

This assignment is due on Friday, September 16 by 5:00 PM in my mailbox in Hock Plaza (Suite 101).

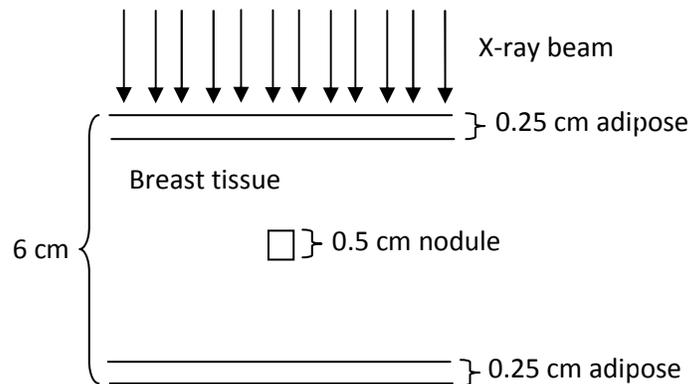
Problem 1: Consider a one-dimensional linear imaging system with two serial components whose PSFs are:

$$h_1(x; \xi) = e^{-(x-\xi)^2/2} \quad h_2(x; \xi) = e^{-(x-\xi)^2/10}$$

You can imagine that h_1 represents the PSF of an extended source and h_2 is the PSF of an intensifier screen. Therefore, these functions represent the total system component response to a shifted impulse $\delta(x - \xi)$.

- (a) What is the FWHM associated with each subsystem? What is the FWHM of the overall system?
- (b) Generate a formulation of the system MTF.
- (c) Choose ONE of the following options:
 - i. Write the (mathematical) output image $g(x)$ given the input signal: $f(x) = \delta(x) + \delta(x - 5) + \delta(x + 2)$. Is the system response “good” or “bad?”
 - ii. Simulate the above system in MATLAB and show the output signal $g(x)$ given the input signal: $f(x) = \delta(x) + \delta(x - 5) + \delta(x + 2)$. Is the system response “good” or “bad?” (Note: Simulation of the system can be done in several ways.)

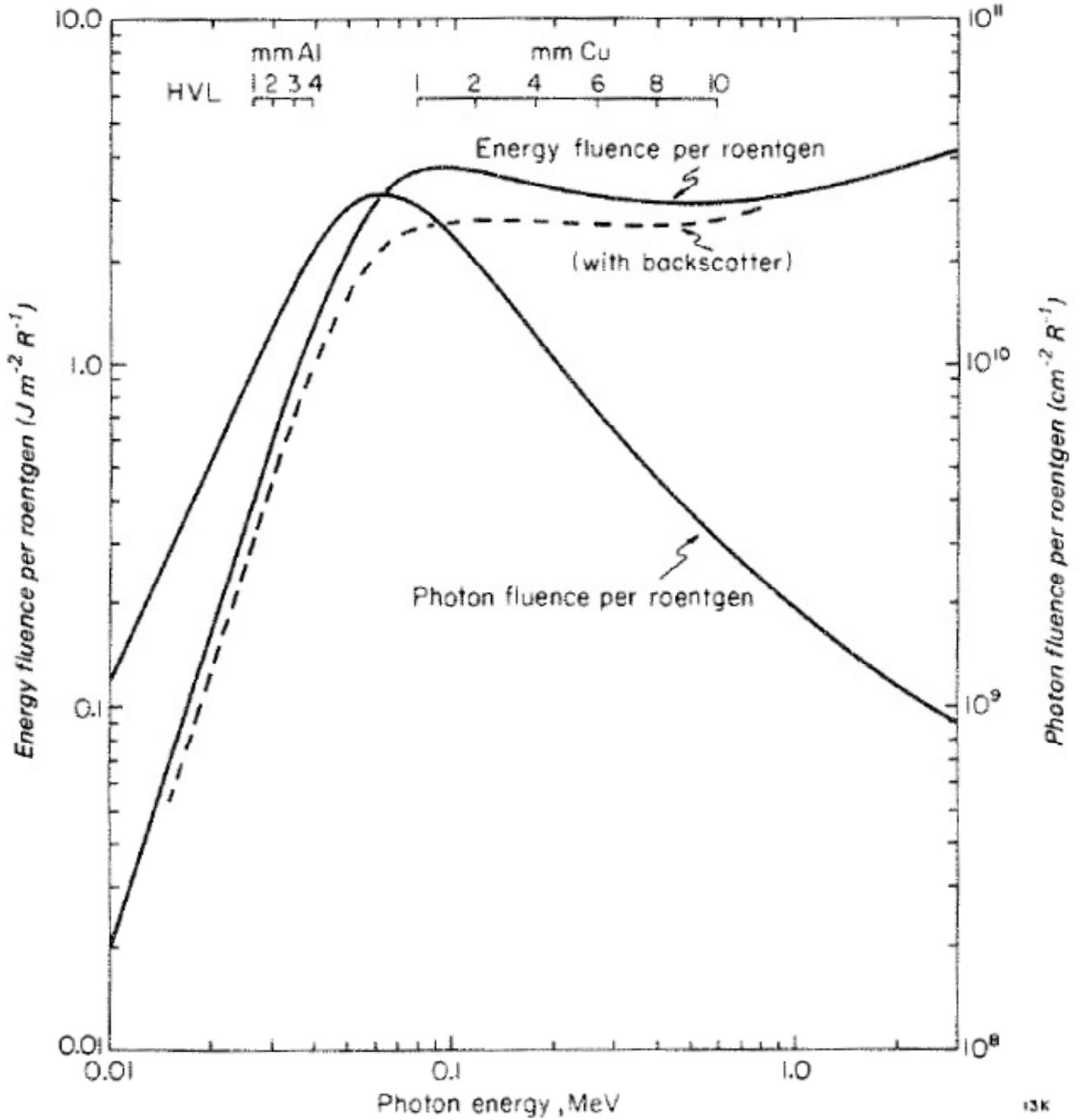
Problem 2: A craniocaudal (CC) mammogram is taken with the patient’s breast compressed to a thickness of 6 cm (reference diagram). The breast contains a cubic nodule of side length 0.5cm. A parallel X-ray beam is incident on the breast surface. The beam is comprised of only two energies: $E_1 = 17.5$ kEv and $E_2 = 19.6$ kEv. The flux of the photons at E_1 is four times that of the photons at E_2 . Mass attenuation coefficients and densities are provided in the table below. In addition, the attached chart for photon fluence per Roentgen has been provided as a convenient reference for this problem.



