

Production & interaction of X-ray



Central ray:

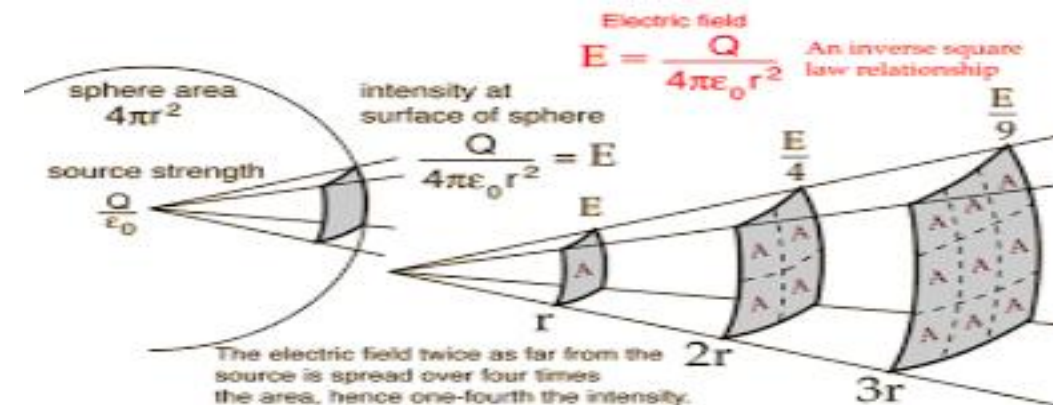
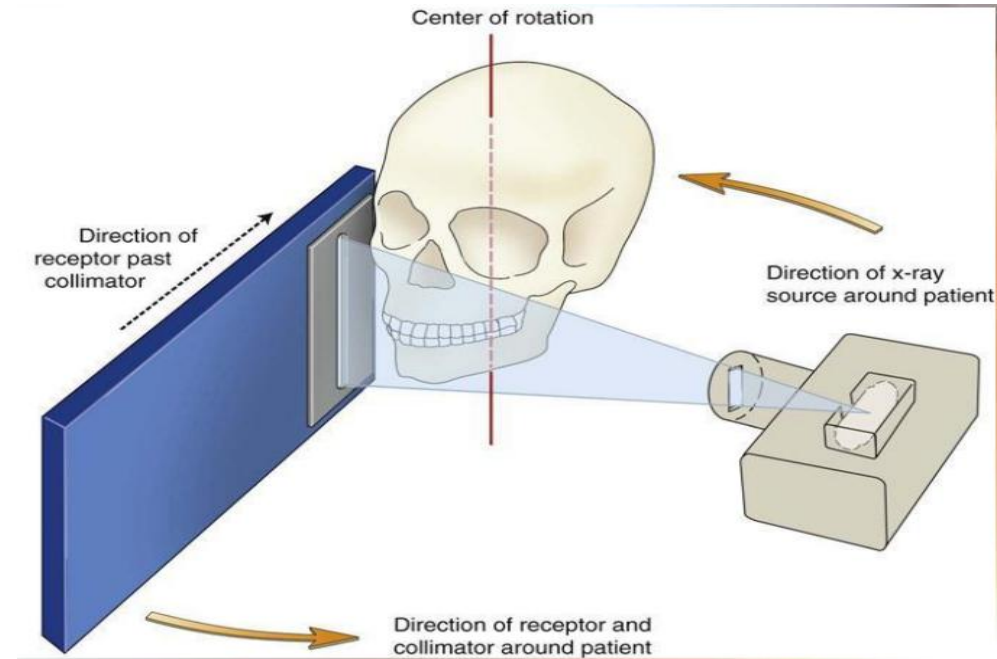
In the beam X – ray photons that traveling in very center of the cone of radiation, called [**central ray**] and this is commonly used to fix and locate the position of X – ray beam.

Inverse square law:

The inverse square law states that for a point source of waves that is capable of radiating omnidirectionally and with no obstructions in the vicinity, the intensity I decreases with the square of the distance, d , from the source

Any point source which spreads its influence equally in all directions without a limit to its range will obey the inverse square law.

