Marking Scheme

1.

(a)	(i)	$T = \dfrac{W}{260 \times 10^{-9}}$ (1 – trans) [or by impl.][allow this mark even if 10^{-9} omitted] $= 11 \times 10^3$ K (1) ((**unit**))	2
	(ii)	Black body [accept: non-reflecting surface / radiates <u>equally</u> in all directions]	1
(b)		Radius is × 70 so area is × 70^2 [or equiv, or by impl.] (1) Temperature is × 2, so T^4 is 2^4 [or equiv. or by impl.] (1) [So] Power is × 80 000 (1)	3
(c)		Absorption [by atoms in the stellar atmosphere or in interstellar gas] of specific wavelengths from the star's continuous spectrum [or from star's radiation / star's light] (1) Any 2 × (1) from: • ….. because photons of specific <u>energy</u> abso rbed ✓ • Photon energies correspond to transitions between [atoms'] energy levels ✓ • Absorbed radiation re-emitted but in all directions ✓	3

2.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*		Rearrangement $\sigma = \dfrac{P}{AT^4}$ and convincing algebra / cancellation of m^2 (1) P has units kg m^2 s^{-3} (1) A has units m^2 and T^4 units K^4 (1)	1 1	1		3	1	
	(b)	(i)	λ_p = 930 ± 20 nm (with units) (1) $T = \dfrac{2.9 \times 10^{-3}}{930 \times 10^{-9}}$ = 3 120 K (1) $A = 1.1 \times 10^{17}$ m^2 (1) $d = 1.87 \times 10^8$ m (1)	1	1 1 1		4	3	
		(ii)	Appears red and infra-red section			1	1		
			Question 4 total	**3**	**4**	**1**	**8**	**4**	**0**

3.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*		Nebula, protostar, mid star, red giant, planetary nebula, white dwarf, black dwarf		1		1		
	(b)		Radiation/light not absorbed by atmosphere			1	1		
	(c)		Any one of these 4 marked [with a cross]. If more than one marked then follow the rule 1 right + 1 wrong = zero 		1		1		
	(d)		Photons collide with matter in star (or equivalent) [1] Force is rate of change of momentum [1] Light has momentum (or $p = \frac{h}{\lambda}$) [1]	1 1	1		3		
	(e)		More massive linked to greater gravitational force [hence density greater] [1] Greater density linked to increased [rate of] fusion [1] Reference to energy released by fusion e.g. more energy released [1]		3		3		
	(f)	(i)	$\lambda = \frac{0.0029}{T}$ used [1] Answer = 145 n[m] or $\frac{0.0029}{20\,000}$ seen (accept 17 000 K to 22 000 K from the graph) [1]	1	1		2	1	
		(ii)	Better to use UV or more radiation in UV or peak emission is not in visible range [1] [But] hot stars also emit visible light [more than colder stars] [1]			2	2		
	(g)		Choice of equation 1 e.g. $0.23 \times 0.2^{2.3}$ (=0.0057) [1] In (approximately) correct place (don't allow as a guess) [1]			2	2	2	
	(h)		Correct use of equation 3 e.g. $1.5 \times 10^{3.5}$ or 4 743 [1] Stated that luminosity or power or rate of use of fuel is 5 000× or 4 743× greater [1] Relevance of factor of 10 understood [1] Factor of 10 $M_\odot$ and 5 000 $L_\odot$ combined for a conclusion [1] e.g. $\frac{10}{5\,000}$ seen or $\frac{10}{4\,743}$ or worded answer e.g. although burning 5 000× faster, it has 10× more fuel so 500× less lifetime		4		4	2	
	(i)		As mass increases radius decreases or vice versa	1			1		
			Question 8 total	**4**	**11**	**5**	**20**	**5**	**0**

