Georgia Institute of Technology

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

Ph.D. Qualifier Exam

Spring Semester 2012

_______________ Your ID Code

MP Radiation Therapy (Day 3)

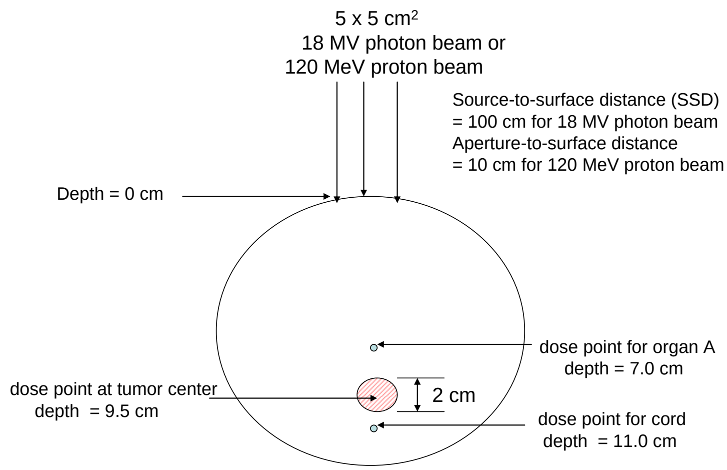
Instructions

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 Radiation Therapy

Answer 4 of the following question.

Q1. Consider a hypothetical clinical case depicted in the following diagram:



Suppose you have options to treat this case either with an 18 MV photon beam or with a 120 MeV proton beam. The treatment goal is to deliver 2 Gy to the target, while minimizing the cord dose. Note that you are **not** allowed to change the beam setup as depicted in the diagram above for the problem. Provide your answers for the following questions:

a. What would be the dose to the organ A from each treatment scenario ?
b. What would be the dose to the cord from each treatment scenario ?
c. Which treatment would provide more uniform dose to the target, 18 MV photon beam or 120 MeV proton beam? Provide the reasoning for your answer. Provide your calculations as well if necessary.

Given:

For 18 MV photon beam, percentage depth doses (PDD) and tissue maximum ratios (TMR) for the 5 x 5 cm^2 are given as:

PDD @ 5 cm = 97.5, PDD @ 10 cm = 79.9, PDD @ 15 cm = 64.5
TMR@ 5 cm = 1.001, TMR@ 10 cm = 0.897, TMR@ 15 cm = 0.786
You may perform a linear interpolation of the above data if necessary.

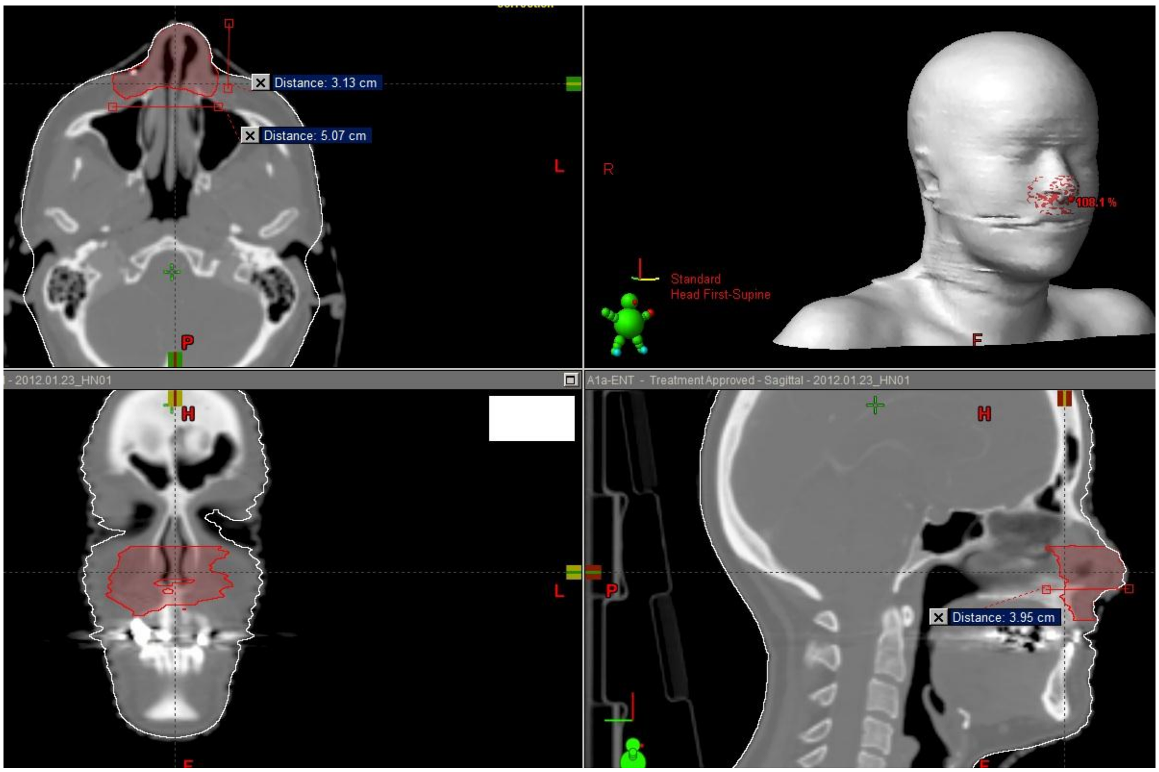
For 120 MeV proton beam, the ratio of dose at the Bragg peak to dose at the entrance is 1.6 and the depth dose curve is approximately flat until the proximal tail of the Bragg peak. The proximal tail starts around 8.5 cm depth. The location of the Bragg peak is around 9.5 cm depth. The full width at half maximum (FWHM) value of the peak is about 0.5 cm. The range of the 120 MeV proton beam is about 10 cm.

