Phonocardiograph (PCG)

It is an instrument used for recording of sounds connected with pumping action of heart. These sound provide an indication of heart rate and its rhythmcity. They also give information regarding effectiveness of blood pumping and valve action.

Origin of heart sounds

The sounds are produced by mechanical events that occur during heart cycle. The sounds can be from movement of heart wall, closure of valves and turbulance and leakage of blood flow.

The first sound corresponds to R wave of ECG, is longer in duration, lower in frequency and greater in intensity than second sound. The sound is produced by closure of valves b/w upper and lower chambers of heart, ie, mitral and tricuspid valves. It occurs at the termination of atrial contraction and at the onset of ventricular contraction. Frequencies of these sounds are 30 to 100 Hz and duration is in the range of b/w 50 to 100 ms.

The second sound is higher in pitch than first, with frequencies about 100 Hz and duration b/w 25 ms to 50 ms. This sound is produced by slight back flow of blood into heart before valves close and then by the closure of valves leading out of ventricles. It occurs at the closure of aortic and pulmonary valves.

The heart also produces third and fourth sounds but they are much lower in intensity and are normally inaudible. The third sound is produced by inflow of blood to ventricles and fourth sound is produced by contraction of atria. These sounds are called diastolic sounds and are generally inaudible in adult and heard among children.

Two types of microphones are used for recording phonocardiogram. They are contact microphone and air coupled microphone. They are further classified into crystal type or dynamic type, based on principle of operation.

The crystal microphone consists of a ~~moving coil~~ wafer of piezoelectric material which generates potentials when subjected to mechanical stresses due to heart sounds.

They are smaller in size and more sensit than dynamic microphone. (3)

The dynamic type microphone consists of a moving coil having a fixed magne core inside it. The coil moves with heart sounds and produces a voltage because of interaction with magnetic flux.

Ballistocardiograph (BCG)

It is a machine that records movement imparted to the body with each beat of heart cycle. These movements occur dur ventricular contraction of heart muscle when the blood is ejected with sufficient force.

In BCG, patient is made to lie on table top which is spring suspended or otherwise mounted to respond to very slight movements along head axis. Sensing devices are mounted on the table to convert these movements into corresponding electrical signals. The sensors usually are piezo electric crystals, resistive elements or permanent magnets moving wrt fixed coils. In all such cases, output of sensor is amplified and fed to an oscilloscope or chart recorder. BCG is mainly used for research purpose and is rarely used in routine clinical applications.

Blood pressure measurement

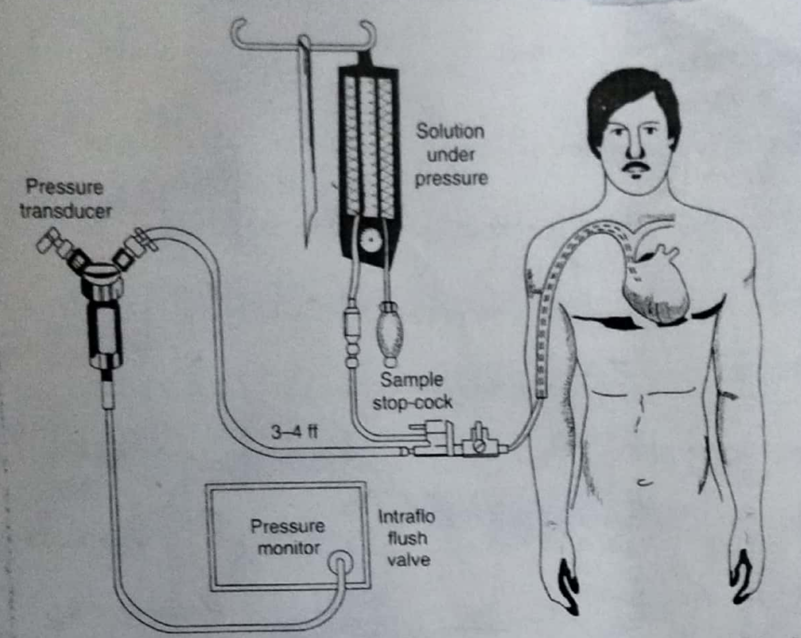
Pressure exerted by blood on the walls of blood vessels, especially on arteries, is known as blood pressure.

Blood is pumped by left side of heart into aorta which supplies it to arteries. Due to resistance in arterioles and capillaries, it loses most of its pressure and returns to heart at a low pressure via highly distensible veins. The right side of the heart pumps it into pulmonary circuit which operates at low pressure. The maximum pressure reached during cardiac ejection is called systolic pressure and minimum pressure occuring at the end of ventricular relaxation is termed as diastolic pressure.

There are 2 basic methods of measuring blood pressure - direct and indirect. Indirect methods consists of simple equipment and cause very little discomfort to the subject but they are intermittent and less informative. They are based on the adjustment of a known external pressure to vascular pressure so that vessel just collapses. But direct methods provide continuous and much more reliable information from probes or transducer inserted directly into blood stream. But additional information is obtained at the cost of increased disturbance to the patient and complexity of equipment

Direct method

It is used when the highest degree of absolute accuracy, dynamic response and continuous monitoring is required. The method is also used to measure pressure in deep regions inaccessible by indirect means. For direct measurement, a catheter or a needle type probe is inserted through a vein or artery to the area of interest. Two types of probes can be used. One type is the catheter tip probe in which sensor is mounted on the tip of the probe and the pressure exerted on it is converted into proportional electrical signal. The other is a fluid filled catheter type which transmits the pressure exerted on its fluid filled column to an external transducer This transducer converts exerted pressure to electrical signals which can be amplified and displayed or recorded.



➤ **Fig. 6.19** *Typical set up of a pressure measuring system by direct method*

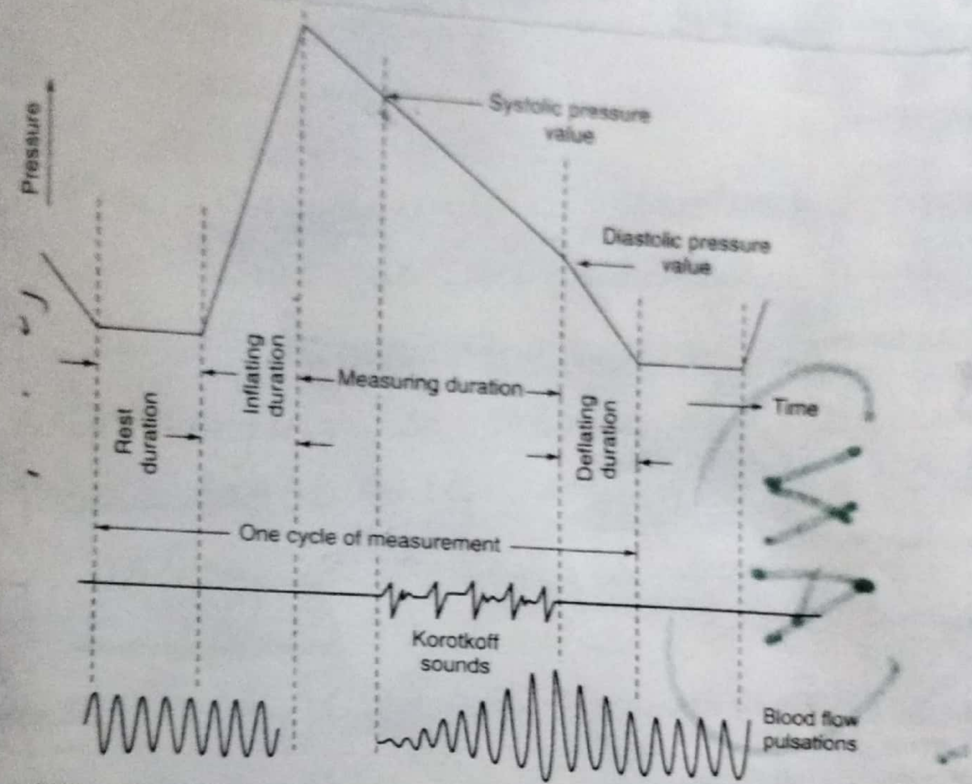
Indirect method

The classical method of making an indirect measurement of blood pressure is by the use of a cuff over the limb containing the artery.

