4/17/17 Lecture 5 outline

• Where we left off last time: Klein Gordon theory, SHO, and Euler Lagrange equations for field theory.

• Charged Klein Gordon theory via $D^\mu = \partial^\mu + iqA^\mu$ covariant derivatives and minimal substitution.

• Spin 1: theory are gauge fields. Example: $S = \int d^4x (-1/4) F_{\mu\nu}F^{\mu\nu} - j^\mu A_\mu / c$.

• Quantization: quantum field in terms of creation and annihilation operators. For KG field,

$$\phi = \int \frac{d^3k}{(2\pi)^3 2\omega_k}(a_k e^{-ikx} + a_k^\dagger e^{ikx})$$

where $[a_k, a_k^\dagger] = (2\pi)^3 2\omega_k \delta^3(k - \vec{k}')$. The fields have $[\phi(\vec{x}, t), \Pi(\vec{y}, t)] = i\delta^3(\vec{x} - \vec{y})$, where $\Pi = \dot{\phi}$.

• Quantize spin 1, photon creation and annihilation operators

$$A_\mu(x) = \sum_{r=1}^{2} \int \frac{d^3k}{(2\pi)^3(2\omega_k)}[a_k^r \epsilon_\mu^r e^{-ikx} + a_k^{r\,\dagger} \epsilon_\mu^{r\,*} e^{ikx}].$$