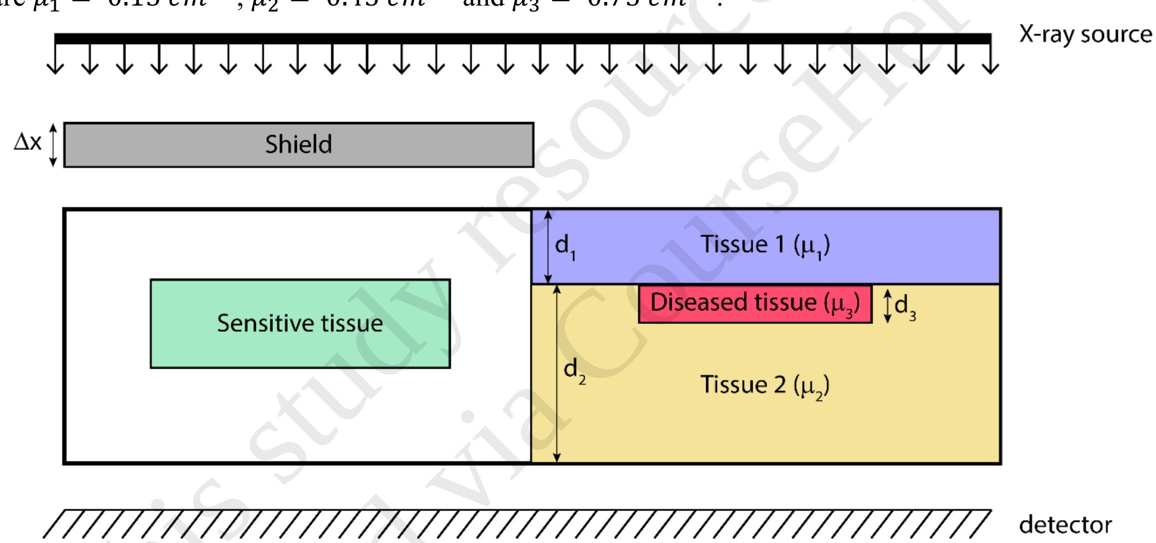
EEE 473/573 Medical Imaging – Fall 2020-2021
Homework 3
Due 16 November 2020, Monday at 23:59

GUIDELINES FOR HOMEWORK SUBMISSION

1. NO submission via E-MAIL (all email submissions will be discarded).
2. Submit a PDF file. Other file types will not be accepted. If there are any handwritten parts, you can scan them (make sure they are legible) and insert into the PDF file. Unclear presentation of results will be penalized heavily. No partial credits to unjustified answers.
3. If your Matlab codes are not included at the end of the PDF file, your Matlab questions will NOT be graded.
4. This is a Turnitin submission. The Turnitin system requires the submitted file to contain at least 20 words in it. If you are submitting a Word file with scanned pages only, the file will be rejected by the system. You can type your name multiple times at the beginning of the file to overcome this problem.
5. Submission system will remain open for 1 day after the deadline. No points will be lost if you submit your assignment within 12 hours of the deadline. There will be a 50% penalty if you submit after 12 hours but within 24 hours past the deadline. No submissions beyond 24 hours past the deadline.