Q2. Discuss about *three dimensional conformal radiation therapy* (3-D CRT) and *intensity modulated radiation therapy* (IMRT). You may highlight the rationale/motivation, differences, technical requirements, etc. ***Note:*** *For this problem, you are* ***not*** *expected to discuss specific implementations of IMRT (e.g., SMLC, DMLC, etc.). Instead, you need to highlight 3-D CRT and IMRT in general (as compared to conventional or 1-/2-D radiation therapy).*

NRE/MP Radiation Therapy – Cont'd.

Q3. Write the Bragg Gray formula for dose calculation to a medium as measured by an ion chamber. What are the Bragg Gray conditions? Are these conditions met for all forms of radiation? What is the Spencer Attix formulation of the BG formula? Explain dose calculation from exposure. Compare and contrast dose calculation from exposure to that from Bragg Gray.

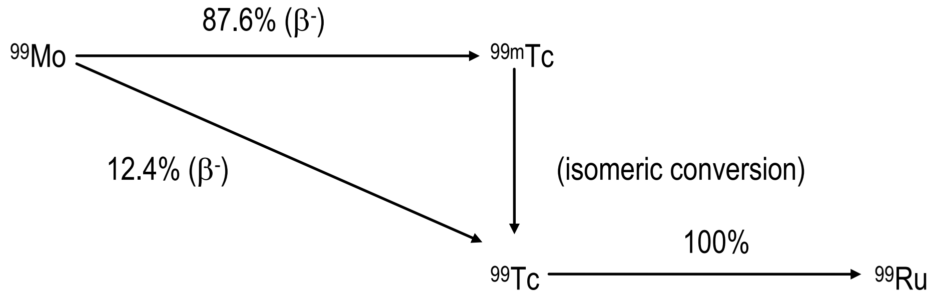
Q4. Discuss the treatment of the following patient (PTV is contoured in red) with a)electrons, b)3D conformal photons and c) IMRT photons. For each technique include energy selection, beam orientation and placement, treatment devices, and immobilization. What is the effect of heterogeneity on the dose distribution? How are the plan qualities evaluated? For the photon calculations discuss forward and inverse planning. How is inverse planning done?



Q5. a. A radiation oncology department is interested in starting a permanent seed prostate brachytherapy program. What is the necessary equipment needed to set up such a program and what are the quality assurance measures needed to be performed? Give specific details.

b. Explain the dose calculation method that is recommended by the AAPM Task group, stating all equations and explanation of each term.

Q6. You are given the following decay scheme and data for this question:



^{99}Mo half-life = 67 hours
^{99m}Tc half-life = 6.02 hours
^{99}Tc half-life = $2.22\text{x}10^5$ years
^{99}Ru is stable

You are a medical physicist who has started a small firm manufacturing medical isotope generators. One of your products is a Mo-99/Tc-99m generator. Your company uses neutron bombardment of Mo-98 to make the radioactive Mo-99 parent for the generator kit. Neutron capture in Mo-98 occurs with a cross section of 0.53 barns (1 barn = 10^{-24} cm^2) and leads to radioactive Mo-99. Exactly, 1.0 μg of Mo-98 is placed in a neutron flux of $2.5\text{x}10^{13}$ neutrons/cm^2/s for 4.0 hours. The radioactive target is immediately removed from the neutron flux.

a. Three hours after removal of the target, what is the activity of the Mo-99 in the target? (Express answer in Ci).

   Emory University has received a shipment of your Mo-99 generator. The shipment contained 1000 mCi of Mo-99 when manufactured. It arrived at the hospital 48 hr after its production. Use this information for parts b and c.

b. If the generator is milked exactly upon arrival at the hospital, how much Tc-99m will be obtained? Assume that 95% of the available Tc-99m is eluted.

c. If the generator is milked 24 hr after the initial milking, how much Tc-99m will be obtained?

   After injecting the patient, a SPECT image exam was performed on the patient. After acquiring the image profiles, a SPECT image needs to be reconstructed from these image profiles. For parts d and e, please use this information.

d. Explain the iterative reconstruction technique known as mulitplicative ART.

e. (Apply multiplicative ART for only one complete iteration to the following image matrix with six ray sums. (Hint: Start with all 1's). Show each step in box form.

10	13	18	
?	?	?	16
?	?	?	14
?	?	?	11