AQA

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

Friday 5 June 2020 Afternoon

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.

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.

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

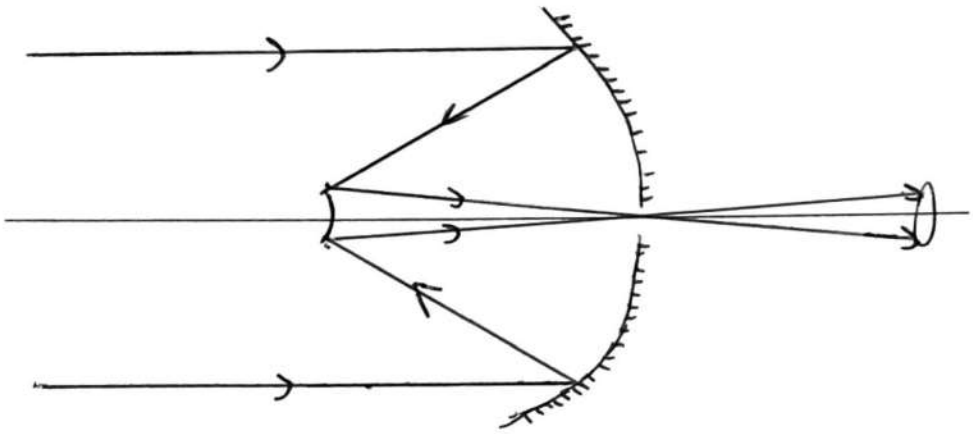
Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 35.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

Section B

Answer **all** questions in this section.

0 1 . 1 Draw a ray diagram for a Cassegrain telescope.
Your diagram should show the paths of **two** rays up to the eyepiece lens.
The rays should initially be parallel to the principal axis.

[2 marks]



0 1 . 2 A spacecraft passes Pluto at a distance of 12 500 km. The telescope on board has an aperture of diameter 0.21 m and operates at a wavelength of 450 nm.

Discuss whether this telescope is suitable for studying a crater with a diameter of approximately 1 km on Pluto.

[3 marks]

$$\text{Resolution} = \frac{450 \times 10^{-9}}{0.21} = 2.14 \times 10^{-1} \text{ radians}$$

The smallest detail $= 2.14 \times 10^{-6} \times 12.5 \times 10^{6} = 27\text{m}$

Yes it is suitable as the resolution is large enough to study the diameter of the crater.

0 1 . 3 The Hubble telescope has an aperture of diameter 2.4 m.

Compare the collecting power of the Hubble telescope with the telescope on the spacecraft in Question **01.2**.

[2 marks]

power ∝ area ! Divide to get power ratio

$$\frac{2.4^2}{0.21^2} = 130$$

∴ The hubble has a much large collecting pow.

0 1 . 4 An astrophysicist had to decide whether to use a reflecting telescope or a refracting telescope on the spacecraft in Question **01.2**.

Discuss which type of telescope to use.

[3 marks]

A refracting telescope can suffer spherical aberrations which affect the image. Reflecting are lighter ~~and~~ ~~heavier~~ and have mirrors. The mirrors mean there is no chromatic aberration. However they can have reduced image brightness due to the secondary mirror blocking some light. The reflecting telescope would still be the better type to use.

10

0 2 **Table 1** summarises some information about four stars in the constellation Cassiopeia.

Table 1

Name	Colour	Apparent magnitude	Distance / ly
Caph	white	2.3	55
Ruchbah	blue/white	2.7	99
Schedar	orange	2.2	228
Tsih	blue	2.2	610

0 2 . 1 Which star has the highest surface temperature?
Tick (✓) **one** box.

[1 mark]

Caph ☐

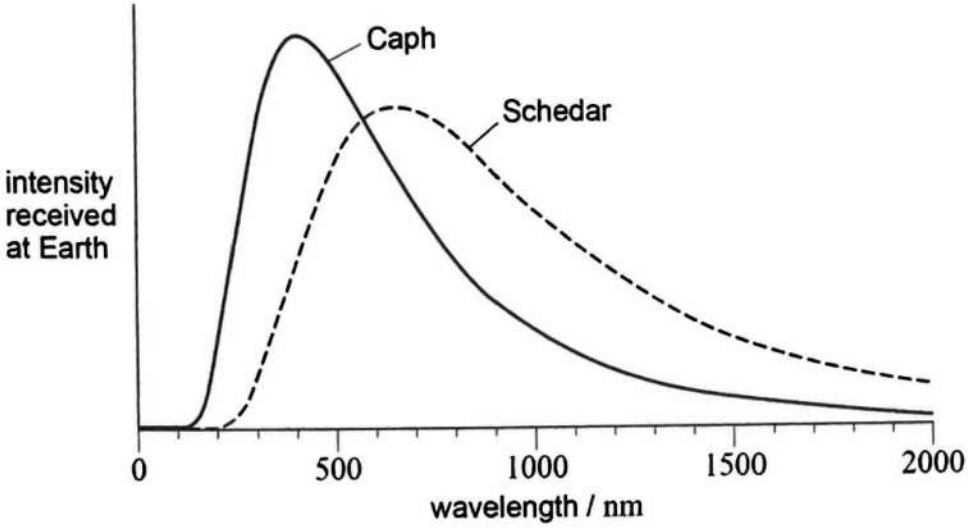
Ruchbah ☐

Schedar ☐

Tsih ☑

0 2 . 2 **Figure 1** shows the intensity received at Earth from two of the stars, plotted against wavelength.
The effect of absorption by the Earth's atmosphere is not shown.

