Principles of Medical Imaging

- Medical imaging is the technique and process of imaging the interior of a body for clinical analysis and medical intervention, as well as visual representation of the function of some organs or tissues (physiology).

- Medical imaging also establishes a database of normal anatomy and physiology to make it possible to identify abnormalities.

- Medical imaging is often perceived to designate the set of techniques that noninvasively produce images of the internal aspect of the body.

- Interpretation of medical images is generally undertaken by a physician specialising in radiology known as a radiologist and the radiographer (also known as a radiologic technologist) is usually responsible for acquiring medical images of diagnostic quality.

- Diagnostic Radiology encompasses a wide variety of modalities, anatomic regions, and clinical conditions.
- The major imaging modalities are:

- X-rays (radiographs)
- Mammography
- Fluoroscopy
- Angiography
- Computed Tomography (CT)
- Ultrasound (with Doppler)
- Magnetic Resonance Imaging (MRI)
- Nuclear Medicine (PET/CT)

An X-ray imaging

- An X-ray, or, much less commonly, X-radiation, is a penetrating form of high-energy electromagnetic radiation.
- The German scientist W.C. Röntgen, discovered it on November 8, 1895. He named it X-radiation to signify an unknown type of radiation.
- The most familiar use of X-rays is checking for fractures (broken bones), but X-rays are also used in other ways, example, chest X-rays can spot pneumonia. Mammograms use X-rays to look for breast cancer.

HISTORY

- 1895
  Discovery of X Rays- **W.K.Roentgen**
- 1896
  first time used in surgery
- 1975
  Diagnostic x-ray Machines
- 1997
  Digital x-ray introduced

- An X-ray machine is a device that is mainly used for the purpose of imaging.
- An X-ray machine is one of the most common medical equipment used in hospitals and laboratories to diagnose infections and locate fractures.

- Also, the security systems installed on the airports, railway stations, or other related places make use of x-ray machines to scan and detect the presence of dangerous substances in the luggage bags.

Working Principle of X-Ray Machine

- An X-ray machine mainly utilizes the basic properties of the X-rays for its operation. The natural tendency of X-rays is to penetrate soft areas with ease and get absorbed by dense areas.

- This ability of the X-rays serves to be the working principle of the X-ray machines and helps the user obtain detailed images of the internal structure of the body organs or the objects with ease.

- The X-rays used by the X-ray machines are produced by accelerating electrons at a relatively higher velocity and then directing them towards a target. On hitting the target, the electrons tend to decelerate and lose energy.

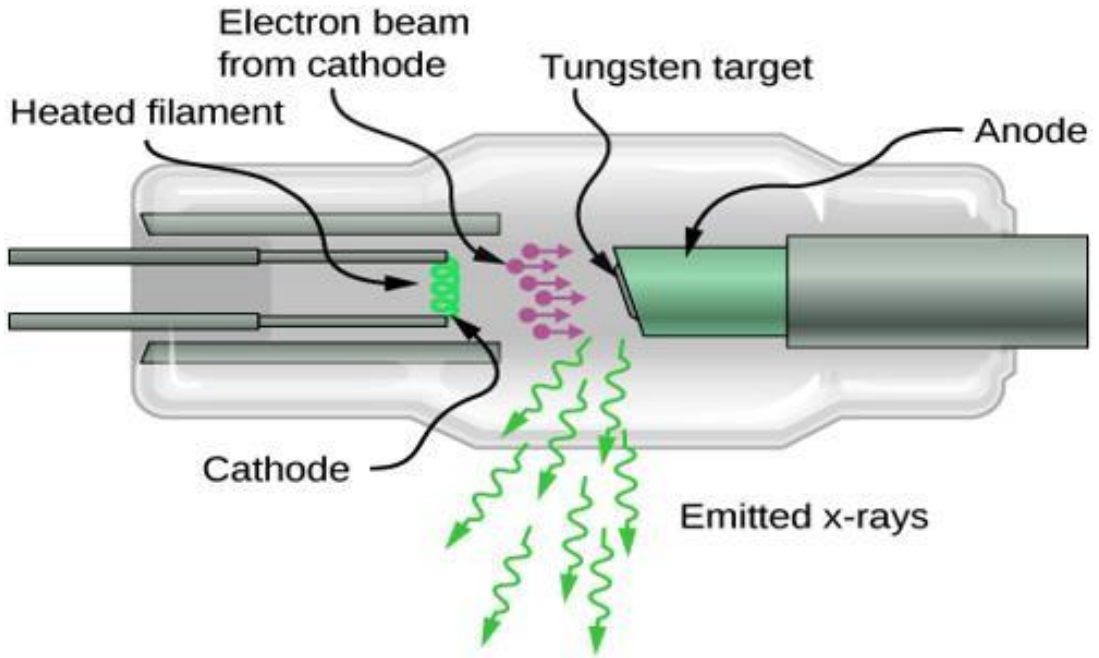
- During the process, a major portion of the kinetic energy possessed by them gets converted into heat energy and the rest portion into x-rays.
- The X-rays are usually produced with the help of an x-ray tube.

