OCR RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT

2864/01

PHYSICS B (ADVANCING PHYSICS)

Field and Particle Pictures

MONDAY 22 JANUARY 2007

Morning

Time: 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

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.
- Show clearly the working in all calculations, and give answers to only a justifiable number of significant figures.
- 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.

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.
- The total number of marks for this paper is 70.
- 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 document consists of **14** printed pages and **2** blank pages.

Answer **all** the questions.

Section A

1 Here is a list of units.

Wb **Wb C^{-1}** **Wb m^{-2}** **Wb s^{-1}**

Which one is an appropriate unit for

(a) magnetic flux density

answer .... [1]

(b) induced emf?

answer .... [1]

2 Fig. 2.1 shows a device for **slowing down** a beam of electrons. The electrons enter the space between a pair of parallel conducting plates held at different potentials.

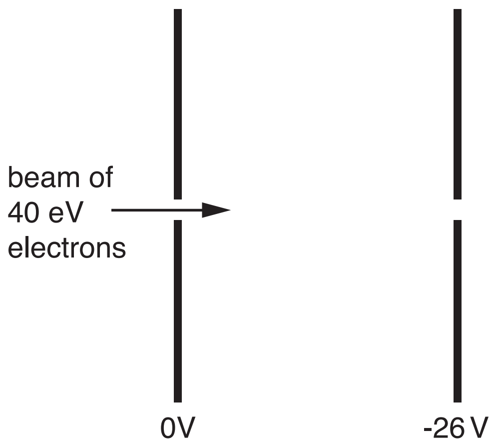


Fig. 2.1

(a) On Fig. 2.1, draw **four** arrowed lines to represent the electric field in the space between the conducting plates. [3]

(b) The electrons pass through the hole in the plate at 0 V with a kinetic energy of 40 eV. What kinetic energy do the electrons have as they pass through the hole in the plate at –26 V? Choose from the list.

–26 eV **0 eV** **+14 eV** **+66 eV**

answer .... eV [1]

3 Fig. 3.1 shows how the flux linkage of a coil of wire changes with time.

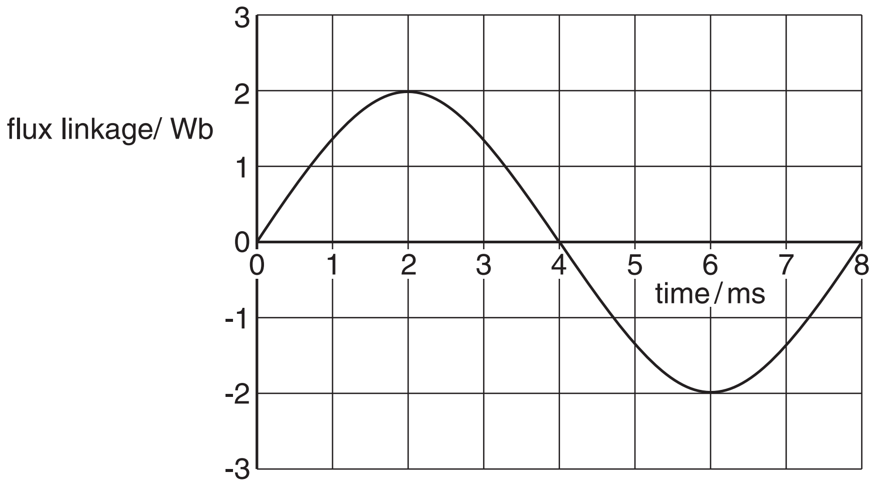


Fig. 3.1

(a) Use the graph of Fig. 3.1 to calculate the peak value of the emf across the coil.

emf = ... V [2]

(b) On Fig. 3.1, sketch a graph to show how the emf induced across the coil changes during this time. [2]

(c) The emf can be increased by increasing the number of turns of wire in the coil.
Suggest **one** other way of increasing the emf.

