RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2864/01

Field and Particle Pictures

Thursday **17 JUNE 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.
- 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 16 printed pages.

Answer **all** the questions.

Section A

1 A mobile phone charging unit contains a transformer.
It converts the 230 V, 50 Hz mains supply into a 6 V alternating supply.

(a) State the frequency of the 6 V alternating supply.

frequency = ... Hz [1]

(b) The primary coil of the transformer has 1840 turns of wire.
Calculate the number of turns on the secondary coil.

number of turns = ... [2]

2 The potential V at a distance r from the centre of a sphere whose charge is Q is given by the following relationship.

$$V = \frac{kQ}{r}$$

Show that the constant k in the relationship can have units of $\mathrm{J\,m\,C^{-2}}$.

[2]

3 Fig. 3.1 shows the initial path **P** of a proton as it approaches close to a nucleus.

Fig. 3.1

(a) Draw on Fig 3.1 to show the path of the proton when it is scattered through 90° by the nucleus. [2]

(b) A beam of 10 MeV protons is fired at a thin metal target.
A small number of protons in the beam are scattered through more than 90°.
Which **one** of the following changes (**A**, **B** or **C**) would result in an **increase** in this number?

A Decreasing the thickness of the metal target.
B Decreasing the energy of the protons in the beam.
C Decreasing the atomic number of the metal target.

answer .... [1]

4 A worker in a nuclear processing plant receives an average absorbed dose of 30 mSv per year from the radioactive materials he works with. He works in the processing plant for 40 years.

(a) Which of the following (**A**, **B**, **C** or **D**) is the best estimate for the **total** energy absorbed by the worker's body from the radioactive materials he works with for 40 years? The quality factor of the radiation is 1.0 and his body mass is 80 kg.

A 0.01 J **B** 1.0 J **C** 100 J **D** 100 000 J

answer .... [1]

(b) The risk of developing cancer from ionising radiation is 3% per sievert per year. Calculate the risk of cancer to the worker of working at the plant for 40 years.

risk = ... % [1]

5 Here is a list of numbers.

10^{-6} 10^{-10} 10^{-14} 10^{-18}

For a nucleus of carbon-12, which value is the best estimate for

(a) the radius, in metres?

radius = ...m [1]

(b) the charge, in coulombs?

charge = ...C [1]

For Examiner's Use

6 Fig. 6.1 shows a number of equipotentials around a charged conductor.

(a) Draw an arrow through the point marked **X** to show the direction of the electric field at that point. [2]

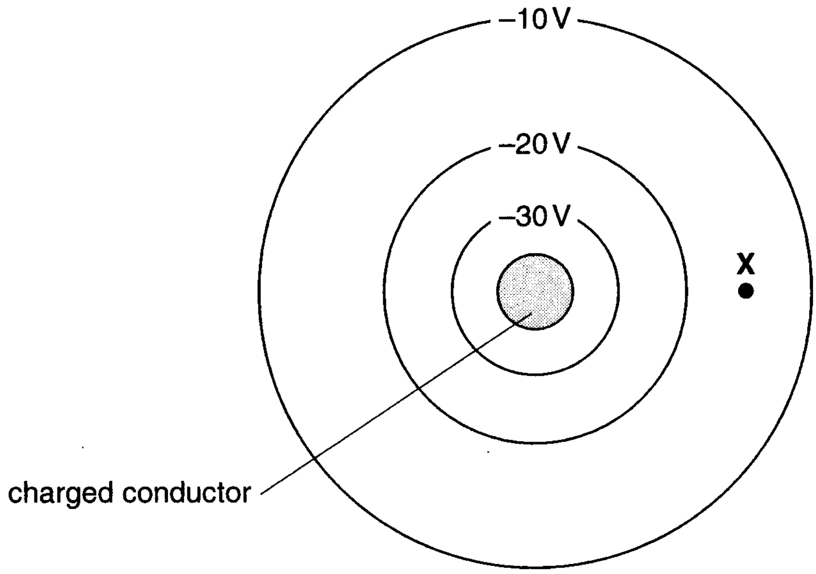

Fig. 6.1

(b) The strength of the electric field around the charged conductor decreases with increasing distance from it.
Describe the feature of Fig. 6.1 which shows this.