Principle of x-ray:

- When high-speed electrons strike a metal, then a short wavelength and high penetrating power electromagnetic radiation are emitted.

- This radiation is X-rays. This is the principle of X-rays.

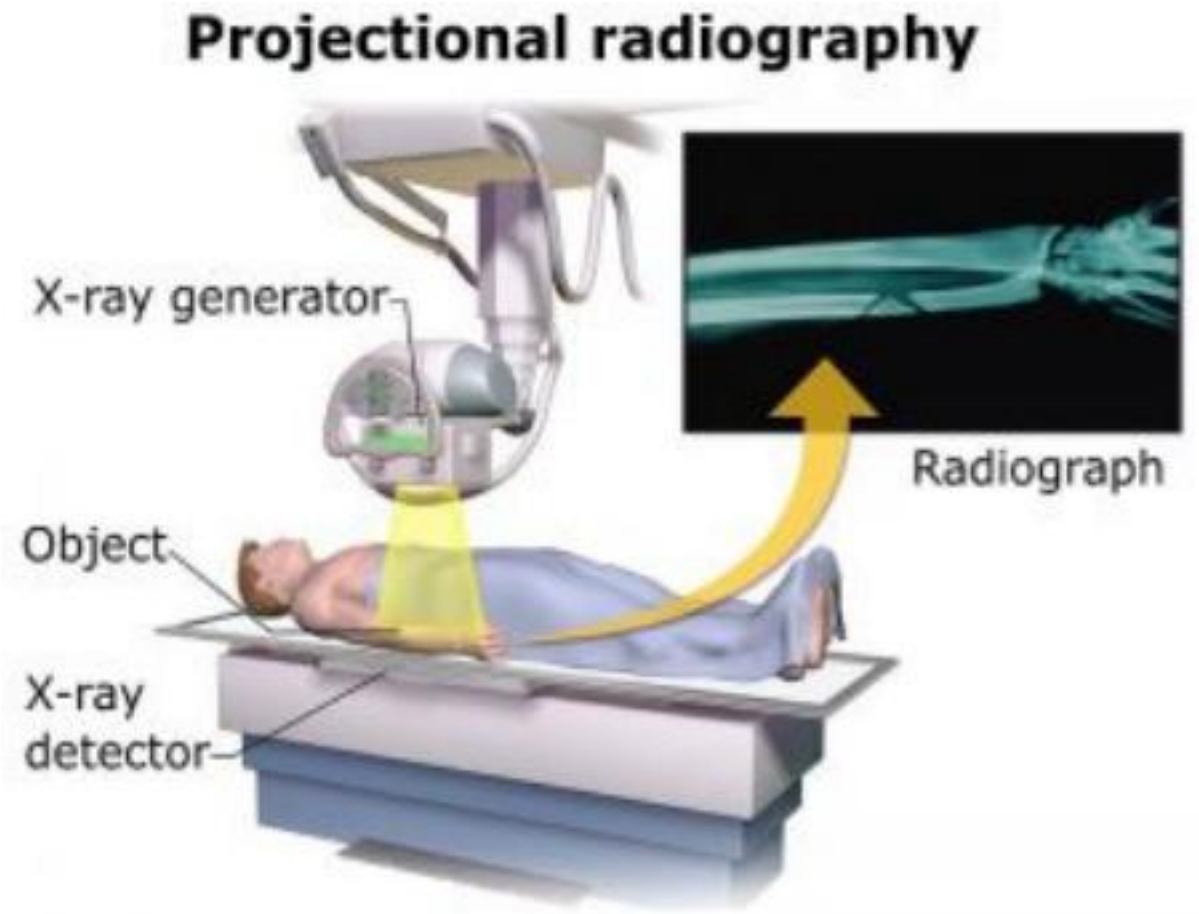
- That means when heavy elements are struck by high energy electrons, then by the agitation of the interior electrons of the atom this ray is produced.



