**X-Ray Quantity**

X-ray quantity is the number of x-ray photons in the useful beam.

The intensity is a measure of quantity of radiation. The term exposure is often used in radiology

# X-Ray Quality

The term quality describes the penetrating power of the radiation.

The penetrability of an x-ray beam is called the x-ray quality. X-rays with high penetrability are termed high-quality x-rays

* High-energy x-rays are able to penetrate tissue more deeply than low- energy x-rays.

1. rays with high penetrability are termed high-quality x-rays

# Factors That Affect X-ray Quantity and Quality

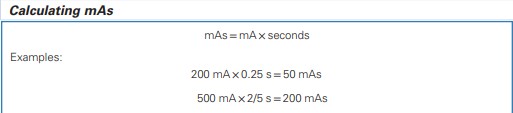
A number of factors under the control of radiographers influence the size and shape of the x-ray emission spectrum and therefore the quality and quantity of the x-ray beam

# Exposure Time

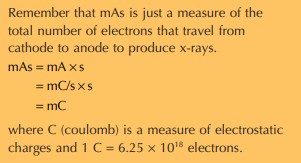
Exposure time determines the length of time over which the x-ray tube produces x-rays.

* + An increase or decrease in mA, exposure time, or mAs directly affects the quantity of x-rays produced;
  + Patient dose is directly proportional to exposure time.
  + **Automatic Exposure Control (AEC)**: These devices terminate the exposure when a specific quantity of radiation has reached the IR

# Effect of mA and mAs (Tube Current and Time)

The product of tube current in milliamperes and exposure time in seconds (mA \* sec) describes the total number of electrons bombarding the target.

**Example:** Calculate the total number of electrons bombarding the target of an x-ray tube operated at 200 mA for 0.1 sec

* The ampere, the unit of electrical current, equals 1 coulomb/sec.
* The product of current and time equals the total charge in coulombs.
* X-ray tube current is measured in milliamperes, where 1 mA = 10−3 amp.
* The charge of the electron is 1.6 × 10−19 coulombs, so

1 mA · s = (10−3𝑐𝑜𝑢𝑙𝑜𝑚𝑏/𝑠𝑒𝑐)(𝑠𝑒𝑐)

1.6×10−19𝑐𝑜𝑢𝑙𝑜𝑚𝑏

𝑒𝑙𝑒𝑐𝑡𝑟𝑜𝑛

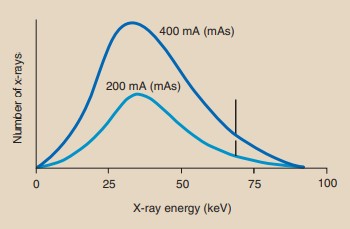
= 6.25 × 1018 electrons

No. of electron = (200 mA)(0.1 sec)( 6.25 × 1018 electrons/mA.sec)

= 1.25 × 1016 electrons

A change in mA or mAs results in a proportional change in the amplitude

of the x-ray emission spectrum at all energies.



1. ray quantity is directly proportional to the mAs

𝐼1 = 𝑚𝐴𝑠1

𝐼2 𝑚𝐴𝑠2

where I1 and I2 are the x-ray intensities at mAs1 and mAs2, respectively

**Example2:** The radiographic technique for a kidneys, ureters, and bladder (KUB) examination uses 74 kVp/60 mAs. The result is a patient

exposure of 2.5 mG𝑦𝑎. What will be the exposure if the mAs can be

reduced to 45 mAs?

𝐼1 2.5mG𝑦𝑎

45

= 60

𝐼1 =

2.5mG𝑦𝑎 × 45

60 = 1.9 mGya

* + The tube current affects only the quantity or the amount of x-ray photons produced but not the quality of the X-rays.

## i.e. the intensity is  mA.

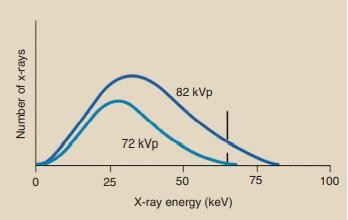
Milliamperage (mA) is a measure of the current flow rate in the x-ray tube circuit. It determines the number of electrons available to cross the tube and thus the rate at which x-rays are produced

# Effect of Kilovolt Peak (kVp) (Tube Voltage)

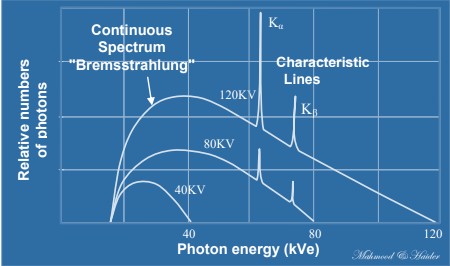
When kVp is increased:

* + The maximum photon energy
  + the X-ray production efficiency
  + The intensity
  + Quality of the X-rays

A change in kVp affects both the amplitude and the position of the x-ray emission spectrum.



A change in kVp has no effect on the position of the discrete x-ray emission spectrum.

