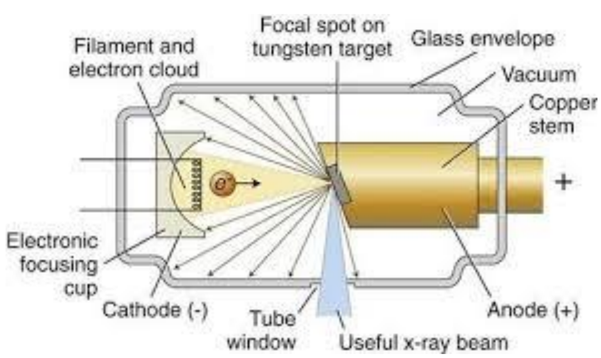
KARNATAKA RADIOLOGY EDUCATION PROGRAM

PRODUCTION OF X RAYS

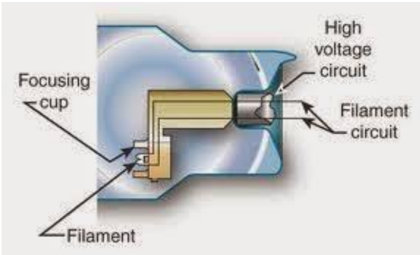
Characteristics of X Ray

The wavelength of the electromagnetic spectrum of X-rays are short
X-Rays require high voltage to produce
X-Rays are used to detect the defects of the human skeleton
X-rays waves always travel in a straight line and they do not carry any electric charge with them And also, the X-Rays are capable of travelling in a vacuum
X-Rays cannot be easily refracted
X-rays waves do not get affected by electromagnetic fields
X-Rays cause photoelectric emissions
X-rays having short wavelength and high penetrating ability are very destructive, this is the reason why they are known as hard x-rays.
The uses of X rays in medicinal fields have less penetrating power and longer wavelengths and hence they are called soft x-rays. X ray waves possess a dual nature.

X RAY TUBE

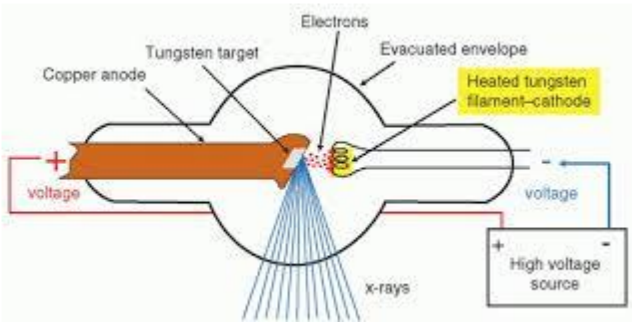


CATHODE



The filament is the cathode of the tube. The high voltage potential is between the cathode and the anode, the electrons are thus accelerated, then hit the anode. There are two designs: end-window tubes and side-window tubes.

ANODE

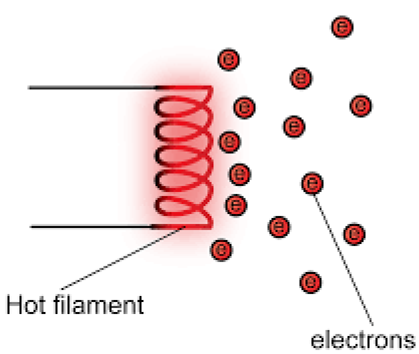


An anode is a small metal disc (usually tungsten or copper) that's affixed to a large copper rotor within an electric motor. These disks rotate at speeds of up to 10,000rpm while enduring temperatures as high as 2000 °C. The anode receives the electron beam from the cathode and emits it as X-ray.

TUNGSTEN

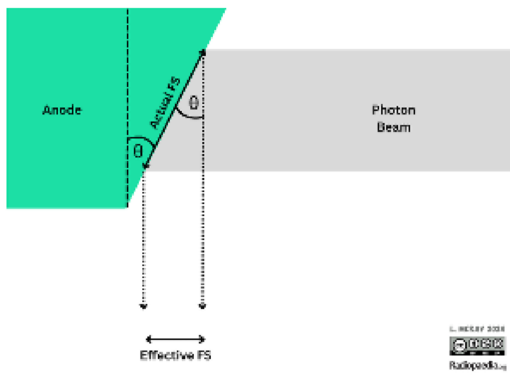
Because of its properties such as high atomic number and high melting point (3,422 °C), tungsten is used as the target material in X-ray tubes [1]. Recently, new technologies utilizing pyroelectric crystals [2] or carbon nanotubes (CNTs) [3], [4], [5] as electron emitters have been developed to produce X-rays.

THERMIONIC EMISSION



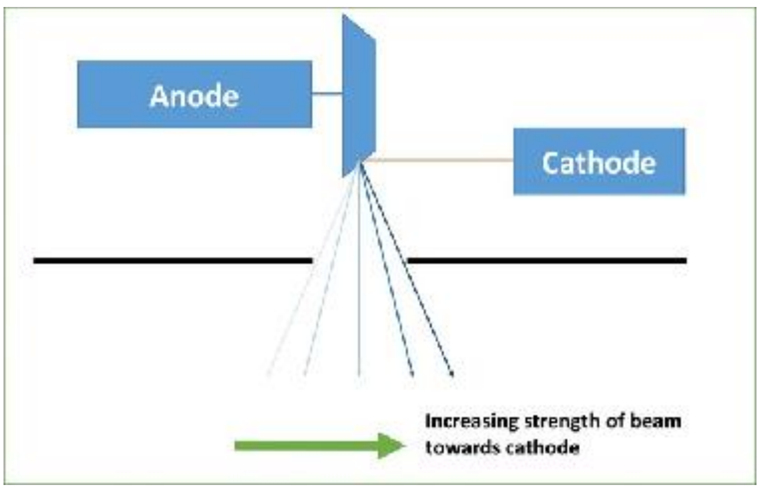
Thermionic emission is the emission of electrons from a heated metal (cathode). This principle was first used in the Coolidge tube and then later in the modern day x-ray tubes.

