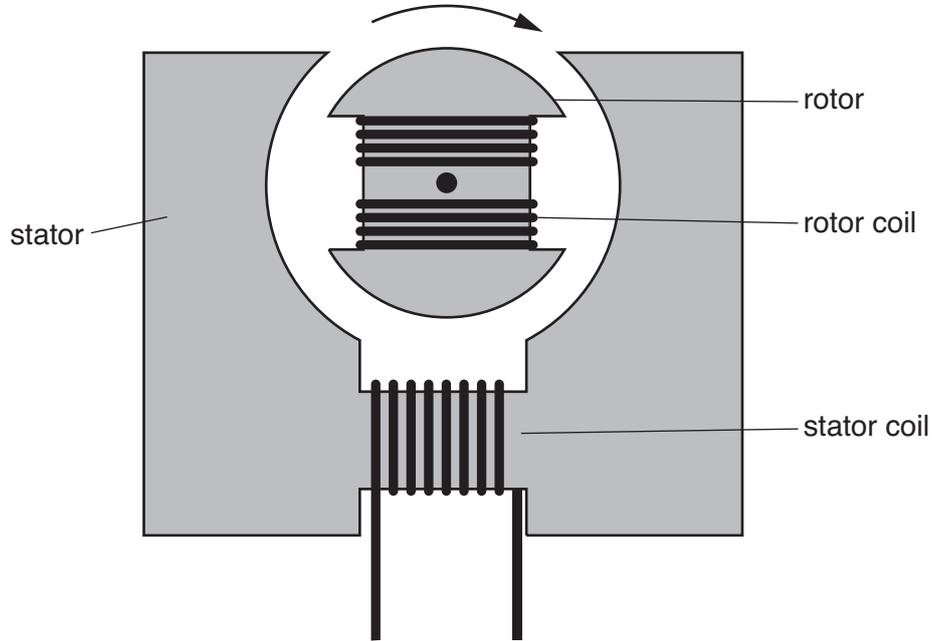


Fig. 10.1

- (a) There is magnetic flux in the stator when there is a current in the stator coil. The stator is made of iron. Explain why this is a good material to use for a motor.

[2]

- (b) The rotor is made from thin sheets of iron, separated by thin sheets of an insulator, instead of solid iron. Explain why.

[3]

(c) The rotor and stator coils are connected in parallel to the same power supply.

(i) Explain why the force on the rotor coil can be increased by increasing the current from the power supply.

[2]

(ii) Suggest and explain **two** other modifications to the motor which would result in an increased force on the rotor coil.

[3]

[Total: 10]

11 This question is about the scattering of electrons from protons.

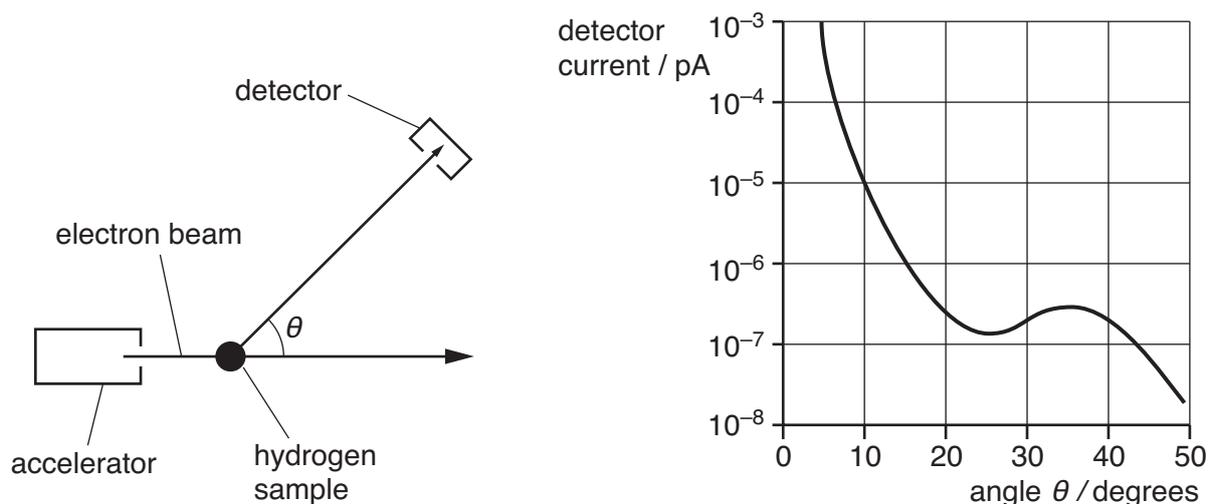


Fig. 11.1

- (a) The electrons from the accelerator have a current of 70 pA.
 Calculate the rate at which electrons arrive at the hydrogen sample.
 $e = 1.6 \times 10^{-19} \text{ C}$

electron rate = s^{-1} [2]

- (b) The accelerator raises the energy of the electrons to 900 MeV.
- (i) Show that this is much greater than the rest energy of an electron.
 $c = 3.0 \times 10^8 \text{ m s}^{-1}$
 $m = 9.1 \times 10^{-31} \text{ kg}$

[2]

- (ii) The momentum p of each electron is related to its energy E by the formula

$$E = pc$$

where $c = 3.0 \times 10^8 \text{ m s}^{-1}$.

