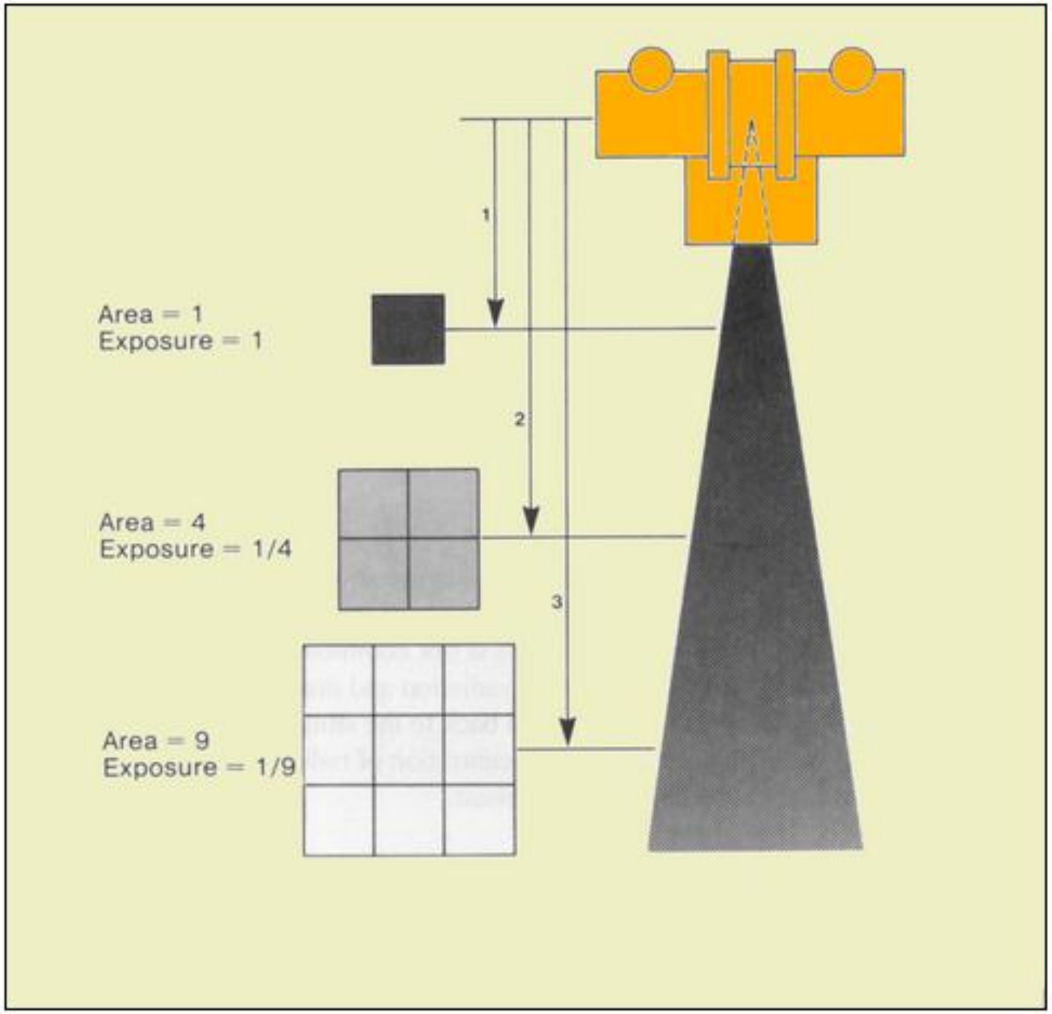
Radiation Quantities

Radiation Units and Conversion Factors

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



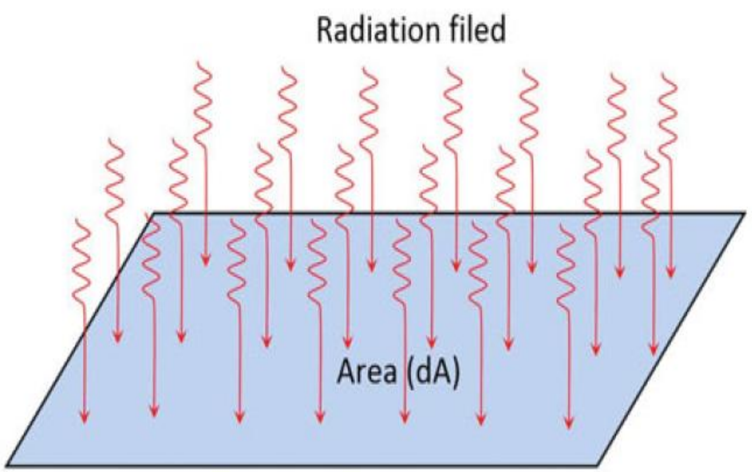
Inverse-Square Effect

Particle fluence (Φ)

- fluence is termed as the flux of radiation particles
- It has units of number of the particles per square meter
- If dN is the number of the particles incident on a cross-sectional area dA

$$\Phi = dN / dA$$

Photon Concentration (Fluence)



Energy fluence (Ψ)

- dR is the radiant energy incident on a sphere of cross-sectional area dA

