Lecture (9)

Medical Physics

Fourth Stage

Department of Physics

College of Science

Al-Muthanna University

2018-2019

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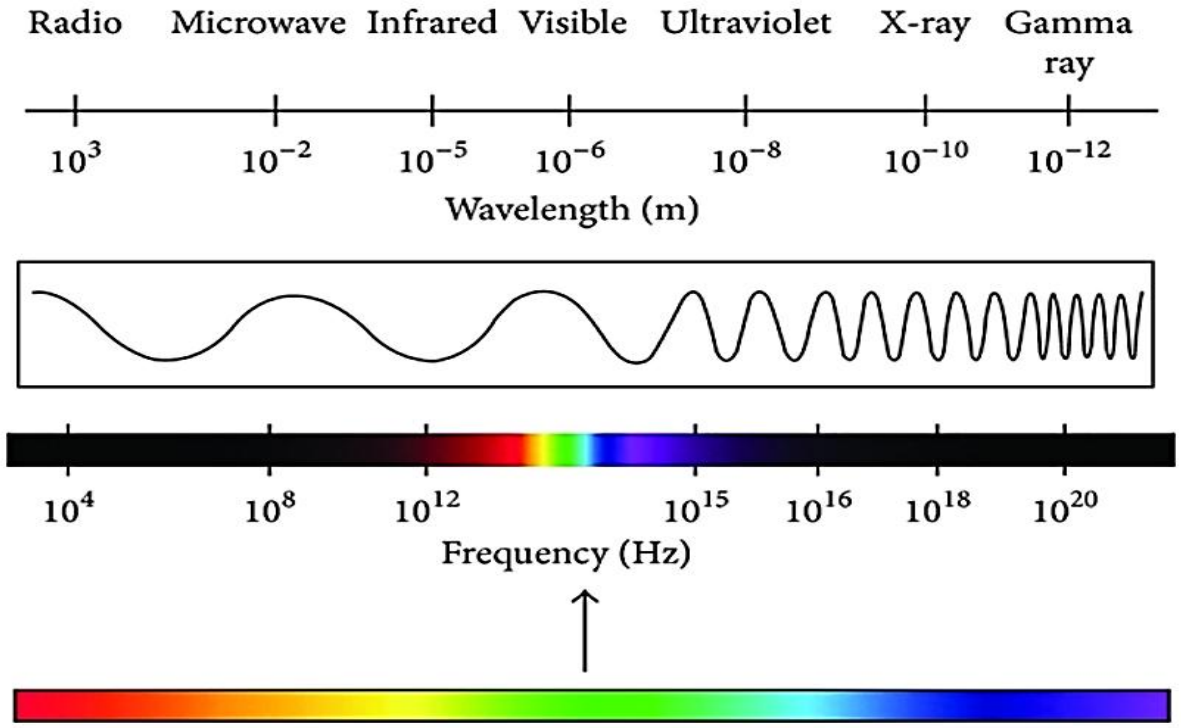
Medical Physics

X-Ray in Medicine

X-Ray and its units

- Are electromagnetic radiation located at low wavelength (λ) end of electromagnetic spectrum. Medical x-ray of the order $\lambda \approx 10^{-10}\ m$
- For x-ray $\lambda \propto voltage\ (V)$



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X-ray Units

1- x-ray dose measured in Rontgen (R). One R is amount of x-ray radiation which will produces 2.08×10^9 ions per cubic cm of air at standard temperature (0 C°) and pressure (760 mm of Hg). $\mathbf{1\ mR = 10^{-3}\ R}$ $\mathbf{1\ \mu R = 10^{-6}\ R}$

2- unit of absorbed dose Rad. One Rad is a radiation dose which results in energy absorption of $1 \times 10^{-2}\ J/kg$ in the irradiated materials.

- One Rad = dose absorbed by soft tissue to one R of x-ray.
- The relation between R and absorbed dose as**:** $\boldsymbol{D = F\ R}$
- Where F is proportional constant which is depend on composition of irradiated material.
- For air F= 0.87 Rad/R and For tissue F=1 Rad/R
- For bone, F is larger and this can be reduced by increasing applied voltage.