Initially the pressure in the cuff is raised to a level well above systolic pressure so that flow of blood is completly terminated Pressure in the cuff is then released at a particular rate. When it reaches a level, which is below the systolic pressure, a brief flow occurs. If the cuff pressure is allowed to fall

Pulses, just below diastolic pressure the flow becomes normal and uninterrupted

The method is based on determining the exact instant at which artery just opens and when it is fully opened. The method given by Korothoff and based on sounds produced by flow changes is the one normally used in conventional sphygmomanometer. The sounds first appear when the cuff pressure falls to just below systolic pressure. They are produced by brief turbulent flow terminated by a sharp collapse of the vessel and persist as the cuff pressure continues to fall. The sounds disappear at just below diastolic pressure when the flow is no longer interrupted. These sounds are picked up by using microphone placed over an artery distal to cuff. The sphygomomanometric technique is an ausculatory method - it depends on operator recognizing the occurance and disappearance of Korothoff sounds with variations in cuff pressure.



5.26 *Principle of blood pressure measurement based on Korotkoff sounds*

TASNIA

Oscillometric Measurement Method

The oscillometric method is a form of ...ect measurement.

The oscillometric technique operates on principle that as an occluding cuff deflates ...m a level above the systolic pressure, the ...ry walls begins to vibrate or oscillate as the ...d flows turbulently through the partially ...cluded artery & these vibrations will be sensed ... the ~~monitoring~~ transducer system monitoring ...ff pressure. As the pressure in the cuff further ...ecrease, the oscillations increase to a maximum ...mplitude & then decrease until the cuff fully ...eflates & blood flow returns to normal.

The cuff pressure at the point of maximum oscillations usually corresponds to the mean arterial pressure. The actual determination of blood pressure by an oscillometric device is performed by a proprietary algorithm developed by the manufacturer of the device.

The oscillometric method is based on oscillometric pulses generated in the cuff during inflation or deflation. Blood pressure values are usually determined by the application of mathematical criteria to the locus or envelope formed by plotting a certain characteristic, called oscillometric pulse against the baseline pressure. The baseline-to-peak amplitude, to peak amplitude or a quantity based on partial or full time integral of the oscillometric pulse can be used as the oscillometric pulse index. The baseline cuff pressure at which the envelop peaks (max ht) is generally regarded as MAP (mean arterial pressure). Height based & slope based criteria have been used to determine systolic & diastolic pressures.

Measurement sites for oscillometric blood pressure measurement include the upper arm, forearm, wrist, finger & thigh.

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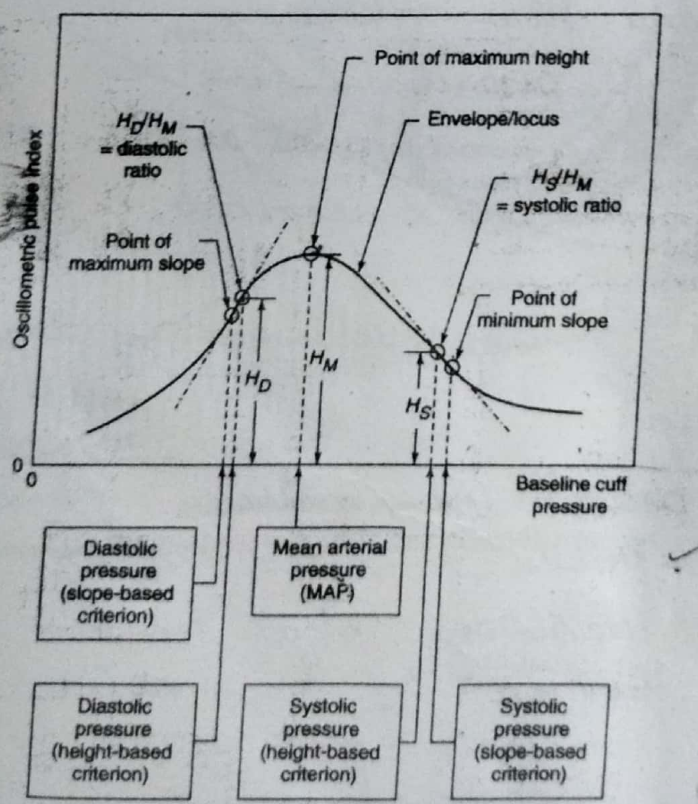
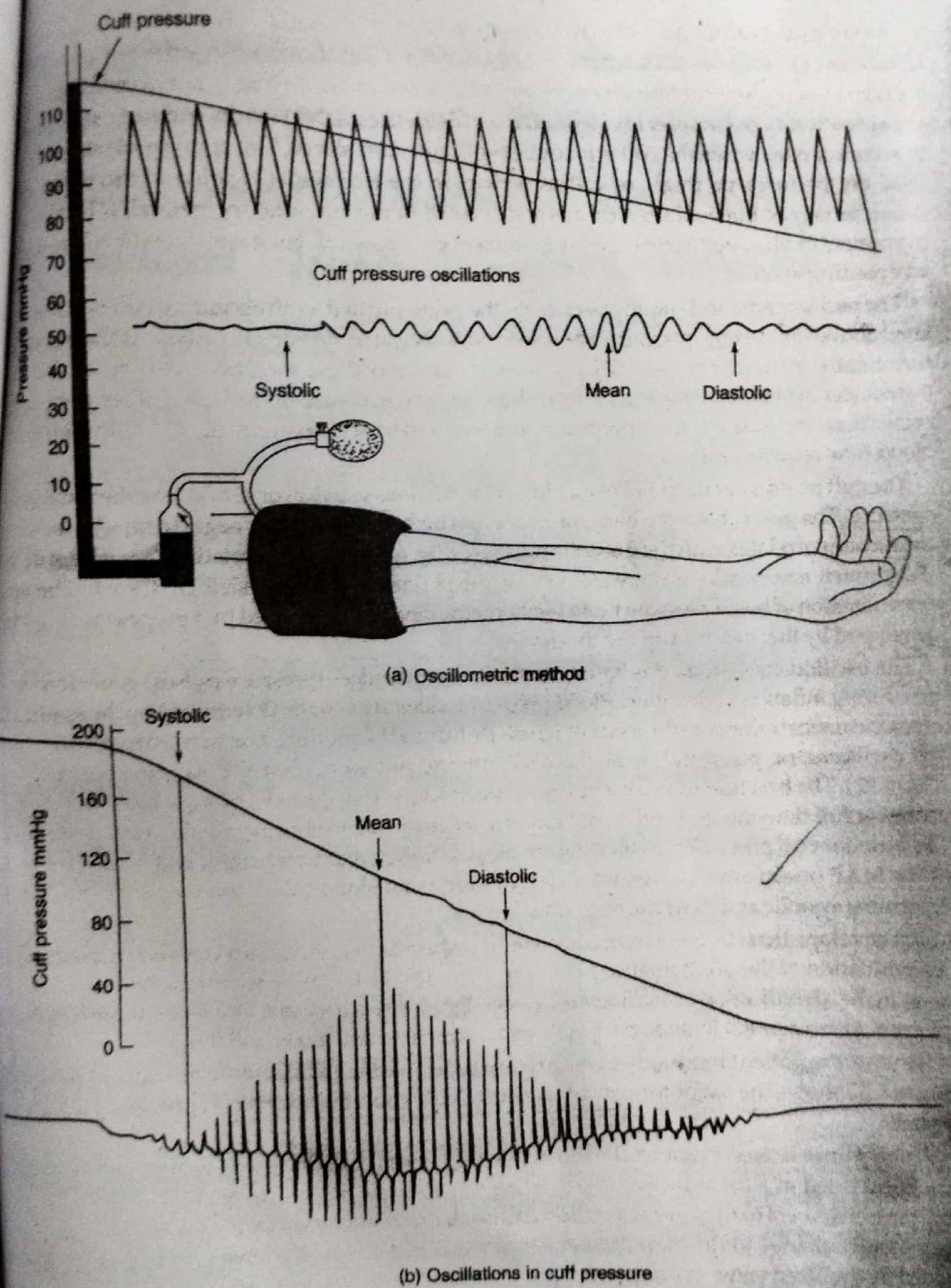