	ρ (g/cm ³)	$\mu/\rho(E_1)$ (cm ² /g)	$\mu/\rho(E_2)$ (cm ² /g)
Adipose Tissue	0.95	1.2	0.8
Breast Tissue	1.02	1.2	0.8
Nodule	1.025	1.2	0.8

Estimates from: <http://www.nist.gov/physlab/data/xraycoef/index.cfm>

Ignoring any scatter, what is the minimum patient entrance exposure (in mR) required to reliably detect the nodule?



Johns, HE & Cunningham, JR, The Physics of Radiology, 4th Ed., Thomas, Springfield, 1983, (p. 262)

Some problems may be adapted from Prince, JL & Links, JM (2006), Medical Imaging Signals and Systems

Problem 3: Calculate $DQE(u,v)$ for a nonideal detector with the following PSF:

$$h(x,y) = \frac{1}{2\pi} e^{-(x^2+y^2)/2}$$

Assume that the input to the detector is a uniform, monoenergetic x-ray beam with Poisson characteristics (i.e. white noise).

Problem 4: Consider an X-ray imaging system which uses film without the use of image intensifier screens. For simplicity, assume that a constant number of photons per unit are incident on the image receptor. Also, all techniques below produce ODs within the linear region of the film.

- (a) With all other factors are held constant, the X-ray tube kVp is increased and the mAs appropriately adjusted to produce optimal film exposure. How will the increasing kVp affect SNR? Explain.
- (b) Assuming the same conditions as in (a), what would be the effect on patient dose? Explain.
- (c) Your TA has undergone a PA chest examination using proper technique: 120 kVp, 5.0 mAs. Now consider each of the following changes to the original acquisition. Indicate the net effect on the subject contrast: I=increase, D=decrease, N=no effect.
 - i. Increase in patient thickness
 - ii. Reduction in kVp
 - iii. Increase in detector efficiency
 - iv. Reduction in x-ray field size
 - v. Use of a high atomic number contrast media
- (d) The original technique is modified by the addition of an image-intensifier screen. Using a graph, indicate the change in system MTF (show before and after plots on the same graph).

Problem 5: Enhance the obscured high-frequency details within the image provided ('image.raw'). Briefly describe the details you observe and how you uncovered them. Provide any code that you produce. Your descriptions may be purely mathematical or they may be textual. Please be succinct in your responses.

HINTS: Open the image using the following code:

```
fname = 'image.raw';
fid = fopen(fname, 'r');
res = fread(fid, [512, 512], 'single');
fclose(fid);
```

Also, be aware that some filtering techniques may have undesirable effects near the perimeter of your image. These effects can alter the way your image is displayed, especially if you are not careful in MATLAB. Therefore, use appropriate display techniques (e.g. IMTOOL in MATLAB provides window/level and cropping utilities).