4.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*		An object that absorbs all electromagnetic radiation [incident upon it]	1			1		
	(b)		Conversion of temperature 310 K (1) Use of $P = \sigma A T^4$ (1) P = 1047 [W] No he is incorrect / conclusion (1)			3	3	2	
	(c)	(i)	Reasonable attempt at two black body graphs skewed normal distribution curves (1) Curve labelled blue all above curve labelled red (1) λ_{max} blue to the left of λ_{max} red (1)	1	1 1		3		
		(ii)	For distribution to have a peak wavelength of green other colours are emitted / green is in the middle of the (light) spectrum (1) Star will appear white (1)			2	2		
			Question 4 total	**2**	**2**	**5**	**9**	**2**	**0**

5.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		**Indicative content:** 1. Wavelength at peak intensity and Wien's Law [can be used to] determine [surface] temperature of the star. 2 Power emitted per square meter or area can be calculated using Stefan's law [details not required] 3. Colour of star can be deduced from wavelength of max intensity / spectrum. 4. Line **absorption** spectrum shown. 5 Line spectrum arises from passage of [continuous] spectrum/light/radiation / photons through stellar atmosphere 6 absorbing atoms/elements can be identified from wavelength of lines **Other relevant points:** • Total area under graph represents total power radiated • Absorption spectrum indicates temperature and generation of star • Redshift gives radial / recessional/ velocity/ distance • Reference to inverse square law and distance	6			6		
			5-6 marks At least 5 relevant points given *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** At least 3 relevant points given *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** At least 1 relevant points given *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*						
	(b)	(i)	Recall of $I = P \div 4\pi R^2$ in any form (1) Substitution: P (or Luminosity) = $1.32 \times 10^{-8} \times 4\pi \times (1.58 \times 10^{17})^2$ (1) $P = 4.1(4) \times 10^{27}$ W seen (1)	1	1 1		3	3	
		(ii)	Substitution: $P = A\sigma T^4$ in any form e.g.: $4 \times 10^{27} = A \times 5.67 \times 10^{-8} \times (7\,700)^4$ (1) [Accept $4.1(4)10^{27}$ for P] $A = 2.0 \times 10^{19}$ m^2 (1) [2.1×10^{19} if 4.14×10^{27} used] Diameter = 2.5×10^9 m (1) [2.6×10^9 if 2.1×10^{19} used] Use of πR^2 rather than $4\pi R^2 \rightarrow 5 \times 10^9$ m (2 marks)	1 1	1		3	3	
			Question 6 total	**9**	**3**	**0**	**12**	**6**	**0**

6.

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
6	*(a)*		5.1 [eV]	1			1		
	(b)		Particular wavelengths of the light are absorbed (1) Atoms or electrons are raised to higher energy levels (1) Light re-radiated in all directions (1)	3			3		
	(c)	(i)	Energy $(=\frac{hc}{\lambda}) = 3.4 \times 10^{-19}$ [J] (1) Conversion to eV = 2.1 [eV] (1) Correct conclusion with justification – does correspond to energy difference in levels (1)			3	3	2	
		(ii)	Wien's Law $\lambda_{max} = \frac{W}{T}$ (1) $T = \frac{2.9 \times 10^{-3}}{\lambda_{max}}$ (1) Temperature = 29 000 [K] (1)	1	1 1		3	3	
			Question 6 total	**5**	**2**	3	**10**	**5**	**0**

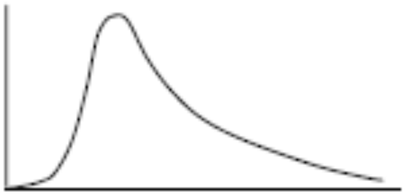
7.

