PHAS1102 – Physics of the Universe
Problem class 2 – Stellar astrophysics
Notes for answers

Question 1

From $(B - V) = -0.2$ and $(B - V)_o = -0.3$ we get a colour excess
$E(B - V) = (B - V) - (B - V)_o = 0.1$
and then $A_V \sim 3.1\ E(B - V) = 0.3$.

The colour of the star is redder than if there was no extinction because dust scatters blue light more than red.

Applying the distance modulus equation: $m_V - M_V = 5\log_{10} d - 5 + A_V$ we get
$1.0 + 3.4 = 5\log_{10} d - 5 + 0.3$ and $d = 66$ pc

We can apply the expression relating flux ratios and magnitude differences to the <u>absolute visual magnitudes</u> of the star and the Sun:

$$M_{\rm Sun} - M_{\rm star} = 2.5\log_{10}\frac{f_{\rm star}}{f_{\rm Sun}} = 4.8 + 3.4 = 8.2$$

thus

$\dfrac{f_{\rm star}}{f_{\rm Sun}} = 1905$ i.e. the star is approximately 2000 times brighter than the Sun in the V band.

Question 2

The mass of the star is M = 10 solar masses = 2×10^{31} kg
and its luminosity $L = 10^4$ solar luminosity = 4×10^{30} J s^{-1}

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

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

$$E_{total} = 0.0071 \times 0.1 \times M \times c^2$$

$$= 0.0071 \times 0.1 \times (2 \times 10^{31}) \times (9 \times 10^{16}) \text{ Joule}$$

$$= 1.3 \times 10^{45} \text{ Joule}$$

and it will radiate for

$$\frac{E_{total}}{L} = \frac{1.3\times10^{45}}{4\times10^{30}}\text{ s} = 3\times10^{14}\text{ s} = 10^{7}\text{ yr}$$

The star is much more massive than the Sun, thus it evolves faster. It is likely that the core of the star will eventually collapse to a neutron star.

Question 3

Hydrostatic equilibrium is 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. Main sequence stars have reached such a balance.

Question 4

When a star runs out of hydrogen (as nuclear fuel) in its core, the core collapses. As a result, the core's temperature increases and additional energy is radiated away. With a slightly higher temperature, the fusion in the hydrogen shell around the core becomes more efficient. So overall the star puts out more energy than it did as a main sequence star. The increased gas pressure pushes on the outer part of the star, expanding it into a red giant.

Question 5

$$m_{\text{before}} - m_{\text{after}} = 2.5\log_{10}\frac{f_{\text{after}}}{f_{\text{before}}} = 20$$

$$\frac{f_{\text{after}}}{f_{\text{before}}} = 10^{8}$$

Question 6

Carbon is only manufactured in the interiors of giant stars via the nuclear fusion of helium. It escapes these giant cores as stellar winds, planetary nebula ejections and supernova explosions.
The ejected carbon then mixes with other atoms to chemically enrich the interstellar medium. Some of these form dust (and organic molecules) in Giant Molecular Clouds. Dense regions of these clouds then collapse to form stars and terrestrial planets like the Earth.