Surname	Centre Number	Candidate Number
Other Names		2

GCE AS/A Level

1322/01 – **LEGACY**

S16-1322-01

PHYSICS – PH2
Waves and Particles

P.M. THURSDAY, 9 June 2016

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**18**	
2.	**10**	
3.	**13**	
4.	**9**	
5.	**11**	
6.	**10**	
7.	**9**	
Total	**80**	

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ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

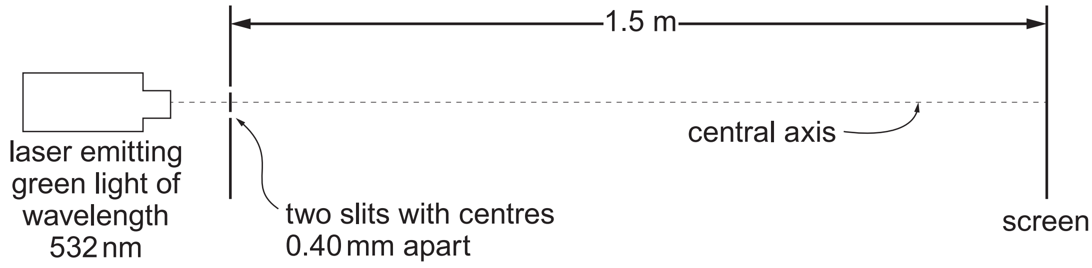
Use black ink or black ball-point pen.
Write your name, centre number and candidate number in the spaces at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 80.
The number of marks is given in brackets at the end of each question or part-question.
You are reminded of the necessity for good English and orderly presentation in your answers.
You are reminded to show all working. Credit is given for correct working even when the final answer is incorrect.

Answer **all** *questions.*

1. *(a)* A modern version of Young's double slit experiment is set up as shown.



(i) Calculate the fringe separation. [2]

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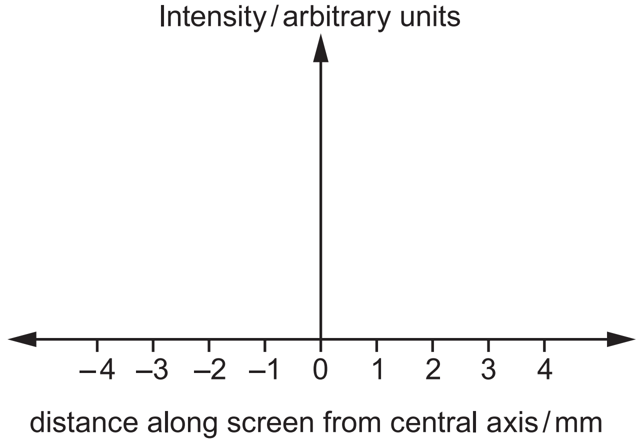
(ii) Assuming that there is a bright fringe on the central axis, sketch below a graph of light intensity against distance from the central axis. [3]



(iii) State **two** ways in which the pattern will change if the screen is brought closer to the slits. [2]

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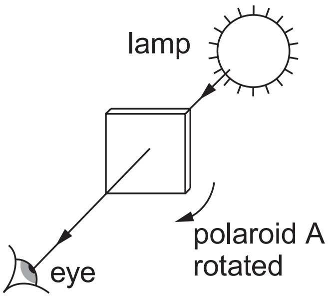
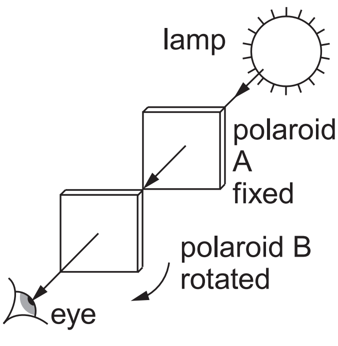
(iv) **Explain** what would happen if the following changes were made, individually.

I. A red laser is used instead of a green laser. [1]

II. One of the slits is blocked up. [2]

(b) Green light from the laser is now shone normally on to a diffraction grating. The centres of the slits are 1 500 nm apart. **Second order** beams are observed at $45° \pm 1°$ to the normal. Calculate maximum and minimum values for the wavelength according to these readings. [3]

(c) Light from a filament lamp behaves like an *unpolarised, transverse* wave. This can be shown using polarising filters *(polaroids)*. Two experiments are carried out as described briefly in the first column of the table below. In the second column state what is observed and, in the third column, give a brief explanation of what is observed. [5]

What is done	What is observed	Explanation
		
		