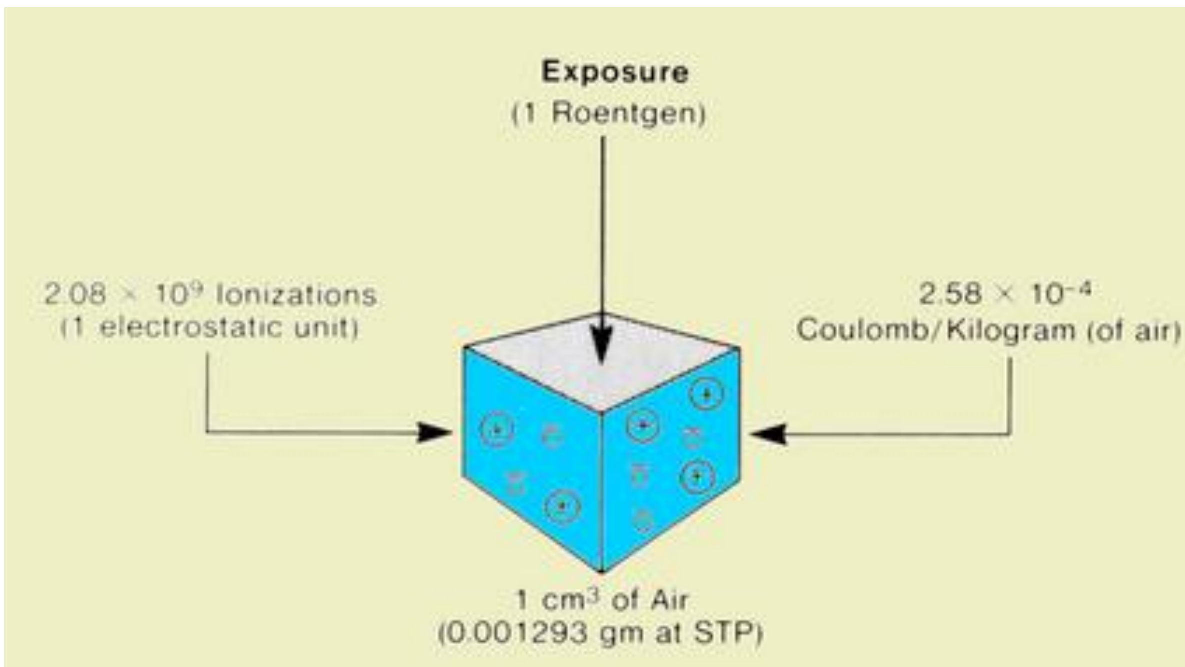
$$\Psi = dR / dA$$

EXPOSURE

- amount of radiation delivered to a point

$$1\ \mathbf{R} = 2.58 \times 10^{-4}\ \mathbf{C/kg}$$

$$1\ \mathbf{C/kg} = 3876\ \mathbf{R}$$



A 60-watt light bulb emits 60 joules/sec of energy (1 Joule/sec == 1 watt). Pretend for a moment that all of this energy is emitted in the form of photons with wavelength of 600 nm (this isn't true, of course -- as a blackbody, a light bulb emits photons of a wide range in wavelengths). Calculate how many photons per second are emitted by such a light bulb.