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
7	*(a)*		Continuous spectrum due to radiation of all wavelengths emitted from surface of star [1] [superimposed] line absorption spectrum (due to passage of radiation) through atmosphere (of star) [1]	2			2		
	(b)	(i)	Use of $I = \frac{P}{4\pi R^2}$ [1] Substitution: $\frac{I_S}{I_V} = \frac{9.7 \times 10^{27} \times [4\pi](2.4 \times 10^{17})^2}{1.5 \times 10^{28} \times [4\pi](8.1 \times 10^{16})^2}$ [1] **Alternative for 2nd mark:** Calculation of either intensity: $I_{Sirius} = 1.18 \times 10^{-7}$ [W m^{-2}] or $I_{Vega} = 2.07 \times 10^{-8}$ [W m^{-2}] Ratio = 5.7 [1]	1	1 1		3	2	
		(ii)	Shape of curve below that of Sirius at all points [1] Peak at $(1, \lambda_{max})$ **ecf** [1]		2		2		
		(iii)	Substitution into $P = 4\pi R^2 \sigma T^4$ i.e. $9.7 \times 10^{27} = 1.8 \times 10^{19} \times 5.67 \times 10^{-8} \times T^4$ [1] $T = 9.9 \times 10^3$ K (9 874 K) [1] Substitution into $\lambda_{max} = \frac{W}{T} = \frac{2.90 \times 10^{-3} [\text{m K}]}{9.9 \times 10^3 [\text{K}]}$ **ecf** [1] $\lambda_{max} = 2.9 \times 10^{-7}$ [m] [1]	1 1	1 1		4	4	
	(c)		Reference to multiwavelength astronomy / using different parts of the em spectrum [1] Early photographs used visible light so limited / extra wavelengths **provide extra information** [1] Extra detail provided e.g. link between wavelength and temperature such as quasars at gamma / X-rays [1] This detail could be evidence for the 2nd mark.			3	3		
			Question 7 total	5	6	3	14	6	0

8.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*	(i)	Reference to expected relationship: i.e. $I \alpha \frac{1}{R^2}$ (1) Valid strategy e.g. IR^2 = constant (1) [Award 2 marks for this] Data from graph used appropriately to confirm relationship: e.g. $(2 \times 10^{11})^2 \times 0.8 = 3.2 \times 10^{22}$ $(4 \times 10^{11})^2 \times 0.2 = 3.2 \times 10^{22}$ (1)			3	3	2	
		(ii)	Correct substitution of corresponding pairs of values into $I = \frac{P}{4\pi R^2}$ regardless of units used (1) Correct re-arrangement and correct unit conversions to show clearly that $P \approx 4 \times 10^{26}$ W e.g. $P = 1.4 \times 10^3 \times 4\pi \times (1.5 \times 10^{11})^2$ (1)	1	1		2	1	
	(b)		**Either:** λ_{peak} found from graph (= 500×10^{-9}) (1) Wien's law to find T_{sun} i.e. $\frac{2.9 \times 10^{-3}}{500 \times 10^{-9}}$ (= 5 800 K) (1) [(**ecf** on λ_{peak}]. Substitution into $P = 4\pi R^2_{sun}\sigma T^4$ (**ecf** on T) e.g. $4 \times 10^{26} = 4 \times \pi \times R^2_{sun} \times 5.67 \times 10^{-8} \times (5\,800)^4$ (1) [Allow A instead of $4 \times \pi \times R^2_{sun}$ but not $\pi \times R^2_{sun}$] or $A = 6.2 \times 10^{18}$ m^2. $R_{sun} = 7.0 \times 10^8$ m (1) **Or:** Luminosity from *(a)*(ii) (**ecf**) and radius substituted into $P = 4\pi R^2_{sun}\sigma T^4$ (1) T calculated [expect 5830 K] (1) λ_{peak} calculated from Wien's law [5830 K $\rightarrow$ 497 nm] (1) λ_{peak} found from graph (= 500 nm) (1) Appropriate comparison and comment: e.g. **Either** 700 000 km close to 696 342 km so reasonable comment. **Or** 700 000 km is '1000s' of km different, so unreasonable. **Or** λ_{peak} calculated in good agreement with graph (1)			5	5	4	
	(c)		**Any 2 ×(1) from:** • Inaccurate instruments • Atmospheric distortions (e.g. refraction) • Earth/sun distance uncertainty • Uncertainty regarding solar surface- defining edge of sun • Sun varies in size over time. • Shape of disc is non-spherical • Brightness of disc overwhelms eye / instruments			2	2		
			Question 8 total	**1**	**1**	**10**	**12**	**7**	**0**

9.