[1]

4 The nuclear equation shows plutonium-240 being converted into americium-241.

(a) Complete the equation by entering the nucleon and proton numbers for particle X. [1]

$$^{240}_{93}\text{Pu} + ^{\cdots\cdots}_{\cdots\cdots}\text{X} \rightarrow ^{241}_{94}\text{Am} + ^{0}_{-1}\text{e} + ^{0}_{0}\overline{\nu}$$

(b) Circle the correct name of particle X.

alpha particle **beta particle** **neutron** **proton** [1]

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

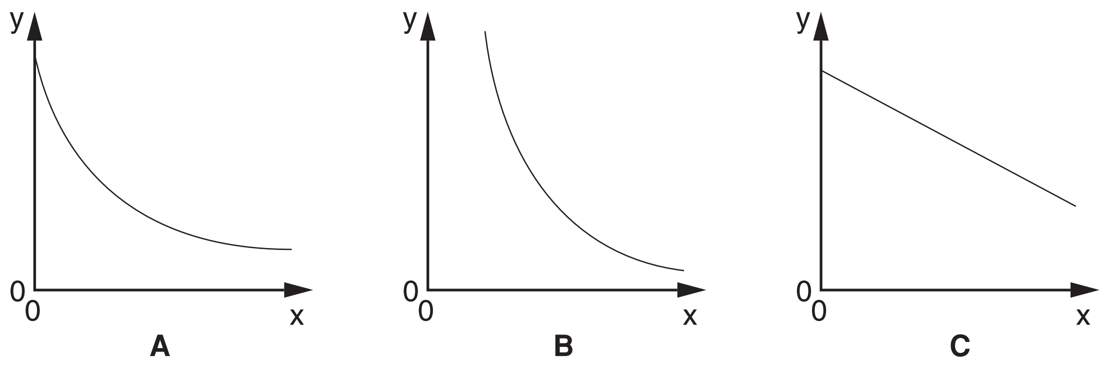


Fig. 5.1

Which graph, **A**, **B** or **C**, in Fig 5.1 is obtained when the y and x axes represent the two quantities given below?

(a) y-axis: the **electric field strength** around a proton
x-axis: the **distance** from the centre of the proton

answer .... [1]

(b) y-axis: the **activity** of a radioisotope
x-axis: **time**

answer .... [1]

6 Fig. 6.1 shows some of the electric field lines between a point charge and a charged plate.

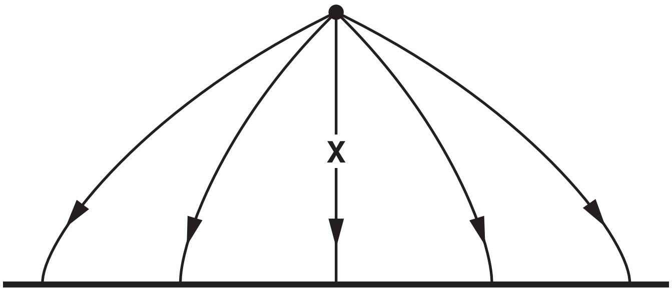


Fig. 6.1

On Fig. 6.1, draw a line to show the shape of the equipotential through the point **X**. [2]

7 An alpha particle ${}^{4}_{2}\mathrm{He}$ has a head-on collision with a stationary gold nucleus ${}^{197}_{79}\mathrm{Au}$.
The centres of the two particles are 1.2×10^{-13} m apart when they are at their closest.
Calculate the final kinetic energy of the alpha particle after the collision.
Assume the gold nucleus is stationary after the collision.

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

energy = ... J [3]

[Section A Total: 20]

Section B

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

8 This question is about the energy levels of the electron in a hydrogen atom.

(a) The energy E_n of the electron in a hydrogen atom is given by

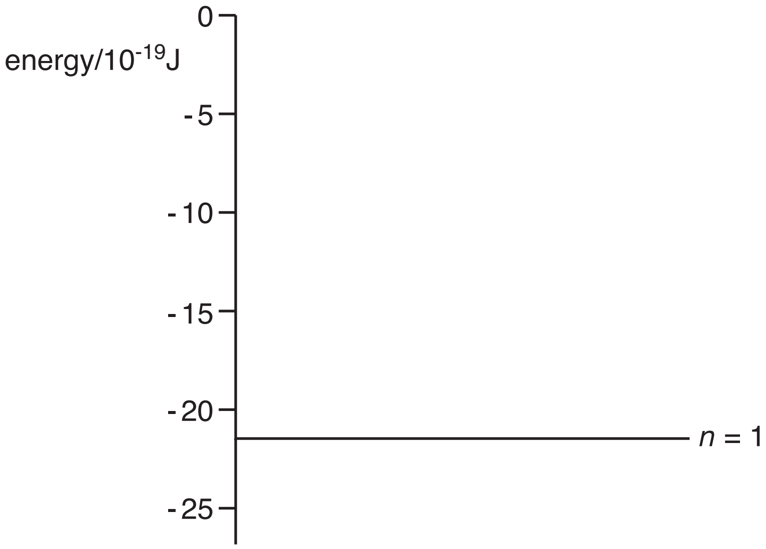
$$E_n = -\frac{E_1}{n^2} \text{ where } n = 1,2,3 \ldots$$