This problem asks you to calculate how many photons per second are emitted from a 60-watt light bulb.

Since 60 watts is 60 Joules per second, we know that we need enough photons to carry 60 Joules of energy each second.

- So how much energy does one 600nm photon carry? We'll need to use the relation between energy and wavelength

E_{photon} = h c / lambda

= (6.63 x 10^{-34} J s) x (3.00 x 10^{8} m/s)/ 600 x 10^{-9} m

= 3.32 x 10^{-19} J

- OK, so how many of these photons will we need to make 60 Joules? Let's assume we need some number **N** of them. Then,

  60 Joules = N x 3.32 x 10^{-19} J

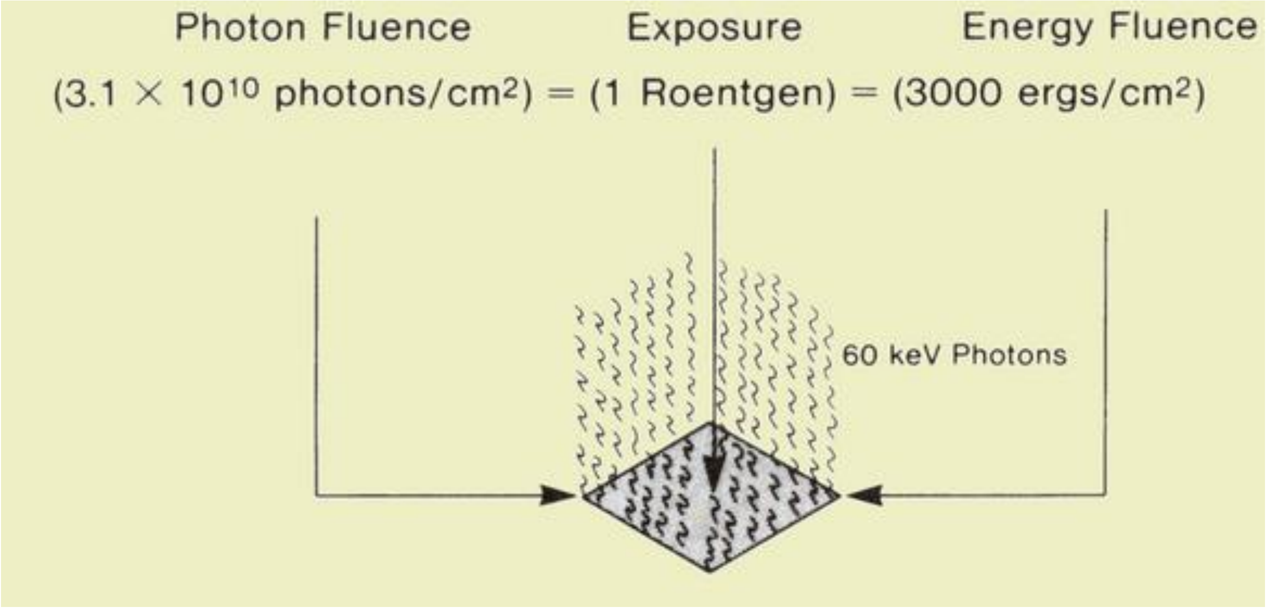
$$N = 60\ \text{J} / 3.32 \times 10^{-19}\ \text{J}$$

