# Mark schemes

**1** (a) App magnitude is how bright object appears in sky
Abs magnitude is how bright object would appear if 10 parsecs away

*Magnitude must be related to brightness or max 1*

**2**

(b) Use of $I = P / 4\pi r^2$
$9.8 \times 10^{27}$
W

**3**

(c) Sirius (is closer)

Sirius is 10 pc from Earth or apparent magnitude = absolute magnitude

Explains that data shows that Regel would appear ( much) brighter if at 10 pc but is seen to be much dimmer (so must be further away)
**OR**
Appears brighter

Even though it has a lower luminosity / even though it has a lower surface temperature

**2**

**[7]**

**2** (a) (i) apparent magnitude: brightness as seen from Earth **(1)**

(ii) absolute magnitude: inherent brightness or brightness seen from 10 pc **(1)**

**2**

(b) (i) distance = $\frac{470}{3.26}$ = 144 (pc) **(1)**

(ii) $m - M = 5 \log\left(\frac{d}{10}\right)$ **(1)**

$m = -4.2 + 5 \log\left(\frac{144}{10}\right) = 1.6$ **(1)**

(allow C.E. for value of *d* from (i))

(iii) Elnath **(1)**
reason: (either by calculation or reference to – 4.2 being brighter than – 3.2)
Elnath is actually dimmer than Bellatrix **(1)**
but appears to have same brightness, so must be closer **(1)**

**6**

**[8]**

**3** (a) Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidates answer should be assessed holistically. The answer will be assigned to one of 3 levels according to the following criteria:

**0 marks**

**Level 1 (1-2 marks)**
Lower level (Poor to limited): 1 or 2 marks
The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.
Calculations:
No relevant calculations. At 1 mark the time period may be quoted as 2 days rather than four.
Discussion
Only one graph discussed (or both very poorly).
At 1 mark there may some attempt to discuss eclipsing or going towards / away.
At 2 marks one discussion will be more correct.

**Level 2 (3-4 marks)**
Intermediate level (Modest to adequate): 3 or 4 marks
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.
Calculations:
Some attempt to use Doppler equation. At four marks there may be only a couple of minor errors.
Discussion:
Correctly links at least one graph to the movement of the two stars in terms of eclipsing or movement relative to each other and the Earth.

**Level 3 (5-6) marks**
High level (good to excellent): 5 or 6 marks.
The information conveyed by the answer is clearly organised, logical and coherent using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.
Calculations:
Doppler equation applied correctly (perhaps a minor error at 5 marks).
At the highest level, the use of 4 days and velocity to give the radius may be seen.
Discussion:
2 graphs discussed. Mostly correct. At 5 marks there may be some minor incorrect statements − e.g. referring to red shift rather than Doppler shift.

**Examples of the points made in the response**

The explanations expected in a good answer should include most of the following physics ideas:

The time period, T, is the time from the first dip in the light curve to the third dip. (I)
This is approximately 4 days. (L)
This is one full cycle for the wavelength graph. (I)
One full cycle is approximately 4 days. (I)
When one star passes in front of the other the amount of light received changes. (L)
The brightest (lowest value of) apparent magnitude occurs when both stars can be seen. (I)
The dips occur when one star is in front of the other. (I)
The similarity in the dips suggests that both stars have similar temperatures / sizes. (H)
The variation in wavelength is due to the Doppler effect. (I)
The peaks and troughs occur when the stars are moving at their greatest velocity away from / towards us. (H)
The biggest change in wavelength is 656.52 nm - 656.28 nm = 0.24 nm. (I)
The orbital speed, v, is therefore $\Delta\lambda \times c / \lambda$ (I)

= 0.24 × 3 × 108 / 656.28 = 1.1 × $10^5$ ms−1. (H)

The orbital radius is therefore v / (2π / T) = 6.1 × $10^9$ m. (H)

*The letter next to each statement suggests the minimum level of answer the statement may be seen in.*

**6**

(b) The temperature (9200K) indicates that the star is in spectral class A. ✓

Hydrogen Balmer lines are strongest in A class stars and therefore would be more easily measured. ✓

*Reference to class A not essential if it is clear that stars contain hydrogen in n = 2 state.*

**2**

(c) m – M = 5 log (d / 10)
d (in parsec) = 7.7 × $10^{17}$ / 3.08 × $10^{16}$ = 25 pc ✓
dimmest m = 1.981 ✓
dimmest M = 1.981 – 5 log (25 / 10)
= −0.009 ✓

*Allow range 1.980 to 1.982 for m.*

*Allow c.e. for either d or m.*
*If both incorrect, no marks are awarded.*

**3**

**[11]**

**4** (a) use of m-M = 5 log (d/10) **(1)**

to give –2.8 = 5 log (d/10) **(1)**

and therefore d = 2.75 pc **(1)**

**3**

(b) (i) use of PA/PB = $\sigma A_a T_a^4 / (\sigma A_b T_b^4)$

gives PA/PB = $(2400/12)^2(10000/25000)^4$ **(1)**

= 1(.024) × $10^3$ **(1)**

**2**

(ii) difference in apparent (or absolute) magnitude = 9.8 **(1)**

so difference in brightness = $2.5^{9.8}$

= 7.9(4) × $10^3$ **(1)**

**2**

(iii) the spectrum of a star is related to its temperature **(1)**

hotter stars produce a lot of power outside the visible region **(1)**

the absolute (or apparent) magnitude refers to brightness – the visible region of the spectrum **(1)**

