August 2015 QE

Part I: Physical Basis of Medical Imaging [20 points]

(10 pts) 1. At what energy does radiation become ionizing? Why *is* this level considered to be "ioniizing"?

(10 pts) 2. 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: Fourier-Based Imaging [40 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

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

(20 pts) 3. Derive $F_s(u, v)$, the 2D Fourier transform of $f_s(x, y)$.
paragraph*(20 pts) 4. 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.

Part III. Nucear Magnetic Resonance Imaging (40 points)

(10 pts) 5. Write the Larmor Equation and define all terms.

(15 pts) 6. Describe the physical pheonomena underlying each of the T_1, T_2 and T_2^* time-constants.

(15 pts) 7. Explain how application of a gradient field may be used to augment a free-induction decay (FID) experiment to produce a *projection* of an object. How is this projection related to the axis along which the gradient field is applied?