OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2864/01

Field and Particle Pictures

Friday **31 JANUARY 2003** Afternoon 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 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 50 minutes on Section B.
- The number of marks is given in brackets [ ] at the end of each question or part question.
- There are four marks 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.

For Examiner's Use

Answer **all** the questions.

Section A

1 Here is a list of particles.

alpha
electron
neutrino
proton

(a) Which particle has the smallest mass? ....

(b) Which particle has the greatest magnitude of charge? ....

(c) Which particle is made from three quarks? .... [3]

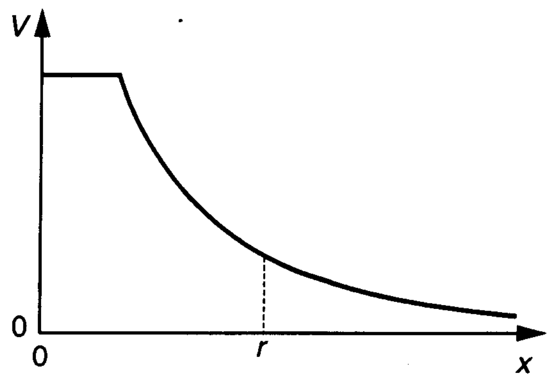
2 The magnetic flux linkage of a coil of wire increases steadily by 90 mWb in a time of 450 μs.

(a) Show that the rate of change of magnetic flux linkage is 200 Wb s^{-1}.

(b) State the emf induced across the coil by the rate of change of magnetic flux linkage.

emf = ... V [3]

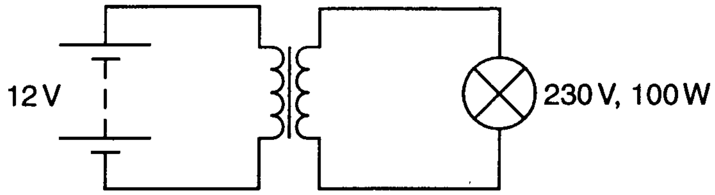
3 The graph shows the variation of electric potential *V* with distance *x* from a charged particle.



State the feature of the graph which could be used to calculate the magnitude of the electric field *E* at distance *r*.

[1]

4 A transformer cannot be used to run a 230 V, 100 W mains lamp directly from a 12 V car battery.



Which **one** of the following is the correct reason for this?

A The internal resistance of the battery will not allow enough current in the primary coil.
B Eddy currents in the iron core will heat up the iron core.
C The current from the battery will produce a steady flux in the secondary coil.

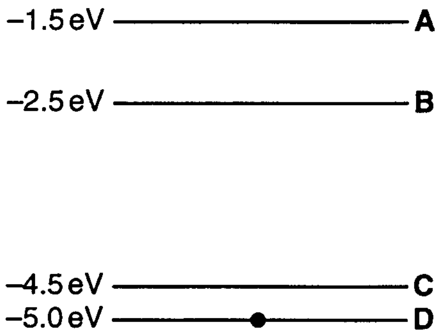
answer .... [1]

5 An alpha particle moving at $1.5 \times 10^7\,\mathrm{m\,s^{-1}}$ enters a magnetic field. The field has a strength of 0.25 T at right angles to the velocity of the alpha particle.
Calculate the force on the alpha particle in the field.
charge on alpha particle = $3.2 \times 10^{-19}\,\mathrm{C}$

force = ... N [2]

For Examiner's Use

6 The diagram shows part of the energy level diagram for an atom.



There are four energy levels, labelled **A**, **B**, **C** and **D**. The atom is initially in energy level **D**. An electron of energy 3.0 eV collides with the atom. This causes the atom to change energy level.

