Astron 211 Problem Set 5

Given: Oct 4. Due: Oct 11 at the beginning of class

Homework Policy: You can consult class notes and books. Always try to solve the problems yourself; if you cannot make progress after some effort, you can discuss with your classmates or ask the instructor. However, you cannot copy other's work: what you turn in must be your own. Make sure you are clear about the process you use to solve the problems: partial credit will be awarded.
Reading: Kutner Chapters 10, 11, 8.3, 8.4

Problem 1 Kutner Problem 11.5

For a $1.5\,M_\odot$ neutron star with radius $R = 15\,\mathrm{km}$ rotating 100 times per second, compare the gravitational force on an object at the surface with the force required to produce the circular motion for that object (at the star's equator). In other words, compare the weight of an object with the centripetal force on it.

Problem 2 Kutner Problem 9.4

Estimate the lifetime of a $10\,M_\odot$ star on the main sequence to give off energy stored from gravitational collapse (i.e., what is the Kelvin-Helmholtz timescale for this star).

Problem 3 Kutner Problem 9.5

Calculate the mass corresponding to the binding energy of an H atom. What fraction of the mass of the atom is this?

[Note that this is for an *atom*, not a nucleus. So this is the energy it releases when you bring a proton and an electron together, which is the ionization energy of a H atom. Ionization energies are given in Table 3.1 in Kutner.]

Problem 4 Order of Magnitude: Neutrinos and Opacity [10 pts]

When a massive star collapses and explodes in a supernova and leaves behind a neutron star, most of the energy released is in the form of neutrinos.

a. If the just-formed star has a mass $M = 1.4M_\odot$ and a radius $R = 10\,\mathrm{km}$, estimate the mean nucleon density, in m^{-3}.

b. Assuming a cross section for scattering of neutrinos on neutrons of $\sigma_{\nu,n} = 10^{-46}\,\mathrm{m}^2$; find the mean free path, in m, of a neutrino inside the neutron star, assuming the density you found in (a).

c. How many seconds does it take a typical neutrino to emerge from the neutron star in a random walk (assume they are traveling at the speed of light)?

d. Twelve electron anti-neutrinos (think of them as just neutrinos) from supernova 1987A were detected by the Kamiokande neutrino detector in Japan (a roughly spherical tank filled with 3 kton of water). Assuming a cross-section of $\sigma_{\nu,\mathrm{water}} = 10^{-47}\,\mathrm{m}^2$, roughly how many neutrinos are passing through your body a second?

e. If the number density of nucleons in lead is $10^{31}\,\mathrm{m}^{-3}$, what is the mean free path of a neutrino?