Quantum Theory Interview Questions

5 and 6 October 2023

1 Early Interviews

If you would like to volunteer to take your interview on Wednesday 4 October, please let Bindiya or Dan know by noon on Thursday 28 September.

2 Quantum Theory Part I: Interview Questions

a) Compare the Schrödinger, Heisenberg and Interaction picture. Explain how the interaction picture helps with handling time-dependent potentials.

b) Show that when a constant potential is applied to a system, the probability of finding the system in any f^{th} state at time t is maximum when $E_f = E_i$, where E_i is the energy of the initial state of the system. Deduce Fermi golden rule from this expression.

c) Describe the benefits of using Density matrix for ensembles. Construct a density matrix for a pure spin 1/2 system and a mixed spin system. Build a density matrix for a composite system and extract information about one part from a composite system's density matrix.

d) Examine the functioning of the path integral formulation in the context of particles (probability amplitude for a free particle) and fields (probability amplitude for a free field), elucidate its transformation as Euler Lagrangian equation in classical limits. Explore the connection between the introduction of a source term in the Lagrangian of a free field and the emergence of a propagator.

3 Quantum Theory Part II: Interview Questions

a) Explain the LSZ reduction formula. What assumptions were made? What are the implications of the LSZ reduction formula?

b) What are the Feynman rules for the n-point function for a theory if the interaction terms are $\mathcal{L}_{\text{int}}$? Draw the Feynman diagrams that contribute to the n-point function. Write down the analytic expressions associated with one or two of these diagrams. [1]

c) Explain how to compute a Heisenberg picture n-point function using the interaction picture, Wick's theorem, and Feynman propagators. How is this procedure related to Feynman diagrams?

d) Answer one of the following questions related to regularization or renormalization (of your choice):

[1] Dan will choose $\mathcal{L}_{\text{int}}$, which n-point function you will compute, the order of perturbation theory, and which diagram(s) you will write analytic expressions for so be sure you understand the process.

i) Explain the Casimir effect and sketch how to compute the Casimir force.

ii) Explain the renormalization of the delta prime potential in non-relativistic quantum mechanics.

iii) What is the Källén-Lehmann spectral representation and why is it important? Where does it come from? How is it related to renormalization?

4 Expectations and Suggestions

- The interview will consist of two questions from this list together with follow-up questions. You will receive one question from Bindiya's part of the course and one question from Dan's part of the course.
- Each question will be chosen from this list using a random number generator.
- You will receive your question(s) by email at the beginning of your 20-minute preparation time. You are encouraged to write notes during your preparation time.
- The interview will last approximately 30 minutes, including feedback to you.
- Please be prepared to share equations (using the blackboard or another method).
- It may be extremely helpful to practice answering the interview questions with your classmates. It may only be very helpful. Either way it is encouraged.
- If you understand the concepts, can apply your knowledge, and communicate your understanding, you will pass the interview.
- Feel free to email Bindiya or Dan if you have any additional questions while reviewing.
- These questions may be slightly revised. The final version will be posted by 28 September 2023.