Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Astrophysics

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 50 minutes on this section.

Materials

For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

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.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- 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 paper is 35.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

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

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Section B

Answer **all** questions in this section.

0 1 . 1 Draw a ray diagram to show how a converging lens can cause spherical aberration.

[1 mark]

principal axis

0 1 . 2 Draw a labelled ray diagram for an astronomical refracting telescope in normal adjustment.

Show **three** non-axial rays passing through both lenses.
Label the principal foci of the lenses.

[3 marks]

principal axis

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0 1 . 3 The James Lick telescope is an astronomical refracting telescope.
When in normal adjustment, the distance between the lenses of the telescope is $17.4\ \text{m}$ and the angular magnification is 750

Calculate the focal length of the eyepiece lens.

[2 marks]

focal length = _____ m

0 1 . 4 The James Lick telescope can be used to identify binary stars.

Two techniques are available using this telescope:
- using a processed image from a CCD, and
- direct observation using the naked eye.

Compare the use of a CCD with the use of the naked eye to observe binary stars with this telescope.

[3 marks]

9

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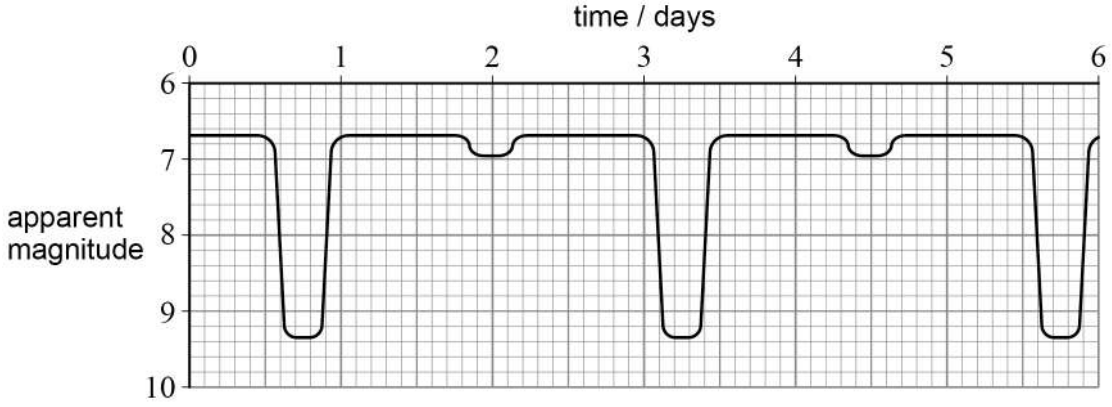
0 2 U Cephei is an eclipsing binary system consisting of two stars that orbit their common centre of mass.
The primary star is class B; the secondary star is class G.

Figure 1 shows the variation of apparent magnitude of U Cephei with time as observed from Earth.

Figure 1



0 2 . 1 Explain the shape of the graph in **Figure 1**.

[2 marks]

Question 2 continues on the next page

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A particular spectral line has a wavelength of $486.136\ \text{nm}$ when measured from a source in the laboratory.
This line is also present in the absorption spectrum of the primary star of U Cephei.
When observed from Earth, the wavelength of the primary star's absorption line varies as shown in **Table 1**.

Table 1

	Wavelength / nm
maximum value	486.498
minimum value	485.672

0 2 . 2 State why the average of the values in **Table 1** is different from the laboratory value.

[1 mark]

0 2 . 3 Show that the orbital speed of the primary star is about $250\ \text{km s}^{-1}$.

[3 marks]

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0 2 . 4 Calculate the orbital radius of the primary star.

[2 marks]

orbital radius = _____ m

0 2 . 5 Which absorption lines would be most prominent in the spectrum of the primary star? Tick (✓) **one** box.

[1 mark]

- hydrogen ☐
- hydrogen and helium ☐
- ionised metals ☐
- neutral metals ☐

0 2 . 6 A different eclipsing binary star system is thought to consist of a white dwarf star and a neutron star.

Discuss how astronomers could confirm this.

[2 marks]

_____

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_____

11

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0 3 3C 273 was the first quasar to be discovered.
IC 1101 is one of the largest galaxies known.
Table 2 shows some information about these objects.

Table 2

	Absolute magnitude	**Apparent magnitude**	**Distance / Mpc**
quasar 3C 273	**X**	12.8	760
galaxy IC 1101	−22.8	14.7	320

0 3 . 1 State the property of the quasar that led to its discovery.

[1 mark]

0 3 . 2 Show that the absolute magnitude **X** of quasar 3C 273 is about −27

[2 marks]

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0 3 . 3 Assume that the quasar and the galaxy are both viewed from the same distance.

Explain which would be the brighter object.

Go on to calculate the ratio $\frac{\text{brightness of brighter object}}{\text{brightness of dimmer object}}$.

[3 marks]

ratio = _____

0 3 . 4 The black hole at the centre of IC 1101 has a mass of $7.1 \times 10^{11}\ M_S$ where M_S is the mass of the Sun.

Calculate the average density within the event horizon of the black hole.

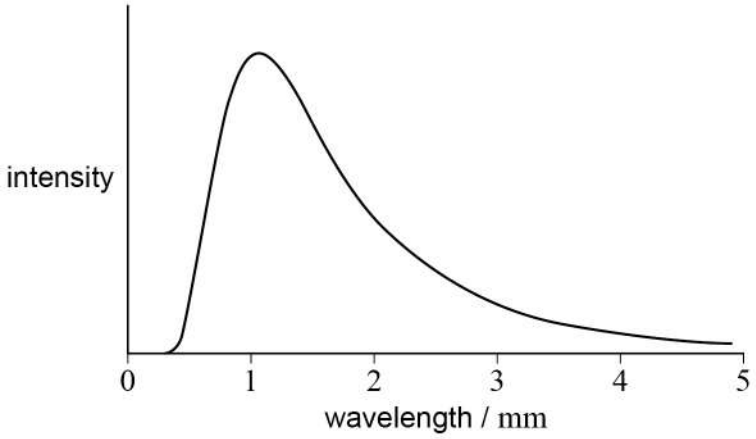
[3 marks]

average density = _____ kg m^{-3}

9

0 4 In the middle of the 20th century, there were two competing theories of the Universe. In 1964, electromagnetic radiation was observed coming from all directions in space. **Figure 2** shows the distribution of this radiation as observed from Earth.

Figure 2



The graph provides evidence for one of these theories of the Universe.

Discuss the main features of this theory of the Universe.

In your answer, you should include:
- the main predictions and evidence for the theory, and
- a suitable calculation.

[6 marks]

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END OF QUESTIONS

6

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