Physics 322 Problem Set #5
(Waves of Matter Part Duex: Bohr Atoms and Bound States)

Due Friday, February 20 at 4:00 pm

ASSUMED READING: Before starting this homework, you should read Chapter 4.5 through 4.6 and 5.1 through 5.3 of Harris' *Modern Physics*. You should also read section 4.7 of Harris, but that will not be required for this homework.

SCORING: There are 60 points possible on this Problem Set (not including extra credit). Scoring per problem is indicated.

1. **[Harris 4.10] (5 Extra Credit Points)** Starting with the assumption that a general wave function may be treated as an algebraic sum of sinusoidal functions of various wave numbers, explain concisely why there is an uncertainty principle. **HINT:** You will need to read section 4.7 and understand it to answer this one well.

2. **[Harris 4.48] (10 points)** The ρ_0 is a subatomic particle of fleeting existence. Data tables don't usually quote its lifetime. Rather, they quote a "width," meaning energy uncertainty, of about 150 MeV. Roughly what is its lifetime?

3. **[Harris 4.53 modified] (10 points)** The energy of a particle of mass m bound by an unusual spring is $p^2/2m + bx^4$.
   - **a.** Classically, it can have zero energy. Quantum mechanically, however, though both x and p are "on average" zero, its energy can not be zero. Why?
   - **b.** Roughly speaking, Δx is a typical value of the particle's position. Explain why this is the case.
   - **c.** Making a reasonable assumption about a typical value for its momentum, find the particle's minimum possible energy. **HINT:** How do you find the minimum of any function?

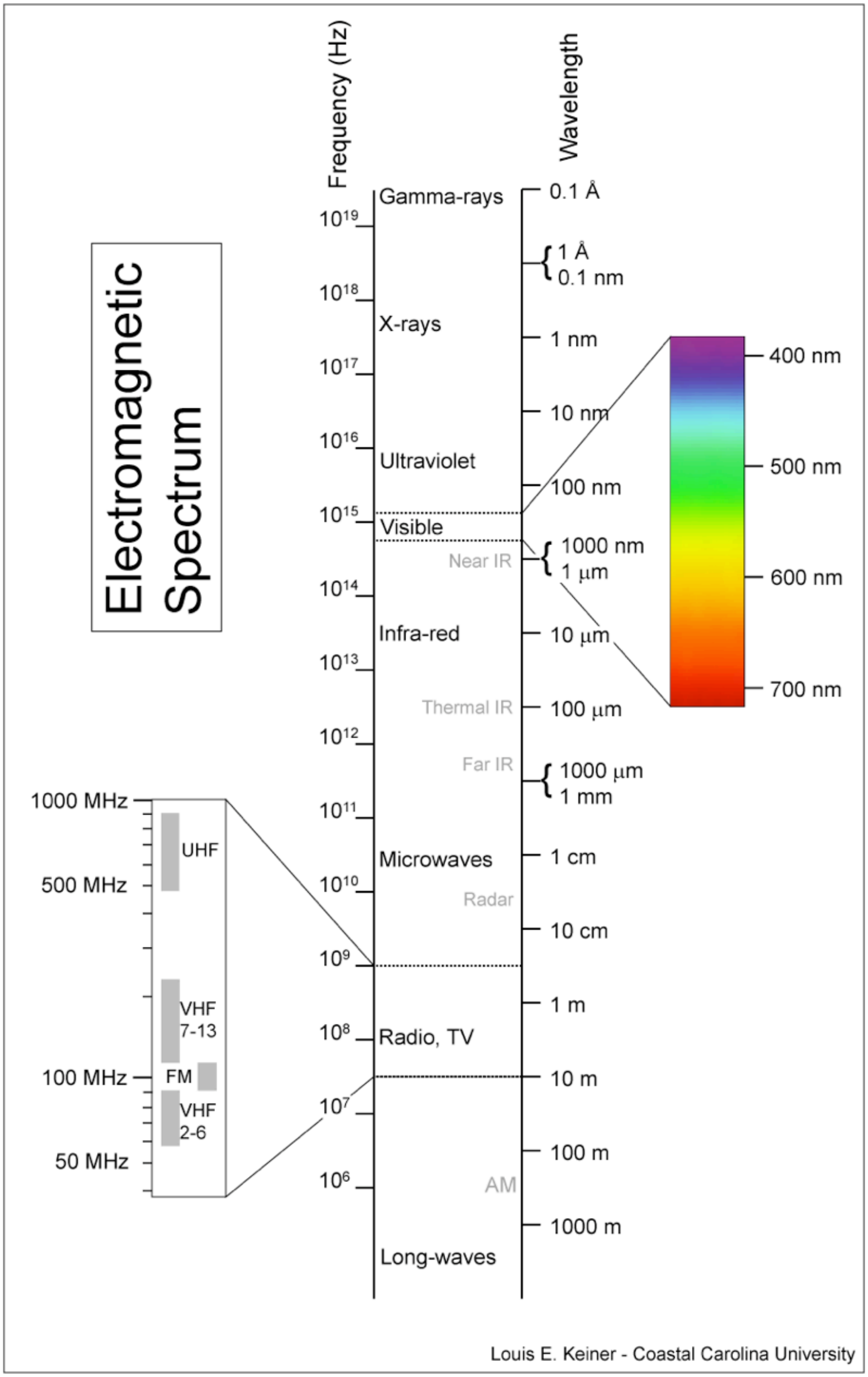
4. **[Harris 4.54 modified] (10 points)** The allowed electron energies predicted by the Bohr model of the hydrogen atom are correct.
   a. Determine the five lowest allowed electron energies.
   b. The electron can "jump" from a higher to a lower energy with a photon carrying away the energy difference. Determine the wavelengths emitted by electrons jumping into the "ground state" (the lowest energy state, $n=1$) of the hydrogen atom from the first, second, and third excited states ($n=2,3,$ and 4 respectively). What kind of light are photons with these wavelengths typically considered to be? **HINT:** As an aid, a diagram of the electromagnetic spectrum is attached to this homework. Be careful, its wavelength axis is logarithmic.
   c. Determine wavelengths emitted by electrons jumping into the "first excited state" (the lowest energy state above the ground state) of the hydrogen atom from the three energy states immediately above that in energy. What kind of light are photons with these wavelengths typically considered to be?

5. **(10 points)** The Bohr model of the hydrogen atom could be extended to other atoms but for the problem of multiple electrons, such that we would have to deal with the electrostatic forces between the electrons affecting their energies. So why don't we consider a $Z\text{-}1$ times ionized atom with an atomic number of Z. In other words, atoms with Z protons, some number of neutrons, and a single electron.
   a. What changes would you need to make the Bohr model of the atom to take into account the Z protons in the nucleus? In essence, what would change in the Bohr model if you had to deal with Z protons in the nucleus instead of just one?
   b. Write an expression for the allowed energies of the single electron in a $Z\text{-}1$ times ionized atom of atomic number Z.

6. **[Harris 5.3] (5 points)** The term *interaction* is sometimes used interchangeably with *force*, and other times interchangeably with *potential energy*. Although force and potential energy certainly are not the same thing, what justification is there for using the same term to cover both?

7. **[Harris 5.5] (5 points)** Just what is stationary in a stationary state? The particle? Something else?

8. **[Harris 5.6] (5 points)** When is the temporal part of the wave equation zero? What is this important?



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