The Hashemite University
Department of Physics
Fall Semester 2016/2017

Second Exam
Graduate QM
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1. Consider the elastic scattering from the potential $V(r) = V_0 e^{-r/2a}$, where $V_0 > 0$.

   a) Find the differential scattering cross section in the first Born approximation (5 points)

   b) Find the total scattering cross section for the low energy limit (3 points)

   c) Find the total scattering cross section for the high energy limit (4 points)

2. Consider a 1D-harmonic oscillator with $H_0 = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 x^2$. The eigenstates of the oscillator are denoted by $|n\rangle$ with energies $E_n^{(0)} = \hbar\omega(n + \frac{1}{2})$.

   Suppose a perturbation $H' = \lambda x^2$ is introduced. Recall that for 1D harmonic oscillator ,
   $x = \sqrt{\frac{\hbar}{2m\omega}}\,(A + A^\dagger)$, $A|n\rangle = \sqrt{n}\,|n-1\rangle$, *and* $A^\dagger|n\rangle = \sqrt{n+1}\,|n+1\rangle$

   a) Calculate the energy of the *n*th level to first order in λ (5 points)

   b) Calculate the eigenstate of the *n*th level to first order (4 points)

3. Show that $[\vec{L}, \vec{L}.\vec{S}] = i\hbar\, \vec{S} \times \vec{L}$ (4 points)