Figure 1



Discuss what information can be found from **Figure 1** about the temperature and colour of these stars.
Support your answer with suitable calculations.

[4 marks]

$T = \frac{w}{\lambda}$

Caph $T = \frac{2.90 \times 10^{-3}}{410 \times 10^{-9}} = 7073\,k$

Schedar $T = \frac{2.90 \times 10^{-3}}{660 \times 10^{-9}} = 4393\,k$

We can use wiens law and the graph to find the temperature.
The temperature of Caph and schedar are 7073 k and 4393 k respectively.
We can see that schedar is redder as it has a longer wavelengths than Caph

Question 2 continues on the next page

0 2 . 3 State which star in **Table 1** is dimmest on the absolute magnitude scale.

[1 mark]

Caph

0 2 . 4 Calculate the absolute magnitude of Schedar.

[3 marks]

$$m - M = 5 \log \frac{d}{10}$$

$$M = m - 5 \log \frac{d}{10}$$

lightyears to parsecs $d = 228$ ly

1 parsec = 3.26 ly

ly $= \frac{1}{3.26}$ $d = 69.9$

$M = 2.2 - 5 \log \left(\frac{70}{10}\right)$

$= -2.03$

absolute magnitude = -2.0

0 2 . 5 Tsih has a mass over 15 times the mass of the Sun.
Tsih may eventually collapse to form a black hole.

Calculate the radius of the event horizon for a black hole with a mass 15 times that of the Sun.

[2 marks]

$M_{Tsih} = 15 M_\odot$

$R_s \approx \frac{2GM}{c^2}$

$= \frac{2G15M_\odot}{c^2}$

$= (2 \times 6.67 \times 10^{-11} \times 15 \times 1.99 \times 10^{30}) / c^2$

radius = 4.4×10^4 m

11

0 3 Type 1a supernovae can be used as standard candles.

0 3 . 1 State what is meant by a standard candle.

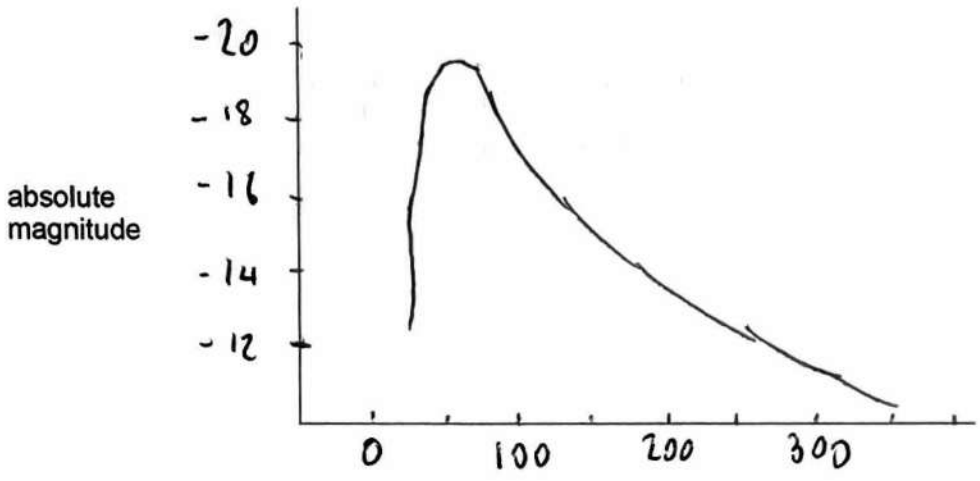
[1 mark]

It means it has a known absolute magnitude.

0 3 . 2 Sketch on **Figure 2** the light curve for a type 1a supernova.
Annotate your graph with suitable scales and a unit for time.

[3 marks]

Figure 2



Question 3 continues on the next page

0 3 . 3 Measurements of type 1a supernovae are used to find a value for the Hubble constant.

The distance from Earth is known for many type 1a supernovae.

Describe how these values of distance are used, with other data, to find the Hubble constant.

Your answer should include:

- the other data needed and how these data are used
- the graph plotted, including appropriate units for the axes
- how the Hubble constant is obtained and any limitations on the result.

[6 marks]

To find the Hubble constant, you would need the redshift data for the supernovae. You could use this to find the velocity of recession. You would also need to measure the wavelength of the spectral lines.

You would then plot a graph of velocity vs distance from earth. Suggested units you could use are km/s for velocity and Mpc for distance.

Hubbles constant can be calculated by taking the gradient of the graph.

One limitation could be that you would need from lots of supernva. Also, at large distances, the acceleration of the univer will affect the calculation.

Do not write outside the box

0 4 **Table 2** gives data about the supergiant star Melnick 34 and the Sun.

Table 2

Name	Radius / m	Surface temperature / K
Melnick 34	1.4×10^{10}	53 000
Sun	7.0×10^{8}	5 700

0 4 . 1 Calculate $\frac{\text{power output of Melnick 34}}{\text{power output of the Sun}}$.

[2 marks]

$P = \sigma A T^4$

$\text{power ratio} = \frac{A_M T_M^4}{A_\odot T_\odot^4}$

$= 3.0 \times 10^6$

answer = ~~3×10^6~~ 3.0×10^6

0 4 . 2 Discuss why the evolution of a supergiant star in the local part of our galaxy could be dangerous for life on Earth.

[2 marks]

Stars near the end of their lyfe cycle will undergo supernova collapse which produces a gamma ray burst. This could be dangerous to life on earth.

4

END OF QUESTIONS