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

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.

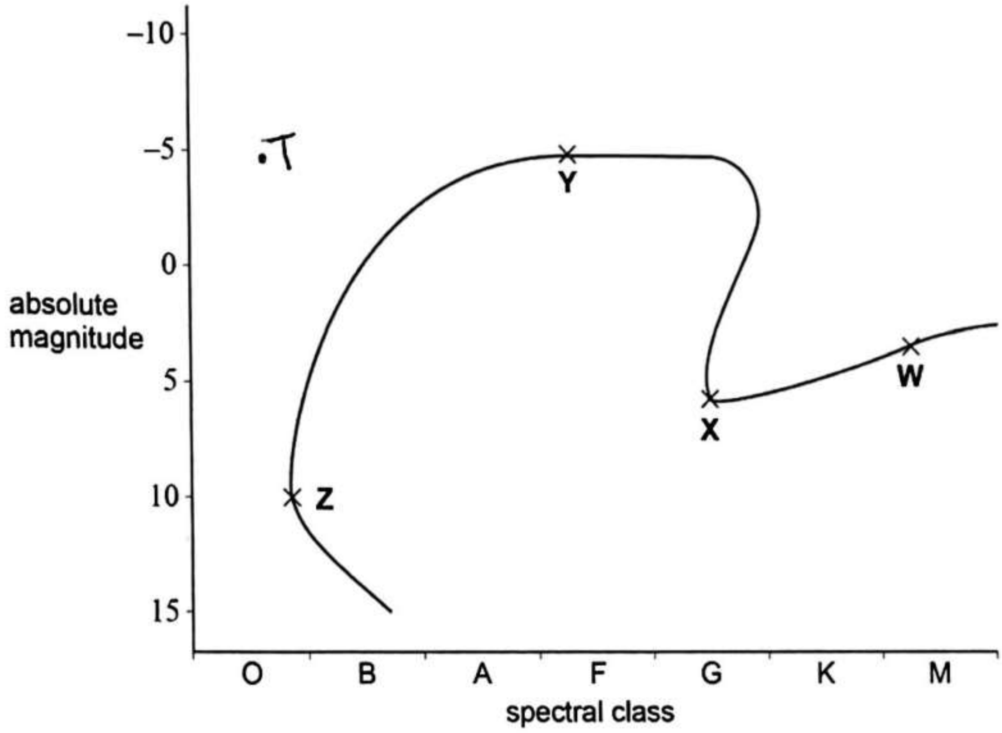
For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

Section B

Answer **all** questions in this section.

0 1 **Figure 1** shows the evolution of a star similar to the Sun on a Hertzsprung-Russell (HR) diagram.

Figure 1



0 1 . 1 State the evolutionary stage of the star at each of the points **W**, **X**, **Y** and **Z**.

[3 marks]

W Protostar

X main sequence star

Y Red giant

Z white dwarf.

Theta Carinae is a star with a radius five times that of the Sun. It has a surface temperature of 31 000 K.

0 1 . 2 Annotate **Figure 1** with a **T** to show the position of Theta Carinae.

[1 mark]

An astronomer suggests that an Earth-sized planet orbits Theta Carinae.

0 1 . 3 Explain **one** difficulty with using the transit method to detect this planet.

[2 marks]

The transit method measures how much light is blocked out by the planet. This star is very large and so very little light will be blocked out by an Earth-sized planet.

0 1 . 4 The astronomer suggests that the Earth-sized planet receives a similar amount of power from Theta Carinae as the Earth does from the Sun.

The average power output of the Sun is 3.8×10^{26} W.

Determine the orbital radius of the Earth-sized planet orbiting Theta Carinae.

[5 marks]

$P = \sigma A T^4$

$= 5.67 \times 10^{-8} \times 4\pi R^2 \times 3100^4$

$= 8.0 \times 10^{30}$ W

$\frac{P_{Theta}}{P_{Sun}} = \frac{8.0 \times 10^{30}}{3.8 \times 10^{26}} = 21.1 \times 10^3$

$\Rightarrow$ planet must be $\sqrt{21.1 \times 10^3}$ times further away.

