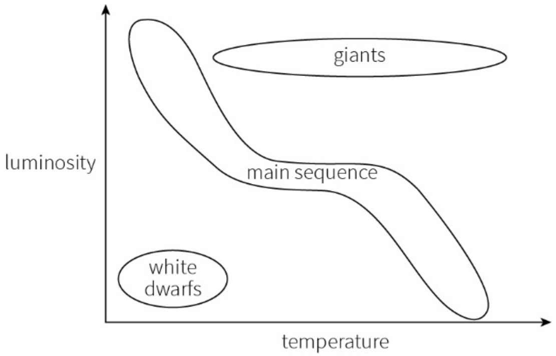
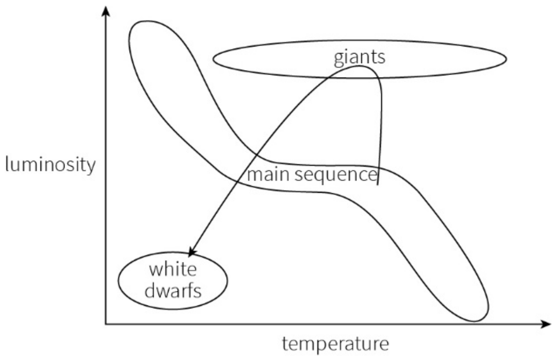
A Level OCR Physics

Chapter 19 Astrophysics and cosmology

Q	Answers	Extra information	Mark	AO	Spec reference
1(a)		All three labels correct – 2 marks 1 label correct – 1 mark x-axis labelled – 1 mark Allow giants/red giants/ super giants	3	1	5.5.1
(b)		Line from main sequence area to red giants Line from giants to white dwarf Arrow to show direction	1 1 1	1	5.5.1
(c)	The amount of hydrogen fuel / mass The rate of fusion/using up of nuclear fuel / luminosity		1 1	1	5.5.1
(d)	When fusion ends, outer material will be pushed away to form a planetary nebula. Core remains behind as the white dwarf		1 1	2	5.5.1
(e)	As gravity pulls matter in atoms are forced together, but electrons with the same spin cannot occupy the same (quantum) state This produces electron degeneracy pressure that counteracts the force of gravity	Electrons cannot occupy the same state Electron degeneracy	1 1	2	5.5.1

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(f)	Maximum mass is the Chandrasekhar limit/maximum mass is 1.44 × mass of the Sun		1	1	5.5.1
2(a)	You need to give electrons energy to ionise them / get them out of the atom		1	1	5.5.2
(b)	$\Delta E = \frac{hc}{\lambda}$ so $\lambda = \frac{hc}{\Delta E}$ $\Delta E = \left(-4.3 \times 10^{-19}\right) - \left(-8.9 \times 10^{-19}\right)$ $= 4.6 \times 10^{-19}$ J $\lambda = \frac{hc}{\Delta E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{4.6 \times 10^{-19}}$ $= 4.3(2) \times 10^{-7}$ m	ΔE correct Substitution Answer	1 1 1	2	5.5.2
(c)	Correct suggestions e.g.: If the gas was heated, e.g. as part of a star undergoing fusion, then you would observe an emission spectrum If the gas lies between the observer and a star that emits all wavelengths of radiation then an absorption spectrum is observed	One mark for each suggestion	2	1	5.5.2
(d)	No The emission of the photon of wavelength 432 nm is close to line 3 in the transition to level 2 The other 2 possible transitions are between -8.0×10^{-19} J and -8.9×10^{-19} J, which a change in energy of 0.9×10^{-19} J and wavelength of 2210 nm and between -4.3×10^{-19} J and -8.0×10^{-19} J, which a change in energy of 3.7×10^{-19} J and wavelength of 537.6 nm There are no lines at these wavelengths	Comment about line calculated in part **2(b)** Calculation of wavelength for transition to same level Answer Comment	1 1 1 1	3	5.5.2

