* Attendance, 0-1
* Lab reports, 1-10 pts
* Pre-lecture reading assignments, due on Monday

X-Rays

2D

fluoroscopy – x-ray movies

atom – 1 Angstrom

X-rays have wavelengths smaller than an atom

So X-rays will interact w things that are comparable to wavelength

* Electron-volt, potential is 1 V, particle is 1 electron, then unit of energy
* Quantum of visible light has energy – a few eV
* order of keV – that will be low energy photons
* X-ray is on
* More like particles than waves, so assumptions – don’t diffract, do scatter
* Crook’s tubes – cathode rays
* Fluorescent screen started glowing when Crook’s tube was energized
* Rontgen – X-rays
* Gamma rays
* Both x and gamma rays are the same, only diff is the history of discovery
* (gamma rays from nuclear, radioactive events)
* (x rays come from electric events, electrons)
* lateral cervicacl spine – bone absorb more X-rays
* if detector was film, radiographs – used to record them on film
* expose film with light, areas where light hits it, silver deposits and turns dark
* unexposed places transparent
* radiographs – black, intensity high; white, intensity low
* backwards of the hand, so post-processing
* bones attenuate more than soft tissues, more than air
* how X-rays are propagated and attenuated
* uniform material, shine X-rays through it, all of same energy, then X-rays absorbed exponentially
* T is thickness
* Mu is parameters characteristic for material and energy (linear attenuation coeff)
* [T] = cm, [mu] = 1/cm
* why exponential? Radioactivity decays, cells killed by antiobiotics, etc. – same reason for all
* go down to a small enough space that probability for something happening is low, prob per unit distance is in exponent
* when go to macroscopic, derive this
* denser, more likely to happen
* energy of photon
* what happens when visualize table?
* Nothing
* Or absorption (primary photon disappears)
* Or scatter (deflection event, photon changes direction and usually changes energy)
* Mu – prob per unit length that something happens
* Independent
* So probabilities are additive
* Total attenuation coeff is sum of attenuation coeffs by each mechanism
* … other absorption mechanisms more relevant at higher energies (like photonuclear events, shattering nuclei)
* PE – photoelectric effect
* Quantum event (even though it’s depicted as a wiggly line)
* Each shell has certain binding energy
* K shell most tightly, close to nucleus
* How closely it’s held quantified with binding energy
* Free an electron
* E- complete absorbed, excites inner-shell electron
* Energy of photon > energy of electron binding
* Conversation of momentum, not hard bc photon not much mass, atom heavy
* K shell binding of Ca, let’s say 70 keV X-ray photon, 10 keV, 60 keV photoelectron
* Photoelectron – what does it find? Changes are will excite another atom, collisions w other electrons, e- e- interactions, create more radiation
* Contributes to radiation dose
* Absorbed w/in microns, secondary radiation doesn’t go far
* Einstein explained this with visible light
* Visible light, current flows (but not at red)
* Not a classical phenomenon, must be quantized
* Very quickly with higher atomic numbers, Z^3
* Proportional to density
* Decreases w increasing photon energy E^-3
* Compton scattering
* Free electron
* Photon-electron collision
* Two body collision
* Electron is heavier, so photon will bounce back for most possible energy change, or graze and nothing really happens (no way to conserve momentum and have electron go backwards)
* Energy of scatteed electron is dependent on dose
* “hot” electrons – energetic, will go and ionize other things, 5 eV to ionize an atom
* so 10,000 eV, create several thousand ionization events
* scattered electron takes most of energy, photon keeps most energy
* scattered photon is quite penetrating, but scattering is a bad thing
* contribute dose to personnel
* not a good source of monoenergetic photons, so what we have is already a broad spectrum
* Compton scattering, proportional to electron density
* Electron density and physical density almost proportional
* So often describe x-rays are viewing density
* Decreases slowly with increasing incident photon energy
* Coherent/Rayleigh scattering – x-ray changes direction, but doesn’t lose energy
* Almost diffraction
* Increases with Z^2, not as fast as PE effect
* Never dominant in diagnostic imaging, so prob is low
* As energy increases, wavelength smaller, so less time finding it
* Cortical bone
* Log scale
* PE, Compton scattering decreases
* Total attenuation is up to 60 kEV, dom by PE, then dom by Compton scattering
* Contrast media – iodine
* 30 kEV, binding energy of iodine
* 1/eV until get to binding energy of iodine, then possible for photon to ionize K shell, but becomes MOST likely to do so, do discontinuous rise
* barium (GI tract), iodine – very similar, to a physicist they’re the same
* soft tissues, PE for <20
* coherent scattering never doms
* bone, 60 kEV
* high atomic number materials, pE always
* what photon energy for hand?
* Discriminate soft tissue and bone,, want low energy bc want to use PE
* Tradeoff btw contrast and penetration
* How do we make X-rays?
* Take electrons, accelerate them to high KEs on order of 100,000 eVs and slam into metal target
* Broad spectrum of X-rays
* Brehmsstrahlung – braking (stopping electrons) or characteristic X-rays, ionize inner electrons
* 1% of energy of electron beam is converted to X-rays, very inefficient process
* transmit all energy to photon, unlikely possibility that all energy will be given from e- to photon
* tungsten – retains physical properties, must go to very high temps (metallurgic)
* efficiency of BRehmmstrahlung goes up with AV
* kVp – historic purposes, add a p to kV (kV peak)
* max energy in spectrum
* mA – current in tube
* 200 mA vs 400 mA, spectrum gets twice as bright
* exposure time
* white light, put red filter in front of it, rest of lights absorbed, rest were able to pass
* filter for X-rays, pass through filter and have narrow band x-rays
* what interactions for X-rays? Pretty stupid, previous things were what we found
* want a narrow point source, not a diffuse light
* or else get shadows
* stove consumes a lot of energy

for chest radiography, 140 keV

live dynamic range, bc heart opaque but lungs transparent

almost no magnifications

object in contact with detector

bc focal spot is big, want resolution of 100 um

low contrast, delta mu\*t

scatter is a problem – like a haze of milk

scatter to primary ratio

affects high turnover cells more, so gut, blood cells, skin