Question			Expected Answer	Mark	Additional Guidance
1	(a)		The speed of recession of a <u>galaxy</u> is proportional to its distance (from Earth / observer)	B1	
	(b)	(i)	$v = \dfrac{\Delta\lambda}{\lambda} \times c$ $v = 0.15 \times 3.0 \times 10^8$ speed $= 4.5 \times 10^7$ (m s^{-1})	M1 A0	**Allow**: '15% of $3.0 \times 10^8 = 4.5 \times 10^7$ (m s^{-1})' **Not**: '$0.15c$'
		(ii)	distance $= v / H_0$ (Any subject) distance $= \dfrac{4.5 \times 10^7 \times 3.1 \times 10^{22}}{65 \times 10^3}$ distance $= 2.15 \times 10^{25}$ (m)	C1 A1	Possible ecf from **(b)(i)** **Allow**: 1 mark for 2.15×10^n, n $\neq$ 25
		(iii)	$H_0 = \dfrac{65 \times 10^3}{3.1 \times 10^{22}}$ (= 2.10×10^{-18} s^{-1}) age $= 1 / H_0 = 4.77 \times 10^{17}$ (s) age $= 1.49 \times 10^{10}$ (y)	C1 A1	**Allow**: 1 mark for 1.49×10^n, n $\neq$ 10
	(c)		Any <u>two</u> from: 1. Spectra from galaxies show shift to longer wavelengths (suggests galaxies are moving away from the Earth) 2. The more distant galaxies are moving faster (than the ones closer to our galaxy) 3. Existenc of <u>microwave</u> background radiation (which is the same in all directions) / The temperature of universe is 3 K (after cooling due to expansion) / gamma (radiation) became <u>microwaves</u> (as the universe expanded) 4. Existence of primordial helium (produced in the early stages of the universe) 5. Temperature fluctuations (predicted and observed)	B1 $\times$ 2	**Not** 'red-shift' for 1. **Allow**: Reference to <u>CMB</u> (radiation) in 3. **Not** bald 'ripples' for 5.
			Total	8	

Question			Expected Answer	Mark	Additional Guidance
2	**(a)**		Diagram showing (star,) 1 AU, 1 pc and angle of 1 arc second	B1	
			Distance from a base length of 1 AU that subtends an angle of 1 (arc) second or Parsec is a distance that gives a (stellar) parallax of 1 second (of arc) / 1/3600°	B1	**Allow**: 1 pc is the distance calculated using: 1 AU/tan(1/3600°) **Not**: 1 pc = 3.26 ly **Not**: 1 pc = 3.1 ×10^{16} m
	(b)	**(i)**	distance (pc) = 1 / 0.275 distance = 3.64 (pc)	B1	

		(ii)	distance in m = 3.1 × 10^{16} × 3.64 = 1.127 × 10^{17} (m)
			
			distance in ly = 1.127 × 10^{17}/9.5 × 10^{15}
			
			distance in ly = 11.9
				C1
				
				A1
					Possible ecf from **(b)(i)**
					
					Alternative:
					    1 pc = 3.26 ly C1
					    distance = 3.26 × 3.64
					    distance 11.9 (y) A1

			Total	5	

	Question		Expected Answer	Mark	Additional Guidance
3	(a)	(i)	Any <u>five</u> from: 1. Gas / dust (cloud) drawn together by gravitational forces 2. Loss in (gravitational) PE / KE increases / PE changes KE / temperature increase 3. Fusion of protons / hydrogen <u>nuclei</u> (produces helium nuclei and energy) 4. A stable star is formed when radiation pressure is equal to gravitational pressure 5. When hydrogen runs out the <u>outer layers</u> of the star expands / <u>core</u> shrinks 6. <u>Red giant</u> formed / eventually (the core becomes) a <u>white dwarf</u> QWC mark for '*correct sequencing of the processes from birth to death*'	B1 × 5 B1	**Allow**: 'Gravitational collapse of dust cloud'
		(ii)	Supernova followed by neutron star / black hole	B1 B1	
	(b)		$\Delta E = \Delta mc^2$ energy = $2.0 \times 10^{30} \times 10^{-6} \times (3.0 \times 10^8)^2$ or 1.8(0) × 10^{41} (J) time = 1.80 × 10^{41}/3.8 × 10^{26} (= 4.74 × 10^{14} s) time = 4.74 × 10^{14}/3.2 × 10^7 time = 1.5 × 10^7 (y)	C1 C1 A1	**Alternative**: rate = 4.22 × 10^9 (kg s^{-1}) C1 time = 2.0 × 10^{24}/4.22 × 10^9 (= 4.74 × 10^{14} s) C1 time = 1.5 × 10^7 (y) A1

Question			Expected Answer	Mark	Additional Guidance
(c)	(i)		Any <u>four</u> from: 1. Protons / hydrogen <u>nuclei</u> to produce He <u>nuclei</u> (positrons and neutrinos) 2. There is electrostatic repulsion (between the protons) / The protons repel (each other because of their positive charge) 3. High temperatures / 10^7 K needed (for fusion) 4. (At high temperatures some of the fast moving) protons come close enough to each other for the strong (nuclear) force (to overcome the electrostatic repulsion) 5. High density / pressure (in the core of the Sun) 6. There is a decrease in mass, hence energy is released / products have greater binding energy	B1 × 4	**Not**: 'heat' in place of temperature in 3.
	(ii)		Kinetic (energy) Electromagnetic / photons	B1 B1	**Not**: heat / thermal (energy) **Not**: 'radiation' / 'wave energy'' **Allow**: Gamma
	(iii)		BE = 4 × 7.2 = 28.8 (MeV) BE = 28.8 × 1.6 × 10^{-13} BE = 4.6 × 10^{-12} (J)	C1 A1	Possible ecf if BE value is incorrect
			Total	19	

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