OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (Advancing Physics) 2864/01

Field and Particle Pictures

Thursday **27 JUNE 2002** Morning 1 hour 10 minutes

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

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 10 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations, and round answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- 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.
- You are advised to spend about 20 minutes on Section A and 50 minutes on Section B.
- You will be awarded marks for the quality of written communication in Section B.

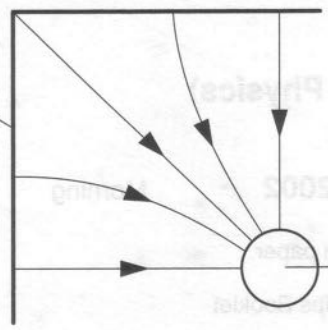
FOR EXAMINER'S USE		
Section	**Max.**	**Mark**
A	**20**	
B	**50**	
TOTAL	**70**	

This question paper consists of 15 printed pages and 1 blank page.

For Examiner's Use

SECTION A

1 The diagram shows five electric field lines between a sphere and a bent plate.



Sketch an equipotential line in the region between the sphere and the bent plate. [2]

2 The primary and secondary coils of a transformer are wound on an iron core. Each coil has a different cross-sectional area and number of turns. Which **one** of the following quantities will be the same for both coils?

A magnetic flux

B magnetic flux density

C magnetic flux linkage

answer .... [1]

3 The radioisotope potassium-40 decays to calcium-40, emitting a beta particle and an anti-neutrino.

(a) State the value of *Z* in this equation which represents the decay.

$$^{40}_{19}K \longrightarrow {}^{40}_{Z}Ca + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}$$

Z = ... [1]

(b) Here are some facts about the decay of potassium-40.

A The decay constant for beta decay is only $1.7 \times 10^{-17}\ s^{-1}$.

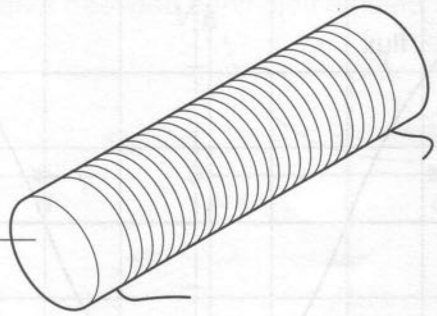
B The beta particles emerge with a wide range of energies.

C The decay product calcium-40 is stable.

Which fact provides the best experimental evidence for the emission of an anti-neutrino in the decay?

answer =.................. [1]

4 An iron rod has 400 turns of wire coiled around it. There is a current in the coil. The rod has a cross-sectional area of $1.25 \times 10^{-5}\,m^2$.



The **flux linkage** of the coil is 4.0×10^{-4} Wb.

(a) Calculate the flux linking **one** turn of the coil.

flux =.................... Wb [1]

(b) Calculate the flux density in the iron.

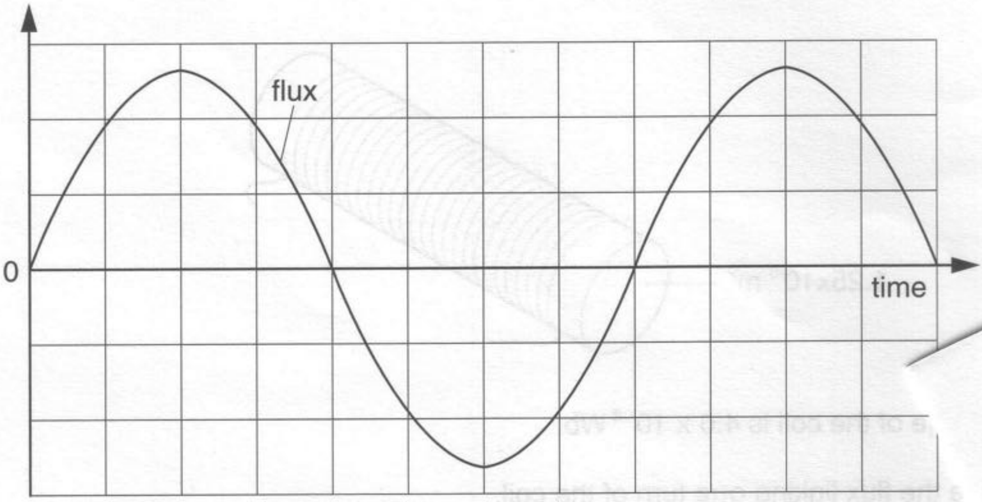
flux density =.................... T [2]

