

Part I: Physical Basis of Medical Imaging [45 points]

(10 points) 1. At what energy does radiation become ionizing? Why is this level considered to be “ionizing”?

(20 points) 2. Describe the *photoelectric effect* and *Compton scattering* in terms of how an incident photon interacts with an atom. In your descriptions, indicate if either (or both?) represent ionizing radiation and specify the nature of the photon(s) that result from the interaction.

(15 points) 3. Which of the following imaging techniques are considered to expose patients to *ionizing* and which to *non-ionizing* radiation? *Briefly* justify your categorization.

- Near Infra-Red Spectroscopy (NIRS)
- Nuclear Magnetic Resonance Imaging (NMRI)
- Positron Emission Tomography (PET)
- Ultrasound
- X-ray/CT

Part II: Two-Dimensional Image Processing [55 points]

Consider the continuous 2D signal, $f(x, y)$. Sampling of this signal may be (ideally) represented as multiplication by the *comb* function:

$$\delta_s(x, y; \Delta x, \Delta y) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \delta(x - m\Delta x, y - n\Delta y)$$

In this case, the sampled signal is

$$f_s(x, y) = f(x, y)\delta_s(x, y; \Delta x, \Delta y)$$

(15 points) 4. Symbolically derive $F_s(u, v)$, the 2D Fourier transform of $f_s(x, y)$. (Show all intermediate steps.)

(10 points) 5. Let $f(x, y)$ be frequency band-limited to $|u| < U$ and $|v| < V$, derive and graphically illustrate the Nyquist sampling criteria related to Δx and Δy .

(10 points) 6. Assume $f(x, y)$ is spatially limited to $|x| < \frac{X}{2}$ and $|y| < \frac{Y}{2}$. If a $X \times Y$ image of $f(x, y)$ is generated using $n_x \times n_y$ pixels, what is the set of points in (u, v) space that have been sampled?

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(10 points) 7. If the “field-of-view” in part c is doubled, to produce a $2X \times 2Y$ image, without increasing the number of pixels, how does the set of sampled points in (u, v) space change?

(10 points) 8. Now assume that the “field-of-view” remains $X \times Y$, but the number of pixels is doubled to $2n_x \times 2n_y$. How does the set of sampled points in (u, v) space change?

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