Principle of Pulse Oximeter

Pulse oximeter (or oximetry) is based on following two principles :

(1) Haemoglobin (Hb) and oxygenated haemoglobin (HbO_2) differ in their absorption of red and infrared light.

(2) The volume of arterial blood in tissue and as such the light absorption by the hemoglobin changes during the pulse.

Pulse oximeter has red and infrared low voltage light emitting diodes (LEDs) and a photo detector. LEDs serve as light source. We know that constituents of human body—blood in arteries and veins, and tissue absorb light differently as shown in Fig. (20).

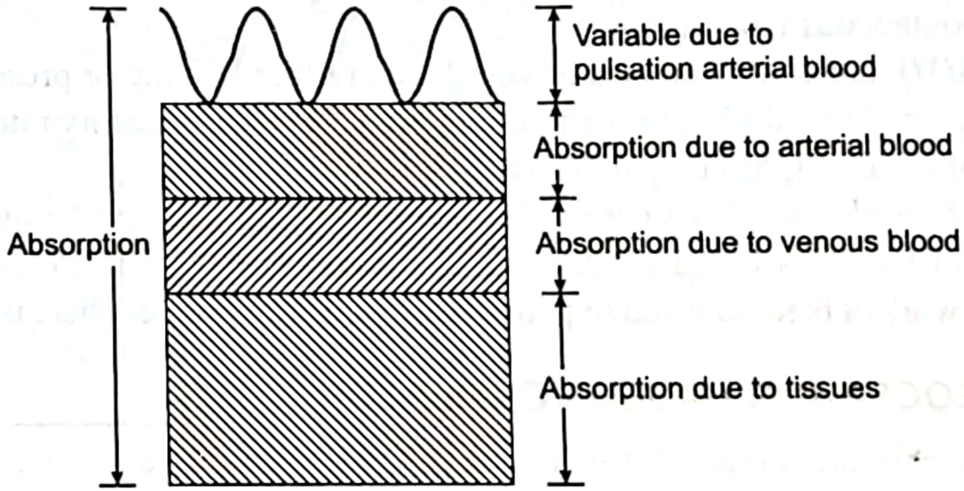

Fig. (20) Components of absorption signal

Oxygen enters the lungs and is then passed on into blood. The blood carries the oxygen to the various organs in our body. The main way O_2 is carried in blood is by haemoglobin.

The pulsating of arterial blood results in changes in the absorption of added haemoglobin (Hb) and oxygenerated haemoglobin (HbO_2) in the path of the light. Also, HbO_2 and Hb absorb light to varying degrees. This varying absorption is translated into waveforms at both—red and infrared wavelengths as

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shown in Fig. (21). From the figure we observe that oxygenated haemoglobin (HbO_2) and deoxygenated haemoglobin (Hb) have different absorption rate. HbO_2 absorbs more infrared light whereas Hb absorbs more red light.

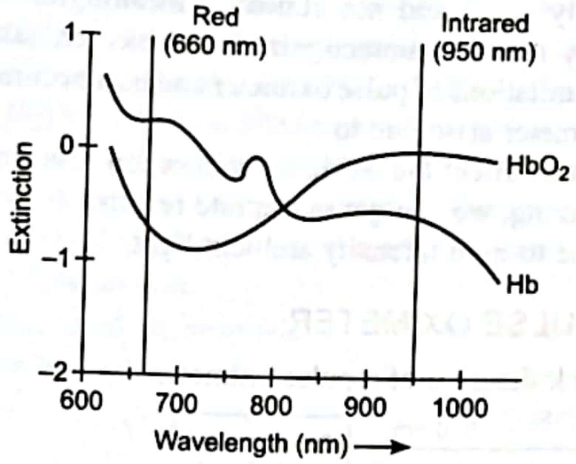

Fig. (21) Absorption waveform of HbO_2 and Hb

The relation of red and infrared signal amplitude can be directly related to arterial oxygen saturation by the relation.

$$\% \text{ oxygen saturation} = \frac{C(HbO_2)}{C(HbO_2) + C(Hb)} \times 100$$

Where, C (Hb) is concentration of deoxygenated haemoglobin and $C(HbO_2)$ is the concentration of oxygenated haemoglobin.

