M1.(a) Apparent magnitude at a distance of 10pc

Allow "brightness".
Do not allow luminosity or magnitude.

1

(b) Absolute magnitude from 15 to -10
Temperature from 50 000K to 2500K

Allow 15 to -15.
Allow 50 000 to 3500 K.

2

(c) (i) S at 5700 K and abs mag 5

The position of S should be consistent with the scales on the axes. Allow ce on scale.
Allow 6000 for T.
If labels not present, or if only correct extreme values on scale, S should be to the right of and below the centre.

1

(ii) W at same abs mag as S, but further to left

Judgements on ii – iv should be based on the position of S. If S is not labelled, it should be based on where S should be.

1

(iii) X at same temperature as S but greater absolute magnitude

1

(iv) Y at same abs mag or above S, on the right hand side of the diagram

1

(d) Similar power output ✓
but is hotter ✓
Ref to $P = \sigma A T^4$ hence W must have smaller diameter than the Sun ✓

Allow luminosity for Power.
Answer must be supported to get the mark.

3

[10]

M2.(a) (i) Similarity both would appear the same brightness
As the apparent magnitudes are the same ✓

Description and explanation needed for mark.

Any references to same size gets zero for 1st mark.

Difference Kocab would appear orange / red, Polaris yellow / white
Due to their spectral classes / different temperatures ✓

Allow different colours + ref to spectral class for second mark

If colour named, should be correct.

2

(ii) Polaris is further from Earth:

Alternative:

Polaris hotter and same size

Both stars same size and Polaris is hotter ✓

As $P = \sigma AT^4$

Hence, Polaris has brighter absolute magnitude / is intrinsically brighter

Same A, would mean that Polaris has greater power output. ✓

Polaris must be further from Earth to appear same brightness as Kocab. ✓

Same apparent brightness, therefore Polaris is further away.

3

(b) (i) $v = Hd$

$v = 0.025 \times 3 \times 10^5 = 7.5 \times 10^3$ km s^{-1} ✓

1st mark is for calculating v

$d = 340 \times 10^6$ l yr = 340 / 3.26 Mpc = 104 Mpc ✓

2nd mark is for working out d in Mpc

$H = 7.5 \times 10^3 / 104 = 72$ kms^{-1} Mpc^{-1} ✓

3rd mark is for calculating H in the correct unit.

3

(ii) Age of Universe = 1 / H

1st mark is for the equation

$= 0.014 \times 10^6 \times 3.26 \times 9.5 \times 10^{15} / 1000$

2nd is for the answer with working

$= 4.3 \times 10^{17}$ seconds

(= 13.6 billion years)

Unit consistent with calculation.

3rd is for a time unit consistent with their answer / working

3

[11]

M3. (a) (i) the brightness of a star as it would appear from a distance of 10 pc ✓

1

(ii) Betelgeuse

Bellatrix is actually a lot brighter than Betelgeuse (the absolute magnitude is a lot more negative), but only appears to be a bit brighter (the apparent magnitude is only a little smaller) so Betelgeuse must be closer ✓

1

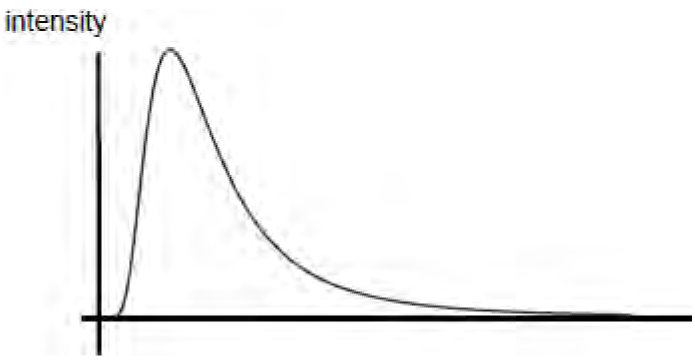
(b) (i) use of $\lambda_{max} T = 0.0029$

gives $\lambda_{max} = 0.0029/22\,000$ ✓

$= 1.32 \times 10^{-7}$ (m) ✓

2

(ii)



steeper LHS than RHS ✓

intensity goes towards zero as the wavelength goes to end of axis ✓

wavelength scale with peak near 130 nm ✓

3

(c) (i) B ✓

1

(ii) helium ✓

1

(iii) temperature too low (for atmosphere of Betelgeuse to have hydrogen in n=2 state) ✓

1

[10]

M4. (a) (i) Segin: spectral class B is hottest **(1)**

(ii) Shedir: class K is closest towards red end **(1)**

(iii) Shedir: 2.2 is smallest value of apparent magnitude **(1)**

(iv) Achird: apparent magnitude lower (brighter) than absolute magnitude and they are equal when star is 10 pc away **(1)**

4

(b) (i) (use of $m - M = 5 \log(d/10)$ gives) $2.2 - (-4.6) = 5 \log\left(\frac{d}{10}\right)$ **(1)**

d = 229 pc **(1)**

(ii) (use of $\lambda_{max}T = 0.0029$ gives) $\lambda_{max} = \frac{0.0029}{12000} = 2.4(2) \times 10^{-7}$ m **(1)**

3

[7]

M5. (a) (i) P has the lowest peak wavelength (λ_{max}) **(1)**
(since) $\lambda_{max}T$ = constant, lowest λ_{max} means highest T **(1)**
[or P has highest peak intensity **(1)**
intensity is power per unit area, or ref to Stefan's law **(1)**]

(ii) $\lambda_{max} = 300 \times 10^{-9}$(m) **(1)**
(use of $\lambda_{max}T = 0.0029$ gives) $T = 9.7 \times 10^{3}$K **(1)** (9.67×10^{3} K)

max 3

(b) (i) A and B **(1)**

(ii) light from the star passes through the atmosphere of the star **(1)**
which contains hydrogen with electrons in n = 2 state **(1)**
electrons in this state absorb certain energies and (hence) frequencies of light **(1)**
the light is re-emitted in all directions, so that the intensity of these frequencies is reduced in any given direction,
resulting in absorption lines **(1)**

max 4

[7]