OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) **2864/01**

Field and Particle Pictures

Thursday **20 JANUARY 2005** 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.

For Examiner's Use

Answer **all** the questions.

Section A

1 Protons and neutrons are each made up of a different combination of **three** quarks.

The **u** quark has a charge of $+\frac{2}{3}e$. The **d** quark has a charge of $-\frac{1}{3}e$.

State the combination of three quarks needed to make

(a) a proton

[1]

(b) a neutron.

[1]

2 A nucleus of hydrogen-3 can be formed when a neutron is absorbed by a nucleus of hydrogen-2.

$$^{2}_{1}\text{H} + ^{1}_{0}\text{n} \rightarrow ^{3}_{1}\text{H}$$

The table gives the masses of the three particles in atomic mass units (u).

particle	mass / u
$^{1}_{0}\text{n}$	1.00867
$^{2}_{1}\text{H}$	2.00141
$^{3}_{1}\text{H}$	3.00160

Show that about 1×10^{-12} J of energy is released for each nucleus of hydrogen-3 created in this way.

$u = 1.7 \times 10^{-27}$ kg
$c = 3.0 \times 10^{8}\,\text{m s}^{-1}$

[3]

For Examiner's Use

3 A mercury discharge lamp emits ultraviolet photons of frequency 1.2×10^{15} Hz.

(a) Show that the energy of the ultraviolet photons is about 8×10^{-19} J.

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

[1]

(b) Fig. 3.1 gives some of the energy levels of the mercury atom.

Draw an arrow to show the energy level transition which causes the emission of these ultraviolet photons.

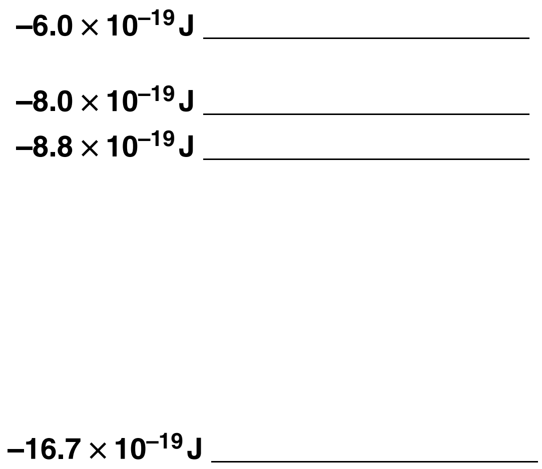


Fig. 3.1

[1]

(c) Here are some statements (**A**,**B** and **C**) about the energy levels shown in Fig. 3.1.

A They are all negative because the electrons in the atom are bound to the nucleus.

B They are all negative because electrons have a negative charge.

C Electrons in different energy levels have the same de Broglie wavelength.

Which **one** of these statements is correct?

answer ....[1]

[Turn over

4 The surface of an isolated conducting sphere is at a negative potential of –160 kV.

The radius of the sphere is 0.1 m.

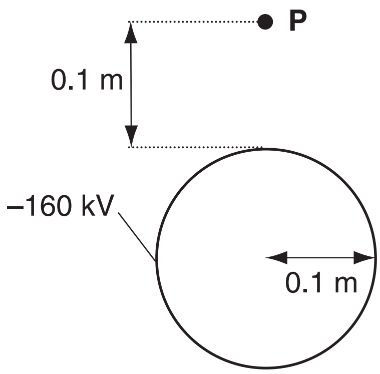


Fig. 4.1

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

(b) Here is a list of potentials.

–320 kV **–160 kV** **–80 kV** **–40 kV**

P is at a distance of 0.1 m from the surface of the sphere.

State which is the best value for the potential at **P**.

potential = ... kV [1]

(c) Draw a line on Fig. 4.1 to show the shape of the equipotential which passes through point **P**. [2]