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Properties of x-ray

1. Short wavelength and high energy.
2. High penetration power, but they can not pass through metals and bones.
3. X-ray are absorbed when passes through matter. The absorption is a function of density of matter.
4. X-ray produces secondary radiation through which they pass. Secondary radiation is useful in the diagnosis.
5. X-ray produces ionizing in the gases.
6. X-ray produces fluorescence in certain materials.
7. It is affects photographic plate.

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Production of x-ray

When electrons collides with high speed target and suddenly stopped, x-ray are produces.

1) The target material must be hard material having high melting point.

2) A source for production of electron.

3) Energy source to accelerate the electron.

4) Free electron path.

5) A mains of focusing electron beam.

6) A target.

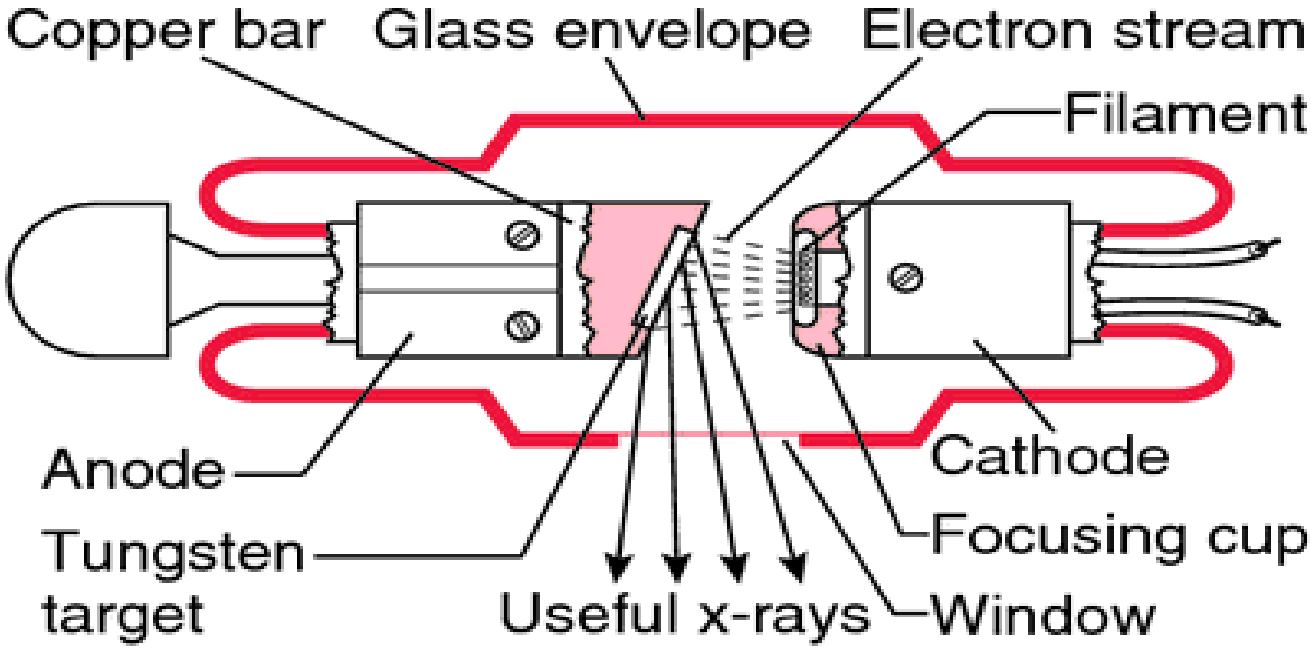
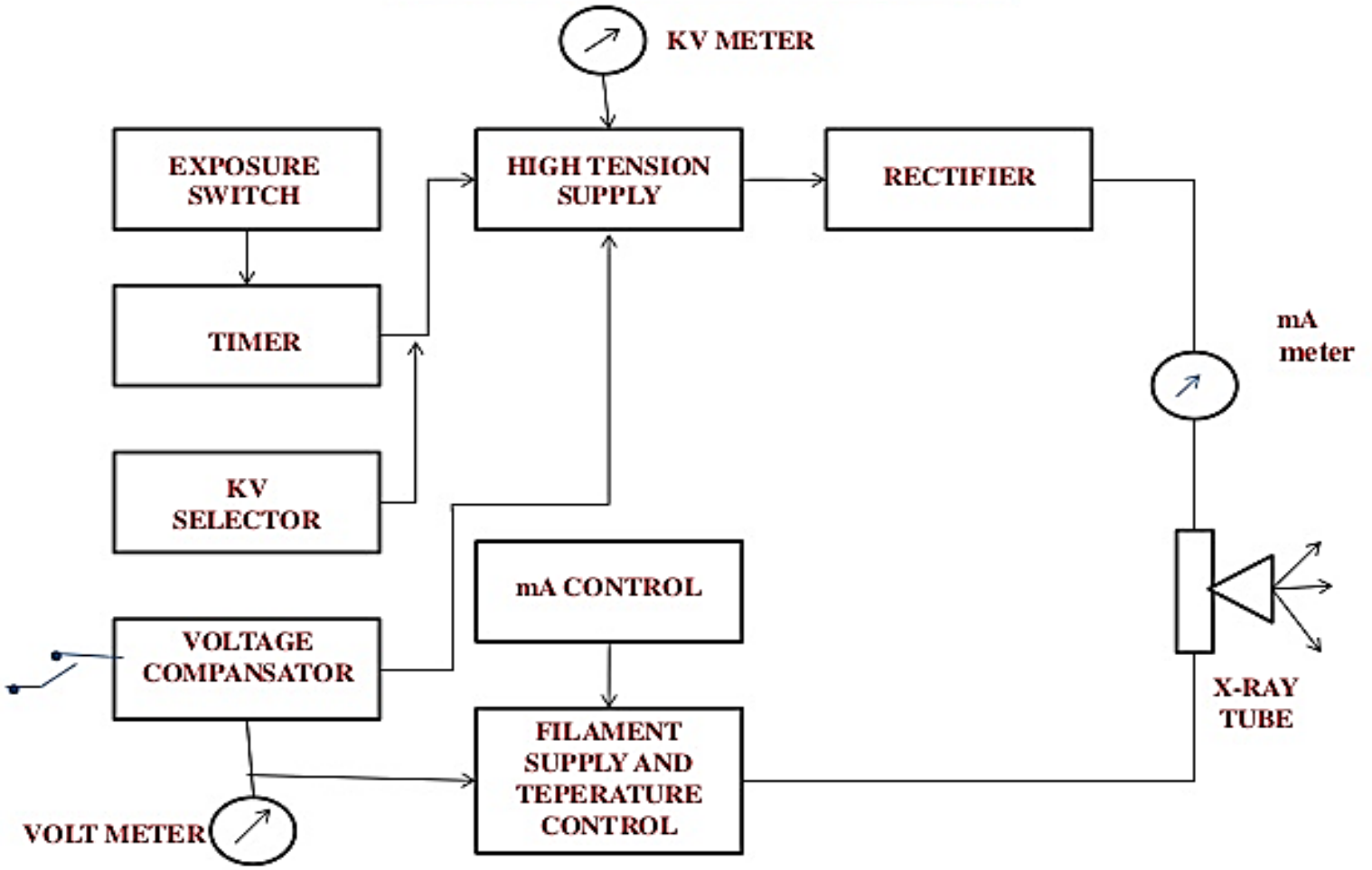


Figure Constriction of stationary Anode x-ray

Block diagram of x-ray machine

1) High voltage generator: for x-ray we need (30-200) kV, this is generated by high voltage step up transformer. We have to use high tension transformer immersed in a special oil. This can be obtained self rectifier supply or half wave rectifier. Half wave rectifier use in mobile x-ray machine such as that in dental clinic.



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- In two pluses or full wave rectifier machine the exposure time reduced to half in comparison with single pulse. It is median and high capacity x-ray unit and it is used for diagnosis purpose.

