MEDICAL INSTRUMENTATION BM T55

UNIT – I BASIC COMPONENTS OF BIOMEDICAL SYSTEM

2 Marks:

1. Define half-cell potential. (May 17, Nov 18, Nov 19, May 19, Apr/May 16)

The voltage developed between an electrode and electrolyte gel at their interface, is called *half cell potential* or *electrode potential.*

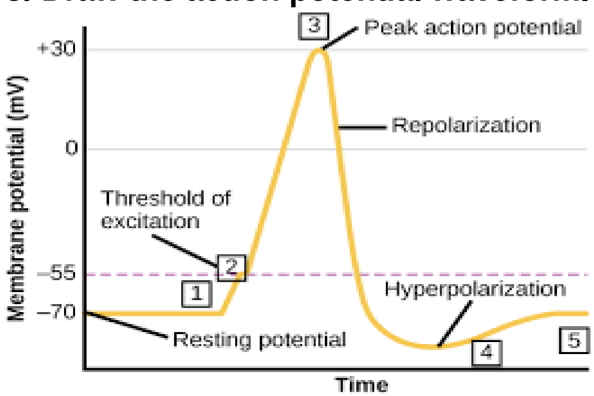
This is due to two reasons-

1. Passage of ions from metal electrode into electrolyte solution.
2. Combination of metallic ions in the electrolyte with electrons in the electrode metal.

2. What is the principle of a thermocouple? (May 17)

The thermocouple working principle is based on the Seebeck Effect. This effect states that when a closed circuit is formed by jointing two dissimilar metals at two junctions, and junctions are maintained at different temperatures then an electromotive force (e.m.f.) is induced in this closed circuit.

3. Draw the action potential waveform. (Nov 17)



4. Explain about notch filter. (May 18, Nov 19)

A notch filter (also known as a band stop filter or reject filter) is defined as a device that rejects or blocks the transmission of frequencies within a specific frequency range and allows frequencies outside that range .....A notch filter is essentially a band stop filter with a narrow stopband and two pass bands.

5. List out some bio signals and its frequency range. (May 18)

- Electrooculogram (EOG) - 0 and 50 **Hz**
- Electrocardiogram (ECG) - 0.05 **Hz** to 100 **Hz**
- Electromyogram (EMG) - 0-500 Hz and most dominant in between 50-150 Hz

6. List out the use of biomedical transducer. (Nov 18)

Applications Magnetic Induction Type Transducerscers

- Electromagnetic flow meter

Applications of Piezoelectric Transducers

- Piezoelectric Transducer acts as a pulse sensor to measure the pulse rate of a human.

Applications of Thermoelectric Transducers

- To measure physiological temperature in remote sensing circuits and biotelemetry circuits.

Applications of Resistive Transducers

- To measure intraarterial and intravenous pressure in the body.

Applications of Capacitive Transducers

- Differential capacitive transducers measure blood pressure.

Application of Inductive Transducers

- To measure tremor in patients suffering from Parkinson's disease.

7. Write the significance of bipolar needle electrode. (May 19)

Bipolar needles may have two central wires, in which case the active and reference electrodes are at the tip and the outside cannula acts as the ground. Because the active and reference electrodes are closer together, using the bipolar electrode minimizes background noise.

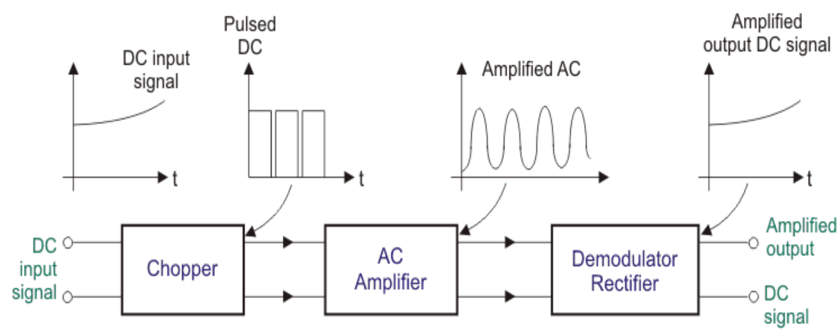
8. What are bio potential electrodes?

Bio-potential electrodes are those sensors which measure the change in the factor by a electrode in form of some graphs or plots, the ECG, EOG and EMG are some of the bio-potential electrode which commonly used in the biomedical fields.

9. Mention the types of electrodes? (Nov 16)

(i) Micro electrodes – Metallic, Non-Metallic
(ii) Depth and Needle electrodes
(iii) Surface electrodes – Metal plate, Suction cup, Adhesive tape, Multipoint electrodes.

10. Draw the diagram of Chopper amplifier.



Schematic Diagram of a Chopper Amplifier

11. Write the expression for the Nernst equation. (Sep 20)

$$E_{hc} = -2.303 \frac{RT}{nF} log_{10} \frac{C_1 f_1}{C_2 f_2}$$

where R - Gas constant = 8.314KJ/Kmol/K

T – Absolute temperature in Kelvin

F – Faraday constant=96500 coulombs

n – valency of ion

C_1, C_2 – concentration of the selected ion on the two sides of the membrane.

f_1, f_2 – activity co-efficient of ion on the two sides of the membrane

In dilute solution $f_1 = f_2 = 1$.

12. What is the need of a bio signal preamplifier? (Sep 20)

Biological/bioelectric signals have low amplitude and low frequency. Therefore, to increase the amplitude level of biosignals amplifiers are designed. The outputs from these amplifiers are used for further analysis and they appear as ECG, EMG, or any bioelectric waveforms.

11 Marks:

1. Explain in detail the different types of electrodes available for biomedical applications. (Sep 20, Nov 19, Nov 18, Apr 19, Apr 18)

(i) Micro electrodes – Metallic, Non-Metallic
(ii) Depth and Needle electrodes
(iii) Surface electrodes – Metal plate, Suction cup, Adhesive tape, Multipoint, Floating electrodes.

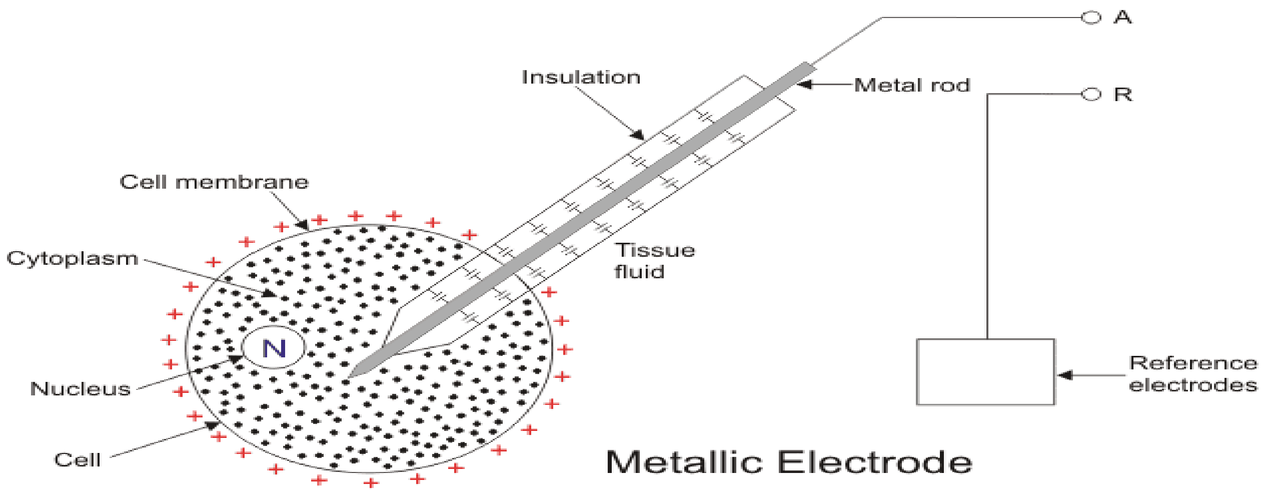
Microelectrodes
Microelectrode measures the electric potential from within a single cell. It has very small diameter tips that can penetrate deep into the cell without damaging the human cell. The functions of microelectrodes are potential recording to inject medicines. Generally, when microelectrode is inside cell, reference electrode is outside the cell. It has high impedances in range of mega ohm due to their small size. Two types of microelectrode are

- Metal Microelectrode
- Non- Metallic (Micropipette)

Metal Microelectrode
The tungsten filament or stainless steel wire made into minute structure forms the tip of the microelectrode. This technique is electro pointing. The insulating material covers the entire electrode for safety purpose.
Few electrolytic processing is done to reduce the impedance. Measurement of bioelectric potentials requires two electrodes. The resulting voltage potential is the difference between the potential of microelectrode and reference electrode. The total sum of the three potentials is as follows.

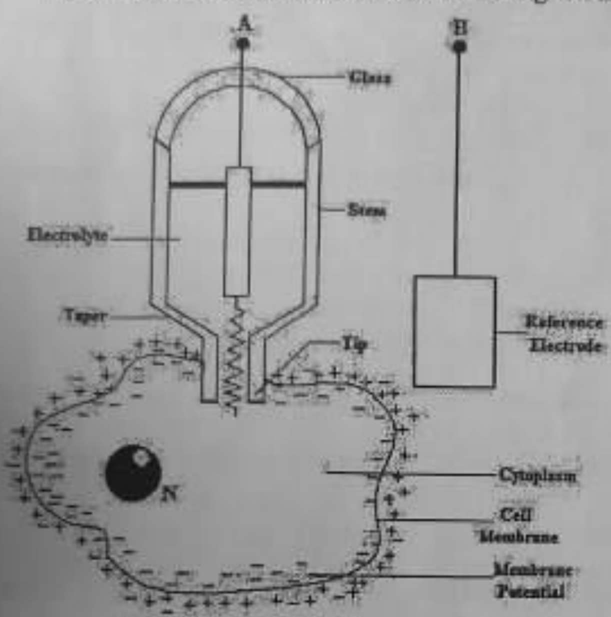
$$E = E_A + E_B + E_C$$

Where,
E_A – metal electrode-electrolyte potential at microelectrode tip.
EB – Reference electrode-electrolyte potential.
E_C – Variable cell membrane potential.



b) Micro-pipet or Non-metal micro electrodes

Non-metallic micro electrode is made up of a glass micropipet with 1 micron tip diameter. It is filled with an electrolyte usually 3M KCl. This electrolyte is compatible with cellular fluids. A thin flexible metal wire made of chlorided silver tungsten or stainless steel is inserted into the stem of micropipette. One end of the metal wire is fixed to a rigid support while the other end which is free rests on the cell as shown is fig. 1.5a.



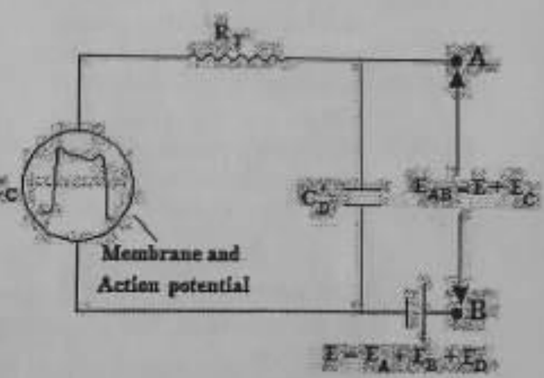


Fig. 1.5b Approximate equivalent circuit

Fig. 1.5a Micropipet

There are four potentials present here

E_A – Potential between electrolyte and metal wire in the micropipet.

E_B – Potential between reference electrode and extra-cellular fluid.

E_C – Variable cell membrane potential

E_D – Potential existing at the electrode tip due to different electrolytes present in the micropipet and cell.

The potential between electrode terminals A and B is given by

$E_{AB} = E_C + E'$ where $E' = E_A + E_B + E_D$

An approximate equivalent circuit of a non-metal electrode (micropipet) is shown in fig. 1.5b.

2. Depth and Needle Electrodes

When electrodes are to be used to measure bio-electric potential among a group of cells, it is necessary to penetrate the skin (percutaneous electrodes). Hence depth and needle electrodes are used.

a) Depth electrodes

Each electrode consist of a bundle of teflon insulated platinum (90%) - iridium (10%) alloy wires, bonded to a central supporting stainless steel wire. The ends of individual wires in the bundle constitute individual electrodes. The active area of depth electrode is about $0.5mm^2$. In some depth electrodes, the supporting steel wire is in the form of capillary tube which is used to inject medicines.

b) Needle electrodes

Needle electrodes are used in recording muscle action (EMG) and nerves' action (Electroneurography). A short length of fine insulated metal wire is bent at its one end and the bent portion is inserted through the lumen(hollow cavity) of the needle and is advanced into the muscle. The needle is withdrawn and the bent wire is resting inside the muscle. The reference electrode is placed on the skin. This type of electrode is called *Monopolar*.

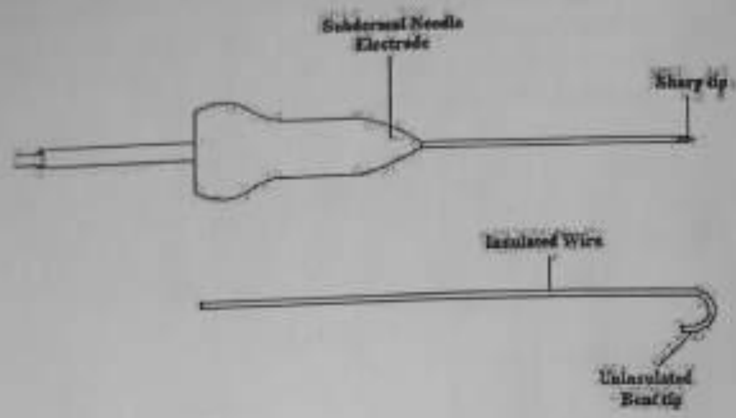


Fig. 1.6 Needle electrodes

When two insulated wires are inserted into the lumen of the hypodermic needle, then the electrode is called *Bipolar*. Here one wire acts as active electrode and the other acts as the reference. The electrodes are bare only at the tip and the rest is coated with Teflon insulation.

3. Surface electrodes

When potentials are to be measured on the surface, surface electrodes are used. They are found in different forms and shapes. Larger electrodes are used in ECG measurement while smaller ones are used in EEG and EMG. There are different types of surface electrodes

a. Metal plate electrodes
b. Suction cup electrodes
c. Adhesive tape electrodes
d. Multipoint electrode
e. Floating electrode

a) Metal plate electrodes

Rectangular (3.5cm × 5 cm) and circular (4.75cm dia) plates made of german silver, nickel silver and nickel plated steel are used as surface electrodes. They are mostly used when the electrodes are to be clamped on the limbs (hands and legs). Hence these electrodes are also called as *Limb electrodes*.

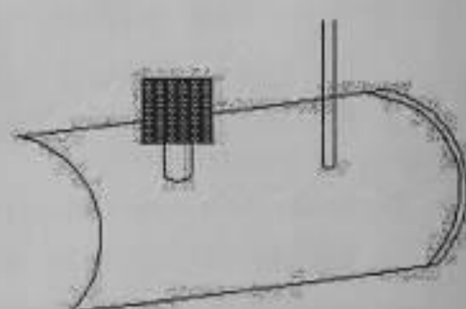


Fig. 1.7a Metal plate electrode

These electrodes are connected via long cables to the output device.
These electrodes have typical contact dc resistances in the range of 2 to 10kΩ.

b) Suction cup electrodes

It is used when the surface to be attached is flat and the underlying region is soft tissue. Although physically large the area of contact is small because only rim is in contact with the skin. This electrode has a hollow tube attached to the electrode rim on one end and a hollow rubber bulb on the other end.

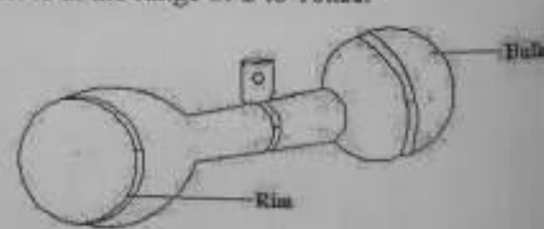


Fig. 1.7b Suction cup electrode

The rubber bulb is pressed to fix the electrode on the body surface, by using the vacuum created.

Adhesive tape electrode

It consists of a light weight metallic screen backed by a pad for electrode paste. It is also called *pre-gelled electrode*. Nowadays these electrodes are used as *disposable electrodes*. The adhesive packing holds the electrode in place and slows down evaporation and avoids squeezing out of electrode paste present. The backside of the pad has a terminal to be connected by clips to the external circuit.

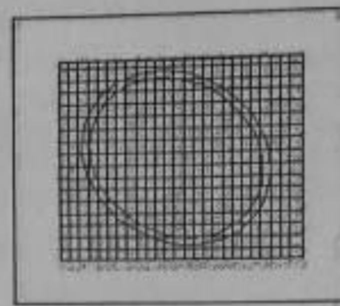


Fig.1.7c Adhesive tape electrode

Multipoint electrode

The multipoint electrode is used for ECG measurements. It contains nearly 1000 fine active pointed contact points. When the region to be examined has hairs, multipoint electrodes can be used without removing the hairs. Since the contact is made through many points, the contact impedance is very less.

c) Floating electrode

The purpose of this electrode is to eliminate unwanted noises produced due to movement artefacts. Here the electrode is placed at a higher level from the skin. The conductive path between the electrode surface and skin is formed by an electrolytic bridge, which is an electrolyte paste or jelly. Floating electrodes are attached to the skin with the help of adhesive rings surrounding the electrode.

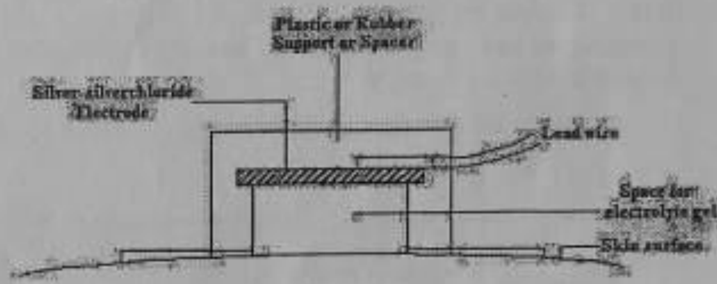


Fig. 1.7d Floating electrode

Application of electrodes

Micro electrodes are used

1. to measure bio-electric potential of single cell
2. to detect pleurosis(accumulation of fluids in the outer layer of lungs) in lungs.

Depth electrodes are used

to study electrical activity of the neurons in superficial (outer) layers of brain

Needle electrodes are used

1. to record peripheral nerve action potentials.
2. in ERG (electro-retinography).

Metal plate electrodes

1. are used while recording ECG.
2. are used in recording echo-cardiography.

Suction cup electrodes

1. are used in ECG recording.

2. are used in EMG.

Adhesive tape electrodes are used

1. in recording ECG.
2. in EOG (Electro-oculography)
3. in treadmill testing

Multipoint electrodes are used

1. to study bio-electric potential on head
2. to study bio-electric potential in regions with hair.

Floating electrodes are used

1. in long term monitoring.
2. in exercise testing.

2. What are the limitations of a simple operational amplifier circuit? Draw the circuit of a differential amplifier and derive an expression for the output voltage. (Sep 20, May 19, Nov 19, Nov 16)

Limitations of a simple operational amplifier circuit:

- The input current isn't exactly zero.
- The input offset current isn't exactly zero either.
- The input impedance isn't infinite.
- There is a limited common mode voltage range.
- The output impedance isn't zero.
- There are voltage gain limitations including phase shifts.

Differential Amplifier

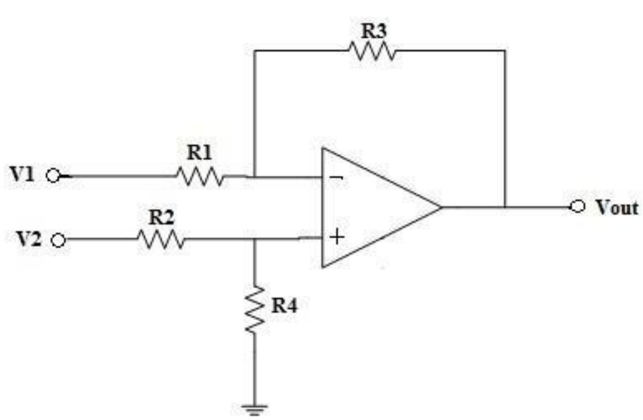


Fig.- Differential Amplifier Circuit

The difference amplifier shown in the above circuit is a combination of both inverting and non-inverting amplifiers. If the non-inverting terminal is connected to ground, the circuit operates as an inverting amplifier and the input signal V_1 is amplified by – (R_3 / R_1).

Similarly, if the inverting input terminal is connected to ground, the circuit behaves as a non-inverting amplifier. With the inverting input terminal grounded, R_3 and R_1 function as the feedback components of a non-inverting amplifier.

Input V_2 is potentially divided across resistors R_2 and R_4 to give V_{R4}, and then V_{R4} is amplified by (R_3 + R_1) / R_1.

With $V_2 = 0$,

$$V_{O1} = -(R_3 / R_1) * V_1$$

With $V_1 = 0$,

$$V_{R4} = \{R_4/(R_2+R_4)\}*V_2$$

and

$$V_{O2} = \{(R_1+R_3)/R_1\}*V_{R4}$$

Therefore,

$$V_{O2} = \{(R_1 + R_3) / R_1\} * \{R_4 / (R_2 + R_4) \} * V_2$$

If the input resistances are chosen such that, $R_2 = R_1$ and $R_4 = R_3$, then

$$V_{O2} = \{R3 / R_1\} * V_2$$

Now, according to superposition principle if both the input signals V_1 and V_2 are present, then the output voltage is

$$V_O = V_{O1} + V_{O2}$$

$$= \{-(R_3 / R_1) * V_1\} + \{R3 / R_1\} * V_2$$

Which results in,

$$V_O = (R_3 / R_1) * \{V_2 – V_1\}$$

When the resistors R_3 and R_1 are of the same value, the output is the direct difference of the input voltages applied. By selecting R_3 greater than R_1, the output can be made an amplified version of the difference of the input voltages.

Common Mode Rejection Ratio (CMRR)

The ability of a differential amplifier to reject common mode input signals is expressed in terms of common mode rejection ratio (CMRR). The common mode rejection ratio of a differential amplifier is mathematically given as the ratio of differential voltage gain of the differential amplifier to its common mode gain.

$$CMRR = | A_d / A_c |$$

Ideally, the common mode voltage gain of a differential amplifier is zero. Hence the CMRR is ideally infinite.