Uses of Pulse Oximeter

The purpose of a pulse oximeter is to know if the human blood is well oxygenated. Medical professionals use pulse oximeters to monitor the health of people with conditions that affect blood oxygen levels. Pulse oximeters are used by doctors while treating patients with diseases such as asthma, pneumonia, lung cancer, anemia, heart diseases etc.

Doctors use pulse oximeter for following reasons :

(1) To assess whether the patient needs some help for breathing.
(2) To evaluate how helpful a ventilator is.
(3) To monitor oxygen levels during or after surgery.
(4) To assess a person's ability to tolerate increased physical activity.
(5) To assess how well the lung medicine is working.
(6) For sleep studies.

Hence pulse oximeter finds application in operating rooms, ICU, ambulances, delivery suites/wards, sleep laboratories, etc.

Advantages of Pulse Oximeter

(1) Simple and convenient to use.
(2) Non-invasive.
(3) Require no warm up time and have fast response time.
(4) Cost-effective.
(5) Separate respiratory and circulatory variables.
(6) Give continuous measurements.
(7) Have light weight and compactness. Hence, user friendly.

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5.3 SPHYGMOMANOMETER

The word "sphygmomanometer" is a combination of Greek word sphygmos meaning beating of the heart or pulse plus manometer which is a device for measuring pressure or tension. The arterial blood pressure in humans is routinely measured by the auscultatory method using a sphygmomanometer and a stethoscope. Blood pressure is considered a good indicator of the status of cardio-vascular system.

A sphygmomanometer has three parts as shown in Fig. (7).

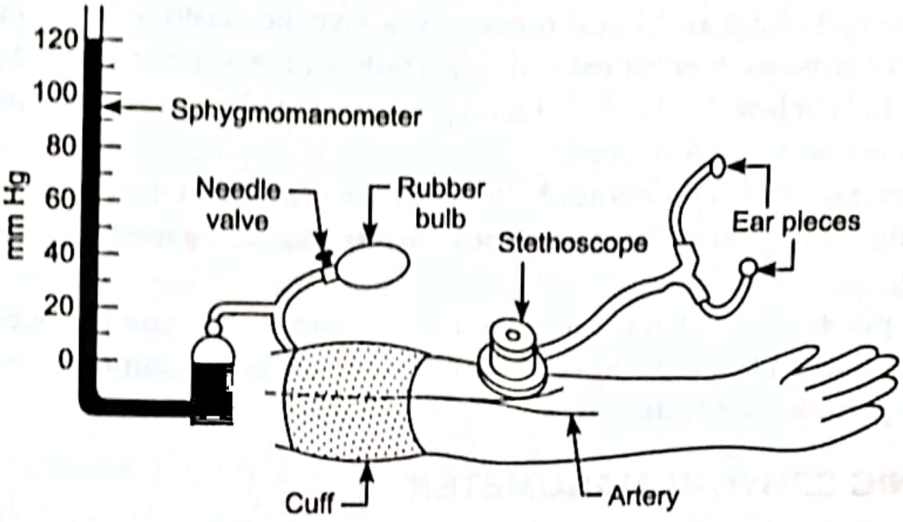

Fig. (7) Sphygmomanometer

(1) *Cuff*: It is inflated with air. The cuff consists of a rubber bladder inside an elastic fabric covering. It can be wrapped around the upper arm.

(2) *Manometer* : It measures air pressure in the cuff.

(3) *Stethoscope* : It is used for listening to the sound which the blood makes as it flows through the brachial artery (which is the major artery found in our upper arm).

For a young adult in good health, the average blood pressures in different parts of the circulatory system are as follows :

(1) Brachial artery

Systolic 110–120 mm Hg

Diastolic 65–80 mm Hg

(2) Capillaries 20–30 mm Hg

(2) Veins 0–20 mm Hg (in veins near the heart)

Working Principle

The cuff is wrapped around the patient's upper arm midway between elbow and shoulder. Cuff is inflated and pressure is raised to a value above the expected systolic pressure. The pressure in the cuff is slowly lowered using a needle valve while putting the chest-piece of stethoscope over the brachial artery at the elbow. At a certain level, soft tapping sounds corresponding to heart beat are heard through the stethoscope. As the pressure is further lowered, sounds become louder and finally disappear.

