OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2865/01

Advances in Physics

Thursday **26 JANUARY 2006** Morning 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Insert (Advance Notice Article for this question paper)
Data, Formulae and Relationships Booklet
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 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

- Section A (questions 1–6) is based on the Advance Notice article, a copy of which is included as an insert. You are advised to spend about 60 minutes on Section A.
- The number of marks is given in brackets [ ] at the end of each question or part question.
- There are four marks for the quality of written communication on this paper.
- 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		
Qu	**Max.**	**Mark**
1	8	
2	9	
3	11	
4	9	
5	8	
6	12	
7	16	
8	13	
QWC	4	
TOTAL	90	

This question paper consists of 23 printed pages and 1 blank page and an insert.

For Examiner's Use

Answer **all** the questions.

Section A

The questions in this section are based on the Advance Notice article.
You are advised not to spend more than 60 minutes on this section.

1 This question is about the physical properties of the polymer PTFE (lines 19–29 and Fig. 1 in the article).
Fig. 1.1 shows a plot of resistivity and cost for a number of materials.

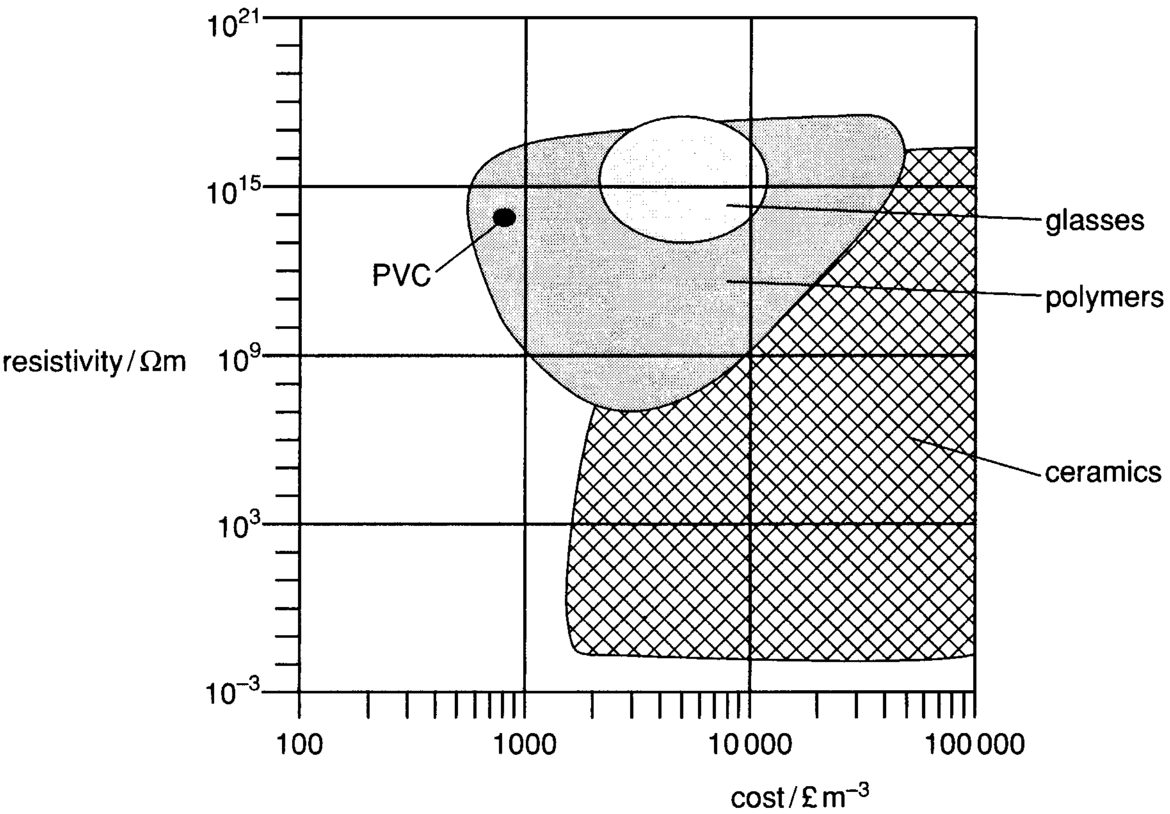


Fig. 1.1

A point for PVC is shown plotted on the graph.
PTFE has a resistivity of 10^{16} Ω m, and costs about £20 000 per cubic metre.

