

Ph.D. Qualifying Examination
Interactions

1. (10 min.) The radionuclide ^{132}Te is used as a radioisotopic-generator to produce the radionuclide ^{132}I for use in research. Using the data below calculate:
 - (a) The time at which the maximum activity of ^{132}I will occur.
 - (b) The maximum activity of ^{132}I that will occur in the generator assuming that none is removed during the time interval.

DATA:Activity of $^{132}\text{Te} = 10 \text{ kBq}$ Half-life of $^{132}\text{Te} = 76.8 \text{ hours}$ Half-life of $^{132}\text{I} = 2.28 \text{ hours}$

2. (20 min.) Consider the $^9_4\text{Be}(p, \alpha)$ reaction. The kinetic energy of the incident proton is T_p ; the kinetic energy of the alpha is T_α ; the alpha emerges at an angle of 90 degrees with respect to the direction of the incident proton. Derive an equation for the kinetic energy of the recoil nucleus, T_R . If $T_p = 2 \text{ MeV}$ and $T_\alpha = 4 \text{ MeV}$, find T_R .
3. (15 min.) A beam of 100 keV photons interacts via Compton scattering. For this interaction, and a photon scattering angle of 30 degrees, calculate the following:
 - (a) the energy of photons scattered;
 - (b) the energy of the recoiling electron;
 - (c) the angle of the recoiling electron; and
 - (d) the maximum energy of the recoiling electron, over all scattering angle.
4. (20 min.) An accelerator-driven system produces an isotropic point source of 4 MeV photons. The dose equivalent rate at 10 feet is 100 rem/hr with no shielding. Find the thickness of the concrete shield needed to reduce this dose rate to 2 mrem/hr at contact with the outer face of the shield. The shield starts at 10 feet and extends outward so the distance from the source also increases. The density of concrete is 2350 kg/m^3 and the concrete's mass attenuation coefficient for 4 MeV photons is $0.0319 \frac{\text{cm}^2}{\text{g}}$. Buildup factors for concrete are as given below:

mean free paths	4	7	10	15	20
B, buildup factor	3.22	5.01	6.88	10.1	13.4

5. (10 min.) Consider how neutron radiography works.
- (a) Use the example of lead brick 2x4x8 inches with a cavity 1/2 x 2 x 3 inches carved out of the middle of it. A small wax candle is placed in the cavity. Describe the image you expect to see when this object is placed between the neutron source and a photographic film with a cadmium converter plate, and describe the physical processes that lead to this image.
 - (b) Describe the image you expect to get with conventional 250 keV x-ray radiography. Explain the difference.
6. (10 min.) Detector question grab-bag.
- (a) In cylindrical gas proportional counters the gas can be ionized anywhere in the volume, depending on the path of the ionizing radiation, giving a spectrum of electron and ion drift times. However, the gas multiplication is relatively constant no matter where the ionization started. How can this be?
 - (b) In gas-flow proportional counters, the beta plateaus are sloped upward more than alpha plateaus. Why?
 - (c) Name three types of detectors that could be used in real time to measure thermal neutron fields at a level that would be of interest in worker protection.
 - (d) How does a compensated ion chamber measure low neutron fields in the presence of high gamma fields?
7. (15 min.) A thin Indium foil was irradiated for 10 hours using a small neutron source, producing ^{116m}In ($t_{1/2} = 54$ minutes). The 1.09 MeV photon emitted from ^{116m}In (yield = 53%) was counted using a HPGe detector. The count was started 45 minutes after the foil was removed from the neutron source and a 60 minute count collected 1034 net counts in the peak. The overall peak efficiency for the detector and geometry is 9.2%. What was the activity of the foil at the end of the neutron irradiation?
8. (10 min.) Because of the wave-particle duality of matter, we know that electrons and neutrons both "Bragg-scatter" from crystals similarly to electromagnetic radiation. What must be the velocity of an electron to give the same scattering pattern (neglecting electrostatic attraction) as a nonrelativistic neutron whose kinetic energy is E_n ? A symbolic solution is adequate (i.e. do not substitute numbers into your solution).

9. (10 min.) An isotropic point source of neutrons is located on the axis of a cylindrical detector at a distance Z from the entrance window. The window has an opaque or black disk, i.e., the disk is completely absorbing to incident neutrons, of radius R_1 in the center of the window. The outer radius of the window is R_2 . Thus, the window is an annulus of inner radius R_1 and outer radius R_2 and only neutrons going through the annular region are counted. Starting with a differential solid angle, and in terms of the given quantities, derive the relation for the geometric efficiency of the detector.