(a) If the collision raises the atom to energy level **B**, how much energy is the colliding electron left with?

energy = ... eV [1]

(b) Which energy level (**A**, **B** or **C**) will the atom definitely **not** be in after the collision?

energy level .... [1]

7 The equation shows a possible neutron-induced fission for a nucleus of plutonium-239.

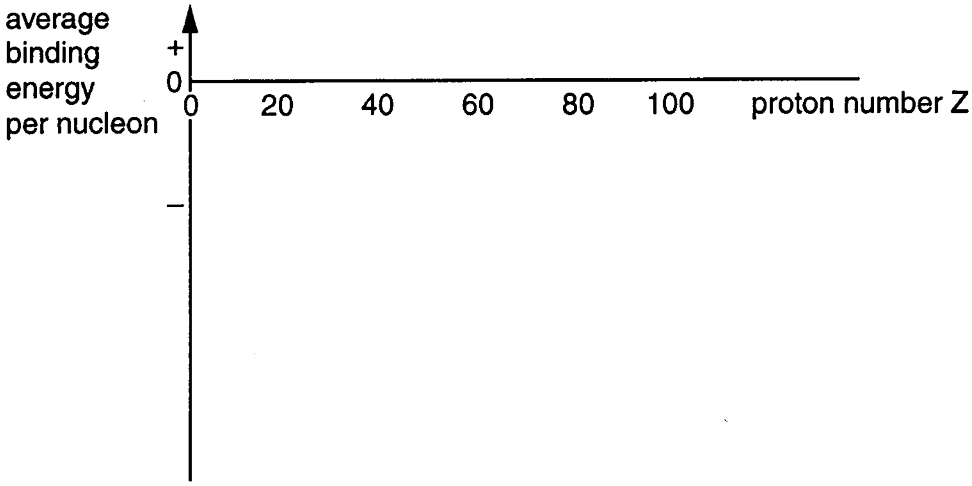
$$^{239}_{94}\text{Pu} + ^{1}_{0}\text{n} \longrightarrow ^{100}_{42}\text{Mo} + ^{134}_{52}\text{Te} + \text{neutrons}$$

How many neutrons are emitted?

number of neutrons = ... [1]

For Examiner's Use

8 On the axes below, sketch a graph to show how the average binding energy per nucleon of a nucleus varies with increasing proton number Z.



[4]

9 The force F on a conductor in a transverse magnetic field is given by

$F = IlB$

where I is the current in the conductor
l is the length of the conductor
B is the magnetic flux density

Show that the unit of magnetic flux density B is equivalent to kg A^{-1} s^{-2}.

[3]

[Section A Total: 20]

For Examiner's Use

Section B

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

10 This question is about the risks of ionising radiation.

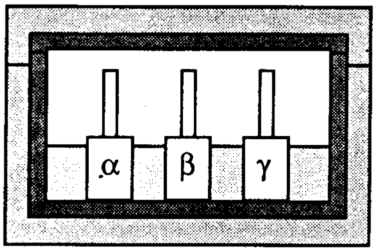
A school purchases the three radioactive sources shown in the table.

source	emission	half-life/year
cobalt-60	gamma photons	5.3
strontium-90	beta particles	28.1
americium-241	alpha particles	458

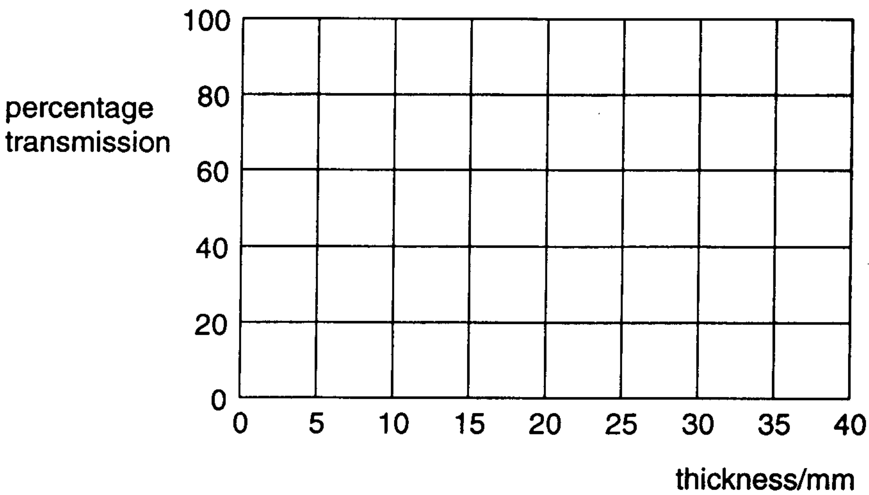
(a) All three sources are delivered to the school with the **same** activity of 4.0×10^4 **Bq**. This means that the alpha particle source contains the largest **number of unstable** nuclei. Explain this fact.