[1]

7 Caesium-133 and caesium-128 are different isotopes of the same element.

(a) Complete the sentence below by choosing the appropriate word from this list.

electrons **neutrons** **protons**

An atom of caesium-133 has 5 more .... than an atom of caesium-128. [1]

(b) Caesium-133 is a stable isotope. It does not undergo radioactive decay.
Caesium-128 is unstable and is radioactive.

Which of the following (**A**, **B** or **C**) is the most likely emission from the radioactive decay of caesium-128?

A alpha particle **B** proton **C** positron

answer .... [1]

For Examiner's Use

8 The charge on a conductor produces an electric field strength at its surface.

(a) Calculate the charge required to produce an electric field strength of $5 \times 10^6\,\mathrm{V\,m^{-1}}$ at the surface of a conducting sphere of radius 0.025 m.

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

charge = ... C [2]

(b) The **maximum** electric field strength at the surface of a conductor in air is about $5 \times 10^6\,\mathrm{V\ m^{-1}}$. Suggest why there is such a limit.

[1]

[Section A Total: 20]

For Examiner's Use

Section B

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

9 This question is about generating electricity with the simple dynamo shown in Fig. 9.1.

(a) The rotor is a permanent magnet, with poles marked N and S.

(i) On Fig. 9.1, sketch one **complete** flux loop which passes through the poles. [2]

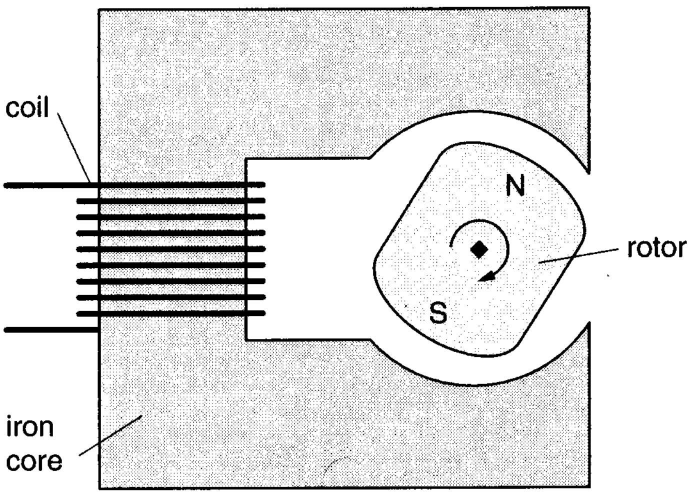

Fig. 9.1

(ii) Give **two** reasons why the core of the dynamo is made from iron, a magnetic material.

[2]

(b) The graph of Fig. 9.2 shows how the emf generated across the coil of the dynamo varies with time.

(i) On Fig. 9.2, sketch a graph to show how the **flux** linking the coil varies with time. [2]