Characteristics of a Differential Amplifier

- High Differential Voltage Gain
- Low Common Mode Gain
- High Input Impedance
- Low Output Impedance
- High CMRR

3. What are chopper amplifiers? Draw and explain the working of mechanical chopper amplifiers. (Nov 18, May 19, Nov 17, May 17)

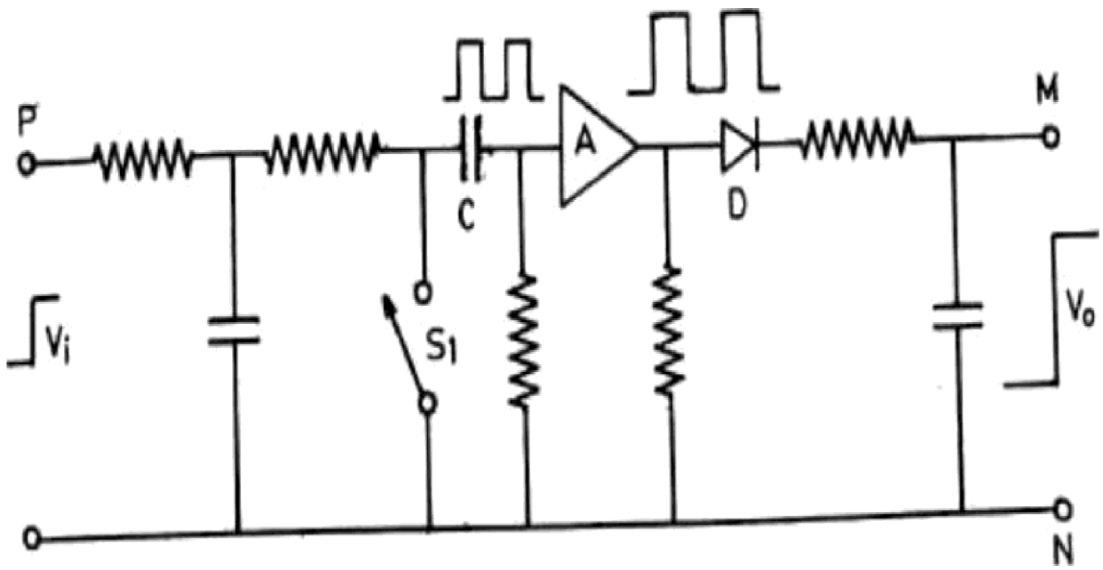
3.8 CHOPPER AMPLIFIER

Chopper amplifier is used in the biomedical measurement because biosignals have the frequency range from d.c. to few hundred Hertz. Chopper amplifiers are available in the form of mechanical choppers and nonmechanical choppers. The chopper is used to convert the d.c. or low frequency signal into a high frequency signal. Then this modulated high frequency signal is amplified by conventional a.c. amplifier. Finally the amplified signal is demodulated and filtered to get amplified d.c. or low frequency signal. It is well known that the chopper amplifier has no drift.

3.8.1 Mechanical Chopper Amplifier

In the above figure 3.20, the chopper S_1 is an electromagnetically operated switch or relay. It connects alternatively the input terminal of the a.c. amplifier 'A' to the reference terminal 'Q' which is usually connected to ground. When the amplifier input terminal is

yggfexo1 witb g, it 1 t&h cixuitsd sld tile iaput olnF** ^-*"'^ the thoyjw ,*
opa, Its sapkfi« faelws i6cugd
g\Qjsx fa a.a Oltkg wfying from zero to the value of the input voltage. By this process a steady d.c. or slowly varying signal is chopped into a train of square wave pulses having a frequency equal to the rate of the chopper. After amplification the chopped signal is rectified with a diode 'D'. The rectified signal is then filtered and the amplified d.c. or slowly varying signal is obtained at the output terminals M and N.



Note: It is apparent that the responses S_1 and S_2 at the input and output terminals of ihe chopping or sampling rate. For faithful reproduction of a signal by this means it is important that the signal being chopped is not changed appreciably between samples. For example if the signal is changing slowly, it is necessary to use a high chopping rate. The chopping rate should be atleast ten times greater than the highest frequency component of the signal for good fidelity. Using mechanical choppers we cannot achieve high chopping rates d h

4. Explain in detail about biomedical/physiological transducers. (Nov 17, May 17, May 16, Nov 16)

Transducers are devices which convert one form of energy into another. Because of the familiar advantages of electric and electronic methods of measurement, it is the usual practice to convert all non-electric phenomenon associated with the physiological events into electric quantities.

A number of factors decide the choice of a particular transducer to be used for the study of a specific phenomenon. These factors include:
• The magnitude of quantity to be measured.
• The order of accuracy required.
• The static or dynamic character of the process to be studied.
• The site of application on the patient's body, both for short-term and long-term monitoring.
• Economic considerations.

Classification:

By the process used to convert the signal energy into an electrical signal. For this, transducers can be categorized as:
1. **Active Transducers**: It converts one form of energy into another form without using an external power source. Example: Photovoltaic cell. It converts light energy into electrical energy.
Types of Active Transducers

1. Magnetic Induction Type
2. Piezoelectric Type
3. Photovoltaic Type
4. Thermoelectric Type

2. **Passive Transducers**: It converts one form of energy into another form with the help of an external power source. It utilizes the principle of controlling DC voltage or AC carrier signal. Example: Strain Gauge, Load cell.
Types of Passive Transducers

1. Resistive Type
2. Inductive type
3. Capacitive Type

<u>Active Transducers:</u>

Magnetic Induction Type Transducers:

When an electrical conductor moves in a magnetic field, it changes the magnetic flux through the conductor. This produces a voltage, which is proportional to the rate of change of flux. Induced EMF is given as

$$e = -B \times l \times V$$

Where B is the magnetic induction, l is the length of the conductor, and V is the velocity of the moving conductor.
The negative sign indicates that the direction of induced EMF and the direction of induced current are in the opposite direction.
The inverse magnetic effect is also true. When current passes through the electrical

conductor placed in the magnetic field, mechanical force F acts on the conductor.

$F = B \times i \times l$

Applications Magnetic Induction Type Transducers:

- Electromagnetic flow meter
- Heart sound Microphones
- Indicating instruments
- Pen motor in biomedical recorders

Piezoelectric Transducers:

When compression or tension is applied to the crystal, charge separation occurs in the crystals. This produces electrical voltage resulting in Piezoelectric Effect. Piezoelectric transducers convert displacement or pressure into an electrical value. Barium Titanium, Rochelle salt, Lithium Niobate are few piezoelectric transducer materials.

Applications of Piezoelectric Transducers

- Piezoelectric Transducer acts as a pulse sensor to measure the pulse rate of a human.

Photovoltaic Transducers:

When light or any other radiation of wavelength falls on the metal or semiconductor surface, it ejects electrons. This is the Photoelectric Effect. Photoemissive, Photoconductive and photovoltaic are the types of Photoelectric Transducers. Among these, Photovoltaic is an active transducer which generates an electrical voltage in proportion to the radiation incident on it.

Applications of Photovoltaic Transducers

- In Photoelectric Plethysmography silicon photovoltaic cells acts as pulse sensor.
- To measure sodium and potassium ion concentration in a sample using light absorption techniques.

Thermoelectric Transducers:

These transducers work based on the Seebeck Effect. Seebeck effect states that, when two junctions of the thermocouple are at two different temperatures, it generates a potential voltage. The generated voltage is proportional to the difference in temperature between two junctions of the thermocouple.

Applications of Thermoelectric Transducers

- To measure physiological temperature in remote sensing circuits and biotelemetry circuits.
- In the doctor’s cold box to store plasma, antibiotics, etc.

Passive Transducers:

Resistive Transducers:

The strain gauge, photoresistor, photodiode, phototransistor, and thermistor come under resistive type passive transducers. They have a common working principle, which states that the measured parameter results in a small change in the resistance of a transducer. Usually, a Wheatstone bridge measures the resistance change.

Applications of Resistive Transducers

- Finger-mounted strain gauge measures small changes in blood volume flowing via the finger.
- LDR or photoresistor measures the pulsatile blood volume changes.

Capacitive Transducers:

A capacitor has two conducting surfaces. A dielectric medium acts separating gap between two surfaces. Capacitive transducers measure the change in displacement due to change in the area of conducting plates, the thickness of the dielectric medium and distance between the plates.

Applications of Capacitive Transducers

- Differential capacitive transducers measure blood pressure.

Inductive Transducers:

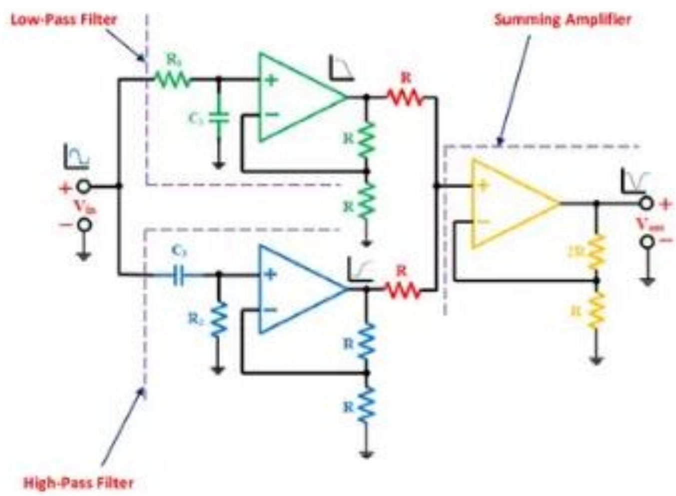
Inductive transducer works based on the change in reluctance and number of turns in the coil. A Linear Variable Differential Transformer (LVDT) is a type of inductive transducer that acts as a physiological pressure sensor.

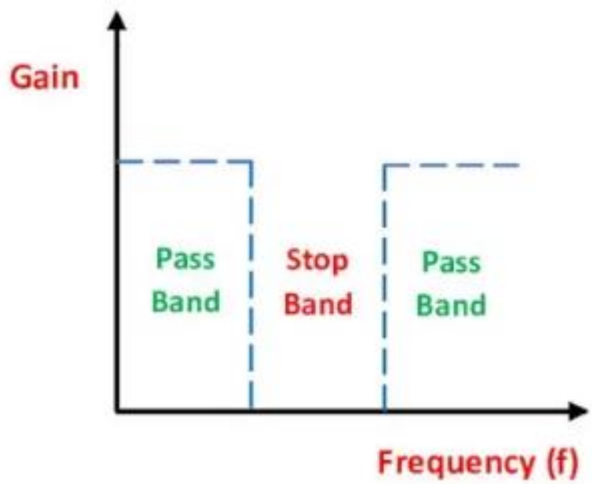
Application of Inductive Transducers

- To measure tremor in patients suffering from Parkinson's disease.

5.What is a Notch Filter (Bandstop Filter)?
A notch filter (also known as a bandstop filter or reject filter) is defined as a device that rejects or blocks the transmission of frequencies within a specific frequency range and allows frequencies outside that range. Notch filters eliminate transmission of a narrow band of frequencies and allow transmission of all the frequencies above and below this band. As it eliminates frequencies hence, it is also called a band elimination filter.

A notch filter is essentially a band stop filter with a narrow stopband and two passbands. As in the band-pass case, a band-reject filter can be either wideband or narrow-band.





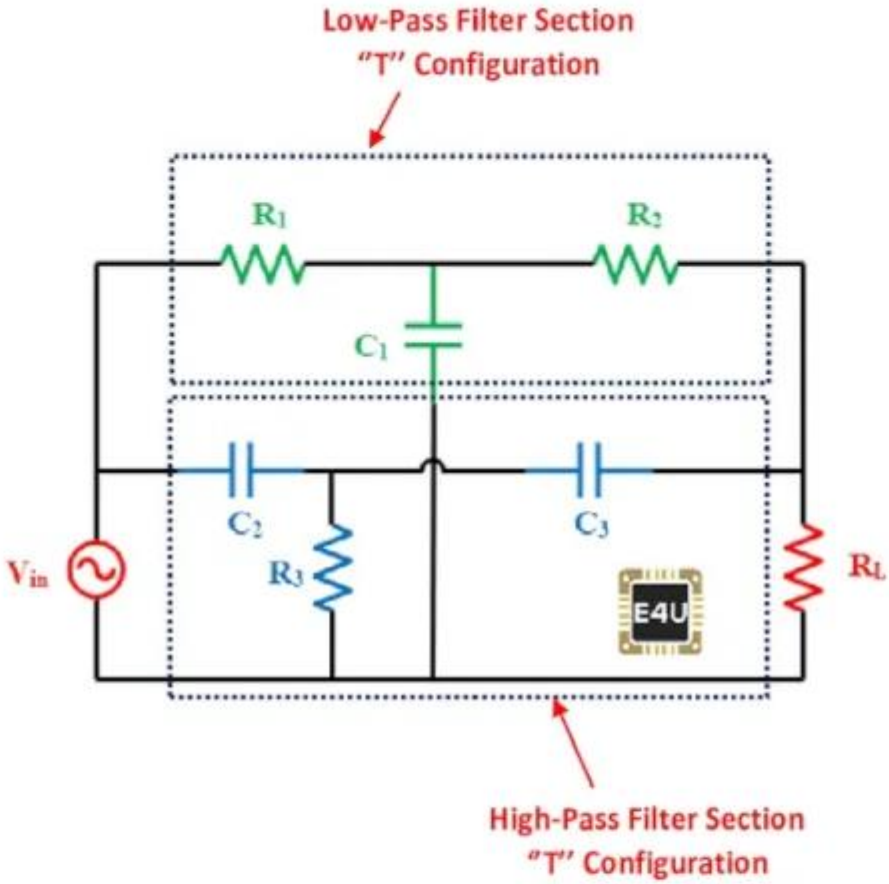
If the filter is wideband, it is referred to as a band-reject filter and if the filter is narrow-band, it is referred to as a notch filter. The characteristics of a band-stop filter are exactly the reverse of the bandpass filter. Hence, the notch filter is a complement of the bandpass filter.

For example, if a Notch Filter has a stopband frequency from 100 MHz to 200 MHz, then it will pass all the signals from DC to frequency of 100 MHz and above 200 MHz, it will only reject frequency between 100 MHz to 200 MHz.

Thus, the function of a Notch Filter is to passing all those frequencies from zero (DC) up to lower cut-off frequency(fL) and above higher cut-off frequency(fH), and reject all those frequencies that lie in the bandwidth region i.e., BW= fH-fL.

Notch Filter Circuit

The notch filter is a combination of low pass and high pass filters similar to the bandpass filter design, but the difference is that we connect both the filters in parallel connection instead of cascading connection. The circuit diagram of the notch filter is shown in the below figure.



The upper portion of the notch filter circuit is a passive RC low pass filter. This portion comprises two resistors R1, R2,and capacitor C1 in the form of a ‘T’ configuration. This filter will allow the signals having frequencies lower than the higher cut-off frequency (fH).

The lower portion of the notch filter circuit is a passive RC high-pass filter. This portion comprises two capacitors C2, C3,and resistor R3 also in the form of ‘T’ configuration. This filter will allow the signals having frequencies higher than the lower cut-off frequency (fL). This combination of both ‘T’ configuration is commonly known as a ‘Twin-T’ filter.

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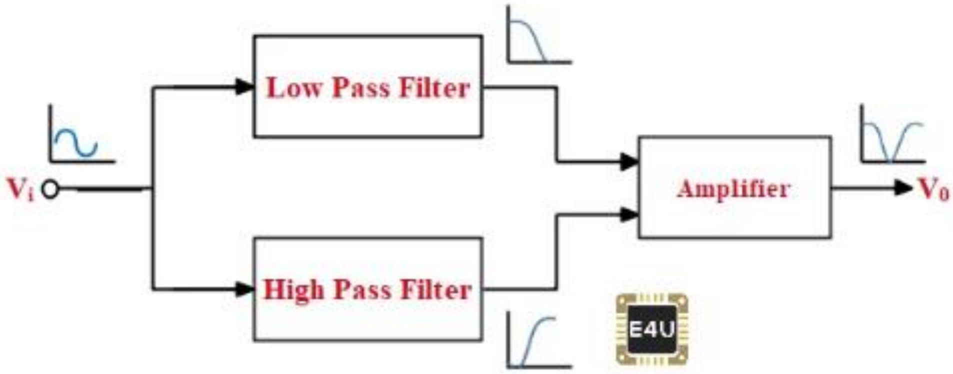
The typical configuration and a frequency response of a notch filter is shown in the figure below.



Typical Configuration of a Notch Filter

MEDICAL INSTRUMENTATION BM T55

UNIT – II MEASUREMENT OF PHYSIOLOGICAL PARAMETERS

2 Marks:

1. What are the different methods used for measuring cardiac output? (May 16)

- Doppler echocardiography
- dilution methods and especially thermo dilution method
- Fick's principle, traditional method
- non-invasive modifications of Fick's method

2. Define Doppler Effect. (May 16)

The Doppler Effect describes the change in the observed frequency of a wave when there is relative motion between the wave source and the observer ..... Waves come in a variety of forms: ripples on the surface of a pond, sounds (as with the siren above), light, and earthquake tremors all exhibit periodic wave motion.

3. Define the term: Vector Cardiograph. (May 19)

Vector cardiography is the technique of analyzing the electrical activity of heart by obtaining ECG along three axes.

• The display is known as vector cardiogram.

• This gives the representation of distribution of electrical potential generated by the heart ,and produces loop type patterns on the CRT screen.

4. What are the dynamic characteristics of a measurement system? (Nov 16)

The set of criteria defined for the instruments, which are changes rapidly with time, is called 'dynamic characteristics'.

E.g.: Fidelity, Bandwidth, Speed of response, Measurement lag.

5. What is sensitivity? (Nov 16)

Sensitivity is a measure for how strong a stimulus has to be, before a system reacts to it; the smaller a stimulus is sufficient to elicit a reaction

6. What is Plethysmography? (Dec 19)

Plethysmography measures changes in volume in different areas of your body. It measures these changes with blood pressure cuffs or other sensors. These are attached to a machine called a plethysmograph.

Plethysmography is especially effective in detecting changes caused by blood flow. It can help your doctor determine if you have a blood clot in your arm or leg. It can also help your doctor calculate the volume of air your lungs can hold.

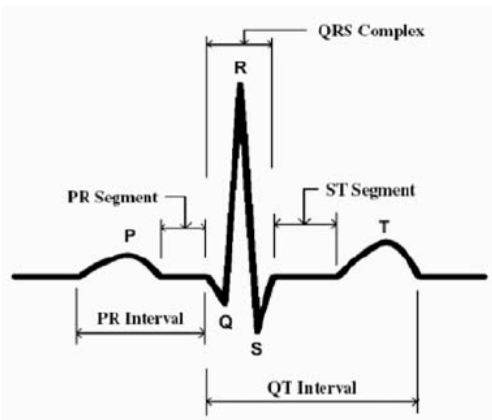
7. Differentiate acidic pH from basic pH (Dec 19)

Acidic pH	Basic pH
1. If the concentration of hydrogen ions (H+) in the liquid is high, it is acidic	1. If the concentration is low, it is basic (alkaline)
2. pH below 7.0 is acidic	2. pH above 7.0 is alkaline, or basic

8. Define cardiac output. (Dec 19)

Cardiac output is the volume of blood the heart pumps per minute. Cardiac output is calculated by multiplying the stroke volume by the heart rate. Stroke volume is determined by preload, contractility, and afterload.

9. Draw the ECG waves and mention its part. (May 18)



10. Write the pH value of acid, base and neutral. (May 18)

The range goes from 0 - 14, with 7 being neutral. pHs of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base.

11. Define tidal volume. (Dec 17)

Tidal volume is the amount of air that moves in or out of the lungs with each respiratory cycle. It measures around 500 mL in an average healthy adult male and approximately 400 mL in a healthy female.

12. What are the different heart sounds of heart? (Dec 17)

A normal heartbeat has two sounds, a lub (sometimes called S1) and a dub (S2). These sounds are caused by the closing of valves inside your heart. Other heart sounds are S3 and S4.

13. What is arterial pressure? How is it measured? (May 17)

In general, an individual's “blood pressure,” or systemic arterial pressure, refers to the pressure measured within large arteries in the systemic circulation. This number splits into systolic blood pressure and diastolic blood pressure.

When arterial pressure is measured using a sphygmomanometer (i.e., blood pressure cuff) on the upper arm, the systolic and diastolic pressures that are measured represent the pressure within the brachial artery

14. Explain the terms bradycardia and tachycardia. (Sep 20)

Bradycardia is a slower than normal heart rate. The hearts of adults at rest usually beat between 60 and 100 times a minute. If you have bradycardia, your heart beats fewer than 60 times a minute.

In tachycardia, an abnormal electrical impulse starting in the upper or lower chambers of the heart causes the heart to beat faster. Tachycardia is the medical term for a heart rate over 100 beats per minute.

15. Explain the term residual volume and mention its normal value. (Sep 20)

It is the volume of air remaining in the lungs after maximal exhalation. Normal adult value is averaged at 1200ml (20-25 ml/kg) . It is indirectly measured from summation of FRC and ERV.

11 Marks:

1. a) With neat diagram explain the working of ECG system.
b) Explain the ECG Lead System. (Sep 20, May 19, Dec 19, May 18)

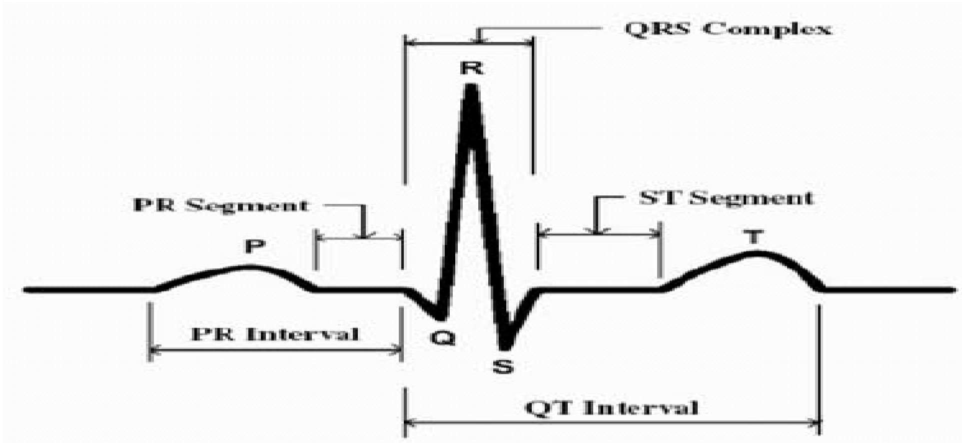
a) Electrocardiogram refers to the recording of electrical changes that occurs in heart during a cardiac cycle. It may be abbreviated as ECG or EKG.

Electrocardiograph:

- It is an instrument that picks up the electric currents produced by the heart muscle during a cardiac cycle of contraction and relaxation.

Working principle of electrocardiograph:

- It works on the principle that a contracting muscle generates a small electric current that can be detected and measured through electrodes suitably placed on the body.
- For a resting electrocardiogram, a person is made to lie in the resting position and electrodes are placed on arms, legs and at six places on the chest over the area of the heart. The electrodes are attached to the person's skin with the help of a special jelly.
- The electrode picks up the current and transmit them to an amplifier inside the electrocardiograph. Then electrocardiograph amplifies the current and records them on a paper as a wavy line.
- In an electrocardiograph, a sensitive lever traces the changes in current on a moving sheet of paper.
- A modern electrocardiograph may also be connected to an oscilloscope, an instrument that display the current on a screen.



- P-wave:
  - It is a small upward wave that appears first
  - It indicates atrial depolarization (systole), during which excitation spreads from SA node to all over atrium
  - About 0.1 second after P-wave begins, atria contracts. Hence P-wave represents atrial systole
- QRS wave:
  - It is the second wave that begins as a little downward wave but continues as a large upright triangular wave and ends as downward wave
  - It represents the ventricular depolarization (systole)
  - Just after QRS wave begins, ventricles starts to contracts. Hence QRS wave represents ventricular systole
- T- wave:
  - It is third small wave in the form of a dome-shaped upward deflection.
  - It indicates ventricular repolarization (diastole)
  - It also represents the beginning of ventricular diastole
  - ** ATRIAL DIASTOLE MERGES WITH QRS-WAVE
- P-R interval:
  - It represents the time required for an impulse to travel through the atria, AV node and bundle of his to reach ventricles.
- S-T segment:
  - It is measured from the end of S to the beginning of T- wave
  - It represents the time when ventricular fibres are fully depolarized.

