Astrophysics - Mark Scheme

Q1.

Question Number	Answer	Mark
	A	1

Q2.

Question Number	Answer	Mark
(a)(i)	Use of $F = \frac{L}{4\pi d^2}$ **(1)** $L = 3.8 \times 10^{26}$ (W) **(1)** Example of calculation $L = 4\pi d^2 F = 4\pi(1.50 \times 10^{11}\,\text{m})^2 \times 1.36 \times 10^3\,\text{Wm}^{-2} = 3.845 \times 10^{26}\,\text{W}$	2
(a)(ii)	Use of $L = 4\pi r^2 \sigma T^4$ **(1)** $r = 1.5 \times 10^{10}$ m **(1)** Allow full ecf from (i) [show that value gives 1.48 x 10^{10} m] Example of calculation $r = \sqrt{\frac{L}{4\pi\sigma T^4}} = \sqrt{\frac{100 \times 3.85 \times 10^{26}\,\text{W}}{4\pi \times 5.67 \times 10^{-8}\,\text{Wm}^{-2}\text{K}^{-4} \times (4000\,\text{K})^4}}$ $r = 1.45 \times 10^{10}\,\text{m}$	2

(b)(i)	(Observed wavelength is less, so) source is approaching Earth **(1)** Use of $\frac{v}{c}=\frac{\Delta\lambda}{\lambda}$ **(1)** $v = 7.82\times10^{5}\ \text{m s}^{-1}$ [accept $v = 2.606 \times 10^{-3}\ c$] **(1)** [incorrect value of λ in denominator gives $v = 7.84 \times 10^{5}\ \text{ms}^{-1}$] [If $v = 7.8\times10^{5}\ \text{m s}^{-1}$ or $v = 2.6\times10^{-3}\,c$, check denominator; unless 656.29 substituted then max 2] **Or** (Observed wavelength is less, so) source is approaching Earth **(1)** Use of $z=\frac{\Delta\lambda}{\lambda}$ **(1)** $z = 2.606 \times 10^{-3}$ **(1)** [incorrect value of λ in denominator gives $z = 2.612 \times 10^{-3}$] [If $z = 2.6 \times 10^{-3}$ check denominator; unless 656.29 substituted then max 2] Example of calculation $\Delta\lambda = (654.58 - 656.29)\ \text{nm} = -1.71\ \text{nm}$ $v=\frac{c\,\Delta\lambda}{\lambda}=\frac{3.0\times10^{8}\ \text{m s}^{-1}\times1.71\ \text{nm}}{656.29\ \text{nm}}=7.82\times10^{5}\ \text{m s}^{-1}$	**3**

(b)(ii)	$\lambda_B < \lambda_Y$ **(1)** $\lambda_{max} \propto \frac{1}{T}$ therefore $T_B > T_Y$ (and statement is incorrect) **(1)** **Or** $\lambda_{max}T$ = a constant, so the cooler the star the larger the value of λ_{max} **(1)** Wavelength of yellow light is greater than the wavelength of blue light, so statement is incorrect **(1)**	**2**
	Total for Question	**9**

Q3.

Question Number	Answer	Mark
	A is correct the correct answer because red giant stars are cooler (Wien's law) and brighter (Stefan's law).	**1**

Q4.

Question Number	Answer	Mark
	A	**1**

Q5.

Question Number	Answer	Mark
	The only correct answer is B *A is not correct because standard candles enable distances to be determined* *C is not correct because radiation flux depends upon distance and luminosity* *D is not correct because the surface temperature is not characteristic of a standard candle*	1

Q6.

Question Number	Answer	Mark
	The only correct answer is C *A is not correct because* $t = 1/H_0$, *and* H_0 *has increased by 20%* *B is not correct because* $t = 1/H_0$, *and* H_0 *has increased by 20%* *D is not correct because* $t = 1/H_0$, *and* H_0 *has increased by 20%*	1

Q7.

