OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2864/01

Field and Particle Pictures

Tuesday **20 JANUARY 2004** 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.
- 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 units.

$J\,s^{-1}$ Gy Sv s^{-1}

Write down the correct unit for λ, the radioactive decay constant. ....[1]

2 Here are three correct statements about the transmission of a beam of alpha particles through a thin gold foil.

A Nearly all the mass of an atom is in a very small nucleus.
B Both atomic nuclei and alpha particles have positive charges.
C Alpha particles and electrons have opposite charges.

Which statement (**A**, **B** or **C**) is the best explanation for the fact that most of the alpha particles pass straight through the foil?

answer ....[1]

3 Current in a coil of wire produces a flux density B.
Winding the coil around iron instead of wood increases the flux density to $\mu_r B$.
Here are four possible values for μ_r.

1 10^3 10^6 10^9

State the best estimate for the value of μ_r. answer ....[1]

4 Here are three physical systems.

A a charged conducting sphere
B a pair of parallel charged conducting plates
C a long thin charged wire

(a) State which system (**A**, **B** or **C**) is linked to the relationship $E = \frac{kQ}{r^2}$.

answer ....[1]

(b) State the meaning of the symbol E in the relationship $E = \frac{kQ}{r^2}$.

[1]

5 Fig. 5.1 shows electric equipotential lines between a charged sphere and an earthed plate.

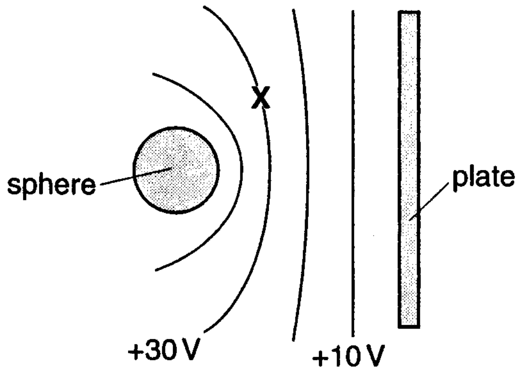


Fig. 5.1

(a) On Fig. 5.1, draw an arrow to show the direction of the electric field at the point labelled **X**. [2]

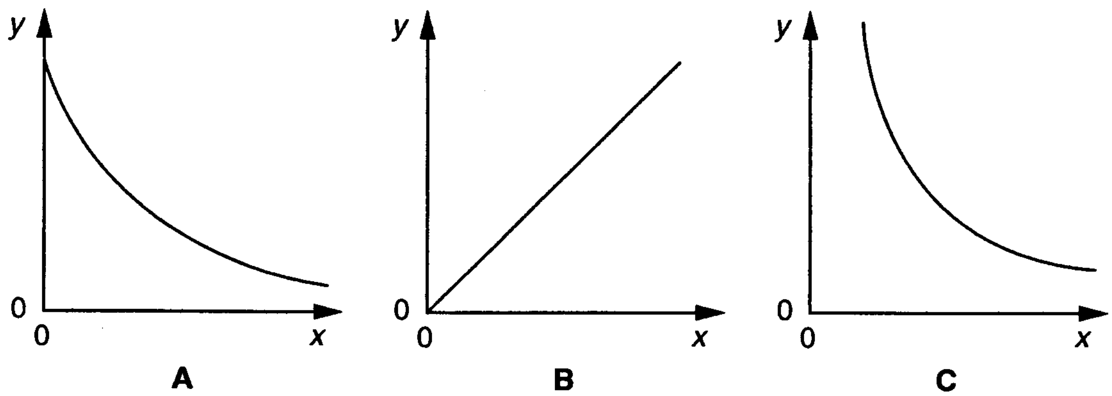
(b) Here is a list of potentials.

+50 V **0 V** **–10 V** **–50 V**

The potential of the sphere is +50 V.

State the best value for the potential of the plate. ....[1]

6 Here are three graphs.



Each row of the table shows possible pairs of x and y variables.

y variable	x variable	graph
activity of a sample of radioactive material	time	
electric potential around a nucleus	distance from the nucleus	

Complete the third column with the most appropriate graph (**A**, **B** or **C**) for each row. [2]

7 Here are three statements about the path of an electron in a vacuum.

A It follows a parabolic path.
B It follows a circular path.
C It follows a straight path.

Select the statement (**A, B** or **C**) which best describes the path of an electron which is

(a) initially moving at **right angles** to a uniform magnetic field ....[1]

(b) initially moving **parallel** to a uniform magnetic field. ....[1]

8 Fig. 8.1 shows the de Broglie standing wave for a proton bound in a nucleus, when the proton is in the energy level labelled E_2.