(a)	(i)	$\lambda_{Peak} = \dfrac{2.90\times10^{-3}\,\text{K m}}{2.5\times10^{7}\,\text{K}}$ (1) = 1.16×10^{-10} [m] (1)	2
	(ii)	X-ray / γ-ray	1
	(iii)		1
	(iv)	Spectral intensity low <u>in high λ 'tail'</u> but not zero.	1
(b)		$P = \sigma A \times (2.5 \times 10^{7}\,\text{K})^4$ [or by impl.] (1) $A = 4\pi \times 11000^2$ [or by impl.] (1) [= 1.52×10^{9} m^2] $P = 3.4 \times 10^{31}$ W (1) UNIT mark	3
(c)		$A_2T_2^{\,4} = A_1T_1^{\,4}$ (1) or $T_2^{\,4} = \dfrac{3.4\times10^{31}}{5.67\times10^{-8}\times3.04\times10^{9}}\,\text{K}^4$ e.c.f from (b) $T_2 = 2.1 \times 10^{7}$ K (1)	2

10.

(a)	(i)	= 5.4 [± 0.2] [day] (1) P = 0.70 [± 0.1] x10^{30} [W] (1) ecf	2
	(ii)	$I = \dfrac{P}{4\pi r^2}$ (1) [or equivalent, or by implication] $r = 2.6\text{x}10^{20}$ [m] (1) ecf [1 mark only lost if factor of 4 omitted]	2
(b)	(i)	λ_{peak} = 450 n[m] (1) [±10 nm] T = 6400 [K] (1) [ecf on λ_{peak}]	2
	(ii)	$A = \dfrac{P}{\sigma T^4}$ (1) [transposition at any stage] = 10 x 10^{21} [m^2] (1) [or by implication] ecf on T $r = \sqrt{\dfrac{A}{4\pi}}$ (1) [= 2.8 x 10^{10} [m]] [or by implication] d = 5.6 x 10^{10} [m] (1) ecf (missing factor of 4 loses 1 mark)	4

11.

7	*(a)*	(i)	$T = \frac{W}{260 \times 10^{-9}}$ (1 – trans) [or by impl.][allow this mark even if 10^{-9} omitted] $= 11 \times 10^3$ K (1) **((unit))**	2
		(ii)	Black body [accept: non-reflecting surface / radiates <u>equally</u> in all directions]	1
	(b)		Radius is × 70 so area is × 70^2 [or equiv, or by impl.] (1) Temperature is × 2, so T^4 is 2^4 [or equiv. or by impl.] (1) [So] Power is × 80 000 (1)	3
	(c)		Absorption [by atoms in the stellar atmosphere or in interstellar gas] of specific wavelengths from the star's continuous spectrum [or from star's radiation / star's light] (1) Any 2 × (1) from: • ….. because photons of specific <u>energy</u> abso rbed ✓ • Photon energies correspond to transitions between [atoms'] energy levels ✓ • Absorbed radiation re-emitted but in all directions ✓	3
				[9]

12.

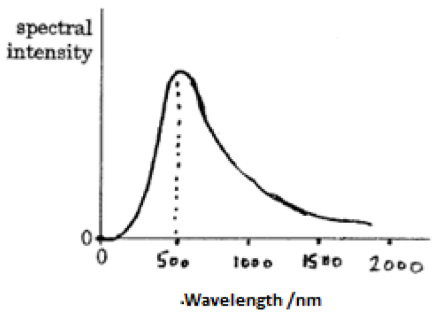
(a)	(i)	Ultraviolet [or u-v]	[1]
	(ii)	$\lambda_{peak\ int}$ = <u>55 nm</u> and $T = \frac{W}{\lambda_{peak\ int}}$ or by implication (1) T = 53 000 K (1) ecf on 50 or 60 nm	[2]
	(iii)	In tail of curve [or equivalent] greater intensity at smaller λ. Accept blue end of visible nearer peak than red end.	[1]
(b)	(i)	$I = \frac{P}{4\pi r^2}$ (1) or equivalent so $P = 2.11 \times 10^{33}$ [W] (1) or by implication So $P/P_{sun} = 5.49 \times 10^6$ or $5 \times 10^6\ P_{sun} = 1.9 \times 10^{33}$ [W] (1)	[3]
	(ii)	$A = \frac{P}{\sigma T^4}$ with A as subject ecf on P and T (1) or by implication $r = \sqrt{\frac{A}{4\pi}}$ (1) or $d = \sqrt{\frac{A}{\pi}}$ or by implication $d = 4.0 \times 10^{10}$ [m] (1) [one mark lost for factor of 2 or 10^n adrift.]	[3]