This comes from strictly geometrical considerations. The intensity of the influence at any given radius r is the source strength divided by the area of the sphere. Being strictly geometric in its origin, the inverse square law applies to diverse phenomena. Point sources of gravitational force, electric field, light, sound or radiation obey the inverse square law. It is a subject of continuing debate with a source such as a skunk on top of a flag pole; will its smell drop off according to the inverse square law?



Energy conversion to x – ray:-

• X – ray photons result from conversion of kinetic energy of cathode electrons into X – ray photon energy, and this basically accomplished by **2 ways:-**

• **First:-** • Electrons can be brought to stop on the surface of the anode (target) through collision with tungsten atoms of the target giving up all of their **kinetic energy to X – ray photons such photons will be of high energy (short wave length photons).**

• Some of cathode electrons giving up only part of their energy and the resultant X – ray photons have low energy (long wave length photons) and most of X – ray photons are created by this manner.

• **Second:**

• When cathode electrons able to dislodge one or more orbital electrons of tungsten atom.

For example cathode electron must possess more than 69,000 electron volts to dislodge K orbital electron of tungsten atom and this is only occurred when X – ray machine set at **70 Kilovolts** or more. Then after the dislodgment of K electron from its shell an electron from L shell falls into **the empty place of K shell.**

The Inverse Square Law

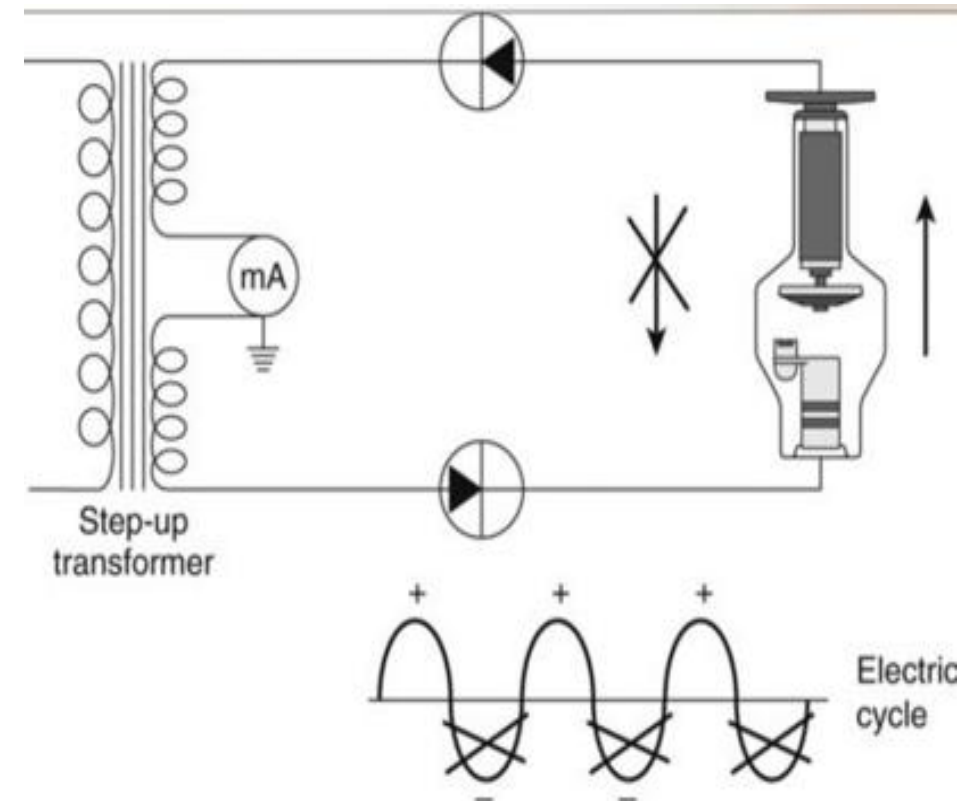
$$\frac{I_1}{(I_2)} = \frac{(d_2)^2}{(d_1)^2}$$

I_1 is the initial intensity of radiation, d_1 is the initial distance, and d_2 is the final distance, and I_2 is the final intensity.