$$= 1.8 \times 10^{20}$$

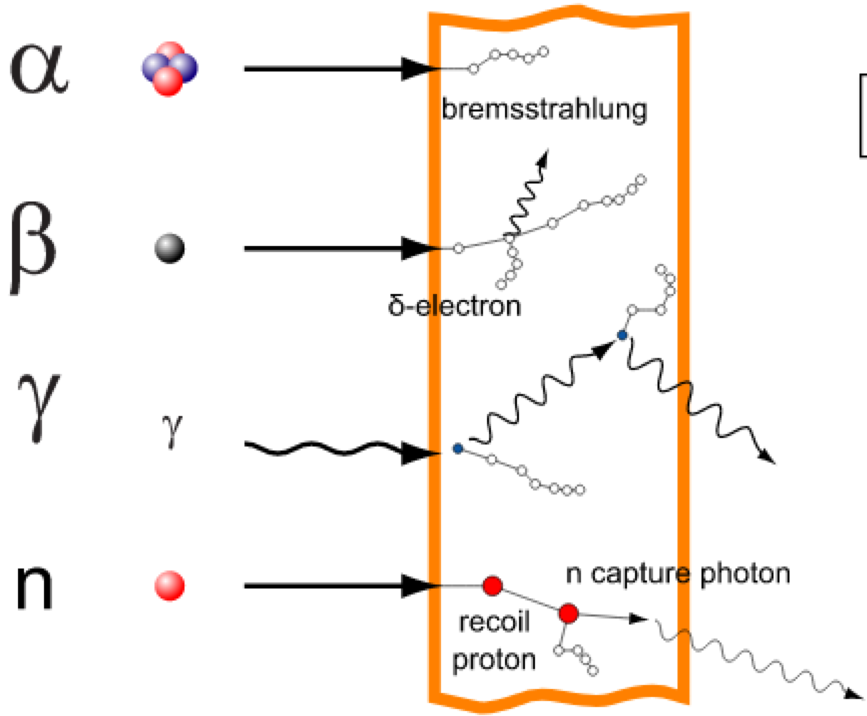
So, in order to emit 60 Joules per second, the light bulb must emit **1.8 x 10^{20} photons per second.**

Relationship between Exposure and Photon Concentration

- **Exposure is a quantity of radiation concentration**
- 1J = $6.241509 \cdot 10^{18}$ eV



Interaction of ionizing radiation with matter



charged particles interact strongly and ionize directly

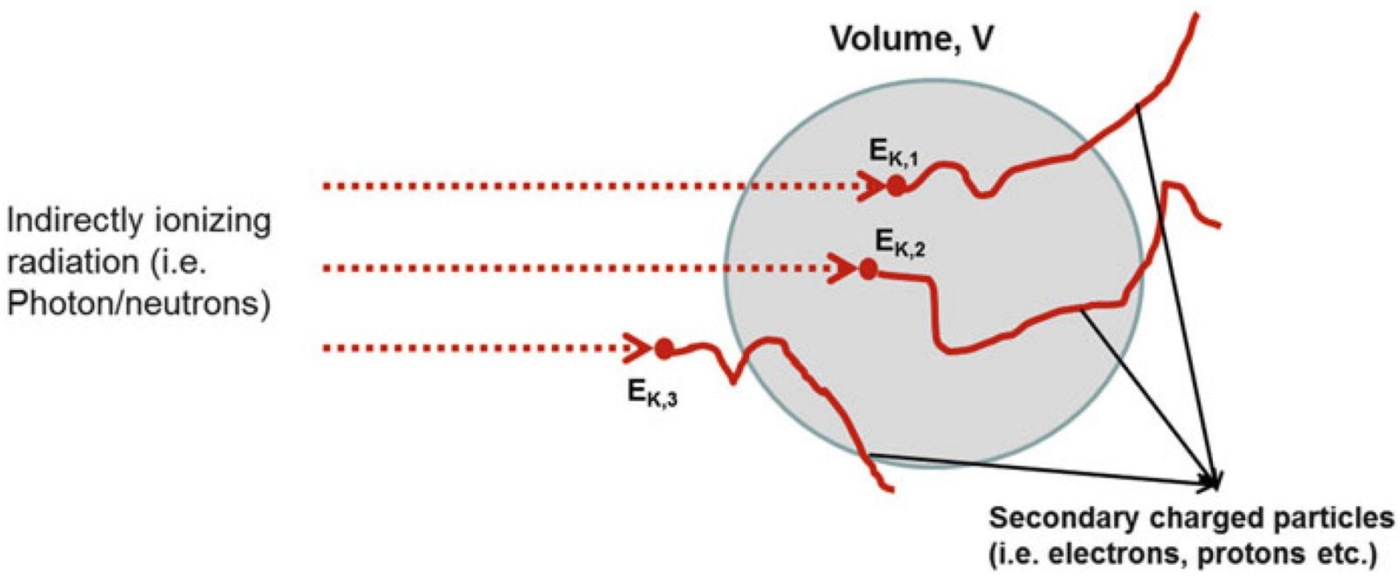
neutral particles interact less, ionize indirectly and penetrate farther