5 Fig. 5.1 shows a single coil of wire in the uniform field between opposite poles of a pair of magnets.

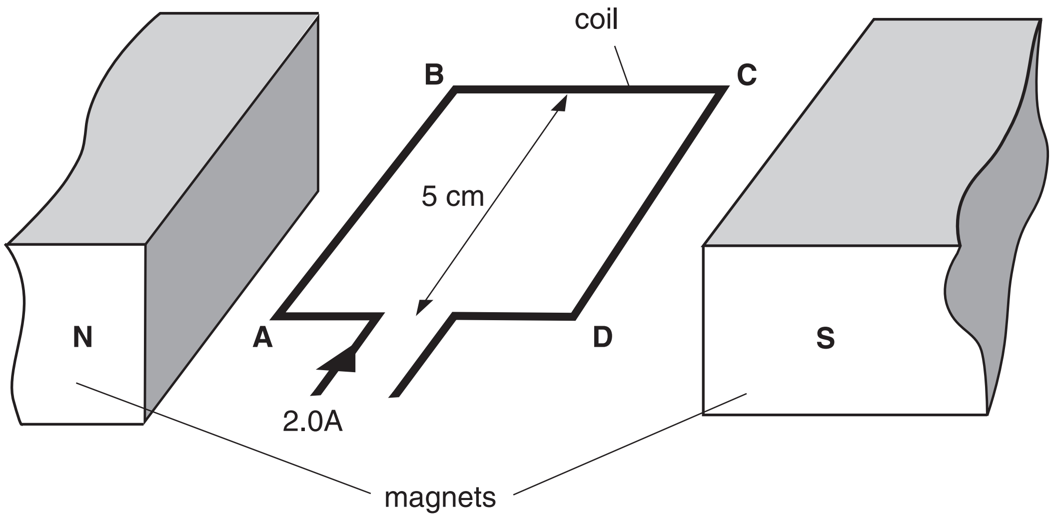


Fig. 5.1

The average flux density between the poles is 25 mT.

(a) Calculate the vertical magnetic force on side **AB** when it carries a current of 2.0 A.

The length of side **AB** is 5.0 cm.

force = ... N [2]

(b) Here are three statements about the magnetic force on side **BC** when the coil carries a current.

A It has the same value and direction as the force on side **AB**.

B It has the same value but the opposite direction to the force on side **AB**.

C There is no magnetic force on side **BC**.

State which **one** of the three (**A**, **B** or **C**) is correct.

answer ....[1]

For Examiner's Use

6 The graph of Fig. 6.1 shows the variation of binding energy per nucleon with the total number of nucleons in a nucleus.

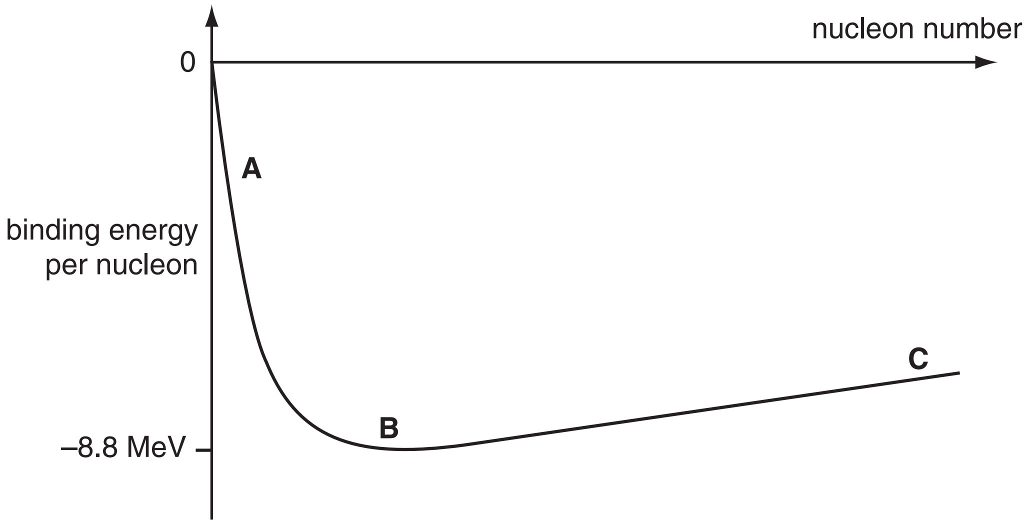


Fig. 6.1

Three regions (**A**, **B** and **C**) are marked on the graph.

State the region (**A**, **B** or **C**) which

(a) contains the nucleon number 56 ....[1]

(b) contains nuclei which can be used to provide energy by nuclear fusion ....[1]

(c) contains nuclei which undergo nuclear fission. ....[1]