[2]

(b) The sources arrive in a lead-lined box. This absorbs **all** of the emissions **from the alpha** and beta sources, but not from the gamma source.



(i) 10 mm of lead absorbs half of the gamma photons incident on it.
Sketch a graph on the axes below to show how the transmission **of the gamma** photons through the lead depends on its thickness.



[3]

(ii) The lead of the box is 25 mm thick. The activity of the gamma photon source is 4×10^4 Bq.

Use the graph to estimate the number of gamma photons escaping from the box per second.

number per second = ... s^{-1} [2]

(c) A student keeps the beta particle source in his pocket for an hour before returning it to its box.

(i) Explain why the student can only absorb at most half of the particles emitted by the source when it is in his pocket.

[1]

(ii) The activity of the beta particle source is 4×10^4 Bq.
The energy of each beta particle is 8.8×10^{-14} J.
Show that the **maximum** energy absorbed from the source by the student is about 6 μJ.

[2]

(iii) The student considers the risk that he has taken.

He assumes that the dose of 6 μJ is shared evenly over his mass of 60 kg. This gives a dose equivalent of 0.1 μSv.
The whole-body dose equivalent from background radiation is about 2 mSv per year, equivalent to 4 nSv per hour.
The student concludes wrongly that keeping the beta particle source in his pocket has increased his risk of cancer considerably.

Discuss the student's assumption and conclusion.

[2]

[Total: 12]

For Examiner's Use

11 This question is about controlling electrons in an oscilloscope.

Details of the accelerating plates of the oscilloscope are shown in Fig. 11.1.

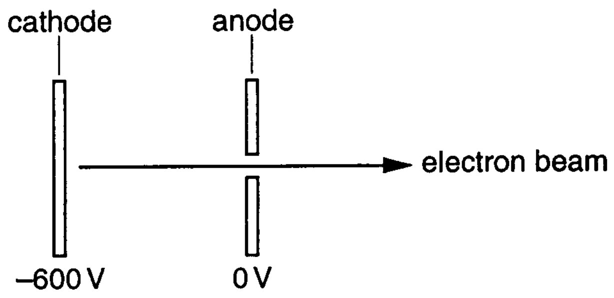


Fig. 11.1

Electrons from the cathode are accelerated towards the anode. The electrons travel in a vacuum.

(a) Electrons leave the cathode at a potential of −600 V with negligible kinetic energy. They are accelerated towards the anode at 0 V.

(i) On Fig. 11.1, sketch an equipotential line for −200 V between the anode and the cathode. [2]

(ii) Show that the kinetic energy gained by the electrons passing from cathode to anode is about 1×10^{-16} J.

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

[2]

For Examiner's Use

(b) The electrons approach a pair of deflecting plates on their way towards the screen, as shown in Fig. 11.2.

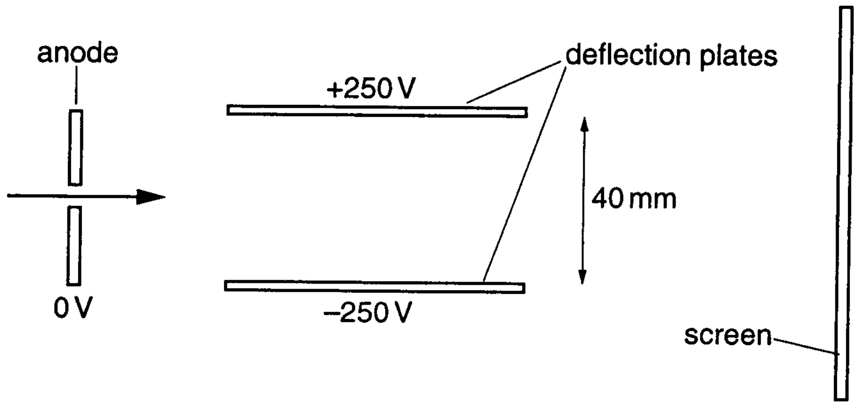


Fig. 11.2

(i) On Fig. 11.2, sketch **five** lines to represent the electric field in the space between the deflecting plates. [2]

(ii) State the potential difference between the deflecting plates.

p.d. = ... V [1]

(iii) Calculate the electric field strength between the deflecting plates.
Include the unit in your answer.

electric field strength = ... unit .... [3]

(c) **(i)** Sketch on Fig. 11.2 the path followed by the electrons as they pass between the deflecting plates and hit the screen. [3]

(ii) Explain the shape of the path followed by the electrons as they pass between the deflecting plates.

