Quiz 1 XRD 090403

Ideally for the diffraction experiment we desire monochromatic, collimated, coherent, unpolarized radiation.

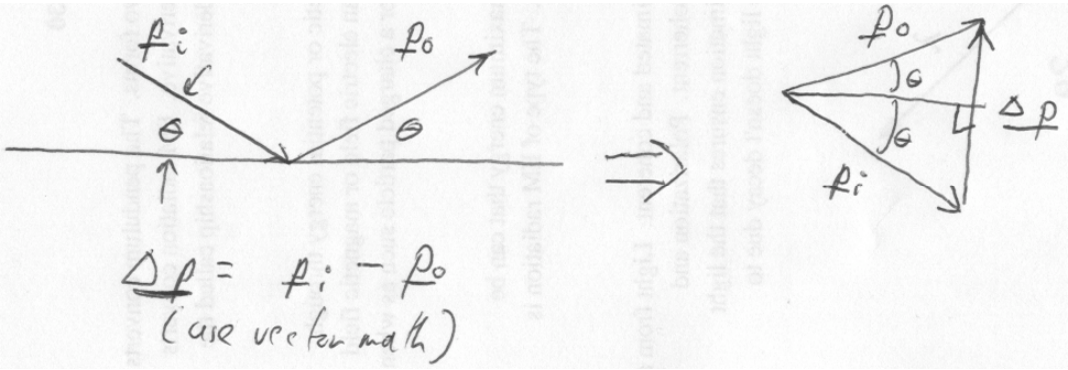
a) Write Bragg's law.

b) Explain why these 4 requirements are needed to use Bragg's law. (For example what would happen if the radiation were polychromatic).

c) Scotch tape when unrolled in a vacuum releases x-rays with a peak energy of 15 keV per photon. What wavelength radiation is produced in Å (x-rays are typically near 1 Å in wavelength). Postulate on what event could give rise to this energy. (Planck's constant is 6.63 x 10^{-34} Js and the speed of light is 3 x 10^{8} m/s and 1 J = 6.24×10^{15} keV) (Canara CG, Escobar JV, Hird JR *Nature* **455** 1089-1092 (2008)).

d) Briefly explain (1 or 2 sentences with any equations you can muster) why a cell phone can not cause cancer.

e) Consider that a photon is a perfectly elastic ball that is incident on a surface as shown below. Calculate the energy change ΔE and the momentum change **Δp** in terms of the wavelength.



ANSWERS: Quiz 1 XRD 090403

a) $d = \frac{\lambda}{2}\frac{1}{\sin\theta}$

b) Bragg's law relates the d-spacing to the wavelength so if more than one wavelength is incident we will smear out the d-spacing determination.
Bragg's law relates 1/d to the sin of half of the diffracted angle relative to the incident beam. If the beam is divergent or convergent the angle will be smeared out and the d-spacing will be in accurate.
Bragg's law relies on interference between waves created at molecular sites. This relies on the incident wave being coherent. We can not get interference effects from incoherent waves.
Polarized light can be used to diffract but it brings up difficulties since the plane of polarization must match the plane of diffraction or no diffraction will be observed. We will discuss this in detail later (no points on this part).

c) For a rule of thumb 10keV electrons are about 1.5 Å wavelength which is close to the type of x-rays that are commonly used from a lab x-ray generator (Cu K-α radiation). Higher energy is related to lower wavelength since $E = hc/\lambda$. Given the values from the question, 15keV x-rays have a wavelength of about 0.83 Å.
The mechanism to generate these x-rays is not known. The paper postulates that the polyacrylic glue becomes positively charged and the polyethylene tape becomes negatively charged so that an arc forms during peeling that leads to electrons being accelerated by a voltage drop of 1,000 kV. The electrons decelerate completely when they hit the positive glue and this change in momentum of a charged particle leads to emission of electro magnetic waves. One problem with this description is that this scenario would lead to significant buildup of heat sufficient to burn the tape.

d) $E = hc/\lambda$ so for wavelengths on the order of meters E is on the order of 1×10^{-6} eV. This is sufficient to move electrons in a metal but cannot ionize DNA, RNA or proteins to cause cancer. There isn't enough energy per photon to ionize molecules and cause cancer.

e) $|\mathbf{p}| = h/\lambda$. The event is elastic so there is no change in energy and the absolute value of momentum is also unchanged. The momentum changes and from the figure the change in momentum is equal to $|\underline{\Delta p}| = \frac{2h}{\lambda}\sin\theta = \frac{h}{d}$