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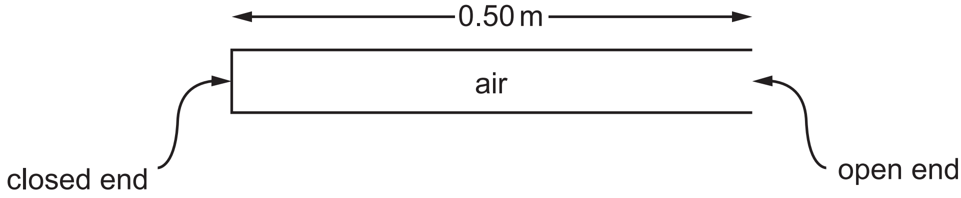
2. *(a)* A stationary sound wave is set up in air in the tube shown in the diagram. The speed of sound in the air is 342 m s^{-1}.



(i) There is an antinode of displacement at the open end of the tube, and a node at the closed end. Calculate the lowest frequency possible for the stationary wave. [2]

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(ii) The wave speed given above is for progressive waves. Explain how the stationary wave arises from progressive waves. [2]

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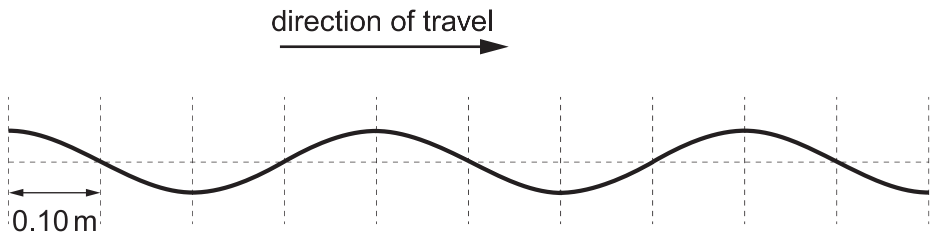
(b) Waves are travelling to the right along a taut string at a speed of 5.0 m s^{-1}. The diagram shows part of the string at time t = 0.



(i) **On the same diagram**, draw this part of the string at time t = 0.10 s. [2]

(ii) Calculate the frequency. [2]

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(iii) The wave source (not shown) is now adjusted to increase the frequency. Explain the effect that this will have on the wavelength, stating any assumption that you make. [2]

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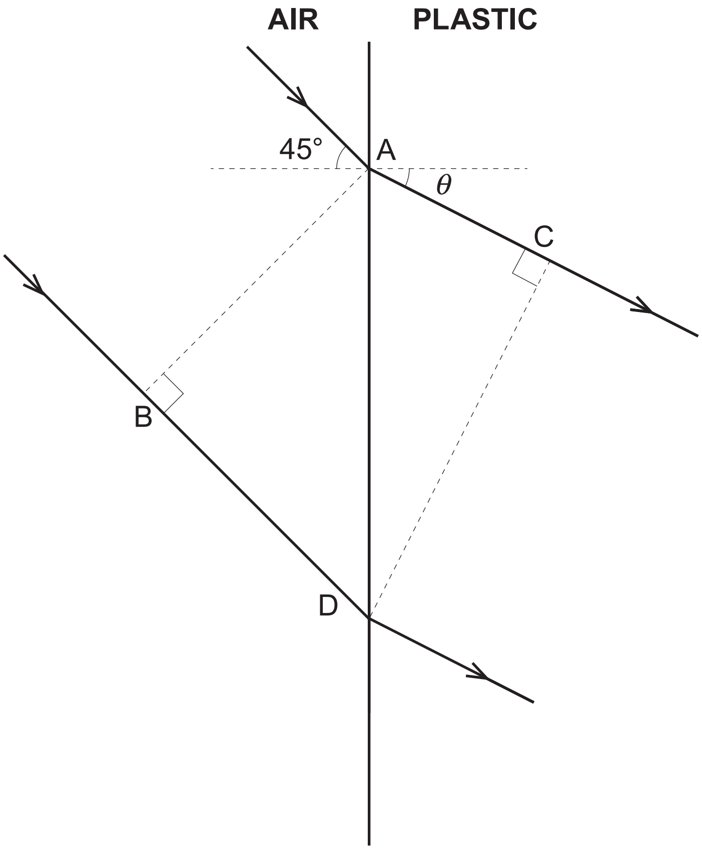
3. *(a)* The diagram, which is **actual size**, shows a beam of light travelling through air and entering transparent plastic. A wavefront moves from AB to CD as it enters the plastic.



