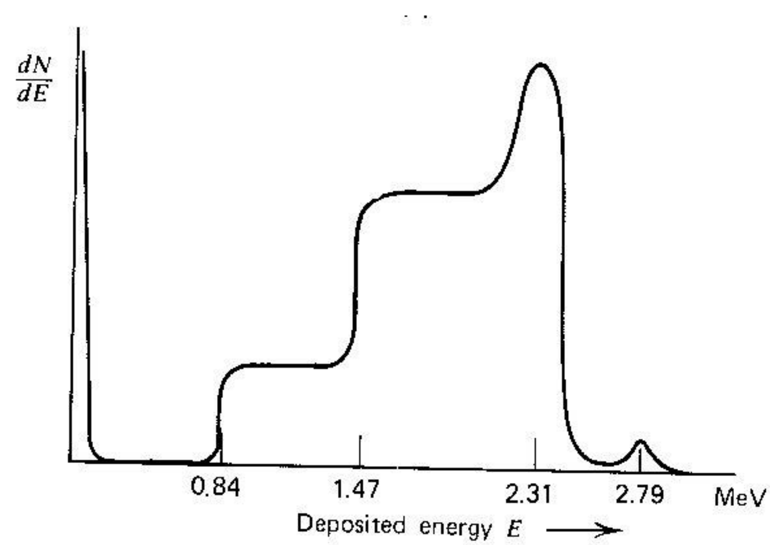
Interactions, Measurements and Theory of Radiation **Fall 2010**

1. **(15 minutes)** A particular counting system has a stable average background rate (measured over a long time) of 50 counts per minute. A decaying isotope is counted and a 10 minute count yields 1683 counts. After 24 hours, the source is counted for 20 minutes and yields 1683 counts again.
   a. **(5 minutes)** What is the half life of the source?
   b. **(10 minutes)** What is the uncertainty in the half life from counting statistics?

2. **(15 minutes)** Consider the detection of neutrons using gas-filled detectors.
   a. **(5 minutes)** Identify and label the features of the pulse height spectrum shown below. This spectrum was collected using a 0.5" diameter $^{10}BF_3$ tube measuring thermal neutrons.



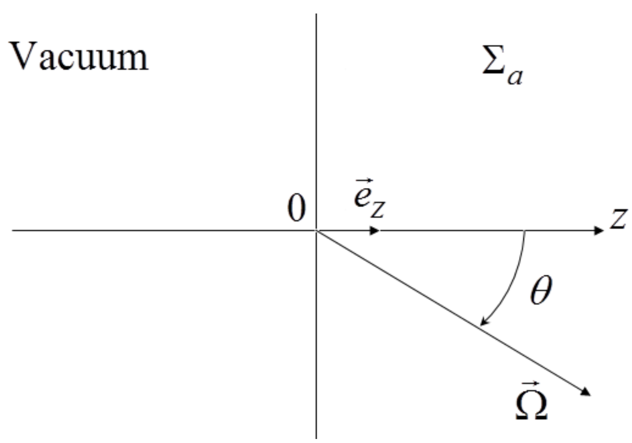
   b. **(10 minutes)** Compare the detection mechanisms for thermal neutrons using $^{10}BF_3$ tubes, ^3He tubes, compensated ion chambers, uncompensated ion chambers, and fission chambers. Discuss the associated benefits and inherent problems of these detectors for the detection of thermal neutrons.

3. **(15 Minutes)** Let $_{Z}X^{A}$ denote a nuclide with atomic number Z and mass number A, let M'(Z,A) denote the nuclear mass of the nuclide in *amu*, let M(Z,A) denote the neutral atomic mass of the nuclide in *amu*, and let m_0 denote the mass of the electron in *amu*. Assume that the annihilation of 1 *amu* of mass yields 931.5 Mev of energy.
   a. What is the product nuclide resulting from beta decay of $_{Z}X^{A}$?
   b. Give an expression for the Q-value in *MeV* using nuclear masses.
   c. Re-express the Q-value in terms of neutral atomic masses by assuming that $M(Z,A)=M'(Z,A)+Zm_0$.
   d. What error is made when this is done?

4. **(20 minutes)** The following angular flux is incident on the right half space:

$$\psi_{inc.}(\vec{\Omega}) = \frac{3}{2\pi} q_0 \eta^2, \text{ neutrons/(cm}^2\text{ s sr)},$$

where $\eta = \cos\theta$, θ is the angle between $\vec{\Omega}$ and $\vec{e}_z$, and $\vec{e}_z$ is perpendicular to the boundary of the half space as shown below. The medium of the right half space has only a constant absorption cross section, Σ_a. The medium to the left of the half space is a vacuum. Using the transport equation, find the angular flux $\psi(\vec{r},\vec{\Omega})$ in the right half space.



5. **(10 minutes)** Explain the nature of the characteristic blue glow that can be observed in nuclear reactors. Your explanation must include a brief overview of physical origins including initiating particles, involved phenomena and explanation of the color. Discuss this phenomenon considering water, helium and sodium.

6. (**10 minutes**) Recall that the critical energy, E_{crit} for induced fission is that excitation energy of the compound nucleus that is necessary for fission. For neutron collisions with ^{244}Cm, the induced fission critical energy is 6.2 MeV. Show your calculations that determine whether this nucleus is fissile or fissionable.

7. (**10 minutes**) The Department of Food Science at Texas A&M University wants to build an irradiation facility on campus for research and testing of food products. The current design assumes that the irradiation source will be ^{60}Co with an initial activity of 5 MCi (i.e., 5 million curies).
    a. (80%) The source will be removed from its container and moved manually into the room, but the Radiation Safety Officer wants to know the exposure rate of the unshielded source. The handling rod for the source is 4 meters long. Calculate the exposure rate at a distance of 4 meters from the unshielded source.
    b. (20%) What is the maximum working time for a single individual involved in this operation?
    State all assumptions and show all your work. Useful data: Γ (^{60}Co) = 13.2 R cm^2 h^{-1} mCi^{-1}

8. (**10 minute**s) Briefly explain the underlying mechanisms and specify an example of a material having a high efficiency to achieve each of the following functions (1) to absorb gamma rays; (2) to slow down fast neutrons; and (3) to capture thermal neutrons.

9. **(15 minutes)** Neutron cross sections for reactions that involve a compound nucleus exhibit "resonances" – sharply increased magnitudes in narrow neighborhoods of certain neutron energies. Consider radiative capture in U-238 as an example of a reaction that exhibits such resonances, and **explain** these resonances in terms of certain energy values that govern them. Energy values that you may consider include: the neutron kinetic energy (in the lab and/or center-of-mass frame), the U-238 kinetic energy (in the lab and/or center-of-mass frame), allowed excitation energy levels in various nuclei, etc.