OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2865/01

Advances in Physics

Thursday **22 JUNE 2006** Afternoon 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	12	
2	10	
3	11	
4	10	
5	8	
6	8	
7	15	
8	12	
QWC	4	
TOTAL	90	

This question paper consists of 20 printed pages 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 an early theory of the Sun's energy source (lines 19–23 in the article).

(a) A solar water heating panel of area $3\,m^2$ on a house roof is perpendicular to the solar radiation.
Water flows through the panel at a rate of $0.17\,kg\,s^{-1}$. The temperature of the water increases by $4\,°C$ when it flows through the panel.

(i) Show that the solar energy absorbed by the panel in 1 second is about 3000 J.

specific thermal capacity of water $c = 4200\,J\,kg^{-1}\,°C^{-1}$

[2]

(ii) Calculate the solar power per square metre absorbed by the $3\,m^2$ panel.

[1]

(iii) The solar power per square metre arriving at the outer surface of the Earth's atmosphere is $1400\,W\,m^{-2}$.
Suggest why your answer to part **(ii)** is different from this.

[1]

For Examiner's Use

(iv) At the Earth's distance from the Sun, the energy emitted by the Sun each second passes through the surface of a sphere of area 2.8×10^{23} m^2, as shown in Fig. 1.1.

A diagram has been removed due to third party copyright restrictions

Details: A diagram of a sphere with the Earth on the edge of the sphere and the Sun in the centre. The Sun is a distance 1.5 x 10^11m from the Earth

Fig. 1.1

Use the value given in (a)(iii) to show that the total power emitted by the Sun is about 4×10^{26} W.

[2]

(b) Fig. 1.2 shows a meteor at point **Y** before it falls into the Sun.

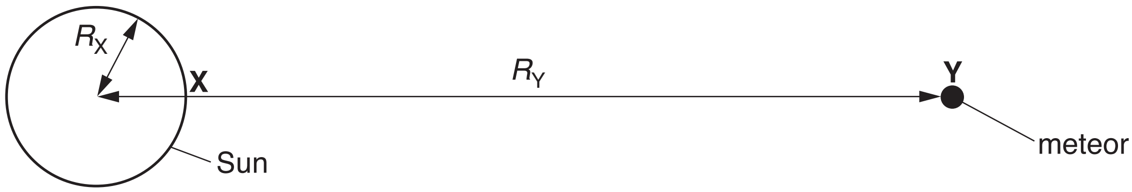

Fig. 1.2

The gravitational potential difference ΔV_{XY} between points **X** and **Y** is given by

$$\Delta V_{XY} = \frac{GM}{R_X} - \frac{GM}{R_Y}$$ **equation 1**

(i) Explain why, when $R_Y \geqslant 100\, R_X$, $\Delta V_{XY} \approx \frac{GM}{R_X}$ **equation 2**

[1]

(ii) Use equation 2 above to show that the gravitational potential difference between the surface of the Sun and a distant point is about $2 \times 10^{11}\,\text{J kg}^{-1}$.

$G = 6.7 \times 10^{-11}\,\text{N m}^2\,\text{kg}^{-2}$
$M = 2.0 \times 10^{30}\,\text{kg}$
$R_X = 7.0 \times 10^{8}\,\text{m}$

[2]

(iii) Explain why the kinetic energy gained when a distant meteor of mass 1 kg falls to the Sun's surface is about 2×10^{11} J.

[1]

(iv) Calculate the total mass of meteors that would need to fall into the Sun every second to provide the 4×10^{26} W that the Sun emits.

mass per second .... kg s^{-1} [2]

[Total: 12]

2 This question is about the modern theory of the Sun's energy source (lines 41–54 in the article).

Fig. 2.1 shows stage 1 of the series of nuclear reactions taking place in the Sun's core.

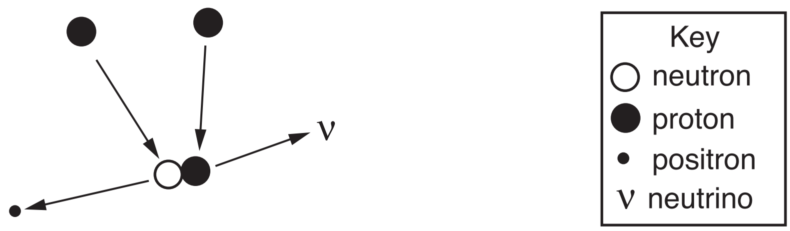

Fig. 2.1

(a) Complete the balanced equation for the nuclear reaction shown in Fig. 2.1.

