NE 155/255, Fall 2019
Nuclear Physics Terms, continued
September 11, 2019

---

3. **double-differential scattering x-sec** ($\sigma_s(E, \hat{\Omega} \to E', \hat{\Omega}')dE'd\hat{\Omega}'$): measure of the probability that a neutron of energy E and moving in direction $\hat{\Omega}$ scatters off of a specific nucleus into energy range $[E', E' + dE']$ and direction range $[\hat{\Omega}', \hat{\Omega}' + d\hat{\Omega}']$.

   We can think of this as the fractional probability multiplied by the total scattering cross section

$$\sigma_s(E, \hat{\Omega} \to E', \hat{\Omega}') = \sigma_s(E) f_s(E, \hat{\Omega} \to E', \hat{\Omega}')$$
$$\text{where} \int_0^{E_0} dE' \int_{4\pi} d\hat{\Omega}'\, f_s(E, \hat{\Omega} \to E', \hat{\Omega}') = 1$$
$$\sigma_s(E) = \int_0^{E_0} dE' \int_{4\pi} d\hat{\Omega}'\, \sigma_s(E, \hat{\Omega} \to E', \hat{\Omega}')$$

4. **fission yield** ($\nu(E)$): average # of neutrons released by a fission induced by a neutron of energy E.

5. **fission spectrum** ($\chi(E)dE$): average # of neutrons produced from fission that are born with energy in $[E, E + dE]$. This is normalized such that

$$\int_0^{\infty} \chi(E)dE = 1\,.$$

   - U-235: $\chi(E) = 0.453e^{-1.036E}\sinh(\sqrt{2.29E})$
   - Pu-239: $\chi(E) = 0.6739\sqrt{E}e^{-E/1.41}$

6. **particle angular density** ($n(\vec{r}, E, \hat{\Omega}, t)d\vec{r}d\hat{\Omega}dE$): expected number of particles in volume element d^3r at $\vec{r}$ whose energies are in $[E, E + dE]$ and direction of motion is in $[\hat{\Omega}, \hat{\Omega} + d\hat{\Omega}]$ at time t.

   Note:

$$
\begin{aligned}
n(\vec{r}, E, \hat{\Omega}, t) &= \frac{1}{mv} n(\vec{r}, v, \hat{\Omega}, t) \\
n(\vec{r}, v, \hat{\Omega}, t) &= v^2 n(\vec{r}, \vec{v}, t) \\
n(\vec{r}, \vec{v}, t) &= \frac{m}{v} n(\vec{r}, E, \hat{\Omega}, t)
\end{aligned}
$$

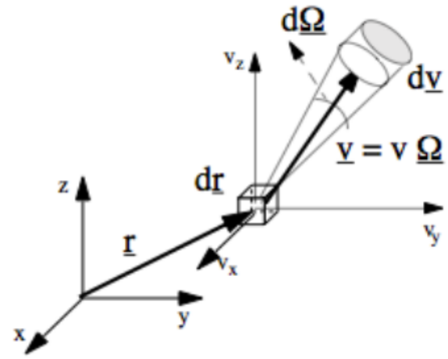

Figure 1: Differential volume, velocity (energy), and angle

7. **particle density**: ($N(\vec{r}, E, t)d^3rdE$): expected number of particles in d^3r at $\vec{r}$ whose energies are in $[E, E + dE]$ at time t.

$$
N(\vec{r}, E, t)d^3rdE = \int_{4\pi} d\hat{\Omega}\, n(\vec{r}, E, \hat{\Omega}, t)d^3rdE
$$

8. **angular flux**: $\psi(\vec{r}, E, \hat{\Omega}, t) \equiv vn(\vec{r}, E, \hat{\Omega}, t)$ [neutrons / (cm^2 s MeV steradian)] can be thought of as path length per unit volume about $\vec{r}$ passed by neutrons with energies...

9. **scalar flux**: $\phi(\vec{r}, E, t) \equiv vN(\vec{r}, E, t)$ [neutrons / (cm^2 s MeV)] can be thought of as the number of neutrons that penetrate a sphere of 1 cm^2 cross sectional area at $\vec{r}$ with energies in dE about E at time t.

$$
= \int_{4\pi} d\hat{\Omega}\, \psi(\vec{r}, E, \hat{\Omega}, t)
$$

10. **interaction rate density**: expected number of j reactions per volume per energy at time t.

$$\int_{4\pi} d\hat{\Omega}\, \Sigma_j v n(\vec{r}, E, \hat{\Omega}, t) = \Sigma_j \phi(\vec{r}, E, t)$$

11. **angular current density** or partial current: $\vec{j}(\vec{r}, E, \hat{\Omega}, t) = \vec{v} n(\vec{r}, E, \hat{\Omega}, t)$;

    $\vec{j}(\vec{r}, E, \hat{\Omega}, t) \cdot \hat{e}\, dA\, dE\, d\hat{\Omega}$ is the expected number of particles crossing dA per second along unit direction $\hat{e}$ with energy in $[E, E + dE]$ and direction in $[\hat{\Omega}, \hat{\Omega} + d\hat{\Omega}]$ at time t.

12. **net current**: $\vec{J}(\vec{r}, E, t)$ is the net # of particles crossing a unit area per second along a direction normal to that area with energies in $[E, E + dE]$ at time t.

$$\vec{J}(\vec{r}, E, t) = \int_{4\pi} d\hat{\Omega}\, \hat{\Omega} \psi(\vec{r}, E, \hat{\Omega}, t)$$