> Fig. 6.32 *Criteria for oscillometric blood pressure determination*



➤ **Fig. 6.31** ***Illusration of oscillometric method of blood pressure measurement***

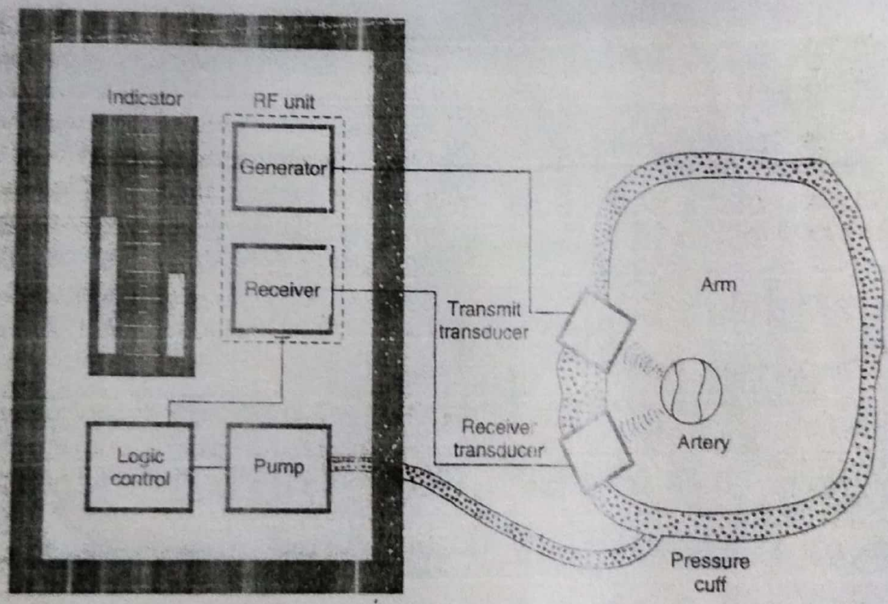
Ultrasonic Doppler shift Method.

It is a form of indirect measurement.

An occlusive cuff is placed on the arm in the usual manner, with an ultrasonic transducer on the arm over the brachial artery. The cuff is inflated first to above systolic pressure & then deflated at a specified rate. A low energy ultrasonic beam at a frequency of 2 MHz is transmitted into arm. The portion of ultrasound that is reflected by the arterial wall shifts in frequency when the wall of artery moves. Above systolic, the vessel remains closed due to the pressure of the occluding cuff & monitor signals are not received. As the cuff pressure falls to the point where it is just overcome by brachial artery pressure, the artery wall snaps open. This opening wall movement, corresponding to the occurrence of first Korotkoff sound, produces a Doppler shift which is interpreted by logic in the instrument as systolic & displayed accordingly. With each subsequent pulse wave, a similar frequency shift is produced until at the diastolic pressure the artery is no longer occluded. It's rapid motion suddenly disappears & Doppler-shift becomes relatively small. The strument notes the sudden diminution in amplitude of Doppler shift & cuff pressure at this point is displayed against diastolic pressure

Advantages :-

Disadvantages :-



➤ Fig. 6.35 *Measurement of blood pressure using ultrasonic Doppler-shift principle*

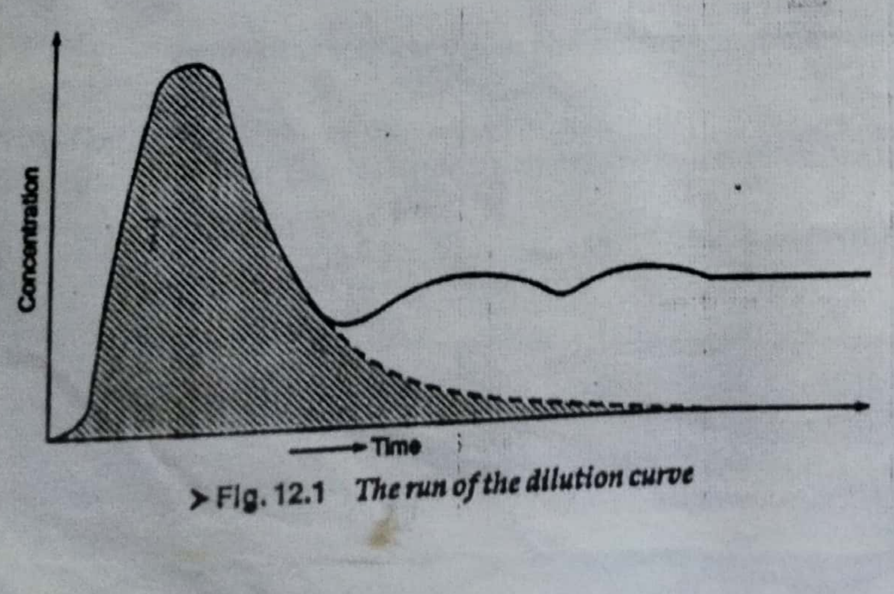
Cardiac output

It is the quantity of blood delivered by heart to aorta per minute. It is a major determinant of oxygen delivery to tissues. A fall in cardiac output may result in low blood pressure, reduced tissue oxygenation, acidosis, poor renal function and shock. Cardiac output is 4 to 6 l/min.

Indicator dilution method

It states that if we introduce into or remove from a stream of fluid a known amount of indicator and measure the concentration difference upstream and downstream of the injection site, we can estimate the volume flow of fluid. The method employs several different types of indicators. Two methods can be employed for introducing the indicator - it may be injected at a constant rate or as bolus.

In bolus injection method, a small but known quantity of an indicator such as dye or radioisotope is administered into circulation. It is injected into a large vein or preferably into right heart itself. After passing through the right heart, lungs and left heart, indicator appears in arterial circulation. The presence of indicator in peripheral artery is detected by a suitable photoelectric transducer and is displayed on a chart recorder.



