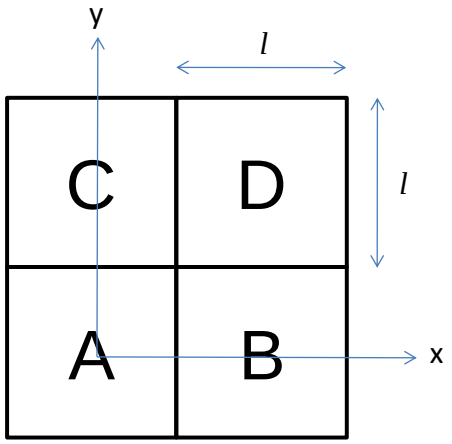
Lecture 5 and 6 – exercises

1. The linear attenuation coefficient for a NaI(Tl) crystal for the radiotracer elements $^{99}Tc^{m}$, ^{68}Ga, ^{131}I and ^{111}I are 2.2, 1.7, 1.3 and 1.2 cm^{-1} respectively. For 6 mm and 1 cm thickness crystals, calculate the relative signal intensities for each radiotracer element

2. Suppose the true count rate in a gamma camera is 10,000 events per second, but the measured rate is only 8,000 events per second. What is the dead time of the system?

3. Consider a ^{99m}Tc γ-ray with an energy of 140.5 keV that is detected using a NaI(Tl) scintillator coupled to 4 photomultiplier tubes (PMT) arranged in a 2×2 array, see diagram below. NaI(Tl) has a photon yield of 38 photons per keV. Assume that the PMTs have a quantum efficiency of 30%.



a) On average, how many visible photons are detected in total by the four PMTs if the γ-ray is completely absorbed by the scintillator.

b) The detection window of the pulse-height analyser is set to collect events in the range from 1520-1680 visible photons. Assuming that the detection process is limited only by shot-noise on the detected visible photons, calculate the probability that this γ-ray event is registered by the detection electronics.

The integral of the Gaussian probability distribution function, P_G, over the range $x = (\mu - n\sigma)..(\mu + n\sigma)$ is tabulated below:

n	P_G
1	0.683
2	0.954
3	0.997

Here, μ is the mean of the Gaussian distribution and σ is the standard deviation.

c) Calculate the *x* and *y* coordinates of a detected γ-ray relative to the centre of PMT A in terms of the signal *S* recorded at each of the detectors. Assume relative values of S_A = 1, S_B = 2, S_C = 1 and S_D = 2 and that *l* = 1 cm

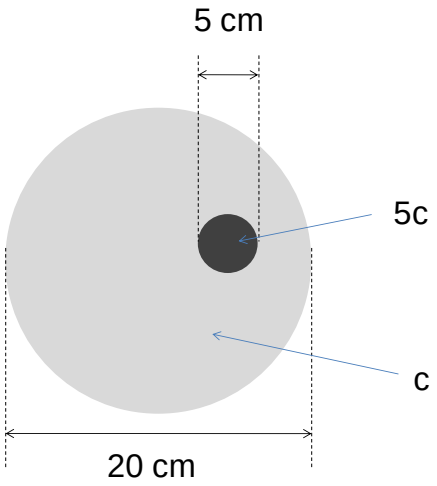
d) Use the formula you derived in part c) and the standard formula for error propagation (below) to find a formula for σ_x.

$$f = f(a_1, a_2, ..., a_n)$$

$$\sigma_f{}^2 \cong \left(\frac{\partial f}{\partial a_1}\right)^2 \sigma_{a1}{}^2 + \left(\frac{\partial f}{\partial a_2}\right)^2 \sigma_{a2}{}^2 + ... + \left(\frac{\partial f}{\partial a_n}\right)^2 \sigma_{an}{}^2$$

Then calculate σ_x using the values for *S* given in part c) and the total number of photons detected.

4. Consider an image acquired using a gamma camera of the test object shown in the figure below. The image was produced from the detection of 10^5 γ-ray events. The number of counts recorded per unit area in the 'lesion' indicated by the small dark circle is 5 times higher than in the region indicated by the light-grey large circle.



a) Calculate the number of γ-ray events recorded in the dark grey 'lesion'. Also calculate the number of γ-ray events recorded in the light grey region for an area that is the same size as the 'lesion'.

b) What is the contrast-to-noise ratio for the dark grey region compared to the light grey region?