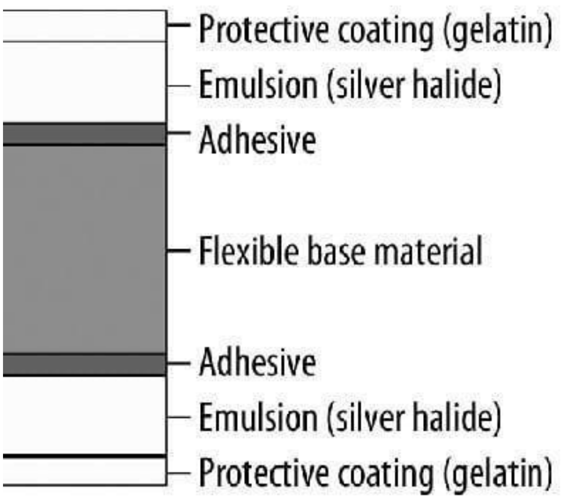
BM E75 - RADIOLOGICAL EQUIPMENTS

UNIT-I

MEDICAL X-RAY EQUIPMENT

2 Marks:

1. Analyse the cross section of X-ray films. (Nov/Dec 2018)



2. List out the limitations of direct fluoroscopy.(Nov/Dec 2018)

- Patient dose should not exceed 10R per minute.
- Radiation should be minimal (related to the risk it changes).
- It uses ionizing radiation.
- May be limited by patient mobility and ability to comply.
- Fluoroscopy should always be performed with the lowest acceptable exposure for the shortest time necessary.

3. Define Angiography.(Nov/Dec 2019,May 2019)

Angiography or arteriography is a medical imaging technique used to visualize the inside, or lumen, of blood vessels and organs of the body, with particular interest in the arteries, veins, and the heart chambers. This is traditionally done by injecting a radio-opaque contrast agent into the blood vessel and imaging using X-ray based techniques such as fluoroscopy.

4.(a) List some properties X-rays. (Nov/Dec 2019)

(b)List the nature of X-rays.(April/May 2018)

(c)List some characteristics of X-rays. (Nov/Dec 2017)

- Highly Penetrative
- Highly Absorptive
- Highly Ionizing
- Produce Fluorescence

5. What is Mammography? (May 2019)

Mammography (also called mastography) is the process of using low- energy X-rays (usually around 30 kVp) to examine the human breast for diagnosis and screening.

The goal of mammography is the early detection of breast cancer, typically through detection of characteristic masses or micro calcifications.

6. What are the advantages of intensifying screens?(Nov 2016)

•Intensifying screens are used in the x-ray cassette to intensify the effect of the x-ray photon by producing a larger number of light photons.

•It decreases the mAs required to produce a particular density and hence decreases the patient dose significantly.

•Reduce patient exposure.

•Increase x-ray tube life.

7. What are Collimators?(Nov 2016)

•A collimator is a device which narrows a beam of particles or waves.

•To narrow can mean either to cause the directions of motion to become more aligned in a specific direction, or to cause the spatial cross section of the beam to become smaller.

8. Differentiate between cine angiography and digital subtraction angiography.(April/May 2018)

CINE ANGIOGRAPHY	DIGITAL SUBTRACTION ANGIOGRAPHY
Cine angiography uses fluoroscopic technique.	It is also a fluoroscopic technique.
Cardiac catheterization is used.	It is an Invasive procedure.
It provides a standard diagnosis of aortic root lesions.	It provides an image of the blood vessels in the brain to detect a problem with blood flow.
It is used to record the images.	It can be used for digital signatures but not for encryption.

9. What is cine angiography?(Nov/Dec 2017)

The use of motion-picture recording to trace the passage of dye through blood vessels, for the diagnosis of heart and blood vessel disease and the recording by motion pictures of blood vessels following injection of a radiopaque contrast medium.

Eg: Stress echocardiogram and coronary cine angiography.

10. Define time of exposure. (April/May 2018)

•The exposure time, respectively period of exposure is generally understood to mean the time span for which the film of a traditional camera or a sensor of a modern digital camera is actually exposed to the light so as to record a picture.

•The exposure time is given in seconds. In combination with the aperture it determines the incidental light quantity.

11 Marks:

1. What is DSA? Discuss the principle of operations.(Nov/Dec 2018)

Digital subtraction angiography (DSA) is a fluoroscopic technique used extensively in interventional radiology for visualizing blood vessels. Radiopaque structures such as bones are eliminated ("subtracted") digitally from the image, thus allowing for an accurate depiction of the blood vessels.

Indications

There are numerous indications for angiography and their number has been on the rise ever since interventional radiology has been shown to successfully supplant many open vascular procedures. Salient examples include:

- endovascular aneurysm repair
- arterial balloon angioplasty
- arterial stenting
- endovascular embolization
- thrombectomy

Contraindications

Renal insufficiency and hypersensitivity to iodinated contrast media are relative contraindications.

Procedure

Preprocedural evaluation

•Patient evaluation should include, but is not limited to: Presence of atherosclerotic disease (e.g. Prior myocardial infarction)

•Diabetes

•Renal function status

•Medications

•Allergies and previous exposure to iodinated contrast media

•Prior surgical procedures, especially vascular

•Reports from previously performed angiograms, if any

•Review of any relevant vascular imaging studies,

•E.g. Preprocedural CT angiogram

Positioning/room set up

•The angiography suite must be equipped with a crash cart and monitoring equipment. Patient heart rate and blood oxygenation are monitored continuously, while blood pressure is measured intermittently via a self- inflating cuff.

•All procedures should be performed under strict aseptic conditions, including attire, technique and preparation.

•Depending on the procedure and the patient's condition, an anaesthesiologist may be required to administer conscious sedation or even general anaesthesia.

•The patient can be positioned with their head on either end of the bed to facilitate convenience of vascular access and maneuvering for the interventional radiologist.

Equipment

The fluoroscopy unit consists of a C-arm unit that can be rotated axially and sagittally around the floating-top table. The distance between the X-ray tube and the image intensifier can be adjusted, as can collimation and several other parameters. In dedicated angiography units, there is a second set of controls for the angiographer (radiographer).

DSA technique

•Digital subtraction angiography is used to produce images of the blood vessels without interfering shadows from overlapping tissues. This provides a clear view of the vessels and allows for a lower dose of contrast medium .

•The non-contrast image (mask image) of the region is taken before injecting contrast material and therefore shows only anatomy, as well as any radiopaque foreign bodies (surgical clips, stents, etc.) As would a regular x-ray image.

•Contrast images are taken in succession while contrast material is being injected. These images show the opacified vessels superimposed on the anatomy and are stored on the computer.

•The mask image is then subtracted from the contrast images pixel by pixel. The resulting subtraction images show the filled vessels only.

•Recording can continue to provide a sequence of subtracted images based on the initial mask.

•The subtraction images can be viewed in real-time. Even if the patient lies still, there is bound to be some degree of misregistration of images due to movement between the acquisition of the mask image and the subsequent contrast images. The effect is prominent at high-contrast interfaces, such as bone-soft tissue, metal staples and coils, and bowel air. Pixel shifting (either manual or automatic), i.e. moving the mask retrospectively, can minimize misregistration, but focal movement such as bowel peristalsis, will not be corrected.

•It should be noted that since image subtraction causes a decrease in signal-to-noise ratio, the subtraction images appear noisier than the source images. The inevitable solution to this is to increase ma. There are also algorithms in place for reducing scatter.

Procedural technique

For every purpose, there is at least one technique, but common to them all is the application of DSA for visualization:

•The patient lies on the angiography table

•Local anaesthesia is administered at the intended puncture site (usually lidocaine hydrochloride 1% or 2% w/v)

•In certain procedures (e.g. A child undergoing cerebral angiography), general anaesthesia is performed

•The seldinger technique is used to gain access to a blood vessel

•Ultrasound is often used for visualizing the vessel in real-time for puncturing

•A standard access kit includes a straight 18 gauge needle and .035" guide wires, on which the diagnostic and therapeutic catheters are threaded

•In many cases, a micro-introducer access kit (.018" guide wire threaded through a 21 gauge initial access needle) is used for access, either for the entire procedure or to be replaced with the standard kit. Using a micro- introducer facilitates less traumatic entry and can be retrieved without massive bleeding should there be a need for re-puncturing

•On procedure completion, hemostasis is applied to the puncture site

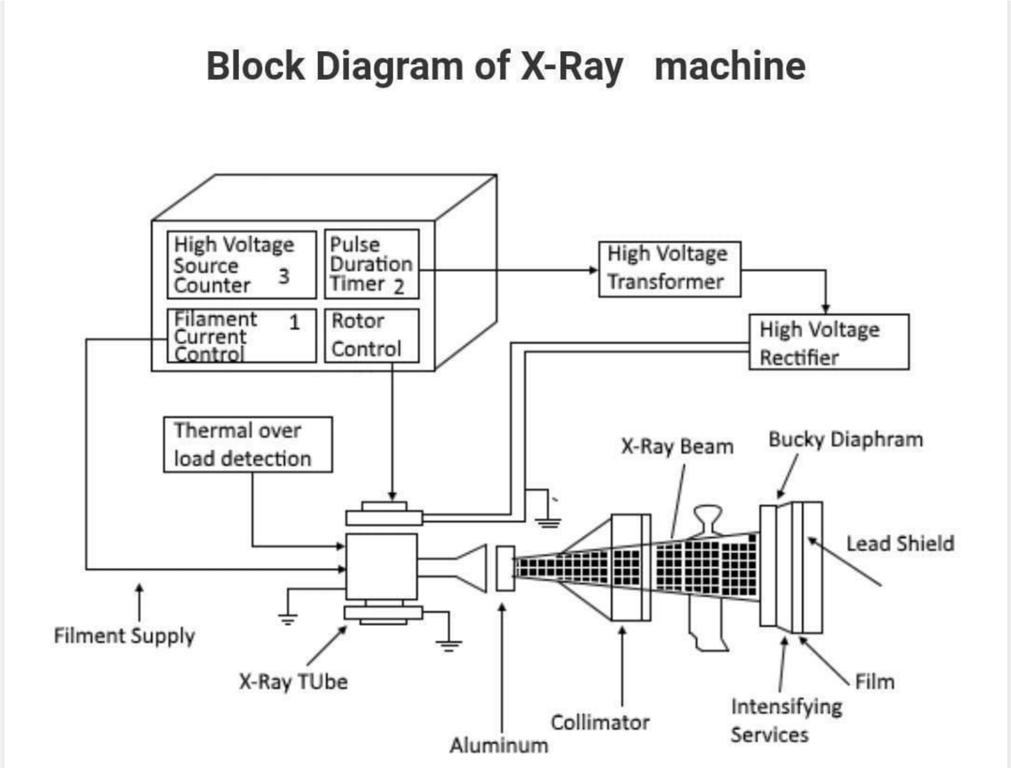
•**Postprocedural care**

•This depends on the nature of the procedure and whether it was performed on an inpatient or outpatient basis.

•Patient should be immobilized for 4-6 hours and keep on supine position. Frequent observations should be done to look for puncture site hematomas, which is the commonest complication.

2. Explain the Working of X-ray equipment (machine)with a neat diagram.(Nov/Dec 2019,Nov 2016)

Three types of rays emits continuously from a radium material. These rays are known as alpha rays (a rays). Beta rays (p rays) and gamma rays (x rays). Gamma rays also know as x-rays. The frequency of x-rays as approximately 1020 Hz and its wave length is approximately 10"10 meter. X- rays are electromagnetic wave which is widely used in medical field and industries for inspection of human body or any other thing.



Production of x-rays:

X-rays can be produced with the help of high vacuum tube with a heater, cathode and anode. Vacuum tube is operate at very high voltage. A special electron tube (vacuum tube) is shown in Fig No 11 which is used for production of x-rays. Such a tube has a hot filament cathode an anode made a very heave metal Electron flow from the cathode to anode as in any diode tube. However a large DC voltage is used between cathode and anode of x- rays tube.

Working of X-Ray Machine:

High voltage source and high voltage transformer

High voltage source is responsible for providing high voltage to the H.V transformer for a decided time. The H.V transformer produces 20 KV to 200 KV at the O/P. These voltages are used to determine the contrast of the image. High voltages have higher contrast.

High voltage rectifier

This rectifier rectifies the high voltage produced by the H.V.T and supplies them to the anode of the X-ray tube

Thermal overload detector

The heat of the X-ray tube (should not be increase by a specified range). If the heat is exceed from a specified value, and then the thermal over load detector is used to turn off system.

Rotor control

Most of the X-ray tube anodes are rotated by an induction motor, in order to limit beam power at any spot and helps to cool the anode.

Pulse duration timer

The duration of the time must be very small so that

1. The patient does not receive the excessive dose.
2. The film does not become over exposed.
3. The X-ray tube does not over neat. The pulse duration timer determines this pulse duration.

Aluminium Filter

The X-ray beam used in the medical field which contains a broad band of frequencies (1) The unwanted frequencies in the x-ray based create side effects

e.g extra dose for patient causing tumor also reduce the contrast in the image. These are called soft x-ray. To eliminate these effects Aluminium filter is used.

Collimator

Another mean to reduce the dose of patient is to confine the x-ray beam only on the region of interest on the body of patient. An external collimator placed between patient and filter does this.

Diaphragm

X-rays inside the patient create x-ray scattering, which tends to burned the image to absorb the scattered x-rays and eliminate the burning of an image a lead grid is used which is called diaphragm.

Film and lead shield

The x-rays passed from the desired region of the patient body are made to strike on the film where they produce an image of the body soft and hard parts. A lead shield is use to collect the x-rays after striking on film.

The H.V. source produces high voltage supply, which are rectified by rectifier and applied to anode of the x-ray tube Filament supply is also provided. As a result x-rays tube producing an x-ray beam which is passed through the body and produces image of body and the film, which is examined in laboratory

Application of the X-Ray

- Detection of the fraction in bones
- Infection of lungs, kidneys and other injury
- Presence of Tumour

Use of X-rays in industry

- For industrial radiography and fluoroscopy.

- For measuring the thickness of material
- Inspection of metals.
- Inspection of fruits before packing.

3.Describe in detail about fluoroscopy equipment with a block diagram. (Nov/Dec 2019, April/May 2018,Nov/Dec 2017)

 Fluoroscopy is an imaging technique that uses X-rays to obtain real-time moving images of the interior of an object. In its primary application of medical imaging

 A fluoroscope allows a physician to see the internal structure and function of a patient, so that the pumping action of the heart or the motion of swallowing.

 For example, can be watched. This is useful for both diagnosis and therapy and occurs in general radiology, interventional radiology, and image-guided surgery.

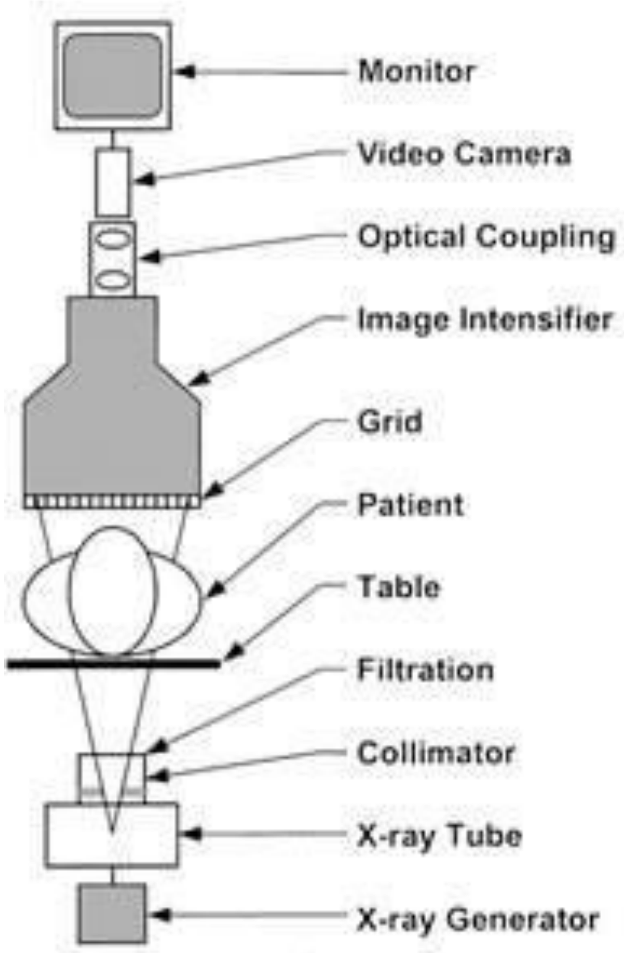
 Fluoroscopy, or real-time projection X-ray imaging, has been in clinical use since shortly after Roentgen‟s discovery of X-rays. Early fluoroscopes consisted simply of an X-ray source and a fluorescent screen, between which the patient was placed.

 After passing through the patient, the remnant beam impinged upon the fluorescent screen and produced a visible glow, which was directly observed by the practitioner.

 In modern systems, the fluorescent screen is coupled to an electronic device that amplifies and transforms the glowing light into a video signal suitable for presentation on an electronic display.

 One benefit of the modern system compared to the earlier approach is that the fluoroscopist need not stand in close proximity to the fluorescent screen in order to observe the live image.

 This results in a substantial reduction in radiation dose to the fluoroscopist. Patients receive less radiation dose as well, because of the amplification and overall efficiency of the imaging system.



X-ray Source

The high-voltage generator and X-ray tube used in most fluoroscopy systems is similar in design and construction to tubes used for general radiographic applications. For special purpose rooms such as those used for cardiovascular imaging, extra heat capacity is needed to allow angiographic “runs,” sequences of higher-dose radiographic images acquired in rapid succession to visualize opacified vessels. These runs are often interspersed with fluoroscopic imaging in a diagnostic or interventional procedure, and the combination can result in a high demand on the X-ray tube. Special X-ray tubes are generally found in such systems.

Beam Filtration

It is common for fluoroscopic imaging systems to be equipped with beam hardening filters between the X-ray tube exit port and the collimator. Added aluminium and/or copper filtration can reduce skin dose at the patient‟s entrance surface, while a low kVp produces a spectral shape that is well-matched to the barium or iodine k-edge for high contrast in the anatomy of interest.

Collimation

Shutters that limit the geometric extent of the X-ray field are present in all X-ray equipment. In fluoroscopy, the collimation may be circular or rectangular in shape, matching the shape of the image receptor.

Patient Table and Pad

Patient tables must provide strength to support patients and are rated by the manufacturer for a particular weight limit. It is important that the table not absorb much radiation to avoid shadows, loss of signal and loss of contrast in the image.

Anti-Scatter Grid

Anti-scatter grids are standard components in fluoroscopic systems, since a large percentage of fluoroscopic examinations are performed in high-scatter conditions, such as in the abdominal region. Typical grid ratios range from 6:1 to 10:1. Grids may be circular (XRII systems) or rectangular (FPD systems) and are often removable by the operator.

Image Receptor — X-ray Image Intensifier (XRII)

The X-ray image intensifier (Figure 2) is an electronic device that converts the X-ray beam intensity pattern (aka, the “remnant beam”) into a visible image suitable for capture by a video camera and displayed on a video display monitor. The key components of an XRII are an input phosphor layer, a photocathode, electron optics and an output phosphor.

Image Receptor — Flat Panel Detector (FPD)

In recent years we have seen the introduction of fluoroscopic systems in which the XRII and video camera components are replaced by a “flat panel detector” (FPD) assembly. When flat panel X-ray detectors first appeared in radiography, they offered the advantages of a “digital camera” compared with existing technologies.

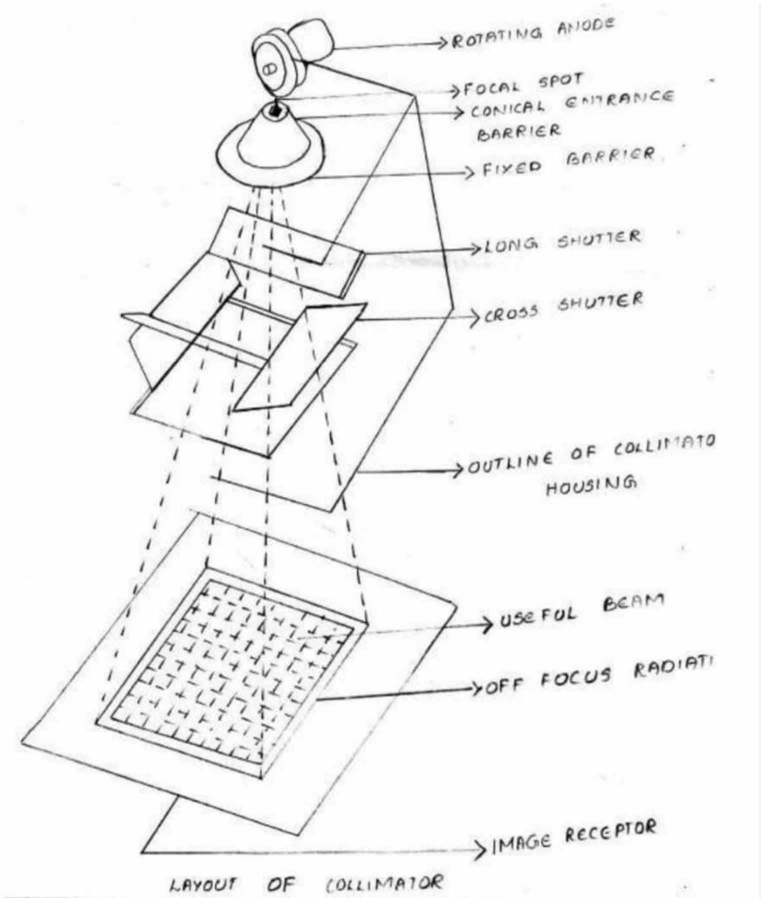
Image Display

Fine details and subtle contrast differences in the anatomy of interest. Medical image display technology has been fortunate to “ride on the coattails” of the television industry over the last several years.

Q4. Write notes on:(May 2019)

(A)Collimator

A collimator is a device that narrows a beam of particles or waves. To "narrow" can mean either to cause the directions of motion to become more aligned in a specific direction (i.e. collimated or parallel) or to cause the spatial cross section of the beam to become smaller.



Collimators are used to in order to increase the image contrast and to reduce the dose to the patient; the x-ray beam must be limited to the area of interest.

The collimator is placed between the x-ray tube and the patient. > It consists of a sheet of lead with a circular or rectangular hole of suitable size. Alternatively, it consist of four adjustable lead strips which can be moved relative to each other. In practice, it is advisable to use the smallest possible field size. This result in a low dose to the patient and simultaneously increases the image contrast, because less scattered radiation reaches the image plane.

Types of collimator:

There are four types of collimator. They are as follows

1. Parallel hole collimator
2. Pin hole collimator
3. Converging collimator
4. Diverging collimator

Parallel hole collimator

The parallel hole collimator is most commonly used.

- It consists of thousands of parallel holes, the hole may be triangular, circular, square, or hexagonal.
- The thick septa collimators are used with ratio pharmaceuticals that emit high energy photons.
- No collimator will give the expected spatial resolution and efficiency.
- The collimator to object distance (COD) will not affect the image size.

Pin hole collimator

Pin hole collimator is used to produce magnified image of small object such as thyroid.

- It consists of 5 mm diameter hole in a piece of lead.
- The magnification decreases with increasing COD.

Converging collimator

- Converging collimator has too many holes.
- The focal point in front of a camera, it gives a magnified image.
- The magnification increases as the COD increases.

- It produces a minimized image and magnification increases with increasing COD.

Diverging collimator

- The diverging collimator is infusion to the parallel hole collimator.
- This collimator is rarely used.

Uses of collimators:

Collimators are used to

> Improve contrast and visibility of detail.

> Increase the image contrast.

> Reduce the dosage.

> Reduce the scattering effect.

> Focus the radiation.

(B)Bucky Grid System

 The grid was invented by Gustavo Bucky already in 1913 and is still the most effective device for reduction of scattered radiation. It is usually made of a thin plate, in which very thin strips of high-attenuating material, commonly lead, is placed in a linear, parallel pattern.

 The Bucky factor is the ratio of radiation on the grid to the transmitted radiation. It indicates the increase in patient dose due to the use of a grid. It is typically two to six.

 The contrast improvement factor is the ratio between the contrast with a grid and without a grid. It is typically two.

 Image contrast can be improved by increasing the grid ratio by increasing the height of the lead strips or reducing the interspaced. However, this leads to increased x-ray tube loading and radiation exposure to the patient.

 Grids are placed between the patient and the x-ray film to reduce the scattered radiation reaching the detector (produced mainly by the Compton effect) and thus improve image contrast.

- They are made of parallel strips of high attenuating material such as lead with an interspaced filled with low attenuating material such as carbon fibre or organic spacer.

- The strips can be oriented either linear or crossed in their longitudinal axis. As scattered radiation is increased in "thicker" patients and at larger field sizes, grids are useful in such scenarios to improve image contrast.

- The working ability of a grid is described by the grid ratio, which is the ratio of the height of the lead strips (h) to the distance between two strips,

i.e. the interspace (D).

- A grid ratio of 8:1 is generally used for 70-90 kVp technique and 12:1 is used for >90 kVp technique. The strip line density (number of strips per cm) is 1/(D+d), where d is the thickness of the strip. This is typically 20- 60 strips per cm.

Types

- focused grids (most grids): strips are slightly angled so that they focus in space so must be used at specified focal distances
- parallel grid: used for short fields or long distances
- moving grids (also known as Potter-Bucky or reciprocating grids): eliminates the fine grid lines that may appear on the image when focused or parallel grids are used; cannot be used for portable films.

Uses

Grids are commonly used in radiography, with grid ratios available in even numbers, such as 4:1, 6:1, 8:1, 10:1 or 12:1. Generally used where the anatomy is >10 cm:

- abdomen
- skull
- spine (except lateral cervical)
- contrast studies
- IVU

- RGU
- MCU
- barium studies (including lateral cervical)
- breast (mammography): uses 4:1 grid ratio

5. Draw the block diagram of X-ray and explain the principle, production of x Rays for medical imaging.(May 2019)

X-rays are produced whenever electrons collide at very high speed with matter and are thus suddenly stopped. The energy possessed by the electrons appears from the site of the collision as a parcel of energy in the form of highly penetrating electromagnetic waves (X-rays) of many different wavelengths, which together form a continuous spectrum. X-rays are produced in a specially constructed glass tube, which basically comprises.

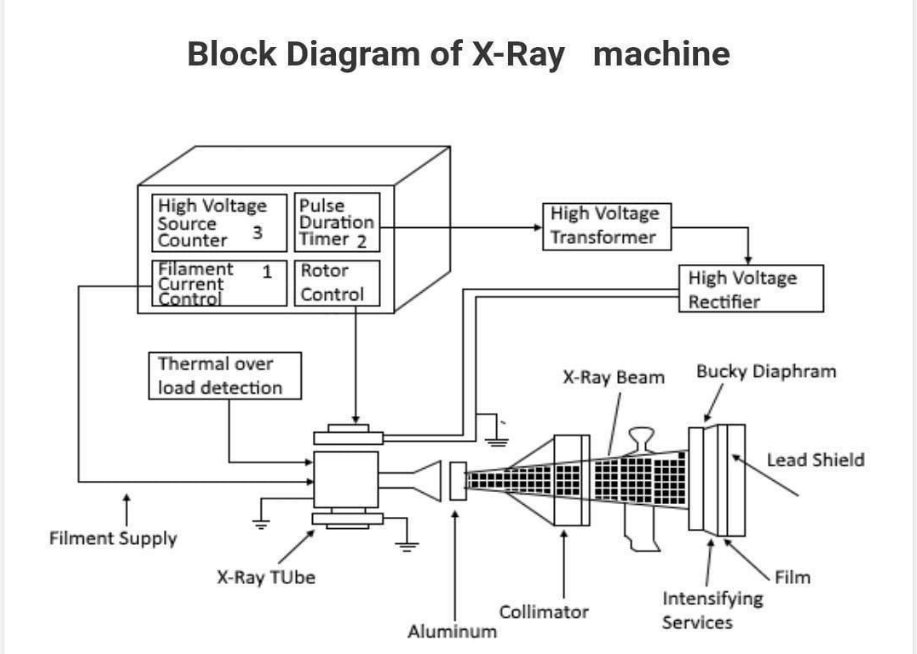
(i) a source for the production of electrons,

(ii) a energy source to accelerate the electrons,

(iii) a free electron path,

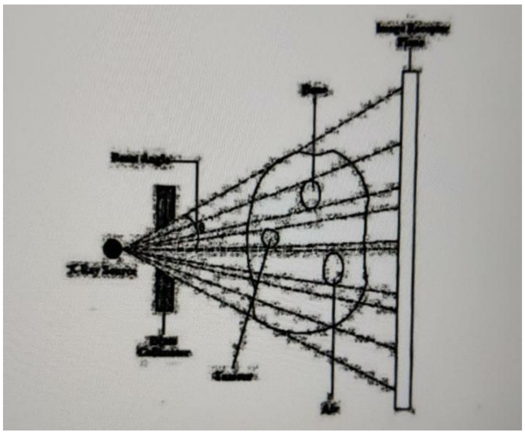
(iv) a means of focusing the electron beam and

(v) a device to stop the electrons.