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These sounds are known as *Korotkow sounds*. The level at which sounds begin to be heard is the systolic blood pressure of the individual and the level at which sounds disappear is the diastolic pressure as shown in Fig. (8).

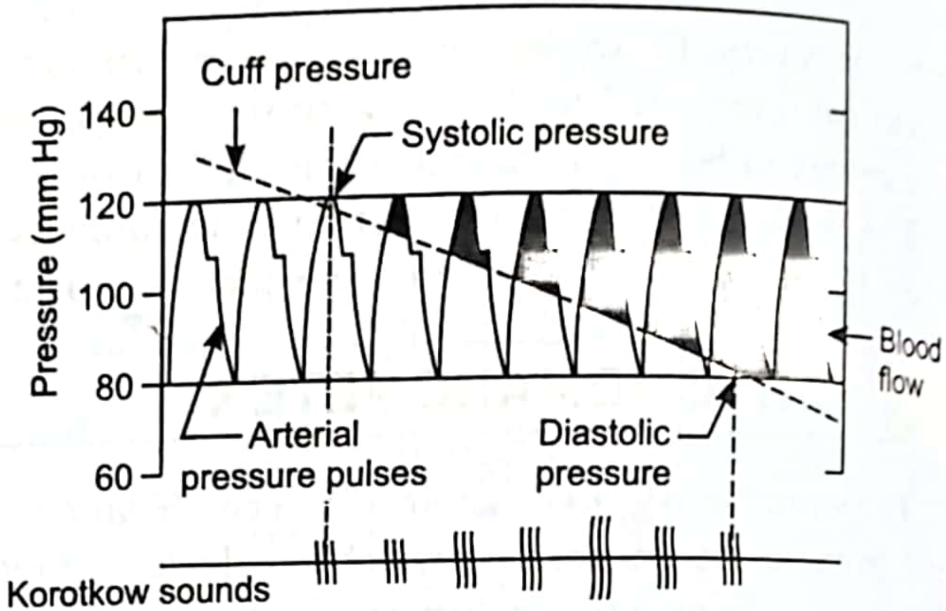

Fig. (8) Measurement of blood pressure using a sphygmomanometer and a stethoscope

Korotkow sounds are produced by turbulent flow of blood in the brachial artery. With cuff-pressure higher than systolic blood pressure, the blood flow in the brachial artery ceases completely and no sounds are heard. When the cuff-pressure is just below the systolic pressure, blood tickles down the artery at the peak of each systole. As long as the cuff pressure is above the diastolic blood pressure, the blood flow in the brachial artery remains intermittent and hence turbulent producing a sound with each systole. When the cuff pressure falls below the diastolic blood pressure, the blood flow becomes continuous and laminar. Hence sounds are no more produced.

To read the blood pressure, observer notes both the gauge pressure at the onset of Korotkow sound (systolic) and when sounds disappear. These pressures are recorded in the ratio of systolic over diastolic form (120/80 mm Hg).

The cuff must be placed at heart level to obtain a pressure that is uninfluenced by gravity. The accuracy of method depends on hearing ability of the observer and how accurately he is able to read the changing pressure gauge when the Korotkow sounds are heard.

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5.5-2 X-RAY MACHINE

A simplified block diagram of X-Ray machine is shown in Fig. (12). There are two main parts.