(i) By measuring **lengths** on the diagram show that the speed of light in the plastic is approximately $2 \times 10^8\,\text{m}\,\text{s}^{-1}$. [3]

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(ii) Calculate θ, the angle of refraction, giving your working. Assume $n_{air} = 1$. [2]

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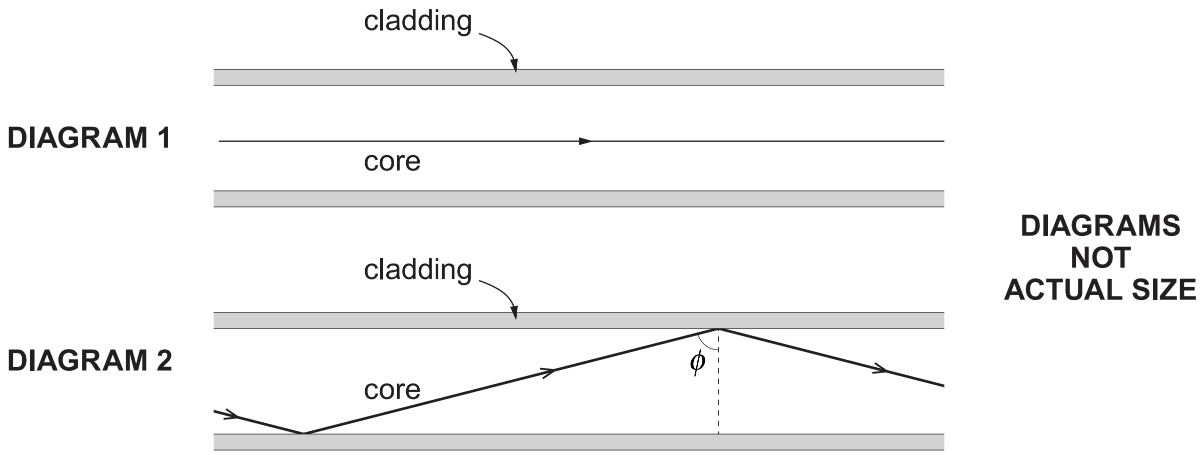
(b) Light takes 1.86 μs to travel through 360 m of multimode fibre by the **quickest** route, as shown in diagram **1**, and 1.91 μs to travel through the same fibre by the **slowest** route, as shown in diagram **2**.



(i) Calculate the refractive index of the core of the fibre. [2]

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(ii) Calculate the angle ϕ. [2]

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(iii) Explain why it is not possible to have slower routes than that shown in diagram **2**. [2]

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(iv) Explain why multimode fibres are used for transmitting data over short distances only. [2]

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4. *(a)* Einstein's photoelectric equation may be written:

$$E_{k\,max} = hf - \phi$$

In terms of *energy*, state the meanings of:

(i) hf .... [1]

(ii) ϕ ....

.... [1]

(b) The *work function* of sodium is 3.65×10^{-19} J. Light of various frequencies (see below) is shone on to a sodium surface. In each case calculate the **maximum** kinetic energy of the emitted electrons, or explain in terms of photons, with an appropriate calculation, why there is no emission.

(i) violet light of frequency 7.40×10^{14} Hz [2]

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(ii) a mixture of violet light of frequency 7.40×10^{14} Hz and blue light of 6.82×10^{14} Hz [1]

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(iii) yellow light of frequency 5.22×10^{14} Hz [2]

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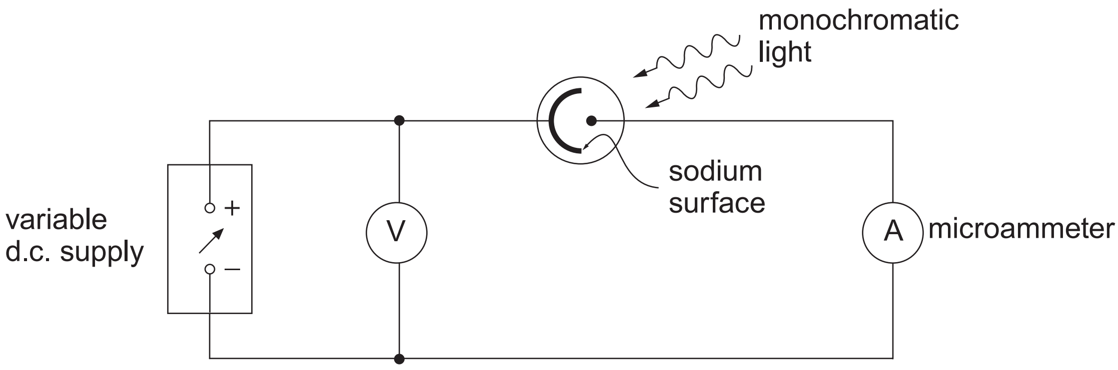
(c) The diagram shows a circuit set up to determine the maximum kinetic energy, $E_{k\,max}$, of electrons ejected from a sodium surface by light of a certain frequency.



