



GOOD MORNING

Radiation Physics

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Associate Professor

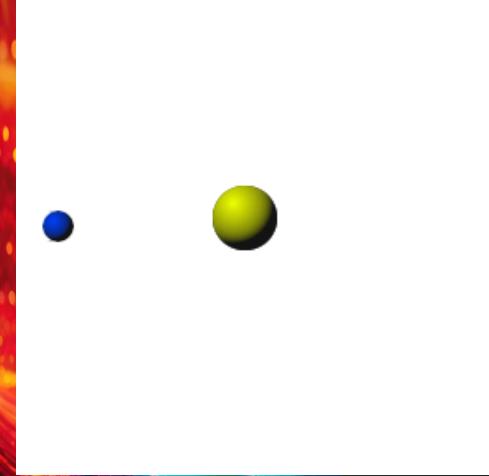
Oral medicine & Radiology

OMFD -1
3rd YR 25-26





Radiation Physics



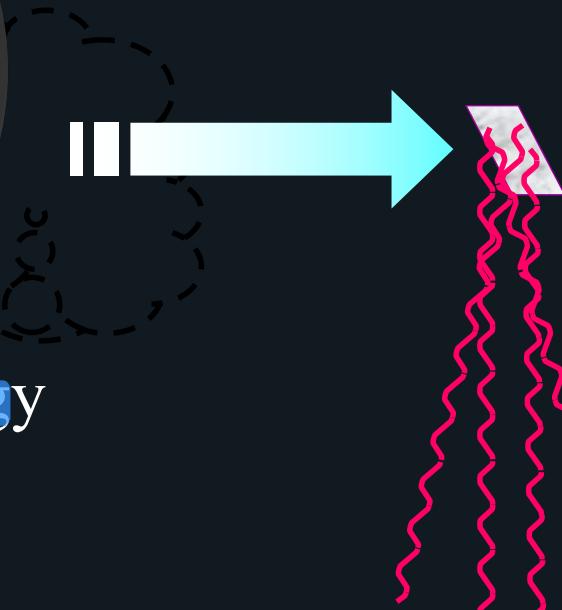
Lecture Learning Outcome

- Describe the composition of atom, mechanism of production of x-ray.
- Name the parts and function of the x-ray tube and machine.
- Describe the process of generating x-rays.
- Describe the factors affecting the x-ray production.
- Explain the interaction of x-rays with matter.

ORIGIN OF DENTAL RADIOLOGY AND THE X-RAY MACHINE

❖ Discovery of the x-rays by **Sir Wilhelm Conrad Roentgen** Nov 8th Friday in 1895.

↳ **Timeline:**



Father of Radiology

FATHER OF DENTAL RADIOLOGY

Learning outcomes:



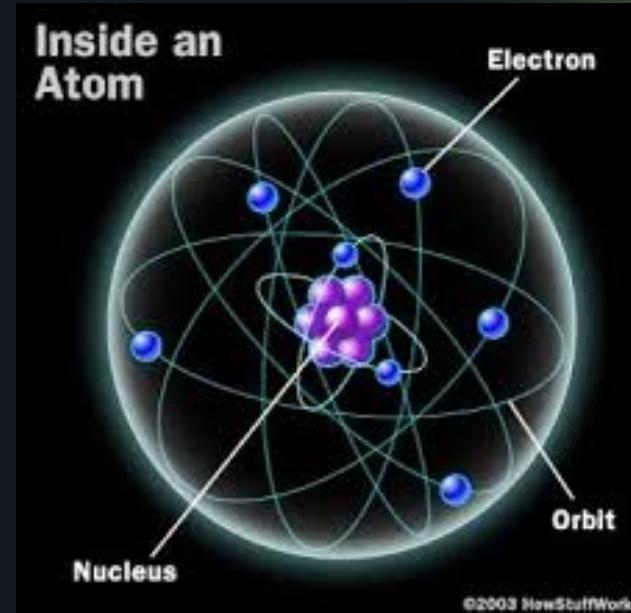
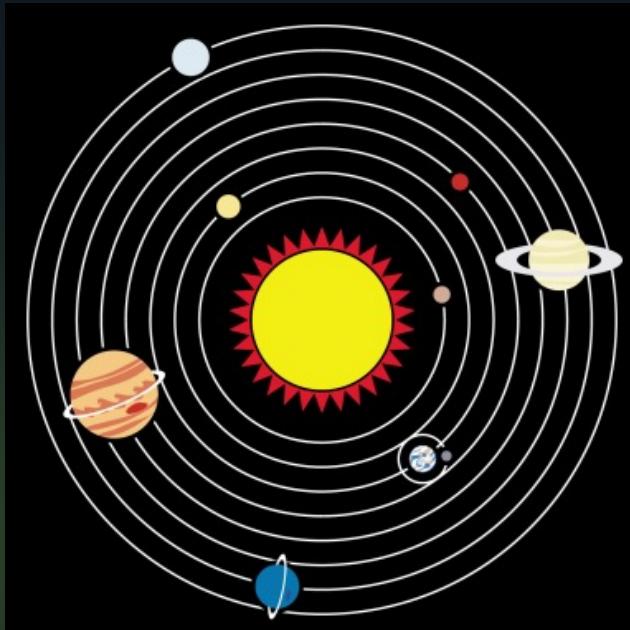
CHARLES EDMOND KELL (DDS) (1865-1928)

-Atom - & is the fundamental unit of matter.

Atomic Structure

BOHR'S ATOMIC MODEL- NEILS BOHR- 1913

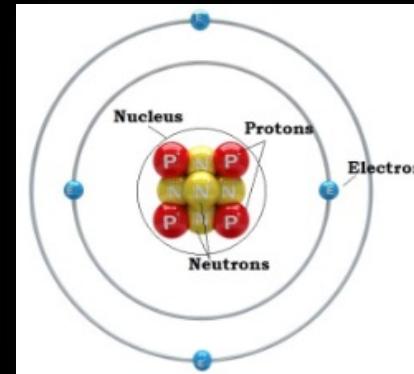
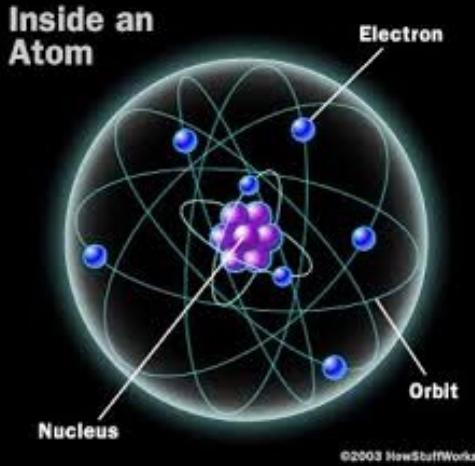
viewed atom as miniature of solar system with nucleus at center & revolving electrons.



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Nucleus:

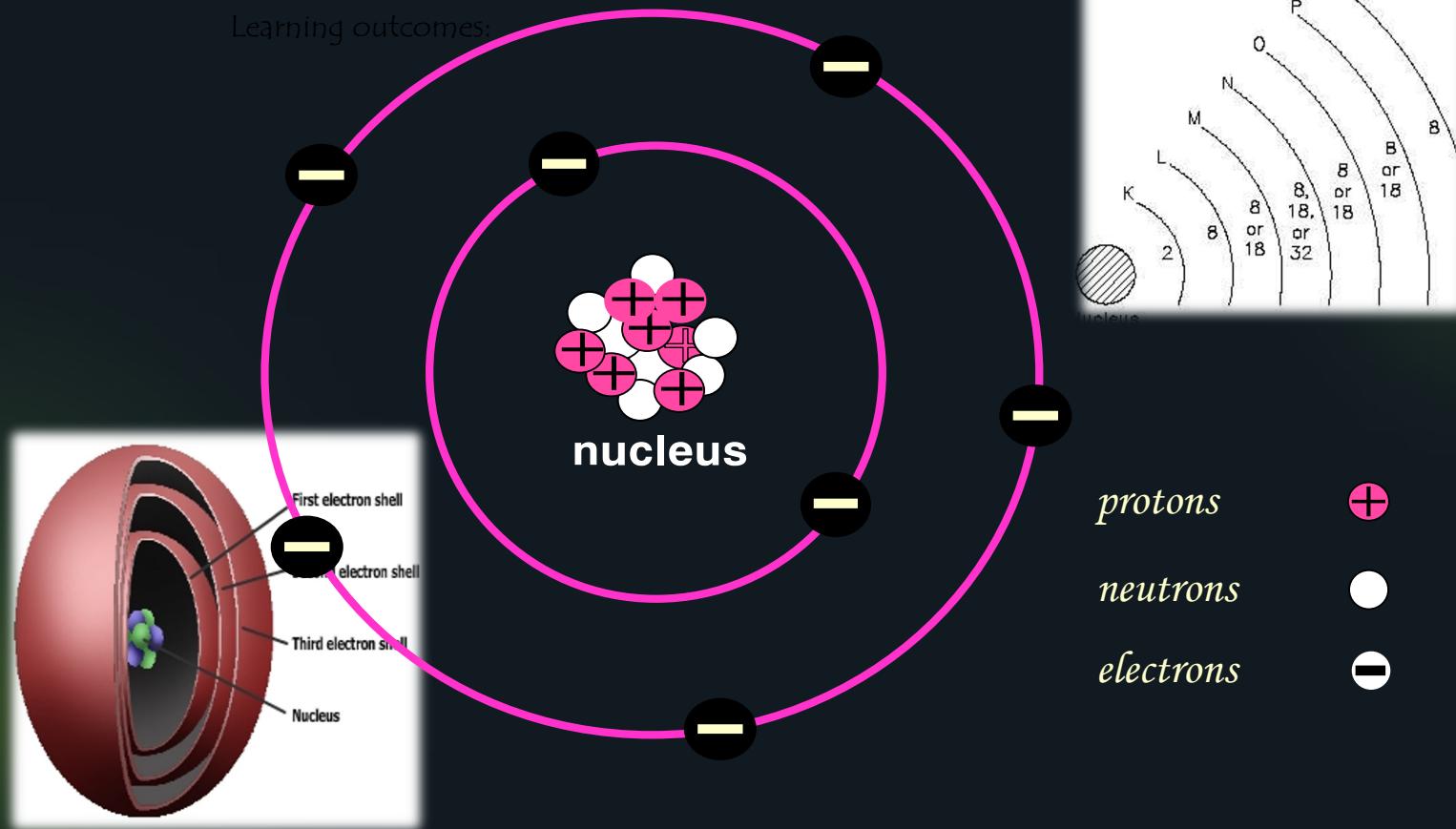
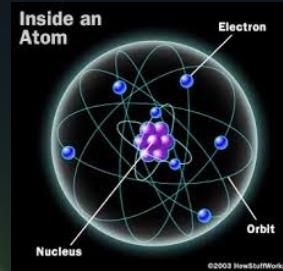
1. Protons – carry (+1) electrical charge
2. Neutrons – carry no electrical charge



- ELECTRONS: negatively charged particles.
Electrons travel around nucleus in orbits / shells.

