Surname		Other Names	
Centre Number			Candidate Number									
Candidate Signature												

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General Certificate of Education
January 2002
Advanced Level Examination

AQA
ASSESSMENT and QUALIFICATIONS ALLIANCE

PHYSICS (SPECIFICATION A) PHA5/W
Unit 5 Nuclear Instability: Astrophysics Option

Monday 28 January 2002 Morning Session

In addition to this paper you will require:
- a calculator;
- a pencil and a ruler.

Time allowed: 1 hour 15 minutes

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided. All working must be shown.
- Do all rough work in this book. Cross through any work you do not want marked.

Information
- The maximum mark for this paper is 40.
- Mark allocations are shown in brackets.
- The paper carries 10% of the total marks for Physics Advanced.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are expected to use a calculator where appropriate.
- In questions requiring description and explanation you will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary where appropriate. The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Data Sheet

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

DATA SHEET

DATA SHEET

TURN OVER FOR THE FIRST QUESTION

SECTION A NUCLEAR INSTABILITY

Answer **all** parts of the question.

1 (a) The nuclide $^{203}_{83}Bi$ can decay by *electron capture* to become an isotope of lead as shown in the following equation,

$$^{203}_{83}Bi + {}^{0}_{-1}e^{-} \longrightarrow {}^{203}_{82}Pb + \nu_e + Q.$$

(i) Explain what is meant by electron capture.

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(ii) Give **one** reason why electromagnetic radiation is emitted following this process.

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(iii) Give the equation for another process in which $^{203}_{83}Bi$ is converted into an isotope of lead.

$^{203}_{83}Bi \longrightarrow$

(5 marks)

(b) The nuclide $^{203}_{83}Bi$ is also an α particle emitter. An initial measurement of the α particle activity of a sample of this isotope gives a corrected count rate of 1200 counts s^{-1}. After an interval of 24 hours the corrected rate falls to 290 counts s^{-1}.
Assume that corrections have been made for the radiation both from daughter products and background radiation.

(i) Show that the decay constant of $^{203}_{83}Bi$ is about $1.6 \times 10^{-5} s^{-1}$.

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(ii) Calculate the half-life of this sample.

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(iii) Calculate the number of $^{203}_{83}Bi$ nuclei in the sample when the corrected count rate was 1200 counts s^{-1}.

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(5 marks)

10

SECTION B ASTROPHYSICS

Answer **all** questions.

2 A converging lens of power 10 D produces a magnified image of a small object. The image is 0.25 m from the centre of the lens and is the same way up as the object.

(i) State **one** other property of the image.

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(ii) Determine the focal length of the lens.

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(iii) Show that the object should be placed approximately 0.07 m from this lens for the image to be formed.

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(iv) Draw a ray diagram below to show how this image is formed. Mark the positions of the object, image and the principal foci of the lens.

A scale diagram is **not** required.

(7 marks)

3 (a) (i) Draw the diffraction pattern produced when light from a star passes through a circular aperture.

(ii) Explain what is meant by the "Rayleigh criterion" for the resolution of **two** stars. Draw a diagram to help if you wish.

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(3 marks)

(b) The star Arich in the constellation Virgo is two stars separated by an angle of 1.1×10^{-5} radians when viewed from Earth. Calculate the minimum diameter of a telescope objective which would just allow the two stars to be resolved. Assume the light from the star has a wavelength of 5.7×10^{-7} m.

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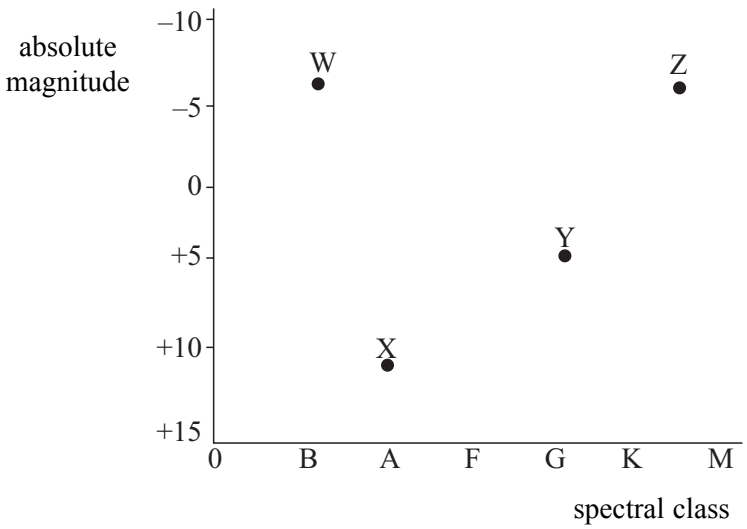
(2 marks)

5

4 The absolute magnitude and spectral class of four stars W, X, Y and Z are plotted using the axes below.



(a) Draw and label, on the diagram above, the regions occupied by the main sequence, white dwarf stars and red giant stars. *(2 marks)*

(b) The following observations were made for the star Alnilam in the constellation of Orion.

apparent magnitude:	1.7
distance from Earth:	1350 light years
spectrum:	strong hydrogen Balmer absorption lines

(i) Explain what is meant by *apparent magnitude*.

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(ii) Calculate the distance in parsecs of Alnilam from the Earth.

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(iii) Hence calculate the absolute magnitude of Alnilam.

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(iv) Which of the stars, W, X, Y or Z is Alnilam? Explain your answer.

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(7 marks)

(c) The stars shown on the graph could represent the position of a star at different times during its evolution. Write down the correct sequence, using some or all of the letters, that would best represent the evolution of the Sun starting from its present position.

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(1 mark)

10

5 Quasars are star-like objects whose spectra have very large red shifts.

(a) What property of quasars led to their discovery?

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(1 mark)

QUESTION 5 CONTINUES ON THE NEXT PAGE

(b) 3C 48 is a quasar which has one of the largest red shifts ever measured. A particular spectral line has a value of 279.8 nm when measured using a laboratory source. The equivalent line in the spectrum of this quasar is 382.5 nm.

(i) Calculate the speed of this quasar relative to the Earth, ignoring relativistic effects.

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(ii) Show that the distance to the quasar is approximately 2×10^9 pc.
Assume the Hubble constant is 65 km s^{-1} Mpc^{-1}.

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(3 marks)

(c) To have the same apparent magnitude as Quasar 3C 48, the Sun would have to be placed approximately 2×10^3 pc from the Earth.

(i) Assuming the distance to the quasar is 2×10^9 pc, use the inverse square law to estimate the ratio of the power output of Quasar 3C 48 to that of the Sun.

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(ii) A controversy exists concerning the nature of quasars. List the properties which give rise to this controversy.

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(4 marks)

END OF QUESTIONS