Application of ECG:

- it indicates the rate and rhythm or pattern of contraction of heart
- it gives a clue about the condition of heart muscle and is used to diagnose heart disorders
- it helps the doctors to determine whether the heart is normal, enlarged or if its certain regions are damaged

b) ECG Lead system:

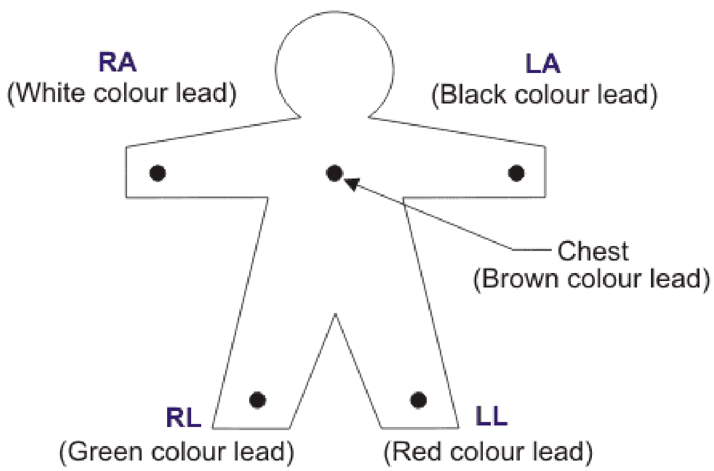
The electrical signals from the heart are measured with surface electrodes. The resulting electrode potential in the heart conducts to the body surface. Standardized electrode positions are used to record the ECG. The three types of electrode systems are

1. Bipolar limb leads or standard leads
2. Augmented unipolar limb leads
3. Chest leads
4. Frank lead system

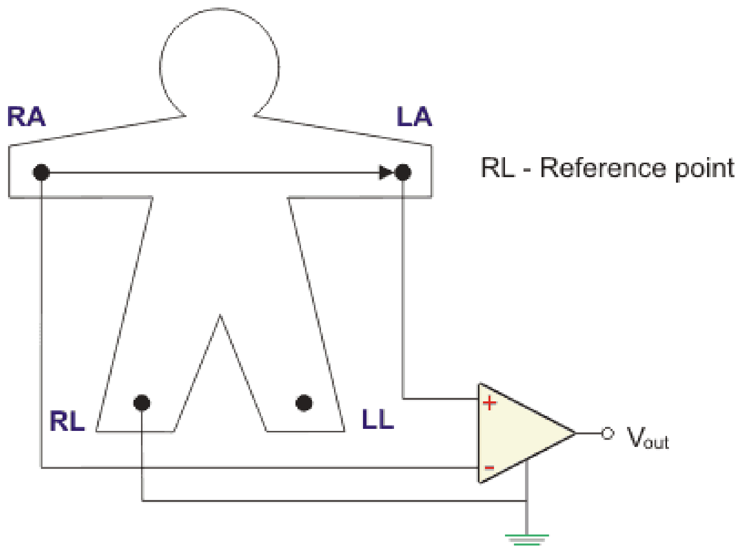
I) Bipolar Limb leads – Standard Lead I, Lead II and Lead III

This lead system is also known as Einthoven lead system. Two electrodes record the ECG signal. As shown in figure from four body locations of our body namely Right Arm(RA), Left Arm(LA), Right Leg(RL) and Left Leg(LL) potentials are recorded.

Final output is the difference between the electrical potential generated between these two electrodes. Right leg is the ground reference electrode.

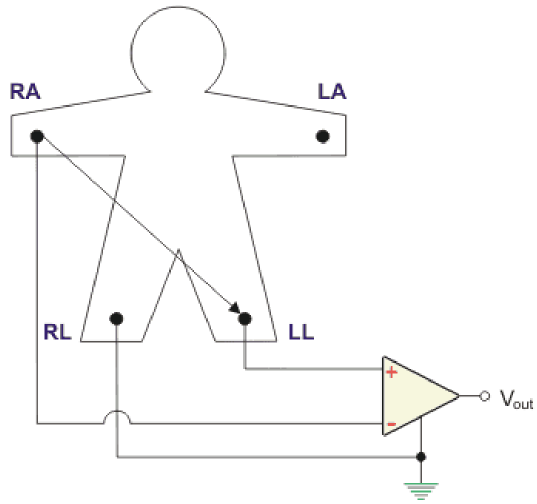


Lead I



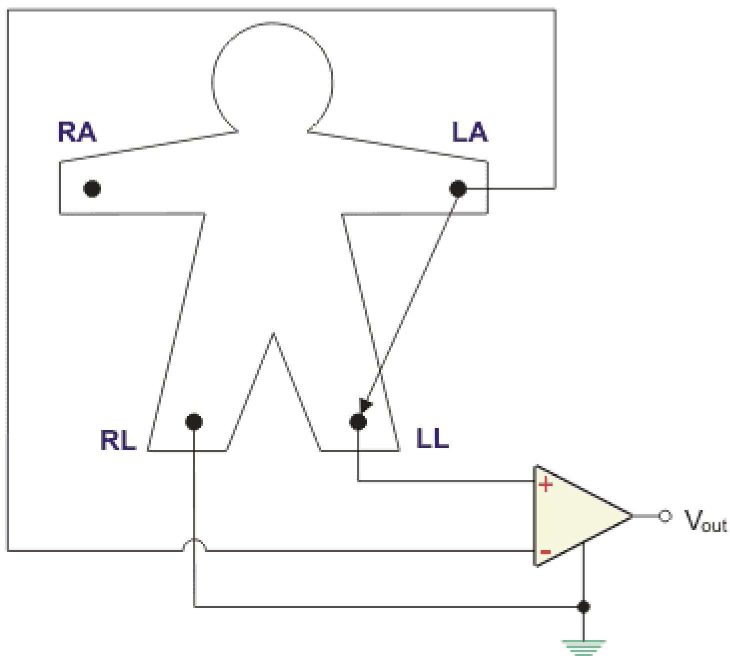
Voltage drop occurs from left arm to right arm. Generated voltage is V_I.

Lead II



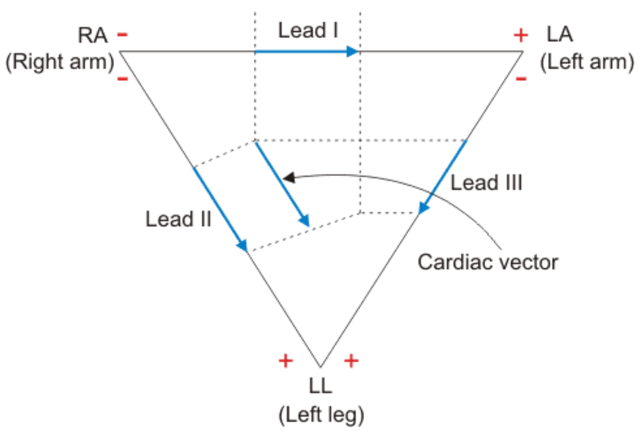
Voltage drop occurs from left leg to right arm. Generated voltage is V_{II}.

Lead III

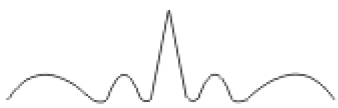
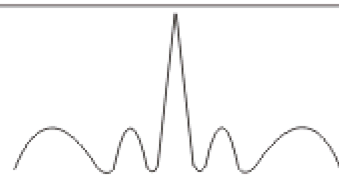
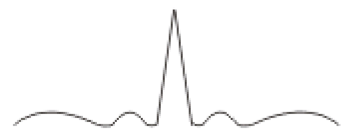


Voltage drop occurs from left leg to left arm. Generated voltage is V_{III}.

Einthoven Triangle



Einthoven triangle is the closed path formed between right arm, left arm, left leg and right arm. Einthoven has defined that cardiac electric vector is two dimensional along the frontal plane of the body. Along the projections of the triangle, vector sums on three sides of triangle is zero. We can tell, by Kirchhoff's law, the amplitude of R wave along the lead III is equal to the summation of amplitude of R wave along lead I and lead II.

Lead I	Lead II	Lead III
		
R-wave amplitude = 0.07 to 1.13 mV	R-wave amplitude = 0.18 to 1.68 mV	R-wave amplitude = 0.03 to 1.31 mV

If $V_1 = 0.53$ mV (for lead-I)

$V_2 = 0.71$ mV (for lead-II)

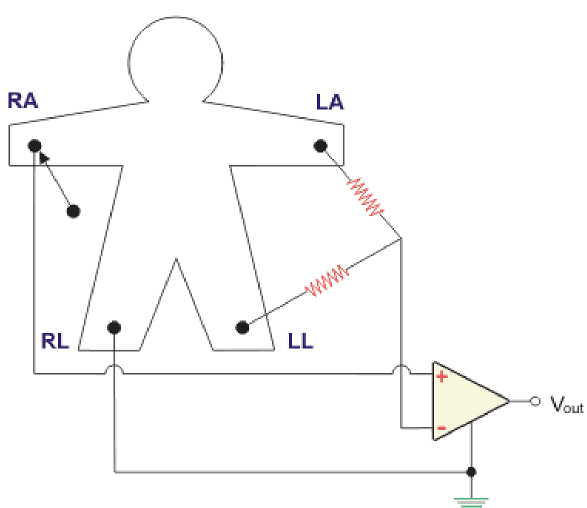
$V_3 = 0.38$ mV (for lead-III)

Always $V_2 \approx V_1 + V_3$ (Kirchoff's voltage law is followed)

II) Augmented Unipolar Leads:

. Central terminal relates to the center of the body. Two equal and large resistors are used. Pair of limb electrodes is connected to the resistors. The center joint connection of this resistive network forms the central terminal. The remaining portion of the limb electrode forms the exploratory electrode. In this lead system, a very small increase in ECG voltage can be found. Three types of connections are used.

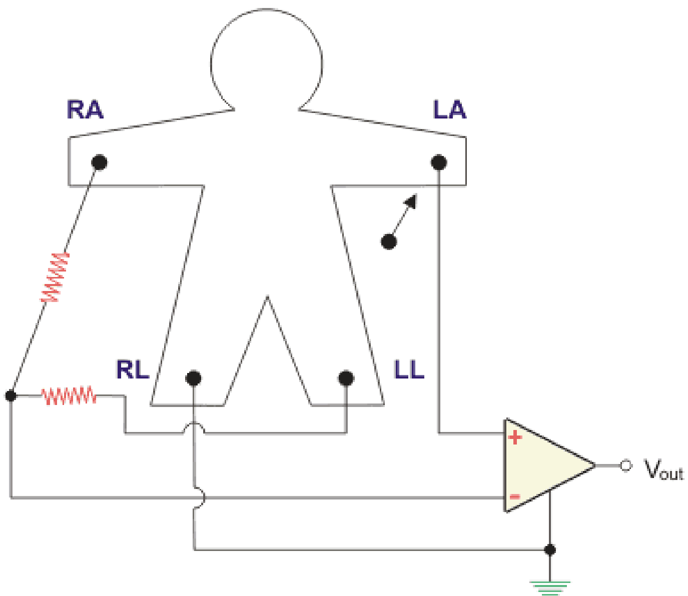
Lead aVR



Two resistors are connected to left arm and left leg. The middle point of the resistor connection is connected with negative terminal. Right arm is connected with the positive terminal of the amplifier. Here also right leg acts as a reference terminal.

$$aVR = -V_1 - \frac{V_3}{2} \ (V_1 \ and \ V_3 \ are \ bipolar \ lead \ voltage)$$

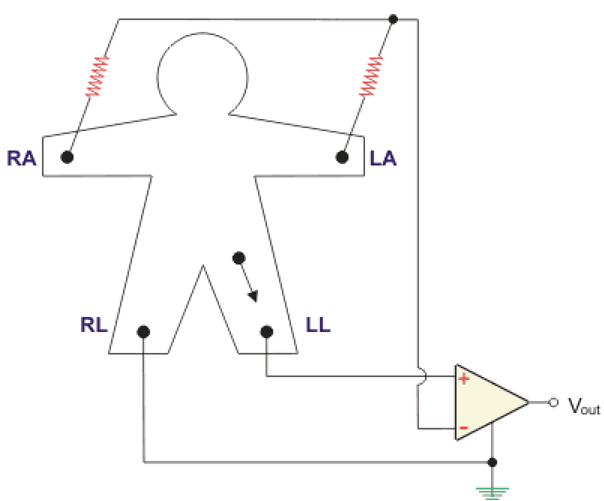
Lead aVL



Two resistors are connected to right arm and left leg. The middle point of the resistor connection is connected with negative terminal. Left arm is connected with the positive terminal of the amplifier. Right leg acts as a reference terminal.

$$aVL = V_1 - \frac{V_2}{2} \ (V_1 \ and \ V_3 \ are \ bipolar \ lead \ voltage)$$

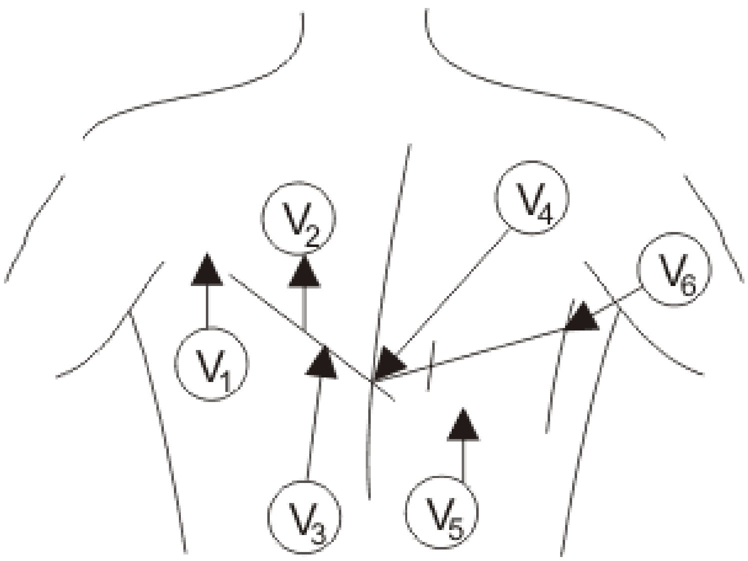
Lead aVF



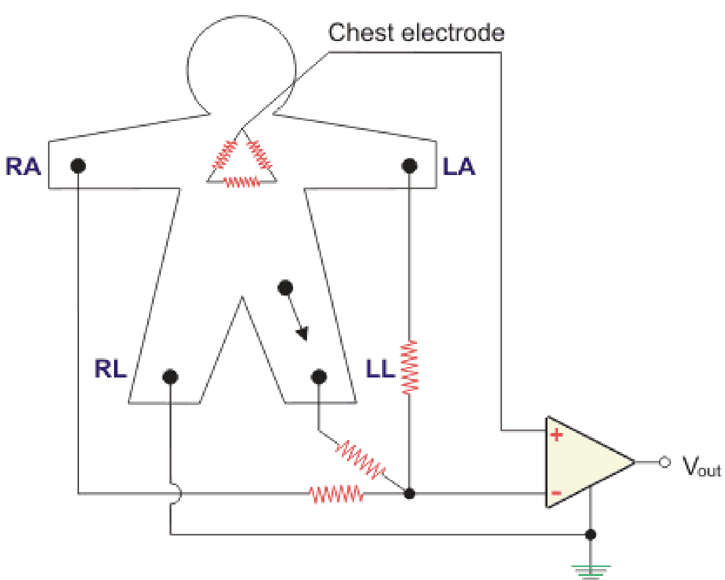
Two resistors are connected to right arm and left arm. The middle point of the resistor connection is connected with negative terminal. Left leg is connected with the positive terminal of the amplifier. Here also right leg acts as a reference terminal.

$$aVF = -V_2 - \frac{V_1}{2} \ (V_1 \ and \ V_3 \ are \ bipolar \ lead \ voltage)$$

III) Chest Leads:



V_1 – Fourth intercostal space of right sternal margin,
V_2 – Fourth intercostal space at left sternal margin,
V_3 – Midpoint between V_2 and V_4,
V_4 – Fifth intercostal space at mid – clavicular line,
V_5 – Same as V_4 position but on anterior auxiliary line,
V_6 – Same as V_4 position but on mid auxiliary line.



IV) Frank Lead System:

In this method, the state of heart is studied 3 dimensionally. Here information are got from 12 lead system - 3 Bipolar leads, 3 Unipolar leads, 6 Chest leads. This method is also called as corrected orthogonal lead system.

2. Write in detail about measurement of blood pressure. (Dec 19, May 19, Dec 18, Dec 17)

Blood Pressure Measurement

- **Direct (invasive)**
  1. **Extravascular Method**
     - The vascular pressure is coupled to an external sensor element via a liquid filled catheter.

[**Catheter** – is a long tube introduced into the heart or a major vessel by way of a superficial vein or artery.]

  2. **Intravascular**
     - A sensor is placed into the tip of a catheter that is placed in the vascular system.

- **Indirect (non invasive)**
  - **Sphygmomanometer**

  Consists of an inflatable pressure cuff and a manometer to measure the pressure in the cuff.

Direct Measurement
Extra Vascular

- The extra vascular sensor system is made up of a catheter.
- The catheter is connected to a three way stopcock and then to a pressure sensor
- It is filled with a saline-heparin solution.
- It must be flushed with solution every few minutes to prevent blood clotting at the tip.

- Physician inserts the catheter
  - Either by means of a *surgical cut-down*, which exposes the artery or vein.
  - or by means of *percutaneous insertion* which involves the use of a special needle or guide-wire technique.
- Blood pressure is transmitted via the catheter column to the sensor and finally to the diaphragm which is deflected.
- The displacement of the diaphragm is sensed electronically.

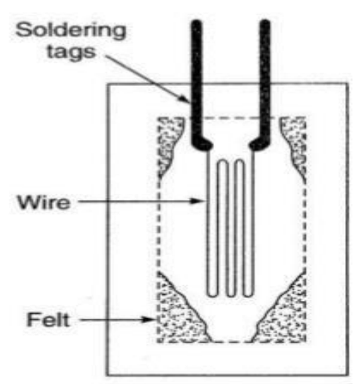
Direct Measurement

Intravascular

- The sensor is placed at the tip of the catheter.
- Enables the physician to obtain a high frequency response in detection of pressures at the tip of the catheter.
- Types of sensors
  1. Strain-gage systems
     - bonded onto a flexible diaphragm at the catheter tip.
  2. Fibre-optic device
     - Measures the displacement of the diaphragm optically by varying reflection of light from the back of the deflecting diaphragm.

Bonded Strain Gage pressure transducer

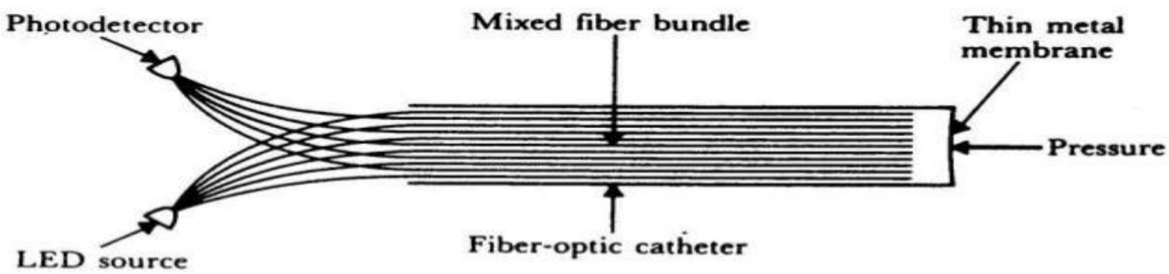
- Consists of strain-sensitive gages which are firmly bonded with an adhesive to the membrane or diaphragm whose movement is to be recorded.
- Made by taking a length of a very thin wire or foil which is formed into a grid pattern and bonded to a backing material.
- Is then attached to the diaphragm.
- Deflection of the diaphragm causes corresponding strain in the wire gage.
- Causes a corresponding change in the resistance which is proportional to the pressure.



Fiber optic type pressure transducer

- Measures the displacement of the diaphragm optically by the varying reflection of light from the back of the deflecting diaphragm.

- Inherently safer electrically



Indirect Blood Pressure Measurement - Sphygmomanometer

- The pressure cuff on the upper arm is first inflated to a pressure well above the systolic pressure.

- At this point no sound can be heard through the stethoscope, which is placed over the brachial artery, for that artery has been collapsed by the pressure of the cuff.

- The pressure in the cuff is then gradually reduced.

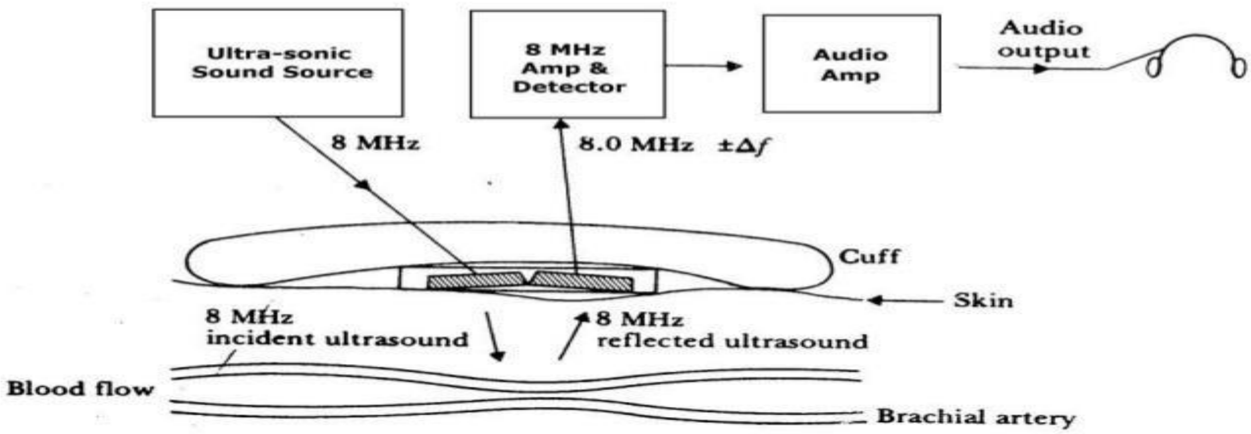
Ultrasonic Based Blood Pressure Measurement

- Employs a transcutaneous Doppler sensor that detects the motion of the blood-vessel walls in the various states of occlusion.

- The Doppler ultrasonic transducer is focused on the vessel wall and the blood.

- The reflected signal (shifted in frequency) is detected by the receiving crystal and decoded.

Ultrasonic Based Blood Pressure Measurement...



3. Describe the method used for respiration rate measurement in detail. (Dec 18, May 18, May 17, May 16, Nov 16)

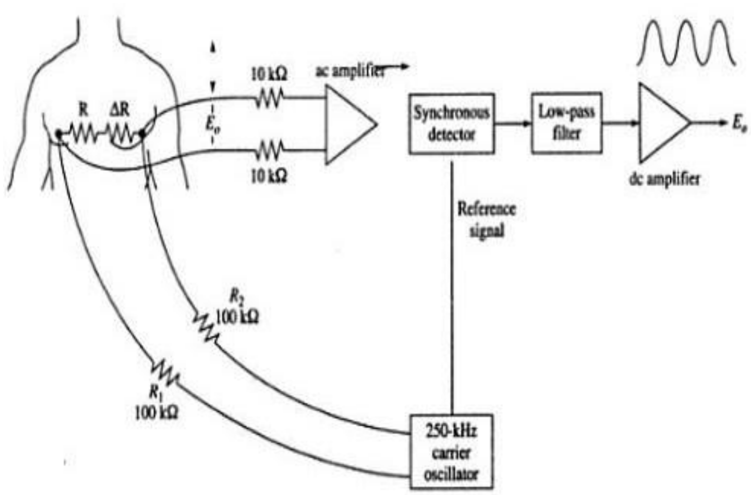
The respiration rate is the number of breaths a person takes per minute. The rate is usually measured when a person is at rest and simply involves counting the number of breaths for one minute by counting how many times the chest rises. Respiration rates may increase with fever, illness, and other medical conditions.