7 The graph of Fig. 7.1 shows the variation of electric field strength E with distance r from a charged particle.

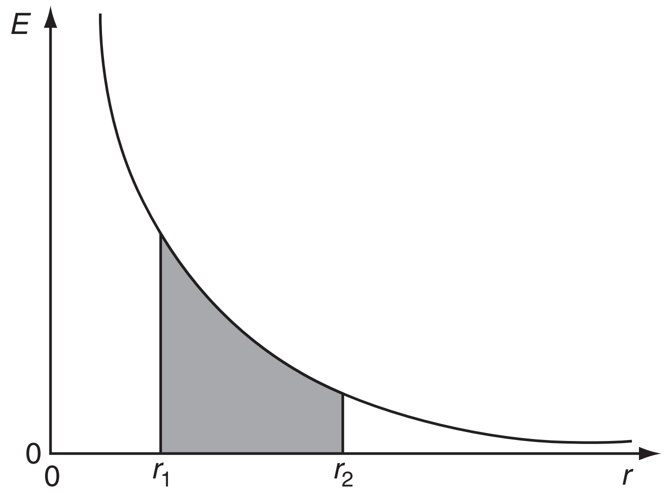


Fig. 7.1

Here are some statements about the shaded area shown on the graph.

A The area gives the average electric force between points r_1 and r_2.

B The area gives the work needed to move an electron from r_1 to r_2.

C The area gives the potential difference between points r_1 and r_2.

State which **one** of **A**, **B** or **C** is correct.

answer ....[1]

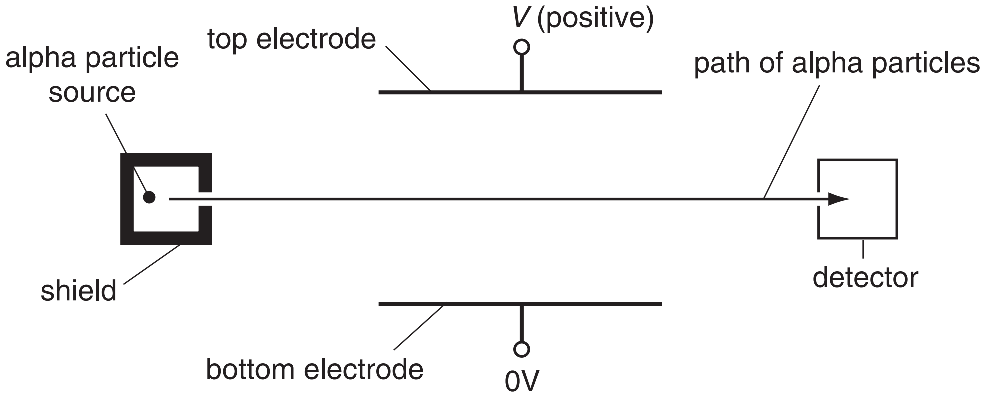
[Section A Total: 20]

Section B

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

8 This question is about the forces on charged particles in magnetic and electric fields.

Fig. 8.1 shows part of a device for measuring the speed of alpha particles. All of the apparatus is in a vacuum.



not to scale

Fig. 8.1

Alpha particles emerge through a hole in the shield around the source and pass between a pair of flat, parallel electrodes. The bottom electrode is at 0 V.

(a) The top electrode is at a positive potential V. On Fig. 8.1, sketch **five** lines to represent the electric field between the electrodes. [2]

(b) Each alpha particle experiences an electric force of 7.0×10^{-13} N as it passes between the electrodes.

(i) Show that the electric field strength between the electrodes is about $2 \times 10^{6}\,\mathrm{N\,C^{-1}}$.

charge on alpha particle = $+3.2 \times 10^{-19}$ C

[2]

(ii) The electrodes are separated by a distance of 3.0 mm.
Calculate the potential of the top electrode.

potential = ... V [2]

(c) There is a uniform magnetic field in the region between the electrodes. This creates a magnetic force on the alpha particles, which can balance the electric force. This allows the alpha particles from the source to reach the detector.

(i) Complete the sentences.

The angle between the magnetic field direction and the electric field direction is

....

The angle between the magnetic field direction and the direction of motion of the

alpha particles is ....

[2]

(ii) A magnetic field of strength 0.13 T is needed to balance the electric force.

Use this information to calculate the velocity of the alpha particles which reach the detector.

charge on alpha particle = 3.2×10^{-19} C

velocity = ... $m\,s^{-1}$ [2]

(d) The source is replaced by another which emits alpha particles of greater energy.

Explain why these alpha particles will **not** enter the detector if there are no other changes to the apparatus.

[2]

[Total: 12]

For Examiner's Use

9 This question is about the risk to a patient of using a radioactive tracer for diagnosis.

The isotope iodine-131 is a beta emitter which decays to a stable isotope of xenon.