The number of electrons equals the number of protons
- atom is electrically neutral.

Atom consists max of 7 shells – K,L,M,N,O,P,& Q,(no of electrons it can hold- K-2, L-8,M-18,N-32,O-50,P-72,Q-98 so on) representing different energy levels.



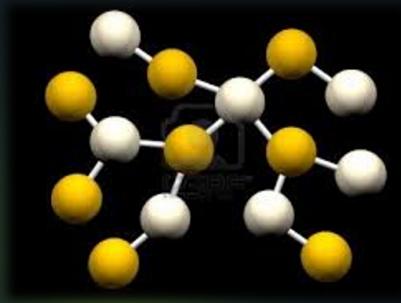
- The electrons are maintained in their orbits around the nucleus by two opposing forces.
- 1) Electrostatic force
- 2) Centrifugal force

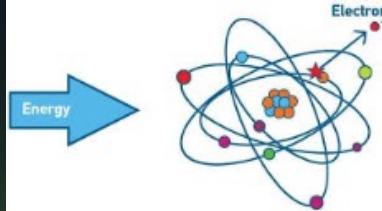
--Atom + atom+ atom+ ... = Molecule

- Molecule is formed by -
 - a) by transfer of electrons
 - b) by sharing of electrons from outer shells.
-
- If it gains electron- becomes –vly charged(>electrons)
 - If it loses electrons - +vly charged (> protons).

-An atom that gains or loses electrons becomes electrically unbalanced-is known as an

-

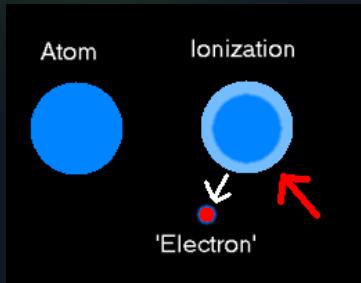




IONIZATION: *refers to a process of converting an atom into an ion.*

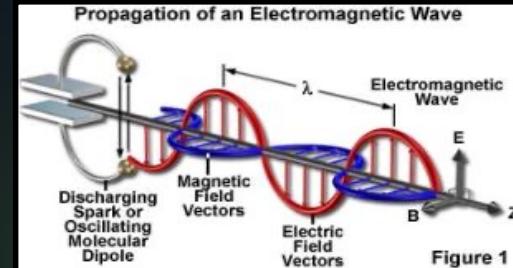
Learning outcomes:

Ionizing radiation: def as radiation that is capable of producing ions by removing or adding an electron to an atom.



2 basic forms of radiation:

- Particulate radiation
- Electromagnetic radiation



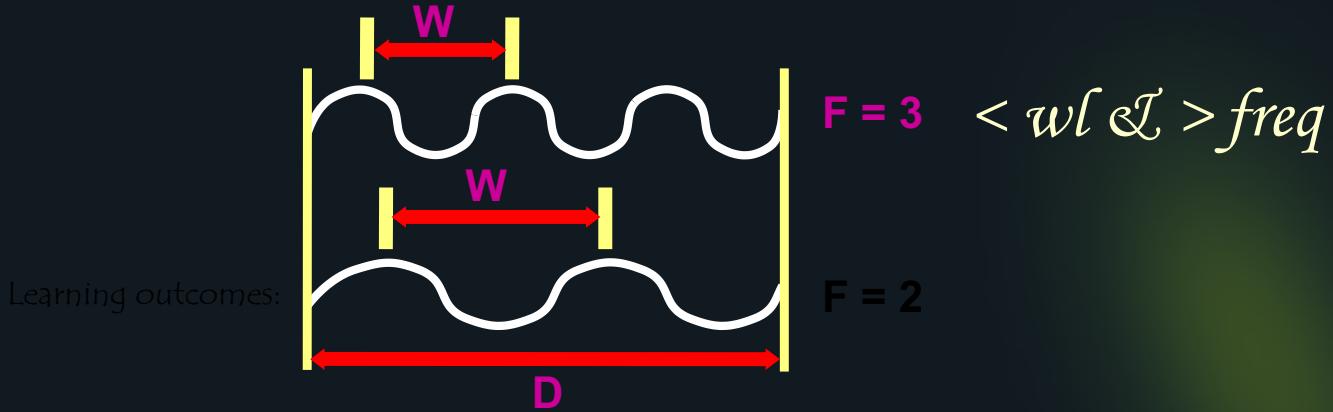
Electromagnetic Radiation

Electromagnetic radiation represents the movement of energy through space as a combination of electric and magnetic fields.

Eg: radio waves, TV waves, visible light, and gamma rays.

X-rays belong to Electromagnetic Radiation.

They travel through space in wave form.



WAVES -2 basic properties: **wavelength** and **frequency**.

The **wavelength (W)** is the distance from the crest of one wave to the crest of the next wave.

The **frequency (F)** is the number of waves in a given distance (D).

If the distance between waves decreases (W becomes shorter), the frequency will increase.



X-ray Energy

Learning outcomes:

The shorter the wavelength - **higher the frequency**, greater the energy - the more easily the wave will pass through the object

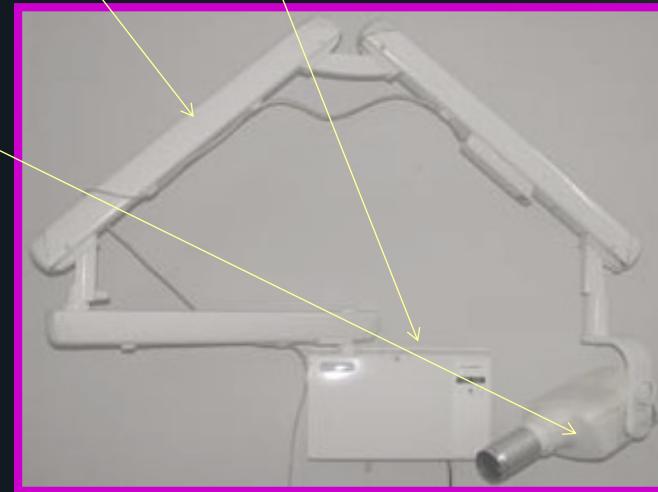
PROPERTIES OF X-RAYS

- X-RADIATION : are high-energy waves, ionizing electromagnetic radiation.
- They have no mass, no weight, no electric charge.
- Travel at the speed of light- 3×10^8 m/sec
- ❖ Wide range of wavelength
- They are invisible
- X-rays travel in wave motion along a straight line.
- ❖ An x-ray beam cannot be focused to a point

X-RAY MACHINE

Intraoral x ray units

- THE CONTROL PANEL
- THE EXTENSION ARM
- THE TUBE HEAD



THE CONTROL PANEL

-Most units – fixed calibrations –

Tube voltage (kVp) - **60-70 kVp, introray**

(The kVp primarily controls the energy or penetrating quality of the x-ray beam.)

-Tube current(mA) - setting determines the heating of the filament

(quantity). -7 -10 mA.

Exposure time (Sec)– Adjusted.

Exposure time controls quantity of exposure(0.3 to 1sec or 3 sec)



THE TUBE HEAD

1. METAL HOUSING

Learning outcomes:

2. INSULATING OIL

3. TUBEHEAD SEAL

4. TRANSFORMER

5. ALUMINUM DISCS

6. LEAD COLLIMATORS



Tube head seal

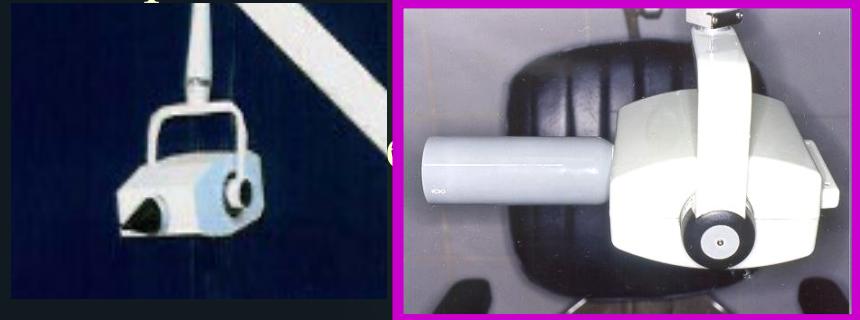


POSITION INDICATING DEVICE (PID)

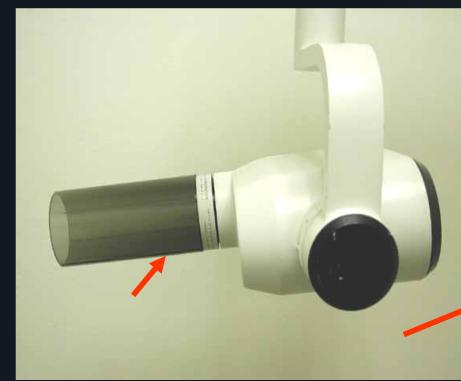
Open ended, lead –lined cylinder - it aims and shapes the x-ray beam.

