

2.

P5.17

$$\text{Speed} = 30 \text{ km/s}$$

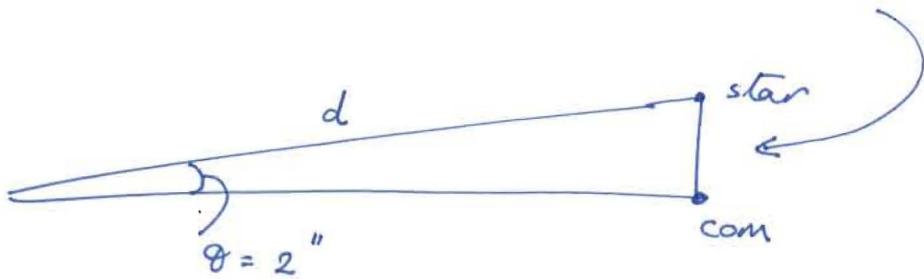
$$\text{Period} = 10 \text{ years.}$$

$$\text{velocity} = \frac{2\pi r}{\text{period}}$$

$$30 \text{ km/s} = \frac{2\pi \times \text{radius in km}}{10 \times 365 \times 24 \times 3600 \text{ sec}}$$

$$\text{So radius in km} = \frac{30 \times 10 \times 365 \times 24 \times 3600}{2\pi}$$

$$= 1.51 \times 10^9 \text{ km}$$



$$\sin \theta = 9.7 \times 10^{-6}$$

$$= \frac{1.51 \times 10^9 \text{ km}}{d}$$

$$\text{So } d = 1.55 \times 10^{14} \text{ km}$$

$$= 5.02 \text{ pc.}$$

(15)

3.

P5.20

Astrometric binary is 10 pc from Sun.

Visible star is 2" from center of mass.

This is  $9.7 \times 10^{-6}$  radians

$$\text{At } 10 \text{ pc, this is } \cancel{\frac{10 \times 3.086 \times 10^{18} \text{ cm}}{9.7 \times 10^{-6}}} = 3 \times 10^{14} \text{ cm.}$$

Using Kepler's 3rd law

$$\frac{4\pi^2 R^3}{G} = (m_1 + m_2) P^2$$

$$\text{Period} = 30 \text{ years} = 9.46 \times 10^8 \text{ sec}$$

$$\text{Sum of masses} = \frac{4\pi^2 R^3}{G P^2}$$

$$= \frac{4\pi^2 (3 \times 10^{14})^3}{6.67 \times 10^{-8} \times (9.46 \times 10^8)^2}$$

$$= 1.79 \times 10^{34} \text{ g}$$

$$= \cancel{8.95 M_{\odot}} 8.95 M_{\odot} - \text{So unseen companion has mass of } 7.75 M_{\odot}$$

P5.24

Use mass-luminosity relationship, eq<sup>2</sup> 5.43b

(a) Intermediate mass :  $\frac{L}{L_{\odot}} = \left(\frac{M}{M_{\odot}}\right)^4$  So  $L = 0.062 L_{\odot}$   
 for  $M = 0.5 M_{\odot}$

(b)

High mass :  $\frac{L}{L_{\odot}} = (5)^{2.8}$  So  $L = 90 L_{\odot}$

**Q6.3**

Optical depth changes monotonically

with distance travelled ; → more distance, higher  $\tau$ .

10. It's not a simple ~~&~~ linear relationship, but it  
is a single-valued transformation (at any  $\lambda$ , etc)

**Q6.7**

(a) If the first spectral line has a lower optical

5. depth, we will be able to see further before  
the atmosphere becomes optically thick.

- (b) H $\alpha$  has a high optical depth because of all that  
hydrogen. So we only see down into the chromosphere,  
5. we don't even get to the photosphere.

**Q6.13**

Most of the mass is in the photosphere, which

10. has a lower temperature, and that is the source of  
the blackbody radiation we see.

P 6.5 - Fraction absorbed is  $f = 1 - \exp(-\tau)$ , so  $\tau = \ln(1 - f)$

| $f$     | $\tau$ |
|---------|--------|
| 0.01    | 0.010  |
| 20. 0.1 | 0.105  |
| 0.5     | 0.693  |
| 0.99    | 4.6    |

- ① (a) The rate at which the Sun is converting mass to energy is

10

$$\frac{L_\odot}{c^2} = 4.26 \times 10^{12} \text{ g/s} = 6.75 \times 10^{-14} M_\odot/\text{yr.}$$

- (b) Sun loses mass via the solar wind at  $10^{-14} M_\odot/\text{yr.}$

10

This is smaller.

- (c) The Sun spends about  $10^{10}$  years on the main sequence.

10

$$7.75 \times 10^{-14} \times 10^{10} = 7.75 \times 10^{-4} M_\odot \cancel{\text{yr}}. \text{ Negligible.}$$

2

Assuming that the Sun is composed entirely of hydrogen atoms, the number of atoms in the Sun is approximately

$$N \simeq \frac{1 M_\odot}{m_H} = 1.2 \times 10^{57}.$$

If each atom releases 10 eV of energy during a chemical reaction, the time scale for chemical reactions would be

$$t_{\text{chem}} = \frac{E_{\text{chem}}}{L_\odot} = \frac{1.2 \times 10^{58} \text{ eV}}{3.83 \times 10^{33} \text{ ergs s}^{-1}} \simeq 5 \times 10^{12} \text{ s} = 1.6 \times 10^5 \text{ yr.}$$

This is much shorter than the age of the solar system, and so the Sun's energy cannot be chemical.

3

For the low mass star, the luminosity is

$$10^{-4.3} \times L_\odot = 3.83 \times 10^{33} \times 5 \times 10^{-5} \text{ ergs/s}$$

$$= 1.92 \times 10^{+29} \text{ ergs/s}$$

If the star is pure hydrogen and, because of convection, each H nucleus participates in fusion

$$\text{mass participating} = 0.072 M_\odot$$

Amount of energy released

$$\begin{aligned}
 = (\Delta m) c^2 &= 0.007 \times 0.072 M_{\odot} \times c^2 \text{ ergs} \\
 &= 1.00 \times 10^{30} \times c^2 \text{ ergs} \\
 &= 8.96 \times 10^{50} \text{ ergs.}
 \end{aligned}$$

20 Lifetime is therefore  $\frac{8.96 \times 10^{50} \text{ ergs}}{1.92 \times 10^{29} \text{ ergs/s}} = 4.67 \times 10^{21} \text{ sec}$

$$= 1.48 \times 10^{14} \text{ years}$$

For the  $85 M_{\odot}$  star, only 10% is available for fusion because it is not fully convective.

$$\text{mass participating} = 85 M_{\odot} \times 0.1$$

20 amt of energy released  $= 0.1 \times 0.007 \times 85 M_{\odot} \times c^2 \text{ ergs}$

Lifetime is therefore  $\frac{0.007 \times 0.1 \times 85 M_{\odot} \times c^2 \text{ ergs}}{3.83 \times 10^{33} \times 1.014 \times 10^6 \text{ ergs/s}}$

$$\begin{aligned}
 &= 2.74 \times 10^{13} \text{ sec} \\
 &= 8.7 \times 10^5 \text{ years}
 \end{aligned}$$