Describe how you would use the apparatus to determine $E_{k\,max}$. [2]

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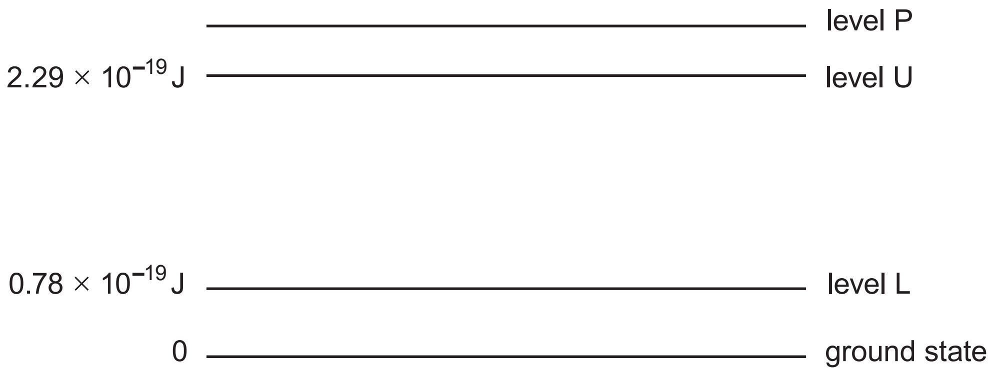
5. A simplified energy level diagram is given for the amplifying medium in a four level laser, which is pumped using light. Stimulated emission involves levels U and L.



(a) (i) Calculate the wavelength of the emitted radiation, and name the region of the electromagnetic spectrum in which it lies. [3]

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(ii) The power supplied to the laser is 5.0 W, and its efficiency is 0.70%. Calculate the number of photons of this wavelength emitted per second. [3]

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(b) Explain **in terms of the energy level diagram** how a population inversion between levels U and L is brought about. [3]

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(c) Explain how stimulated emission differs from spontaneous emission and why stimulated emission can give light amplification. [2]

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6. *(a)* Stars emit radiation as *black bodies*. State what is meant by a *black body*. [1]

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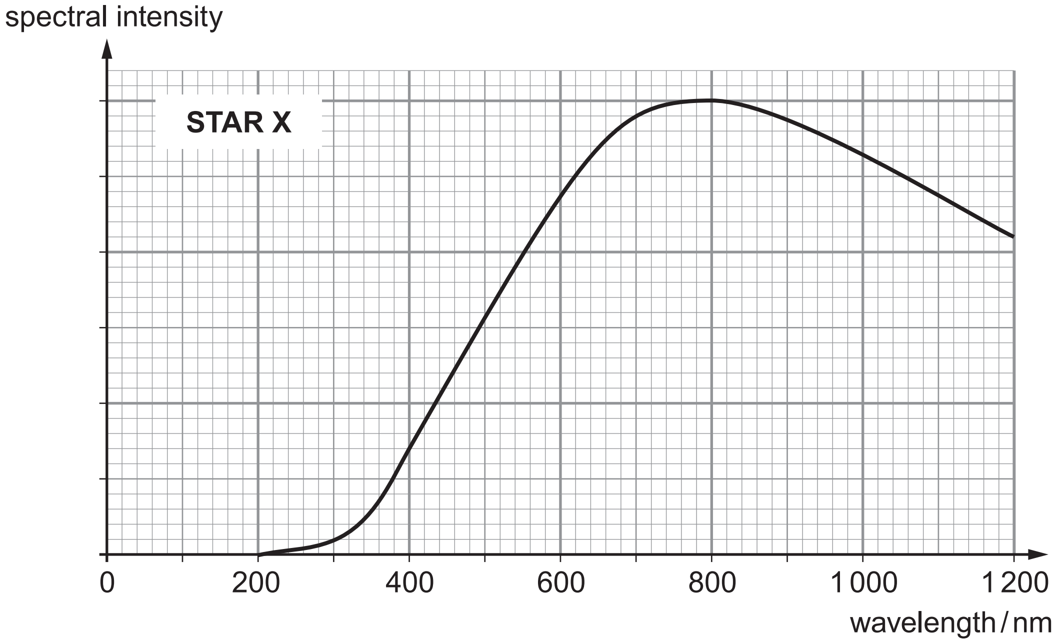
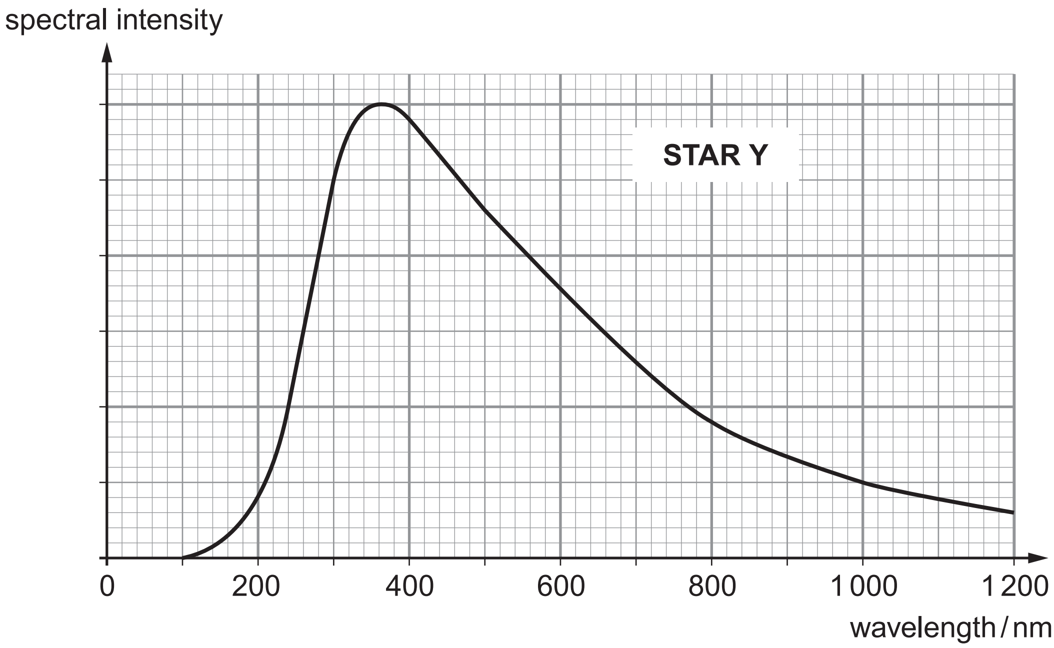
(b) The spectra of two stars, X and Y, are given below. The vertical scales are arbitrary.