(a) (i) Complete the equation for the beta decay of iodine-131.

$$^{131}_{53}\text{I} \longrightarrow \, ^{\dots\dots\dots}_{\dots\dots\dots}\text{Xe} \; + \; ^{0}_{-1}\text{e} \; + \; ^{0}_{0}\bar{\nu}$$

[2]

(ii) Name the particle represented by the symbol $\bar{\nu}$.

name ....[1]

(b) The half-life of iodine-131 is 8.1 days.

Show that the decay constant of iodine-131 is about $1 \times 10^{-6}\,\text{s}^{-1}$.

1 day = 86 400 s

[2]

(c) A patient is injected with a freshly made solution of iodine-131. The iodine-131 becomes concentrated in the thyroid gland. The initial activity of the iodine-131 in the thyroid gland is then 2.5×10^{5} Bq.

(i) Show that the initial number of iodine-131 nuclei in the thyroid gland is about 2.5×10^{11}.

[2]

(ii) The maximum energy of the beta particles emitted by iodine-131 is 0.81 MeV. The mass of the thyroid gland is 0.060 kg.

Show that the dose equivalent received by the gland after all the iodine-131 has decayed can be no more than 0.5 Sv.

[2]

(iii) The risk to the patient of developing cancer is 3% per sievert. The extra risk of developing cancer as a result of exposure to the iodine-131 is to be limited to 0.1%.

Calculate the maximum number of iodine-131 nuclei which should be allowed to settle in the patient's thyroid gland during the treatment.

number of nuclei = ... [2]

(d) Suggest reasons why the calculations made in **(c)(ii)** lead to an over-estimate of the dose equivalent received by the gland.

[2]

[Total: 13]

10 This question is about the changing magnetic fields in transformers.

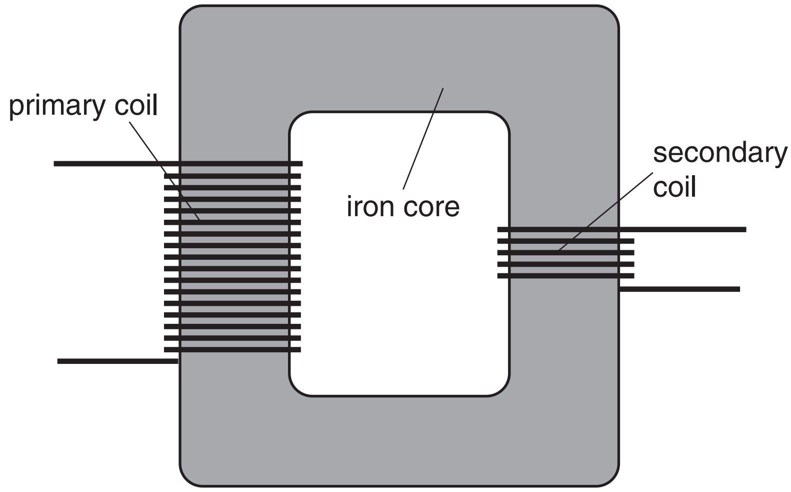


Fig. 10.1

An iron core is wound with primary and secondary coils of insulated copper wire to make a transformer, as shown in Fig. 10.1.

(a) On Fig. 10.1, sketch **two** complete loops of magnetic flux which pass through the secondary coil, when there is a current in the primary coil. [2]

(b) The ends of the secondary coil are now connected to an oscilloscope to obtain the emf-time graph of Fig. 10.2.

On the axes of Fig. 10.2, sketch the variation with time of the magnetic flux in the secondary coil.

