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OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS B (ADVANCING PHYSICS) 2865/01

Advances in Physics

Candidates answer on the Question Paper

OCR Supplied Materials:
- Insert (Advance Notice article for this question paper) (inserted)
- Advancing Physics Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator
- Ruler (cm/mm)

Tuesday 29 June 2010
Afternoon

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.
- Show clearly the working in all calculations, and round answers to only a justifiable number of significant figures.
- Section A (questions 1–6) is based on the Advance Notice article.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **90**.
- 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.
- There will be four marks for the quality of written communication assessed throughout the paper.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max**	**Mark**
1	**8**	
2	**10**	
3	**9**	
4	**9**	
5	**8**	
6	**12**	
7	**16**	
8	**14**	
QWC	**4**	
TOTAL	**90**	

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Turn over

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 polymers (lines 17 – 26 and Fig. 1 in the article).

(a) The deformation of polythene (Fig. 1.1) can be described in terms of the rotation and stretching of the bonds between carbon atoms in the molecular chains.

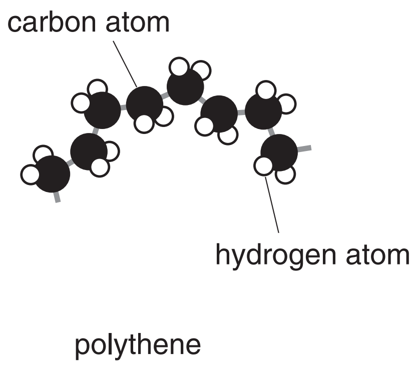

Fig. 1.1

Fig. 1.2 shows the stress-strain graph for polythene.

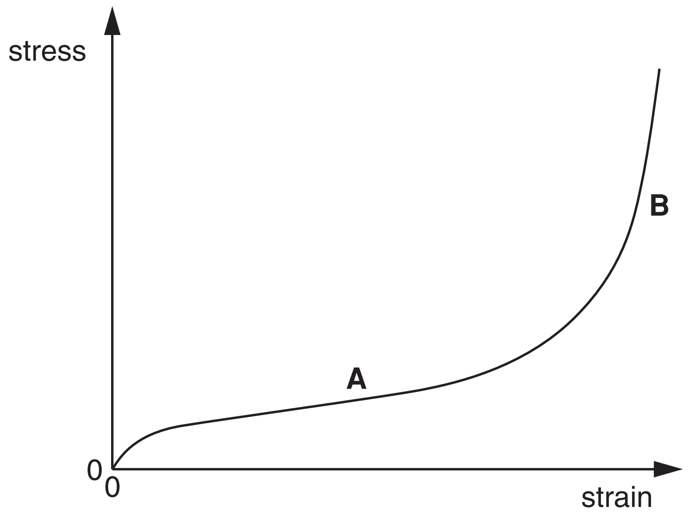

Fig. 1.2

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(i) Describe what you would feel if you stretched a thin strip of polythene until it broke.

[2]

(ii) Explain, in terms of the structure shown in Fig. 1.1, the change in stiffness of polythene as it is extended.

You should compare the two regions **A** and **B** in your answer.

[2]

(b) Polythene, PVC and PTFE are all composed of long chains of carbon atoms. They differ only in the other atoms joined to the carbon atoms.

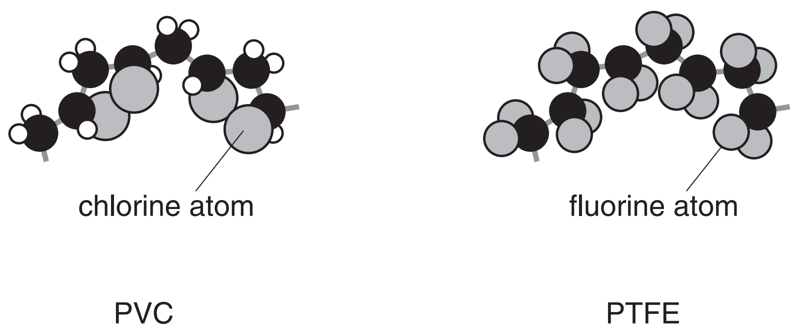

Fig. 1.3

(i) Use the differences between these three structures to explain why polythene is the most flexible of the three polymers.

[2]

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(ii) PTFE is much stiffer than PVC, although fluorine atoms are much smaller than chlorine atoms. Use the structures shown in Fig. 1.3 to explain this difference.

