GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff School of Mechanical Engineering

Ph.D. Qualifiers Exam – Fall Semester 2010

Day 3: Imaging
EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

- Please sign your name on the back of this page—

Georgia Institute of Technology

The George W. Woodruff School of Mechanical Engineering
Nuclear & Radiological Engineering/Medical Physics Program

Ph.D. Qualifier Exam

Fall Semester 2010

_______________ Your ID Code

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 - Imaging

<u>Answer 4 of the following questions.</u>

Q1. What is the "beam hardening effect" in X-ray CT? How does it affect the CT number and thus the image quality?

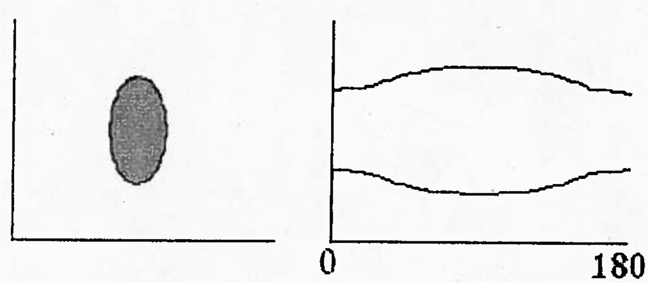
Q2. A thin layer of phosphor is often used as "image intensifying screen" with a X-ray film. How does it work? Discuss how the phosphor changes the x-ray detection efficiency and the image quality in terms of signal-to-noise ratio (SNR) and spatial resolution. Use drawings if necessary.

Q3. **Technetium Generator.** ^{99m}Tc is used in more than 90% of nuclear medicine studies. This radionuclide is produced by an on-site generator. This question examines the technetium generator with three questions.

a. Describe <u>in detail</u> both the radioactive parent-daughter process involved in the technetium generator (include half-lives for each of the radionuclides) and the daily eluting process used to extract ^{99m}Tc from the generator.
b. Assume there exists initially 10^8 atoms of ^{99}Mo in a technetium generator. Determine the number of stable ^{99}Tc produced in 24 hours.
c. In the technetium generator, show mathematically that if $\lambda 2 >> \lambda 1$, then the radioactivities of the parent and daughter nuclei become equal in value at long times.

Q4. **Nuclear Medicine Imaging Quality, Reconstruction and Application to Oncology Imaging.** This question examines image quality associated with nuclear medicine imaging studies (planar and tomographic studies) as well as the its application to oncology imaging. There are three parts.

a. Three parameters which affect the image signal-to-noise ratio (SNR) in nuclear medicine are the thickness of the detector crystal, the length of the lead septa in the antiscatter grid, and the FWHM of the energy window centered around 140 keV. For each parameter, does an increase in the value of the particular parameter increase or decrease the image SNR? In each case, name one other image characteristic (e.g., CNR, spatial resolution) that is affected, and explain whether theis image characteristic is improved or degraded.
b. The following elliptical object is imaged with a corresponding sinogram. Use for questions B1, B2, and B3.



b1. Does 0° correspond to imaging from top to bottom or right to left? Justify.
b2. Assuming the object was rotated by 45° and by 90°, draw the subsequent two sinograms.
b3. If the original object was shifted in the space by a few millimeters to the left but with the same region covered by the imaging system, draw the subsequent sinogram.

c. Describe in sufficient detail the process of integrating a patient's PET/CT imaging study for head-and-neck cancer acquired during diagnosis into the radiation treatment planning process.

Assume the PET/CT study was acquired prior to the radiation treatment simulation and planning process. Address the technical challenges in using the PET imaging study for tumor volume delineation.

Q5. A 2 MHz ultrasound transducer transmits 3 cycles per pulse at a pulse repetition rate of 1000 Hz.

a. What is the temporal pulse duration of the pulse?
b. What is the spatial pulse length of the pulse?
c. What is the approximate axial resolution of this transducer/pulse?
d. If the field of view of this transducer operating in B-mode is defined by a 60° sweep and a depth of 6 cm, what is the maximum refresh rate (frame rate) if the beam width is 2.0 mm at 5 cm. Ignore beam focusing and assume no overlap in beam positions.
e. What could you do to increase the frame rate in d)?

Q6. a. What is the procession frequency of hydrogen protons (ω) at the location x = 3 cm, z = 3 cm, and y = 0 cm (from the iso-center of a magnetic field) when G_x is 40 mTesla/meter, $G_z = G_y$ and B_0 = 0.1 Tesla? The gyromagnetic ratio for hydrogen is (42.6 MHz/Telsa).

b. What RF bandwidth would be needed to excite a 5 mm slice using a slice selection gradient G_z = 20 mTesla/meter?
c. What would be the period (time in msec) of the pulse in c)?
d. What is a disadvantage of using a higher gradient G_z to get a thinner slice? What is a disadvantage of using a narrow bandwidth RF pulse to get a thinner slice?
e. Explain why T1 is always longer than T2.