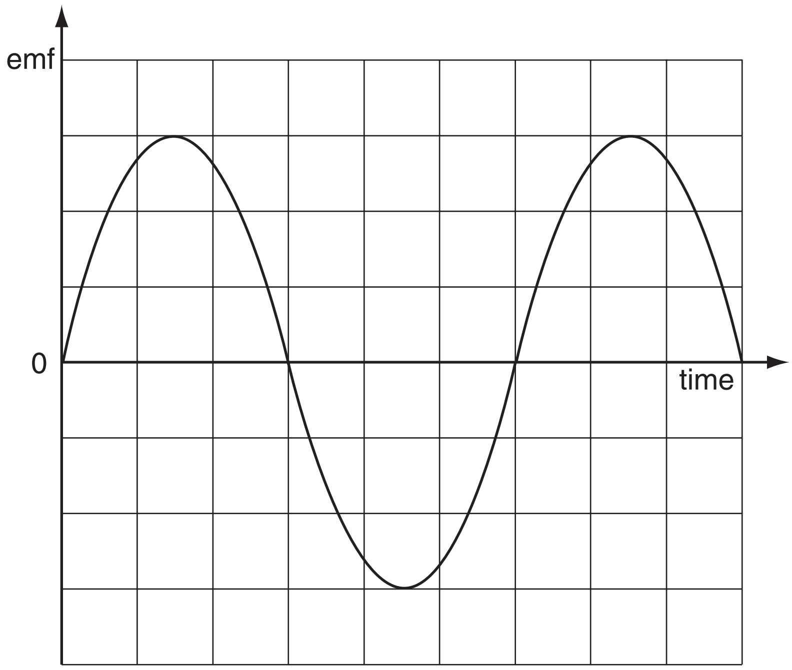


Fig. 10.2

[2]

For Examiner's Use

(c) For an ideal transformer, the magnetic flux in the secondary coil is the same as the magnetic flux in the primary coil.

Use this to explain why the quantity

$$\frac{\text{emf across the coil}}{\text{turns of wire in the coil}}$$

has the same value for both primary and secondary coils in an ideal transformer.

[2]

(d) In a real transformer, eddy currents in the iron core will alter the flux in the two coils.

(i) Explain why eddy currents are set up in the core and suggest why this alters the flux in the core.

[2]

(ii) State and explain how the core should be constructed so as to reduce eddy currents.

[2]

[Total: 10]

11 This question is about the scattering of a beam of protons from a thin target made of uranium metal.

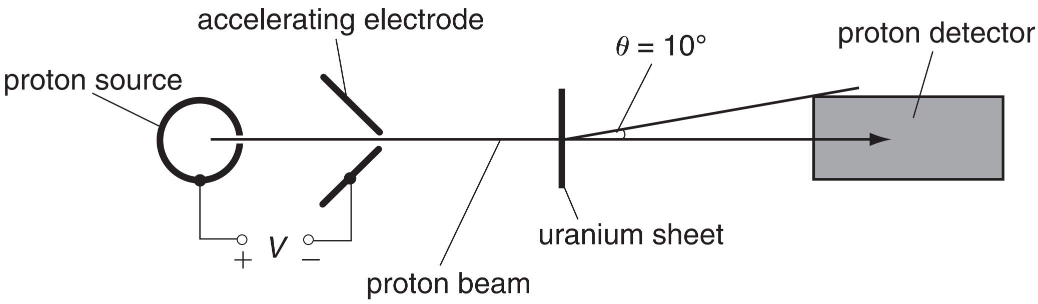


Fig. 11.1

Fig. 11.1 shows some apparatus in a vacuum. A beam of protons is accelerated towards a thin sheet of uranium. Those protons which emerge deflected by an angle θ of 10° or less enter the detector and are counted.

(a) The protons are accelerated to a speed of $1.5 \times 10^{7}\,\mathrm{m\,s^{-1}}$ as they pass between the source and the accelerating electrode.

Calculate a value for the accelerating potential difference V.

$m_p = 1.66 \times 10^{-27}\,\mathrm{kg}$
$e = 1.6 \times 10^{-19}\,\mathrm{C}$

V = ... V [3]

(b) One of the protons passes close to a uranium nucleus, and is deflected by an angle θ = 45°.

(i) On Fig. 11.2, complete the path **P** of the proton as it passes by the nucleus.

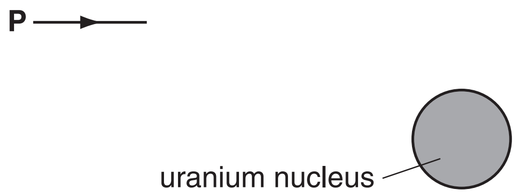


Fig. 11.2

[1]

For Examiner's Use

(ii) Explain why the proton follows the path you have drawn in Fig. 11.2.

[2]

(c) (i) The accelerating p.d., *V*, is increased. The rate at which protons reach the uranium sheet does not change. However, the rate at which protons reach the detector increases.
Explain why the rate at which protons reach the detector increases.

[2]

(ii) Some of the protons are involved in head-on collisions with uranium nuclei in the target. By considering the energy transfers involved, show that the distance of closest approach of a 5.0 MeV proton to a uranium nucleus is about 3×10^{-14} m. A uranium nucleus contains 92 protons.

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

[2]

(iii) When the proton energy is increased above about 20 MeV, the rate at which charged particles are counted by the detector increases suddenly.
Suggest a reason for this.

[1]

[Total: 11]

Quality of Written Communication [4]

[Section B Total: 50]

END OF QUESTION PAPER