Principle:

Principle of X-ray imaging ,X-Rays are capable of passing through opaque objects through which light cannot Various anatomical structures of the body have different densities for the X-Rays. When X-ray from point source penetrate a section of the body, various internal structures of the body also is depending upon their absorption capacities. The radiation that leaves the body has intensity variation, depending upon absorption. This spatial intensity variation is an internal structure of the body. The X-ray intensity distribution is visualized by a suitable device to photographic film as shown in image.



Special techniques in X-ray imaging are Special techniques used to obtain usable images from certain body structures are:

1. Grids
2. Contrast media
3. Cardiac catheterization
4. Fluoroscopy
5. Angiography
6. Tomography

Stationary mode tubes and rotating anode tubes are the two main types of X-ray tubes:

Stationary anode tube

The normal tube is a vacuum diode in which electrons are generated by thermionic emission from the filament of the tube. The electron stream is electro statically focused on a target on the anode by means of a suitably shaped cathode cup. The kinetic energy of the electrons impinging on the target is converted into X-rays. Most electrons emitted by the hot filament become current carriers across the tube. It is, therefore, possible to independently set

(i) Tube current by adjusting the filament temperature.

(ii) Tube voltage by adjusting primary voltage.

Rotating anode tube

With an increasing need in radiology for more penetrating X-rays, requiring higher tube voltages and current, the X-ray tube itself becomes a limiting factor in the output of the system. This is primarily due to the heat generated at the anode. The heat capacity of the anode is a function of the focal spot area. Therefore, the absorbed power can be increased if the effective area of the focal spot can be increased. This is accomplished by the rotating anode type of X-ray tubes

Crookes tube (cold cathode tube)

Crookes tubes generated the electrons needed to create X-rays by ionization of the residual air in the tube, instead of a heated filament, so they were partially but not completely evacuated. They consisted of a glass bulb with around 10−6 to 5×10−8 atmospheric pressure of air (0.1 to 0.005 Pa). They had an aluminium cathode plate at one end of the tube, and a platinum anode target at the other end. The anode surface was angled so that the X-rays would radiate through the side of the tube.

The cathode was concave so that the electrons were focused on a small (~1 mm) spot on the anode, approximating a point source of X-rays, which resulted in sharper images. The tube had a third electrode, an anticathode connected to the anode. It improved the X-ray output, but the method by which it achieved this is not understood. A more common arrangement used a copper plate anticathode (similar in construction to the cathode) in line with the anode such that the anode was between the cathode and the anticathode.

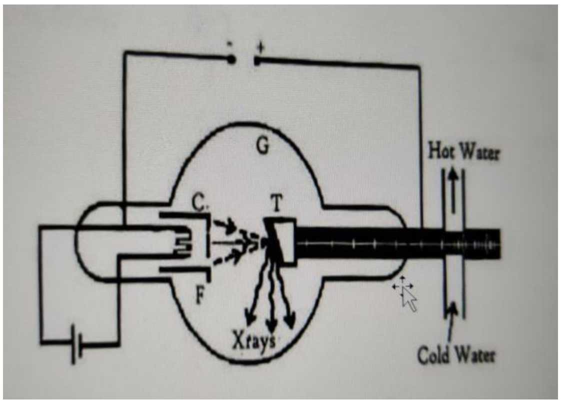
Coolidge tube (hot cathode tube)

In the Coolidge tube, the electrons are produced by thermionic effect from a tungsten filament heated by an electric current. The filament is the cathode of the tube. The high voltage potential is between the cathode and the anode; the electrons are thus accelerated, and then hit the anode.

There are two designs: end-window tubes and side-window tubes. End window tubes usually have "transmission target" which is thin enough to allow X-rays to pass through the target (X-rays are emitted in the same direction as the electrons are moving.) In one common type of end-window tube, the filament is around the anode ("annular" or ring-shaped), the electrons have a curved path (half of a toroid).

X-ray tube

CT, radiography, and fluoroscopy all work on the same basic principle: an X-ray beam is passed through the body where a portion of the X-rays are either absorbed or scattered by the internal structures, and the remaining X-ray pattern is transmitted to a detector (e.g., film or a computer screen) for recording or further processing by a computer.



These exams differ in their purpose:

Radiography - a single image is recorded for later evaluation. Mammography is a special type of radiography to image the internal structures of breasts.

Fluoroscopy - a continuous X-ray image is displayed on a monitor, allowing for real-time monitoring of a procedure or passage of a contrast agent (“dye”) through the body. Fluoroscopy can result in relatively high radiation doses, especially for complex interventional procedures (such as placing stents or other devices inside the body) which require fluoroscopy be administered for a long period of time.

CT - many X-ray images are recorded as the detector moves around the patient's body. A computer reconstructs all the individual images into cross- sectional images or “slices” of internal organs and tissues. A CT exam involves a higher radiation dose than conventional radiography because the CT image is reconstructed from many individual X-ray projections.

6. Analyses the sensitometric curve of an x-ray film and its importance in assessing film performance.(Nov/Dec 2018)

Sensitometric methods employed for determining the characteristic curve of interest in medical imaging are described. These methods are based on the way in which various recording systems are exposed. In diagnostic radiology, an x-ray intensity scale sensitometer is used for measurements of the characteristic curves of conventional film and screen-film systems. The effect of reciprocity law failure on the sensitometric evaluation of screen-film systems is illustrated.

The shape of the characteristic curves as a function of the light spectrum emitted from three types of intensifying screens is presented. Sensitometric techniques for quality control of automatic processors are also discussed. In radiation therapy, a sensitometric technique is described for determination of the proper characteristic curve for a film which can be placed beneath the patient before radiation treatment and removed afterwards so that an image of the anatomy actually irradiated is obtained. A characteristic curve can also be obtained by means of which photographic densities measured on the therapy verification film is related to exit absorbed dose.

In diagnostic radiology, an x-ray intensity scale sensitometer is used for measurements of the characteristic curves of conventional film and screen-film systems.

An x-ray sensitometer is used to measure the characteristic curve of radiographic films exposed with fluorescent intensifying screens. During exposure, x-ray kilo voltage, tube current, and exposure times remain constant. Radiation intensity is varied by automatic, stepwise increase of the focus-film distance. The x-ray source utilized a conventional radiation therapy x-ray machine modified for necessary output stability. Normally, 80 kVp x rays are used with 0.5 mm Cu + 3 mm Al filtration at the tube. Focal spot-film distance ranges from 10 to 126 inches. This exposure latitude gives a complete characteristic curve of film-screen systems with excellent reproducibility.

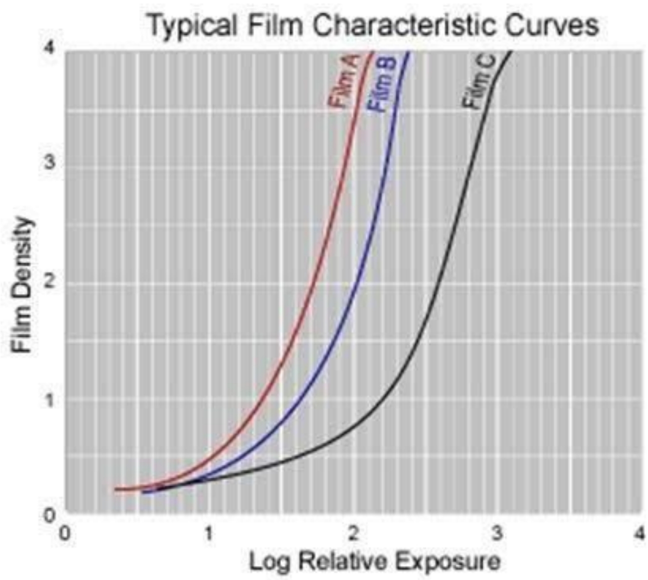
H and D curve:

A graph in which the density of the photographic film (vertical axis) is plotted against the logarithm of the relative exposure (horizontal axis), to illustrate the photographic characteristics of an emulsion (e.g. on an x-ray film).

Plots of film density (log of opacity) versus the log of exposure are called characteristic curves, Hurter–Driffield curves,H–D curves,HD curves, H & D curves,D–logE curves,or D–logH curves.At moderate exposures, the overall shape is typically a bit like an "S" slanted so that its base and top are horizontal.

There is usually a central region of the HD curve which approximates to a straight line, called the "linear" or "straight-line" portion; the slope of this region is called the gamma. The low end is called the "toe", and at the top, the curve rounds over to form the "shoulder". At extremely high exposures, the density may come back down, an effect known as solarisation.

Different commercial film materials cover a gamma range from about 0.5 to about 5. Often it is not the original film that one views but a second or later generation. In these cases the end-to-end gamma is approximately the product of the separate gammas.



Photographic paper prints have end-to-end gammas generally somewhat over 1. Projection transparencies for dark surround viewing have end-to-end gamma approximately 1.5. A full set of HD curves for a film shows how these vary with developer type and time.

7. Describe the functioning of digital fluoroscopy in detail?(Nov 2016)

Digital fluoroscopy is a form of x-ray that allows us to view deep structures of the body in real time. It provides very detailed images of function and structure of areas like the intestines, the bladder, the cardiac muscle and stomach.

Unlike regular x-ray which records the image to film, digital fluoroscopy records a series of images to a computer. Once digitized, we can view the area being examined in real time on a computer monitor.

Digital fluoroscopy enables radiologists to view motion and assess the anatomy and function of different parts of the body. Fluoroscopy is frequently used to evaluate the gastrointestinal tract, including the oesophagus, stomach, the first section of the small intestine called the duodenum,‟ and the colon.

The digital fluoroscopy procedures that are commonly used to evaluate the gastrointestinal tract include esophagram, upper GI series (barium swallow) and barium enema. These tests assist physicians in diagnosing problems of the digestive tract (e.g. ulcers, tumors, hiatal hernias, reflux, scarring, inflammation and blockages).

Digital fluoroscopy is also used to evaluate the kidney function in angiography and venography procedures (placement of tubes in an artery or vein), pain management procedures (e.g. nerve root blocks) and some imaging guided biopsies.

Function:

During a fluoroscopy procedure, an X-ray beam is passed through the body. The image is transmitted to a monitor so the movement of a body part or of an instrument or contrast agent (“X-ray dye”) through the body can be seen in detail

Digital Fluoroscopy is a form of X-ray that allows us to view deep structures of the body in real-time. It provides very detailed images of function and the structure of areas like the intestines, bladder, cardiac muscle, and stomach.

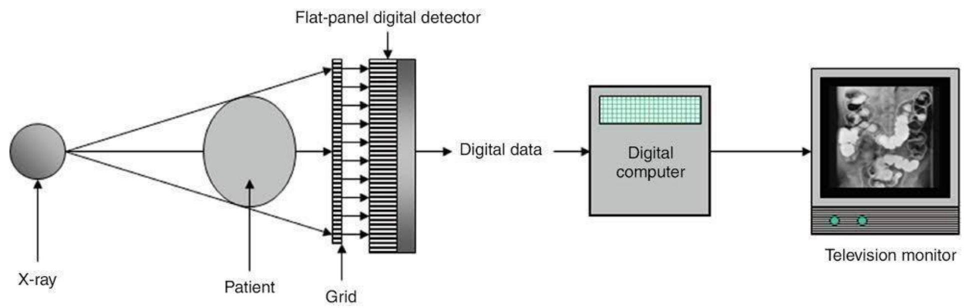
Unlike a regular X-ray which records the image to film, digital fluoroscopy records a series of images to a computer. Once digitized, we can view the area being examined while it is moving and functioning on a computer monitor.

Digital fluoroscopy tests often include oral or intravenous contrasts to be given prior to testing. You will be positioned on a large flat table; this table can move and be tilted at different angles during your exam.

A moveable X-ray camera extends over a portion of the table, captures images and sends these images to a nearby television monitor for viewing by the radiologist performing your exam.

Conventional fluoroscopy:

It produces a shadowgraph-type image on a receptor that is directly produced from the transmitted x-ray beam. Image-intensifier tubes serve as the fluoroscopic image receptor. These tubes usually are coupled electronically to a television monitor for remote viewing.



Digital fluoroscopy:

It is a digital x-ray imaging system that produces dynamic images obtained with an area x-ray beam. The difference between conventional fluoroscopy and DF is the nature of the image and the manner in which it is digitized.

Although the intravenous route is still widely used, intra arterial injections are also used with DF.

A DF examination is conducted in much the same manner as a conventional fluoroscopic study. To the casual observer, the equipment is the same, but such is not the case

A computer has been added, as have multiple monitors and a more complex operating console.

Operation:

It operates in the radiographic mode. Tube current is measured in hundreds of mA instead of less than 5 mA, as in image-intensifying fluoroscopy.

Images from DF are obtained by pulsing the x-ray beam in a manner called pulse-progressive fluoroscopy.The fraction of time that the x-ray tube is energized is called the duty cycle.

A major change from conventional fluoroscopy to DF is the use of a charge-coupled device (CCD) instead of a TV camera pickup tubethe use of a charge-coupled device (CCD) instead of a TV camera pickup tube - The charge- coupled device (CCD) was developed in the 1970s for military applications, especially in night vision scopes. Today, CCDs are used in the home camcorder, commercial television, security surveillance, and astronomy.

Charge-Coupled Device

The CCD has greater sensitivity to light (detective quantum efficiency [DQE]) and a lower level of electronic noise than a television camera tube. The result is a higher signal-to-noise ratio (SNR) and better contrast resolution. These characteristics also result in substantially lower patient dose. The response of the CCD to light is very stable.

Flat Panel Image Receptor

Another improvement in DF - The FPIR is much smaller and lighter and is manipulated more easily than an image intensifier. The FPIR imaging suite provides easier patient manipulation and radiologist/technologist movement, and there are no radiographic cassettes.

Advantages of DF:

Digital image processing can be used in diagnostic imaging departments for the Picture Archiving and Communication System (PACS). The file room can be replaced by a magnetic or optical memory device about the size of a desk.

8. Discuss the components of X-ray tube with a neat sketch.(April/May 2018)

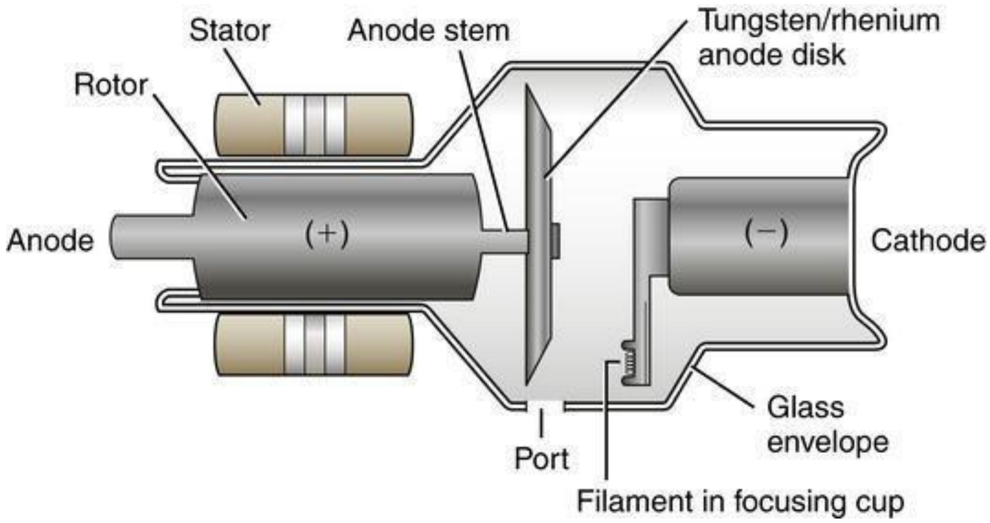
The x-ray tube contains two principal elements: filament (also acts as cathode): boils off electrons by thermionic emission. target (also acts as anode): electrons strike to produce x-rays.

The x-ray tube serves the function of creating x-ray photons from electric energy supplied by the x-ray generator. The process of creating the x-ray beam is very inefficient, with only 1% of the electric energy converted to x-ray photons and the remaining 99% converted to heat in the x-ray tube assembly. Thus, to produce sufficient x-ray output for diagnostic imaging, the x-ray tube must withstand and dissipate a substantial heat load, a requirement that affects the design and composition of the x-ray tube.

The major x-ray tube components are the cathode and anode assemblies, the tube envelope, the rotor and stator (for rotating anode systems), and the tube housing. The design of the x-ray tube determines the basic characteristics of the x-ray beam such as focal spot size, x-ray field uniformity, and the x-ray energy spectrum. These x-ray beam characteristics are important because they affect radiologic parameters such as spatial resolution, image contrast, and patient dose.

X-ray Tube

Although there are several specialty designs of the x-ray tube, they do have basic components in common. This text focuses on the design used for general medical radiography. The general-purpose x-ray tube is an electronic vacuum tube that consists of an anode, a cathode, and an induction motor all encased in a glass or metal enclosure (envelope). the anode is the positive end of the tube and the cathode is the negative end of the tube. The anode incorporates an anode target and an induction motor, half of which is inside and half of which is outside the protective enclosure; the anode is discussed in detail shortly. The cathode consists of the focusing cup and filament with its supporting wires.



The main purpose of the enclosure is to maintain a vacuum within the tube. Because the production of x-rays involves the interaction between filament electrons and the anode target, if any air were present, the electrons from the air would contribute to the electron stream, causing arcing and damage to the tube.

The glass envelope variety is generally made of borosilicate glass because it is very heat resistant. However, as these tubes age, vaporized tungsten from the filament deposits on the inside of the glass (called “sun tanning” because of the bronze discoloration of the glass), which causes problems with arcing and damage.

The metal envelope variety provides a constant electric potential between the electron stream from the cathode and the enclosure, thereby avoiding the arcing problem and extending tube life. Both enclosure types have a specially designed target window for the desired exit point of the x-rays produced. The target window is fashioned to minimally interfere with (absorb) the x-rays. It is usually about 5 cm square and is a place on the enclosure that has been made thinner than the rest. This thinned section reduces the amount of absorption by the enclosure.

The anode is the positive end of the tube. It provides the target for electron interaction to produce x-rays and is an electrical and thermal conductor. Remember that electricity is flowing through the x-ray tube and the electrons flowing from cathode to anode are a part of that flow of electricity. Some of the electrons interact with the target to produce x-rays and the rest continue as current flow through the x-ray circuit. A tremendous amount of heat is also generated during the process and the anode is designed to dissipate this heat.

9. Explain in detail the electrical and thermal rating of an X-ray tube.(April/May 2018)

An x-ray tube rating is the maximum allowable kilowatts (kW) in 0.1 second. When the electron beam strikes the target material in the anode only 1% of the kinetic energy of the electrons is converted into x-rays whilst the rest is converted into thermal energy.

Tube ratings are the defined input parameters (kVp, mA, exposure) that can be safely used during its operation without causing damage to the x-ray tube itself and unique to each individual x-ray tube model. An x-ray tube rating is the maximum allowable kilowatts (kW) in 0.1 s.

When the electron beam strikes the target material in the anode only 1% of the kinetic energy of the electrons is converted into x-rays whilst the rest is converted into thermal energy. Increasing the kVp, mA, or exposure time increases the thermal energy produced per examination. Thermal energy is dissipated in the anode and surrounding x-ray tube. If too much heat is created (or not enough is dissipated), excess residual thermal energy will damage the anode and tube.

By creating tube ratings the operator can ensure that the parameters set are appropriate for the examination whilst minimizing the risk of damage to the x-ray tube. Typical x-ray tube ratings are between 5-100kW and are dependent on focal spot size.

To produce x-radiation, relatively large amounts of electrical energy must be transferred to the x-ray tube. Only a small fraction (typically less than 1%) of the energy deposited in the x-ray tube is converted into x-rays; most appears in the form of heat. This places a limitation on the use of x-ray apparatus. If excessive heat is produced in the x-ray tube, the temperature will rise above critical values, and the tube can be damaged. This damage can be in the form of a melted anode or a ruptured tube housing.

In order to prevent this damage, the x-ray equipment operator must be aware of the quantity of heat produced and its relationship to the heat capacity of the x-ray tube.The heat produced during x-ray production can be a limiting factor:

In the use of small focal spots that are desirable for good image detail, one example is magnification mammography.

In CT, especially with spiral scanning of relatively large anatomical regions. One of the major challenges in developing x-ray tubes for modern, high performance, CT systems is to provide design features to accommodate the high levels of heat produced.

Heat is produced in the focal spot area by the bombarding electrons from the cathode. Since only a small fraction of the electronic energy is converted in x-radiation, it can be ignored in heat calculations. We will assume all of the electron energy is converted into heat. In a single exposure, the quantity of heat produced in the focal spot area is given by

Heat (J) = KVe x MAS

or

Heat (J) = w x KVp x MAS.

Where KVe is the effective KV value and KVp is the peak KV value.

In this relationship, w is the waveform factor; its value is determined by the waveform of the voltage applied to the x-ray tube. Values for most waveforms encountered in diagnostic x-ray machines are: constant potential, 1.0; three-phase, 12 pulse, 0.99; three-phase, 6-pulse, 0.96; single-phase, 0.71.

The relationship between a quantity of heat expressed in heat units and in joules is given by

Heat (HU) = 1.4 x heat (J).

Since the product of the joules-to-heat unit conversion factor (1.4) and the waveform factor for single-phase (0.71) is equal to 1, the following relationship is obtained:

Heat (HU) = KVp x MAS.

Here it is seen that for single-phase operation, the heat produced in heat units is the product of the KVp and MAS. In fact, this is why the heat unit is used. In the earlier days of radiology, when most equipment was single-phase, it was desirable to calculate heat quantities without having to use a waveform factor. This was achieved by introducing a new unit, the heat unit. For three- phase, six-pulse equipment, the heat in heat units is given by

Heat (HU) = 1.35 x KVp x MAS.

The factor of 1.35 is the ratio of the waveform factors, 0.96/0.71.The rate at which heat is produced in a tube is equivalent to the electrical power and is given by

Power (watts) = w x KVp x MA.

The total heat delivered during an exposure, in joules or watt-seconds, is the product of the power and the exposure time.

In order to evaluate the problem of x-ray tube heating, it is necessary to understand the relationship of three physical quantities: (1) heat, (2) temperature, and (3) heat capacity. Heat is a form of energy and can be expressed in any energy units. In x-ray equipment, heat is usually expressed in joules (watt-seconds) or heat units.

For a given object, the relationship between temperature and heat content involves a third quantity, heat capacity, which is a characteristic of the object. The general relationship can be expressed as follows:

Temperature = heat / heat capacity.

The heat capacity of an object is more or less proportional to its size, or mass, and a characteristic of the material known as the specific heat. As heat is added to an object, the temperature increases in proportion to the amount of heat added.

When a given amount of heat is added, the temperature increase is inversely proportional to the object's heat capacity. In an object with a large heat capacity, the temperature rise is smaller than in one with a small heat capacity. In other words, the temperature of an object is determined by the relationship between its heat content and its heat capacity.

Relationship among Heat, Temperature, and Heat Capacity

In x-ray tube operation, the goal is never to exceed specific critical temperatures that produce damage. This is achieved by keeping the heat content below specified critical values related to the tube's heat capacity.

In most x-ray tubes there are three distinct areas with critical heat capacities, as shown below. The area with the smallest capacity is the focal spot area, or track, and is the point at which heat is produced within the tube. From this area, the heat moves by conduction throughout the anode body and by radiation to the tube housing; heat is also transferred, by radiation, from the anode body to the tube housing.

10. Explain about Angiography and explain its types in detail.(April/May 2018)

Angiography or arteriography is a medical imaging technique used to visualize the inside, or lumen, of blood vessels and organs of the body, with particular interest in the arteries, veins, and the heart chambers. This is traditionally done by injecting a radio-opaque contrast agent into the blood vessel and imaging using X-ray based techniques such as fluoroscopy.

The term angiography has been applied to radionuclide angiography and newer vascular imaging techniques such as CO2 angiography, CT angiography and MR angiography. The term isotope angiography has also been used, although this more correctly is referred to as isotope perfusion scanning.

Types of angiography

- coronary angiography – to check the heart and nearby blood vessels.
- cerebral angiography – to check the blood vessels in and around the brain.

- pulmonary angiography – to check the blood vessels supplying the lungs.
- renal angiography – to check the blood vessels supplying the kidneys.
- Digital subtraction angiography (DSA) -is a fluoroscopic technique used extensively in interventional radiology for visualizing blood vessels.

Coronary angiography:

Coronary CT angiography is the use of computed tomography angiography to assess the coronary arteries of the heart. The subject receives an intravenous injection of radiocontrast and then the heart is scanned using a high speed CT scanner, allowing physicians to assess the extent of occlusion in the coronary arteries, usually in order to diagnose coronary artery disease.

Coronary angiography is a procedure that uses a special dye (contrast material) and x-rays to see how blood flows through the arteries in your heart. Coronary angiography is often done along with cardiac catheterization. During the procedure a long, thin, flexible tube called a catheter is inserted into a blood vessel in your groin or arm. Using X-ray images as a guide, the tip of the catheter is passed up to the heart and coronary arteries. It is important to detect blockages because over time they can cause chest pain, especially with physical activity or stress, or a heart attack. If you are having a heart attack, coronary angiography can help your doctors plan your treatment.

A coronary angiogram is a procedure that uses X-ray imaging to see your heart's blood vessels. The test is generally done to see if there's a restriction in blood flow going to the heart.Coronary angiograms are part of a general group of procedures known as heart (cardiac) catheterizations. Cardiac catheterization procedures can both diagnose and treat heart and blood vessel conditions.

Cerebral angiography:

Cerebral angiography is a form of angiography which provides images of blood vessels in and around the brain, thereby allowing detection of abnormalities such as arteriovenous malformations and aneurysms. It was pioneered in 1927 by the Portuguese neurologist Egas Moniz at the University of Lisbon, who also helped develop thorotrast for use in the procedure.

CT angiography of the cerebral arteries (also known as a CTA carotids or an arch to vertex angiogram) is a noninvasive technique allows visualization of the internal and external carotid arteries and vertebral arteries and can include just the intracranial compartment or also extend down to the arch of the aorta.

In cerebral angiography, a catheter (long, thin, flexible tube) is inserted into an artery in the arm or leg. Using the catheter, a technician injects a special dye into the blood vessels that lead to the brain. It is a way to produce x-ray pictures of the insides of blood vessels.

Cerebral angiography can help diagnose: aneurysm. arteriosclerosis. arteriovenous malformation. vasculitis, or inflammation of the blood vessels. brain tumors.

Pulmonary angiography:

Pulmonary angiography is medical fluoroscopic procedure used to visualize the pulmonary arteries and much less frequently, the pulmonary veins. Conventional pulmonary angiography is a minimally invasive procedure performed most frequently by an interventional radiologist or interventional cardiologist. This form of angiography has the added benefit of the ability to treat certain conditions.

Pulmonary angiography (or pulmonary arteriography) is medical fluoroscopic procedure used to visualize the pulmonary arteries and much less frequently, the pulmonary veins.

Pulmonary angiography is performed using the technique described by Seldinger in 1953. 7 The veins used for catheterization of the pulmonary artery are the femoral, jugular and upper extremity vein. Of these, the right femoral vein is preferable because it provides a relatively straight course to the inferior vena cava and right heart.

Renal angiography:

A renal angiogram is an imaging test to look at the blood vessels in your kidneys. Your healthcare provider can use it to look at the ballooning of a blood vessel (aneurysm), narrowing of a blood vessel (stenosis), or blockages in a blood vessel.

In case of renal angiography, CT is the preferred procedure. CT procedures require that a tracer (contrast material or radioactive chemical) be injected in order to highlight tissues and blood vessels and offer detailed images of the same.

