1	a.i.	Venus		1
	a.ii.	Appears smallest when separation is greatest (AW)		1
	b.i.	**Any two from**:		
		Fewer epicycles/no need for epicycles	1	
		Sun in centre	1	
		Earth in orbit/moving (around Sun)	1	
		Earth rotates	1	2
	b.ii	Either, any **two pieces of evidence**:		
		Jupiter's moons	1	
		craters/mountains on moon	1	
		rings of Saturn	1	
		Or:		
		Evidence with correct explanation gains 2 marks.		
		Jupiter's moons 1: all bodies do not orbit the Earth	1	
		Mountains on moon 1: not a perfect (sphere)	1	
		Rings of Saturn 1: all bodies do not orbit the Earth	1	2
				Total 6
2	a.	Planets move in ellipses (Sun at one focus)		1
		Planet sweeps out equal areas in equal times.		1
		Period^2 α radius^3 / T^2/r^3 = constant 1		
	b.i.	$v/c = \Delta\lambda / \lambda$		1
		$\Delta\lambda = 656.3 \times 10^{-9} \times 6.1 / 3 \times 10^8$ (ignore minus sign)		1
		$\Delta\lambda = 1.33 \times 10^{-14}$ m		1
	b.ii.	Graph: any 4 points plotted correctly		1
		all correct		1
	b.iii.	graph: draw curve, reasonable attempt		1
	b.iv.	Either point where star moves perpendicular to line of sight		1
	b.v.	time = 72 h ± 1h (ecf read value from their graph ± 1h)		1
	b.vi.	$r = \sqrt[3]{(6.7 \times 10^{-11} \times 4 \times 10^{30} \times [72 \times 3600]^2 / 4\pi^2)}$ ecf		1
		$r = 7.70 \times 10^9$ m ecf .		1
		(use of t = 72h 1/2)		
				Total 13

3.	a.	correct reference to 1 AU	1
		parallax of 1 arcsecond (marks can be gained on labelled diagram)	1
	b.i.	Diphda	1
		(Diphda) has smallest apparent magnitude	1
	b.ii.	Menka is largest as absolute magnitude is least	1
	c.	$m - M = 5\log (d/10)$ / correct substitution	1
		$d/ 10 = 10^{(m- M)/5}$	1
		$d = 39.8$ pc	1
			Total 8

4.	a.	**Any 6 from**		
		Nuclear/hydrogen burning ends	1	
		Mass > Chandrasekhar limit	1	
		Expanding gas/planetary nebular/red giant	1	
		Gravitational collapse /ref. to burning He or higher metals	1	
		Correct ref. to (Fermi) pressure/ radiation pressure (must have ref. to pressure or force from radiation.)	1	
		Neutron star (neutron by itself, not enough)	1	
		Correct reference to Schwarzschild radius/ allow mass> 3M/ allow ref. critical radius	1	
		Black Hole	1	6
	b.i.	Mass = $3.8 \times 10^{26} / (3 \times 10^{8})^2$		1
		Mass = $4.2(2) \times 10^{9}$ kg s^{-1}		1
	b.ii.	$3.8 \times 10^{26} = 10^{44}$ / time		1
		time = $8.2(2) \times 10^{9}$ y		1
				Total 10

5	a.	Universe is isotropic/ same in all directions		1
		homogenous/ evenly distributed		1
	b.	**Any 5 from**		
		Uniform intensity in all directions/ everywhere	1	
		Structure in background intensity/ripples	1	
		Produced when matter and radiation decoupled	1	
		Originally gamma radiation	1	
		(gamma) red-shifted to microwave/originally higher energy	1	
		Evidence that universe began with big bang.	1	
		Temperature corresponds to 2.7K / 3K / that predicted by big bang model	1	5
	c.	**Any 2 from**		
		No experimental evidence/ no physical evidence	1	
		State of matter unknown/ laws of physics unknown	1	
		Energies unreproducible/ ref. to very high temperature	1	2
				Total 9
6	a.	Open: Universe expands for all time		1
		Flat: expands to a limit (but never reaches it)		1
		Closed: Universe contracts/ collapses back		1
		reference to role of gravity/ critical density		1
		Marks for a. can be gained on <u>labelled</u> diagram.		
	b.	$H_o^2 = 1x10^{-26} \times 8 \times \pi \times 6.67 \times 10^{-11} / 3$		1
		$H_o = 2.36 \times 10^{-18}\ s^{-1}$		1
				Total 6

7.	a.	Situation; 2 observers, clocks, relative motion and time interval defined	1
		Speed of light constant	1
		Interval measured	1
		Improper observer measures longer time because longer path.	1
		Other detail	1
	b.i.	$t = 2\pi\ 900 / 0.94c$	1
	bii.	fraction remaining = 0.25	1
	b.iii.	$\sqrt{(1 - v^2/c^2)} = 0.34$ / $\gamma = 2.93$	1
		$t = t_o / \sqrt{(1 - v^2/c^2)}$ / $t = \gamma t_o$	1
		$t = 5.88 \times 10^{-5}$ s ecf from b.i.	1
	b.iv.	ref. to time dilation	1
		'clocks' / time of stationary particles same rate as lab./ half life shorter	1
			Total 12
8.	a.	gravitational fields/gravity and acceleration	1
		produce the same effect / cannot be distinguished	1
	b.i.	spacecraft is accelerating/ larger equivalent gravitational field	1
		clock in spacecraft runs slower	1
		give BOD to:	
		acceleration of rocket is small compared to Earth	1
		clocks synchronous	1
	b.ii.	Moon: smaller gravitational field	1
		Clock in spacecraft runs faster	1
			Total 6