Astronomy 312 - Fragile
Homework 9 (assigned 4/5/16; due 4/14/16)

(3) 1. Calculate the magnitude of the variation in the temperature of the CMB due to the Sun's peculiar velocity.

(3) 2. Consider a comoving sphere whose surface expands with the universe. Let it be centered at the origin and filled with CMB photons. Show that the relationship, $R^4\rho_{\rm rel} = \rho_{\rm rel,0}$, is consistent with the conservation of energy within the sphere.

(3) 3. Show that deep in the radiation era when $R \ll R_{r,m}$ that Eq. (29.84) is well approximated by Eq. (29.86).

(3) 4. Using arguments similar to those presented in class for the characteristic timescale for photon scattering, one can show that the number of collisions between a neutron and a proton that occur within a time Δt is $n_p\sigma v\Delta t$, where n_p is the number density of protons, σ is the neutron's collision cross section, and v is the speed of the neutron. Evaluate $n_p\sigma v\Delta t$. If the result is $\gg 1$, then each neutron would have had ample opportunity to combine with a proton (lending to the formation of helium nuclei). Let Δt be the characteristic timescale of the universe at the time of helium formation, and use $\sigma = \pi(2r)^2$, where $r \simeq 10^{-15}$ m is the radius of a neutron. The number density of protons can be estimated from the baryonic mass density when $T = 10^9$ K.