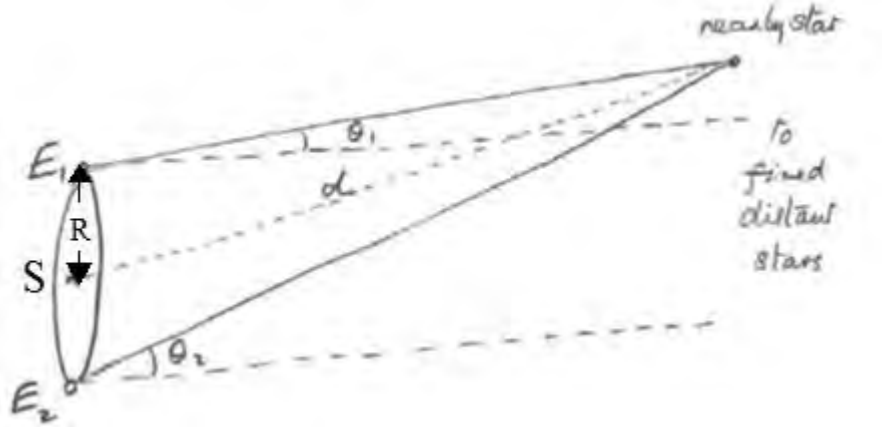
Question Number	Answer		Mark
1(a)(i)	**MAX 3** The star is viewed from two positions at 6 month intervals **Or** opposite ends of its orbit diameter about the Sun	**(1)**	
	The change in angular position of the star against background of fixed stars is measured	**(1)**	
	Trigonometry is used to calculate the distance to the star [Do not accept Pythagoras]	**(1)**	
	The diameter/radius of the Earth's orbit about the Sun must be known	**(1)**	
	Full marks may be obtained from a suitably annotated diagram e.g  [Accept 1 AU for R and the symmetrical diagram seen in many text books]		**3**
1(a)(ii)	(If stars are too far away) the angular displacement is too small to determine **Or** (If stars are too far away) the uncertainty in the angular displacement is too large [Accept the idea that stars appear not to move against the background of fixed/distant stars. Accept parallax angle for angular displacement.]	**(1)**	**1**
***1(b)**	**(QWC Spelling of technical terms must be correct and the answer must be organised in a logical sequence.)** The Pleiades cluster is closer to the Earth than was previously thought	**(1)**	
	So the stars are not as luminous as was previously thought	**(1)**	
	So the luminosity of similar stars in other galaxies have been overestimated	**(1)**	
	Hence the distances to other galaxies have been overestimated	**(1)**	**4**
	Total for Question		**8**

Question Number	Answer		Mark
2(a)(i)			

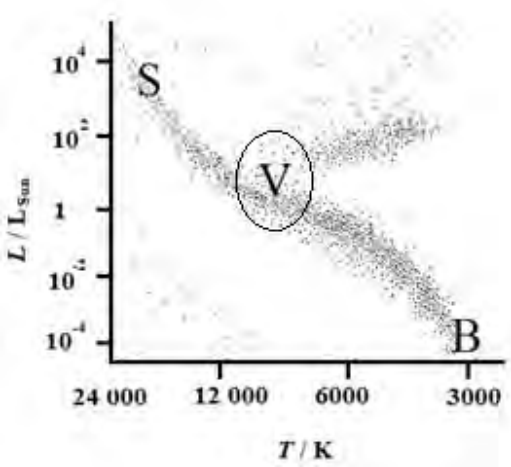
Star	Type of Star
Spica **(S)**	**Main sequence [accept blue giant]**
Vega **(V)**	**Main sequence [accept giant]**
Barnard's Star **(B)**	Dwarf

(1) **(1)**

2

2(a)(ii)

S, V and B correctly marked **(1)**



1

2(b)

Use of $\lambda_{max}T = 2.898\times10^{-3}$ **(1)**

$\lambda_{max} = 9.7 \times 10^{-7}$ m **(1)**

This is in the infra-red region (so any visible light will be in red end of spectrum) **(1)**