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3(a)	$\lambda_{max} T = 2.9 \times 10^{-3}$ mK $T = 2.9 \times 10^{-3} / (290 \times 10^{-9})$ $= 10\,000$ K	Use of Wein's law Answer and unit	1 1	2	5.5.2
(b)	$d = 10^{-3}/1000 = 10^{-6}$ m $n\lambda = d\sin\theta,\ n\Delta\lambda = d\sin\Delta\theta = d\Delta\theta$ for small angles $n = 1,\ \Delta\lambda = d\Delta\theta = 10^{-6}$ m $\times\ 0.5\times10^{-3} = 5\times10^{-10}$ m	Calculation of d Answer	1 1	2	5.5.2
(c)	One from The peak wavelength would be at approximately double/bigger than that of the curve for Sirius Intensity of curve would be lower than Sirius		1	2	5.5.2
(d)	**Level 3 (5–6 marks)** Calculations to determine the ratio of power using both Stefan's Law and the inverse-square Law *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Partial calculations to determine the ratio of power using both Stefan's Law and the inverse-square Law *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited comparison not necessarily containing calculations which describes the factors associated with intensity. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**Indicative scientific points may include:** Description: - Luminosity is linked to radius and temperature of the star - As distance to Earth increases, intensity decreases - Assuming no light is absorbed or scatter/star behaves like a black body Luminosity calculation:-use of Stefan's Law to calculate luminosity of both stars (or use ratios) - $L = 4\pi r^2 \sigma T^4$ - luminosity of Sirius = 7.125 $\times\ 10^{27}$ W	6	3`	5.5.2

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		- luminosity of Arcturus = 7.39 × 10^{28} W - Acturus is 10.4× more luminous Intensity calculation: - Use of inverse-square law - $I \propto \frac{L}{d^2}$ - Comparing ratios, Arcturus decreases by 15.63× as much - Therefore Sirius is 1.5× brighter on Earth overall than Arcturus			
4(a)	Light second The Moon is about 1.4 light seconds/small number of light seconds/large number of metres from Earth/AU too big		1 1	1	5.5.3
(b)	The position of a distant star is observed relative to the background stars at one point of the Earth in its orbit, which is analogous to what the student first sees with one eye closed. The star is then observed 6 months later, which is analogous to what the student sees when the other eye is closed Parallax is the apparent movement of distant stars relative to the background, just as the thumb appears to move relative to the poster.		1 1 1	3	5.5.3
(c)	p is the parallax angle in seconds of arc and d is the distance in parsecs The parsec is defined as the distance at which one astronomical unit subtends an angle of one second, so if p is measured in seconds of arc, d can be found in parsecs		1 1	1	5.5.3

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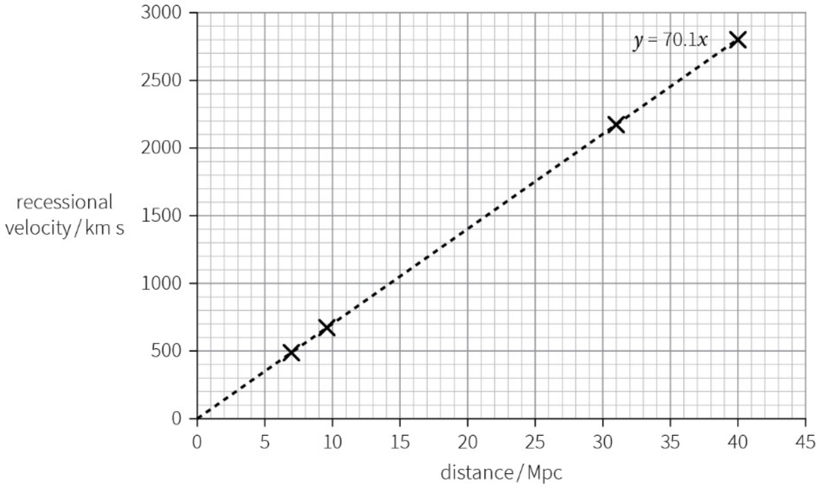
(d)	Angle = 0.04 seconds of arc, so $d = 1/p$ = 25 parsecs = 7.74 × 10^{17} m	Distance in parsecs Answer	1 1	3	5.5.3
5(a)	$\frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$ $v = \frac{c \times \Delta\lambda}{\lambda} = \frac{3 \times 10^{8} \times (403.4 - 402.5) \times 10^{-9}}{402.5 \times 10^{-9}}$ = 670 × 10^3 m/s = 670 km/s	Substitution Answer	1 1	2	5.5.3
(b)	 $v = H_0 d$ Gradient is the Hubble constant = H_0 = 70.1 km/s/Mpc = 70.1 × 10^3 m/s /10^6 × 3.08×10^{16} m/Mpc = 2.28×10^{-18} s^{-1} age of the universe = 1/ H_0 = 1/2.28×10^{-18} s^{-1}	Graph axes/labels – 1 mark Points plotted with straight line through (0,0) Allow gradients from 65 – 75 Gradient calculated Use of age = 1/H_0 Answer	1 1 1 1 1	2	5.5.3

