Question Number	Answer		Mark
1(a)(i)	16 µm [accept ±1µm]	**(1)**	**1**
1(a)(ii)	Use of $\lambda_{max}T = 2.898\times10^{-3}$ Temperature = 180 K (ecf from (a)(i)) [161 K for 18 µm, 170 K for 17 µm, 193 K for 15 µm, 207 K for 14 µm] <u>Example of calculation</u> $T = \frac{2.898\times10^{-3}\text{ mK}}{16\times10^{-6}\text{ m}} = 181\text{K}$	**(1)** **(1)**	**2**
1(b)	Mass of the Sun G **Or** gravitational constant **Or** 6.67×10^{-11} ($\text{N m}^2\text{ kg}^{-2}$) [can be next to either answer prompt]	**(1)** **(1)**	**2**
1(c)	Use of $g = \frac{GM}{r^2}$ Field strength = $5.6 \times 10^{-6}\text{ N kg}^{-1}$ [accept m s^{-2}] <u>Example of calculation</u> $g = \frac{6.67\times10^{-11}\text{ N m}^2\text{ kg}^{-2}\times1.9\times10^{27}\text{ kg}}{(1.5\times10^{11}\text{ m})^2} = 5.63\times10^{-6}\text{ N kg}^{-1}$	**(1)** **(1)**	**2**
	Total for question		**7**

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>2(a)(i)</td><td>Use of $\lambda_{max}T=2.898 \times 10^{-3}$

Correct answer

Example of calculation:
$T = \dfrac{2.898 \times 10^{-3}\ mK}{5.2 \times 10^{-7}\ m} = 5570\,K$</td><td>(1)

(1)</td><td>(2)</td></tr>
<tr><td>2(a)(ii)</td><td>Use of $F=L/4\pi d^2$

Correct answer

Example of calculation:
$L = 1370\ Wm^{-2} \times 4\pi \times (1.49 \times 10^{11}\,m)^2 = 3.8 \times 10^{26}\ W$</td><td>(1)

(1)</td><td>(2)</td></tr>
<tr><td>2(a)(iii)</td><td>Use of $L=4\pi r^2 \sigma T^4$

Correct answer (7.46×10^8 m)

Example of calculation:
$r^2 = \dfrac{3.82 \times 10^{26}\ W}{4\pi \times 5.67 \times 10^{-8}\ Wm^{-2}K^{-4} \times (5570\,K)^4} = 5.57 \times 10^{17}\ m^2$
$r = \sqrt{5.57 \times 10^{17}\ m^2} = 7.46 \times 10^8\ m$

<table><tr><th></th><th>3.8×10^{-26} W</th><th>4×10^{26} W</th></tr><tr><td>5570 K</td><td>7.46</td><td></td></tr><tr><td>6000 K</td><td>6.4</td><td></td></tr></table></td><td>(1)

(1)</td><td>(2)</td></tr>
<tr><td>2(b)

QWC</td><td>The answer must be clear, use an appropriate style and be organised in a logical sequence

High temperature AND high density/pressure

Any two reasons from:
Overcome coulomb/electrostatic repulsion
<u>Nuclei</u> come close enough to fuse/for strong (nuclear) force to act
High collision rate/collision rate is sufficient</td><td>

(1)

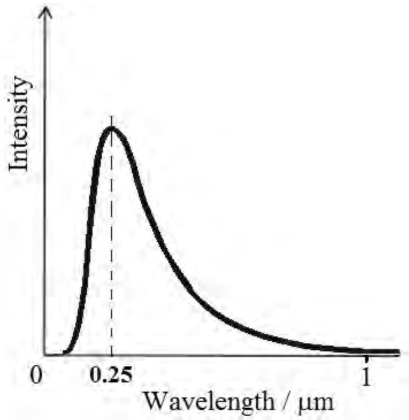
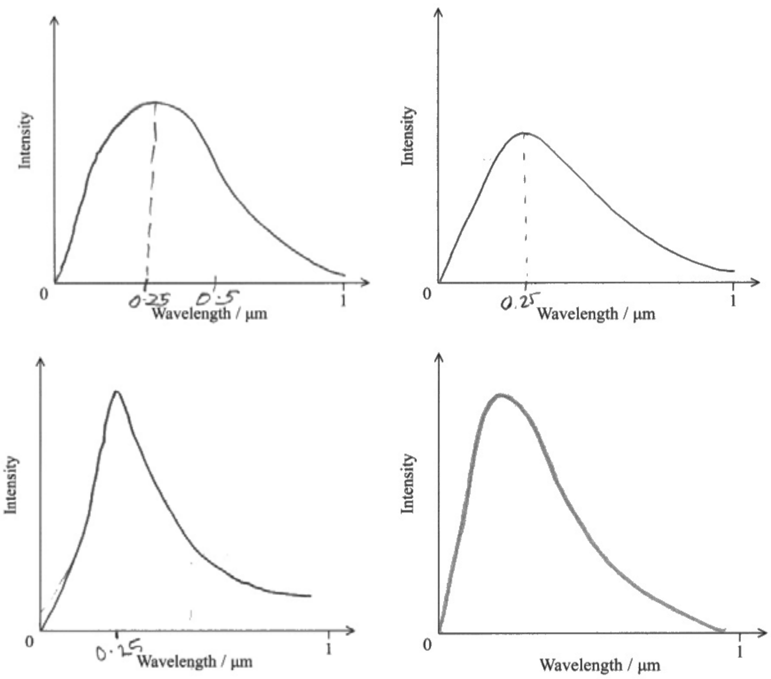
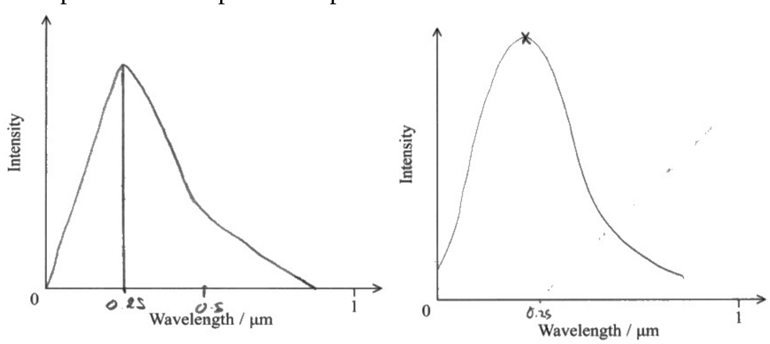
(1)
(1)
(1)</td><td>(max 3)</td></tr>
<tr><td></td><td>Total for question</td><td></td><td>(9)</td></tr>
</table>