Renin keeps blood pressure normal. People with kidney disease may also develop high blood pressure, which can in turn be associated with other problems such as heart attacks and stroke. Erythropeitin tells the body to make red blood cells. Lack of this hormone can result in anaemia.

Digital subtraction angiography:

Digital subtraction angiography (DSA) is a fluoroscopic technique used extensively in interventional radiology for visualizing blood vessels. Radiopaque structures such as bones are eliminated ("subtracted") digitally from the image, thus allowing for an accurate depiction of the blood vessels.

There are numerous indications for angiography and their number has been on the rise ever since interventional radiology has been shown to successfully supplant many open vascular procedures. Salient examples include:

- endovascular aneurysm repair
- arterial balloon angioplasty
- arterial stenting
- endovascular embolization
- thrombectomy

11. Explain about the image intensifier tubes used in the x ray machine with a neat diagram and write down the nature of x-rays and tissue contrast in x-rays with neat sketch.(April/May 2018, Nov/Dec 2017)

An image intensifier or image intensifier tube is a vacuum tube device for increasing the intensity of available light in an optical system to allow use under low-light conditions, such as at night, to facilitate visual imaging of low-light processes, such as fluorescence of materials in X-rays or gamma rays (X-ray image intensifier), or for conversion of non-visible light sources, such as near- infrared or short wave infrared to visible.

They operate by converting photons of light into electrons, amplifying the electrons (usually with a microchannel plate), and then converting the amplified electrons back into photons for viewing. They are used in devices such as night- vision goggles.

Image intensifier tubes (IITs) are optoelectronic devices that allow many devices, such as night vision devices and medical imaging devices, to function.

They convert low levels of light from various wavelengths into visible quantities of light at a single wavelength.

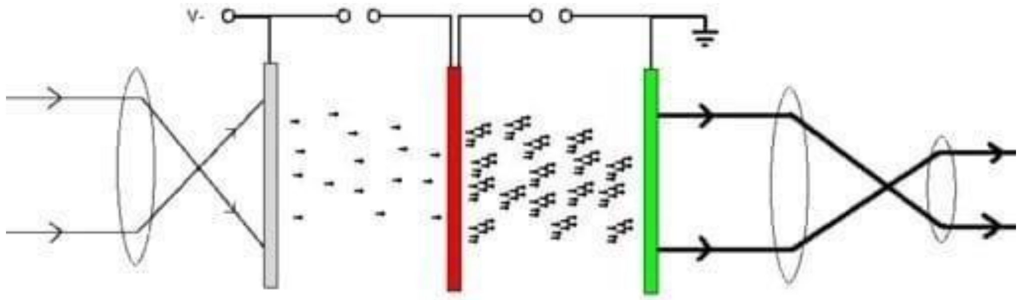


Image intensifiers convert low levels of light photons into electrons, amplify those electrons, and then convert the electrons back into photons of light. Photons from a low-light source enter an objective lens which focuses an image into a photocathode.

The photocathode releases electrons via the photoelectric effect as the incoming photons hit it. The electrons are accelerated through a high-voltage potential into a microchannel plate (MCP). Each high-energy electron that strikes the MCP causes the release of many electrons from the MCP in a process called secondary cascaded emission.The MCP is made up of thousands of tiny conductive channels, tilted at an angle away from normal to encourage more electron collisions and thus enhance the emission of secondary electrons in a controlled Electron avalanche.

All the electrons move in a straight line due to the high-voltage difference across the plates, which preserves collimation, and where one or two electrons entered, thousands may emerge.

A separate (lower) charge differential accelerates the secondary electrons from the MCP until they hit a phosphor screen at the other end of the intensifier, which releases a photon for every electron.

The image on the phosphor screen is focused by an eyepiece lens. The amplification occurs at the microchannel plate stage via its secondary cascaded emission.

The phosphor is usually green because the human eye is more sensitive to green than other colors and because historically the original material used to produce phosphor screens produced green light (hence the soldiers' nickname 'green TV' for image intensification devices).

The nature of x-rays are given below:

- Highly Penetrative
- Highly Absorptive
- Highly Ionizing
- Produce Fluorescence

Tissue contrast:

To distinguish different tissues, we need to obtain contrast between them. Contrast is due to differences in the MR signal, which depend on the T1, T2 and proton density of the tissues and sequence parameters.

The higher the signal is, the brighter it will appear on the MR image. Interpretation is based on analysis of tissue contrast, for given signal weightings (T1, T2, T2* or PD).

MR image could be compared to the representation of a painting with only 2 colors. For example, red would correspond to the T1 effect, yellow to the T2 effect, and pigment density to proton density. If we change the TR and TE, we can see better the red or yellow part of the painting better.

Magnetic resonance imaging demands that tissue contrast and signal-to- noise advantages be sought in each component of the imaging system. One component of magnetic resonance imaging in which contrast and signal-to- noise ratios are easily manipulated is in the choice of pulse sequences and interpulse delay times.

Optimization of pulse sequences is carried out for the two distinct cases of

(a) a fixed number of sequence repetitions and

(b) a fixed total imaging time.

Analytic expressions are derived or approximate expressions are provided for the interpulse delay times that optimize contrast-to-noise ratios in each pulse sequence.

RADIOLOGICAL EQUIPMENTS BME75

UNIT-II

COMPUTER TOMOGRAPHY

2 Marks:

1. Define pitch of multi slice CT. (Nov/Dec2018)

Multislice spiral CT is mainly characterized by the three parameters: the number of detector arrays, the detector collimation, and the table increment per x-ray source rotation. The pitch in multislice spiral CT is defined as the ratio of the table increment over the detector collimation in this study

2. Compare and contrast axial and helical scanners. (Nov/Dec2018)

Helical CT has expanded the traditional CT capability by enabling the scan of an entire organ in a single breath-hold. ... The difference in the naming convention between helical and spiral CT is due mainly to different CT manufacturers. For all practical and technical purposes, there is no difference between the two.

3. What is the principle of CT? (Nov/Dec2019)

CT uses ionizing radiation, or x-rays, coupled with an electronic detector array to record a pattern of densities and create an image of a “slice” or “cut” of tissue. The x-ray beam rotates around the object within the scanner such that multiple x-ray projections pass through the object.

4. Define Collimator. (Nov/Dec2019)

A collimator is a device which narrows a beam of particles or waves. To narrow can mean either to cause the directions of motion to become more aligned in a specific direction (i.e., make collimated light or parallel rays), or to cause the spatial cross section of the beam to become smaller (beam limiting device).

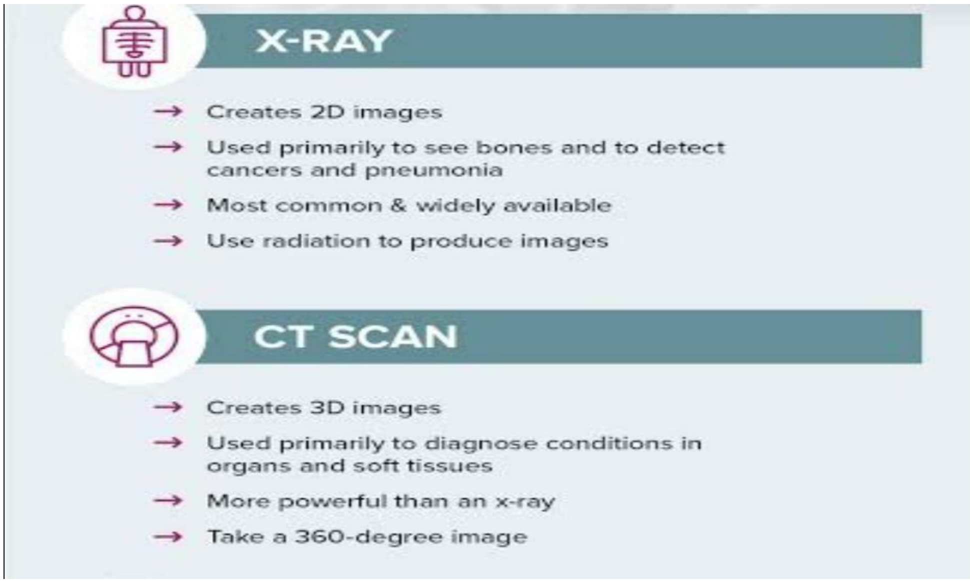
5. What is tomography? (May 2019)

A computerized tomography (CT) scan combines a series of X-ray images taken from different angles around your body and uses computer processing to create cross-sectional images (slices) of the bones, blood vessels and soft tissues inside your body. CT scan images provide more-detailed information than plain X-rays do.

6. What is image construction technique? (May 2019)

Image construction is a mathematical process that generates tomographic images from X-ray projection data acquired at many different angles around the patient. Image reconstruction has fundamental impacts on image quality and therefore on radiation dose.

7. How computer tomography differs from conventional X-ray technique? (Nov 2016)



8. Mention the steps involved in filter back projection algorithm. (Nov 2016)

Filtered back projection is an analytic reconstruction algorithm designed to overcome the limitations of conventional back projection; it applies a convolution filter to remove blurring. It is achieved via an algorithm of 250,000 mathematical equations that can be solved by a high capacity computer.

9. Explain the difference between the scanning systems in first generation and third generation. (April/May2018)

FIRST GENERATION	THIRD GENERATION
Parallel beam geometry	Fan beam,Rotating detector
Moves in straight line	There is a change from transverse and rotational movement
Single detector is used	Fan shaped beam detectors is used
System is slow	System is fast compared to first generation

10. Write short notes on viewing system in computed tomography (April/May2018)

The term "computed tomography", or CT, refers to a computerized x-ray imaging procedure in which a narrow beam of x-rays is aimed at a patient and quickly rotated around the body, producing signals that are processed by the machine's computer to generate cross-sectional images or "slices" of the body.

For example, to examine the circulatory system, a contrast agent based on iodine is injected into the bloodstream to help illuminate blood vessels.

11. How is CT number calculated in CT imaging? April/May2018)

The value of the CT number is calculated from the x-ray attenuation properties of the corresponding tissue voxel. There are two distinct motions of the x-ray beam relative to the patient's body during CT imaging. One motion is the scanning of the beam around the body as we have just seen.

12. What are the characteristics of CT detector? (April/May2018)

All detectors can be evaluated in terms of their various fundamental characteristics, including spectral response, linearity, quantum efficiency, dynamic range, response time, and susceptibility to noise.

11 Marks:

1. **a) Compare the performance of Tomographic technique done at various plain of movement. (Nov/Dec 2018)**
   b) Explain the principle behind Tomography (Apr/May 2018)

Computed tomography (CT) scanning is an extremely common imaging modality in modern medicine. With advancements in technology, it is rapidly replacing many diagnostic radiographic procedures.

Basic Principles

CT scans are created using a series of **x-rays**, which are a form of radiation on the electromagnetic spectrum. The scanner emits x-rays towards the patient from a variety of angles – and the detectors in the scanner measure the difference between the x-rays that are absorbed by the body, and x-rays that are transmitted through the body. This is called **attenuation**.

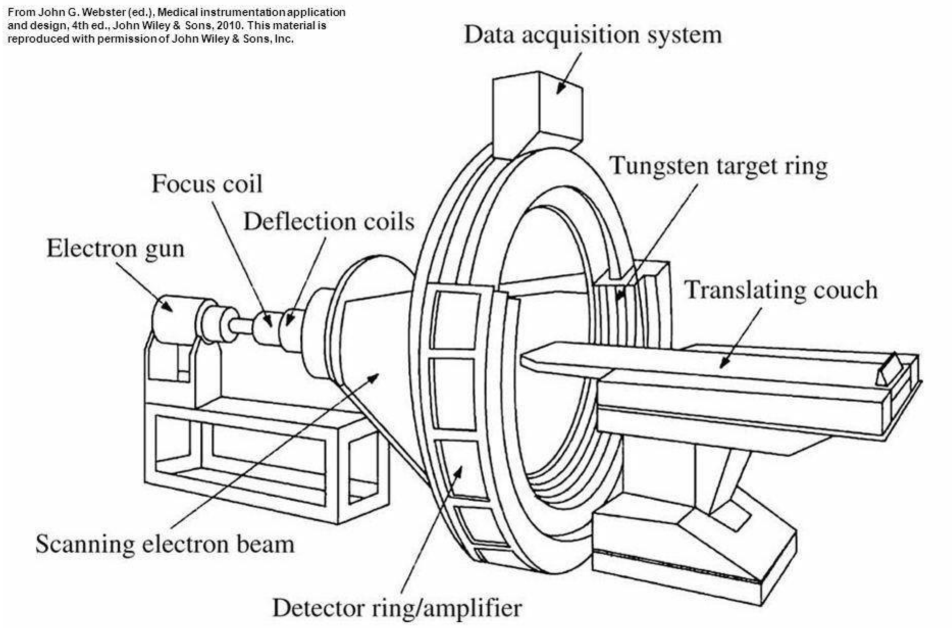
The amount of attenuation is determined by the density of the imaged tissue, and they are individually assigned a **Hounsfield Unit** or **CT Number.**

- **High density tissue** (such as bone) absorbs the radiation to a greater degree, and a reduced amount is detected by the scanner on the opposite side of the body
- **Low density tissue** (such as the lungs), absorbs the radiation to a lesser degree, and there is a greater signal detected by the scanner.

Conventional x-rays provide the radiographer with a two-dimensional image, and require the patient to be moved manually to image the same region from a different angle. In contrast, because of the advanced mathematical algorithms involved with CT, the **three-dimensional planes** of the human body can be imaged and displayed on a monitor as stacked images, detailing the entirety of the field of interest.

This is accomplished by acquiring **projections** from different angles and through a process known as **reconstruction**, the three-dimensional data is viewable on a two-dimensional monitor.

The data collected can theoretically never be a perfect replica of what is being scanned, but is a close enough representation to be used for medical diagnostic purposes.



Purpose

CT-scans provide detailed cross-sectional images of various internal structures for example internal organs, blood vessels, bones, soft tissue etc, and can be used for:

- Diagnostic purposes
- Guidance for specific treatment or further tests- surgeries, biopsies and radiation therapy
- Detection and monitoring of conditions- Cancer, heart disease, lung nodules, liver masses

Indications for CT Scans:

- Traumatic injuries
- Degenerative conditions, such as stenosis and osteoarthritis when an MRI is contraindicated
- Post-operative conditions
- Neoplastic conditions
- Infectious processes
- Image guidance during injections, biopsy’s and aspirations
- Abnormalities of bony alignment, such as scoliosis
- Processes involving the spinal cord when MRI is contraindicated

Technique

Most modern CT machines take continuous pictures in a helical (or spiral) fashion rather than taking a series of pictures of individual slices of the body, as the original CT machines did. Helical CT has several advantages over older CT techniques: it is faster, produces better 3-D pictures of areas inside the body, and may detect small abnormalities better. The newest CT scanners, called multislice CT or multidetector CT scanners, allow more slices to be imaged in a shorter period of time.

Digital geometry processing is used to generate a three-dimensional image of the inside of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation. CT produces a volume of data which can be manipulated, through a process known as "windowing", in order to demonstrate various bodily structures based on their ability to block the X-ray/Röntgen beam.

Sometimes, CT involves the use of a contrast (imaging) agent, or "dye." The dye may be given by mouth, injected into a vein, given by enema, or given in all three ways before the procedure. The contrast dye highlights specific areas inside the body, resulting in clearer pictures. Iodine and barium are two dyes commonly used in CT

Benefits/Risks

When used appropriately, the benefits of a CT scan far exceed the risks. CT scans can provide detailed information to diagnose, plan treatment for, and evaluate many conditions in adults and children. Additionally, the detailed images provided by CT scans may eliminate the need for exploratory surgery.

Concerns about CT scans include the risks from exposure to ionizing radiation and possible reactions to the intravenous contrast agent, or dye, which may be used to improve visualization. The exposure to ionizing radiation may cause a small increase in a person's lifetime risk of developing cancer.

Exposure to ionizing radiation is of particular concern in pediatric patients because the cancer risk per unit dose of ionizing radiation is higher for younger patients than adults, and younger patients have a longer lifetime for the effects of radiation exposure to manifest as cancer. However, in children and adults, the risk from a medically necessary imaging exam is quite small when compared to the benefit of accurate diagnosis or intervention.

2. a) Draw an analogy between various generations of CT. (Nov/Dec 2018)
b) Explain about different generations of CT scanner. (Nov/Dec 2019)

c) Discuss the techniques, advantages, disadvantages and applications of Third generation and Fifth generation of CT. (May 2019)

Computer tomography has two basic functions: user and utility. The user function carries out the tasks associated with the preparation of the scanner for operation, the management of the scanning process itself, the acquisition of the projection data, image reconstruction, support functions aiding diagnosis from the reconstructed images and archiving of the tomographic images.

The utility function deals with the technical parameters of the scanner, the diagnosis of errors and other service tasks. A CT scanner consists of the following main elements

- Data acquisition system that carries out the X-ray projections,
- Computer to reconstruct the images from the projections and to assist in the analysis of the reconstructed images,
- a variable power supply,
- a monitor to display the routine operation of the computer system and to act as an interactive interface in the diagnosis of the reconstructed images,
- a documentation camera to produce an image on film similar to traditional X-ray images,
- other data archiving systems, such as tape or disk, collectively referred to as storage devices,

The scanner itself is situated behind a screen to protect the operators from the harmful effects of the X-rays emitted by the tube. The other components of the CT system are located in the same room as the Technicians and doctors.

Whatever the differences in design of the different generations of scanners, the main elements remain the same. Figure 3.2 presents three orthogonal views of a standard design of data acquisition system. Some elements of the apparatus are immediately recognisable, while others are part of the larger units and are not visible.

The main components of the scanner design are:

- The gantry with a central opening, into which the patient is moved during the examination. This is the most recognisable element of the CTscanner;
- The X-ray tube, the source of the X-rays that pass through the body situated in the gantry and carry the information about the structure of the body to the detectors. The information is in the form of a series of projections;
- The detector array converts the projection values, in the form of radiation Intensities, into electrical quantities. Usually, the whole detector array rotates synchronously with the X-

ray tube around the test object;

- The table allows the patient to be maneuvered easily into position. The table can be controlled manually before the actual scan begins, but it moves automatically during the scan. The table can be moved into or out of the gantry along the axis of the patient"s body, as well as up and down. This allows the patient to be appropriately positioned depending on which part of the body is being examined.

- The scanner also contains a number of sub-systems that drive and control the device, enable precise positioning of the patient during the scan as well as facilitate Communication with the patient.

The evolution of CT scanners has been marked by changes to the design of the projection sub-systems of the data acquisition system. In comparing these designs, only those that represent commonly used classes of CT devices are listed below; non-typical or prototype designs have been omitted.

The design of each of the CT scanner generations contains one of three basic Tube-detector projection systems

- a projection system using a parallel beam of radiation (a parallel-beam System),
- a system using a beam of radiation in the shape of a fan (a fan-beam system),
- a system using a beam of radiation in the shape of a cone (a cone-beam system).

First-Generation Scanners

First-generation scanners sometimes called pencil beam or translation/rotation Single detector scanners; belong to the class of device that uses a parallel-beam projection system.

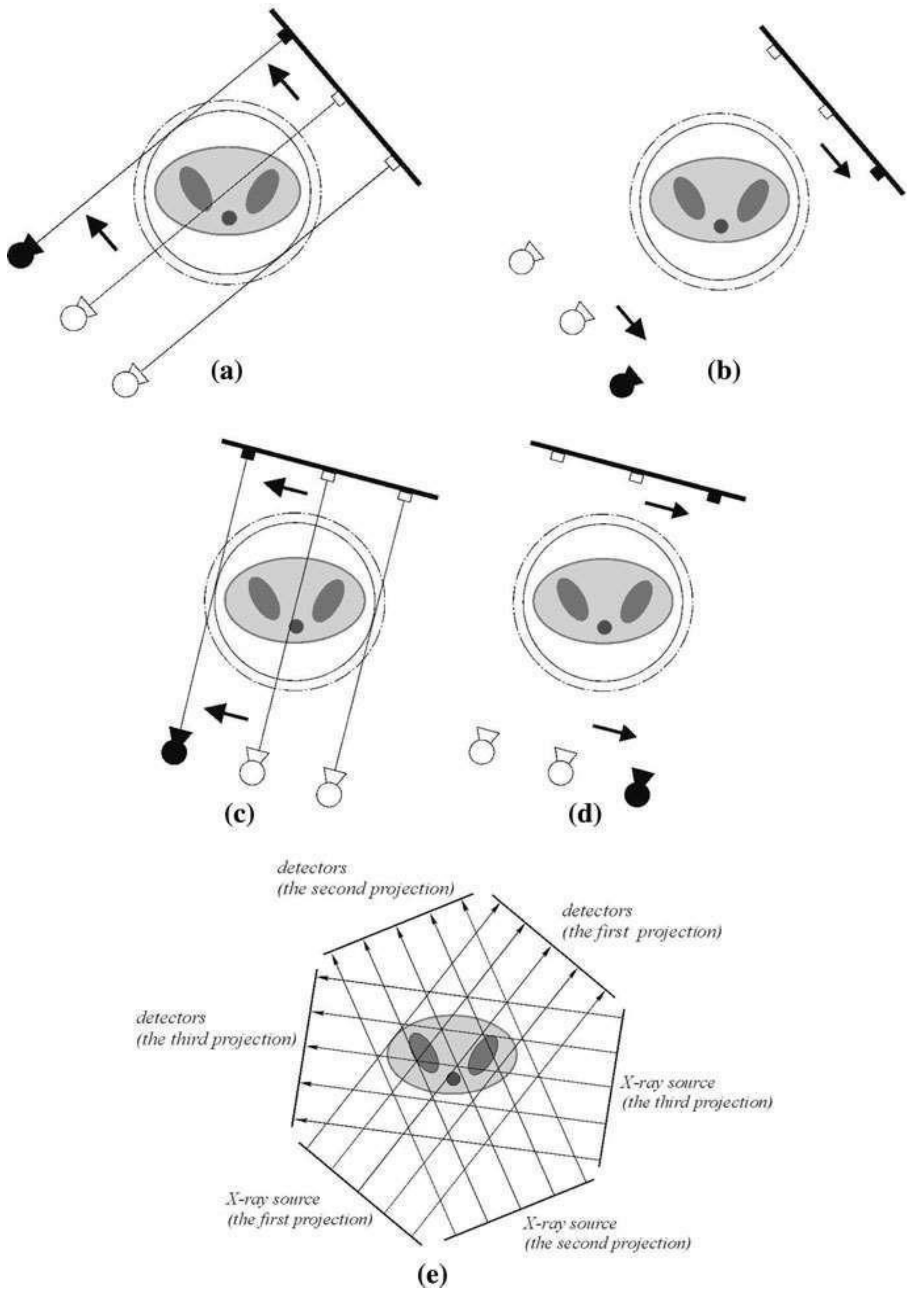
In this type of scanner, there are two components to the movement of the rigidly coupled tube-detector system: a lateral movement to make a single projection and a circular movement about the central opening in the gantry to gather all the projections necessary to reconstruct the image.

The acquisition of the individual projections can be either continuous or discrete, but each of these projections is obtained only at a discrete angle of rotation of the projection system. It is easy to see how this method of scanning is not fast enough (it takes approximately 5 min); both the single detector and the X-ray tube must travel a distance equal to the diameter of the gantry opening, twice during each projection.

First-generation scanners are prime examples of devices having a parallel-beam

Projection system. The procedure for obtaining images of successive cross-sections With this type of scanner is explained using below diagram.

The short arrows in the diagram show the positioning of the patient lying on the table while successive cross-sections are obtained. They represent the small sliding Movements of the table that take place after all the projections needed to reconstruct the image of a single slice have been performed. After each movement, the procedure for the collection of the projections for the next image is repeated.



Design: single X-ray source and single X-ray detector cell to collect all the data for a single slice Source and detector, rigidly coupled

Beam: Pencil beam translated across patient to obtain set of parallel projection measurements at one angle.

- Source/detector rotate slightly and a subsequent set of measurements are obtained during a translation past patient.
- Process is repeated once for each projection angle until 180 projections, across a 24 cm.
- Translation and rotation process, this geometry is referred to as atranslate/rotate scanner.

Disadvantages:

- Earliest versions:4.5 minutes for a single scan and thus were restricted to some regions (patient motion controlled)
- Later versions: procedures = series of scans procedure time reduced somewhat by using two detectors so that two parallel sections were acquired in one scan.
- Contrast resolution of internal structures was unprecedented, images had poor spatial.
- Resolution very poor.

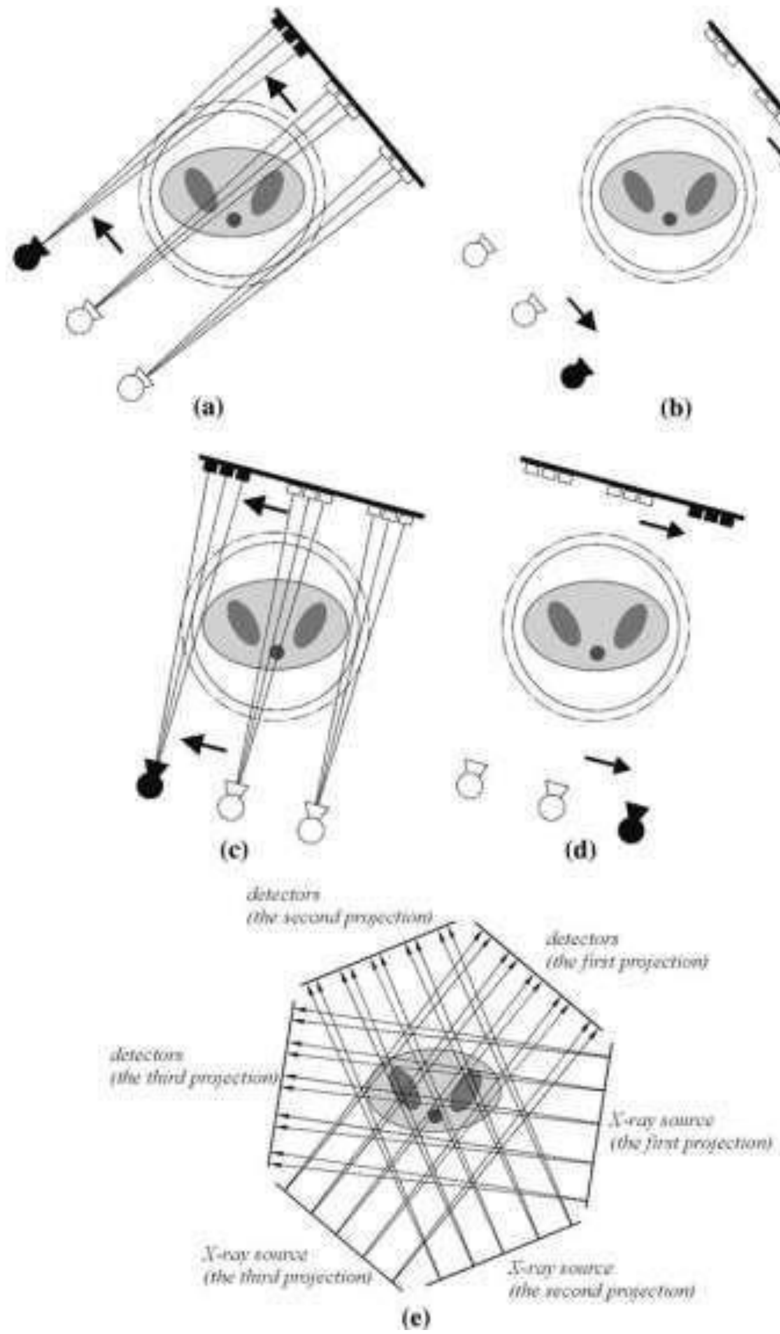
Second-Generation Scanners

Great progress was made (compared to the design of first-generation scanners) when scanners with a larger number of detectors in the array were introduced around 1972. These second-generation scanners, sometimes called partial fan-beam or translation/rotation multiple detector scanners, had between 3 and 52 detectors in the array. The use of the fan-shaped radiation beam [3, 18] enabled the projections to cover a larger area of the patients body at any one time and resulted in the reduction of the number of projections needed to reconstruct an image of satisfactory quality. Figure below illustrates the scanning sequence for this generation of scanner.

In this approach, the time to obtain the projections necessary for the reconstruction of one image was reduced to about 300 s, even though the movement of the tube- detector array was still a combination of lateral and rotational motion. This system can be considered as a transitional stage between the parallel-beam projection system and the fan-beam system.