Commonly used methods are:

1. Displacement method
2. Thermistor method
3. Impedance pneumography

Impedance pneumography:

It is an indirect method used for the measurement of respiratory rate. It is comparatively simpler method because it does not require any placement of mask on the face, fixing of tubes etc. In this method we place only an electrode over the thorax region of patient.

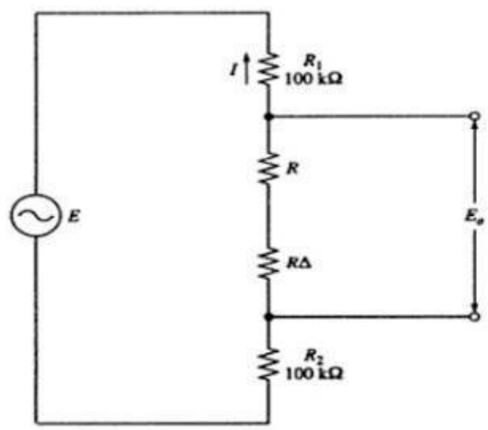


Here a low voltage ac signal is applied to the chest of patient through surface electrodes. High value fixed resistors connected in series with each electrode create a constant ac current source. Usually the current through the patient's chest is very small.

Advantages of impedance pneumograph:

1. Artifacts can be easily recognized
2. Electrically safe
3. Equipment is easy to use
4. The ability to obtain ECG from same electrode makes it useful during surgical anesthesia.
5. It is comfortable to the patient

The equivalent circuit of measurement technique is shown below.



The voltage drop across the resistance represents the patient's thoracic impedance

E0 = I(R + ΔR), where E0 is the output voltage in Volts.
I = Current through the chest in Ampere.
R = Chest Impedance without respiration in Ohms.
ΔR = Change in chest impedance caused by respiration in Ohms.

The signal E0 is amplified by the ac amplifier and applied to a synchronous AM detector. Amplitude variations in E0 are caused due to change in resistance (ΔR) which changes the respiration waveform. A LPF is used after the synchronous detector to remove carrier signal. DC amplifier after LPF is used to increase the output waveform up to a level as required by the display device.

4. Describe in detail a method to determine Total Lung Capacity. (Dec 17)

A number of the lung volumes can be measured by Spirometry- Tidal volume, Inspiratory reserve volume, and Expiratory reserve volume. However, measurement of Residual volume, Functional residual capacity, and Total lung capacity is through body plethysmography, nitrogen washout and helium dilution technique.

LUNG VOLUME:

- **Tidal Volume(TV)**

It is the amount of air that can be inhaled or exhaled during one respiratory cycle. This depicts the functions of the respiratory centres, respiratory muscles and the mechanics of the lung and chest wall.

The normal adult value is 10% of vital capacity (VC), approximately 300 -500ml (6-8 ml/kg); but can increase up to 50% of VC on exercise

- **Inspiratory Reserve Volume(IRV)**

It is the amount of air that can be forcibly inhaled after a normal tidal volume.IRV is usually kept in reserve, but is used during deep breathing. The normal adult value is 1900-3300ml.

- **Expiratory Reserve Volume(ERV)**

It is the volume of air that can be exhaled forcibly after exhalation of normal tidal volume. The normal adult value is 700-1200ml. ERV is reduced with obesity, ascites or after upper abdominal surgery

- **Residual Volume(RV)**

It is the volume of air remaining in the lungs after maximal exhalation. Normal adult value is averaged at 1200ml (20-25 ml/kg) .It is indirectly measured from summation of FRC and ERV and cannot be measured by spirometry.

In obstructive lung diseases with features of incomplete emptying of the lungs and air trapping, RV may be significantly high. The RV can also be expressed as a percentage of total lung capacity and values in excess of 140% significantly increase the risks of barotrauma, pneumothorax, infection and reduced venous return due to high intra thoracic pressures as noticed in patients with high RV who require surgery and mechanical ventilation thus needs high peri-operative inflation pressures.

- **Inspiratory capacity(IC)**

It is the maximum volume of air that can be inhaled following a resting state. It is calculated from the sum of inspiratory reserve volume and tidal volume. IC = IRV+TV

- **Total Lung Capacity(TLC)**

  It is the maximum volume of air the lungs can accommodate or sum of all volume compartments or volume of air in lungs after maximum inspiration.

  The normal value is about 6,000mL (4-6 L). TLC is calculated by summation of the four primary lung volumes (TV, IRV, ERV, RV).

  TLC may be increased in patients with obstructive defects such as emphysema and decreased in patients with restrictive abnormalities including chest wall abnormalities and kyphoscoliosis.

- **Vital Capacity(VC)**

  It is the total amount of air exhaled after maximal inhalation. The value is about 4800mL and it varies according to age and body size. It is calculated by summing tidal volume, inspiratory reserve volume, and expiratory reserve volume. VC = TV+IRV+ERV.

  VC indicates ability to breathe deeply and cough, reflecting inspiratory and expiratory muscle strength.VC should be 3 times greater than TV for effective cough. VC is sometimes reduced in obstructive disorders and always in restrictive disorders

- **Function Residual Capacity(FRC)**

  It is the amount of air remaining in the lungs at the end of a normal exhalation. It is calculated by adding together residual and expiratory reserve volumes. The normal value is about 1800 – 2200 mL. FRC = RV+ERV.

  FRC does not rely on effort and highlights the resting position when inner and outer elastic recoils are balanced. FRC is reduced in restrictive disorders. The ratio of FRC to TLC is an index of hyperinflation. In COPD, FRC is upto 80% of TLC.

Spirometry:

A **spirometry** is a pulmonary function test that measures how much air a person breathes out, and how quickly. Pulmonary function tests measure how well the lungs are working. It is an office-based diagnostic test that is short, simple, and commonly used. Spirometer is used to perform spirometry.

A **spirometer** is an apparatus for measuring the volume of air inspired and expired by the lungs. A spirometer measures ventilation, the movement of air into and out of the lungs. The spirogram will identify two different types of abnormal ventilation patterns, obstructive and restrictive.

MEDICAL INSTRUMENTATION BM T55

UNIT – III IMAGING SYSTEM AND TELEMETRY

2 Marks:

1. What is telemedicine? (Nov 16, May 17, Nov 19)

Telemedicine is the application of telecommunications and computer technology to deliver health care from one location to another. The telemedicine technology includes hardware, software, medical equipment and communications link. The technology infrastructure is a telecommunication network with input and output devices at each connected location.

2. List out some of the application of biotelemetry? (May 16)

- RF transmission for monitoring astronauts in space.
- Patient monitoring where freedom of movement is desired, such as in obtaining an exercise ECG.
- Special internal technique such as tracing acidity or pressure through gastrointestinal tract.

3. Define X-ray generation efficiency. (May 16)

The **efficiency** of **x**-**ray production** is **defined** as the total **x**-**ray** energy expressed as a fraction of the total electrical energy imparted to the anode. The two factors that determine **production efficiency** are the voltage applied to the tube, KV, and the atomic number of the anode, Z.

4. List out the application of PET scan. (Nov 19)

- Major use is in oncologic imaging.
- However it has a multitude of clinical applications in cardiology, neurology and psychiatry as well.

5. Define PET. (Nov18)

Positron emission tomography (PET) is an imaging technique that uses radioactive substances to visualize and measure metabolic processes in the body.PET is mainly used in the area of medical imaging for detecting or measuring changes in physiological activities.

6. Give principle of a PET. (May 17)

The principle of positron emission tomography (PET) is that radiation emitted from a radiopharmaceutical injected intravenously into a patient is registered by external detectors positioned at different orientations.

7. What are the elements of bio-telemetry system? (Nov 17, May 19)

Transducer which converts biological variable into electrical signal. The signal conditioner amplifies and modifies the signal for effective transmission. The transmission link connects the input blocks to readout device.

8. What is the principle of X-ray machine? (Nov 17)

X-rays are a type of radiation called electromagnetic waves. X-rays are generated via interactions of accelerated electrons with electrons of tungsten nuclei within the tube anode. X-ray imaging creates pictures of the inside of your body.

9. Explain principle behind ultrasound. (May 18)

Ultrasonic images are made by sending pulses of ultrasound into tissue using a probe. The ultrasound pulses echo off tissues with different reflection properties and are recorded and displayed as an image.

10. List out the significance of telemetry. (Nov 18)

1. It helps us to record the biosignals over long periods and while the patient is engaged in his normal activities.

2. For future reference (or) to study the treatment effect, the biotelemetry is essential one.

11. List modes of operation of ultrasound imaging. (sept 2020)

(i) A scan imaging (ii) B scan imaging (iii) M scan imaging

12. Mention any two applications of CT scans. (sept 2020)

1. CT scans can detect bone and joint problems, like complex bone fractures and tumors.

2. They can help locate a tumor, blood clot, excess fluid, or infection.

13. Differentiate between CT and MRI system. (May 19)

- A CT or MRI scan can assess the size and shape of body organs and tissue, but they cannot assess how these work.
- A PET scan can show how an organ works, but without a CT or MRI image, it can be difficult to pinpoint the exact location of activity within the body.

11 MARKS:

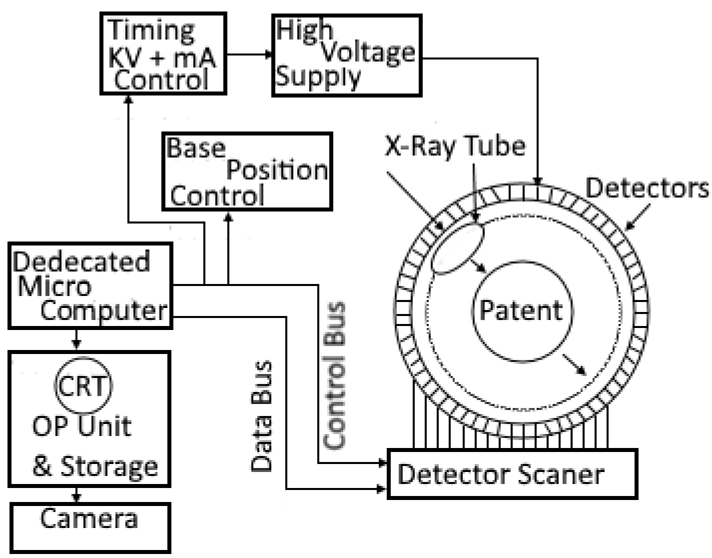
1. Describe the mechanism and working principle of CT scan?

(Or)

Explain different types of scanners used in CT. [2016(may, nov), 2017, 2020]

PRINCIPLE:

Measurements are taken from the transmitted X-rays through the body and contain information on all the constituents of the body in the path of the X-ray beam. By using multidirectional scanning of the object, multiple data are collected. The mathematical basis for producing an image of the cross-section of these body is that if one measures the total attenuation along rows and columns of a matrix, one can compute the attenuation of the matrix elements at the intersections of the rows and columns. Computer performs the calculations and obtains an information. This information can be presented in a conventional raster form and from these results a two dimensional picture (slice) can be obtained.



The timing, anode voltage (kV) and beam counter (mA) are controlled by a computer through a control bus. The high voltage d.c power supply drives an X-ray tube that can be mechanically rotated along the circumference of a gantry. The patient is lying in a tube through the center of the gantry. The X-rays pass through the patient and are partially absorbed and the remaining X-ray photons impinge upon several of as many as 1000 radiation detectors fixed around the circumference of the gantry. The detector response is directly related to the number of photons impinging on it and so to tissue density. When they strike the detector, the X-ray photons are converted to scintillations. The computer senses the position of the X-ray tube and samples the output of the detector along a diameter line opposite to the X-ray tube. The output unit then produces a visual image of a transverse plane cross-section of the patient on the cathode ray tube. It can also be photographed with a produce a hard copy record.

Data Presentation

Most scanners now present the data obtained as an analogue display of each tissue slice on a cathode ray tube. Presentation is usually in the form of a gray scale in which whiteness is proportional to the X-ray attenuation coefficient of tissues at each point of the scan.

Thus radioopaque materials appear white and radioluscent tissue appears black. The range can be varied by changing the gate or window width (W) at will so that tissues within a wide range of densities or a narrow range can be evaluated. The central point or level can be varied.

Scan Artifacts

With such complicated apparatus using X-rays, sophisticated photon recording systems and computer programming there are many sources of errors which can produce artifacts. These can be classified into 4 types:

1. Noise
2. Motion artifacts
3. Artifacts due to high differential absorption in adjacent tissues.
4. Technical errors and computer artifact.

Applications of CT:

1. Its major applications is in medical field. In medical, it is used to detect the injury in the human brain.
2. It is used to detect inner wounds.
3. To know the size and extent of damage of organs as a result of the lesions.
4. To ensure the presence of tumour and to determine the stage of a tumour.
5. To guide biopsy needle and to guide minimally invasive procedures.

2. Write hardware components needed for ultrasound instrumentation. Explain principle, instrumentation and application of ultrasound imaging. [2019]

- Ultrasound scan is a diagnostic imaging technique, or therapeutic application of ultrasound.
- It is used to create an image of internal body structures such as tendons, muscles, joints, blood vessels, and internal organs.
- It is also known as sonography or ultrasonography.
- Ultrasound are sound waves with frequencies which are higher than those audible to humans (>20,000 Hz).
- Ultrasonic images are made by sending pulses of ultrasound into tissue using a probe.
- The ultrasound pulses echo off tissues with different reflection properties and are recorded and displayed as an image.
- "Diagnostic ultrasound is recognized as a safe, effective, and highly flexible imaging modality capable of providing clinically relevant information about most parts of the body in a rapid and cost-effective fashion".

Basics of Ultrasonic Waves

- Ultrasonic waves are directional and the ultrasonic beams can be obtained by little spreading.
- Its wavelength is shorter, hence it can be used to investigate the properties of small internal structure.
- Ultrasonic waves can be transmitted through longitudinal, transverse or shear mode.
- For the purpose of medical imaging, longitudinal waves alone can be used since it can propagate in liquid, solid and gas.

Types of Ultrasonic Imaging

Imaging can be operated in three modes:-

(i) A scan imaging (ii) B scan imaging (iii) M scan imaging

1. A mode imaging:

Simplest form of ultrasound imaging which is based on the pulse-echo principle. A scans can be used to measure distances. A scan only give one dimensional information. Used for echo-encephalography (electrical activity of the brain) and echo-ophthalmoscopy (fundus of the eye).

In A mode, the returning echoes are displayed on the monitor as spikes originating from a single vertical or horizontal baseline. The depth of the echo is determined by the position of the spike on the axis, with the top or left side of the monitor being the most superficial and the bottom or right side being farther away. The height of the spike correlates to the amplitude of the echo.

2. B mode imaging:

B stand for Brightness. B scans give two dimensional information about the cross section. Generally used to measure cardiac chambers dimensions, assess valvular structure and function. In B mode, echoes are represented by dots on a line that form the basis of a two-dimensional image. The brightness of each dot indicates the amplitude of the returning echo. Its location relative to the transducer is displayed along the vertical axis of the monitor, with the top of the monitor representing the transducer. The returning echo's location along the axis is based on the amount of time it takes for the ultrasound wave to be transmitted from the transducer and reflected back. Echoes arising from structures in the near field (close to the transducer) take less time than those coming from the far field (farther away from the transducer) because they travel a shorter distance.

3. M mode imaging:

M stand for Motion. This represents movement of structures over time. M mode is commonly used for measuring chamber dimensions. This is analogous to recording a video in ultrasound. M mode is used in echocardiography and allows the sonographer to measure the heart to assess cardiac function and chamber size. M mode uses a single B-mode line, with the amplitude of the echoes indicated by the brightness of the displayed dots. The difference is that the information obtained from that single line is constantly swept across the monitor so that the motion of the body part being investigated is displayed along the horizontal axis.

Benefits:

- They're generally painless and don't require needles, shots or cuts.
- You aren't exposed to ionizing radiation, so the procedure is safer than X-rays and CT scans.
- Ultrasound captures images of soft tissues that don't show up well on X-rays.
- Ultrasounds are widely accessible and less expensive than other methods.

Limitations:

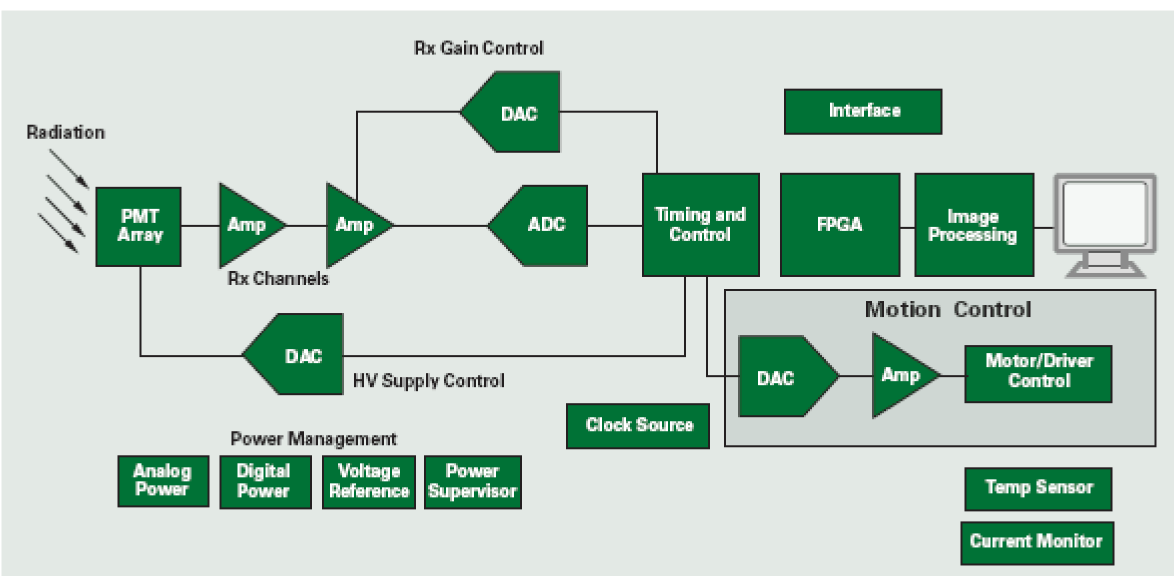
- Ultrasonic devices have trouble penetrating bone.
- Body habits have large influence on image quality.

- It performs very poorly when there is a gas between transducer and organ of interest.
- Method is operator dependent.

3. Write imaging technique of PET scanning with neat block diagram. [2019]

Positron emission tomography (PET) is an imaging technique that uses radioactive substances to visualize and measure metabolic processes in the body.PET is mainly used in the area of medical imaging for detecting or measuring changes in physiological activities like metabolism, blood flow, regional chemical composition, and absorption, and therefore, also called a functional imaging technique.

Positron emission tomography is an imaging modality for obtaining in vivo cross-sectional images of positron-emitting isotopes that demonstrate biological function, physiology or pathology. In this technique, a chemical compound with the desired biological activity is labelled with a radioactive isotope that decays by emitting a positron, or positive electrons. The emitted positron almost immediately combines with an electron and the two are mutually annihilated with the emission of two gamma rays. The two gamma ray photons travel in almost opposite directions, penetrate the surrounding tissue and are recorded outside the subject by a circular array of detectors. A mathematical algorithm applied by computer rapidly reconstructs the spatial distribution of the radioactivity within the subject for a selected plane and displays the resulting image on the monitor. Thus, PET provides a non-invasive regional assessment of many biochemical processes that are essential to the functioning of the organ being visualized.



Block diagram PET

Working:

The PET detector is comprised of an array of thousands of scintillation crystals and hundreds of photomultiplier tubes (PMTs) arranged in a circular pattern around the patient. The scintillation crystals convert the gamma radiation into light which is detected and amplified by the PMTs.

The manufacturers of PET imaging equipment continue to improve the diagnostic performance of these systems. Their focus has been on increasing the timing accuracy and the localization of gamma-ray photon detection. Random gamma rays exist in the environment and the PET imaging system must differentiate a random photon from photon pairs generated within the body. To do this, the system must detect a time-correlated photon pair or, more simply stated, the presence of two protons generated at the same time and traveling in opposite directions. The system accomplishes this by analyzing the location of the photon pairs striking the circular detector array to ensure that they are traveling in opposite directions. The system must also accurately measure when the photon pair strike the detector to ensure that they were generated at approximately the same time. Using this information, the PET system can discriminate random photon noise from the desired signal.

To reduce cost and complexity, most modern PET systems have many more scintillating crystals than PMTs. Given the disparity between the number of crystals and PMTs, the system must determine which of the many scintillating crystals was struck by a photon. It does this by analyzing the signal strength from the output of the PMTs in the vicinity of the crystal of interest.

The current signal from each PMT output is converted to a voltage and amplified by a low-noise amplifier (LNA). The signal generated by the PMT is a pulse with a fast attack and slow decay. The signal strength from each PMT is determined by digitally integrating the area under this time-domain pulse. The system uses a variable-gain amplifier (VGA) after the LNA to compensate for variability in the sensitivity of the PMTs.

The signals from a number (typically four or more) of physically close PMTs are summed, and this combined signal drives the input of an ultra-high-speed comparator. A DAC generates the comparator's reference voltage to compensate for DC offsets. Extremely high accuracy is required to calculate time of flight, so a digital timestamp is generated using the comparator's output signal and an ultra-high-speed clock. In this way, timing information can be compared for multiple PMTs that are physically separated by a significant distance.

The photon pair defines a line on which the collision took place. This is called the line of response (LOR). By analyzing tens of thousands of LORs, the backend image signal processor can display the collision activity as a 3-D image.

Advantage of PET:

- It is a relatively painless procedure that measures both anatomy and metabolic function within the patient’s body as images are captured in a single scan.
- The actual scan only takes about a half an hour to complete.
- Easy, Nondisruptive. Aside from the initial injection of the radioactive material, the exam is noninvasive and requires no recovery or downtime afterward. Patients may immediately assume normal activities after a PET/CT scan.

Disadvantage of PET:

- Pregnant women should not undergo PET/CT scans because the radioactive tracers used may be dangerous to the baby.
- Diabetics may undergo a PET/CT scan, but with certain precautions. Because the radioactive material is combined with glucose and then injected into the patient, this can be a concern for some diabetic patients.

4. Emphasis on MRI imaging with neat diagram. [2017, 2018(may,nov), 2019]

Magnetic resonance imaging (MRI), also known as nuclear magnetic resonance imaging, is a scanning technique for creating detailed images of the human body. The scan uses a strong magnetic field and radio waves to generate images of parts of the body that can't be seen as well with X-rays, CT scans or ultrasound. MRI is also used to examine internal body structures and diagnose a variety of disorders, such as strokes, tumors, aneurysms, spinal cord injuries, multiple sclerosis and eye or inner ear problems. It is also widely used in research to measure brain structure and function, among other things.

Working:

The human body is mostly water. Water molecules (H_2O) contain hydrogen nuclei (protons), which become aligned in a magnetic field. An MRI scanner applies a very strong magnetic field, which aligns the proton "spins."

The scanner also produces a radio frequency current that creates a varying magnetic field. The protons absorb the energy from the magnetic field and flip their spins. When the field is turned off, the protons gradually return to their normal spin, a process called precession. The return process produces a radio signal that can be measured by receivers in the scanner and made into an image.

Protons in different body tissues return to their normal spins at different rates, so the scanner can distinguish among various types of tissue. The scanner settings can be adjusted to produce contrasts between different body tissues. Additional magnetic fields are used to produce 3-dimensional images that may be viewed from different angles. There are many forms of MRI, but diffusion MRI and functional MRI (fMRI) are two of the most common.

