Georgia Institute of Technology

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

Ph.D. Qualifier Exam

Fall Semester 2007

_______________ Your ID Code

Medical Physics (Day 3)

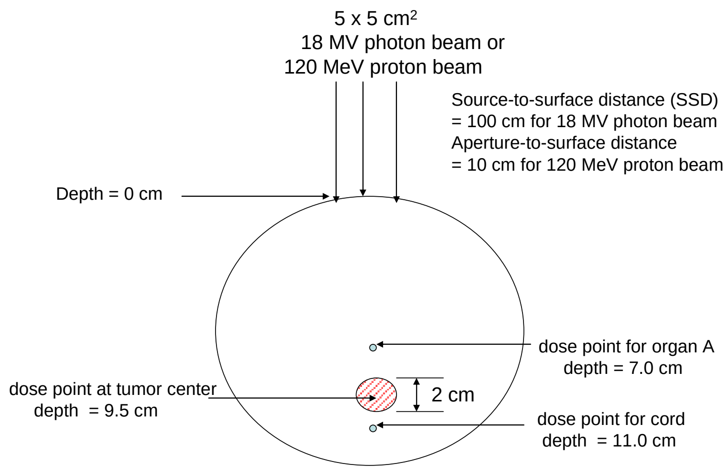
Instructions

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 problems from 1) through 3). Please try to provide your answers for the following questions:

1. What would be the dose to the organ A from each treatment scenario?
2. What would be the dose to the cord from each treatment scenario?
3. 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.
4. If the dose uniformity within the target is not satisfactory (e.g., minimum and maximum doses within the target deviate from the target dose more than 20%), what would you do to improve it for each treatment scenario? Note you may now alter the treatment setup depicted in the diagram. You may also apply existing and/or new techniques to accomplish your goal here.

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.

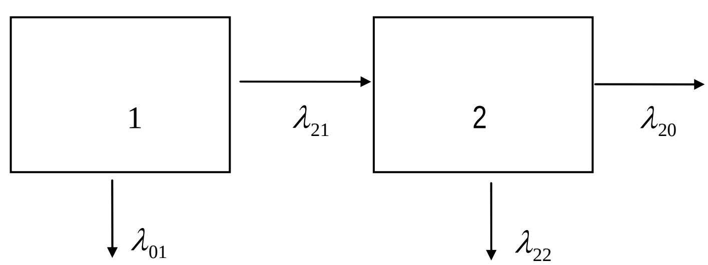
For 120 MeV proton beam, the ratio of dose at the Bragg peak to dose at the entrance is 1.6 and the depth dose curve is approximately flat until the proximal tail of the Bragg peak. The proximal tail starts around 8.5 cm depth. The location of the Bragg peak is around 9.5 cm depth. The full width at 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. A 9 MeV photon enters a volume V and undergoes a Compton interaction which produces a 1 MeV scattered photon and an electron with kinetic energy 8 MeV. The electron produces a bremsstrahlung x-ray (2 MeV) before leaving V with a 3 MeV of remaining kinetic energy. The 2 MeV bremsstrahlung x-ray undergoes a Compton interaction which produces a 1 MeV scattered photon and an electron with kinetic energy of 1 MeV, and this electron deposits all of its energy within V. Note the Compton-scattered photons escape from V. Determine the following within V (Show your work):

   a) the energy transferred
   b) the net energy transferred
   c) the energy imparted

3. An experiment is designed to measure the flow of a radionuclide from one organ to another. A well-known scientist has designed a model to test her theories. Part of the model is given below in block form. The scientist asks you to calculate the time (in minutes), if any, when compartment 1 concentration equal concentration in compartment 2. The following data is provided:

   $C_1(t=0) = 100\ \mu l$ and $C_2(t=0) = 10\ \mu l$ (where C represents the amount of concentration)
   Rate of transfer constants:
   $\lambda_{01} = 0.065\ min^{-1}$
   $\lambda_{21} = 0.0347\ min^{-1}$
   $\lambda_{20} = 0.5331\ hr^{-1}$
   $\lambda_{22} = 0.3465\ hr^{-1}$



4. Gamma camera collimator:

   a.) Calculate the magnification/minification factor (I/O) for the following collimator types: parallel hole, converging hole, diverging hole

   The following data should be used:
   collimator thickness = 2 cm
   object to collimator distance = 25 cm
   distance from the collimator face to convergence point = 45 cm

   b.) For converging and diverging hole collimators, if the source (or object) to collimator distance increases, qualitatively describe what happens to (a) field of view, (b) sensitivity, (c) spatial resolution of the system.

c.) Calculate the septal thickness for a lead parallel hole collimator having hole diameters 0.25 cm and lengths of 2.5 cm. The collimator septa should attenuate at least 95% of the radiation. The mass attenuation coefficient for lead is 1.89 cm^2/g, and density of lead is 11.3 g/cm^3.

5. 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?

6. A TAR or a PDD can be used to calculate the correct timer setting for a Co-60 treatment unit. Explain what a TAR and a PDD are and the method for obtaining each. What is the relationship between the two? What advantages or disadvantages do they have? Can both be used for a 6MV photon beam? What is the equation that would be used to calculate the Co-60 timer setting?