ASTRONOMY QUALIFYING EXAM
Fall 2018

Possibly Useful Quantities

$L_\odot = 3.9 \times 10^{33}$ erg s^{-1}
$M_\odot = 2 \times 10^{33}$ g
$M_{bol\odot} = 4.74$
$R_\odot = 7 \times 10^{10}$ cm
1 AU = 1.5 $\times 10^{13}$ cm
1 pc = 3.26 Ly. = 3.1 $\times 10^{18}$ cm
a = 7.56 $\times 10^{-15}$ erg cm^{-3} K^{-4}
c = 3 $\times 10^{10}$ cm s^{-1}
$\sigma = ac/4 = 5.7 \times 10^{-5}$ erg cm^{-2} K^{-4} s^{-1}
k = 1.38 $\times 10^{-16}$ erg K^{-1}
e = 4.8 $\times 10^{-10}$ esu
1 fermi = 10^{-13} cm
$N_A = 6.02 \times 10^{23}$ moles g^{-1}
G = 6.67 $\times 10^{-8}$ g^{-1} cm^3 s^{-2}
$m_e = 9.1 \times 10^{-28}$ g
h = 6.63 $\times 10^{-27}$ erg s
1 amu = 1.66053886 $\times 10^{-24}$ g

1 Problem #1

The equation of radiative transfer in spherical coordinates is

$$\mu \frac{\partial I_\nu}{\partial r} + \frac{(1-\mu^2)}{r} \frac{\partial I_\nu}{\partial \mu} = \eta_\nu - \chi_\nu I_\nu$$

a) Derive the two moment equations. (8 points)

b) Show that the condition of radiative equalibrium implies that the divergence of the bolometric flux is zero, that is, the bolometric luminosity is constant. (2 points)

2 Problem #2

You want to observe the main sequence turn-off (MSTO) of a Globular cluster with high precision. The cluster has a distance of 6 kpc and the MSTO has an absolute V magnitude of 4.0 with a B-V color index of 0.3. If you get stuck on a particular part, pick a fiducial value to carry through the problem to obtain partial credit.

$$\lambda_B = 440 \text{ nm } \Delta\lambda_B = 99 \text{ nm } \mathrm{F}_{0,B} = 4.063\times10^{-20} \text{ erg cm}^{-1} \text{ s}^{-1} \text{ Hz}^{-1}$$
$$\lambda_V = 550 \text{ nm } \Delta\lambda_V = 88 \text{ nm } \mathrm{F}_{0,V} = 3.636\times10^{-20} \text{ erg cm}^{-1} \text{ s}^{-1} \text{ Hz}^{-1}$$

a) Using the distance and absolute magnitude, what is the apparent magnitude of a star at the MSTO in this cluster in both B-band and V-band? (1 point)

b) What is the flux density of the star with the same apparent magnitude and color as in part 1 in B-band and V-band? (1 point)

c) How much observing time is needed to reach S/N = 100 on the APO ARCSAT 0.5 m telescope? (4 point)

d) This estimate will be a bit optimistic, what other factors should be considered in determining the S/N in photometry? (2 points)

e) What is the diffraction limit of the APO 0.5 m telescope in B-band? Do you expect observations to be seeing limited or diffraction limited? (1 points)

f) The telescope has a focal length of 4 m. What is the plate scale of the telescope and how large should the CCD pixels be (physical size) to Nyquist sample 0.5″ seeing? If the CCD chip is 4096×4096 pixels, what is the field of view in arcseconds? (1 points).

3 Problem #3

Assume a Salpeter initial mass function $\xi(M) = \xi_o \mathrm{M}^{-2.35}$ and recall that $\mathrm{N}_{total} = \int \xi(M)dM$ and $\mathrm{M}_{total} = \int M * \xi(M)dM$.

a) Assume the smallest mass star is 0.3 M_{Sun}. Show that only $\sim$2.2% of all stars have M $>$ 5 M_{Sun}. (3 points)

b) Assume the smallest mass star is 0.3 M_{Sun}. Show that stars with M $>$ 5 M_{Sun} account for $\sim$37% of the mass of all stars. (3 points)

c) The Pleiades cluster has a total mass M $\sim$ 800 M_{Sun}. Assume the smallest mass star in the Pleiades is 0.3 M_{Sun}. Show that the cluster has $\sim$700 stars. (4 points)

4 Problem #4

The center of our galaxy contains a supermassive black hole with mass of 4.5×10^6 $M_\odot$, 8 kpc from the sun.

a) Discuss the complications inherent in studying the black hole at the center of the galaxy. (1 point)

b) A star the mass of our sun is in orbit around this black hole. It has a period of 20 years. What is the proper motion in arc seconds per year observed for this star? Assume for the moment that the orbit is a circle in the plane of the sky. (4 points)

c) How close could a star the mass of our sun be to this black hole before it is torn apart? (3 points)

(d) What would the eccentricity of the 20-year orbit be if, at perihelion, the distance of the star from the black hole was the value in part c.? (2 points)

5 Problem #5

a) Use hydrostatic equilibrium to find a differential equation relating a planetary atmosphere's pressure gradient, $\frac{dP}{dz}$, to the planet's surface gravity (g), temperature (T), mean atmospheric molecular mass (m), and pressure at a given height ($P(z)$). Assume that temperature is constant, the mass of the atmosphere is tiny compared to the planet's mass, and the height of the atmosphere is tiny compared to the planet's radius. (4 points)

b) Solve your relation in part **a** to show how the planet's atmospheric scale height depends on T, m, and the planet's surface gravity or g. (2 points)

c) Assume that the planet and its star are perfect blackbodies and that the planet's albedo is 0. Furthermore, assume that all the stellar radiation that strikes the planet is redistributed evenly around the planet and that this process sets the planetary temperature. By what factor will the planet's atmospheric scale height increase/decrease if its circular orbit is moved from 1 to 4 AU. (4 points)

6 Problem #6

Define/explain 10 of the following and indicate their relevance in astronomy. Be sure to clearly indicate which of the 10 you would like graded (otherwise the 1st 10 items will automatically be graded)

a) G dwarf problem (1 point)
b) Einstein radius (1 point)
c) Extinction & reddening (1 point)
d) Sgr A* (1 point)
e) Optical depth (1 point)
f) Fundamental plane (1 point)
g) Tully Fisher relationship (1 point)
h) Malmquist Bias (1 point)
i) Lyman-alpha forest (1 point)
j) Quasar (1 point)
k) Jean's Mass (1 point)
l) Roche limit (1 point)
m) Eddington Limit (1 point)
n) Chandrasekhar limit (1 point)