RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT

2864/01

PHYSICS B (ADVANCED PHYSICS)

Field and Particle Pictures

THURSDAY 14 JUNE 2007

Morning

Time: 1 hour 15 minutes

Additional materials:
Data, Formulae and Relationships Booklet
Electronic calculator

Candidate Name

Centre Number

Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre Number and Candidate number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED. ANSWERS WRITTEN ELSEWHERE WILL NOT BE MARKED.
- Show clearly the working in all calculations and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

- The number of marks for each question is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is 70.
- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- Four marks are available for the quality of written communication in Section B.
- The values of standard physical constant are given in the Data, Formulae and Relationship 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 document consists of **16** printed pages.

Answer **all** the questions.

Section A

1 Here is a list of physical quantities.

electric field strength **electric potential** **magnetic flux density** **flux linkage**

Which one is measured in units of

(a) $J\,C^{-1}$

answer .... [1]

(b) $Wb\,m^{-2}$?

answer .... [1]

2 Fig. 2.1 shows the path of an alpha particle as it scatters off a gold nucleus.

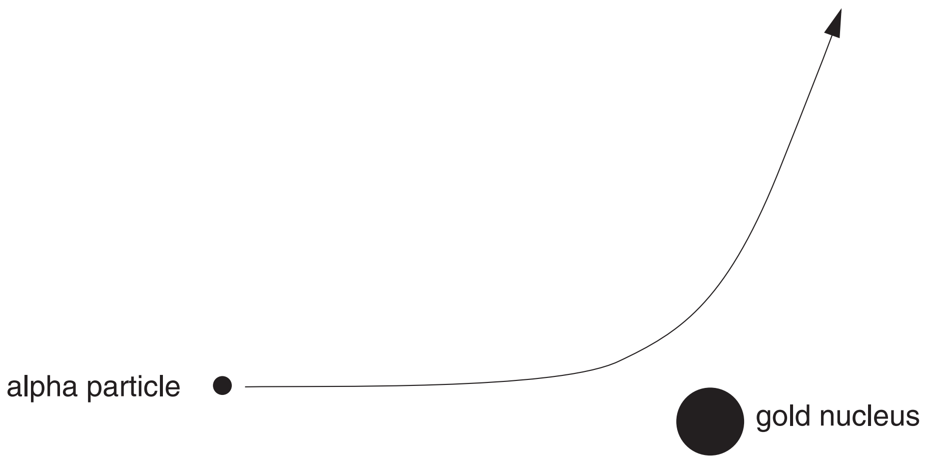

Fig. 2.1

On Fig. 2.1, sketch the path of an alpha particle with the **same** initial path, but **less** kinetic energy. [2]

3 A hydrogen atom in its ground state can be modelled as an electron at a constant distance of 0.53×10^{-10} m from a proton.

Calculate the electrical force of attraction between the two particles in this model.

$e = 1.6 \times 10^{-19}$ C
$k = 9.0 \times 10^{9}$ N m^{2} C^{-2}

force = ... N [3]

4 Fig. 4.1 shows four different coils wound around the same iron ring.

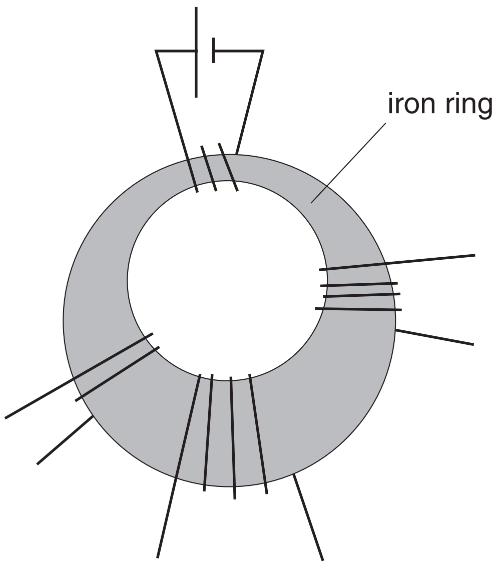

Fig. 4.1

The current in the top coil sets up loops of flux in the iron ring.

