Theoretical Lecture

Lecture One: X-Ray Machine

1. History of X-ray

X-rays were discovered by Wilhelm Roentgen, the German physicist in 1895 when he was investigating the conduction of electricity through gases at low pressure in glass tubes.

He noticed that the positive electrodes in the tubes gave off invisible rays which made fluorescent screens to glow and fogged photographic plates.

The rays were highly penetrating, they passed through black paper and even thicker objects. They were not deflected in magnetic field.

As their nature was not known he called them X-rays; later, they were shown to be electromagnetic radiation of very short wavelength.

In his discovery Roentgen found that the X-ray would pass through the tissue of humans leaving the bones and metals visible.

One of Roentgen's first experiments late in 1895 was a film of his wife Bertha's hand with a ring on her finger (shown below on left).

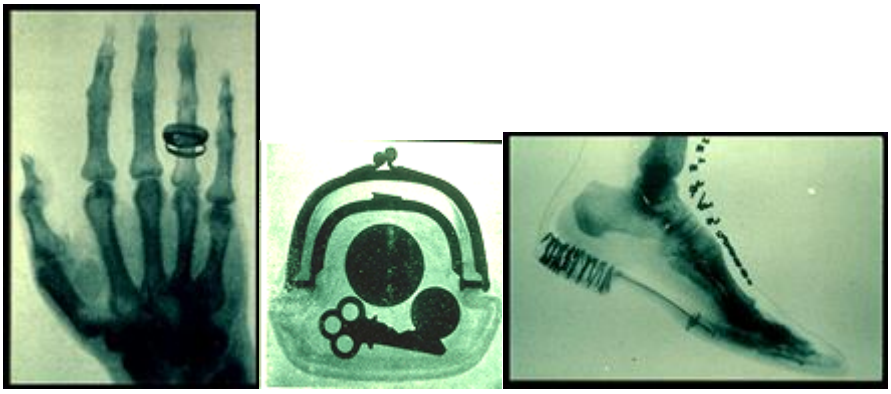

Figure1: The early x-rays.

2. Properties of X-Rays

1. X-rays are electromagnetic radiation of shorter wavelength (1-100nm).
2. They travel in straight line with a velocity equal to light.
3. X-rays are not influenced by electric and magnetic fields.

4. X-rays penetrate through substances that are opaque to visible light.

5. X-rays produce fluorescence in materials like calcium tungstate, and cesium iodide, etc.

6. X-rays affect the photographic film and form latent image.

7. X-rays produce ionization and excitation in the substances through which they pass.

8. X-rays produce chemical changes in substances through which they pass.

9. X-rays produce biological effects in living organisms. The cells can be either damaged or killed due to X-ray exposure.

2. X-ray Machine parts:

Figure2: X-Ray Machine.

X-ray has three main components:

1. X-Ray Tube:

Include cathode (electron source), anode (target), vacuum and glass tube.

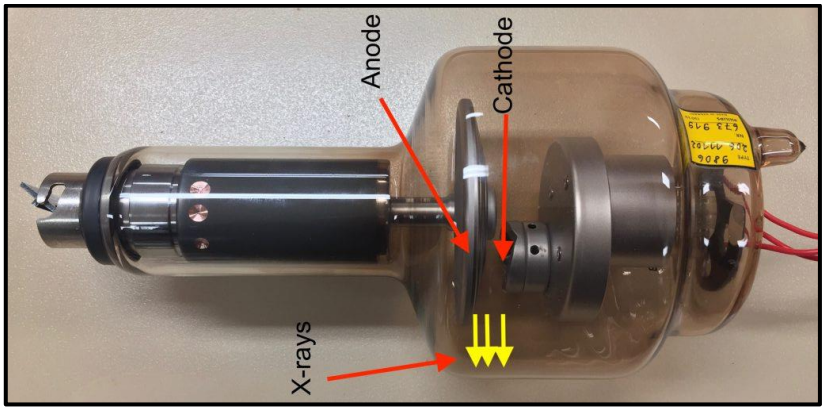

Figure 3: x-ray tube.

2. Operating Console:

Allows the radiologic technologist to control the x-ray tube current and voltage so that the useful x-ray beam is of proper quantity and quality.

Figure4: operating console.

3. High Frequency Generator:

A high frequency generator powers the x-ray tube, high frequency generator are used for x-ray because operate on single phase and give less voltage ripples.

***Other parts*:**

1. Collimator And Grid :

Collimator*:* is a device used to minimize the field of view. Lead shutter are used to restrict the beam. Collimator is attached to the x-ray below the glass window where the useful beams are emitted.

