

Please write clearly in block capitals.

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

Surname

StemUp Model Solution

Forename(s)

Candidate signature

A-level PHYSICS

Paper 3

Section B Astrophysics

Thursday 29 June 2017

Morning

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.
- 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	



J U N 1 7 7 4 0 8 3 B A 0 1

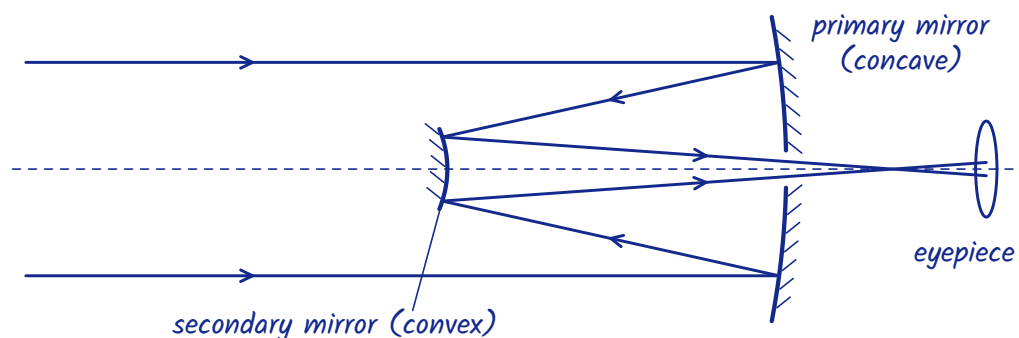
Section B

Answer **all** questions in this section.

0 1

Draw the ray diagram for a Cassegrain telescope. Your diagram should show the paths of two rays, initially parallel to the principal axis, as far as the eyepiece.

[2 marks]



2

0 2

The Kielder Observatory in Northumberland includes two optical telescopes attached to the same mount, so that they can be used to view the same object. Some of the properties of these telescopes are summarised in **Table 1**.

Table 1

Telescope	Type	Objective diameter/mm
A	refractor	70
B	reflector	400

0 2 . 1

The telescopes are used to view the same object.

Suggest which telescope in **Table 1** produces the brighter image. Support your answer with a suitable calculation.

[3 marks]

$$\text{Collecting power} \propto \text{area of objective} \propto D^2$$

$$B : A = 400^2 : 70^2 \text{ so } (400 \div 70)^2 = 32.7$$

B collects about 33 times as much light as A

The brightness of the image depends on the collecting power, which is proportional to D^2 (the area of the objective).

B has the larger diameter, so B (the reflector) gives the brighter image.



0 2 . 2

The minimum angular resolution of a telescope can be determined using the Rayleigh criterion.

Explain what is meant by the Rayleigh criterion.

[2 marks]

Two objects (point sources) can just be resolved when the centre of the central maximum of the diffraction pattern (Airy disc) of one image coincides with the first minimum (edge of the Airy disc) of the diffraction pattern of the other image.

Any closer than this and the two images cannot be distinguished.

0 2 . 3

Discuss which of the two telescopes in **Table 1** would be better at resolving the images of two objects that are close together.

[2 marks]

B is better, because it has a much larger objective diameter (400 mm compared with 70 mm).

The minimum angular resolution $\theta \approx \lambda/D$, so the minimum angular separation that can be resolved depends on $1/D$. For the same wavelength B can resolve objects about $400/70 \approx 5.7$ times closer together than A.

7

Turn over for the next question

Turn over ►



0 3

Table 2 summarises some of the properties of four stars in the constellation Hercules.

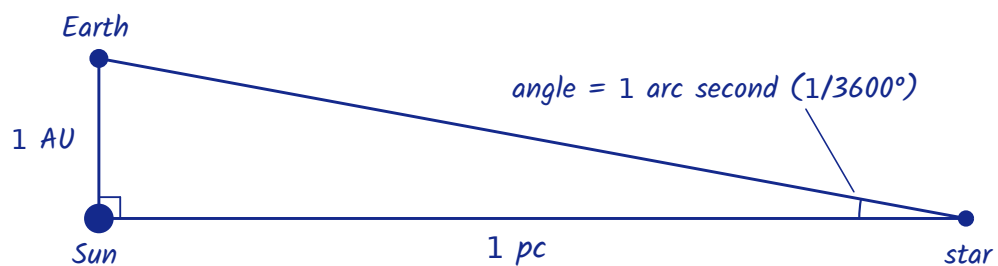
Table 2

Star	Distance/pc	Spectral class	Apparent magnitude
Kornephoros	43	G	2.8
Rasalgethi	110	M	3.0
Rutilicus	11	G	2.8
Sarin	23	A	3.1

0 3 . 1

Define the parsec. You may use a diagram as part of your answer.