➤ Fig. 12.1 *The run of the dilution curve*

During the first circulation period the indicator would mix up with the blood and will dilute just a bit. When passing before the transducer, it would reveal a big and rapid change of concentration. This is shown by the rising portion of dilution curve. A fraction of the injected indicator would once again pass through the heart and enter atrial circulation. A second peak would then appear. When the indicator is completly mixed up with blood, curve becomes parallel to time axis.

$$Q = \frac{M \times 60}{\text{Area under curve}} \ l/min$$

M = Quantity of injected indicator

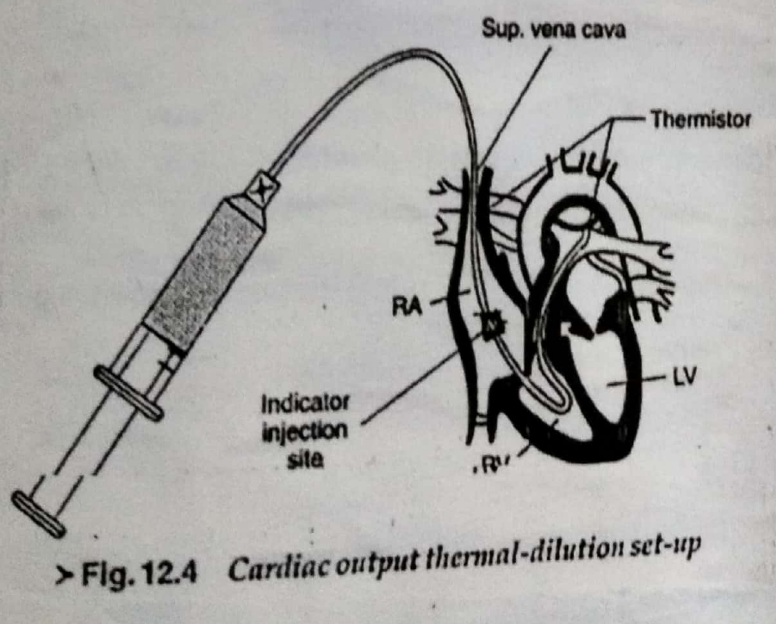
Q = Cardiac output.

Thermal dilution technique

A thermal indicator of known volume introduced into either right or left atrium will produce a resultant temperature change in pulmonary artery or in aorta.

$$\text{Cardiac o/p} = \frac{\text{Const.} \times (\text{blood temp} - \text{injectate temp})}{\text{Area under dilution curve.}}$$

A solution of 5% Dextrose in water at room temperature is injected as a thermal indicator into right atrium. It mixes in the right ventricle and is detected in pulmonary artery by means of a thermistor mounted at the tip of a catheter probe. The injectate temperature is also sensed by a thermistor and the temperature difference b/w injectate and the blood circulating in the pulmonary artery is measured. The reduction in temperature in pulmonary artery is integrated wrt time and blood flow is computed electronically.



> Fig. 12.4 *Cardiac output thermal-dilution set-up*

Measurement of cardiac rate

Heart rate is derived by the amplification of ECG signal and by measuring either the average or instantaneous time intervals b/w two successive R peaks.

1) Average calculation

An average rate is calculated by counting the no. of pulses in a given time

2) Beat to beat calculation.

This is done by measuring the time in seconds, between two consecutive pulses and converting this time into beats/min.

$$\text{Beats/min} = \frac{60}{T}$$

3) Combination of beat-to-beat calculation with averaging.

This is based on four or six beats average. It is similar to beat-to-beat monitoring system.

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Ventilators

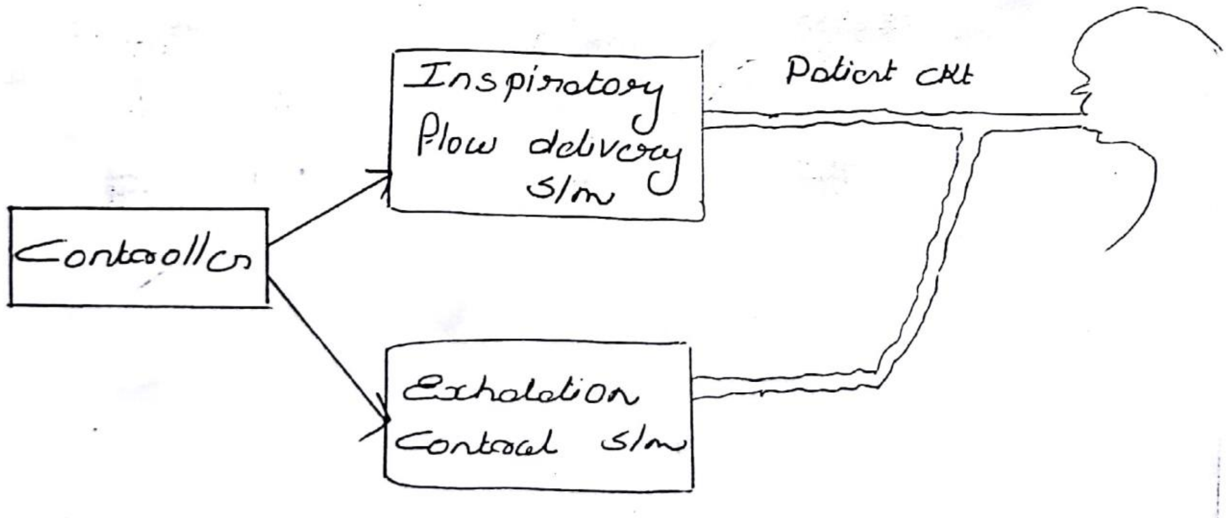
MODULE V

It is a machine designed to move breathable air into & out of the lungs to provide breathing for a patient who is physically unable to breath. They are used in ICU or in anesthesia.

Two types of Ventilators

⇒ Negative ventilator : generates the flow by applying -ve pressure

⇒ Passitive Ventilator: generates the flow by applying +ve pressure.



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A positive pressure ventilator consists of

i) air reservoir or turbine
ii) air and oxygen supplier
iii) set of valves & tubes

The air reservoir is pneumatically compressed several times a minute to deliver room air to patient. The flow valves are there. Air - O_2 supplier mixes suitable amount of air & O_2 which pushes air through ventilator. The exhaled air being realized usually through one way valve called patient manifold.

Types of Ventilators

⇒ Anaesthesia ventilators : They are simple & small equipment used to give regular assisted breathing during operation.

⇒ Intensive Care Ventilators : They are complicated. It deliver air to patient when he tries to inhale

Ventilator Terms

Lung compliance : Ratio of volume delivered to pressure rise.

Air way resistance : Ease with which air flows through tubular respiratory structures.

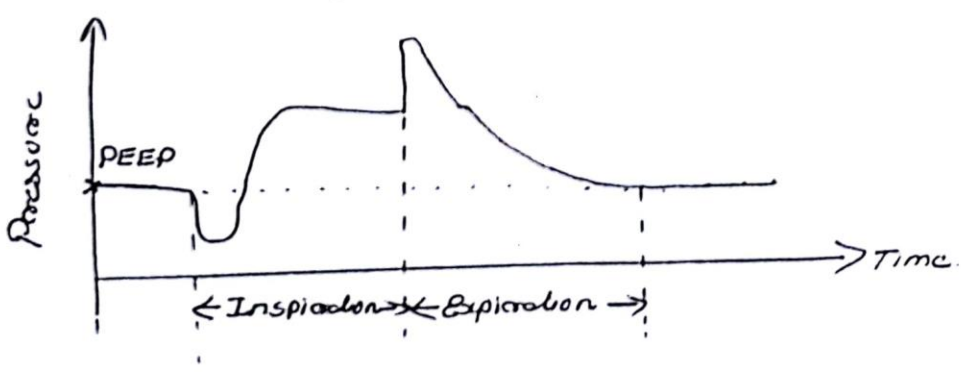
Mean Airway Pressure : Integral taken over one complete cycle

Inspiratory Pause Time : When pressure in patient ckt & alveoli is equal, there is a period of no flow. This period is inspiratory pause time.