Question Number	Answer	Mark
	C is correct because P and T increase when the current through the filament increases, so λ_{max} decreases (Wien's law).	1

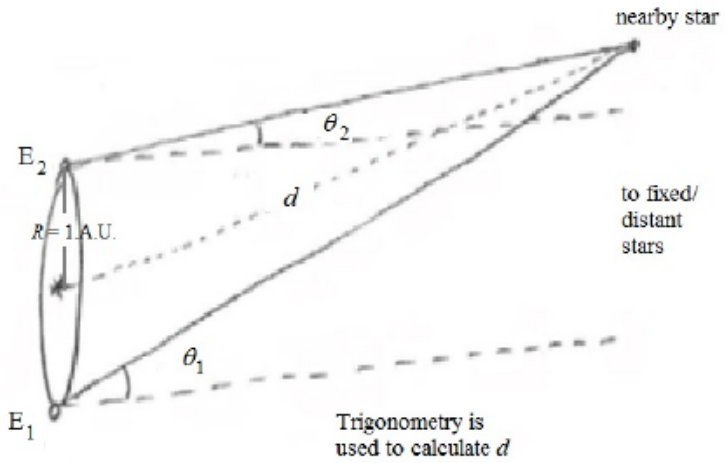
Q8.

Question Number	Answer	Mark
	D	1

Q9.

Question Number	Answer	Mark
	A	1

Q10.

Question Number	Answer	Mark
	The star is viewed from two positions at 6 month intervals **Or** The star is viewed from opposite ends of the Earth's orbit diameter about the Sun **(1)** The change in angular position of the star against backdrop of fixed stars is measured **(1)** Trigonometry is used to calculate the distance (to the star) [Do not accept Pythagoras] **Or** The diameter/radius of the Earth's orbit about the Sun must be known **Or** The distance to the Sun is 1AU **(1)** Full marks may be obtained from a suitably annotated diagram e.g  [Accept the symmetrical diagram seen in many text books]	3
	Total for question	3

Q11.

Question Number	Answer	Mark
	The only correct answer is C ***A** is incorrect, as radiation flux decreases with distance from the source and Q is further away than P.* ***B** is incorrect as radiation flux decreases with distance from the source and Q is further away than P* ***D** is incorrect as, the parallax angle for P is greater than that for Q and so P is closer than Q*	**(1)**

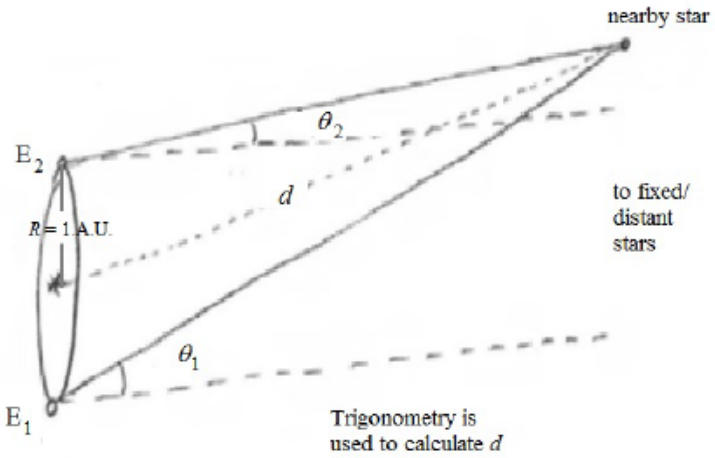
Q12.

	Answer		Mark
(a)(i)	Standard candle has a known luminosity	(1)	
	(Radiation) flux/brightness of standard candle is measured at the Earth	(1)	
	Inverse square law used to calculate distance **Or** reference to $F = \frac{L}{4\pi d^2}$ with L and F identified as luminosity and radiation flux	(1)	**3**
(a)(ii)	Idea that (radiation) flux/brightness/intensity is too small to measure (for more distant galaxies) (accept idea of not enough light arriving)	(1)	**1**
*(b)	**(QWC Spelling of technical terms must be correct and the answer must be organised in a logical sequence.)** Doppler shift formula used to calculate velocities (accept $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ **Or** $\frac{\Delta f}{f} = \frac{v}{c}$ **Or** $z = \frac{v}{c}$ for "Doppler shift formula")	(1)	
	Nebulae/galaxies were moving away from the Earth	(1)	
	The further away the galaxy the faster it was moving (from the Earth) **Or** correct reference to the Hubble equation, $v = H_0 d$ with symbols defined	(1)	
	Therefore <u>all</u> galaxies are moving away from each other (so universe must be expanding)	(1)	**4**
	Total for Question		**8**

Q13.

