# NUCL 510 Nuclear Reactor Theory I
**Fall 2011**

## HW#3: Neutron Interactions

Due September 15

1. Two mono-energetic neutron beams, each of intensity $5\times10^8$ neutrons/cm$^2$-sec, cross at an angle of 45°. Compute the neutron flux and current in the region where the beams intersect.

2. The density distribution function mono-energetic neutrons at a point $\vec{r}$ is

   $$n(\vec{r},\vec{\Omega}) = ne^{-\chi/\lambda}(1+\cos\theta)$$

   where $n$ and $\lambda$ are constants, and $\theta$ is the angle between $\vec{\Omega}$ and the z-axis. Compute at $\vec{r}$ (a) the neutron density, (b) the flux, and (c) the current.

3. Neutrons are produced uniformly and isotropically throughout a spherical chamber containing a mixture of $^3$H and $^2$H gases at high temperature (~$10^8$ °K) and low density. (The neutrons originate in the $^3$H(d,n)$^4$He and $^2$H(d,n)$^3$He fusion reactions.) Show that the neutron flux and current at any point on the surface of the chamber are given by $\varphi = SR/2$ and $\vec{J} = SR\vec{e}_r/3$, respectively, where $S$ is the source density (neutrons/cm$^3$-sec), $R$ is the radius of the chamber, and $\vec{e}_r$ is a unit radial vector. The neutron mean free path in the medium is essentially infinite.

4. For an energy-independent s-wave scattering, the energy transfer function for a monatomic gas is given by

   $$f_s(E\to E') = \frac{\eta^2}{2E}\left\{\mathrm{erf}\left(\eta\sqrt{\frac{E'}{kT}}-\rho\sqrt{\frac{E}{kT}}\right)\mp\mathrm{erf}\left(\eta\sqrt{\frac{E'}{kT}}+\rho\sqrt{\frac{E}{kT}}\right)\right.$$
   $$\left.+e^{(E-E')/kT}\left[\mathrm{erf}\left(\eta\sqrt{\frac{E}{kT}}-\rho\sqrt{\frac{E'}{kT}}\right)\pm\mathrm{erf}\left(\eta\sqrt{\frac{E}{kT}}+\rho\sqrt{\frac{E'}{kT}}\right)\right]\right\}$$

   where

   $$\eta = \frac{A+1}{2\sqrt{A}},\quad \rho = \frac{A-1}{2\sqrt{A}}$$

   and the upper signs are to be used for $E' > E$ and the lower signs for $E' < E$. Plot the energy transfer functions of incident neutrons of 0.025 eV, 10 eV and 100 eV for the following targets: (a) H-1 at 300 °C, (b) O-16 2000 °C and (c) U-238 at 2000 °C.