[2]

[Total: 8]

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2 This question is about the properties of uranium hexafluoride (lines 39 – 45 in the article).

(a) (i) Use the ideal gas equation $pV = nRT$ and the kinetic theory equation $pV = \frac{1}{3}Nm\overline{c^2}$ to show that the mean square speed of gas molecules, $\overline{c^2}$, is given by

$$\overline{c^2} = \frac{3RT}{N_A m}$$

where N_A is the Avogadro constant, m the mass of one molecules and R the molar gas constant.

[2]

(ii) The table below gives the mass of uranium hexafluoride and nitrogen molecules. Air consists mostly of nitrogen.

molecule	mass/ 10^{-26} kg
uranium hexafluoride	58
nitrogen	4.6

Explain why the mean square speed of uranium hexafluoride molecules is much less than that of air molecules, provided that both gases are at the same temperature.

[1]

(iii) Calculate the r.m.s. speed $\sqrt{\overline{c^2}}$ of uranium hexafluoride molecules at a temperature of 290 K.

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

Avogadro constant, $N_A = 6.0 \times 10^{23}\,\mathrm{mol^{-1}}$

$\sqrt{\overline{c^2}}$ = ... $\mathrm{m\,s^{-1}}$ **[2]**

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(b) In the uranium hexafluoride produced from uranium for refining, some molecules will contain the lighter isotope U-235 and some will contain the heavier isotope U-238.

The table below shows the r.m.s. speeds of the two types of uranium hexafluoride at a temperature of 290 K.

molecule	$\sqrt{\overline{c^2}}$ / m s^{-1}
$^{235}UF_6$	144.0
$^{238}UF_6$	143.4

(i) Explain why these values have had to be calculated from higher precision data than the data quoted in **(a)(ii)**.

[1]

(ii) Calculate the mean separation between the two types of uranium hexafluoride molecule if they both travelled for two minutes along a straight-line path.

mean separation = ... m **[2]**

(iii) Although the molecules of uranium hexafluoride travel at high speeds, they diffuse through air, and through holes, relatively slowly.

Explain, in terms of the movement of the molecules through air, why diffusion is a slow process.

[2]

[Total: 10]

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3 This question is about keeping charged particles moving around in a ring (lines 65 – 92 and Fig. 2 in the article).

(a) Fig. 3.1 shows a plan view of Fermilab's Main Ring. Consider protons moving at a constant speed of $2.97 \times 10^8\,\text{m s}^{-1}$ (99% of the speed of light) as shown by the arrows.

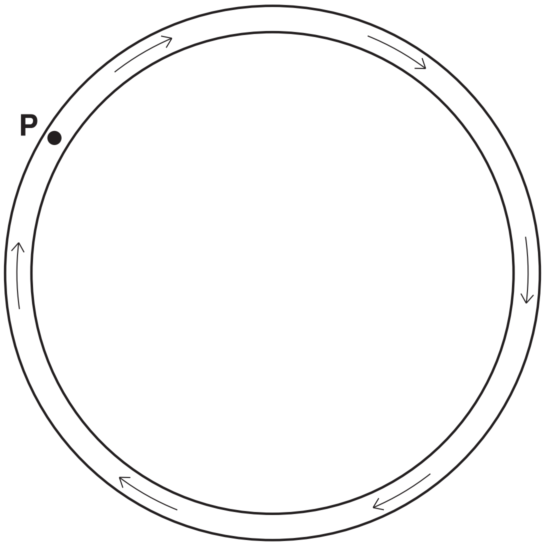

Fig. 3.1

(i) One of the protons in the Main Ring is labelled **P**.

Draw an arrow to indicate the resultant force acting on this proton. **[1]**

(ii) This force is provided by a magnetic field.

Here are some statements about the direction of the magnetic field.

Put a tick (✓) next to **each** correct statement.

The magnetic field is in the same direction as the centripetal force.	☐
The magnetic field is perpendicular to the velocity of the protons.	☐
The magnetic field is parallel to the plane of the diagram in Fig. 3.1.	☐
The magnetic field is perpendicular to the resultant force on the protons.	☐

[1]

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

Explain why the antiprotons have to follow a path around the Main Ring in the opposite direction to that taken by the protons.

[2]

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(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 82 – 83 in the article) .

Calculate the rest energy of a proton to check that this statement is true.