KERMA

- Kinetic Energy Released per unit MAss

- The initial kinetic energy transferred to the primary ionizing particles from indirectly ionizing radiation

- It is measured in joules per kilogram or Gy



The kinetic energy transferred to charged particles may be spent in two different ways

Collisional KERMA

Radiative interaction

The KERMA can be expressed as $K = K_c + K_r$

CEMA

- Converted Energy per unit Mass

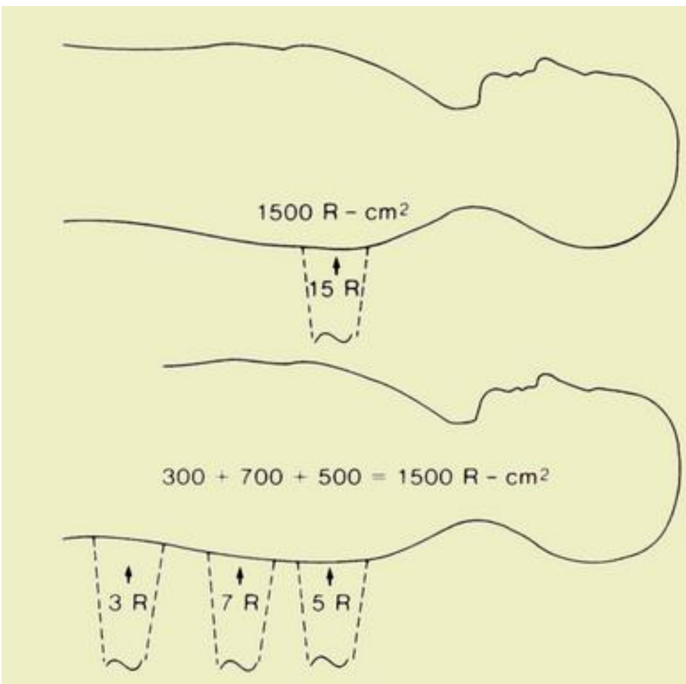
- It is a measure of the energy lost by directly ionizing radiation (i.e., electrons, protons, heavy ion beam etc.)

- It is also measured in joules per kilogram or Gray (Gy)

Surface Integral Exposure (SIE)

- SIE is the product of the exposure in roentgens and the exposure area in square centimeters
- units of roentgens-square centimeters ($R\text{-}cm^2$)
- The significance of SIE is that it describes total radiation imparted to a patient
- whereas exposure indicates only the concentration of radiation at a specified point.

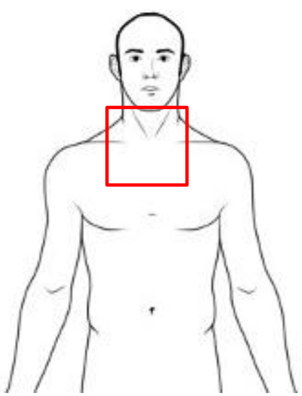
compare exposure (concentration) & SIE (total radiation)