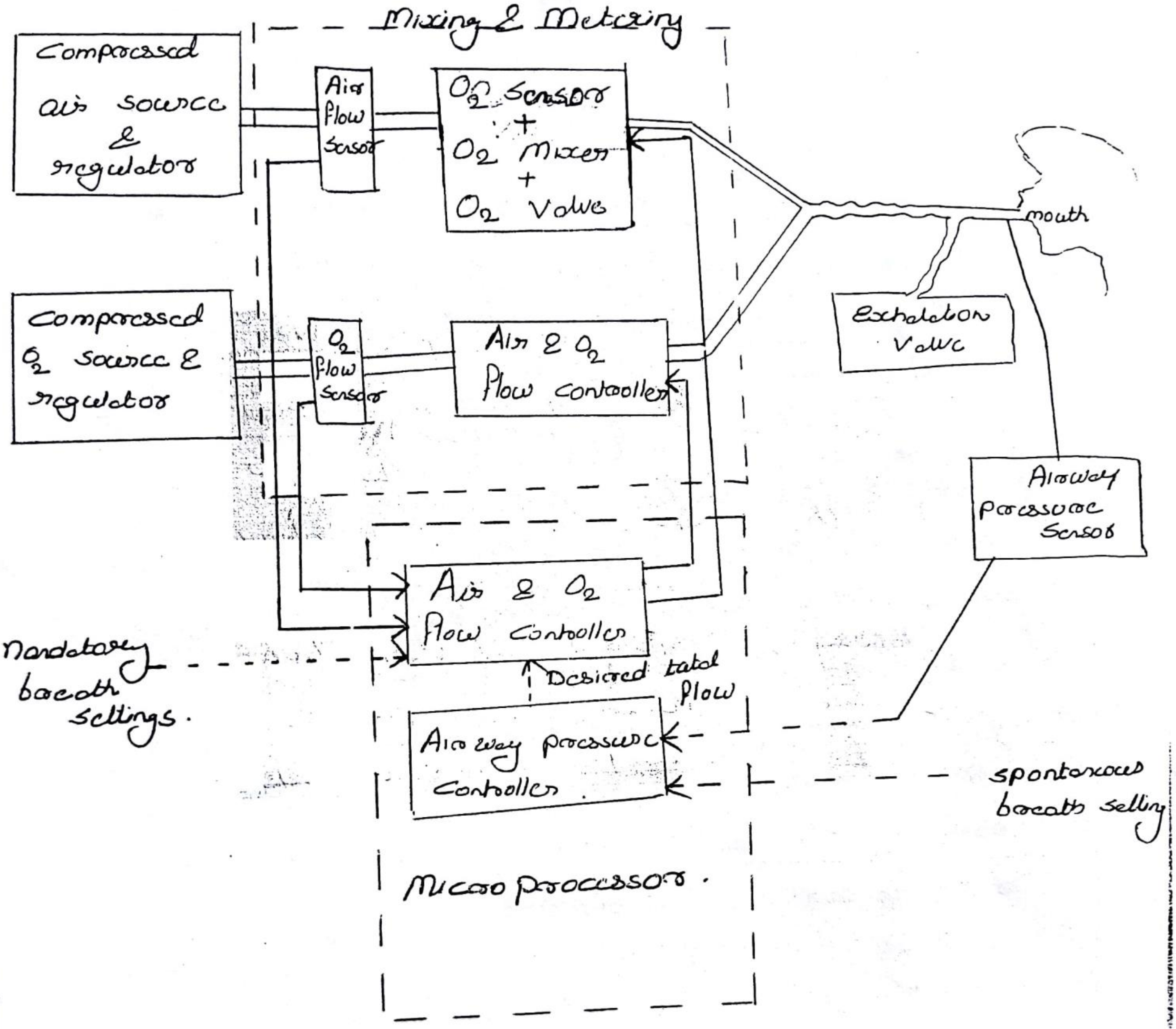
Inspiratory Flow : Positive flow above zero line

Expiratory flow : Negative flow below zero line

PEEP : Positive End Expiratory Pressure is a therapist selected pressure level at the end of expiration.



MODERN VENTILATORS



Ventilator machine consists of two seperate but interconnected s/m.

i) pneumatic flow s/m
ii) Electronic control s/m.

The Pneumatic s/m allow the flow of gas through Ventilator. These gases enter the air/oxygen mixer, where they combine at required percentage. Bidirectional flow sensors measure the gas flow in patient breathing ckt. The flow sensors usually consists of orifice & by measuring the pressure drop across the orifice, the patients flow can be calculated. The microprocessor controls each valve to deliver the desired inspiratory air & oxygen flow for mandatory & spontaneous ventilation.

A high pressure valve is used to provide safety in case the pressure in patient ckt exceeds. The Electronic Control S/m may use one or more microprocessors & softwares to perform monitoring & control functions in a ventilator. These parameters include, respiration rate, tidal volume, PEEP etc. The microprocessor utilizes the above parameters to compute desired inspiratory flow trajectory.

~~Vent~~ For measurement of fraction of oxygen in inspired air, a fuel type oxygen sensor is used.

Ventilators are life saving equipment & so it need regular maintenance.

Dialyzers

The dialyzer is the part in the artificial kidney s/m in which blood is free from waste products. It uses during kidney failures. It mixes & monitors the dialysate which is a fluid that helps to remove waste products. Dialysate is a mixture of pure water & chemicals.

The dialyzer is the meeting point of two circuits, one in which the blood circulates & other in which dialysate flows.

There are two main types of kidney dialysis 1) Hemodialysis & 2) Peritoneal dialysis

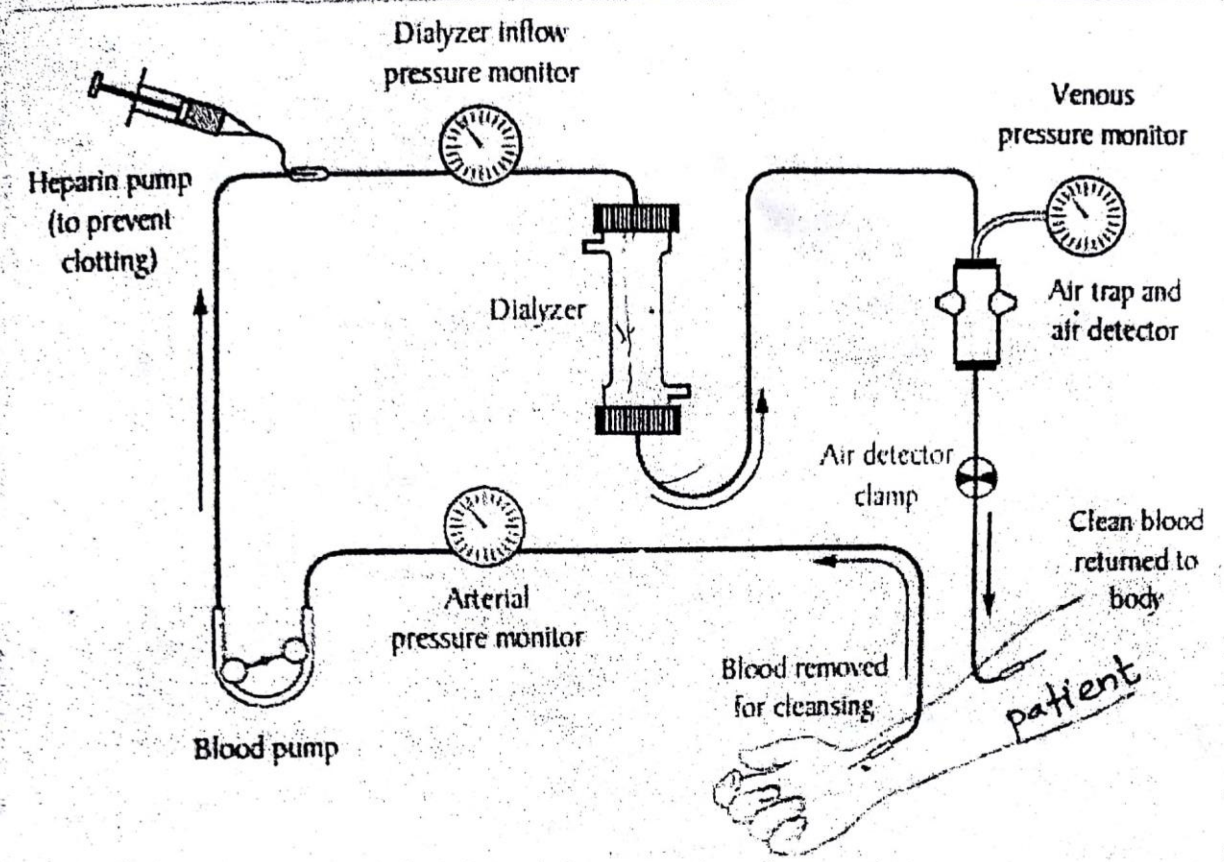
Hemodialysis

It removes waste & water by circulating blood outside the body through an external filter called dialyzer that contains semipermeable membrane. Semipermeable membrane is a thin layer of material that contains holes of various sizes and semipermeable membrane in dialyzer in one direction & dialysate flows in opposite direction. Water & other waste removes b/w these dialysate & blood by means of diffusion, Osmosis & Ultra filteration.