5 In an experiment to sterilise fruit, apples are exposed to an absorbed dose of 4.0 Gy ($J\,kg^{-1}$). Calculate the energy absorbed by an apple of mass 0.12 kg.

energy =.................... J [2]

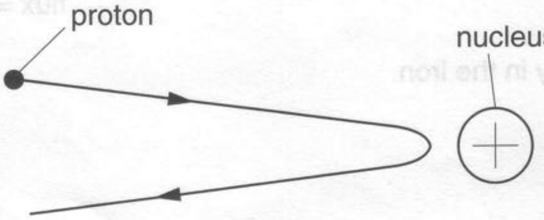
For Examiner's Use

6 The graph shows how the magnetic flux in a coil changes with time.



Draw on the graph to show how the voltage induced across the coil changes with t

7 The diagram shows the path followed by a 4 MeV proton as it almost collides head-on \
large nucleus.



Another proton, with the same initial path, almost collides with the same nucleus. The proton has an energy of **more** than 4 MeV.

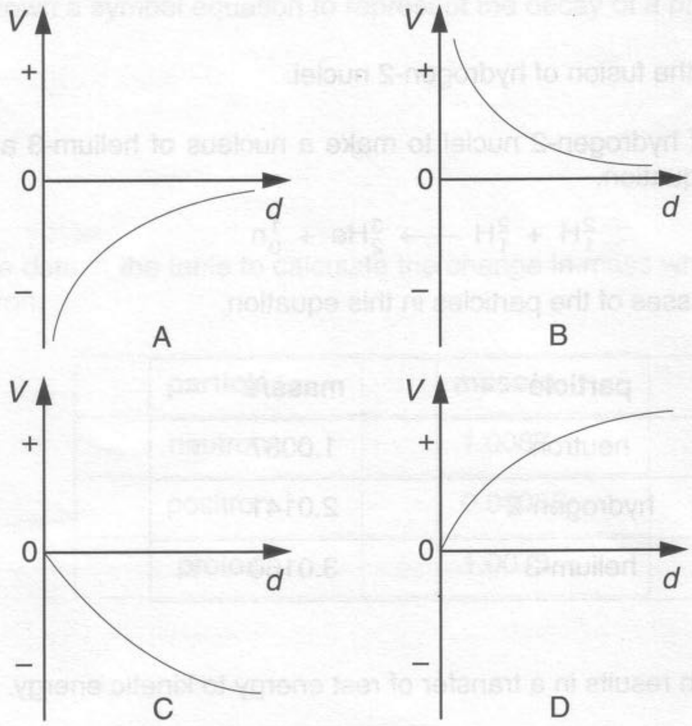
State and explain what difference this change would make to the distance of closest approach with the nucleus.

[2]

8 Dust inhaled into the lungs can contain specks of material which emit ionising radiation. There is a risk that this can give rise to lung cancer. Discuss briefly why the risk is greatest for a material which emits alpha particles.

[2]

9 The graphs show how the electrical potential V around an object depends on the distance d from its centre.



Which graph best shows the variation of potential with distance from a **proton**?

answer = ... [1]

10 A carbon-12 nucleus has a charge of $+1.92 \times 10^{-18}$ C.
Calculate the electric field strength at a distance of 5.0×10^{-11} m from the centre of the nucleus. State the unit with your answer.

electric field = ... [3]

For Examiner's Use

SECTION B

Up to four marks in this section will be awarded for the quality of written communication.

11 This question is about the fusion of hydrogen-2 nuclei.

The fusion of a pair of hydrogen-2 nuclei to make a nucleus of helium-3 and a neutron is given by this symbol equation.

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n$$

The table gives the masses of the particles in this equation.

particle	mass/u
neutron	1.0087
hydrogen-2	2.0141
helium-3	3.0160

(a) The fusion reaction results in a transfer of rest energy to kinetic energy.

(i) Show that the decrease of mass resulting from the fusion of two hydrogen-2 nuclei is 0.0035 u.

