PHY-851 QUANTUM MECHANICS I

Homework 1, 25 points

September 5 - 12, 2001

Introduction. Reading: *Merzbacher*, Chapters 1,2.

1. /4/ A photon with the wave length 0.02 nm underwent Compton scattering by an angle of 120° off an electron at rest. The scattered photon knocked out the deepest bound electron from a molibdenum atom. Evaluate the value of kinetic energy of the emitted photoelectron.

2. /3/ *Merzbacher*, Problem 1, p. 11.

3. /4/ *Merzbacher*, Problem 2, p. 11.

4. /8/ In systems with free moving charge carriers (metals, plasmas), electric charge Ze of a nucleus or an impurity is *screened* by a cloud of free charges of the opposite sign. The size of the cloud, called the *Debye radius* r_D, becomes smaller as the density of free carriers increases. The resulting electrostatic potential (*Yukawa potential*),

$$\phi(r) = \frac{Ze}{r} e^{-\kappa r}, \quad \kappa = \frac{1}{r_D}, \tag{1}$$

   in contrast to the pure Coulomb potential ($\kappa \to 0$, $r_D \to \infty$), exponentially falls off at distances greater than r_D where the system "center + cloud" looks neutral. It is observed that in hot hydrogen plasmas spectral lines gradually disappear with the increasing electron density. Explain this phenomenon by showing (with the aid of the Bohr-Sommerfeld quantization rule) that there is only a *finite* number of quantum bound states supported by the screened potential (1).

5. /6/ Consider a head-on collision of the excited positively charged He^+ ion with the hydrogen atom in its ground state. What should be the minimum relative velocity of their approach in order to make possible the following process: the He^+ ion emits a photon, corresponding to the longest wave length of the Balmer series, and this photon subsequently excites the hydrogen atom?