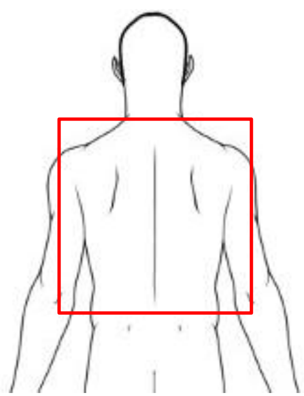


- **the beam area was 10 cm x 10 cm (100 cm^2)**
- **the total exposure time was 5 minutes**
- **an exposure rate of 3 R/min**
- **SIE is 1,500 R- cm^2**

Radiographic Examination

SIE = 100mR x 100 cm^2
= 10 R- cm^2



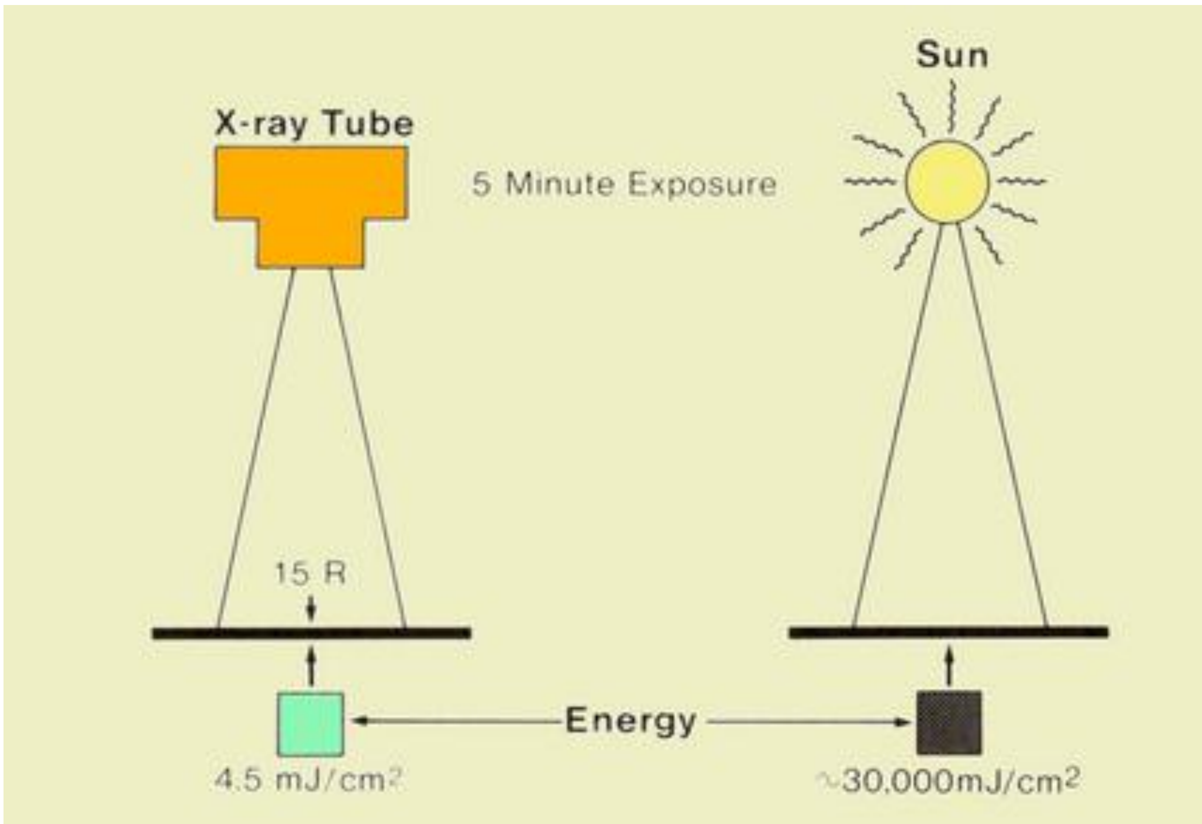


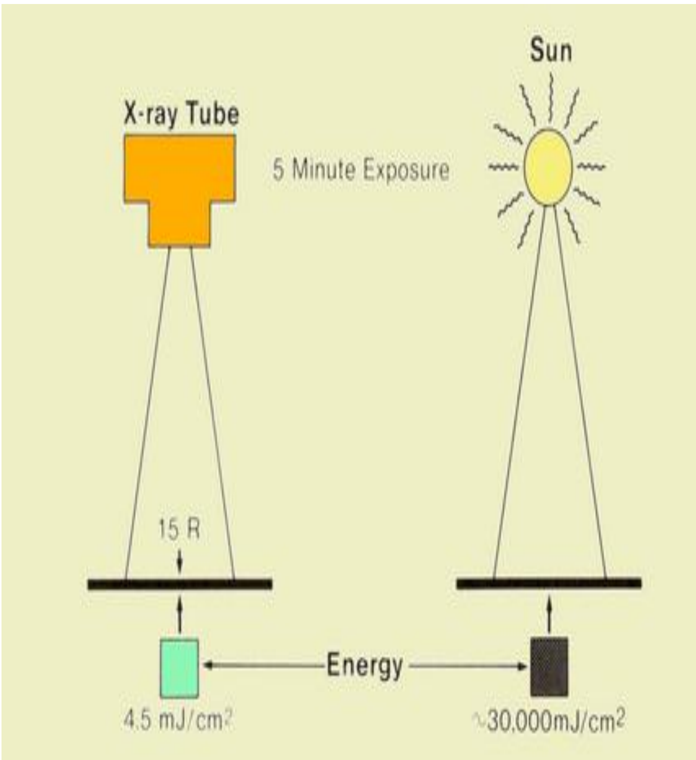
SIE = 100mR x 1000 cm^2
= 100 R- cm^2

- same exposure (100 mR) is delivered to both patients