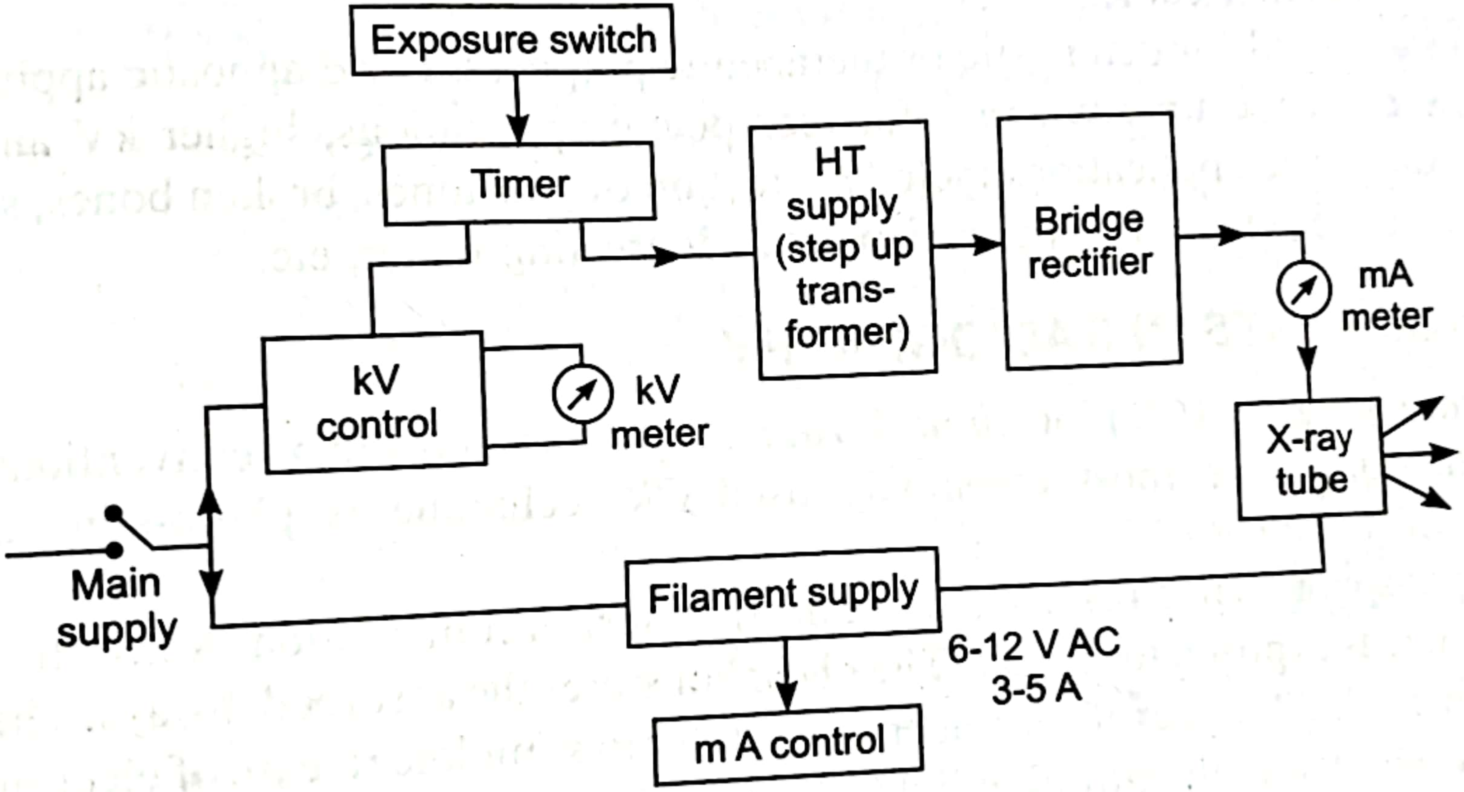

Fig. (12) Block diagram of X-ray machine

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(1) One part is for producing high voltage to be applied to cathode and anode of the tube. There is a high voltage step up transformer followed by a rectifier. Voltage between exposures is changed through kV control in the primary of HT transformer. The current through the tube is measured by a wattmetter. The exposure switch controls the timer and hence the duration of the application of kV. The kV meter is connected across primary of HT transformer and is calibrated in kV.

(2) Second part is for heating the filament of X-ray tube. The filament is heated with 6 to 12 volt AC supply at a current of 3 to 5 ampere. It is the filament temperature which determines the tube current (mA). Hence filament temperature control has an attached mA selector. The filament current is controlled by using a variable choke or a rheostat in the primary side of the filament transformer.

Various types of timers, *e.g.*, electronic timers, automatic timers, ionization timers and photo timers etc. are used. *Electronic timers* work on charging and discharging of a capacitor. *Photo timer* is a system which responds to intensity of light which reaches it and allows the light to be coupled to a photo multiplier tube. It converts the light signal into an electrical signal. In *inonisation timers*, very small current passed by ionization chamber is amplified and is used to send a signal to generator to stop exposure.

