

Mark Scheme

Q1.

Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is C: luminosity is proportional to temperature⁴ which means a 16-fold increase, and luminosity is proportional to area, which is proportional to diameter², and so means a 4-fold decrease, so there is a 4-fold increase overall A is not the correct answer because this only accounts for the decrease due to decreasing diameter B is not the correct answer because this is the answer obtained if the power applied to temperature is 2 instead of 4 D is not the correct answer because the effect of area is not included	1

Q2.

Question Number	Answer	Mark
	D - 8L	1
	Incorrect Answers: Correct method: $\div 2$ for area change and $\times 24$ for temperature change A – only applies $\div 2$ for area change B – applies $\div 2$ for area change and $\times 2$ for temperature change C – applies $\div 1/2$ for area change and $\times 2$ for temperature change Or applies $\div 2$ for area change and $\times (2 \times 4)$ for temperature change	

Q3.

Question Number	Answer	Mark
	B	1

Q4.

Question Number	Answer	Additional guidance	Mark
	A	(5.1×10^{-6} m)	(1)

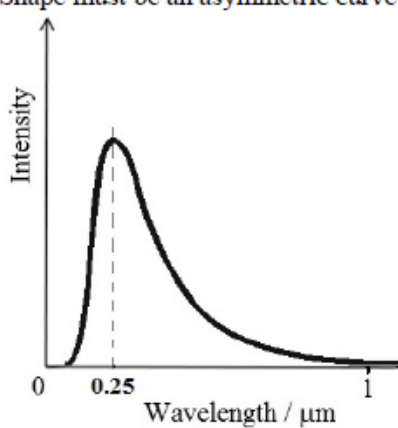
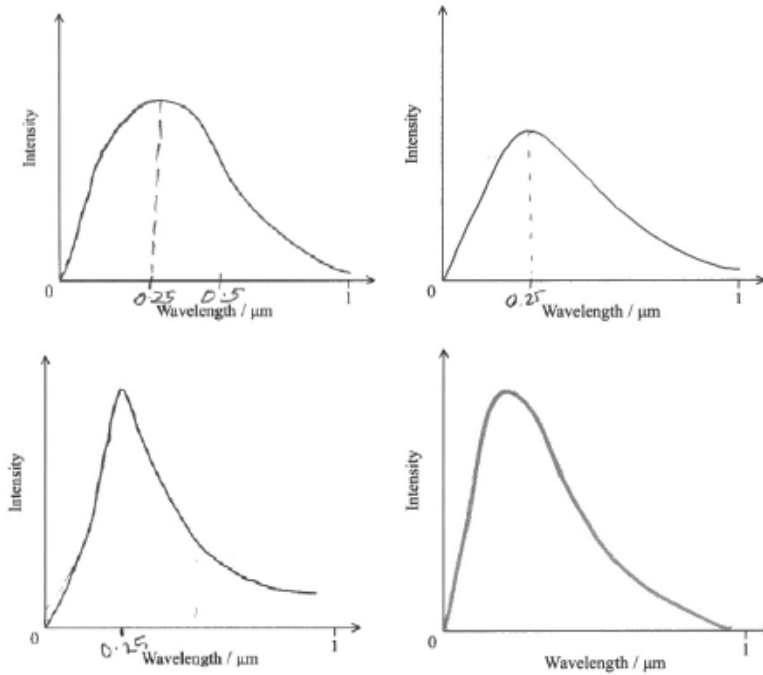
Q5.

Question Number	Answer	Mark
	D	1

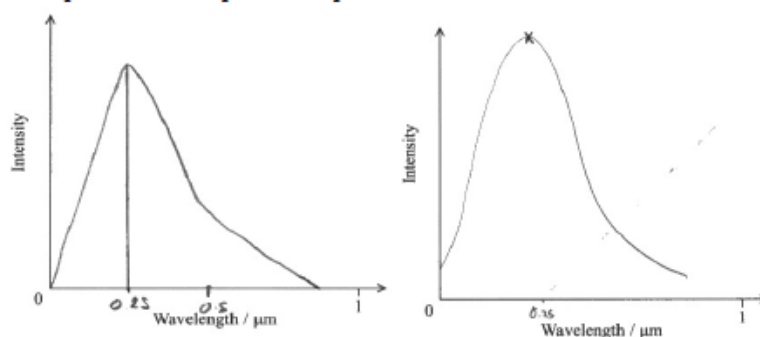
Q6.