[2]

[Total: 15]

[Turn over

12 This question is about the ground state energy of a hydrogen atom.

A hydrogen atom in its ground state has an energy of -2.2×10^{-18} J. The most probable separation between electron and proton is 5.3×10^{-11} m in this state.
This is modelled in Fig. 12.1.

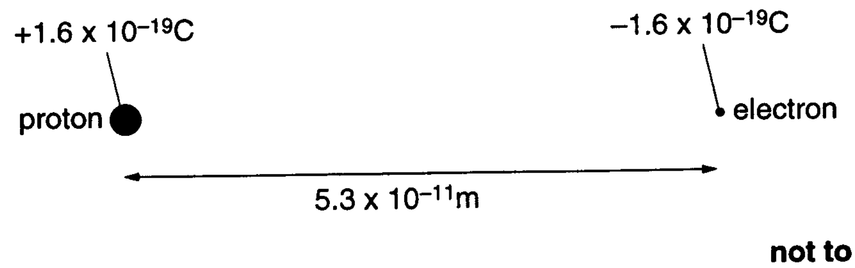


Fig. 12.1

(a) The electron has electrical potential energy.

(i) Show that the electrical potential is about +27 V at a distance of 5.3×10^{-11} m from the proton.
$e = 1.6 \times 10^{-19}$ C, $k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9$ N m^2 C^{-2}

[2]

(ii) Show that the potential energy of the electron is about -4.3×10^{-18} J at this distance from the proton.

[2]

For Examiner's Use

The kinetic energy of the electron in a ground state hydrogen atom is $+2.2 \times 10^{-18}$ J.

(b) **(i)** Show that this suggests an electron momentum of 2.0×10^{-24} kg m s^{-1}.

$m_e = 9.1 \times 10^{-31}$ kg

[3]

(ii) Show that the de Broglie wavelength for an electron with this momentum is about 3×10^{-10} m.

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

[2]

(c) Suggest why the electron in a ground state hydrogen atom has a de Broglie wavelength of the same order of magnitude as the diameter of the atom.

[3]

[Total: 12]

For Examiner's Use

13 This question is about an induction motor. Part of the induction motor is shown in Fig. 13.1.

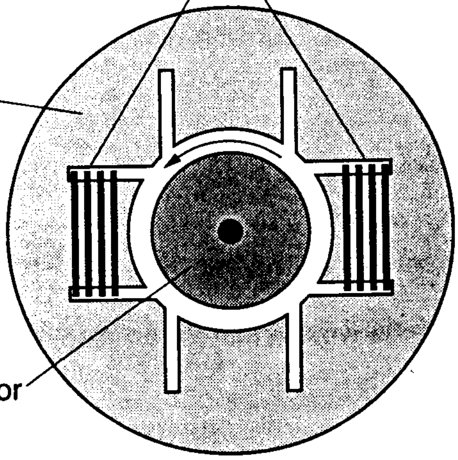


Fig. 13.1

(a) One pair of coils is shown in Fig. 13.1. At one instant, there is a current in these coils. This current produces a **horizontal** magnetic field of strength B_H in the rotor. On Fig. 13.1, sketch one **complete** line of flux in the motor due to this current. [1]

(b) In fact, the motor has **two** pairs of coils, as shown in Fig. 13.2.

