INTERACTIONS WITH MATTER

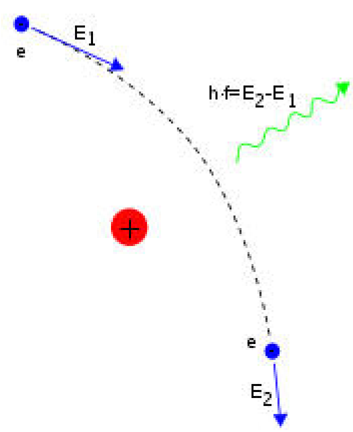
Electron Interaction with target

- 99% of kinetic energy of incident electrons is converted to heat
- 1% of kinetic energy of incident electrons is converted to x-rays
- Two types of electron interaction with target create useful x-ray photons

1. Bremsstrahlung Interactions

-- Due to deceleration of incident electron near the nucleus of a target atom

[Remember, accelerating (or decelerating) charge emits electromagnetic radiation. When an electron is deflected by a nucleus, it has changed its velocity. So it is accelerating. This causes it to emit an x-ray photon.]



-- Wide range of frequencies possible.

[The electron can be deflected very slightly, in which case it loses very little energy and produces a low-frequency photon. Or in can be deflected strongly enough to loses all of its kinetic energy and produce a high-energy photon. Or anything in between.]

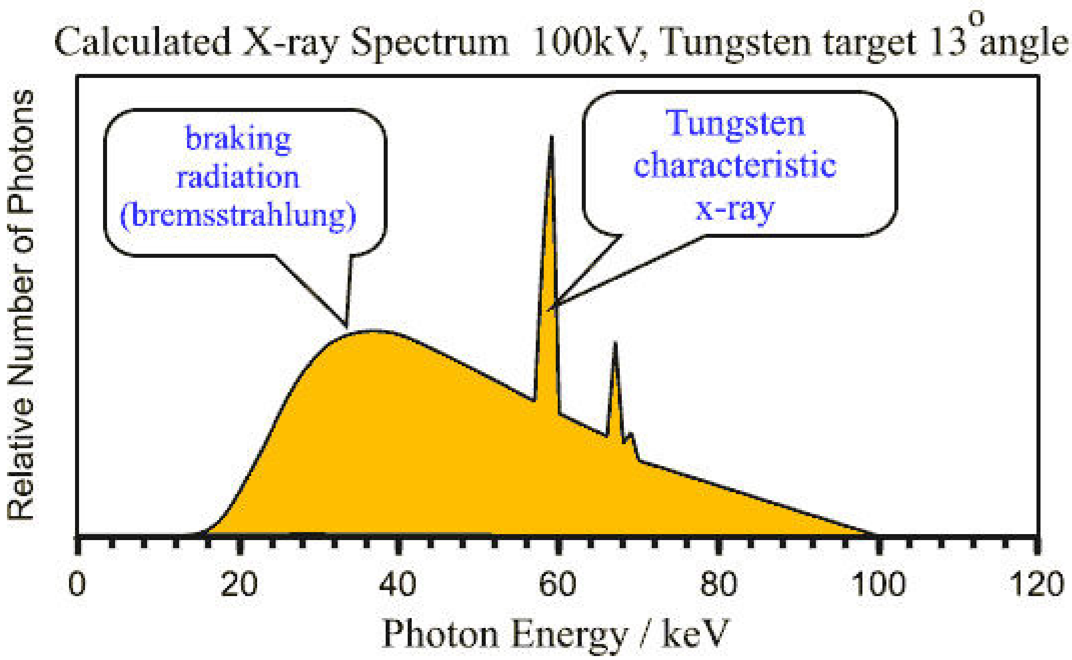
2. Characteristic Interactions

-- Due to incident electron knocking an inner shell electron out an atom (of the target material)

-- Only a fixed set of frequencies possible.
[These correspond to the energy differences between the outer shells and inner shell into which electrons fall]

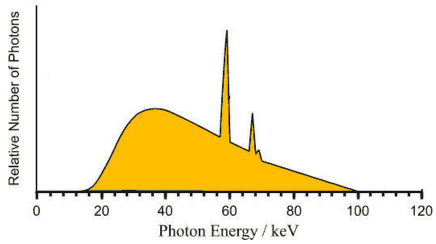
-- Characteristic Cascade occurs when an inner shell electron that was knocked out of the atom by the incident electron is replaced by an electron from the next shell outward, which is in turn replaced by an electron from the next shell outward from that, and so on.