Question Number	Answer	Mark
	A	1

Q7.

Question Number	Answer	Mark
	Curve with peak at $0.25\mu\text{m}$ (labelled or in correct position) (1) Shape must be an asymmetric curve and must not have intensity at $\lambda = 0$ (1) 2  Examples of acceptable shapes: 	

Examples of unacceptable shapes:



Question Number	Answer	Mark
	The star cools, so temperature T reduces (1) The star contracts (under gravitational forces), so area A reduces (1) $L = \sigma AT^4$ hence L is reduced (mark dependent upon either mp1 or mp2) (1)	3

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
	- Use of $\lambda_{\max}T$ with data for one star (1) - Use of $\lambda_{\max}T$ with data for all three stars (1) - Statement that values are similar/constant for each star AND comparison with Wein's Law constant (1)	<u>Example of calculation</u> $\lambda_{\max}T = 132 \text{ nm} \times 21500 \text{ K} = 2.838 \times 10^6 \text{ nm K}$ $\lambda_{\max}T = 245 \text{ nm} \times 11600 \text{ K} = 2.842 \times 10^6 \text{ nm K}$ $\lambda_{\max}T = 287 \text{ nm} \times 9940 \text{ K} = 2.844 \times 10^6 \text{ nm K}$	3

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	- Use of $\lambda_{\max}T = 2.898 \times 10^{-3} \text{ m K}$ (1) $\lambda_{\max} = 910 \text{ nm}$ (1) - Yes, because peak emission occurs at a wavelength close to 950 nm (1)	Ignore references to the wavelength of red light <u>Example of calculation:</u> $\lambda_{\max} = \frac{2.898 \times 10^{-3} \text{ m K}}{3200 \text{ K}} = 9.06 \times 10^{-7} \text{ m}$	3

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	- Use of $\lambda_{\max} T = 2.9 \times 10^{-3}$ (1) $T = 5800 \text{ K}$ [accept 5780 K and 6000 K] (1) - Use of $L = 4\pi r^2 \sigma T^4$ (1) $r = 6.9 \times 10^8 \text{ m}$ (1)	Example of calculation: $T = \frac{2.9 \times 10^{-3} \text{ mK}}{5.02 \times 10^{-7} \text{ m}} = 5780 \text{ K}$ $r = \sqrt{\frac{3.85 \times 10^{26} \text{ W}}{4\pi \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (5800 \text{ K})^4}} = 6.91 \times 10^8 \text{ m}$	4

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: - The peak of the curve is higher (1) - The rate at which energy is radiated is proportional to temperature to the power of 4. (1) - The peak of the curve is displaced to the left (1) - The wavelength at which maximum rate of energy radiated occurs is inversely proportional to the temperature (1)	MP1 and MP3 allow correct sketch on graph MP2 allow reference to Stefan's law MP4 allow reference to Wien's law	4

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
	- Use of $L = 4\pi r^2 \sigma T^4$ (1) - Use of $I = \frac{L}{4\pi d^2}$ (1) $I = 1.37 \text{ (kW m}^{-2}\text{)}$ (1) - This is less than $2 \text{ (kW m}^{-2}\text{)}$ and so the claim is false. (1)	<u>Example of calculation:</u> $L = 4\pi(6.96 \times 10^8 \text{ m})^2 \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (2.898 \times 10^{-3} \text{ m K})^4$ $L = 3.88 \times 10^{26} \text{ W}$ $I = \frac{3.88 \times 10^{26} \text{ W}}{4\pi(1.50 \times 10^{11} \text{ m})^2} = 1372 \text{ W m}^{-2}$	4

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
	- Use of $\lambda_{\text{max}} T = 2.898 \times 10^{-3} \text{ m K}$ (1) ... with sensible temperature expressed in Kelvin (1) - E.g. $\lambda_{\text{max}} = 9.89 \times 10^{-6} \text{ m}$ for 293 K (1) - Value is greater than max wavelength of red light so is in IR region (1) Or (if starting from 700 nm) - Use of $\lambda_{\text{max}} T = 2.898 \times 10^{-3} \text{ m K}$ $T = 4100 \text{ K}$ - Comparison with stated sensible temperature ($^{\circ}\text{C}$ or K) - Temperature is too high so wavelength greater than max wavelength of red light so is in IR region	<u>Example of calculation</u> $\lambda_{\text{max}} T = 2.898 \times 10^{-3} \text{ m K}$ $\lambda_{\text{max}} = 2.898 \times 10^{-3} \text{ m K} / 293 \text{ K}$ $\lambda_{\text{max}} = 9.89 \times 10^{-6} \text{ m}$ MP4 consistent with calculation	4