2) High frequency generator: it gives high voltage and reduces ripple significantly. Low ripple give more efficient output and shorter exposures for radiographs.

The comparison of wave phase:

- Single phase (100 %)
- Three phase (3-12) % ripple
- High frequency (1-2) % ripple

3) High tension cable: Centre of cable consist of three conductors individually. This is surrounded by semiconducting rubber. Semiconducting rubber is also surrounded by non conducting rubber which provide insulation. The cable is shielded by copper braiding which is grounded. The cable has capacity of (130-230) P farad/m.

4) Collimator and grid

- To increase contract and to reduce the dose to the patient.
- To limit area of interest.
- Collimator is made of lead with circular or rectangular hole.
- Collimator is kept between XRT and patient.
- Grids are inserted between patient and film cassette, in order to reduce loss of contrast due to scattered radiation. Grids consist of thin lead strips separated by low attenuation material.

5) Exposure timing system

To initiate and terminate x-ray exposure. It can be mechanically or microcontroller based mechanical controller are the electronic timer based on SCR. There are two types of electronic timer: **- Digital timer using IC** **- RC timing circuit**

X-Ray

Fluoroscopy

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CT Scan

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x-ray in Diagnosis

1. **Still picture x-ray:** are useful in examination of bone, internal organs, tissue and structures. This is useful for detection of broken bone and tumors. Wavelength used in diagnosis $(0.01\ to\ 10^{-10})\ m$.
2. **Fluoroscopy (continuous picture of x-ray):** this is useful for examination of functioning of organs, a contrast substances fill the body and show anatomically ships. The wavelength is that of still picture x-ray but energy level are conceder less due to long exposure time. Tumors and blockage can be detected.
3. **Motion picture x-ray (Angiography):** is an examination of circulatory system. In case of heart it is called cardio-angiography. which is useful in detection of heart problem like blockage in the vein or problem in the valve. Angiography is also possible in case of kidney and brain. It is use to study kidney stone. Brain Angiography is known as cerebra angiography.
4. **X-ray still picture scan (Tomography):** this is useful for examination of bones, organs, tissue from many different angles. It is x-ray image of slices of body section. This provides more information than 2-D film.

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Hazards of x-ray

Precaution while use x-ray:

1. Exposure to large area is more dangerous than same exposure to small area. (EAP = Exposure to area product).
2. Thickness of tissue: compress tissue to reduce amount of radiation.
3. Use of the filter to the beam: adding filter reduces intensity of radiation.
4. A void unnecessary radiation to the patient.
5. Biological effect of ionizing radiation (the effect will be on hair and skin).

There are two types of effects:

a) Somatic effect: affect individual directly loss of hair, age dependent induction of cancer.

b) Genetic effect: Mutation in reproductive cell.

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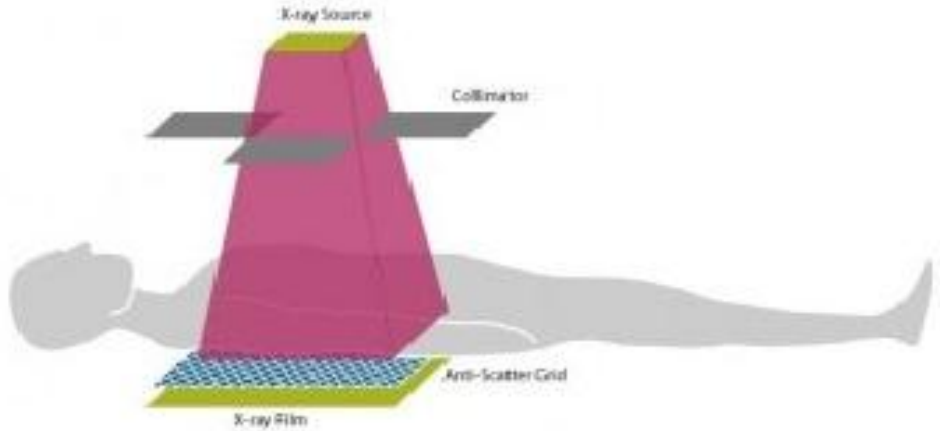
X-Ray

