1. (a) retrograde motion (arises naturally) 1
without epicycles OR by planets overtaking each other. 1

(b) Ptolemaic model v.successful
Lack of accurate data } two 1
Copernican model gave less accurate results than epicycles 1
or any other sensible comment (eg lack of observed stellar parallax)

4

2. (a) $F=Gm_1m_2/r^2$ with terms identified (or in words) 1

(b) $Gm_vM/r^2 = m_vv^2/r$ 1
$v^2 = GM/r$ 1
$v = 2\pi r/T$ 1
$(2\pi/T)^2 = GM/r$ and rearrange 1

(c) $0.62y = 0.62x365x24x60x60 = \underline{1.96x10^7\ s}$ 1

$r = \sqrt[3]{\frac{6.67x10^{-11}x2x10^{30}x(1.96x10^7)^2}{4\pi^2}}$ 1

$= 1.09 \times 10^{11}$ m 1

8

3. (a)(i) correct MS position relative to (ii) 1
(ii) correct MS position relative to (i) 1
(iii) correct position above MS 1
(iv) correct position below MS 1

(b) any two differences + explanation eg
MS lifetime
Planetary nebula/Supernova
White dwarf/neutron star or black hole 4

8

4. (a)(i) measure of brightness as seen from Earth (allow measure of intensity) 1
(ii) measure of brightness as seen from 10 pc (allow measure of intensity) 1

(b)(i) $I = k/r^2$, or in words (allow $I = 1/r^2$) 1

(ii) *0.4-2.7 = 5 lg (r/10)* /
lg r/10 =-0.46 1
r = 3.47 1
parsec 1

6

5. (a) $v = H_o r$, *with terms identified* *1*

(b)(i) use of Doppler
equation 1 1

(ii) correctly plotted: (-1 each error or omission, max 2) 2
line of best fit through the origin 1

(iii) H_o = gradient of graph 1
$= 48 - 54$ km s^{-1} Mpc^{-1} 1

8

6. (a) collapse under gravity
GPE → KE: temperature rises
Temperature rises
fusion reactions start 3
(b)(i) primordial He – formed in big bang 1
(ii) first stars would have contained virtually no elements heavier than He
OR solar He abundance > primordial 1

5

7. (a) Any **two** from: Newtonian gravity spherical universe, uniform density 2
(b) $\rho_o = 3 \times (1.6 \times 10^{-18})^2 / 8\pi \times 6.67 \times 10^{-11}$ 1
$= 4.58 \times 10^{-27}$ (kg m^{-3}) 1
$\rho_o = 4.58 \times 10^{-27} / 1.7 \times 10^{-27}$ 1
= 2.7 H atoms m^{-3} 1
(c) open: $\rho < \rho_o$, will continue to expand forever, graph 2
flat: $\rho = \rho_o$, will just continue to expand forever, graph 2
closed: $\rho > \rho_o$, will expand and then contract back to a big crunch, graph 2

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8. (a)(i) unaccelerated. 1
(ii) The speed of light is constant for all inertial observers 1
(b) A valid thought experiment described eg:
set up: eg train/tunnel/lamps 1
observer A at rest rel. to train sees front lamp come on 1st 1
observer B at rest rel. to tunnel sees lamps come on together 1
so train longer than tunnel according to A 1
(c)(i) $t = s/v = 4.2/0.98$ 1
= 4.29 y
(ii) $l = l_o/\gamma$ 1
$\gamma = 1/\sqrt{(1 - v^2/c^2)} = \underline{5.02}$ 1
$l = 4.2/5.02 = 0.84$ ly 1
(iii) $t = l/v = 0.84/0.98$ 1
$\underline{= 0.85 \text{ y}}$ 1

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9. (a) gravitational fields from other planets 1
+ detail eg proximity of large masses, change in speed etc. 1
(b)(i) major axis rotates 1
about focus 1
Perihelion shift defined ie as angle shown on diagram 1
(ii) GR predicted Mercury perihelion shift which agreed exactly with observation 1

6

70

10.(a)	cable has resistance	1
	hence there is a pd across cable (itself)	1
	this is not available to user	1
	(energy dissipated in cable could get ½ of last two marks)	
(b)	air emerging from aerogenerator is moving	(1)
	detail: hence it has KE/eddies	(1)
	work/energy used against friction	(1)
	(ohmic) heating in generator	(1)
	any 2	2 max
(c)(i)	m = $\pi R^2 l r$	1
	= $\pi(0.75)^2$ x 8 x 1.3	1
	(=18.4 kg)	1
(ii)	ke = ½ mv^2	1
	= ½ x 18 x 8^2 = 576 J (allow 588 J from ½ x 18.4 x 8^2)	1
(iii)	average power output = (40/100) x 576 = 230 W (allow 235 W from 0.4 x 588)	1
(d)	$W = P t$ $7 \times 10^6 = 230\ t$	1
	t = 3.0(4) x 10^4 s (= 8.45 h) (allow 2.98 x 10^4 from 7 x 10^6 = 235 t)	1
(e)(i)	chemical (not potential or electrical)	1
(ii)	energy dissipated/wasted as heat inside batteries	1
(f) (i)	$E = Pt$	1
	= 160 x 40 x 3600 = 2.3 x 10^7 J	1
(ii)	total stored energy = 2.3 x 10^7 x 100/80	1
	= 2.88 x 10^7 J	1
(iii)	no. of batteries = 2.88 x 10^7/ (7 x 10^6)	1
	(= 4.1) ie 5	1