## Problem 1

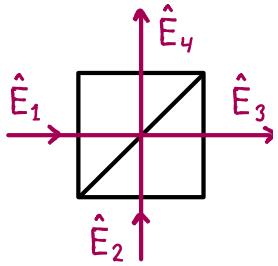
Describe in your own words the sequence of steps required to go from a classical theory to a quantum theory in the cases (a) and (b) described below. Each sequence ends when the classical dynamical variables become quantum mechanical observables. Be clear and concise and try to stay close to the suggested number of steps and overall word count. Excessive detail is discouraged. No equations allowed.

(a) Motion of a harmonically bound particle. **(**Approximately 4 steps, ≤ 100 words total) (15%)

(b) The electromagnetic field in a cavity. (Approximately 7 steps, ≤ 200 words total) (35%)

## Problem 2

Consider a beam splitter with inputs and outputs labeled as on the figure, and having transmission and reflection coefficients $t$ and $r$.




(a) Given the input state $|\Psi_{in}\rangle = |1\rangle_1 |0\rangle_2$, write down an expression for the output state $|\Psi_{out}\rangle$. (10%)

(b) As discussed in class, $|\Psi_{out}\rangle$ is an entangled state. What degrees of freedom of the field are entangled? (10%)

(c) Assume you know $|\Psi_{in}\rangle$, $t$, and $r$, but do not have access to the output in port 3. How would you describe the output in port 3 in isolation? Is it a pure or mixed state? (15%)

(d) Write out the density operator describing the state in port 3. For which values of $t$ and $r$ will it be pure and for which values will it be mixed? (15%)