

1. (3 pts) (a) Explain the difference between classical and quantum uncertainty. (b) Can an electron exhibit both classical and quantum uncertainty at the same time?
2. (6 pts) (a) Using the Bohr model, find the wavelength of the emitted photon when a hydrogen atom makes a transition from the $n = 5$ to $n = 3$ energy level. (b) What series is this photon part of (Balmer, Lyman, Paschen, etc.)? (c) What is the longest wavelength that a hydrogen atom can emit? (d) What is the shortest wavelength that a hydrogen atom can emit. (e) What is the maximum radius that the electron's orbit can have? (f) What is the minimum radius?
3. (6 pts) Wein's law tells us that an object at room temperature (300 K) emits the most blackbody radiation near a wavelength of 9.66 microns. (a) Find the highest quantum number n which an electron in a hydrogen atom can have and *not* be ionized by a photon at this wavelength. If you do experiments with atoms excited up to these high levels, you have to worry about the blackbody radiation given off by your apparatus. (b) According to the Bohr model, what is the radius of the electron's orbit when it is in this state? (c) If the atom is between two metal plates, spaced 1 cm apart, how much voltage would I have to put across the plates in order to field ionize a hydrogen atom in this state?
4. (6 pts) Lets take a look at the correspondence principle. Classically, an electron orbiting a proton should emit light at the orbital frequency and harmonics of the orbital frequency. (a) According to the Bohr model, what is the radius of an electron in the $n = 1000$ level of a hydrogen atom? (b) What velocity does the Bohr model predict for an electron in this state. (c) According to the Bohr model, what is the frequency at which the electron orbits the nucleus. (d) What are the frequencies of the photons which a hydrogen atoms emits when going from $n = 1000$ to $n = 999$, $n = 1000$ to $n = 998$, and $n = 1000$ to $n = 997$?
5. (3 pts) Calculate the ground state energy of positronium. Positronium is a hydrogen-like "atom," but consisting of an electron and a positron rather than an electron and a proton. A positron has the same charge as a proton but the same mass as an electron (it is the anti-matter equivalent of an electron).
6. (6 pts) Consider an electron confined to move in 1 dimension. (a) If I measure the position of an electron to within 1 micrometer, what is the minimum possible uncertainty in its velocity after I make the measurement? (b) After I make the measurement, the electron is left to travel freely in one dimension. One second after I make the measurement, what is the minimum possible uncertainty in the electrons position? (c) What is the minimum possible uncertainty in the electrons velocity one second after I make the measurement in (a)? (d) Show that your answers to (b) and (c) satisfy the uncertainty relationship.

Extra problems I recommend you work (not to be turned in)

- Electrons are shot, one at a time, through a pair of slits and detected on a screen behind the slits. Briefly describe how and when an electron behaves as a particle and how and when it behaves as a wave.
- Explain the correspondence principle in your own words.
- Read section 4.8, and then calculate the accelerating potential V at which you would expect the first current dip to occur at if the electrons were going through hydrogen gas.