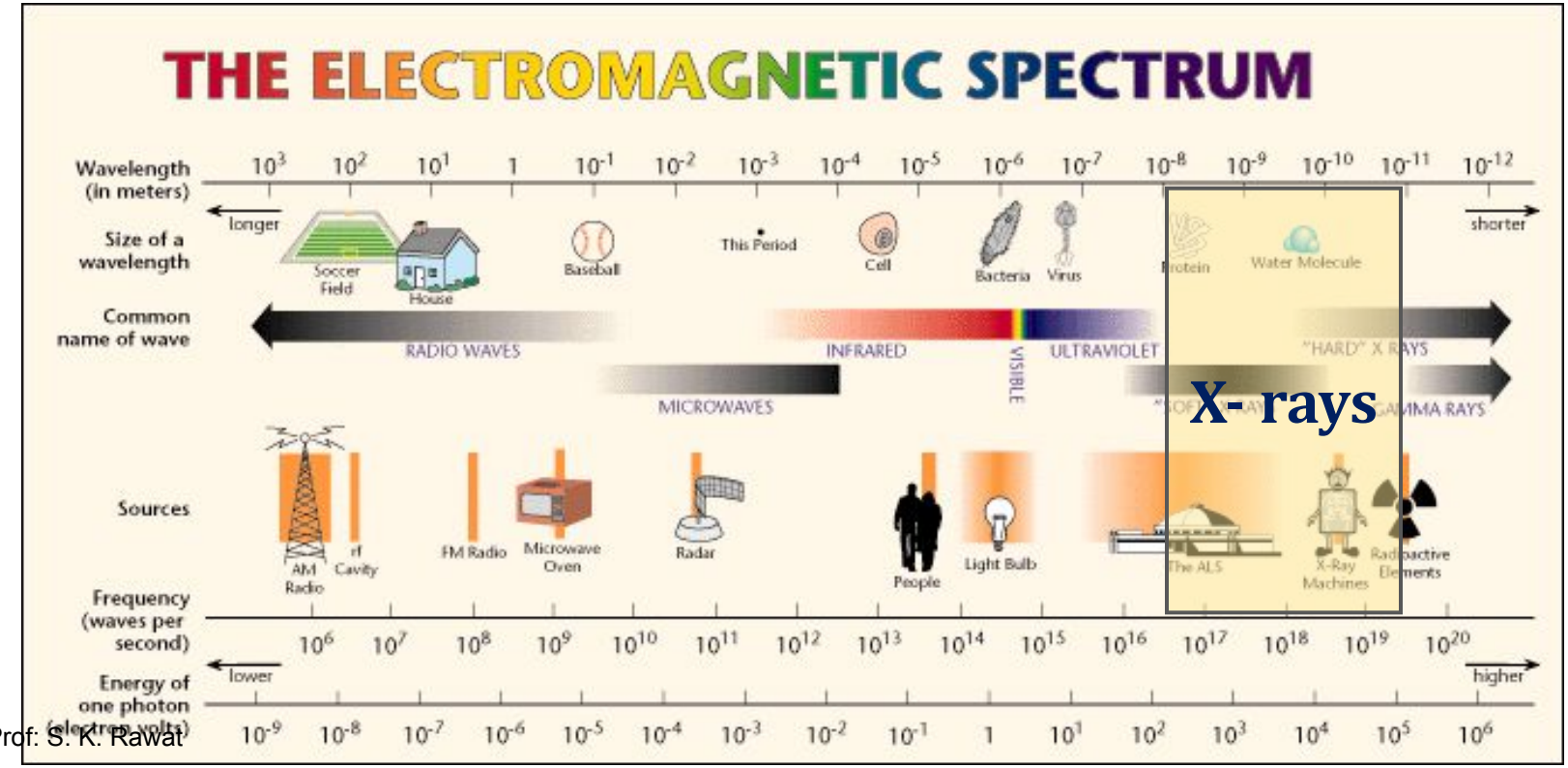
X-RAY

OBJECTIVES

- ***After studying this topic YOU will be able to***
- Illuminate the origin of X-rays.
- Explain the production of X-rays using Coolidge's X-ray tube.
- Write formula for minimum wavelength of X-ray and solve numerical on it.
- State properties of X-rays.
- List applications of X- rays: engineering, medical and scientific.