(ii) Calculate the kinetic energy resulting from this mass decrease.

1 u = 1.66 x 10^{-27} kg.

kinetic energy =.................... J [4]

For Examiner's Use

(b) A proton bound in a nucleus can decay into a neutron by emitting a positron and a neutrino.

(i) Write down a symbol equation to represent the decay of a proton.

(ii) Use the data in the table to calculate the change in mass when a proton decays to a neutron.

particle	mass/u
neutron	1.0087
positron	0.00055
proton	1.0073

change of mass =.................... u

(iii) Use your answer to **(b) (ii)** to suggest why this decay is not possible for a free proton.

[5]

[Turn over

For Examiner's Use

12 This question is about the simple d.c. motor shown in Fig. 12.1.

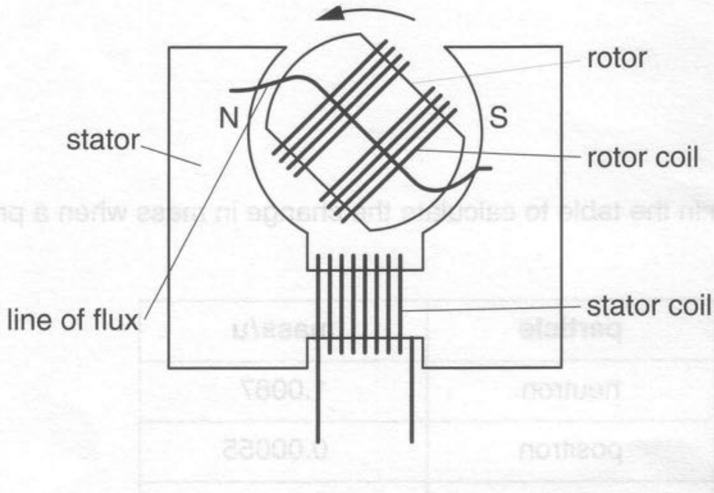


Fig. 12.1

(a) There is current in both the rotor and stator coils. Complete the line of flux drawn in Fig. 12.1. [2]

(b) The rotor is turning anticlockwise.

(i) Mark the north and south poles of the rotor appropriately.

(ii) Explain what causes the rotor to turn.

[4]

For Examiner's Use

(c) The rotor and stator coils are connected to separate power supplies whose voltage can be altered independently.

(i) The graph of Fig. 12.2 shows the voltage across the rotor being changed suddenly.

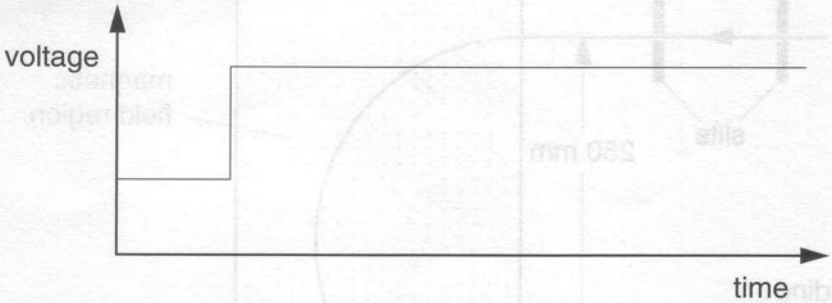


Fig. 12.2

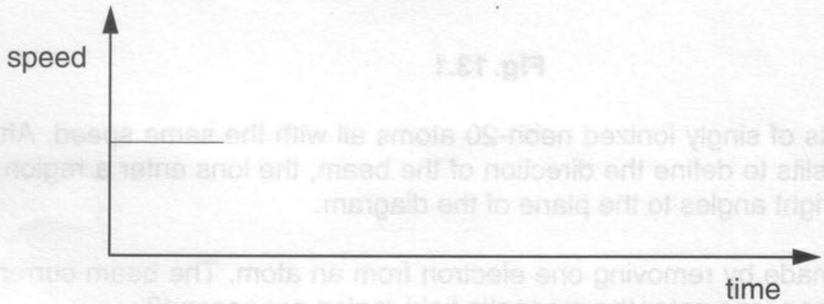


Fig. 12.3

Complete the graph of Fig. 12.3 to show how the speed of the rotor changes over the same time. [2]

(ii) Surprisingly, when the voltage across the **stator coil**, which provides the magnetic field across the rotor, is increased, the rotor actually slows down.

