PHY293 Problem Set #1

September 14, 2010
Due: September 20, 2010 at 5:00pm

1) H-atom: When the electron in a hydrogen atom bound to the nucleus moves a small distance from its equilibrium position, a restoring force at a given radius is given by:

$$k = e^2/4\pi\epsilon_0 r^2$$

where $r = 0.05$ nm may be taken as the radius of the atom (the equilibrium radius of the electron relative to the proton). Show that the electron can oscillate about this radius, executing simple harmonic motion and find the natural frequency ω_0.

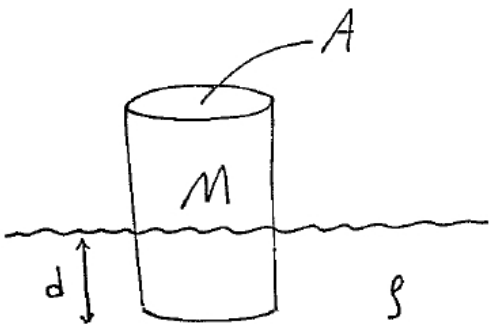
The continual acceleration and deceleration of the electron causes it to emit electromagnetic radiation. What is the typical wavelength of this radiation (hint – revised ... $\lambda = c/\omega$). Where does this wavelength lie in the electromagnetic spectrum? Are they X-rays, infra-red irradiation, etc?

You may find it useful to know: $e = 1.6 \times 10^{-19}$C; $m_e = 9.1 \times 10^{-31}$ kg; $\epsilon_0 = 8.85 \times 10^{-12}$ N^{-1} m^{-2} C^2 and $c = 3 \times 10^8$ m/s.

2) Bobber: As shown in the figure below, consider a cylinder floating upright in the water. Assume it has a total mass, M and a cross-sectional area A, total height l (not shown on sketch) and that the density of the water is ρ.

(a) Using Archimedes' principle, how far will the cylinder sink (ie. d shown on the sketch)?

(b) What is the frequency of oscillation, for small displacements away from equilibrium? Ignore damping.



3) Massive spring: A mass M is suspended at the end of a spring of length l and spring constant k. If the mass of the spring is m and the velocity of an element dy of its length is proportional to its distance from the fixed end of the spring, show that the kinetic energy of this element is:

$$\frac{1}{2}\left(\frac{m}{l}dy\right)\left(\frac{y}{l}v\right)^2,$$

where v is the velocity of the suspended mass M. Hence, by integrating over the length of the spring, show that its total kinetic energy is $\frac{1}{6}mv^2$ and, from the expression we discussed in class for the total energy of an oscillating system, show that the frequency of oscillation is given by:

$$\omega^2 = \frac{k}{M + m/3}.$$