CHAPTER 13 "The Deaths of Stars"

Problems

1. From Box 12.2, main sequence lifetime is determined from $M^{2.5} \times \text{Sun's main-sequence lifetime}$, with $M$ symbolizing the mass of a star expressed in solar masses. With $M = 0.5 \, M_\odot$, the time needed for such a star to end its main-sequence phase (Note: not really its entire energy-generating lifetime, which includes the post-main sequence phase–another 25% or so more) is $5.7 \times 9.8 \times 10^7 \, \text{yr}$, which equals $= 56$ billion years. (Note: The universe is only 13.7 billion years old.)

And this is a minimum age, because these M-Type dwarf stars burn a higher proportion of the hydrogen than the more massive ones that follow the mass-luminosity and mass-lifetime relations.

3. If one solar mass is expelled in 100,000 years, then, the solar masses blown away in one year is $1 \div 100,000 = 0.00001$ solar masses per year. In a half-million years, then, the amount expelled will be the amount expelled per year times the number of years. For ease of calculating, expressing the rate loss as $10^5$ times $5 \times 10^5$, or simply, 5 solar masses blown away in 500,000 years, leaving the star with just 3 solar masses.

7. Find the age of a planetary nebula that is 1 pc in diameter and is expanding at a rate is 30 km/s. So when, in years, did the progenitor star start to expand away into the universe?

First, note that the distance from the star it has expanded to is one radius, or 0.5 pc. (It started at zero and in “X” number of years has covered a distance of 0.5 pc. This invokes the basic relation between distance, rate, and time (when rate is constant, as it is here). The simple relation is spelled out quantitatively as $d=rt$. We are solving for time here, its age. We solve for the “t” factor from the other two factors by dividing both sides by $r$ to get that $t=d/r$.

This is straightforward enough, but we need to make sure we have distance and rate expressed in the same distance units. This means we must find the number of km in a parsec; easy to find since the authors give you the number of km in one parsec, $3.1 \times 10^{13}$ km. Therefore, the age of the planetary nebula, to two significant figures, is:

$$\frac{3.1 \times 10^{13} \, \text{km/pc} \times \frac{1}{2} \, \text{pc}}{30 \, \text{km/s}} = 5.2 \times 10^{11} \, \text{s}$$

If this answer satisfies you and this is as far as you went (or would go), then you are not thinking, AND you ignored the authors’ helpful conversion factor to express your answer in years rather than seconds. With almost a trillion seconds, this time unit is meaningless. We commonly use years even if their number is in the billions.

$$\frac{5.2 \times 10^{11} \, \text{s}}{3.2 \times 10^7 \, \text{s/yr}} = 1.6 \times 10^4 \, \text{yr} \text{ or } 16,000 \, \text{yr}$$

Chapter 14 "Neutron Stars and Black Holes"

Problem
9. The distance travelled by a spot on the neutron star's surface in one second is $1121 \times C$, its circumference. $C = 2\pi R$. With $R = 10$ km, $C = 62.8$ km. Therefore, at the surface, the neutron star is moving $70,338$ km/s! Expressed relative to the speed of light, 300,000 km/s, its $v/c = 0.235$ or $23.5\%$ of the speed of light!