UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

PH 102 / LeClair Summer II 2009

Problem Set 9: Quantum & Atomic Physics

Instructions:

1. Answer all questions below. Show your work for full credit.
2. Due at the beginning of the final exam
3. You may collaborate, but everyone must turn in their own work

1. The light emitted by an ordinary light bulb consists of photons, each of which has an energy given by $E = f$. Consider a 60 W bulb, and for simplicity assume that it emits only green light with $\lambda = 530\,\text{nm}$. How many photons does the bulb emit in 1.0 s?

2. A molecule is known to exist in an unstable higher energy configuration for $\Delta t = 10\,\text{nsec}$, after which it relaxes to its lower energy stable state by emitting a photon. **(a)** What uncertainty in the frequency Δf of the emitted photon is implied? **(b)** If this state is being probed with Nuclear Magnetic Resonance (NMR) at a frequency of $f \approx 500\,\text{MHz}$, what is the relative uncertainty in the measurement, $\Delta f / f$?

3. In a coordination compound, the so-called "crystal field" gives rise to a difference in energy levels for some of the electrons in a transition metal ion. That is, electrons can occupy one of two states, separated by the crystal field splitting energy Δ.

The octahedral complex $[Cr(NH_3)_6]^{3+}$ has a crystal field splitting of $\Delta_o \sim 2.16\,\text{eV}$, while $[Co(NH_3)_6]^{3+}$ has $\Delta_o \sim 2.84\,\text{eV}$. What color are these compounds? Make use of the table below. If a compound absorbs a certain color of light, it exhibits the color *complementary* to the color of absorbed light.

Table 1: *Absorbed wavelength λ and observed color*

λ (nm)	absorbed color	observed color
400	violet	greenish-yellow
450	blue	yellow
490	blue-green	red
570	yellow-green	violet
580	yellow	dark blue
600	orange	blue
650	red	green

4. The energy required to break one O=O bond in ozone (O_3, O=O=O) is about 500 kJ/mol. What is the maximum wavelength of the photon that has enough energy to photodissociate ozone by breaking one of the O=O bonds?