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

rest energy = …………… GeV **[3]**

(ii) The table below shows the total energy for protons of different velocities, the velocities written as a percentage of the speed of light.

v/c (percentage)	total energy E / GeV
10%	0.96
20%	0.97
40%	1.0
60%	1.2
80%	1.6
90%	2.1
99%	6.6
99.9%	20
99.99%	66
99.999%	210
99.9999%	660

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Use your answer to **(i)** and data in this table to illustrate how the equation

$$E^2 = (pc)^2 + (\text{rest energy})^2$$

can be simplified to

$$E \approx pc$$

for sufficiently high values of v/c.

[2]

[Total: 9]

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4 This question is about superconducting electromagnets (Figs. 3 and 4 and lines 87 – 111 in the article).

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

[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.

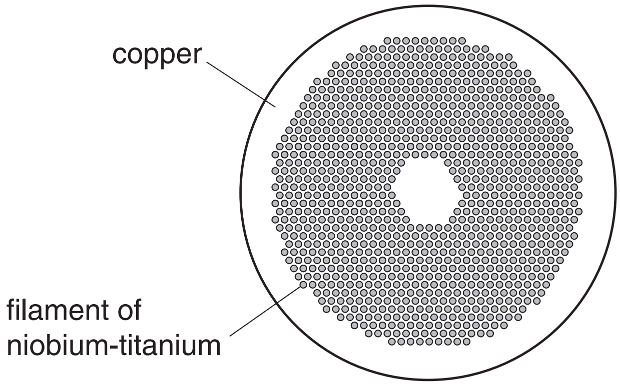

Fig. 4.1

Below a temperature of 10K, 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 97 – 99 in the article).

[2]

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(c) The article describes the catastrophic effects of a temperature rise in the superconducting magnets (lines 102 – 106 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]

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5 This question is about medical images of the head (Fig. 5 and lines 110 – 122 in the article).

(a) (i) Show that 50 MHz radio frequency photons have an energy of about 2×10^{-7} eV as suggested in the article (lines 115 and 117).

$h = 6.6 \times 10^{-34}$ J s
$e = 1.6 \times 10^{-19}$ C

[2]

(ii) Explain why an X-ray image, which can be produced with an exposure of a tenth of a second, is likely to be much more harmful to a patient than an MRI scan which may involve exposure to the radiation for 30 minutes.

[2]

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(b)

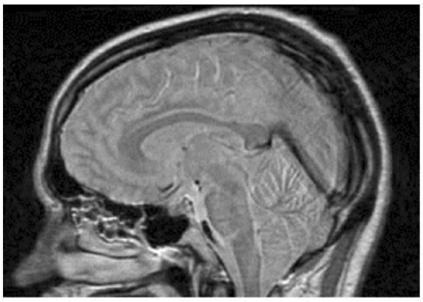

Fig 5.1 MRI

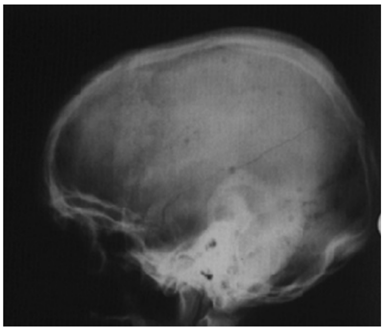

Fig 5.2 X-ray

Suggest why the MRI image, Fig. 5.1, reveals much more detail of the structure of the brain than the X-ray image, Fig. 5.2.

[2]

(c) Explain **two** advantages of having images stored digitally rather than on conventional film.

[2]

[Total: 8]

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6 This question is about the energy needed to put satellites into orbit (lines 125 – 127 in the article). The International Space Station (ISS) orbits the Earth with an orbit of mean radius 6.8×10^6 m.

(a) **(i)** What provides the centripetal force required to bend the path of the space station into a circular orbit?

[1]

(ii) Explain why the ISS and its contents are said to be in 'free fall' (line 135 in the article).

[2]

(iii) Use Newton's Gravitational Law and the formula for centripetal force to show that the orbital speed v of the ISS should be given by the equation

$$v = \sqrt{\frac{GM}{r}}$$

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

[2]

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(iv) Calculate the kinetic energy that the ISS has while in orbit.

$GM = 4.0 \times 10^{14}$ N m^2 kg^{-1}
mass of ISS = 1.9×10^5 kg
$r = 6.8 \times 10^6$ m

kinetic energy = ... J **[2]**

(b) Calculate the change in gravitational **potential energy** of the ISS moving from the surface of the Earth into its orbit.

radius of the Earth = 6.4×10^6 m
orbital radius of the ISS = 6.8×10^6 m
mass of ISS = 1.9×10^5 kg

change in gravitational energy = ... J **[3]**

(c) Explain why the total energy required to place the ISS in orbit around the Earth is greater than the sum of the answers to parts **(a)(iv)** and **(b)**.

