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Centre number

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Candidate number

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Surname Matheson

Forename(s) Lewis

Candidate signature 

I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Astrophysics

A Level Physics Online . com

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.

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.

For Examiner's Use	
Question	Mark
1	
2	
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TOTAL	



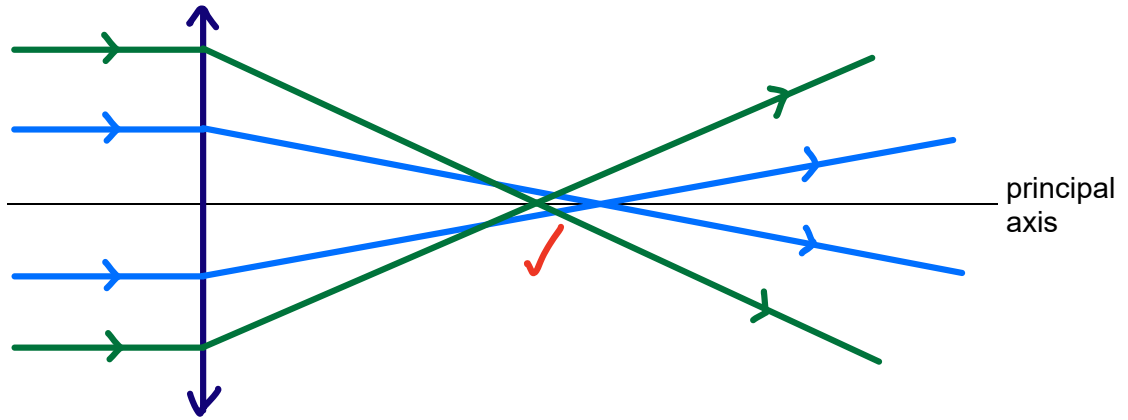
Section B

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]