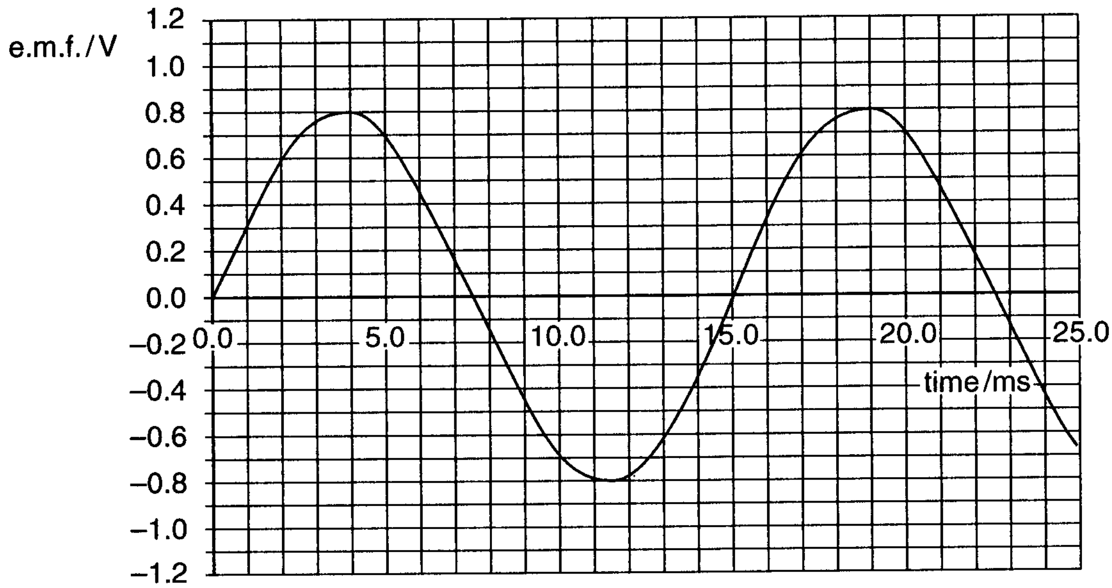

Fig. 9.2

(ii) Use information from the graph to show that the rotor is spinning at about 70 revolutions per second.

[2]

(c) The core is made from solid iron. The emf across the coil increases when the solid iron core is replaced by one made from thin sheets of iron glued together. Explain why this change increases the emf across the coil.

[3]

[Total: 11]

For Examiner's Use

10 This question is about the nucleus of plutonium-239.

(a) The nucleus of plutonium-239 contains neutrons and protons.

(i) The table gives the masses of free neutrons and protons.

nucleon	mass / kg
neutron	1.674×10^{-27}
proton	1.673×10^{-27}

Calculate the total mass of the separate neutrons and protons that could make a nucleus of $^{239}_{94}Pu$.

total mass = ... kg [3]

(ii) The mass of a single nucleus of $^{239}_{94}Pu$ is 3.962×10^{-25} kg.
Explain why this mass is different from your answer in **(i)**.

[2]

(b) When a nucleus of plutonium 239 decays, it emits an alpha particle. The graph of Fig. 10.1 shows the variation of potential energy of the alpha particle with distance from the centre of the nucleus of plutonium-239, before the decay. The standing wave for the lowest energy state of the alpha particle is shown.

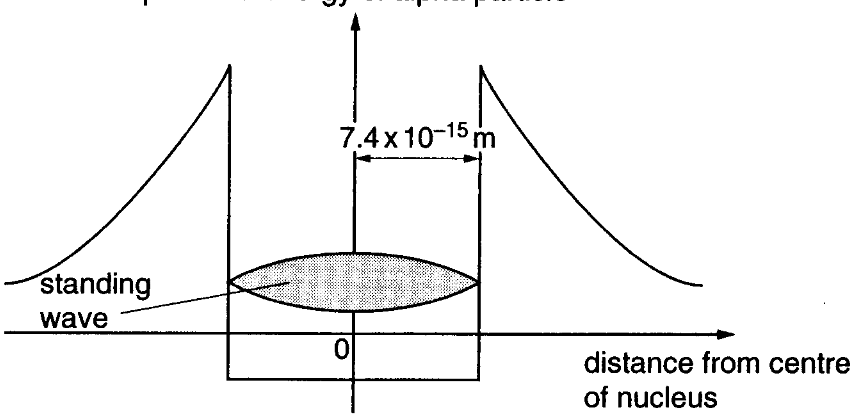

Fig. 10.1

For Examiner's Use

(i) The radius of a plutonium-239 nucleus is 7.4×10^{-15} m.
Show that the de Broglie wavelength λ of the alpha particle in its ground state is about 3×10^{-14} m.

[1]

(ii) Hence show that the momentum p of the alpha particle in its ground 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.

$m_{alpha} = 6.7 \times 10^{-27}$ 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 and explain how the alpha particle is able to escape.

[2]

[Total: 12]

For Examiner's Use

11 This question is about the dangers of plutonium in nuclear reactor waste.

Small specks of plutonium-239 have been known to escape from nuclear waste. Fortunately, their radioactivity makes them relatively easy to detect in the environment.

(a) Plutonium-239 decays naturally into uranium-235 by emitting an alpha particle.

(i) Complete the equation representing the decay of plutonium-239.

$$^{239}_{94}\mathrm{Pu} \longrightarrow {}^{235}_{\cdots\cdots}\mathrm{U} + {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{He}$$ [2]

(ii) The half-life of plutonium-239 is 7.6×10^{11} s.
Show that a sample containing only 2.5×10^{14} nuclei of plutonium-239 can be detected when the background count is 1 Bq.

