Georgia Institute of Technology

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

Ph.D. Qualifier Exam

Spring Semester 2008

_____ Your ID Code

Medical Physics (Day 3)

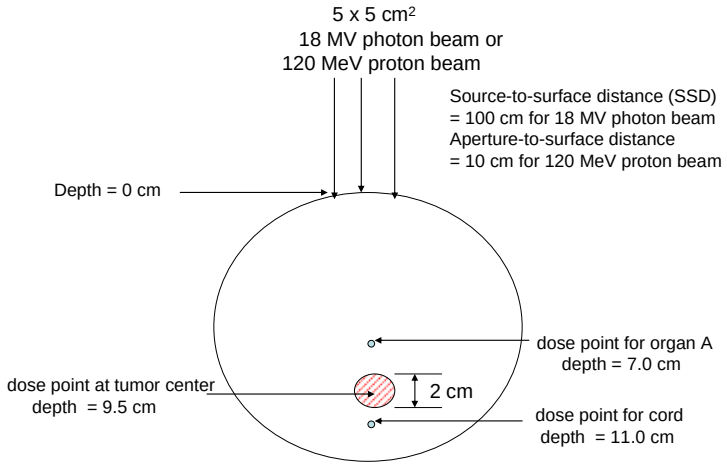
Instructions

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 Physics

Answer 4 of the following question.

1. 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. Please try to 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.

2. Describe the concept of "linear-quadratic model ($E=\alpha D+\beta D^2$)", and how it is applied to obtain effective doses in radiotherapy. What are the typical values of α/β for tumors, early reaction tissues, and late reaction tissues? What does it mean for a tissue having a high or low value of α/β?

3. PET Imaging (A-C):
   a. Describe the fundamentals of PET imaging including mode of decay, method of operation and equipment used.
   b. Explain the "time of flight" design for PET imaging.
   c. List and describe three real world effects that limit the performance of PET or require that corrections be made.

4. Emission tomographic image reconstruction:
   The following 3x3 image representation with the horizontal and vertical projection data (2x3 sinogram) is obtained from the gamma camera. This may be used for problems in this question.

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

   a. Explain and apply backprojection reconstruction for image matrix with 2x3 sinogram. Show each step in block form.
   b. Explain and apply <u>multiplicative</u> algebraic reconstruction technique (ART) for only one complete iteration to the image matrix with 2x3 sinogram. Show each step in box form.
   c. Explain and apply <u>additive</u> ART for only one complete iteration to the image matrix with 2x3 sinogram. Show each step in box form.

5. In the AAPM Task Group 51 the dose to water at 10 cm depth due to a photon beam is given by the following equation:

$$D_w^Q = Mk_Q N_{D,w}^{^{60}Co}$$

   where $M = P_{ion} P_{TP} P_{elec} P_{Pol} M_{raw}$

   Describe the measurement setup for the determination of absolute dose. Explain in detail the purpose of each of the factors in the equation and the method and/or equation to determine its value. If the value is supplied by another, how is its value determined? How and why does the setup differ for the measurements to determine k_Q? When and why is a lead sheet used?

6. Explain in detail the method(s) of energy deposition of a 6MV linac produced photon beam with a patient being treated for lung cancer. What factors determine the probability of interaction and where the energy will be deposited?