The cleaned blood is then returned to the body. Ultrafilteration occurs by increasing the hydrostatic pressure across the membrane. This is achieved by applying -ve pressure to dialysate.

Advantages : low mortality rate.
better control of blood pressure
less diet restriction

Disadvantages : Restricts independance
Requires more supplies
Required reliable technology



Hemodialyzer

Lithotripsy

Kidney stones can cause great discomfort to the patient as they are passed through the urinary tract & their presence may eventually lead to loss of function of affected kidney. An open incision surgical technique known as lithotomy can be used to remove the stone & this procedure includes all the risks, complications, discomfort & disability of major surgery. Lithotripsy refers to non-invasive or minimally invasive surgical techniques for removing kidney stones without these risks & complications.

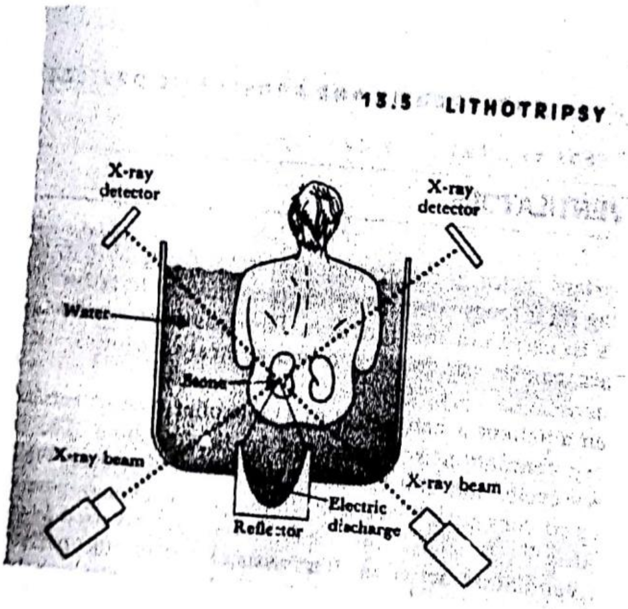
Two types of lithotripsy

i) Percutaneous Lithotripsy

In this method, a probe is guided under X-ray
fluoroscopy through a small incision into the location
of kidney stone. Either mechanical shock waves are
produced at tip by spark or the probe contains an
ultrasonic transducer that produce ultrasonic waves.
Each of these forms of energy is used to break the
kidney stones.

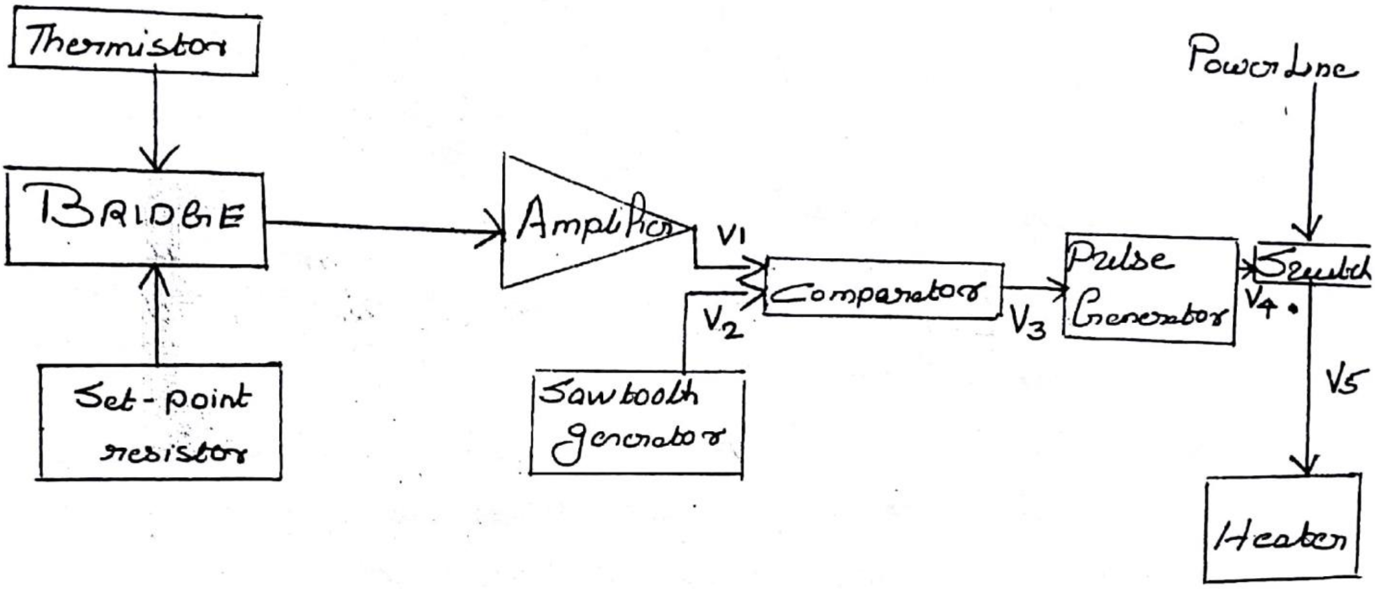
ii) Extracorporeal Shock-Wave lithotripsy

It is an noninvasive method to break up kidney stones. Fig: shows the basic structure. Many mechanical shock waves are produced by a reflector & these shock waves converges at a point several centimeter away from reflector. The reflector & patient are submerged in demineralized, degassed water in such a way that the patient can be moved until the stone is located at the focal point of shock wave. An X-ray s/m is used to establish the position of stone & it monitor disintegration. A high voltage pulse or shock wave is propagated through the water to focal point. Up to 2000 shock waves may be necessary to reduce kidney stone to 1 to 2 mm fragments, so that it can pass through urinary tract.



Infant Incubator

The care of premature newborns requires an environment in which temperature is elevated & controlled; because they are unable to regulate their own temperature. Such controlled temperature environments are maintained in infant incubators. The temperature control s/m is as shown.



The temperature in the air supply line varies a thermistor resistance that is compared with a fixed resistance that corresponds to the set temperature. The bridge o/p is amplified, giving the voltage V_1 at the o/p, which is proportional to the difference in temperature b/w thermistor & the set point. If the temperature of the air entering infant's chamber is lower than set temperature, power is applied to heater to correct ~~for~~ for this difference.

Some incubators, instead of controlling the air temperature directly, use the skin temperature of infant as a control parameter. The temperature of infant & thermistor is placed against the skin of infant & the controller is set to maintain the infant's skin at a given temperature. If the infant is cooler than the set point the air entering the chamber of incubator is heated an amount proportional to the difference b/w the set temperature & the baby's actual temperature.

Incubator also have a simple alarm s/m to alert the clinical staff if there is any dangerous overheating of device.

