Fundamentals of Radio-physics

First Semester

Lecture1: The x-ray tube

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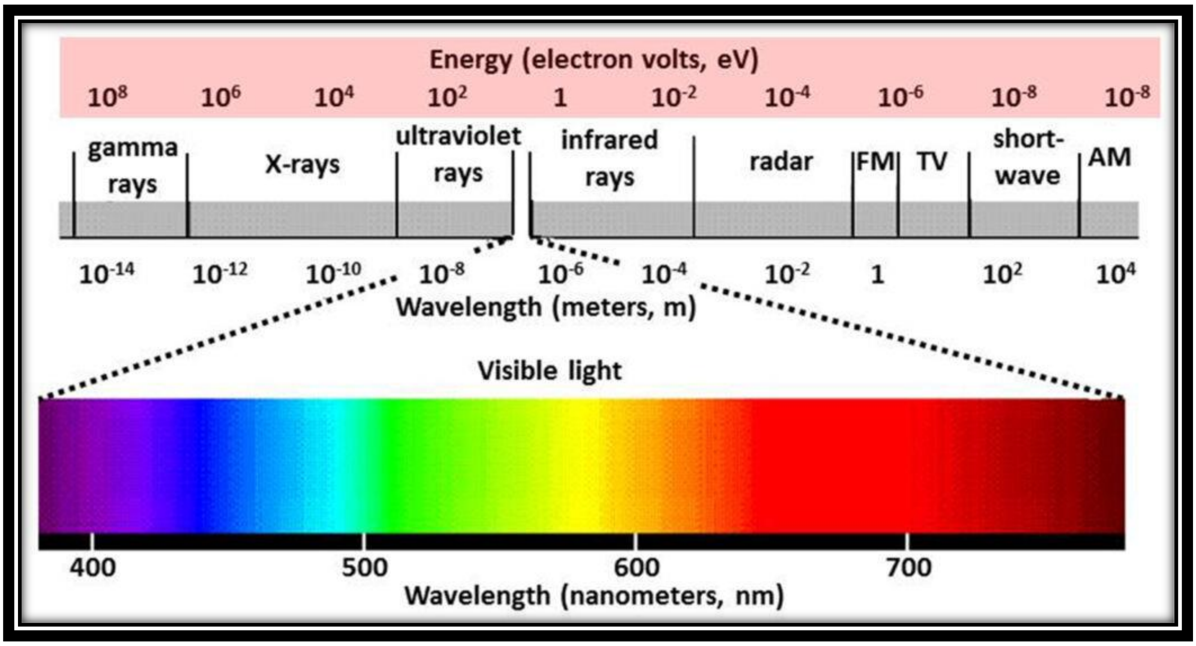
What is x-ray?

X-rays, or roentgen rays, are photons a form of electromagnetic radiation or energy of extremely short wavelength.

The shorter the wavelength of an electromagnetic radiation form, the greater its energy and, as a rule, the greater its ability to penetrate various materials.

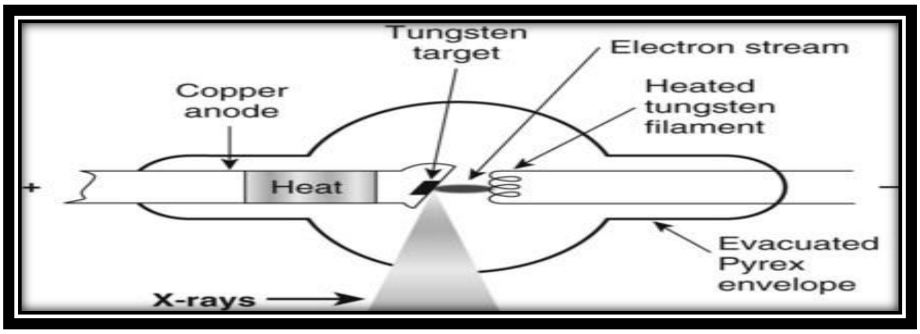


X-ray Tube

An x-ray tube consists of two electrodes sealed into an evacuated glass envelope.

1-The cathode is the negative side of the x-ray tube; it has two primary parts, a filament (fine tungsten coil) and a focusing cup.

