Homework 5

Due **February 20 at 2pm in class**

Please show all work, writing solutions/explanations clearly, or no credit will be given. You are encouraged to work together, but everyone must turn in independent solutions: do not copy from others or from any other sources.

1. During a Type I supernova explosion, a certain number N_o of ^{56}Ni nuclei are created. These undergo the radioactive decay sequence $^{56}\text{Ni} \rightarrow {}^{56}\text{Co} \rightarrow {}^{56}\text{Fe}$. The half–lives of ^{56}Ni and ^{56}Co are 6.24 and 79 days, respectively.

   (a) Write down expressions for the number of ^{56}Ni, ^{56}Co, and ^{56}Fe nuclei as functions of time after the explosion (t, in days).

   (b) If each ^{56}Ni decay produces E_{Ni} ergs of energy and each ^{56}Co decay produces E_{Co} ergs, and these energies are immediately radiated by the supernova, what is the luminosity of the supernova as a function of time?

2. The supernova SN1987a occurred in the Large Magellanic Cloud (at a distance of 55 kpc). Assume that it involved a core collapse which created a neutron star, and that most of the binding energy of the neutron star was radiated as neutrinos, which had an average energy of 10 MeV. Roughly, how many neutrinos from this supernovae passed through your professor's 6-year old body as he lay blissfully asleep?

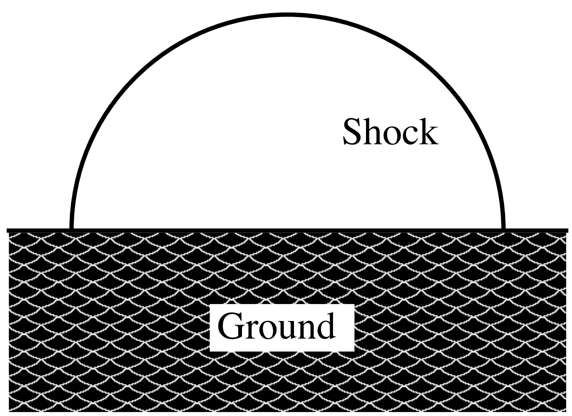
3. The neutrinos from SN1987a all arrived within about 12 seconds of one another. They had energies which ranged from 6 to 40 MeV. Assume that the range in the arrival times is due to the combination of a range in emission times and a range in the travel times from the supernova to the Earth. Use the observed range in arrival times to set an upper limit on the rest mass energy of the neutrino (in eV).

4. During the first atomic bomb test at Alamogordo, Enrico Fermi is supposed to have performed a simple test to quickly determine the yield E (the total energy released by the bomb). Assume that Fermi was located at a safe distance of $R = 10$ km from the explosion. Assume that shock wave was very weak at this distance, so that the pressure increase in the shock ΔP was much smaller than the atmospheric pressure P_o. Fermi dropped small pieces of paper out of his pocket as the explosion occurred.

   Afterward, he found that some of the paper was located $\Delta R = 40$ cm behind the position at which it had been dropped. Assume that the paper was so light that it simply traveled with the surrounding air before falling to the ground. Neglect the kinetic energy of the shocked gas at the distance where Fermi measured it, and also neglect any radiation emitted during the explosion. Assume the geometry of the shock associated with the explosion is a hemisphere, with the ground being the flat surface of the hemisphere. Ignore any energy which goes into the ground. Note that the adiabatic index for air is approximately $\gamma = 7/5$.

   (a) Estimate the yield E of the bomb in ergs. (Hint: what is the work done is displacing the atmosphere from R to $R + \Delta R$?)

   (b) Convert the yield to kilotons of TNT equivalent. Note that 1 kT $= 4.2 \times 10^{19}$ ergs.



5. Describe your project as you currently envision it, or, if you don't have a clear idea of what you want to do yet, schedule a meeting with me via email to discuss options in more detail.