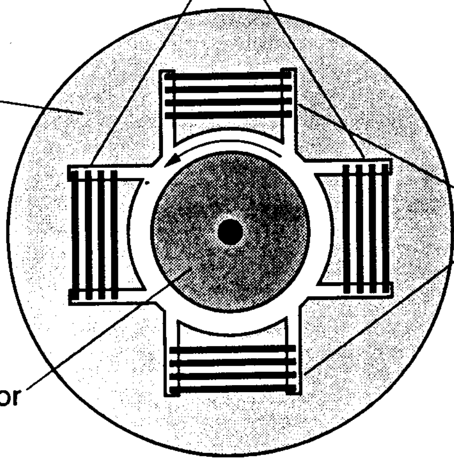


Fig. 13.2

The pair of coils labelled **H** produce a **horizontal** magnetic field through the rotor. The pair of coils labelled **V** produce a **vertical** magnetic field through the rotor. There is an alternating current in each pair of coils, but there is a **phase difference** between these currents. This results in horizontal and vertical magnetic fields, B_H and B_V respectively which vary with time, as shown in Fig. 13.3.

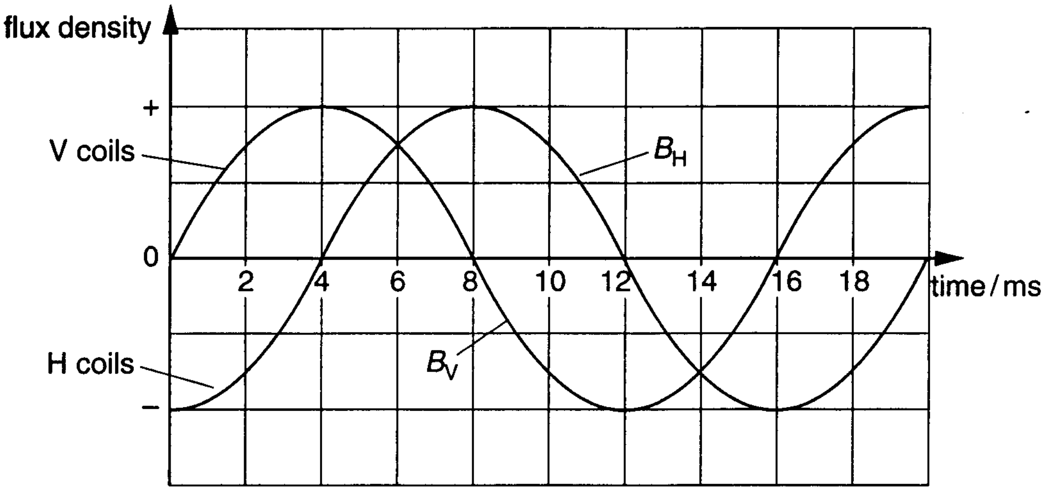
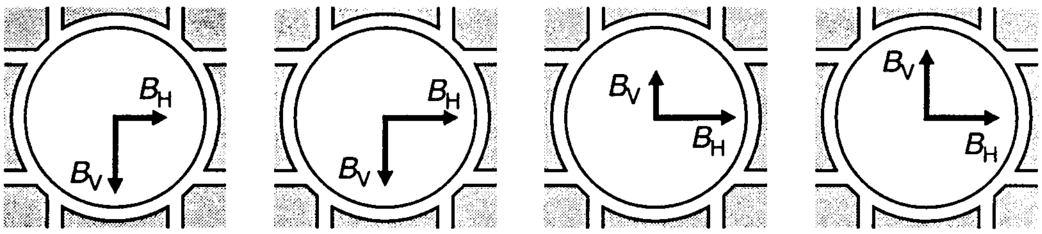


Fig. 13.3

(i) State the phase difference between the horizontal, B_H, and the vertical, B_V, magnetic fields.

phase difference = ... [1]

(ii) The magnitude and direction of the horizontal and vertical magnetic fields through the rotor, at **any** instant, can be represented by vectors.
These two vectors at times of 5 ms, 6 ms, 9 ms and 10 ms are shown below.



Complete each vector diagram to show the magnitude and direction of the **resultant** magnetic field at that instant. [1]

(iii) Describe how the direction of the **resultant** magnetic field changes with time.

[1]

(iv) The rotor, as shown in Fig. 13.2, rotates continuously in an **anticlockwise** direction, as the alternating currents change.
Explain why this is so.

[3]

[Total: 7]

Quality of Written Communication [4]

[Section B Total: 50]