$$^{1}_{1}H + ^{1}_{1}H \rightarrow ^{......}_{......}H + ^{......}_{......}.......... + ^{0}_{0}\nu$$

[2]

(b) Stage 2 of the series of nuclear reactions in the Sun's core is

$$^{2}_{1}H + ^{1}_{1}H \rightarrow ^{3}_{2}He + \gamma$$

(i) Use the table of data following to show that the mass of the products of this reaction is about 9×10^{-30} kg **less than** the mass of the reactants.

nuclear species	mass/u
$^{1}_{1}H$	1.00728
$^{2}_{1}H$	2.01410
$^{3}_{2}He$	3.01605

$u = 1.67 \times 10^{-27}$ kg

[2]

(ii) Show that about 8×10^{-13} J of energy is produced in a reaction of this type.

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

[2]

(c) The series of nuclear reactions in the proton-proton chain liberates 4.3×10^{-12} J for every four protons ($^{1}_{1}H$) fused into one helium-4 nucleus.

(i) Show that the energy produced by the fusion of 1 kg of hydrogen is about 6×10^{14} J.

mass of proton, $m_p = 1.67 \times 10^{-27}$ kg

[2]

(ii) Show that the Sun can produce energy at 4×10^{26} W for several billion years (lines 51–53 in the article), assuming that 2.0×10^{29} kg of hydrogen is available for fusion.

1 year = 3.2×10^{7} s

[2]

[Total: 10]

3 This question is about objects orbiting the Sun (lines 86–105 in the article).

(a) The space observatory SOHO orbits the Sun in a circular orbit as shown in Fig. 3.1.

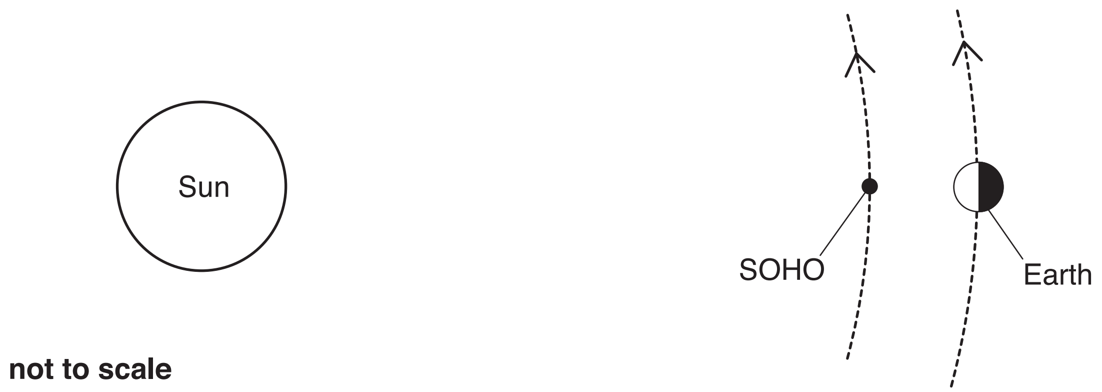

Fig. 3.1

It is possible to show that the speed v of an isolated object in a circular orbit of radius R about the Sun is given by $v = \sqrt{\frac{GM}{R}}$ where M is the mass of the Sun.

(i) Draw a ring around **each** of the **two** equations below which would be used to prove this relationship.

$F = \frac{mv^2}{R}$ $\quad$ $F = \frac{GMm}{R^2}$ $\quad$ kinetic energy $= \frac{1}{2}mv^2$ $\quad$ potential energy $= -\frac{GMm}{R}$

[1]

(ii) Explain why the equation $v = \sqrt{\frac{GM}{R}}$ would predict that SOHO should orbit the Sun in less than the period of the Earth (1 year).

[2]

(iii) Draw and label arrows showing the gravitational forces acting on SOHO on Fig. 3.1 above. [1]

(iv) Explain why the equation $v = \sqrt{\frac{GM}{R}}$ does not apply to SOHO in the position shown above.

[2]

(b) Comet Halley orbits the Sun in an elliptical orbit (Fig. 3.2).

