PHYS 234: Recitation 10

(Quiz: Apr 8, 2020)

*Potentially useful constants:* $c = 3 \times 10^{8}$ m/s, $h = 6.6 \times 10^{-34}$ J·s, $m_e = 9.1 \times 10^{-31}$ kg.

1. **Estimation:** If the deBroglie wavelength of an object is smaller than its size, the object is particle-like; otherwise it is wavelike. Estimate the deBroglie wavelength of a baseball when thrown by the pitcher. Report your answer in multiples of the baseball's size. *Clearly state your assumptions and how you came to the numbers you estimate.*

2. **Essay:** Explain how a rainbow forms.

3. The bond energies in DNA are about 300 kJ/mol. Calculate the maximum wavelength, in nanometers, of a photon required to break one bond.

4. At 510 nm, the dark-adapted human eye can detect a 100 ms flash of light with a power as low as $4 \times 10^{-16}$ W.

A. Calculate the number of photons produced by the flash.

B. Given that only about 10% of photons arriving at our eye actually reach the retina, and that these photons are spread over about 350 cells (the so-called "rod" cells), calculate the average number of photons that each rod cell receives. If this number were less than one, it would mean that the rod cells in our eye could actually detect single photons.

5. When a receptor molecule in the human eye absorbs a photon, one of its free electrons enters an excited state. The additional energy of the excited state must equal the energy of the photon, which is a function of its wavelength. Here we will see that electron's energy is set by the size of the receptor molecule. Therefore, the typical size of molecules determined what wavelength of light our eyes evolved to see.

A. As a free electron orbits the molecule, its deBroglie wavelength is on the order of the size of the molecule itself. Assuming a typical molecule size of 1 nm, determine the momentum $p$ of the electron.

B. Calculate the kinetic energy $E = p^2/2m_e$ of the electron.

C. Assuming that the additional energy of the excited state is on the order of the kinetic energy that the electron already has, and that this additional energy must be equal to the energy of the photon, calculate the wavelength of the photon that the molecule absorbs. Is it roughly within the visible spectrum of the human eye?