- **Design:** multiple detectors B/C X-ray source emits radiation over a large angle, the efficiency of measuring projections was greatly improved
- Source and array of detectors are translated as in a first generation system but since beam measured by each detector is at a slightly different angle with respect to object, each translation step generates multiple parallel ray projections.
- Multiple projections obtained during each traversal past the patient this scanner is significantly more efficient and faster than 1stgeneration.

- This generation is a translate/rotate scanner second generation ct scanners.



Merits

- reducing scan time
- The trunk could be imaged
- By adding detectors angularly displaced, several projections could be obtained in a single translation

- Early versions: 3 detectors each displaced by1°Since each detector viewed the x-ray tube at a different angle, a single translation produced 3 projection.
- The system could rotate 3° to the next projection rather than 1° make only 60 translations instead of 180 to acquire a complete section. Scan times were reduced X 3.
- Later versions: up to 53 detectors Fast enough (tens of seconds)to permit acquisition during a single breath hold
- First designs to permit scans of the trunk. Because rotating anode tubes could not.

Third-Generation Scanners

Further steps to improve the CT scanner were next directed towards the elimination of the lateral movement of the tube-detector system. In 1976, scanner designers managed to limit the movement in the projection system exclusively to rotational movement. This was the so-called fan-beam or continuous rotation scanner. By fan-beam, we mean here a projection system with a beam of radiation in the shape of a fan with an angular spread of between 40 and 55 degrees, enough to encompass the whole of the test object, as shown in Fig. below.

An obvious consequence of this modification was the need to increase the number of detectors in the array moving synchronously with the rotating X-ray tube (up to 1,000 detector elements). As a result of these design changes, the time to acquire a reconstructed image was reduced to about 5 s. Scanners of this generation are examples of the implementation of the fan-beam projection system in its purest form.

In this scanner, after all the projections have been made for the first image, the table moves and the whole procedure is repeated for the next cross-section of the body. The sequence of projections for reconstructing the images.

- Improvement in detector and data acquisition technology detector array with enough, high spatial resolution cells to allow measurement of a fan-beam projection of entire patient cross-section

- Sampling considerations required scanning an additional arc of one fan angle beyond 180°, although most scanners rotate 360°for each scan.

- Current helical scanners are based on modifications of rotate-rotate designs Scan times = few seconds or less, and recent versions are capable of sub second scan times

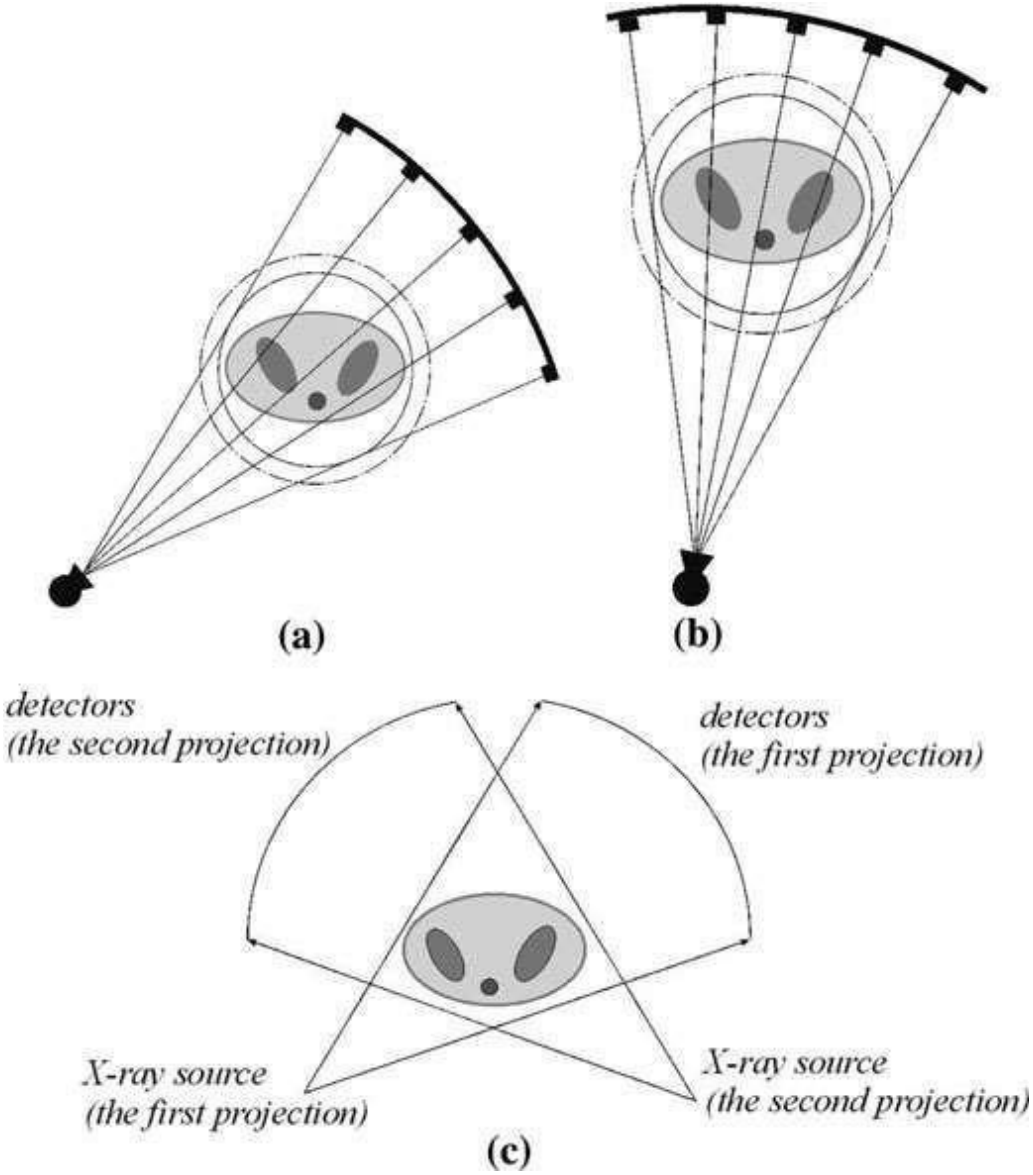
- Imaging process is significantly faster than 1st or 2nd generation systems

- Number of detectors increased substantially (to more than 800detectors)

- Angle of fan beam increased to cover entire patient Eliminated need for translational motion

- Mechanically joined x-ray tube and detector array rotate together

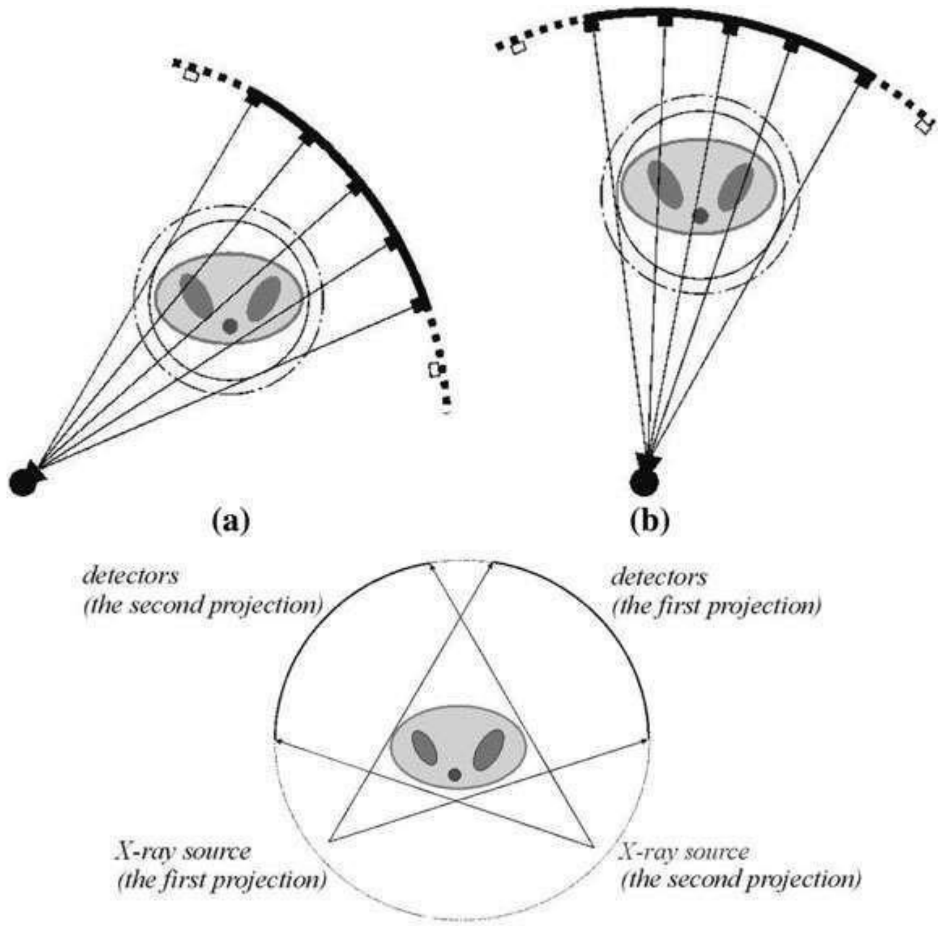
- Newer systems have scan times of½second
- Cons: very high performance detectors are needed to avoid ring artifacts and the system is more sensitive to aliasing than 1st or 2nd generation scanners



Fourth-Generation Scanners

The next, fourth generation of scanners, introduced in 1978, differed only slightly from the third generation. In the earlier designs, the detector array moved around the test object together with the X-ray tube. Now the rotation of the array was eliminated by arranging it on a stationary ring with a radius larger than the radius of the circle described by the tube.

The result was a scanner known as the rotate-fixed scanner; the word rotate in the name refers to the movement of the tube and the word fixed to the array of detectors. In order to maintain an adequate resolution of the radiation intensity measurements, the number of detectors in the array was increased and now ranged from 600 to 5,000 detector elements. The time taken to obtain one image using this design however was still about 5 s. The group to which this scanner belonged remained the same; it was still classified as a fan beam scanner.



(c)

- Design: also eliminated translate-rotate motion Circular array of FIXED detectors, Source only rotates within a stationary ring of detectors
- Larger fan beam
- Shorter scanning time
- Early versions: had some 600detectors
- Later versions: had up to4,800

Limitation: less efficient use of detectors, less than 1/4 are used at any point during scanning Only the x-ray generator and tube rotate at 360, thus shortening the scanning time even more.

3. a) Describe in detail about the image constructions techniques in CT (Nov/Dec 2019)

b) With a neat diagram explain the principle of CT image reconstruction (May 2019)
c) Using back projection algorithm explain the concepts of image reconstruction in CT (Nov/Dec 2017)

CT perfusion imaging requires the reconstruction of a series of time-dependent volumetric datasets. The sequence of CT volumes measures the dynamics of contrast agent both in the vasculature and in the parenchyma.

CT image reconstruction refers to the computational process of determining tomographic images from X-ray projection images of the irradiated patient. Image reconstruction is a compute-intensive task and one of the most crucial steps in the CT imaging process.

There are three major families of CT reconstruction algorithms. All algorithms that have been discussed so far correspond to the class of analytical reconstruction methods. This name refers to the fact that they are derived from an analytical formulation of the inverse Radon transform.

In contrast, algebraic reconstruction approaches have in common that the tomographic reconstruction problem is formulated as a discretized system of linear equations that needs to be solved afterwards. This system of linear equations represents the projection that is the Radon transform in 2D, of the irradiated object, while its numerical solution corresponds to the computation of the inverse Radon transform.

Finally, using statistical reconstruction methods, the probabilistic nature of X-ray generation, absorption, and detection as well as photon statistics are incorporated into the model of the imaging system. Especially for the case of noisy projection data, such a more detailed incorporation of the underlying physics can lead to quality improvements of the images.

Toggle Mode

The so-called toggle mode (or shuttle mode) is a technique for CT scanners to increase the size of the imaged field-of-view, i.e. the coverage in head-feet direction. The method is only applicable, if a certain slab of a volume needs to be scanned repeatedly, as it is the case for cardiac and brain perfusion CT.

In a conventional perfusion scan, only the volume that is covered by the source and the detector rotation is acquired while the patient remains stationary on the table. For a reasonably accurate perfusion image, the patient should be repeatedly imaged at a frequency of about 1 Hz. CT gantries, however, can rotate at a much higher speed at a frequency of about 3 Hz.

This fast rotation speed can therefore be exploited to increase the imaged field-of-view while maintaining a reasonable temporal sampling rate of the patient. The patient table is moved back and forth and the imaged volume is therefore increased in axial direction.

Noise and Artifact Reduction

As previously described, missing data on a circular trajectory creates a typical cone- beam artifact when reconstruction with an approximate algorithm is performed. Such artifact can be suppressed by extended reconstruction methods as proposed in Many FBP reconstruction methods are derived in a continuous domain. The data, however, is acquired in a discrete manner. This discrepancy is often neglected, but may lead to major reconstruction artifacts, if it is not handled with caution.

As filtering is applied in many reconstruction algorithms, a truncation of the view in the filtering direction introduces high frequencies that corrupt the resulting reconstruction. This problem is usually corrected by an extrapolation step that is applied before or during the filtering.

Another source of artifact emerges from under-sampled data. In this case, reconstruction is performed using only few projections or limiting the angular range. While reconstruction can still be performed correctly, if at least 180° or more are acquired for each point of the reconstructed object, reconstruction from less data suffers from limited angle-artifact.

In general, most reconstruction algorithms do not model noise, beam-hardening, scatter, and photon starvation explicitly. They are often compensated in processing steps that are handled before or after the reconstruction and are basically independent of the reconstruction method.

C-arm CT Reconstruction

For most CT scanners, the acquisition geometry is identical to the ideal geometry as they are built for this purpose. However, there are devices that do not fulfill this requirement, but are still able to reconstruct cone-beam CT data. Rotational angiography systems for instance, deviate considerably from the ideal trajectory. The geometry of these machines can be calibrated using standard camera calibration methods. Therefore, a phantom of known geometric properties is scanned and the projection geometry is computed from markers of known location on the phantom.

4. Illustrate in detail about any one X-Ray detector with suitable diagram (Nov 2016)

An overview of the two types of detector systems employed with CT. Both types of systems are usually arranged in linear arrays with up to about 1,000 detector elements or as rings with even more elements in the case of systems with geometry. At least one commercial system uses two adjacent rows of detector elements in order to scan two slices simultaneously.

For scintillation based detectors the most commonly used scintillator materials have been cesium iodide (CsI) and cadmium tungstate, as well as ceramic scintillators employing rare- earth oxides and oxysulfides. A particularly critical parameter for CT detector scintillators is their afterglow behavior. Since CT data acquisition systems do not use pulse counting as in most nuclear applications, but rather integrate the detector current, the afterglow leads to measurement errors near tissue/air and tissue/bone interfaces.

Data correction schemes have been developed to at least compensate for first-order effects related to the detector afterglow. Compared to the rare-gas ionization detector, the scintillation detector usually has a lower geometric efficiency (ratio of active versus ineffective frontal area), which is, however, generally more than compensated for by the latter's higher quantum efficiency.2 In fan beam systems a collimator is usually employed in front of the scintillator elements to reduce the effects of scattering.

X-ray Detectors

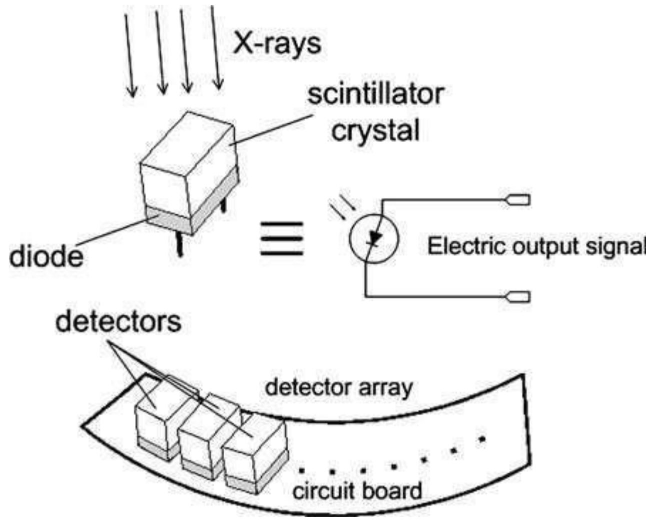
X-ray detectors have a similar function in computed tomography to photographic film in conventional X-ray radiography, that of creating the image from a projection of X-rays . The following types of X-ray detector are currently used in computed tomography

- **Xenon proportional chambers**, in which the electrical output signal is proportional to the intensity of the radiation that ionizes the gas atoms inside micro gap gas chambers (MGC).
- **Scintillation detectors:** Most third-generation scanner use xenon proportional chambers, as they are much cheaper than the scintillation detectors used in subsequent generations. The gas in the ionization chamber of a xenon detector is at high pressure (about10atm)

In this detector, a high voltage of about 140 kV is applied across the electrodes. The voltage must not be too large however or it could cause so-called gas amplification. If an X-ray photon penetrates the detector's window (typically aluminum), there is a high probability of it ionizing the xenon inside. The probability of this happening is proportional to the length of the chamber and the Pressure inside. The current that flows between the electrodes and through the gas ionized by the X-rays is proportional to the intensity of the X-rays. Xenon proportional chambers work in such a way that almost no heating occurs after the ionization event, and so it only takes a short time for them to return to a state of readiness. This is highly significant when applying the technique to spiral projection systems.

The high voltage electrodes are often made of tantalum and the ion-collecting electrodes of copper. To get some idea of the dimensions of these detectors, the length of a xenon chamber is often quoted as 6 cm and the width of a single cell as about 1 mm (1.5 mm). Because of the difficulty of obtaining suitably convergent electrodes while maintaining the standard 8 cm length of chamber, chambers are currently produced with a length of 3 6 cm. In general, the efficiency of these detectors is about 60%, and their main advantages are low cost and small size.

In later generations of CT scanner, from the fourth generation onwards, ceramic (scintillation) detectors are used to measure X-ray intensity.



When X-rays strike a scintillator crystal a range of physical phenomena are produced, namely the photoelectric effect,

- Compton effect,
- Pair production.

Scintillation detectors make use of the photoelectric effect. Photons of X-rays knock electrons out of their orbit and these, in the presence of a phosphor, produce a flash of light (luminescent radiation) in the ultraviolet or visible range of wavelengths. Detector arrays in the newer scanners are constructed with scintillation detectors made from materials such as sodium iodide (NaI) doped with thallium (Tl), caesium iodide (CsI), cadmium tungstate ($CdWO4$), zinc sulphide (ZnS), naphthalene, anthracene and other compounds based on rare earth elements, or gadoliniumoxysulfide ($GD2O2S$) and finally from rare earth based garnet material (98% garnet, 2% rare earth cerium).

The scintillator crystals have a thickness of 1 2 mm and are shaped so that the majority of the photons created as described above pass through the rear wall of the crystal. Here, a photomultiplier amplifies the light signal and photo-detectors convert the light into an electrical signal.

Scintillation detectors have a high time resolution. This is because the duration of the flash in a scintillator is extremely short; for example for NaI, it lasts 0.25 ns. In addition, because the materials from which scintillations are made have a large

atomic number, these sensors absorb radiation strongly and this affects their detection efficiency. Because there are two processes involved in this type of measurement, we have to take care that the light contact between the scintillator and the photo-detectors is good enough to maintain an adequate level of detection efficiency.

An individual semiconductor detector has greater measurement sensitivity than an individual ionization chamber in a xenon detector, but ionization chambers can be packed much more densely, so that the overall sensitivities of the xenon and the semiconductor detectors are very similar.

Detector Parameters

The literature lists the following parameters that describe the quality of measurements achieved by various X-ray detectors

- Quantum efficiency,
- Energy resolution,
- stability overtime,
- spatial resolution,
- resistance to irradiation damage,
- Internal detector noise.

5. (a) Detail description about spiral scanning with neat diagram and explain about ultra-fast CT scanning in detail. (Apr/May 2018)
(b)With neat diagram explain the functions of spiral CT scanning. (Nov/Dec 2017)

This is a scanning technique in which the X-ray tube rotates continuously around the patient while the patient is continuously translated through the fan beam. The focal spot therefore, traces a helix around the patient. The projection data thus obtained allow for the reconstruction of multiple contiguous images. This operation is often referred to as helix, spiral, volume, or three-dimensional CT scanning.

This technique has been developed for acquiring images with faster scan times and to obtain fast multiple scans for three-dimensional imaging to obtain and evaluate the 'volume' at different locations. Multiple images are acquired while the patient is moved through the gantry in a smooth continuous motion rather than stopping for each image.

The projection data for multiple images covering a volume of the patient can be acquired in a single breath hold at rates of approximately one slice per second. The reconstruction algorithms are more complex because they need to account for the spiral or helical path traversed by the X-ray source around the patient Spiral CT has a special advantage in that it allows images to be reconstructed at arbitrary positions and arbitrary spacing, also resulting in overlapping.

The continuous acquisition of whole sections of the body, largely independent of respiration or movement, also permits the reliable localization of small lesions. Continuous data acquisition in the trunk of the body with the possibility of the reconstruction of overlapping slices could not previously be achieved.

Use of Slip Rings:

In a conventional CT scanner, the input power is applied to the transformer, which is located separately from the gantry. The transformer steps up the voltage to the level of 80–150 kV. The high voltage is supplied by special cables, which are attached to the X-ray tube in the gantry. A sophisticated cable management system allows the tube free access for about 400 degrees of rotation in either direction. Therefore, the tube must rotate first in one and then in the opposite direction during scanning.

In third and fourth generation CT systems, it was realized that the power and signal cables would have to be eliminated as they would otherwise have to be re-wound between scans. A completely new concept to achieve this, was developed, by using self-lubrication slip ring technology, to make the electrical connections with rotating components.

The high voltage is then connected to a ring inside the gantry. The X-ray tube has cables which are attached to metal brushes that make physical contact with the ring and transfer the high voltage to the X-ray tube. This allows for unlimited freedom of rotation in either direction for the X-ray tube. The high voltage slip rings have proven to be virtually maintenance-free and extremely reliable over several years of testing.

The special arrangement of the slip rings has rendered the use of oil or gas for insulating the high voltage unnecessary and thus precluded the possible danger of a leak. In practical operation, electric power of upto 40 kW and voltage of up to 140 kV can be transmitted.

In an alternative arrangement, low voltage slip rings can be used to connect the input power directly to the ring inside the gantry. A small high frequency transformer is located inside the gantry at a distance of about one metre from the X-ray tube. The transformer has cables which make physical contact with the ring through metal brushes to transfer the low voltage to the transformer. The high voltage generated by the transformer is then supplied to the X-ray tube by short high voltage cables. This allows for unlimited freedom of rotation, in either direction for the X-ray tube.

X-ray Source:

In CT scanners, the highest image quality, free from disturbing blurring effects, is obtained with the aid of pulsed X-ray radiation. During rotation, high voltage (120 kV) is applied at all times. A grid inside the tube prevents the electron current from striking the anode except when desired, allowing the X-rays to be emitted in bursts. As the gantry rotates, an electric signal is generated at certain positions of the rotating system, e.g., in the 4.8 second scan, 288 electrical pulses are generated at intervals of 1/60 s around the circle. Each pulse turns on the X-rays for a short period of time. The number of pulses, the pulse duration and tube current determine the dose to the patient. These factors can be selected by the operator in the same way that they are selected in conventional X-ray systems.

Detectors:

For a good image quality, it is important to have a stable system response and in that detectors play a significant role. The detectors used in CT systems must have a high overall efficiency in order to minimize the patient radiation dose, have large dynamic range, be very stable with time and insensitive to temperature variations within the gantry. Figure 20.9 shows the three types of detectors commonly used in CT scanners. Fan-beam rotational scanners mostly employ xenon gas ionization detectors.

RADIOLOGICAL EQUIPMENTS

UNIT-III MAGNETIC RESONANCE IMAGING

2 Marks

1. a) What is larmour frequency (Nov/Dec2018)

b) Define larmour frequency (Nov/Dec2019, Nov/Dec2017)

The Larmor frequency is **independent of the polar angle between the applied magnetic field and the magnetic moment direction**. This is what makes it a key concept in fields such as nuclear magnetic resonance (NMR) and electron paramagnetic resonance (EPR), since the precession rate does not depend on the spatial orientation of the spins.

2. What are the characteristics needed for the radio to be used for imaging (Nov/Dec2018)

The radio imaging method (RIM), a technology used practically for geophysical surveys, was applied to biomedical measurements. The characteristics of a subject between a pair of simple loop antennas were measured by using a feeble electromagnetic wave of low frequency. Water distribution inside the human body was expected to be measured, as well as the original method imaged mineral distributions.

3. What are the different types of magnets used in MRI systems (Nov/Dec2019)

Magnets used for MRI are of three types:

- Permanent
- Resistive and
- Superconductive.

4. What is spiral CT (May 2019)

A procedure that uses a computer linked to an x-ray machine to make a series of detailed pictures of areas inside the body. The x-ray machine scans the body in a spiral path Spiral CT scan also creates more detailed pictures and may be better at finding small abnormal areas inside the body.

5. What are the advantages of MRI (May2019)

An MRI scanner can be used to take images of any part of the body (e.g., head, joints, abdomen, legs, etc.), in any imaging direction. MRI provides better soft tissue contrast than CT and can differentiate better between fat, water, muscle, and other soft tissue than CT (CT is usually better at imaging bones).

6. What is meant by T1 and T2 weighted imaging (Nov2016)

The most common MRI sequences are T1-weighted and T2-weighted scans. T1-weighted images are produced by using short TE and TR times ..... Conversely, T2-weighted images are produced by using longer TE and TR times. In these images, the contrast and brightness are predominately determined by the T2 properties of tissue.

7. Write the principle of MRI Technique (Nov2016, Nov/Dec2017)

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body. MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves to generate images of the organs in the body.

8. Mention the limitations of photo timers (April/May 2018)

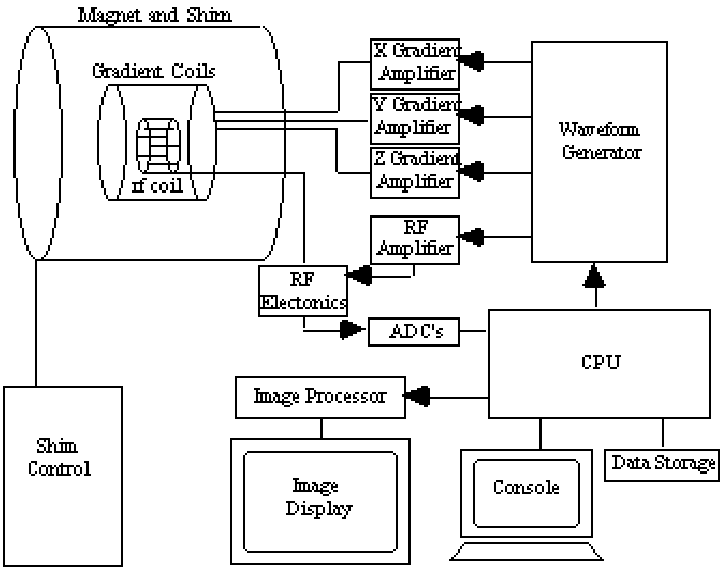
Photo-timers is for controlling x-ray exposure includes an array of x-ray sensors, and digital processing electronics for calculating x-ray exposure by selecting one or more signals from the x-ray sensors, and calculating the x-ray exposure from the selected signals.

9. What are the applications of photo timers? (April/May 2018)

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body. MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves to generate images of the organs in the body.

10. Draw the block diagram of MRI system and explain the principle behind MRI (April/May 2018)

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body. MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves to generate images of the organs in the body.