(i) The range of visible wavelengths is roughly 400 nm - 700 nm. Identify the likely *colours* of the two stars, giving your reasoning. [2]

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(ii) Show clearly that the ratio:

$$\frac{\text{Kelvin temperature of surface of Y}}{\text{Kelvin temperature of surface of X}}$$ is approximately 2,

giving your own value for the ratio to two significant figures. [3]

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(iii) Calculate the ratio:

$$\frac{\text{Power of electromagnetic radiation emitted by Y } \textbf{per m}^{\mathbf{2}} \text{ of surface}}{\text{Power of electromagnetic radiation emitted by X } \textbf{per m}^{\mathbf{2}} \text{ of surface}}$$ [1]

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(iv) Measurements show that:

$$\frac{\text{Total power of electromagnetic radiation emitted by Y}}{\text{Total power of electromagnetic radiation emitted by X}} = 9.0$$

The diameter of X is 1.5×10^9 m. Calculate the diameter of Y. [3]

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7. *(a)* The charge on a proton is e and the charge on a neutron is 0. Account for these values in terms of quarks. [2]

(b) **A**, **B** and **C** are three interactions which are from part of a sequence of interactions in a star such as the Sun. Symbols of the form ${}^{A}_{Z}\mathrm{X}$ represent nuclei.

A ${}^{3}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{7}_{4}\mathrm{Be} + \gamma$

B ${}^{7}_{4}\mathrm{Be} + \mathrm{e}^{-} \rightarrow {}^{7}_{3}\mathrm{Li} + \nu_{\mathrm{e}}$

C ${}^{7}_{3}\mathrm{Li} + {}^{1}_{1}\mathrm{H} \rightarrow 2\,{}^{4}_{2}\mathrm{He}$

(i) Baryon number (as well as energy and momentum) is conserved in all interactions. Name **two** other conserved quantities and explain how each is conserved in **B** above. [2]

(ii) In **B** there is only one change of nucleon type, and this can be traced to a single change of quark flavour. Identify the change in nucleon type and the change in quark flavour. [2]

(iii) Identify the change in **isotope** between the beginning and the end of the sequence **A**, **B**, **C** taken as a whole. [1]

(iv) Interaction **A** could be described both as a *fusion interaction* and as an interaction involving the electromagnetic force. Explain why both these descriptions are correct. [2]

END OF PAPER

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