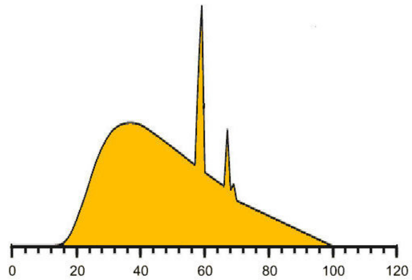
Emission Spectrum



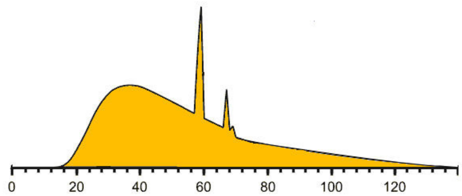
- Most photons are produced by Bremsstrahlung.
- Spectrum has peaks at the frequencies associated with characteristic interactions
- High end of spectrum terminates at "kV_p", the maximum possible photon energy.
- The average photon energy is about 35% of the kV_p.
- If the radiographer increases the current to the x-ray tube, the amplitude of the spectrum will increase.
- If the radiographer increases the voltage to the x-ray tube, the amplitude of the spectrum will increase at higher frequencies and kV_p will increase.
- For kV_p = 90 keV and a tungsten target, x-ray beam composition is

15% due to Characteristic Interactions
85% due to Bremsstrahlung Interactions





Higher Current



Higher Voltage

History of Radiography Video

- Wilhelm Röntgen discovered x-rays in 1895.

- William Coolidge invented the hot cathode x-ray tube in 1913.

- Fluoroscopy is the creation of real-time moving images by have the x-rays strike a fluorescent screen.
  [In modern fluoroscopes, screen images are recorded by a video camera and played back (live or recorded) through a video monitor.]

Milliamperage-Seconds Conversions

mA – a unit of charge = $\frac{1}{100}$(1 Ampere)

milliAmpere-second -- a unit of charge = $\frac{1}{1000}$(1 Ampere) X (1 second)

mAs – the abbreviation for millampere-second

radiograph – an x-ray image (commonly referred to as an "x-ray")

density of a radiograph – the degree of blackness in the image

density is proportional to the number of electrons that hit target the target
which is equal to the cumulative charge of electrons that hit the target
which is equal to (electron current) X (exposure time)
which can be expressed in units of (mA) X (seconds)
which we abbreviate as mAs

➔ density is proportional to mAs

Sample Milliamperage Conversion Problems

Q. A radiograph is produced by setting the milliamperage to 600 mA and the exposure time to 0.5 seconds. What milliamperage would produce a radiograph of equal density if the exposure time were set instead to 1.5 seconds?

A. To have same density, the same amount of charge must reach the target. That is mAs must be the same for both exposure times. We must find the current I the will achieve this.

(600 mA)(0.5 s) = I x (1.5 s)

$$I = \frac{(600mA)(0.5s)}{1.5s} = (600mA)(0.333) = \textbf{200 mA}$$

Q. A radiograph is produced by setting the milliamperage to 900 mA and the exposure time to 1.5 seconds. What exposure time would produce a radiograph of equal density if the milliamperage were set instead 300 mA?