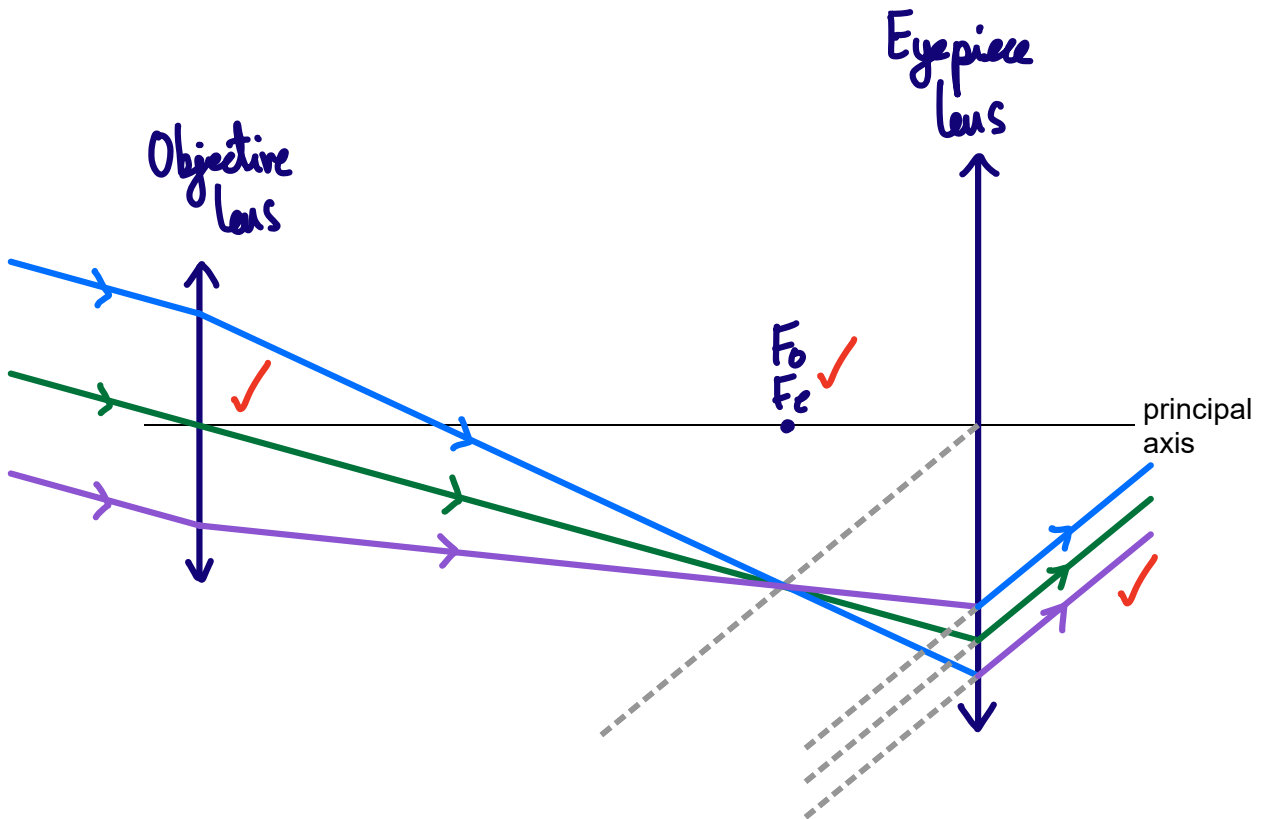


0 1 . 2

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]



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 m and the angular magnification is 750

Calculate the focal length of the eyepiece lens.

[2 marks]

$$M = \frac{f_o}{f_e} = 750$$

$$f_o + f_e = 17.4$$

$$f_o = 17.4 - f_e$$

$$\frac{17.4 - f_e}{f_e} = 750$$

$$\frac{17.4}{f_e} = 751$$

$$f_e = 17.4 / 751$$

$$f_e = 2.317 \times 10^{-3}$$

$$\frac{17.4}{f_e} - 1 = 750 \checkmark$$

focal length = 2.32×10^{-3} m \checkmark

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]

Resolution of CCD is better, this is due to the high number of pixels \checkmark so stars can more easily be seen as separate. \checkmark

CCDs have a greater quantum efficiency and can be exposed for a long time, so dimmer stars can be observed. \checkmark



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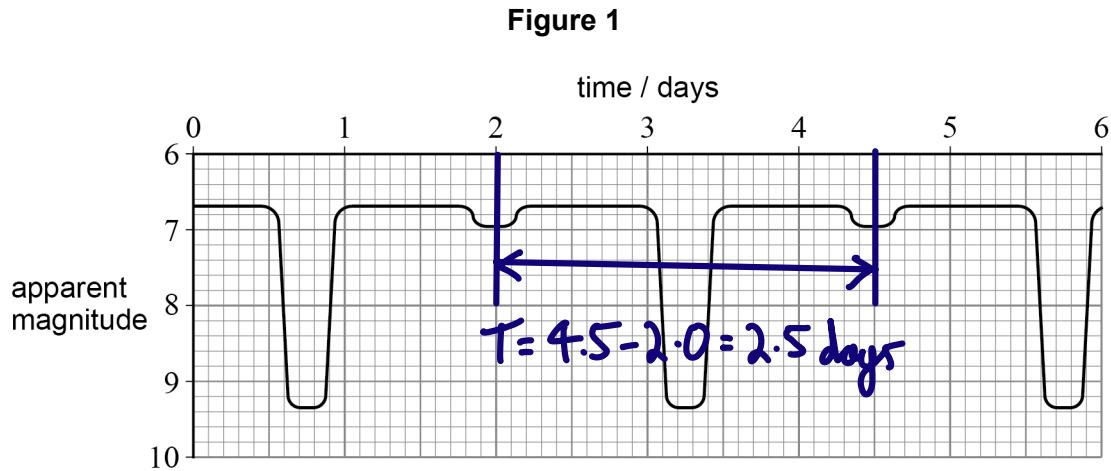


0 2

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.



0 2 . 1

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

[2 marks]

Minima caused by one star passing in front of the other. ✓ The deeper minima is caused by the cooler star (G) passing in front of the brighter star (B). ✓

Question 2 continues on the next page

Turn over ►



A particular spectral line has a wavelength of 486.136 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

$$\text{Average} = 486.085 < 486.136$$

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

[1 mark]

The light is blue shifted \therefore U Cephei is moving towards us. ✓

0 2 . 3 Show that the orbital speed of the primary star is about 250 km s⁻¹.

[3 marks]

$$z = \frac{v}{c} = \frac{\Delta\lambda}{\lambda}$$

$$v = \frac{c \Delta\lambda}{\lambda} = \frac{3.00 \times 10^8 \times \left(\frac{486.498 - 485.672}{2} \right)}{486.085} \quad \checkmark$$

$$v = \underline{2.55 \times 10^5 \text{ m s}^{-1}} \checkmark \approx 250 \text{ km s}^{-1}$$