WHAT ARE X-RAYS?

- X-rays are high energy electromagnetic radiations of very short wavelength (0.1A° – 100A°) having high penetrating power and travelling in straight line with velocity of light.



ORIGIN OF X-RAYS

- When a high energetic electron is incident on the atom, the electron penetrates inside the atom and will either remove electron or get deflect from the innermost electron.

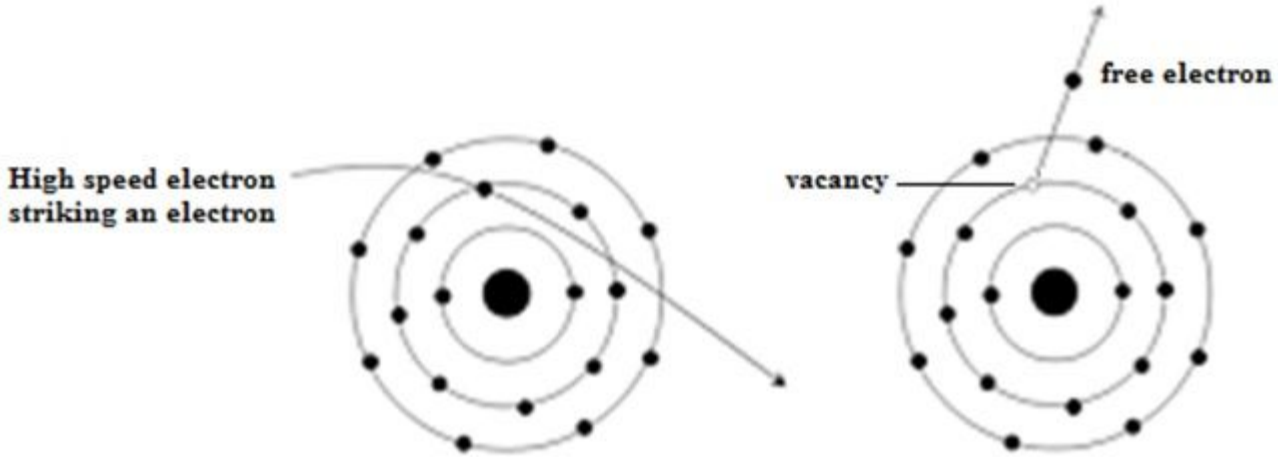
- As a result, some rays will produce which are called X-rays. X-rays are highly energetic radiations with the wavelength from 10^{-11} to 10^{-9} m. Depending on the origin X-rays are divided into two types:

  - Characteristics X-rays (Line spectra)

  - Continuous X-rays (Bremsstrahlung).

