BMB/Bi/Ch 173 – Winter 2017

Homework Set 1.1 – Assigned 1-10-17, Due 1-17-17 by 10:30am

TA: Wen Zhou (201 Kerckoff, office hour: Fri 1/13 5-6pm, Mon 1/16 by appointment)

1. (25 points) Various Waves/Particles and Applications
In the table below,
I. In the table, place the following types of radiation next to their corresponding wavelength: microwave, x-ray, visible, radio, UV, gamma ray.
II. Using the wavelengths provided, calculate the energy of each type of radiation in joules. Hint: **$E = hc/\lambda$**
III. Fill in the application(s) column with the following (some may be used twice): diagnostic PET scan, heating up food quickly, fluorescent light microscopy, crystallography, communication on walkie talkies.

Wavelength	Radiation	Energy (J)	Application(s)
10 km			
50 cm			
485 nm			
230 nm			
20 nm			
5 pm			
2-4 pm	Electron		
~1 Å	Neutron		Neutron diffraction

IV. Which of the above techniques/applications might be able to break single covalent bonds between carbons during illumination? (C-C bonds have an energy around ~350 kJ/mol) How could this impact an imaging experiment?

2.(28 points) Electron accelerations
I. (6 points) What is the classical energy of an electron that initially travels at 0 m/s and has experienced a uniform 200kV? What is the speed? What is the associated de Broglie wavelength?
II. (10 points) When the speed of particle is traveling close to the speed of light, the classical description of motion isn't accurate anymore. Use the

following relativistic relation, calculate the “actual” relativistic wavelength of electrons that have traveled down a 200kV potential.

$$p^2c^2 = E^2 - m_0^2c^4$$

E | total energy of particle ($E = m_0c^2 + KE$)
KE | kinetic energy of particle
c | speed of light
p | momentum
m_0 | rest mass of an object
h | Planck’s constant = 6.626*10^-34 J*s
λ | wavelength
charge of electron = 1.60*10^19 C
mass of electron = 9.11*10^-31 kg

III. (12 points) The probability of scattering is proportional to the amount of time that the electrons spend in the sample. In other words, the faster the electrons travel, the less frequently they scatter. Therefore, for thicker sample imaging, people have attempted to build high voltage EM to increase the velocity of the electrons. Calculate and compare the velocities of electrons traveling down 200kV and 5MV potentials. Why is it hard to increase the speed of electrons?

3. (27 Points) Lenses and Electron Microscopes

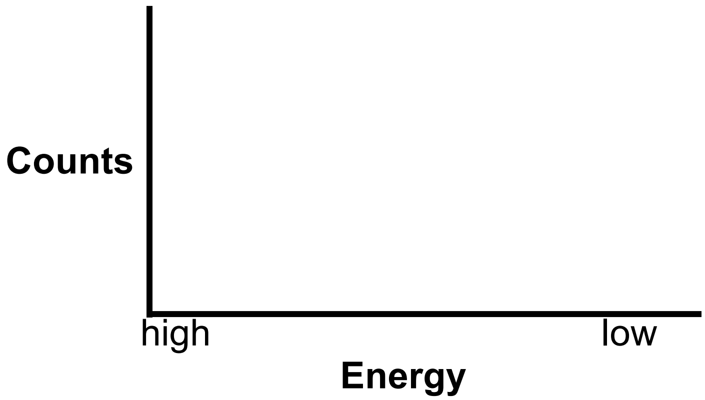
I. (7 points) Explain how optical lenses work using the concept of optical path lengths.

II. (10 points) What are electron lenses made of? How do electron lenses work in terms of magnification? Why do they cause image rotation as well as magnification? Use a diagram.

III. (10 points) Explain briefly the optical path lengths in electron lenses.

4. (20 points) Energy filters and applications

I. (6 points) Draw on the graph the distribution of energies of electrons right before and after passing through the sample. Mark the elastically and inelastically scattered electrons.



II. (7 points) What is the function of an energy filter?

III. (7 points) Electron energy-loss spectroscopy (EELS) is an analytical technique that is based on inelastic scattering of electrons in a thin specimen. How could energy filters be used in EELS? Draw an example energy filter range on the graph above. How can this technique be useful in structural biology studies?