OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2864/01

Field and Particle Pictures

Friday **20 JANUARY 2006** Morning 1 hour 15 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 15 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 provided 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 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.
- 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 question paper consists of 14 printed pages and 2 blank pages.

SP (NF/SLM) S87862/4

Answer **all** the questions.

Section A

1 Here is a list of units.

N C^{-1} **V** **Wb** **Wb m^{-2}**

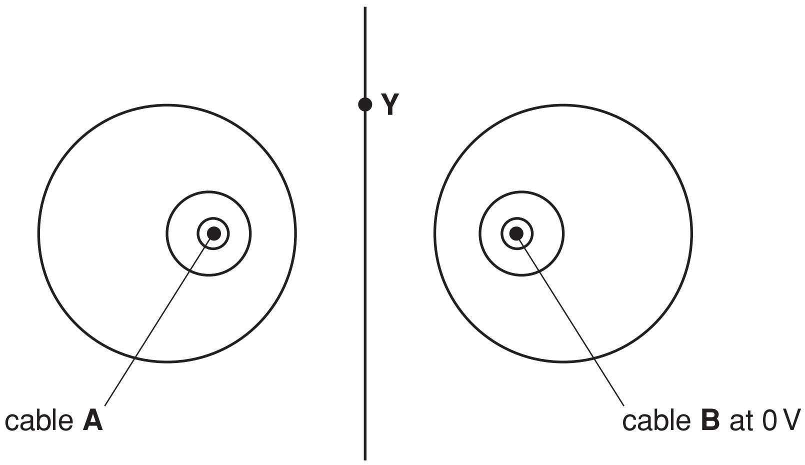
(a) Which is the correct unit for electric field strength?

answer .... [1]

(b) Which is the correct unit for magnetic field strength?

answer .... [1]

2 The diagram shows some equipotentials at intervals of 20 kV around a pair of cables **A** and **B**. Cable **B** is at 0 V.



(a) Here are some values for potential.

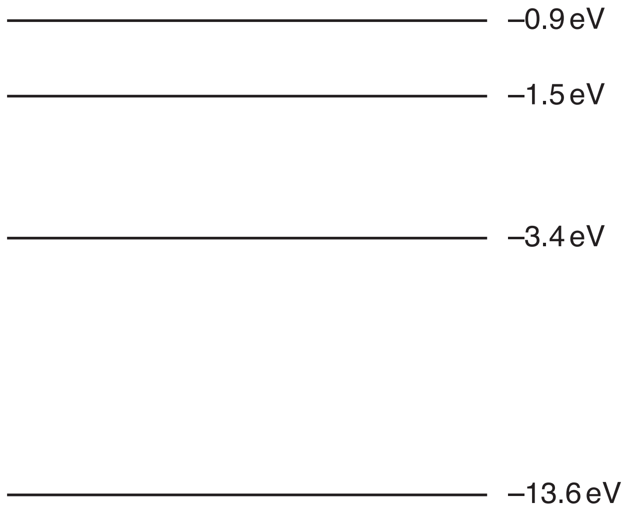
+8 kV **+20 kV** **+160 kV**

Which one is the correct value for the potential of cable **A**?

answer .... [1]

(b) Sketch the electric field line which goes from cable **A** to cable **B** through point **Y**. Include an arrow to show the direction of the field. [2]

3 The diagram shows the four lowest energy levels for a hydrogen atom.



(a) A photon of energy 1.9 eV is emitted by the atom.
Draw an arrow on the diagram to show the change of energy levels involved. [1]

(b) In its ground state, the hydrogen atom has an energy of –13.6 eV. An electron of energy 12.0 eV has an inelastic collision with a hydrogen atom in its ground state.

(i) Explain why the hydrogen atom cannot take all of the energy from the electron.

[1]

(ii) Calculate the energy of the electron after the collision.

energy = ... eV [1]

4 A step-down transformer is used to convert the 230 V, 50 Hz mains supply into a 6 V supply.

Here are some statements about the flux in the transformer.

