PJD

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

# PHYSICS B (ADVANCING PHYSICS) 2864/01

## Field and Particle Pictures

Friday 20 JUNE 2003 Afternoon 1 hour 10 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 10 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 50 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.**



[Turn over

For Examiner's Use

Answer **all** the questions.

## Section A

1 Here is a list of units.

**A** **C** **J C$^{-1}$** **T**

Choose the correct unit for

**(a)** electric potential ......................................

**(b)** magnetic flux density ......................................

[2]

2 Fig. 2.1 shows a loop of flux in an electromagnet.

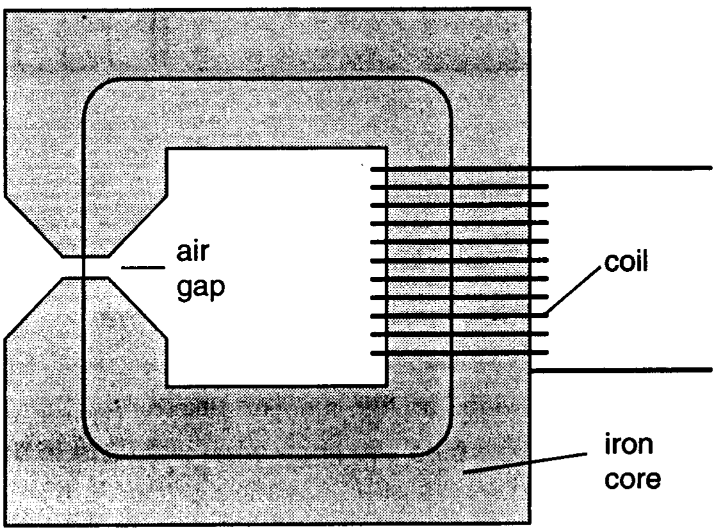



**Fig. 2.1**

**(a)** The flux density in the air gap is greater than the flux density in the iron core.

Show this by drawing **two** more loops of flux for the electromagnet. [2]

**(b)** Here are some changes to the electromagnet.

**A** decrease the number of turns in the coil
**B** decrease the gap between the poles
**C** decrease the current in the coil

Which **one** of these changes will **increase** the flux density in the gap between the poles?

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

For Examiner's Use

3 Silicon-31 is an emitter of beta particles. It has a half life of $9.4 \times 10^3$ s.

**(a)** Show that its decay constant $\lambda$ is about $7 \times 10^{-5}$ s$^{-1}$.

[1]

**(b)** The activity of a radioactive source can be calculated with the relationship

$$\frac{\Delta N}{\Delta t} = -\lambda N.$$

Use the relationship to show that the decay constant has units of s$^{-1}$.

[1]

**(c)** Calculate the number of silicon-31 atoms needed to make a source of activity $3 \times 10^3$ Bq.

number of atoms = ............................ [1]

For Examiner's Use

4 Fig. 4.1 shows some equipotential lines around an electricity power cable at +500 V.

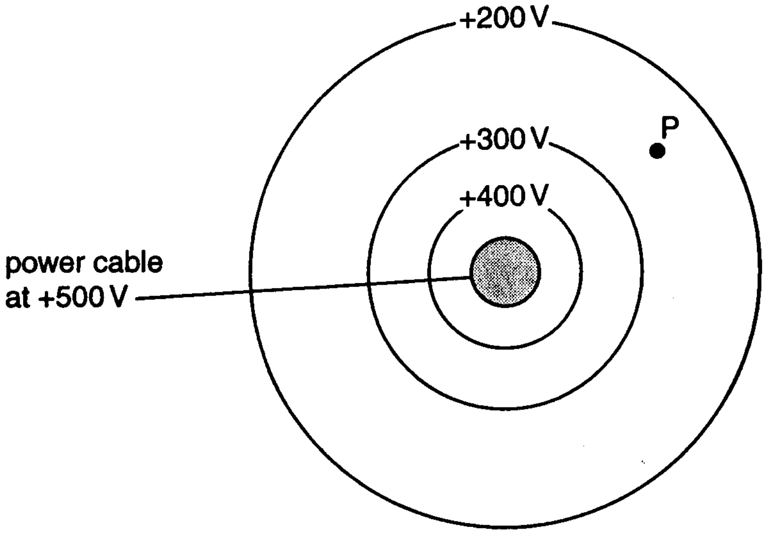



**Fig. 4.1**

**(a)** What feature of the diagram shows that the electric field strength is strongest next to the power cable?

[1]