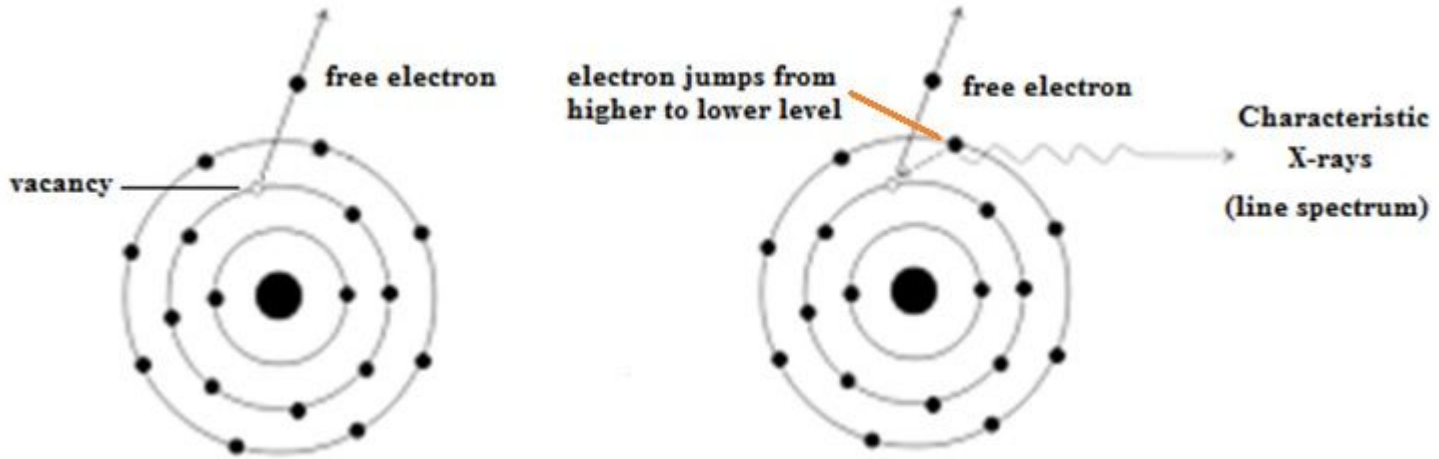
CHARACTERISTICS X-RAYS

- *X-rays which are emitted when a highly energetic charge particle ejects an electron from the inner shells of the incident atoms is called characteristics X-rays.*
- When high energetic electron is incident on target element, then this incident electron knocks out electron from either K, L or M shell.
- As a result vacancy is created in the shell.



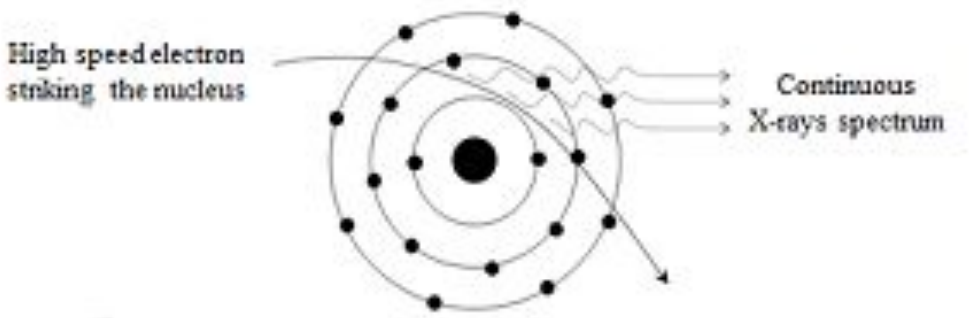
CHARACTERISTICS X-RAYS

- To fill up this vacancy, electron from the higher orbit jump to lower orbit as shown in Fig. below.
- As a result, electron transition takes place and the energy difference is radiated in form of X-rays with small and definite wavelength.
- As the X-rays spectra consists of sharp lines and the characteristic of target material, therefore is called as characteristic X-rays or line spectra.