3 types-

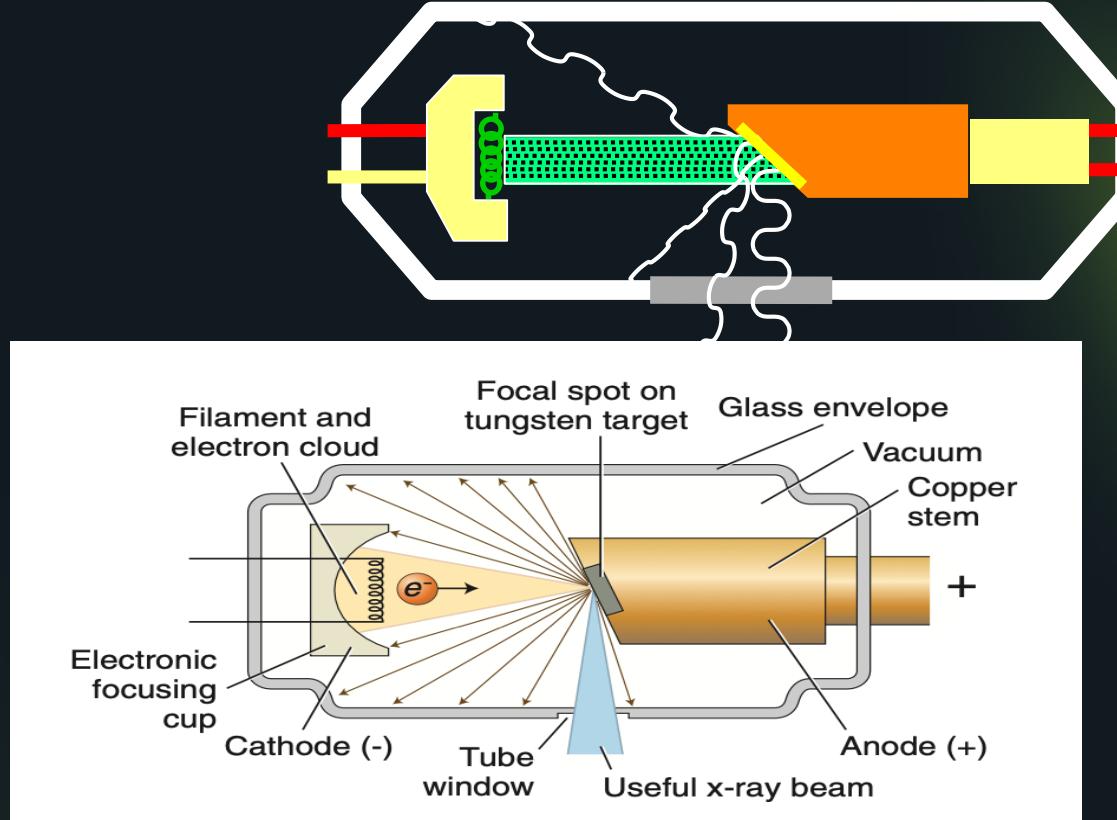
1. Conical ,2.Rectangular & 3. Round - lead



ANGLE METER- is a device that indicates the angle of x-ray beam in vertical plane



THE X-RAY TUBE



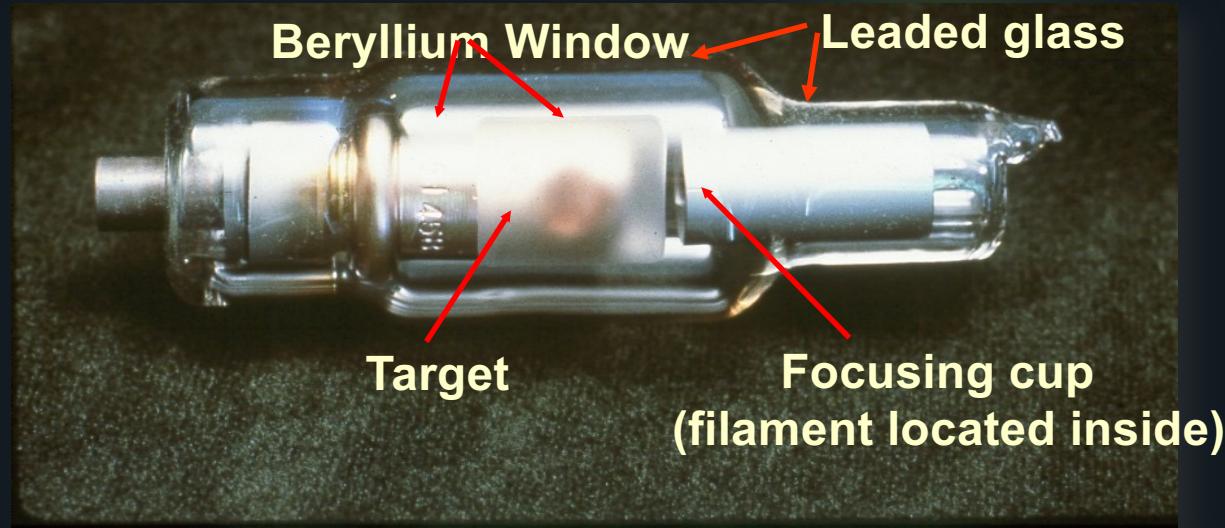
X-RAY TUBE WITH MAJOR COMPONENTS

THE X-RAY TUBE

X-rays are produced in the x-ray tube, which is located in the x-ray tubehead

The components of x-ray
tube include

- A leaded glass housing
- A negative cathode
- A positive anode

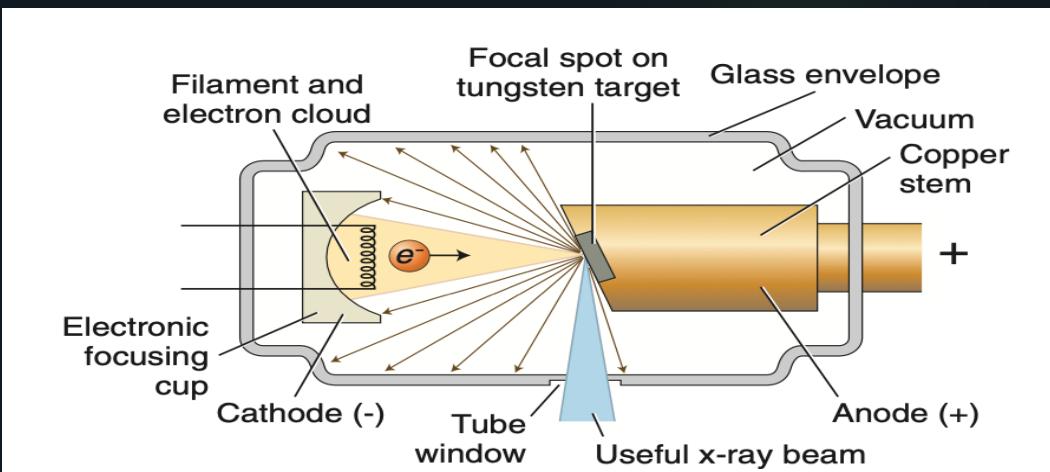


LEADED – GLASS HOUSING

-is a leaded glass vacuum tube(borosilicate) that prevents x-ray from escaping in all directions(except at window)



-One central area of it has a “WINDOWS” that permits the x-ray beam to exit the tube



CATHODE - A NEGATIVE ELECTRODE

THE cathode - two principal parts:

- 1) The filament – Tungsten
- 2) The focusing cup – Molybdenum

THE FILAMENT – TUNGSTEN

is the source of electrons within the x-ray tube,

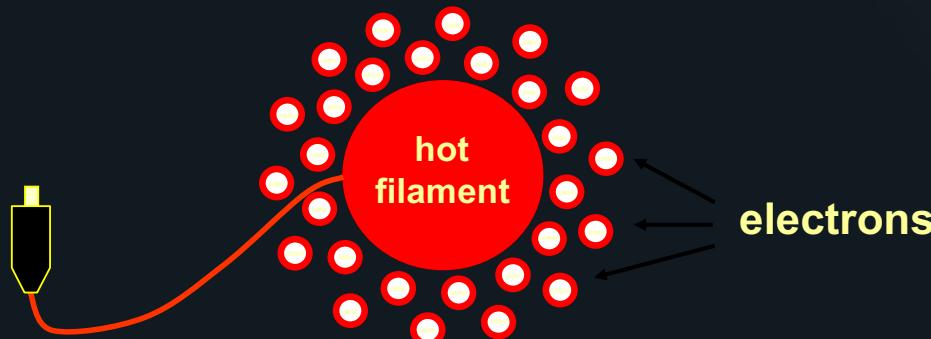
THE FOCUSING CUP – MOLYBDENUM

The filament is located in a focusing cup, - molybdenum which electrostatically directs the electrons on to the tungsten target of the anode.



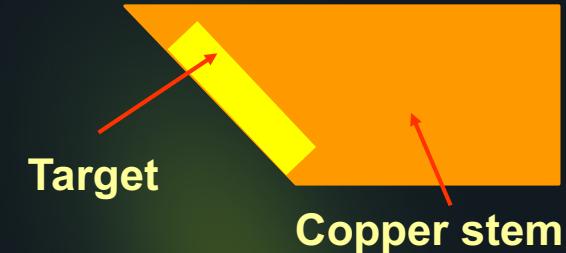
Thermionic Emission

When you depress the exposure button, electricity flows through the filament in the cathode, causing it to get hot. The hot filament then releases electrons which surround the filament (thermionic emission). The hotter the filament gets, the greater the number of electrons that are released.