13. *(a)*	(i)	$\lambda_{peak} = \dfrac{2.90\text{x}10^{-3}}{9900}$ [m] **or equivalent** (1) $\lambda_{peak} = 293 \times 10^{-9}$ [m] (1)	2
	(ii)	Peak between 280 and 300 nm (1) Curve goes through origin [with zero gradient at origin] and is consistent with approaching zero at very long wavelengths (1)	2
	(iii)	Blue accept white or violet or purple	1
(b)		$A = \dfrac{L}{\sigma T^4}$ with A as subject, with symbols or data or 1.84×10^{19} m^2 (1) Attempt to use $A = 4\pi r^2$ and $d = 2r$ or $A = \pi l^2$ (1) $d = 2.4 \times 10^9$ m ecf on slips of 2^n or 10^n if already penalised (1)	3
(c)	(i)	Absorption accept excitation **Don't accept** pumping	1
	(ii)	Dark / black lines crossing or missing wavelengths [continuous] spectrum or coloured background	1
	(iii)	B almost absent **and** any reference to populations of levels (1) First excited state not populated [so no transitions start here] or all electrons in ground state (1)	2

14.

Question			Marking details	Marks Available
7	*(a)*		$r = 3.07 \times 10^{10}$ m **and** $L = 1.99 \times 10^{29}$ W **or** by implication (1) $L = \sigma 4\pi r^2 T^4$ (1) Correct algebra including fourth-rooting (1) $T = 4\,150$ K **UNIT mark** (1) [Take 5 865 K arising from $A = \pi r^2$ as **ecf**] If only Sun considered $T = 5\,776$ K **award 3 marks only**	4
	(b)		Attempted use of λ_{max} = 700 - 750 [nm] in Wien's Law (1) 3 867 – 4 140 [K] (1)	2
	(c)		Black body absorbs all [electromagnetic] radiation (accept light) falling on it. [Accept: Black body emits more radiation per second [or equivalent] [at every wavelength] than any other body at same temperature. **Don't accept** it is a perfect emitter.	1
	(d)		Spectrum peaks in red or equivalent. Accept infra-red. (1) $r = 44.2\ R_{\odot}$ is sufficient. Must compare with the Sun. (1)	2
			Question 7 Total	**[9]**

15.

Question			Marking details	Marks Available
	(a)	(i)	$A = 4\pi(8.54 \times 10^8\ [\text{m}])^2$ (1) $[9.16 \times 10^{18}\ [\text{m}^2]]$ $P = 5.67 \times 10^{-8} \times$ area attempt $\times 5790^4$ (1) [W] $P = 5.84 \times 10^{26}$ [W] and consistency **ecf on slips** (1) [One mark to be lost for slips e.g. powers of 10, factors of 2, 4, π] Or alternative solution using Stefan's law is acceptable.	[3]
		(ii)	$I = \dfrac{power}{4\pi(4.1x10^{16})^2}$ (1) $I = 2.76 \times 10^{-8}$ Wm^{-2} **UNIT (1)** [penalty of 1 mark for slips of 10^n, 4, π etc no penalty if same slip as in (i)]	[2]
		(iii)	$\lambda_{pmax} = \dfrac{2.9x10^{-3}}{5790}$ (1) $= 5.01 \times 10^{-7}$ [m] (1) GRAPH - Goes through origin and doesn't hit the axis (1) Peak at ~ 500 nm (Apply **ecf**) (1)  	[4]
	(b)		P goes up and T goes down and then A goes up (1) Because $A = \dfrac{P}{\sigma T^4}$ or any convincing explanation (1)	[2]
			Question 6 Total	**[11]**