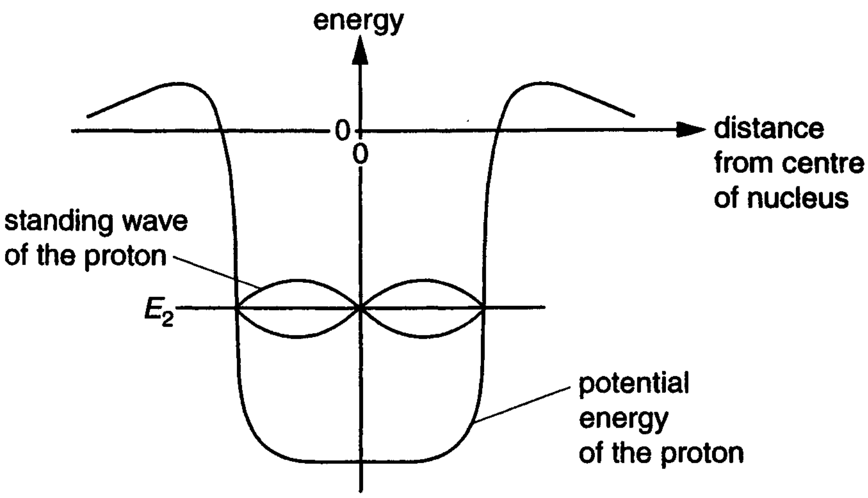


Fig. 8.1

The graph shows how the potential energy of the proton varies with its distance from the centre of the nucleus. The proton can be regarded as trapped in a box.

On Fig. 8.1, sketch a standing wave for the proton when it has a greater energy, but is still bound in the nucleus. [3]

9 The graph of Fig. 9.1 shows how the average binding energy per nucleon varies with nucleon number.

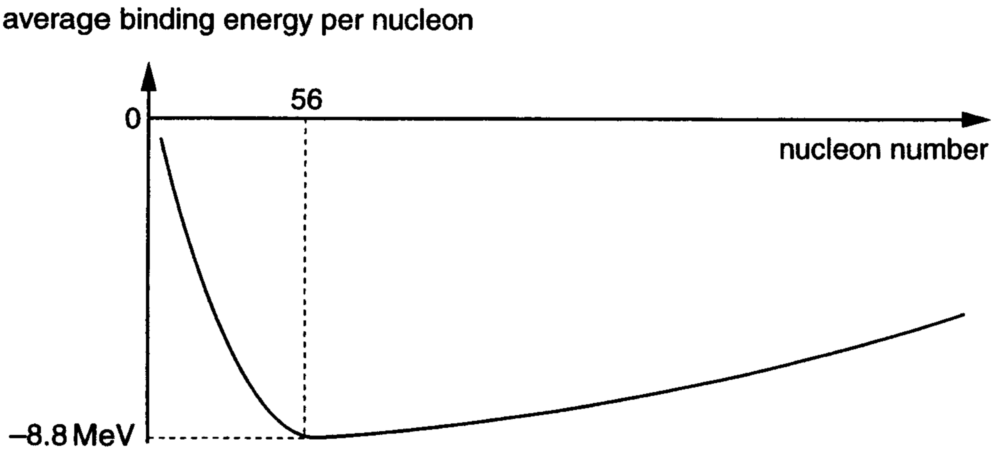


Fig. 9.1

(a) Circle the region of the graph which contains the fissile elements used for generating electricity by a nuclear fission chain reaction. [1]

(b) The average binding energy per nucleon for a nucleus of iron-56 is –8.8 MeV.

(i) Show that the energy required to separate all the nucleons in a single nucleus of iron-56 is about 1×10^{-10} J.

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

[2]

(ii) Calculate the change of mass corresponding to the energy change of **(b)(i)**.

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

change of mass = ... kg [2]

[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.

10 This question is about the emf induced in a coil of wire.

Figs. 10.1 and 10.2 show different views of a simple seismometer (earthquake detector).