The cross-sectional area of the ring is different for each coil.

Which **one** of the following quantities is most nearly the same for all four coils?

Put a ring around the correct answer.

magnetic flux **magnetic flux density** **magnetic flux linkage**

[1]

5 Strontium-90 is a radioactive waste product of nuclear power stations. Strontium-90 emits beta particles of energy up to 0.54 MeV.

(a) Should any of this isotope get into our food, it would be quickly absorbed into bones and teeth.

Explain why these beta particles are more of a risk to humans than gamma photons of the same energy.

[2]

(b) Strontium-90 has a decay constant of $7.8 \times 10^{-10}\,\text{s}^{-1}$. An accident at a nuclear power station results in strontium-90 with activity of 300 kBq being absorbed into a person's bones. Calculate the activity 56 years later.

1 year = 3.2×10^{7} s

activity = ... Bq [2]

6 Study the graphs **A**, **B** and **C**.

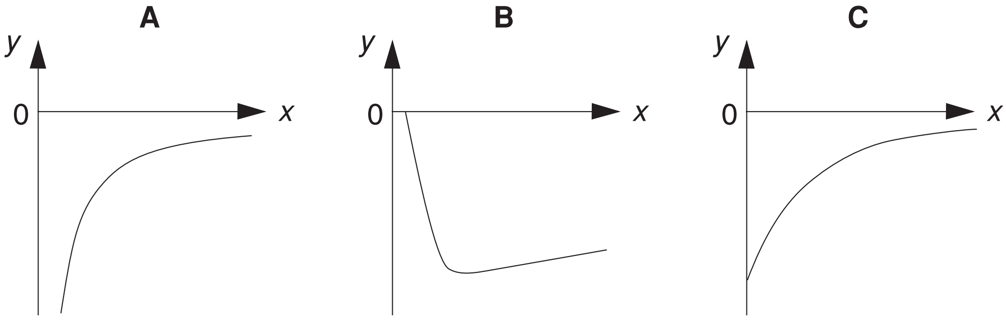

Fig. 6.1

Which graph, **A**, **B** or **C**, is obtained when the *y* and *x* axes represent the two quantities given below?

(a) *y*-axis: the **binding energy per nucleon** of a nucleus

x-axis: the **nucleon number** of the nucleus

answer .... [1]

(b) *y*-axis: the **electric potential** near an electron

x-axis: the **distance** from the electron

answer .... [1]

7 For the relationship $E = \frac{V}{d}$, state the quantity represented by the symbol E and the conditions for which the relationship is valid.

[2]

8 The recommended maximum absorbed dose limit for someone who works with radioactive materials is 20 mSv per year. The risk of developing cancer from radioactivity is 3% per sievert. Calculate the increased risk of developing cancer for someone who has an absorbed dose of 20 mSv per year for 40 years.

risk = ……………………… % [2]

9 Fig. 9.1 shows some equipotential surfaces in a region where there is an electric field.

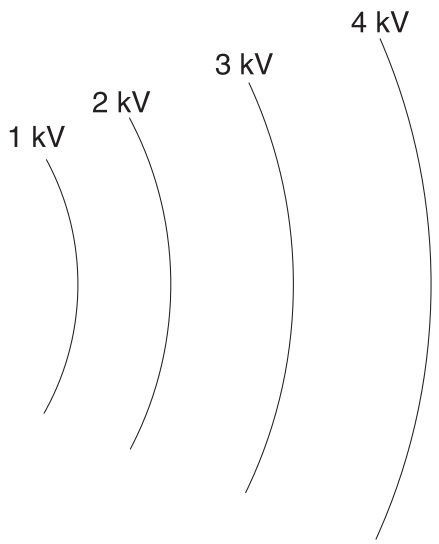

Fig. 9.1

On Fig. 9.1, sketch three lines to represent the electric field.