Diffusion MRI

This form of MRI measures how water molecules diffuse through body tissues. Certain disease processes — such as a stroke or tumor — can restrict this diffusion, so this method is often used to diagnose them, Filippi said. Diffusion MRI has only been around for about 15 to 20 years, he added.

Functional MRI

In addition to structural imaging, MRI can also be used to visualize functional activity in the brain. Functional MRI, or fMRI, measures changes in blood flow to different parts of the brain. It is used to observe brain structures and to determine which parts of the brain are handling critical functions. Functional MRI may also be used to evaluate damage from a head injury or Alzheimer's disease. fMRI has been especially useful in neuroscience .

MRI Instrumentation:

The basic components of a MRI system are shown in above diagram. There is magnet which provides a strong, uniform, steady magnet field. Nowadays superconducting magnets are used in the MRI systems. The superconducting magnetic coils are cooled to liquid helium temperature and can produce very high magnetic fields. Hence the signal to noise ratio of the received signals and image quality are better than the conventional magnets used in the MRI. Different gradient coil systems produce a time varying, controlled spatial non-uniform magnetic fields in different directions. The patient is kept in this gradient field space. There are also transmitter and receiving R.F. coils surrounding the site on which the image is constructed. There is a superposition of a linear magnetic field gradient on to the uniform magnetic field applied to the patient. When this superposition takes place, the resonance frequencies of the processing nuclei will depend on the positions along the direction of the magnetic field gradient. This produces a one dimensional projection of the structure of the 3-D object. The slice of the image depends upon the gradient magnetic field. The receiver nuclear magnetic resonance signals picked up by the receiver coil and is fed into the receiver for signal processing. The image is constructed by the computer and is displayed on the television screen.

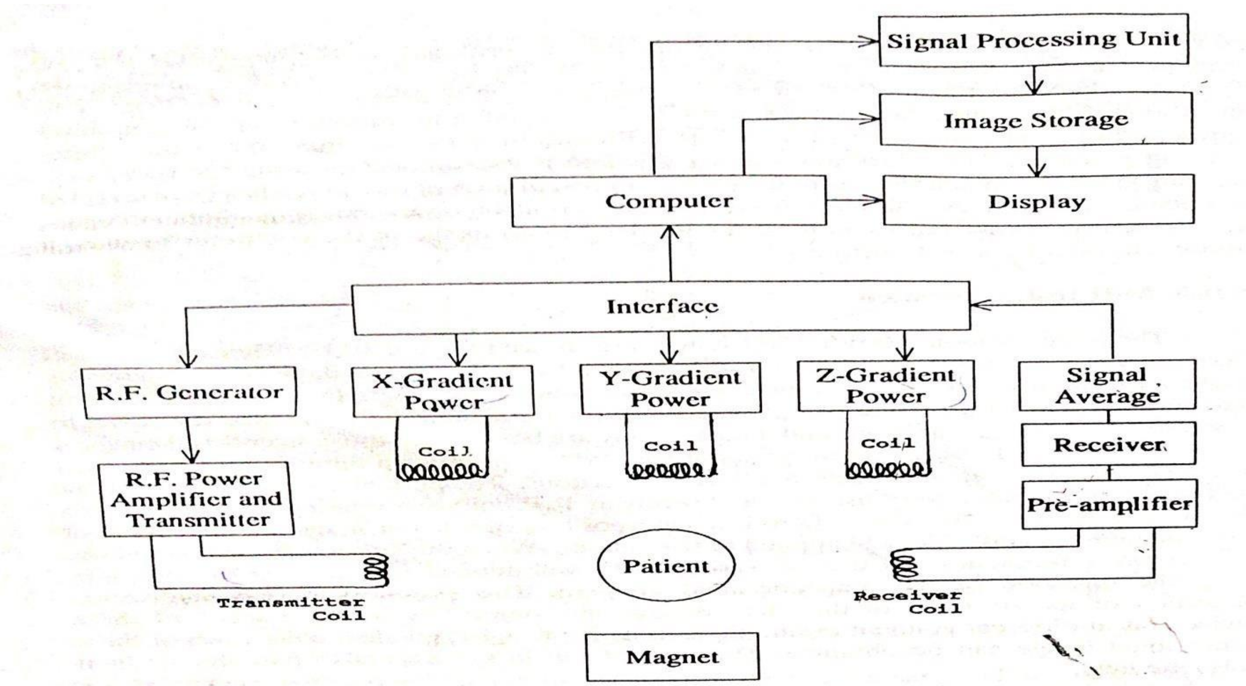


Fig.10.18. Block diagram of a MRI system

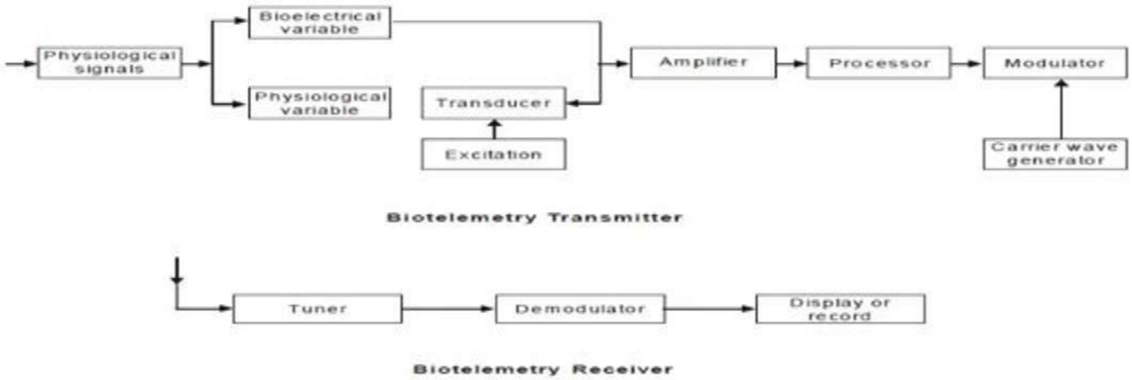
5. Detail the basic elements of telemetry. [2018(may, nov)]

(or)

Explain in detail about bio-telemetry system. [2016]

- Biotelemetry is a method of measuring biological parameters from a distance.
- The transmission of data from the point of generation to the point of reception can be done in various ways.
- The measurement and transmission of data at a distance is done by radio, cellular or other means.

- The telemetry transmitter and receiver plays an major role in the biotelemetry system.
- The main part in this system is Modulation system.



Modulation system:
The modulation systems used in wireless telemetry for transmitting biomedical signals are:

1. Amplitude Modulation (AM)
2. Frequency Modulation (FM)

1. Amplitude Modulation:

- When the amplitude of high frequency carrier signal is modified in accordance with the intensity of the signal, the process is called amplitude modulation.
- The frequency and phase angle of the carrier signal is kept constant and only the amplitude is modified.

Advantages of amplitude modulation :

- Simple to understand and implement.
- Requires limited bandwidth.
- Need low frequency carrier.
- less costly compared to frequency modulation.
- To use for long distance propagation .

Disadvantages of Amplitude Modulation:

- An amplitude modulation signal is not efficient in terms of its power usage.
- It is not efficient in terms of its use of bandwidth.
- AM detectors are sensitive to noise hence an amplitude modulation signal is prone to high levels of noise.
- Reproduction is not high fidelity.

2. Frequency Modulation:

- Frequency modulation is a technique or a process of encoding information on a particular signal (analogue or digital) by varying the carrier wave frequency in accordance with the frequency of the modulating signal.

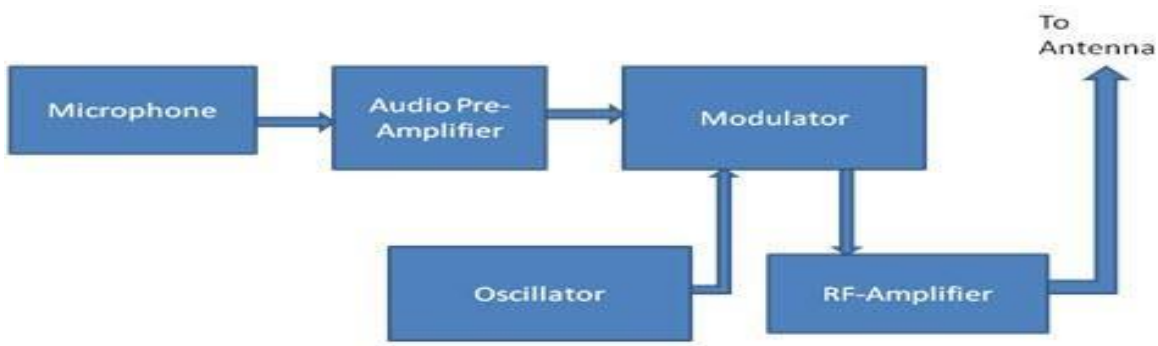
- It offers a great advantage in radio transmission as it has a larger signal-to-noise ratio.

Advantages and Disadvantages of Frequency Modulation:

Advantages	Disadvantages
Less interference and noise.	Equipment cost is higher. Has a large bandwidth.
Power Consumption is less as compared to AM.	The receiving are of FM signal is small.
Adjacent FM channels are separated by guard bands.	The antennas for FM systems should be kept close for better communication.

Frequency Modulated Transmitter:

- The FM transmitter is a low power transmitter and it uses FM waves for transmitting the sound, this transmitter transmits the audio signals through the carrier wave by the difference of frequency.



Advantages of the FM Transmitters:

- The FM transmitters are easy to use and the price is low
- The efficiency of the transmitter is very high
- It has a large operating range

Disadvantages of the FM Transmitter:

- In the FM transmitter, the huge wider channel is required.
- The FM transmitter and receiver will tend to be more complex.
- Due to some interference, there is poor quality in the received signals.

Frequency Modulated Receiver:

- FM receiver is an electronic device that receives radio waves and converts the information carried by them to a usable form. An antenna is used to catch the desired frequency waves.
- Frequency modulation is used in a radio broadcast in the 88-108MHz VHF band. This bandwidth range is marked as FM on the band scales of radio receivers, and the devices that are able to receive such signals are called FM receivers.

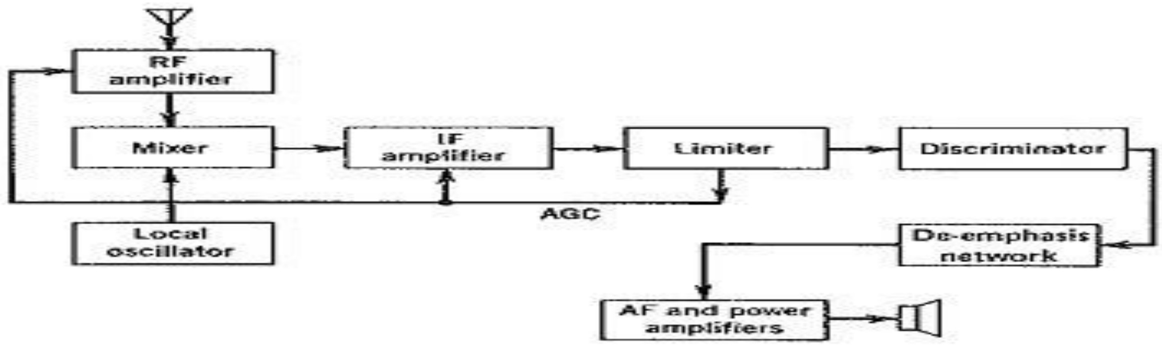
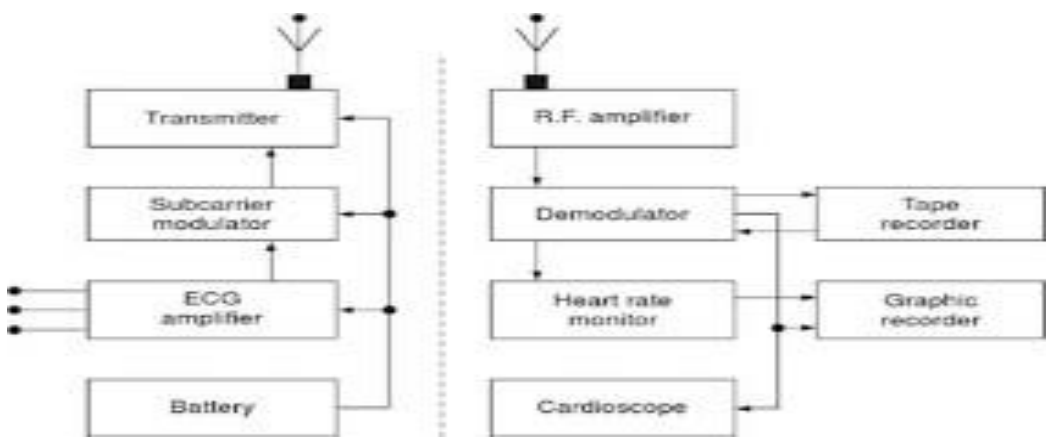


FIGURE 6-28 FM receiver block diagram.

6. Explain in detail single channel ECG telemetry system. [2017]



There are two main parts:

- The Telemetry *Transmitter* which consists of an ECG amplifier, a sub-carrier oscillator and a UHF transmitter along with dry cell batteries.
- *Telemetry Receiver* consists of a high frequency unit and a demodulator, to which an electrocardiograph can be connected to record, a cardioscope to display and a magnetic tape recorder to store the ECG. A heart rate meter with an alarm facility can be provided to continuously monitor the beat-to-beat heart rate of the subject**.**

7. Explain about multichannel telemetry. [2017]

- Multi-channel telemetry offers the possibility of simultaneously surveying several physiological parameters of the person being monitored.
- With appropriate preamplifiers, the multi-channel systems permit the transmission of the following parameters simultaneously ECG and heart rate, respiration rate, temperature, intravascular and intra-cardiac blood pressure.
- In multi-channel telemetry, the number of sub-carriers used are the same as the number of signals to be transmitted. Each channel therefore has its own modulator.
- The RF unit—the same for all channels—converts the mixed frequencies into the transmission band. Similarly, the receiver unit contains the RF unit and one demodulator for each channel.
- Pulse width modulation is better suited for multi-channel biotelemetry systems. Such systems are insensitive to carrier frequency shifts and have high noise immunity.

For multi-channel radiotelemetry, various channels of information are combined into a single signal. This technique is called *multiplexing*. There are two basic methods of multiplexing. These are:

• ***Frequency–division multiplexing:*** The method makes use of continuous-wave sub-carrier frequencies. The signals frequency–modulate multiple subcarrier oscillators, each being at such a frequency that its modulated signal does not overlap the frequency spectra of the other modulated signals. The frequency modulated signals from all channels are added together through a summing amplifier to give a composite signal in which none of the parts overlap in frequency. This signal then modulates the RF carrier of the transmitter and is broadcast.

• ***Time–division multiplexing*:** In this technique, multiple signals are applied to a commutator circuit. This circuit is an electronic switch that rapidly scans the signals from different channels. An oscillator drives the commutator circuit so that it samples each signal for an instant of time, thereby giving a pulse train sequence corresponding to input signals. A frame reference signal is also provided as an additional channel to make it easy to recognize the sequency and value of the input channels.

8. With neat block diagram explain working of typical telemedicine system. [2020]

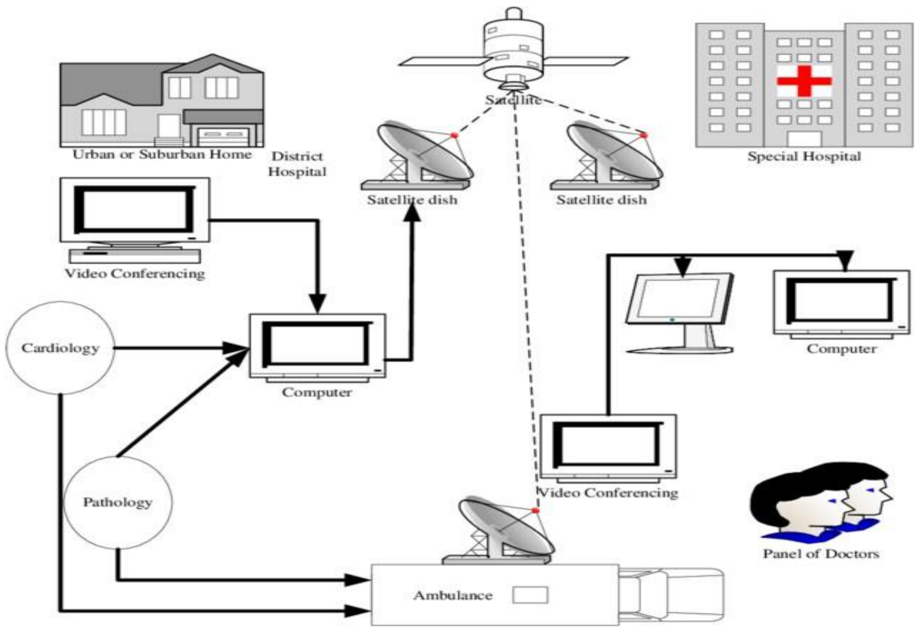
- Telemedicine is the application of telecommunications and computer technology to deliver health care from one location to another.
- In other words, telemedicine involves the use of modern information technology to deliver timely health services to those in need by the electronic transmission of the necessary expertize and information among geographically dispersed parties, including physicians and patients, to result in improved patient care and management, resource distribution efficiency and potentially cost effectiveness.

Applications of Telemedicine:

- Although telemedicine can potentially affect all medical specialties, the greatest current
- applications are found in radiology, pathology, cardiology and medical education.
- ***Teleradiology:*** Radiological images such as X-ray, CT or MRI images can be transferred from one location to another location for expert interpretation and consultation. The process involves image acquisition and digitization.
- ***Telepathology:*** To obtain an expert opinion on the microscopic images of pathology slides and biopsy reports from specialists.
- ***Telecardiology:*** Telecardiology relates to the transmission of ECG, echocardiography, colour , Doppler, etc.
- ***Tele-education:*** Delivery of medical education programmes to the physicians and the paramedics located at smaller towns who are professionally isolated from major medical centers
- ***Teleconsultation:*** Specialist doctors can be consulted either by a patient directly or by the local medical staff through telemedicine technology. In the latter case, the patient is substituted by his/her electronic patient record (EPR) which has complete information on the physical and clinical aspects of the patient.

Essential parameters for telemedicine:

- The following components relating to a patient are considered essential from the point of view of telemedicine:
- ***Primary Patient Data****:* Name, age, occupation, sex, address, telephone number, registration number, etc.
- ***Patient History*****:** Personal and family history and diagnostic reports.
- ***Clinical information*****:** Signs and symptoms are interpretations of data obtained from direct and indirect patient observations. Direct observations include data obtained from the senses (sight, sound, touch, smell, etc.) and through mental and physical interaction with the patient, while indirect observations include data obtained from diagnostic instruments such as temperature, pulse rate, blood pressure.
- ***Investigations:*** Complete analysis reports of haemotology and biochemistry tests, stool and urine examination.
- ***Data and Reports*****:** Radiographs, MRI, CT, ultrasound and nuclear medicine images and reports; pathology slides, electrocardiogram, spirogram.


Satellite
Urban or Suburban Home
District
Hospital
Special Hospital
Satellite dish
Satellite dish
Video Conferencing
Cardiology
Computer
Computer
Pathology
Video Conferencing
Panel of Doctors
Ambulance

MEDICAL INSTRUMENTATION
BM T55

UNIT V ELECTRICAL SAFETY

2 MARKS:

1. List out the parameters used to reduce shock hazards. (Nov 16)

- Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
- Use safe work practices every time electrical equipment is used.
- Multi-plug adapters must have circuit breakers or fuses.
- Minimize the potential for water or chemical spills on or near electrical equipment

2. What is meant by current leakage? (May 16, May 18, Nov 18)

Leakage current is the **current** that flows through the protective ground conductor to ground. In the absence of a grounding connection, it is the **current** that could flow from any conductive part or the surface of non-conductive parts to ground if a conductive path was available (such as a human body).

3. Differentiate micro and macro shock. (Nov 16, May 17, Nov 17, May 18, Nov 18, Nov 19, May 19, Sep 20)

Micro shock	Macro shock
1. The first contact is body surface.	1. The first contact is body surface
2. The second contact is heart.	2. The second contact is also body surface
3. The physiological effect on body varies depending upon the range of current.	3. Mostly cause bums and in high magnitude causes death
4. Causes contraction of heart muscles and fibrillation.	4. Contraction of body muscles

4. List few grounding methods of instruments. (May 17, Nov 17, Sep 20)

- Safety Earth (SE) / Dirty Earth / Protective Earth / Electrical Earth / Power Earth.
- **Instrument** Earth (IE) / Electronic Earth / Reference Earth / Clean Earth / Signal Earth.
- Intrinsic Safety (IS) Earth for IS circuit.

5. What do you mean by biohazards? (Nov 19)

Biological hazards, also known as biohazards, refer to biological substances that pose a threat to the health of living organisms, primarily that of humans. E.G.:

- Human blood and blood products. This includes items that have been contaminated with blood and other body fluids or tissues that contain visible blood.
- Animal waste. ...
- Human body fluids. ...
- Microbiological wastes. ..

6. What does ICRP stand for? Mention the system of radiation protection recommended by ICRP. (May 19)

International Commission on Radiological Protection. ICRP suggested general principles of radiation protection as three key words; justification, optimization and dose limit. Because medical exposure of patients has unique considerations, it is not appropriate to apply dose limits or dose constraints.

11 MARKS:

1. What are the preventive measures to be taken for shock hazards? Explain. (Nov 16, Nov 17, May 18, Nov 19, May 16, Sep 20)

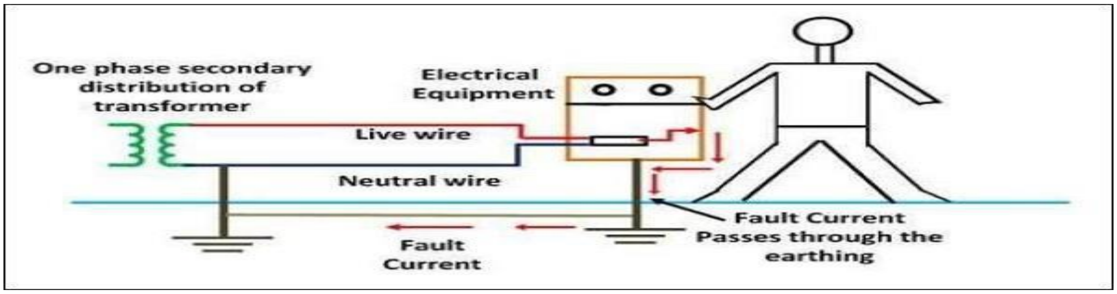
METHODS OF ACCIDENT PREVENTION:
In order to reduce the possibility of shock hazards in electrosurgical equipment's, a number Of protective methods have evolved. They are
1. Grounding
2. Double insulation
3. Protection by low voltage
4. Ground - fault circuit interrupter
5. Isolation of patient- connected parts
6. Isolated power distribution systems.

1. Grounding:

- The principle of this method is to bypass the fault current and maintaining the body current within safe limits, even if contact and body resistances are very small.
- This is done by making the ground resistance Ri very small by connecting the equipment case to ground by a separate wire.
- In this case if short circuit occurs, the short circuit current flows to case and returns to the substation through ground wire.
- This fault current will be sufficient to trip a circuit breaker and remove power from the faulty equipment.

Disadvantages:

- l. Any break in ground wire connection will result in a hazard.
- 2. Tripping of circuit breaker by earth fault current might cut power to other devices which might include life saving instruments.