**3**

**[10]**

**5** (a) brightness (or apparent magnitude) of star from a distance of 10 pc **(1)**

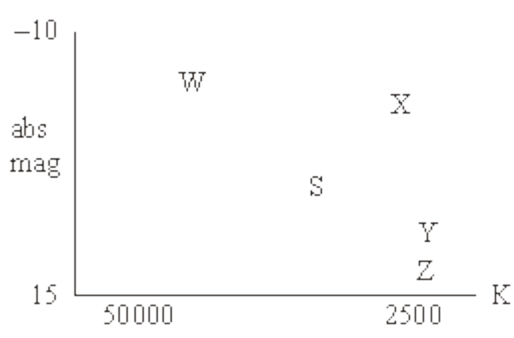
**1**

(b) (i) temperature from 50000 K to 2500 K **(1)**
absolute magnitude from +15 to –10 **(1)**

(ii) S at 6000 K, and abs mag 5 **(1)**

(iii) W above and to left of S **(1)**
X above and to right of S **(1)**
Y below and to right of S **(1)**
Z below and to right of S **(1)**

**7**




**[8]**

# Examiner reports

**1**

(a) Relatively few students identified magnitude with brightness and clear coherent responses were rare. Relatively few mentioned 10 pc when they were referring to absolute magnitude. Most who discussed this only referred to them being at the same distance.

(b) Most students identified the correct unit and a good proportion realised that the inverse square law had to be applied but correct answers were rare.

(c) Relatively few were able to give a convincing explanation as to why the data suggested that Sirius was closer. The data clearly suggested that Sirius is 10 pc from Earth and this was identified by some students. Explaining why the data suggested that Rigel was further away proved more difficult.

**2**

The definitions of apparent magnitude and absolute magnitude in part (a) were well known although some candidates used the term magnitude in their answers for which no credit was then given.

In part (b) the calculations were usually correct. Although full credit was given in part (iii) to answers which simply calculated the distance to Elinath, the most able candidates argued correctly, on the basis of values of apparent magnitude and absolute magnitude, that Elinath was the closer of the two stars.

**3**

Question (a) gave students an opportunity to show what they know about eclipsing binary stars and the full range of marks were awarded. At the highest level, answers were seen that correctly described how the motion of the two stars gives rise to each graph, with calculations of the time period, orbital speed and, in some cases, orbital radius. Some students incorrectly suggested that the change in apparent magnitude was due to changing distances, rather than one star blocking the other. There was some confusion with students suggesting that low apparent magnitudes means dimmer, and the time period was incorrectly given as 2 days, or 8 days, in some answers. Some students also confused the Doppler shift of the second graph with cosmological red shift and suggested using Hubble's Law to determine the distance to the binary system. The guidance booklet for astrophysics, available on the AQA website, includes an analysis of a binary system that may be helpful to teachers and students unfamiliar with this area.

Many students correctly identified the stars as class A, but fewer went on to say that these stars would have strong Hydrogen Balmer lines and therefore make measurement easier.
Many students are clearly well practised in the use of the magnitude-distance equation. Some were confused about the unit of distance to use in the equation, however, and some had difficulty determining the value of the apparent magnitude when the system was dimmest.

**4** The calculation of distance using apparent and absolute magnitudes in part (a) was very well done on the whole. Common errors included; the use of natural logarithms rather than base 10; using incorrect values for the magnitudes, so that the difference became +2.8 rather than .2.8 for example; and algebra problems. This question provided the opportunity to test units, and most candidates knew that the equation provided a distance in parsec. Other units of distance were not given credit unless they were consistent with the method of calculation.

Most candidates knew that the calculation in part (b) (i) required the use of Stefan's Law and either calculated the ratio, cancelling the constants or calculated each power separately and worked out the ratio, both of which could gain full credit. Although this question was generally well answered, some candidates did not square the diameters (or radii) of the stars. Several candidates also calculated the volumes of the stars rather than their surface areas.

In part (b) (ii), generally, the relationship between apparent magnitude and brightness was not understood well. There were some imaginative attempts to obtain the value of 8000. The best answers stated that a difference in magnitude of 5 was equivalent to a difference in brightness of 100, and used this and the difference in magnitudes to obtain the correct answer. The use of Pogson's Law was another acceptable method of obtaining the correct answer.

Part (b) (iii) tested the students understanding of the relationship between temperature and spectra and it was generally poorly answered. It was common to see answers which tried to involve the surface area of the stars, rather than concentrating on the difference in the amount of their power output that would be in the visible region. The best answers often quoted Wien's Law, with many candidates even calculating the values of the wavelength of the peak in the intensity curve. They then went on to state that, being hotter, Sirius B produced more of its total power output in the UV region compared to Sirius A. The ratio of brightness is therefore much greater than the power ratio as the absolute magnitude deals with only visible light, whereas the power output is across all wavelengths.

**5** In part (a) correct definitions of absolute magnitude were common. Incorrect answers quoted 1 pc rather than 1 O pe as the distance, or did not include a distance at all. Stating the answer as 'the magnitude of a star at 10 pc' gained no credit. It was clear from other answers that some candidates think that the magnitude of a star is its size.

The Hertzsprunsg-Russell diagram, in part (b) has been a regular feature of this examination, in recognition of its importance in astronomy. There were many marks available for this section but relatively few candidates were awarded them all. In part (i) there were problems with the scales, getting the values the wrong way round or out of the acceptable range. The absolute magnitude axis was often labelled as relative luminosity and the temperature scale replaced by OBAFGKM. In part (ii) positioning the Sun caused problems. It was easiest to award in cases where the absolute magnitude (5) and temperature (≈ 6 000 K) were marked on the axes. A lot of flexibility was allowed in part (iii) in the positions of the four stars. The most common mistake was placing Y at the same absolute magnitude as the Sun. A star the same size as the Sun but significantly cooler should, according to Stefan's Law, be dimmer. Star Z was commonly placed in the White Dwarf area, presumably to make the diagram symmetrical.