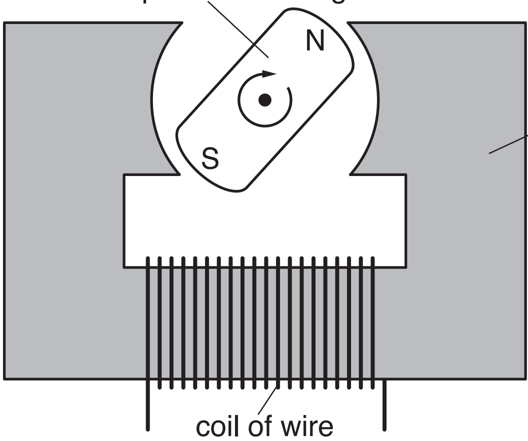
A Most of the flux is in the soft iron core.
B The flux changes at a frequency of 50 Hz.
C The flux is greater in the secondary coil than in the primary coil.

Which **one** of the statements **A**, **B** or **C** is **false**?

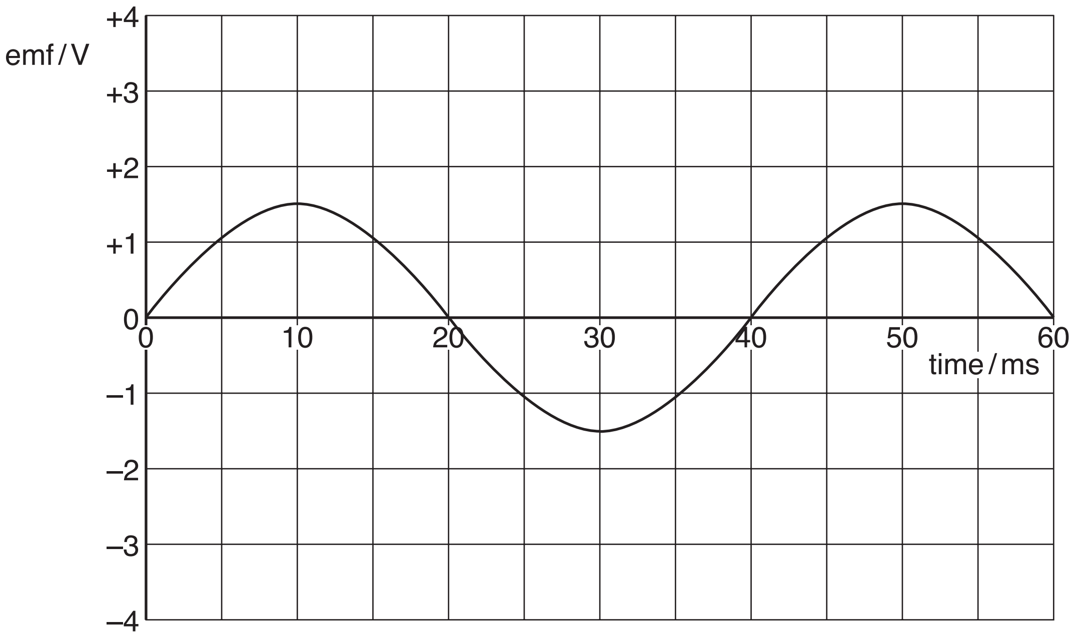
answer .... [1]

[Turn over

5 The diagram shows a cross-section through a simple AC generator.



The graph shows how the emf induced in the coil varies with time as the magnet is rotated.



(a) Explain how rotating the magnet causes an emf in the coil.

[2]

(b) Show that the magnet rotates at 25 revolutions per second.

[1]

(c) Draw on the graph to show how the emf varies with time when the magnet is rotated at 50 revolutions per second. [2]

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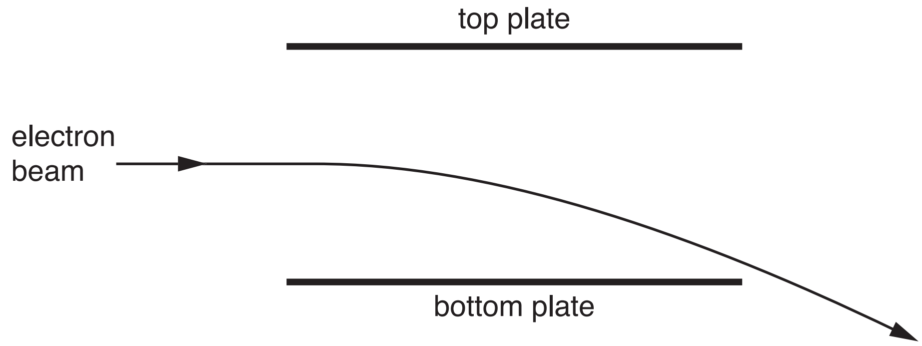
6 The diagram shows an electron beam passing between a pair of parallel conducting plates.