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	$= 4.39 \times 10^{17}$ s $= 14.2 \times 10^{9}$ years				
(c)	- cosmological background radiation is radiation left over from the Big Bang with a peak in the microwave region		1	1	5.5.3
(d)	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	5.5.3
(e)	$V = Hd$ H = 1/age of the universe $d = V$ × age of the universe $= 7.54 \times 13.8 \times 10^{9} \times 3.1 \times 10^{7}$ m $= 3.22 \times 10^{18}$ m $= 3.22 \times 10^{18}/3.08 \times 10^{16} = 105$ pc Or $= 3.22 \times 10^{18}/9.46 \times 10^{15} = 341$ ly	Use of H Answer in m Answer in pc/ly	1 1 1	3	5.5.3
6(a)	Isotropic Homogeneous	Both for mark	1	1	5.5.2
(b)	$\lambda_{max} T = 2.9 \times 10^{-3}$ mK $\lambda_{max} = 2.9 \times 10^{-3} / T$ $= 2.9 \times 10^{-3} / 2.7$ $= 1.07 \times 10^{-3}$ m	Substitution Answer	1 1	2	5.5.2
(c)	Stars in the Milky Way can be moving towards our Solar System, and hence be blue-shifted (as well as red-shifted) due to gravity		1	1	5.5.3

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	The space between galaxies is expanding, so you only see red-shift of radiation from galaxies		1		
(d)	The wavelength will increase As the universe expands		1 1	1	5.5.3
(e)	$\frac{mv^2}{r} = \frac{GMm}{r^2}$ $M = \frac{rv^2}{G}$ $r = 2.6\times10^4 \times 3\times10^8 \times 365 \times 24 \times 3600 = 2.45\times10^{20}$ m $T = 250 \times 10^6 \times 365 \times 24 \times 3600 = 7.88\times10^{15}$ s $v = \frac{2\pi r}{T} = \frac{2\pi \times 2.45\times10^{20}}{7.88\times10^{15}} = 1.95\times10^5$ m/s $M = \frac{2.45\times10^{20} \times (1.95\times10^5)^2}{6.67\times10^{-11}} = 1.40\times10^{41}$ kg Only 5% of this is visible Visible mass = $0.05 \times 1.40\times10^{41}$ kg = 7.00×10^{39} kg.	Use of centripetal force and Newton's law Distance in metres Calculation of speed Calculation of mass Calculation of visible mass	1 1 1 1 1	3	5.2.2 5.4.2
7(a)	From top: protostar, main sequence star Left: White dwarf Right: Red supergiant, supernova, neutron star/black hole	Both correct, in order – 1 mark All correct, in order – 1 mark	1 1 1	1	5.5.1
(b)	A white dwarf / red giant It is 9 billion years older than we see it on Earth		1 1	1	5.5.1