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
	- Use of $\lambda_{\max} T = 2.898 \times 10^{-3} \text{ m K}$ (1) - Use of $A = 4\pi r^2$ (1) - Use of $L = \sigma A T^4$ (1) $L = 1.63 \times 10^{29} \text{ W}$ (1)	<u>Example of calculation</u> $7.43 \times 10^{-7} \text{ m} \times T = 2.898 \times 10^{-3} \text{ m K}$ $T = 3900 \text{ K}$ $A = 4\pi (3.14 \times 10^{10} \text{ m})^2$ $= 1.24 \times 10^{22} \text{ m}^2$ $L = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times 1.24 \times 10^{22} \text{ m}^2 \times (3900 \text{ K})^4$ $L = 1.63 \times 10^{29} \text{ W}$	4

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	- Use of $P = IV$ (1) - Use of $L = A\sigma T^4$ (1) $T = 1800 \text{ K}$ (1)	<u>Example of calculation</u> $P = 2.0 \text{ V} \times 0.37 \text{ A} = 0.74 \text{ W}$ $0.74 \text{ W} = 0.35 \times 3.9 \times 10^{-6} \text{ m}^2 \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times T^4$ $T^4 = 9.56 \times 10^{12} \text{ K}^4$ $T = 1758 \text{ K}$	3

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: - Electrons collide with (lattice) ion and transfer energy (1) Or Current in wire causes temperature of wire to increase - So the amplitude of vibration (of the lattice ions) increases (1) - Electrons make more frequent collisions (with lattice ions), so the resistance increases (1)		3

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	Max TWO from: (For a black body radiator) Stefan(- Boltzmann) law applies (1) Or (For a black body radiator) $L = \sigma AT^4$ (1) - The rate of energy transfer from the wire is determined by its surface area (1) - Increasing the length increases the surface area, so more energy is radiated away (and the temperature does not change) (1)		2

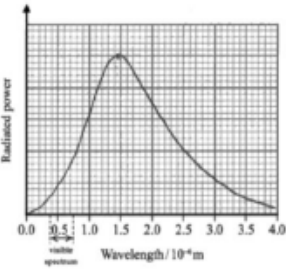
Q18.

Question Number	Answer		Mark
	Use of $\lambda_{\max} T = 2.898 \times 10^{-3} \text{ m K}$ $T = 3400 \text{ (K)}$ Use of $L = 4\pi r^2 \sigma T^4$ $r_B = 6.8 \times 10^{11} \text{ (m)}$ [8.82 $\times 10^{11} \text{ m}$ if $T = 3000 \text{ K}$, 6.87 $\times 10^{11} \text{ m}$ if $T = 3400 \text{ K}$] $r_B/r_S = 980$ [1270 if $T = 3000 \text{ K}$, 988 if $T = 3400 \text{ K}$] <u>Example of calculation</u> $T = \frac{2.898 \times 10^{-3} \text{ m K}}{850 \times 10^{-9} \text{ m}} = 3410 \text{ K}$ $r_B = \sqrt{\frac{4.49 \times 10^{31} \text{ W}}{4\pi \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (3410 \text{ K})^4}} = 6.83 \times 10^{11} \text{ m}$ $\frac{r_B}{r_S} = \frac{6.83 \times 10^{11} \text{ m}}{6.95 \times 10^8 \text{ m}} = 983$	(1) (1) (1) (1) (1)	5

Q19.