**(b)** On Fig. 4.1, draw a line to represent the direction of the electric field at point P.

[2]

5 Here are some facts about the scattering of a beam of high energy electrons from a sample of protons.

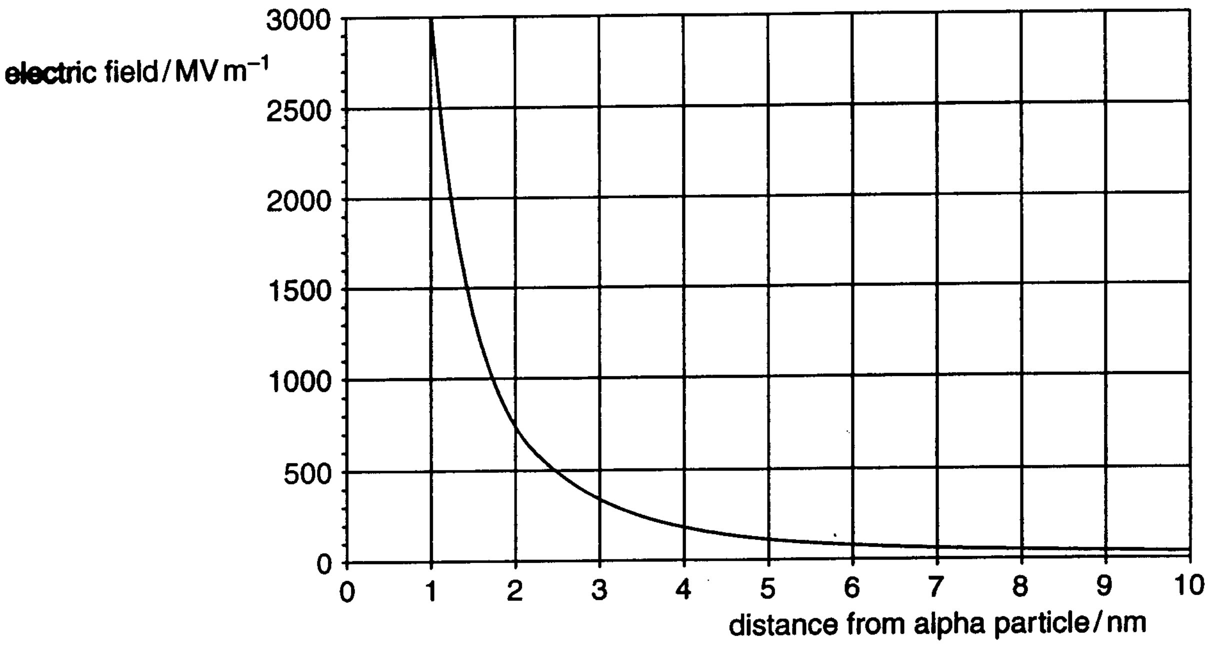
**A** Most of the electrons in the beam are not scattered at all.
**B** Some electrons are scattered through large angles.
**C** New particles, other than protons and electrons, are emitted from the sample.

Which **one** of these facts provides the best evidence for the presence of quarks in protons?

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

For Examiner's Use

6 The graph shows how the electric field strength, in $MV\,m^{-1}$, around an alpha particle, changes with distance, in nm, from its centre.




**(a)** Show that the area of one square of the grid represents a potential of 0.5 V.

[1]

**(b)** The graph can be used to estimate the electrical potential at a point 1.0 nm from the centre of an alpha particle.

Shade the correct area on the graph for this estimate.

[1]

For Examiner's Use

7 The typical dose equivalent for a chest X-ray is $2 \times 10^{-4}$ Sv.
A dose equivalent of 1 Sv gives a person a 3% probability of developing cancer.

Calculate the probability of a person developing cancer from one chest X-ray per year for 25 years.

probability = ........................ % [2]