- X-rays are electromagnetic radiations have a wavelength ranging from 10 picometers to 10 nanometers, corresponding to frequencies in the range 30 petahertz to 30 exahertz (3×10^{16} Hz to 3×10^{19} Hz) and energies in the range 145 eV to 124 keV.

- X-ray wavelengths are shorter than those of UV rays and typically longer than those of gamma rays.

- X-rays can be broadly classified into two types, namely, soft X-rays and hard X-rays.



Block Diagram of an X-Ray Machine

The working of an x-ray machine can be easily explained with the help of a functional block diagram. Generally, an x-ray machine consists of the following 10 blocks:

1. High Voltage Source: The main purpose of using a high voltage source control to power an x-ray machine is to allow the proper operation of the x-ray tube. The voltage value typically ranges from 30 to 150 kilovolts (kV).

2. High Voltage Transformer: The high voltage produced by the high voltage source on the input side of the machine is coupled to a step-up transformer. The transformer tends to uplift the voltage and produce a signal at its output range of 20-200 kV.
3. High Voltage Rectifier: The AC supply cannot be used to operate the x-ray machine, hence the task of converting AC supply into DC supply.

4. X-ray Tube: The input signal received by the x-ray tube from rectifier circuits is used to generate multiple beams of high power x-rays, used for imaging & detection purposes.

5. Collimator: The serious side effects of x-rays exposure to the healthy cells is mainly controlled with the help of a collimator, placed between the patient and the filter.
6. Aluminium Filter: To minimize the unwanted frequency effects to a certain level, aluminium filters are attached to the internal circuitry of the device.

7. Rotor Control: A rotor control present in the x-ray machine is used to limit the beam power according to the usage and helps to cool down the anode.
8. Thermal Overload Detection: The main purpose of a thermal overload detection mechanism attached to the X-ray machine is to turn off the machine in case the heat level surpasses a certain threshold value.

9. Diaphragm: The scattered radiations falling on the surface of the diaphragm get absorbed up to a significantly high level.

10. Film and Lead Shield: The main purpose of the lead shield is to collect the x-rays after they strike the film. The image so formed can now be processed and analysed by the person in charge.

PARTS OF X-RAY MACHINE

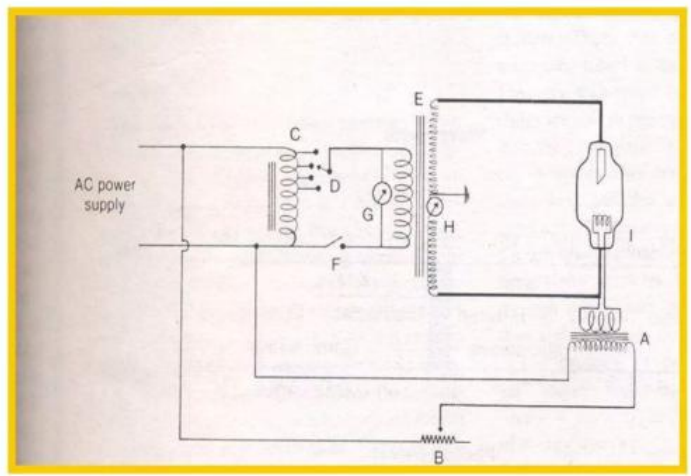
1. X-ray tube
2. Transformer
3. Tube stand
4. Control panel

