OXFORD CAMBRIDGE AND RSA EXAMINATIONS

**Advanced GCE**

# PHYSICS B (ADVANCING PHYSICS) 2864/01

Field and Particle Pictures

Thursday **15 JUNE 2006** 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 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 question paper consists of 16 printed pages.**

SP (SM/JG) S93490/5

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Answer **all** the questions.

## Section A

**1** Here is a list of units.

**$JC^{-1}$**   **$NC^{-1}$**   **Nm**   **Wb**

Which is the correct unit for

**(a)** electrical potential

answer .............................. [1]

**(b)** electric field strength?

answer .............................. [1]

**2** The Einstein mass-energy relationship is $E = mc^2$.

What is meant by the energy $E$ in the relationship?

[1]

**3** Strontium-90 decays into an isotope of yttrium, emitting a beta particle and an antineutrino.

Complete the nuclear equation for the decay.

$$^{90}_{38}\text{Sr} \rightarrow \, ^{0}_{\cdots\cdots}\text{e} + \, ^{0}_{0}\bar{\nu} + \, ^{\cdots\cdots}_{\cdots\cdots}\text{Y}$$

[2]

**4** Strontium-90 has a half-life of $8.9 \times 10^8$ seconds.

Calculate the number of strontium-90 nuclei required for a sample to have an activity of 500 Bq.

number of nuclei = .............................. [2]

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5 Here are the first five lines of a poem which describes a particle. The name of the particle has been replaced by a space.

**An extract of text has been removed due to third party copyright restrictions**

Details: An extract from the poem Cosmic Gall by John Updike

From Cosmic Gall by John Updike (1963)

(a) The table summarises the properties of four different particles.

| particle | has negligible mass | has zero charge | interacts very weakly with matter |
|---|---|---|---|
| electron | no | | |
| neutrino | yes | | |
| neutron | no | | |
| photon | yes | | |

Complete the table with the words yes or no. [2]

(b) Select from the table the particle which the poem best describes.

Write it in the space in the poem. [1]



[Turn over

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**6** An alpha particle is scattered by 90° as it passes close to a gold nucleus.

**(a)** Fig. 6.1 shows four different paths for the alpha particle.

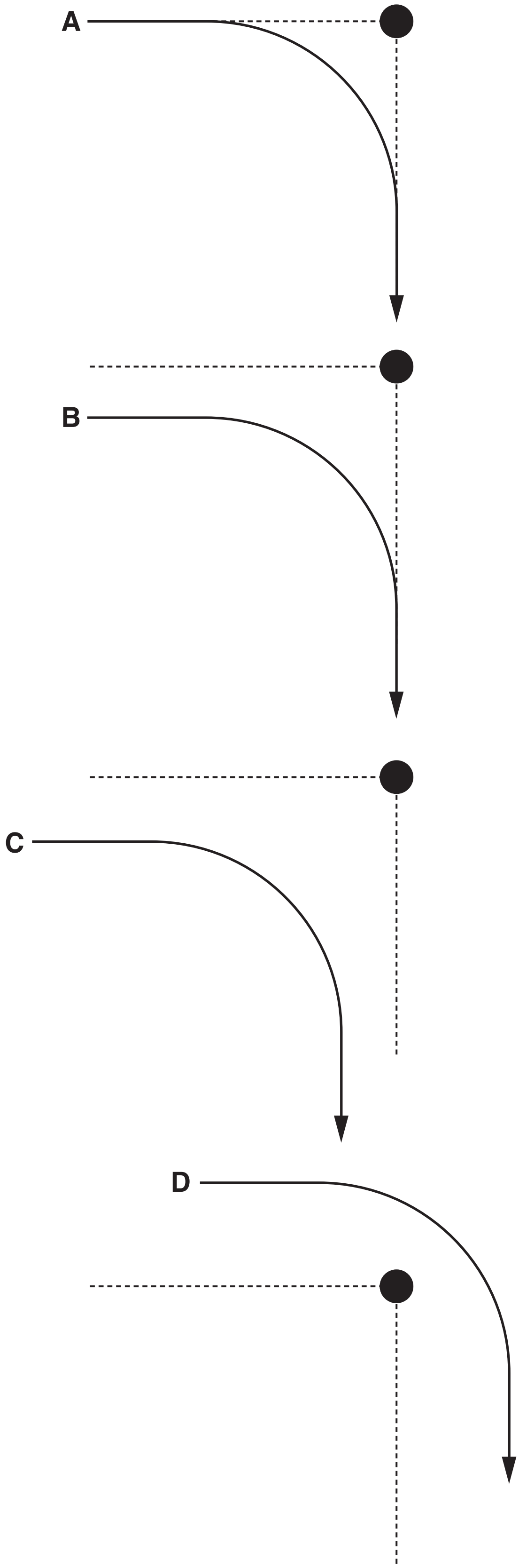


**Fig. 6.1**

Which **one** of the paths (**A**, **B**, **C** or **D**) could be correct?