Rectification:

- The main supply to the X – ray machine of **240 volts** has **2 functions**:-
- **A – Generate the high potential difference (kV) to accelerate the electrons across the x – ray tube via the step up transformer.**
- **B – Provide the low – voltage current to heat the filament via the step – down transformer.**
- **However, the incoming 240 volts is an alternating current with typical wave form as shown:-**

- Half of cycle is (+) and other half is (-) but for production of X – ray only the positive half of the cycle can be used to ensure that the electrons from the cathode filament are always drawn towards the anode target.
- Thus, the stepped – up high voltage applied across the X – ray tube needs to be rectified to eliminate the negative half of the cycle.

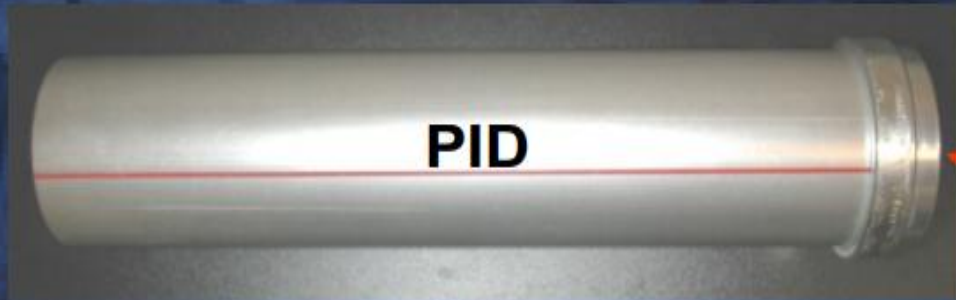


• Filtration:

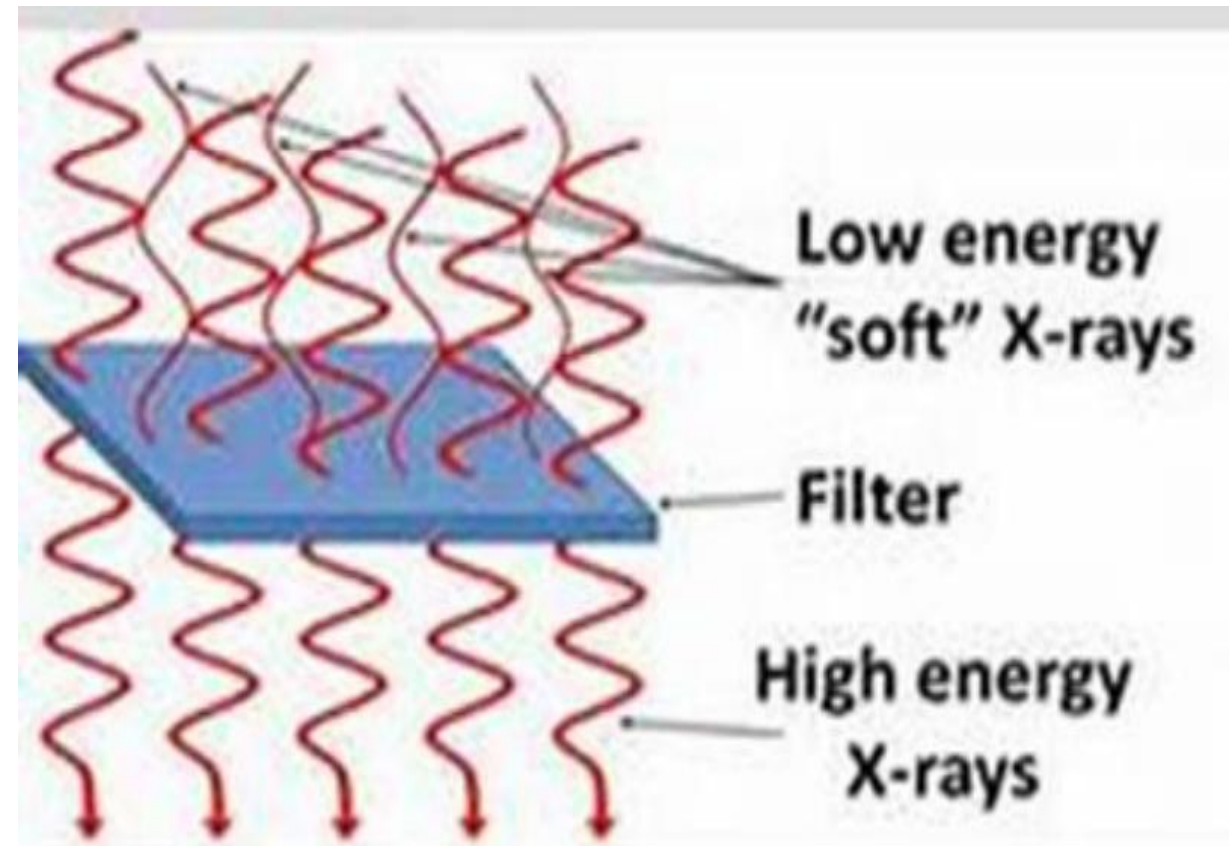
X – ray used in dentistry must be able to penetrate dental hard tissues (teeth and bone).

