Physics GR6038 Professor Christ
due 04/20/2025

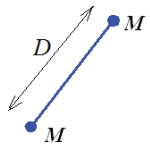
Problem Set #21

71. Consider the scattering of a particle of mass m and momentum $\vec{p}$ by a target particle of mass M at rest. If the particles interact through the potential

$$V(\vec{r}, \vec{r}\,') = \lambda \delta^3(\vec{r} - \vec{r}\,')$$

find the differential scattering cross section $d\sigma/d\Omega$ to lowest order in λ in the laboratory system. Here the differential solid angle $d\Omega$ refers to the direction of the scattered particle with mass m. Your result should be valid for any relative size of M and m.

72. Two particles, each of mass M, are separated by a massless, rigid rod of length D.



(a) Write down the Hamiltonian for such a quantum mechanical rigid rotor in terms of the square of the angular momentum operator $\vec{L}$ and the total momentum operator $\vec{P}$ for the system and find its energy eigenstates and eigenvalues.

(b) Calculate to lowest order in λ the cross section for the scattering of a third particle with momentum $\vec{p}$ and mass $m \ll M$ by such a rigid rotor for the case that the rotor is at rest and initially and finally in its ground state. The beam and target particles interact through the potential:

$$V(\vec{r}_1, \vec{r}_2, \vec{r}\,) = \lambda \sum_{i=1}^{2} \delta^3(\vec{r} - \vec{r}_i)$$

where $\vec{r}_1$ and $\vec{r}_2$ locate the two particles of mass M while $\vec{r}$ is the position of the third particle with mass m.

73. Find the differential cross section $d\sigma/d\Omega$ to order e^4 for the elastic scattering of a non-relativistic positron from unexcited atomic hydrogen, including the effects of proton recoil. [This is the same as the scattering problem that will be discussed in class on Monday except in this problem the effects of proton recoil should be included.]