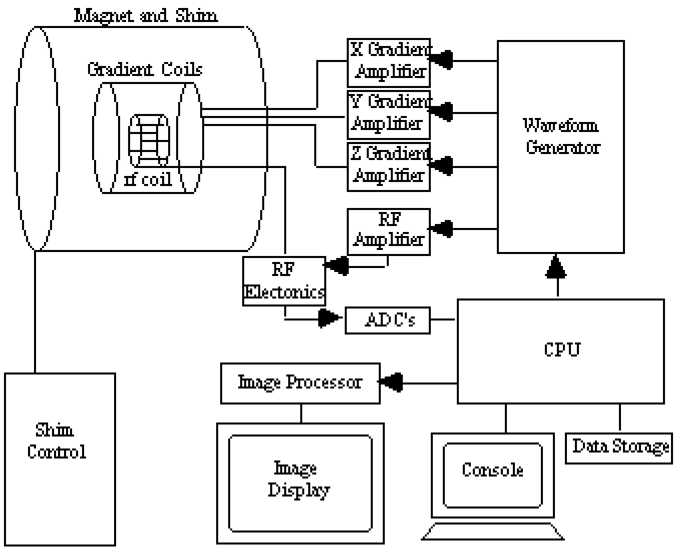


11. Write short notes about the three types of magnet used in MRI (April/May 2018)

- Permanent MRI magnets use permanently magnetized iron like a large bar magnet that has been twisted into a C-shape where the two poles are close together and parallel.
- Resistive (air core) MRI magnets operate at room temperature using standard conductors such as copper in the shape of a solenoid or Helmholtz pair coil.
- Superconductive MRI magnets use a solenoid-shaped coil made of alloys such as niobium/titanium or niobium/tin surrounded by copper.

11 Marks:

1. **Write down the working principle of magnetic resonance imaging (Nov/Dec 2018)**
   Magnetic Resonance Imaging (MRI) is a non-invasive imaging technology that produces three dimensional detailed anatomical images. It is often used for disease detection, diagnosis, and treatment monitoring. It is based on sophisticated technology that excites and detects the change in the direction of the rotational axis of protons found in the water that makes up living tissues.



Working Principle :

MRIs employ powerful magnets which produce a strong magnetic field that forces protons in the body to align with that field. When a radiofrequency current is then pulsed through the patient, the protons are stimulated, and spin out of equilibrium, straining against the pull of the magnetic field. When the radiofrequency field is turned off, the MRI sensors are able to detect the energy released as the protons realign with the magnetic field. The time it takes for the protons to realign with the magnetic field, as well as the amount of energy released, changes depending on the environment and the chemical nature of the molecules. Physicians are able to tell the difference between various types of tissues based on these magnetic properties.

To obtain an MRI image, a patient is placed inside a large magnet and must remain very still during the imaging process in order not to blur the image. Contrast agents (often containing the element Gadolinium) may be given to a patient intravenously before or during the MRI to increase the speed at which protons realign with the magnetic field. The faster the protons realign, the brighter the image.

The three magnets used in MRI are

- Permanent MRI magnets use permanently magnetized iron like a large bar magnet that has been twisted into a C-shape where the two poles are close together and parallel.
- Resistive (air core) MRI magnets operate at room temperature using standard conductors such as copper in the shape of a solenoid or Helmholtz pair coil.

- Superconductive MRI magnets use a solenoid-shaped coil made of alloys such as niobium/titanium or niobium/tin surrounded by copper.

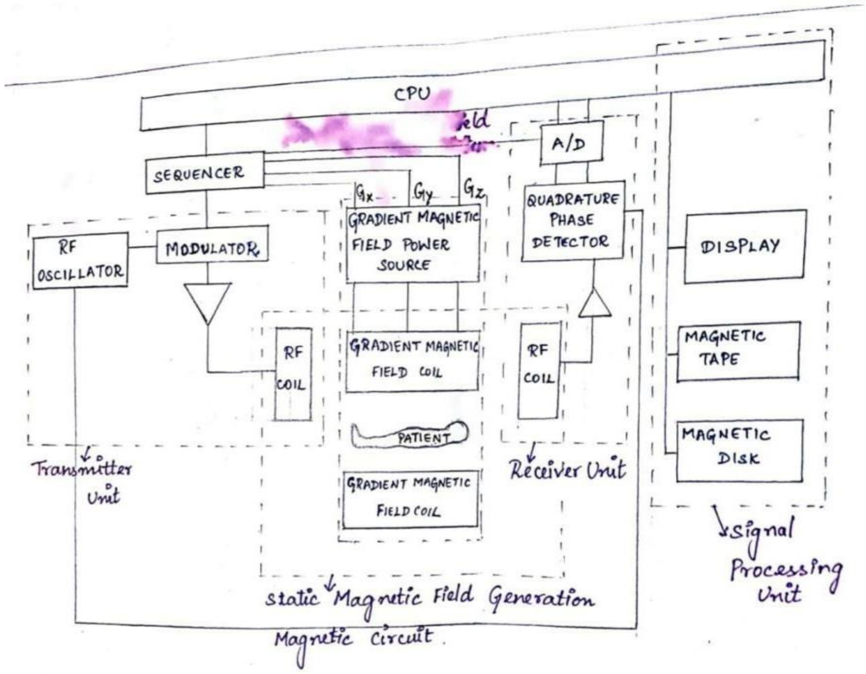
2. a) Give a detailed description of about generation of gradient magnetic field? (Nov 2016)

b) Explain in detail about the generation of gradient magnetic field(Nov/Dec2017)

c) Discuss the use of gradient coil in MRI (Nov/Dec2018)

GRADIENT MAGNETIC FIELD:

A magnetic field that changes in strength in a given direction. Such fields are used in magnetic Resonance Imaging (MRI) to select a region for imaging and to encode the location of MRI signals received from the object being imaged.



GENERATION OF GRADIENT MAGNETIC FIELD IN MRI.

Gradient coils:

- Gradient coils are used to spatially encode the positions of protons by varying the magnetic field linearly across the imaging volume.
- The larmour frequency will then vary function of position in the x y and z-axes.
- Scan speed is dependent on performance of the gradient system.
- Stronger gradients allow for faster imaging, for higher resolution.
- Types of Gradient:

  X Gradient -Frequency Encoding

Y Gradient- Encoding Phase

Z Gradient - Slice Selection

GENERATION OF GRADIENT MAGNETIC FIELD:

- The transmitter system radiates a radio frequency (RF) signals so as to cause nuclear of the atoms magnetic resonance in the atomic nucleus of the tissues of patient by the RF magnetic pulse sent from the sequencer and comprises an RF oscillator, an RE coil modulator an RF amplifier and on the transmission side
- RF pulse from RF oscillator modulated by is amplitude modulated by the modulator in accordance with the instruction of the sequencer
- The amplitude modulated RF pulse in amplified & supplied to the RF coil disposed in proximity of patient / subject so that electromagnetic subject that waves can be irradiated the to the subject
- The receiver unit detects echo signals (NMR signals) emitted due to nuclear magnetic resonance of tissue of subject and comprises RF coil, ADC, amplifier & detector on the reception side.
- The NMR signals generated response to electromagnetic waves from the transmission side.
- Then it is fed to ADC to the digital signal processing unit.

3. a)Describe the MRI system with block diagram (Nov/Dec2018)

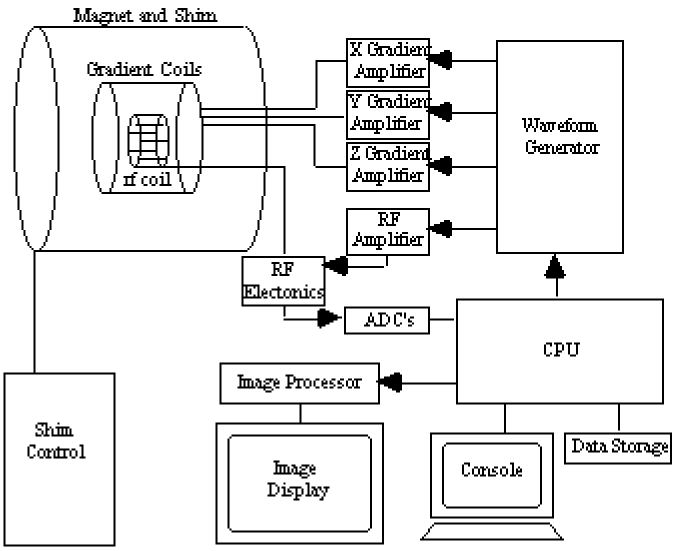
b) Describe about the basic components of MRI system using a neat diagram (Nov/Dec2017)

c) Explain the block diagram of MRI and explain in detail and give the medical applications (April/May 2018)

An MRI scanner is made up of four components: the magnet, gradient coils, r.f. transmitter and receiver, and the computer. In this section the general design and construction of these components is discussed.

The Magnet: The magnet is the most expensive part of the whole scanner. The earliest systems were based around water-cooled resistive magnets, and for particular applications it is possible to use permanent magnets, but the majority of modern scanners use superconducting magnets. The reason for this is the high fields now desirable for MRI.

Whole body resistive and permanent magnets are limited to around 0.3 T field strength, before their weight becomes prohibitively large. Superconducting magnets are able to generate much larger fields, and there are a number of 4.0 T whole body scanners now available. These magnets are constructed from materials such as NbTi alloy, which below a critical temperature of about 9 K loses its resistivity. Once started the current will flow in the coils indefinitely, provided that the temperature is kept below the critical temperature by cooling with liquid helium. The fields from such magnets are very stable with time, which is essential for an MRI system.



The Gradient Coils: The requirement of the gradient coils are twofold. First they are required to produce a linear variation in field along one direction, and secondly to have high efficiency, low inductance and low resistance, in order to minimise the current requirements and heat deposition.

R.f. Transmission and Reception: The third main component of an MRI scanner is the r.f. coil. There are many different designs of coils, but they fall into two main categories; surface coils and volume coils.As the name suggests, a surface coil rests on the surface of the object being imaged. In its simplest form it is a coil of wire with a capacitor in parallel. The inductance of the coil, and the capacitance form a resonant circuit which is tuned to have the same resonant frequency as the spins to be imaged. In practice, since the coil is connected to a power amplifier which will have an output impedance of 50W, and the coil will have an input impedance of the order of kilo-ohms, then on transmission a lot of the power will be reflected back.

Control and Processing: The scanning operation is controlled from a central computer. This specifies the shape of gradient and r.f. waveforms, and timings to be used, and passes this information to the waveform generator, which outputs the signals and passes them to be amplified and sent to the coils. The NMR signal, once it has been phase sensitively detected, is turned to a digital signal by an analogue to digital converter. The digital signal is then sent to an image processor for Fourier transformation and the image is displayed on a monitor.

Applications:

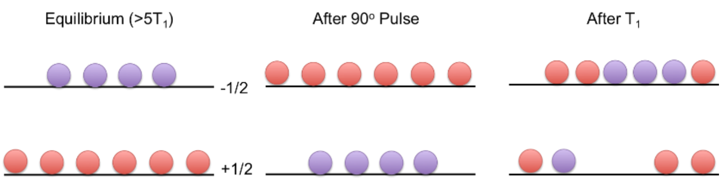
The following are examples in which an MRI scanner would be used:

- anomalies of **the brain** and **spinal cord**.
- tumors, cysts, and other anomalies in various parts of the body.
- breast cancer screening for women who face a high risk of breast cancer.
- injuries or abnormalities of the joints, such as the back and knee.

4. Explain in Detail about the T1 and T2 relaxation with diagram (Nov/Dec2019)

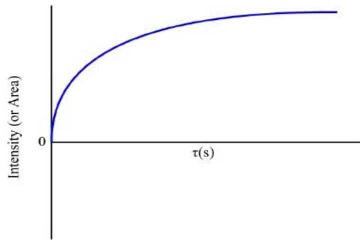
T_1 Relaxation: T_1 relaxation, also known as spin lattice or longitudinal relaxation is the time constant used to describe when ~63% of the magnetization has recovered to equilibrium. The T_1 of a given spin is dictated by field fluctuations (both magnetic and electric) that occur in the sample. Consequently, T_1 measurements can tell us important information regarding inter and intra molecular dynamics of the system. Several factor may cause this alternating field: molecular motion, J-Coupling, Dipolar Coupling, Chemical Shift Anisotropy, and quadrupole-phonon interactions.

We can also look at relaxation from the energy level standpoint. Initially, we have a Boltzmann distribution of spins in the (For I=1/2) in two energy levels, with the lower energy level slightly more populated than the higher energy level. After a pulse these spin populations are inverted and now the higher energy level has more spins in it. Eventually, these spins will go back to their lower energy state due to relaxation. The timescale on which this occurs is T_1.



From the Bloch Equations, we know that magnetization is along the Z-axis is

Mz=M0(1−exp(−t/T1))



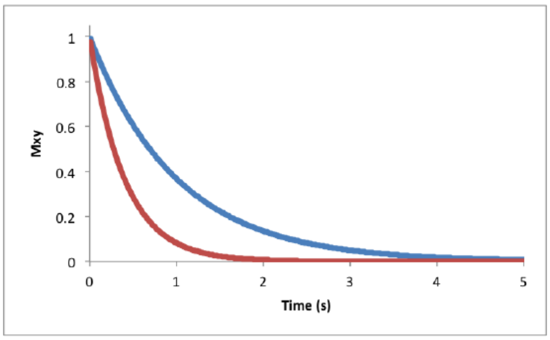
$T_{1\rho\rho}$ Relaxation: $T_{1\rho\rho}$ is the relaxation of the magnetization during a spin lock. This becomes particularly important in the cross-polarization.

T_2 Relaxation: T_2 relaxation is also known as spin-spin or transverse relaxation. T_2 relaxation involves energy transfer between interacting spins via dipole and exchange interactions. Spin-spin relaxation energy is transferred to a neighboring nucleus. The time constant for this process is called the ***spin-spin relaxation time (T_2)***. The relaxation rate is proportional to the concentration of paramagnetic ions in the sample. This mechanism is largely temperature independent. T_2 values are generally much less dependent on field strength, B, than T_1 values.

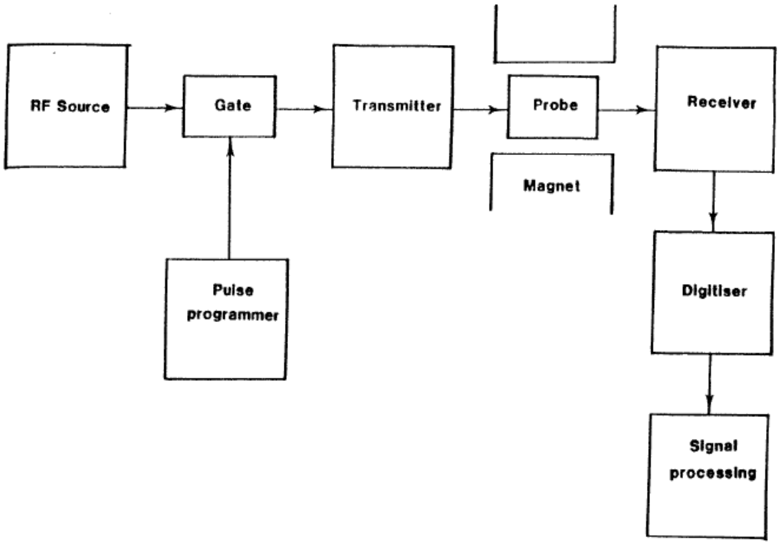
In the process of relaxation, the component of magnetization in xy-plane will become zero as M_0 returns to z-axis. Time constant T_2 is used here to describe spin-spin relaxation with the following function. This process involves energy changing between the spin-active and their adjacent nuclei.

Mxy=Mxy0 exp(−t/T2)

T_2* Relaxation: In an ideal NMR spectrometer, the external magnetic field is completely homogeneous. However, all magnets have small inhomegneities in them. Consequently, nuclei experience different magnetic fields which changes the precessional frequency of each nucleus. The change in Larmor frequency results in dphasing in the transverse plane and is known as T_2*



5. Explain the principle of Nuclear MRI (May 2019)



Nuclear magnetic resonance (NMR) is a physical phenomenon in which nuclei in a strong constant magnetic field are perturbed by a weak oscillating magnetic field (in the near field) and respond by producing an electromagnetic signal with a frequency characteristic of the magnetic field at the nucleus. This process occurs near resonance, when the oscillation frequency matches the intrinsic frequency of the nuclei, which depends on the strength of the static magnetic field, the chemical environment, and the magnetic properties of the isotope involved; in practical applications with static magnetic fields up to ca. 20 tesla, the frequency is similar to VHF and UHF television broadcasts (60–1000 MHz). NMR results from specific magnetic properties of certain atomic nuclei. Nuclear magnetic resonance spectroscopy is widely used to determine the structure of organic molecules in solution and study molecular physics and crystals as well as non-crystalline materials. NMR is also routinely used in advanced medical imaging techniques, such as in magnetic resonance imaging (MRI).

All isotopes that contain an odd number of protons and/or neutrons have an intrinsic nuclear magnetic moment and angular momentum, in other words a nonzero nuclear spin, while all nuclides with even numbers of both have a total spin of zero. The most commonly used nuclei are h and c, although isotopes of many other elements can be studied by high-field NMR spectroscopy as well.

A key feature of NMR is that the resonance frequency of a particular sample substance is usually directly proportional to the strength of the applied magnetic field. It is this feature that is exploited in imaging techniques; if a sample is placed in a non-uniform magnetic field then the resonance frequencies of the sample's nuclei depend on where in the field they are located. Since the resolution of the imaging technique depends on the magnitude of the magnetic field gradient, many efforts are made to develop increased gradient field strength.

The principle of NMR usually involves three sequential steps:

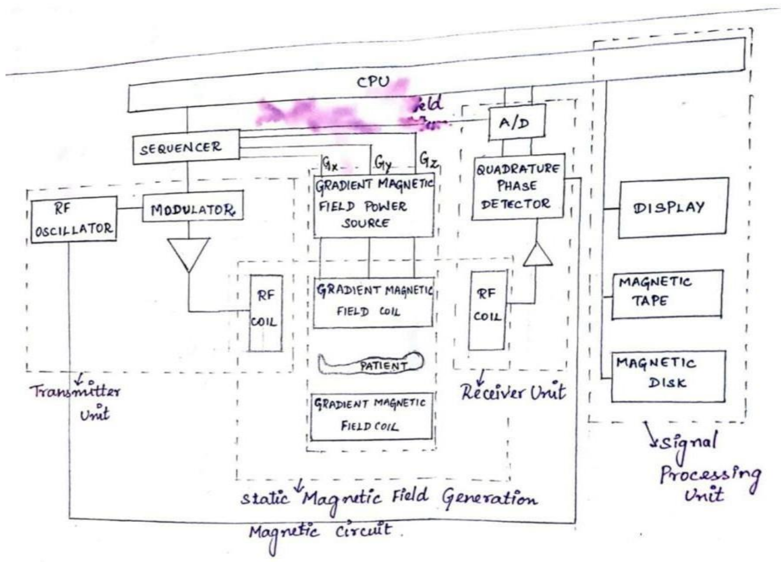
- The alignment (polarization) of the magnetic nuclear spins in an applied, constant magnetic field B_0.
- The perturbation of this alignment of the nuclear spins by a weak oscillating magnetic field, usually referred to as a radio-frequency (RF) pulse. The oscillation frequency required for significant perturbation is dependent upon the static magnetic field (B_0) and the nuclei of observation.
- The detection of the NMR signal during or after the RF pulse, due to the voltage induced in a detection coil by precession of the nuclear spins around B_0. After an RF pulse, precession usually occurs with the nuclei's intrinsic Larmor frequency and, in itself, does not involve transitions between spin states or energy levels.

The two magnetic fields are usually chosen to be perpendicular to each other as this maximizes the NMR signal strength. The frequencies of the time-signal response by the total magnetization (M) of the nuclear spins are analyzed in NMR spectroscopy and magnetic resonance imaging. Both use applied magnetic fields (B_0) of great strength, often produced by large currents in superconducting coils, in order to achieve dispersion of response frequencies and of very high homogeneity and stability in order to deliver spectral resolution, the details of which are described by chemical shifts, the Zeeman effect, and Knight shifts (in metals). The information provided by NMR can also be increased using hyperpolarization, and/or using two-dimensional, three-dimensional and higher-dimensional techniques.

NMR phenomena are also utilized in low-field NMR, NMR spectroscopy and MRI in the Earth's magnetic field (referred to as Earth's field NMR), and in several types of magnetometers.

6. Explain the following:

a) Use of Gradient GX coil in MRI



GENERATION OF GRADIENT MAGNETIC FIELD IN MRI.

GRADIENT MAGNETIC FIELD:

A magnetic field that changes in strength in a given direction. Such fields are used in magnetic Resonance Imaging (MRI) to select a region for imaging and to encode the location of MRI signals received from the object being imaged.

Gradient coils:

- Gradient coils are used to spatially encode the positions of protons by varying the magnetic field linearly across the imaging volume.
- The larmour frequency will then vary function of position in the x y and z-axes.
- Scan speed is dependent on performance of the gradient system.
- Stronger gradients allow for faster imaging, for higher resolution.

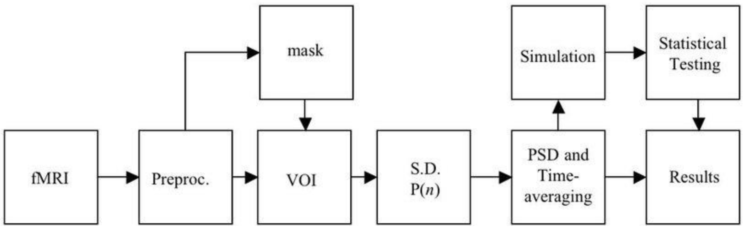
- Types of Gradient:
  X Gradient -Frequency Encoding
  Y Gradient- Encoding Phase
  Z Gradient - Slice Selection

GENERATION OF GRADIENT MAGNETIC FIELD:

- The transmitter system radiates a radio frequency (RF) signals so as to cause nuclear of the atoms magnetic resonance in the atomic nucleus of the tissues of patient by the RF magnetic pulse sent from the sequencer and comprises an RF oscillator, an RE coil modulator an RF amplifier and on the transmission side
- RF pulse from RF oscillator modulated by is amplitude modulated by the modulator in accordance with the instruction of the sequencer
- The amplitude modulated RF pulse in amplified & supplied to the RF coil disposed in proximity of patient / subject so that electromagnetic subject that waves can be irradiated the to the subject
- The receiver unit detects echo signals (NMR signals) emitted due to nuclear magnetic resonance of tissue of subject and comprises RF coil, ADC, amplifier & detector on the reception side.
- The NMR signals generated response to electromagnetic waves from the transmission side.
- Then it is fed to ADC to the digital signal processing unit.

b)FMRI (May 2019)

Functional magnetic resonance imaging or functional MRI (fMRI) measures brain activity by detecting changes associated with blood flow. This technique relies on the fact that cerebral blood flow and neuronal activation are coupled. When an area of the brain is in use, blood flow to that region also increases.



The primary form of fMRI uses the blood-oxygen-level dependent (BOLD) contrast, discovered by Seiji Ogawa in 1990. This is a type of specialized brain and body scan used to map neural activity in the brain or spinal cord of humans or other animals by imaging the change in blood flow (hemodynamic response) related to energy use by brain cells. Since the early 1990s, fMRI has come to dominate brain mapping research because it does not require people to undergo injections or surgery, to ingest substances, or to be exposed to ionizing radiation. This measure is frequently corrupted by noise from various sources; hence, statistical procedures are used to extract the underlying signal. The resulting brain activation can be graphically represented by color-coding the strength of activation across the brain or the specific region studied. The technique can localize activity to within millimeters but, using standard techniques, no better than within a window of a few seconds. Other methods of obtaining contrast are arterial spin labeling and diffusion MRI. The latter procedure is similar to BOLD fMRI but provides contrast based on the magnitude of diffusion of water molecules in the brain.

In addition to detecting BOLD responses from activity due to tasks/stimuli, fMRI can measure resting state fMRI, or taskless fMRI, which shows the subjects' baseline BOLD variance. Since about 1998 studies have shown the existence and properties of the default mode network (DMN), aka 'Resting State Network' (RSN), a functionally connected neural network of apparent 'brain states'.

fMRI is used in research, and to a lesser extent, in clinical work. It can complement other measures of brain physiology such as EEG and NIRS. Newer methods which improve both spatial and time resolution are being researched, and these largely use biomarkers other than the BOLD signal. Some companies have developed commercial products such as lie detectors based on fMRI techniques, but the research is not believed to be developed enough for widespread commercialization.

7. a) How do Nuclei Interacts with static magnetic field and radio frequency wave . Explain? (Nov 2016)

b) Explain about the interactions of nuclei with static magnetic field and radio frequency wave (April/May2018)

MRI uses the same physical effect as **N**uclear **M**agnetic **R**esonance (NMR) spectroscopy, in which the identity of an unknown compound (like a potential new drug) may be identified by the resonant properties (the jiggling of protons) of the atoms that comprise it. In fact, the only reason that the technique is called MRI and not NMR is because it premiered during the Cold War, during which patients were hesitant to undergo any sort of “nuclear” treatment!

NMR spectroscopy was originally developed to help chemists who had created strange compounds that they couldn’t identify. In the technique (and just as in MRI), an unknown sample is placed in a static magnetic field, briefly excited with radio-frequency photons (light), and then allowed to re-emit those photons. NMR works because the characteristic frequency of the re-emitted photons varies very slightly based on the structure of the molecule. A proton all by itself may absorb and reemit 900 MHz photons, but when it gets near other charges (such as in a large hydrocarbon chain), the magnetic field around it is gets twisted and distorted and so its resonant frequency may shift to something like 906 MHz. This means that NMR may be used to generate “spectra” corresponding to the amount of resonance at various frequencies, which in turn reveals details of the structure of molecules. So if a chemist looks at the NMR spectrum of her unknown sample and sees a huge peak near 906 MHz, then she knows that her sample probably has at least one hydrocarbon chain somewhere on it.

The main difference between NMR spectroscopy and MRI imaging is that NMR generates information (a spectrum of light corresponding to chemical structure) based on the **frequency** of emitted radiation (which is related to the speed of the jiggling protons). MRI instead generates information (images of the body) using the **intensity** of radiation (the quantity of re-emitted photons) arriving from various parts of body. Protons in dense or solid structures tend to be more or less prone to misalignment when the disrupting radio waves are applied to the body’s tissue, resulting in a lower number of re-emitted photons coming from that region and thus a darker area in the resulting image.

Generally, using stronger stationary magnetic fields results in nicer MRI images. Because the water molecules in the body are warm, they are constantly jiggling around and colliding with one another. This jiggling tends to knock the alignment of protons in random directions, and so if the stationary magnetic field is too weak, these thermal forces will prevent protons from lining up, resulting in a dimmer MRI image.

The images get even better when the radio waves are applied multiple times, with the images from each subsequent re-emission merged together to yield a final, combined image. It's like taking the same picture multiple times on your camera and blending them together in your favorite image editor to get a better exposed image. The main limitation of this method is ensuring that the patient lies still long enough that the image doesn't get blurry!

Sometimes there is not enough difference in structure between two tissues to see them using MRI. For example, a healthcare provider may want to check out an unusual blood vessel (such as a blood vessel with a blood clot), but such an image may be difficult to see because the neighboring fat and muscle tissue re-emit photons at a similar rate as the blood vessel. There just isn't enough contrast between the different structures. To solve this problem, the healthcare provider may inject a **contrast agent**, such as Gadolinium (III), into the patient's bloodstream. Atoms of Gd(III) have really unusual electrical properties that cause them to disrupt the effective magnetic field experienced by protons in the bloodstream, which in turn changes the amount of photons that the protons will absorb and emit. This causes the blood vessels to stand out from neighboring tissues in subsequent MRI images.

8. Write detailed notes on :

a) Automatic Exposure controls and

Automatic exposure control is a device incorporated into radiographic and mammographic imaging systems. Its function is to automatically terminate exposure when a preset amount of radiation has been detected.

Automatic exposure control systems help to provide a consistent optical density/signal-to-noise ratio, regardless of patient-centric factors such as size and density.

Automatic exposure control systems also help to reduce 'dose creep' that can occur with inadvertent radiation overexposure by the technologist.

The first generation of automatic exposure control systems are phototimers, which have now largely been superseded by ionization chambers.

In radiography, the automatic exposure control device is placed in front of the image receptor. In mammography, the automatic exposure control device is placed underneath the image receptor.

Automatic Exposure Control (AEC) is an X-ray exposure termination device.

A medical radiography x-ray exposure is always initiated by a human operator but an AEC detector system may be used to terminate the exposure when a predetermined amount of radiation has been received. The intention of AEC is to provide consistent x-ray image exposure, whether to film, a digital detector or a CT scanner. AEC systems may also automatically set exposure factors such as the X-ray tube current and voltage.