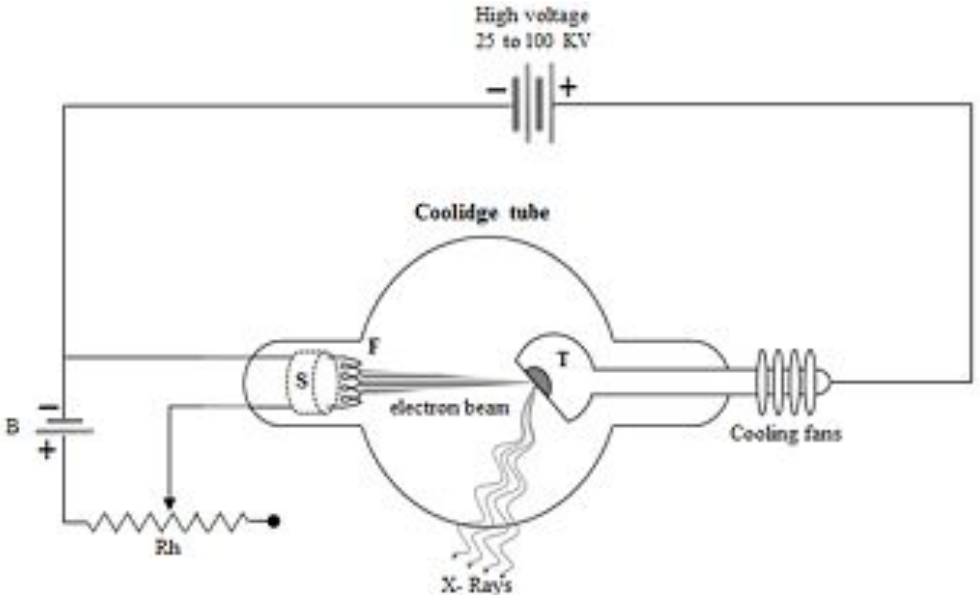
CONTINUOUS X-RAYS

- *The X-rays emitted when fast moving electron is rapidly slows down by an electric field around the nucleus is called continuous X-rays.*
- When high energetic electron is made incident on the nucleus, then this electron will be deflected by the innermost electron in the atom.
- Thus the velocity of incident electron is reduced and this gives rise to loss of energy as shown in Fig. below.
- As a result loss of energy is given out in form of electromagnetic radiation with continuously varying wavelength called continuous X-rays.



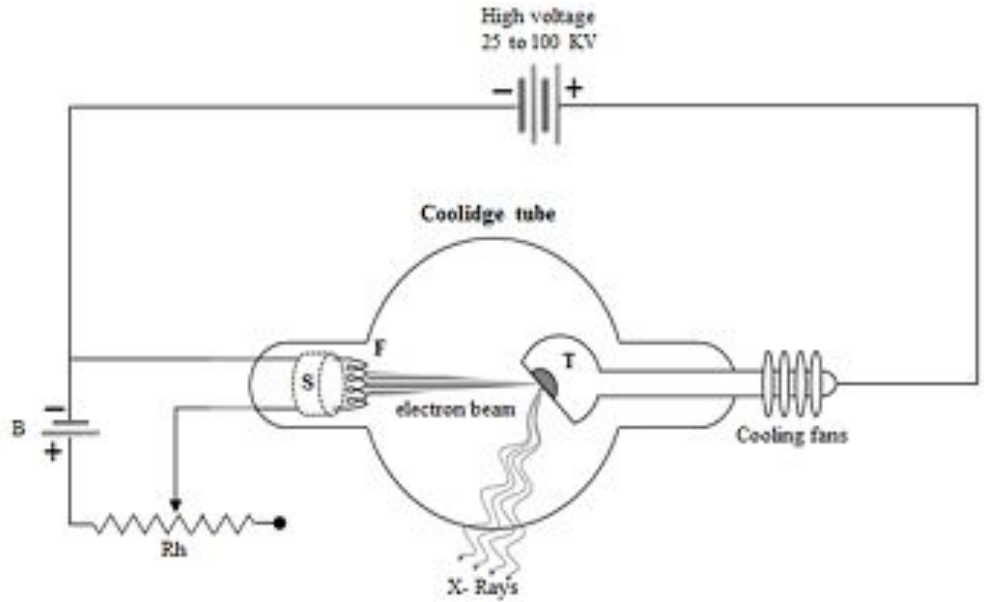
PRODUCTION OF X-RAYS USING COOLIDGE'S TUBE

- A focused beam of electrons is accelerated towards the target (T) by applying a varying high potential difference (25 to 100 KV) between the filament (F) and target (T).
- When these accelerated electrons collide with the target, they give up their kinetic energy and thereby produce X-rays.
- The X-rays spread out from the target and easily pass through the glass tube walls containing the lead sheet with small window allowing passage of X-rays.