2-The anode is the positive side of the x-ray tube; it conducts electricity, radiates heat, and contains the target. Usually of tungsten



Cathode

The cathode assembly normally consists of two parts

(a)an electron source (emitter)

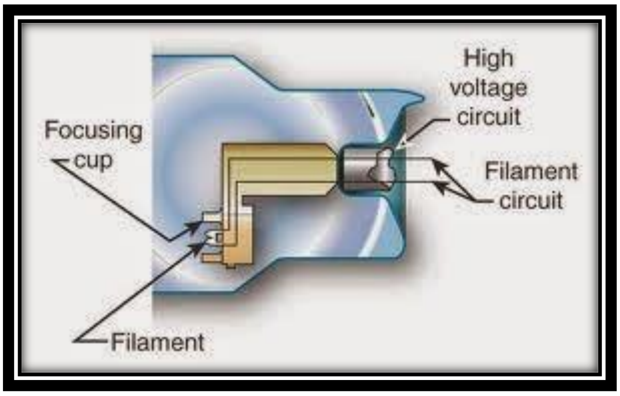
(b)an auxiliary electrode surrounding it

•The electron emitter is usually a coiled wire filament 0.2–0.3 mm in diameter of reasonably high resistance.

•A metal is chosen for the cathode that will give a copious supply of electrons by thermionic emission at temperatures where there is very little evaporation of metal atoms into the vacuum (e.g. tungsten, melting point of 3370°C).

- Filament, surrounded by a focusing cup

Focusing cup is used to focus the electrons on a small area (focal spot) in the anode Tungsten vaporization with deposition on the inside of the glass enclosure is the most common cause of tube failure.



- An x-ray tube filament emits electrons when it is **heated**.
- When the current through the filament is sufficiently high, the outer- shell electrons of the filament atoms are “boiled off” and ejected from the filament. This phenomenon is known as **<u>thermionic emission</u>**

The Filaments

many x-ray tubes have two filaments (dual focus) so that the tubes can have a greater variety of exposures

 When the small filament is activated, its electrons are directed to a tiny focal spot on the target.

□ **The small filament and focal spot** provide finer image detail when a relatively small exposure is appropriate—for example, when imaging a small body part such as a toe or wrist

□ **The large filament provides** more electrons and is aimed at a somewhat larger target area. The combination of large filament and large focal spot is used when a large exposure is required, such as for radiographs of the lumbar spine or the abdomen.

Focusing Cup

The focusing cup controls the width of the electron distribution, and directs the electron toward the target

□ Because all of the electrons accelerated from cathode to anode are electrically negative, the electron beam tends to spread out owing to electrostatic repulsion.

□ Some electrons can even miss the anode completely.

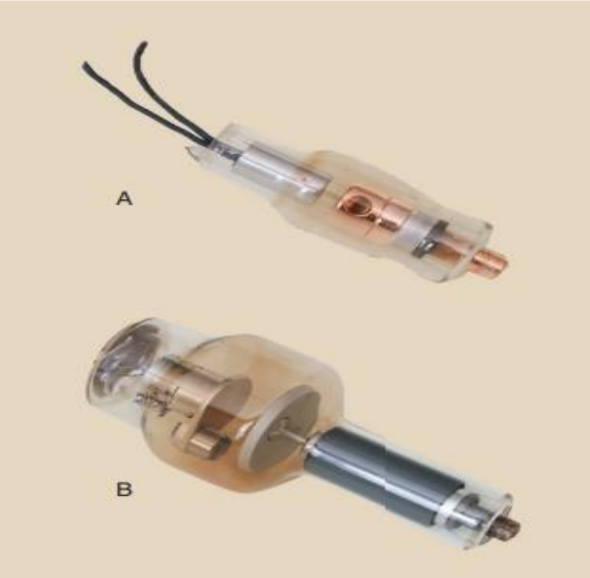
Space charge effect: When the applied kV is zero or small, the electrons surrounding the filament forms a cloud, resulting in space charge effect. As the kVp is increased, (0–40 kV) the effect of space charge reduces gradually and the tube current also increases.

Saturation: Above 40 kVp, the space charge effect is overcome, and the tube current is controlled by the filament current. This is called the saturation

The Anode

anode is the positive side of the x-ray tube. There are two types of anodes, stationary and rotating

General-purpose x-ray tubes use the rotating anode because they must be capable of producing high-intensity x-ray beams in a short time



- The target is the area of the anode struck by the electrons from the cathode.
- In anode design as shown in figure 3, the anode surface is steeply angled to the electron beam.

Tungsten is the material of choice for the target for general radiography for three main reasons:

1-A high conversion efficiency for electrons into X-rays. High atomic numbers are favoured since the X-ray intensity is proportional to Z. At 100 keV, lead (Z = 82) converts 1% of the energy into X-rays but aluminium (Z = 13) converts only about 0.1%

2-A high melting point so that the large amount of heat released causes minimal damage to the anode, therefore can stand up under high tube current without pitting or bubbling.
3-A high conductivity so that the heat is removed rapidly