**Georgia Institute of Technology**

The George W. Woodruff School of Mechanical Engineering

Nuclear & Radiological Engineering/Medical Physics Program

Ph.D. Qualifier Exam

Fall Semester 2015

\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Your ID Code

**Medical Imaging (Day 3)**

Instructions

1. Use a separate page for each answer sheet (no front to back answers)
2. The question number should be shown on each answer sheet

3. **ANSWER 4 OF 6 QUESTIONS ONLY**

4. Staple your question sheet to your answer sheets and turn in

**NRE/MP Medical Imaging**

**Answer any 4 of the following 6 questions**.

**Question 1.**

Show all work. Use gyromagnetic ratio ( = 42.5 [MHz/Tesla]

An MRI image has a pixel size of 0.5 x 0.5 mm and has 256 lines in k-space.

1. What is the FOV in the x-direction?
2. If the slice thickness is 2.0 mm and the slice selection gradient (Gz) is 20 milliTesla/meter, what if the RF pulse bandwidth?
3. If the TR is 800 millisec and the TE is 10 millisec, how long will it take for one image slice to be acquired?
4. Will the image be T1, T2, or proton density weighted (and say why in one sentence)

**Question 2.**

As shown in the figure below, a planar x-ray imaging system is used to take the image of a water phantom containing a piece of bone inside. Given that the x-ray beam is parallel, that the incident fluence is  photons cm-2, that the x-ray imager has a pixel size of 200 µm x 200 µm, and that the imager’s x-ray detection efficiency is 80%, calculate the contrast-to-noise ratio (CNR) between pixels A and B. Other data: the linear attenuation coefficients for water and bone are 0.2 cm-1 and 0.5 cm-1, respectively.

Incident x-ray beam

5 cm

20 cm

Water

Bone

A

B

X-ray imager





**Question 3.**

A 2D object contains a uniform disc with a diameter of 100mm and one rod at the center with a diameter of 1mm. A monoenergetic x-ray source generates a 1D projection profile on the object. At the used x-ray energy, the disc has a linear attenuation of 0.02 mm-1 and the rod has a linear attenuation of 0.04 mm-1. The image contrast is defined as the maximum signal difference between inside and right outside the projection of the rod divided by the signal right outside the projection of the rod. The contrast to noise ratio (CNR) is defined as the ratio of image contrast over the standard deviation of signal noise right outside the projection of the rod.

* 1. Calculate the image contrast.
  2. If the scatter signal is modeled as a DC signal plus Poisson noise, how does the CNR change as the scatter increases from zero? Justify your answer with mathematical derivations.

**Question 4.**

The position of a magnetic moment in the rotation frame of a Cartesian coordinator system is shown in the figure below. In the same figure, draw the direction of the B1 field that positions the magnetic moment to the positive x axis (you may ignore the effects of relaxation).

*z*

*y*

*x*

B0

*o*

θ

φ

**Question 5.**

For the following CT images, identify possible sources of image artifacts and discuss artifact correction methods.

1. 
2. 
3. 

**Question 6.**

Consider a 2D parallel-beam CT reconstruction problem with projections covering rotation angles of 180 degrees. If a filter of (instead of the ramp filter, ) is used in the filtered-backprojection reconstruction with other steps unchanged, describe the effects of this filter on the reconstructed image. (Hint: use the central-slice theorem to analyze.)