In some clinical situations, large portions of the skin surface must be exposed. For that purpose incubators with radiant warmers have been developed. The infant is placed on a mattress under a radiant heating element [The radiant element consists of an electric heating element such as a coil of high resistivity wire used in heaters. A heat reflector focus heat onto the mattress. The current through heating element is controlled so that overheating is avoided.] Low walls surround the mattress so that there is no risk of the infant falling off the device, but the remainder of area surrounding infant is open to allow access to patient.

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Heart-Lung Machine

A heart-lung machine maintains blood circulation & oxygenate blood during heart surgery.

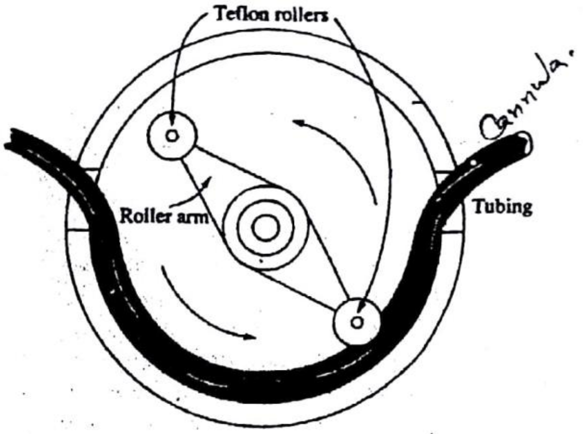

Figure 9-53
Peristaltic pump head.

Fig: shows a diagram of heart-lung m/c pump head called Peristaltic Pump. The Peristaltic pump consists of tubing through which blood to & from the Patient's body is carried & is called CANNULA. Two rollers are placed on rotating arm which compresses the tubing forcing the blood to flow in a wave like pattern.

Schematic representation of heart lung machine is shown. It uses 5 pump heads. one for perfusion of body, 2 suckers & 2 for perfusion of coronary artery. Also there is an oxygenator / heat exchanger. It has two sides O_2^- side (side through which blood enters) & O_2^+ side (side through which blood leaves).

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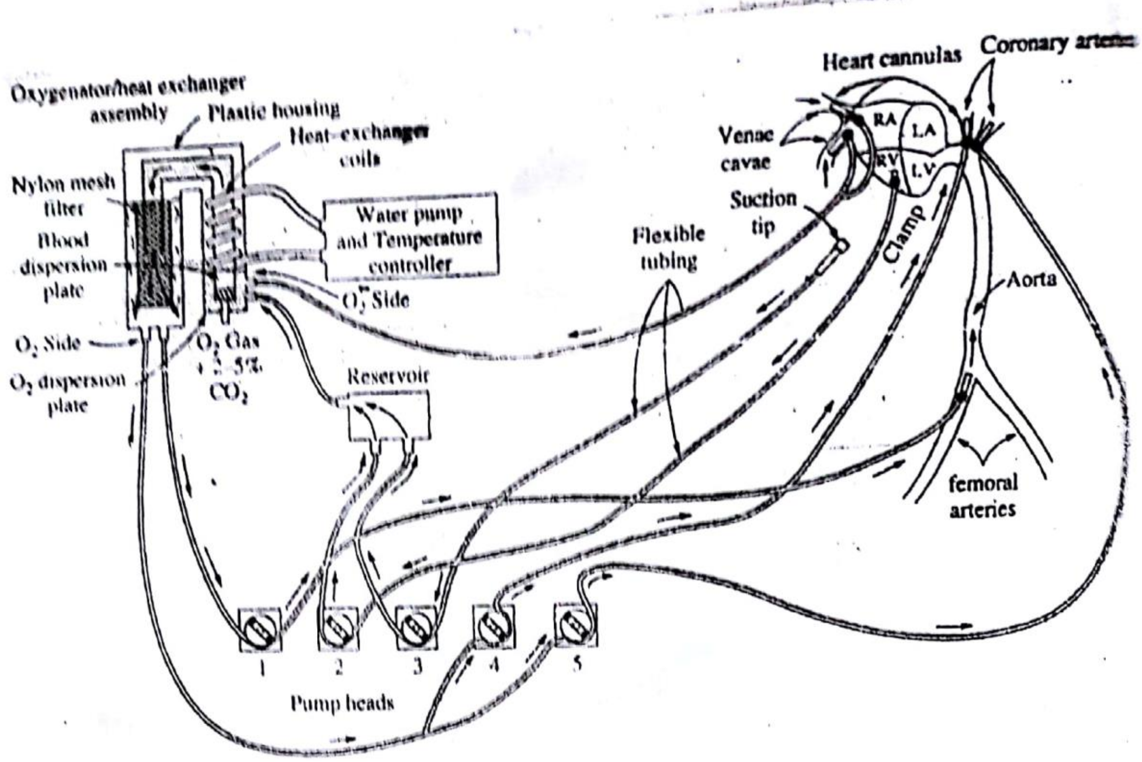


Figure 9-54
Schematic representation of the heart-lung machine.

The oxygenator consists of heat exchanger coil & a filter. The heat exchanger circulate water around the blood & oxygenate it.

The blood is taken from patient's Vena cava by using a Y-adapter. Blood flows from Venacava through tubing to O_2^- side of oxygenator. Another tubing carries blood from O_2^+ side through pump head 1 & back to patient's artery. Pump heads 2 & 3 act as suckers. The blood from suckers is delivered to reservoir tank & then transferred to oxygenator.

Computer Tomography

Tomography is derived from greek word 'tomos' meaning to write a slice. In CT, the picture is made by viewing the patient via X-ray imaging from numerous angles, by mathematically reconstructing the detailed structure & displaying reconstructed image on a Video monitor

Basic Principle.

CT differs from conventional X-ray techniques is that pictures displayed are not photographs but are reconstructed from large no: of absorption profiles taken at regular angular intervals around a slice, with each profile being made up from a parallel set of absorption values through object.

In CT, X-rays from a finely collimated source are made up to pass through a slice of patient from a variety of directions. CT involves the determination of attenuation characteristics for each small volume of tissue in the patient which constitute the transmitted radiation intensity recorded from various irradiation directions. It is these calculated tissue attenuation characteristics that actually compose the CT image.

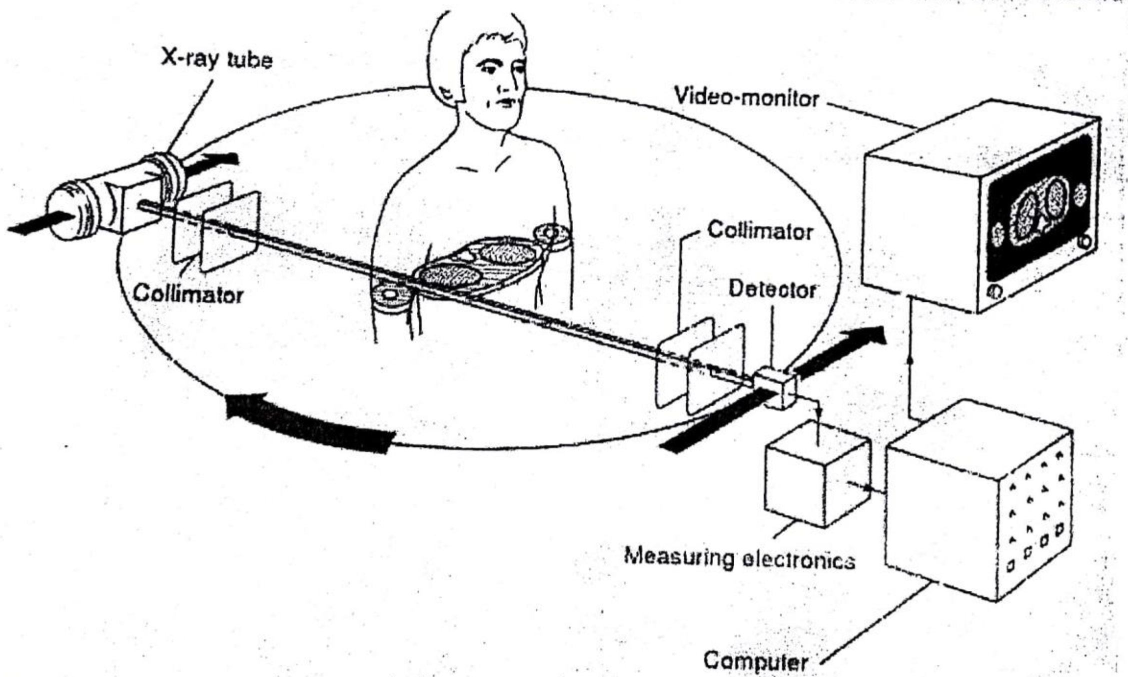
$$I_t = I_0 e^{-\mu x}$$

I_t = Transmitted intensity

I_0 = Incident radiation intensity

μ = Attenuation co-efficient of tissue

x = thickness of tissue.