OPERATION:

Projectional Radiography:

In projectional radiography an AEC system uses one or more physically thin radiation ionization chambers (the "AEC detector") which is positioned between the patient being x-rayed and the x-ray film cassette. Where low energy x-rays are used such as in mammography the AEC detector is placed behind the image receptor to avoid creating a shadow.

In a simple AEC system a weak ionization signal from the AEC detector is integrated as a ramp shaped voltage waveform. This ramp signal rises until it matches a pre-set threshold. At this point the x-ray exposure is terminated. AEC devices are calibrated to ensure that similar exams have linearity in optical density.

Computed Tomography:

Modern computed tomography (CT) scanners have AEC systems which aim to maintain image quality for patients of varying sizes, whilst keeping doses as low as reasonably practicable. The systems are also designed to maintain quality with the varying size and attenuation of an individual patient over their length. Implementations vary between manufacturers, some systems are based on a desired noise level in the image, while others are based on a specified reference output (milliampere second, mAs).

CT AEC systems use the initial "scanogram", a fixed angle planning view, to determine the relative size of the patient, and variation over their length. The tube output is then adjusted for overall size. The output is also typically modulated for each rotation in response to changes in attenuation over patient length. Some systems adjust output during each rotation, which is known as rotational modulation, based on measured attenuation in the previous rotation.

b) Serial film chargers (April/May2018)

A serial radiograph system has an improved film changer featuring reusable film pack containers. An exposure station through which X-rays are directed is virtually free of X-ray absorbing material providing a "see through" station. As a consequence of the "see through" exposure station, an image intensification tube positioned under the exposure station provides an unobstructed fluoroscopic image with minimum X-ray dosage to a patient.

The film changer utilizes film packs, each of which has a semienclosed, partially sealed, pouch. Each pouch contains a sheet of radiographic film between a pair of intensifying screens. A plurality of the film packs are stacked in a novel supply magazine and are sequentially transported to the exposure station by a transport system having a plurality of pinch roll pairs. An evacuator pinch roll pair causes uniform engagement of the screens with the film as the film pack is transported into the exposure station by exhausting the air from the pouch and creating a vacuum as it passes through the rolls. The rolls then clamp unsealed edges of the pouch in releasably sealing contact during X-ray exposure of the film for maintaining the engagement of the film and the screens by maintaining the vacuum.

The present invention relates generally to serial radiographic systems and more particular to an improved X-ray film changer and method for storing and transporting X-ray film packs.

In serial radiography, a series of radiographs are produced by sequentially feeding a series of X-ray films, one at a time, to an exposure station. The exposure station is aligned with a source of X-rays which directs a beam of X-rays through the exposure station for exposing the films.

High-speed X-ray systems expose films at frame rates of up to six per second. High speed in radiography is desirable not only for minimizing the duration of the examination during which the patient must be immobile, but more importantly, for assuring that a timely exposure will accurately record an event of short duration.

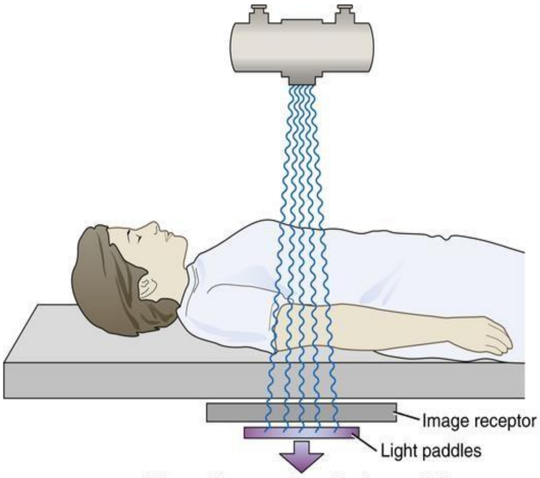
Certain vascular studies are examples of medical diagnostic techniques which require high-speed exposures at high frame rates. With such a study a fluid which is relatively opaque to

X-rays is injected into a patient's blood stream. Rapid sequence radiographs produce diagnostically useful information about the patient's blood vessels. This radiographic sequence must be rapid because the opaque material passes very quickly through that portion of a patient that is under investigation.

This high-speed requirement has posed problems in developing an optimized system. Such a system should be characterized: (a) by a minimum of system vibration, (b) by a minimum of noise, (c) by a "see through" exposure station allowing unobstructed fluoroscopy, (d) generally as an efficiently compact system which does not require expensive and bulky vacuum generating apparatus or mechanisms for opening evacuated pouches, (e) by assurance that there is intimate film contact with a pair of intensifying screens which usually accompany the film, and (f) avoiding any possibility of a film being scratched or otherwise damaged during transport or exposure

9. **Discuss the types of photo timers with its characteristics and applications in medical field (April/May2018)**

   Phototimers use a fluorescent (light-producing) screen and a device that converts the light to electricity. A **photomultiplier (PM) tube** is an electronic device that converts visible light energy into electrical energy. A photodiode is a solid-state device that performs the same function. Phototimer AEC devices are considered exit-type devices because the detectors are positioned behind the image receptor so that radiation must exit the image receptor before it is measured by the detectors. Light paddles, coated with a fluorescent material, serve as the detectors, and the radiation interacts with the paddles, producing visible light. This light is transmitted to remote PM tubes or photodiodes that convert this light into electricity. The timer is tripped and the radiographic exposure is terminated when a sufficiently large charge has been received. This electrical charge is in proportion to the radiation to which the light paddles have been exposed. Phototimers have largely been replaced with ionization chamber systems.



Two types of AEC systems have been used:

- Phototimers and
- Ionization chambers.

Phototimers represent the first generation of AEC systems used in radiography, and it is from this type of system that the term phototiming has evolved.

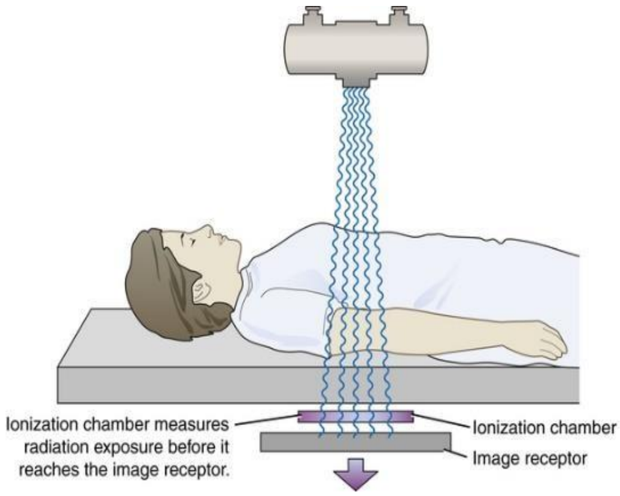
Phototimers:

Phototimers is for controlling x-ray exposure includes an array of x-ray sensors, and digital processing electronics for calculating x-ray exposure by selecting one or more signals from the x-ray sensors, and calculating the x-ray exposure from the selected signals.

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body. MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves to generate images of the organs in the body.

Ionization Chamber Systems:

An **ionization** or **ion chamber** is a hollow cell that contains air and is connected to the timer circuit via an electrical wire. Ionization-chamber AEC devices are considered entrance-type devices because the detectors are positioned in front of the image receptor so that radiation interacts with the detectors just before interacting with the image receptor. When the ionization chamber is exposed to radiation from a radiographic exposure, the air inside the



chamber becomes ionized, creating an electrical charge. This charge travels along the wire to the timer circuit. The timer is tripped and the radiographic exposure is terminated when a sufficiently large charge has been received. This electrical charge is in proportion to the radiation to which the ionization chamber has been exposed. Compared with phototimers, ion chambers are less sophisticated and less accurate, but they are less prone to failure. Most of today's AEC systems use ionization chambers.

RADIOLOGICAL EQUIPMENTS

UNIT-IV NUCLEAR MEDICINE SYSTEMS

2 MARKS

1. **a)What are radioisotopes.(Nov/Dec2018)**

   b) Define radioisotopes.(Nov/Dec2019)

   c) What are radioisotopes.Give example.(May 2019)

Radioisotopes may occur in nature or be made in a laboratory. In medicine, they are used in imaging tests and in treatment. Also called radionuclide.

Many elements have one or more isotopes that are radioactive. These isotopes are called radioisotopes. An example of a radioisotope is carbon-14. The nuclei of radioisotopes are unstable, so they constantly decay and emit radiation.

2. **Compare the principle of PET and SPECT.(Nov/Dec2018)**

PET	SPECT
High sensitivity	Low sensitivity
A resolution limited by technology	A good resolution but with a physical limit
It is routinely used and is the primary functional imaging tool used to evaluate the heart	Positron emission tomography (**PET**) has been applied to the study of the heart
SPECT scans measure gamma rays	**PET** scans produce small particles called positrons

3. **What is scintillation?(Nov/Dec2019)**

   Scintillation is a flash of light produced in a transparent material by the passage of a particle (an electron, an alpha particle, an ion, or a high-energy photon). See scintillator and scintillation counter for practical applications.

4. **List out the applications of PET scan. (May 2019)**

- PET scans are often used to diagnose a condition or to track how it is developing.
- Used alongside a CT or MRI scan, it can show how a part of the body is working.
- PET scans are often used to investigate epilepsy, Alzheimer's disease, cancer, and heart disease.

5. **What is the need of ionization chambers?(Nov 2016)**

   The ionization chamber is the simplest of all gas-filled radiation detectors, and is widely used for the detection and measurement of certain types of ionizing radiation; X-rays, gamma rays, and beta particles.

6. **Give the advantage of pulse height analyser.(Nov 2016)**

   A pulse-height analyzer using conversion of pulse amplitude to time is described. It has an accuracy resolution, linearity, and stability better than one percent. It can be exposed to pulse rates of several thousand per second and records on tape up to 50 pulses per second.

7. **What is digital subtraction angiography?(April/May2018)**

   Digital subtraction angiography (DSA) is a fluoroscopic technique used extensively in interventional radiology for visualizing blood vessels. Radiopaque structures such as bones are eliminated ("subtracted") digitally from the image, thus allowing for an accurate depiction of the blood vessels.

8. **Define Temporal Filteration.(April/May2018)**

   Temporal filtering methods were applied to iodine signal-to-noise ratio (SNR) restoration in intravenous hybrid subtraction digital subtraction angiography (DSA). Thus, when matched filtering techniques were applied to the hybrid image sequence, the resultant SNR increased to about 70% of that of temporal subtraction.

9. **What is the characteristics required for the radionuclide to be used for imaging?(Nov/Dec2017)**

   The important physical variables to consider include the radionuclide half-life, the type, energy, and branching ratio of particulate radiation and the gamma-ray energies and abundances. A radioisotope used for diagnosis must emit gamma rays of sufficient energy to escape from the body and it must have a half-life short enough for it to decay away soon after imaging is completed. The radioisotope most widely used in medicine is Tc-99, employed in some 80% of all nuclear medicine procedures.

10. Write the use of position logic circuit in nuclear imaging.(Nov/Dec2017)

The position logic circuit analyzes the information provided by multiple PMTs to determine the spatial location of the incident gamma ray's interaction with a scintillator crystal. The information stored by the gating circuit is used to reconstruct a SPECT image.

11. Write the principle behind PET and SPECT.(April/May2018)

- Photon emission computed tomography (SPECT, or less commonly, SPET) is a nuclear medicine tomographic imaging technique using gamma rays.
- It is very similar to conventional nuclear medicine planar imaging using a gamma camera.
- Positron emission tomography (PET) is a nuclear medicine, functional imaging technique that is used to observe metabolic processes in the body.
- The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide (tracer), which is introduced into the body on a biologically active molecule.

12. What is the of X-Y positioning circuit and explain about pulse height analyser.(April/May2018)

- X-Y positioning is of utmost importance in fused deposition modeling (FDM).
- This method produces a prototype part by feeding a material filament to as scanning X-Y head. A droplet of material is melted at the tip of the nozzle and expelled to be hardened at its designated position.
- A pulse-height analyzer using conversion of pulse amplitude to time is described. It has an accuracy resolution, linearity, and stability better than one percent.

11 MARKS:

1. Discuss the different types of nuclear radiation with its characteristics and applications in medical field.(Nov/Dec2018)

Nuclear Radiation refers to processes whereby unstable nuclei become more stable by emitting energetic particles. The three types of nuclear radiation refer to alpha, beta, and gamma radiation. In order to become stable, a nucleus may emit an alpha particle (a helium nucleus) or a beta particle (an electron or a positron). Often, losing a particle this way leaves the nucleus in an *excited state*. Then, the nucleus releases the excess energy in the form of a gamma-ray photon.

A matter is ultimately made up of atoms. Atoms, in turn, are made up of **protons**, **neutrons** and **electrons**. Protons are positively charged and electrons are negatively charged. Neutrons are not charged. Protons and neutrons reside inside the **nucleus** of the atom, and protons and neutrons are together called **nucleons**. Electrons are found in a region around the nucleus, which is much larger than the size of the nucleus itself. In neutral atoms, the number of protons is equal to the number of electrons. In neutral atoms, the positive and negative charges cancel each other, giving a zero net charge.

The Three Types of Nuclear Radiation:

Alpha Beta and Gamma Radiation

As we mentioned before, the three types of nuclear radiation are alpha, beta, and gamma radiation. In alpha radiation, a nucleus becomes more stable by emitting two protons and two neutrons (a helium nucleus). There are three types of beta radiation: beta minus, beta plus and electron capture. In beta minus radiation, a neutron can transform itself into a proton, releasing an electron and an electron antineutrino in the process. In beta plus radiation, a proton can transform itself into a neutron, giving off a positron and an electron antineutrino. In electron capture, a proton in the nucleus captures an electron of the atom, transforming itself into a neutron and releasing an electron neutrino in the process. Gamma radiation refers to the emission of gamma-ray photons by nuclei in excited states, in order for them to become de-excited.

Alpha Radiation:

Alpha radiation is another name for the alpha particles emitted in the type of radioactive decay called alpha decay. Alpha particles are helium-4 (^4He) nuclei.

- alpha radiation is the least penetrating (of alpha, beta, and gamma); typically it goes no more than a few cm in air

- like all kinds of radioactive decay, alpha decay occurs because the final state of the nucleus (the one decaying) has a lower energy than the initial one (the difference is the energy of the emitted alpha particle, both its binding energy and its kinetic energy)

- alpha decay involves both strong and electromagnetic interactions (or forces), unlike beta and gamma decay

Beta Radiation:

In beta radiation, a nucleus decays by emitting an electron or a positron (a positron is the *antiparticle* of the electron, having the same mass but the opposite charge). The nucleus does not contain electrons or positrons; so, first a proton or a neutron needs to transform, as we will see below. When an electron or a positron is released, in order to conserve lepton number, an electron neutrino or an electron antineutrino is also released. The energy of beta particles (which refers to either electrons or positrons) for a given decay could take a range of values, depending on how much of the energy released during the decay process has been given to the neutrino/antineutrino. Depending on the mechanism involved, there are three types of beta radiation: **beta minus, beta plus and electron capture**.

Gamma Radiation:

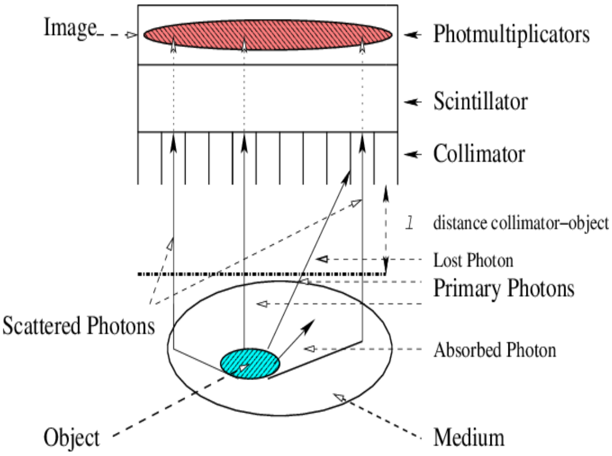
Gamma rays or gamma radiation is a stream of high-energy electromagnetic radiation given off by an atomic nucleus undergoing radioactive decay. Before we can delve further into the details of the topic, we need to understand the basics of radioactivity and what is meant by radioactivedecay.

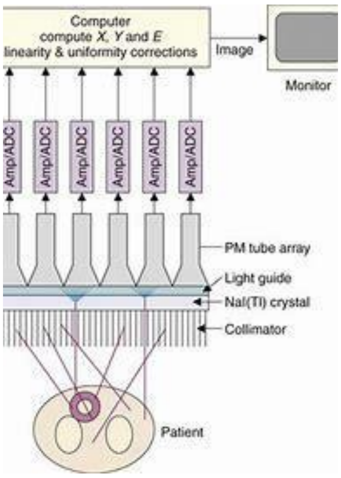
2. **Draw the block diagram of**
   i. **Gamma camera with its components(Nov/Dec2018)**
   ii. **Explain the working of Gamma camera(Nov/Dec2019)**
   iii. **Explain the principle of operation of gamma camera with block diagram((Nov/Dec2017)**
   iv. **Explain the gamma camera.(May 2019)**

GAMMA CAMERA:

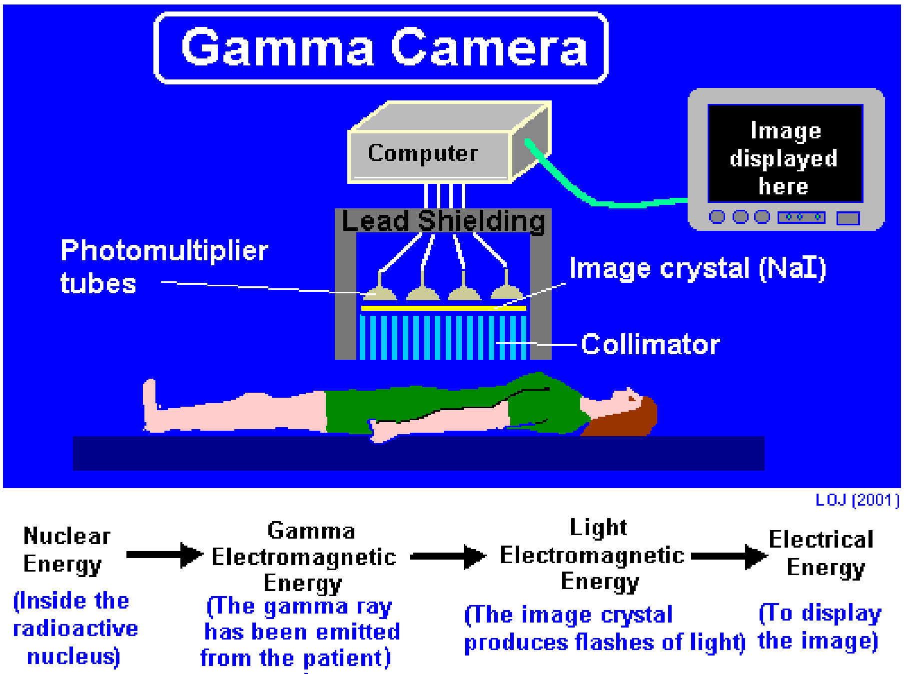
- Is a device used to image gamma radiation radioisotopes this technique is called also scintillation camera.

- Gamma camera is used to view and analyse images of the human body or the distribution of the medically ingested, injected or inhaled radionuclides.





Gamma Camera Components:



Collimators:

The collimator provides an interface between the patient and the scintillation crystal by allowing only those photons traveling in an appropriate direction.

Types of collimators:

A) By the accepted energy.

B) By the geometric shape.

C) By the resolution

Light pipe:

- This sits between the scintillation crystal and the photomultiplier tubes
- Silicone grease is used to ensure good contact between the scintillation crystal, the light pipe and the photomultiplier tubes.

Crystal:

- Any damage to the crystal results in an inoperable scintillation camera and requires costly replacement of the crystal.
- The large surface area, as well as the hygroscopic and brittle nature of the crystal, calls for constant care to avoid puncturing the housing or otherwise damaging the crystal.
- The chosen material for the crystal is Na-I (Tl).
- The Na-I (Tl) crystal is stationary.
- The crystal transform the gamma-ray photon > Light photon

Photomultiplier Tubes:

- The Photocathode transform the light photon → electron.
- The PMT multiplies the electron to be a significant detected signal.
- Photomultiplier tubes (photomultipliers or PMTs for short), members of the class of vacuum tubes, and more specifically vacuum phototubes, are extremely sensitive detectors of light in the ultraviolet, visible, and near-infrared ranges of the electromagnetic spectrum. These detectors multiply the current produced by incident light by as much as 100 million times (i.e., 160 dB), in multiple dynode stages, enabling (for example) individual photons to be detected when the incident flux of light is low.

Pre-amplifier:

This converts the current produced at the anode of the PMT to a voltage pulse. The amplitude of the voltage pulse is directly proportional to the charge produced at the anode and, therefore, the amount of light received by the PMT, which is proportional to the number of gamma photons that hit the scintillation crystal.

Energy calculation:

For each scintillation formed, the calculated absorbed energy (Z value) that caused it depends on the energy of the gamma photon that was emitted from the patient and the proportion of the energy that was absorbed into the crystal.The gamma photon energy absorbed by the scintillation crystal depends on its interaction with that photon which results in a spectrum of Z values.

- All energy absorbed: gamma photon interacts with crystal via photoelectric effect.
- Part of the energy absorbed: photon undergoes one or more Compton interactions.

Scatter rejection:

If a gamma photon scatters within the patient's body (via Compton scatter) it will change direction and, therefore, will not hit the detector at a location corresponding to its location of origin. It is important to reject these scattered photons as they degrade the image contrast and spatial resolution. This cannot be done by the collimator and is, therefore, done electronically by a process called **energy discrimination**.

Image formation*:*

Each PMT corresponds to a coordinate on the scintillation crystal. This is then mapped out onto a matrix. Each time a gamma photon that falls within the acceptable energy window is detected it is mapped on to its corresponding coordinate within the image.

Image acquisition is controlled by the user and may be terminated when:

- Preset number of counts obtained
- Preset time passed

Image display:

The digital image is displayed upon a monitor with each pixel corresponding to a memory location in the matrix and the brightness / colour scale corresponding to the count number in that location.

Advantages:

- The imaging time is only 1-2min.
- It can distinguish 2 sources about 5mm apart.

Disadvantages:

- When gamma rays pass through the human body, they ionize the tissue.
- Ionization from gamma rays can cause three different reactions in living cell

tissues.

- If a gamma ray burst hit the Earth at high intensity, it would negatively interact with the upper atmosphere, creating nitrogen oxides that would lead to the destruction of the Earth's ozone layer.

3. a)Explain in detail about the radiation detectors.(Nov/Dec2018)

b) What is radiation detectors and explain about the various types of radiation detectors in detail?(April/May2018)

Radiation detector or a particular detector is a **device used to detect, track, or identify ionizing particles**, such as those produced by cosmic radiation, nuclear decay, or reactions in a particle accelerator. Radiation detectors can measure the particle energy and other attributes such as momentum, spin, charge, particle type, in addition to merely registering the presence of the particle.

A radiation detector is a device for measuring nuclear, electromagnetic or light radiation. A nuclear radiation detector identifies nuclear radiation by measuring the emission of ionizing radiation of alpha particles, beta particles and gamma rays.

A radiation Detector or particle detector is a device that measures this ionization of many types of radiation, like- beta radiation, gamma radiations, and alpha radiation with the matter. Thus, creating electrons and positively charged ions.

Radiation Detector is an instrument used to detect or identify high-energy particles, such as those produced by nuclear decay, cosmic radiation, or reactions in a particle accelerator.

Type of Detectors

Scintillator

When excited by ionizing radiation, a scintillator exhibits scintillation which is nothing but the property of luminescence. When a scintillator is coupled to an electronic light sensor such as a photomultiplier tube (PMT), photodiode, or silicon photomultiplier, a scintillator detector. Scintillator-type detectors first convert light into electrical pulses. They use vacuum tubes to perform so.

Gaseous Ionization Detectors

A radiation detection instrument used in particle physics to detect the presence of ionizing particles, and in radiation protection applications to measure ionizing radiation is called Gaseous ionization detectors.

Geiger Counter

Geiger-Mueller counter, commonly called the Geiger counter is the most commonly used detector. A central wire in between a gas-filled tube at high voltage is used to collect the ionization produced by incident radiation. Although it cannot distinguish between them, it can detect alpha, beta, and gamma radiation.

Types of radiations

The types of radiation detected by these detectors are Alpha, Beta, and Gamma radiation.

Alpha radiation

- Alpha particles or double ionized helium nuclei are the fast-moving helium atoms.
- They have high energy ranging in MeV.
- They have low penetration depth; typically a few cms of air or skin due to their large mass.

Beta radiation

- They are fast-moving electrons.
- Their energy ranges from hundreds of KeV to several MeV.
- They have better penetration depth due to their comparatively lighter mass. Typically, several feet of air, several millimeters of lighter materials.

Gamma radiation

- They are the stream of photons.
- Typical energy ranges from Several KeV to Several MeV.

- They have comparatively very low mass. Thus, possess good penetration depth. Typically, a few inches of lead.

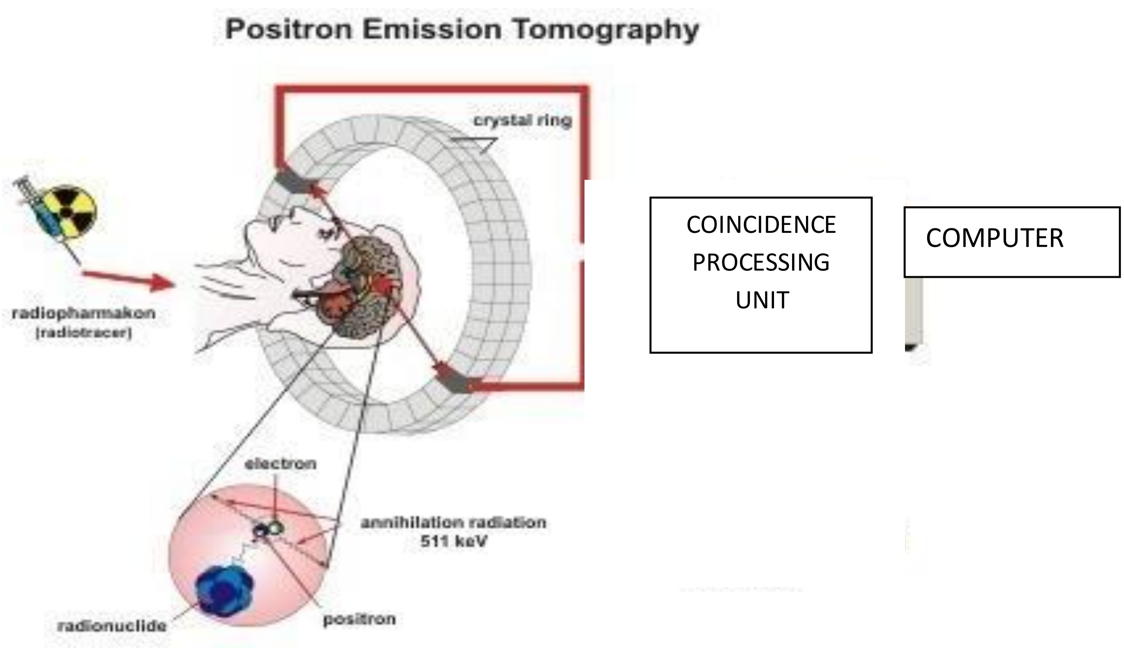
4. **a) What are positron? How is it used for imaging?**

   The positron or antielectron is the antiparticle or the antimatter counterpart of the electron. The positron has an electric charge of +1 e, a spin of 1/2 (the same as the electron), and has the same mass as an electron. When a positron collides with an electron, annihilation occurs. A positron is a particle of matter with the same mass as an electron but an opposite charge. It is a form of antimatter because, when a positron encounters an electron, the two completely annihilate to yield energy.

PET is uses positron for imaging technique:

Positron-emission tomography (**PET**) is a nuclear medicine functional imaging technique that is used to observe metabolic activity (energy usage) and molecular function in the body.

CONSTRUCTION



A PET scanner is provided with a patient table, array of detectors provided with scintillator crystal which collects the photons and a photo multiplier tube which converts these light photons to electrical signals, then a coincidence processing unit which provides the positional information and replaces the conventional collimator and computer for producing 3D images.