Question Number	Acceptable Answers	Additional Guidance	Mark
	- Use of $L = 4\pi r^2 \sigma T^4$ (1) - Luminosity and temperature of Sirius A read from graph (1) - Use of Luminosity of Sirius A with luminosity of the Sun. (1) $\frac{r_{\text{Sirius A}}}{r_{\text{Sun}}} = 1.84$ Or $r = 1.28 \times 10^9 \text{ m}$ (1) - Comparison between candidate's ratio and given ratio with valid conclusion Or Comparison between $2 \times r_{\text{Sirius}}$ and r_{Sun} with a valid conclusion (1)	<u>Example of calculation</u> $L = 4\pi(6.96 \times 10^8 \text{ m})^2 \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (5800)^4$ $\therefore L = 3.91 \times 10^{26} \text{ W}$ Luminosity of Sirius = $30 L_{\text{Sun}}$ and $T = 10\,000 \text{ K}$ $r = \sqrt{\frac{30 \times 3.91 \times 10^{26} \text{ W}}{4\pi \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (10\,000 \text{ K})^4}}$ $\therefore r = 1.28 \times 10^9 \text{ m}$ $\frac{r_{\text{Sirius A}}}{r_{\text{Sun}}} = \frac{1.28 \times 10^9 \text{ m}}{6.96 \times 10^8 \text{ m}} = 1.84$ $1.84 \approx 2$, therefore claim is correct	5

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	- Use of $\lambda_{\max} T = 2.898 \times 10^{-3} \text{ m K}$ (1) $\lambda_{\max} = 1.4 \times 10^{-6} \text{ (m)}$ (1) - correct black body radiation shape (1) - peak at correct wavelength (1) - line not zero at long wavelength and not positive at 0.0 on wavelength axis (1)	<u>Example of calculation and graph</u> $\lambda_{\max} \times 2026 \text{ K} = 2.898 \times 10^{-3} \text{ m K}$ $\lambda_{\max} = 1.43 \times 10^{-6} \text{ m}$ 	5
(ii)	- Most radiation at infrared or $\lambda_{\max}$ isn't in the visible spectrum or only a small proportion of radiation/power in visible spectrum (1) - Ratio of useful output/input is therefore very small Or so proportion of energy transfer that is useful is small (1)		2

Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	- All the stars are in the main sequence (1) - In an older cluster there would be red giant stars (1)		2
(ii)	MAX 4 - The most massive stars experience much greater gravitational forces (1) - So core temperature and density is greatest (1) - The rate of fusion in the core is greatest (1) - Or the power generated in the core is greatest (1) - The (surface) temperature is greatest - The surface area of these stars is greatest - So according to Stefan's Law the power radiated from these massive stars is greatest		4

Q22.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• use of $I = L / 4\pi d^2$ (1) • $L = 6.53 \times 10^{23} \text{ W}$ (1) • $= 0.17\%$ of Sun (1)	<u>Example of calculation</u> $3.25 \times 10^{-11} \text{ W m}^{-2} = L / 4\pi(4.00 \times 10^{16} \text{ m})^2$ $L = 6.53 \times 10^{23} \text{ W}$ $6.53 \times 10^{23} \text{ W} / 3.85 \times 10^{26} \text{ W} = 0.17\%$	3
(ii)	• use of $L = \sigma AT^4$ (1) • $T = 3124 \text{ (K)}$ (1) • Statement relating calculated values of T and L to main sequence on H-R diagram (1)	<u>Example of calculation</u> $6.53 \times 10^{23} \text{ W} = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times 4\pi (9.81 \times 10^7 \text{ m})^2 \times T^4$ $T = 3124 \text{ K}$	3

Q23.

Question Number	Answer	Mark
(a)	(B2 =) $2.9 \times 10^{-3} / A_2$ Or (B2 =) $2.9 \times 10^{-3} / \lambda_{\text{max}}$ Or (B2 =) $2.9 \times 10^{-3} / 6.85$ (1) $\times 10^{-7}$ [Ignore incorrect powers of 10]	1
(b)	Use of $L = \sigma T^4 A$ (1) $A = 0.21(48) \times 10^{19} \text{ (m}^2\text{)}$ (1) For max 1 Use of $A = 4\pi R^2$ to give $A = 2.1(1) \times 10^{18} \text{ (m}^2\text{)}$ <u>Example of calculation:</u> $A = \frac{0.392 \times 10^{26} \text{ W m}^{-2}}{5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (4230 \text{ K})^4} = 2.148 \times 10^{18} \text{ m}^2$	2
(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

Q24.