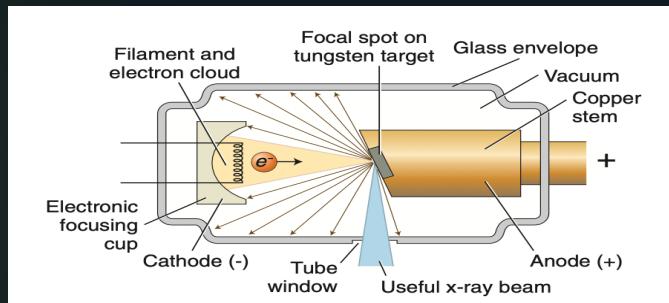
ANODE - A POSITIVE ELECTRODE

Consists of a tungsten plate embedded in a solid copper block.

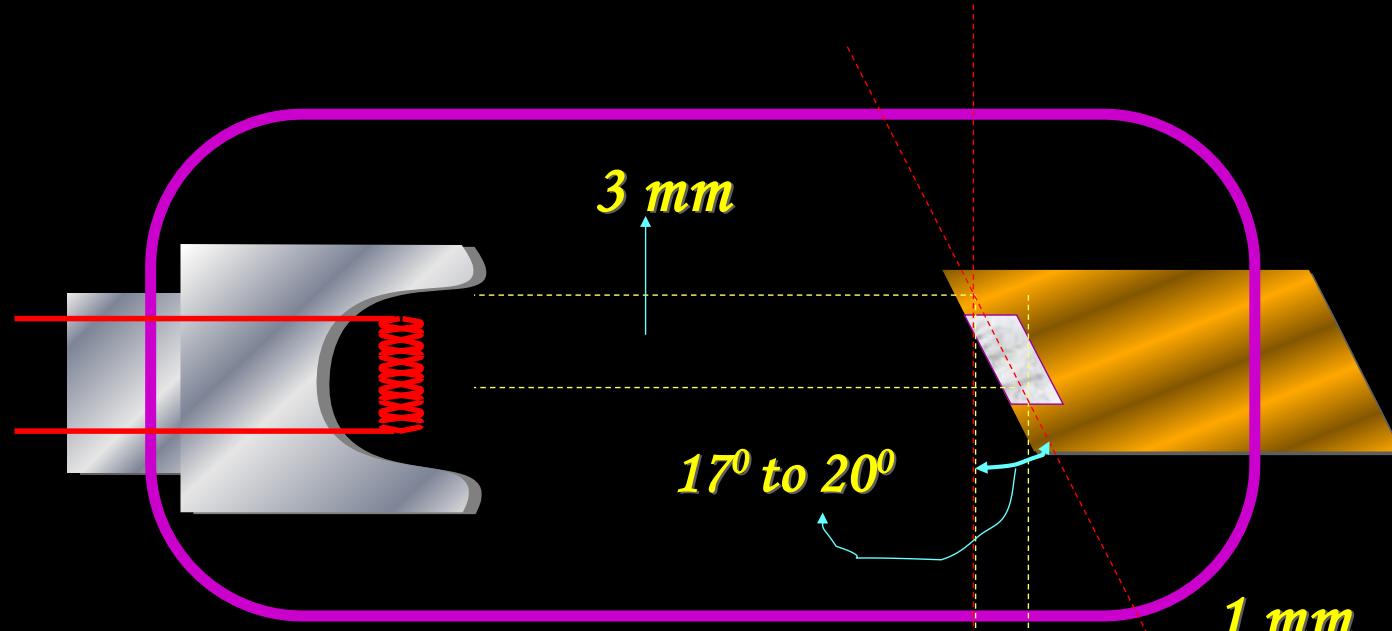


- COPPER STEM –dissipate the heat away from the tungsten target.

TUNGSTEN - is to convert the kinetic energy of the electrons into the x-ray photons.



FOCAL SPOT- Is the area on the target at which electrons are absorbed & x rays are generated



- The smaller the focal spot - the sharper the image of the teeth
- In order to get a small focal spot **-the LINE FOCUS PRINCIPLE –**
target is placed at an angle of $17\text{-}\underline{20}^\circ$ w.r.t. electron beam..

TRANSFORMERS- -is a device that is used to either increase or decrease the voltage in an electrical circuit.

Step-Down Transformer

If the voltage flowing through the filament is too high, the filament will burn up. --the current flows through a step-down transformer before reaching the filament.
and is determined by the mA setting.

STEP UP TRANSFORMER :

- Controlled by kVp setting.

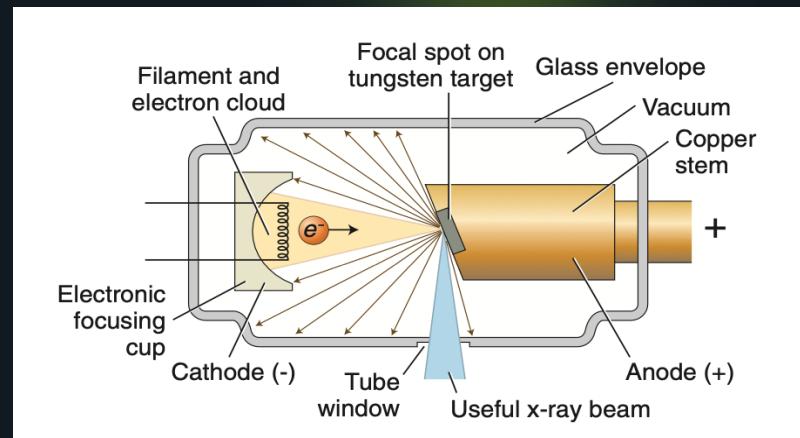


X-ray Production

- ❖ THE KINETIC ENERGY of electrons is converted to x ray via one of two mechanism:

1. Bremsstrahlung / Braking radiation
2. Characteristic radiation

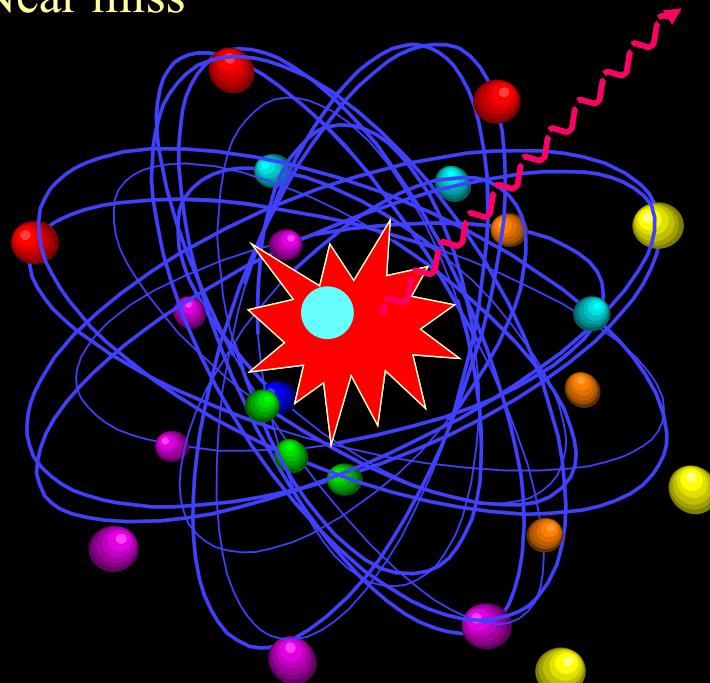
Learning outcomes:



Bremsstrahlung Radiation

2 possibilities can take place

- a. Direct hit interaction
- b. Near miss



1). (rare) –high speed electron may hit nucleus of tungsten atom – resulting in transformation of all its kinetic energy of an electron , into a single x ray photon

'Direct hit' Interaction

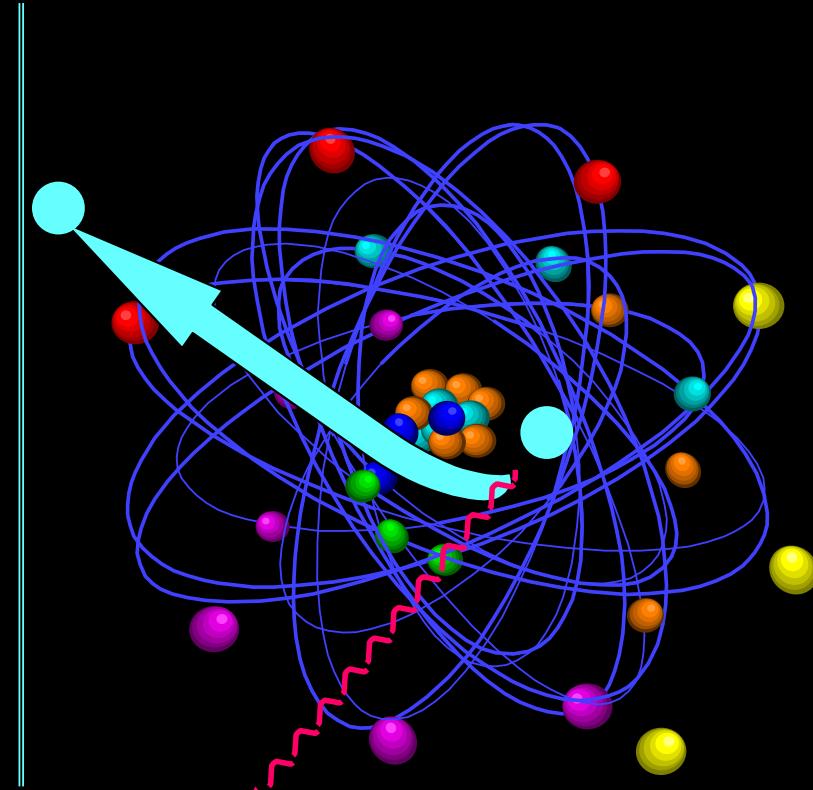
Bremsstrahlung Radiation

'Near miss' Interaction

In this interaction - the electron is attracted toward +vly

Charged nuclei , - its path is altered towards nucleus - & Loses some of its velocity.