2. Double insulation:

- In double insulated equipment's, the equipment case is made up of non-conductive material usually a suitable plastic.
- If metal parts are accessible then they are attached to the main body through an addition layer of insulation.
- This ensures a larger fault resistance. These instruments need not he grounded and are usually provided with two pin plug.

Disadvantages:

- These equipment's should be designed waterproof as spilling over of conductive fluids like saline or urine or submerged operation of equipment in conductive fluid will make double insulation ineffective.

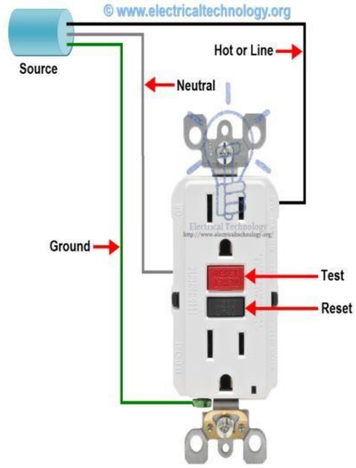
3. Protection by low voltage:

- This method is accomplished by operating equipment's at low input voltage using batteries, instead of line voltage at 115 or 230V ac.
- Low voltage can also be obtained using step down transformer.
- For low power equipments, the step down transformer can be made an integral part of the equipment.
- A step down transformer isolates supply voltage from ground.

4. Ground - fault circuit interrupter:

- A Ground fault circuit interrupter, sometimes called a GFCI , is an electrical safety device that is mandatory in locations throughout a home where water can come into contact with a wall plug. This includes bathrooms and kitchens.
- GFCIs make sure that all of the electric current going out of an electrical outlet goes back in the wall socket and not going through a person to make a path to (electrocution).
- The GFCI monitors the electric current in the hot line and the neutral line .
- When these two currents are equal operation is normal and there is no ground fault.
- However when these two values become unequal by as little as 4-5 mA another path to the ground (ground fault) may be present, in this case the GFCI will open thereby preventing electric shock to a person.
- A GFCI has a reset button to restore it to original conditions after it has opened the circuit, as well as a test button to ensure it is functioning properly.
- It's also a good idea to test the GFCI by pressing the 'test' button every month or so to make sure that it turns off the electricity.

- This can be done by plugging in something like a nightlight, or cell phone charger, and pressing the test button, if the power to the device turns off, the GFCI still works. If not, it should be replaced.



GFCI
Ground Fault Circuit Interrupter

5. Isolation of patient- connected parts:

- Patient-connected medical devices are required to provide two means of protection (MOP) to prevent applied parts and other accessible parts from exceeding the limitations of voltage, current, or energy.
- A compliant protective earth connection provides 1 MOP, basic isolation also provides 1 MOP, and reinforced insulation provides 2 MOP.
- Means of protection can be categorized as means of operator protection (MOOP) or means of patient protection (MOPP). In devices intended for patient connection, 2 × MOPP are required.
- Power architectures for use in medical devices with type BF and CF classification are required to provide 2 × MOPP from primary to secondary, 1 × MOPP from primary to earth and additional safety isolation from the secondary output of the power system to earth also rated at 1 × MOPP, all at the (highest rated) incoming AC line voltage

6. Isolated power distribution systems:

- **Normal distribution** systems are provided with very low ground return resistance. Electrical **accidents in bio-medical** equipment's involving ground contact of patients can be avoided if this **ground return resistance is** made very large.
- But it is not possible to operate our general purpose **distribution system with** large ground return resistance. Hence special power distribution systems **with transponders having** ungrounded secondaries are used to supply limited number of medical **equipment's. This can increase** the safety margin.
- In **this type of isolated** power distribution system, when a short occurs between any one of the two wires and equipment case and when a person touching ground comes in contact with the case, he or she will not be subjected to shock hazards as neither of the conductors are grounded.

2. Write a detail note on physical and health effects on radiation hazards. (Nov 16, Nov 17)

Radiation exposure may be internal or external, and can be acquired through various exposure pathways.

Internal exposure to ionizing radiation occurs when a radionuclide is inhaled, ingested or otherwise enters into the bloodstream (for example, by injection or through wounds). Internal exposure stops when the radionuclide is eliminated from the body, either spontaneously (such as through excreta) or as a result of a treatment.

External exposure may occur when airborne radioactive material (such as dust, liquid, or aerosols) is deposited on skin or clothes. This type of radioactive material can often be removed from the body by simply washing.

Exposure to ionizing radiation can also result from irradiation from an external source, such as medical radiation exposure from X-rays. External irradiation stops when the radiation source is shielded or when the person moves outside the radiation field.

People can be exposed to ionizing radiation under different circumstances, at home or in public places (public exposures), at their workplaces (occupational exposures), or in a medical setting (as are patients, caregivers, and volunteers).

Exposure to ionizing radiation can be classified into 3 exposure situations. The first, planned exposure situations, result from the deliberate introduction and operation of radiation sources with specific purposes, as is the case with the medical use of radiation for diagnosis or treatment of patients, or the use of radiation in industry or research. The second type of situation, existing exposures, is where exposure to radiation already exists, and a decision on control must be taken – for example, exposure to radon in homes or workplaces or exposure to natural background radiation from the environment. The last type, emergency exposure situations, result from unexpected events requiring prompt response such as nuclear accidents or malicious acts.

Medical use of radiation accounts for 98 % of the population dose contribution from all artificial sources, and represents 20% of the total population exposure. Annually worldwide, more than 3600 million diagnostic radiology examinations are performed, 37 million nuclear medicine procedures are carried out, and 7.5 million radiotherapy treatments are given.

Health effects of ionizing radiation

Radiation damage to tissue and/or organs depends on the dose of radiation received, or the absorbed dose which is expressed in a unit called the gray (Gy). The potential damage from an absorbed dose depends on the type of radiation and the sensitivity of different tissues and organs.

The *effective dose* is used to measure ionizing radiation in terms of the potential for causing harm. The sievert (Sv) is the unit of effective dose that takes into account the type of radiation and sensitivity of tissues and organs. It is a way to measure ionizing radiation in terms of the potential for causing harm. The Sv takes into account the type of radiation and sensitivity of tissues and organs.

The Sv is a very large unit so it is more practical to use smaller units such as millisieverts (mSv) or microsieverts (μSv). There are one thousand μSv in one mSv, and one thousand mSv in one Sv. In addition to the amount of radiation (dose), it is often useful to express the rate at which this dose is delivered (dose rate), such as microsieverts per hour (μSv/hour) or millisievert per year (mSv/year).

Beyond certain thresholds, radiation can impair the functioning of tissues and/or organs and can produce acute effects such as skin redness, hair loss, radiation burns, or acute radiation syndrome. These effects are more severe at higher doses and higher dose rates. For instance, the dose threshold for acute radiation syndrome is about 1 Sv (1000 mSv).

If the radiation dose is low and/or it is delivered over a long period of time (low dose rate), the risk is substantially lower because there is a greater likelihood of repairing the damage. There is still a risk of long-term effects such as cancer, however, that may appear years or even decades later. Effects of this type will not always occur, but their likelihood is proportional to the radiation dose. This risk is higher for children and adolescents, as they are significantly more sensitive to radiation exposure than adults.

Epidemiological studies on populations exposed to radiation, such as atomic bomb survivors or radiotherapy patients, showed a significant increase of cancer risk at doses above 100 mSv. More recently, some epidemiological studies in individuals exposed to medical exposures during childhood (paediatric CT) suggested that cancer risk may increase even at lower doses (between 50-100 mSv).

Prenatal exposure to ionizing radiation may induce brain damage in foetuses following an acute dose exceeding 100 mSv between weeks 8-15 of pregnancy and 200 mSv between weeks 16-25 of pregnancy. Before week 8 or after week 25 of pregnancy human studies have not shown radiation risk to fetal brain development. Epidemiological studies indicate that the cancer risk after fetal exposure to radiation is similar to the risk after exposure in early childhood.

3. Write in detail about the effects of electric current on human body. (May 17, Nov 18)

Physiological effects of electrical currents:

- The effect of current on the body depends upon the magnitude of the current passed and the pathway of current through the body.
- Current is passed through the body when two contacts are made via an electric source.
- First contact is the surface of the body. The second contact may be heart or surface of the body.
- When the contacts are on body surface, a current intensity less than 5mA is considered unharmful.
- But the sensation can be either unpleasant or painful when contact is made by grasping a conductor.

Current	Effect
1mA	Barely perceptible
1-3mA	Perception threshold (most cases)
3-9mA	Painful sensation
9-25mA	Muscular contraction (can't let go)
25-60mA	Respiratory paralysis (may be fatal)
60mA or more	Ventricular fibrillation (probably fatal)
4 A or more	Heart paralysis (probably fatal)
5 A or more	Tissue burning (fatal if vital organ)

- ❑ A current in excess of 1OmA or 20mA can tetanize the arm muscles and make it impossible to release (let go) the conductor.
- ❑ Currents above 75mA can cause ventricular fibrillations. Current in excess of I to 2A can cause contraction of heart.
- ❑ Depending upon the location of second contact, two effects of current occur in the body.

They are:

1. Macro shock
2. Micro shock

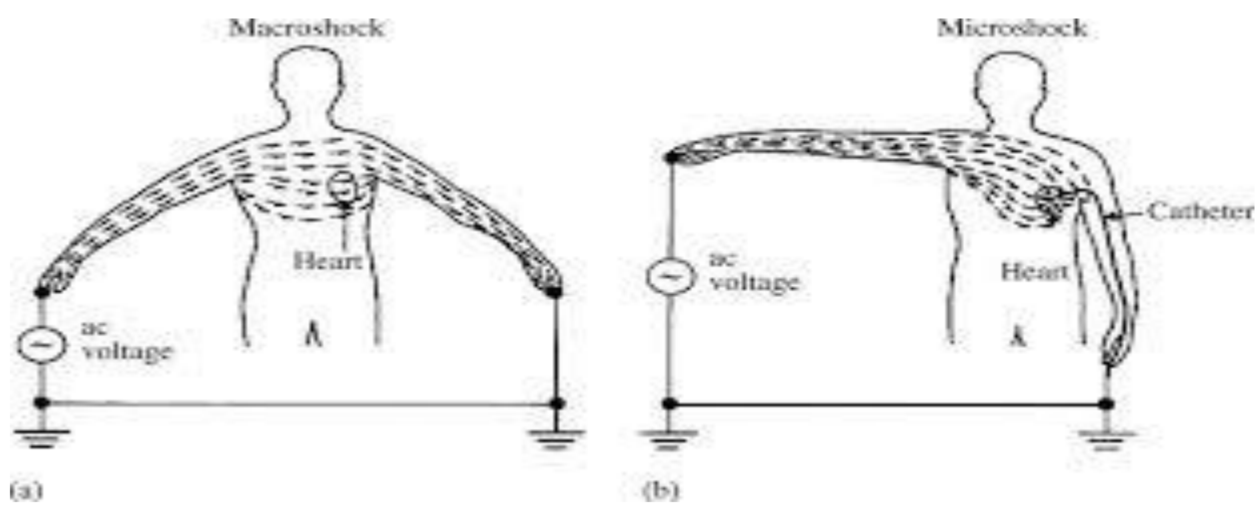
1. Macro shock:

- Like the first contact, if the second contact is also surface of the body mostly the limb, then the physiological effect due to flow of current between the two contacts in the body surface is termed as ***macro shock***.
- This type of current produces unwanted effects in the body.

- If the magnitude is very less, electrical burns and damages of tissues at the point of contact occurs due to high current density at the point of contact.
- In industrial accidents and lightening accidents, the dissipated electrical energy is very high and causes burns involving larger parts of the body, damage to the internal organs and can result in death.
- A high intensity stimulating current can cause contraction of muscles(tetanus).
- Depending on the intensity of current, the effect ranges from pleasant to painful and excess current may cause death.

2. Micro shock:

- If the location of second contact is heart, while the first contact is body surface, then the physiological effect due to current flow between heart and body surface is called as micro shock.
- The current sensitivity of the heart is higher than the surface of the body. The heart muscles react differently to electric current than any other muscles.
- An excess current first causes extra systolic contraction of heart. A further increase stops the heart activity completely but resumes if the current is removed in a short time.
- A further increase causes fibrillation in heart muscles. When ventricular fibrillation occurs, the heart is unable to pump blood and can cause death.
- In human beings ventricular fibrillation is the cause of death in majority of fatal accidents.



The contact for current Pathway can happen at the heart in the following situations-

- 1. An insulation failure of the electrical devices used at heart surface.
- 2. A fluid-filled catheter positioned wrongly into the heart rather than into the vein.
- 3. Pacing catheters delivering electrical stimulation to the heart can malfunction.

- 4. Fluid filled catheter used to take samples and inject dye solution to the heart provides a current pathway.

Type of current ranging (mA) Physiological effect:

- **1. Threshold** - 1 to 5 - Tingling sensation.
- **2.Pain** - 5 to 8 - Intense or painful sensation
- **3. Let-go** - 8 to 20 - Threshold of involuntary muscle contraction.
- **4. Paralysis** - >20 - Respiratory paralysis and pain.
- **5. Fibrillation** – 8 to 1000 - Ventricular and heart fibrillation.
- **6.Defibrillation** - 1000 to 10,000 - Sustained myocardial contraction temporary respiratory paralysis and possible tissue

4. What is leakage current? Explain. (May 17, May 19)

LEAKAGE CURRENTS:

Leakage current is an inherent flow of non-functional current from the live electrical parts of an instrument to accessible metal parts. This current flows through the third wire connection to Ground. Leakage currents occur by the presence of a finite amount of insulation impedance like

a. Capacitance

b. Resistance

Leakage current due to Capacitance:

This type of leakage current occurs due to capacitance present in between two Conductors separated in space. Mostly they occur in the primary of power transformer which Is capacitive coupled to the other parts of the transformer or instrument. In this case an Appreciable amount of leakage current is present.

Leakage current due to Resistance:

Resistance also creates a small amount of leakage current flow but the magnitude is very less compared to capacitive leakage current.

To avoid leakage current, equipment is provided with three wire connection. The leakage current effectively drains through the third contact(ground).

Types of Leakage current:

According to the current path, leakage current is divided into

a. Enclosure leakage current

b. Earth leakage current

c. Patient leakage current

Enclosure leakage current:

This Leakage of current flows to the enclosure part of a machine through a person, in contact with the enclosure or in contact with other parts of the enclosure. This current will produce serious effects to person coming in direct with the ground line or through a capacitance.

Earth leakage current:

The earth leakage current flows from main parts of the apparatus to the earth via the earth conductor.

Patient leakage current:

The patient leakage current is the current which flows through the patient from or to the applied parts. E.g. Leakage current through patients' electrode circuit.

If the medical equipment is properly grounded, then the leakage current drains through the ground point.

5. A) Explain open ground problems and earthing methods. (May 18, Nov 18, Nov 19, Sep 20)

A) Open ground:

An open ground is when you have a three-prong receptacle that is not connected to an equipment grounding conductor. This is unsafe because an appliance that is designed to use an equipment ground to discharge an unsafe fault condition will not have a conductor to discharge that fault. Open grounds are common in houses built prior to the adoption of the 1962 electrical code. When old two-prong receptacles are replaced with modern three-prong receptacles and a grounding conductor is not added, you create an open ground.

Problems:
Ungrounded **outlets** increase the chance of: Electrical fire. Without the **ground** present, errors that occur with your **outlet** may cause arcing, sparks and electrical charge that can spawn fire along walls, or on nearby furniture and fixtures. Health hazard.

Earthing methods:
There are several methods of earthing like wire or strip earthing, rod earthing, pipe earthing, plate earthing or earthing through water mains. Most commonly used methods of earthing are pipe earthing and plate earthing.

Earthing Mat:

Earthing mat is made by joining the number of rods through copper conductors. It reduced the overall grounding resistance. Such type of system helps in limiting the ground potential. Earthing mat is mostly used in a placed where the large fault current is to be experienced. While designing an earth mat, the following step is taken into consideration.

- In a fault condition, the voltage between the ground and the ground surface should not be dangerous to a person who may touch the noncurrent-carrying conducting surface of the electrical system.
- The uninterrupted fault current that may flow into the earthing mat should be large enough to operate the protective relay. The resistance of the ground is low to allow the fault current to flow through it.The resistance of the mat should not be of such a magnitude as to permit the flow of fatal current in the live body.
- The design of grounding mat should be such that the step voltage should be less than the permissible value which would depend on the resistivity of the soil and fault required for isolating the faulty plant from the live system.

Earthing Electrode:

In this type of earthing any wire, rod, pipe, plate or a bundle of conductors, inserted in the ground horizontally or vertically. In distributing systems, the earth electrode may consist of a rod, about 1 meter in length and driven vertically into the ground. In generating substations, grounding mat is used rather than individual rods.

Pipe Earthing:

This is the most common and best system of earthing as compared to other systems suitable for the same earth and moisture conditions. In this method the galvanized steel and perforated pipe of approved length and diameter in place upright in a permanently wet soil, as shown below. The size of the pipe depends upon the current to be carried and type of soil.

Normally, the size of the pipe uses for earthing is of diameter 40 mm and 2.5 meters in length for ordinary soil or of greater length in case of dry and rocky soil. The depth at which the pipe must be buried depends on the moistures of the ground.

The pipe is placed at 3.75 meters. The bottom of the pipe is surrounded by small pieces of coke or charcoal at a distance of about 15 cm. Alternate layers of coke and salt are used to increase the effective area of the earth and to decrease the earth resistance respectively.

Another pipe of 19 mm diameter and minimum length 1.25 meters is connected at the top of GI pipe through reducing socket.

During summer the moisture in the soil decreases, which causes an increase in earth resistance. So a cement concrete work is done to keep the water arrangement accessible, and in summer to have an effective earth, 3 or 4 buckets of water are put through the funnel connected to 19 mm diameter pipe, which is further connected to GI pipe.

The earth wire either GI or a strip of GI wire of sufficient cross section to carry faulty current safely is carried in a GI pipe of diameter 12 mm at a depth of about 60cm from the ground.

Plate Earthing:

In Plate Earthing an earthing plate either of copper of dimension 60cm×60cm×3m of galvanized iron of dimensions 60 cm× 60 cm×6 mm is buried into the ground with its face vertical at a depth of not less than 3 meters from ground level.

The earth plate is inserted into auxiliary layers of coke and salt for a minimum thickness of 15 cm. The earth wire (GI or copper wire) is tightly bolted to an earth plate with the help of nut or bolt. The copper plate and copper wire are usually not employed for grounding purposes because of their higher cost.

Earthing Through Water Mains:

In this type of earthing the GI or copper wire are connected to the water mains with the help of the steel binding wire which is fixed on copper lead as shown below.

The water pipe is made up of metal, and it is placed below the surface of the ground, i.e. directly connected to earth. The fault current flow through the GI or copper wire is directly get earthed through the water pipe

MEDICAL INSTRUMENTATION BM T55

UNIT – IV ASSISTING AND THERAPEUTIC EQUIPMENTS

2 Marks:

1. Name parts found in object end and viewing end of endoscope. [May 16]

- A thin, long flexible tube
- A lens or lens system
- A light transmitting system
- The eyepiece

2. Why is calibration of audiometers necessary? [May 16]

It is the components such as cables, jacks, and transducers that may have an adverse effect on the accuracy of test results, which is the primary reason they should all be calibrated at the same time. Daily wear and tear, the age of your audiometer, any prolonged exposure to moisture, and not-so-gentle handling can affect calibration and cause damage to these components. This why the manufactures and many governing bodies require annual calibrations.

3. List out types of endoscopes. [Nov16, sept 20]

1. Bronchoscope	6. Ophthalmoscope
2. Cardioscope	7. Otoscope
3. Cystoscope	8. Proctoscope
4. Gastroscope	9. Sigmoidoscope
5. Laparoscope	10. Thoracoscope

4. What is diathermy? [Nov 16]

It is a treatment process by which cutting, coagulation, etc. of tissues are obtained.

5. Name the electrodes used in surgical diathermy unit. [May 17]

Needle electrode and ball electrode.

6. What are the types of ventilators? [May 17]

1. Pressure limited ventilators
2. Volume limited ventilators
3. Servo-controlled ventilators

7. What is the use of biphasic D.C. defibrillators? [Nov 17]

They are more convenient, accurate, effective, and cost less and are able to prevent further damage to the heart. **Biphasic** machines require relatively lower peak current in order to lower the risk to heart damage, and are able to adjust impedance to work equally on different types of patients.

8. What is the purpose of audiometer? [Nov 17]

An audiometry exam tests how well your hearing functions. It tests both the intensity and the tone of sounds, balance issues, and other issues related to the function of the inner ear.

9. What is the instrument used for internal examination. [May 18]

Endoscopes

10. Emphasis on surgical diathermy. [Nov 19]

Diathermy is the use of high frequency alternate polarity radio-wave electrical current to cut or coagulate tissue during surgery. It allows for precise incisions to be made with limited blood loss and is now used in nearly all surgical disciplines.

11. What is the use of electrotherapy treatment? [Nov 19]

Electrotherapy includes a range of treatments using electricity to reduce pain, improve circulation, repair tissues, strengthen muscles, and promote bone growth, leading to improvements in physical functioning.

12. Mention the components of heart lung machine. [May 19]

The components of these machines include pumps, oxygenators, temperature regulators, filters, intracardiac suction, filtration, and temperature control.

13. Give principle of hemodialysis. [May 19]

The principle of hemodialysis is the same as other methods of dialysis; it involves diffusion of solutes across a semipermeable membrane. Hemodialysis utilizes counter current flow, where the dialysate is flowing in the opposite direction to blood flow in the extracorporeal circuit.

14. List the methods of dialysis and explain them. [sept 20]

1. **Extracorporeal Dialysis (Hemodialysis) -** Blood is purified by an artificial kidney machine, blood is taken out from the body and waste products diffuse through a semi – permeable membrane which is continuously rinsed by a dialyzing solution or dialysate.
2. **Intracorporeal Dialysis (Peritoneal Dialysis) -** The peritoneal cavity in our body is used as semi – permeable membrane and by passing the dialysate into it, waste products are removed the blood by diffusion.

11 Marks:

1. What is ventilator? Give its importance respiratory failures.

(Or)

Explain functioning of ventilator with neat diagram. [May 2016, May 2017, Sept 2020]

A ventilator is a control system where the output is a flow of oxygen-enriched air with certain specifications. A mechanical ventilator is a machine that assists a patient's breathing during surgery or in situations where they cannot breathe on their own due to a critical illness.