(i) The value of E_1 is 14 eV. Show that the energy of the electron in its lowest energy state ($n=1$) is about -2×10^{-18} J.

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

[1]

(ii) On the energy level diagram of Fig. 8.1, draw lines to show the energy levels of the electron for $n=2$ and $n=3$. Label them with their value of n.



[2]

Fig. 8.1

(iii) Explain why the energy of an electron needs to be greater than zero if it is to escape from the atom.

[2]

(b) Fig 8.2 shows a sample of hydrogen being bombarded with a beam of electrons from a particle accelerator.

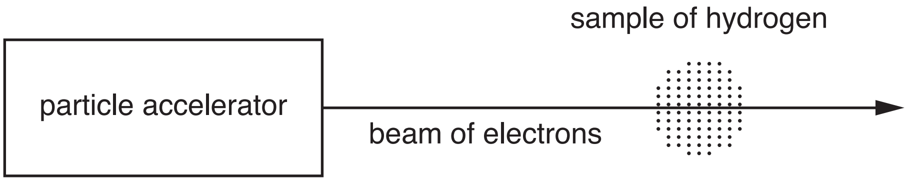


Fig. 8.2

Each electron in the beam has an energy of 18×10^{-19} J when it approaches the sample.

(i) Use Fig. 8.1 to explain why some of the electrons leave the sample with an energy of only about 1×10^{-19} J.

[2]

(ii) The sample of hydrogen emits photons as the electrons pass through.
Calculate the wavelength of the photons.

$h = 6.6 \times 10^{-34}$ J s
$c = 3.0 \times 10^{8}$ m s^{-1}

wavelength = ... m [2]

(iii) The energy of the electrons in the beam is raised to 20×10^{-19} J. Explain why the sample of hydrogen now emits photons of three different wavelengths, instead of just one. You may use a diagram.

[2]

[Total: 11]

9 This question is about the risks involved in using radioactive material in smoke detectors. Fig. 9.1 shows a cross-section through a smoke detector mounted on a ceiling.

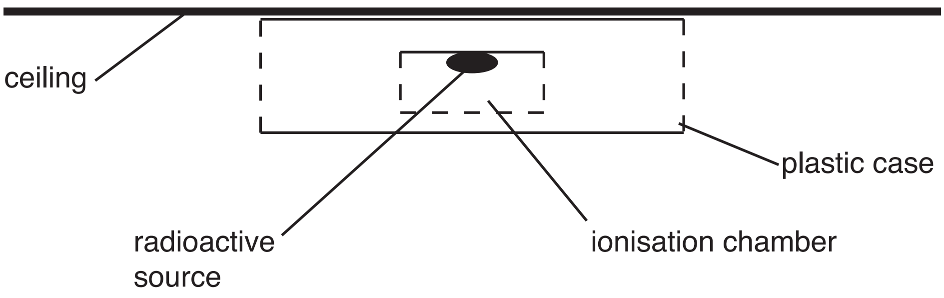


Fig. 9.1

The smoke detector uses americium-241, an emitter of alpha particles, to ionise air inside the ionisation chamber. Any smoke in the chamber absorbs the ions, reducing the conductivity of the air in the chamber.

(a) A typical smoke detector contains 2.0×10^{-10} kg of americium-241.

(i) Show that 2.0×10^{-10} kg of americium-241 contains about 5×10^{14} nuclei of the isotope.