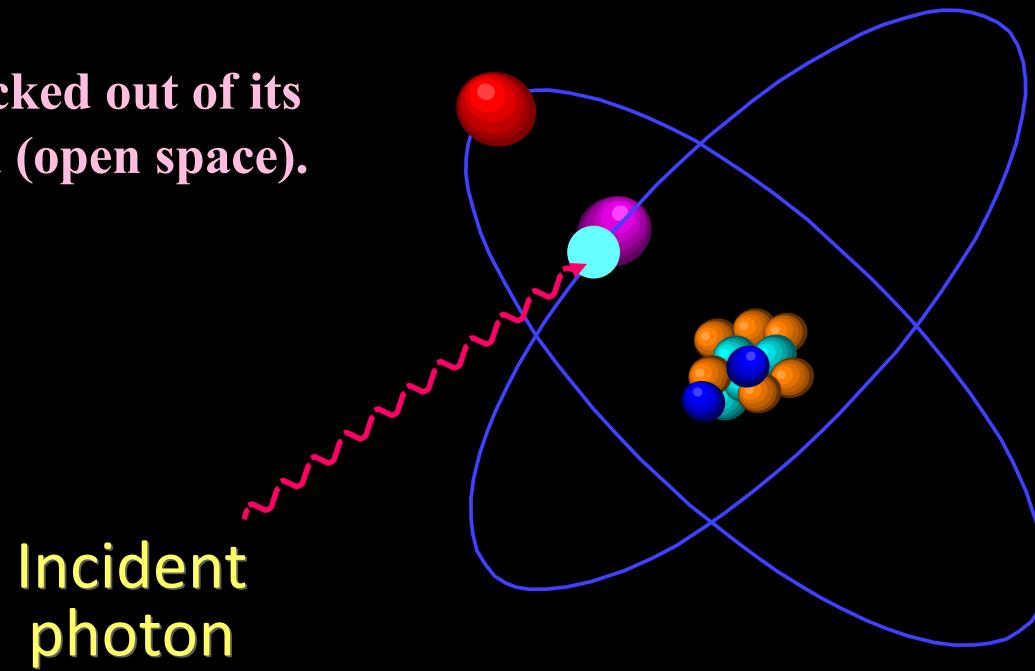
This deceleration causes electron to lose kinetic energy which is given off in the form of many photons



'Near miss' Interaction

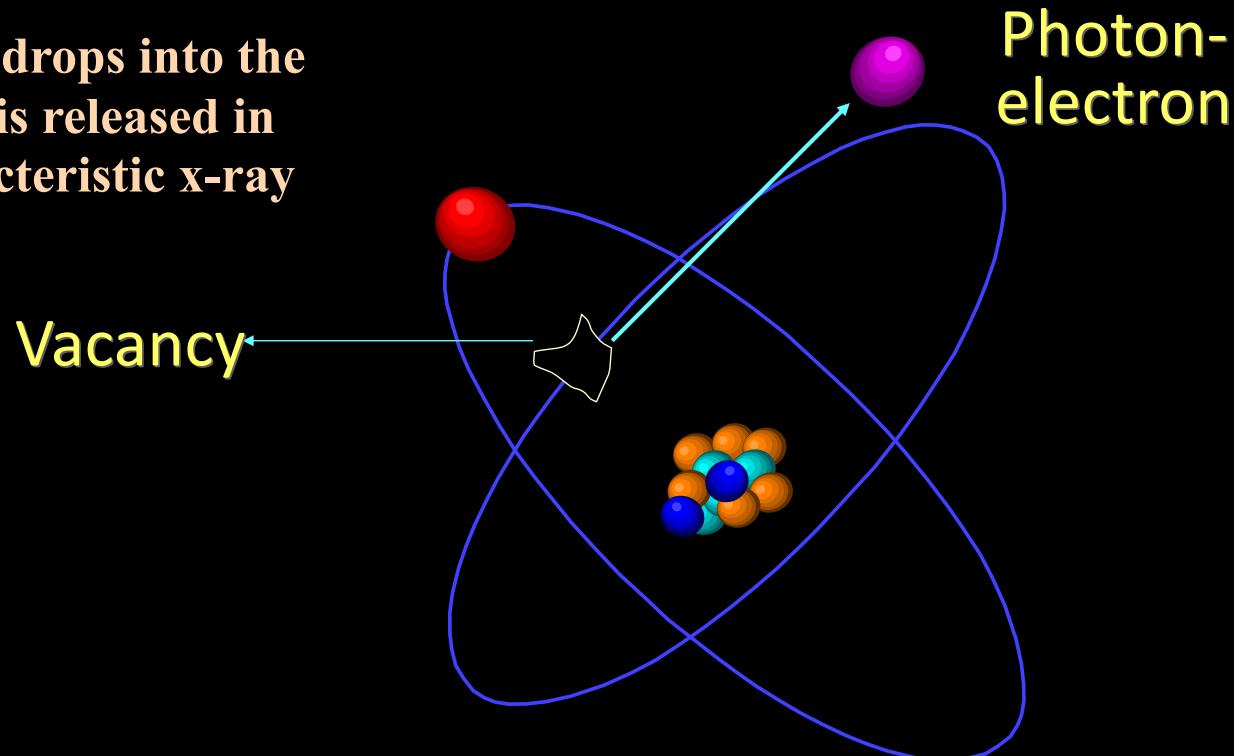
Characteristic Radiation

- High-speed electron from the filament collides with an electron in one of the orbits of a target atom
- the electron is knocked out of its orbit, creating a void (open space).

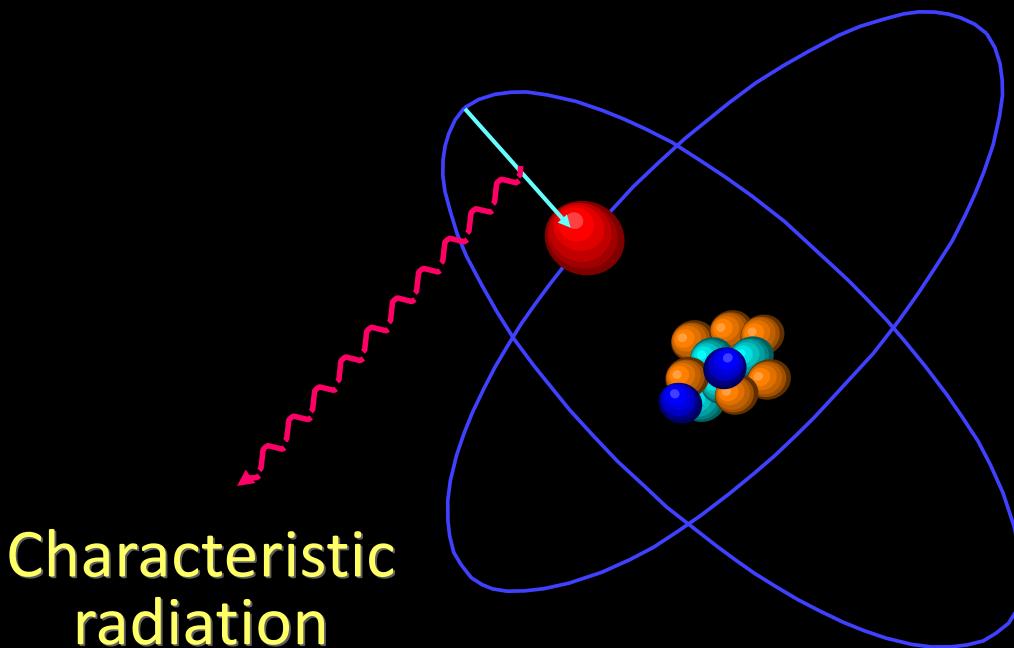


This space is immediately filled by
an electron from an outer orbit.

-When the electron drops into the
open space, energy is released in
the form of a characteristic x-ray



Photoelectric Effect



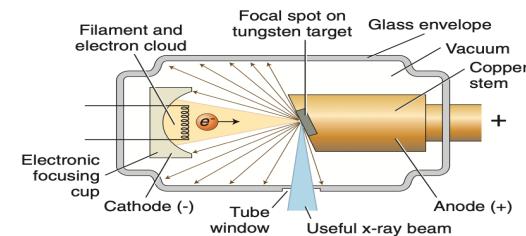
Factors Controlling the X-ray Beam

Learning outcomes:

1. Tube Voltage (***kVp***).
 - Controls quality of x-ray beam
 2. Tube Current (***mA***).
 - Quantity of x-ray beam
 3. Exposure Time (***S***)
 - Quantity of x-ray beam
 4. Filtration
 - Quality of x-ray beam
 5. Collimation.
 - Size of x-ray beam
 6. Inverse square law.
 - Quality of x-ray beam
-

TUBE CURRENT (mA)(7-10 m A)

The mA setting determines the heating of the filament.



Increased tube current(mA)

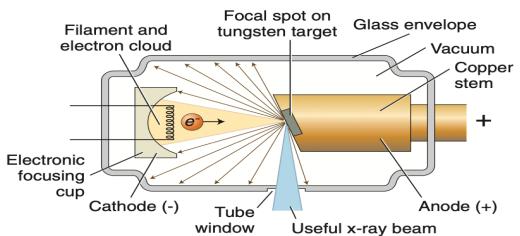
The hotter the filament, the more electrons released;

more electrons crossing the x-ray tube,

Increased number of x-rays that result.

Doubling the mA setting results in twice as many x-rays. –dark image.

TUBE VOLTAGE (kVp)(70kVp)



The kVp primarily controls the energy or penetrating quality of the x-ray beam.