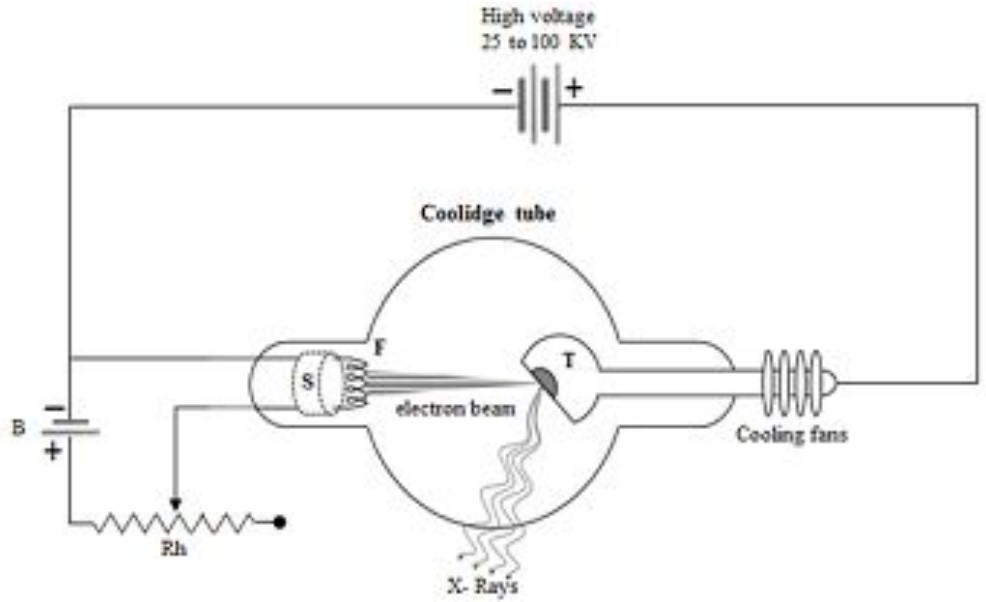
PRODUCTION OF X-RAYS USING COOLIDGE'S TUBE

- X rays are produced by modern X-rays tube designed by Coolidge as shown in Fig. below. It consists of highly evacuated hard glass tube having two electrodes, cathode (K) and anode (A).
- The concave cathode consists of tungsten filament (F) and is heated by passing current through a low tension battery (B).
- The electrons are emitted by the process of thermionic emission from cathode.



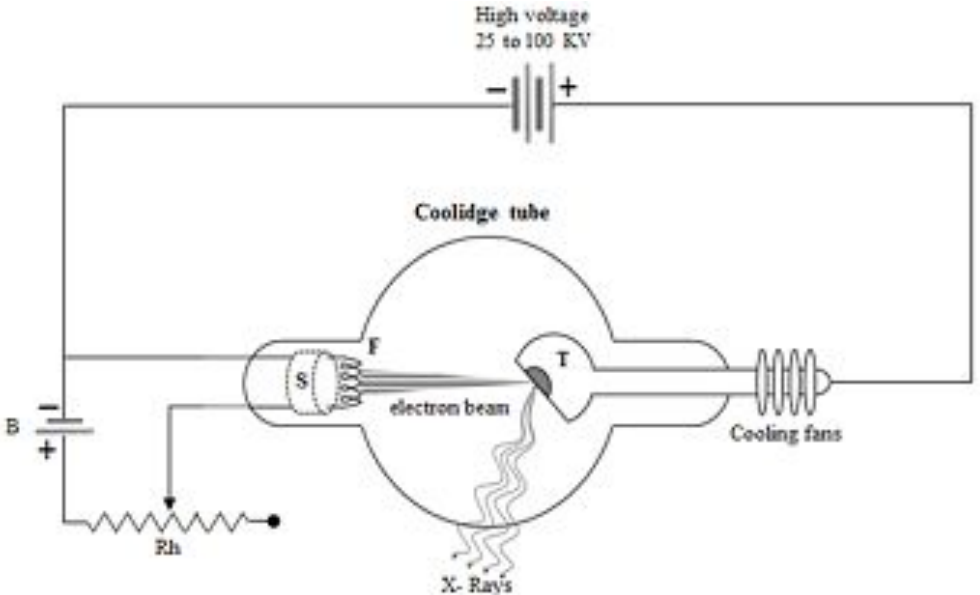
PRODUCTION OF X-RAYS USING COOLIDGE'S TUBE

- The filament is surrounded by molybdenum cylinder (S) kept at negative potential to the filament.
- The anode is a copper block which contains a small target (T) of tungsten or molybdenum, on which electrons are focused by cathode.
- The target is placed at an angle of 45° with the path of electron beam.



PRODUCTION OF X-RAYS USING COOLIDGE'S TUBE

- Here small amount of electron energy gets converted into kinetic energy while the rest is dissipated as heat.
- Thus target get heated up and in order to save it a constantly cooling arrangement is provided by cooling fans.
- The quality of X-rays is measured in terms of penetrating power which depends on the high voltage between filament (F) and target (T).
- X-rays with high penetrating power are called Hard X-rays and those with low penetrating power are called as Soft X-rays.