answer .............................. [1]

**(b)** Here are some statements about the alpha particle when it scatters off the nucleus.

**A** The potential energy of the alpha particle decreases as it approaches the nucleus.

**B** The kinetic energy of the alpha particle is about the same before and after scattering.

**C** The kinetic energy of the alpha particle decreases as it moves away from the nucleus.

Which **one** of the statements (**A**, **B** or **C**) is true?

answer .............................. [1]

**7** The risk of developing cancer from exposure to radioactive materials is 3% $Sv^{-1}$.

A physics teacher demonstrates the properties of radioactive sources many times during a forty year career. The extra dose equivalent for the teacher due to this activity is 0.1 mSv per year.

Estimate the extra risk of cancer for the teacher due to handling the radioactive sources.

risk = .............................. % [2]

8 Fig. 8.1 shows a simple generator.

**A diagram has been removed due to third party copyright restrictions**

Details: A diagram of a simple generator

Fig. 8.1

When the magnet is rotated at 3000 r.p.m., the emf across the coil has an amplitude of 12 V.

(a) What is the amplitude of the emf when the magnet is rotated at 9000 r.p.m.?

emf = ............................... V [1]

(b) Suggest two other modifications which will increase the emf induced across the coil.

[2]

**9** The graph in Fig. 9.1 shows the variation of binding energy per nucleon with nucleon number.

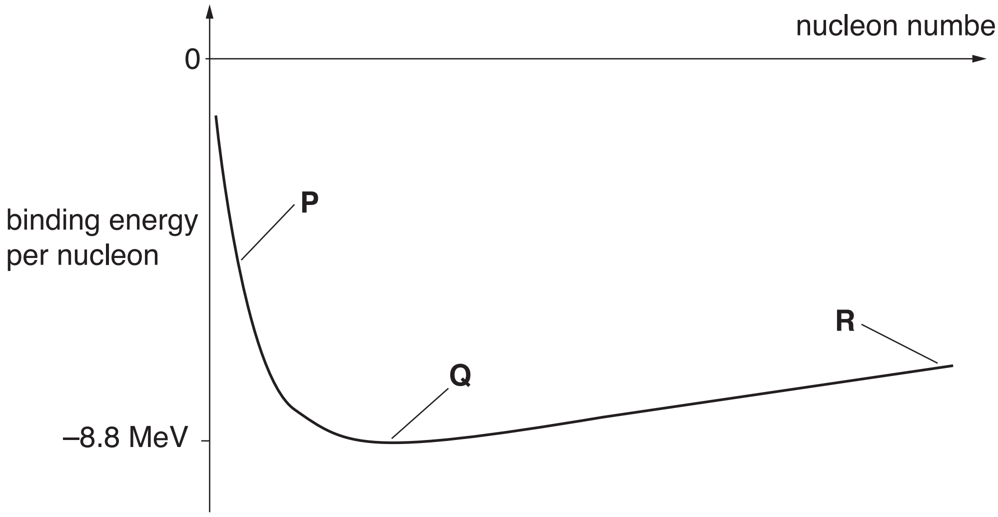


**Fig. 9.1**

**(a)** Three regions of the graph have been labelled.

Which **one** of the regions **P**, **Q** or **R** contains the nuclei which are the most stable?

answer .............................. [1]

**(b)** Here are four stages of an explanation of why binding energy is always negative.

**A** The colliding nucleons bind to each other, losing energy as photons.

**B** Separated nucleons are unbound, so have an energy of zero.

**C** Nucleons are attracted to each other by the strong nuclear force.

**D** So they accelerate towards each other, gaining kinetic energy.

The first stage is **B**. Complete the boxes to show the best order of the other stages of the explanation.

| B | → | | → | | → | |
|---|---|---|---|---|---|---|

[2]

[Section A Total: 20]

## Section B

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

10 The apparatus shown in Fig. 10.1 is used to collect the isotopes uranium-238 and lead-206 in a sample of rock.

**A diagram has been removed due to third party copyright restrictions**

Details: A diagram of the apparatus used to collect the isotopes uranium-238 and lead-206 in a sample of rock

Fig. 10.1

Ions from the sample of rock emerge from the source towards an electrode at 200V.