8 Fig. 8.1 shows the construction of a commercial transformer.

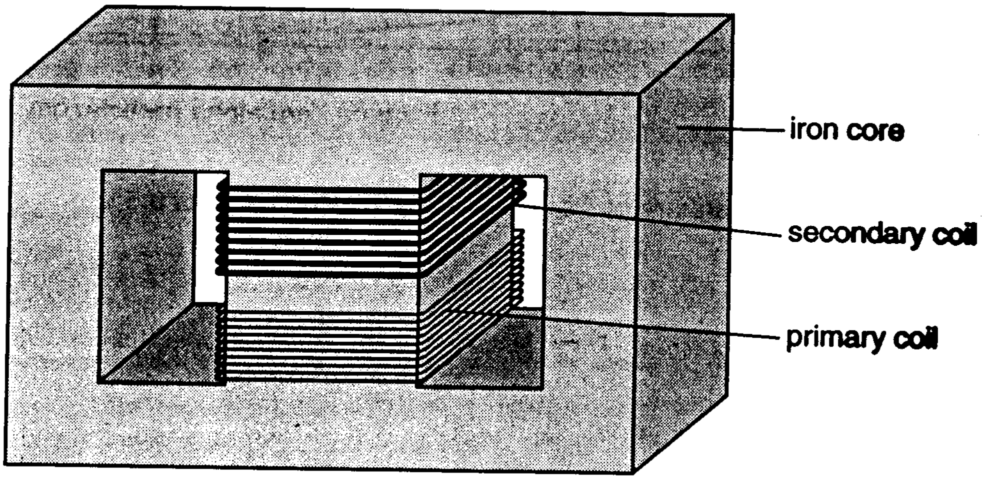



**Fig. 8.1**

**(a)** Here are some facts about the construction of the transformer.

**A** Both coils are wound on the same part of the core.
**B** The wire in the secondary coil is thicker than the wire in the primary coil.
**C** The iron core is made from thin sheets.

Which **one** of these facts ensures that the rate of change of magnetic flux in the primary coil is equal to that in the secondary coil?

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

**(b)** The primary coil of the transformer has 1000 turns and the secondary coil has 200 turns. The primary coil is connected to a 400 V, 50 Hz supply.

Calculate the voltage across the secondary coil, and state its frequency.

voltage = ................................ V

frequency = ............................ Hz

[3]

[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 using changing magnetic flux to control the current in an electric circuit.

**(a)** Fig. 9.1 shows a **fluorescent tube**.

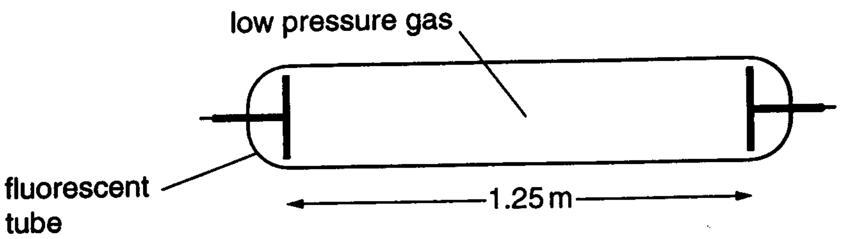



**Fig. 9.1**

The tube contains a low pressure gas. The gas is normally an electrical insulator. When an alternating potential difference is applied across the tube, the electric field between the electrodes helps to ionise the gas, making it into a conductor.

**(i)** The maximum potential difference across the electrodes is 325 V. The distance between the electrodes is 1.25 m.
Calculate the maximum electric field strength between the electrodes.

field strength = .................. V m$^{-1}$ [2]

**(ii)** Suggest how the electric field helps to ionise the gas.

[2]

**(b)** Fig. 9.2 shows the fluorescent tube in series with a choke.

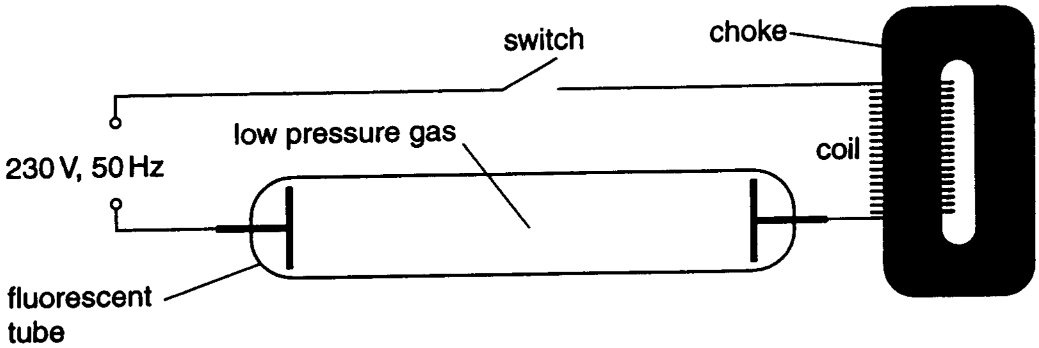



**Fig. 9.2**

The **choke** is a low resistance coil of wire wound on a loop of iron. This controls the current in the tube when it is conducting. The graph of Fig. 9.3 shows how the **flux linkage** through the choke coil changes with time when the tube is conducting.

