Problem-1 (30 points): Give the definitions of the following dose terms and the corresponding conventional and SI units :

(Solution)

a) absorbed dose

① The energy absorbed per unit mass of absorber medium due to radiation exposure.

② Hence, it can be used for any materials including the human body.

③ Units

- conventional unit : rad ≡ "energy of 100 ergs absorbed by a gram of medium"

  ≡ 1 rad = 100 ergs/g

- SI-unit : Gy(gray) ≡ "energy of 1 Joule absorbed by a kilogram of medium"

  ≡ 1 Gy = 1 J/㎏ = 100 rads

b) dose equivalent

① The absorbed dose modified by the biological effectiveness to human due to radiation type and other modifying factors ;

② Units

- conventional unit : rem(roentgen equivalent in man)

  · in case DR(absorbed dose) is given by rad

- SI-unit : Sv(sievert)

  · in case DR is given by Gy ≡ 1 Sv = 100 rems

c) exposure

① The number of ion pairs produced in air by γ- or X- radiation

② Units

- conventional unit : roentgen(R, r)

  ≡ exposure quantity of γ- and x-radiation which produces ion pairs which are equivalent to 1 esu/㎤ of STP air

- SI-unit : Xunit(=C/㎏ of air) ≡ 1 Xunit = 3880 r

Problem-2 (30 points):

a) Neglecting any attenuation by air, calculate the photon flux (photons/sec.cm^2) at the location of 5 meters away from a Co-60 point source of 1 Ci.

b) Calculate the absorbed dose (rad) to a soft tissue if it is placed at the location for 1 hour?

c) What is the corresponding dose-equivalent (rem) if a person stays at the location for 1 hour?

Data: 1 MeV = 1.6x10^{-6} ergs

Half-life of Co-60: $T_{1/2}$ = 5.2 years

Gamma-ray energies emission per nuclear transformation of Co-60:

$E_{\gamma 1}$ = 1.173 Mev (100%)

$E_{\gamma 2}$ = 1.332 MeV (100%)

Mass energy absorption coefficients:

$(\mu_e/\rho)_{tissue}$ = 0.030 cm^2/g for 1.173 MeV gamma

$(\mu_e/\rho)_{tissue}$ = 0.029 cm^2/g for 1.332 MeV gamma

(Solution)

a) $\Phi(r=500cm) = \phi_{v1}(r=500cm) + \phi_{v2}(r=500cm)$

$$= \frac{3.7\times10^{10}\,Bq}{4\pi(500cm)^2}\times1 + \frac{3.7\times10^{10}\,Bq}{4\pi(500cm)^2}\times1$$

= 2.36x10^4 photons/sec · cm^2

b) Absorbed dose rate of air:

$$D(Gy/\sec) = (1.6\times10^{-10})\sum_i \left(\frac{\mu_e(E_i)}{\rho}\right)_{tissue} E_i \phi_i$$

= (1.6x10^{-10})[(0.030x1.173x1)+(0.029x1.332x1)]x1.18x10^4

= 1.39x10^{-7}Gy/sec = 1.39 x10^{-5} rads/sec = 5.01x10^{-2} rads/hr

Hence, if one stays in the radiation field for 1 hr, the absorbed dose by the soft tissue becomes :

∴ D = 5.01x10^{-2} rads/hr x 1hr = 5.01x10^{-2} rads

c) $H = \sum_H D_R w_R N_R$ = 5.01x10^{-2} radsx1x1 = 5.01x10^{-2} rem

Problem-3 (20 points): Find the absorbed dose in the unit of “rad” by air to 1 Roentgen of gamma exposure.

Data: energy required for ionization of dry air: w = 34 eV/i.p.

electron charge; q = 1.6×10^{-19} Coulomb/electron

1 MeV = 1.6×10^{-6} ergs

1 Coulomb = 3×10^{9} esu

(Solution)

Roentgen (R) is defined as the number of ion pairs produced in air by γ- or X-radiation, whose quantity is equivalent to 1 esu per cm^3 of air in the STP (standard temperature and pressure: 0^oC and 1 atm) condition. The air density in STP condition is 1.293×10^{-3} g/cm^3 for your information.

1 R $\equiv$ 1 esu/cm^3 of STP air

$= [(1\ esu/cm^3)/\{(3 \times 10^9\ esu/C)(1.6 \times 10^{-19}\ C/electron)\}]/(1.293 \times 10^{-3}\ g/cm^3)$

$= 1.61 \times 10^{12}$ i.p./g of air

Since the energy required to produce 1 i.p.(ion pair) in air is; w = 34 eV/i.p.,

1 R = $(1.61 \times 10^{12}$ i.p./g of air)(34 eV/i.p.)(10^{-6} MeV/eV)

= 5.48×10^{7} MeV/g(air)

= (5.48×10^{7} MeV/g(air))(1.6×10^{-6} ergs/MeV)

= 87.7 ergs/g(air)

Since 1 rad = 100 ergs/g;

$\therefore$ 1 R = 87.7 ergs/g(air) = 0.877 rads(air)

Prblem-4 (20 points): Calculate the exposure rate (R/hr) at 1 meter away from a Na-24 point source of 1 Ci.

Data: Na-24: $T_{1/2}$ = 14.96 hour

E_γ = 1.369 Mev (100%) & 2.754 MeV (100%)

$(\mu_e/\rho)_{air}$ = 0.027 cm^2/g for 1.369 MeV gamma

$(\mu_e/\rho)_{air}$ = 0.021 cm^2/g for 2.754 MeV gamma

(Solution)

a) The **energy absorption rate** by the medium is given by:

$$\dot{D} = (1.6x10^{-6})\sum_i \left(\frac{\mu_e(E_i)}{\rho}\right)_m E_i\phi_i \qquad \text{ergs/g.sec}$$

where, $(\mu_e(E_i)/\rho)_m$ = mass energy absorption coefficient of medium for photon energy E_i, cm^2/g, $E_i\phi_i$ = energy flux of photon i, $MeV/sec.cm^2$, and $1.6x10^{-6}$ = ergs/MeV

At r cm away from a point source of q (Bq), since the photon flux is given by: $\phi_i = f_i\, q / 4\pi r^2$, the energy absorption rate in the medium becomes:

$$\dot{D} = (1.6x10^{-6})\frac{q}{4\pi r^2}\sum_i \left(\frac{\mu_e(E_i)}{\rho}\right)_m E_i f_i \qquad \text{ergs/g.sec}$$

Hence, the absorbed dose rate of air becomes:

$$\dot{D} = (1.6x10^{-6})\frac{q}{4\pi r^2}\sum_i \left(\frac{\mu_e(E_i)}{\rho}\right)_{air} E_i f_i$$

$$= (1.6x10^{-6})\frac{(1Ci)(3.7x10^{10}tps/Ci)}{4\pi(100cm)^2}[(0.027cm^2/g)(1.369MeV)(1)+(0.021cm^2/g)(2.754MeV)(1)]$$

= $4.47x10^{-2}$ ergs/g.sec

= $4.47x10^{-4}$ rads/sec

= 1.61 rad/hr

Hence, the exposure rate becomes:

$\dot{X}$ (R/hr) = $\frac{1}{0.877}\dot{D}$ (rad/hr-air) = $\frac{1}{0.877}(1.61\ rads/hr)$ = <u>1.84 R/hr</u>