1. A boundary region between carbon and aluminum media is traversed by a fluence of \(4.10 \times 10^{11}\) electrons/cm\(^2\) with energy of 12.5 MeV. Ignoring delta rays and scattering, what is the absorbed dose \(D_c\) in the carbon adjacent to the boundary, and what is the dose ratio \(D_{Al}/D_c\), given the collisional stopping power of 12.5 MeV electrons in C and Al is 1.769 MeV cm\(^2\)/g and 1.658 MeV cm\(^2\)/g respectively?

The dose in carbon is given by the energy fluence multiplied by the collisional stopping power, or

\[
D_c = 4.10 \times 10^{11} \text{ electrons/cm}^2 \times 1.769 \text{ MeV cm}^2/\text{g} \\
= 7.253 \times 10^{11} \text{ MeV/g} \times 1.602 \times 10^{-13} \text{ J/MeV} \times 10^3 \text{ g/kg} \\
= 116.2 \text{ J/kg} \\
= 116.2 \text{ Gy}
\]

The dose ratio \(D_{Al}/D_c\) is equal to the ratio of the collisional stopping powers:

\[
D_{Al}/D_c = \frac{1.658}{1.769} = 0.937
\]

2. A small air-filled cavity has copper walls with thickness equal to the maximum electron range. The cavity volume is 0.100 cm\(^3\), the air density is 0.001293 g/cm\(^3\), and a given gamma ray exposure generates a charge (either sign) of \(7.00 \times 10^{-10}\) C.

a) What is the average absorbed dose in the cavity air?

The exposure in the cavity is the charge collected divided by the mass of air. The mass of the air is given by

\[
m = \rho V \\
= 0.001293 \text{ g/cm}^3 \times 0.100 \text{ cm}^3 \times 10^{-3} \text{ kg/g} \\
= 1.293 \times 10^{-7} \text{ kg}
\]

The exposure in the cavity is then given by

\[
X = \frac{Q}{m} \\
= \frac{7.00 \times 10^{-10} \text{C}}{1.293 \times 10^{-7} \text{kg}}
\]
Converting this to Roentgens by dividing by $2.58 \times 10^{-4}$, we get

$$X = 2.098 \times 10 = 21.0 \text{ R}$$

Converting exposure to dose in air, we multiply exposure by 0.876 cGy/R, so

$$D = 0.876 \text{ cGy/R} \times 21.0 \text{ R}$$

$$= 18.4 \text{ cGy}$$

$$= 0.184 \text{ Gy}$$

b) Apply Bragg-Gray theory to estimate the absorbed dose in the adjacent copper wall assuming a mean energy of 0.45 MeV for the cavity-crossing electrons, given the collision stopping power of 0.45 MeV electrons in air and Cu is 1.845 MeV cm$^2$/g and 1.402 MeV cm$^2$/g respectively?

To estimate the absorbed dose in a medium, we need to multiply the absorbed dose in air by the ratio of the collisional stopping powers of electrons in the medium to that of air, so

$$D_{\text{Cu}} = \frac{(S/\rho)_{\text{Cu}}}{(S/\rho)_{\text{air}}} D_{\text{air}}$$

$$= 0.184 \frac{1.402}{1.845}$$

$$= 0.1398 \text{ Gy}$$

c) Suppose the mean electron energy is in error by 34% and should have been 0.65 MeV. Redo part (b). What is the resulting percentage error in $D_{\text{Cu}}$, given the collision stopping power of 0.65 MeV electrons in air and Cu is 1.725 MeV cm$^2$/g and 1.312 MeV cm$^2$/g respectively?

In this case

$$D_{\text{Cu}} = 0.184 \frac{1.312}{1.725}$$

$$= 0.1399 \text{ Gy}, \text{ an error of } < 0.1\%$$