Physics 143 - First Quiz
October 2, 2000

I will abide by the Duke Honor Code

This is a closed book exam, with calculators and one crib sheet allowed. Only work shown in the blue book will be graded. However, please hand in these sheets with the blue book. TOTAL POINTS: 45.

1. (6 points) A xenon arc lamp is covered with an interference filter that only transmits light of 400 nm wavelength. When the transmitted light strikes a metal surface, a stream of electrons emerges from the metal. If the intensity of the light striking the surface doubles,

(a) are more electrons emitted in a given time interval? Explain.
(b) are the emitted electrons more energetic? Explain.

2. (3 points) In High Energy Particle Physics experiments, researchers can measure distances over which a particle travels as small as 1 μm using clever experimental techniques. Suppose that they have just discovered a new exotic particle that travels 1 μm before it decays when the particle travels at a speed of 0.99c, where c is the speed of light. Estimate the proper lifetime of the exotic particle.

3. (6 points) Plot the energy of a particle of mass m as a function of its speed. Make sure to label your axes, indicating important scales. Use your plot to discuss why a particle of mass m cannot travel at the speed of light. What impact does your answer have on our ability to travel faster than the speed of light?

4. (3 points) In a Modern Physics Lab, you are asked to determine the pressure P exerted on a surface of area A by a force F. You assign errors of ΔA and ΔF to your measurements of the area and force, respectively. What error should you assign to your measurement of P?

5. (3 points) What historic experiment illustrated that photons posses momentum \( p = \frac{h}{\lambda} \), where \( h \) is Planck's constant and \( \lambda \) is the wavelength of the light? Who predicted this property of light?

6. (6 points) Dan is driving down the highway in his car.

(a) Estimate the size of the de Broglie wavelength characterizing Dan and the car. (Hint: You have to make some estimates in this problem - I am just looking for order-of-magnitude estimates! Justify your assumptions!).

(b) How slow would Dan and the car have to travel before the quantum fuzziness of the system starts to become apparent?

7. (3 points) How many photons per second are emitted by a helium-neon laser (the one that you see in a supermarket checkout line) that emits a beam of power 1 mW? (Hint: You have to make some estimates in this problem!).
8. (3 points) Two spaceships A and B are moving in opposite directions. An observer on Earth measures the speed of A to be 0.9c and the speed of B to be 0.9c. What is the speed of spaceship B as viewed by an observer who is on spaceship A?

9. (6 points) An atom initially in a state of energy $E_m$ makes a transition to a state of lower energy $E_n$ and emits a photon. In the Bohr model discussed in class, the energy of the photon is equal to $E_{\text{Bohr}} = E_m - E_n$. In reality, the energy of the photon is slightly different than this value because the atom recoils when it emits the photon. Denote this energy by $E_{\text{actual}}$. (Hint: I don’t want any derivations in this problem - just give my a physical justification for your answer).

(a) Is $E_{\text{actual}}$ larger than or smaller than $E_{\text{Bohr}}$? Explain.
(b) Does $|E_{\text{actual}} - E_{\text{Bohr}}|$ depend on the mass of the atom? If so, how? Explain.

10. (6 points) You are told that the wavefunction for a new ‘particle’ existing only along the $x$–axis is given by

$$\psi(x,t) = \begin{cases} 
0 & x < L/2 \\
1/\sqrt{T} & -L/2 \leq x \leq L/2 \\
0 & x > L/2 
\end{cases}$$

(a) Make a sketch of the probability distribution function corresponding to this wavefunction. Make sure you label your axes with important scales indicated.

(b) Determine the standard deviation $\sigma_x$ for this probability distribution.