جامعة المعقل
Almaaqal University

Physics of diagnostic X-ray

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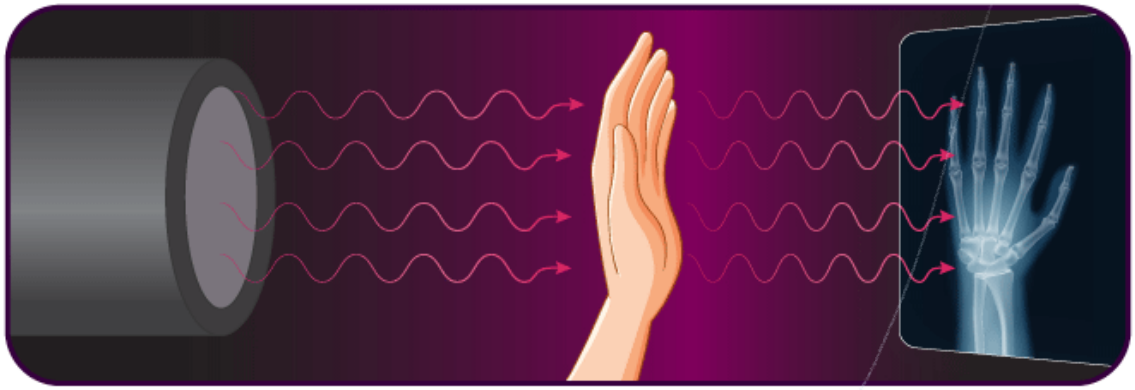
Physics of diagnostic X- Ray:

Define: X-Rays or X-radiation as a form of electromagnetic radiation(EMR). They are powerful waves of electromagnetic energy. electromagnetic radiation of a very short wave length & very high penetrating power. It is useful in diagnosis & radio therapy Most of them have a wavelength ranging from 0.01 to 10 nanometers, corresponding to frequencies in the range 3×10^{16} Hz to 3×10^{19} Hz and energies in the range 100 eV to 100 keV. the minimum distance at which X-ray is being taken (50 m).

X-ray imaging creates pictures of the inside of your body. The images show the parts of your body in different shades of black and white. This is because different tissues absorb different amounts of radiation. Calcium in bones absorbs x-rays the most, so bones look white. Fat and other soft tissues absorb less and look gray. Air absorbs the least, so lungs look black.

The most familiar use of x-rays is checking for fractures (broken bones), but x-rays are also used in other ways. For example, chest x-rays can spot pneumonia. Mammograms use x-rays to look for breast cancer.



Properties of X-Rays

The X-Rays properties are given below:

1-They have a shorter wavelength of the electromagnetic spectrum.

2-Requires high voltage to produce X-Rays.

3-They are used to capture the human skeleton defects.

4-They travel in a straight line and do not carry an electric charge with them.

5-They are capable of travelling in a vacuum.

6-The amount of energy carried by each photon depends on the frequency of radiation.:

$E = h \upsilon = h c / \lambda$

Where

h = Plank's constant = $6.6*10^{-34}$ (joule. Sec)