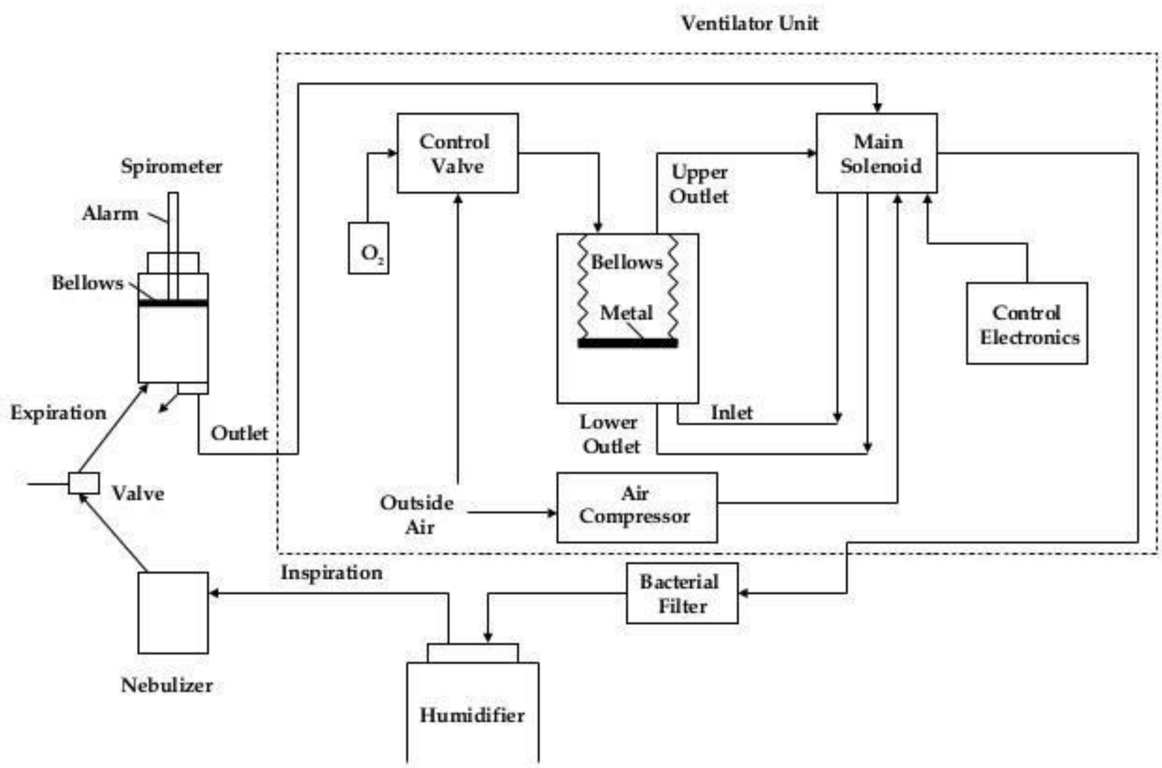
The ventilator treatment gives the following:

1. **Adequate ventilation** by which enough oxygen is supplied and the right amount of carbon dioxide is eliminated. Thus hyperventilation which creates respiratory alkalosis and hypoventilation which creates respiratory acidosis are avoided.

2. Elimination of respiratory work.

3. **Increased intrathoracic pressure** which prevents atelectasis that is collapse of portions of the lung and counteracts edema of the lung.

Block Diagram of a Ventilator with its Accessories



Working:

- During inspiration, the compressor draws air through an air filter and passes it to the main solenoid.
- Main solenoid forces the bottom inlet valve of the bellows chamber to open and the lower outlet valve to close.
- Oxygen is passed into bellows chamber in a controlled manner by means of a control valve. The high pressure in the bellows chamber compresses the bellows and forces the upper outlet valve to open.

Humidifier – In order to prevent damage to the patient's lungs, the applied air or oxygen must be humidified either by heat vaporization or by bubbling an air stream through a jar of water.

Nebulizer – Produces a fine spray of water or medication into the patient's inspired air in the form of aerosols.

- When the medicated air is forced into lungs through the valve number 1, the suction spirometer is in closed condition.
- When the inspiration is complete, the main solenoid switches the directions of the pneumatic air to do the expiration cycle.

Spirometer – used to measure the volume of exhaled air.

- During expiration, air is sucked into the spirometer chamber through the valve number 1.
- The volume of the chamber is varied by means of a light weight piston that moves freely I a cylinder as air is withdrawn.
- Meanwhile, the room air is drawn from the air inlet filter by the air compressor and is directed to close the upper outlet valve of the bellows.
- The weight of the bellows causes the bottom outlet valve to open.
- The main solenoid directs air to close the inlet valve of the internal bellows chamber.
- Through the outlet valve 2, the expired air reaches the main solenoid.
- After the end of patient expiration, the system electronics trip the main solenoid thereby initiating the patient inspiration part of the cycle.

Types of regulation on ventilators:

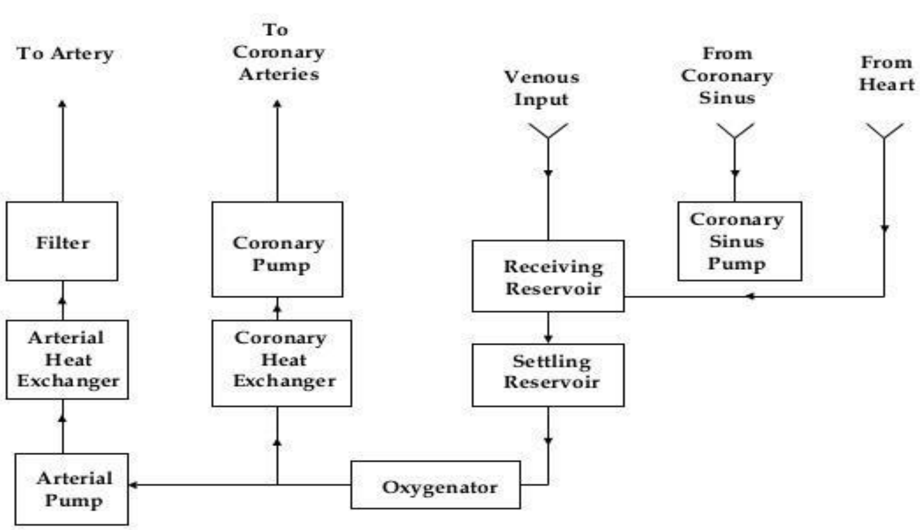
1. Pressure limited ventilators: It is based on the principle that the insufflation is terminated when the gaseous mixture pumped into the patient's lungs reaches a pre-set pressure. These are so simple in design and reliable in operation.

2. Volume limited ventilators: It is based on the principle that for each breath, a constant volume of air is delivered. During insufflations, the constant volume of air is sent into the lungs by applying pressure to a chamber containing constant volume. This ventilator does not give desired ventilation in case where the pre-set maximum pressure cannot completely empty the chamber.

3. Servo-Controlled ventilators: This is based on the usage of modern electronic control techniques such as that the flow to and from the patient is controlled by feedback circuits. The electronic unit controls the amplifies and logic circuits that controls the ventilation. It also monitors pressures, activates alarms and computes mechanical lung parameters.

2. Explain the mechanism of heart lung machine. [Nov 2016, May 2018, Nov 2019]

Model of the Heart – Lung Machine



A heart-lung machine is an apparatus that does the work both of the heart (i.e., pumps blood) and the lungs (i.e., oxygenates the blood) during, for example, open-heart surgery. The basic function of the machine is to oxygenate the body's venous supply of blood and then to pump it back into the arterial system. Blood returning to the heart is diverted through the machine before returning it to the arterial circulation. Some of the more important components of these machines include pumps, oxygenators, temperature regulators, and filters. The heart-lung machine also provides intracardiac suction, filtration, and temperature control.

Working:

- Usually two cannulas are inserted into the right side of the heart to collect the returning venous blood.
- The collected venous blood is directed into a receiving reservoir of heart lung machine by gravity drainage.
- The accumulated blood in the operating field is also collected and passed into the receiving reservoir by suction devices.
- Then the blood is passed into the settling reservoir or debubbling chamber and then it is passed oxygenator.
- In the oxygenator, the blood is exposed to an atmosphere rich in oxygen.
- From the oxygenator, a pump raises the pressure of the blood to the mean arterial pressure from which it flows into an arterial heat exchanger.
- Arterial heat exchanger is necessary during hypothermic or low temperature operation for two reasons.
- First to reduce body metabolism and therefore to reduce oxygen consumption during the operation, thereby operation time can be increased.
- Second, the brain damage due to oxygen starvation is reduced.
- From the arterial heat exchanger, the blood passes through a filter to prevent the possibility of particles or bubbles returning to the body.
- Systemic circulation is maintained by returning this arterial oxygenated blood to a major artery.
- To ensure that the coronary arteries and the heart itself are properly perfused with blood. Individual cannulas are inserted into each of the coronary arteries and blood is pumped through them.

Requirements of an ideal oxygenator:

1. Lower priming volume 2. Minimum trauma to blood 3. Simple, safe and reliable operation 4. Ensured sterilization 5. No micro embolus formation 6. Short preparation time

Types:

• Bubble oxygenator

• Film oxygenator (Foam, Screen, Blood film over sponge and Rotating disc film)

• Membrane oxygenator

• Liquid – liquid oxygenator

3. What is need of a cardiac defibrillator? Draw schematic diagram of a synchronized D.C. defibrillator and explain function of each component. [Nov 2017, May 2019]

(Or)

Write short on AC Defibrillator and DC Defibrillator. [Sept 2020]

- An electronic device that creates a sustained myocardial depolarization of a patient’s heart in order to stop ventricular fibrillation or atrial fibrillation.
- Fibrillation may be converted to a more efficient rhythm by applying a high voltage shock to the heart.
- The instrument for administering the electric shock is called a defibrillator.
- The sudden cardiac arrest can be treated using a defibrillator and 80% of the patients will be cured from the cardiac arrest can be the treatment is given within one minute of the attack.

Types Based on the electrodes placement:

- Internal Defibrillator
- External Defibrillator

Based on the nature of voltage applied:

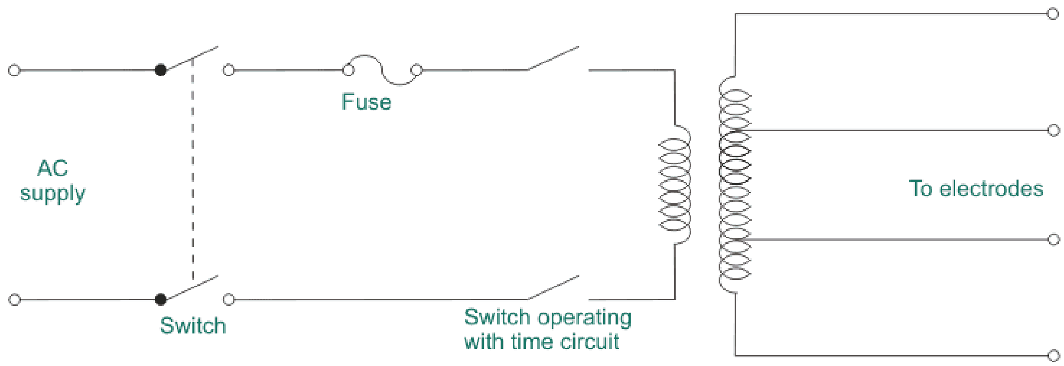
- A.C. Defibrillator
- D.C. Defibrillator
- Synchronized D.C. Defibrillator
- Square Pulse Defibrillator
- Double Square Pulse Defibrillator
- Biphasic D.C. Defibrillator

Sl. No.	Internal Defibrillator	External Defibrillator
1.	Used when chest is opened. Large spoon shaped electrodes are used.	Paddle shaped electrodes are used.
2.	Shock voltage is in the range from 50 to 1000 V.	Shock voltage is in the range from 1000 to 6000 V.
3.	Contact impedance is about 50 ohms.	Contact impedance is about100 ohms.
4.	Duration of the shock is about2.5 to 5 milliseconds.	Duration of the shock is 1 to 5 milliseconds.

AC Defibrillator:

- Earliest and simplest type.
- Appropriate voltages for internal and external defibrillation are available.
- Consists of a step – up transformer with various tappings on the secondary side.
- An electronic timer is connected to the primary of the transformer.

- The timer connects the output to the electrodes for a pre – set time.
- Duration of the counter shock may be from 0.1 to 1 second.
- For external defibrillation, voltages are in the range from 250 to 750 V.
- For internal defibrillation, it is from 60 to 250 V.
- Large currents are required in the case of external defibrillation causing a violent contraction of the thoracic muscles and also results in occasional burning of the skin.
- It produces atrial defibrillation while arresting the ventricular defibrillation.
- No undesirable side effects.
- Ventricular defibrillation is terminated by passing a high energy shock through discharging a capacitor to the exposed heart or chest.

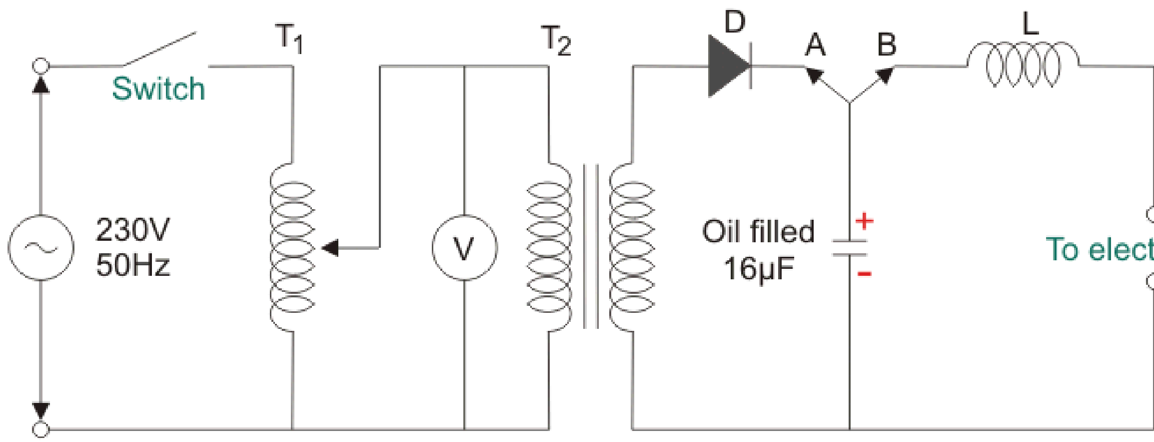


AC Defibrillator

Circuit:

- A variable auto transformer T1 forms the primary of a high voltage transformer T2.
- The output voltage of T2 is rectified by a diode rectifier and is connected to a vacuum type high voltage change over switch.
- In position A, that switch is connected to one end of an oil filled capacitor having capacity of 16uF.
- In this position the capacitor charges to voltage, set by the positioning of the auto transformer.

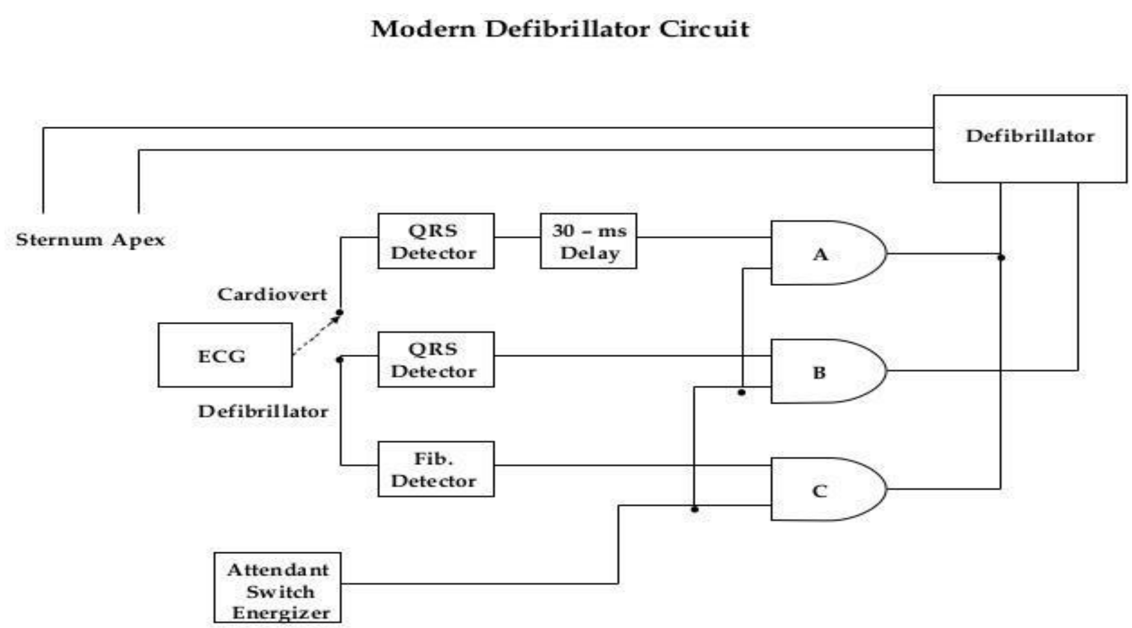
DC Defibrillator:



DC Defibrillator

- During the delivery of shock to the patient, a foot switch or a push button switch mounted on the handle of the electrode is operated and the switch changes over to position B.
- Capacitor discharges across the heart through the electrodes.
- An inductor 'L' is placed one of the leads so that the discharge from the capacitor is slowed by the induced counter voltage.
- The shape of the waveform that appears across the electrodes will depend upon the value of capacitor and inductor used in the circuit.
- Its amplitude depends upon the discharge resistance (around 50 to 100 ohms).
- The success of defibrillation depends on the energy stored in the capacitor and not on the value of voltage used.
- For internal defibrillation energies up to 100 J are required whereas for external defibrillation energies up to 400 J are required.
- Discharging duration range is from 5 to 10 milliseconds.

Synchronized D.C. Defibrillator:



- There are two vulnerable zones in a normal cardiac cycle, T and U wave segments.
- If the counter shock falls in the T wave segment then ventricular defibrillation is developed.
- If the counter shock falls in the U wave segment then atrial defibrillation is developed.
- For termination of ventricular tachycardia, atrial fibrillation and other arrhythmias it is essential to use a defibrillator with synchronizer circuit.
- It includes diagnostic circuitry, used to assess the fibrillation before defibrillation pulse is delivered and synchronizer circuitry, used to deliver the defibrillation pulse at the correct time.
- The ECG of the patient is obtained.The switch is placed in the defibrillator mode if ventricular fibrillation is suspected.

- The QRS detector in that mode consists of a threshold circuit that would pass a signal as output if R wave is absent in the ECG.
- The AND gate ‘B’ delivers on signal to the defibrillator only when the R wave is absent.
- The fibrillation detector searches the ECG signal for frequency components above 150 Hz.
- If they are present, fibrillation is probable and it give an output signal.
- When the AND gate B and AND gate C are simultaneously triggered, the defibrillation pulse is delivered.
- In the cardioversion or synchronization mode, the defibrillator is synchronized with the ECG unit.
- The ECG signal is given to the QRS detector. Its output is used to time the delivery of the defibrillation pulse with a delay of 30 milliseconds.
- This delay allows the attendant to defibrillate atrium without inducing ventricular fibrillation.

Square Pulse Defibrillator:

- The Capacitor is discharged through the subject by turning on a series SCR.
- When sufficient energy has been delivered to the subject, a shunt SCR short circuits the capacitor and terminates the pulse.
- The output can be controlled by varying the voltage on the capacitor or duration of discharge. Defibrillation is obtained at less peak current and there is no side effect.

Double Square Pulse Defibrillator:

- Used after the open heart surgery. 8 - 60 V double pulse is applied with a mean energy of 2.4 watt – second.
- When the first pulse is delivered some of the fibrillating cells will be excitable and will be depolarized.
- Cells which are refractory during the occurrence of first pulse will continue to fibrillate.
- The second pulse operates on these cells. Complete defibrillation can be obtained by means of selecting proper pulse – space ratio Biphasic D.C. Defibrillator.
- Delivers d.c. pulses alternatively in opposite directions. More efficient for defibrillation of the ventricular muscles.

Biphasic D.C. Defibrillator:

Biphasic d.c. defibrillator is similar to the double square pulse defibrillator such that it delivers d.c. pulses alternatively in opposite directions. This type of wave form is found to be more efficient for defibrillation of the ventricular muscles.

4. Explain about working and therapeutic regarding dialysis machine. [Nov 2016, Nov 2017, Nov 2019]

Process by which the waste products in the blood are removed and restoration of normal pH of blood is obtained by an artificial kidney machine.

Involves three physical processes:

- Diffusion
- Osmosis
- Ultrafiltration

Two types:

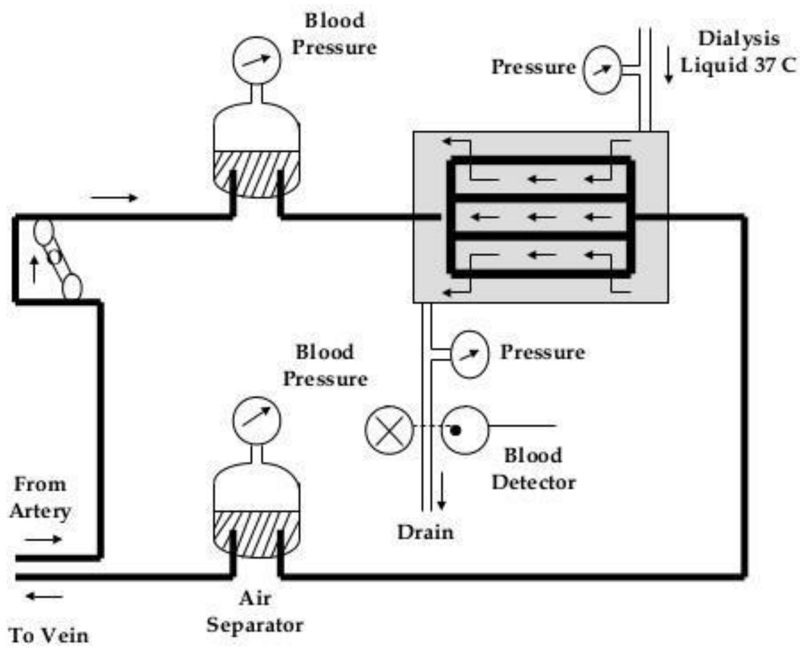
- Extracorporeal Dialysis (Hemodialysis)
- Intracorporeal Dialysis (Peritoneal Dialysis)

Sl. No.	Extracorporeal Dialysis	Intracorporeal Dialysis
1.	Blood is purified by an artificial kidney machine, blood is taken out from the body and waste products diffuse through a semi – permeable membrane which is continuously rinsed by a dialyzing solution or dialysate.	The peritoneal cavity in our body is used as semi – permeable membrane and by passing the dialysate into it, waste products are removed the blood by diffusion.
2.	More effective	Less effective
3.	Technically complex and risky	Simple and risk free
4.	Dialysing time is 3 to 6 hours	Dialysing time is 9 to 12 hours

Hemodialysis:

- For short term use, a double lumen catheter is inserted into the femoral vein and for long term use, an arterio – venous shunt which is a permanent connection between an artery and a vein and inserted below the skin in the hand by a minor operation, is used to take the blood from the artery to the dialysing unit.
- The arterio – venous shunt is opened and connected to the dialyzer.
- Using a blood pump the blood is pumped into a number of planar sheets of cellophane which are pressed together in a frame.
- Blood flows in alternate spaces and the dialysate flows in the others.
- When the volume of the blood flow through the spaces is very small, then the arterial pressure is enough to maintain the flow in the dialysing unit where the blood pump is not necessary.
- Through the cellophane sheets, urea, creatinine, uric acid and phosphates are diffused from blood to dialysate.
- There is a blood leak detector to detect rupture of a membrane.
- Pressure monitoring meters are present at the input and output.
- A thermostatic control is provided to maintain the blood at 37o C.

