NERS555: Introduction to Radiological Physics and Radiation Dosimetry
Assignment 5 Fall 2018

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Due: November 15, 2018, before class starts

1. Consider a slab of water, thickness t, that is optically thin to photons, and thin to electrons. The slab is irradiated by 20 MeV electrons at normal incidence.

   (a) Recalling the discussion in class, describe in detail, what "thin" means for both electrons and photons.

   (b) i. Find the dose deposited in the slab in the form of an equation and state all your assumptions.

   ii. Without resorting to data tables or figures not given in the notes, provide approximate numerical answers for the energy deposited in the slab, per each incident electron, assuming the slab is 1.0 cm thick. You should discuss the effects, if any, of electron scatter, δ generation and transport, electron absorption in the slab. You may ignore bremsstrahlung production. Quote your results to the appropriate number of significant digits.

   iii. What would the fluence have to be to make the dose in the slab equal to 2.0 Gy?

   (c) Some bremsstrahlung photons are created in the slab. How can you account for the dose that results from the creation of bremsstrahlung in the thin slab? Recall that photons do not deposit does directly. Only the electrons set in motion by them deposit dose.

2. With the same is slab now irradiated by photons of 1 MeV rather than 20 MeV electrons. Estimate the dose deposited in the slab. If you make an approximation of any nature, describe and justify it in some detail. You would benefit by consulting your results obtained in Assignment 2 as well as the factors you mentioned in the last part of the previous question.

   There is no need to evaluate this numerically yet. We shall leave that to the next problem.

3. Combine your results of the previous two problems, however, the incident fluence of the photons (1 MeV monoenergetic) is 100 times greater than the incident electron fluence (20 MeV monoenergetic).

   (a) How thick must the slab be to make the dose from incident photons equal to the dose from incident electrons? Is this value of t still "thin"? Explain.

   (b) Find a thick-slab solution for equal dose with the same irradiation conditions. Why does there have to be one?

4. Sketch a representative central axis depth dose profile that one would obtain from a measurement of dose due to a megavoltage, broad beam of monoenergetic electrons. On the plot identify all the following features, and explain each of them in a sentence or two.

   (a) Surface dose. Provide an expression for it.

   (b) Surface dose, under the assumption of δ-ray equilibrium. Provide an expression for it.

   (c) δ-ray buildup region.

   (d) Depth of onset of δ-ray quasi-charged particle equilibrium.

   (e) The fluence "hump".

   (f) Region of particle loss.

   (g) Energy-range straggling.

   (h) Bremsstrahlung tail. Provide an approximate mathematical form for it.

   (i) What does "broad beam" mean? How would the plot change if the beam was not "broad"?

5. Sketch a representative central axis depth dose profile that one would obtain from a measurement of dose due to a megavoltage, monoenergetic photons. Overlay, on top of this plot, the dose one would calculate in the collision kerma approximation. On the plot identify all the following features, and explain each of them in a sentence or two.

   (a) Surface dose. Why is the surface does not zero?.

   (b) Buildup region. Explain the shape qualitatively.

   (c) Peak region. What determines the depth of the peak dose?

   (d) Fall off region. Explain the shape, and provide an approximate mathematical form.

   (e) Region of transient charged particle equilibrium.

   (f) Explain the offset between the dose and collision kerma in the region of transient charged particle equilibrium.

6. **extra credit** Two thick-walled, air-cavity ionization chambers, identical in all respects except for the wall material (Lead in one case, Aluminum in the other) are placed in a spatially uniform, monoenergetic 1 MeV photon beam.

   Assume that the irradiation conditions are such that you may consider there to exist a state of charged-particle equilibrium (CPE) in the chambers. Two measurements are performed and the dose to the sensitive material is measured for both chambers. What range of values should you expect for a measurement of the ratio of the dose to the sensitive material in the Lead chamber to the dose to the sensitive material in the Aluminum chamber?

   You may assume that the charged particle spectrum in the sensitive material is comprised of monoenergetic 500 keV electrons.

   You should employ the data in the NIST databases (now linked to, on the course main web page).