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

[2 marks]

$$v = \frac{s}{t} = \frac{2\pi r}{T} \quad r = \frac{vT}{2\pi} = \frac{2.55 \times 10^5 \times 2.5 \times 24 \times 60^2}{2\pi}$$

$$T = 2.5 \text{ days from Fig 1} \checkmark$$

$$r = 8.76 \times 10^9$$

orbital radius = 8.8×10^9 \checkmark m

0 2 . 5 Which absorption lines would be most prominent in the spectrum of the primary star?
Tick (\checkmark) **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]

White dwarf in the O or B spectral class
and has a high temperature, but it is not bright. \checkmark
Neutron stars have periodic radio emissions
which would be blocked by white dwarf
when it passes between us and the neutron
star. \checkmark



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]

Very powerful radio emissions. ✓

0 3 . 2

Show that the absolute magnitude X of quasar 3C 273 is about -27

[2 marks]

$$m - M = 5 \log \left(\frac{d}{10} \right) \checkmark$$

$$M = m - 5 \log \left(\frac{d}{10} \right) = 12.8 - 5 \log \left(\frac{760 \times 10^6}{10} \right)$$

$$M = \underline{-26.6} \checkmark \approx -27$$



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 $\frac{\text{brightness of brighter object}}{\text{brightness of dimmer object}}$.

$$M_{\text{Quasar}} = -26.6 \quad M_{\text{Galaxy}} = -22.8 \quad [3 \text{ marks}]$$

The magnitude of the quasar is more negative so it is the brighter object. ✓

Difference of 1 equal to 2.51 times brighter

$$\frac{I_2}{I_1} = 2.51^{M_1 - M_2} = 2.51^{(-22.8 - (-26.6))}$$

$$= 2.51^{3.8} = 33 \quad \checkmark$$

$$\text{ratio} = \underline{33} \quad \checkmark$$

0 3 . 4

The black hole at the centre of IC 1101 has a mass of $7.1 \times 10^{11} M_{\text{S}}$ where M_{S} is the mass of the Sun.

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

$$R_s = \frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 7.1 \times 10^{11} \times 1.99 \times 10^{30}}{(3.00 \times 10^8)^2} \quad [3 \text{ marks}]$$

$$R_s = 2.094 \times 10^{15} \text{ m} \quad \checkmark$$

$$V = \frac{4}{3} \pi R_s^3 = \frac{4}{3} \pi \times (2.094 \times 10^{15})^3 = 3.847 \times 10^{46} \text{ m}^3 \quad \checkmark$$

$$\rho = \frac{m}{V} = \frac{7.1 \times 10^{11} \times 1.99 \times 10^{30}}{3.847 \times 10^{46}} = 3.672 \times 10^{-5}$$

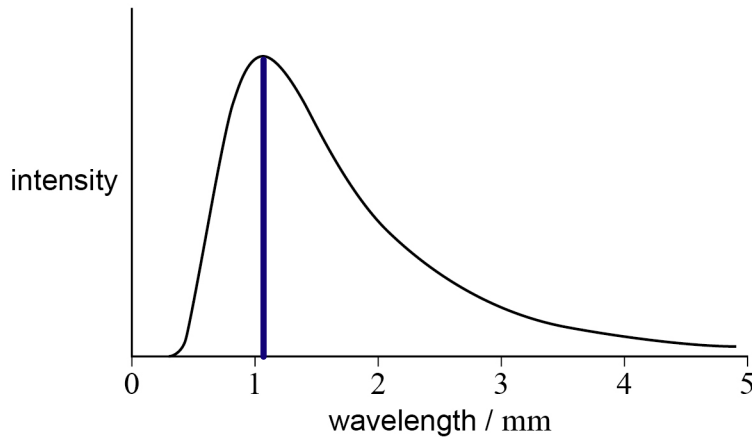
average density = $\underline{3.7 \times 10^{-5}} \quad \checkmark$ kg m⁻³



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. → Big Bang

In your answer, you should include:

- the main predictions and evidence for the theory, and
- a suitable calculation.

[6 marks]

Big Bang: universe has expanded from a single point.

Redshift: Theory states all distant galaxies are moving away from us with the recession velocity increasing with distance due to expansion of universe. ✓✓



CMBR: Theory predicts black body radiation at microwave wavelengths from all directions, indicating the universe used to be small, hot and dense but has since expanded. ✓✓

The peak of graph in microwave region $\approx 1.1 \times 10^{-3}$ m and has a curve consistent with black body radiation.

$$\text{Wien's law } \lambda_{\text{peak}} T = 2.9 \times 10^{-3}$$

$$T = \frac{2.9 \times 10^{-3}}{1.1 \times 10^{-3}}$$

$$T = 2.64 \text{ K}$$

\therefore consistent with theory. ✓✓

END OF QUESTIONS



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1 6



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