[2 marks]



One parsec is the distance at which 1 AU (the mean Earth to Sun distance) subtends an angle of 1 arc second, i.e. $1/3600$ of a degree.

0 3 . 2

Deduce which star is larger, Kornephoros or Rutilicus.

[3 marks]

Both stars are spectral class G, so they have similar (about the same) surface temperatures.

They have the same apparent magnitude (2.8), but Kornephoros is much further away (43 pc compared with 11 pc), so Kornephoros must have a greater power output (luminosity), i.e. a brighter absolute magnitude.

By Stefan's law $P = \sigma AT^4$, with the same T , a greater P means Kornephoros has a greater surface area, so Kornephoros is the larger star.



03.3

One of the four stars has the peak in its black-body radiation curve at a wavelength of $1.0 \mu\text{m}$.

Calculate the corresponding temperature for this curve.

[2 marks]

$$\text{Wien's law: } \lambda_{\text{max}} T = 2.9 \times 10^{-3} \text{ m K}$$

$$T = 2.9 \times 10^{-3} \div 1.0 \times 10^{-6}$$

$$T = 2900 \text{ K}$$

temperature = 2.9×10^3 K

03.4

Explain which star produced the black-body radiation curve described in question 03.3.

[2 marks]

Spectral class is related to temperature: a temperature of about 2900

K corresponds to spectral class M (red star, below about 3500 K).

Rasalgethi is the only class M star in Table 2, so it is Rasalgethi.

03.5

Which star has the brightest absolute magnitude?
Tick (✓) the correct box.

[1 mark]

Kornephoros

☐

Rasalgethi

☒

Rutilicus

☐

Sarin

☐

Question 3 continues on the next page

Turn over ►



03.6

Determine the absolute magnitude of Sarin.

[3 marks]