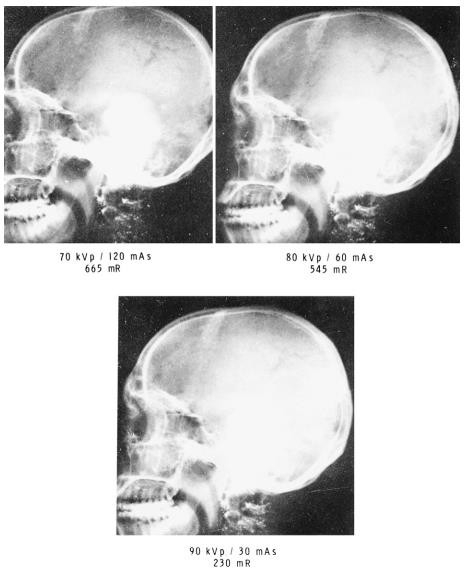


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The rule states that a 15% increase in kVp is equivalent to doubling the mAs.

* A 15% increase in kVp does not double the x-ray intensity but is equivalent to doubling the mAs to the image receptor.
* To double the output intensity by increasing kVp, one would have to raise the kVp by as much as 40%.
* Radiographically, only a 15% increase in kVp is necessary because with increased kVp, the penetrability of the x-ray beam is increased.
* Therefore, less radiation is absorbed by the patient, leaving a proportionately greater number of x-rays to expose the image receptor

## i.e. Radiation exposure (E) ∝ (kVp)2



In other words, if were doub[led, the x-ray intensity would increase by a factor of four.

𝐼1

𝐼2

= (𝑘𝑉𝑝1)

𝑘𝑉𝑝2

2

Where 𝐼1and 𝐼2 are the X-ray intensities at 𝑘𝑉𝑝1and 𝑘𝑉𝑝2, respectively.

**Example:** A lateral chest technique calls for 110 kVp, 10 mAs and results in an x-ray intensity of 0.32 mG𝑦𝑎. What will be the intensity if the kVp is increased to 125 kVp and the mAs remains fixed?

0.32 mG𝑦𝑎

𝐼2

110 2

= ( ) 125

125 2

𝐼2 = (0.32 mG𝑦𝑎) (110)

𝐼2 = (0.32 mG𝑦𝑎)(1.14)2

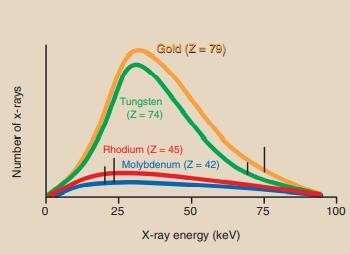
𝐼2 = (0.32 mG𝑦𝑎)(1.29) = 0.41 mG𝑦𝑎

## Effect of Target Material

The atomic number of the target affects both the number (quantity) and the effective energy (quality) of x-rays.

As the atomic number of the target material increases:

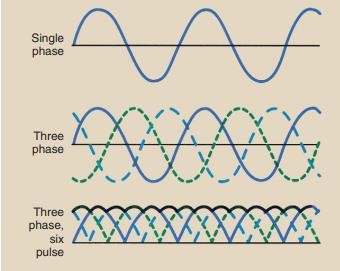
* + Increase characteristic energy
  + enhances the efficiency of x-ray production
  + Increase energy of bremsstrahlung x-rays.



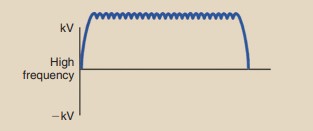
# Effect of Voltage Waveform

There are five voltage waveforms: half-wave–rectified, full-wave– rectified, three-phase/six-pulse, three-phase/ 12-pulse, and high-frequency waveforms

* The x-rays produced when the single-phase voltage waveform has a value near zero are of little diagnostic value because of their low energy; such x-rays have low penetrability.
* With three-phase power, the voltage applied across the x-ray tube is nearly constant, never dropping to zero during exposure.

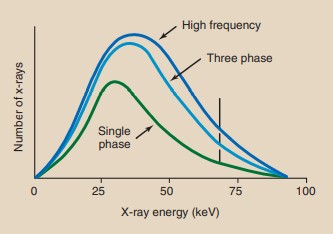


* High-frequency generators produce a nearly constant potential voltage waveform, improving image quality at lower patient radiation dose.



Where an x-ray emission spectrum from a full-wave–rectified unit, all operated at 92 kVp and at the same mAs:

* + The x-ray emission spectrum that results from high-frequency operation is more efficient than that produced with a single-phase or a three phase generator
  + Increased quantity of x-ray photons
  + Increased average energy
  + Minimum and maximum energy is constant



# Effect of Added Filtration

* + Filters are thin sheet of material (Al,Cu).
  + The purpose of using filter is to reduce patient exposure at the skin level.
  + Filters alter both the quality and quantity of X-rays by selectively removing the low energy photons in the spectrum.
  + This reduces the photon number (quantity) and shifts the average energy to higher values by increasing the quality.