- there is a difference in the exposed area
- the patient on the right received 10 times as much radiation as the patient on the left

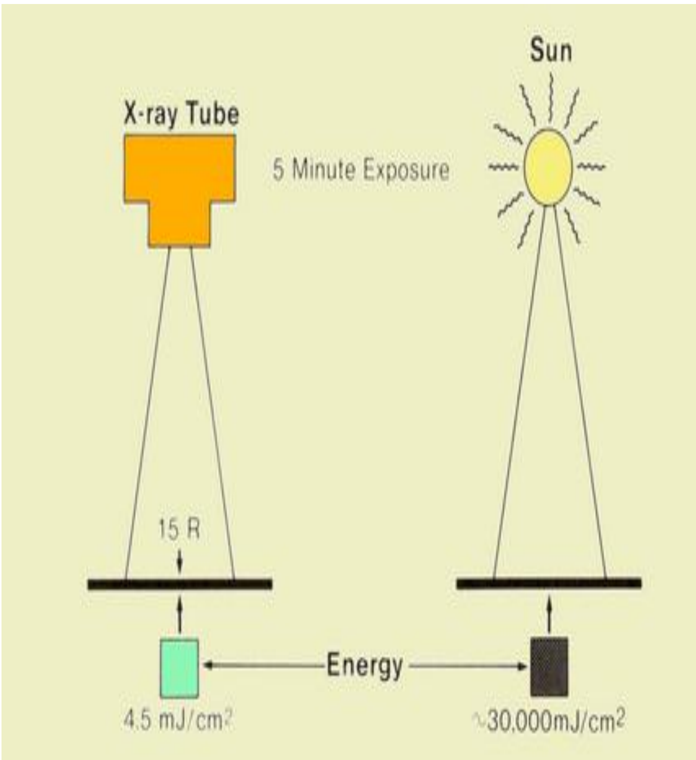
Energy fluence (concentration)

- the amount of radiation energy delivered to a unit area





- 1R = 0.3 mJ/ cm^2.
- A factors of 5 minutes at the rate of 3 R/min.
- 15-R exposure delivers x-ray energy to the patient with
- a concentration (fluence) of 4.5 mJ/cm^2