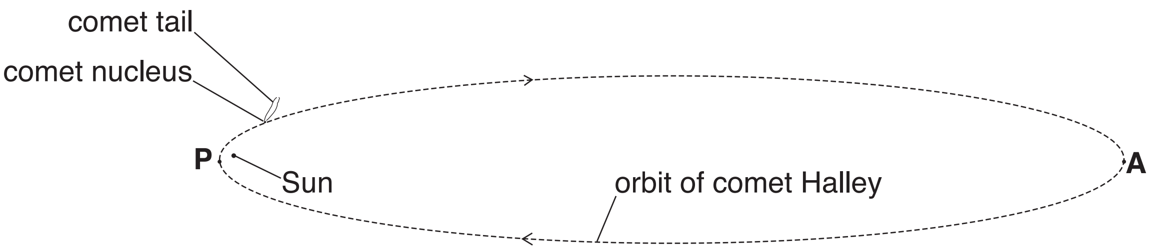

Fig. 3.2

At point **A**, comet Halley is 60 times further from the Sun than it is at point **P**.

State which one of the values below gives the following ratio.

$$\frac{\text{the magnitude of the force on comet Halley at point } \mathbf{A}}{\text{the magnitude of the force on comet Halley at point } \mathbf{P}}$$

$\frac{1}{3600}$ $\qquad$ $\frac{1}{60}$ $\qquad$ 60 $\qquad$ 3600

ratio ....[1]

(c) The dust tail of a comet (lines 106–115 in the article) points away from the Sun as shown in Fig. 3.3

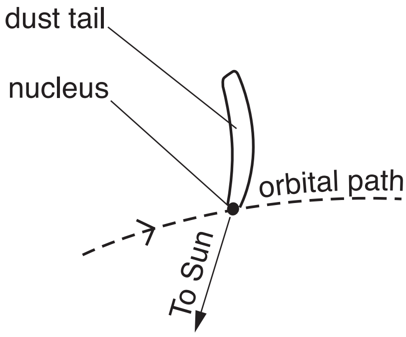

Fig. 3.3

(i) Explain why the tail points away from the Sun.

[2]

(ii) Explain why the tail curves in the direction shown in Fig. 3.3.

[2]

[Total: 11]

For Examiner's Use

4 This question is about sunspots (lines 56–77 in the article).

(a) Use Fig. 2 in the article to calculate the mean sunspot period between 1750 and 2000.

[1]

(b) The energy per second emitted by hot objects like the Sun is given by

$$\text{power emitted} = \sigma A\, T^4$$

where A is the area of the surface, σ is a constant and T is the temperature.

(i) Show that the power emitted by a sunspot at 4000 K is about 20% of the power emitted by an identical area of the Sun's photosphere at 5800 K.

[2]

(ii) The planet Mercury is close to the Sun and appears as a bright 'star' near the horizon just before sunrise or just after sunset. From the Earth, Mercury looks about the same size as a sunspot. Mercury reflects only 10% of the solar radiation that strikes it.

Explain why Mercury appears bright while sunspots appear dark.

[2]

(c) The large magnetic flux density in sunspots is due to loops of the Sun's magnetic field escaping as shown in Fig. 4.1 below (lines 69–75 in the article).

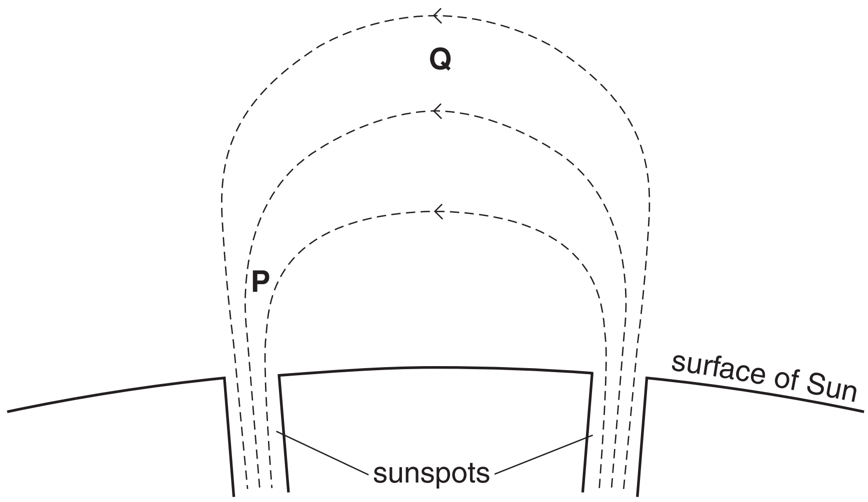

Fig. 4.1

(i) The flux density at point **P** is greater than that at **Q**.
Explain how the diagram shows this.

[1]

(ii) Suggest why sunspots often occur in pairs, as shown in Fig. 4.1.

