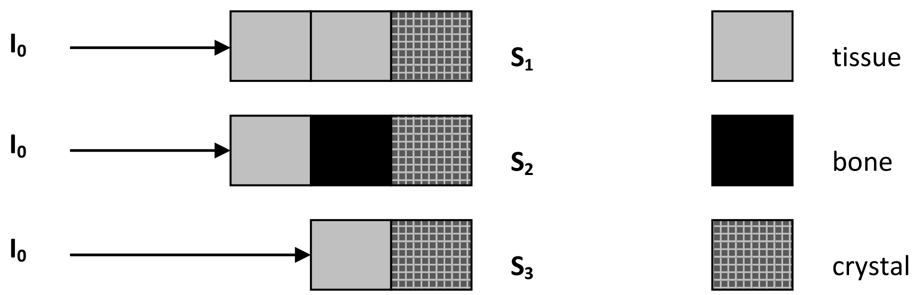
Problem 1 – Crystal Sensors

In the figure to the right, calculate the relative intensities of the signals S_1, S_2 and S_3 <u>produced</u> (i.e. absorbed) by each scintillation crystal. The value of μ_{tissue} is 0.5 cm^{-1}, μ_{bone} is 1 cm^{-1}, and $\mu_{crystal}$ is 2 cm^{-1}



Problem 2 – Radiation Detection

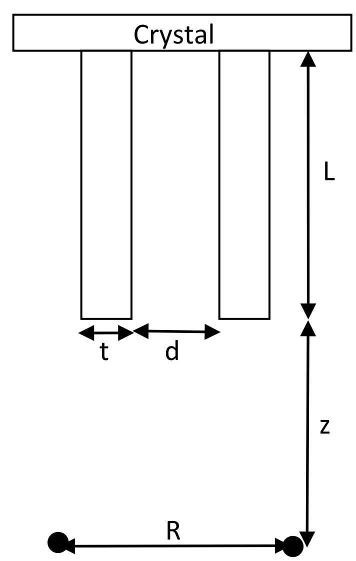
A γ ray from ^{241}Am (60 keV) is absorbed completely in an NaI(T1) crystal. The photomultiplier tube has 10 dynodes, with each dynode providing an electron multiplication factor of 3. About 80% of the light from the crystal is absorbed by the photocathode, which has a photocathode efficiency (number of electrons emitted per light photon absorbed) of 0.05. Assuming that 30 photons of light are produced in the NaI(T1) crystal per kilo electron volt of energy absorbed, compute the number of electrons received at the anode of the photomultiplier tube.

Problem 3 – SNR Considerations

In a nuclear medicine scan using ^{99m}Tc (half-life= 6h, wavelength of the emitted γ = 8.79 10^{-12} m), the image signal-to-noise ratio (SNR) for a 30-min scan was 50:1 for an injected radioactive dose of 1 mCi ($3.7\text{x}10^7$ disintegrations per second). Imaging began immediately after injection.

a) If the injected dose were doubled to 2 mCi, what would be the image SNR for a 30-min scan?
b) If the scan time was doubled to 60 min with an initial dose of 1 mCi, what would be the image SNR?
c) What would be the SNR if an iron structure of 2 cm thickness would be placed in front of the detector ? (For iron: ρ=7.87 g/cm^3, and μ/ρ = 0.196 cm^2/g for 150keV photons)

Hint: $SNR \propto \sqrt{\#counts}$



Problem 4 – Collimation I

Derive an equation for how a parallel-hole collimator affects resolution (minimal distance R(L,z,d), between two distinguishable objects) for two point sources at a distance z of the collimator.

Hint: Consider that two objects are no more distinguishable if the distance between them is that short, that they appear in the same crystal pixel.

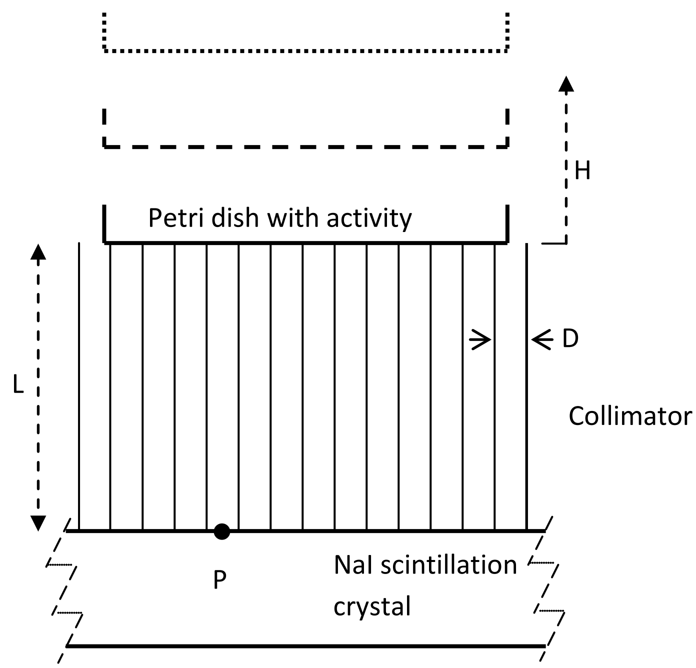
Problem 5 – Collimation II

Imagine a collimator as used on a gamma camera in nuclear medicine. For the sake of simplicity assume that the holes in the collimator are round (instead of hexagonal) with a diameter D of 1.45 mm and a length L of 24.1 mm. Also assume no radiation penetrates the collimator material (usually lead). The sensitivity of a gamma camera with collimator is measured by filling a Petri dish (diameter of about 10 cm) with a thin layer of radioactive nuclide containing fluid, placing this dish on top of the collimator and measuring the number of counts for a certain time after this. The sensitivity for the nuclide in question can be expressed in counts per minute per MBq activity.

a. In an experiment with 51.80 MBq ^{99m}Tc, 5.88×10^5 counts are measured in 2 minutes. According to the manufacturer the sensitivity is 202 cnts/(min·µCi) (American manufacturers still use Ci instead of Bq, 1µCi = 37 kBq). What is the difference between the sensitivity of the measurement and the factory specification?

b. From measurements in which the dish is placed at different distances H of the collimator it appears that the sensitivity is independent of this distance H. Explain this quantitatively.

Hint: The surface of the Petri dish that can be seen from P is circular; calculate the surface of the dish that can for example be seen from point P in the accompanying sketch. Then calculate what part of the radiation goes from a point in that surface of the dish through a surface dA around P, and combine the results(surface of a circle = πR^2, surface of a sphere = $4\pi R^2$).



c. What part of the radiation is used by the collimator (i.e. reaches the crystal)?
To calculate it, determine how many crystal parts are under the Petri dish (of surface S), as well as the proportion of the total activity A in front of each hole. Determine then the radiation intensity seen by each crystal part and finally by the total crystal. You find then the geometric efficiency ε of the setup.

d. If you use the factory specifications for the sensitivity, which part of the disintegrations in the Petri dish really leads to a count?

e. Give at least two possible causes for the difference between the answers in c and d.