Various *interlocking and safety devices* are used to save the X-ray tube. This prevents an over exposure from being made in circumstances which would result in overheating of target. As the anode of the tube must rotate, an interlock circuit is provided in the tube stator circuit. This circuit does not allow the exposure to occur if some fault in stator circuit prevents the tube anode from rotating. To ensure exposure to be made only when anode has reached its maximum speed, (about 3000 RPM after a time interval of 0.7 second), an *automatic delay* (0.8 s to 2 s) in introduced through a slugged relay so that exposure does not take place before (0.9 s to 2 s).

Also *overload interlocks* are provided to protect the X-ray tube against an exposure overloading it when the selected exposure factors are too high.

X-rays tubes are classified on the movement of anode. In *stationary anode tubes*, the heat generated due to collisions is conducted away by various means like circulating a coolant, *e.g.*, water or oil through a cavity provided in anode. Whereas in *tubes with rotating anodes*, there is removal of target from electron beam before it reaches too high a temperature under the electron bombardment and rapid replacement of it by another cooler target.

X-Rays tubes are used for diagnostic or therapeutic purposes. For diagnostic applications we use high mA and low exposure time whereas for therapeutic applications, higher kV and low mA are required. Typical diagnosis applications include detection of gallstones, broken bones, swallowed pins and ulcers of stomach. Therapeutic applications include treating tumor, etc.

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5.8 VENTILATOR

Ventilator is a machine that supports breathing. It is also called a breathing machine or respirator. These machines are mainly used in hospitals as a form of life support. Ventilators are used when oxygen levels are low in a patient or when there is severe shortness of breath from an infection such as pneumonia.

Ventilators are used to :

(i) Deliver a high concentration of oxygen into the lungs.

(ii) Helps to get rid of carbon dioxide.

(iii) Decrease the amount of energy a patient uses on breathing. The body can concentrate on fighting infection or recovering.

(iv) Breathe for a person who is not breathing due to injury in brain or spinal cord.

A modern ventilators has three basic physical parts : a main unit, a user interface and a mobile stand. The main unit contains all the mechanical and electronic components.

Working of a Ventilator

A ventilator uses pressure to blow air into the lungs. This pressure is known as *positive pressure.* Such ventilators are known as *positive pressure ventilators.* Negative pressure ventilator are also available. Here the air is pulled out of the lungs. A patient usually exhales the air on their own but the ventilator can do it for the patient also. The amount of oxygen the patient receives can be controlled through a monitor connected to the ventilator. A ventilator is mostly used for short periods such as during surgery. However for serious lung diseases or other abnormal conditions, ventilators are used for a long period or even for rest of patient's life.

A ventilator blows air into the airway through a breathing tube. One end of the tube is inserted into patient's windpipe and the other end is attached to the ventilator. The breathing tube serves as an airway

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5.8-2 MICROPROCESSOR BASED VENTILATOR

Input control signals are obtained for a lung machine, CO_2 analyser, gas analyser and oxygen consumption meter. A microprocessor with EPROM, A/D converter and CRT controller is used in closed loop control where patient therapy is monitored and controlled. Continuous ventilation adjustment is provided in response to patient's metabolism. Such a system is shown in Fig. (19).

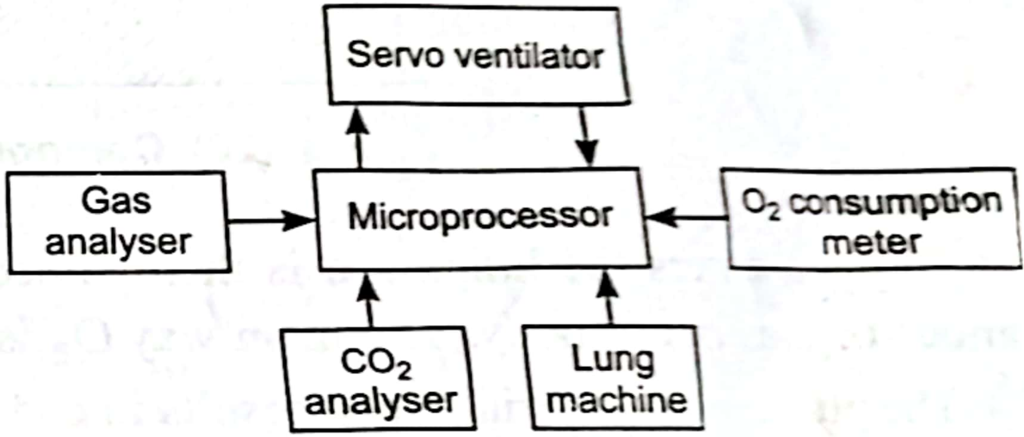

Fig. (19) Microprocessor based mechanical ventilator

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Principle of Ultrasound Scanning

