Physics 25 Problem Set 9

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due Monday, June 5

Please make your work neat, clear, and easy to follow. It is hard to grade sloppy work accurately. Generally, make a clear diagram, and label quantities. Derive symbolic answers, and then plug in numbers after a symbolic answer is available.

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1. Find the total number of photons per second that come out of:

   (a) The KTMS transmission towers just east of Goleta Beach, which radiate a total power of 2.5 kW at a frequency of 1250 KHz.

   (b) A lightbulb that emits 100 W at a wavelength of 560 nm.

2. An electron in a hydrogen atom decays from the $n = 2$ level to the $n = 1$ level, and emits a photon. The hydrogen atom is in a distant galaxy, which is moving away from us with a speed v, which relative to the speed of light is $v/c = \beta = 0.8$.

   (a) What is the wavelength of the photon λ_0 observed by an observer at rest with respect to the atom?

   (b) What is the wavelength of the photon λ that is observed on earth? Be careful to think through whether the photon's wavelength is shorter or longer.

   (c) In astrophysics, the quantity z is defined as the ratio λ/λ_0; derive an expression for z as a function of β.

3. Imagine a particle of mass m moving in one dimension in a potential $V(x) = (1/2)kx^2$. Make the assumptions detailed starting on page 100 of the notes, or page 230 of the text, that $\sqrt{\overline{p_x^2}} \approx \hbar/\sqrt{\overline{x^2}}$ to estimate the spatial size of the ground state, by minimizing the total energy. How much smaller does the ground state get if the 'spring constant' k is increased by a factor of 16?

4. An electron moves in one dimension, and it starts of at $x = -\infty$ and moves to the right; the electron's initial kinetic energy is 25 eV. The electron feels no potential energy as long as $x < 0$, but the potential energy goes through an abrupt step at $x = 0$, and rises to a level of $V_0 = 9\,\text{eV}$ for $x > 0$.

   (a) Find the probability that the electron reflects back off the step in potential energy.

   (b) Find the probability that the electron goes forward and is transmitted into the $x > 0$ region.

   (c) Imagine now that the initial kinetic energy of the electron is only 5 eV, and that the potential energy returns to zero at $x = 1\,\text{nm}$, forming a potential 'wall' that is 9 eV tall and 1 nm thick. What is the approximate probability that the electron tunnels through the wall?