(a) Ions pass through a hole in the 200V electrode with negligible velocity. They are accelerated towards another electrode at 0V.

(i) On Fig. 10.2, draw four arrowed lines to represent the electric field between the electrodes.

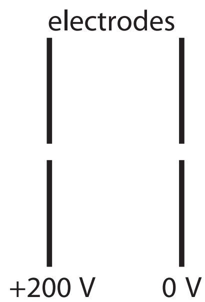


Fig. 10.2

[2]

**(ii)** By considering the energy changes of the ions in the electric field region, show that the momentum gained by a lead-206 ion is about $5 \times 10^{-21}$ N s.

mass of lead-206 ion = $3.5 \times 10^{-25}$ kg
charge of ion = $1.6 \times 10^{-19}$ C

[3]

**(b)** The accelerated lead-206 ions enter a region of uniform magnetic field *B* acting at right angles to the plane of Fig. 10.1. They follow a circular path in this region and end up being trapped in a collector.

**(i)** Draw an arrow through the point labelled **X** to show the direction of the magnetic force on the ions at that point. [1]

**(ii)** By considering the magnetic force as a centripetal force, calculate the radius of the circular path.

$B = 0.12$ T

radius = ............................. m [3]

**(c)** Ions of lead-206 and uranium-238 have the **same** charge and kinetic energy when they enter the region of uniform magnetic field.

Explain why the uranium-238 ions follow a path of greater radius than the lead-206 ions.

[2]

[Total: 11]

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**11** The age of the Solar System can be estimated by measuring the ratio of the isotopes lead-206 and uranium-238 in rock samples. The method assumes that all of the lead-206 in the sample is due to the decay of uranium-238 which was present when the solar system was formed. Lead-206 is a stable isotope.

**(a)** Uranium-238 decays into lead-206 by several stages.

The overall decay can be represented with this equation.

$$^{238}_{92}\mathrm{U} \rightarrow ^{206}_{82}\mathrm{Pb} + \text{decay products}$$

It is suggested that **all** of the decay products are alpha particles.

Use the equation to show that this cannot be correct.

[4]

**(b)** Describe and explain how the number of lead-206 nuclei changes with time after the creation of the uranium-238 nuclei, during two half lives of the decay sequence.

[2]

**(c) (i)** On the axes of Fig. 11.1, sketch a graph to show how the ratio

$$R = \frac{\text{number of lead-206 nuclei}}{\text{number of uranium-238 nuclei}}$$

in a sample of rock will change with time $t$. Take $t = 0$ to be the instant of creation of the uranium-238. The half life of the decay sequence is $5 \times 10^9$ years.

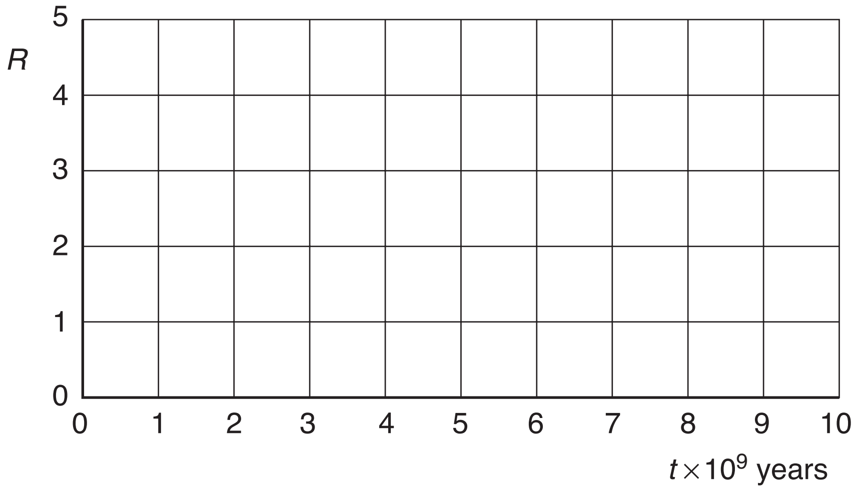


**Fig. 11.1**

[3]

**(ii)** Use the equation $N = N_0 e^{-\lambda t}$ to show that $R = e^{\lambda t} - 1$.

[2]

**(iii)** A sample of rock which is analysed has a value of $R = 0.81$.

Use $R = e^{\lambda t} - 1$ to calculate the age of the rock.