Increased kVp

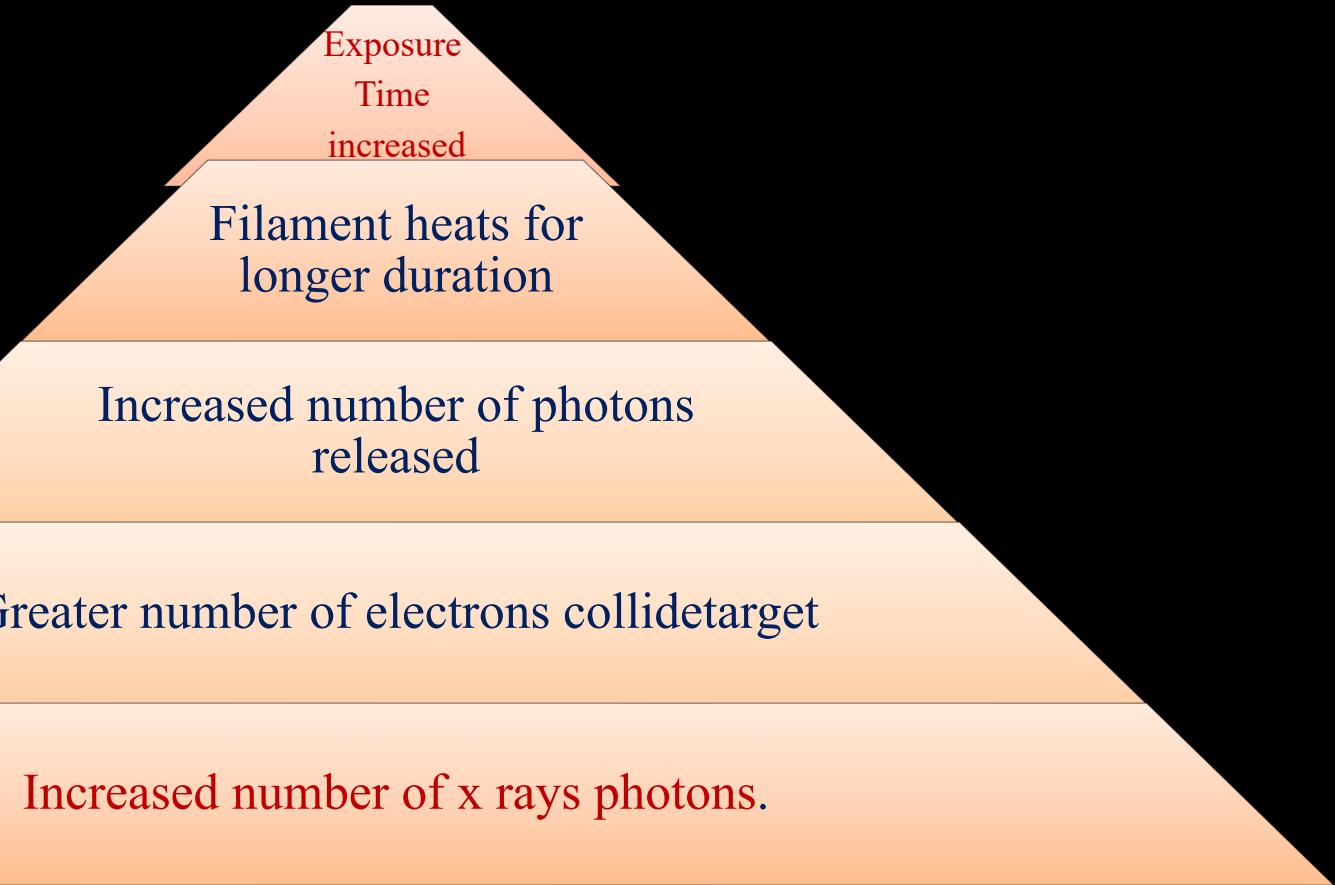
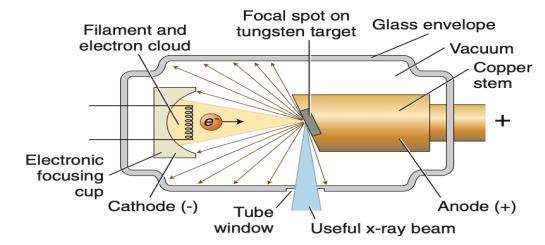
Potential difference increased between cathode & Anode

Electrons move at high velocity towards anode

Electrons strike focal spot at high speed higher conversion into x ray photons.

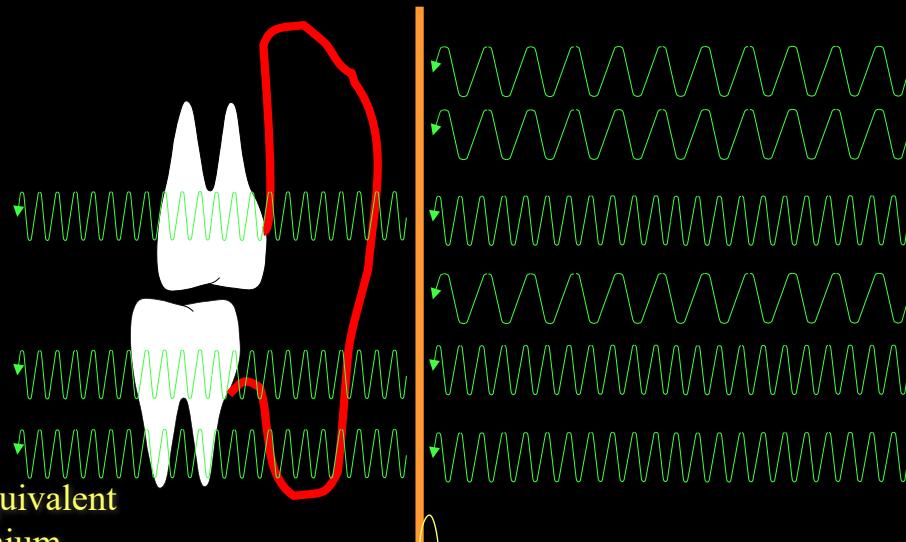
❖ EXPOSURE TIME (Sec)

Exposure time controls quantity of exposure - increase in number of x rays.



FILTRATION

“Filtration is removal of low-energy photons from the x-ray beam to reduce skin dosage”

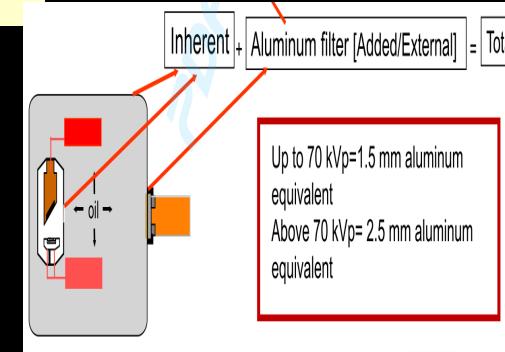


Inherent filtration : glass envelope, oil
= 0.2 mm of Al equivalent

Added filtration : discs of Aluminium

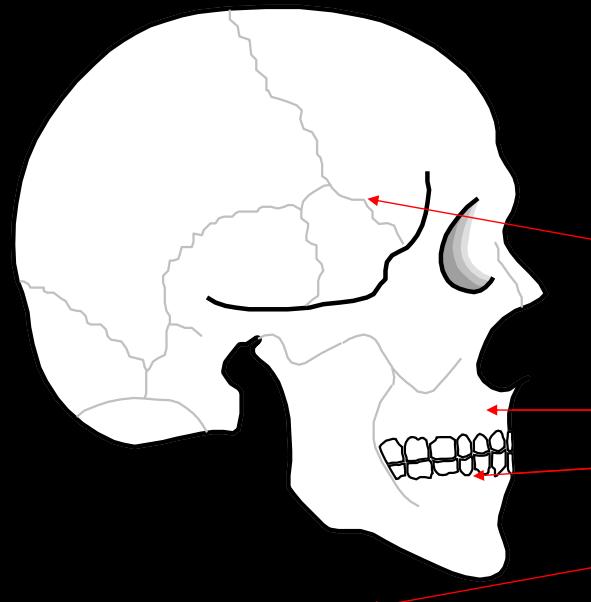
Total filtration = 1.5 mm of Al up to 70 kVp

Aluminium
Filter

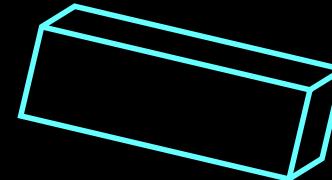


COLLIMATION

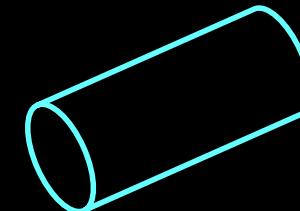
“Collimation is controlling the size and the shape of the x-ray beam to reduce tissue exposure”



Divergent
x-ray beam



Rectangular
3.5 cm x 4.5 cm
beam at the skin
(60% reduces
exposure)



Cylindrical
7 cm
diameter
beam at the
skin

Inverse Square Law

- ❖ Intensity of an x-ray beam is inversely proportional to the square of distance from the source

$$\frac{I_1}{I_2} = \frac{[D_2]^2}{[D_1]^2}$$

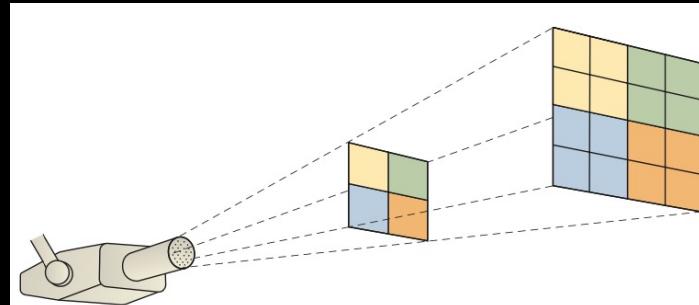
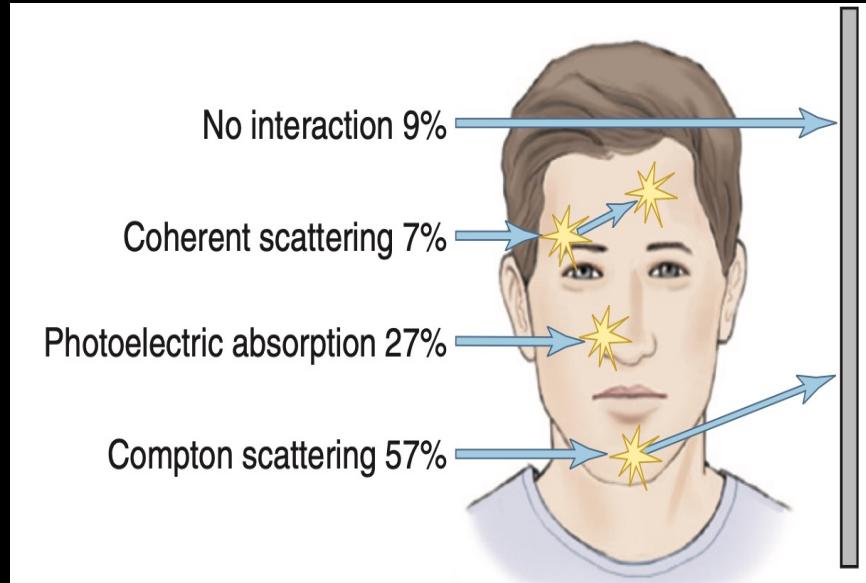


FIGURE 1-20 Intensity of an x-ray beam is inversely proportional to the square of the distance between the source and the point of measure. When the distance from the source to a target is doubled, the intensity of the beam decreases to one quarter.

