BCHM485 Graded HW#1 (20 points) Due date/time: Feb 24, 2025 by 11:59pm

You don't need to show all your calculations – simple answers typed in or written in the allocated spaces will be sufficient, unless you want me to follow your math. In problems 1-3, if your answers contain m, h or $\hbar$ or other constants, keep them as letters, no need to substitute them with their numeric values.

<u>Problem 1.</u> (6 points) Consider a particle of mass m moving along axis x. Which of the functions listed below are eigenfunctions of the kinetic energy operator of the particle? If they are, what at are the corresponding eigenvalues? (here a and b are constants)

(A) $3e^{i7x}$; **(B)** $3e^{iax}+4ie^{-iax}$; **(C)** $\sin(bx)-a\cos(bx)$.

<u>Problem 2</u> (4 points). A quantum mechanical particle of mass m is in a state described by the wave function (not normalized): $\Psi=\left(5e^{ix}-3e^{i2x}+ie^{-i4x}\right)/\sqrt{2L}$. Assume it's a free particle defined in the interval $(-L,L)$ where $L\to\infty$. Using the postulates of QM, answer the following questions:

(**A**) List all values of the linear momentum, p, that can be obtained in a single measurement and their probabilities.

(**B**) Calculate the average value of p that you expect to obtain as a result of a very large number of measurements.

Problem 3 (6 points). A particle in the 1D box ($0 \le x \le a$) is in the state with n=5. Answer the following questions:

(**A**) Write the expression for the wave function describing this particle. Make sure the wave function is normalized and *explicitly* includes the time dependence.

(B) In which points inside the box you are unlikely to find the particle? List their coordinates.

(**C**) What is the probability to find this particle in the interval between $0.3a$ and $0.5a$?

Problem 4 (4 points). As a simplified model of the hydrogen atom, consider an electron in a cube with the size of 1 Å (=10^{-10} m) (approximately the diameter of the lowest orbit in Bohr's model).

(**A**) Calculate the energy difference, ΔE, between the ground state and the first excited state of the electron.

(**B**) Compare your result in A with the average kinetic energy (½ k_BT per degree of freedom) at room temperature (assume 300 K) to answer the question whether classical or quantum mechanics should be used to describe the electron in this model.