Astronomy 45
Introduction to Astrophysics

Final Examination — 2:15 Thursday May 17
Spring 2001 — Boylston 103

Part A consists of questions requiring short answers and counts for 40% of the total score. Part B consists of proofs and problems and counts for 60%. You can use calculators. The following data may be useful:

1 AU = 1.496×10^{8} km

G = 6.67×10^{-8} cm^{3} s^{-2} g^{-1}

$\sigma = 5.67 \times 10^{-5}$ ergs cm^{-2}s^{-1} K^{-4}

$a = 7.56 \times 10^{-15}$ ergs cm^{-3} K^{-4}

$L_{\odot} = 3.90 \times 10^{33}$ ergs s^{-1}

$R_{\odot} = 6.96 \times 10^{5}$ km

$M_{\odot} = 1.99 \times 10^{33}$ g

1 $W = 10^{7}$ ergs s^{-1}

$B_{\nu}(T) = \frac{2h\nu^3}{c^2} \frac{1}{e^{h\nu/kT} - 1}$

$k = 1.38 \times 10^{-16}$ ergs K^{-1}

$h = 6.63 \times 10^{-27}$ ergs sec

$c = 3 \times 10^{10}$ cm s^{-1}

Part A

Short Answers

1. What is quadrature for a superior planet ?

2. Define the unit 1 parsec.

3. What are the two fundamental conservation laws that govern the motion of the planets?

4. What is the difference between a refracting and a reflecting telescope?

5. If the temperature of a star, radiating as a blackbody is doubled, by what factor is its luminosity increased?

6. Capella is 160 times more luminous than the Sun. The Sun has an absolute magnitude of 4.8. What is the absolute magnitude of Capella?

7. What is a Lagrange point in the gravitational field exerted by a pair of stars orbiting about each other?

8. Distinguish between Pop I and Pop II stars.

9. What are the conservation rules governing nuclear reactions?

10. What prevents white dwarfs from collapsing gravitationally?

11. The red shift $z > 1$ does not imply that $v > c$. Why not?

12. What are the three mechanisms for transporting heat in stars?

13. Define the Hubble constant and give the units in which it is expressed.

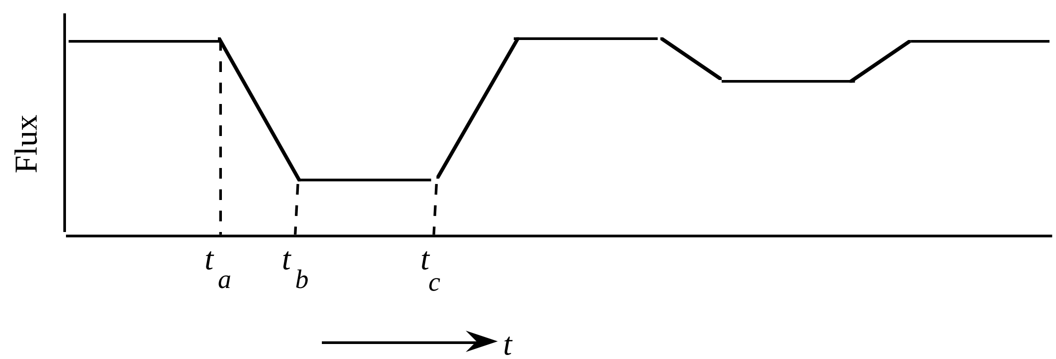
14. What is coronal equilibrium?

Part B
Problems

1. How far from the star Rigel would a body have to be to have the same temperature as the Earth, given that the Sun has a surface temperature of 5800 K and Rigel has a surface temperature of 11,600 K and a radius of 35 $R_\odot$? How far from Barnard's star which has a temperature of 2900 K and radius of 0.5 $R_\odot$?

2. The light curve for an eclipsing binary system is shown in the figure.

   The orbital period is 6.31 years. The maximum radial velocities of the two stars are 5.4 km s^{-1} and 22.4 km s^{-1}, respectively. The angle of inclination is 90° and the stars are in circular orbits. The time that elapses between first contact t_a and the brightness minimum t_b is t_b-t_a= 0.58 days. The duration of the primary eclipse is t_c-t_b= 0.64 days. Determine the total mass, the ratio of the stellar masses and the individual stellar masses. Then obtain the individual stellar radii. Which star is hotter?



3. Show that the black body function $B_\lambda(T)$ peaks at a wavelength that is inversely proportional to the temperature T.

   The cosmic background radiation intensity is a near perfect match to that of a black body at a temperature T = 2.73K.

3. (cont.)

a) What is the energy density?

b) Make the approximation that all the photons have a wavelength equal to the wavelength λ=(0.2898/T) cm at which B_λ (T) peaks. What is the corresponding photon number density?

c) Assume that matter consists of protons of mass 1.67×10^{-27} kg. The mass density is $\rho = 4 \times 10^{-31}$ g cm^{-3}. What is the ratio of the photon and matter number densities?

4. The escape velocity is the minimum velocity a particle must have to escape the gravitational attraction of a body. If the particle has mass M and a radius R, obtain an expression for the escape velocity. Calculate the escape velocity for Earth given that its mass is 6.0×10^{24} kg and and its radius is 6400 km. The mass of a molecule of O_2 is 5.30×10^{-23} g. If the temperature is 300 K, calculate the average velocity. Is this larger or smaller than the escape velocity?

5. The equation of motion of an expanding sphere of radius R and density $\rho(t)$ is

$$\ddot{R} = -\frac{4\pi}{3} G\rho(t)R\,.$$

where t is the time. If R_0 is the present radius and $R(t)=R_o a(t)$, derive the Lemaitre equation relating $\dot{a}^2$ to a for a matter-dominated Universe. Then define the Hubble constant $H(t)$ and obtain an expression for it for a flat Universe. How does H_0 vary with time in a matter-dominated flat Universe?

6. A star has a luminosity L_ν that varies inversely as the frequency ν. Calculate the ratio of the number of photons that can ionize hydrogen to the number that can ionize helium given that the ionization potential of hydrogen is 13.6 eV and the ionization potential of helium is 24.6 eV. What is the relative size of an HII and a HeII Stromgren sphere given that the recombination coefficients of hydrogen and helium are respectively $\alpha_H = 4.2\times10^{-13}$ cm^3 s^{-1} and $\alpha_{He} = 2.7\times10^{-13}$cm^3 s^{-1}?