THE UNIVERSITY OF BRITISH COLUMBIA

Science 1 Physics Assignment # 3:

QUANTUM MECHANICS

19 Jan. 2000 — finish by 26 Jan. 2000

1. Photon Drive: A laser generates 1 kW of power continuously in a beam of light of wavelength $\lambda = 600$ nm. The beam uniformly illuminates a circular spot 1 cm in radius.

(a) How many photons does the beam contain *per unit volume*?

(b) What is the *momentum* of a *single photon* in the beam?

(c) If the beam is completely absorbed by a blackbody, what *thrust* (force) does it exert on the blackbody?

plus Tipler Ch. 25, problems **26, 35, 38** & **51**;

...*and* Tipler Ch. 26, problems **8, 10, 12** & **13**.

JUST FOR FUN: **Guns** *vs.* **Lasers** — Somewhere in deep space a battle is being fought between two adversaries 1,000 km apart. One side has an ultraviolet laser cannon that "shoots" a beam of 10.204 eV photons through a circular aperture of diameter a = 2 mm. The other side is using an "ideal rifle" in which *individual lead atoms* are used as "bullets." These atoms are prepared in a plane wave state where their positions are completely uncertain but their velocity (v = 5000 m/s) and direction are precisely determined; these bullets are then "collimated" through a 2 mm diameter hole in a steel plate. [Treat the bullets as ideal point particles.] Each weapon has just enough beam power to burn a 10 *cm* hole in the adversary's hull in 1 s at close range.

1. Using the Rayleigh formula

$$\sin\theta_1 \;=\; 1.22\,\frac{\lambda}{a}$$

for the angle θ_1 of the first minimum of the diffraction pattern from light of wavelength λ passing through a circular aperture of diameter a, calculate the diameter of the laser beam at its "target" (twice the distance from the central maximum to the first minimum).

2. Convert Rayleigh's criterion into an *uncertainty relation* between the uncertainty Δp_y in the transverse momentum of the photons and the uncertainty Δy in their transverse position at the "muzzle" of the cannon. Compare the result with the standard form $\Delta y\ \Delta p_y\ \ge\ \hbar/2$ and briefly discuss any differences.

3. How good a marksman can one be with the "ideal rifle?" *I.e.*, what will the "pattern" of holes in the target look like? Sketch of the distribution of "hit" positions, *including scale*.

4. If you were unfortunate enough to be caught in such a battle, which weapon would you choose? Explain your reasoning.