Astron 299/L&S 295 Problem Set 4

Given: Oct 5. Due: Wednesday, Oct 12 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 2, 3, 9, 22.4, 6.2

Problem 1 Kutner 2.13

Problem 2 Kutner 2.14

Problem 3 Kutner 2.18

Problem 4 Kutner 2.19

Problem 5 Kutner 9.6

Problem 6 Order of Magnitude: Hamburgers [20 pts]

a. If you drive by a McDonalds, you will see (depending on where you are) "95 billion served." Estimate the number of cows that required.

b. Would the energy of all the calories you have consumed as food be enough to eject you from the solar system? To escape from the solar system you would need to escape from the Earth, then escape from the Sun.

c. NASA pays about \$20,000 per kilogram to get rockets away from Earth. For comparison, 1kW hr=3.6×10^6 J costs about 15 cents and 1 gal gas $\sim 10^8$ J costs about \$1.50. Is NASA wasting our money by sending rockets away from the Earth?

d. There are about 1000 kcal in a bacon double cheeseburger. If that was being perfectly converted to thrust, at what rate would you have to eat burgers to maintain escape velocity near Earth's surface? Remember that power (energy per time) is force (the force needed to resist gravity and maintain a constant velocity) times velocity.

Problem 7 Order of Magnitude: Neutrinos and Opacity [10 pts]

Most of the energy released in the collapse of a massive star to a neutron star 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?