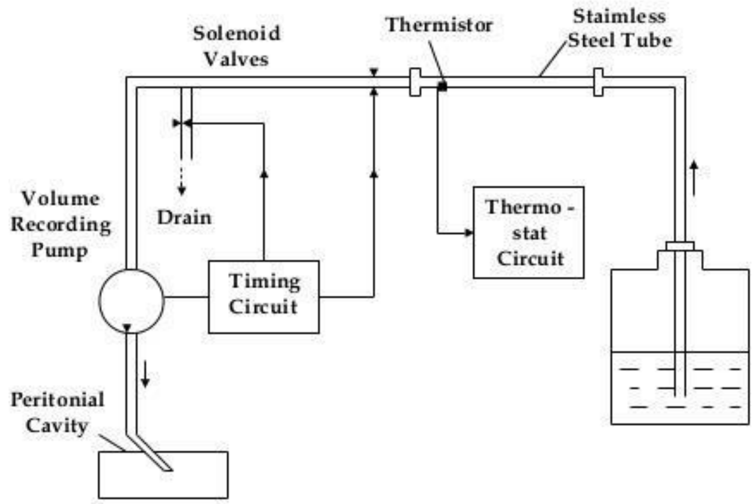
Hemodialyser



Peritoneal Dialysis:

- The membrane in the peritonial cavity is used as a semi – permeable membrane.
- A catheter is inserted in the abdomen through a puncture just below the navel.
- A sterile dialysate about 1.5 to 2 litres is allowed to flow in to the peritonial cavity.
- The diffusion takes place in 10- 30 minutes and the dialysate is the removed from the cavity.
- This procedure is repeated 20 to 30 times to remove all the waste products from the blood.
- This procedure is done in an automatic manner using electronic control circuitry Peritonial Dialysis.
- First the dialysate is pumped into the abdominal cavity through the volume recording pump.
- The dialysate is kept at 37o C by thermostatic control.
- When the dialysate is about 2 litres, a timing circuit will deliver a signal to stop the dialysate flow into the abdomen.
- Next the timing circuit allows the diffusion up to 30 minutes.
- After that it runs the sucking pump so that the dialysate in the abdominal cavity is pumped and sent out through the drain.
- Once again the volume of the outgoing dialysate is measured.
- When the volume of the dialysate is reached 2 litres, then the working of the sucking pump is stopped and the fresh dialysate is allowed once again to enter into the abdominal cavity through the volume recording pump.
- The above procedure is repeated 20 to 30 times.

Peritonial Dialysis



5. Draw block diagram of shortwave diathermy unit and explain.

(Or)

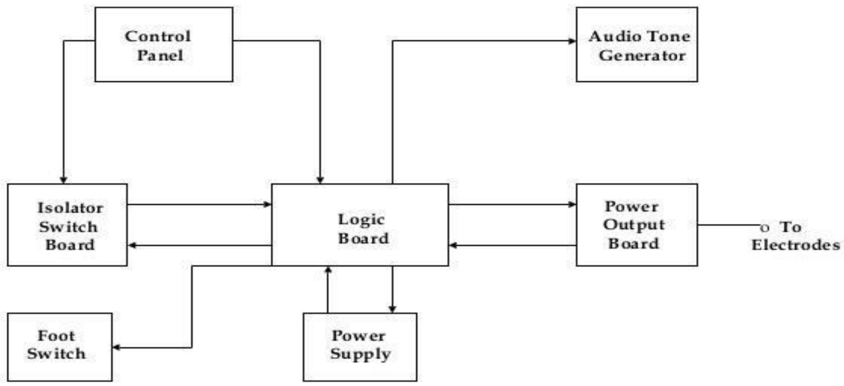
Explain the working and function of diathermy. [May 2016, Nov 2018]

Treatment process by which cutting, coagulation, etc. of tissues are obtained.

Various electro surgery techniques using diathermy unit:

- **Fulguration** – The electrode is held near the tissue without touching it and due to passage of electric arc, the destruction of superficial tissue takes place.
- **Desiccation** – Produces dehydration in the tissue.
- **Electrotomy** – The electrode is kept above the skin, an electric arc is sent which helps in tissues cutting.
- **Coagulation** – The electrode is kept near the skin, high frequency current is sent through the tissue in the form of bursts and heating it locally so that it coagulates from inside.
- **Blending** – The electrode is kept above the skin, the separated tissue or nerves can be combined together by an electric arc.

Block Diagram of Electrosurgical Diathermy Unit



- The logic board is the main part of the unit which produces the necessary waveform for cutting, coagulation and hemostasis modes of operation.
- An astable multivibrator generates 500 kHz square pulses.
- This is divided into a number of frequency using binary counters.
- These frequencies are used as system timing signals.
- The output of the push – pull amplifier is given to a transformer so that the voltage is stepped up.
- To indicate each mode of operation, the diathermy unit is provided with an audio tone generator.
- The isolator switch provides an isolated switching control between the active hand switch and the rest of the unit.
- The logic board receives information from the foot switch, finger switch and alarm sensing points.

Shortwave Diathermy:

- Heating is carried out at a high frequency of 27.12 MHz and a wavelength of 11 metres.
- In this method the output of R.F. oscillator is applied to the pair of patient electrodes.
- The R.F. energy heats the tissues and promotes the healing of injured tissues and inflammations.
- The electrodes or pads are not directly in contact with the skin.
- Layers of towel are interposed between the metal and the surface of the body.
- The pads are placed so that the portion of the body to be treated is sandwiched between them.

- The pads form the capacitor plates and the body tissues between the pads act as dielectric.
- When the R.F. current is applied to the pads, the dielectric loss of the capacitor produces heat in the intervening tissues (Capacitor method).
- Sometimes a flexible cable is coiled around the arm or knee or any other portion of the patient's body where plate electrodes are inconvenient to use (Inductor method).
- When R.F. current is passed through the cable, deep heating in the tissue results from electrostatic field set up between its ends and heating of the superficial tissues is obtained by eddy currents set up by magnetic field around the cable.

6. Describe the function of pacemaker and its uses.

(Or)

Discuss the different modes of operation of pacemaker. [May 2017, May 2018]

An electric impulse generator for starting and/or maintaining the normal heart beat. Used either externally or internally. Pulse repetition rate is 70 pulses/min. Duration of each pulse is between 1 and 2 ms.

Methods of Stimulation:

- External Stimulation - used temporarily to restore the normal rhythm of the heart during cardiac standstill.
- Internal Stimulation – used for long term pacing where permanent damage has been done.

Types of electrodes used:

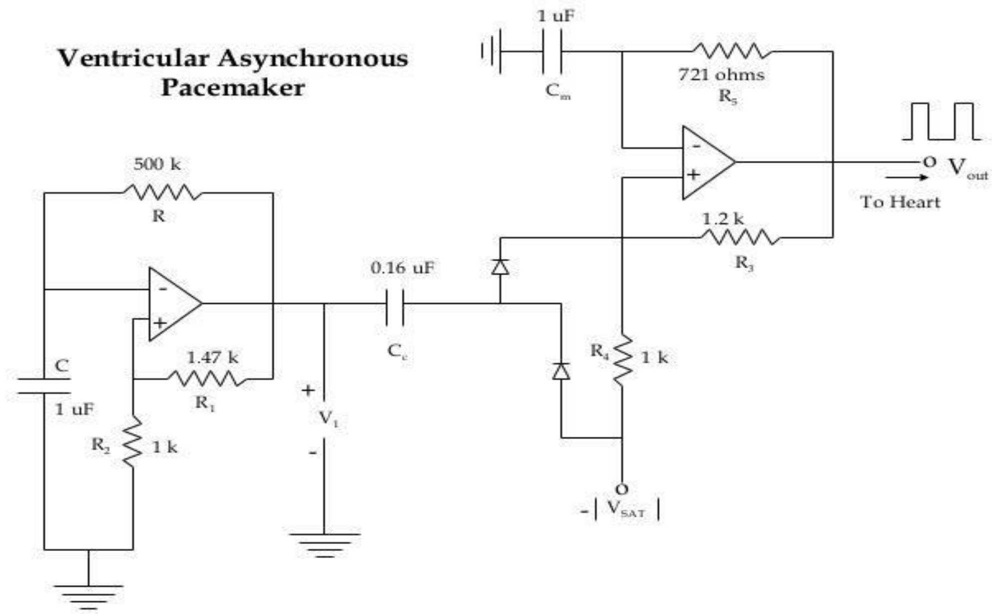
- Bipolar Electrode – there are two electrodes (stimulating and contact electrodes).
- Unipolar Electrode – only stimulating electrode and the return path is made through body fluids.

Modes of Operation:

1. Ventricular Asynchronous Pacemaker (fixed rate pacemaker)
2. Ventricular Synchronous Pacemaker
3. Ventricular Inhibited Pacemaker (demand pacemaker)
4. Atrial Synchronous Pacemaker
5. Atrial Sequential Ventricular Inhibited Pacemaker

1. Ventricular Asynchronous Pacemaker:

- Can be used in atrium or ventricle, has simplest mechanism and longest life.
- Cheap, easy to check and lest sensitive to outside interferences.
- Suitable for patients with a stable, total AV block, a slow atrial rate or atrial arrhythmia.



- Basically a simple astable multivibrator which produces stimulus at a fixed rate irrespective of the behaviour of heart rhythm.
- There may be competition between the natural heart beats and the pacemaker beats. Such an event can be dangerous if the pacemaker impulse reaches the heart during a certain vulnerable period (the apex of the T wave), the ventricular fibrillation may occur.
- Consists of a square wave generator (first differential amplifier circuit) and a positive edge triggered monostable multivibrator (second differential amplifier circuit with diodes).
- The square wave generator is astable multivibrator which periodically switches between the output voltages |Vsat| and - |Vsat|.
- The output of the square wave generator is coupled to the positive edge triggered monostable multivibrator circuit.
- A positive edge at the trigger input will pass through the capacitor Cc and the diode, raising the voltage at the lower node (non inverting terminal) of the second differential amplifier.

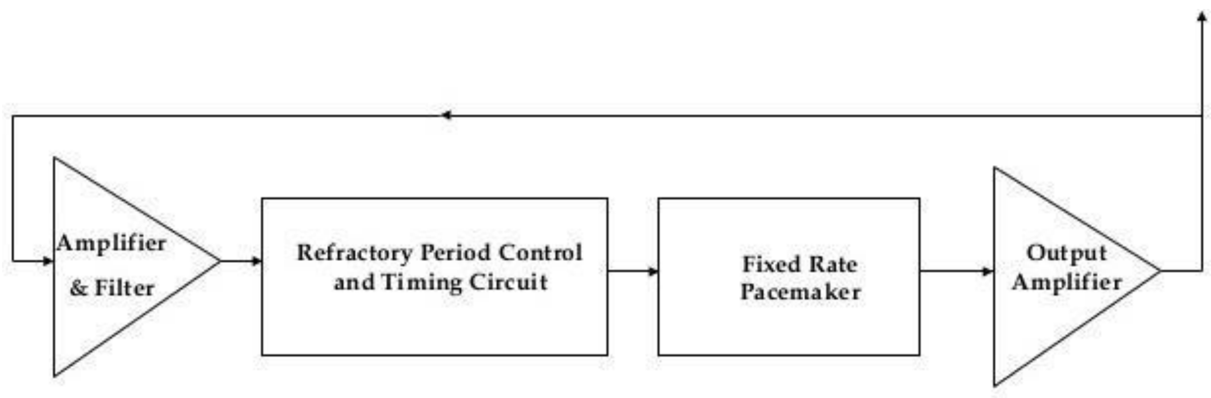
Disadvantages:

- Hear rate cannot be increased to match greater physical effort.
- Stimulation with a fixed frequency results in the ventricles and atria beating at different rates. This varies the stoke volume of the heart causing some loss in the cardiac output.
- Possibility for ventricular fibrillation will be more, when used for patient with unstable block, due to interference between the ventricular contraction evoked by the pacemaker and the atria.

2. Ventricular Synchronous Pacemaker:

- Used for patients with short periods of AV block or bundle block.
- Does not compete with normal heart activity.

- A single transverse electrode placed in the right ventricle both senses the R wave and delivers the stimulation eliminating the need for a separate sensing electrode.
- A R-wave from an atrial generated ventricular contraction triggers the ventricular synchronized pacemaker which provides an impulse falling in the lower part of the normal QRS complex ensuring that the pacemaker does not interfere with the sinus rhythm.
- If atrial generated ventricular contractions are absent, the pacemaker provides impulses at a basic frequency of 70 impulses / minute.
- It provides impulses only when the atrial generated ventricular contractions are absent thereby conserving energy.



Working:

- Using the sensing electrode, the heart rate is detected and is given to the timing circuit in the pacemaker.
- If the detected heart rate is below a certain minimum level, the fixed rate pacemaker is turned on to pace the heart.
- If a natural contraction occurs, the asynchronous pacer's timing circuit is reset so that it will time its next pulse to detect heart beat.
- Otherwise the asynchronous pacemaker produces pulses at its preset rate.
- The pacemaker detect noise and interpret as its ventricular excitation, this is eliminated by the incorporation of refractory period circuit or gate circuit after either a paced or natural contraction .

Advantages:

- Can be used to arrest ventricular fibrillation.
- No chance of side effects.
- When the R wave is appearing with lesser amplitude, the circuit amplifies it and delivers it in proper form.
- If the R wave period is too low or too high, the asynchronous pacer in the circuit is working up to the returning of the heart into normal one.

Disadvantages:

- Atrial and ventricular contractions are not synchronized.

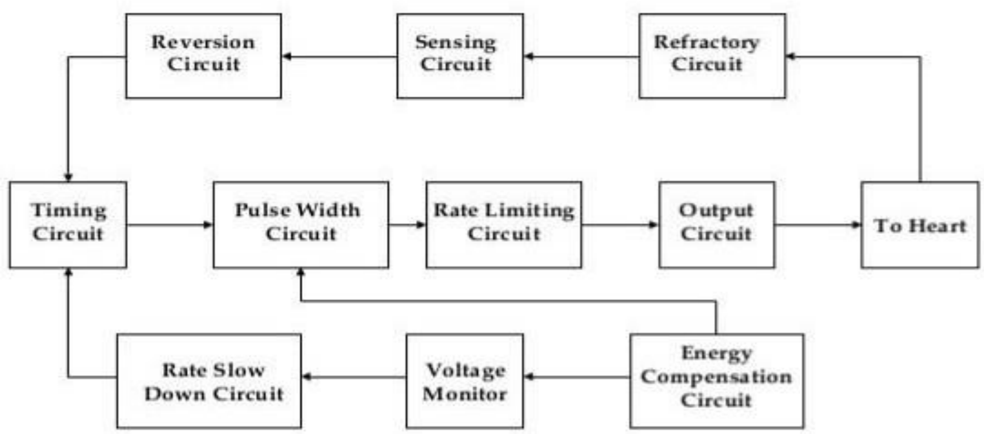
- The older pacemakers were affected by external interferences, but this is eliminated in the newer ones by connecting a low pass filter in the input circuit of the pacemaker.

3. Ventricular Inhibited Pacemaker:

- Allows the heart to pace at its normal rhythm when it is able to.
- If the R wave is missing for a preset period of time, the pacer will supply a stimulus.
- Also called as a ‘demand pacemaker’.
- A piezoelectric sensor is present inside the pacemaker casing.
- When the sensor is slightly stressed or bent by the patient’s body activity, the pacemaker can increase or decrease its rate automatically enabling it to match with the greater physical effort.
- It is similar to the ventricular synchronous pacemaker.
- Its output is suppressed as long as the natural R waves are present whereas in the case of synchronous pacemakers an impulse is emitted with the occurrence of each sensed R wave.

Working:

- The sensing electrode picks up the R wave.
- The refractory circuit provides a period of time following an output pulse or sensed R wave during which the amplifier in the sensing circuit will not respond to outside signals.



- The sensing circuit detects the R wave and resets the oscillator.
- The reversion circuit allows the amplifier to detect the R wave in low level signal to noise ratio.
- In the absence of R wave it allows the oscillator in the timing circuit to deliver pulses at its preset rate.
- The timing circuit consists of an RC network, a reference voltage source and a comparator which determines the basic pulse rate of the pulse generator .
- The pulse width circuit determines the duration of the pulse delivered to the heart.
- The limiting circuit limits the pacing rate to a maximum of 120 pulses per minute.
- The output circuit provides a proper pulse to stimulate the heart.

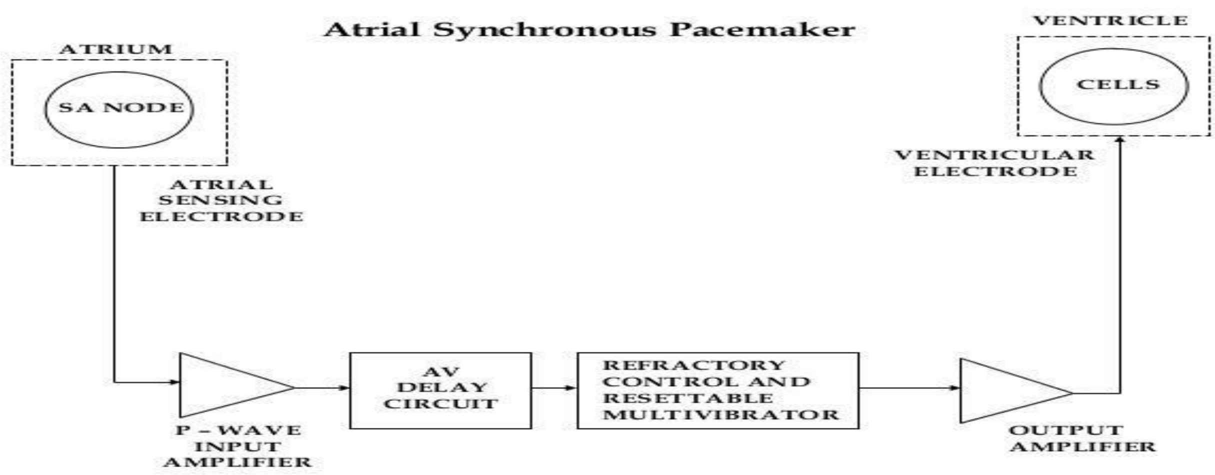
- The voltage monitor senses the cell depletion and signals the rate slow – down circuit and energy compensation circuit.
- The rate slow – down circuit shuts off some of the current to the basic timing network to cause the rate to slow – down 8 + 3 beats per minute when cell depletion has occurred.
- The energy – compensation circuit produces an increase in the pulse duration as the battery voltage decreases to maintain constant stimulation energy to the heart.

4. Atrial Synchronous Pacemaker:

- Used for young patients with stable block.
- Temporary pacing

Used in:

- Physiologic investigation.
- Stress testing and coronary artery diseases.
- Evaluation of severity of mitral stenosis.
- Evaluation of various conduction mechanisms.
- Terminating atrial flutter and paroxymal atrial tachycardia.
- Temporary pacing for atria fibrillation.



Working:

- The atrial activity is picked up by a sensing electrode placed in a tissue close to the dorsal wall of the atrium.
- The detected P wave is amplified and a delay of 0.12 second is provided by the AV delay circuit.
- This is necessary corresponding to the actual delay in conducting the P wave to the AV node in the heart.
- The signal is then trigger the resettable multivibrator and the output of the multivibrator is given to the amplifier which produces the desired stimulus.
- The stimulus is delivered to the ventricle through the ventricular electrode.

5. Atrial Sequential Ventricular Inhibited Pacemaker:

- Has the capability of stimulating both the atria and ventricles and adopts its method of stimulation to the patients' needs.
- If atrial function fails, this pacemaker will stimulate the atrium and then sense the ventricular beat.
- If it is working properly it will discontinue its ventricular stimulating function.
- If atrial beat is not conducted to the ventricle, the pacemaker on sensing this will fire the ventricle at a preset interval of 0.12 second.

7. Explain the components of an audiometer system with suitable block diagram. [May 2019]

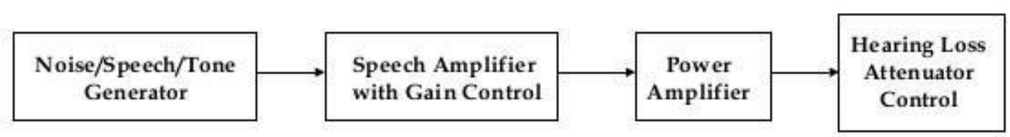
(Or)

Draw schematic of evoked response audiometer and explain in detail. [May 2018]

- Electronic - acoustic instrument for measuring human level in terms of loudness and pitch of sounds.
- Used to get diagnostic information about the acuity of hearing.

Types:

- Pure Tone (a single frequency sound) Audiometers - to measure hearing loss
- Speech Audiometers
- Screening Audiometers – to determine the threshold of hearing



Automatic Bekesy audiometer:

To finish the measurement in a short time, Bekesy audiometer is used and it gives the audiogram directly.

The details of the various blocks in the circuit are given below:

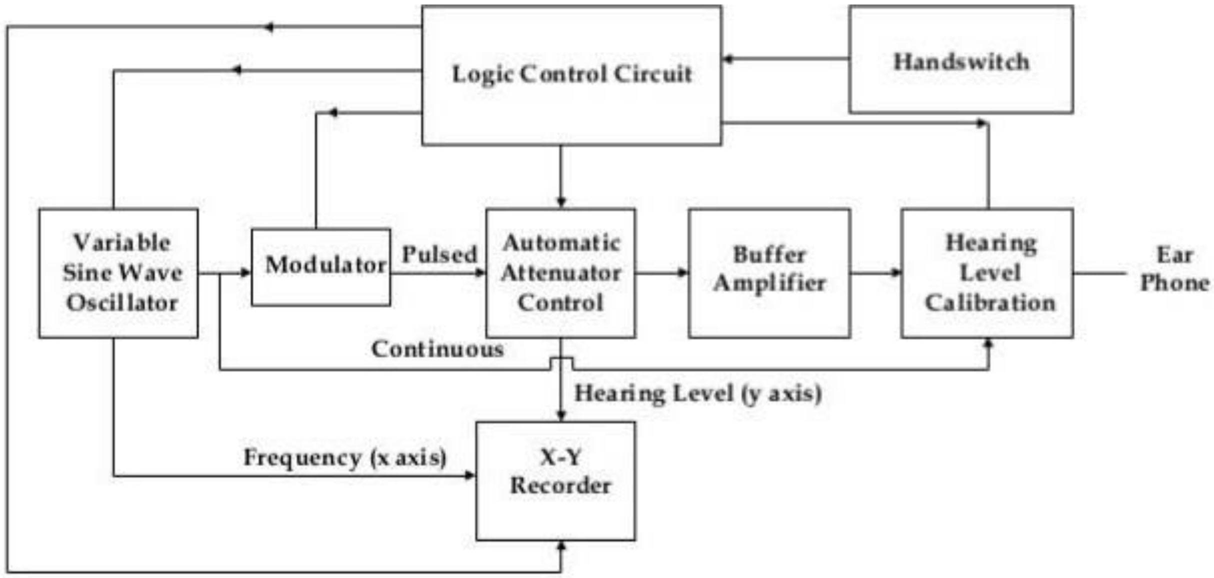
Variable Sine Wave Oscillator – generates test signals, the sequence is first prescribed to the left ear (each 30 seconds) masking the right ear and then vice versa.

Modulator – consists of two modes namely pulsed and continuous mode.

Automatic Attenuator and Recorder – the wiper of the pen drive of the X –Y recorder is attached to potentiometer in the attenuator.

Hand Switch – the pen drive is controlled via the logic circuit by the hand switch, operated by the patient (pressing the switch increases the sound level while releasing the switch decreases the sound level).

Buffer Amplifier – isolates the attenuator from the calibration circuit.



Procedure:

- The instrument generates a pure tone signal which is presented to the patient through an air conduction ear phone.
- The patient is told to press a hand switch till the tone is heard and release the switch once the tone is heard.
- Since the hand switch is connected with the logic circuit, a motor drives attenuator.
- A pen connected to the attenuator traces a continuous record of the patients' intensity adjustments on the audiogram chart paper.
- When the sound is heard by the patient, the hand switch is released and the motor reverses.
- The logic control circuit simultaneously changes the frequency of tone and the measurement is repeated.
- The resultant curve is properly calibrated in terms of hearing loss for different frequencies.

Evoked response audiometer:

To determine the disorder in the acoustical branch of the brain, the evoked response EEG resulting from an auditory stimulus is used. Along with pure tone audiometer, the EEG leads are also connected to the scalp of the patient. At the end of the measurements, the presence of characteristic amplitudes and latencies in the EEG waveform gives diagnostic information about the status of the acoustic part of the brain.