Chapter 2

X -Rays

X-ray is one kind of electromagnetic radiation which is probably, most well-known for its ability to penetrate human skin and reveal images of the bones beneath it. Advances in technology have led to more powerful and focused X-ray beams as well as ever greater applications of these light waves, from imaging teensy biological cells and structural components of materials like cement to killing cancer cells.

Chapter Objectives:

After completing this section, we should be able to

- Know the history about the discovery of X-ray and it's properties.
- How x-ray is produced.
- Know different type of X-ray--Soft and Hard x-ray
- Know the uses of x-ray

History of X- ray

X-ray was discovered by Wilhelm Conrad Roentgen, a professor at Germany. According to the Non-destructive resonance Center's "History of Radiography", Roentgen noticed crystals near a high-voltage cathode ray tube exhibiting a fluorescent glow, even when he shielded them with dark paper. Some form of energy was being produced by the tube that was penetrating the paper and causing the crystals to glow. Roentgen called the unknown energy "X-radiation". Experiments showed that this radiation could penetrate soft tissues but not bone, and would produce shadow images on photographic plates.

For this discovery, Roentgen was awarded the very first Novel Prize in Physics, in 1901.

In the classical description of electromagnetic radiation, X-rays are waves similar to radio, TV, and light waves, but with a much smaller wavelength, λ of the order of 1 Å (10^{-10} m). The wave nature of X-rays give rises to the phenomena of interference at an atomic scale, which provide the various scattering and diffraction techniques that will be covered in this book. Moreover, there is also a quantum description of the electromagnetic fields based on the particle nature of electromagnetic radiation, which means that it behaves as a beam of photons created and annihilated by interacting with matter. Absorption and detection of X-ray photons are intrinsically quantum phenomena explored in techniques for analyzing materials by absorption spectroscopy and X-ray fluorescence.

X-rays are roughly classified into soft X-rays and hard X-rays. Soft X-rays have relatively short wavelengths of about 10^{-8}m, and so, they fall in the range of the electromagnetic (EM) spectrum between ultraviolet (UV) light and gamma-rays. Hard X-rays have wavelengths of about 10^{-10} m. These electromagnetic waves occupy the same region of the EM spectrum as gamma-rays. The only difference between them is their source: X-rays are produced by accelerating electrons, whereas, gamma-rays are produced by atomic nuclei in one of four nuclear reactions.

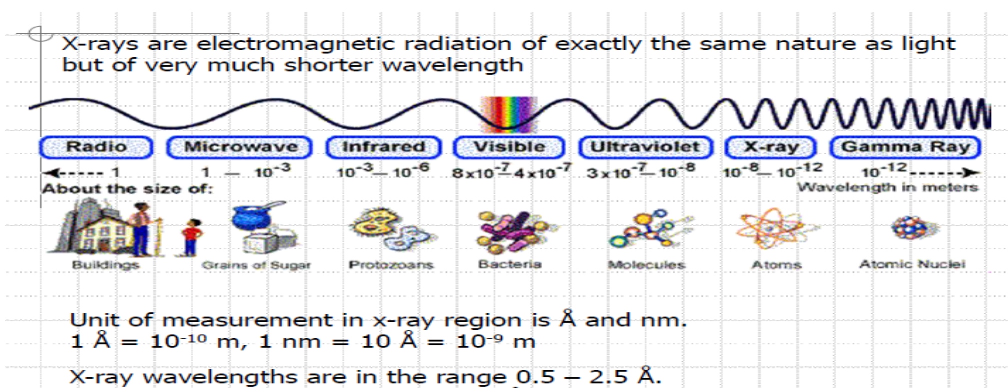

FIGURE- 2-1
E. M. Radiation

Properties of x-Rays

There are so many distinguishable properties of X- rays

- X-ray is highly invisible electromagnetic wave
- X-ray is electrically neutral and cannot be deflected by electrical and magnetic field
- It can penetrate through matter
- It can travel with the velocity of light along straight line
- It can ionize gases indirectly
- It can cause fluorescence of certain crystals
- It affects photographic film
- It produces chemical and biological changes
- It produce secondary and scatter radiation
- It can be made reflect, refract and diffract. X-rays show the phenomenon of Interference polarization.
- It shows particle like properties in interacting with matter as in photoelectric effect and Compton effect.