Interaction of X-rays With Matter

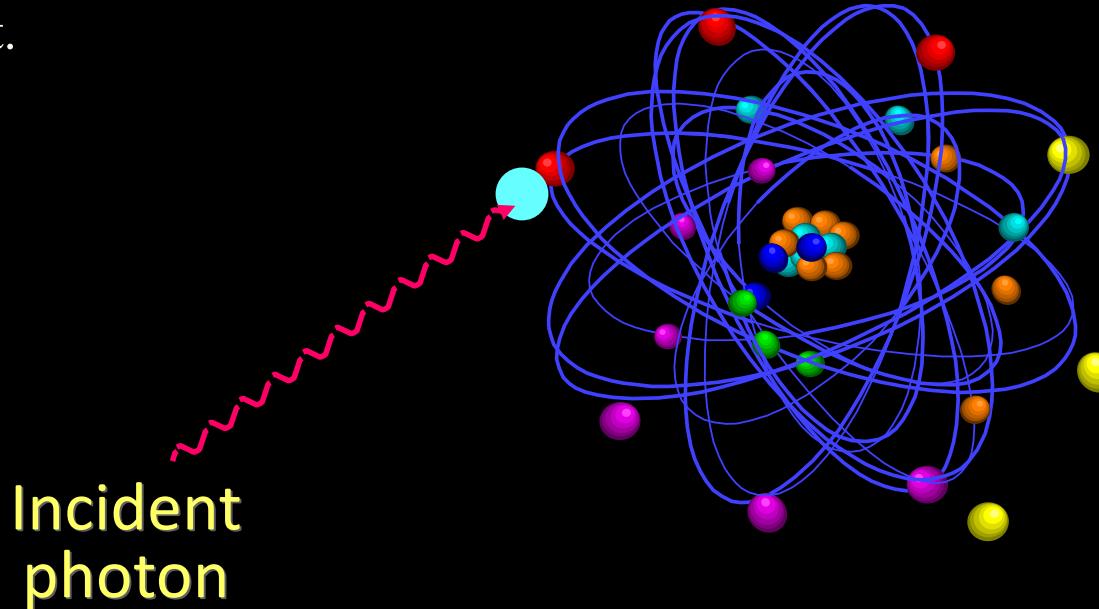
1. Coherent Scattering
2. Photo-electric absorption
3. Compton scattering



Interaction of X-rays With Matter

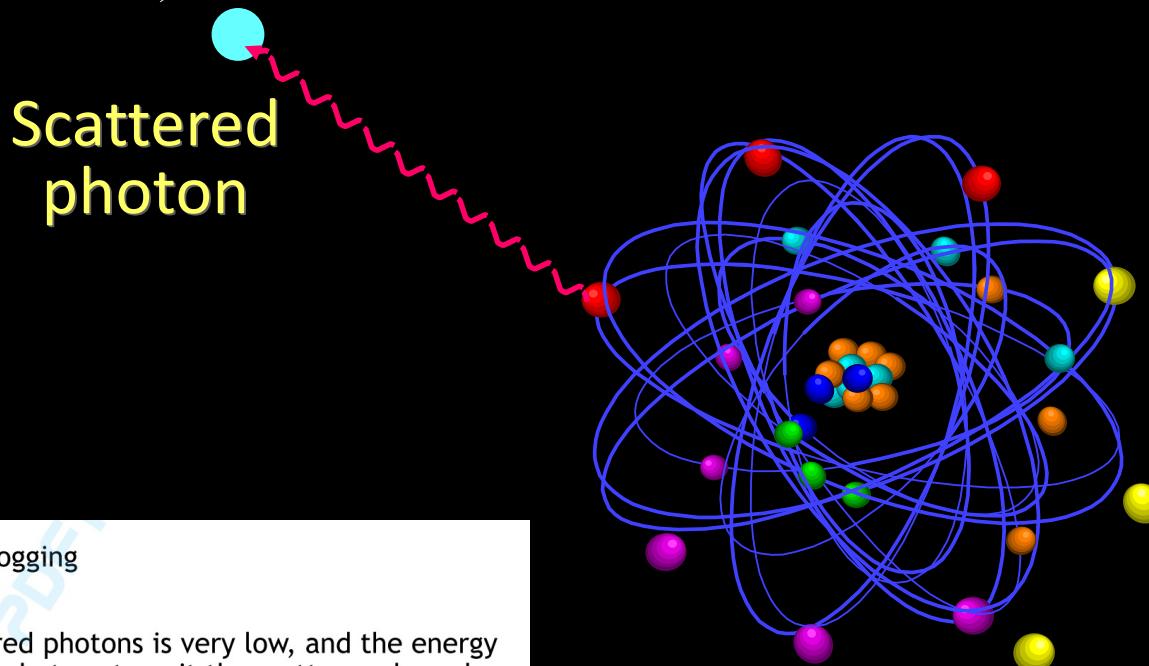
1. Coherent Scattering ('Thomson effect')

- ❖ Low Incident photon passes near the outer shell electron of an atom
- ❖ It momentarily excites the outer shell electron & ceases to exist.



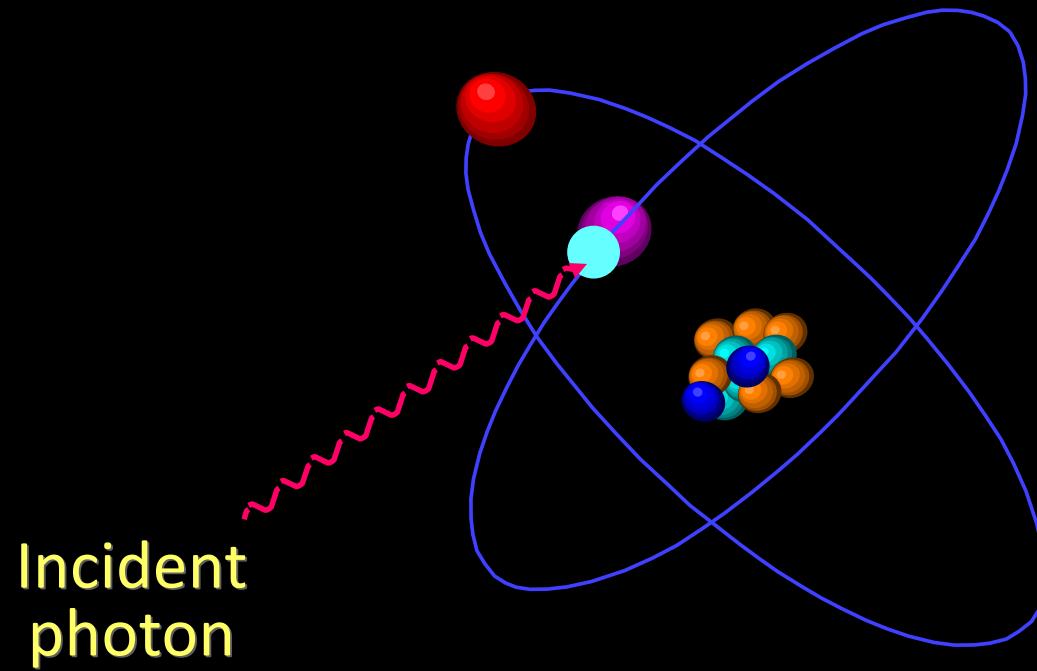
Coherent Scattering ('Thomson effect')

- ❖ Excited atom quickly returns to resting state & generate another x-ray photon with same frequency (as incident photon)-as a result direction is altered (scattered)