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

[2]

(ii) Americium-241 has a half-life of 1.5×10^{10} s.
Show that the decay constant of the radioisotope is about $5 \times 10^{-11}\,s^{-1}$.

[1]

(iii) Calculate the activity of the americium-241 in the smoke detector.

activity = ... Bq [2]

(b) Nuclei of americium-241 decay by emitting alpha particles. Suggest why the radioactive material in the smoke detector is not a hazard when the isotope is inside the detector.

[2]

(c) In the event of a fire, some of the radioactive material in the detector could be breathed in by someone close by. The risk of developing cancer from this event is modelled as follows

- 1% of the radioactive material (2.0×10^{-12} kg) is breathed in
- the material is evenly spread through the person's lungs, of mass 2.0 kg.

(i) Use your answer to **(a)(iii)** to show that the annual dose equivalent from the event for this person is about 0.1 Sv per year.

energy of alpha particles = 8.7×10^{-13} J
quality factor for alpha particles = 20
1 year = 3.2×10^{7} s

[2]

(ii) The risk of developing cancer from radioactive materials is 3% Sv^{-1}.
Comment on the risks posed by the radioactive materials in smoke detectors given by this model. Support your answer with calculations.

[3]

[Total: 12]

10 This question is about using an electromagnet to lift a heavy load.

Fig. 10.1 shows a coil of insulated wire wrapped around the centre of an iron core. An iron bar is pulled up to the core when the switch is closed. The lamp glows when there is current in the coil.

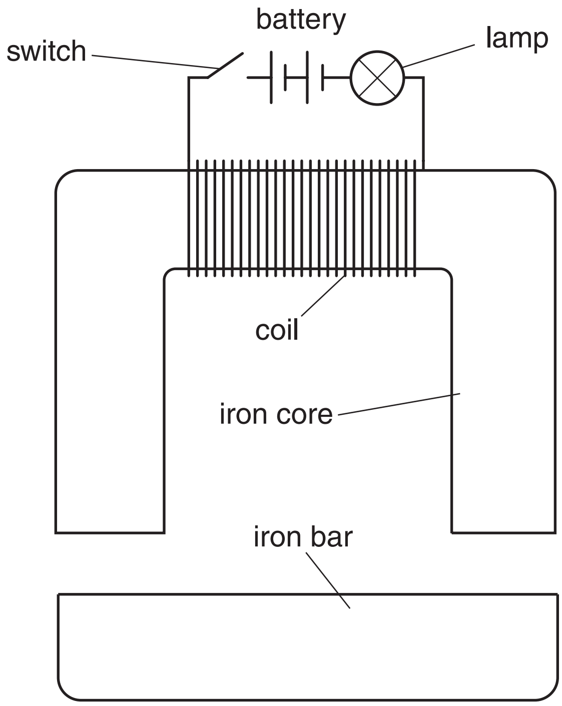


Fig. 10.1

(a) **(i)** On Fig. 10.1, sketch **two** complete loops of flux produced by the coil when the switch is closed. [2]

(ii) Use ideas of magnetic flux to explain why the iron bar is pulled up to the iron core when the switch is closed.

[2]

(b) **(i)** Suggest why the flux density in the iron core increases as the iron bar moves towards the iron core.

[1]

(ii) Suggest **three** other modifications to the arrangement which would increase the flux density in the iron core.

[3]

(c) Weights are added to the iron bar until it is suddenly pulled away from the iron core.
Explain why the brightness of the lamp momentarily increases at the instant that the iron bar stops touching the iron core.

[2]

(d) The electromagnet of Fig. 10.1 uses direct current from a battery. When the same electromagnet uses alternating current from a generator, the iron core heats up.
Explain why it heats up.

[3]

[Total: 13]

11 This question is about the use of electrons to probe the structure of protons.

The diameter of a proton has been determined by recording the angular distribution of high speed electrons scattered from a hydrogen target, as shown in Fig. 11.1.