LINE FOCUS PRINCIPLE



The line focus principle in radiography explains the relationship between the actual focal spot on the anode surface and the effective focal spot size.

HEEL EFFECT

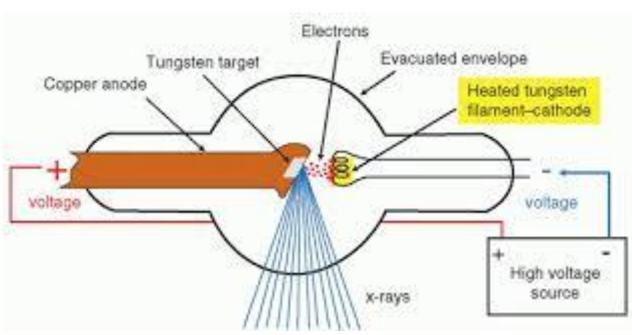


The anode heel effect in radiography is a well-described physical phenomenon, whereby radiation intensity varies along the anode–cathode axis of the X-ray tube, decreasing towards the anode. Photons emitted towards the tube's anode side are attenuated more than those emitted towards the cathode.

The anode heel effect can be exploited by placing the head of a female patient at the cathode end of the X-ray tube to achieve a significant dose reduction to the ovaries and hence a lower effective dose in lumbar spine radiography.

Four basic Requirements for X-ray production*

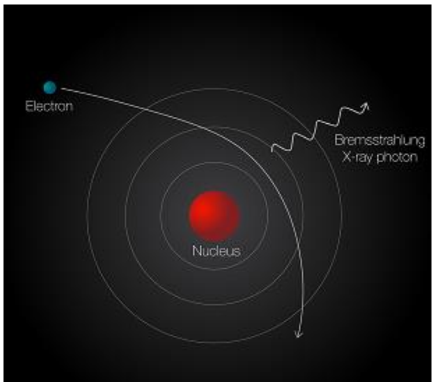
Vacuum. Source of electron (cathode) Target for the electrons (Anode) Voltage= potential difference (Transformer)



X-rays are produced due to sudden deceleration of fast-moving electrons when they collide and interact with the target anode. In this process of deceleration, more than 99% of the electron energy is converted into heat and less than 1% of energy is converted into x-rays.

BREMSSTRAHLUNG RADIATION

X-rays are produced by high-energy electrons bombarding a target, especially targets with a high proton number (Z). When bombarding electrons penetrate the target, some electrons travel close to the nucleus due to the attraction of its positive charge and are subsequently influenced by its electric field. The interaction of the electric fields causes these electrons to slow down and bend around the nucleus (much like a car driving around a corner). In doing so, the electron loses a portion of kinetic energy (KE).



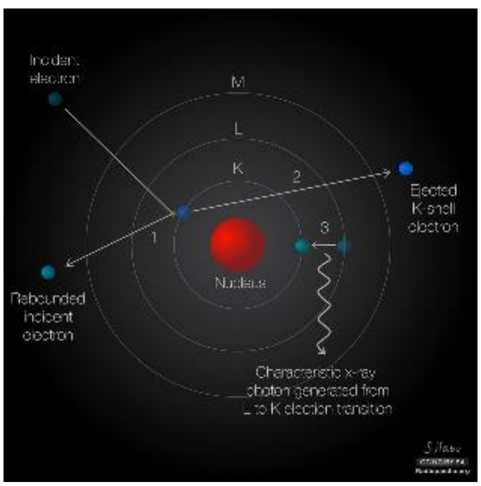
The principle of the conservation of energy states that this energy cannot be lost but rather is conserved in the form of photon emission, whereby the energy of the emitted photon is described as: the energy of X-ray photon = initial KE of electron - final KE of electron

Thus, the total energy in the system remains the same

The closer the electron travels to the nucleus, the more it will slow down and the greater the change in kinetic energy.

X-ray photons emitted in this manner are referred to as bremsstrahlung radiation

CHARACTERICSTIC RADIATION



Characteristic radiation is a type of energy emission relevant for X-ray production. As opposed to the continuous spectrum of bremsstrahlung radiation, characteristic radiation is represented by a line spectrum. As each element has a specific arrangement of electrons at discrete energy levels (dependent on the composition of the nucleus). Therefore, it can be appreciated that the radiation produced from such interactions is 'characteristic' of the element involved.

Characteristic radiation never exists in isolation and the line spectra is usually superimposed on the continuous spectra of bremsstrahlung radiation

Factors influencing X-ray beam quantity and quality:

- **Tube voltage (kV): beam quantity is approximately proportional to the square of the tube potential and increase quality**
- **Generator type/voltage waveform: reducing ripple increases beam quantity**
- **Beam filtration: increasing filtration reduces beam quantity and increase quality**
- **Current (mA): beam quantity is directly proportional to current no change in quality**
- **Exposure time (seconds): beam quantity is directly proportional to exposure time**
- **Anode material: beam quantity is directly proportional to the atomic number (Z) of the anode material**

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REF : Christensen's Physics of Diagnostic Radiology,Radiopedia.