X-RAY

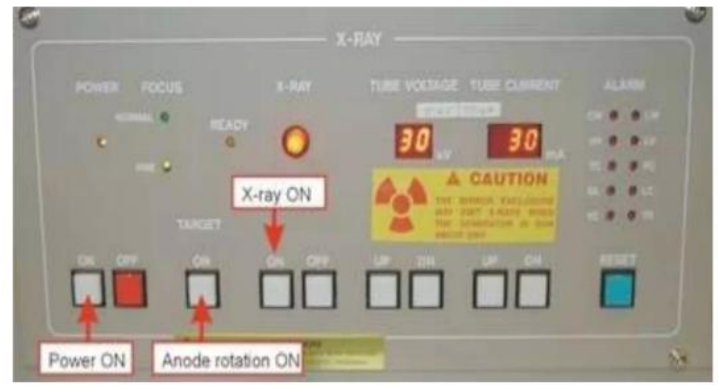
- X-rays are electromagnetic radiation.
- X-ray machine sends individual x-ray particles through the body.
- The images are recorded on a computer or film.

X-RAY MACHINE

2. TRANSFORMER



3. CONTROL PANEL



Production Of X-Rays

X-rays can be produced with the help of high vacuum tube with a heater, cathode and anode. Vacuum tube is operate at very high voltage. A special electron tube (vacuum tube) is shown in Fig No 11 which is used for production of x-rays. Such a tube has a hot filament cathode an anode made a very heave metal. Electron flow from the cathode to anode as in any diode tube. However a large DC voltage is used between cathode and anode of x-rays tube. .

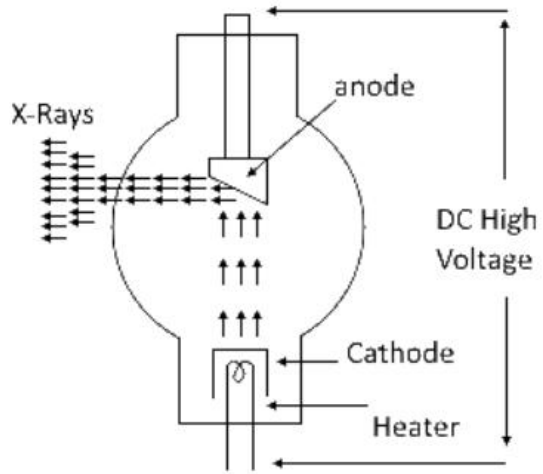


Figure 1: X-Ray Tube

When heater is on and very high anode to cathode voltage is applied the electron emits from cathode and travel toward the anode with very high Velocity, as clear from figure 1, this beam of electron strike the metal anode such speed that new rays are made from the slanting surface of the anode these x-rays seem to bounce sideways ad out thought the well of the tube. As the DC voltage (anode-to-cathode of the x-rays tube) is increased, the wavelength of x-rays decreases. Same tubes now operate at more than a million volts.

