

Question		Expected Answers	Marks	Additional Guidance
1	a	static / homogeneous	B1	Uniform (density)
		infinite / infinite number of stars	B1	Do not allow isotropic or fixed
	b	(i) gradient of graph = H_0	C1	
		value $H_0 = 66 \pm 4$ (Mpc^{-1})	A1	
		(ii) age = $1 / H_0$ ($H_0 = 2.1 \times 10^{-18} \text{ s}^{-1}$) $= (1 / 66 \times 3.2 \times 10^{-20} \times 3.2 \times 10^7)$ $= 1.5 \times 10^{10} (1.48 \times 10^{10})$ (year)	C1 C1 A1	ecf from H_0 value Or correct age in seconds ($4.7 \times 10^{17} \text{ s}$) Answer will depend on H_0 value in (b)(i) Minus one if Mega or kilo omitted
	c	(i) $\rho_c = 3H_0^2 / 8\pi G$ $= [3 \times (2.1 \times 10^{-18})^2] / (8 \times \pi \times 6.67 \times 10^{-11})$ $= 7.9 \times 10^{-27}$ (kg m^{-3})	C1 A1	If units of H_0 not converted or converted incorrectly then maximum one out of two ecf from H_0 value in (b)(i)
		(ii) if average density of the Universe is less than critical then it will be too small to stop it expanding / it goes on forever if the average density of the Universe is greater than the critical value it will cause the contraction (and produce a big crunch) close to critical value and therefore a universe expands that will go towards a limit / expands at an ever decreasing rate asymptotic	B1 B1 B1	do not allow answers open, closed and flat

	d	<p>galaxies are moving apart / universe is expanding</p> <p>if galaxies have always been moving apart then at some stage they must have been closer together / or started from a point</p> <p>evidence in red shift either optical / microwave</p> <p>further away the galaxy the faster the speed of recession</p> <p>the existence of a (2.7 K) <u>microwave</u> background radiation</p> <p>there is more helium in the universe than expected</p> <p style="text-align: right;">MAX 4</p>	<p>(B1)</p> <p>(B1)</p> <p>(B1)</p> <p>(B1)</p> <p>(B1)</p> <p>(B1)</p> <p>B4</p>	<p>Allow stars for galaxies</p> <p>allow from a singularity</p> <p>allow statement that red shift is observed or that blue light becomes red or gamma from big bang has become microwave</p>
		Total	[16]	

Question		Answer	Marks	Guidance
3	(a)	The night sky should be bright / have uniform brightness (but it is not) The line of sight ends on (the surface of a star) or 'number of stars $\propto r^2$ and intensity $\propto 1/r^2$ Any <u>two</u> assumptions about the Universe: Infinite / uniformly distributed matter or stars throughout / static / infinite age	B1 B1 B1	
	(b)	(recessional) speed of <u>galaxy</u> \propto its distance (from the Earth) The universe is finite / it is expanding / it has a beginning / visible light is red-shifted (because of expansion of space) (AW)	B1 B1	Allow: $v = H_0 x$, $v =$ (recessional) speed of galaxy, $x =$ distance and H_0 is Hubble constant / a constant
	(c) (i)	$v = H_0 x$ $3.4 \times 10^7 = H_0 \times 1.4 \times 10^{25}$ $H_0 = 2.4 \times 10^{-18}$ unit: s^{-1}	C1 A1 B1	Note: This is an independent mark Note: Allow full credit for an Hubble constant of 75 with unit $km\ s^{-1}\ Mpc^{-1}$
	(ii)1	age = $\frac{1}{2.4 \times 10^{-18}}$ age = 4.17×10^{17} (s) age = 1.3×10^{10} (years)	C1 A1	Possible ecf from (i)
	(ii)2	distance = $4.17 \times 10^{17} \times 3.0 \times 10^8$ (= 1.25×10^{26} m) distance = $\frac{4.17 \times 10^{17} \times 3.0 \times 10^8}{3.1 \times 10^{16}}$ distance = 4.0×10^9 (pc)	C1 A1	Possible ecf from (ii)1
Total			12	

Question		Answers	Marks	Guidance	
4	(a)	Any <u>four</u> from: 1. (Sun / star formed from) dust cloud / nebula / (hydrogen) gas 2. <u>Gravitational</u> collapse (AW) 3. Temperature of (dust) cloud increases / KE (of cloud) increases / (cloud) heats up 4. Fusion occurs (when temperature is about 10^7 K) 5. Protons / hydrogen nuclei combine to make helium (nuclei) 6. Stable size star is produced when thermal / radiation pressure is equal to gravitational pressure Steps sequenced correctly – QWC mark	B1×4 B1	Must use ticks on Scoris to show where the marks are awarded	
	(b)	Any <u>two</u> from: 1. Very dense star 2. Hot star / high surface temperature / low luminosity 3. No fusion reactions take place / leaks away photons (from earlier fusion reactions) 4. Its collapse is prevented by Fermi pressure / mass less than 1.4 solar masses (AW)	B1×2	Must use ticks on Scoris to show where the marks are awarded Not: small in size, but <u>allow</u> 'smaller than main sequence star / Sun'	
	(c)	(i)	Flat or universe will expand towards a (finite) limit or the rate of expansion will become/tend to zero	B1	
		(ii)	Hubble constant = 1/age $H_0 = 1 / 4.4 \times 10^{17} (= 2.273 \times 10^{-18} \text{ s}^{-1})$ $\text{density} = \frac{3H_0^2}{8\pi G}$ $\text{density} = \frac{3H_0^2}{8\pi G} = \frac{3 \times (2.273 \times 10^{-18})^2}{8\pi \times 6.67 \times 10^{-11}}$ $\text{density} = 9.2 \times 10^{-27} \text{ (kg m}^{-3}\text{)} \text{ or } 9.24 \times 10^{-27} \text{ (kg m}^{-3}\text{)}$ density is about $10^{-26} \text{ (kg m}^{-3}\text{)}$	C1 C1 A1 A0	Allow: 2 marks for a bald $9.24 \times 10^{-27} \text{ (kg m}^{-3}\text{)}$ answer Note: This mark can only be scored if working is shown

Question		Answers	Marks	Guidance
	(iii)	number = $9.24 \times 10^{-27} / 1.7 \times 10^{-27}$ number = 5.4 (Allow 5)	C1 A1	Possible ecf from (c)(ii) Allow: 2 marks for ' $10^{-26} / 1.7 \times 10^{-27} = 5.9$ or 6'
	(d)	$\frac{1}{2}mv^2 = \frac{3}{2}kT$ / speed $\propto \sqrt{T}$ ratio = $\sqrt{\frac{10^8}{2.7}}$ ratio = 6.1×10^3 or 6.09×10^3	C1 A1	
		Total	15	