SPA 3609 Tutorial 1, Questions with outline answers for formative feedback

1. Calculate the wavelength of the primary gamma ray emitted when a ^{137}Cs nucleus decays.
   a. ^{137}Cs has primary gamma ray energy of 662 keV. Using $E = hc/\lambda$ student should get 1.9 pm.
2. A 1 GeV proton passes through 300 µm of silicon (a typical silicon strip sensor thickness). If 3.6 eV of energy is required to produce one electron-hole pair in the silicon, approximately how many will be produced?
   a. Use the approximation that a MIP (for a 1 GeV proton this is a reasonable approximation) loses 2 MeV $g^{-1}.cm^{-2}$ Looking up the density of silicon (2.33 gcm^{-3}) and transforming, we get ~ 4.6 MeV per centimetre leading to a predicted ionisation loss in the silicon sensor of 140 keV producing ~ 39000 e-h pairs.
3. Using the formula on slide 18 of Lecture 2 and the reference on slide 19, determine the percentage difference between the simple formula approximation for *Critical Energy* and that in the table for the elements C, Ti and W.
   a.

Element	Table (MeV)	Formula (MeV)
C	82	84
Ti	26	26
W	8.0	8.1

4. At approximately what distance in air (at STP) from the source would you be safe from alpha particles emitted by the decay of ^{241}Am (used in some smoke detectors)?

[NOTE gamma rays are also produced by the isotope, so don't take this value as indicative of what you need for radiation protection purposes in practice!]

This is quite a tricky problem, although conceptually straightforward.

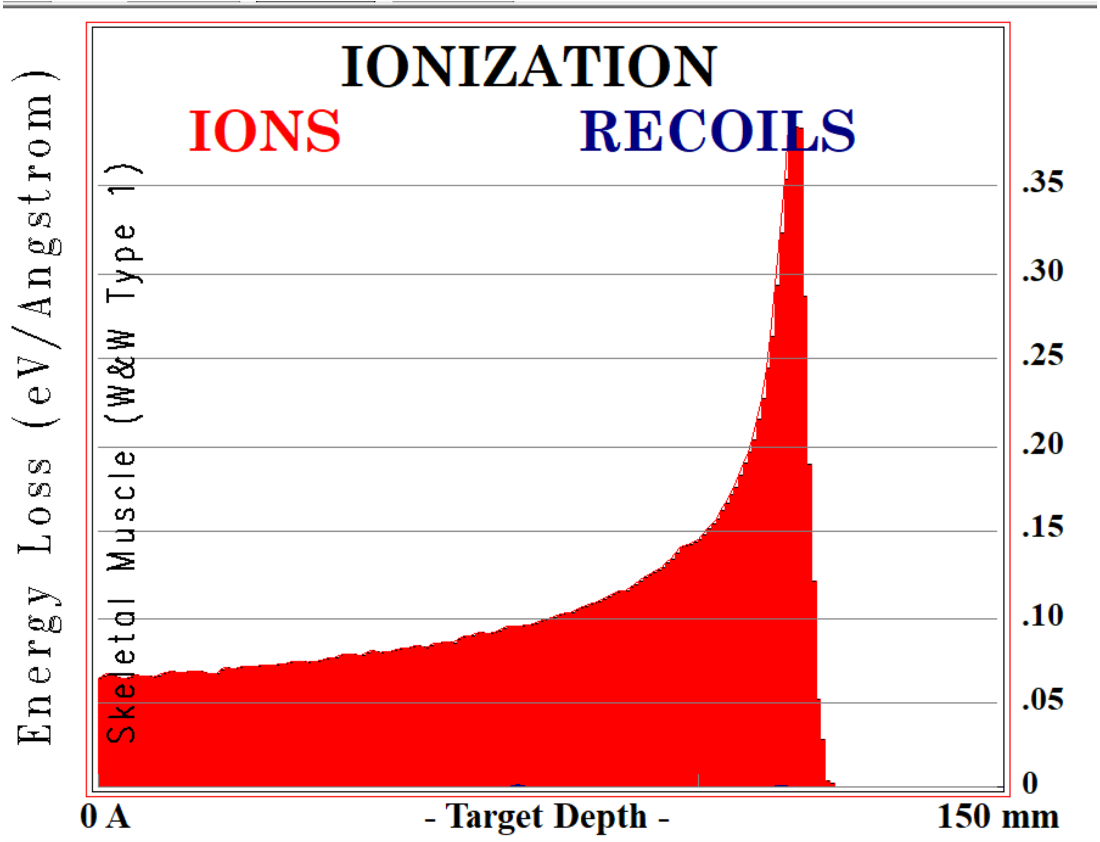
Alpha particle energy is ~ 5.5 MeV. Using the SRIM Monte Carlo and using Nitrogen (gas) with a density of 0.000125 gcm-3 I get the longitudinal range for alpha particles to be 34 mm. Initial energy loss from SRIM is ~ 0.1 eV/nm.

Estimate $\beta\gamma$: $(\gamma - 1) = 5.5\times10^6/3.73\times10^9 = 0.00147$ thus $\beta = 0.054$ (non-relativistic velocity). Approximating using the muon in copper "stopping power" plot (PDG reviews, figure 33.1, also in my lecture notes) expect about 4×80 MeV $g^{-1}cm^2$ Factor of 4 comes from the 2+ charge on the alpha compared to 1+ on the muon. This implies 0.47 MeV per centimetre energy loss, this would predict a range of just over 110 mm. The SRIM result uses the fact that dE/dx increases as β

decreases and is compatible with the rough estimate (also data is for copper not nitrogen).

5. How is the "Bragg Peak" used in "hadron cancer therapy" with protons or higher atomic number ions such as carbon?

   Just looking for students to appreciate the rapid increase in ionisation towards the end of the ion range in a material thus most damage (to a tumour) occurs if you choose the beam energy such that the tumour is located at the end point and damage to health tissue preceding the tumour in depth is minimised. Also important for treating tumours of the eye where you want to have little damage behind the eyeball (i.e. the brain!). Typical proton beam energies are in the range 70 to 220 MeV.



SRIM simulation of 130 MeV proton beam entering skeletal muscle.