---

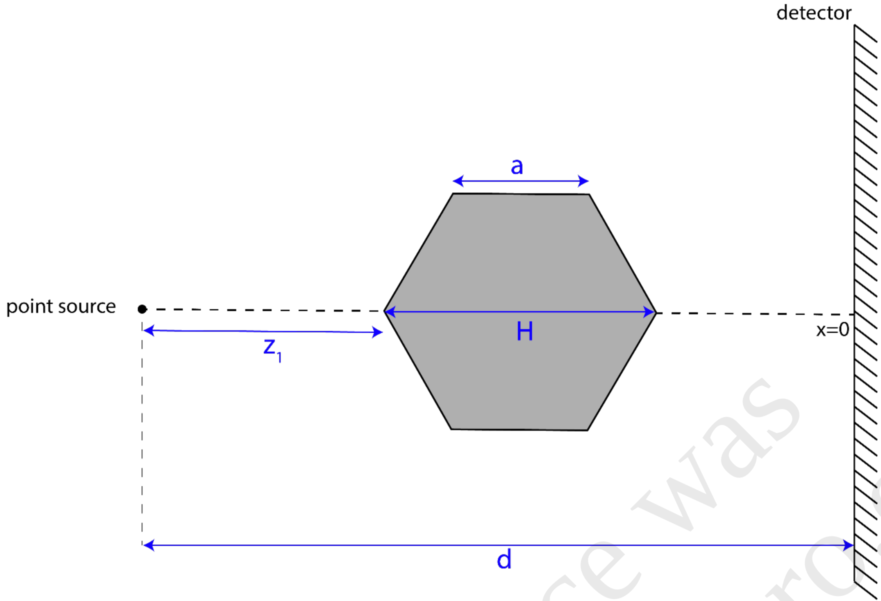
1) Suppose that we are imaging a body with a line source x-ray imaging system to diagnose a diseased tissue as shown below. The thicknesses of tissue 1 is $d_1 = 1.5$ cm and tissue 2 is $d_2 = 4\ cm$. The estimated diseased tissue length $d_3 = 1\ cm$. The linear attenuation coefficients of these three tissues are $\mu_1 = 0.15\ cm^{-1}$, $\mu_2 = 0.45\ cm^{-1}$ and $\mu_3 = 0.75\ cm^{-1}$.



a) Find the detected intensity when rays pass through the diseased tissue. This is the "target" intensity, I_d. Find the detected intensity when rays pass through tissue 1 and 2 (but not through the diseased tissue). This is the "background" intensity, I_b. Then, calculate the local contrast of the diseased tissue. Assume narrow beam geometry with monoenergetic x-ray photons.

b) Consider that there are sensitive tissues in the body that we would like to protect from x-ray exposure. We find two shields in the lab with thicknesses of $\Delta x_a = 5\ mm$ and $\Delta x_b = 1.5\ mm$, with corresponding linear attenuation coefficients of $\mu_a = 6.5\ cm^{-1}$, $\mu_b = 17\ cm^{-1}$. We want the shield to provide at most 5% transmission (i.e., at least 95% attenuation of x-ray photons). Explain whether any of these shields meet this requirement.

2) A uniform hexagon with side length $a = 20\ cm$ and vertex to vertex length $H = 40\ cm$ is being imaged with a point source x-ray imaging system, $d = 2\ m$ away from the detector. The object with linear attenuation coefficient $\mu_0 = 0.03\ cm^{-1}$ is placed between the source and the detector as shown below. Assuming I_0 is the intensity of the incident beam, formulate the intensity on the detector along the x-axis, $I_d(x)$ for $z_1 = 0.5\ m$ and $z_1 = 1.5\ m$, separately. Do not ignore obliquities.



3) **MATLAB Question**: Include your MATLAB codes in your solution.

For Question 2, assume that the detector has a size of 128 cm with 512 elements on it (i.e., it generates an x-ray image of 512 pixels). We place the object at the two locations indicated in Question 2 (i.e., $z_1 = 0.5\ m$ and $z_1 = 1.5\ m$) and take x-ray images separately for those two cases.

a) Plot the 1-D normalized intensity profiles (i.e., $\frac{I_d(x)}{I_0}$) for these two cases.

b) Compare the two plots and comment on their differences.

4) Find the 2D radon transform, $g(l, \theta)$, of the 2D Gaussian function $f(x, y) = e^{-\frac{x^2+y^2}{2}}$.

5) A 2D object is shown below, where $r = 15\ cm$. The linear attenuation coefficients are $\mu_1 = 0.25\ cm^{-1}$, $\mu_2 = 0.05\ cm^{-1}$, and $\mu_3 = 0.35\ cm^{-1}$. This object is imaged with a CT scanner using parallel-ray geometry.

a) Find and sketch $g(l, 0°)$.

b) Find and sketch $g(l, 90°)$.