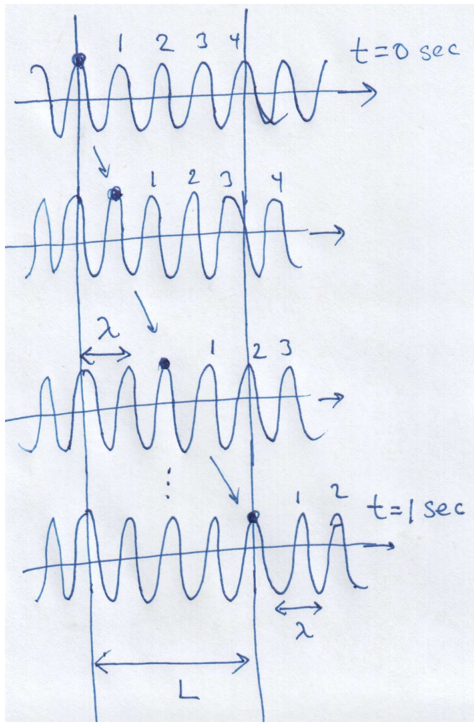
1 Morning class Week 2 Day 4: Waves

1. **Waves**



   (a) The picture shows a wave as it moves along. The top frame is the wave when $t = 0$ sec. t is time. The bottom frame is $t = 1$ sec. The two vertical lines are two fixed points in space. v is the velocity of the wave. λ is the wavelength. ν is the frequency, the number of times the equivalent points in the wave passes by a fixed point in one second. To help visualize the wave's motion, I have placed a filled dot in each frame: the filled dot travels from left to right. Based on the picture express λ in terms of L, see picture.

   (b) Find ν. Hint: it is a whole number.

   (c) Velocity is the distance the wave travels in one second, ie., the distance the filled dot travels in a second. What is v for the wave in question in terms of λ and ν?

   (d) Based on the picture suggest a proportionality relation between v and λ if ν is constant.

   (e) Based on the picture suggest a proportionality relation between v and ν if λ is constant.

   (f) Write an equation relating v to some combination of ν and λ. This equation is true for all waves.

2. **Light**

   (a) State the result you found previously for waves relating v, λ, and ν. If possible state this result without looking the result up.

   (b) For light E=hν, the relation between energy and ν holds for all objects travelling at the speed of light. $h = 6.6 \times 10^{-34}$ J sec, where J stands for Joules, a unit of energy equal to kg·m^2/s^2. The speed of light, $c = 3.0 \times 10^8$ m/s^2. Do some algebra and show $E = hc/\lambda$.

(c) For light, what is the proportionality relation between E and λ?

(d) For light, what is the proportionality relation between E and ν?

(e) The above are expressions for a single photon of light. Write an expression for the energy of n moles of photons.

(f) What is the proportionality relation between E and n?

(g) Red light has a wavelength of around 700 nanometers. In units of Joules, how much energy is there in one mole or red light photons?

(h) The lowest energy ultraviolet light has a wavelength of 350 nanometers. Without using a calculator, how much energy is there in one mole of this lowest energy ultraviolet light?

(i) A Mohammed Ali punch corresponds to 20 kg moving at 50 miles/hour. Recalling that 2 miles/hour is one meter a second, calculate the kinetic energy of an Ali punch in units of kg m^2/s^2. How many Joules is that?

(j) How do the above two answers compare with the energy of a Mohammed Ali punch?

3. **Electrons**

(a) Electrons have mass. So for electrons we have $\mathrm{p} = mv$ and $E_K = \frac{1}{2}mv^2$. The mass of an electron is 8.1 $\times 10^{-31}$ kg. Use algebra to find an expression for E_K in terms of m and p.

(b) Electrons are also waves. They have a wavelength, expressed by the de Broglie formula $\lambda = h/\mathrm{p}$. Use algebra to find an expression for the kinetic energy of a single electron in terms of m, h, and λ

(c) The above are expressions for a single electron. Write an expression for the energy of n moles of electrons in terms of m, h, and λ.

(d) For electrons, what is the proportionality relation between E and λ?

(e) For electrons, what is the proportionality relation between E and v?

(f) For electrons, what is the proportionality relation between E and m, holding v constant?

(g) For electrons, what is the proportionality relation between E and m, holding λ constant?

(h) For electrons, what is the proportionality relation between E and n?

(i) In the hydrogen atom, electrons move at 1/137 the speed of light. What is the kinetic energy of one mole of hydrogen electrons?

(j) How many times bigger in energy is one mole of hydrogen electrons than one punch from Mohammed Ali?

4. **Oxygen atoms:** A mole of oxygen atoms move on the average at 300-400 m/s at STP. How much energy is there in the translational energy of one mole of oxygen atoms at STP?

5. **Review** please everything you have learned doing this problem set. What relations are there between the waves, light, electrons section and the gases section we just completed?