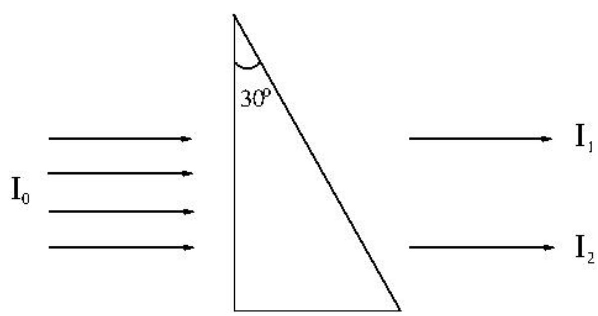
1. **(15 Minutes)** A monoenergetic beam of photons is incident upon a 30° copper wedge (Z=29, ρ = 8.96 g cm^{-3}). The exiting uncollided beam intensity is measured at 1.73 cm (denoted by I_1) and 5.2 cm (denoted by I_2) from the top of the wedge, respectively (as shown in the figure below). Given that I_1/I_2 = 3.26, what is the energy of the incident photons?

Mass Attenuation Coefficient for Cu		
Energy (MeV)	μ_{en}/ρ (cm^2/g)	μ/ρ (cm^2/g)
0.01	1.48E+02	2.16E+02
0.05	2.613	2.192
0.1	2.95E-01	4.58E-01
0.2	5.78E-01	1.56E-01
0.4	3.12E-02	9.41E-02
0.6	2.86E-02	7.63E-02
0.8	2.68E-02	6.61E-02
1	2.56E-02	5.90E-02



2. **(20 Minutes)** A neutron with a kinetic energy of 1.0 MeV traveling along the x-axis in the positive-x direction collides with a B-10 nucleus that is traveling along the x-axis in the negative-x direction (that is, directly towards the neutron). The B-10 nucleus has a kinetic energy of 0.1 MeV. The neutron is absorbed into the B-10 nucleus and an α-particle and Li-7 nucleus are emitted from the reaction. The α-particle has a kinetic energy of 1.5 MeV. The Li-7 nucleus following the reaction is left in an unexcited state. Determine the energy and direction (with respect to the original direction of the neutron) of the Li-7 nucleus. Note that the B-10 target nucleus was not at rest when it interacted with the neutron.

3. **(15 Minutes)** In this problem you will be asked to estimate the concentration of an activity in units of disintegrations per minute per unit mass (dpm/g) **and** the uncertainty of the measurement. It is not necessary for you to know the identity of the radionuclide or the half-life of the material to answer this question correctly.

A one gram sample is to be processed in a chemical laboratory. A series of blank chemical processes showed that the chemical recovery (also known as the chemical yield) was 70 ± 5%. In addition, before the measurement, it was determined that the counting efficiency for this radionuclide was 20 ± 2%. After processing the sample was counted in the same exact geometry using a measurement system with a precise timer. The measured count rate of the sample was 30 ± 5 counts per minute (cpm). Calculate the following:

a. The activity concentration of the sample.
b. The associated uncertainty in the activity concentration.

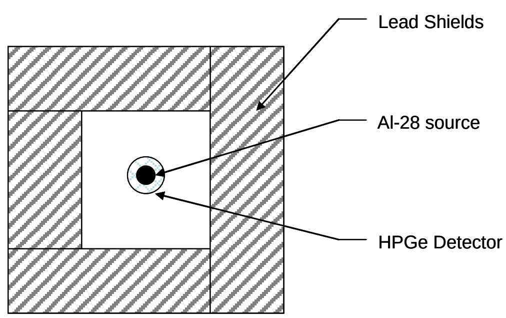
4. **(15 minutes)** Consider a homogeneous slab of thickness 2X (cm) placed in a vacuum. The medium is purely absorbing with macroscopic cross section, Σ_a (cm^{-1}).
   a. A uniform isotropic volumetric source, Q_v (n/cm^3-s), is present in the slab. Using the integro-differential transport equation, compute the angular flux (n/cm^2-s-str) at an arbitrary point within the slab for $\mu > 0$.
   b. An isotropic surface source, Q_s (n/cm^2-s), is placed at the left face of the slab. Using the integro-differential transport equation, compute the angular flux (n/cm^2-s-str) at an arbitrary point within the slab.

5. **(15 minutes)** Estimate the minimum mass of a neutron detector if it must produce one measureable energy deposition event per second when exposed to a fluence rate of 1 n/cm^2-s. Assume that the neutron kerma factor for the relevant material and detector configuration is 2 x 10^{-11} Gy-cm^2/n, and that the energy deposited by a neutron interaction in this detector is 1 MeV.

6. **(15 minutes)** Consider neutron, proton and α -particle beams. Which nuclides would you select as target materials for producing ${}^{24}_{11}Na$ using each of these beams? To get credit, you must justify your answer.

7. **(10 minutes)** You are asked to construct a device that will provide minimum uninterrupted thermal power of 40 W for 40 years using the alpha decay of ^{238}Pu. What is the initial mass of ^{238}Pu needed to meet the design criteria? (Data: The half-life of ^{238}Pu is 87.7 yr, and the alpha particle energy is 9 x 10^{-13} J/decay).

8. **(15 minutes)** Consider gamma-ray spectroscopy using an intermediate-sized well-type HPGe detector where the source being counted is surrounded by the HPGe as shown below.



a. Assume that the source is a relatively high activity ^{28}Al source sitting directly on the detector (^{28}Al emits a single 1778 keV photon per decay). Sketch what the measured energy spectrum would look like. Label and briefly explain pertinent features of your sketch.
b. If the detector was instead extremely large what would you expect the measured energy spectrum to look like?