$R = 1.5 \times 10^{11} \times \sqrt{21.1 \times 10^3} = 2.2 \times 10^{13}$ m

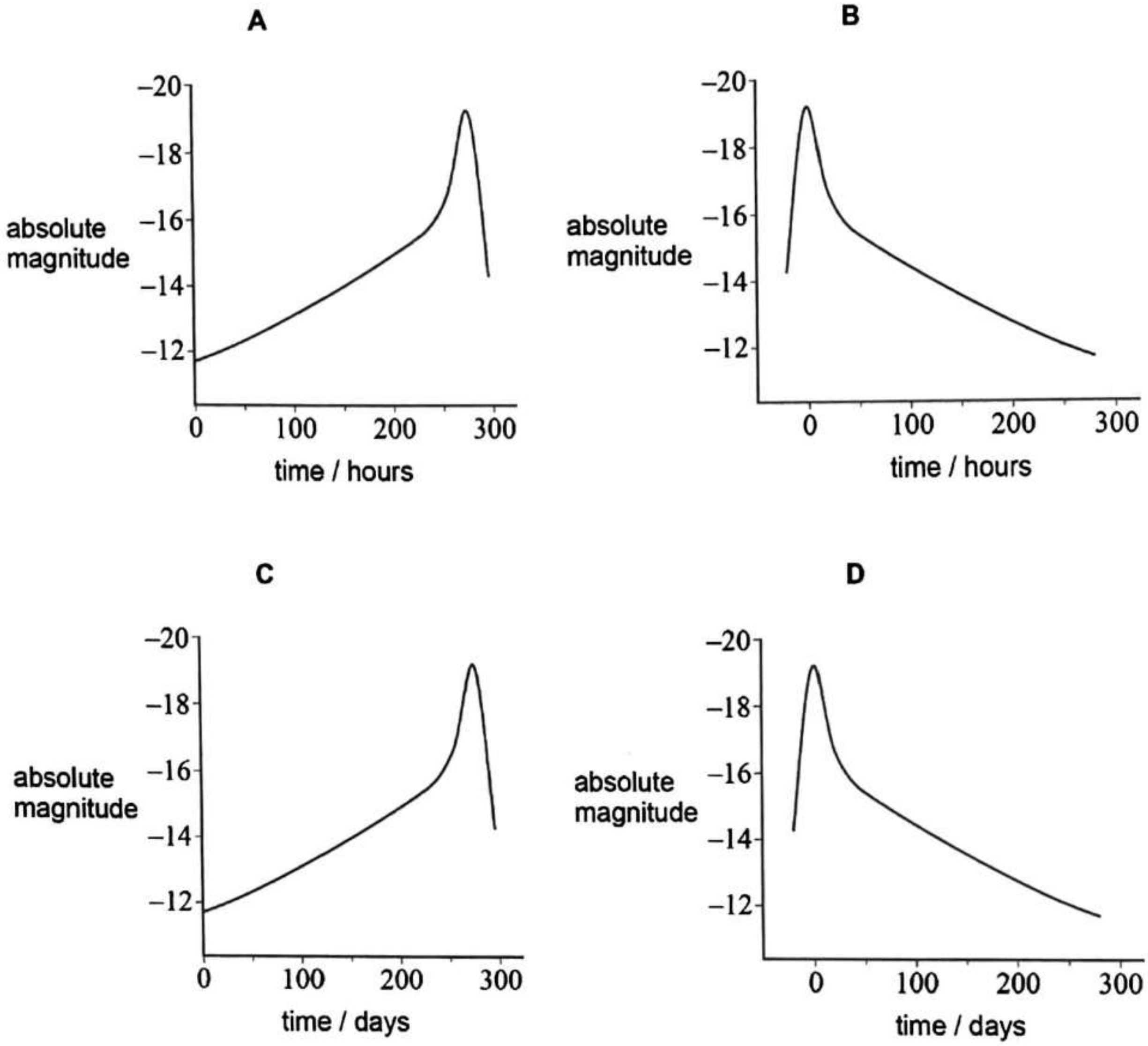
orbital radius = 2.2×10^{13} m

11

0 2 . 1 Which graph shows the light curve for a typical type 1a supernova?

Tick (✓) **one** box.

[1 mark]



A ☐

B ☐

C ☐

D ☑

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0 2 . 2 The Andromeda galaxy is approximately 7.7×10^5 pc from Earth.

Deduce whether a type 1a supernova which occurred in Andromeda can be observed from Earth with the naked eye.

[3 marks]

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

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

$$= 5\log\left(\frac{7.7\times10^5}{10}\right) - 19.3 = 5.1$$

m is less than the Hipparcos limit which is m=6 and hence this supernova cannot be seen by the naked eye.