Question Number	Answer		Mark
3(a)	Use of $P = 4\pi r^2 \sigma T^4$ Power = 2.3×10^{17} W [Temperature in ^{o}C or incorrect conversion to Kelvin can score 1st mark] <u>Example of calculation</u> $P = 4\pi(6.4\times10^{6}\text{ m})^{2} \times 5.67\times10^{-8}\text{ W m}^{-2}\text{ K}^{-4} \times (298\text{ K})^{4}$ $\therefore P = 2.3\times10^{17}\text{ W}$	**(1)** **(1)**	**2**
3 (b)	Use of $\lambda_{max}T = 2.898\times10^{-3}$ λ_{max} = 9.7×10^{-6} m [Temperature in ^{o}C or incorrect conversion to Kelvin can score 1st mark] <u>Example of calculation</u> $\lambda_{max} = \dfrac{2.898\times10^{-3}\text{ m K}}{298\text{ K}} = 9.7\times10^{-6}\text{ m}$	**(1)** **(1)**	**2**
3 (c)	Infra-red (radiation/light/wave) [accept Infrared/IR]		**1**
	Total for question		**5**

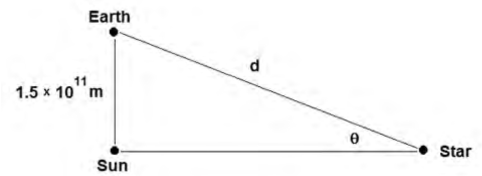
Question Number	Answer	Mark
4(a)	Use of $pV=NkT$ (1) $T =$ 870 (K) OR p = 12.4 (atmospheres) (1) If final pressure is given as 1.24×10^6 Pa, then just "use of" mark <u>Example of calculation</u>: $T = \frac{pV}{Nk} = \frac{12 \times 1.0 \times 10^5 \text{ Nm}^{-2} \times 3.00 \times 10^{-4} \text{m}^3}{3 \times 10^{22} \times 1.38 \times 10^{-23} \text{JK}^{-1}} = 869.6 \text{ K}$ OR $p = \frac{NkT}{V} = \frac{3 \times 10^{22} \times 1.38 \times 10^{-23} \text{ JK}^{-1} \times 900 \text{ K}}{3 \times 10^{-4} \text{ m}^3}$ $\therefore p = 1.24 \times 10^6 \text{Pa} = \frac{1.24 \times 10^6 \text{Pa}}{3 \times 10^{-4} \text{Pa}} = 12.4$	**2**
4(b)*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) <u>Atoms/molecules</u> would gain energy (1) <u>Atoms/molecules</u> would escape from the liquid OR liquid propellant would vaporise / turn into gas OR the amount of gas in can would increase (1) Pressure would increase due to **both** temperature/energy increase **and** increase in amount of gas OR pressure would increase more for the same temperature increase OR pressure would be greater than 12 atmospheres before 900 K (1) Can would explode before 900 K reached (1)	**Max 3**
	Total for question	**5**

