

- |    |     |  |                                     |          |
|----|-----|--|-------------------------------------|----------|
| 1. | (a) | Any 2 from<br>Sun in centre<br>Circular orbits<br>Constant orbital speed   | 1<br>1<br>1                         |          |
|    | (b) | Any 2 from<br>Elliptical orbits<br>Sun at <u>focus</u> (accept diagram)<br>Non-constant speed (accept equal areas in equal times)<br>No epicycles  | 1<br>1<br>1<br>1                    | Total 4  |
| 2. | (a) | i. $F = GMm/r^2$ or $F \propto Mm/r^2$ <u>with labels</u><br>ii finite universe contracts/ resultant force on stars  | 1<br>1                              |          |
|    | (b) | Any 2 from<br>i. (satellite B) has larger circumference/smaller velocity<br>(satellite B) Gravitational field strength is less<br>(satellite B) Centripetal force is less<br><br>ii.(accept calculation from either satellite)<br>$r_1^3 / T_1^2 = r_2^3 / T_2^2$<br>satellite A<br>$r_2^3 = 7000^3 \times 57.2^2 / 1.63^2$<br>$r_2 = 75,030$ km<br>(= 75,000 km )<br>satellite B<br>$r_2^3 = 67100^3 \times 57.2^2 / 1.63^2$<br>$r_2 = 75,320$ km<br>(= 75,000 km ) | 1<br>1<br>1<br><br>1<br>1<br>1<br>1 |          |
|    | (c) | i. measure of brightness as seen from Earth.<br><br>ii. $m_1 - m_2 = 2.5(1) \log (I_2 / I_1)$<br>$10^{12/2.5} = I_2 / I_1$<br>$I_2 / I_1 = 60,000$<br>Accept:<br>ratio of 2.5 for each unit of apparent magnitude intensity<br>$I_2 / I_1 = (2.5)^{12}$<br>$I_2 / I_1 = 60,000$<br><br>interchanging $I_2$ and $I_1$ numerically gives 2/3   | 1<br><br>1<br>1<br>1<br>1<br>1<br>1 |          |
|    | (d) | Land-based are (any 3) 1 mark for each<br>more light can be collected/ made larger<br>more stable<br>more manoeuvrable<br>cheaper to build/repair<br>longer lifetime/ not exposed to high velocity particles<br>greater access   |                                     | Total 14 |

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3.	(a)	uniform intensity detected in all directions/ isotropic	1
	(b)	Hydrogen and helium in early stars and sun	1
		Sun has greater proportion of helium than early stars/ H changed to He by fusion in sun.	1
		Virtually no higher elements in first stars/ sun contains traces of higher elements (accept specific examples up to iron)	1
	(c)	Any 4 from ( each point scores 1 mark)	
		Dark lines	
		Crossing continuous spectrum	
		Absorption occurs in stellar atmosphere	
		Only get information about atmosphere	
		Measurement of wavelength	
		Combinaton of lines unique to element.	Total 8
4.	(a)	1. correct position of M	1
		2. correct position of W	1
	(b)	(i) Any 3 from	
		A has red giants / B has no red giants	1
		A has white dwarfs/ B has no white dwarfs	1
		A has high and low mass stars/ B has high mass only	1
		Reference to spectral types	1
		(ii) Any 2 from	
		B has an excess of hot/bright/main sequence stars	1
		presence of red giants/ white dwarfs in A with reference to timescale.	1
		High mass stars shorter lived than low mass	1
			Total 7
5.	(a)	Any 5 from	
		red shift data for galaxies (accept stars)	1
		calculate velocity from red shift	1
		galaxies/ stars receding from Earth	1
		distance data for galaxies/ stars	1
		velocity $\propto$ distance / $v/r = \text{constant}$ / v-r graph straight line	1
		universe began at a single point	1
	(b)	Any two	
		stars rotate around galactic centre	1
		star with velocity component towards Earth	1
		reference to motion/shape of galaxy	1
		or other valid points eg blue shift	
	(c)	$H_0 = 75/ 3 \times 10^{19} \text{ s}^{-1}$	1
		$t \approx 1/ 2.5 \times 10^{-18}$	1
		$t \approx 4 \times 10^{17} \text{ s}$	1

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5.	(d)	critical density is that for flat universe	1
		density $> \rho_0$ universe closed/contracts/big crunch	1
		density $< \rho_0$ universe open/ expands forever	1
		any 2 from	
		fate unknown because size/mass/density universe uncertain	1
		fate unknown because $\rho_0 / H_0$ not known	1
		Total	15
6.	(a)	(i) 7 points plotted correctly	1
		all points plotted correctly	1
		(ii) both sides of graph correct	1
		peak drawn/ lines merge asymptotically	1
		(iii) 10 days $\pm$ 1/2 day	1
	(b)	(i) one ray with correct curvature	1
		second ray drawn, deviation correct, rays meet at Earth.	1
		(ii) reference to focussing effect	1
		max intensity when Earth in line (with star-black hole)	1
	(c)	gravity causes space-time curvature	1
		light takes shortest path	1
		<i>alternative explanation:</i>	
		<i>acceleration leads to curvature of light beam.</i>	1
		<i>use of principle of equivalence</i>	1
		Total	11

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|----|-----|--|----|
| 7. | (a) | speed of light invariable  | 1  |
|    |     | All inertial reference frames equivalent/no frame preferred/<br>laws of physics are the same in all inertial frames. | 1  |
|    | (b) | Any 5  |    |
|    |     | Observer A at rest at midpoint of tunnel   | 1  |
|    |     | Observer B moving in train (at constant speed)   | 1  |
|    |     | Train same length as tunnel according to stationary<br>observer A (who sees lights flash simultaneously)             | 1  |
|    |     | Train longer than tunnel according to observer B<br>( who sees lights flash at different times)                      | 1  |
|    |     | Explanation of what length contraction is.   | 1  |
|    |     | Any other valid point: symmetry, c is constant,<br>how lights come on.   | 1  |
|    | (c) | (i) $v = 11000 \times 10^3 / 2.73 \times 10^{-13}$<br>(= $4.03 \times 10^{19} \text{ ms}^{-1}$ )                     | 1  |
|    |     | (ii) velocity > c  | 1  |
|    |     | no matter/energy/information/transferred between Earth<br>observatories/ reference to c as limiting speed            | 1  |
|    |     | (iii) $v = 2\pi \times 9.46 \times 10^{18} / 1.49$<br>(= $4 \times 10^{19} \text{ ms}^{-1}$ )                        | 1  |
| 8. |     | As for common question in Telecommunications unit.   |    |
|    |     | Total  | 11 |