Arnold Sommerfeld Center   Ludwig–Maximilians–Universität München

Prof. Dr. Viatcheslav Mukhanov   Winter term 2022/2023

Exercises on Quantum Mechanics II (TM2)
Problem set 1, discussed October 24 – October 28, 2022

Problem 1

(i) What is the functional derivative of the following functionals:

$$A[q] = \int (q^2 + q)\, dt \qquad \text{and} \qquad B[q] = \cos[q(4)] \tag{1}$$

with respect to $q(t_1)$?

(ii) Calculate the second functional derivative, defined by

$$\frac{\delta^2 S}{\delta q(t_1)\delta q(t_2)} = \frac{\delta}{\delta q(t_2)}\left(\frac{\delta S}{\delta q(t_1)}\right), \tag{2}$$

for a particle in an arbitrary potential, whose action is given by

$$S = \int dt \left(\frac{1}{2}\dot{q}^2 - V(q)\right) \tag{3}$$

Problem 2

Consider a system with a time-independent Hamiltonian.

(i) Write down the equation that determines the time-evolution of a wave function in the position representation $\psi(x,t) = \langle x|\psi(t)\rangle$. Separate it into two, one having the dependence on time, and one known as the *time-independent Schrödinger equation*.

(ii) What is the general solution of the one that involves time-dependence? How does the probability density evolve in time for such a state?

Problem 3

Consider the wavefunction $\psi(x,t) = Ae^{-\alpha x^2}e^{i\omega t}$, for some positve constants α and ω.

(i) Find the value of A by enforcing that the wavefunction is normalized.

(ii) Find $\langle x \rangle$, $\langle x^2 \rangle$, and $\langle (x - \langle x \rangle)^2 \rangle = \langle x^2 \rangle - \langle x \rangle^2$ for this wavefunction.

(iii) Assume that this wavefunction is associated with the position of a particle. What is probability to find this particle in a interval between x and $x + dx$?

Problem 4

Consider a beam of particles of unit mass with energy E that have been sent from $x \to -\infty$ to the the following potential:

$$V(x) = \begin{cases} V_0, & 0 < x < a; \\ 0, & \text{else}. \end{cases} \tag{4}$$

where $V_0 > 0$.

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Daniela Niemeyer

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Table of Contents Exercises On Quantum Optics Problem Set 2 Autumn Eth Z

1. Understanding the eBook Exercises On Quantum Optics Problem Set 2 Autumn Eth Z
   - The Rise of Digital Reading Exercises On Quantum Optics Problem Set 2 Autumn Eth Z
   - Advantages of eBooks Over Traditional Books
2. Identifying Exercises On Quantum Optics Problem Set 2 Autumn Eth Z
   - Exploring Different Genres
   - Considering Fiction vs. Non-Fiction
   - Determining Your Reading Goals
3. Choosing the Right eBook Platform
   - Popular eBook Platforms
   - Features to Look for in an Exercises On Quantum Optics Problem Set 2 Autumn Eth Z
   - User-Friendly Interface
4. Exploring eBook Recommendations from Exercises On Quantum Optics Problem Set 2 Autumn Eth Z
   - Personalized Recommendations
   - Exercises On Quantum Optics Problem Set 2 Autumn Eth Z User Reviews and Ratings
   - Exercises On Quantum Optics Problem Set 2 Autumn Eth Z and Bestseller Lists
5. Accessing Exercises On Quantum Optics Problem Set 2 Autumn Eth Z Free and Paid eBooks

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