[2]

(iii) Each sunspot in Fig. 4.1 has about the same cross-sectional area as the Earth (1.3×10^{14} m^2).
The magnetic flux in the sunspot is 2.0×10^{13} Wb.

Calculate the average flux density B in the sunspot.

B = ... unit .... [2]

[Total: 10]

For Examiner's Use

5 This question is about charged particles arriving at the Earth (lines 131–147 in the article).

(a) A Coronal Mass Ejection leaves the Sun at 500 km s^{-1}.
Show that this takes about 3 days to reach the Earth.

Earth-Sun distance = 1.5×10^{11} m

[2]

(b) (i) Explain why a proton moving perpendicular to magnetic field lines travels in a circular path (Fig. 5.1).

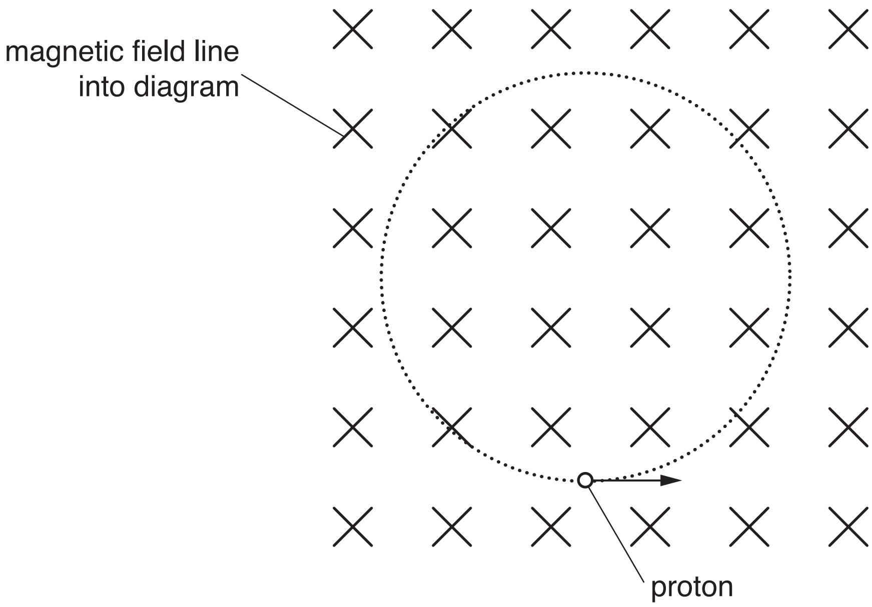

Fig. 5.1

[2]

For Examiner's Use

(ii) Protons arrive at the Earth at an angle to the Earth's magnetic field. They have a component of velocity v_y perpendicular to the magnetic field, and a component v_x parallel to the magnetic field (Fig. 5.2).

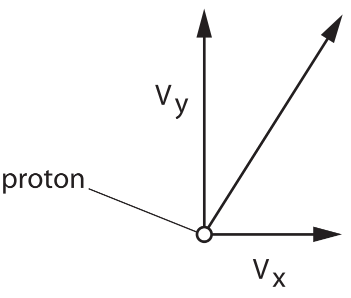

Fig. 5.2

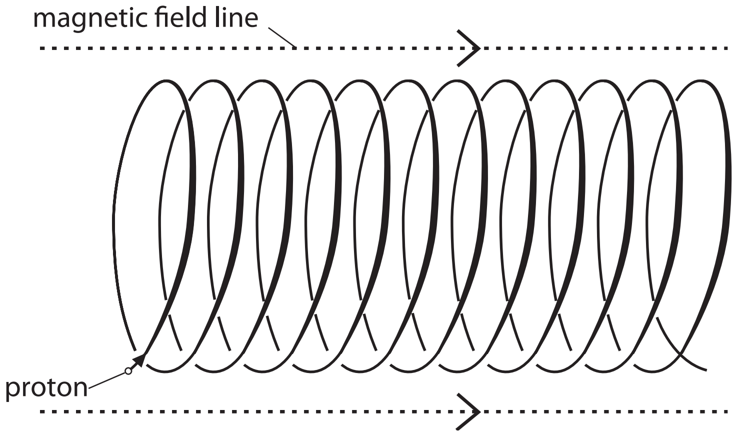

Fig. 5.3

Explain why protons follow the helical path shown in Fig. 5.3.

[2]

(iii) Auroras (lines 144–147 in the article) are seen when a Coronal Mass Ejection reaches the Earth (Fig. 5.4).

