M1.(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)

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

The orbital radius is therefore $v / (2\pi / T) = 6.1 \times 10^9$ 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) $= 7.7 \times 10^{17} / 3.08 \times 10^{16} = 25$ 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]

M2.(a) Spectral class A✓

1

The temperature range for A class is 7500 K to 11 000 K✓

1

(b) Lowest value of apparent magnitude indicates the brightest star. ✓

1

Vega has the lowest apparent magnitude (so is brightest) ✓

1

(c) Closest of three stars is Altair✓

1

Using $m - M = 5 \log (d / 10)$

To give $0.77 - 2.21 = - 1.44$✓

1

And $d = 5.2$ pc✓

Allow ce for calculation of wrong star

1

(d) Deneb is the largest✓

No mark for unsupported answer

1

It has approximately the same temperature, but has a much brighter absolute magnitude and therefore greater power ouput✓

1

To have a much greater power output for a similar temperature, it must have a greater area✓

As $P = \sigma A T^4$

1

Allow alternative:
from position on HR diagram, from T and M,
Altair and Vega are main sequence stars
Deneb is a giant star
so Deneb largest.

(e) Using $\lambda_{max} T = 0.0029$

1

To give $\lambda_{max} = 0.0029 / 7700$✓

$= 3.8 \times 10^{-7}$ m✓

1

[12]