(a) Plot PTFE on Fig. 1.1. [2]

(b) PVC and PTFE are both used as electrical insulators. Use Fig. 1.1 to suggest why

(i) PVC is used for domestic wiring

[1]

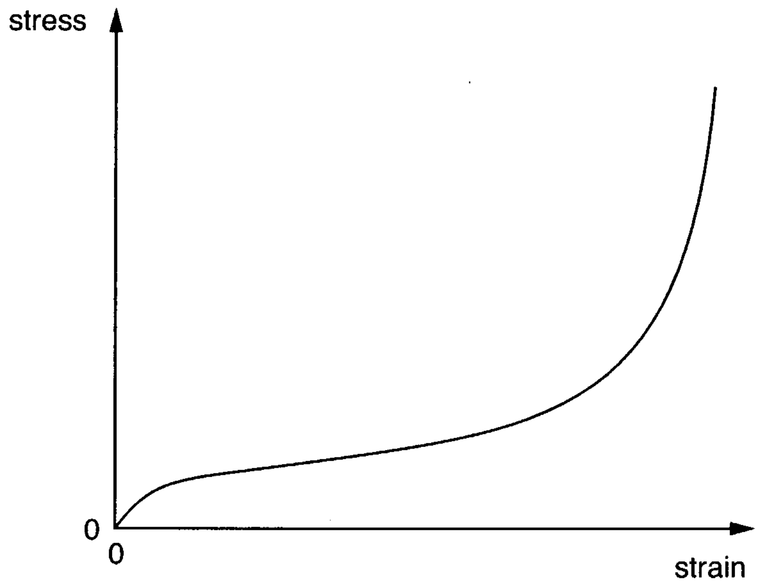
(ii) PTFE is used for the electrical connections to high-voltage equipment.

[1]

(c) The deformation of polythene can be described in terms of the movements of the molecular chains.

A bonds rotate
B bond angles become deformed

Fig. 1.2 shows the stress-strain graph for polythene.
Circle and label the appropriate sections **A** and **B**.



[2]

Fig. 1.2

(d) Polythene and PTFE are both composed of long chains of carbon atoms. They differ only in the other atoms joined to the carbon atoms. (Fig. 1.3).

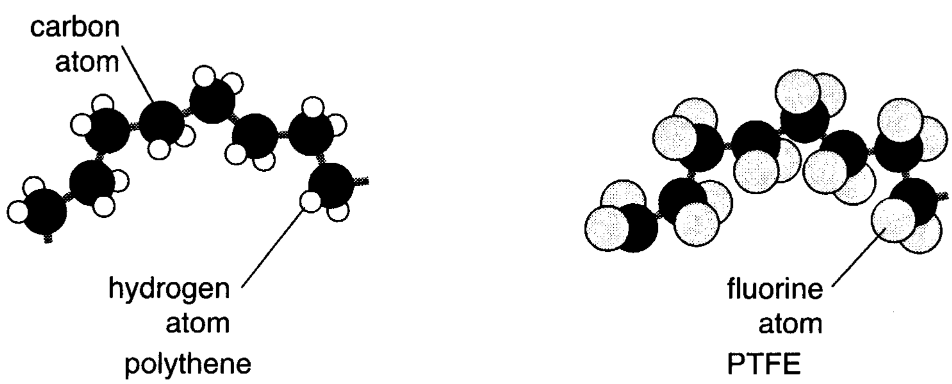


Fig. 1.3

[Turn over

For Examiner's Use

(i) Use the differences between these two structures to suggest why PTFE is **stiffer** than polythene (lines 19–24 in the article).

[1]

(ii) Sketch on Fig. 1.2, a possible stress-strain graph for PTFE. [1]

[Total: 8]

For Examiner's Use

2 This question is about the properties of uranium hexafluoride (lines 39–46 in the article).

(a) Use the table below to show that a molecule of uranium hexafluoride (UF_6) is more than ten times as massive as an air molecule (lines 39–41 in the article). Most air molecules consist of two nitrogen atoms bonded together.

atom	nucleon number
uranium	238
fluorine	19
nitrogen	14

[2]

(b) **Equation 1** relates the motion of N molecules each of mass m and mean square speed $\overline{c^2}$ in an ideal gas to the pressure p and volume V of the gas.

$$pV = \frac{1}{3}Nm\overline{c^2} \qquad \textbf{equation 1}$$

Equation 1 can be rewritten as

$$pV = \frac{1}{3}M\overline{c^2} \qquad \textbf{equation 2}$$

(i) State what the quantity $M = Nm$ in **equation 2** represents.