16. *(a)*	(i)	Power $= \text{intensity} \times 4\pi r^2$ (1) $= 3.8[5] \times 10^{26}$ W (1) [1 mark lost for factors of 2, 3 or 10^n adrift]	2
	(ii)	absorption by atmosphere.	1
(b)	(i)	$A = \dfrac{3.85 \times 10^{26}}{5.67 \times 10^{-8} \times 5780^4}$ m^2 [e.c.f.] (1) $= 6.1 \times 10^{18}$ m^2 (1) [6.08×10^{18} m^2]	2
	(ii)	*Either* $d = 2\sqrt{\dfrac{A}{4\pi}}$ [or equiv.] (1) $= 1.39 \times 10^9$ m (1) **Or** $A = 4\pi\left[\dfrac{d}{2}\right]^2$ (1) $= 6.15 \times 10^{18}$ m^2 (1)	2
(c)		$\lambda_{I\,max} = \dfrac{W}{T} = \dfrac{2.90 \times 10^{-3}\ \text{mK}}{5780\ \text{K}}$ (1) $= 500$ nm [which is in the visible] (1) Sketch graph of correct general shape (1) with peak at 500 nm [e.c.f.] (1)	4
			[11]

Examiner's Comments

1. (mean mark: 3.5/9 = 39 %)

(a) *(i)* Most candidates used Wien's law correctly, to work out Rigel's surface temperature. Those who failed were often thrown by the way the formula is presented on the equation sheet - in terms of . The sheet is provided to confirm candidates' recall of formulae which they should already know how to use!

(ii) The assumption made was that the star radiates as a black body. Equal radiation in all directions wasn't given the mark as it's not relevant to the shape of the spectrum.

(b) For those candidates with good algebraic competence the question could be answered neatly in this way:

P Rigel = 4Π(70r Sn)2(2T Sun)4 = 4Π70 2 r Sun 2 2 4 T Sun 4 = 70 2 x 2 4 = 78000

P Sun 4Πr Sun 4 4Πr Sun 2 TSun 4

We did see this sometimes, but there were many more instances where something similar was attempted, but with at least one pair of brackets omitted - with bad consequences.

Less mathematically able candidates were probably better served by more numerical approaches. One mark was awarded immediately, for example, if we saw 110004/55004. It was perfectly acceptable to make up a figure for the Sun's radius so that the ratio of surfaces areas could be handled in the same way.

(c) Explanations of why dark lines appear at specific wavelengths in a star's spectrum were in general disappointing. We wanted answers in terms of photons and energy levels in atoms, but many candidates who attempted this approach did not give coherent accounts.

*This comment originally referred to question **7** on paper **1322/01 (06/06/2011)***

2. There are no examiner comments available for this question

3. There are no examiner comments available for this question

4. There are no examiner comments available for this question

5. There are no examiner comments available for this question

6. There are no examiner comments available for this question

7. There are no examiner comments available for this question

8. There are no examiner comments available for this question

9. Mean mark: 6.6/10 = 66%

(a) *(i)* Using Wien's law gave little trouble.

(ii) Gamma ray or X-ray was accepted as the region including a wavelength of . UV and IR were the commonest unacceptable answers.

(iii) A humped graph passing through the origin and not threatening to hit zero at high wavelengths was required. Note that the graph slope at the origin is zero; the graph climbs off the l axis a little way from the origin.

(iv) A few candidates used the curious wrong reasoning that no visible light would be emitted because the peak wavelength was not in the visible, but many realised that the total power was so high that some visible would be emitted in the long l 'tail'.

(b) Stefan's law was used, with complete success by many, though the usual errors abounded. There were incorrect formulae used for the surface area of a sphere, and incorrect powers of 10. Sometimes the unit of power was wrong or omitted.

(c) Estimating the surface temperature of the expanded star was the 'difficult' last part of the question but, surprisingly, correct answers were common - and often came from candidates who had met with little success earlier in the question.

