Radiation protection rules:

EXTERNAL RADIATION PROTECTION

The three basic methods used to reduce the external radiation hazard are time, distance, and shielding. Good radiation protection practices require optimization of these fundamental techniques.

A. Time

The amount of radiation an individual accumulates will depend on how long the individual stays in the radiation field, because:

Dose (mrem) = Dose Rate (mrem/hr) x Time (hr)

Therefore, to limit a person’s dose, one can restrict the time spent in the area. How long a person can stay in an area without exceeding a prescribed limit is called the "stay time" and is calculated from the simple relationship:

Stay Time = limit(mrem)/ Rate Dose(mrem/hr)

Example: How long can a radiation worker stay in a 1.5 rem/hr radiation field if we wish to limit his dose to 100 mrem?

Stay Time =(100rem/1500mrem/hr)=0.067=4 minutes

B-Distance

The amount of radiation an individual receives will also depend on how close the person is to the source.

1. The Inverse Square Law - Point sources of x- and gamma radiation follow the inverse square law, which states that the intensity of the radiation (*I*) decreases in proportion to the inverse of the distance from the source (*d*) squared:

$I\alpha\ 1/d^2$

This can be rewritten:

$I=K(\ 1/d^2\ )$ where *K* is a constant of unknown value

So, for an intensity I_1 at distance d_1, and another intensity I_2 at distance d_2:

$I_1=K(1/d_1^2)$

$I_2=K(1/d_2^2)$

Now solve for the relationship by eliminating *K*:

$I_1/I_2=(K/d_1^2/k/d_2^2)$

$I_1/I_2=d_2^2/d_1^2$

Or

$I_1d_1^2/I_2d_2^2$

Therefore, by knowing the intensity at one distance, one can find the intensity at any other distance.

Example: The exposure rate one foot from a source is 500 mR/hr. What would be the exposure rate three feet from the source?

I_1= 500 mR/hr

d_1=1 foot

d_2=3 feet

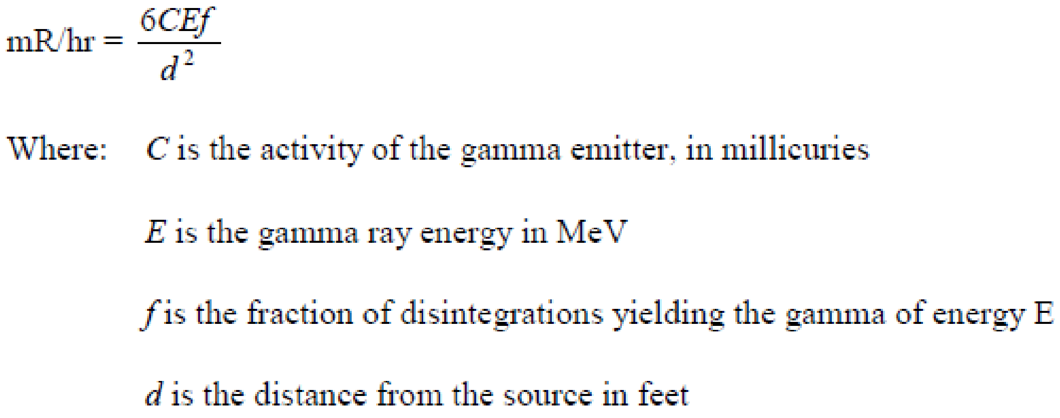
$I_2=I_1d_1^2/d_2^2=(500*(1)^2/(3)^2)=(500/9)=$ 55.6 mR/hr

2-Gamma Constants:

Gamma radiation levels (in R/hr) for one curie of many radionuclides at a distance of one meter have been measured. These gamma constants can be used to determine 1) the expected exposure rate at a given distance (using the inverse square law) for a known quantity of a radionuclide, or 2) the activity of a radionuclide from a measured exposure rate. . To determine the gamma radiation level in R/hr at one meter per curie, or equivalently, mR/hr at one meter per millicurie, you must divide the tabulated gamma constants (Γ) by 10.

3-Gamma Exposure Rate Formula

The exposure rate from a gamma point source can be approximated from the following expression:



$$\text{mR/hr} = \frac{6CEf}{d^2}$$

Where: C is the activity of the gamma emitter, in millicuries

E is the gamma ray energy in MeV

f is the fraction of disintegrations yielding the gamma of energy E

d is the distance from the source in feet

If more than one gamma ray is emitted by the radionuclide of interest, then the contribution from each one must be calculated separately and summed. This expression is accurate to about 20% for gamma emitters with energies ranging from 0.07 MeV to 4 MeV.

