BMB/Bi/Ch 173 – Winter 2018

Homework Set 1.1 – Assigned 1-9-18, due 1-16-18 by 10:30 a.m.

TA: Rachael Kuintzle. Office hours: SFL 229, Friday 1/12 3:30-5pm and Monday 1/15 5:30-7pm.

1. (40 points) Radiation Wavelengths and Applications

When filling out the table below, consider creating an Excel file so you can conveniently drag the equation. Watch your units!

I. In the table, place the following types of radiation next to their corresponding wavelengths: 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, electron microscopy.

Wavelength	Radiation	Energy (J)	Application(s)
10 km			
50 cm			
550 nm			
180 nm			
8 nm			
5 pm			
2-4 pm	Electron	NA	
~1 Å	Neutron	NA	Neutron diffraction

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

2. (60 points) Electron Accelerations

You will need the following constants and equations:

de Broglie equation: $\lambda = h/p$
h | Planck's constant = $6.62607004 \times 10^{-34}$ m^2 kg / s
λ | wavelength
p | momentum
Classical momentum equation: $p = m_0 v$
Kinetic energy: $eV = (m_0 v^2)/2$
v | particle velocity
V | acceleration voltage
m_0 | rest mass of electron = 9.109×10^{-31} kg
e | charge of electron = 1.609×10^{-19} C
c | speed of light = 2.998×10^8 m/s

Relativistic equations

Relativistic momentum: $p_{rel} = \sqrt{eV\left(\frac{eV}{c^2} + 2\,m_0\right)}$
Law of energy conservation: $(m - m_0)\,c^2 = eV$
Relativistic mass: $m = \frac{m_0}{\sqrt{1-\left(\frac{v^2}{c^2}\right)}}$

I. The probability of scattering is roughly 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. Fill out the table below to compare the classical versus relativistic properties of electrons traveling down 300 kV and 5MV potentials. (You may want to create an Excel spreadsheet for this problem as well.)

Potential	Classical velocity (m/s)	Classical wavelength (pm)	Relativistic velocity (m/s)	Relativistic wavelength (pm)	Relativistic mass (kg)
300 kV					
5 MV					

II. As you can see, when the speed of a particle is close to the speed of light, the classical description of motion isn't accurate anymore and it becomes more difficult to increase the speed of electrons. Why does it become difficult?

III. In electron microscopy, electrons only contribute useful information to an image when the electron is elastically scattered by the sample one time. If the upper bound on sample thickness is 500 nm when you accelerate an electron with a 300 kV potential (a sample > 500 nm has a high probability of scattering an electron more than once), what is the upper bound on sample thickness if you use an acceleration potential of 5 MV? Assume that the probability of scattering is exactly proportional to the time each electron spends in the sample.

(FYI: There is such thing as a 5 MeV EM instrument; it is three stories tall and 50x more expensive than a 300 kV microscope.)