Block Diagram of X-Rays machine

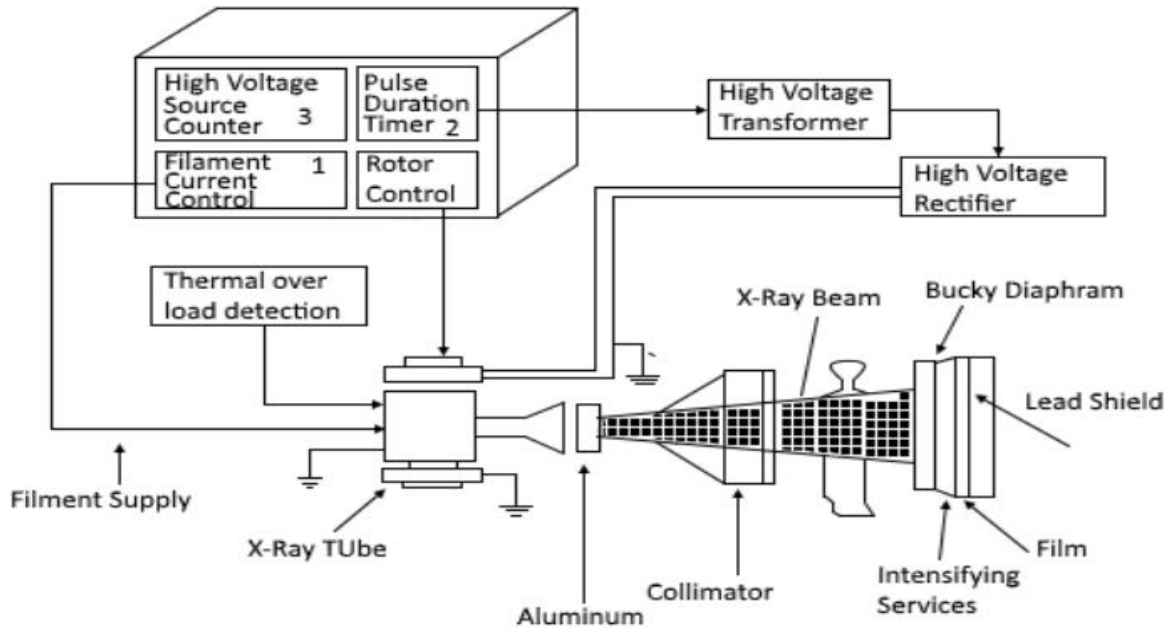


Figure 2: Block Diagram of X-Ray

Operation/Working Of X-Ray Machine

High Voltage Source And High Voltage Transformer

High voltage source is responsible for providing high voltage to the H.V transformer for a decided time. The H.V transformer produces 20 KV to 200 KV at the O/P. These voltages are used to determine the contrast of the image. High voltages have higher contrast.

High Voltage Rectifier

This rectifier rectifies the high voltage produced by the H.V.T and supplies them to the anode of the X-ray tube.

Thermal Overload Detector

The heat of the X-ray tube (should not be increase by a specified range). If the heat is exceed from a specified value, and then the thermal over load detector is used to turn off system.

Rotor control

Most of the X-ray tube anodes are rotated by an induction motor, in order to limit beam power at any spot and helps to cool the anode.

Pulse duration timer

The duration of the time must be very small so that

1. The patient does not receive the excessive dose,
2. The film does not become over exposed.
3. The X-ray tube does not over neat. The pulse duration timer determines this pulse duration.

Aluminum Filter

The X-ray beam used in the medical field which contains a broad band of frequencies.(1) The unwanted frequencies in the x-ray based create side effects e.g extra dose for patient causing tumor also reduce the contrast in the image. These are called soft x-ray. To eliminate these effects Aluminum filter is used.

Collimator

Another mean to reduce the dose of patient is to confine the x-ray beam only on the region of interest on the body of patient. An external collimator placed between patient and filter does this.

Diaphragm

X-rays inside the patient create x-ray scattering, which tends to burned the image to absorb the scattered x-rays and eliminate the burning of an image a lead grid is used which is called diaphragm.

Film And Lead Shield

The x-rays passed from the desired region of the patient body are made to strike on the film where they produce an image of the body soft and hard parts. A lead shield is use to collect the x-rays after striking on film.

The H.V. source produces high voltage supply, which are rectified by rectifier and applied to anode of the x-ray tube. Filament supply is also provided. As a result x-rays tube producing an x-ray beam which is passed through the body and produces image of body and the film, which is examined in laboratory.