$\lambda = 4.8 \times 10^{-18}\,\text{s}^{-1}$

age = .............................. s [2]

[Total: 13]



**[Turn over**

**12** Some people carry a rechargeable battery inside their body. The battery is used to power a surgical implant, such as a heart pacemaker or artificial heart. The battery can be charged at regular intervals by coils on either side of the skin, as shown in Fig. 12.1.

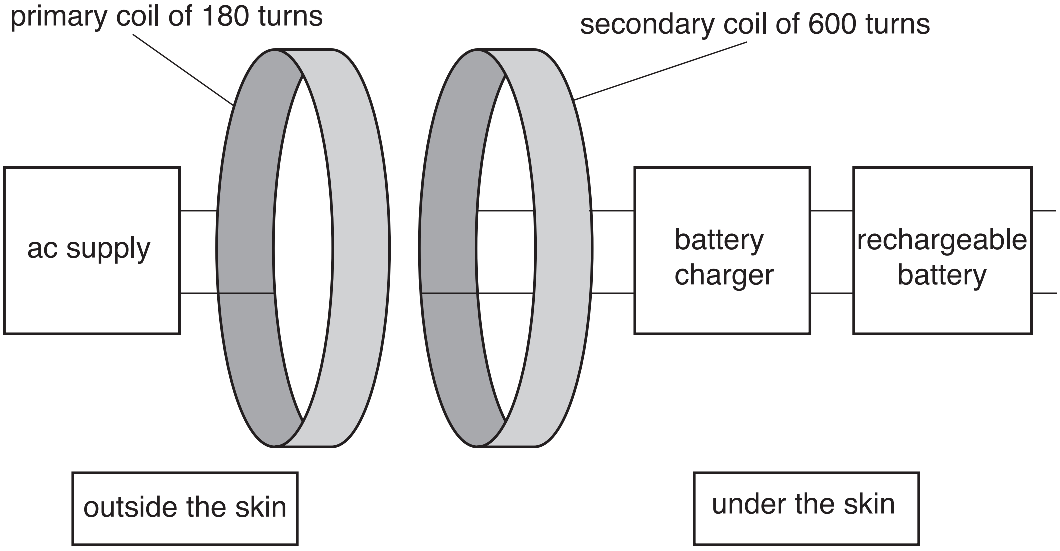


**Fig. 12.1**

The secondary coil is implanted under the skin. When the battery is to be charged, a primary coil connected to an ac supply is placed on the skin over the secondary coil, making a transformer.

**(a)** Explain how an alternating emf across the primary coil results in an alternating emf across the secondary coil.

[2]

**(b)** In normal use, the emf across the **secondary** coil has an amplitude of 5.0V.

**(i)** Calculate the amplitude of the emf across the primary coil, assuming ideal transformer behaviour. Use data from Fig. 12.1.

emf = .............................. V [2]

**(ii)** Suggest **one** reason why, in practice, the amplitude of the emf across the primary coil needs to be much greater than the value calculated in **(b)(i)**.

[1]

**(c)** The graph of Fig. 12.2 shows the variation of the emf across the secondary coil with time.

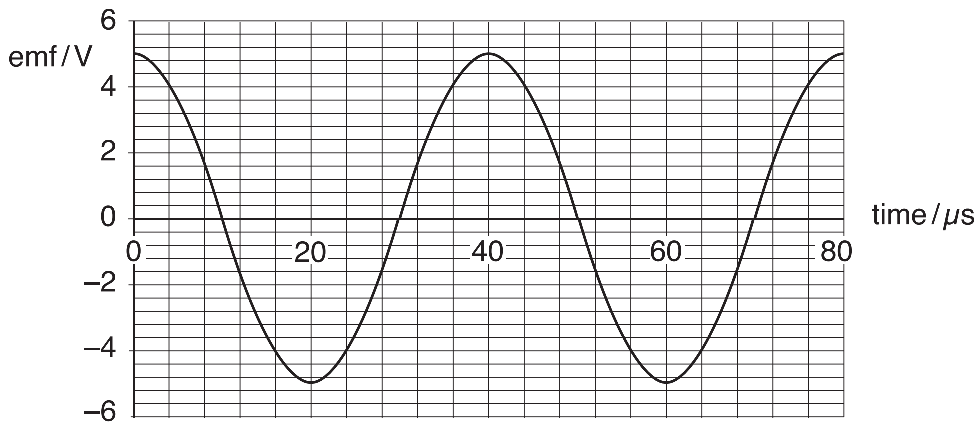


**Fig. 12.2**

**(i)** On Fig. 12.2, sketch the variation of the flux linkage in the secondary coil with time. [2]

**(ii)** Use the graph to estimate the amplitude of the flux linkage in the secondary coil.

[3]

[Total: 10]

**13** A long molecule in a purple food dye absorbs green light. Photons are absorbed by the molecule, causing one of its electrons to move up to an excited state. The electron is free to move along the length of the molecule, so it can be modelled as a particle in a long narrow box.