Example of calculation

$$\lambda_{max}T = 2.898\times10^{-3} = \frac{2.898\times10^{-3}\,\text{mK}}{3000\,\text{K}} = 9.66\times10^{-7}\,\text{m}$$

3

2(c)

Use of $L = 4\pi r^2\sigma T^4$

Or use of $L = \sigma AT^4$ and $A = 4\pi r^2$ **(1)**

$r = 1.8 \times 10^9$ m **(1)**

Example of calculation

$$r = \sqrt{\frac{L}{4\pi\sigma T^4}} = \sqrt{\frac{50.1\times3.85\times10^{26}\,\text{W}}{4\pi\times5.67\times10^{-8}\,\text{Wm}^{-2}\text{K}^{-4}\times(9500\,\text{K})^4}} = 1.82\times10^9\,\text{m}$$

2

2(d)

The brightness of a source , F, is given by $F = \frac{L}{4\pi x^2}$ where L is the luminosity and x the distance to the source

Or reference to the inverse square law for brightness **(1)**

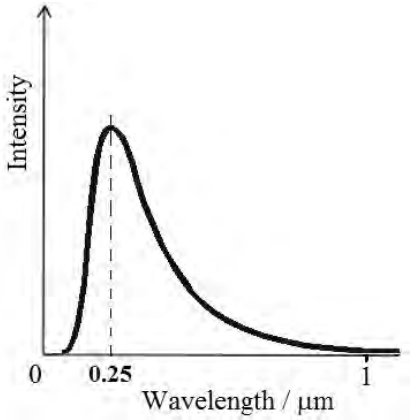
If distance is increased, then the brightness decreases [dependent upon MP1] **(1)**

Vega must be much closer than Spica **(1)**

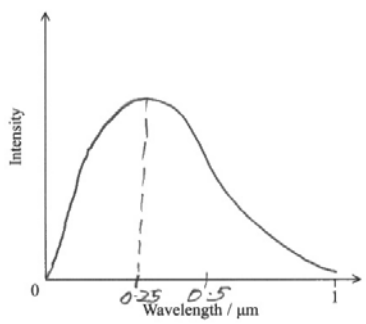
3

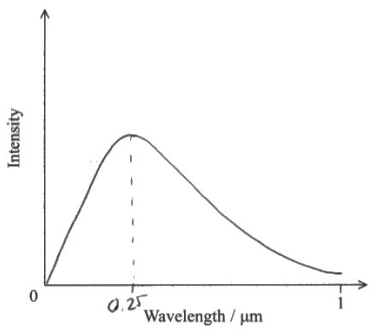
Total for Question **11**

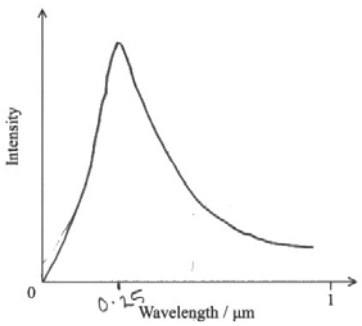
Question Number	Answer		Mark
3(a)	Curve with peak at 0.25μm (labelled or in correct position) Shape must be an asymmetric curve and must not have intensity at $\lambda = 0$	**(1)** **(1)**	**2**

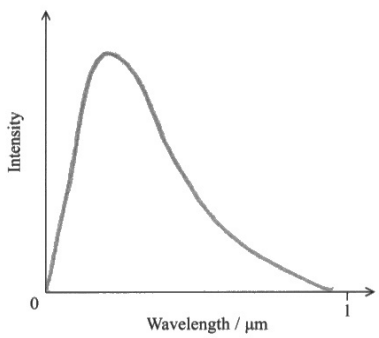


Examples of acceptable shapes:

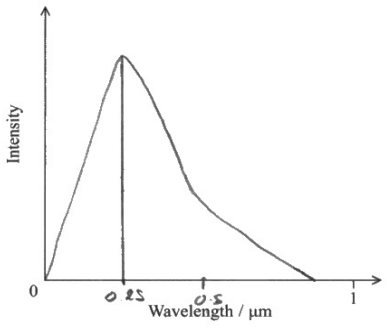


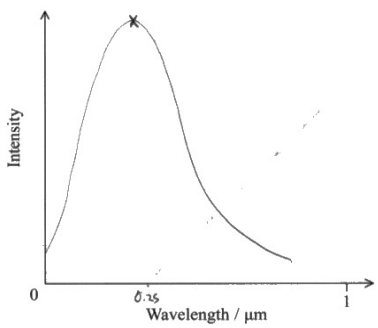




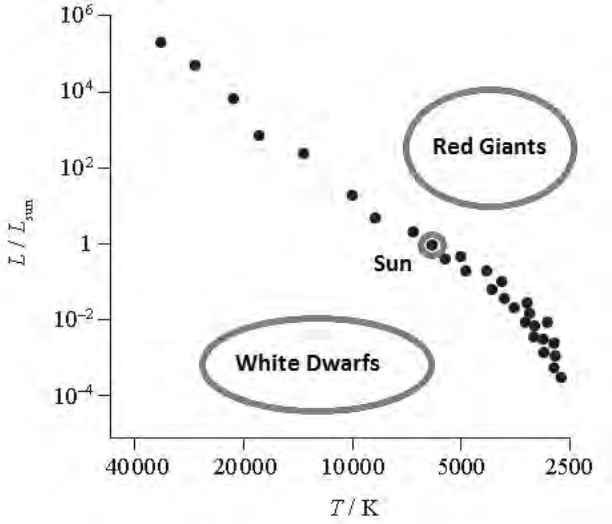


Examples of unacceptable shapes:





3(b)(i)	T = 11 500 K (allow 11 250 K to 11 750 K)	**(1)**	**1**
3(b)(ii)	At least 2 pairs of values read from graph Use of $\lambda_{max}\ T$ = constant Use values to show $\lambda_{max}\ T$ = a constant Example of calculation: $\lambda_{max}\ T = 0.25\times10^{-6}\times11500 = 2.9\times10^{-3}$ $\lambda_{max}\ T = 0.5\times10^{-6}\times5800 = 2.9\times10^{-3}$	**(1)** **(1)** **(1)**	**3**
3(c)(i)	A standard candle is a (stellar) object of known luminosity		**1**
***3(c)(ii)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Standard candle's flux/ brightness (on Earth) is measured/determined Use inverse square law [Reference to $F=L/4\pi d^2$ with symbols defined] (Hence) distance to standard candle is calculated/determined [do not accept "measure" or "find" for "calculate"] [accept star/cluster for standard candle] [accept a re-arrangement of $F=L/4\pi d^2$ with d as subject as indication that d is calculated]	**(1)** **(1)** **(1)**	**3**
3(c)(iii)	Idea that trigonometric parallax is the change in position of a star against the background of more distant stars **Or** parallax angle is the angle subtended at the star by the radius of the Earth's orbit [Mark can be obtained from a fully labelled diagram] If star is too distant the angle is too small to measure	**(1)** **(1)**	**2**
	Total for Question		**12**

Question Number	Answer		Mark
4(a)			
(i)	Sun's position identified [single point identified]	**(1)**	
(ii)	White dwarf region Red giant region	**(1)** **(1)**	**3**
***4(a)(iii**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) White dwarf stars have: high temperature T (because λ_{max} is small) low luminosity L $L = \sigma A T^4$ linked to a determination of the surface area	 **(1)** **(1)** **(1)**	**3**
4(b)	The star cools, so temperature T reduces The star contracts (under gravitational forces), so area A reduces $L = \sigma A T^4$ hence L is reduced (mark dependent upon either mp1 or mp2)	**(1)** **(1)** **(1)**	**3**
4(c)(i)	${}^{7}_{3}\text{Li} + {}^{1}_{1}\text{X} \rightarrow 2 \times {}^{4}_{2}\text{He}$ X is a proton [Accept X is hydrogen/H]	**(1)** **(1)**	**2**
4(c)(ii)	Attempt at calculation of mass difference Use of 1 MeV = 1.60×10^{-13} J $\Delta E = 2.77 \times 10^{-12}$ (J) Example of calculation: $\Delta m = 6533.8\text{MeV/c}^2 + 938.3\text{MeV/c}^2 - \left(2 \times 3727.4\text{MeV/c}^2\right) = 17.3\text{MeV/c}^2$ $\Delta E = 17.3\text{MeV}$ $\Delta E = 17.3\text{MeV} \times 1.60 \times 10^{-13}\,\text{J MeV}^{-1} = 2.768 \times 10^{-12}\,\text{J}$	**(1)** **(1)** **(1)**	**3**