[2]

[Total: 12]

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Section B

7 This question is about oscillations in loaded vehicles.

A small delivery truck can be thought of as a box supported by four springs, one at each wheel (the suspension of the truck). In this question, only the two **rear** springs will be considered.

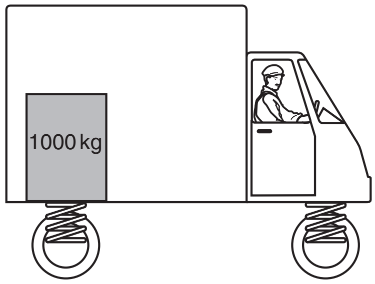

Fig. 7.1

(a) The spring constant k in $F = kx$ of each spring is $2.6 \times 10^4\,\text{N m}^{-1}$.

(i) Explain why the spring constant of the two rear springs together is $5.2 \times 10^4\,\text{N m}^{-1}$.

[2]

(ii) Show that the back of the truck will move down about 20 cm when it is loaded with 1 tonne (1000 kg), placed above the rear wheels as in Fig. 7.1.

[2]

The part of the truck body supported by the rear wheels has a mass of 500 kg.

(b) Show that the period of oscillation of an unloaded truck is about 0.6 s.

[2]

(c) A truck oscillates with a time period exactly double that of an unloaded truck. Is it carrying more than the maximum permitted load of 1 tonne? Show your working.

[3]

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'Speed bumps' are put on the road into a large supermarket to slow the traffic. (Fig. 7.2)

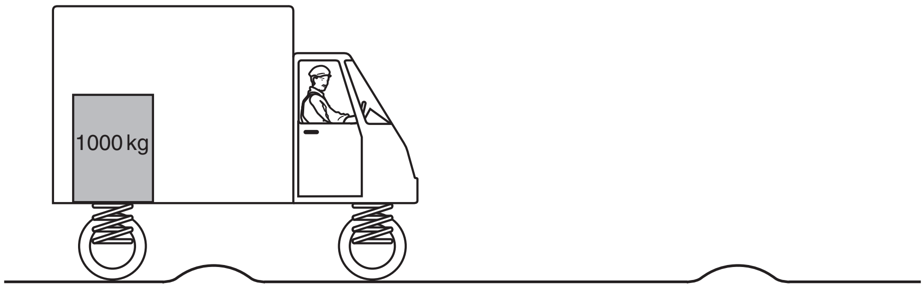

Fig. 7.2

(d) Explain why the truck will oscillate after passing quite rapidly over a speed bump.

[2]

(e) If the truck travels at a certain speed over the set of speed bumps, the vertical oscillations can become very large. Explain why this is so.

[2]

(f) Free oscillations of the suspension, as shown in the graph below, would be uncomfortable, so friction is used to damp them by reducing the amplitude.