A. mAs must be the same for both currents (milliamperages). Find the exposure time T that achieves this.

(900 mA)(1.5 s) = (300 mA) x T

$$T = \frac{(900mA)(1.5s)}{300mA} = 3 \times 1.5s = \textbf{4.5 seconds}$$

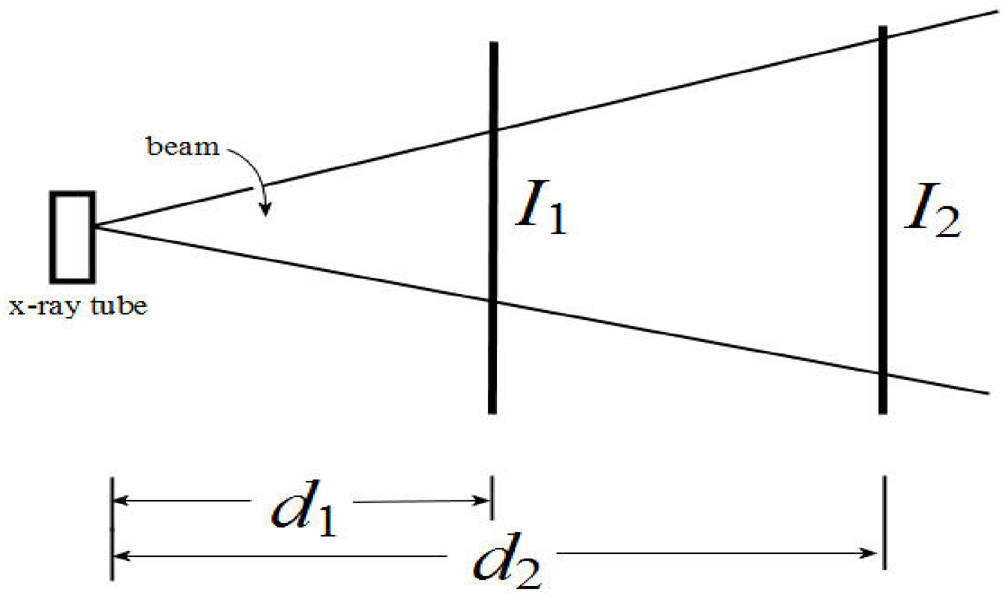
Inverse Square Law

In words – the intensity of x-ray radiation is inversely proportional to the distance between the the x-ray tube and the image receptor (film)

In math -- $I = \dfrac{\beta}{d^2}$

where
β is a constant of proportionality,
d is the distance from the x-ray tube

NOTE: I stand for *Intensity* here *not* current.



$I_1 = \dfrac{\beta}{d_1^2}$ $\qquad$ $I_2 = \dfrac{\beta}{d_2^2}$

$I_1 d_1^2 = \beta$ $\qquad$ $I_2 d_2^2 = \beta$ $\qquad$ => $\qquad$ $I_1 d_1^2 = I_2 d_2^2$

So

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

where
I_1 is the beam intensity at a distance d_1 from the x-ray source, and
I_2 is the beam intensity at a distance d_2 from the x-ray source.

Sample Inverse Square Law Problems

Q. If the radiation dose to a patient was 10 milliroentgens (mR) at a 40-inches distance, to what dose would she be exposed if the distance were reduced to 30 inches?

A. Realize that dose is proportional to beam intensity.

So we can replace the I 's in the inverse square law formula above with D's for dose.

$$\frac{D_1}{D_2} = \frac{d_2^{\,2}}{d_1^{\,2}}$$

d_2 = 40 inches, D_2 = 10 mR,
d_1 = 30 inches, D_1 = ?

Solve for unknown D_1. Plug in known values.

$$D_1 = \frac{d_2^{\,2}}{d_1^{\,2}} D_2 = \frac{40^2}{30^2}(10\ mR) = \mathbf{17.77mR}$$

Q. If the radiation dose to a patient is 250 mR at a distance of 22 inches, at what distance would he be exposed to a dose of 10 mR?

d_1 = 22 inches, D_1 = 250 mR
d_2 = ? , D_2 = 10 mR

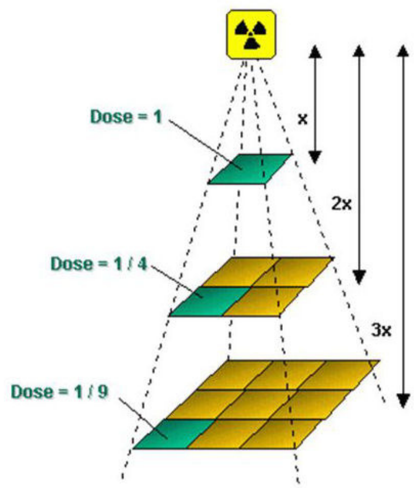
A. Solve equation above (in the previous example) for d_2.

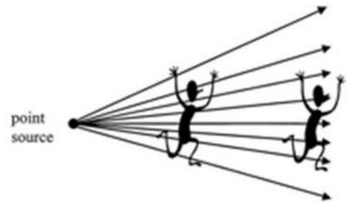
$$d_2^{\,2} = \frac{D_1}{D_2} d_1^{\,2}$$

$$d_2 = \sqrt{\frac{D_1}{D_2}} d_1$$

Plug in known values.

$$d_2 = \sqrt{\frac{250}{10}}(22\ inches) = 5 \times (22\ inches) = \mathbf{110}\ inches$$





- Patient dose can be significantly reduced by increasing the distance to the X-ray tube