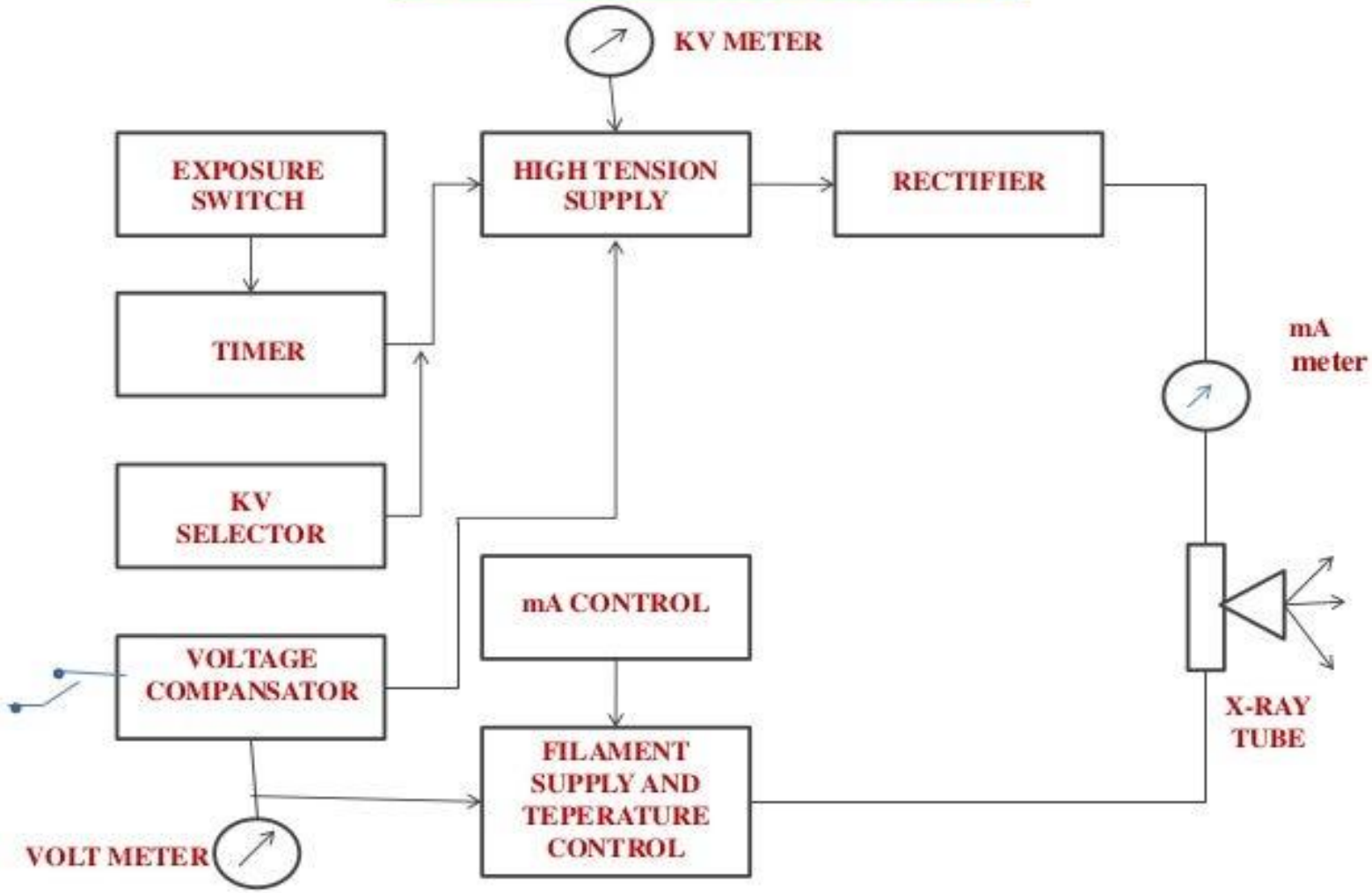
Application Of The X-Ray

1. Detection of the fraction in bones.
2. Infection of lungs, kidneys and other injury.
3. Presence of Tumour.
4. X-rays are used for treatment for Tumour.

Use Of X-Rays In Industry

1. For industrial radiography and fluoroscopy.
2. For measuring the thickness of material.
3. Inspection of metals.
4. Inspection of fruits before packing.

BLOCK DIAGRAM



Working of X-Ray Machine.....

- The partial and complete passing of radiations through the object tends to form an impression of the internal structure of the object on the film.

- For instance, in medical diagnosis when the X-rays come in contact with the bones and tissues of a human being, a corresponding black and white image gets reflected on the surface of the metal film.

- Finally, the hard copy of the image is developed and processed to enhance the information contained by it.
- The image developed by the X-ray machine is generally black and white in nature.