Ultrasound scanning is based on the fact that ultrasound travels through tissue and fluids bounces back or echoes off denser surface. This phenomenon is used to create an image. The denser object the ultrasound hits, the more of the ultrasound bounces back. This bouncing back (or echo) giv varying shades of gray on the image implying different densities.

The transducer or wand is used to emit and to receive sound waves from various tissues in the bod The transducer is placed against the patient's skin with a thin layer of coupling gel. This gel displaces th air which would reflect the ultrasound beam. The transducer is moved over the part of the body that is t be examined.

As sound waves travel into the patient, wave fronts spread out. Diminishing of the overall beam intensity occurs. Beam attenuation also occurs secondary to partial tissue absorption with associated heat conversion.

At tissue interfaces, the beam is partially reflected and transmitted. The reflected sound waves (or

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echoes) travel back to the transducer. They are converted into electrical signals and amplified. The amplitude of the returning wave partially depends on the degree of beam absorption.

A shade of gray is assigned to each amplitude. Typically, strong echoes are assigned a shade near the white end of the spectrum. Weak echoes are assigned a shade near the black end of the spectrum. Also, we can calculate the depth of the reflecting tissue from the known total beam travel time and the average sound velocity in human tissue (1540 m/s).

Uses of Ultrasound Scanning

Ultrasound scanning is used for diagnostic as well as therapeutic uses.

- They are used for imaging of the abdomen (liver, gall bladder, pancreas, kidneys), pelvis (female reproductive organs), fetus (for detecting abnormalities in baby), vascular system, breasts, chest, etc.
- Ultrasound-guided interventions are used to facilitate lesion biopsy, abscess drainage and radio frequency ablation.

Health issues such as cysts, gallstones, abnormal growths in the liver or pancreas, fatty liver disease, liver cancer, etc. can be diagnosed using ultrasound scanning. However, they are inferior to CT scans for detecting certain cancer tumors or other abnormalities within the body.

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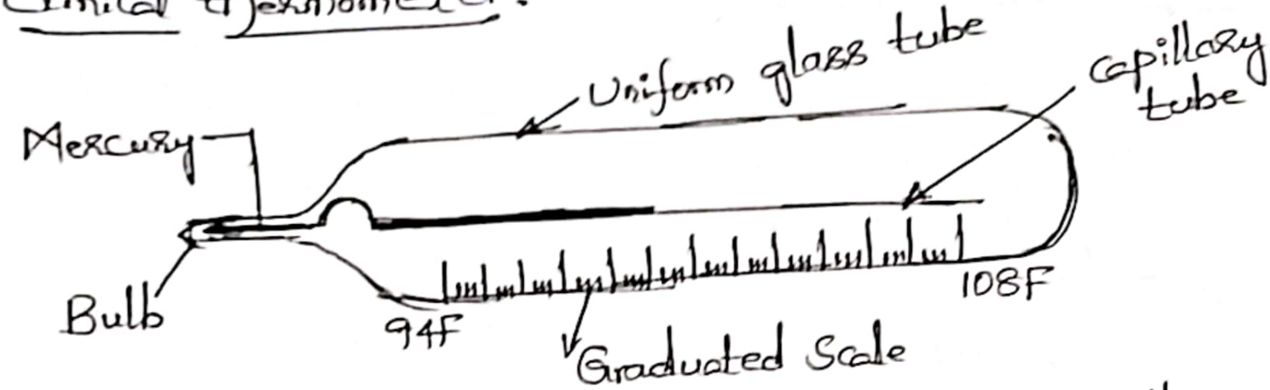
Biomedical Instruments – Unit-V

Clinical thermometer:



→ Clinical thermometer is used to measure the exact temperature of the body.
→ Clinical thermometer is also called as Doctors thermometer.
→ It is usually made up of glass and consists of mercury filled bulb inside at one of its ends.
→ A clinical thermometer is used to measure temp ranging from 35°C to 42°C (celcius) or 95°F-108°F
→ Temp is given by reading the scale inscribed on the side of the thermometer.