Production of X- rays- *Modern Coolidge Tube*

X-rays are produced, when fast moving electrons strike a metal target of suitable material. The basic arrangements for production of X-rays are:

- a source of electrons called Cathode
- effective means of accelerating the electrons
- a target metal of high atomic weight called Anode

The modern type of X-ray tube designed by Coolidge is shown in Figure 2-2. It consists of a highly evacuated hard glass bulb containing a cathode and an anode target. The pressure inside the tube is 10^{-6}mm of mercury.

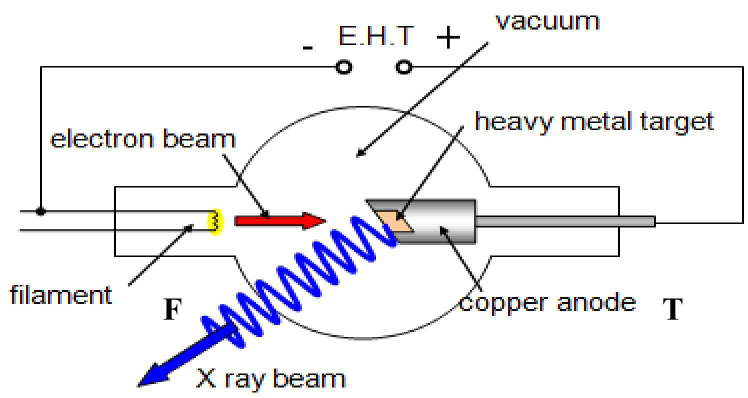

FIGURE- 2-2
Coolidge tube

The cathode is a tungsten filament F and is heated by passing a current through it from a low tension battery. The electrons are emitted by the process of thermionic emission from the cathode. The filament is surrounded by a molybdenum cylinder kept at a negative potential to the filament. Hence, the electrons emitted from the filament are collimated into a fine pencil of electron beam.

The target T consists of a copper block in which a piece of tungsten or molybdenum is fixed. The anode should have the following characteristics:

(i) high atomic weight - to produce hard X-rays
(ii) high melting point - so that it is not melted due to the bombardment of fast moving electrons, which cause lot of heat generation.
(iii) high thermal conductivity - to carry away the heat generated.

To prevent damage to the anode it has to be cooled, either by air cooling, using fins, or by pumping cooling liquid through it. It may even be rotated during use to spread the wear over a larger area.

A high potential of about 20 kV is applied between filament F and the target T. Due to this high potential difference, the electrons emitted from the filament are accelerated. The anode is sloped at about 45^o to the electron beam. Being good conductor of heat, copper or molybdenum helps to conduct the heat efficiently to the water cooling system. When these accelerated electrons strike the target, they lose their kinetic energy. Most of their energy produces heat and less than 0.05 per cent of the kinetic energy of the electrons is converted into X-radiation.

The intensity of X-rays depends upon the number of electrons striking the target. i.e. the rate of emission of electrons from the filament. This can be controlled by varying the filament current.

Uses of X-rays

Since the discovery of X-radiation, they are used in various fields and for various purposes. Some key uses of X-Ray are given below.

Medical Use: They are used for medical purposes to detect the breakage in human bones -can damage living tissue - hence their use for the destruction of tumours.

Security: They are used as a scanner to scan the luggage of passengers in airports, rail terminals, and other places.

Astronomy: It is emitted by celestial objects and are studied to understand the environment.

Industrial Purpose: It is widely used to detect the defects in the welds, checking metal castings for defects; crystal analysis.

Restoration: They are used to restore old paintings.

Check Up

- What is X-ray?
- What are it special characteristic?
- How can it be produced in Coolidge Tube?
- What are their uses?