I will abide by the Duke Honor Code  

This is a closed book exam, but you are allowed two crib sheets. Only work shown in the blue book will be graded.

TOTAL POINTS: 54 (3 points each problem)

1. Explain why a wave packet moves with the group velocity rather than with the phase velocity.

2. A thin film with an index of refraction \( n = 1.5 \) for light of wavelength 600 nm is inserted in one arm of a Michelson interferometer. If a shift of 12 fringes occurs, what is the thickness of the film?

3. How does the Compton effect differ from the Photoelectric effect?

4. A particle of mass \( m \) is confined in a one-dimensional box of length \( L \) (this is a known, given length). The particle does not experience any forces in the box, but the potential energy goes to \( \infty \) at the boundaries of the box. Estimate the lowest energy of the particle according to quantum theory using the Heisenberg uncertainty principle (just give me an algebraic expression). In what limit does your answer agree with the predictions of classical mechanics?

5. What is the typical wavelength of green light?

6. What is the typical size of an atom?

7. What is the typical size of an atomic nucleus?

8. Explain, using Bohr’s model of the atom, why some spectral lines are observed in emission but not in absorption.

9. How can a scanning tunneling microscope have the resolution to image individual atoms?

10. What is the physical reality of Schrödinger’s wavefunction?

11. Explain briefly how an undulator (or wiggler) works.

12. An electromagnetic wave is specified (in SI units) by the following expression

\[
\vec{E} = \vec{E}_o \exp \left[ \frac{\pi \times 10^7}{3} (\sqrt{5x + 2y}) - (9.42 \times 10^{15})t \right].
\]

Is it possible to determine the direction of propagation just by knowing the value of \( \vec{E}_o \) and the fact that the field must be transverse? Explain.

13. For the field given in Problem 12, find the propagation vector \( \vec{k} \).
14. Sketch the probability density for finding a particle in a box for a few of the lowest quantum numbers characterizing the particle. Explain how the wave nature of quantum mechanics is manifest in your sketches.

15. Consider the function

\[ \psi(x,t) = A \sin \left[ \pi \left( \frac{x}{a} + \frac{t}{b} \right) \right], \]

where \( A, a, \) and \( b \) are constants. Does this function represent a traveling wave? Explain.

16. Make a sketch of the function given in Problem 15 for \( t = b \). Make sure to label your axes and give the locations and values of minima, maxima, and zeros of the function.

17. Why did the success of the kinetic theory of gas law help convince people that matter is composed of atoms?

18. What experimental observation concerning blackbody radiation forced Planck to propose a model where the walls of the radiator consists of oscillators that can only absorb or emit quantized units of energy? Explain.