*This comment originally referred to question **6** on paper **1322/01 (20/01/2012)***

10. (a) *(i)* Extracting the period (5.4 ± 0.2 days) from the Cepheid brightness graph and reading off the mean power from the second graph, was conceived as an easy 'process task'. Alas, it proved, a terrible stumbling block for almost everyone. The problem may have been caused by candidates not understanding what 'period of brightness variation' meant - especially for a non-sinusoidal graph. This is regretted. Quite often, though, the second of the two marks was given on the ecf principle, and it was very rare for candidates to have no answer at all to take to the next part of the question.

(ii) Finding the distance away from us of the star, given its radiation power, and the intensity of light that we receive from it, defeated many candidates - as it has done when asked in previous papers. No equation is given on the data sheet; candidates have to remember it or derive it - a one-liner. It was depressing to see a number of candidates attempting to put figures into Stefan's law, even though temperature did not feature in this part of the question.

(b) *(i)* Most candidates found the star's temperature correctly using Wien's law, though a few did not know which wavelength to use, and/or made mistakes with the algebra. It is not guaranteed that outrageous answers (e.g. a stellar temperature of 3.8 x 10-38 K), if not remarked upon, will attract full ecf credit.

(ii) It was good to see many successes in working out the star's diameter, with fewer mistakes (such as failures to raise *T* to the fourth power, or wrong area formulae) than sometimes seen.

*This comment originally referred to question **8** on paper **1322/01 (25/05/2012)***

11. (a) *(i)* Most candidates used Wien's law correctly, to work out Rigel's surface temperature. Those who failed were often thrown by the way the formula is presented on the equation sheet - in terms of . The sheet is provided to confirm candidates' recall of formulae which they should already know how to use!

(ii) The assumption made was that the star radiates as a black body. Equal radiation in all directions wasn't given the mark as it's not relevant to the shape of the spectrum.

(b) For those candidates with good algebraic competence the question could be answered neatly in this way:

We did see this sometimes, but there were many more instances where something similar was attempted, but with at least one pair of brackets omitted - with bad consequences.

Less mathematically able candidates were probably better served by more numerical approaches. One mark was awarded immediately, for example, if we saw 110004/55004. It was perfectly acceptable to make up a figure for the Sun's radius so that the ratio of surfaces areas could be handled in the same way.

(c) Explanations of why dark lines appear at specific wavelengths in a star's spectrum were in general disappointing. We wanted answers in terms of photons and energy levels in atoms, but many candidates who attempted this approach did not give coherent accounts.

This comment originally referred to question ***7*** *on paper* ***1322/01 (06/06/2011)***

12. (a) *(i)* λ max is 55 nm, which is indisputably in the ultraviolet region. This was the commonest answer, though visible was quite popular, and we saw more than one gamma.

(ii) As usual Wien's law was almost always selected and correctly applied.

(iii) To deduce that the star is blue, candidates needed to say that the intensity (from the trend of the graph) is going to be greater at 400 nm than 700 nm, or that the peak of the graph is closer to the blue (shorter wavelength) end of the visible region. The mark was often not given. The curious phrase “the star's wavelength” was sometimes seen.

(b) *(i)* There was rather more success than in the past in calculating the star's luminosity from its intensity, and the comparison with Psun was generally convincing.

(ii) Many candidates (probably the majority if we include those who made slips of factors of 2 or 4) applied Stefan's law correctly to find the star's diameter. Quite often the wrong figure for the luminosity was imported from (b)*(i)* , incurring a small penalty.

This comment originally referred to question ***7*** *on paper* ***1322/01 (05/06/2013)***

13. (a) *(i)* Mistakes in the Wien's law calculation were rare.

(ii) The spectral intensity against wavelength sketches could be rather sloppy, with positive (rather than zero) gradients at the origin, peaks noticeably out of place and/or high wavelength tails hitting the wavelength axis.

(iii) With the peak wavelength, one would expect the star to be bluish. We accepted blue, violet, white, but not yellow, orange or red. Most candidates (but not by a huge majority) were given the mark.

(b) The Stefan's law calculation was very well done, with, perhaps, fewer candidates than in the past using rather than, or forgetting to double the radius to get the diameter, though these faults were still seen.

