Physics 3143 — Homework # 1

§ 1. Show that the Planck radiation law and the Raleigh-Jeans law become identical if the size of the quantum $\epsilon = h\nu$ is allowed to vanish or if the temperature becomes very high.

§ 2. Prove that Wien's displacement law for λ_{max} requires that $\epsilon = h\nu$ in the Planck radiation law. Derive Wien's law from Planck's relation.

7 3. Show that the angular momentum has the same dimensions as Planck's constant, i.e. energy · time.

7 4. What is the maximum wavelength seen in each of the Lyman, Balmer, Paschen, Brackett, and even Pfund series for hydrogen?
(ans. 122, 656, 1880, 4050, 7460 nm)

7 5. In 1932, Harold Urey discovered deuterium (the heavy isotope of hydrogen with a nucleus containing one proton and one neutron) by observing that the $n=4 \rightarrow n=2$ (Balmer series) line in a hydrogen spectrum had a nearby weak neighboring line. What is the separation in wavelength of these lines? (use $m_D = 3.344 \times 10^{-27}$ kg)
(ans. 0.132 nm).

7 6. Positronium is a hydrogen atom with the proton replaced by a positron (a positron is identical to an electron in nearly every respect, except that its electric charge is positive). Calculate E_1 for positronium. (ans. −6.80 eV.)

7. A muonic atom is an atom containing a muon (a muon is identical to an electron in nearly every respect except that its mass is 206.768262(30) times the electron mass). Calculate the energy of an $n=2$ to $n=1$ transition in a lead ($Z=82$) muonic atom. (ans. 14.2 MeV.). Calculate the radius of the $n=1$ orbit for the muon in a lead muonic atom. (Compare with the nuclear radius of lead which is $\sim 7\times10^{-15}$ m (use $m_{Pb} = 3.454 \times 10^{-25}$ kg) (ans. 3.1×10^{-15} m).

8. What is the speed of an electron in the $n=1$ orbit of:
   (a) a hydrogen atom? (ans. 2.19×10^{6} m/s)
   (b) a uranium ($Z=92$) atom? (ans. 2.01×10^{8} m/s)

9. Using $m = m_0 / (1 - v^2/c^2)^{1/2}$ to describe the (special) relativistic effects on an electron orbiting with a speed v in an atom, estimate the percentage correction to the $n=1$ energy in:
   (a) a hydrogen atom. (ans. 0.0024%)
   (b) a uranium atom. (ans. 35%)

10. The work function of zinc is 3.6 eV. What is the maximum energy of the photoelectrons ejected by ultraviolet light of wavelength 3000 Å?

7 11. In an experiment on the photoelectric effect, a cesium plate is illuminated with ultraviolet light of wavelength 2000 Å. The stopping potential is found to be 4.21 volts. What is the work function of the cesium surface?

7 12. Derive $E\,(\text{eV.}) = 1240/\lambda\,(\text{nm})$ for photons.

7 13. In addition to the line $\lambda = 2537$ Å, the mercury spectrum has a strong line at $\lambda = 1849$ Å. In a Franck-Hertz experiment, at what voltage would one expect a current drop associated with the second line?

7 14. Find the energy of the $n = 1$ state (the ground state) in the hydrogen atom to the highest precision permitted by the fundamental constants. Use 1 eV. $= 1.602\,177\,33\,(49) \times 10^{-19}$ Joules. (ans. $-13.605\,698\,1\,(40)$ eV.).