Astrophysics PST (2) - Solutions

1. The mass of the star is M = 5 solar masses = 1 x 10^{31} kg
and its luminosity L = 600 solar luminosity = 2.28 x 10^{29} J s^{-1}

Fraction of mass liberated per H-butning reaction =
Mass deficit/mass of 4 protons = 0.0286/4.0312 = 0.0071

The total energy that the star will be able to radiate is

$$E_{total} = 0.0071 \times 0.1 \times M \times c^2$$
$$= 0.0071 \times 0.1 \times (1 \times 10^{31}) \times (9 \times 10^{16}) \text{ Joule}$$
$$= 6.39 \times 10^{44} \text{ Joule}$$

and it will radiate for

$$\frac{E_{total}}{L} = \frac{6.39 \times 10^{44}}{2.28 \times 10^{29}} \text{ s} = 2.8 \times 10^{15} \text{ s} = 8.9 \times 10^{7} \text{ yr}$$

[Btw, check understanding of what is meant by hydrostatic equilibrium!
I.e. a balance between the force of gravity inward and the pressure of hot gases pushing outward.
A balance or 'equilibrium' must be attained in order for a star to have a stable *size*.]

2.
a) According to Hubble classification scheme:
SBc galaxy -- galaxy has a small nucleus, with a bar-like structure through it. The spiral arms emerge from the ends of the bar and are loosely wound.

Sa galaxy $-$ galaxy has a relatively large nucleus, plus tightly wound spiral arms (no central bar).

To shift Lyα from visible (rest wavelength 121.6 nm) to visible (> 370 nm)

Redshift z = Δλ/λ = (370.0 – 121.6)/121.6 = 2.04

For redshifts 2.04 or greater the Lyα line will be shifted to wavelengths longer than 370 nm.

Quasar 3C 273 distance:

Hubble law, distance d = v / H_o = c z /H_o

= 3 x 10^5 x 0.16 / 75 = 640 Mpc

3.

$$f_{\text{Andromeda}}/f_{\text{quasar}} = (L_{\text{Andromeda}}/L_{\text{quasar}})(d^2{}_{\text{quasar}}/d^2{}_{\text{Andromeda}})$$
$$d^2{}_{\text{quasar}}/d^2{}_{\text{Andromeda}} = (f_{\text{Andromeda}}/f_{\text{quasar}})(L_{\text{quasar}}/L_{\text{Andromeda}})$$
$$d_{\text{quasar}}/d_{\text{Andromeda}} = \sqrt{(f_{\text{Andromeda}}/f_{\text{quasar}})(L_{\text{quasar}}/L_{\text{Andromeda}})}$$
$$d_{\text{quasar}}/d_{\text{Andromeda}} = \sqrt{(10^4)(10^3 L_{\text{MW}}/3L_{\text{MW}})}$$
$$d_{\text{quasar}} = \sqrt{10^7/3} \times 0.7 \text{ Mpc} = 1826 \times 0.7 \text{ Mpc} = 1.28 \times 10^3 \text{ Mpc}$$

4.

$$v_{\text{rot}}^2 = \frac{GM}{r}$$

$$v_{\text{rot}}^2 = \frac{6.7\times10^{-11}\times1.2\times10^{11}\times2\times10^{30}}{8.5\times10^3\times3.1\times10^{16}}$$

$$v_{\text{rot}} = 247 \text{ km s}^{-1}.$$

For circular orbit, $\mathrm{P(orb)} = 2\pi \mathrm{r}/v_{\text{rot}}$

$$= \frac{2\pi\times8.5\times10^3\times3.1\times10^{16}}{2.47\times10^5} \times \frac{1}{3.16\times10^7} = 2.1 \times 10^8 \text{ yr}$$

5. As the question sheet states this is a bit of a mis-use of the Hubble law!
But it gives a useful feel for how fast the expansion is!

Hubble law $v = H_o . d$

For given value of $H_o = 75$ km/s/Mpc
$= 75 \times 10^3 / 3.1 \times 10^{16} \times 10^6$

$= 2.419 \times 10^{-18}$ sec^{-1}

Now for distance (Atlantic) = 6000 km
$v = 2.419 \times 10^{-18} \times 6000 = 1.451 \times 10^{-14}$ km s^{-1}
$= 1.451 \times 10^{-9}$ cm s^{-1}

Distance (cosmic expansion) in a year = 1.451×10^{-9} cm s^{-1} $\times 3 \times 10^7 = 0.043$ cm

This compares with plate tectonic movement of continents of around 2 cm per year.