[2]

(iii) Calculate the mass of 2.5×10^{14} nuclei of plutonium-239.

$1\ \mathrm{u} = 1.7 \times 10^{-27}$ kg

mass = ... kg [1]

(iv) Such a small speck of plutonium could easily be breathed in and become stuck in lung tissue. This gives a large increase in the risk of developing lung cancer.
By considering the properties of alpha particles, explain why the risk is increased.

[3]

For Examiner's Use

(b) Plutonium can be made to undergo fission by bombarding it with a beam of protons. A typical reaction is shown below.

$$^{239}_{94}\text{Pu} + {}^{1}_{1}\text{p} \longrightarrow {}^{133}_{53}\text{I} + {}^{99}_{42}\text{Mo} + \text{neutrons}$$

(i) Calculate the number of neutrons produced by this reaction.

number of neutrons = ... [1]

(ii) For this reaction to work, a proton must approach to within 7.4×10^{-14} m of the centre of the plutonium nucleus.
By considering the electrical potential energy of the proton as it approaches the nucleus, calculate the minimum kinetic energy of the proton.

charge of nucleus = $+1.5 \times 10^{-17}$ C
charge of proton = $+1.6 \times 10^{-19}$ C
electric force constant $k = 9.0 \times 10^{9}$ N m^2 C^{-2}

kinetic energy = ... J [2]

[Total: 11]

[Turn over

For Examiner's Use

12 This question is about the motion of charged particles in magnetic and electric fields.

Fig. 12.1 shows a strip of conducting material. Part of the strip lies in a region of uniform magnetic field.

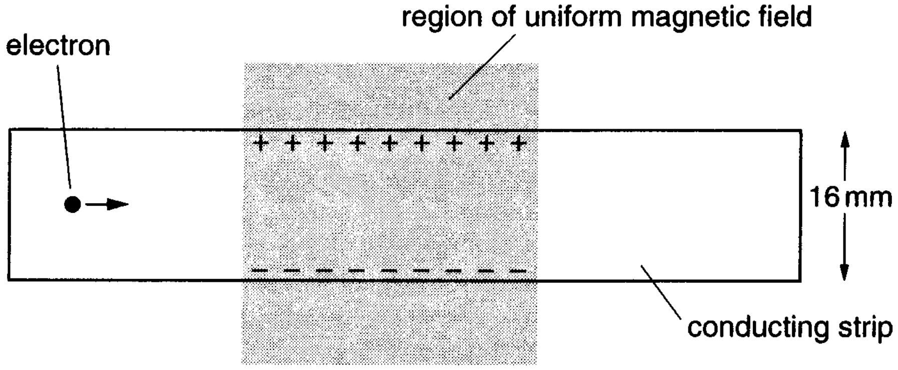

Fig. 12.1

The strip is part of an electric circuit. Electrons flow through the strip from left to right at a steady speed.

(a) The uniform magnetic field has a flux density of $0.12\,\text{Wb}\,\text{m}^{-2}$, pointing into the plane of Fig. 12.1. This results in a magnetic force of $9.6 \times 10^{-23}\,\text{N}$ on each electron which enters the field.
Calculate the speed of the electrons as they enter the magnetic field.

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

speed = ... unit .... [3]

(b) Suggest why the magnetic force on the moving electrons results in **opposite** charges appearing at the edges of the conducting strip as shown in Fig. 12.1.

[2]

For Examiner's Use

(c) The charges at the edge of the strip in the uniform field region set up an electric field across the strip.

(i) Draw lines on Fig. 12.1 to represent that electric field and show its direction. [2]

(ii) The electric field results in a p.d. of 9.6 μV across the strip, which is 16 mm wide.

Show that when the electrons pass through the magnetic field region, the electric force cancels out the magnetic force of 9.6×10^{-23} N.

[2]

(d) The p.d. across the edges of the strip is directly proportional to the magnetic field strength at right angles to it.
By equating expressions for the electric and magnetic forces on the moving electrons in the magnetic field region, show that this is so.

[3]

[Total: 12]

Quality of Written Communication [4]

[Section B Total: 50]

END OF QUESTION PAPER