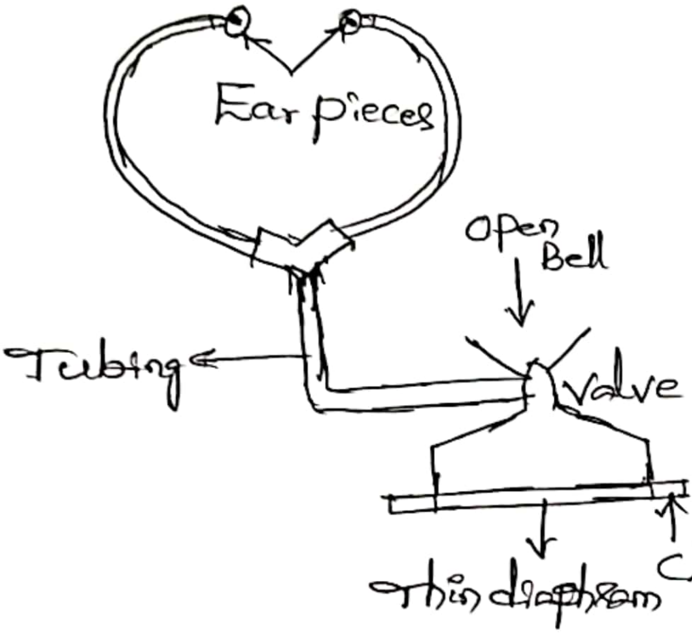
Working:

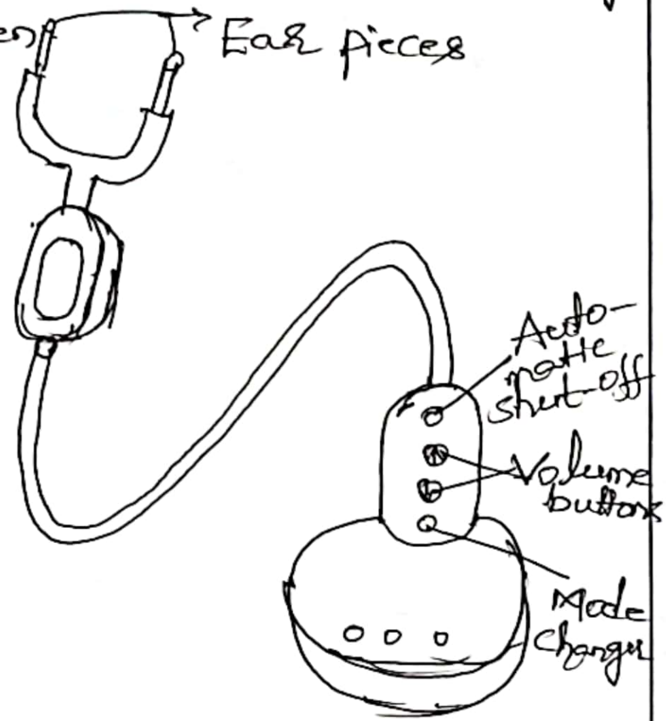
→ A clinical thermometer is placed in bottom of mouth for measuring body temp because the body, the mercury inside the bulb heats up and expands, and raises to certain level in the capillary tube.
→ The new level in the scale indicates exact body temp.
→ According to the construction the mercury column breaks & thus remains stationary in the tube
→ To reset the thermometer, you need to swing it sharply many times.
→ then the mercury column returns to the bulb.