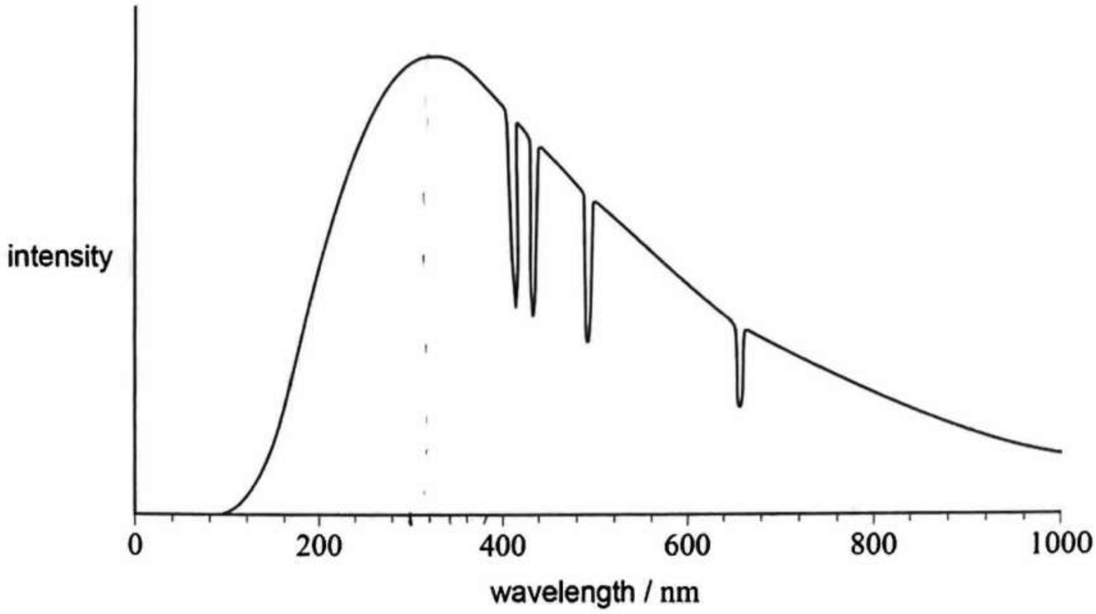
4

Turn over for the next question

0 3 Miaplacidus and Avior are two stars in the constellation Carina.
Miaplacidus is a class A star.
Avior is a class K star.

Figure 2 shows how the intensity of radiation arriving at the Earth varies with wavelength for **one** of these stars. Only the important features of the variation are shown.

Figure 2



Deduce, with reference to **Figure 2**, the identity of the star.

In your answer you should:

- explain the overall shape of the graph
- describe the processes in the star that lead to the decreases in intensity
- state the identity of the star.

[6 marks]

The overall shape shows a black body spectrum where λ_{max} is inversely proportional to the temperature. The dips in the spectrum are due to absorption of particular wavelengths by gasses in the outer layers of the star.

This star is miaplacidus (class A) because $T = \frac{2.9 \times 10^{-3}}{320 \times 10^{-9}} = 9000\ K$

So the temperature is class A.

6

Turn over for the next question

0 4 IC2497 is a galaxy that contained a quasar. It is believed that the quasar stopped emitting radiation several thousand years ago.

0 4 . 1 Suggest why the quasar stopped emitting radiation.

[2 marks]

Quasars are formed around black holes. The black hole at the centre of IC2497 no longer has matter falling into it.

0 4 . 2 IC2497 has a red shift of 0.0516

Determine the distance from the Earth to IC2497.
Give an appropriate unit for your answer.

[4 marks]

$z = \frac{v}{c}$ so $v = zc = 0.0516 \times 3.0 \times 10^8$

$= 1.55 \times 10^7 \text{ ms}^{-1}$

$= 1.55 \times 10^4 \text{ kms}^{-1}$

$v = Hd$ so $d = \frac{v}{H} = \frac{1.55 \times 10^4}{65}$

$= 238 \text{ Mpc}$.

distance = 238 unit = Mpc.

6

0 5 . 1 Explain what is meant by the Rayleigh criterion.

[2 marks]

The Rayleigh criterion identifies the minimum subtended angle between 2 objects whose images can be resolved. This minimum angle is when the central maximum of one object coincides with the first minimum of the second object.

0 5 . 2 A telescope uses wavelengths in the range 90 nm to 120 nm.

Explain why this telescope must be located in space.

Go on to discuss **one** advantage that this telescope has compared to a telescope with the same aperture that uses visible light.

[3 marks]

The telescope is detecting U-V wavelengths which are shorter than visible light. The U-V is absorbed by the ozone and so the telescope must be in space. U-V light gives a better resolution because ~~the~~ shorter wavelengths diffract less.

Question 5 continues on the next page

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Do not write outside the box

0 5 . 3 **Table 1** shows information about two telescopes.

Table 1

Telescope	Diameter / m	Dish shape
Arecibo	305	spherical
Lovell	76	parabolic

Each telescope detects radio waves with a wavelength of 21 cm.

Compare the performances of the telescopes in **Table 1** when both are used to observe the same faint radio objects.

[3 marks]

Collecting power ∝ diameter^2.

$\Rightarrow \frac{\text{Arecibo}}{\text{lovell}} = \frac{305^2}{76^2} = 16.1$

Resolving power

$\theta = \frac{\lambda}{D} \Rightarrow \propto \frac{1}{D}$.

$\frac{\text{Arecibo}}{\text{lovell}} = \frac{76}{305} = 0.25$.

Arecibo is creates a brighter image but Lovell will likely have better detail because the parabolic shape will remove spherical aberration.

8

END OF QUESTIONS