X-ray Machine



X-ray scan procedure

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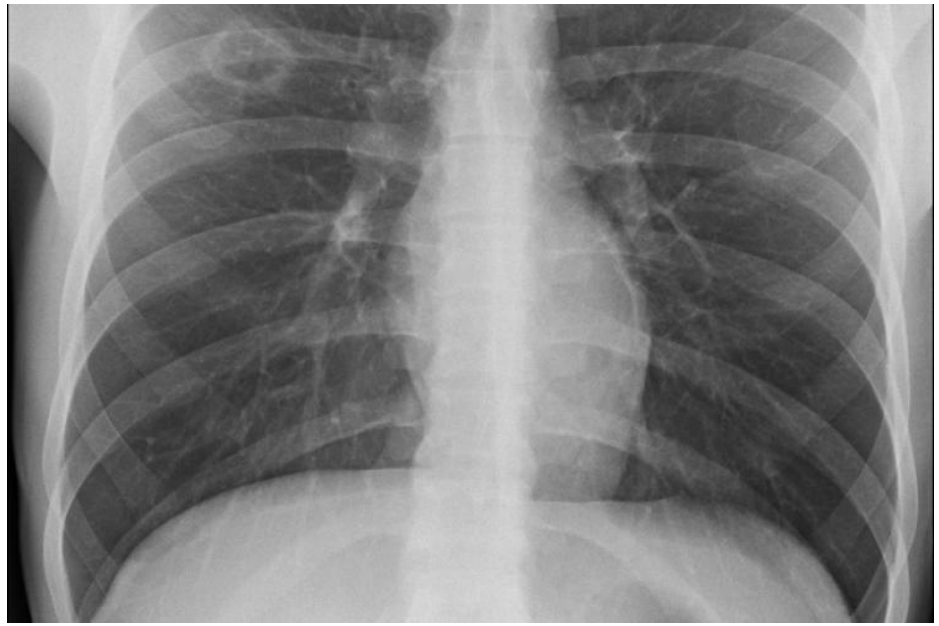

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Motion picture x-ray (Angiography)