(a) Draw **five** arrowed lines on the diagram to represent the electric field between the plates. [3]

(b) The electric field strength between the plates is $8.0 \times 10^4\,\text{V m}^{-1}$.
The plates are separated by $5.0 \times 10^{-2}\,\text{m}$.
Calculate the potential difference between the plates.

potential difference = ... V [2]

7 Here are three correct statements about the fission of a nucleus of uranium-235 when it absorbs a slow neutron.

A On average, about three neutrons are released.
B The total number of nucleons in the products is also 236.
C The total rest energy of the products is less than the rest energy of the original nucleus.

Which **one** of the statements (**A**, **B** or **C**) best explains why a chain reaction can be set up in a critical mass of uranium-235?

answer .... [1]

[Section A Total: 20]

[Turn over

For Examiner's Use

Section B

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

8 This question is about the use of magnetic fields to slow down road vehicles.

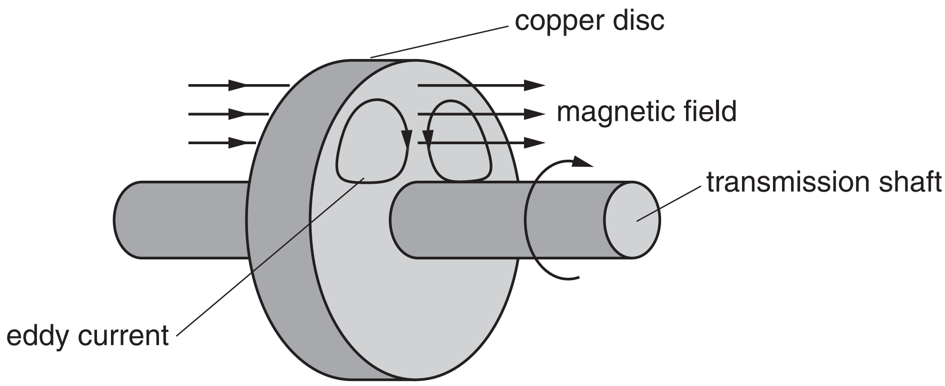


Fig. 8.1

Fig. 8.1 shows a copper disc fastened to the transmission shaft of a vehicle.
There is a magnetic field through part of the disc when slowing the vehicle.

(a) As the copper disc rotates, eddy currents apply a braking force to the shaft.

(i) Explain why eddy currents are induced in the copper disc.

[2]

(ii) Explain why the eddy currents result in a **force** on the disc which **brakes** the motion of the disc.

[2]

(iii) Explain why the braking force decreases as the speed of the disc decreases.

[2]

The magnetic field is created by an electromagnet, as shown in Fig. 8.2.

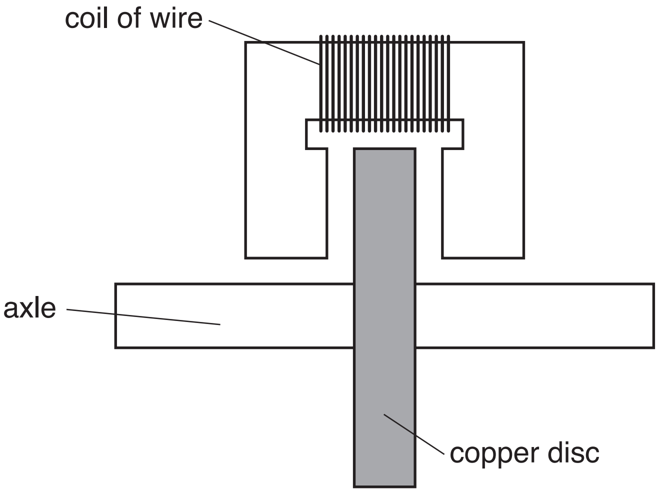


Fig. 8.2

(b) (i) On Fig. 8.2, sketch **two** flux loops produced by the electromagnet. [2]

(ii) Suggest a suitable material for the core of the electromagnet.
Give a reason for your answer.

[2]

(c) Suggest and explain one modification to the system which would increase the braking force at a given speed.