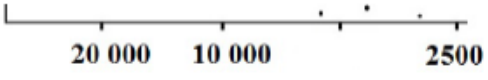
	Answer	Mark
(a)(i)	Peak wavelength is in the middle of the visible region of the electromagnetic spectrum (1)	**1**
(a)(ii)	Curve A because λ_{max} is smaller **Or** curve A because peak is shifted left (1)	**1**
(a)(iii)	(The curve peaks at a smaller wavelength so) the star emits more blue/UV radiation (1) The area under the curve is larger so the star has a greater power output (per unit surface area of the star) **Or** the peak of the curve is higher so the star has a greater power output (per unit surface area of the star) (1) (credit can be given for candidates who incorrectly identify curve C.)	**2**
(b)	We need to know/determine the star's luminosity *(L)* (1) and it's (surface) temperature (*T*) (1) *r* is calculated using Stefan's Law [accept reference to $L = 4\pi r^2 \sigma T^4$ if *L* and *T* defined] **Or** *L* and *T* plotted on Hertzsprung-Russell diagram and star type identified (1)	**3**

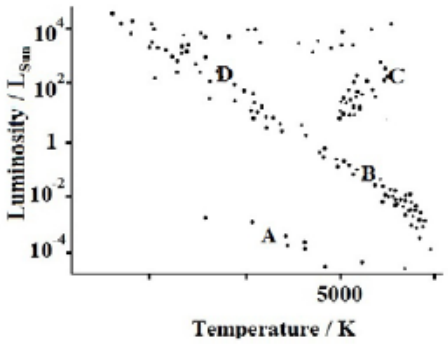
Q14.

	Answer	Mark
(c)	The star is viewed from two positions at 6 month intervals **Or** the star is viewed from opposite ends of the diameter of the Earth's orbit about the Sun (1) The change in angular position of the star against backdrop of distant/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  [Accept the symmetrical diagram seen in many text books]	4
	Total for Question	**11**

Q15.

Question Number	Answer		Mark
(a)	Age of the universe = $1/H_0$ [Accept age of universe is inversely proportional to H_0]	(1)	
	Since the measured value of the Hubble constant is smaller, our estimate of the age of the universe is now larger	(1)	2
(b)(i)	Dark matter cannot be detected via the em-interaction [accept light but do **not** accept radiation on its own] [accept cannot be seen]	(1)	
	But it has mass **Or** But it exerts a gravitational force	(1)	2
(b)(ii)	(The increased proportion of dark matter may mean that)		
	the gravitational force which reduces expansion may be larger **Or** the density of the universe may be greater than the critical density	(1)	
	(Hence) the universe is more likely to reach a maximum size (before contracting) **Or** (Hence) the universe is more likely to be closed	(1)	
	[Ignore references to 'Big Crunch']		2
	Total for Question		6

Question Number	Answer		Mark
(a)(i)	(Extremely dense) to maintain a sufficiently high collision rate	(1)	
	(At a very high temperature) to give the nuclei/protons enough energy to overcome the (electrostatic) repulsion **Or** (At a very high temperature) to bring the nuclei/protons close enough to experience the strong (nuclear) force	(1)	2
(a)(ii)	Gravitational potential energy decreases (as cloud collapses)	(1)	
	Decrease in (gravitational) potential energy equals increase in internal energy	(1)	2
(a)(iii)	Mass is converted to energy	(1)	
	according to $\Delta E = c^2 \Delta m$, where Δm is the mass deficit/lost	(1)	
	Although energy released per fusion is small, fusion rate is very large	(1)	3
(b)(i)	Reverse scale	(1)	
	Logarithmic with realistic values [max T = 50,000 K, min T = 2500 K]	(1)	2
	e.g. 		
(b)(ii)	A white dwarf	(1)	
	B C		
	D main sequence [accept blue giant]	(1)	2