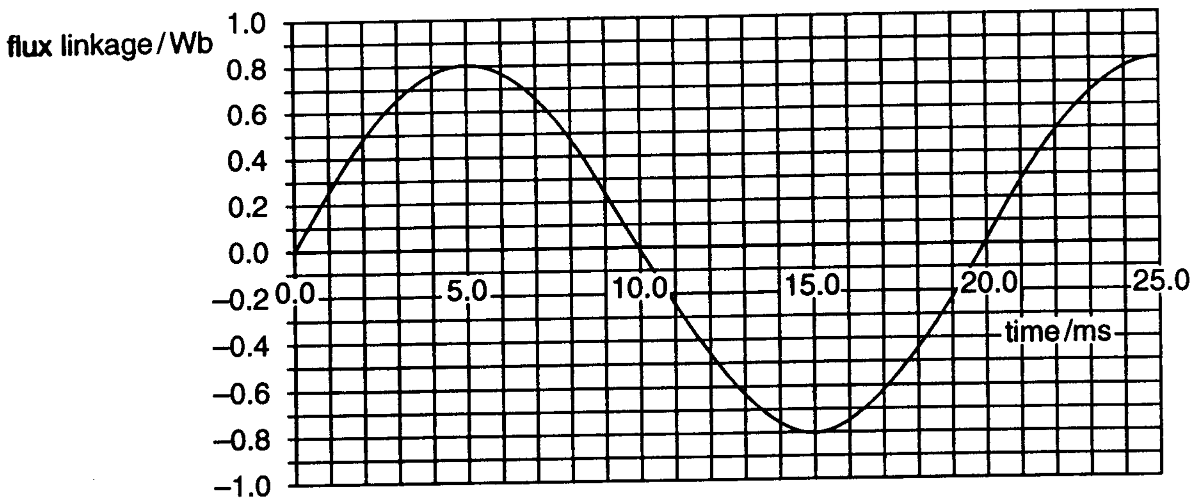



**Fig. 9.3**

**(i)** By measuring a suitable gradient on the graph, find the peak voltage across the coil. Show the gradient clearly on the graph.

peak voltage = .......................... V [2]

**(ii)** Draw on the graph to show how the voltage across the coil changes with time. The vertical scale is not important.

[1]

**(c)** Use ideas about electromagnetism to suggest how the choke in Fig. 9.2 prevents the alternating current in the tube from becoming too large.

[2]

[Total: 9]

For Examiner's Use

**10** This question is about the elastic scattering of protons from a nucleus of lead-206.

**(a)** Fig. 10.1 shows the path **A** followed by a proton, scattered by a nucleus of lead-206.

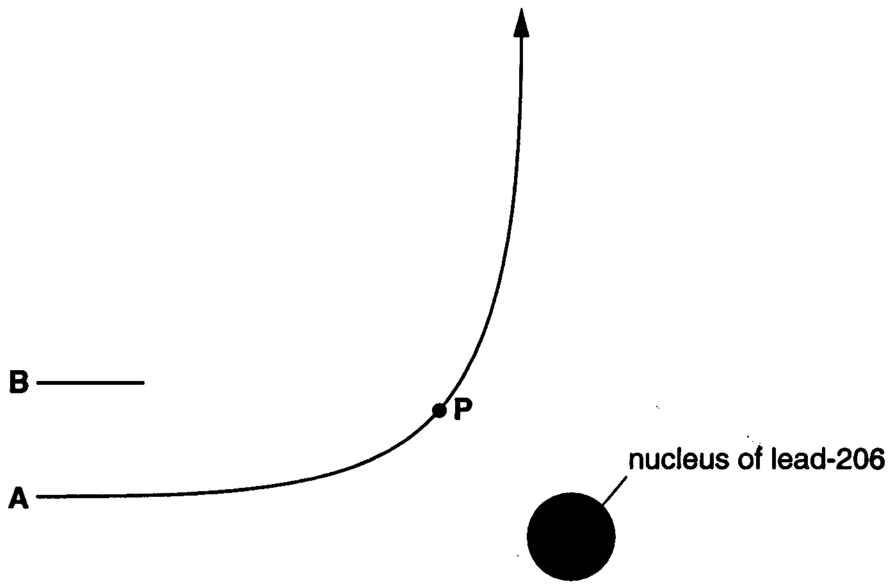



**Fig. 10.1**

**(i)** On Fig. 10.1, sketch the path **B** followed by another proton with the same initial energy.

[3]

**(ii)** Explain why these protons follow different paths.

[2]

**(b)** The distance of closest approach to the nucleus for the proton on path **A** is $3.4 \times 10^{-14}$ m. A lead nucleus contains 82 protons.