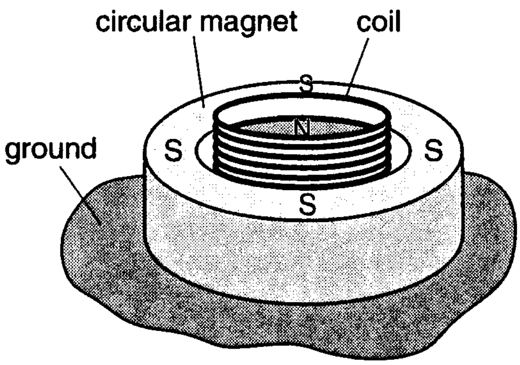


Fig. 10.1

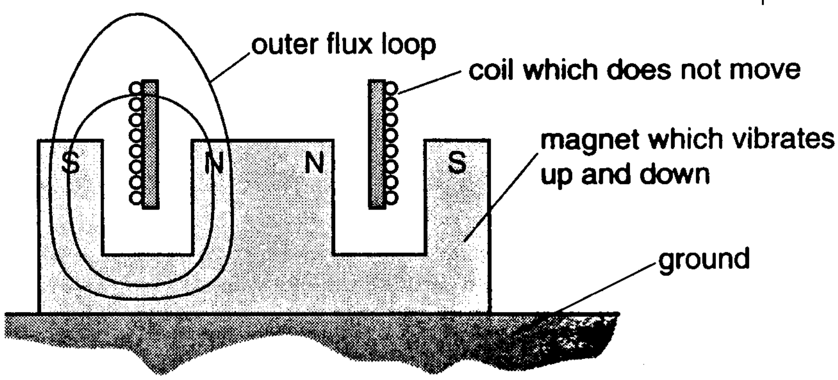


Fig. 10.2

The circular magnet sits on the ground and vibrates in a vertical direction when there is an earthquake. The cylindrical coil, which does not move, sits between the poles of the magnet. The movement of the magnet induces an emf in the coil.

(a) Fig. 10.2 shows two loops of flux linking the electric and magnetic circuits.

(i) Mark with an X the point on the outer flux line where the flux density is **lowest**. [1]

(ii) On Fig. 10.2, sketch **one** other flux loop. [1]

(b) When the magnet is not moving, the flux linkage of the coil is 1.2×10^{-3} Wb turns.

To test the seismometer, the coil was completely removed from the field of the magnet in a time of 0.25 s.

Calculate the average emf across the coil during this time.

emf = ... V [2]

(c) The graph of Fig. 10.3 shows how the flux linkage of the coil varies with time during an earthquake.

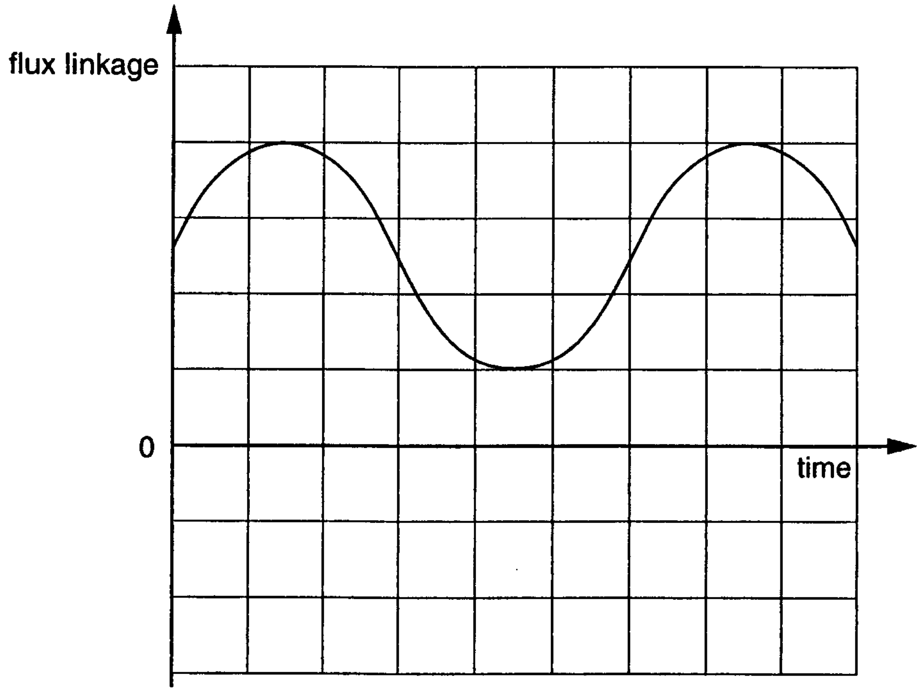


Fig. 10.3

(i) On Fig. 10.3, sketch a graph to show how the emf across the coil changes with time. [3]

(ii) In order to increase the amplitude of the emf across the coil during an earthquake, the construction of the seismometer is to be modified.