Question Number	Answer	Mark
5(a)	**Max 4** Assumption: that no energy is transferred to the surroundings OR all energy transferred from washers to water OR energy required to raise temperature of container is negligible OR no water evaporates (1) Measure the mass of the washers and water (using a balance) (1) (Use a thermometer to) measure the temperature of the water before and after the washers are plunged into the water (1) Equate thermal energy lost by steel to the energy gained by water (1) Use a (standard) value for the specific heat capacity of the water OR specific heat capacity of water is known (1)	**Max 4**
5(b)(i)	Infra-red (1)	**1**
5(b)(ii)	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ (1) T = 1450 (K) OR $\lambda_{max} = 1.93 \times 10^{-6}$ (m) (1) Example of calculation $T = \frac{2.898 \times 10^{-3}\ \text{mK}}{2 \times 10^{-6}\ \text{m}} = 1450\ \text{K}$	**2**
5(b)(iii)	Use of $L = 4\pi r^2 \sigma T^4$ (1) Correct substitution of radius (1) L = 1970 W [2250W if show that value used] (1) Example of calculation $L = 4\pi \times (2.5 \times 10^{-2}\ \text{m})^2 \times 5.67 \times 10^{-8}\ \text{Wm}^{-2}\text{K}^{-4} (1450\text{K})^4 = 1970\ \text{W}$	**3**
5(b)(iv)	Curve with higher peak (1) Shifted over to left (1)	**2**
	Total for question	**12**

Question Number	Answer	Mark
6(a)	(B2 =) 2.9×10^{-3}/A2 **Or** (B2 =) $2.9 \times 10^{-3}/\lambda_{max}$ **Or** (B2=) $2.9 \times 10^{-3}/6.85 \times 10^{-7}$ **(1)** [Ignore incorrect powers of 10]	**1**
6(b)	Use of $L = \sigma T^4 A$ **(1)** $A = 0.21(48) \times 10^{19}$ (m^2) **(1)** For max 1 Use of $A = 4\pi R^2$ to give $A = 2.1(1) \times 10^{18}$ (m^2) Example of calculation: $A = \dfrac{0.392 \times 10^{26}\ \text{W m}^{-2}}{5.67 \times 10^{-8}\ \text{W m}^{-4}\ \text{K}^{-4} \times (4230\ \text{K})^4} = 2.148 \times 10^{18}\ \text{m}^2$	**2**
6(c)	Flux/brightness/intensity measured and distance to star determined **(1)** (Luminosity calculated using) $L = 4\pi d^2 F$ **(1)** **Alternative mark scheme:** Temperature and type of star identified [e.g. main sequence] **(1)**	
	Hertzsprung-Russell diagram used to find luminosity **(1)**	**2**
	Total for question	**5**

Question Number	Answer		Mark
7(a)	Curve with peak at 0.25μm (labelled or in correct position)	**(1)**	
	Shape must be an asymmetric curve and must not have intensity at λ = 0	**(1)**	**2**
	 Examples of acceptable shapes:  Examples of unacceptable shapes: 		

7(b)(i)	T = 11 500 K (allow 11 250 K to 11 750 K) **(1)**	**1**
7(b)(ii)	At least 2 pairs of values read from graph **(1)** Use of $\lambda_{max} T$ = constant **(1)** Use values to show $\lambda_{max} T$ = a constant **(1)** <u>Example of calculation:</u> $\lambda_{max} T = 0.25 \times 10^{-6} \times 11500 = 2.9 \times 10^{-3}$ $\lambda_{max} T = 0.5 \times 10^{-6} \times 5800 = 2.9 \times 10^{-3}$	**3**
7(c)(i)	A standard candle is a (stellar) object of known luminosity	**1**
***7(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 **(1)** Use inverse square law [Reference to $F=L/4\pi d^2$ with symbols defined] **(1)** (Hence) distance to standard candle is calculated/determined **(1)** [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]	**3**
7(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 **(1)** [Mark can be obtained from a fully labelled diagram] If star is too distant the angle is too small to measure **(1)**	**2**
	Total for Question	**12**

Question Number	Answer	Mark
8(a)	**Max 6** The young star cluster consists (mainly) of main sequence stars **(1)** The old star cluster has a truncated main sequence **(1)** The old star cluster has lost its heaviest main sequence stars **(1)** The old star cluster has (many) red giant stars **(1)** The old star cluster has (some) white dwarf stars **(1)** Massive main sequence stars are the first stars (to deplete sufficient hydrogen in their core) to evolve into red giant stars. **(1)** Some red giant stars have evolved into white dwarf stars in the old cluster **(1)**	**6**
8(b)(i)	Star A is closer to Earth than Star B **(1)**	**1**
8(b)(ii)	 Use of appropriate trigonometric relationship **(1)** $d = 4.0 \times 10^{16}$ m **(1)** <u>Example of calculation:</u> $\sin\theta = \frac{1.5\times10^{11}\,\text{m}}{d}$ $d = 4.01 \times 10^{16}$ m	**2**
8(c)	$\lambda_{max} = 1.0 \times 10^{-6}$ m **(1)** Use of $\lambda_{max}T = 2.9 \times 10^{-3}$ **(1)** $T = 2900$ K **(1)** <u>Example of calculation:</u> $T = 2.9 \times 10^{-3}$ m K$/1.0 \times 10^{-6}$ m $= 2900$ K	**3**
	Total for question	**12**