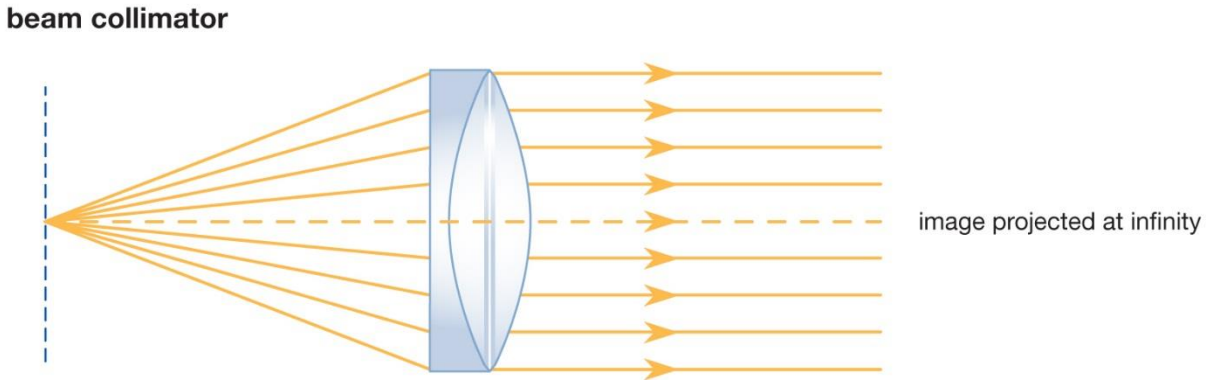

Figure5: collimator.

Grid: similar to collimator except they have different positions. Placed right after the patient. Use to filter the deflected ray that can block the image that produced by the device.

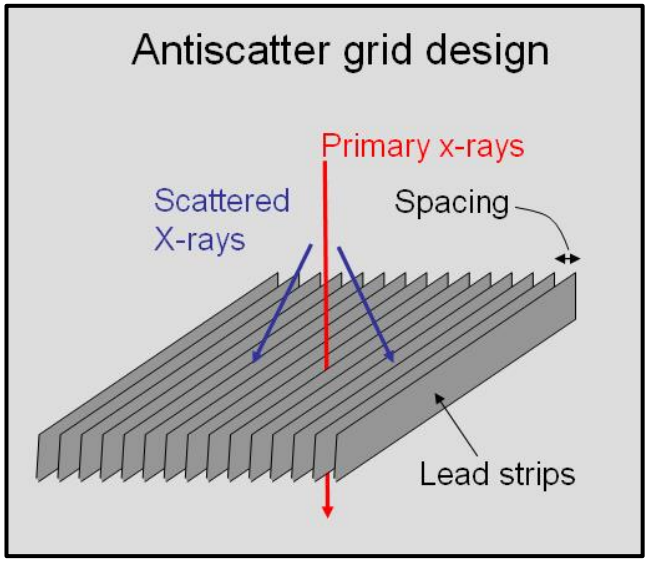

Figure6: grid of x-ray.

2. X-Ray Film:

is a sensitive material (sheet) for the x-ray. A film that has been exposed to x-rays shows an image of the x-ray intensity. It turn black when the x-ray interact with it and stay white where the x-ray are absorbed, that causes an image to be formed in black, greys and white.

Figure5: x-ray film

3. Production of x-ray:

X-rays are produced when fast moving electrons are stopped by means of a target material. The moving electrons possess kinetic energy. When the electron is suddenly stopped, its kinetic energy is converted into heat and X-rays. This conversion is taking place in the target material. Therefore, the interaction of electron with the target is the basis for X-ray production. See (figure6).

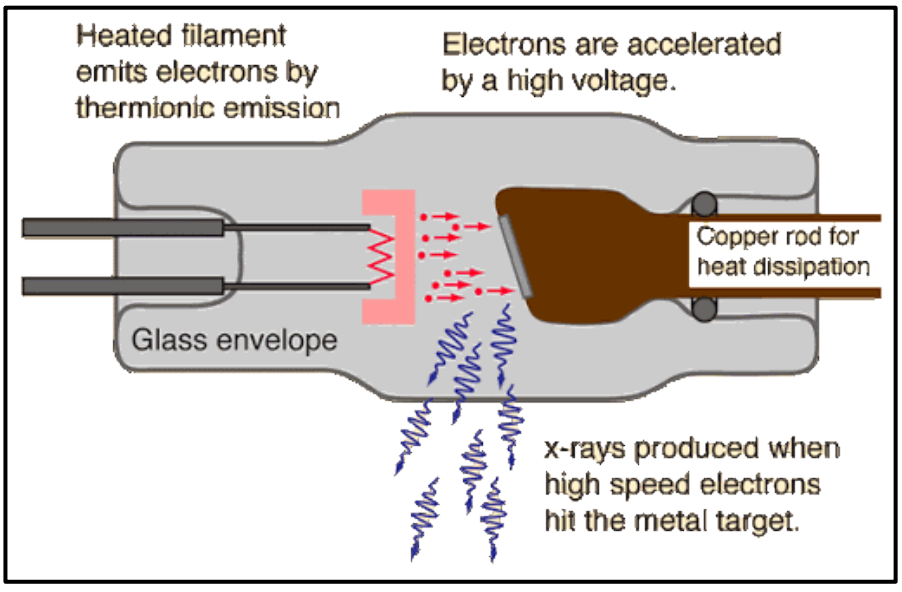

Figure 6: X-Ray Production.

