Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2015

Physics A PHYA5/2AR

Unit 5A Astrophysics
Section B

Thursday 18 June 2015 9.00 am to 10.45 am

For this paper you must have:
- a calculator
- a pencil and a ruler
- a Data and Formulae Booklet (enclosed).

R

Time allowed
- The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 50 minutes on this section.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this section is 35.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

Section B

The maximum mark for this section is 35. You are advised to spend approximately 50 minutes on this section.

1 (a) **Table 1** summarises some of the properties of Vesta, one of the largest objects in the asteroid belt between Mars and Jupiter.

Table 1

Diameter / m	Distance from the Sun / AU	
	smallest	largest
5.4×10^5	2.15	2.57

1 (a) (i) Calculate the largest possible distance, in m, between the Earth and Vesta.

[2 marks]

distance = ... m

1 (a) (ii) Show that when Vesta is at a distance of 1.73×10^{11} m from Earth, the angle subtended by Vesta to an observer on Earth is about 3×10^{-6} radian.

[2 marks]

1 (b) Observations of Vesta have been made by the Infrared Telescope Facility (IRTF) in Hawaii.

1 (b) (i) Draw a ray diagram for a Cassegrain telescope.

[2 marks]

1 (b) (ii) The IRTF includes a camera capable of detecting infrared radiation with wavelengths in the range $1.0\ \mu m$ to $5.0\ \mu m$.

The smallest angle the telescope can resolve is 3.3×10^{-7} radian.

Calculate the diameter of the objective of the telescope.
Give your answer to a suitable number of significant figures.

[2 marks]

diameter of objective = ... m

Question 1 continues on the next page

1 (c) Discuss the level of detail the IRTF would be able to detect on the surface of Vesta, when Vesta is 1.73×10^{11} m from Earth.

[2 marks]

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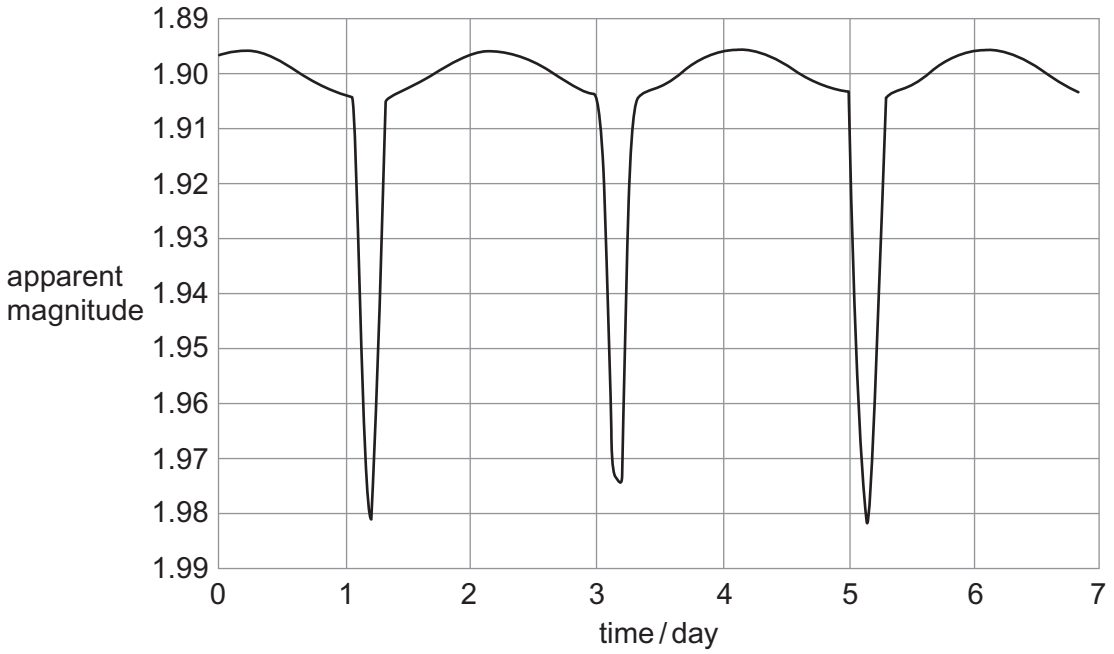
10

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

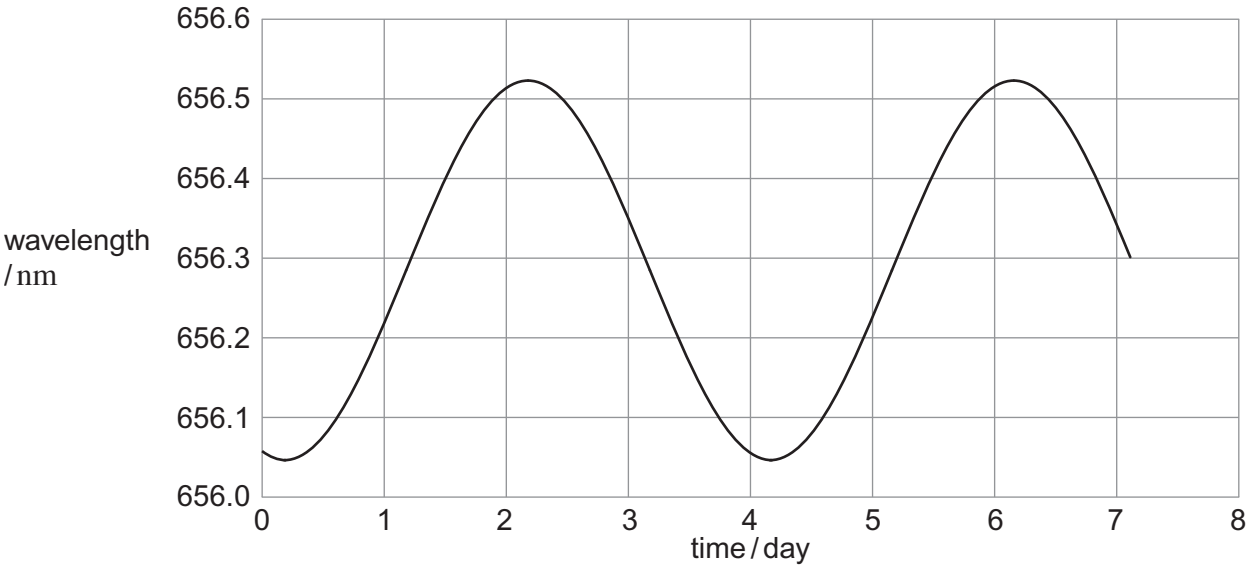
2 Menkalinan is an eclipsing binary star system in the constellation of Auriga. **Figure 1** shows the variation in apparent magnitude with time (light curve) for Menkalinan.