Suggest why this happens.

[2]

13 This question is about the motion of charged particles in magnetic fields.

Fig. 13.1 shows the path of a beam of ions in a vacuum as they pass through a magnetic field.

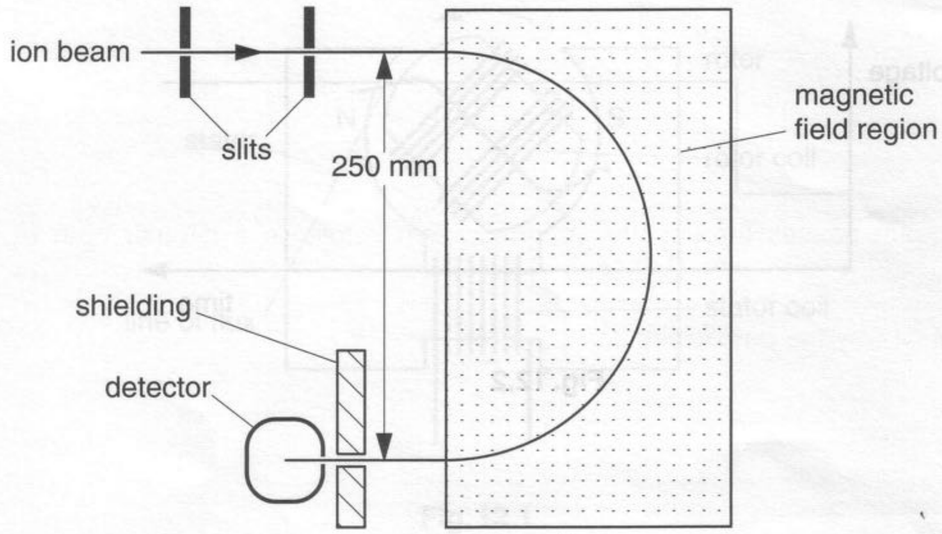


Fig. 13.1

The beam consists of singly ionized neon-20 atoms all with the same speed. After passing through a pair of slits to define the direction of the beam, the ions enter a region of uniform magnetic field at right angles to the plane of the diagram.

(a) Each ion is made by removing one electron from an atom. The beam current is 20 μA. How many neon ions enter the magnetic field region per second?

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

number of ions = ... s^{-1} [2]

(b) The ions are accelerated as they pass between the slits. The ions enter the first slit with a speed of 100 $m\,s^{-1}$ and leave the second slit with a speed of $3.0 \times 10^5\,m\,s^{-1}$. The mass of a neon-20 atom is 3.32×10^{-26} kg.

(i) Calculate the increase of kinetic energy of a single ion as it passes between the slits.

kinetic energy increase = ... J

For Examiner's Use

(ii) Show that the potential difference between the slits must be greater than 5 kV.

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

[4]

(c) As the beam passes through the magnetic field it follows a circular path of radius 0.125 m.

(i) Explain why the path is circular.

(ii) Each neon-20 ion has a speed of $3.0 \times 10^5 \text{ m s}^{-1}$.
Show that the centripetal force required on an ion of mass 3.32×10^{-26} kg is 2.4×10^{-14} N.

(iii) By considering the magnetic force on a neon-20 ion, calculate a value for the magnetic flux density.

magnetic flux density = ... T [6]

(d) On one occasion the neon-20 beam is contaminated with a small amount of neon-22. However, none of the neon-22 ions arrive at the detector. Explain why.

[2]

[Turn over

14 This question is about the scattering of electrons from nuclei.

(a) The volume $\frac{4}{3}\pi r^3$ of a nucleus of radius r is approximately proportional to the number of nucleons in it.

(i) What does this tell you about the arrangement of nucleons in a nucleus?

(ii) Show that the radius r of a nucleus is given by the formula

$$r = r_0 A^{1/3}$$

where A is the atomic mass number and r_0 is a constant.

(iii) Use the formula to show that the diameter of a neon-20 nucleus is 6.5×10^{-15} m. The constant $r_0 = 1.2 \times 10^{-15}$ m.

