NOTE: I might have missed some formulas! please check

Dose

$N = N_0 e^{-\lambda t}$ no. of radioactive nuclei left after time t

τ - half life
λ - decay constant $\Big\}$ $\lambda = \frac{\ln 2}{\tau}$

activity $Act = \lambda N$ $[Act] = Bq$ disintegrations / s

1 curie (Ci) = 3.7×10^{10} Bq
1 Gray (Gy) = 100 rads = 1 J/kg

1 eV = 1.6×10^{-19} J
1 MeV = 1.6×10^{-13} J

dose rate $DR = \frac{\text{energy / time}}{\text{mass}} = \frac{Act \cdot \text{Energy/decay}}{\text{mass}}$

$= \frac{\text{flux} \times \text{energy / decay}}{\text{density} \times \text{width of body}}$

→ always make sure that units cancel to give $\frac{J}{kg \cdot s} = Gy/s$ (or Gy/d etc)

total dose (committed dose) $D_\infty = \frac{DR_0}{\lambda_{eff}} = \frac{\text{initial dose rate}}{\text{effective } \lambda} = \int_0^\infty DR_0 e^{-\lambda_{eff} t} dt$

$\lambda_{eff} = \lambda_{nuclear} + \lambda_{bio} = \ln 2 \left(\frac{1}{\tau_n} + \frac{1}{\tau_b} \right)$ (λ_{bio}: biological removal constant)

effective half life $\tau_{eff} = \left(\frac{1}{\tau_n} + \frac{1}{\tau_b} \right)^{-1}$

$\frac{\text{no. of particles/s}}{\text{area}}$ = flux : no. of particles passing through unit area per second: φ_0

have material of finite thickness x, with absorption μ

$\varphi_x = \varphi_0 e^{-\mu x}$ flux left in beam after it passes through material

$\varphi = \varphi_0 - \varphi_x = \varphi_0 (1 - e^{-\mu x})$ flux absorbed

$\varphi_0 = \frac{\text{activity}}{4\pi r^2}$, r distance from source (for point source)

rule of thumb: 1 MeV γ/cm·s → DR ~ 2.5 mrads / hr dose after time t $\int_0^t (DR_0) e^{-\lambda_{eff} t} dt$

population P

- no. of deaths due to natural causes $M = 25\% P$ (expected)
- incidence of fatal cancer $= 4 \times 10^{-2} \times$ no. Sieverts $= 4 \times 10^{-4} \times$ no. of rems

no. of deaths from fatal cancer $N = 4 \times 10^{-2} \times$ no. Sv $\times$ P

- actual no. of deaths is $M \pm \sqrt{M}$
  $\sqrt{M}$ is standard error
- if no. of fatal cancer deaths due to recieved radiation N is greater than 3 standard errors, then the radiation is a significant cause.

Target

- single hit single target : surviving cells C_D after a dose D administered to initial no. C_0 is

$$C_D = C_0 e^{-\lambda D}$$

λ: constant determined from experimen, in units of 1/Gy or 1/rad

- sensitive volume $V_s = \frac{\lambda}{2}$ $[V_s] = \mu m^3$ when $[\lambda] = 1/rad$

- RBE relative biological effectiveness

$$= \frac{\text{dose of } \gamma \text{ or X-rays}}{\text{dose of neutrons}}$$ causing same biological effect (eg. 25% cell death)

- Poisson statistics $P(x,m) = \frac{m^x e^{-m}}{x!}$ m : average no. of occurence; x : actual no. of occurence

P(x,m) gives probability of x occurances, when m is the average

eg. $P(0, C_0)$ is probability that all cell die (0 survival) when on average C_0 no. of cells survive.

multi target single hit

probability of survival (no hit) $= 1 - [1 - P(0,m)]^r$
where r = no. of targets
$m = -\lambda D$ (in this case only!)

can approximate above by...
survival fraction $S_F = \begin{cases} 1 & \text{for low dose} \\ r e^{-\lambda D} & \text{for high dose, usually when } S_F < 0.5 \end{cases}$

Heat Engines

efficiency of ideal (Carnot) engine (heat → work)

$$\eta = \frac{\text{Work out}}{\text{heat in}} = \frac{W}{Q_H} = \frac{T_H - T_C}{T_H} = 1 - \frac{T_C}{T_H}$$

↳ the greater the temperature difference (T always in K), the greater the efficiency of heat engine

$W = \eta Q_H$
heat wasted Q_C (or Q_{out}) $= Q_H - W = (1-\eta) Q_H$

for ideal situation have relation $\frac{Q_H}{T_H} = \frac{Q_C}{T_C}$

heat pump (take work → heat) have coefficient of performance
$CP = \frac{Q_H}{W} = \frac{T_H}{T_H - T_C}$
for refrigerator etc $CP = \frac{Q_C}{W} = \frac{T_C}{T_H - T_C}$