Describe **two** modifications which would increase the emf.
Explain how they work.

[3]

[Total: 10]

For Examiner's Use

11 This question is about using electric fields to control the motion of charged particles.

Fig. 11.1 shows a machine for printing labels on sacks of flour.

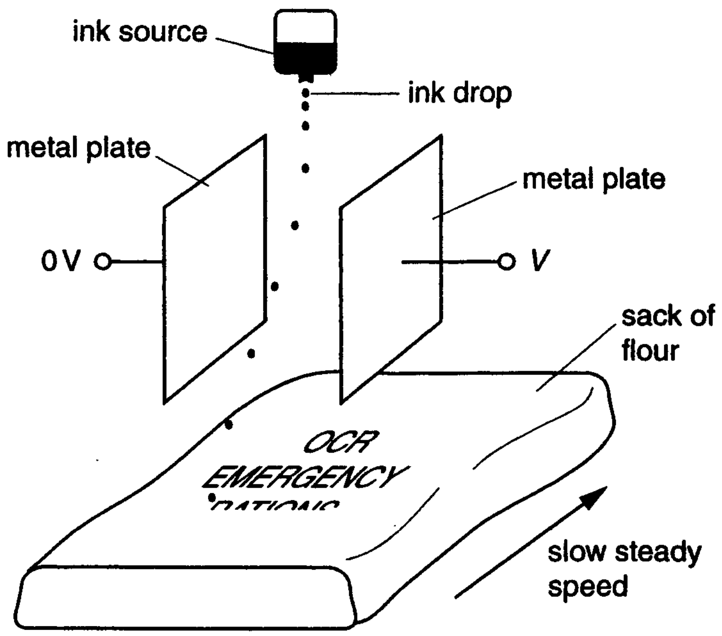


Fig. 11.1

Drops of ink are charged as they leave the ink source. They fall between a pair of metal plates, onto a sack which is on a conveyor belt moving at a steady speed. By varying the voltage V of the right-hand metal plate, the point of impact of each drop on the sack can be controlled.

(a) Each ink drop has a charge of +0.80 nC.

Calculate the number of electrons which need to be removed from the drop as it leaves the source.

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

number of electrons = ...[2]

(b) (i) On Fig. 11.1, the positively charged drops are pushed to the left.
State and explain the sign of the potential V required on the right-hand plate.

[1]

For Examiner's Use

(ii) On Fig. 11.2, draw **three** lines to represent the uniform electric field between the parallel plates.

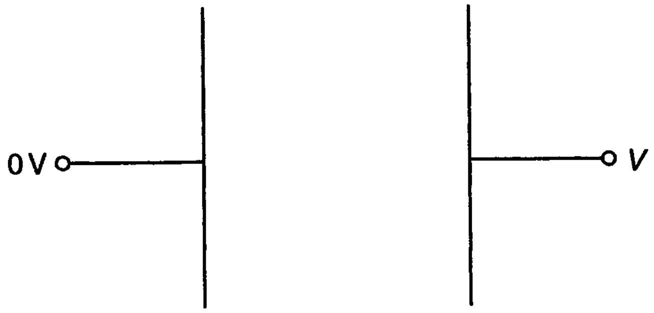


Fig. 11.2

[3]

(c) (i) The force F on a charge Q in an electric field E is given by the expression

$$F = QE.$$

Use this to show that the potential V of the right-hand plate of Fig. 11.2 is given by the expression

$$V = \frac{Fd}{Q}$$

where d is the separation between the plates.

[2]

(ii) Use the data listed below to calculate the value, in volts, of the potential V.

$F = 3.6\,\mu\text{N}$
$d = 150\,\text{mm}$
$Q = 0.80\,\text{nC}$

V = ... V [2]

[Total: 10]

[Turn over

For Examiner's Use

12 This question is about the risks involved with dental X-ray photography.

(a) A single dental X-ray exposes a patient to a dose equivalent of 16 μSv.
A dose equivalent of 1 Sv gives the patient a 3% probability of developing cancer in a lifetime.

(i) Suppose that a patient has two dental X-rays each year for sixty years.
Show that the associated risk of developing cancer is about 0.006%.

