3.6.2 One-speed and two-speed approximations

As described earlier, the crudest approach to the energy discretization is to assume that all the neutrons have the same energy, a thermal energy in thermal reactors since the heat produced is mostly dependent on the thermal neutron flux. This basic approach is termed the *one-speed approximation* and the diffusion theory based on this approximation is *one-speed diffusion theory.* The next level of approximation is to assume two classes of neutrons each with a single neutron energy. This *two-speed model* applied to thermal reactors assumes one class of thermal neutrons and a second class of fast neutrons combined with a model for the slowing down of the fast neutrons to the thermal neutrons.

It is appropriate here to focus first on the simplest approach, namely the one-speed approximation. With this approximation, scattering between energy levels is no longer an issue and the fourth (or [D]) term in the neutron continuity equation 1, section 3.5 drops out. The result is the following governing equation for the neutron flux, $\phi(x_i, t)$ (where the independent variable, E, is now dropped since all neutrons are assumed to have the same speed):

$$\frac{1}{\bar{u}}\frac{\partial \phi}{\partial t} - \frac{\partial}{\partial x_j}\left(D(x_i)\frac{\partial \phi}{\partial x_j}\right) + \Sigma_a \phi = S(x_i, t) \tag{1}$$

This is called the *one-speed neutron diffusion equation* and its solution is known as *one-speed diffusion theory.*

Before moving to examine this theory in some detail, note that the ratio, D/Σ_a, is a key parameter that appears in the diffusion equation 1. The square root of this ratio has the dimension of length and allows the definition of a quantity, L, known as the *neutron diffusion length*:

$$L = \left[\frac{D}{\Sigma_a}\right]^{\frac{1}{2}} \tag{2}$$

A neutron moving within an absorbing and scattering medium will exhibit classical random walk and, by Rayleigh's scattering theory, a single neutron will therefore typically travel a distance of $6^{\frac{1}{2}}L$ before it is absorbed. Typical values for L at normal temperatures are of the order of 60 cm. Note that this is not small compared with the dimensions of a reactor core and therefore diffusion theory can only provide a crude (but nevertheless useful) approximation for reactor neutronics.