The longer wave length x-ray (soft X– ray) are not useful in diagnostic radiology thus removal of these long wave length photons from the beam by passing the beam through a filter made from Aluminum, this filter either built into the X-ray machine by manufacturer or added as an extra filter.

The effect of filtration on x – ray beam is absorption of most of long wave length photons (soft X – ray) so the resulting x – ray beam will consist of mainly X – ray photons of short wave length with high energy photons and high penetrating power that's why they named (hard X – ray beam).



The aluminum filter is usually located in the end of the PID which attaches to the tubehead.



Collimation:-

- **Is a process refers to control of size and shape of X – ray beam.** In diagnostic radiography its essential to get the diameter of circular X – ray beam at patients skin surface is not great than 2.75 inches, while for
- **rectangular X – ray beam the dimensions** at the skin should be approximately $1\frac{1}{2} \times 2$ inches.
- Collimation can achieved by one of 2 methods:-

1. Using diaphragms (round or rectangular shape).
2. Using metal cylinders, cones and rectangular tube.



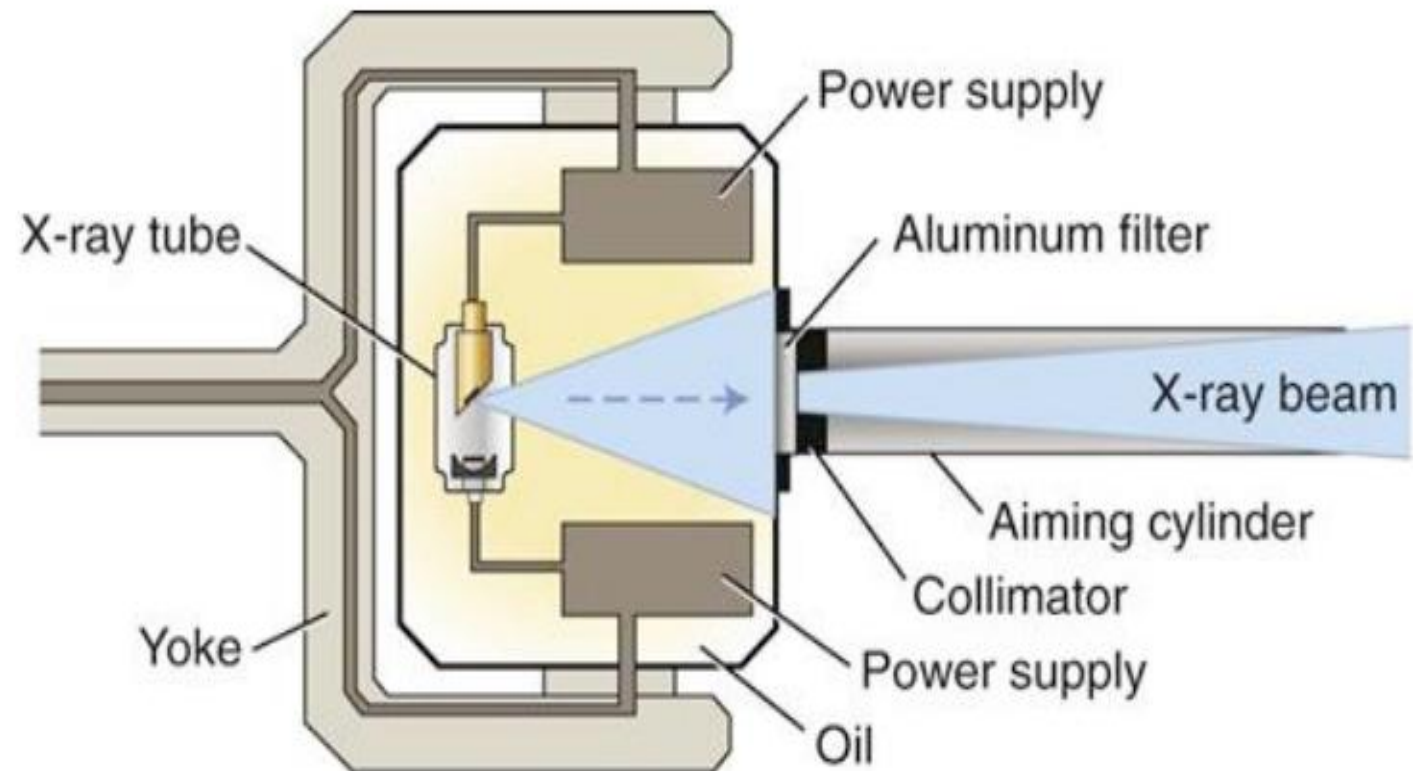
Diaphragm:

- Consists of a metal plate or disk made from lead. A hole is present in the center of the disk allow the beam to pass through it only.
- The shape of X – ray beam determine by the shape of the hole of diaphragm such diaphragm is placed over the opening in the head of X – ray machine.
- X – Ray spectrum:-
- X– Ray beam consist of many photons of different wave length because:
- A - Electrons don't give up all their kinetic energy in identical fashion.
- B – Potential voltage across the X– ray tube changes constantly as the AC voltage varies to DC.
- The minimum photon wavelength means power. **That's why X – ray beam is poly- different wave length.**

Note:- X– ray photon wave length can calculated from this formula:-

$$12.35 / \text{kV} = \text{Minimum photon wavelength in } \text{\AA}^\circ$$

Tube head showing a recessed x-ray tube, components of the power supply, and oil that conducts heat away from the x-ray tube



Definition of terms used in X – ray interaction:-

- **Scattering:** - change in direction of photon with or without a loss of energy.
- **Absorption:** - deposition of energy i.e. removal of energy from the beam.
- **Attenuation:** - reduction in the intensity of X– ray beam caused by absorption and scattering attenuation = absorption + scattering.
- **Ionization:** - removal of an electron from neutral atom.

Absorption of x – ray (interaction with matter):

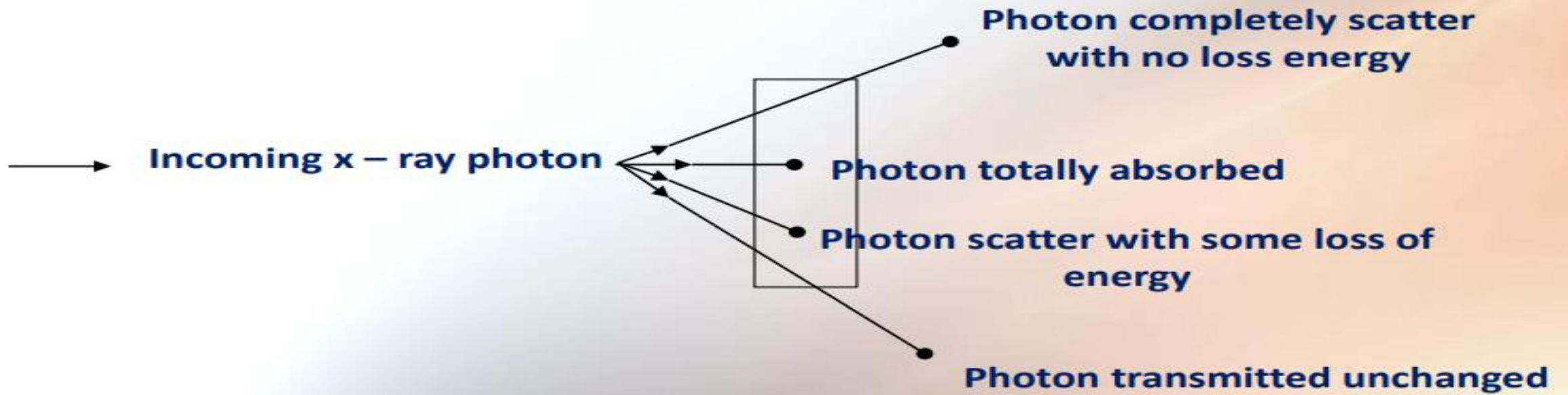
X–Ray are absorbed by any form of matter (**solid, liquid, and gas**) when photons reach an atom, **4 things can happen:-**

