Homework 1 quantum mechanics applications, scattering

February 1, 2023

- Problem 1: Use the first Born approximation to calculate the total cross section for a potential $V(r) = Ae^{-\mu r^2}$ where μ is now a constant (not the reduced mass), A another constant. And consider the mass of the incident particle to be m and k is the wave number of the incident particle.
- Problem 2: Solve the integral for the propagator as described in class.
- Problem 3: The first Born approximation valid as long as V(r) is weak and k is high. Show why this two conditions are necessary.
- Problem 4: In particle physics, if two fermions interact with a scalar particle, the interaction potential may be described by the Yukawa potential, named after Hideki Yukawa. This potential has the form $V(r) = -V_0 \frac{e^{-\mu r}}{r}$ where μ is the mass of the scalar particle and $V_0 > 0$. Find, using first Born approximation (note even though fermions have spin, you can still apply the results from class):
  a. The differential cross section.
  b. The total cross section.
- Problem 6:

  In a scattering experiment it is observed that when a particle with mass m and energy E interacts with a potential of range a, the phase shift of the l-th partial wave is:

$$\delta_l = \sin^{-1}\left(\frac{(iak)^l}{((2l+1)(l!))^{1/2}}\right) \tag{1}$$

  Show that the scattering cross section is:

$$\sigma = \frac{2\pi\hbar^2}{mE}\ exp\left(\frac{-2mEa^2}{\hbar^2}\right) \tag{2}$$