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(c)	Both exert a pressure outwards Radiation pressure is due to photon momentum Gas pressure is due to collisions of gas molecules Gas pressure is much larger than radiation pressure		1 1 1 1	1	5.5.1
(d)	$\frac{1}{2}mv^2 = \frac{Q_1Q_2}{4\pi\varepsilon_0 r}$ Estimate $r = 0.5\times10^{-15}$ m $v = \sqrt{\frac{2Q_1Q_2}{4\pi\varepsilon_0 rm}} = \sqrt{\frac{2\times1.60\times10^{-19}\times1.60\times10^{-19}}{4\pi\varepsilon_0\times0.5\times10^{-15}\times1.673\times10^{-27}}}$ $= 2.3\times10^7$ m/s	Conservation of energy Estimation of r. *Allow values between 0.5 and 3 fm* Substitution Answer	1 1 1 1	2	6.2.4
(e)	$\frac{1}{2}mv^2 = \frac{3}{2}kT$ $v = \sqrt{\frac{3kT}{m}}$ For centre of star: $v = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3\times1.38\times10^{-23}\times15\times10^9}{1.673\times10^{-27}}}$ $= 1.9\times10^7$ m/s For surface of star $v = \sqrt{\frac{3\times1.38\times10^{-23}\times15\times10^9}{1.673\times10^{-27}}}$ $= 1.2\times10^4$ m/s	Use of equation Substitutions Answers (both) Answer Reason	1 1 1 1 1	3	5.1.4

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	Fusion happens in the centre of stars The speed calculated is the rms speed, there will be a distribution of speeds and some protons will have sufficient energy to fuse				
(f)	A (electron) neutrino To conserve lepton number		1 1	2	6.4.2
8(a)	Initially the p.d. across the *LDR* = 6.0 – 3.4 V = 2.6 V Finally the p.d. across the *LDR* = 6.0 V – 3.7 V = 2.3 V Initial current = V/R = 3.4 V/10 × 10^3 = 3.4×10^{-4} A Initial resistance of *LDR* = V/I = 2.6/3.4×10^{-4} = 7647 Ω Final current = V/R = 3.7 V/10 × 10^3 = 3.7×10^{-4} A Final resistance of *LDR* = V/I = 2.3/3.7×10^{-4} = 6216 Ω Percentage change = ((7647− 6216)/7647) × 100 = 19% (18.7) Or use the potential divider equation to determine: $R1$ = 7647 Ω when Vout = 3.4 V $R1$ = 6216 Ω when Vout = 3.7 V	Use of p.d.s across *LDR* Calculation of current Resistances calculated Percentage calculated	1 1 1 1	3	4.2.3
(b)	The change in resistance is limited by the resolution of the voltmeter, which limits the change in resistance that can be detected Minimum change in p.d. is 0.1 V Area of 1cm^2 produced a change of 0.3 V, so minimum area = 1/3 cm^2 = 0.33 cm^2. So minimum diameter = 6.5 mm	Mention of resolution Use of ratios Answer Calculation of diameter	1 1 1 1	3	4.2.3
(c)	The star emits all wavelengths of light The light travels through the atmosphere, and particular wavelengths are		1	3	5.5.2

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	absorbed depending on the elements present, so that an absorption spectrum is observed By comparing the spectrum with the (emission) spectrum of elements on Earth the elements can be identified		1 1		
(d)	Escape velocity does not depend on mass as $\frac{1}{2}mv^2 = \frac{GmM}{r}$ The mean square speed of the gas molecules in the atmosphere is proportional to the temperature of the gas, so $\frac{1}{2}mv^2 = \frac{3}{2}kT$ but is inversely proportional to mass The oxygen and carbon molecules do not have sufficient speed to escape.	Independence of escape velocity on mass Inverse relation of v_{rms} and speed Effect on composition	1 1 1	3	5.1.4 5.4.4