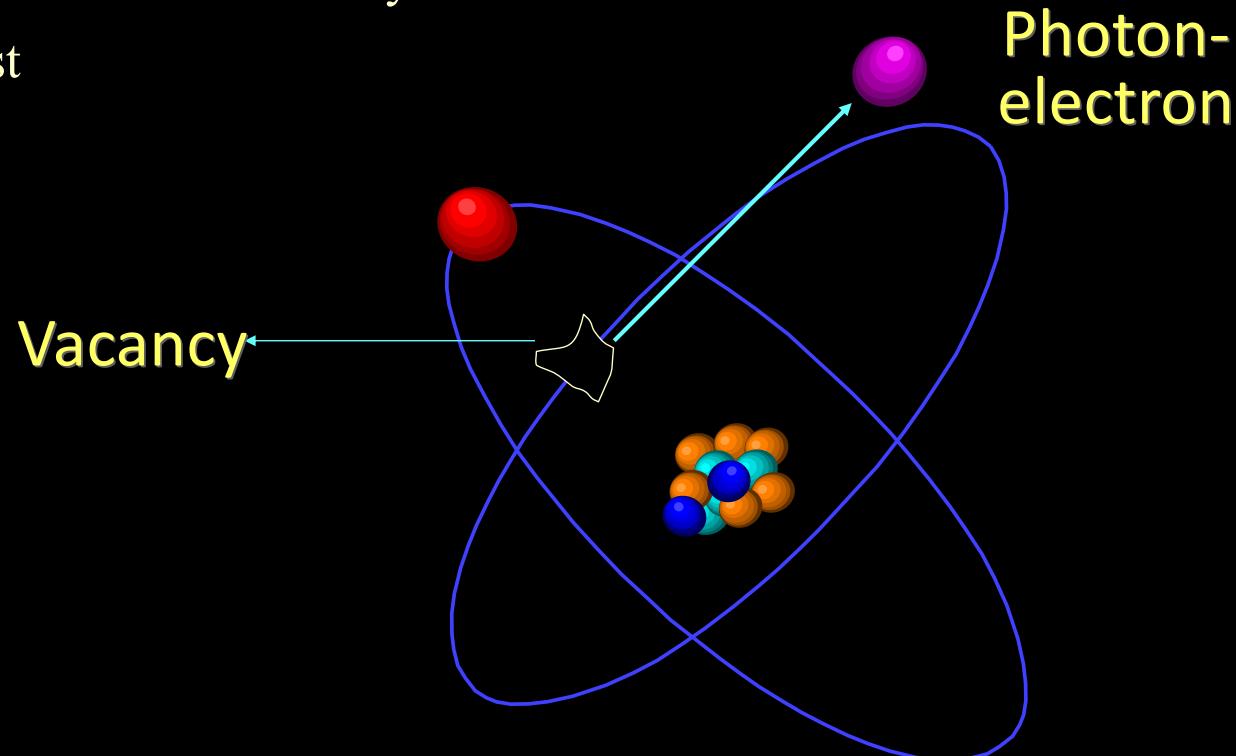
2.Photoelectric absorption

- ❖ Occurs when an incident x-ray photon collides with a bound electron in an atom (usually K-Shell)



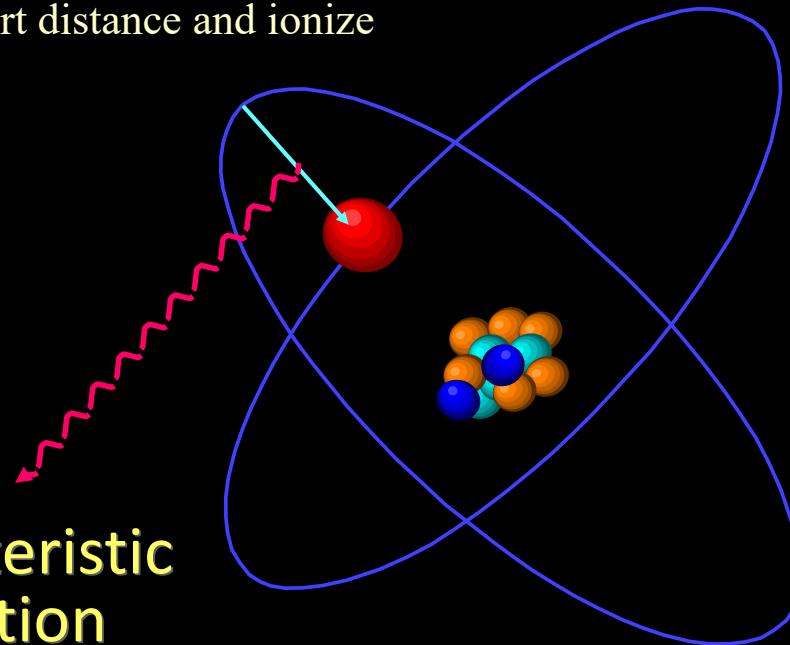
Photoelectric absorption

- ❖ Electron from atom is ejected from shell to form recoil electron and incident xray photon ceases to exist



Photoelectric absorption

- ❖ Electron is replaced by outer shell electron releasing ‘characteristic radiation’.
- ❖ ‘Recoil electrons’ travel short distance and ionize other atoms.



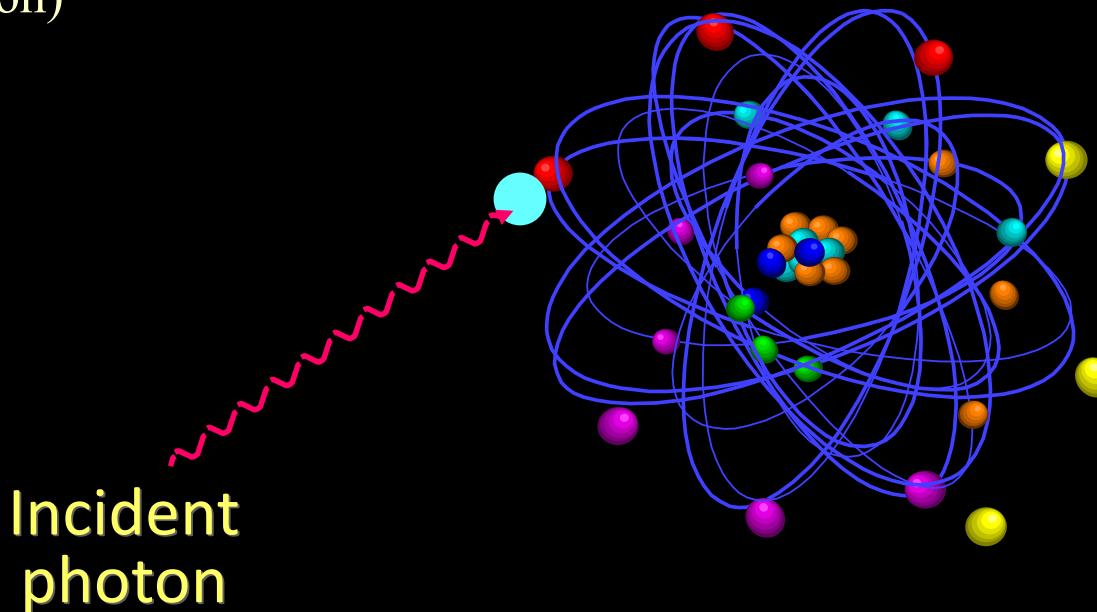
**Characteristic
radiation**

- This is potentially Hazardous to the patient
- Beneficial to the radiographic film as it does not cause Fogging of Radiographic film
- 27% of interactions with the matter are Photoelectric Absorption

Compton scattering

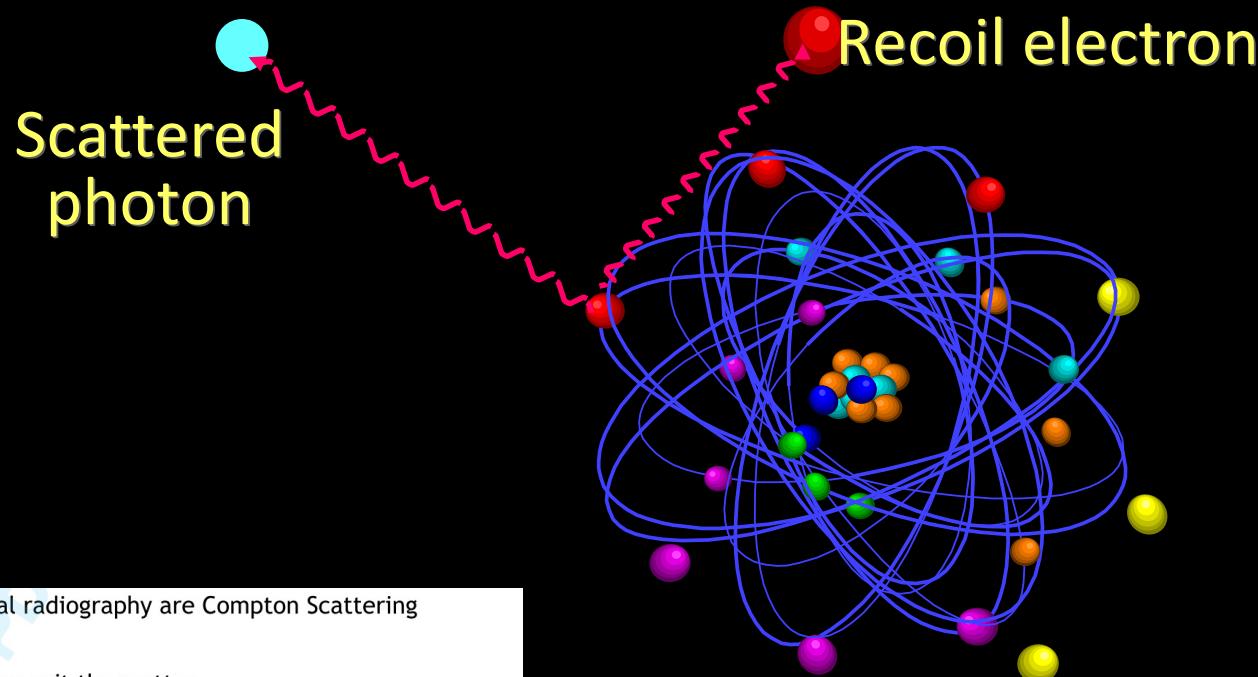
-occurs when x ray photons interacts with an outer orbital electron

Outer shell electron is ejected forms an ‘recoil electron ’ and incident x ray photon is deflected from its path (scattered photon)



Compton scattering

- ❖ Scattered photon continue on their path causing further ionizations.



- About 57% of interaction in dental radiography are Compton Scattering
- 30% of Compton scattered photons exit the matter
- Advantageous to patient but disadvantageous to the radiographic film as it causes fogging

Conclusion



Radiation is a fundamental phenomenon in physics with profound implications in various fields. Understanding the principles of radiation physics is crucial for safe and responsible use in medicine, industry, and research.

Reference:

White and Pharoah ,Oral Radiology- Principles & interpretation edt 7,
chap 1, pg 1-15