(b)(iii)	 4 correct labels 2 marks 3 correct labels 1 mark 2 correct labels 1 mark 1 correct label 0 marks (2)	2
(c)(i)	A standard candle is a star of known luminosity (1)	1

*(c)(ii)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) If Polaris were closer, Its ("known") luminosity would be less than had been thought (1) Idea that distances to other astronomical bodies would be less than had been thought (1) So the Hubble constant would be greater than had been thought **Or** appropriate reference to $v = H_0 d$ (1) As age = $1/H_0$, the universe would not be as old as had been thought. (1)	4
	Total for Question	18

Q16.

Question Number	Answer	Mark
	The only correct answer is C *A is not correct because the temperature should decrease from X to Y* *B is not correct because the temperature should decrease from X to Y* *D is not correct because the temperature should decrease logarithmically from X to Y*	1

Q17.

Question Number	Answer	Mark
	A **Mass: larger** / **Temperature: higher**	**1**
	Incorrect Answers: (the top end of the main sequence is at the top left of the graph) B – the temperature scale is a reverse scale so the left hand end of the main sequence is a higher temperature than the Sun which is near the middle C – stars at the top end of the main sequence have larger masses than the Sun D – stars at the top end of the main sequence have larger masses than the Sun and higher temperatures	

Q18.

Question Number	Answer	Mark
(a)(i)	$L/A = 70$ (MW m^{-2}) [read from graph, allow 65 → 70] (1) Use of $A = 4\pi r^2$ (1) $L = 4.3 \times 10^{26}$ (W) [$3.96 \times 10^{26} \rightarrow 4.30 \times 10^{26}$] (1) [Use of the Stefan Boltzmann equation could score MP2 and MP3 only] Example of calculation $L = 70\times10^{6}\ \text{W m}^{-2} \times 4\pi \times (6.96\times10^{8}\ \text{m})^2 = 4.26\times10^{26}\ \text{W}$	**3**
(a)(ii)	Use of $F = \frac{L}{4\pi d^2}$ (1) F = 1.5×10^3 W m^{-2} (1) (allow full ecf from (i)) [using the 'show that' value gives F = 1.4×10^3 W m^{-2}] Example of calculation $F = \frac{4.26\times10^{26}\ \text{W}}{4\pi(1.50\times10^{11}\ \text{m})^2} = 1506\ \text{W m}^{-2}$	**2**
(a)(iii)	Only half/part of the Earth is illuminated by the Sun at any one time (1) The idea that the calculated value of F is for radiation meeting the atmosphere at 90°, which is only true one place (the value is less at all other positions). (1)	**2**

Question Number	Answer		Mark
(b)(i)	Use of $\lambda_{max}T = 2.898\times10^{-3}$	(1)	
	$\lambda_{max} = 4.9\times10^{-7}$ (m)	(1)	2
	Example of calculation: $\lambda_{max} = \frac{2.898\times10^{-3}\ \text{mK}}{5900\ \text{K}} = 4.91\times10^{-7}\ \text{m}$		
b(ii)	5×10^{-7} m is approximately the middle of the (visible) wavelength range	(1)	
	(So) all the (visible) wavelengths are included, producing white light [accept colours/frequencies for 'wavelengths']	(1)	2
	Total for question		**11**

Q19.

Question Number	Answer	Mark
	The only correct answer is A	
	***B** is not correct because $F \propto L/d^2$*	
	***C** is not correct because $F \propto L/d^2$*	
	***D** is not correct because $F \propto L/d^2$*	**(1)**

Q20.

