
Note all problems will be worth 8 points, except as indicated below.

Problems from Liboff:
14.3
14.6 (4 pts)
14.7

Additional problems:
1. Consider the scattering from a spherical delta-function shell,
   \[ V(r) = \alpha \delta (r - a), \] where \( \alpha \) and \( a \) are constants.
   (a) Calculate \( f(\theta) \), \( d\sigma/d\Omega \), and \( \sigma \) in the low-energy Born approximation.
      (In the low energy Born approximation, \( k \) is very long, and the exponential is assumed nearly
      constant and can be factored out of the integral, giving \( f(\theta) = \frac{m}{2\pi \hbar^2} \int V(\mathbf{r}) d^3 r \).
   (b) Calculate \( f(\theta) \) and \( d\sigma/d\Omega \) for arbitrary energies, in the Born approximation.

2. (16 pts)
   (a) At a center-of-mass energy of 5 MeV, the phase shifts describing the elastic scattering of a
      neutron by a certain nucleus have the following values:
      \( \delta_0=32.5^\circ, \delta_1=8.6^\circ, \delta_2=0.4^\circ \).
      Assuming all other phase shifts to be negligible, plot \( d\sigma/d\Omega \) as a function of scattering angle.
      What is the total cross section \( \sigma \)? For simplicity, take the reduced mass of the system to be
      that of the neutron.
     (b) The same if the algebraic sign of all three phase shifts is reversed.
     (c) The same if the sign of only \( \delta_0 \) is reversed.
     (d) Using the results of part (a), calculate the total number of neutrons scattered per second
         out of a beam of \( 10^{10} \) neutrons per cm\(^2\) per sec, of cross-sectional area 2 cm\(^2\), incident
         upon a foil containing \( 10^{21} \) nuclei per cm\(^2\). How many neutrons per second would be
         scattered into a counter at 90\(^\circ\) to the incident beam and subtending a solid angle of \( 2 \times 10^{-5} \)
         steradians?