c = velocity of light = $3* 10^{8}$ m/sec

υ = frequency of radiation

X – rays production

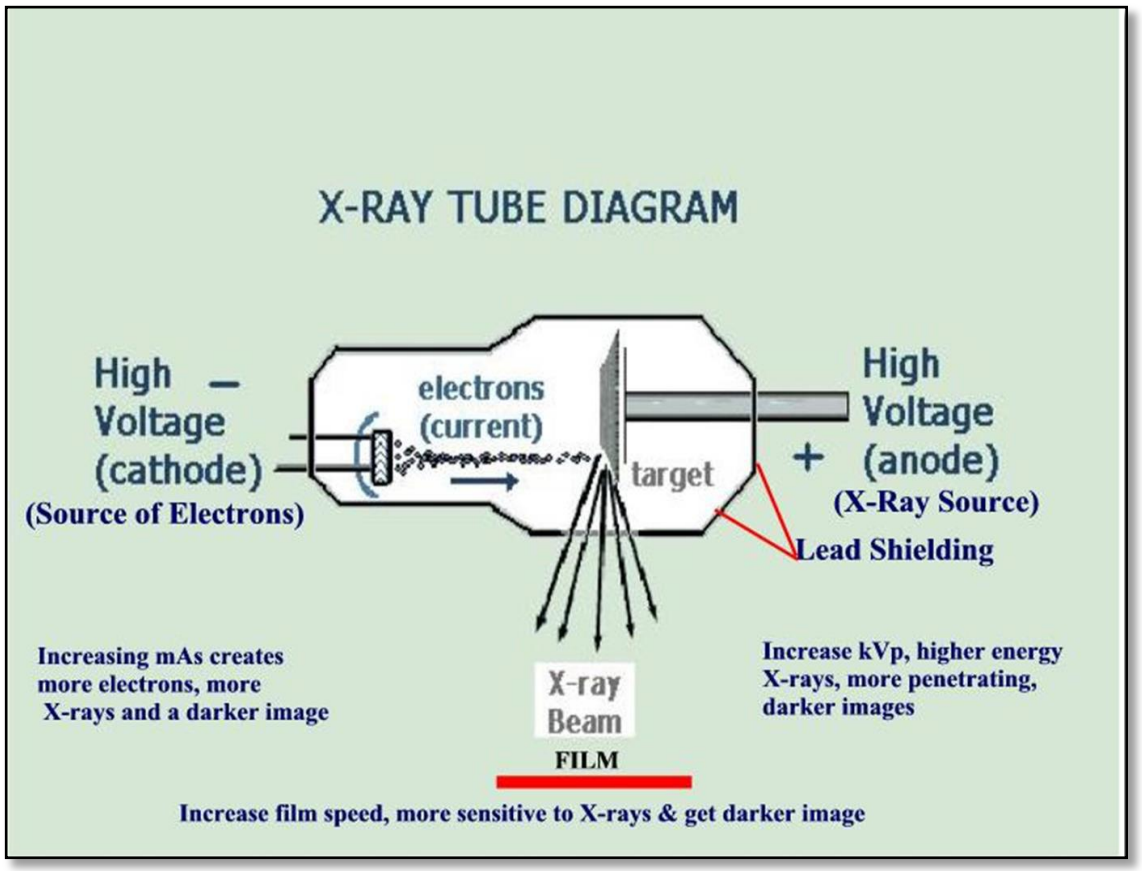
1-source of electrons .

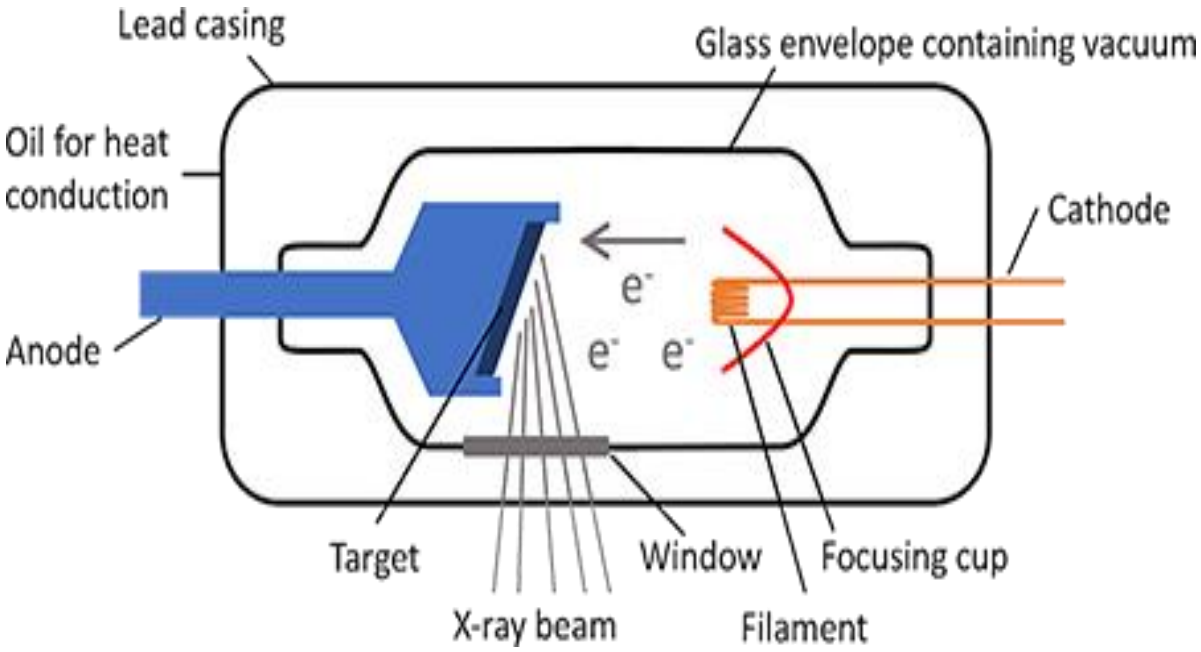
2. Target (anode) which is strike by the electrons which have a negative charged and these electrons are repelled by the cathode at attracted to the anode reaching it with very high kinetic energy.

3- High positive voltage applied between the cathode and anode to accelerate the negative electrons. In diagnostic radiography, this usually within the range 40 to 120 Kev.