$$m - M = 5 \log(d/10) \quad \text{with } d \text{ in parsecs}$$

$$3.1 - M = 5 \log(23/10) = 5 \log(2.3)$$

$$3.1 - M = 1.8$$

$$M = 3.1 - 1.8 = 1.3$$

absolute magnitude = 1.3

13



Turn over for the next question

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

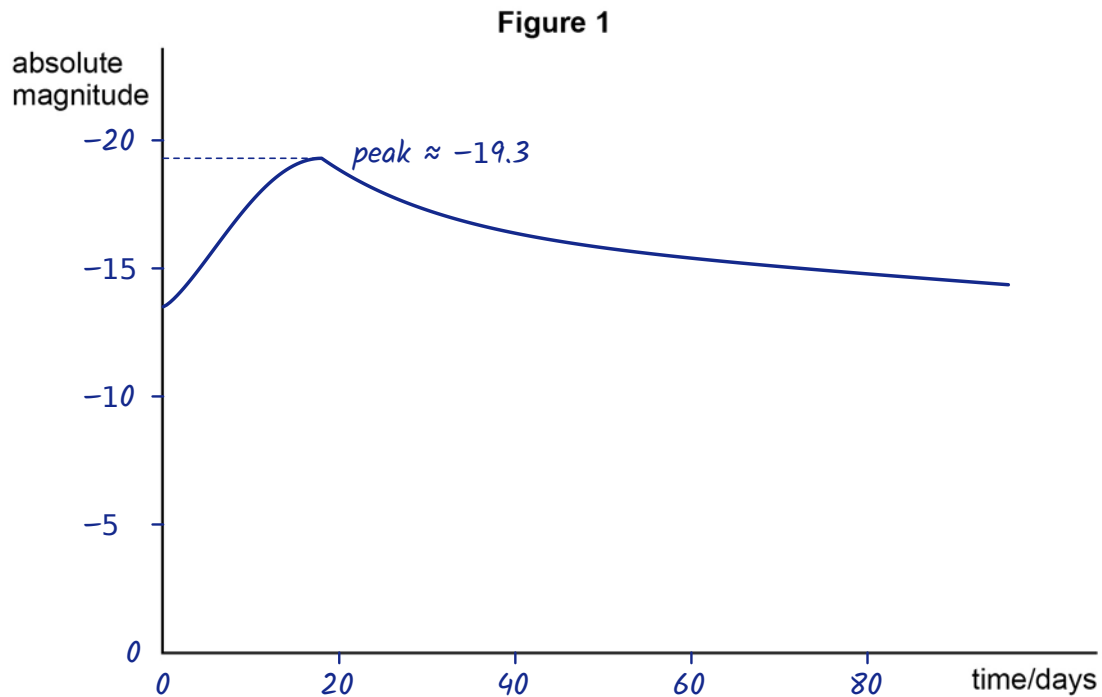
Turn over ►



0 4 . 1

Sketch, on the axes in **Figure 1**, the light curve for a typical type 1a supernova. Label the axes with suitable scales.

[3 marks]



0 4 . 2

Type 1a supernovae can be used as standard candles.

Explain what is meant by a standard candle.

[1 mark]

*An object whose absolute magnitude (luminosity) is known, so
measuring its apparent magnitude allows its distance to be calculated.*



0	4	.	3
---	---	---	---

Measurements of type 1a supernovae in 1999 led to a controversy concerning the behaviour of the Universe.

Describe this controversy and how the measurements led to it.

[3 mark]

The 1999 measurements showed that distant type 1a supernovae were dimmer (further away) than predicted from their redshift using Hubble's law, so the measurements did not agree with predictions.

This suggested that the expansion of the Universe is accelerating (expanding at an increasing rate), rather than slowing down as expected.

It is controversial because there is no known energy source for this accelerated expansion; it is explained by an unknown dark energy.

7

Turn over for the next question

Turn over ►



0	5
---	---

According to NASA nearly 2000 exoplanets had been discovered by 2016, and the search continues. One aim of this search is to find an Earth-like planet orbiting a Sun-like star.

Discuss the difficulties associated with the detection of an Earth-like planet orbiting a Sun-like star.

In your answer you should compare the methods that are used in the search and suggest which may be the most successful.

[6 marks]

Detecting an Earth-like planet is difficult because it is small, has a small mass compared with a Sun-like star, is very close to its star and is very faint and cool compared with it.

Transit method: when the planet passes in front of the star (from our point of view) the star's brightness dips periodically. The orbit must be aligned with our line of sight to eclipse the star, so many planets are never seen. An Earth-like planet is small, so the dip is tiny (about 0.01%), and with a one-year orbit there is only one transit per year, but it can be detected with sensitive space telescopes (e.g. Kepler) provided it is not too far away.

Radial velocity (Doppler) method: the star and planet orbit their common centre of mass, so the star's spectral lines show a periodic Doppler shift (red then blue). An Earth-like planet has a mass much less than a Sun-like star, so the star's wobble is very small (about 0.1 m s^{-1}) and the shift is slight. It could be detected only with very highly sensitive spectrometers.

Direct observation (imaging): this is very unlikely to succeed, because an Earth-like planet is too small, too close to the star (tiny angular separation) and too cool and dim to be seen against the glare of the much brighter Sun-like star.

Judgement: the transit method is likely to be the most successful, since space telescopes can measure very small dips in brightness and



*most exoplanets have been found this way; radial velocity is useful to
confirm the planet and find its mass.*

6

END OF QUESTIONS



There are no questions printed on this page

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Copyright Information

For confidentiality purposes, from the November 2015 examination series, acknowledgements of third party copyright material will be published in a separate booklet rather than including them on the examination paper or support materials. This booklet is published after each examination series and is available for free download from www.aqa.org.uk after the live examination series.

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team, AQA, Stag Hill House, Guildford, GU2 7XJ.

Copyright © 2017 AQA and its licensors. All rights reserved.

