1. Universe is isotropic /same in all directions B1
Homogeneous / evenly distributed B1
[2]

2. Any four from:
Uniform intensity in all directions / everywhere
Structure in background intensity / ripples
Produced when matter and radiation decoupled
Originally gamma radiation
(gamma) red-shifted to microwave / originally higher energy
Evidence that universe began with big bang
Temperature corresponds to 2.7 K / 3K / that predicted by big bang model B1 × 4
Link between evidence and explanation. (1)
[5]

3. Any two from:
No experimental evidence / no physical evidence
State of matter unknown / laws of physics unknown
Energies unreproducible / ref. to very high temperature B1 × 2
[2]

4. Open: Universe expands for all time
Flat: expands to a limit (but never reaches it) B1
Closed: Universe contracts / collapses back B1
Reference to role of gravity / critical density B1
Marks for (a) can be gained on a labelled diagram B1
[4]

5. $H_o^2 = (1 \times 10^{-26} \times 8 \times \pi \times 6.67 \times 10^{-11}) / 3$ C1
$H_o = 2.36 \times 10^{-18}\ s^{-1}$ A1
[2]

6. $(5.2 \times 1.5 \times 10^{11}) = 7.80 \times 10^{11}$m 1
[1]

7. $v \propto r$ / $v = H_o \times r$ (1)
labels (including one reference to Earth/Sun/Galaxy) (1) 2
[2]

8. infinite Universe (1)
all lines of sight end on star (1)
so night sky should be bright/ not dark (1)

either
expanding Universe/light undergoes red shift (1)
more distant galaxies have greater red shift (1)
or
age of Universe is finite (1)
light from distant stars not yet reached Earth (1)

[5]

9. (i) **accept description of plan view or side view.**
side: central bulge (1)
galactic disc each side (1)
plan: accumulation of stars in centre. (1)
spiral arms (minimum of 2 arms) (1) 2

(ii) correct position of Sun (accept 28000ly from centre) (1) 1

[3]

10. (i) hydrogen / helium gas (1)
formed after big bang / remnants of supernovas (1)

(ii) critical density is condition for flat Universe. (1)
dark matter increases density of Universe. (1)
density greater than critical density. (1)
Universe will contract / big crunch. (1)

[6]

11. **any 4 from:**
end of H burning/red giant/supergiant (1)
onset of He fusion/fusion of heavier nuclei (1)
gravitational collapse of core (1)
supernova explosion/ star explodes (1)
suitable mass limit (chanderasekha limit 1.4M) (1)
supported against gavity by neutron gas pressure/ ref to Fermi pressure (1)
internal structure protons and electrons combined/ very thin atmosphere/ metallic crust (1) 4

[4]

12. (i) volume = $4\pi\ (10{,}000)^3 /3 = 4.2 \times 10^{12}$ (1)
density = $3.5 \times 10^{30} / 4.2 \times 10^{12}$ ecf (1)
density = 8.4×10^{17} kg/m^3 (1) 3

(ii) any **two** from
density (very) much greater than material on Earth (1)
quotes typical density on Earth $1 - 10^4$ kg m^{-3} (1)
atomic structure collapsed / density same as atomic nucleus (1) 2

[5]

13. (i) energies/temperatures irreproducible on Earth / laws of Physics break down (1) 1

(ii) temperature decreases (1)
universe expanding/work done against attractive forces/ energy converted to mass (1) 2

(iii) **any 3** from
protons and electrons separate initially (1)
matter-radiation equilibrium/charge prevents passage of em waves (1)
proton-electron recombination /formation of atoms (1)
gamma/ em waves no longer absorbed (1) 3

[6]

14. **any 5** from:
star-light shows red shift (1)
galaxies (stars) receding from Earth (1)
recessional velocity proportional to distance (1)
cosmological microwave background radiation (CMBR) (1)
uniform intensity in all directions (1)
small ripple (1)
(black body temperature) 2.7 K (3K) (1)
High ratio of helium to hydrogen (1)
Indicates very high temperatures existed (1)
ratio too high to originate from stellar fusion (1) 5

[5]

matter-radiation equilibrium/<u>charge</u> prevents passage of em waves (1)
proton-electron recombination /formation of atoms (1)
gamma/ em waves no longer absorbed (1) 3

[6]

15. (i) $H_0 = 75 / 3.1 \times 10^{19}$ (1)
$t_0 = 1 / H_0 = 4.13 \times 10^{17}$ s (1)
$t_0 = 4.13 \times 10^{17}$ s / $365 \times 24 \times 3600 = 1.3 \times 10^{10}$y (1) 3

(ii) any two from
universe expands to a limit/ flat universe (1)
but never reaches that limit (1)
density of universe = critical density (1) 2

(iii) curve: passes through P (1)
curves over and back to time axis (1) 2

(iv) Universe not so old (no ecf from (iii)/ Universe will end
in big crunch (no ecf from iii) / universe has finite lifetime (1) 1

[8]

16. (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

[4]

17. 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 α distance / v/r = constant / v-r graph straight line	1
universe began at a single point	1

[5]

18.

critical density is that for flat universe	1
density > p_0 universe closed/contracts/big crunch	1
density < p_0 universe open/ expands forever	1
any 2 from	
fate unknown because size/mass/density universe uncertain	1
fate unknown because p_0 / H_0 not known	1

[5]

19.

Planets move in <u>ellipses</u> (Sun at one focus) (1) Planet sweeps out equal <u>areas</u> in equal times. (1) Period^2 α radius^3 / T^2/ r^3 = constant (1)	3

[3]

20. (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) 3

(ii) Graph: any 4 points plotted correctly (1)
all correct (1) 2

(iii) graph: draw curve, reasonable attempt (1) 1

(iv) Either point where star moves perpendicular to line of sight (1) 1

(v) time = 72 h ± (1)h (ecf read value from their graph ± 1 h) (1) 1

(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) 2
(use of t = 72h 1/2)

[10]

21. correct reference to (1) AU (1)

parallax of (1) arcsecond
(marks can be gained on labelled diagram) (1) 2

[2]

22. 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 (1)
(must have ref. to pressure or force from radiation.)

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

[6]

23. **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

[5]

24. **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

[2]

25. 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 labelled diagram. 4

[4]

26. $H_o^2 = 1 \times 10^{-26} \times 8 \times \pi \times 6.67 \times 10^{-11} / 3$ (1)
$H_o = 2.36 \times 10^{-18}\ s^{-1}$ (1) 2

[2]