1. X – Ray photons can pass through the atom **without change occurred to either.**
2. It can be deviated from its **direction by the atom so the x – ray photon after deviation becomes a photon of scattered radiation.**
3. X – Ray **photon interacts with inner – shell electron** of the tissues atom where the X – ray photon disappears and deposits all its energy this process **is pure absorption.** Now the inner – shell electron is ejected with considerable energy (now **called a photo – electron**) into the tissue for further interaction with other electrons of other tissue atoms.

4. 4. When the X – ray photon interacts with free or loosely bond outer shell electron of tissue atom.

So this high – energy ejected photo electron behaves like the original high energy X – ray photons interact and eject other electrons as it passes through the tissues, these ejected electrons that are responsible for the majority of ionization interactions within the tissue and the possible resulting damage attributable to the X– rays.

- While the remainder of X – ray photon energy is scattered from its original path as **scattered X– ray photon**



Primary radiation:

Radiation emerging from the x – ray machine in form of collimated useful X – ray beam

- **Secondary radiation:**

Radiation result from interaction of primary beam with matter

- **Half – value layer:**

It's a method of monitoring the penetration quality of the X – ray beam.

Determination of half – value layer is done by placing **thin filtering material** such as aluminum filter in front of the beam so we continue increase the thickness of filtering material until we have a thickness that reduce the number of X– ray photons in the beam passing through it to (one half) this will representing a half – value layer for such beam of radiation. • High half value:- layer the high penetrating ability of the beam. In oral diagnosis the acceptable value is approximately 2 mm of aluminum

X- ray measuring:

1• X- ray measuring:-

.Traditional units

- Roentgen:- is the amount of x-radiation or gamma radiation which will produce in one cc of air ions carrying one electrostatic unit of either sign .
- Rad: it is a roentgens absorbed dose
- Rem: it is a roentgens equivalent man dose.
- RBE: is a relative biological effectiveness dose.
- Curie

2. International System of Units (SI system)

***Coulomb per Kilogram (C/Kg)** $1\text{C/Kg} = 3876\text{ R}$ $1\text{R} = 2.58 \times 10^{-4}\text{C/Kg}$

***Gray (Gy):** The gray (Gy) is the SI unit used to measure the energy imparted to irradiated matter and is defined as the absorbed radiation dose of one joule (J) per kg $1\text{Gy} = 100\text{ rad}$ $1\text{rad} = 0.01\text{ Gy}$

***Sievert (Sv)** : the SI unit of dose equivalent (the biological effect of ionizing radiation), equal to an effective dose of a joule of energy per kilogram of recipient mass. $1\text{Sv} = 100\text{rem}$ $1\text{rem} = 0.01\text{Sv}$

***Becquerel (Bq)** : One becquerel is defined as the activity of a quantity of radioactive material in which one nucleus decays per second.

<i>Exposure</i>	<i>Conventional Unit</i>	<i>SI Unit</i>	<i>Conversions</i>
Exposure	roentgen (R)	coulomb/kg of air (C/kg)	$1\text{ C/kg} = 3876\text{ R}$ $1\text{ R} = 258\text{ uC/kg}$
Dose	rad (R)	gray (Gy)	$1\text{ Gy} = 100\text{ rad}$
Dose equivalent	rem	sievert (Sv)	$1\text{ Sv} = 100\text{ rem}$
Activity	curie (Ci)	becquerel (Bq)	$1\text{ mCi} = 37\text{ mBq}$



THANK YOU