C. Shielding

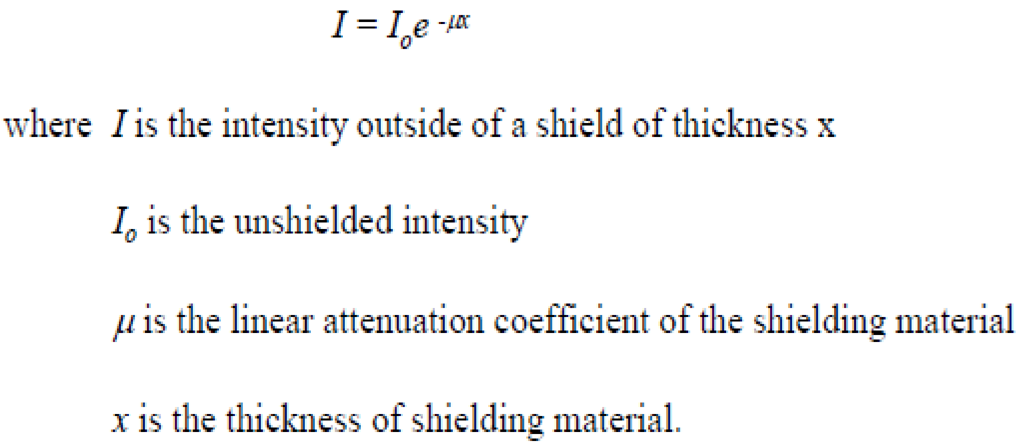
When reducing the time or increasing the distance may not be possible, one can choose shielding material to reduce the external radiation hazard. The proper material to use depends on the type of radiation and its energy.

1. Alpha and Beta Radiation

Alpha particles are easily shielded. A thin piece of paper or several cm of air is usually sufficient to stop them. Thus, alpha particles present no external radiation hazard. Beta particles are more penetrating than alpha particles. Beta shields are usually made of aluminum, brass, plastic, or other materials of low atomic number to reduce the production of bremsstrahlung radiation. The range of beta radiation for various energies in air, plastic and various materials .

2. X and Gamma Radiation

Monoenergetic x- or gamma rays collimated into a narrow beam are attenuated exponentially through a shield according to the following equation:



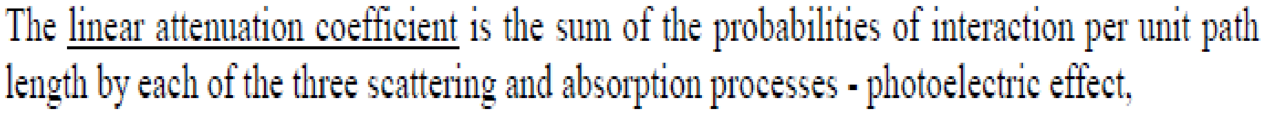
$$I = I_o e^{-\mu x}$$

where I is the intensity outside of a shield of thickness x

I_o is the unshielded intensity

μ is the linear attenuation coefficient of the shielding material

x is the thickness of shielding material.



The linear attenuation coefficient is the sum of the probabilities of interaction per unit path length by each of the three scattering and absorption processes - photoelectric effect, Compton effect, and pair production. Note that μ has dimensions of inverse length (1/cm). The reciprocal of μ is defined as the mean free path, which is the average distance the photon travels in an absorber before an interaction takes place.

Because linear attenuation coefficients are proportional to the absorber density, which usually does not have a unique value but depends somewhat on the physical state of the material, it is customary to use the mass attenuation coefficient, which removes density dependence:

Mass attenuation coefficient $\mu_m = \dfrac{\mu}{\rho}$

where ρ = density (g/cm^3)

For a given photon energy, μ_m does not change with the physical state of a given absorber. For example, it is the same for water whether present in liquid or vapor form. If the absorber thickness is in cm, then μ_m will have units of $\left[\dfrac{\text{cm}^{-1}}{\text{g/cm}^{3}}\right] = \text{cm}^2/\text{g}$.

Values of the mass attenuation coefficient and densities for various shielding materials can be found on pages 46-49 and pages 50-51, respectively.

Using the mass attenuation coefficient instead of the linear attenuation coefficient, the attenuation equation can be rewritten:

$$I = I_o e^{-\mu_m \rho x}$$

3. Half Value Layer

The half value layer (HVL) is the thickness of a shielding material required to reduce the intensity of radiation at a point to one half of its original intensity. It can be calculated by setting $I = \frac{1}{2} I_0$ and solving the attenuation equation for x:

$$0.5 = e^{-\mu x_{1/2}}$$

$$x_{1/2} = -\frac{\ln(0.5)}{\mu}$$

$$x_{1/2} = \frac{0.693}{\mu} = \text{HVL}$$

Half value layers for various shielding materials and selected radionuclides can be found on page 52.

When the HVL is known rather than μ, the total attenuation from *n* half value layers can be calculated by using the following equation:

$$I = \frac{I_0}{2^n}$$