Mercury is a metal & good conductor of heat
why clinical thermometer & mercury is used in

Stethoscope:

→ Def: The stethoscope is an instrument used for listening to the sounds produced by the body.
→ It is primarily used to listen to sounds of lungs, heart and intestinal tract
→ It is also used to listen to blood flow in peripheral vessels & the heart sounds of developing fetuses in pregnant women





→ The acoustic stethoscope is mostly used by medical professionals.
→ It has a diaphram on one side for high pitched sounds & a bell on the other for low-pitched sounds
→ the tubing is thick & heavy which helps to conduct sound.
→ Stethoscope is hearing aid which is used to listen sounds from chest (Stetho- hearts & lungs) by ears of the physician via a column of air.
Main parts of the stethoscope are
1) Bell 2) Tubing 3) Ear pieces

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→ The Length of the tubing is designed at about 25 cm in length & 0.3 cm in diameter
→ Both earpieces are connected to a common bell
→ The open bell acts as an impedance matcher bet skin & air.
→ Closed bell stethoscope is used for listening lung sounds

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... very low (e.g., when the patient is in shock). ... It is of no use when

5.4 ECG MACHINE

Electro Cardio Graph is defined as the recording of electrical activity of heart on a graph paper. The machine which is used to record the electrical activity of the heart is called *ECG machine.* The graph on which the electrical activity is recorded is called *electrocardiogram.* It is a tracing of the electrical activity that is taking place within the heart.

Operating Principle

We know that in human body, trans-membrane ionic currents are generated by ion fluxes across cell membranes and between adjacent cells. These currents are synchronised by cardiac activation and recovery sequences. They generate a cardiac electrical field in and around the heart. This electrical field varies with time during the cardiac cycle.

Depolarization is the electrical changes that take place due to contraction of any muscle. These changes can be detected by electrodes attached on specific locations on the surface of the body. At every heart beat, the heart is depolarized to trigger its contraction. This electrical activity is transmitted throughout the body and can be picked up on the skin.

An ECG machine records this activity *via.,* electrodes on the skin and displays it graphically.

Modern ECG Machine

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Working of ECG Machine

Electrodes are placed in specific locations to detect the currents reaching the skin. Trans-membrane ionic currents are ultimately responsible for the potentials that are recorded as an ECG.

The ECG machine processes the signals picked up from the skin by the electrodes. It produces a graphic representation of the electrical activity of the patient's heart.

- ☐ Electrical activity towards a lead causes an upward deflection.
- ☐ Electrical activity away from the lead causes a downward deflection.
- ☐ Depolarization and repolarization deflections occur in opposite directions. Repolarization is the phase of recovery/relaxation.

The basic pattern of the ECG is shown in Fig. (10). As shown in figure, the pattern comprises of three waves named *P*, *Q R S* (a wave complex) and *T*.

The time between two specific ECG events is called *interval*. The intervals commonly measured on an ECG include the *P R* interval, *Q R S* interval, *Q T* interval and *R R* interval.

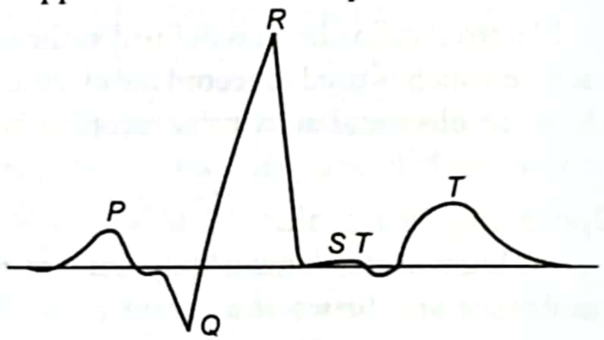

Fig. (10) Basic pattern of ECG

Uses of ECG

ECG is a representation of the electrical events of the cardiac cycle. Each event has a distinctive waveform. The study of waveform can lead to knowing of a patient's cardiac, pathological or physiological condition. ECG helps us to know :

(1) ***Heart rate*** **:** Heart rate is defined as the number of heart beats per minute. It can be determined from ECG through two rules known as the *"rule of 300"* and *"10 second rule"*.

(2) ***Rhythm*** **:** This is checked by the intervals between two *R* waves on two *S* waves.

(2) ***Cardiac axis*** **:** The physical orientation of heart.

(4) It is a diagnostic tool for various heart conditions like blockage of artery in heart or pace maker activity. It is not a direct depiction of abnormalities. Also, it does not record all the heart's electrical activity.

(5) ECG is a recording of electrical activity and not the mechanical function of heart.

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