Angiography Procedure

Angiography Scan

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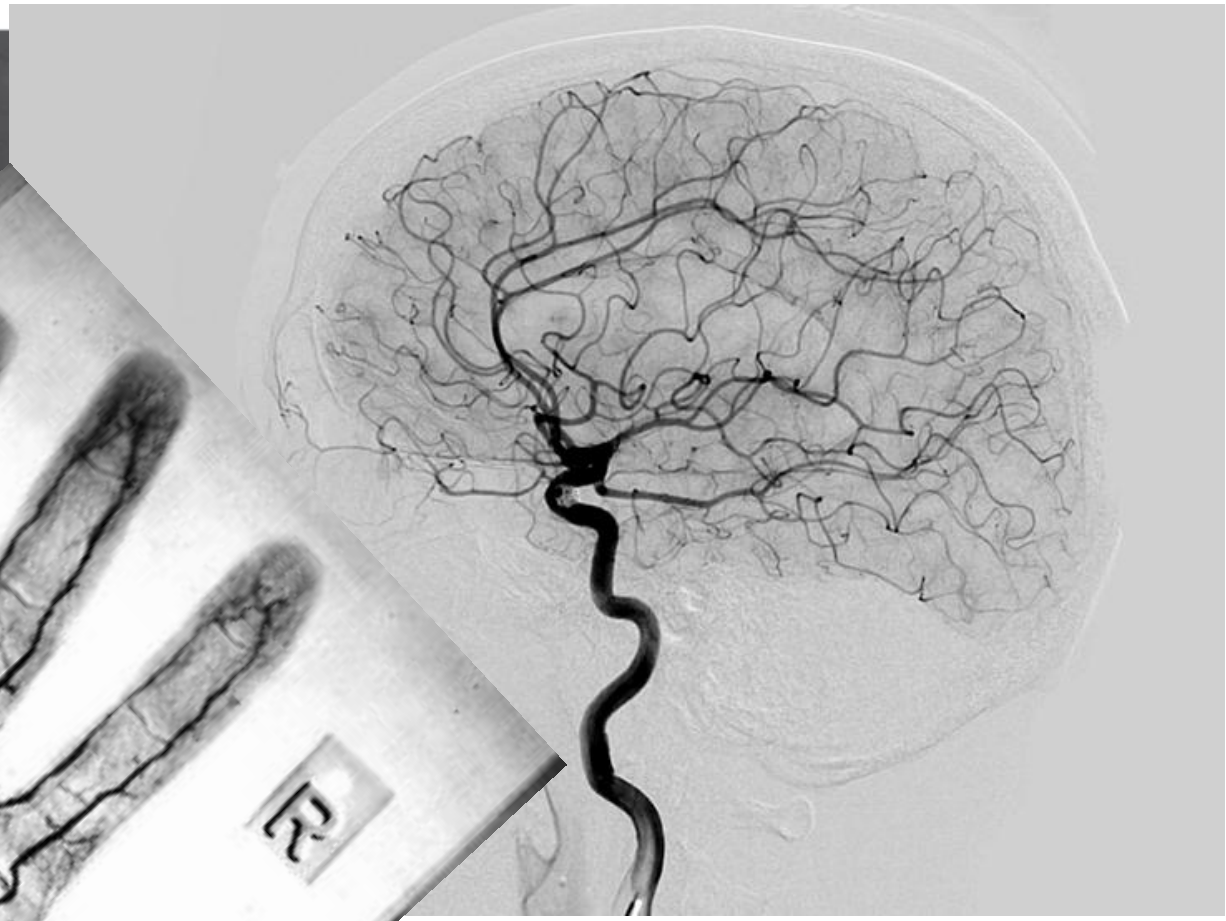
Motion picture x-ray (Angiography)

Normal coronary arteries on the left side of the heart



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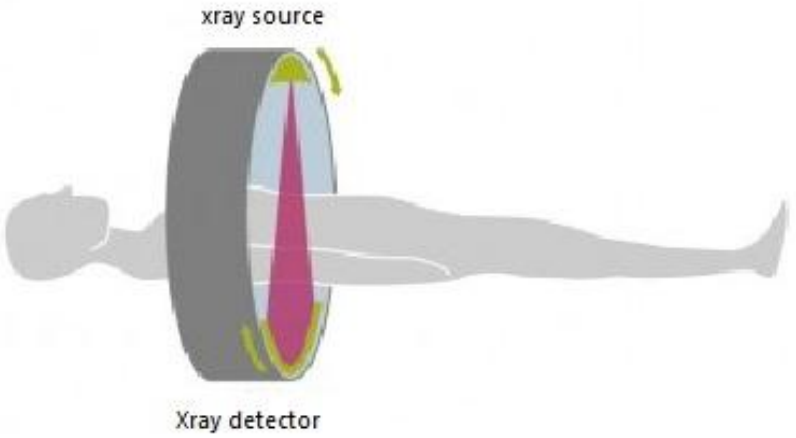
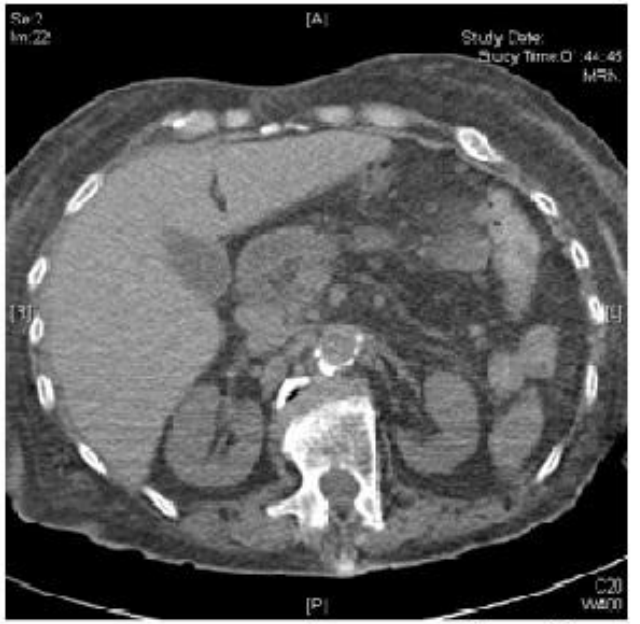
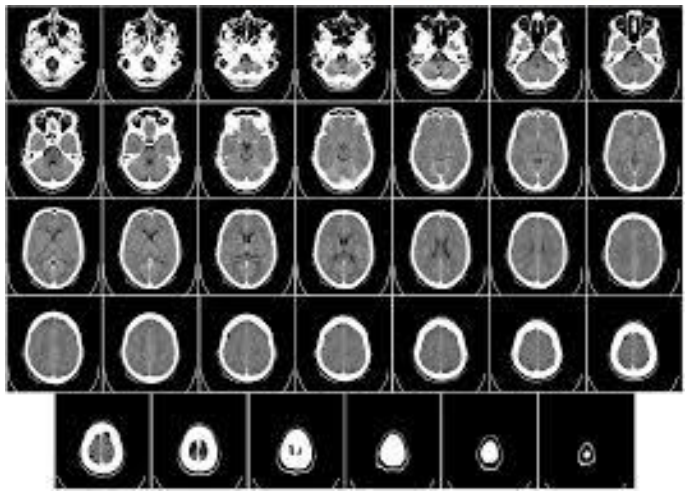
X-ray still picture scan (Tomography)