[1]

For Examiner's Use

(ii) Use **equation 2** to show that the mean-square speed of the molecules in a gas of density ρ is given by

$$\overline{c^2} = \frac{3p}{\rho} \qquad \textbf{equation 3}$$

[2]

(iii) Use **equation 3** to show that the difference in the r.m.s. speeds $\left(\sqrt{\overline{c^2}}\right)$ of uranium-238 hexafluoride and uranium-235 hexafluoride at standard pressure is only about 1 m s^{-1}.

standard pressure = 1.01×10^5 Pa

at standard pressure, density of uranium-235 hexafluoride ρ = 15.5 kg m^{-3}

at standard pressure, density of uranium-238 hexafluoride ρ = 15.7 kg m^{-3}

[2]

(iv) Use your answers to parts **(b)(ii)** and **(iii)** to explain why 'the difference in diffusion speeds is very small indeed, so large-scale apparatus with many stages was needed' (lines 45–46 in the article).

[2]

[Total: 9]

For Examiner's Use

3 This question is about keeping charged particles moving around in a ring (lines 64–67 and Fig. 2 in the article).

(a) Fig. 3.1 shows a plan view of Fermilab's Main Ring. The arrows show the path taken by protons moving at a speed $2.97 \times 10^8\,\mathrm{m\,s^{-1}}$ (99% of the speed of light).

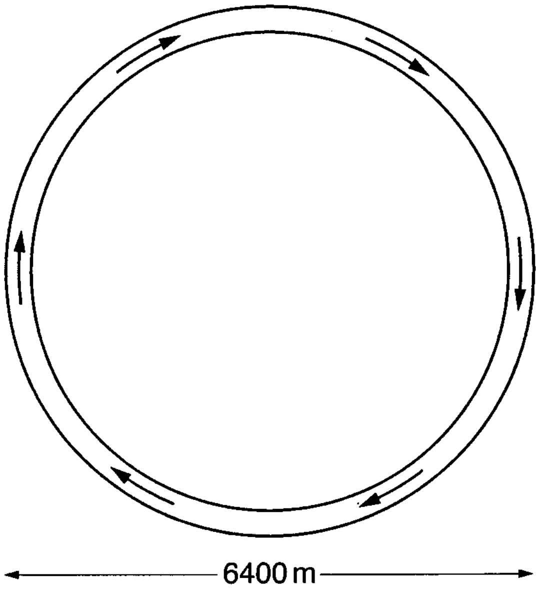


Fig. 3.1

(i) Explain clearly why there must be a force acting on the protons if they are to travel in a circular path.

[1]

(ii) This force is provided by a magnetic field.
Here are four directions in which the magnetic field could be acting.

A radially inwards towards the centre of the circle

B radially outwards away from the centre of the circle

C perpendicular to the plane of the diagram

D the same direction as the proton path

Choose the correct direction from the four directions above.

direction .... [1]

For Examiner's Use

(b) The same ring contains antiprotons (the anti-particles of protons), also moving at a speed of $2.97 \times 10^8\,\mathrm{m\,s^{-1}}$.

(i) Complete the table below comparing the proton and antiproton.

particle	mass / 10^{-27} kg	charge / 10^{-19} C
proton	1.7	+1.6
antiproton		

[1]

(ii) Draw arrows on Fig. 3.1 above to show the path followed by the antiprotons. [1]

(c) **(i)** In the article, it states that 'The job of the Tevatron Ring is to accelerate the protons to energies of 1000 GeV (1 TeV), which is about 1000 times their rest energy' (lines 85–86 in the article).
Show that the rest energy of a proton is about 1 GeV.

$c = 3.0 \times 10^8\,\mathrm{m\,s^{-1}}$
$e = 1.6 \times 10^{-19}\,\mathrm{C}$
$m_p = 1.7 \times 10^{-27}\,\mathrm{kg}$

[3]

(ii) Use the result of **(c)(i)** to explain why, for a proton of total energy $E = 1000$ GeV (1 TeV), the equation

$E^2 = (pc)^2 + (\text{rest energy})^2$ (Line 82 in the article)

can be simplified to

$E \approx pc.$

[2]

(iii) Use the equation $E \approx pc$ and the data from Table 1 in the article to show that the total energy E of a proton travelling at 99.9999% of the speed of light is close to 1 TeV (1.6×10^{-7} J).

[2]

[Total: 11]

For Examiner's Use

4 This question is about superconducting electromagnets (Figs. 3 and 4 and lines 96–109 in the article).

(a) The magnetic field in the conventional magnets in the Fermilab Main Ring is 1.8 T. In the superconducting Tevatron Ring, the field is 4.5 T.

Explain why it was not possible to use conventional electromagnets to achieve a field of 4.5 T.

[2]

(b) The cross-section of the wire used in the superconducting electromagnet coils is shown in Fig. 4.1. About half of the cross-section is niobium-titanium, and half is copper.