- The black area of the film represents the soft portion or the soft tissues of the body, while the white area corresponds to the dense regions or the bones present in the body.

Working of X-Ray Machine

- The working of an X-ray machine can be summarized as a three-step procedure, i.e., exposing the object to the X-rays, absorption and scattering of the radiations, and formation of the image on the film.

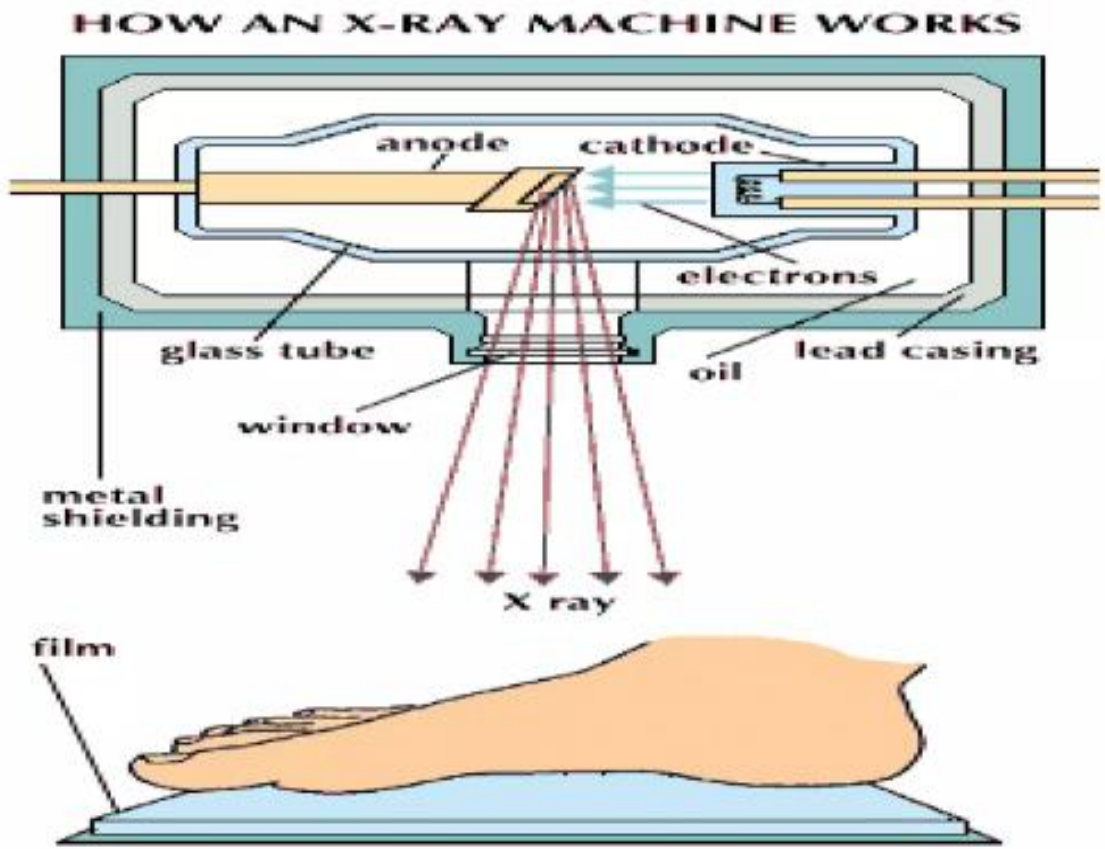
- Initially, the object whose internal image is required to be formed is placed in direct exposure to the x-rays produced by the X-ray tube of the X-ray machine.

- The radiations are directed towards the body part that is required to be examined.

- The basic property of the X-rays enables the radiations to pass through the soft surfaces of the object and get absorbed by the rigid and dense portions.

- The radiations passing through the soft surfaces tend to get scattered, while the radiations falling on the dense surfaces get absorbed.

WORKING


HOW AN X-RAY MACHINE WORKS
anode
cathode
electrons
glass tube
oil
lead casing
window
metal shielding
X ray
film

TECHNOLOGY DEVELOPMENT