AQA

Please write clearly in block capitals.

Centre number | 3 | 2 | 7 | 9 | 5 | Candidate number | 0 | 2 | 8 | 8 |

Surname Matheson

Forename(s) Lewis

Candidate signature

I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Astrophysics

ALevelPhysicsOnline.com

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	
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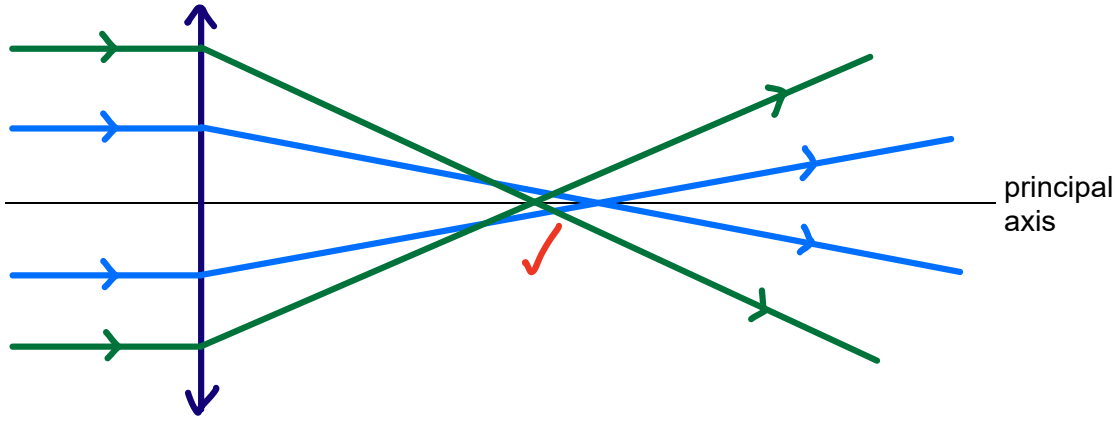
Section B

Answer **all** questions in this section.

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

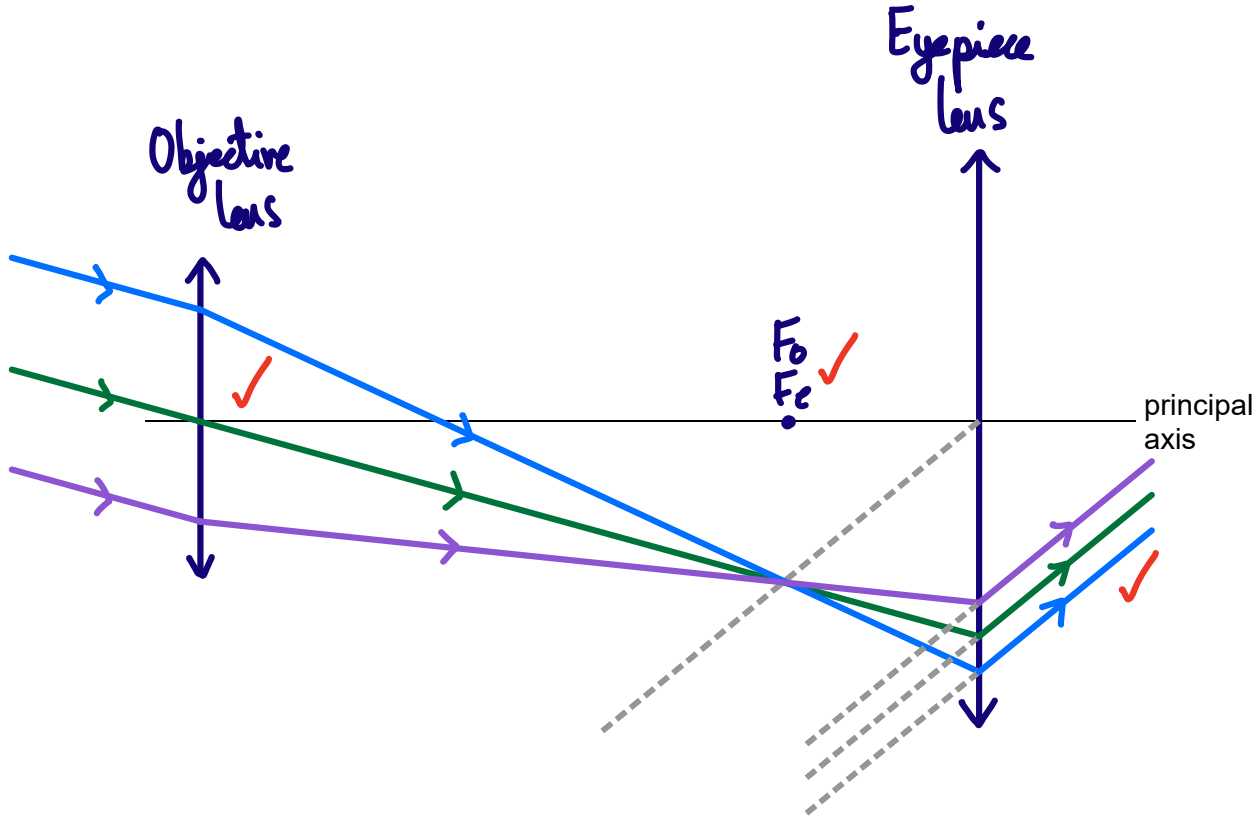
[1 mark]



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]



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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 m and the angular magnification is 750

Calculate the focal length of the eyepiece lens.