Use arrows to indicate the direction of the field. [2]

[Section A Total: 20]

Section B

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

10 This question is about a model of the nucleus.

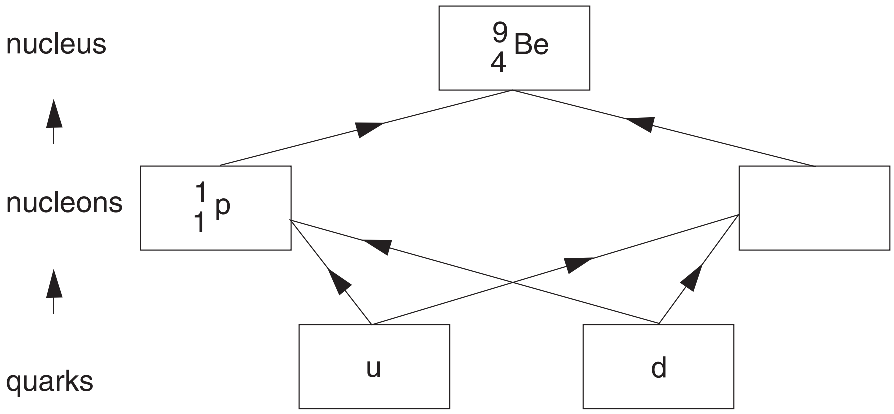

Fig. 10.1

Fig 10.1 shows how each nucleon can be modelled as containing two different types of quark. In turn, a nucleus of beryllium can be modelled as containing two different types of nucleon.

(a) The left-hand nucleon box in Fig. 10.1 contains ${}^{1}_{1}$p. Complete the other nucleon box. [1]

(b) Each quark has a different charge. The u quark has charge $+{}^{2}/_{3}e$ and the d quark has charge $-{}^{1}/_{3}e$, where $e = 1.6 \times 10^{-19}$ C.

(i) State the combination of u and d quarks required to make the nucleon ${}^{1}_{1}$p.

Justify your answer.

[2]

(ii) Particles other than nucleons can be modelled as pairs of quarks (u, d) and anti-quarks ($\bar{u}$, $\bar{d}$).

For example, the positive π^{+} meson can be modelled as u$\bar{d}$.

Write down the **two** quark-antiquark pairs which can model a neutral π^{0} meson.

[1]

(c) The mass of a single ${}^{9}_{4}\text{Be}$ nucleus is 1.4966×10^{-26} kg. This is slightly less than the total mass of its separate nucleons.

(i) How many protons and neutrons are there in a single nucleus of ${}^{9}_{4}\text{Be}$?

number of protons = ...

number of neutrons = ...

[2]

(ii) Show that the mass of a ${}^{9}_{4}\text{Be}$ nucleus is about 1×10^{-28} kg less than the mass of its separate nucleons.

$m_{\text{proton}} = 1.673 \times 10^{-27}$ kg

$m_{\text{neutron}} = 1.675 \times 10^{-27}$ kg

[2]

(iii) Hence calculate the average binding energy per nucleon, in MeV, for a nucleus of ${}^{9}_{4}\text{Be}$.

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

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

average binding energy per nucleon = ... MeV [3]

(d) The nucleons in a nucleus are bound to each other by the strong force.

Explain why this requires the mass of the nucleus to be **less** than the mass of its separate nucleons.

[2]

[Total: 13]

11 This question is about measuring the momentum of alpha particles.

A diagram has been removed due to third party copyright restrictions

Details: A diagram of apparatus used to measure the momentum of alpha particles. The diagram shows a tube with an alpha particle source at one end and a detector at the other. In the middle of the tube is a region of uniform magnetic field.

Fig. 11.1

Fig. 11.1 shows the arrangement of apparatus required. The region of uniform magnetic field extends for about 0.5 m.

(a) (i) On Fig. 11.1, sketch the path of alpha particles as they go from the source to the detector. [1]

(ii) State why there must be a vacuum in the tube.

[1]

(b) In the region of uniform magnetic field the alpha particles follow a path which is part of a circle of radius r.

