Question			Marking points	Further guidance	Marks
1	(a)	(i)	Elliptical orbits + Sun at one focus	Allow 'around sun'	1
			Equal areas in equal times		1
			$T^2 \propto R^3$	Allow $T^2 = R^3$	1
		(ii)	Copernicus - circular orbits		1
	(b)		$F = Gm_1m_2/r^2$, terms defined	Or in words	1
	(c)	(i)	6.09, 1.20	No sig. fig.	1
			6.55, 1.90	penalties	1
		(ii)	4 points plotted correctly		1
			straight line of best fit		1
	(d)	(i)	b = gradient	Allow ecf from (ii)	1
			gradient measured with suitably large triangle	Don't allow derivation from $T^2=kR^3$	1
			$b = 1.5 \pm 0.1$		1
		(ii)	lg 21.2 = 1.326		1
			Interpolate to lg R = 6.18		1
			$R = 10^{6.18} = (1.5 \pm 0.1) \times 10^6$ km		1
2	(a)		A measure of brightness		1
			As seen from Earth		1
	(b)		$m_s - m_g = 2.5 \lg (I_g/I_s)$		1
			$I_s/I_g = 10^{-0.4(ms-mg)}$		1
			$I_s/I_g = 10^{10.184}$	Allow correct ratio	1
			$= 1.53 \times 10^{10}$	in any form	1
	(c)		Doppler effect/redshifted	Allow reddening by	1
			Expanding universe/Hubble law	interstellar extinction	1
3	(a)	(i)	Nuclear fusion	Not 'burning'	1
			Hydrogen	Full credit for pp	1
			to helium	chain equations	1
		(ii)	Mass/luminosity/higher, MS lifetime shorter		1
			at A or vice versa		1
		(iii)	High mass MS stars are short lived	Faster reactions	1
			All have become red giants	Run out of	1
			No new stars being formed	Hydrogen	
	(b)	(i)	Anywhere above MS on branches		1
		(ii)	High mass - more luminous/brighter		B2
			More blue		
	(c)	(i)	Anywhere below left of MS		B1
		(ii)	Very faint	Not v small	B1
4	(a)		Gamma/Xray - opaque	1 mark each, 4	4
			UV - partial	max	
			Visible- transparent		
			IR- partial		
			Radio- partial (-1 for each error down to 0)		
	(b)		Doppler effect		1
			Red/blueshift observed		1
			LHS blueshifted, RHS redshifted		
			Centre not shifted → broadening		1

5	(a)		Infinite universe Each line of sight ends on a star (Or shells argument) so sky bright at night big bang model - finite universe and expanding radiation from distant stars redshifted	 2 for shells argument 4 max for Olbers or other valid point 2 max for Big Bang	1 1 1 1 1 1
	(b)	(i)	H_o = v/r = 21000/300 = 70 km s^{-1} Mpc^{-1}		 1
		(ii)	70 km s^{-1} Mpc^{-1} = 70000/(3 x 10^{22}) s^{-1} $T \approx 1/H_o$ = 1/(2.3 x 10^{-18}) = 4.2 x10^{17} s	Allow ecf from (i)	1 1 1
		(iii)	Rate of expansion is non-uniform Because of gravity	 Or other valid point	1 1
6	(a)	(i)	v = 0.96c $\rightarrow \gamma = 3.6 \pm 0.4$ $t_o = t/\gamma$ = 9.38/3.6 = (2.6 ± 0.3) y	Allow calculation Correct subst.	1 1 1
		(ii)	As v $\rightarrow$c, $\gamma \rightarrow \infty$, so m$\rightarrow \infty$, infinite force needed to accelerate further	 Or accept infinite energy ($E=mc^2$)	1 1 1
	(b)		Muon decay expt Measure count rates High speed muons vs slow muons At top an bottom of mountain Fast muons live longer than slow	Or valid alternative Allow 1/5 for clocks on aircraft. 0/5 for time dilation/length contraction thought expt	1 1 1 1 1
7	(a)		No experimental evidence Or unknown physics	Allow unattainable energies	1
	(b)		Matter/antimatter annihilation With slight asymmetry	 Or wtte	1 1
	(c)		Thermal equilibrium Highly uniform/homogeneous		1 1

7(a)(i) **(ii)**	1015 N (accept 1010-1020) 130 N (accept 125-135) both correct, no unit penalty	1	[1]
(b)	$F = ma$ written or implicit (1015-130) = 1100a so a = 0.80 ms^{-2} (accept 0.80-0.81, accept 0.8 in place of 0.80) (1015+130) can get only 1 0 0 = 1/3 max)	1 1 1	[3]
(c)	18 ms^{-1} (accept 15-21) find largest difference/distance between force graphs (and note speed) *or* clear from graph 'where lines cross' gets 0/1 'it is the terminal velocity' gets 0/1	1 1	[2]
(d)	49.7 ms^{-1} (accept 49.5 - 50.0) speed is max. when driving force equals/balanced by drag force accept 'speed where forces are equal' if speed has been stated correctly	1 1	[2]
(e)	220 N (accept 220 - 225) work done = force x distance = 220x1000 (=2.2x10^5 J) allow ecf from incorrect graph reading 220 x 1000 only gets 1 0 1 = 2/3 22 x (anything) loses last mark	1 1 1	[3]
(f)	work done = 35(2)x1000 = 3.5(2)x10^5 J accept (3.5 - 3.6)x10^5	1	[1]
(g)	distance travelled on 1 litre at 31 ms^{-1} = 2.2x16/3.5(2) = 10.0 km (9.8 - 10.1) allow (total) energy (in 1 litre of fuel) = 16 x 2.2 x 10^5 for 1/2 reference to 22(ms^{-1}) or 31($m\,s^{-1}$) gets 0/2	1 1	[2]
(h)	ke = $\frac{1}{2}mv^2$ = ½ x 1100x31^2 (= 5.29x10^5 J) subs.	1	[1]
(i)	(ke lost =) heat gained = $mc(\theta_2 - \theta_1)$ 5.3x10^5 =8x460 $\Delta\theta$ either of first two lines correct (1) $\Delta\theta$ = 144 K so θ_2 = 144 + 15 = 159 °C calculation of 144 (1) addition of 15 (1) assumption: brakes initially at 15 °C allheat is dissipated in brakes . no heat lost from brakes no air resistance/drag any assumption (1) . not Law of Energy assumption without calculation can score 1/3 any 3	3	[3]
(j)	$W = Fd$ or $F = ma$ and $v^2 - u^2 = 2as$ (1) 5.3x10^5 = 9300d 9300 = 1100 a so a = 8.45($m\,s^{-1}$) so d = 57 m 31^2 (- 0^2) = 2 x 8.45 s so s = 57 m (1) assumption: no work done against (other) drag forces car is on horizontal road air resistance negligible any valid assumption (1) 'constant braking force' and 'constant deceleration' get 0/1 any 2	2	[2]