[2 marks]

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

$f_o + f_e = 17.4$

$f_o = 17.4 - f_e$

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

$\frac{17.4}{f_e} - 1 = 750$ ✓

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

$f_e = 17.4/751$

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

focal length = 2.32×10^{-3} ✓ 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]

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

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

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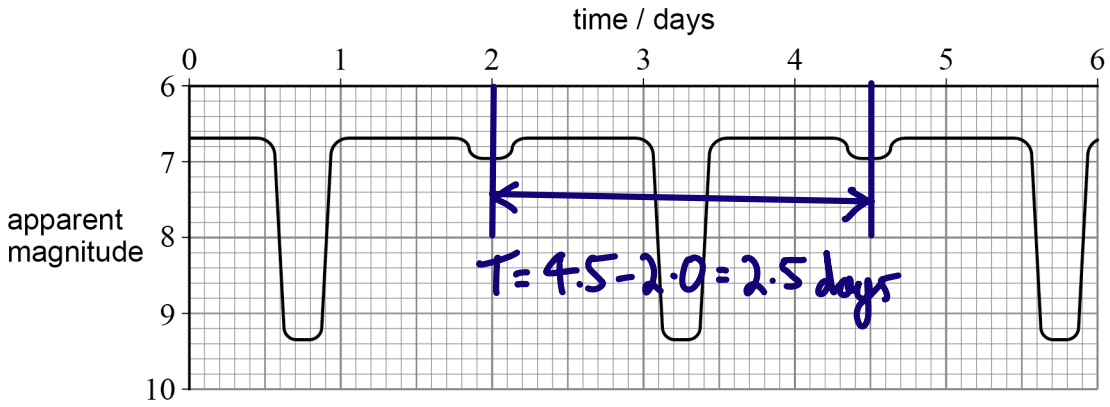
0 2 U Cephei is an eclipsing binary system consisting of two stars that orbit their common centre of mass.
The primary star is class B; the secondary star is class G.

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]

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

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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

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 ∴ 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]

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

$$v = \frac{c\Delta\lambda}{\lambda} = \frac{3.00\times10^{8} \times \left(\frac{486.498 - 485.672}{2}\right)}{486.085}$$ ✓ ✓

$v = 2.55\times10^{5}\ \text{ms}^{-1}$ ✓ $\approx 250\ \text{kms}^{-1}$

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

[2 marks]

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

$T = 2.5$ days from Fig 1 ✓ $\quad r = 8.76 \times 10^9$

orbital radius = 8.8×10^9 ✓ 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]

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

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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]

Very powerful radio emissions. ✓

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

[2 marks]

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

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

$M = -26.6$ ✓ ≈ -27

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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]

$M_{Quasar} = -26.6$ $M_{Galaxy} = -22.8$

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

Difference of 1 equal to 2.51 times brighter

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

$= 2.51^{3.8}$ ✓ $= 33$

ratio = 33 ✓

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]

$R_S = \frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 7.1 \times 10^{11} \times 1.99 \times 10^{30}}{(3.00 \times 10^8)^2}$

$R_S = 2.094 \times 10^{15}$ m ✓

$V = \frac{4}{3} \pi R_S^3 = \frac{4}{3} \pi \times (2.094 \times 10^{15})^3 = 3.847 \times 10^{46}$ m^3 ✓

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

average density = 3.7×10^{-5} ✓ kg m^{-3}

9

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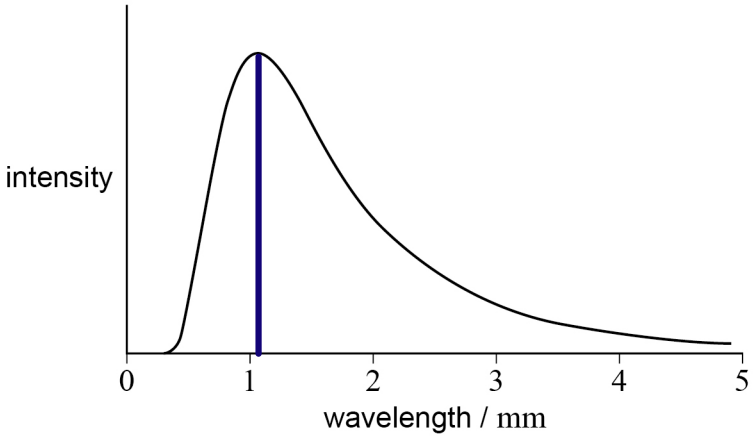
0 4 In the middle of the 20th century, there were two competing theories of the Universe. In 1964, electromagnetic radiation was observed coming from all directions in space. **Figure 2** shows the distribution of this radiation as observed from Earth.

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 recessional velocity increasing with distance due to expansion of universe. ✓✓

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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.

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

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

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

$\therefore$ consistent with theory. ✓✓

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END OF QUESTIONS

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