(i) State the angle between the direction of the magnetic field and the velocity of the alpha particles.

angle = ...° [1]

(ii) The magnetic force on an alpha particle of charge q in a magnetic field of strength B provides the centripetal force for the motion along a circular path of radius r.

Show that the momentum p of the alpha particle is given by

$$p = Bqr.$$

[2]

(c) The uniform magnetic field is provided by an electromagnet. The strength of the field is increased from zero in steps of 50 mT at intervals of one minute. The bar chart of Fig. 11.2 shows the corresponding readings from the detector.

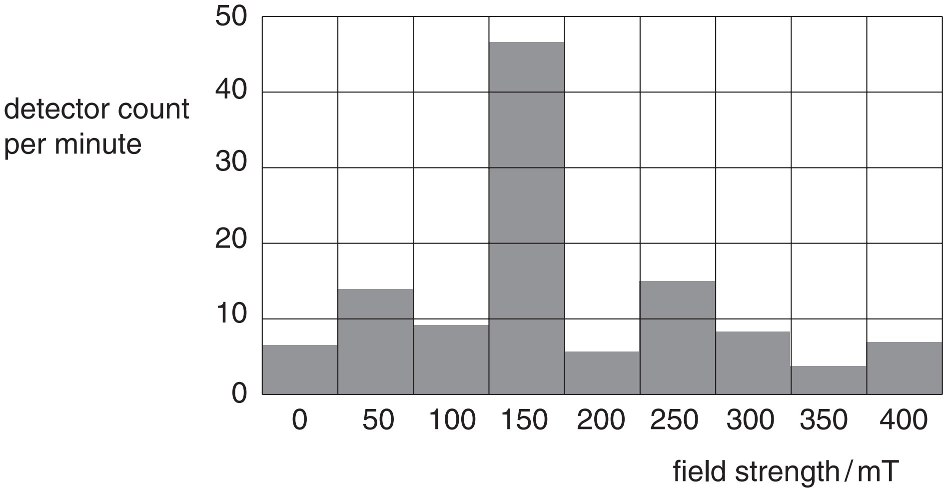

Fig. 11.2

All of the alpha particles from the source have the **same** energy.

(i) Suggest why the detector gives a large reading at one particular field strength.

[1]

(ii) Suggest why the detector gives a reading for all field strengths.

[1]

(iii) Use data from Fig. 11.2 to calculate the momentum of the alpha particles from the source.

$r = 2.5$ m

$q = 3.2 \times 10^{-19}$ C

momentum = ……………………… kg m s^{-1} [3]

[Total: 10]

12 This question is about the use of electromagnetic induction to measure rotational speed.

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Details: A diagram of a pulse counter connected to an insulated copper coil wound around an iron core with a spinning magnet at the ends of the iron core

Fig. 12.1

Fig. 12.1 shows a pulse counter connected to an insulated copper coil wound around an iron core. The counter records the number of times that the emf across the coil goes from negative to positive in each second.

(a) (i) On Fig. 12.1, sketch a loop of magnetic flux which passes through the iron core.

[1]

(ii) Suggest why the core is made of iron, a magnetic material.

[1]

(b) The graph of Fig. 12.2 shows how the emf across the copper coil changes with time.

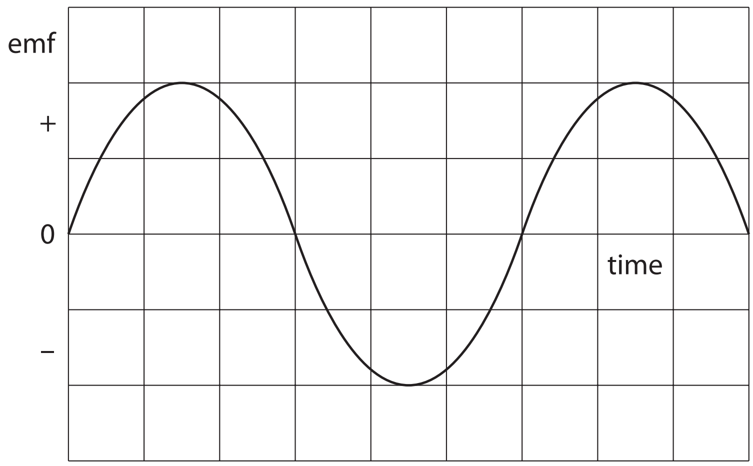

Fig. 12.2

(i) Explain the shape of the graph.