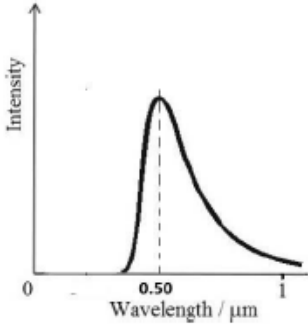
Question Number	Acceptable answers	Additional guidance	Mark
(a)	• Use of $L = 4\pi r^2 \sigma T^4$ (1) • With 270 000 or 1420 (1) • $T = 3494$ K which is smaller than the temperature of the Sun, so it is not correct • Or $T = 0.605 T_{\text{Sun}}$ which is smaller than the temperature of the Sun, so it is not correct (1)	<u>Example of calculation</u> $3.85 \times 10^{26} \text{ W} \times 270\,000 = 4 \times \pi \times 5.67 \times 10^{-8} \times (1420 \times 6.96 \times 10^8 \text{ m})^2 \times T^4$ $T = 3494 \text{ K}$	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• Use of $\lambda_{\text{max}} T = 2.898 \times 10^{-3} \text{ m K}$ (1) • $\lambda_{\text{max}} = 8.29 \times 10^{-7} \text{ m}$ (ecf for T from (a)) (1)	<u>Example of calculation</u> $\lambda_{\text{max}} \times 3494 \text{ K} = 2.898 \times 10^{-3} \text{ m K}$ $\lambda_{\text{max}} = 8.29 \times 10^{-7} \text{ m}$	2

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• Add to top right (1) • Red giant/supergiant (1)	Consistent with the answer from (a) for both marking points Accept hypergiant	2

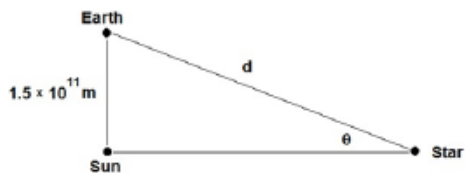
Q25.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	An explanation that makes reference to the following points: - Electrons / atoms exist in discrete/fixed/certain energy levels Or there are only a certain number of specific differences in energy levels of electrons / atoms (1) (Absorbing) a <u>photon</u> causes an electron / atom to move to a higher energy level (1) Or (Absorbing) a <u>photon</u> causes an electron / atom become excited (1) - Photons are (only) absorbed when the <u>photon</u> energy is equal to the difference between energy levels (1) <u>Photon</u> energy depends on frequency/wavelength, so photons of specific frequencies/wavelengths are absorbed, (producing dark lines)	May refer to photon energy $E = hf$	4

(ii)	- Use of $\lambda_{max}T = 2.898 \times 10^{-3} \text{ m K}$ (1) $\lambda_{max} = 5.0 \times 10^{-7} \text{ (m)}$ (1) - Curve with a peak at candidate's value of λ_{max} (1) - Black body asymmetric curve with intensity = 0 when wavelength = 0 (1)	<u>Example of calculation:</u> $\lambda_{max} = \frac{2.898 \times 10^{-3} \text{ m K}}{5800 \text{ K}}$ $= 5.0 \times 10^{-7} \text{ m}$  Meets x axis on left but not on right, steeper on the left than on the right and narrower on the left at every point than on the right	4
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(iii)	An explanation that makes reference to the following points: - Fusion takes place (from hydrogen to helium) (1) - This releases energy and leads to an (outward) pressure/force which balances gravitational forces (1)	Accept high temperature for energy	2
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Q26.

Question Number	Answer	Mark
(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
(b)(i)	Star A is closer to Earth than Star B (1)	1
(b)(ii)	 Use of appropriate trigonometric relationship (1) $d = 4.0 \times 10^{16} \text{ m}$ (1) <u>Example of calculation:</u> $\sin \theta = \frac{1.5 \times 10^{11} \text{ m}}{d}$ $d = 4.01 \times 10^{16} \text{ m}$	2

(c)	$\lambda_{\max} = 1.0 \times 10^{-6} \text{ m}$	(1)	3
	Use of $\lambda_{\max} T = 2.9 \times 10^{-3}$	(1)	
	$T = 2900 \text{ K}$	(1)	
	<u>Example of calculation:</u> $T = 2.9 \times 10^{-3} \text{ m K} / 1.0 \times 10^{-6} \text{ m} = 2900 \text{ K}$		
Total for question			12