4. Electron interaction with the target

When the electron arrives at the target, it interacts in four ways as follows (Figure7).

The electron interaction involves; **(A) ionizational collisions, (B), (C) and (D) radiative collisions.**

A. ***Ionization of target atoms:*** The fast moving electron enters the surface layer of the target and undergoes collisions.

In this process, the incident electron transfers sufficient energy and removes an electron from the atom. This involves small energy transfer, resulting in ionization of target atoms. The incident electron may undergo number of such collisions and each time its direction gets altered.

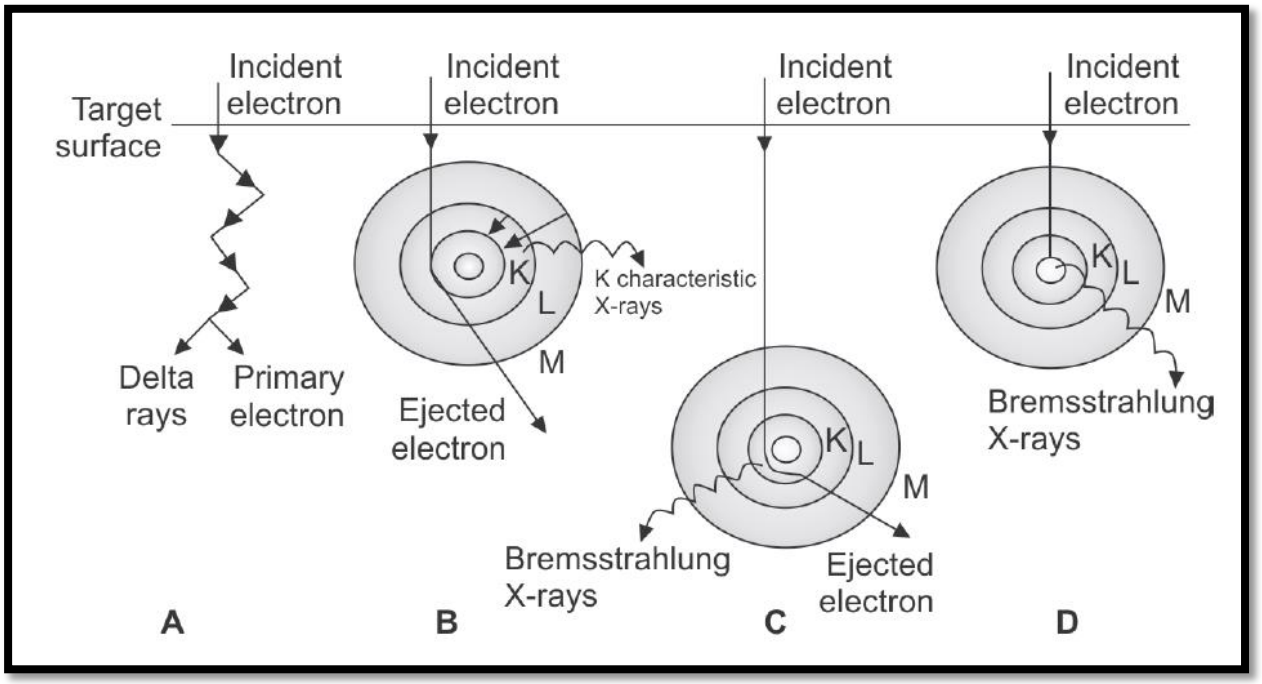

Figure 7: Interaction of electron with target atoms: **(A)** Ionization of target atoms, **(B)** Characteristic X-rays, **(C)** Interaction with nuclear field, **(D)** Interaction with nucleus

B. ***Characteristic X-rays:*** This is an interaction between the incident electron and the electron in the K shell.

In this process, the incident electron directly hit the K shell, transfers sufficient energy and removes the K shell electron. The vacancy in the K shell is filled

by an electron moving inwards from the outer shell. During this transition, the difference in binding energies of the two shells is given out as X-ray photon.

C. ***Interaction with nuclear field:*** The incident electron occasionally reaches nearer to nucleus of an atom in the target. Since the electron is a negative particle, it is attracted by the positive nucleus. It is made to orbit partially around the nucleus, decelerates and goes out with reduced energy. The loss of energy appears in the form of X-ray photons, known as Bremsstrahlung. This process is unlikely at low energies, but dominant at high energies.

D. ***Bremsstrahlung radiation:*** The electron may hit the nucleus directly and is stopped completely in a single collision. The entire electron energy appears as bremsstrahlung radiation. This type of interaction is very rare, but capable of giving high energy X-rays.

Questions:

1- List five of the properties of x-ray?
2- Electron interact with target atoms in four ways, list them and explain two with draw?
3- Explain briefly how the x-ray produce?
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