4(d)	**x 4** • Extremely high temperature and density needed **(1)** • High temperature because nuclei need high <u>energy</u> to overcome the (electrostatic) repulsive force **(1)** • Since nuclei must come very close for fusion to occur **Or** since nuclei must come close enough for (strong) nuclear force to act **(1)** • Very high density is needed to maintain a sufficient collision rate **(1)** • Reference to extreme conditions leading to containment problems **(1)**	**4**
	Total for Question	**18**

Question Number	Answer	Mark
5	(Observed frequency is less, so) source is receding (from Earth) **(1)** Use of $\frac{\Delta f}{f} = \frac{v}{c}$ Or $z = \frac{\Delta f}{f}$ **(1)** $v = 1.5 \times 10^6\ \text{m s}^{-1}$ Or $z = 5.0 \times 10^{-3}$ **(1)** (min 2 sf answer required) <u>Example of calculation:</u> $\Delta f = (4.547 \times 10^{14} - 4.570 \times 10^{14})\ \text{Hz} = (-)2.3 \times 10^{12}\ \text{Hz}$ $v = \frac{c\,\Delta f}{f} = \frac{3.0 \times 10^8\ \text{m s}^{-1} \times 2.3 \times 10^{12}\ \text{Hz}}{4.57 \times 10^{14}\ \text{Hz}} = 1.51 \times 10^6\ \text{m s}^{-1}$	**3**
	Total for question	**3**

Question Number	Answer		Mark
6(a)(i)	Redshift is the (fractional) increase in wavelength received (by an observer)	**(1)**	
	Due to source and observer receding (from each other)	**(1)**	**2**
***6(a)(ii)**	**QWC – Work must be clear and organised in a logical manner using technical wording where appropriate**		
	Measure frequency/wavelength of light (from the galaxy)	**(1)**	
	Compare (measured) frequency/wavelength to the frequency/wavelength for a source on the Earth	**(1)**	
	States appropriate Doppler formula (consistent with mp1/mp2) and how it is used to calculate velocity	**(1)**	**3**
6(b)	(Standard candles are stellar) objects of known luminosity	**(1)**	**1**
6(c)	See $v = H_0 d$ and $v = d/t$ Therefore $t = 1/ H_0$ (dependent mark)	**(1)** **(1)**	**2**
6(d)(i)	If density less than critical value, expansion would continue for ever If density greater than critical, expansion would stop and universe would contract again If density equals critical value, expansion rate would decrease to zero but universe would not contract again	**(1)** **(1)** **(1)**	**3**
6(d)(ii)	The mass of the universe is uncertain because of the amount of dark matter is uncertain	**(1)**	
	The value of the Hubble constant is uncertain	**(1)**	
	Or		
	The amount of dark matter (in the universe) is uncertain Since dark matter doesn't interact via the electromagnetic interaction	**(1)** **(1)**	
	Or		
	The value of the Hubble constant is uncertain Since measurements of distances to distant galaxies are uncertain	**(1)** **(1)**	**2**
	Total for question		**13**

Question Number	Answer	Mark
7	There is a red shift [accept Doppler shift] (1) The galaxy is receding **O**r the galaxy is moving away from us (1) [Do not accept "the universe is expanding"]	**2**
	Total for question	**2**