CT scan: abdomen

Frontal Lateral Oblique



CT scan image

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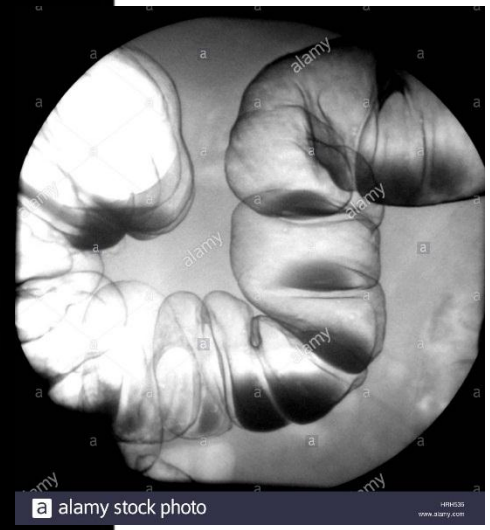
Fluoroscopy (continuous picture of x-ray)

Fluoroscopy Machine



Fluoroscopy Scan

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Problem 1: if an exposure of 0.01 sec is used. What angular rotation of the anode occurs at a rotational rate of 3600 rpm.

Sol.

$$Angular\ speed = 3600\ rpm$$

$$Angular\ speed = \frac{3600}{60} = 60\ rps$$

In 1 sec → 60 revolution

In 0.01 sec → 0.6 revolution

$$Angular\ speed = 60\ \times 0.01 = 0.6$$

Problem 2: if the half value of layer of an x-ray beam is 0.3 mm Al, what is the linear attenuation coefficient of the beam?

Sol.

Given: H V L =0.3 mm = 0.03 cm

$$\boldsymbol{H\,V\,L = \frac{0.693}{\mu}}$$

$$\boldsymbol{\mu = \frac{0.693}{H\,V\,L} = \frac{0.693}{0.03} = 23.1\ cm^{-1}}$$

Problem 3: A fluoroscope can operate continuously at a potential 80 kV and current of 3 mA, what is the power into target?

Sol.

$$\boldsymbol{Power = I \times V}$$

$$\boldsymbol{Power = 3\ mA\ \times 80\ kV}$$

$$\boldsymbol{Power = 3 \times 10^{-3}\ A \times 80 \times 10^{3}\ V}$$

$$\boldsymbol{Power = 240\ A\ V}$$

$$\boldsymbol{Power = 240\ watt}$$

Mammography…? H.W

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