A diagram has been removed due to third party copyright restrictions

Details: A diagram of the Earth showing magnetic field lines and a Coronal Mass Ejection

Fig. 5.4

Suggest why auroras are seen best near the North and South poles of the Earth.

[2]

[Total: 8]

[Turn over

For Examiner's Use

6 This question is about the solar corona.

(a) The vacuum in a TV tube consists of gas at the extremely low pressure of 1.3×10^{-4} Pa.

(i) Show that $1.0\,m^3$ of gas at this pressure and a temperature of 290 K contains about 5×10^{-8} mol.

$R = 8.3\,J\,mol^{-1}\,K^{-1}$

[2]

(ii) Calculate the number of particles per m^3 in the gas at this low pressure.

$N_A = 6.0 \times 10^{23}$ particles mol^{-1}

number = ... particles m^{-3} [1]

(iii) The solar corona contains about 1.6×10^{14} particles m^{-3}.
Explain whether the author of the article is justified in writing 'By terrestrial standards, the corona would be described as a superb vacuum' (lines 124–125 in the article).

[2]

(b) (i) Complete the following table to show typical thermal energies *kT* of protons in the Sun's outer layers.

$k = 1.4 \times 10^{-23}\,\mathrm{J\,K^{-1}}$

	T /K	*kT* /J
corona	1 400 000	
photosphere	5800	

[1]

(ii) Protons at the surface of the Sun each need 3.2×10^{-16} J to escape from the Sun's surface.
Use the values of *kT* above to explain why significant numbers of protons can escape from the corona, but not from the photosphere.

[2]

[Total: 8]

For Examiner's Use

Section B

7 This question is about the use of ionising radiation to sterilise food and other products.

(a) Explain what is meant by the term **ionising radiation**.

[1]

(b) Products can be sterilised either by gamma radiation from a radioactive source or by an accelerated beam of electrons.

Discuss the relative merits of each of these sources of radiation for sterilising large boxes of soft fruit such as strawberries.

[2]

(c) A gamma ray source containing cobalt-60 which is used for sterilising food has an output of 50 kW. The average photon energy is 1.25 MeV.

(i) Show that 1.25 MeV is 2.0×10^{-13} J.
$e = 1.6 \times 10^{-19}$ C

[2]

(ii) Calculate the number of photons emitted per second by the 50 kW source.

number = ... s^{-1} [2]

For Examiner's Use

(d) A 50 kW gamma ray source should be able to irradiate about 12 tonnes of food per hour. The absorbed dose that the food receives is about 4000 gray.

(i) Explain what is meant by absorbed dose in gray.

[1]

(ii) Suggest why only a fraction of the radiation emitted by the source is absorbed by the food.

[1]

(iii) Explain why treating food with gamma rays does **not** make it radioactive.

[2]

(e) Special containers need to be used to transport these gamma ray sources around the country.

State and explain **two physical** properties that these containers should possess.

[4]

[Total: 15]

For Examiner's Use

8 This question is about electrical circuits designed to produce very high voltage pulses. An oscillator supplies an alternating electrical current to coil A shown in Fig. 8.1. This produces an alternating magnetic flux which links coil B.

A diagram has been removed due to third party copyright restrictions

Details: A diagram of two coils, an oscillator supplying an alternating electrical current to coil A and an alternating magnetic flux linking coil B

Fig. 8.1

(a) The graph of Fig. 8.2 shows the variation of magnetic flux through coil B plotted against time.