Figure 1



Analysis of the spectrum of one of the stars shows a periodic variation in wavelength. **Figure 2** shows the results for one of the spectral lines in the Hydrogen Balmer series. The wavelength for this line as measured for a source in a laboratory on the Earth is 656.28 nm.

Figure 2



2 (a) Describe the physical processes that give rise to the shape of each graph. Go on to show how the information in the graphs can be used to determine properties, such as the speed and period, of the Menkalinan binary system. You should include appropriate calculations in your answer.

The quality of your written communication will be assessed in your answer.

[6 marks]

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2 (b) The black body temperature of each star is approximately $9200\ \mathrm{K}$.

Explain why a Hydrogen Balmer line was chosen for the analysis of wavelength variation.

[2 marks]

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2 (c) The distance from the Earth to Menkalinan is 7.7×10^{17} m.

Calculate the value of the absolute magnitude of Menkalinan when it appears dimmest.

[3 marks]

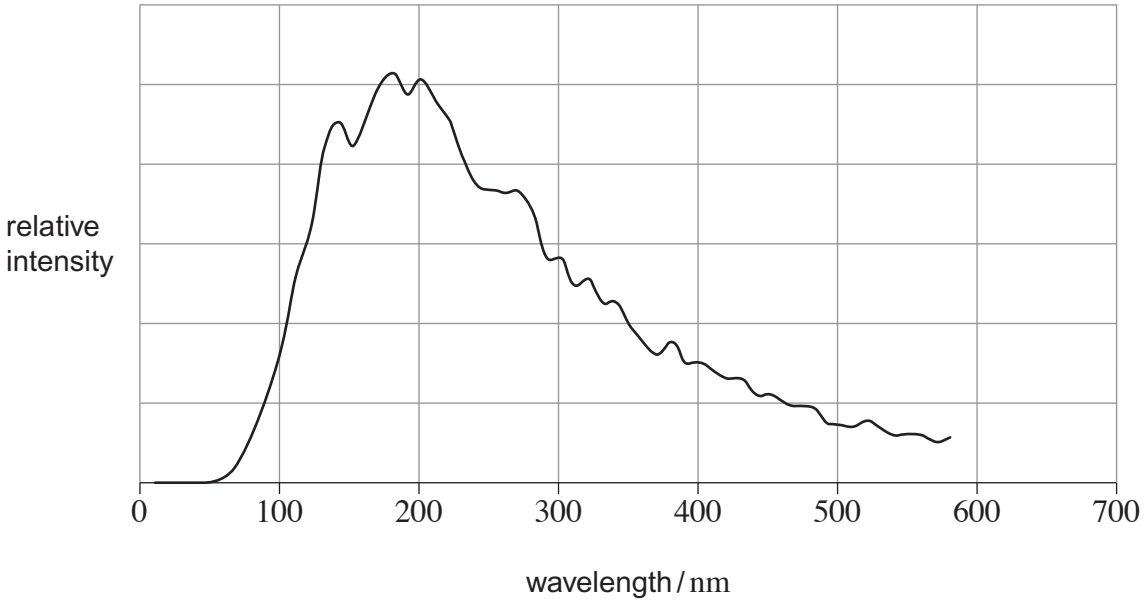
absolute magnitude = ...

11

Turn over for the next question

3 **Figure 3** shows the variation of intensity with wavelength for the star 40 Eridani B.

Figure 3



3 (a) (i) Calculate the black body temperature of 40 Eridani B.

State an appropriate unit for your answer.

[3 marks]

temperature = ... unit .....

3 (a) (ii) 40 Eridani B has a total power output of 4.2×10^{24} W.

Calculate its radius.

[2 marks]

radius = ... m

3 (b) (i) Which of the following regions of the Hertzsprung-Russell diagram does 40 Eridani B belong to?
Tick (✓) the correct answer.

[1 mark]

main sequence	
dwarf star	
giant star	

3 (b) (ii) Give reasons for your answer to part (b)(i).

[2 marks]

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8

Turn over for the next question

4 NGC 3842 is a galaxy which contains one of the biggest black holes ever discovered.

4 (a) State what is meant by a black hole.

[1 mark]

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4 (b) The mass of the black hole in NGC 3842 is believed to be 1.0×10^{10} times greater than that of the Sun.

Calculate the radius of its event horizon.

[2 marks]

radius = ... m

4 (c) NGC 3842 is 3.3×10^{8} light years from the Earth, and is receding at a velocity of 6.3×10^{6} m s^{-1}.

Estimate, using these data, an age in seconds for the Universe.

[3 marks]

age of Universe = ... s

END OF QUESTIONS

6