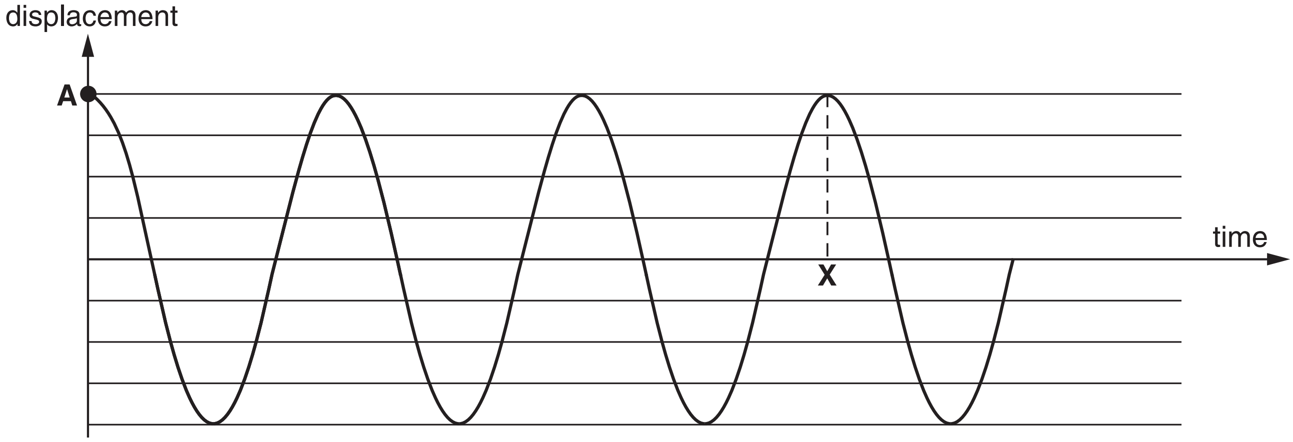

Fig. 7.3

Starting at point **A**, sketch on Fig. 7.3 a graph showing the displacement-time graph you would get if the oscillation was damped so that the amplitude at point **X** was about one-quarter of the starting amplitude. **[3]**

[Total: 16]

8 This question is about low energy mains lamps (CFLs, compact fluorescent lamps)

Fig. 8.1 shows the position of major peaks in the spectrum produced when light from a low energy fluorescent lamp was passed though a diffraction grating.

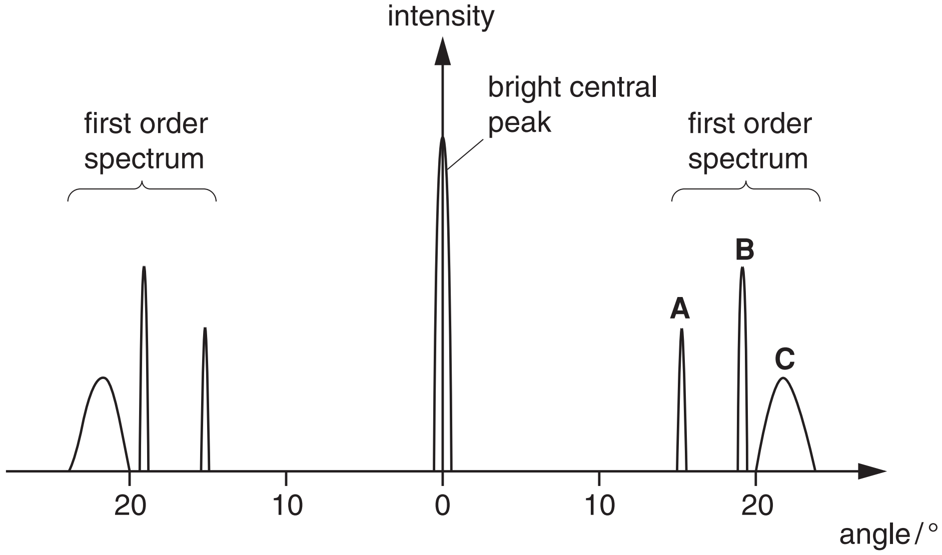

Fig. 8.1

The first order spectrum consists of three major peaks, red, green and violet.

(a) **(i)** The spectral peaks **A**, **B** and **C** on Fig. 8.1 are red, green and violet.

Write the correct colour against each letter.

A .... **B** .... **C** .... **[1]**

(ii) Explain what is meant by the expression 'first order spectrum'.

[1]

(iii) Explain why the bright central peak at 0° appears white.

[1]

(iv) The diffraction grating has 600 lines per millimetre.

Calculate the wavelength of the light producing peak **B**, at $\theta = 19.1°$.

wavelength = ... m **[3]**

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(b) In the CFL, light is emitted both by atoms in the gas inside the lamp and by the fluorescent chemical coating the lamp.

(i) Photons are emitted by the gas when an electron moves between two energy levels.

Identify which of the peaks **A**, **B** and **C** are produced by the gas, and explain your choice.

[2]

(ii) Light is emitted by the fluorescent chemical when it is excited by ultraviolet produced by the gas. Electrons in the fluorescent chemical can be excited to a band of overlapping energy levels.

Identify which of the peaks **A**, **B** and **C** are produced by the fluorescent chemical, and explain your choice.

[2]

(c) Describe how the spectrum from a conventional filament lamp would differ from that above. You can sketch the spectrum on Fig. 8.1 to illustrate your answer.

[1]

QUESTION CONTINUES OVER PAGE

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(d) **(i)** Draw a diagram of a circuit that could be used to determine the power consumption of a **low voltage** lamp.

[1]

(ii) Explain how you would use your measurements to compare the power consumption of two low voltage lamps.

[2]

[Total:14]

Quality of Written Communication [4]

END OF QUESTION PAPER

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