Calculate the de Broglie wavelength of the electrons.

$$h = 6.6 \times 10^{-34} \text{ J s}$$

wavelength = m [2]

- (iii) The graph of Fig. 11.1 is for electrons which are scattered elastically from the protons in the sample of hydrogen. The shape of the graph suggests a diffraction pattern with a distinct minimum.
Use data from the graph to estimate the diameter of a proton.

proton diameter = m [3]

- (c) At much higher energies, the electrons probe **inside** the protons.
By referring to the internal structure of the proton, explain why this can only happen at much higher electron energies.

[2]

[Total: 11]

- 12 This question is about the risks of radiation from a fission reactor. It is proposed that a small nuclear reactor should provide electricity for the first astronauts who journey to Mars.

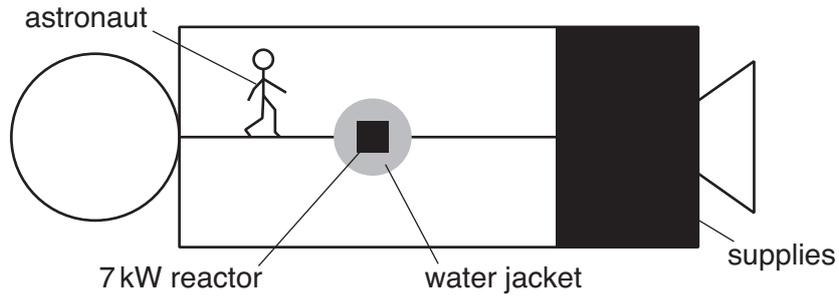


Fig. 12.1

- (a) There is some concern about the hazard due to ionising radiation from the reactor. It is proposed to locate the reactor at the centre of the astronauts' living quarters, as shown in Fig. 12.1.

- (i) The reactor is encased in a water jacket to make it safer. State why the gamma photons from the reactor will be a hazard, but the beta particles will not.

[1]

- (ii) The reactor is run at a constant output power. An astronaut who is 5 m from the centre of the reactor will receive a dose equivalent of about 6 mSv s^{-1} . Calculate the increased risk of cancer due to this hazard from just ten minutes exposure. The risk of developing cancer is 3% per sievert.

risk = % [2]

(iii) This risk is unacceptably high. Suggest and explain **two** modifications to this reactor arrangement which would significantly reduce the hazard to the astronauts.

(b) Each fission of a uranium-235 nucleus in the reactor releases 206 MeV of energy. [4]

(i) State the meaning of the term *fission*.

[1]

(ii) Calculate the rate of fission of nuclei in the reactor required to release energy at a rate of 7.0 kW.

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

rate of fission = s⁻¹ [2]

(iii) Each fission of a uranium-235 nucleus releases about three neutrons. Describe how these neutrons are treated in the reactor so that it can maintain a steady and controlled release of energy.

[4]

[Total: 14]

13 This question is about the nucleus of radium-226.

(a) The nucleus of radium-226 contains neutrons and protons.

(i) The table gives the masses of separate nucleons.

nucleon	mass / kg
proton	1.673×10^{-27}
neutron	1.675×10^{-27}

Calculate the total mass of the separate nucleons which make a single nucleus of ${}^{226}_{88}\text{Ra}$.

total mass = kg [2]

(ii) Explain why the mass of a single nucleus of ${}^{226}_{88}\text{Ra}$ is less than your answer to (i).

[3]

(b) When a nucleus of radium-226 decays, it emits an alpha particle. The graph of Fig. 13.1 shows the variation of potential energy of the alpha particle with distance from the centre of the nucleus before the nucleus decays.

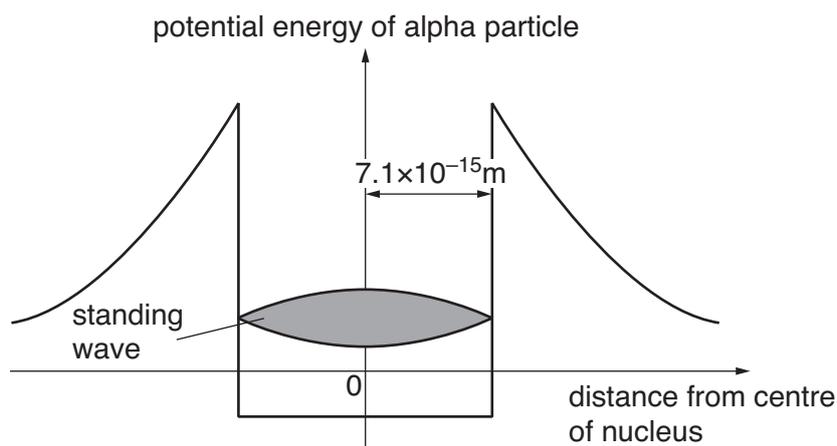


Fig. 13.1

- (i) The standing wave for the lowest energy state of the alpha particle is shown in Fig.13.1. Show that the de Broglie wavelength λ of the alpha particle in the nucleus is about 3×10^{-14} m.
The radius of a radium-226 nucleus is 7.1×10^{-15} m.

[1]

- (ii) Hence show that the momentum p of the alpha particle in its lowest energy state is about 2×10^{-20} N s.
 $h = 6.6 \times 10^{-34}$ J s

[2]

- (iii) Calculate the kinetic energy of the alpha particle in its ground state.
 $m_{\text{alpha}} = 6.7 \times 10^{-27}$ kg

kinetic energy = J [2]

- (c) Although the alpha particle is bound by the other particles in the nucleus, it has a small probability of escaping, causing the decay of the nucleus.
Suggest why the alpha particle has a small probability of escaping.

[1]

[Total: 11]

Quality of Written Communication [4]

[Section B Total: 50]

END OF QUESTION PAPER

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