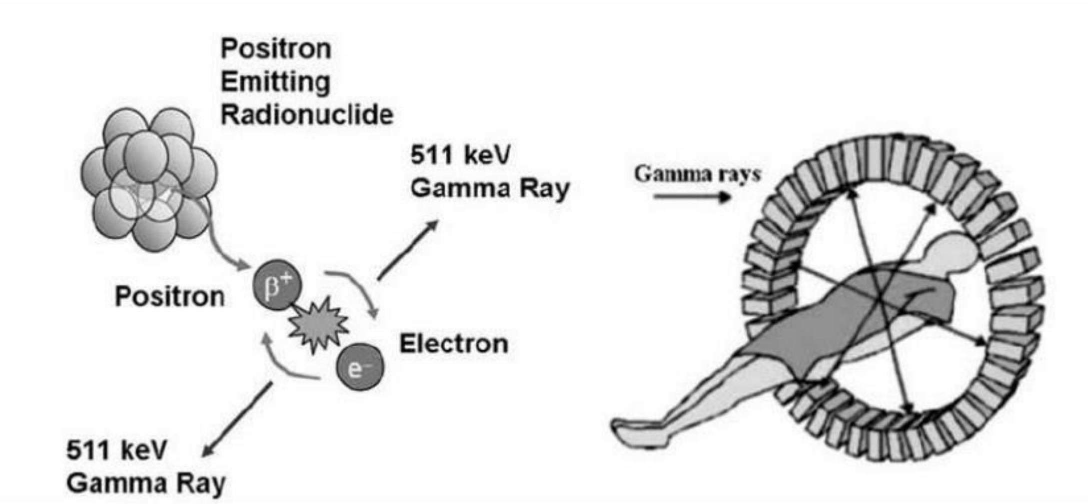
WORKING

A small amount of biologically relevant material like oxygen or glucose (sugar) which have been labeled with radio nuclides such as carbon-11, nitrogen-13, oxygen-15 and fluorine-18 are to be introduced into the body through an I.V.

These short lived tracer then travels through the body and is allowed to get absorbed which usually takes about 60 to 90 minutes to show differences between healthy tissue and diseased tissue.

The most commonly used tracer is [18F] 2-Fluoro-2-Deoxy-D-Glucose more commonly known as "FDG"(fluorodeoxyglucose), so the test is sometimes called an FDG-PET scan.

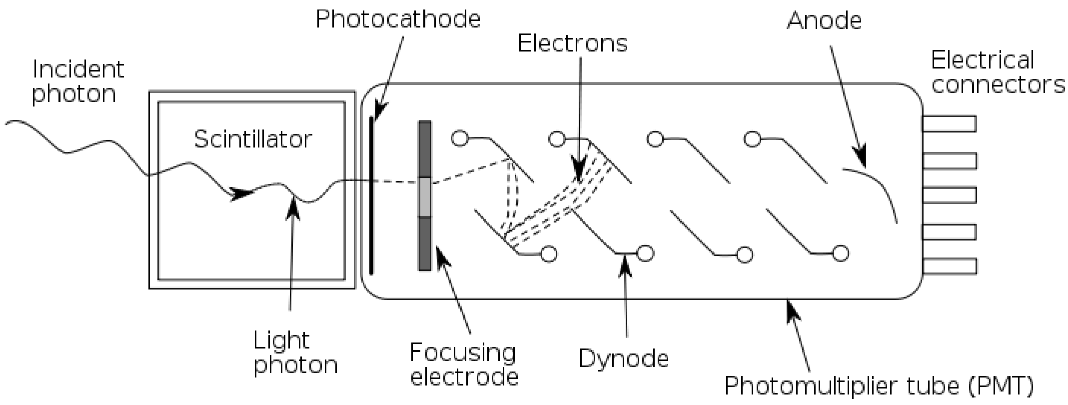
The radioactive tracers becomes trapped in the cells that try to metabolize it. Its concentration in tissue is proportion to the rate of metabolism. Since cancer grows at a faster rate than healthy tissue, cancer cells absorb more of the radioactive tracers.



As the isotope used in the radiolabeled oxygen or glucose undergoes radioactive decay, it emits high energy positrons (anti-matter) which collide with electrons resulting in bursts of γ-radiation (a photon pair) and this process is termed as positron – electron annihilation.

$$\mathbf{e^{+} + e^{-} \rightarrow \gamma + \gamma}$$

A photon detector for PET is typically made by a solid scintillating crystal for the detection of the γ rays, coupled to a light sensor such as a photomultiplier tube (PMT) or a photodiode, which absorbs the light emitted by the scintillator and produces an electrical signal.



These electrical signals are produced as color-coded images of the body by image reconstruction techniques that show both normal and cancerous tissue where the cancerous cells appear as "hot spots" in PET images displayed on the computer monitor.

A coincidence event is assigned to a line of response (LOR) joining the two relevant detectors. In this way, positional information is gained from the detected radiation without the need for a physical collimator. This is known as electronic collimation. Electronic collimation has two major advantages over physical collimation. They have improved sensitivity and improved uniformity of the point source response function.

APPLICATION

PET scanning is used to measure a range of activity of

- blood flow
- blood volume
- oxygen usage
- tissue pH (acidity)
- glucose (sugar) metabolism
- drug activity

b)Compare the principles of PET and SPECT with examples.(May 2019)

PET	SPECT
High sensitivity	Low sensitivity

A resolution limited by technology	A good resolution but with a physical limit
Single photon emission computed tomography (SPECT) imaging is routinely used and is the primary functional imaging tool used to evaluate the heart	Positron emission tomography (PET) has been applied to the study of the heart
SPECT scans measure gamma rays	PET scans produce small particles called positrons

Photon emission computed tomography (SPECT, or less commonly, SPET) is a nuclear medicine tomographic imaging technique using gamma rays. It is very similar to conventional nuclear medicine planar imaging using a gamma camera.

Positron emission tomography (PET) is a nuclear medicine, functional imaging technique that is used to observe metabolic processes in the body. The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide (tracer), which is introduced into the body on a biologically active molecule.

5. **a) Explain radioisotopes and explain how these radioisotopes are used in the field of medicine.(April/May2018)**

b) List out the characteristics needed for radioisotopes to be used for medical applications.(May 2019)

Radioactive isotope, also called radioisotope, radionuclide, or radioactive nuclide, any of several species of the same chemical element with different masses whose nuclei are unstable and dissipate excess energy by spontaneously emitting radiation in the form of alpha, beta, and gamma rays.

Every chemical element has one or more radioactive isotopes. For example, hydrogen, the lightest element, has three isotopes with mass numbers 1, 2, and 3. Only hydrogen-3 (tritium), however, is a radioactive isotope, the other two being stable. More than 1,000 radioactive isotopes of the various elements are known. Approximately 50 of these are found in nature; the rest are produced artificially as the direct products of nuclear reactions or indirectly as the radioactive descendants of these products.

Radioactive isotopes have many useful applications. In medicine, for example, cobalt-60 is extensively employed as a radiation source to arrest the development of cancer. Other radioactive isotopes are used as tracers for diagnostic purposes as well as in research on metabolic processes. When a radioactive isotope is added in small amounts to comparatively large quantities of the stable element, it behaves exactly the same as the ordinary isotope chemically; it can, however, be traced with a Geiger counter or other detection device. Iodine-131 has proved effective in treating hyperthyroidism. Another medically important radioactive isotope is carbon-14, which is used in a breath test to detect the ulcer-causing bacteria *Heliobacter pylori*.

In industry, radioactive isotopes of various kinds are used for measuring the thickness of metal or plastic sheets; their precise thickness is indicated by the strength of the radiations that penetrate the material being inspected. They also may be employed in place of large X-ray machines to examine manufactured metal parts for structural defects. Other significant applications include the use of radioactive isotopes as compact sources of electrical power—e.g., plutonium-238 in spacecraft. In such cases, the heat produced in the decay of the radioactive isotope is converted into electricity by means of thermoelectric junction circuits or related devices.

List of radioisotopes

- Radioactive sodium carbon
- phosphorous
- Iodine
- Gold

These are some very important radioisotopes which are used in daily life. These are manufactured mainly by irradiating substances with neutrons in a nuclear reactor but they can also be made by bombardment with high energy particles from an accelerator.

Uses of radioisotopes in medicine

Radioisotopes are used in medicine for diagnoses and treatment.

- Certain radioisotopes localize in certain parts of the body and cure those parts by the radiation they emit for example. Iodine localizes in the thyroid glands. Hence for the treatment of thyroid glands, radio-iodine can be administrated to the patients. Similarly, radio-phosphorous which is a beta emitter can be used for curing skin diseases. It can be applied to the diseased surface of the body and will cure it slowly Radio. Cobalt has been used for curing cancer due to its n°-activity. It is implanted in the concerned parts in the form of needles.
- To study the way in which a certain foodstuff is absorbed by the body radio-isotopes are mixed with food (fat) and form their radioactivity it is noted whether they are secreted out with urine or absorbed by the body and it is also ascertained which parts of the body most absorb a particular food.

6. **Explain with neat block diagram the working principles of ionization chambers.(Nov2016)**

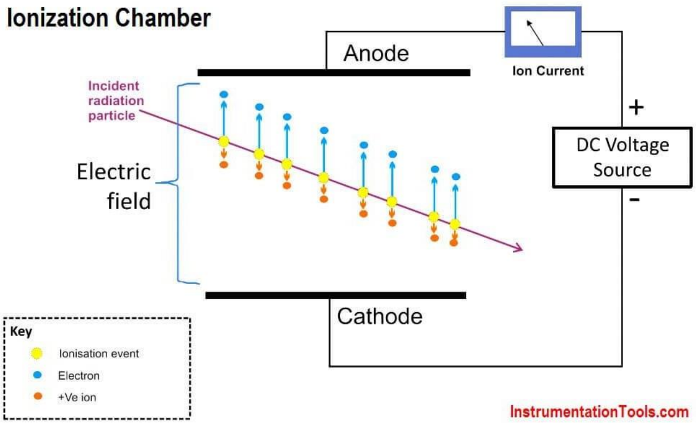
The operating principle of an ionization chamber is simple: **ionizing radiation from the source (X- or gamma rays, electrons) creates an ionization of the gas atoms**. A voltage is applied between the electrodes. Negative charges are attracted by the anode, positive charges by the cathode.

The **ionization chamber** is the simplest of all gas-filled radiation detectors, and is widely used for the detection and measurement of certain types of ionizing radiation; X-rays, gamma rays and beta particles. Conventionally, the term “ionization chamber” is used exclusively to describe those detectors which collect all the charges created by *direct ionization* within the gas through the application of an electric field. It only uses the discrete charges created by each interaction between the incident radiation and the gas, and does not involve the gas multiplication mechanisms used by other radiation instruments, such as the Geiger-Müller counter or the proportional counter.

Ion chambers have a good uniform response to radiation over a wide range of energies and are the preferred means of measuring high levels of gamma radiation. They are widely used in the nuclear power industry, research labs, radiography, radiobiology, and environmental monitoring.

PRINCIPLE OF OPERATION

An ionization chamber measures the charge from the number of ion pairs created within a gas caused by incident radiation. It consists of a gas-filled chamber with two electrodes; known as anode and cathode. The electrodes may be in the form of parallel plates (Parallel Plate Ionization Chambers: PPIC), or a cylinder arrangement with a coaxially located internal anode wire.



A voltage potential is applied between the electrodes to create an electric field in the fill gas. When gas between the electrodes is ionized by incident ionizing radiation, ion-pairs are created and the resultant positive ions and dissociated electrons move to the electrodes of the opposite polarity under the influence of the electric field. This generates an ionization current which is measured by an electrometer circuit. The electrometer must be capable of measuring the very small output current which is in the region of femtoamperes to picoamperes, depending on the chamber design, radiation dose and applied voltage.

Each ion pair created deposits or removes a small electric charge to or from an electrode, such that the accumulated charge is proportional to the number of ion pairs created, and hence the radiation dose. This continual generation of charge produces an ionization current, which is a measure of the *total* ionizing dose entering the chamber. However, the chamber cannot discriminate between radiation types (beta or gamma) and cannot produce an energy spectrum of radiation.

The electric field also enables the device to work continuously by mopping up electrons, which prevents the fill gas from becoming saturated, where no more ions could be collected, and by preventing the recombination of ion pairs, which would diminish the ion current. This mode of operation is referred to as “current” mode, meaning that the output signal is a continuous current, and not a pulse output as in the cases of the Geiger-Müller tube or the proportional counter.

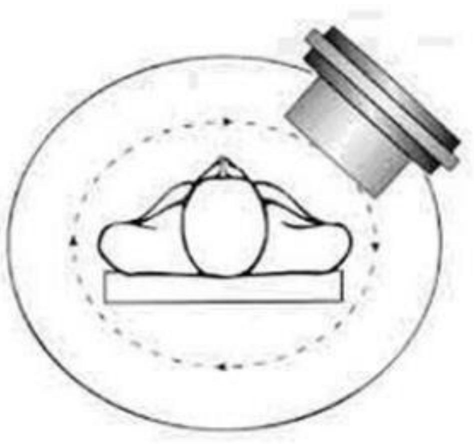
Referring to the accompanying ion pair collection graph, it can be seen that in the “ion chamber” operating region the collection of ion pairs is effectively constant over a range of applied voltage, as due to its relatively low electric field strength the ion chamber does not have any “multiplication effect”. This is in distinction to the Geiger-Müller tube or the proportional counter whereby secondary electrons, and ultimately multiple avalanches, greatly amplify the original ion-current charge.

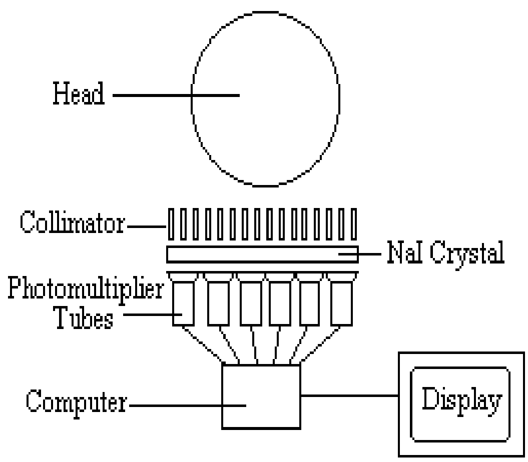
7. With a neat block diagram explain the working principle of SPECT. (Nov2016)

SPECT (SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY)

A Single Photon Emission Computed Tomography (SPECT) scan is a type of functional nuclear imaging test that is aimed to quantify the physiological processes taking place inside the human body without influencing them.

CONSTRUCTION





The above figure shows a patient injected with radiopharmaceuticals and the gamma camera rotating around him absorbing the gamma radiations being emitted while decay of those radioisotopes.

A SPECT camera consists of a gamma camera or a set of gamma cameras mounted on a gantry so that the detector can record projections from many equally spaced angular intervals around the body.

The scintillation (gamma) camera consists of a lead collimator that allows photons travelling in given directions to pass through a large-area scintillator (commonly NaI (Tl) crystal) that converts the energy of γ-*ray* photons to lower-energy photons which are in turn converted to electric signals by photomultiplier tubes (PMTs). The signals from an array of PMTs are processed by electronic circuitry to provide information about the position at which a photon interacts with the crystal. The scintillation camera provides a two-dimensional projection image of the three-dimensional radioactivity distribution or radiopharmaceutical uptake within the patient.

WORKING PROCEDURE

The technique requires delivery of a gamma-emitting radioisotope (a radionuclide) into the patient, normally through injection into the bloodstream which acts as radiation source.

In SPECT scan the tracer stays in your blood stream rather than being absorbed by surrounding tissues.

The radioisotopes typically used in SPECT to label tracers are iodine-123, technetium-99m, xenon-133, thallium-201, and fluorine-18. These radioactive forms of natural elements will pass safely through body.

Most of the time, a marker radioisotope is attached to a specific ligand to create a radioligand. This allows the combination of ligand and radiopharmaceutical to be carried and bound to certain types of tissues, where the ligand concentration is seen by a gamma camera. These radioactive tracers used in SPECT emit gamma radiation that is measured directly.

A gamma camera is used to acquire multiple 2-D projections, from multiple angles. A computer is then used to apply a tomographic reconstruction algorithm to the multiple projections, yielding a 3-D data.

DURATION

Total scan time is about 15 to 20 minutes for whole body scan.

APPLICATION

- This is used to view blood flow through arteries and veins.

- It is helpful in tumor imaging, infection (leukocyte) imaging, thyroid imaging.
- It is also useful in diagnosing stress fractures in the spine (spondylolysis), blood deprived (ischemic) areas of brain following a stroke, seizures and Alzheimer's disease.
- SPECT is also used to diagnose and track the progress of heart diseases, such as blocked coronary arteries.

8. **What is the need for detectors in nuclear imaging?Explain the operation of Scintillation detectors. (Nov/Dec2018)**

The advent of new detector technologies, such as Silicon photomultipliers (SiPMs), and advances in understanding the statistics of scintillation light, are helping achieve improved energy, time, and spatial resolution with scintillation-based detector systems. We have led and collaborated on research efforts that provide insights, and assist the incorporation of novel technologies into new imaging systems. For example, we were one of the first to design a rigorous and comprehensive method to simulate the response to SiPMs to scintillation light. The method quantified the effect of various processes such as saturation and noise on SiPM performance. Similarly, we demonstrated that the Fano factor of scintillation light effects the energy resolution of nuclear-medicine imaging systems.

Detecting and measuring radiation is essential to diagnostic imaging and nonimaging applications. Radiation detectors rely on the interaction of radiation with matter. As radiation interacts with the atoms or molecules of a material, energy is transferred to it, resulting in *ionization* and *excitation*.

Ionization occurs when the transferred energy is great enough to remove an orbital electron from an atom or molecule, producing an ion pair—a negatively charged electron (anion) and a positively charged atom or molecule (cation). Excitation is the transfer of energy to a *bound* electron in atoms or molecules, including crystals, which are often used in detectors.

Radiation detectors can be grouped into the following categories: gas-filled detectors, scintillation detectors, and semiconductor detectors.

SCINTILLATOR DETECTOR:

A scintillation detector is often portable. The scintillation detector is not as versatile as the GM meter, although it can be used to look for contamination from some radioactive materials. The scintillation detector's active portion for detecting radioactivity is a solid crystal (that is the scintillator) with which the radioactive emission must interact. This essentially limit s use of the detector to gamma rays and high-energy beta particles since medium- and low-energy beta particles cannot penetrate the crystal and, therefore, cannot interact.

Scintillators can be made in different sizes, and the thickness of the scintillator determines its ability to absorb and detect certain radiation emissions. A thin scintillator is an excellent choice for low-energy gamma rays and high-energy beta particles. The ray or particle will be absorbed within the thin scintillator and the light produced by this interaction will be able to pass through the remaining thickness to allow the gamma ray to be detected. A high-energy gamma ray is likely to pass right through the thin scintillator without interacting.

A thick scintillator is the choice for radio nuclides emitting high-energy gamma rays. This scintillator is thick enough to absorb the gamma ray but not too thick to prevent the light that is produced from being detected. A thick scintillator is not very good for low-energy gamma rays; they will interact but the scintillator is too thick and will absorb the light that is produced before it can be detected.

A **scintillation counter** or **scintillation detector** is a radiation detector which uses the effect known as **scintillation**. Scintillation is a **flash of light** produced in a transparent material by the passage of a particle (an electron, an alpha particle, an ion, or a high-energy photon). Scintillation occurs in the scintillator, which is a key part of a scintillation detector. In general, a scintillation detector consists of:

- **Scintillator**. A scintillator generates photons in response to incident radiation.
- **Photodetector**. A sensitive photodetector (usually a photomultiplier tube (PMT), a charge-coupled device (CCD) camera, or a photodiode), which converts the light to an electrical signal and electronics to process this signal.

The basic principle of operation involves the radiation reacting with a scintillator, which produces a series of flashes of varying intensity. The intensity of the flashes is proportional to the energy of the radiation. This feature is very important. These counters are suited to measure the energy of gamma radiation (**gamma spectroscopy**) and, therefore, can be used to identify gamma emitting isotopes.

Scintillation counters are widely used in radiation protection, assay of radioactive materials and physics research because they can be made inexpensively yet with good efficiency, and can measure both the intensity and the energy of incident radiation. Hospitals all over the world have gamma cameras based on the scintillation effect and, therefore, they are also called **scintillation cameras.**

The advantages of a scintillation counter are its efficiency and the high precision and counting rates that are possible. These latter attributes are a consequence of the extremely short duration of the light flashes, from about

10^{-9} (organic scintillators) to 10^{-6} (inorganic scintillators) seconds. The **intensity of the flashes** and the amplitude of the output voltage pulse are **proportional to the energy of the radiation**. Therefore, scintillation counters can be used to determine the energy, as well as the number, of the exciting particles (or gamma photons). For gamma spectrometry, the most common detectors include **sodium iodide (NaI) scintillation counters** and high-purity germanium detectors.

9. Explain temporal integration techniques for digital angiography. (April/May2018)

Digital angiography is widely considered simply as a method in which images taken at different times are subtracted from each other. This paper presents some techniques which are performed in the frequency domain after the application of the Fourier transform. Nonselective bypass angiograms and intravenous ventriculograms are taken as examples to show that simple procedures utilizing these techniques exhibit the advantages of improved signal-to-noise ratio in the subtraction images, reduction of motion artifacts, easy application of phase-synchronous subtraction, integration, and quantitative visualization of blood propagation. It is furthermore shown that the storage of the angiographic image sequence as Fourier coefficients leads to data compression and convenient data access in an image database.Digital subtraction angiography (DSA) is a newer method of visualization of vascular structures. Less contrast medium is required, when compared with cerebral angiography. The image produced is made more distinct by the elimination of surrounding and interfering anatomical structures

Consecutively to drastic changes which occurred in cerebral imagery techniques, we have developed a stereotactic apparatus and system based on the integration of several new techniques allowing visualisation of the brain: tomodensitometry (TDM), digital subtraction angiography (DSA), magnetic resonance (MR) and positron emission tomography (PET). TDM, DSA and MR can be performed in stereotactic conditions with the apparatus in situ. They give the computer the anatomic references necessary for all calculations. MR and PET images obtained without stereotactic apparatus can also be integrated into the stereotactic study at the condition that DSA was formerly performed in stereotactic conditions, i.e. with the apparatus in situ. The visualisation of the corpus callosum makes this integration possible. An optimal definition of cerebral tumors or target-structures for intracerebral electrode recording is thus obtained.

10. Explain in detail the working procedure of digital subtraction angiography.(April/May2018)

Digital subtraction angiography (DSA) is a newer method of visualization of vascular structures. Less contrast medium is required, when compared with cerebral angiography. The image produced is made more distinct by the elimination of surrounding and interfering anatomical structures

DEFINITION

Digital subtraction angiography is a computer-based imaging method for visualization of extracranial, intracranial and vascular system by passing a catheter to certain veins and arteries

PURPOSE

- To identify the cause of transient ischemic attacks
- To assess intracranial tumors
- Preoperative and postoperative evaluation for vascular surgery

INDICATIONS

- Transient ischemic attacks
- Serial follow-up for clients with known carotid stenosis
- Intracranial tumors

- Postoperative aneurysm
- Extracranial and intracranial bypass procedure follow-up
- Dural venous sinuses

FACTORS INTERFERENCE

- This examination is very sensitive and even slight physical movements may cause poor imaging
- The art of swallowing results in unsatisfactory images

SPECIAL INSTRUCTIONS

- If an arterial pressure was performed, the affected extremity should be kept straight for 12-24 hours and the client must lie flat
- Do not raise the head of the bed because this can cause a strain the femoral puncture site
- Sudden onset of pain, numbness or tingling, greater degree of coolness and absent is informed to physician immediately

CLIENT PREPARATIONS

- Prepare the client physiologically and psychologically
- Explain the entire procedure thoroughly in simple words
- Instruct the client to make plenty of fluids to keep well hydrated
- No solid food for 2 hours before the procedure
- Inform the client that the entire procedure may take 30-45 minutes
- Obtain informed consent from the client

PROCEDURE

- Place the client comfortably on the treatment table
- Radiographic dye is injected into either the venous or the arterial circulation, but significantly less dye is necessary for arterial angiography

- X-ray film taken before and after dye injection is superimposed on each other all matching imaging are subtracted
- Thus, only the dye enhanced cerebral vessels are left for study and evaluation
- Digital subtraction angiography eliminates the shadows and distortions of bone or other material that sometimes block the viewing of the cerebral vessels
- After completion of the procedure, the catheter is removed
- Pressure is applied to the puncture site for several minutes and sterile dressing is applied

AFTER CARE

- Place the client comfortably on the bed
- Monitor vital signs and neurological status
- Check the catheter site for hemorrhage or hematoma formation
- Instruct the client to increase the fluid intake during the first 24 hours
- Observe for allergic reactions such as nausea, vomiting and urticaria
- Record the procedure in the nurse's record

DISADVANTAGES

- The major disadvantage of digital subtraction angiography involves the client's ability to remain motionless during the entire procedure. Even swallowing interferes significantly with the imaging process. This study cannot be done for uncooperative and children

BM E75 RADIOLOGICAL EQUIPMENTS
UNIT-V

2 MARKS:

1. What is radiation therapy? (May 2019, Nov 2016, Nov 2018)

Radiation therapy is a type of cancer treatment that uses beams of intense energy to kill cancer cells. Radiation therapy most often uses X-rays, but protons or other types of energy also can be used.

The term "radiation therapy" most often refers to external beam radiation therapy. During this type of radiation, the high-energy beams come from a machine outside of your body that aims the beams at a precise point on your body.

2. Write a note on betatron. (Nov 2018)

Betatron is a cyclic accelerator in which the electrons are made to circulate in a toroidal vacuum chamber (doughnut)that is placed into a gap between two magnet poles.

It is essentially a transformer with a torus-shaped vacuum tube as its secondary coil. An alternating current in the primary coils accelerates electrons in the vacuum around a circular path. The betatron was the first machine capable of producing electron beams at energies higher than could be achieved with a simple electron gun.

3. Define Dosimeter. (Nov 2017, Nov 2019)

A radiation dosimeter is a device that measures exposure to ionizing radiation. Radiation dosimetry applies both internally, due to ingested or inhaled radioactive substances, or externally due to irradiation by sources of radiation.

It has two main uses:

- For human radiation protection.
- Measurement of dose in both medical and industrial processes.

4. What is the purpose of film badges. (Nov 2019)

A film badge dosimeter or film badge is a personal dosimeter used for monitoring cumulative radiation dose due to ionizing radiation.

The badge is typically worn on the outside of clothing, around the chest or torso to represent dose to the "whole body". This location monitors exposure of most vital organs and represents the bulk of body mass.

5. What are the different effects of radiation. (May 2019)

Biological effects of radiation are typically divided into two categories. The first category consists of exposure to high doses of radiation over short periods of time producing acute or short term effects. The second category represents exposure to low doses of radiation over an extended period of time producing chronic or long term effects.

6. Mention the safety protocols we follow to prevent radiations. (Nov 2016)

1. Keeping the time of exposure to a minimum,
2. Maintaining distance from the source,
3. When appropriate, placing a shield between yourself and the source, and.
4. Protecting yourself against radioactive contamination by using proper protective clothing.

7. Give short notes about linear accelerator. (May 2018)

A linear accelerator also known as linear particle accelerator has many applications such as they generate X-rays and high energy electrons for medicinal purposes in radiation therapy, serve as particle injectors for higher-energy accelerators, and are used directly to achieve the highest kinetic energy for light particles (electrons and positrons) for particle physics.

8. Write about film badges. (May 2018)

A film badge dosimeter or film badge is a personal dosimeter used for monitoring cumulative radiation dose due to ionizing radiation.

These badges use small x-ray films sandwiched between several filters to help detect radiation. Film badges are inexpensive, easy to use, and easy to process.

9. What are the applications of radiation therapy? (Nov 2017)

- Radiation therapy can help shrink tumors and kill cancerous cells in the early stages.

- Radiation therapy can also help treat symptoms when cancer has spread widely.
- Palliative radiation treatment usually involves lower doses and fewer treatment sessions than curative treatment.

