

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 Outward radiation pressure from the core; inward gravitational pressure.

2.2 Very high temperature, so nuclei move fast enough to overcome their electric repulsion; very high density, so collisions are frequent enough to sustain the reaction rate.

2.3 Bottom left – hot but dim; high temperature with low luminosity forces a small emitting area: tiny stars, Earth-sized.

2.4 $d = 1/p = 1/0.050 = 20$ parsecs = 65 light years.

3.1 Hydrogen fusion on the main sequence until the core runs low; the core contracts and the outer layers swell into a red giant while helium fuses; the outer layers drift off as a planetary nebula; the core remains as a white dwarf, slowly cooling.

3.2 $\Delta m = 4.0313 - 4.0026 = 0.0287 \text{ u}$; $E = 0.0287 \times 931.5 = 26.7 \text{ MeV}$.

3.3 At equal temperature the T^4 factor matches, so $L \propto R^2$; a giant's radius is far larger; with the same surface brightness over a much larger area, its luminosity is greater by R^2 – hence its position at the top right.

3.4 $L/L_{\odot} = (R/R_{\odot})^2(T/T_{\odot})^4 = 100^2 \times (1/2)^4 = 10^4 \times 1/16 = 625$; cooler than the Sun and 625× brighter, it sits in the red-giant region, upper right of the HR diagram.