[2]

[Total: 12]

9 This question is about using alpha particles to produce a beam of neutrons.

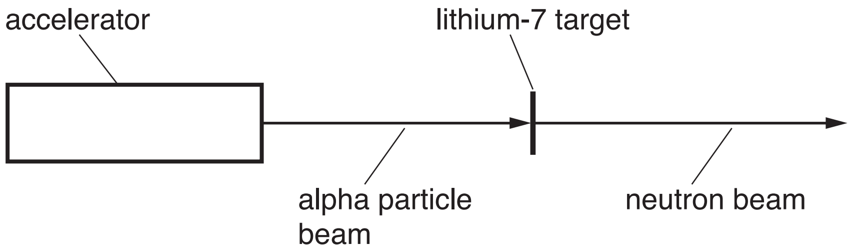


Fig. 9.1

Fig. 9.1 shows a beam of alpha particles incident on a target of lithium-7.

(a) On Fig. 9.2, sketch the trajectory of an alpha particle which approaches a lithium-7 nucleus along the path **P**, and is deflected by about 45°.

[1]

Fig. 9.2

(b) In Fig 9.3, the alpha particle on path **Q** has a head-on collision with a lithium-7 nucleus.

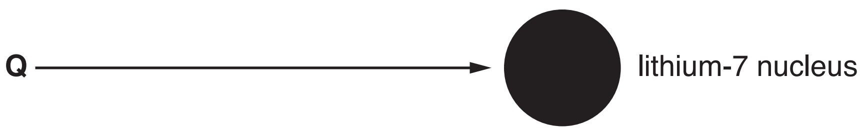


Fig. 9.3

This alpha particle gets to within a distance of 4.2×10^{-15} m from the centre of the nucleus.

(i) By discussing the energy changes of the alpha particle as it moves towards the centre of the nucleus, explain why it needs a **minimum** energy to get so close to the centre of the nucleus.

[2]

(ii) Calculate the minimum energy E required for alpha particles to get to 4.2×10^{-15} m of the centre of a lithium-7 nucleus in a head-on collision.

charge of alpha particle = 3.2×10^{-19} C
charge of lithium nucleus = 4.8×10^{-19} C

$k = \dfrac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}\ \text{N m}^2\ \text{C}^{-2}$

E = ... J [3]

(c) When the alpha particle gets to within 4.2×10^{-15} m of the centre of the nucleus, the following reaction takes place.

alpha particle + lithium-7 ⟶ boron-10 + neutron

The table gives the masses of the particles involved in the nuclear reaction.

particle	mass / u
alpha	4.0015
lithium-7 nucleus	7.0144
boron-10 nucleus	10.0011
neutron	1.0087

(i) Show that there is a decrease of mass of about 1×10^{-29} kg as a result of this reaction.

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

[2]

(ii) Calculate the maximum possible energy of a neutron ejected from the target when the alpha particles in the beam have an energy of 3.3×10^{-13} J.

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

neutron energy = ... J [2]

[Total: 10]

For Examiner's Use

10 Radon-222 is a naturally occurring gas which is radioactive. It is the biggest source of background radiation in the UK, contributing almost half of the average absorbed dose for people who live here.

(a) Radon-222 decays by emitting an alpha particle, becoming polonium-218.
Complete the nuclear equation for the decay of radon-222.

$$^{222}_{......}\text{Rn} \longrightarrow {}^{218}_{84}\text{Po} + {}^{......}_{2}\text{He}$$ [2]

(b) Polonium-218 has a half-life of only 3 minutes. Its decay produces a cascade of short-lived isotopes.
Here is the incomplete nuclear equation for one of the decays in the cascade.

$$^{214}_{83}\text{Bi} \longrightarrow {}^{214}_{84}\text{Po} + \text{X} + \text{Y}$$

X and Y are particles emitted in the decay.

(i) Explain why one of the particles X or Y could be an electron.

[2]

(ii) If X is an electron, suggest why Y could be an antineutrino.

[1]

(c) Alpha particles are emitted during the cascade of decays from radon-222.
Estimates of the cancer risk due to breathing in radon-222 need only consider these alpha particles.

(i) Suggest why gamma photons emitted in the cascade can be neglected when estimating the risk of cancer.

[2]

(ii) The alpha particles emitted by the decay of a radon-222 nucleus have a combined energy of 1.0×10^{-12} J. This contributes 47% of the annual background radiation dose of 2.5 mSv per year.
Show that about 130 nuclei of radon-222 must decay per second in the body of a person of mass 70 kg to provide this dose.

quality factor of alpha particles = 20
1 year = 3.2×10^{7} s

[3]

(d) **(i)** Radon-222 has a half-life of 3.8 days.
Show that the decay constant is about $2 \times 10^{-6}\,\text{s}^{-1}$.

