Fundamentals of Nuclear Engineering and Radiological Protection

4.5/6

RADIOLOGICAL PROTECTION: QUANTITIES AND UNITS

Group Short Assignment

Group 2

27/10/2014

The aim of this assignment is to introduce the quantities and units used in the radiological protection and be an approach to the different equations used to measure the effect of the radiation in the human body.

The corresponding exercises to our group are:

Group	Exercises
1	1,2,5
2	1,3,5
3	2,4,5
4	1,5,6
5	3,4,5
6	4,5,6

1. A point source of Co-60 gamma rays emits equal numbers of photons of 1.17 and 1.33 MeV, giving a flux density of 5.7 10 9 photons/cm 2s at a specified location. What is the energy flux density there, expressed in erg/cm 2 s and J/m 2 min?

3. A 10 MeV gamma-ray enters a volume V and undergoes pair production, thereby disappearing and giving rise to an electron and positron of equal energies. The electron spends half its energy in collision interactions before escaping from V. The positron spends half of its kinetic energy in collisions in V before being annihilated in flight. The resulting photons escape from V. Determine the energy imparted and the energy transferred.

5. A worker received the following mean absorbed doses in different organs:

   a. Stomach: 200 mGy due to alphas, 20 mGy due to photons and electrons.
   b. Liver: 2 mGy due to alphas, 10 mGy due to photons and electrons.

Calculate the equivalent dose in the stomach and the liver, and the corresponding effective dose. Assume that the dose in other organs was negligible.

① Co-60 gamma rays   photons 1,17 and 1,33 MeV $\Phi_T = 5,7 \cdot 10^9$ ph. /cm²·s

$$\Psi = \frac{dR}{da} \xrightarrow[\text{mono } E]{} \Psi = E \cdot \Phi \xrightarrow[2\,ph]{} \Psi_T = \Psi_1 + \Psi_2 = E_1 \cdot \frac{\Phi_T}{2} + E_2 \cdot \frac{\Phi_T}{2}$$

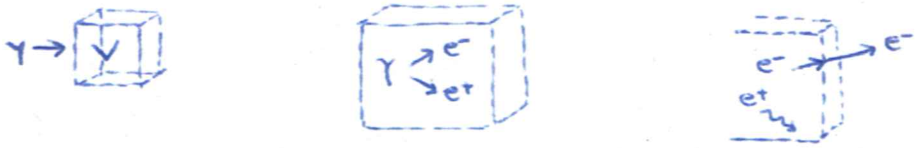
$$\boxed{\Psi_T} = (E_1 + E_2) \cdot \frac{\Phi_T}{2} = (1,17 + 1,33) \cdot 10^6 \text{ [eV]} \cdot \frac{5,7}{2} \cdot 10^9 \text{ [ph/cm}^2 \cdot \text{s]} = \boxed{7,125 \cdot 10^{15} \text{ eV/cm}^2 \cdot \text{s}}$$

$$\boxed{\Psi_T} = 7,125 \cdot 10^{15} \frac{\cancel{eV}}{\cancel{cm^2} \cdot \cancel{s}} \times \frac{1,602177 \cdot 10^{-19} \text{ J}}{1 \cancel{eV}} \times \frac{10^4 \cancel{cm^2}}{1 \text{ m}^2} \times \frac{60 \cancel{s}}{1 \text{ min}} = \boxed{684,93 \text{ J/m}^2 \cdot \text{min}}$$

② 10 MeV gamma-ray   pair production giving an e^- and e^+ $E_{e^-} = E_{e^+}$

We define 3 states:

Beginning (1)   Inside (2)   Out (3)



e^- energy $E_{e^-}^{(1)} = \frac{10}{2} = 5$ MeV $E_{e^-}^{(2)} = E_{e^-}^{(1)}/2$ $E_{e^-}^{(3)} = E_{e^-}^{(2)}$

$E_{e^-}^{(2)} = 2,5$ MeV $E_{e^-}^{(3)} = 2,5$ MeV

e^+ energy $E_{e^+}^{(1)} = \frac{10}{2} = 5$ MeV $E_{e^+}^{(2)} = E_{e^+}^{(1)} - \frac{E_{ke^+}}{2}$ (*)   —

$E_{e^+}^{(2)} = 2,5$ MeV

(*) Calculation $m_0 = m_{e^+} = m_{e^-}$ $E = E_{e^+}^{(1)}$ $E_k = E_{ke^+}$

$$E = \gamma \cdot m_0 \cdot c^2 \rightarrow \gamma = E / m_0 c^2$$

$$E_k = E_0 (\gamma - 1) \underset{E_0 = m_0 \cdot c^2}{=} m_0 \cdot c^2 \cdot (\gamma - 1) = m_0 c^2 \cdot \left(\frac{E}{m_0 c^2} - 1\right) = E - m_0 c^2$$

$$E_{2^+}^{(2)} = E_{e^+}^{(1)} - \frac{E_{e^+}^{(1)} - m_{e^+} c^2}{2} = \frac{2E_{e^+}^{(1)} - E_{e^+}^{(1)} + m_{e^+} c^2}{2} = \frac{E_{e^+}^{(1)} - m_{e^+} \cdot c^2}{2}$$

$$E_{2^+}^{(2)} = \frac{5 \cdot 10^6 - (9,109 \cdot 10^{-31} \cdot (299792458)^2)}{2} = 2,5 \text{ MeV}$$

Now we can determine the energy imparted and the energy transferred:

$$E_{imp} : \dot{E} = (R_{in})_u - (R_{out})_u + (R_{in})_c - (R_{out})_c + \cancel{\Sigma Q}^{\,0} \text{ (elastic process)}$$

$R_{in\,u} = \gamma_e = 10$ MeV $R_{in\,c} = 0$

$R_{out\,u} = E_{e^+}^{(2)} = 2,5$ MeV $R_{out\,c} = E_{e^-}^{(3)} = 2,5$ MeV

$$\boxed{E_{imp} = 10 - 2,5 - 2,5 = 5 \text{ MeV}}$$

$$\boxed{dE_{tr} = (R_{in})_u - (R_{out})_u^{nonr} + \cancel{\Sigma Q}^{\,0} = 10 - 2,5 = 7,5 \text{ MeV}}$$

(5) Worker: stomach 200 mGy α, 20 mGy ph. and e^-
liver: 2 mGy α, 10 mGy ph. and e^-

$$H_T = \sum_R w_R \cdot D_{TR} \qquad w_R = \begin{cases} 20 & \alpha \\ 1 & ph \\ 1 & e^- \end{cases}$$

$$\boxed{H_S} = 20 \cdot 200 \cdot 10^{-3} + 1 \cdot 20 \cdot 10^{-3} = 4{,}02 \text{ Gy} = \boxed{4{,}02 \text{ Sv}}$$

$$\boxed{H_L} = 20 \cdot 2 \cdot 10^{-3} + 1 \cdot 10 \cdot 10^{-3} = 0{,}05 \text{ Gy} = \boxed{50 \text{ mSv}}$$

$$E_T = \sum w_T \cdot H \qquad w_T = \begin{cases} 0{,}12 & \text{stomach} \\ 0{,}05 & \text{liver} \end{cases}$$

$$\boxed{E_S} = 0{,}12 \cdot 4{,}02 = \boxed{482 \text{ mSv}}$$

$$\boxed{E_L} = 0{,}05 \cdot 0{,}05 = \boxed{2{,}5 \text{ mSv}}$$

As a conclusion we can say that the absorbed doses are more harmful for the stomach than for the liver:

$$\begin{cases} E_S > E_L \\ H_S > H_L \end{cases}$$