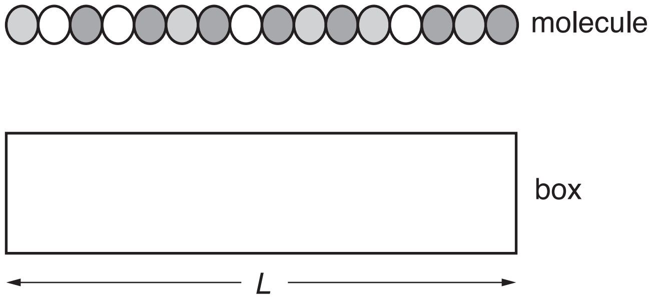


**Fig. 13.1**

**(a) (i)** In the box of Fig. 13.1, sketch a standing wave representing the electron in its lowest energy state. [2]

**(ii)** Use the relationship kinetic energy $E = \frac{p^2}{2m}$ to show that the energy $E_0$ of the electron of mass $m$ in its lowest energy state is given by $E_0 = \frac{h^2}{8mL^2}$ ,

where $L$ is the length of the box.

[2]

**(b)** When photons of green light are absorbed by the dye molecule, the electron jumps from the lowest energy state to the second excited state. The energy levels for the electron are shown in Fig. 13.2.

**(i)** On Fig. 13.2, draw an arrow to represent the absorption of green light.

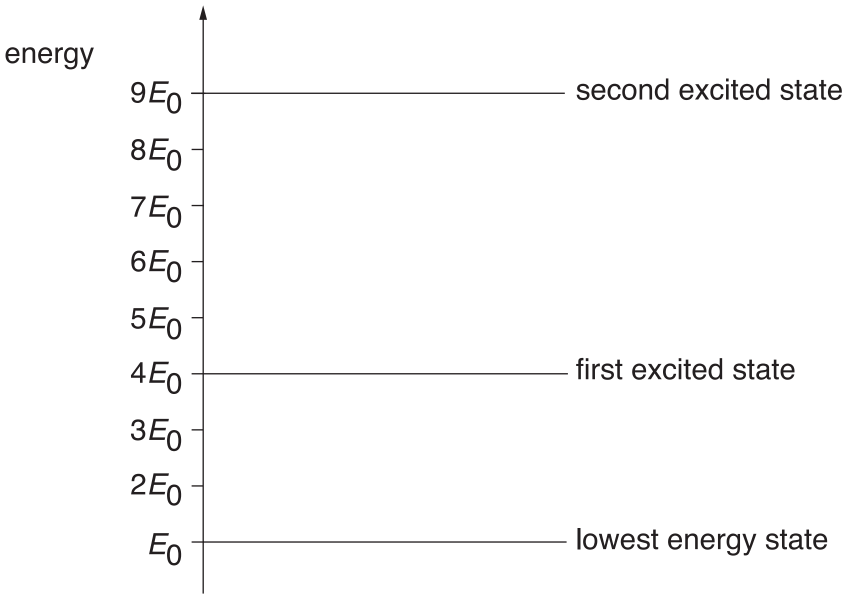


**Fig. 13.2**

[1]

**(ii)** The green light has a wavelength of $5.1 \times 10^{-7}$ m.

Use Fig. 13.2 to show that $E_0$ is about $5 \times 10^{-20}$ J.

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

[3]

**(iii)** Calculate the length $L$ of the molecule required by this model.

$m = 9.1 \times 10^{-31}$ kg

$L$ = ............................ m [2]

**Question 13 continued over the page**



**[Turn over**

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**(c)** Suggest and explain why the energy absorbed by the dye molecule is **not all** re-emitted as photons of green light.

[2]

[Total: 12]

Quality of Written Communication [4]

[Section B Total: 50]

**END OF QUESTION PAPER**

*Copyright Acknowledgements:*

Question 5 Extract from *Cosmic Gall* by John Updike (1963). © John Updike.