

University of Minnesota
School of Physics and Astronomy

2025 Fall Physics 8011
Quantum Field Theory I
Assignment Solution

Lecture Instructor: Professor Zhen Liu

Zong-En Chen
chen9613@umn.edu

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HW2 Due to October 7 11:59 PM

Question 1

Problem 5.1

Work out the LSZ reduction formula for the complex scalar field that was introduced in problem 3.5. Note that we must specify the type (*a* or *b*) of each incoming and outgoing particle.

Answer

Question 2

Problem 6.1

- (a) Find an explicit formula for $\mathcal{D}q$ in eq. (6.9). Your formula should be of the form $\mathcal{D}q = C \prod_{j=1}^N dq_j$, where C is a constant that you should compute.
- (b) For the case of a free particle, $V(Q) = 0$, evaluate the path integral of eq. (7.9) explicitly. Hint: integrate over q_1 , then q_2 , etc, and look for a pattern. Express your final answer in terms of q', t', q'', t'' and m . Restore \hbar by dimensional analysis.
- (c) Compute the $\langle q'', t'' | q', t' \rangle = \langle q'' | e^{-iH(t''-t')} | q' \rangle$ by inserting a complete set of momentum eigenstates, and performing the integral over the momentum. Compare your result in part (b).

Answer

Question 3

Problem 7.3

- (a) Use the Heisenberg equations of motion, $\dot{A} = i[H, A]$, to find explicit expressions for \dot{Q} and \dot{P} . Solve these to get the Heisenberg-picture operators $Q(t)$ and $P(t)$ in terms of the Schrödinger-picture operators Q and P .
- (b) Write the Schrödinger-picture operators Q and P in terms of the creation and annihilation operators a and a^\dagger , where $H = \hbar\omega(a^\dagger a + \frac{1}{2})$. Then, using your result from part (a), write the Heisenberg-picture operator $Q(t)$ and $P(t)$ in terms of a and a^\dagger .
- (c) Using your result from part (b), and $a|0\rangle = \langle 0|a^\dagger = 0$, verify eqs. (7.16) and (7.17).

Answer

Question 4

Problem 7.4

Consider a harmonic oscillator in its ground state at $t = -\infty$. It is then subjected to an external force $f(t)$. Compute the probability $|\langle 0|0 \rangle_f|^2$ that the oscillator is still in its ground state at $t = +\infty$. Write your answer as a manifestly real expression, and in terms of the Fourier transform $\tilde{f}(E) = \int_{-\infty}^{+\infty} e^{iEt} f(t)$. Your answer should not involve any other unevaluated integrals.

Answer