Part 1: Radiographic Tomography Principles [50 points]

(A) [15 pts] 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.

(B) [15 pts] Explain why radiation with energy smaller than 13.6 eV is not considered ionizing.

(C) [20 pts] When positron emission occurs due to radioactive decay, annihilation of the positron leads to two photons being emitted from the object toward the ring of detectors located at radius $\mathcal{R}$. A forward simulation of the detection of these emissions may be generated from knowledge of the location of the source — (x_0, y_0), corresponding to (r_0, θ_0) — and the (ideal) angles at which the two photons are emitted — θ and $\pi + \theta$. Based on this simple forward model, derive equations for the angles associated with the two points—$(\mathcal{R}, \phi_1)$ and $(\mathcal{R}, \phi_2)$—at which the photons will intersect the detector ring. *Note:* we are using two coordinate systems, one rectangular and one polar, each having its origin at the center of the detector ring.

Part 2: Reflection Tomography Principles [50 points]

(A) [25 pts] Draw the expected field pattern for an ultrasound transducer, indicating the geometric, Fresnel and Fraunhofer regions. For a circular transducer of radius $\mathcal{D}$ and probe wavelength λ, provide equations for the distances at which each region begins/ends, and provide an equation for the width of the associated Fraunhofer region as a function of z — the distance from the transducer.

(B) [25 pts] Draw simple schematics of the graphical outputs from each of A-mode, B-mode and M-mode ultrasound imaging. Provide axes where appropriate to indicate the information represented/depicted by each such mode.

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