11 MARKS:

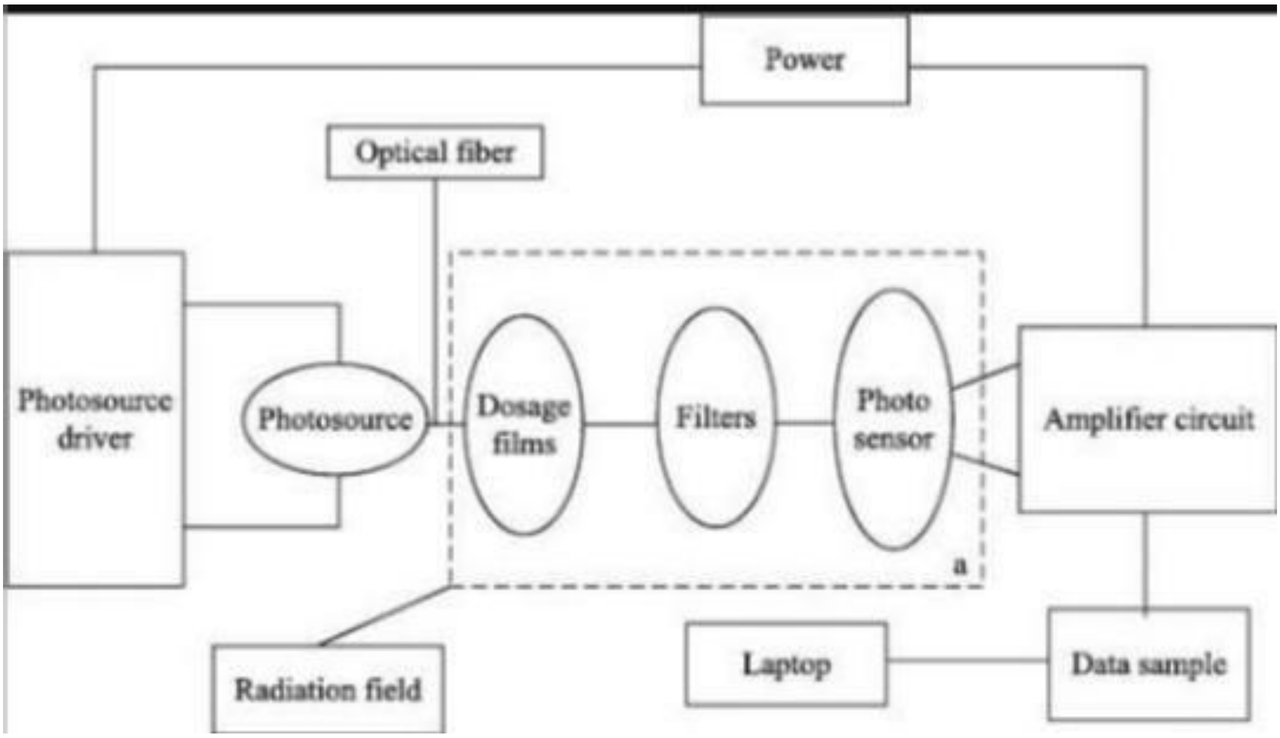
1.(a)Explain in detail about the different types of dosimeters. (Nov/Dec 2019, Nov/Dec 2017)

(b) What is dosimeter? Why do we use dosimeter and explain the types of dosimeters in detail? (Apr/May 2018)

A radiation dosimeter is a device that measures exposure to ionizing radiation. Radiation dosimetry applies both internally, due to ingested or inhaled radioactive substances, or externally due to irradiation by sources of radiation.

It has two main uses:

- For human radiation protection.
- Measurement of dose in both medical and industrial processes.



Block diagram of dosimeter

Types of dosimeter:

1. Electronic personal dosimeter

The electronic personal dosimeter (EPD)is an electronic device that has a number of sophisticated functions, such as continual monitoring which allows alarm warnings at preset levelsand live readout of dose accumulated.

These are especially useful in high dose areas where residence time of the wearer is limited due to dose constraints. The dosimeter can be reset, usually after taking a reading for record purposes, thereby reused multiple times.

2. Film badge dosimeter

Radiographic x-ray film performs several important functions in diagnostic radiology, radiation therapy, and radiation protection. It can serve as radiation detector, relative dosimeter, a display device, and archival medium.

Unexposed x-ray film consists of a base of thin plastic with a radiation sensitive emulsion(silver bromide AgBr grains suspended in gelatin) coated uniformly on one or both sides of the base.

Ionisation of AgBr in the grains, as a result of radiation interaction, forms the latent image in the film. Image becomes visible (film blackening) only after development.

Film gives excellent 2D spatial resolution and, in a single exposure, it provides informationabout the spatial distribution of radiation in the area of interest or the attenuation of radiation by objects.

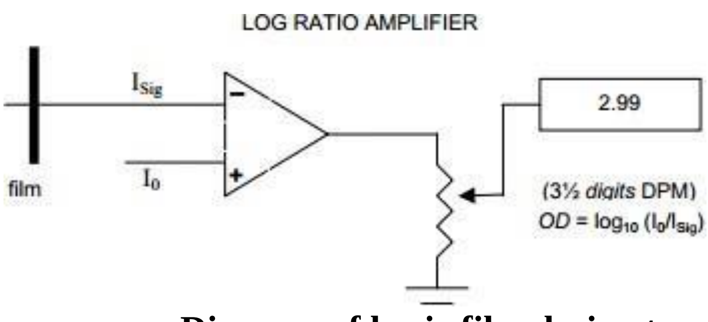


Diagram of basic film dosimeter

Film badge dosimeters are for one time use only. The level of radiation absorption is indicated by a change to the film emulsion, which is shown when the film is developed.

Light transmission is a function of the film opacity and can be measured in terms of optical density (OD) with special devices called densitometers.Optical density is defined as

$OD = \log_{10} (I_0/I)$ and is a function of dose.

I_0 is the initial light intensity and

I is the intensity transmitted through the film.

3. Thermoluminescent dosimeter(tld)

Thermoluminescence (TL) is thermally activated phosphorescence; the most spectacular and the most widely known of a number of different ionizing radiation induced thermally activated phenomena.

TL dosimeters most commonly used in medical applications are LiF:Mg,Ti, LiF:Mg,Cu,P and $Li_2B_4O_7$:Mn, because of their tissue equivalence. Other TLDs, used because of their high sensitivity, are $CaSO_4$:Dy, Al_2O_3:C and CaF_2:Mn.

TLDs are available in various forms (e.g., powder, chips, rods, ribbon, etc.).

A basic TLD reader system consists of a planchet for placing and heating the TLD dosimeter; a photomultiplier tube (PMT) to detect the TL light emission, convert it into an electrical signal, and amplify it; and an electrometer for recording the PMT signal as charge orcurrent.

The TL intensity emission is a function of the TLD temperature T. Keeping the heating rate constant makes the temperature T proportional to time t.

A thermoluminescent dosimeter measures ionizing radiation exposure by measuring the intensity of visible light emitted from a crystal in the detector when heated.

The intensity of light emitted is dependent upon the radiation exposure. The film badge dosimeter is being superseded by the TLD and EPD.

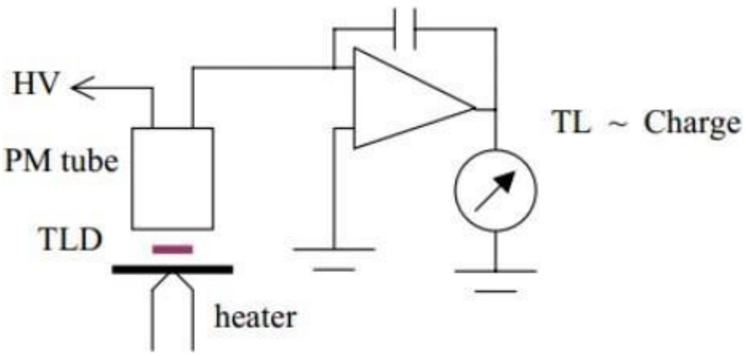


Diagram of TLD reader

Advantages of dosimeter:

- Small, compact, easy to use
- Permanent legal record in film badge dosimeter
- Crystals contained in TLD interact with ionizing radiation as tissue does

Disadvantages of dosimeter:

- Pocket dosimeter is expensive
- Film badge can be affected by heat and humidity
- Records exposure only where worn.

2. Explain in detail about the ICRP regulation. (Nov/Dec 2018)

Radiation is the emission or transmission of energy in the form of waves orparticles through space or through a material medium this includes:

- electromagnetic radiation, such as radio waves, microwaves, visible light, x- rays, and gamma radiation (γ)
- particle radiation, such as alpha radiation (α), beta radiation (β), andneutron radiation (particles of non-zero rest energy)
- acoustic radiation, such as ultrasound, sound, and seismic waves (dependent on a physical transmission medium)
- gravitational radiation, radiation that takes the form of gravitational waves, or ripples in the curvature of spacetime.

Radiation protection:

Radiation protection, sometimes known as radiological protection, is defined by the International Atomic Energy Agency (IAEA) as "The protection of people fromharmful effects of exposure to ionizing radiation, and the means for achieving this.

The Exposure can be from a radiation source external to the human body or dueto an intake of radioactive material into the body.

Fundamentals of radiation protection:

- Fundamental to radiation protection is the reduction of expected dose andthe measurement of human dose uptake.
- For radiation protection and dosimetry assessment the International Committee on Radiation Protection (ICRP) and International Commission on Radiation Units and Measurements (ICRU) have published recommendations and data which is used to calculate the biological effects on the human body, and thereby advise dose uptake limits.
- Supporting this is a necessary range of radiation protection instruments to indicate radiation hazards, and dosimeters to measure dose assisted by preventative techniques such as radiation shielding.

General principles of radiation protection based on ICRP recommendation:

International Commission on Radiological Protection (ICRP) proposed a system of radiation protection with its three principles of justification, optimization and individual dose limitation in publication 26.

The principles of radiological protection,

In ICRP's previous Recommendations, they gave principles of protection as fundamental for the system of protection, and have now

formulated a single set of principles that apply to planned, emergency, and existing exposure situations. In these Recommendations, they also clarified how the fundamental principles apply to radiation sources and to the individual, as well as how the source- related principles apply to all controllable situations.

ALARA:

The national council on radiation protection and measurement recommends using the ALARA(as low as reasonably achievable)principle.

Try to keep the exposure to less than 1/10 recommended dose limit.

1.The principle of justification:

This means that,

- by introducing a new radiation source
- by reducing existing exposure, or by reducing the risk of potential exposure, one should achieve sufficient individual or societal benefit it causes.

2.The principle of optimization of protection:

- the level of protection should be the best under the prevailing circumstances, maximizing the margin of benefit over harm.
- In order to avoid severely inequitable outcomes of this optimization procedure, there should be restrictions on the doses or risks to individuals from a particular source (dose or risk constraints and reference levels).
- One principle is individual-related and applies in planned exposure situations.

3.The principle of application of dose limits:

- The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits recommended by the Commission.

- The concepts of dose constraint and reference level are used in conjunction with the optimization of protection to restrict individual doses. A level of individual dose, either as a dose constraint or a reference level, always needs to be defined.
- The initial intention would be to not exceed, or to remain at, these levels, and the ambition is to reduce all doses to levels that are as low as reasonably achievable, economic and societal factors being taken into account.
- Diagnostic reference levels are already being used in medical diagnosis (i.e., planned exposure situations) to indicate whether, in routine conditions, the levels of patient dose or administered activity from a specified imaging procedure are unusually high or low for that procedure.
- If so, a local review should be initiated to determine whether protection has been adequately optimized or whether corrective action is required.

3. With a neat diagram explain the working principle of thermoluminiscent dosimeter. (Nov 2016)

Thermoluminescence (TL) is thermally activated phosphorescence; the most spectacular and the most widely known of a number of different ionizing radiation induced thermally activated phenomena.

TL dosimeters most commonly used in medical applications are LiF:Mg,Ti, LiF:Mg,Cu,P and $Li_2B_4O_7$:Mn, because of their tissue equivalence. Other TLDs, used because of their high sensitivity, are $CaSO_4$:Dy, Al_2O_3:C and CaF_2:Mn.

TLDs are available in various forms (e.g., powder, chips, rods, ribbon, etc.).

Before they are used, TLDs have to be annealed to erase the residual signal. Well-established reproducible annealing cycles should be used including the heating and cooling rates.

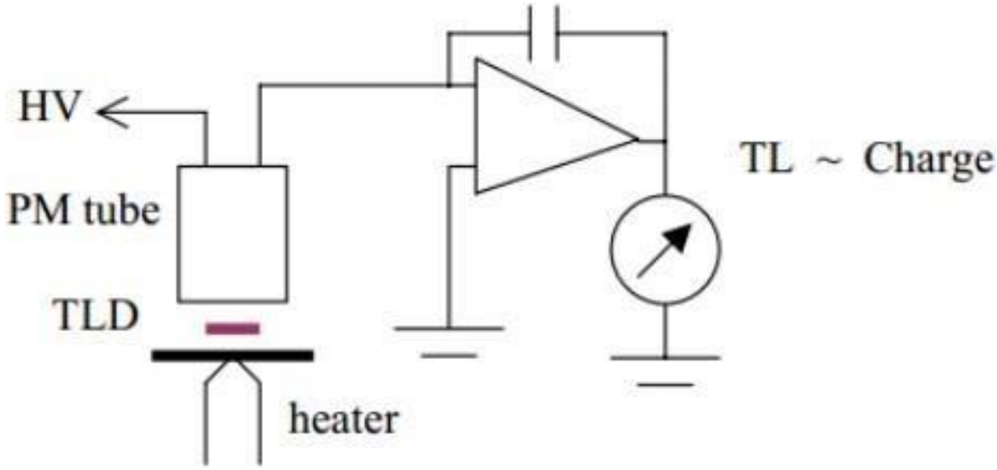


Diagram of TLD reader

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A thermoluminescent dosimeter measures ionizing radiation exposure by measuring the intensity of visible light emitted from a crystal in the detector when heated.

The intensity of light emitted is dependent upon the radiation exposure. The film badge dosimeter is being superseded by the TLD and EPD.

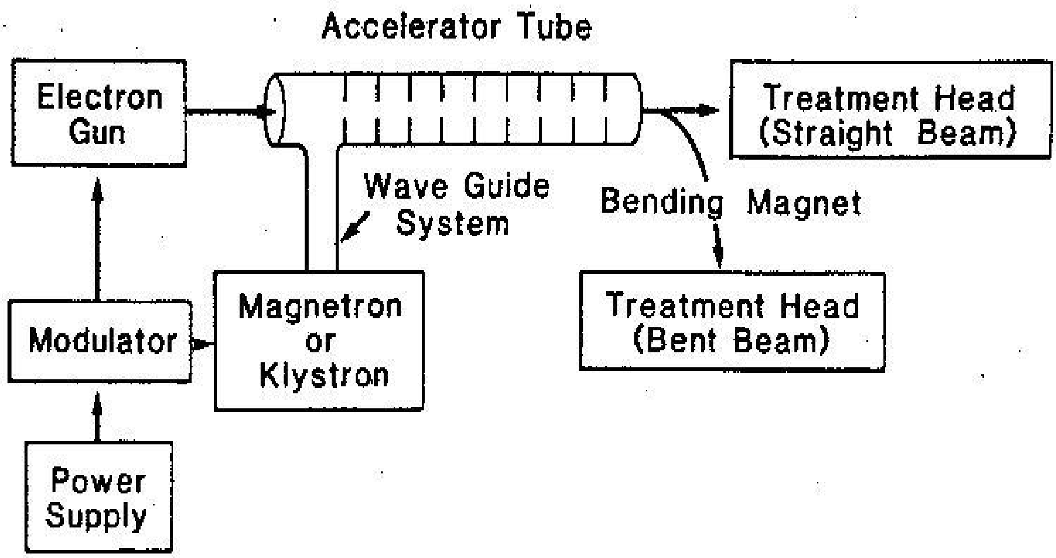
4.Explain the working principle of LINAC. (Nov/Dec 2019, Nov/Dec 2016)

Medical linacs are cyclic accelerators that accelerate electrons to kinetic energies from 4 to 25 MeV using microwave radiofrequency fields:

- 103 MHz : L band
- 2856 MHz: S band
- 104 MHz: X band

In a linac the electrons are accelerated following straight trajectories in special evacuated structures called accelerating waveguides.

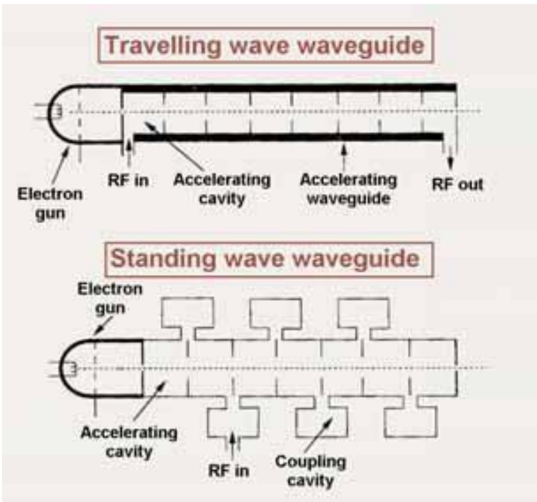
Block diagram of Linear Accelerator



Accelerating waveguide:

In the standing wave accelerating structure each end of the accelerating waveguide is terminated with a conducting disk to reflect the microwave power producing a standing wave in the waveguide.

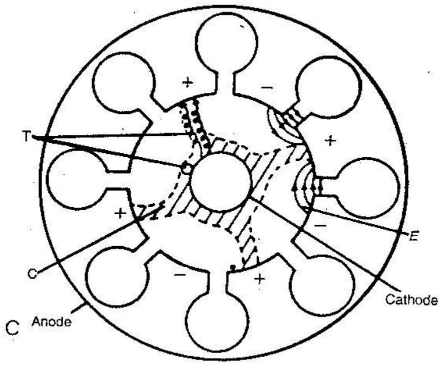
Every second cavity carries no electric field and thus produces no energy gain for the electron (coupling cavities In the travelling wave accelerating structure the microwaves enter on the gun side and propagate toward the high energy end of the waveguide. Only one in four cavities is at any given moment suitable for acceleration.



Magnetron:

- A device that produces microwaves
- Functions as a high-power oscillator
- Generating microwave pulses of several microseconds with repetition rate of
  several hundred pulses per second
- Frequency of microwave within each pulse is about 3000 MHz
- Peak power output:

1. 2 MW (for low-energy linacs, 6MV or less)
2. 5 MW (for higher-energy linacs, mostly use klystrons)



The cathode is heated by an inner filament

↓

Electrons are generated by thermionic emission

↓

Pulse E-field between cathode & anode
Electron accelerated toward the anode

↓

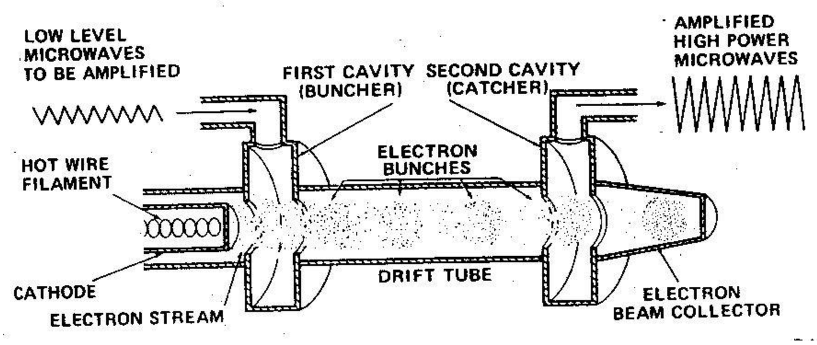
Static B-field perpendicular to the plane of cavities
Electron move in complex spirals toward the resonant cavities

↓

Radiating energy in form of microwave

Klystron:

- Not a generator of microwaves
- Microwave amplifier



Needs to be driven by a low-power microwave oscillator

Electrons produced by the cathode

↓

Electrons are accelerated by –ve pulse into buncher cavity

↓

Lower level microwave set up an alternating E field across the buncher cavity

↓

Velocity of e- is altered by the action of E-field (velocity modulation)

1. Some e- are speed up
2. Other are slowed down

↓

Passed in the drift tube (field-free space)

↓

Electrons arrive catcher cavity

1. Generate a retarding E-field
2. Electrons suffer deceleration
3. KE of electrons converted into high-power microwaves

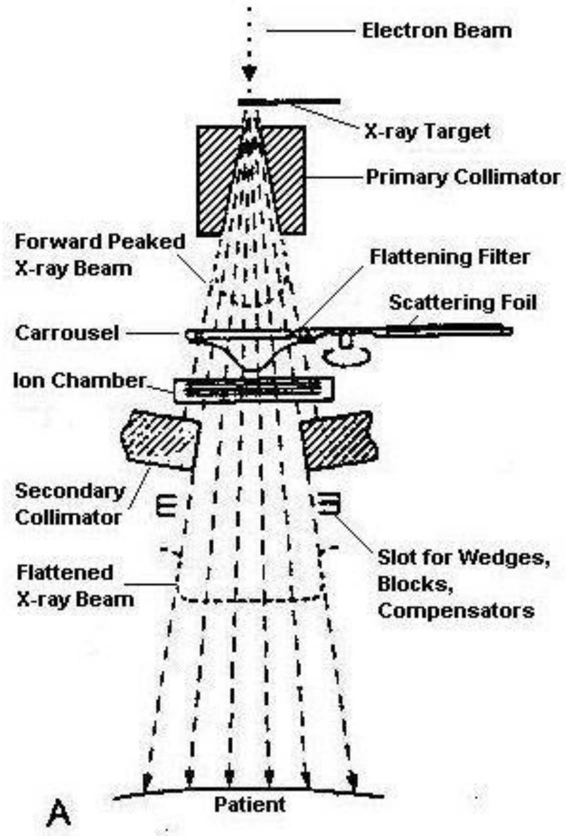
Linac treatment head:

Components of a modern linac treatment head:

- Several retractable x-ray targets (one for each x-ray beam energy).
- Flattening filters (one for each x-ray beam energy).
- Scattering foils for production of clinical electron beams.
- Primary collimator.
- Adjustable secondary collimator with independent jaw motion.
- Dual transmission ionization chamber.
- Field defining light and range finder.

• Retractable wedges.

• Multileaf collimator (MLC).



5. Explain (a) Linear accelerator
(b) Betatron (May 2019)

(a) Linear Accelerator

Medical linacs are cyclic accelerators that accelerate electrons to kinetic energies from 4 to 25 MeV using microwave radiofrequency fields:

• 103 MHz : L band

• 2856 MHz: S band

• 104 MHz: X band

In a linac the electrons are accelerated following straight trajectories in special evacuated structures called accelerating waveguides.

During the past 40 years medical linacs have gone through five distinct generations, each one increasingly more sophisticated:

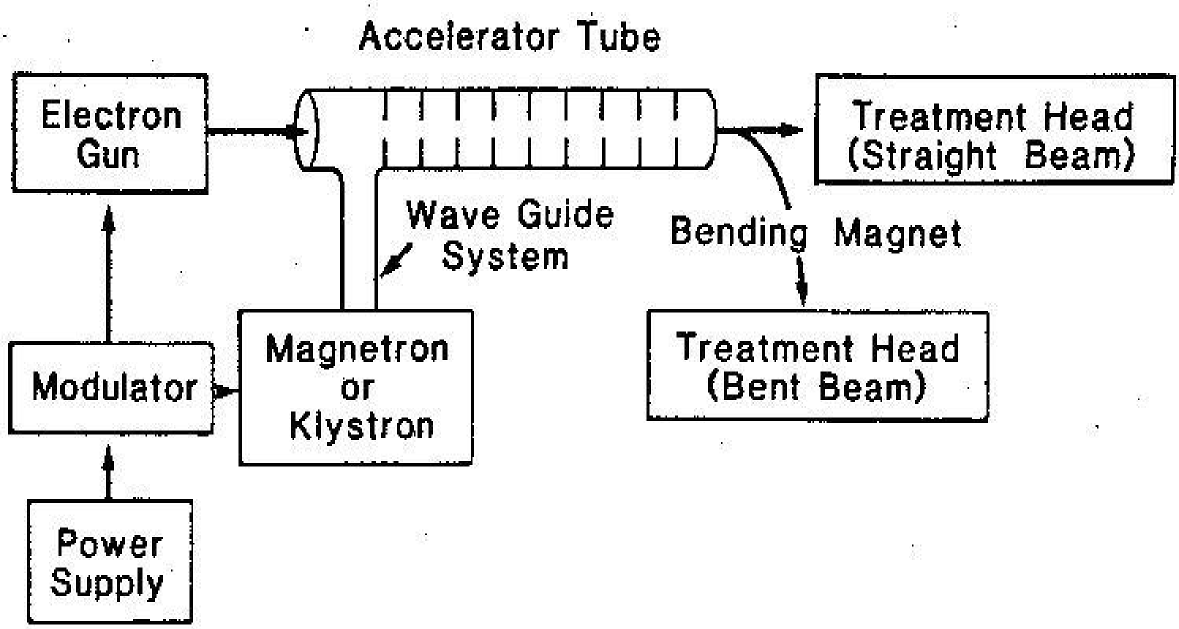
(1) Low energy x rays (4-6 MV)

(2) Medium energy x rays (10-15 MV) and electrons

(3) High energy x rays (18-25 MV) and electrons

(4) Computer controlled dual energy linac with electrons

(5) Computer controlled dual energy linac with electrons combined with



intensity modulation

Use high frequency electromagnetic waves to acelerate charged particles (e.g. electrons) to high energies through a linear tube.

High-energy electron beam – treating superficial tumors

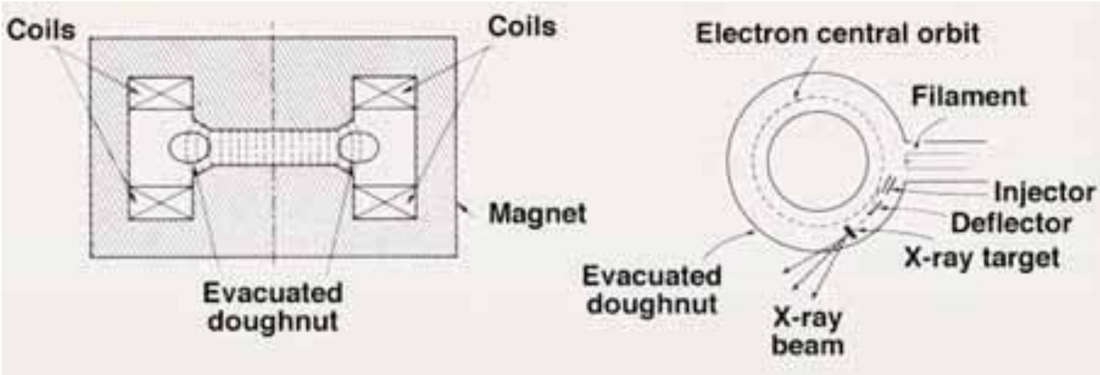
X-rays – treating deep-seated tumors

(b) Betatron:

Betatron is a cyclic accelerator in which the electrons are made to circulate in a toroidal vacuum chamber (doughnut)that is placed into a gap between two magnet poles.

Conceptually, the betatron may be considered an analog of a transformer:

• Primary current is the alternating current exciting the magnet.

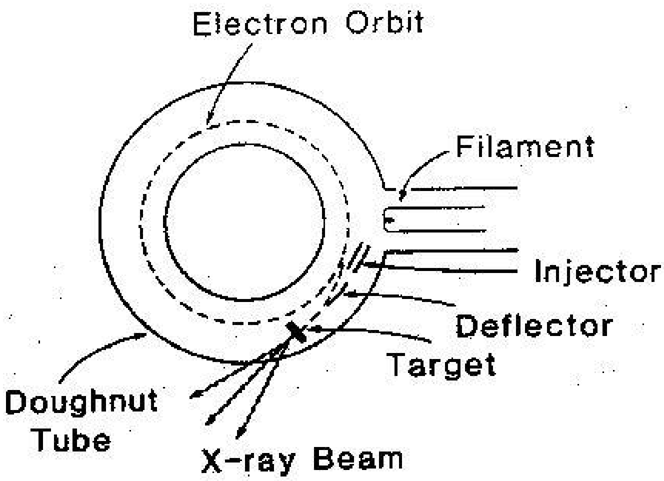


• Secondary current is the electron current circulating in the doughnut.

Electron in a changing magnetic field experiences acceleration in a circular orbit. It is essentially a transformer with a torus-shaped vacuum tube as its secondary coil. An alternating current in the primary coils accelerates electrons in the vacuum around a circular path. The betatron was the first machine capable of producing electron beams at energies higher than could be achieved with a simple electron gun.

Energy of x-rays:

- 6 – 40 MV



Disadvantage:

- low dose rate
- Small field size.