Problem 5.1 *To study neutron absorption cross sections at very low energies, one must often slow down (moderate) energetic* ($\approx 1\,\text{MeV}$) *neutrons that are produced in reactors. Show that paraffin would be a better moderator than aluminum, by specifically calculating the maximum energy that a* $1\,\text{MeV}$ *neutron can transfer in a collision with a proton (within paraffin) as opposed to that with an Al nucleus.*

As we saw in Problem 2.9 (see Eq. (2.48)), in a head-on collision with a target nucleus of mass number A, a neutron scatters backwards ($\theta = \pi$) with an energy

$$E_n = \left(\frac{A-1}{A+1}\right)^2 E_0, \tag{5.1}$$

where E_0 represents the energy of the incident neutron. If the target is paraffin (essentially a chain of CH_2 units), then ignoring the presence of C, for $A = 1$ we get

$$E_n^{(\text{paraffin})} = \left(\frac{A-1}{A+1}\right)^2 E_0 = \left(\frac{1-1}{1+1}\right)^2 E_0 = 0. \tag{5.2}$$

On the other hand, if the target nucleus is aluminum ($^{27}\text{Al}^{13}$), we have $A = 27$, leading to

$$\begin{aligned} E_n^{(\text{aluminum})} &= \left(\frac{A-1}{A+1}\right)^2 E_0 = \left(\frac{27-1}{27+1}\right)^2 E_0 \\ &\approx 0.86 E_0. \end{aligned} \tag{5.3}$$

Thus, we see that paraffin is a much better moderator, since after one collision a neutron can lose all its energy.