Why is a neutron an indirectly ionizing particle while electrons and protons are directly ionizing?

A. Neutrons interact only with the nucleus of a material
B. Neutrons travel longer distances before interaction
C. Neutrons only interact at higher energies
D. Neutrons can interact in a variety of ways

Unlike charged particles, the neutron can only interact with the nucleus (not the electrons) of an atom, distinguishing it from directly ionizing charged particle characteristics.

Which of the following is the best material to filter out 1 MeV neutrons.

A. Boron
B. Hydrogen
C. Nitrogen
D. Tungsten

1 MeV neutrons are most likely to interact via elastic scatter. The hydrogen nucleus has a mass almost equal to that of a neutron, therefore the kinetic energy transfer is maximum.

Which of the following is the best material to filter out thermal neutrons.

A. Boron
B. Hydrogen
C. Nitrogen
D. Tungsten

Boron has a very large neutron capture cross section for thermal neutrons. Captured neutrons will be filtered out.
Elastic neutron scatter results from a head-on collision between a neutron and an $^{56}$Fe nucleus. If the same interaction occurs between a neutron and a $^{112}$Cd nucleus, then, relative to the 1st interaction, we expect the energy of the recoil nucleus to approximately

A. Decrease by a factor of two  
B. Increase by a factor of four  
C. Increase by a factor of two  
D. Remain unchanged

For elastic neutron scatter with a direct impact: $E_r/E_n = 4A/(1+A)^2$. Thus, for sufficiently large $A$ we have $E_r/E_n \sim 1/A$.

Therefore, doubling $A$ (from $A = 56$ to an $A = 112$) results in decreasing $E_r/E_n$ by ½.

Boron neutron capture therapy uses the $^{10}$B($n,\alpha$)$^7$Li reaction to produce therapeutically useful radiation. Most of the radiation dose is delivered by

A. Alpha particles  
B. Gamma rays  
C. Lithium recoil nuclei  
D. Neutrons

We ideally want the dose delivered locally to where the boron is preferentially absorbed by tumor cells. Dose from neutrons and gammas is not locally deposited. Both the recoil lithium nuclei and the alpha particles (from the capture reactions) deposit dose locally, but because of its lower mass, the alpha particle will receive the majority of the energy from the reaction. Therefore, the correct answer is A.

For the same initial number of neutrons, which of the following neutron energies will have the largest reaction cross section?

A. 0.1 MeV  
B. 1 MeV  
C. 10 MeV  
D. 20 MeV

While the cross section for each element will look different, it should always be largest at lower energies.
Which neutron interaction is likely to cause the most damage in human tissue?

A. Elastic collisions  
B. Inelastic collisions  
C. Non-elastic collisions  
D. All collisions are equal

C. Non-elastic collisions

These collisions are likely to generate heavy charged particles, which are densely ionizing.

Which of the following is one of the primary advantages of neutron therapy over high energy photon therapy?

A. Neutron therapy is more cost effective than photon therapy.
B. Neutron radiation is more densely ionizing than photon radiation.
C. The depth dose of neutrons is superior to that of photons.
D. None of the above statements are an advantage of neutron therapy.

B. Neutron radiation is more densely ionizing than photon radiation.

Neutrons interact with target nuclei, resulting in heavy charged particles of high LET.