

Mark Scheme

Q1.

Question Number	Answers	Mark
	The only correct answer is C <i>A is incorrect because luminosity must have the units of power</i> <i>B is incorrect because luminosity must have the units of power</i> <i>D is incorrect because luminosity must have the units of power</i>	1

Q2.

Question Number	Answer	Mark
	A	1

Q3.

Question Number	Answer	Mark
	The only correct answer is C, Y is twice as far away as X. A is not correct because $I = \frac{L}{4\pi x^2}$ and L is the same for each star B is not correct because $I = \frac{L}{4\pi x^2}$ and L is the same for each star D is not correct because $I = \frac{L}{4\pi x^2}$ and L is the same for each star	1

Q4.

Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is C because the correct method for a nearby star is parallax, for a nearby galaxy is standard candle and for a very distant galaxy is red shift A is not correct because only the nearby star method is correct B is not correct because only the nearby galaxy method is correct D is not correct because none of the methods are correct	1

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	D		1

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B A is not correct as the luminosity of P must be less than Q C is not correct as P is closer than Q D is not correct as P is closer than Q		1

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Either (Inverse square law states that) the intensity is inversely proportional to the square of the distance (1) Or $I \propto \frac{1}{x^2}$ with symbols defined - So $I \rightarrow \frac{I}{4}$ and statement is incorrect (1) Or intensity/brightness falls to one quarter and statement is incorrect OR - The power is spread over 4 times the area (1) - So intensity/brightness falls to one quarter and statement is incorrect (1)		2

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: (1) - Hubble is for cosmological distances (1) - is not suitable since S2 is in our galaxy (1) - trigonometrical parallax is suitable for local stars because the parallax angles produced are large enough to measure accurately	e.g. to distant galaxies	3

Q9.

Question Number	Acceptable Answers	Additional Guidance	Mark
	- The star is viewed from two positions at 6 month intervals (1) Or The star is viewed from opposite ends of its orbit diameter about the Sun - The change in angle/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] (1) Or The diameter/radius of the Earth's orbit about the Sun must be known	Marks may be obtained from suitably annotated diagrams e.g MP1 and MP2:	3

Q10.

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> $L = 4\pi(6.96 \times 10^8 \text{ m})^2 \times 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4} \times (5778 \text{ K})^4$ $L = 3.88 \times 10^{26} \text{ W}$ $I = \frac{3.88 \times 10^{26} \text{ W}}{4\pi(1.50 \times 10^{11} \text{ m})^2} = 1372 \text{ W m}^{-2}$	4

Q11.

Question Number	Answer		Mark
	QWC – Work must be clear and organised in a logical manner using technical wording where appropriate Standard candles are (stellar) objects of known luminosity (1) Standard candle's brightness on earth is measured/known/found [accept apparent magnitude or flux in place of brightness] [Do not accept 'used' in place of 'measured'] (1) Use inverse square law $[F=L/4\pi d^2]$ Or use distance modulus method $[M - m = 5\log(d/10)]$ (1) (Hence) distance to standard candle is calculated (1) Dust layer will reduce brightness /magnitude/flux of Cepheid (1) Cepheid will appear to be further away than it is (1) [accept "star" for "standard candle" or for "Cepheid" for MP2 to MP6]		6

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	Mean straight line with positive intercept on the y-axis (1)		1

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	$C = \frac{K}{4\pi d^2}$ used to show $\frac{1}{\sqrt{C}} \propto d$ (1) - Or identifies gradient as $\sqrt{\frac{4\pi}{K}}$ which is constant - Since graph is a straight line, data is consistent with this (1) - However, line doesn't pass through the origin (1) - This indicates a <u>systematic</u> error in measuring the distance (1)		4

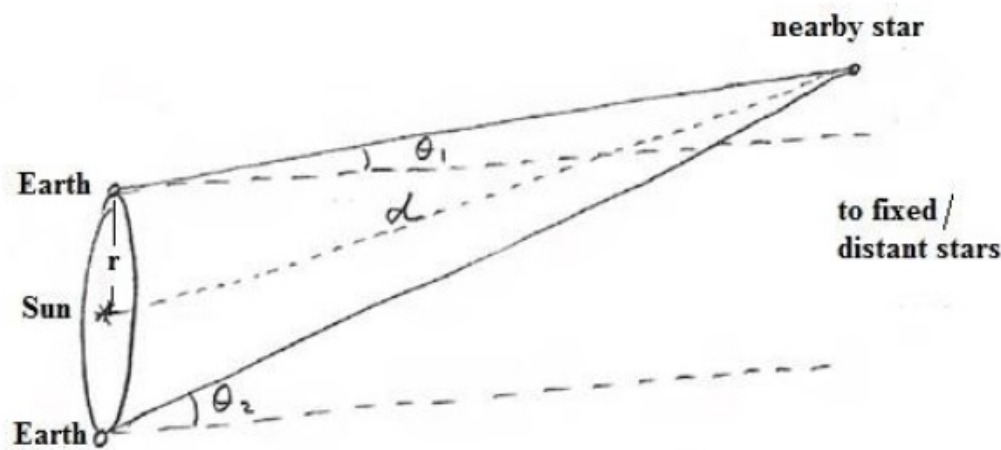
Q13.

Question Number	Answer	Mark
(i)	A standard candle is a (stellar) object of known luminosity	1
* (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
(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

Q14.

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

Q15.

Question Number	Answer	Mark
	QWC – Work must be clear and organised in a logical manner using technical wording where appropriate Parallax: The star is viewed from two positions at 6 month intervals Or the star is viewed from opposite ends of its orbit diameter about the Sun (1) The (change in) angular position of the star relative to fixed/distant stars is measured (1) The diameter/radius of the Earth's orbit about the Sun must be known and trigonometry is used (to calculate the distance to the star) [Do not accept Pythagoras] (1) [the marks above may be obtained with the aid of a suitably annotated diagram] e.g  [Accept the symmetrical diagram seen in many text books] Standard candle: Flux/brightness/intensity of standard candle is measured (1) (1) Luminosity of standard candle is known [accept reference to absolute magnitude Or total power output of star] (1) Inverse square law is used (to calculate distance to standard candle)	6
	Total for question	6

Q16.

Question Number	Acceptable answers	Additional guidance	
(a)	Object of known luminosity (1)		<u>1</u>

Question Number	Acceptable answers	Additional guidance	
(b)	- The (parallax) angle becomes very small (1) Or the diameter of the Earth's orbit is very small - Giving a (very) large percentage uncertainty (1)		<u>2</u>

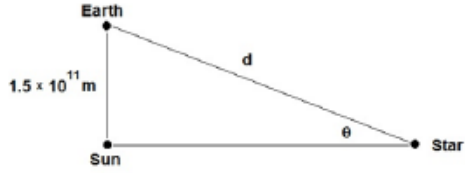
Question Number	Acceptable answers	Additional guidance	
(c)	- Measure change in wavelength / frequency (1) - Determine relative velocity using redshift formula (1) - Then apply $v = H_0 d$ (1)		<u>3</u>

Q17.

Question Number	Answer	Mark
(a)(i)	(A standard candle is) an object of known luminosity (1)	1
(a)(ii)	Flux/brightness/intensity of standard candle is measured (1) Inverse square law used (to calculate distance to standard candle) (1) [Reference to measurement of apparent magnitude of star, m , and distance calculated using $m - M = 5\log(d/10 \text{ pc})$ can score 2 marks]	2
(b)(i)	An increase in the wavelength (of radiation) received from a receding source (1) [accept in terms of a decrease in the frequency]	1
(b)(ii)	Use of $z = v/c$ and $v = H_0 d$ [$z = H_0 d/c$] $d = 1.7 \times 10^{25} \text{ m}$ (1) Example of calculation: $v = zc = 0.12 \times 3 \times 10^8 \text{ m s}^{-1} = 3.6 \times 10^7 \text{ m s}^{-1}$ $d = v/H = 3.6 \times 10^7 \text{ m s}^{-1} / 2.1 \times 10^{-18} \text{ s}^{-1} = 1.71 \times 10^{25} \text{ m}$ (1)	2
*(c)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Max 3 Dark matter has mass but does not emit e-m radiation [accept light] (1) (Dark matter proposed when) observations of galaxies indicated that they must contain more matter than could be seen. (1) The existence of dark matter will increase the (average) density of the universe (1) This may make it more likely that the universe is closed [accept will contract Or end with a “Big Crunch”] (1) Or Idea that this may make the ultimate fate of the Universe less certain	3
(d)	Max 2 The universe started from a small initial point [accept Big Bang] (1) Idea that universe has a finite age (1) Idea that (observable universe is finite because) we can only see as far as (speed of light) $\times$ (age of universe) Or light reaching us must have travelled a finite distance since the Big Bang Or some parts of the universe are so distant, light has not had time to reach us yet (1)	2
	Total for question	11

Question Number	Answer	Mark
(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
(b)	(Standard candles are stellar) objects of known luminosity (1)	1
(c)	See $v = H_0 d$ and $v = d/t$ (1) Therefore $t = 1/H_0$ (1) (dependent mark)	2
(d)(i)	If density less than critical value, expansion would continue for ever (1) If density greater than critical, expansion would stop and universe would contract again (1) If density equals critical value, expansion rate would decrease to zero but universe would not contract again (1)	3
(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 (1) Since dark matter doesn't interact via the electromagnetic interaction (1) Or The value of the Hubble constant is uncertain (1) Since measurements of distances to distant galaxies are uncertain (1)	2
Total for question		13

Q19.

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