[2]

(ii) Calculate the number of radon-222 nuclei required for 130 decays per second.

number = ... [2]

[Total: 14]

11 This question is about using electric and magnetic fields to control electrons.
In Fig. 11.1, electrons are ejected from the inner surface of a curved cathode and accelerate towards a flat anode. Some of the electrons pass through the hole in the anode.

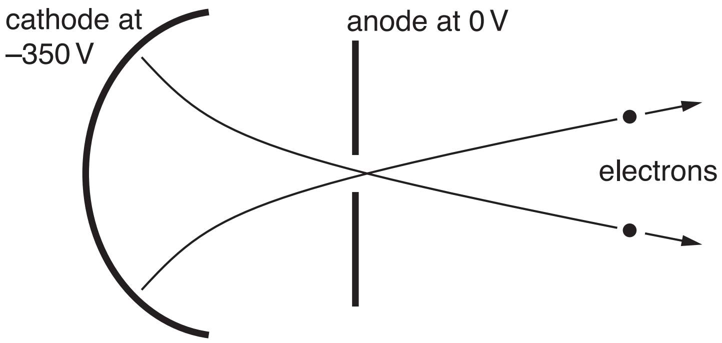


Fig. 11.1

(a) Show that the electrons emerge from the anode with a speed of about $1 \times 10^{7}\ \mathrm{m\,s^{-1}}$.

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

[3]

(b) Electrons pass through the hole in the anode over a range of angles. They move at a steady speed towards a target. A uniform magnetic field **B** along the central axis forces each electron to follow a spiral path, as shown in Fig. 11.2 and Fig. 11.3.

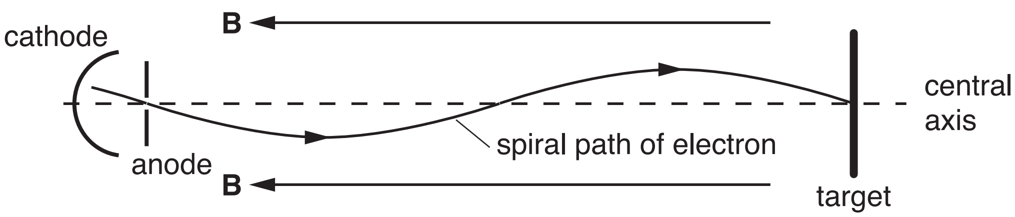


Fig. 11.2

Fig. 11.3 shows the path of an electron between the anode and the target, viewed along the direction of the central axis. From this perspective, the electron goes exactly once around a circle of radius *r* before hitting the target on the central axis.

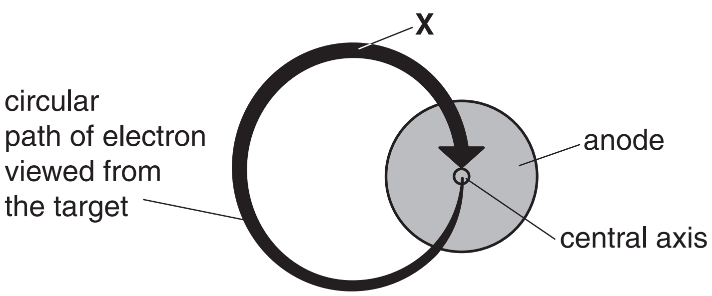


Fig. 11.3

(i) On Fig. 11.3, draw an arrow to show the direction of the magnetic force on the electron at point **X**. [1]

(ii) The electron at **X** has a charge *e* and mass *m*. It has a component of velocity *u* at **right angles** to the magnetic field of strength **B**.
By considering the force on the electron, show that the radius *r* of its circular path is given by $r = \frac{mu}{Be}$.

[2]

(iii) The electron takes a time *T* to go once round the circular path, a distance of $2\pi r$.
Show that *T* is given by $T = \frac{2\pi m}{Be}$.

[2]

(iv) The strength of the magnetic field **B** is such that **all** of the electrons move exactly once round their circle on their way from the anode to the target.
Use the equation for *T* to explain why **all** of the electrons which pass through the anode arrive at the same point on the target.

[2]

[Total: 10]

Quality of Written Communication [4]

[Section B Total: 50]

END OF QUESTION PAPER

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