[3]

(ii) Suppose that everyone in the UK has two dental X-rays each year for sixty years.
Calculate the number of people in the UK who are likely to develop cancer as a result of these X-rays.
Assume that the population of the UK is 55 million.

number = ...[1]

(iii) The annual dose equivalent from background radiation in the UK is about 2 mSv.
By comparing this with the dose equivalent from dental X-rays, discuss the risks to a patient of undergoing dental X-rays for a lifetime. Support your answer with calculations.

[4]

For Examiner's Use

(b) The table gives data for the dose equivalent for the dentist at different distances from an X-ray source, for a single dental X-ray.

distance / m	dose equivalent / μSv	
0.25	2.6	
0.41	0.95	
0.77	0.27	

The dose equivalent for the dentist is inversely proportional to the square of the distance from the X-ray source.

(i) Propose and carry out a test to show that the data in the table fit this relationship. Use the blank column of the table.

[3]

(ii) Suggest **two** reasons why the dose equivalent for the dentist varies with distance from the X-ray source in this way.

[2]

(iii) A dentist is told to limit his dose equivalent from the X-ray source to 0.20 mSv per year. He has to give 4000 dental X-rays in a year.

Use the relationship between dose equivalent and distance to calculate the minimum distance he must keep from the X-ray source each time it is used.

distance = ... m [2]

[Total: 15]

For Examiner's Use

13 This question is about the separation of isotopes by electric and magnetic fields.

The isotope used in commercial fission reactors to generate electricity is ${}^{235}_{92}U$. It has a concentration of only 0.7% in natural uranium. The rest of natural uranium consists of the isotope ${}^{238}_{92}U$.

(a) In one separation process, each atom in a sample of natural uranium is combined with six atoms of fluorine (${}^{19}_{6}F$) to make the molecule UF_6. Three electrons are then removed to make a **UF_6 ion.**

(i) Here is a list of charges.

-4.8×10^{-19} C	**-1.6×10^{-19} C**	**$+1.6 \times 10^{-19}$ C**	**$+4.8 \times 10^{-19}$ C**

Circle the charge of a UF_6 ion. [1]

(ii) Calculate the mass of a single UF_6 ion of uranium-235.
the atomic mass unit $u = 1.7 \times 10^{-27}$ kg.

mass = ... kg [2]

(b) The ions are accelerated through a pd of 5 kV to create a beam of fast-moving ions.

(i) Explain why charged ions, but not neutral molecules, can be accelerated in this way.

[1]

(ii) In the space below, sketch an arrangement of electrodes which could be used to accelerate a beam of UF_6 ions.

Label each electrode with an appropriate potential, and its sign.
Use an arrow to show the path followed by the UF_6 ions.

[3]

For Examiner's Use

(c) The accelerated ions then enter a region of uniform magnetic field directed at right angles to their velocity. The ions follow a semicircular path and enter a collecting trap, as shown in Fig. 13.1.

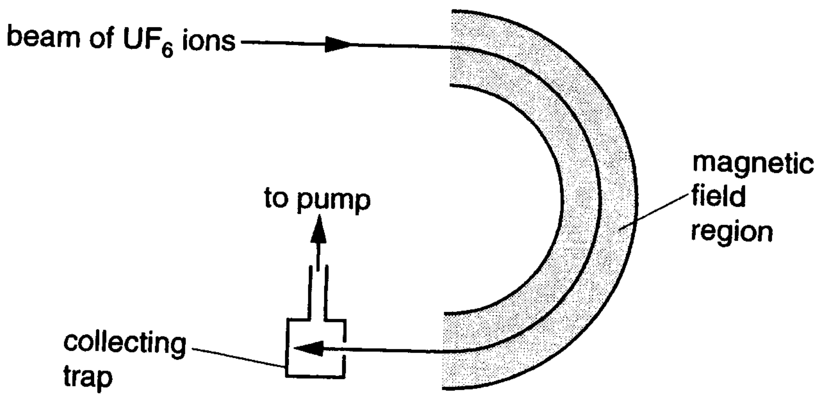


Fig. 13.1

(i) Fig. 13.1 shows the path of UF_6 ions of uranium-235 in the beam. UF_6 ions of uranium-238 in the beam enter the magnetic field region with a greater momentum, because of their greater mass.

On Fig. 13.1, sketch the path followed by UF_6 ions of uranium-238 in the magnetic field region. [1]

(ii) The beam of UF_6 ions has to be kept in a good vacuum to prevent any of the uranium-238 ions arriving in the collecting trap.

Explain why this would happen if there was **not** a good vacuum.

[3]

[Total: 11]

Quality of Written Communication [4]

[Section B Total: 50]