4- An evacuated space (with low pressure 10^{-6} tor): which accelerate the electrons from the cathode to the anode.

5-The space between the tubes insert and the shield is filled with oil, the oil used to cool the target.





Cathode:

Made of thin (0.2 mm) tungsten wire because tungsten:

-has a high atomic number (A 184, Z 74)

-is a good thermionic emitter (good at emitting electron)

-can be manufactured into a thin wire

-has a very high melting temperature (3422°c)

Anode:

-Target made of tungsten for same reasons as for filament

-Rhenium added to tungsten to prevent cracking of anode at high temperatures .

-Set into an anode disk of molybdenum with stem

-Positively charged to attract electrons

-Set at angle to direct x-ray photon beam down towards patient. Usual angle is 5º–15º

NOTE: The energy of most electrons striking the target (99.8%) is dissipated in the form of heat. The remaining few energy (0.2%) produce useful X- rays.

The intensity of X–ray beam produced when the electron strikes the anode is highly dependent on the anode material:

1- the higher the atomic number (Z) of the target, the more efficiency X-ray are produced.

2-The target material used should also have a high melting point since the heat produced when the electrons are stopped in the surface of the target is substantial.

Nearly all X – ray tubes use tungsten targets. The atomic number (Z) of tungsten is 74, and its melting point is about 3400 C°.

X-Rays Uses

Since the discovery of X-radiation, they are used in various fields and for various purposes, are given below:

1- Medical Science: They are used for medical purposes to detect the breakage in human bones.

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

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

4-Industry: It is widely used to detect the defects in the welds.

Production of x-ray:-

There are two different mechanisms by which X-rays are produced.

1- continuous X-Ray: -

When the electron gets close enough to the nucleus of a target atom to be diverted from its path and emits an x-ray photon that has some of its energy of the nucleus. And it is also called white radiation since it is analogous to white light and has a range of wavelengths.

The amount of continuous produced depends upon two factors:

• the Z of the target, the more protons in the nucleus the greater the acceleration of electrons.

• the kilovolt peak-the faster the electrons, the more likely

they will penetrate into the region of the nucleus.

2-Characteristic X-ray:

A fast electron strikes a K electron in a target atom and knocks out of its orbit and free of the atom. The vacancy in the K shell is filled almost immediately when an electron from an outer shell of the atom falls into, as indicated in figure, and in the process, a characteristic K X-ray photon emitted.

when an electron falls from the L level to the K level is called a α characteristic x-ray and that emitted when an electron falls from the M shell to the K shell is called a Kβ x-ray.