**(i)** Calculate the force on the proton due to the nucleus at this distance.

$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9\,\mathrm{N\,m^2\,C^{-2}}$

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

force = .......................... N [3]

**(ii)** On Fig. 10.1, draw an arrow to show the direction of the force on the proton when it is at point **P**. [1]

**(c)** The proton following path **A** is scattered through 90°. When lead is bombarded with a beam of monoenergetic protons, one proton in every 100 million is scattered through more than 90°.

State and explain what will happen to this fraction when the energy of the protons in the beam is increased.

[2]

[Total: 11]

For Examiner's Use

**11** This question is about risks of radiation from a fission reactor.

It is proposed that a small nuclear reactor should provide electricity for the first astronauts who journey to Mars. There is some concern about the hazard due to ionising radiation from the reactor.

**(a)** The uranium-235 fuel produces continuous electrical power during the journey. Each fission of a uranium-235 nucleus releases 206 MeV of energy.

**(i)** State the meaning of the term **fission**.

[1]

**(ii)** Use the idea of binding energies to explain why fission releases energy.

[2]

**(iii)** Each fission of a uranium-235 nucleus releases about three neutrons. Explain how these neutrons can maintain a steady and controlled release of energy in the reactor.

[3]

For Examiner's Use

**(b)** It is suggested that the best location for the reactor is at the centre of the astronaut's living quarters. Waste heat from the reactor would then help to keep the interior of the spacecraft at a comfortable temperature.

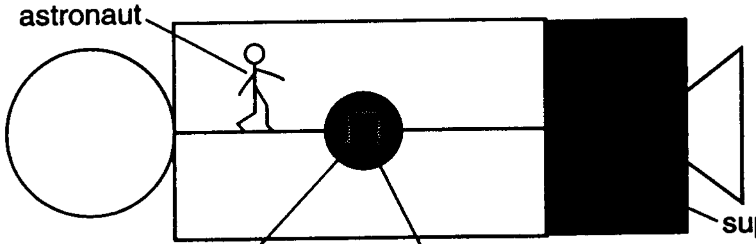



**Fig. 11.1**

The table shows how the energy from a single fission event is typically shared among the various particles involved.

| particle | energy / MeV |
|---|---|
| fission fragments | 166 |
| gamma photons | 15 |
| antineutrinos | 12 |
| beta particles | 8 |
| neutrons | 5 |

**(i)** The reactor is encased in a water jacket to make it safer.
Explain why the gamma photons from the reactor will be a hazard, but the beta particles will not.

[1]

**(ii)** The reactor is run at a constant output power of 5 kW. An astronaut who is 5 m from the centre of the reactor will receive a dose equivalent of about 10 mSv s$^{-1}$. This is unacceptably high.
State and explain **two** modifications to this reactor arrangement which would significantly reduce the hazard to the astronauts.

[4]

[Total: 11]



**[Turn over**

For Examiner's Use

12 This question is about energy levels of atoms in a crystal.

(a) A beam of infrared radiation is passed through a crystal.
The graph of Fig. 12.1 shows the infrared absorption spectrum of the crystal.

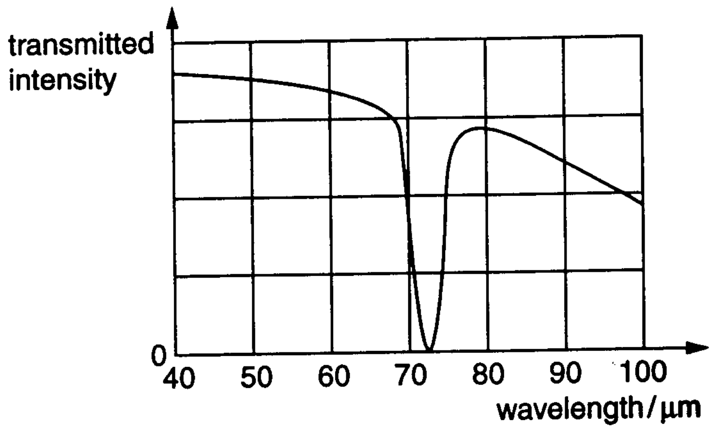



Fig. 12.1

(i) Show that the frequency of the infrared photons absorbed by atoms in the crystal is about $4 \times 10^{12}$ Hz.
$c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$

[3]

(ii) The infrared absorption spectrum suggests that the energy levels of atoms in the crystal are evenly spaced, as shown in Fig. 12.2.