(c) *(i)* The transition shown represented (photon) absorption. We also accepted excitation, but not pumping.

(ii) The question asked for the observed feature of the specimen to be described. We wanted “black lines on a bright background” or something similar. Very often we were given something much more abstract, and often, simply wrong.

(iii) This was conceived as a hard question, and indeed only a minority of candidates realised that populations were the key. In a cool star the first excited state is almost empty, so there are hardly any electrons in a fit state to undergo the 'B' transitions.

This comment originally referred to question ***7*** *on paper* ***1322/01 (09/06/2014)***

14. Q.7 (a) Most candidates knew how to re-arrange Stefan's law to obtain a star's temperature. The commonest mistake, which arose from poor reading of the question, and cost one mark, was to enter data for the Sun rather than for Aldebaran. As usual, some candidates took the area of a sphere as *πr*2; again a single mark penalty. A few candidates did not seem to realise that *luminosity* meant *power*. If only they had looked at the units!

(b) Wien's law was usually used successfully. Examiners had to watch out for candidates obtaining roughly the right figure for temperature by multiplying together the co-ordinates of the peak, as read from the scales. This was seen several times.

(c) A black body is a surface that absorbs all electromagnetic radiation falling on it. That's it. Longer versions, such as “..absorbs all *wavelengths* of e-m radiation..” are not as good. A few candidates attempted to define a black body in terms of its radiation *emission*; this was just as well because the wording needs to be very careful.

(d) Why is *red giant* an appropriate description of Aldebaran? Some candidates tackled only *red* or *giant*. For the *red* part, we accepted the answer most frequently given, that the peak wavelength of 700 nm is at or near the red end of the visible spectrum. We did want the word *peak* or its equivalent. As for *giant*, all that was needed was to refer back to its radius being 44 times that of the Sun. Just to say it was large wasn't enough.

This comment originally referred to question ***7*** *on paper* ***1322/01 (04/06/2015)***

15. Mean mark: 6.3/11 = 57%

(a) *(i)* To show whether or not the star radiated as a black body, most candidates chose to calculate the power emitted using Stefan's law, and to compare it with the given luminosity. An elegant variation was to use the data given to check whether it gave the right value for the Stefan constant. The reasoning was usually clearly set out and the success rate was high. Common faults were to use ∏r2 for the surface area of a sphere, and to omit to draw a conclusion. If, in such a question, the expected result is not confirmed, this should be stated and discussed briefly in the conclusion; a slip (such as a missing factor of 4) will not then attract a double penalty.

(ii) Calculating the intensity on the Earth of the star's radiation elicited, as usual, many bizarre attempts. This may be because no formula is given on the sheet, though this shouldn't have come as a surprise! Common mistakes included evaluation of power/r2 and of power/4∏r2, but with r equal to the star's radius.

(iii) The great majority could use Wien's law successfully to find the wavelength of peak emission. Many good spectra were drawn, but we saw several graphs with positive intercepts on the vertical axis, corresponding to finite spectral intensity at zero wavelength. *This is wrong*. The graph goes through the origin and its slope at the origin is zero; it parts company noticeably from the l axis a little way from the origin.

(b) Most candidates gained a mark for noting that T decreased, power, P, increased, and so *A* increased. Fewer could justify their deduction about *A*; it sufficed to make A the subject of the Stefan's law equation. A significant number of candidates took *P* as constant.

This comment originally referred to question ***6*** *on paper* ***1322/01 (18/01/2013)***

16. (mean mark: 6.7/11 = 42%)

(a) *(i)* The mention of power output of a star meant only one thing to quite a significant minority of students: the Stefan-Boltzmann Law. Not having the star's temperature seemed to be no deterrent to putting some figures into the formula.

(ii) The intensity of radiation measured on the Earth's surface is less than the intensity at 1.50 × 1011 m from the Sun (i.e. at the Earth's orbital radius). Many students attributed the discrepancy to absorption by interstellar dust or other material in 'space', rather than by the Earth's atmosphere. The question clearly needed thinking about a little more carefully!

*This comment originally referred to question **8** on paper **1322/01 (17/01/2011)***