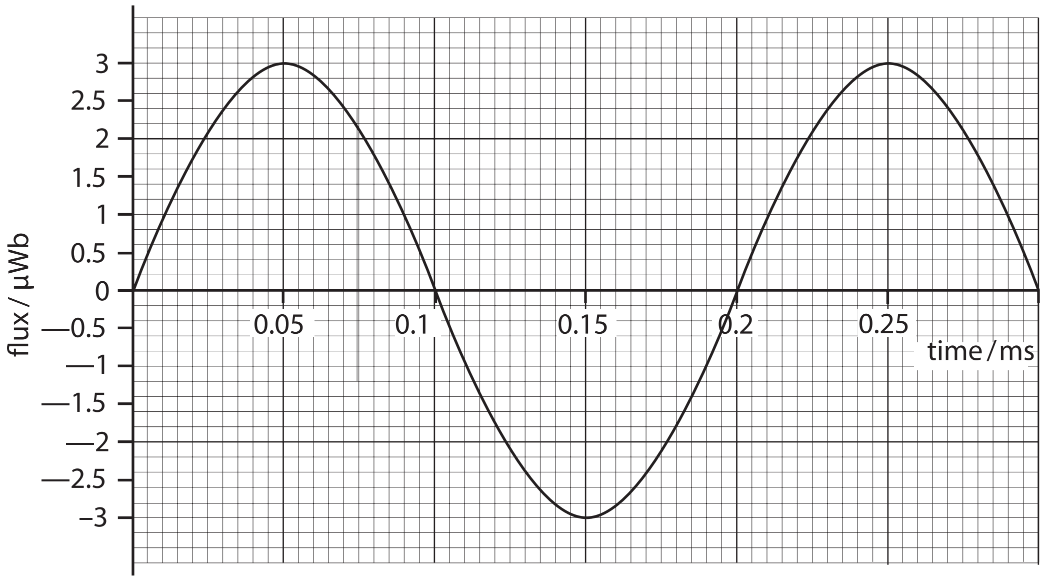

Fig. 8.2

(i) Show that the frequency of this alternating flux is 5000 Hz.

[2]

(ii) Explain why using a higher frequency of alternating flux produces a larger induced voltage in coil B.

[2]

(b) The alternating voltage from coil **B** is converted into a d.c. voltage. This voltage charges the 100 μF capacitor shown in Fig. 8.3.

When the voltage across the capacitor and the spark gap reaches 270 V, a spark forms and the capacitor discharges rapidly through the primary coil of the transformer **T**. This induces a very high voltage pulse across the secondary coil. The process then repeats as the capacitor charges again.

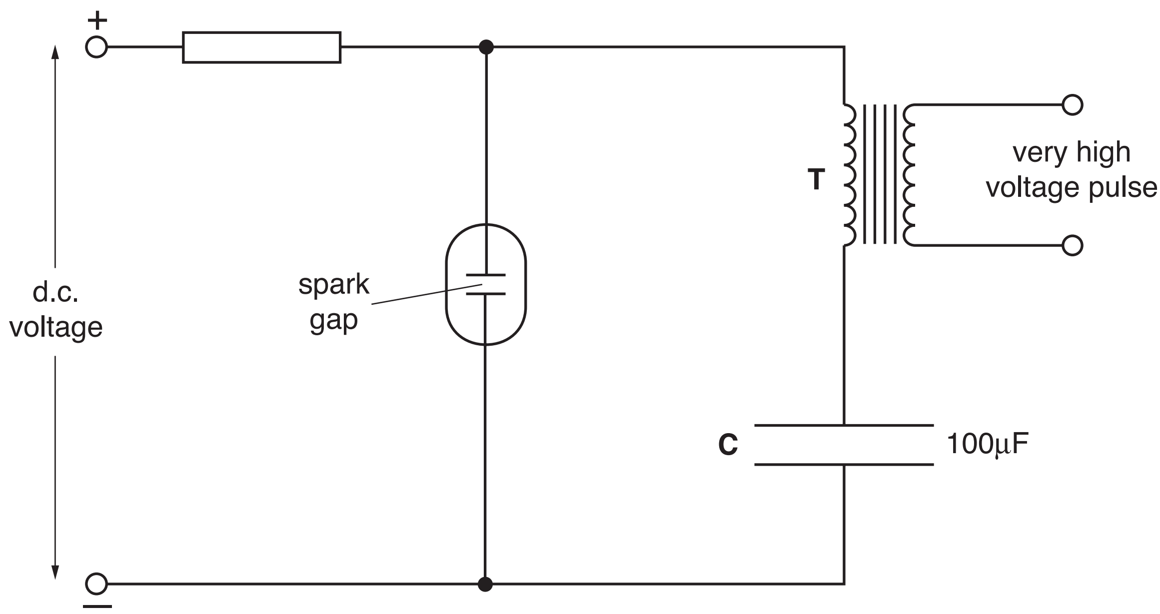

Fig. 8.3

(i) The field strength is $3 \times 10^6\ \text{V m}^{-1}$ when the voltage reaches 270 V. Calculate the separation of the electrodes in the spark gap. Assume that the field is uniform.

[2]

(ii) Calculate the energy stored in the capacitor when the voltage across it is 270 V.

energy = ... J [2]

(iii) The energy stored in the capacitor is transferred to the transformer in 10 ms. Calculate the average power supplied to the transformer during the transfer.

average power = ... W [2]

(c) Suggest and explain **one** application where short electrical pulses of very high voltage would be necessary.

[2]

[Total: 12]

Quality of Written Communication [4]

END OF QUESTION PAPER