- 6000 mJ/ cm^2
- A factors of 5 minutes
- a concentration (fluence) of 30,000mJ/cm^2

two significant differences

- x- and gamma radiation penetrate and deposit energy within the internal tissue
- And the high energy content of the individual photons produces a greater concentration of energy at the points where they are absorbed within individual atoms

Quiz

- During the cancer treatment of a patient, 6 Joule energy is deposited in a 1.5 kilogram tissue exposed to radiation. Find the absorbed dose delivered in Gy to the tissue? How much energy is needed to deliver the same absorbed dose to a tissue whose mass is 0.6 kilogram?
- Hint 1Gy = 1 J/kg

- The amount of energy deposited in the tissue

  $E = 6\ J$

- Mass of the exposed tissue

  $(m) = 1.5\ kg$

- Absorbed dose

  $D = ?$

- $D = E/m$
  $6/1=5$
  $D = 4\ Gy$ (for 1.5 kg)

- If $D = 4\ Gy$ (for 0.6 Kg , E=?)

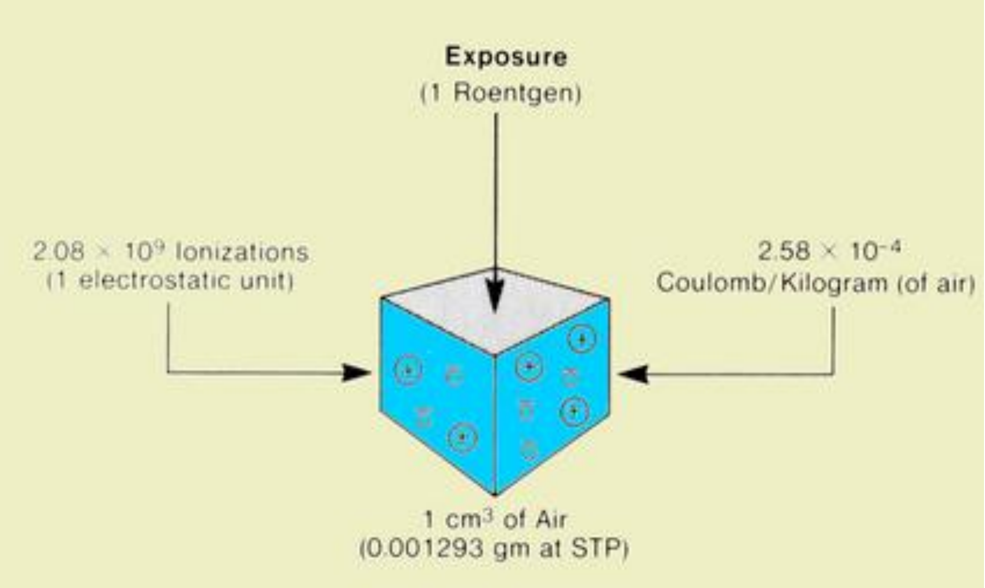
  $E = D \times m$

  $E = 4 \times 0.6$

  $E = 2.4\ J.$

- In an experiment, 2 kg of dry air is exposed to x-rays.

  As a result of ionization in dry air, 5.16×10^{-3} C charge is produced. Determine the Exposure in the units of Roentgen.



Solution Quantity of charge produced as a result of air ionization = 5.16×10^{-3} C.

Quantity of dry air exposed to x-rays = 2 kg

$$
\begin{aligned}
\text{Exposure} &= 5.16 \times 10^{-3}\text{C}/2\text{ kg} \\
&= 2.58 \times 10^{-3}\text{C}/\text{kg} \\
&= 25.8 \times 10^{-4}\text{C}/\text{kg} \\
&= 10 \times 2.58 \times 10^{-4}\text{C}/\text{kg} \\
&= \mathbf{10\ Roentgen}
\end{aligned}
$$

Thus, **Exposure = 10 R**

Stopping Power

- equal to the loss of energy *E* per unit path length, *x*

$$S(E) = -dE/dx$$

- **linear stopping power**

- **mass stopping power**