MINIMUM LENGTH OF X-RAYS

We know that the K.E of an electron having charge e and accelerated by a potential V is given by

$$K.E = \frac{1}{2}mv^2 = eV \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

As the liberated X-ray photon has maximum frequency , thus the K.E of photon is given as

$$K.E = \frac{1}{2}mv^2 = h\upsilon_{max} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

From equations (1) and (2), we get $h\upsilon_{max} = eV$ or $\frac{ch}{\lambda_{min}} = eV \quad \left[\because \upsilon = \frac{c}{\lambda}\right]$

$$\therefore \lambda_{min} = \frac{ch}{eV} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Substituting the values of $c = 3\times10^8\,m/s,\ h = 6.62\times10^{-34}\,J.s,\ e = 1.602\times10^{-19}\,C$ in (3), we get

$$\therefore \lambda_{min} = \frac{3\times10^8\times6.62\times10^{-34}}{1.602\times10^{-19}\times V}$$

$$\therefore \lambda_{min} = \left(\frac{12400\times10^{-10}}{V}\right)m \qquad \ldots\ldots\ldots\ldots \quad (4)$$

$$\therefore \lambda_{min} = \left(\frac{12400}{V}\right)A^\circ \qquad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

Equation (3), (4) and (5) gives the minimum wavelength of X-rays produced.

Ex.3.6 X-ray tube works on 80 KV. Find the minimum wavelength of X-ray produced by X-ray tube. $\left(h = 6.634 \times 10^{-34} Js,\ c = 3 \times 10^{8} m/s,\ e = 1.6 \times 10^{-19} C\right)$ ***(S-13)***

Given: $V = 80\,KV = 80 \times 10^{3}\,V$

Find: λ_{min}

Formula: $\lambda_{min} = \dfrac{12400}{V} A^{o}$

Solution: We know $\lambda_{min} = \dfrac{12400}{V}$

$$= \frac{12400}{80 \times 10^{3}}$$

$$\therefore \lambda_{min} = 0.155 A^{\circ}$$

Ans: Thus, the minimum wavelength is $0.155 A^{\circ}$.

PROPERTIES OF X-RAYS

X-rays are electromagnetic radiations and their properties are similar to those of light. Some properties of X-rays are:

- *X-rays are electromagnetic radiations with short wavelength of order 0.1A° to 100A°.*
- *X-rays travel in straight line with the speed of light, i.e., .*
- *X rays are not deflected by electric and magnetic field. This shows that they are charge less.*
- *X rays have high penetrating power due to which they can pass through even those substances which are opaque to ordinary light.*
- *They can be diffracted by crystals and obey Bragg's law.*
- *They ionize a gas by permitting it to conduct.*
- *They can produce fluorescence in materials like zinc sulphide, barium platinocyanide or cadmium tungstate.*
- *X-rays affect a photographic emulsion and plates.*
- *X-ray can produced damage in living tissue.*
- *X-rays can be polarized.*

APPLICATION OF X-RAYS

Engineering

- X-rays are used to detect any defect in radio values, tennis balls, and rubber tyres.
- X-rays are used for testing the homogeneity of welded joints, insulating materials, etc. without damaging them.
- X-rays photographs can show hidden flaws such as crack, holes and imperfections in welds in the body of aeroplanes and vehicles.
- The diffraction property of X-rays is used to study the crystal structure, arrangements of atoms and molecules in compounds.

APPLICATION OF X-RAYS

Medicine

- X-rays photograph are used by dentists for diagnosing the rupture of teeth.
- Hard X-rays are used by doctors to destroy tumor inside the body and for diagnosing a treatment of different diseases.
- High energy X-rays are used to destroy cancer cells within the body.
- Bone fractures, foreign material such a safety pin swallowed or the presence of diseased area such as tuberculosis can be detected by taking X-rays photograph.

APPLICATION OF X-RAYS

Science

- X-rays are used for studying the structure of crystalline solids and alloys.
- X-rays are used to analyze the structure of crystals, atoms and complex organic molecules.
- X rays are used to retouching and alternations by exposing the under layers of paintings.
- X-rays are used at custom and security posts to detect arms, explosive materials and other precious metals such as gold.