Question Number	Answer	Mark
a	Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K (1) $\lambda_{max} = 9.4 \times 10^{-6}$ m (1) Example of calculation $\lambda_{max} = \frac{2.898\times10^{-3}\text{ m K}}{307\text{ K}} = 9.44 \times 10^{-6}$m	2
b	Use of $P = \sigma AT^4$ (1) $P = 600\ W$ (1) Example of calculation $P = \sigma AT_{body}^4$ $\therefore P = 5.67 \times 10^{-8}$ W m^{-2} K^{-4} $\times$ 1.2 m^2(307 K)^4 $\therefore P = 604$W	2
c	(The infra-red image shows that) the man's skin temperature varies over his body (and so the temperature is an estimate) **Or** some parts of the body radiate at a higher rate than others (1) The man absorbs thermal energy from the surroundings **Or** some emitted radiation would be reabsorbed **Or** the surface area of man has been estimated (1)	2
	Total for Question	6

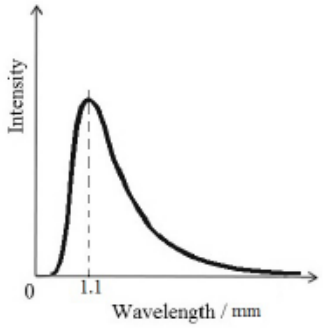
Q21.

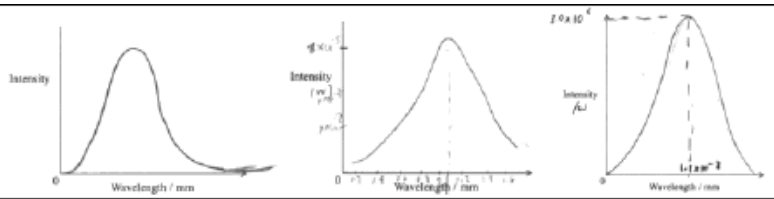
Question Number	Answer	Mark
	D	1

Q22.

Question Number	Answer	Mark
	The only correct answer is **D** A is not correct because there may be sufficient radiation flux B is not correct because the luminosity may be sufficient C is not correct because the angle decreases as the distance increases	1

Q23.

Question Number	Answer		Mark
(a)	Flux varies with distance according to inverse square law	(1)	
	[For inverse square law accept $F = \frac{L}{4\pi d^2}$ or $F \propto \frac{1}{d^2}$]		
	Flux of each star decreases by a factor of 4 as distance is doubled, but number of stars increases by a factor of 4.	(1)	
	Or		
	Attempt to use $F = \frac{L}{4\pi d^2}$ with either $d = 2r$ or $L = 4L$	(1)	
	Correct algebra to show F stays constant. (Dependent mark)	(1)	2
(b)(i)	Use of $L = \sigma A T^4$ where $A = 1\ \text{m}^2$	(1)	
	$L/A = 3.0 \times 10^{-6}\ (\text{W m}^{-2})$	(1)	2
	Example of calculation:		
	$L / A = \sigma T^4 = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4} \times (2.7\ \text{K})^4 = 3.01 \times 10^{-6}\ \text{W m}^{-2}$		
(b)(ii)	Use of $\lambda_{max} T = 2.898 \times 10^{-3}$	(1)	
	$\lambda_{max} = 1.1 \times 10^{-3}$ m	(1)	
	Curve with peak at candidates value for λ_{max} labelled or in the correct position	(1)	
	Shape must be an asymmetric curve and must not have intensity at $\lambda=0$	(1)	4
			
	Example of calculation:		
	$\lambda_{max} = \frac{2.898 \times 10^{-3}\ \text{m K}}{2.7\ \text{K}} = 1.07 \times 10^{-3}\ \text{m}$		
	Examples of graphs that do not meet the "shape" criterion:		

		
(b)(iii)	Peak of curve would be higher **Or** (maximum) intensity would be greater **(1)** **Or** graph would be shifted upwards Peak would be shifted to a smaller wavelength [allow curve would be shifted to the left] **(1)**	**2**
(c)	Idea that there has not been enough time for light from very distant stars to arrive at the Earth **(1)**	**1**
	Total for question	**11**

Q24.

Question Number	Answer	Mark
	C	1