[7]

Electrons are directed towards a sample of neon-20 atoms, as shown in Fig. 14.1.

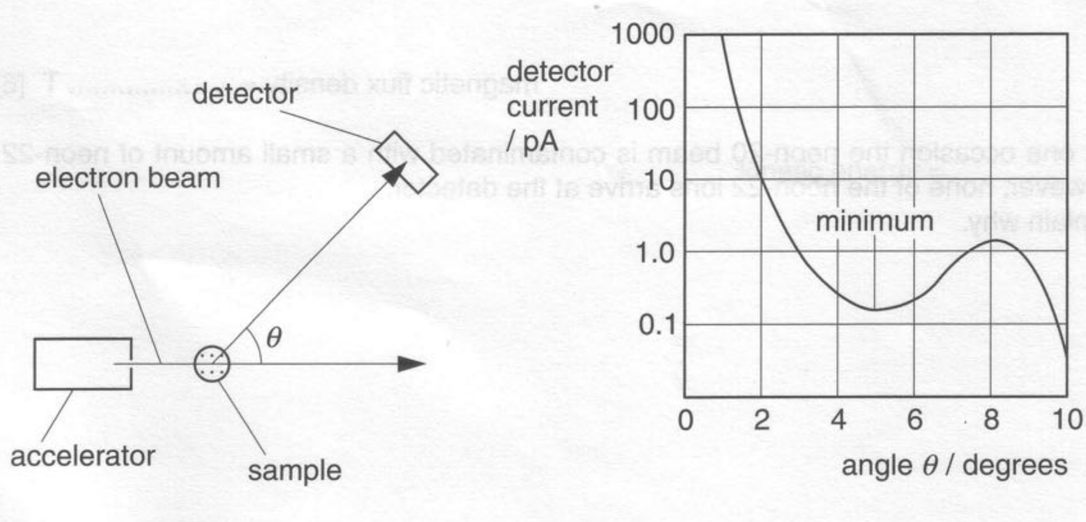


Fig. 14.1

For Examiner's Use

(b) The graph of Fig. 14.1 shows the distribution of the electrons scattered elastically from the sample. The graph shows a diffraction pattern.

By considering the path of electrons around a nucleus, explain why the graph has a minimum. No calculations are required.

[2]

(c) The angle θ for the first minimum of the diffraction of waves with wavelength λ around a circular object of diameter b is given by the formula

$$\lambda = 1.2\, b \sin\theta$$

(i) Use the formula to show that the wavelength of the electrons in the beam is about 7×10^{-16} m.

(ii) Calculate the momentum of the electrons in the beam.
$h = 6.63 \times 10^{-34}$ J s

momentum = ... N s [2]

Question 14 continued overleaf.

(d) The neon-20 sample is replaced with a sample with the same number of argon-40 atoms. The graph of Fig. 14.2 shows what effect this has on the scattering of the electrons in the beam.

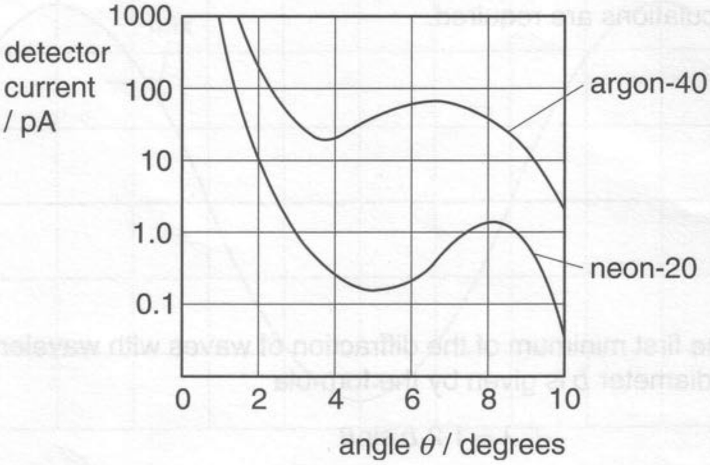


Fig. 14.2

Explain the differences between the two curves in the graph of Fig. 14.2. Both are produced by electron beams of the same energy.

[2]

Quality of Written Communication [4]