The average time between these encounters is the reciprocal of the frequency $\tau_c = \nu_c^{-1} = (\sigma^+ \hat{V} n_v)^{-1}$. The average distance between encounters is the product of the time between encounters and the particle speed $\lambda_c = \tau_c \hat{V} = (\sigma^+ n_v)^{-1}$.

Exmp. 5 considered the motion of an oversize collision particle moving at the mean particle speed through a *stationary* gas of point particles. This is the appropriate model for the consideration of collisions between relatively fast and relatively slow moving particles. Examples of this type include: photons colliding with molecules in a gas or phonons in a solid; phonons colliding with defects or lattice points in a solid, free electrons colliding with phonons in a metal; fast neutrons colliding with fuel or moderator nuclei in a nuclear reactor. The mean free time, $\tau_{c,1-2}$, and mean free path, $\lambda_{c,1-2}$, for collisions between the fast particles, 1, and slow particles, 2 are

$$\tau_{c,1-2} = \frac{1}{\sigma^+_{12} \hat{V}_1 n_{v,2}} \qquad \lambda_{c,1-2} = \frac{1}{\sigma^+_{12} n_{v,2}} \qquad \text{(IIIE-12a,13a)}$$

Exercise 11. A nuclear reactor functions by slowing down the fast neutrons produced in the fission reaction by sequences of collisions with the "moderator." If graphite carbon is employed as the moderator, its cross section for neutron scattering is approximately $4 \cdot 10^{-24}$ cm^2. Estimate the neutron mean free path in a graphite moderator. (Graphite density is about 1.6 g/cm^3.)

A determination of the mean free time and mean free path for collisions between identical particles requires that *relative* particle speeds be accounted for. The result of such a development (see Ref.4, pg. 344) is

$$\tau_c = \frac{1}{\sqrt{2}\, \sigma^+ n_v \hat{V}} \qquad \lambda_c = \frac{1}{\sqrt{2}\, \sigma^+ n_v} \qquad \text{(IIIE-12b,13b)}$$

The mean free time and, especially, the mean free path are important in the classification of transport processes. If the distance between the particle-particle collisions is large in comparison to the average transport distance in the system, then particles move relatively unimpeded throughout the container. Such processes are *dominated by wall-particle collisions* and transport within this regime is called *free particle transport*. In the opposite extreme when the mean free path is small in comparison to the container size, then transport processes are *dominated by particle-particle collisions*. This transport regime is called the *continuum*. Thus a formal classification of transport regimes is obtained by comparing the particle-particle mean free path to a characteristic length parameter of transport, most formally $L \equiv V/A$. This ratio is called the *Knudsen number*.

$$Kn = \frac{\lambda_c}{L} \qquad \text{(IIIE-14)}$$

In molecular gases the continuum regime is usually identified as $Kn < 10^{-2}$, and the free particle regime as $Kn > 10$, the range between them being a transition regime. This