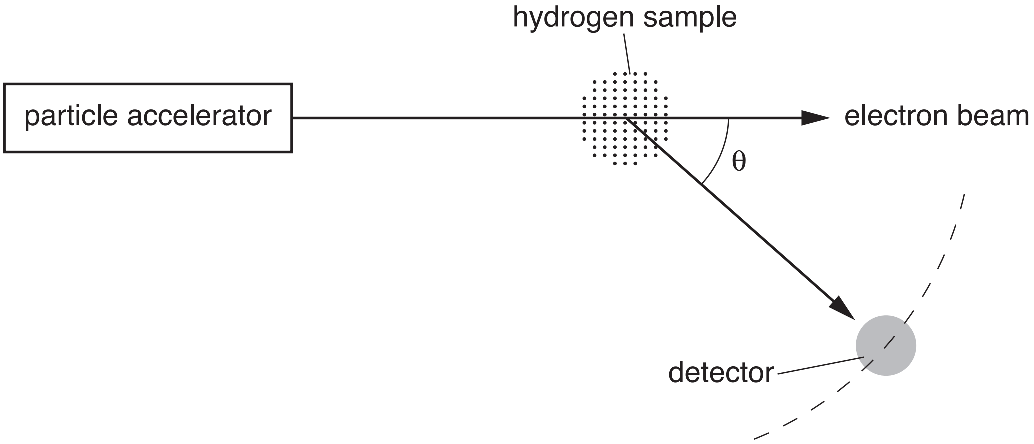


Fig. 11.1

When the de Broglie wavelength of the electrons is comparable to the diameter of the protons, there is evidence of diffraction.

(a) **(i)** The energy E of a high-speed electron is given by

$$E = pc$$

where p is the momentum of the electron and c is the speed of light.
Show that the energy of electrons which have a de Broglie wavelength of 4.8×10^{-15} m (twice the diameter of a proton) is about 4×10^{-11} J.

$c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$
$h = 6.6 \times 10^{-34}\,\mathrm{J\,s}$

[3]

(ii) The electrons are given this energy in a particle accelerator, by repeatedly accelerating them through a potential difference of 100 kV. Calculate the number of times each electron has to pass through this potential difference to acquire an energy of about 4×10^{-11} J.

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

answer .... [2]

(b) Fig. 11.2 shows how the detector current depends on the angle through which the detected electrons are scattered. The graph shows evidence of diffraction.

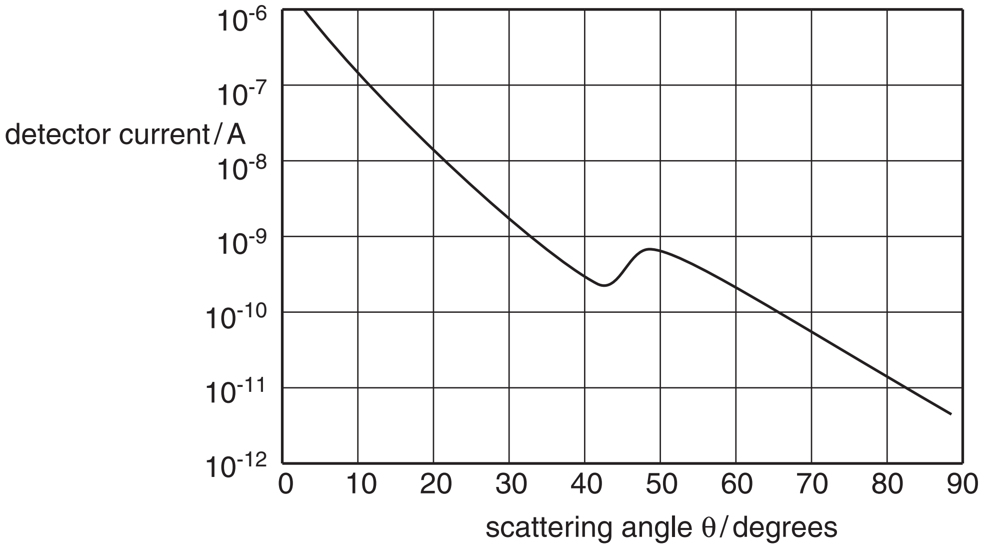


Fig. 11.2

State and explain the feature of the graph which shows that the electrons are being diffracted by the protons.

[2]

(c) At high enough electron energies, the experiment provides evidence for the internal structure of the proton.
Describe what is observed and state what it reveals about the internal structure of the proton.

[3]

[Total: 10]

Quality of Written Communication [4]

[Section B Total: 50]

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