[2]

(ii) On Fig. 12.2, sketch how the flux linkage of the coil changes with time. [1]

(iii) When the magnet spins at 30 revolutions per second, the amplitude of the emf across the 120 turn copper coil is 1.3 V.

Estimate the maximum flux in the core.

maximum flux = ……………………… Wb [2]

(c) The amplitude of the emf for a given rotational speed can be increased by using a stronger magnet which increases the flux density in the coil.

Describe and explain **two other** modifications to the device of Fig. 12.1 to increase the amplitude of the emf for a given rotational speed.

[3]

(d) Explain why the core is made from thin iron sheets glued together rather than being solid iron.

[2]

[Total: 12]

[Turn over

13 Uranium-236 is a long-lived isotope with a half life of about 25 million years. The decay constant λ is determined by measuring the activity A of a known number N of nuclei and using the relationship $A = \lambda N$.

(a) Complete the nuclear equation for the alpha decay of uranium-236.

$$^{236}_{92}\text{U} \rightarrow\ ^{\cdots\cdot}_{\cdots\cdot}\text{Th} +\ ^{\cdots}_{2}\text{He}$$

[2]

(b) Fig. 13.1 shows how apparatus can be used to separate a known number N of atoms of the isotope uranium-236 from a mixture of isotopes, and deposit them on a metal disc.

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Details: A diagram showing a source of uranium irons, an iron accelerator, a magnetic field region, the path of uranium-236 ions, a metal disc and an electron flow

Fig. 13.1

(i) The sentences below describe the sequence of events in the apparatus.

They are in the wrong order.

A A beam of ions of uranium metal leave the source.

B Only uranium-236 ions are deposited on the metal disc.

C The ions emerge from the accelerator with the same kinetic energy.

D The path followed by each ion in the magnetic field region depends on its mass.

Complete the boxes to show the correct order.

A			

[2]

(ii) Each ion which is deposited on the disc is neutralised by an electron which flows from the ion source via an ammeter. The average current recorded by the ammeter is 150 nA. Show that about 8×10^{16} ions are deposited on the disc in 24 hours.

$e = 1.6 \times 10^{-19}$ C
24 hours = 8.6×10^{4} s

[3]

(c) To measure the activity, a detector of nuclear radiations is held just above the metal disc, as shown in Fig. 13.2.

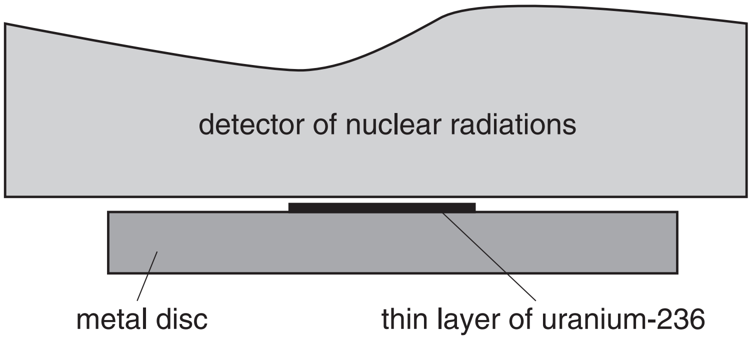

Fig. 13.2

(i) Suggest why only half of the alpha particles emitted by the uranium-236 enter the detector.

[1]

(ii) The detector records 22 146 events in ten minutes with the metal disc in place. When the disc is removed, the detector records a background count of 420 events in ten minutes.

Show that the **total** activity of the uranium-236 is about 70 Bq.

[2]

(iii) Calculate the decay constant of uranium-236.

decay constant = ... s^{-1} [1]

[Total: 11]

Quality of Written Communication [4]

[Section B Total: 50]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE