A Level AQA Physics
22 Stars and cosmology – answers

Question	Answers	Extra information	Mark	AO	Spec reference
01.1	Apparent magnitude is how bright the star appears to be Absolute magnitude is a measure of how bright a star appears to be at a standard distance of 10 parsecs from Earth		1	1	3.9.2.1
01.2	Bellatrix		1 1	2	3.9.2.1
01.3	$m - M = 5\log\left(\frac{d}{10}\right)$ $M = m - 5\log\left(\frac{d}{10}\right)$ $= 1.64 - 5\log\left(\frac{77}{10}\right)$ $= -2.79$	Correct substitution Answer	1 1	2	3.9.2.2
01.4	They are approximately the same temperature as they are the same spectral class The absolute magnitude of Rigel is brighter by a factor of about 2.5 times that of Bellatrix $P = \sigma AT^4$; to have a 2.5 times greater power output at the same temperature, the area of Rigel is about 2.5 times greater	Link between spectral class and temperature Comparison of magnitude Use of Stefan's Law to work out answer	1 1 1 1	3	3.9.2.3
02.1	$\lambda_{max}T = 2.9\times10^{-3}\,\text{mK}$ $\lambda_{max} = \frac{2.9\times10^{-3}}{T} = 2.9\times10^{-7}\,\text{m}$	Use of Wein's law Answer	1 1	2	3.9.2.3

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	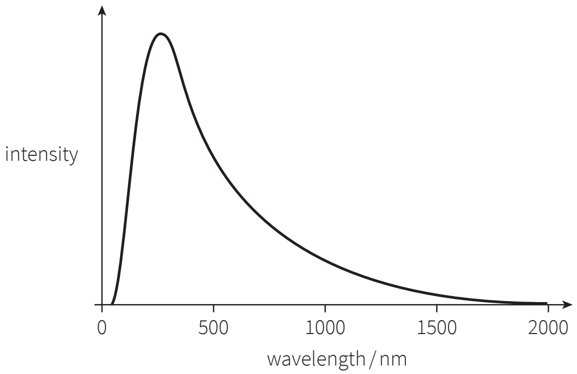	Graph with peak over approximately 300 nm Correct shape on LHS Correct shape on RHS	1 1 1		
02.2	A		1	1	3.9.2.4
02.3	The peak wavelength would be at approximately double/bigger than that of the curve for Sirius The intensity would be much less/the peak would be lower		1 1	2	3.9.2.3
02.4	$P = \sigma A T^4$ $\frac{P_{\text{Sirius}}}{P_{\text{Adhara}}} = \frac{A_{\text{Sirius}}}{A_{\text{Adhara}}} \times \left(\frac{T_{\text{Sirius}}}{T_{\text{Adhara}}}\right)^4$ $= \left(\frac{d_{\text{Sirius}}}{d_{\text{Adhara}}}\right)^2 \left(\frac{T_{\text{Sirius}}}{T_{\text{Adhara}}}\right)^4$ $= \left(\frac{2}{35}\right)^2 \left(\frac{9940}{4290}\right)^4 = 28.4$ Using inverse-square law $P_{\text{Earth}} = \frac{P_{\text{star}}}{R^2}$ $\frac{P_{\text{Sirius}}}{P_{\text{Adhara}}} = 28.4 \left(\frac{R_{\text{Adhara}}}{R_{\text{Sirius}}}\right)^2 = 28.4 \left(\frac{34}{8.6}\right)^2 = 443$ Assuming no light is absorbed or scattered/star behaves like a black body	Use of Stefan's Law substitution Answer Use of inverse-square law substitution Answer Assumption	1 1 1 1 1	3`	3.9.2.3

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OXFORD Revise

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02.5	Each difference of 1 in magnitude produces a difference of 2.5 in intensity The stars differ by 3 in terms of magnitude Which is a difference of $(2.5)^3 = 15.6$	Explicit or implied	1 1 1	3	3.9.2.1
02.6	No, the dimmest star observable has a magnitude of +6		1	1	3.9.2.1
02.7	Correct suggestion, e.g., The scale used Vega as a reference point (zero on the scale) and Vega is not always visible There are stars brighter and dimmer than the stars that were 1 or 6 on the Hipparchus scale		1	1	3.9.2.1
03.1	The star contains hydrogen The electrons in hydrogen start in the $n = 2$ state Absorbing the correct amount of energy excites the electrons, raising them to a higher level When the electrons return, the light is emitted in all directions, and the electrons may do it in several steps or miss out $n = 2$ and jump down to $n = 1$. This results in the gap, or reduction in intensity in the direction of the observer The bigger the jump, the higher the energy difference, the higher the frequency, and the lower the wavelength of light emitted	Starting level = 2 Mechanism for excitation Why there is a reduction in intensity Link to wavelength	1 1 1 1	1	3.9.2.4
03.2	Class A They have the highest abundance of electrons in the $n = 2$ state		1 1	2	3.9.2.4
03.3	There are minima in the curve at the wavelengths corresponding to the wavelengths of the lines		1	2	3.9.2.4
03.4	K		1	1	3.9.2.4
03.5	Number of parsecs = 3.22 pc Number of ly = 3.26 × 3.22 = 10.5 ly	Number of parsecs Number of ly	1 1	2	3.9.2.2

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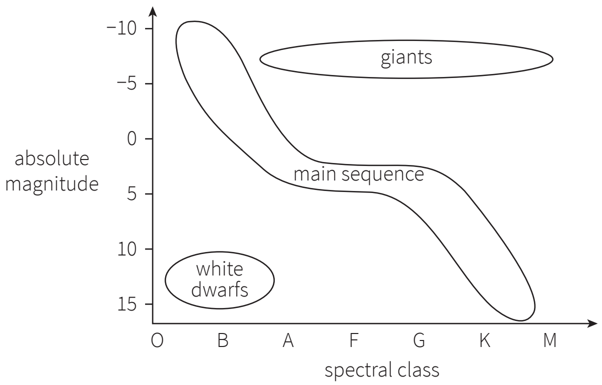
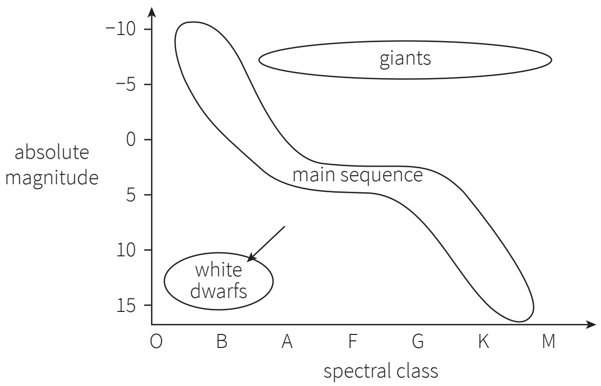
04.1		All three labels correct – 2 marks 1 label correct – 1 mark x-axis labelled – 1 mark	3	1	3.9.2.5
04.2		Line from main sequence area to giants Line from giants to white dwarfs Arrow to show direction	1 1 1	1	3.9.2.5
04.3	The amount of hydrogen fuel The rate of fusion/using up of nuclear fuel		1 1	1	3.9.2.5
04.4	Sirius B was a giant star before it became a white dwarf It cooled, used up its fuel, and collapsed, which initiated helium fusion When the helium is used up, it will expand and the outer material will be pushed away to form a planetary nebula		1 1 1	2	3.9.2.5

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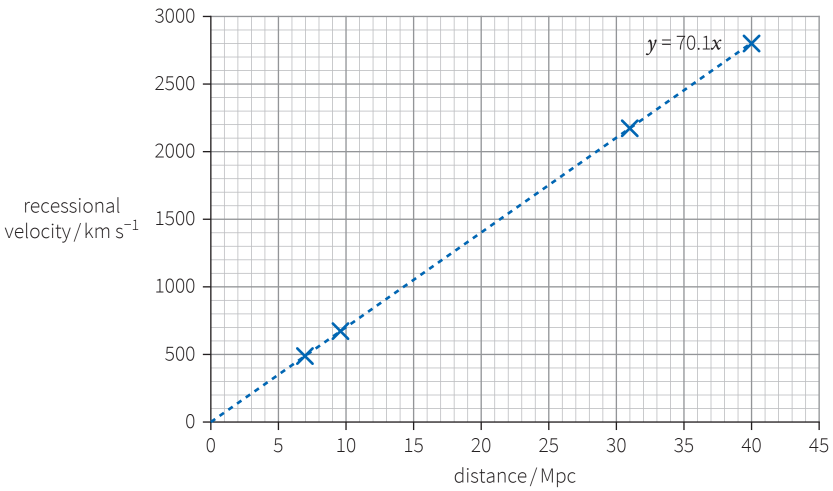
04.5	Gamma ray bursts are a result of the collapse of a supergiant star, which forms a neutron star or a black hole The mass of Sirius B is not large enough		1 1	2	3.9.2.6
05.1	$\frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$ $v = \frac{c \times \Delta\lambda}{\lambda} = \frac{3\times10^{8} \times (403.4 - 402.5) \times 10^{-9}}{402.5\times10^{-9}} = 670\times10^{3}\,\mathrm{m\,s^{-1}}$ $= 670\,\mathrm{km\,s^{-1}}$	Substitution Answer	1 1	2	3.9.3.1
05.2	 $v = Hd$ Gradient is the Hubble constant $= H = 70.1\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ $= \frac{70.1\times10^{3}\,\mathrm{m\,s^{-1}}}{10^{6} \times 3.08\times10^{16}\,\mathrm{m\,Mpc^{-1}}} = 2.28\times10^{-18}\,\mathrm{s^{-1}}$ age of the universe $= \frac{1}{H}$	Graph axes/labels – 1 mark Points plotted with straight line through (0, 0) Gradient calculated Use of age $= \frac{1}{H}$	1 1 1 1 1	2	3.9.3.2

Question	Answers	Extra information	Mark	AO	Spec reference
	$= \frac{1}{2.28\times10^{-18}\,s^{-1}}$ $= 4.39\times10^{17}$ s $= 14.2\times10^{9}$ years	Answer			
05.3	Two pieces of evidence, e.g. Cosmological background radiation is radiation left over from the Big Bang with a peak in the microwave region Hydrogen and helium abundance is accounted for by the brief period of fusion in the early Universe		2	1	3.9.3.2
05.4	Correct suggestion, e.g. The resolution of measuring devices has improved so that the measurements of velocity and distance can be made with more precision The radiation absorbed by detectors in the HST has not been scattered by the atmosphere so there is less spread		1 1 1		3.9.1.3
05.5	$v = Hd$ $H = \frac{1}{\text{age of the Universe}}$ $D = v \times$ age of universe $= 7.54 \times 13.8\times10^{9} \times 3.1\times10^{7}$ m $= 3.23\times10^{18}$ m $= \frac{3.22\times10^{18}}{3.08\times10^{16}} = 105$ pc Or $= \frac{3.22\times10^{18}}{9.46\times10^{15}} = 341$ ly	Use of H Answer in m Answer in pc or ly	1 1 1	3	3.9.3.1 3.9.3.2
06.1	Mass of black hole $= 5\times10^{6} \times 1.99\times10^{30}$ kg $= 9.95\times10^{36}$ kg $R_{\text{black hole}} = \frac{2GM}{c^2} = \frac{2 \times 6.67\times10^{-11} \times 9.95\times10^{36}}{(3\times10^{8})^2}$ $= 1.5\times10^{10}$ m	Substitution Answer	1 1	2	3.9.2.6

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06.2	Density $= \frac{\text{mass}}{\text{volume}}$ $= \frac{3 \times 9.95\times10^{36}}{4\pi(1.5\times10^{10})^3} = 7.04\times10^{5}\ \text{kg m}^{-3}$ Density of Sun $= \frac{2.0\times10^{30}\ \text{kg}}{1.44\times10^{27}\ \text{m}^3} = 1400\ \text{kg m}^{-3}$ This is smaller by a factor of 500 The Sun has insufficient mass to produce an escape velocity that exceeds that of light	 Calculations (both required for mark) Comparison Definition of black hole	1 1 1 1	2	3.9.2.6
06.3	$\frac{P_{\text{quasar}}}{P_{\text{black hole}}} = \frac{10^{42}}{4\times10^{26}} = 2.5\times10^{15} = \left(\frac{d_S}{d_{\text{new}}}\right)^2$ $d_{\text{new}} = \frac{1.5\times10^{11}}{\sqrt{2.5\times10^{15}}} = 3000\ \text{m}$	Use of inverse-square law Answer	1 1	3	3.9.3.2
06.4	The angle subtended by the quasar at the Earth is too small to be detected by a telescope with a dish of the size at the time		1	2	3.9.1.3
06.5	$B = 10^{9}\ \text{T}$, $Q = 2e = 2 \times 1.61\times10^{-19}\ \text{C}$, $v = 1.5\times10^{8}\ \text{m s}^{-1}$ $F = BQv = 0.048\ \text{N}$	Correct charge Answer	1 1	2	3.7.5.2
06.6	The force is perpendicular to the velocity		1	3	3.7.5.1

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Question	Answers	Extra information	Mark	AO	Spec reference
07.1	Angular separation $= \frac{\text{separation}}{\text{distance}}$ $= \frac{23 \times 1.50 \times 10^{11}\ \text{m}}{4.3 \times 9.46 \times 10^{15}\ \text{m}}$ $= 8.5 \times 10^{-5}$ radians Estimate $\lambda = 550 \times 10^{-9}$ m $\theta = \frac{\lambda}{D}$ $D = \frac{\lambda}{\theta} = \frac{550 \times 10^{-9}}{8.5 \times 10^{-5}} = 6 \times 10^{-3}$ m This is very small, and is a minimum so these two stars would easily be resolvable by a small (20 mm diameter) telescope or binoculars	Calculate angle in radians Estimate of wavelength Calculation of diameter Comment Identification of minimum	1 1 1 1 1	2	3.9.1.4
07.2	The gravitational force between the masses provides the centripetal force to keep them in orbit $v = \frac{2\pi r}{T} = \frac{2\pi \times 11.5 \times 1.50 \times 10^{11}}{80 \times 3.1 \times 10^{7}} = 4370\ \text{m s}^{-1}$ $F_g = \frac{-GMM}{d^2} = \frac{-Mv^2}{r}$, and $r = \frac{d}{2}$ $\frac{GM}{d^2} = \frac{2v^2}{d}$ $M = \frac{2dv^2}{G} = \frac{2 \times 23 \times 1.50 \times 10^{11} \times 4370^2}{6.67 \times 10^{-11}}$ $= 1.97 \times 10^{30}$ kg	Identification of centripetal force Velocity Use of Newton's Law of gravitation Answer	1 1 1 1	3	3.6.1.1 3.7.2.1
07.3	The stars are orbiting a common centre of mass so they move in front of each other as they rotate		1	1	3.9.3.1
07.4	The stars have equal brightness The drop in brightness is the always the same		1 1	2	3.9.3.1

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07.5	$\frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$ $v = \frac{c \times \Delta\lambda}{\lambda} = \frac{3\times10^8 \times 0.032\times10^{-9}}{438\times10^{-9}} = 21.9\times10^3\,\text{m s}^{-1}$ $v = \frac{c \times \Delta\lambda}{\lambda} = \frac{3\times10^8 \times 0.018 \times 10^{-9}}{438\times10^{-9}} = 12.3\times10^3\,\text{m s}^{-1}$	Substitution Both answers correct	1 1	2	3.9.3.1
07.6	The star that is moving faster has the smaller orbit Kepler's Third Law: $\frac{R^3}{T^2}$		1 1	2	3.7.2.4
08.1	A light curve with a horizontal line above the x-axis either side of a U-shaped dip x-axis labelled time, y-axis labelled intensity	Both labels needed	1 1	1	3.9.3.4
08.2	Pixel size = $\frac{10^{-2}\,\text{m}}{2048} = 4.8\times10^{-6}\,\text{m}$ The size of the light sensitive cells in the eye are 2×10^{-6} m, which are 2.5 times smaller than those on the CCD		1 1	2	3.9.1.4
08.3	Correct suggestions, e.g. Photons are absorbed by atoms and electrons are given sufficient energy to escape Charge accumulates on a capacitor which produces a pd according to $V = \frac{Q}{C}$		1 1	3	3.2.2.2 3.7.4.1
08.4	The gravitational pull of the star on the planet causes the star to 'wobble' The light from the star is Doppler shifted by an amount proportional to the mass and inversely proportional to the radius of orbit of the exoplanet		1 1	1	3.9.3.4

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OXFORD Revise

Skills box answers

Question	Answer
1	$T = \frac{\text{Wien's constant}}{\lambda_{max}} = \frac{2.90 \times 10^{-3}\,\text{m K}}{(970 \times 10^{-9}\,\text{m})} = 2990\,\text{K}$
2	$P = 4\pi r^2 \sigma T^4 = 4\pi\,(7.9 \times 10^7\,\text{m})^2 \times 5.67 \times 10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4} \times (6000\,\text{K})^4 = 5.76 \times 10^{24}\,\text{W}$
3	Rearrange Stefan's law to make r the subject of the equation: $r = \sqrt{\frac{P}{4\pi\sigma T^4}} = \sqrt{\left(\frac{5.5 \times 10^{32}\,\text{W}}{(4\pi \times 5.67 \times 10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4} \times (25\,000\,\text{K})^4)}\right)} = 4.5 \times 10^{10}\,\text{m}$