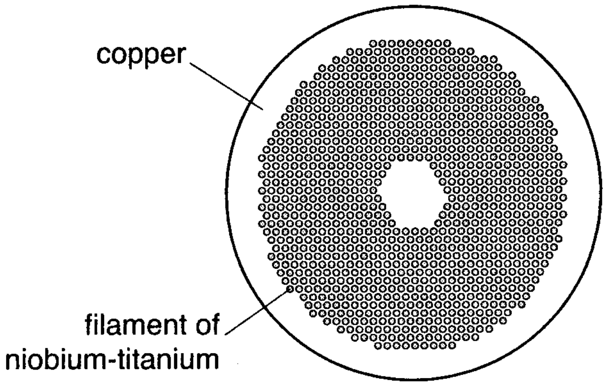


Fig. 4.1

Below a temperature of 10 K, the resistivity of niobium-titanium is zero.

No electrical p.d. is required to maintain the current in the superconducting niobium-titanium. Explain why there is no current in the copper under these circumstances (lines 100–101 in the article).

[2]

For Examiner's Use

(c) The article describes the catastrophic effects of a temperature rise in the superconducting magnets (lines 105–109 in the article).

(i) Explain why a collapse of the magnetic flux leads to a large current in the coil.

[2]

(ii) Explain why this current passes mainly in the copper, not in the niobium-titanium.

[1]

(iii) Explain why the copper could become very hot.

[1]

(d) The large superconducting magnet in an MRI scanner produces a very strong magnetic field inside the scanner.

Suggest why patients must remove any iron or steel objects, such as dental braces, before entering the scanner.

[1]

[Total: 9]

[Turn over

5 This question is about medical images of the head (Fig. 5 and lines 122–125 in the article).

Fig. 5.1 X-ray

Fig. 5.2 MRI

(a) Suggest why X-rays (Fig. 5.1) are better than MRI scans (Fig. 5.2) for investigating possible fractures of the skull.

[2]

(b) A doctor wishes to study the region of the brain marked **X** (the cerebellum). The MRI image is enhanced as shown in Fig. 5.3 to make this region clearer.

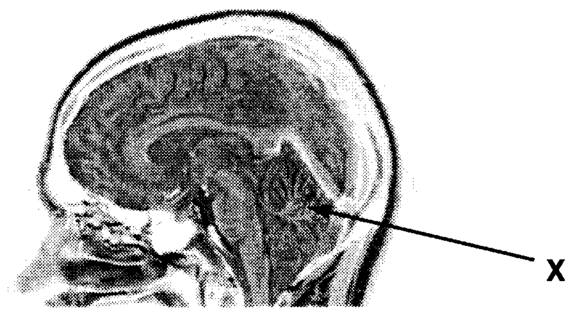


Fig. 5.3 enhanced MRI

(i) This digital image has been enhanced by the process of **inversion**, where light areas have become dark and dark ones light.
Explain this process.

[3]

(ii) Describe one **other** way in which the image could be enhanced to make the structure of region **X** clearer.

[2]

(iii) The scale of the structures in region **X** is small, so an image with high resolution is needed. Explain the meaning of the term *resolution* of an image.

[1]

[Total: 8]

For Examiner's Use

6 This question is about the energy needed to put satellites into orbit (lines 128–130 in the article).
The International Space Station (ISS) orbits the Earth with an orbit of mean radius 6.8×10^6 m.

(a) Use **equation 1**

$$V_{grav} = -\frac{GM}{r} \qquad \textbf{equation 1}$$

to show that the gravitational potential difference between the surface of the Earth and the position of the ISS is given by **equation 2**

$$\Delta V_{grav} = GM\left(\frac{1}{r_E} - \frac{1}{r}\right) \qquad \textbf{equation 2}$$

where r_E is the radius of the Earth, r is the radius of the orbit, G is the gravitational force constant and M the mass of the Earth.

[2]

(b) **(i)** Use **equation 2** above to show that the gravitational potential difference ΔV_{grav} between the surface of the Earth and the position of the ISS is about $4 \times 10^6\ \mathrm{J\,kg^{-1}}$.

$GM = 4.0 \times 10^{14}\ \mathrm{N\,m^2\,kg^{-1}}$
$r_E = 6.4 \times 10^6$ m
$r = 6.8 \times 10^6$ m

[2]

For Examiner's Use

(ii) Calculate the gravitational potential energy gained by the ISS as it is put into orbit.

mass of ISS = 1.9×10^5 kg

gravitational potential energy .... J [1]

(iii) The ISS orbits the Earth once every 90 minutes.
Calculate its kinetic energy in orbit.

kinetic energy .... J [3]

(iv) Suggest why the energy required to put the ISS into orbit is much greater than the sum of the two energies in parts **(ii)** and **(iii)**.

[2]