Quantum Mechanics 2, Spring 2016

Assignment #5, Due 31/05/2016

1. Consider the low energy elastic scattering of a plane wave with wavenumber k from the spherically symmetric potential $V(r) = V_0 e^{-\alpha r}$. Calculate $f(\vec{k'}, \vec{k})$ up to second order in Born approximation.

2. For the scattering off a hard sphere of radius R,

   (a) Sketch the total S-wave ($l = 0$) scattering cross section as a function of k, illustrating the following points: (i) low energy behaviour (ii) high energy behaviour (iii) resonances: positions and strengths.

   (b) Calculate the phase shift and the cross section for P-wave ($l = 1$) scattering. Sketch the total P-wave scattering cross section as a function of k, illustrating the same points as above.

   (You may use Mathematica or any other plotting software.)

3. A particle of mass m moves under the influence of a repulsive spherically symmetric potential: $V(r) = V_0$ for $r < R$, zero outside. Determine the S-wave phase shift when $E < V_0$. Compare the cross section thus obtained with that obtained from the first order Born approximation.

4. Consider the problem of finding the binding energy of deuteron (as discussed in Sakurai).

   (a) Determine the value of the effective range r_0 of the proton-neutron potential.

   (b) A proton (938 MeV, spin 1/2) and a pion (140 MeV, spin 0) undergo scattering through a N (1440 MeV, spin 1/2) resonance. Calculate the cross section at the resonance in barns.

5. Sakurai Chapter 7, problem 9 (The spherically symmetric repulsive δ-shell potential)

6. A nucleus with radius R absorbs all the neutrons incident on it. Let the de Broglie wavelength of the neutrons be smaller than the nuclear size. Determine the total (elastic) scattering cross section and the total (inelastic) absorption cross section.

Not to be submitted

1. Sakurai Chapter 7, problem 1 (Edition 1994: one-dimensional reflection / transmission)

2. Sakurai Chapter 7, problem 2 (Edition 1994: total cross section with first / second order Born approximation)

3. Sakurai Chapter 7, problem 3 (Edition 1994: potential barrier and angular distribution)