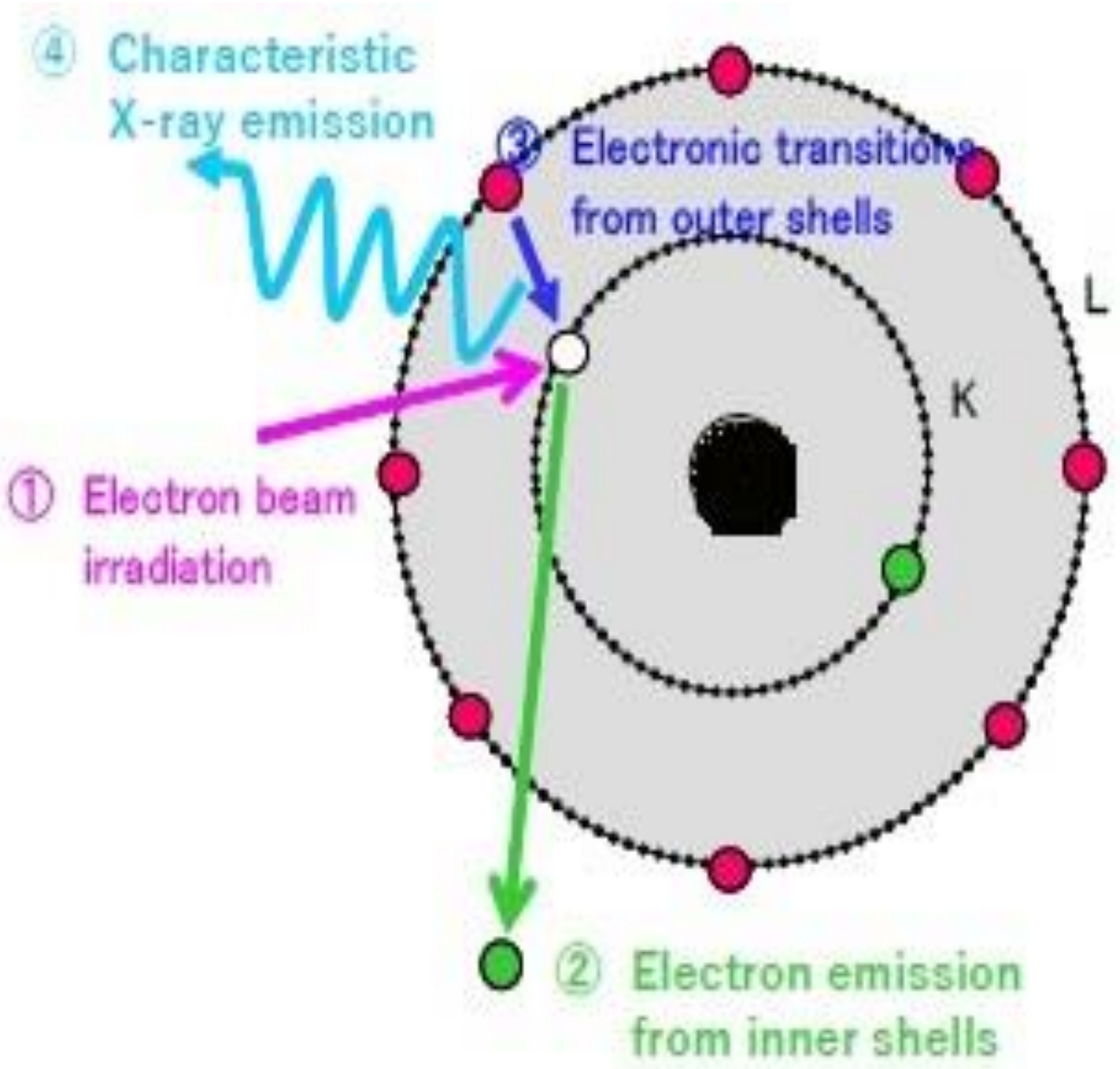


Fig. 2. Mechanism of electron and characteristic X-ray emission resulting from electron irradiation.

Radiation and Medical X-rays

Medical x-rays are used to help doctors see what is happening inside the body. X-rays pass through objects, including internal organs, body tissue and clothing. The x-rays project a picture onto film or send a digital image to a computer. Bones appear white on x-ray images because denser objects absorb more radiation. Less dense parts of the body, such as skin and muscles, remain dark on x-ray images because the radiation passes through them. A medical x-ray produces a picture that can help find broken bones, tumors and foreign objects in the body. X-rays are also used in other types of examinations and procedures, including CT scans, mammograms and fluoroscopy. Medical x-rays, dental x-rays, and mammograms use relatively low amounts of radiation. CT scans and fluoroscopic procedures result in higher radiation doses due to the need for multiple images and/or a longer exposure time. However, medical imaging is a very powerful and valuable technique that can provide important and lifesaving information

Dental X-rays

Dental x-rays are pictures of your teeth from the crown to the roots. They allow the dentist to see inside and between your teeth and check the overall condition of the bones of your jaw and face. During a dental x-ray, radiation passes through your cheek and gums and creates an image using the special x-ray film clamped between your teeth. Some x-ray machines create a digital image instead of using film. Conventional dental x-rays use a small amount of radiation to take the pictures. More detailed images may be needed in certain circumstances, such as planning for orthodontics or dental implants. In these cases, cone beam computed tomography may be used, which results in higher doses than other dental examinations (for more information, see CT Scans below)

Dental X-rays show:

1-Cavities, especially small areas of decay between teeth.

2-Decay beneath existing fillings.

3-Bone loss in your jaw.

4-Areas of infection.

5-The position of unerupted or impacted teeth.

6-Abscessed teeth(infection at the root of your tooth or between your gums and your tooth)

7-Cysts and some types of tumors.

Before the x-ray

Make sure to let your healthcare provider or radiologist (medical professional specially trained in radiation procedures) know if you are pregnant or think you could be pregnant.

You may be asked to remove anything metallic you are wearing like jewelry or clothing with buttons or zippers.

Find information on special considerations pregnant women and children.

Mature female doctor checking x-ray with mature female patient

During the x-ray

You may need to stand or lay down in a certain position or angle while the image is completed.

For some dental x-rays you will be asked to bite down on a device that is placed in your mouth in a few different positions.

Depending on the part of your body being x-rayed, you might be provided with a lead covering to prevent radiation from reaching other parts of your body.

Medical and dental x-rays use very small amounts of radiation and only expose the smallest area of the body needed to get the image to check for a health concern. Your risk of any long-term effects of ionizing radiation from x-rays depends on the part of the body being x-rayed (some organs or tissues are more sensitive than others) and the amount of radiation exposure, which may include the total number of medical procedures using radiation, over time