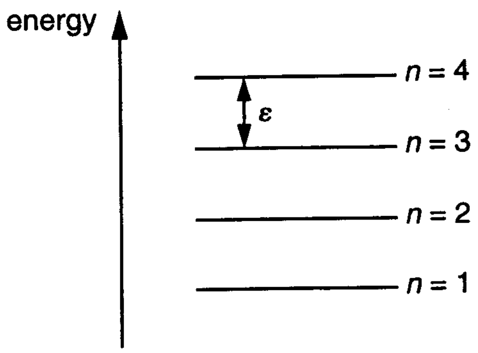



Fig. 12.2

The photons are absorbed when atoms move from one energy level to the next level.

On Fig. 12.2, draw an arrow to show the absorption of an infrared photon by the atom in the state $n = 2$.

[1]

**(iii)** Use your answer to **(i)** to calculate a value for $\varepsilon$, the separation of the energy levels.
$h = 6.6 \times 10^{-34}$ J s

$\varepsilon$ = ........................ J [2]

**(b)** The oscillating motion of an atom in the crystal changes when it absorbs or emits an infrared photon. The bonds between each atom and its neighbours restrict its movement. This suggests a very simple model of a particle trapped in a box.
Fig. 12.3 shows a standing wave pattern for an atom in such a box when $n = 3$.

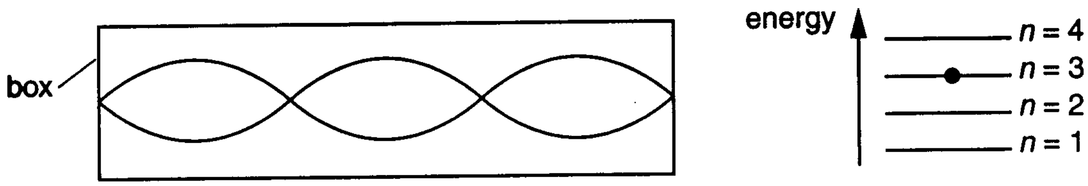



**Fig. 12.3**

**(i)** On Fig. 12.4 draw the standing wave for an atom when $n = 1$.

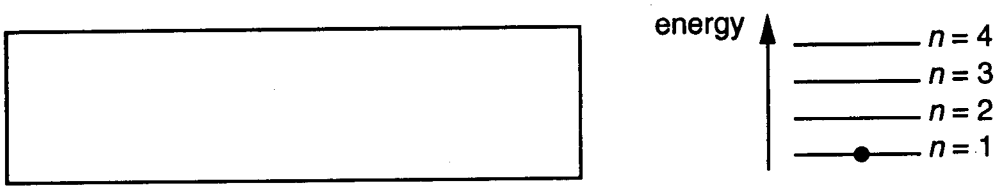



**Fig. 12.4**

[2]

**Question 12 continued over the page.**

For Examiner's Use

(ii) The kinetic energy $E$ of an atom of mass $m$ with momentum $p$ is given by the formula

$$E = \frac{p^2}{2m}.$$

Show that the de Broglie wavelength $\lambda$ of the atom is given by

$$\lambda = \sqrt{\frac{h^2}{2mE}}.$$

[3]

(iii) When the atom is in its lowest energy state, the energy $E$ is $1.35 \times 10^{-21}$ J. Calculate the de Broglie wavelength of the atom in its lowest energy state.
$m = 5.1 \times 10^{-26}$ kg

wavelength = ........................ m [1]

(c) (i) Use your answer to **(b)(i)** and **(b)(iii)** to estimate the length of the box which traps the particle when $n = 1$.

length = ........................ m [1]

(ii) The model only predicts the correct energy levels if the length of the box trapping the particle increases with increasing energy.

Show this by calculating the length of the box for $n = 3$.

length = ........................ m [2]

**[Total: 15]**

Quality of Written Communication [4]

**[Section B Total: 50]**