> **Fig. 20.3** ***The technique of producing CT images. The X-ray tube and the detector are rigidly coupled to each other. The system executes translational and rotational movement and transradiates the patient from various angular projections. With the aid of collimators, pencil thin beam of X-ray is produced. A detector converts the X-radiation into an electrical signal. Measuring electronics then amplify the electrical signals and convert them into digital values. A computer then processes these values and computes them into a matrix-line density distribution pattern which is reproduced on a video monitor as a pattern of gray shade***

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System components

All CT s/m consists of 4 major subsystems

1) Scanning system - It takes suitable readings for a picture to be reconstructe & include X-ray source & detectors.

2) Processing Unit - It convert these readings into intelligible picture information.

3) Viewing Part - It presents the information in visual form.

4) Storage Unit - It enables the information to be stored for subsequent analysis

Advantages of CT

1) Quick & Painless
2) can help diagnose & guide treatment for a wider range of conditions than X-ray
3) can detect presence of tumors, lesions etc
4) Can be used to check, if a previously treated disease has occured

Disadvantages.

i) Small increased risk of cancer

ii) Injection of dye can cause Kidney problems

iii) Some procedures require anesthesia

Applications

1) CT is an important diagnostic & therapeutic tool for CNS. It helps in detection of following

(a) injuries ⇒ It detects small injuries in bone, Presence or absence of bleeding etc.

(b) Oncology ⇒ It is used for detecting cancerous areas

2) Radiotherapy ⇒ CT is the first stage & image is transferred to treatment s/m for marking out the area of radiotherapy

3) Detection of lesions in thorax

Ultrasonic Imaging

Ultrasonic waves are sound waves having frequency ~~between~~ above 20 KHz. They are used as an important imaging modality and diagnostic tool in medical practise. It is used because of following reasons.

1) Ultrasonic waves can be easily focussed, ie, they are directional and beams can be obtained with very little spreading.

2) They are inaudible.

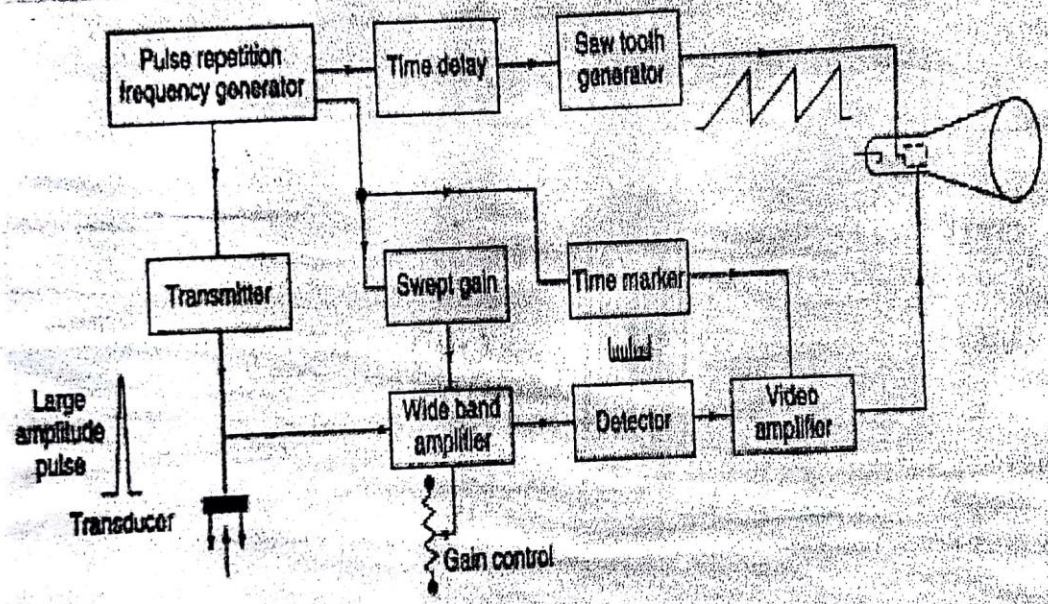
3) By using high frequency ultrasound, it is possible to investigate properties of very small structures.

4) Extremely useful in dynamic studies.

Medical ultrasound

The use of ultrasound in medical field can be divided into 2 areas - therapeutic and diagnostic. In therapeutic applications, systems operate at ultrasonic power levels of upto several watts/cm² while diagnostic equipments operates at power level below 100mW/cm². Therapeutic equipment is designed to agitate the tissue to the level where thermal heating occurs in the tissue and is useful for the treatement of muscular ailments.

Basic pulse echo apparatus.



➤ **Fig. 23.5** *Block diagram of a basic pulse-echo system*

It is used for the detection and location of defects in the structures at varying depths of the body. It is because the time of travel of a short pulse can be measured with greater ease compared to continuous waves. Echoencephalograph, ecocardiograph and

4

ultrasound scanners are based on this principle. It consists in transmitting a train of pulses into the body and detecting the energy reflected from the surface boundary seperating two media of different acoustic impedence.

The transmitter generates a train of pulses at a repetition frequency determined by PRF generator. These are converted into corresponding pulses of ultrasonic waves by a piezo electric crystal acting as transmitting transducer. The echos from the target are picked up by the same transducer and amplified suitably for display on CRT. The x plates of CRT are driven by the time base which starts at the instant when the transmitter radiates a pulse. In this way, the position of echo along the trace is proportional to the time taken for a pulse to travel from transmitter to discontinuity and back again. Knowing the velocity of ultrasonic waves, and speed of horizontal movement on CRT, the distance of target from transmitting end can be estimated.

MAGNETIC RESONANCE IMAGING

What is MRI?

MRI is a non-invasive imaging technology that produces three dimensional detailed anatomical images without the use of damaging radiation. It is often used for disease detection, diagnosis, and treatment monitoring.

How does MRI work?

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

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

What is MRI used for?

MRI scanners are particularly well suited to image the non-bony parts or soft tissues of the body. They differ from computed tomography (CT), in that they do not use the damaging ionizing radiation of x-rays. The brain, spinal cord and nerves, as well as muscles, ligaments, and tendons are seen much more clearly with MRI than with regular x-rays and CT; for this reason MRI is often used to image knee and shoulder injuries.

One kind of specialized MRI is functional Magnetic Resonance Imaging (fMRI.) This is used to observe brain structures and determine which areas of the brain "activate" (consume more oxygen) during various cognitive tasks. It is used to advance the understanding of brain organization and offers a potential new standard for assessing neurological status and neurosurgical risk.

Nuclear Magnetic Resonance

It is a phenomenon in which nuclei in a magnetic field absorb & re emit electromagnetic radiation. It is used in MRI

Basic NMR components

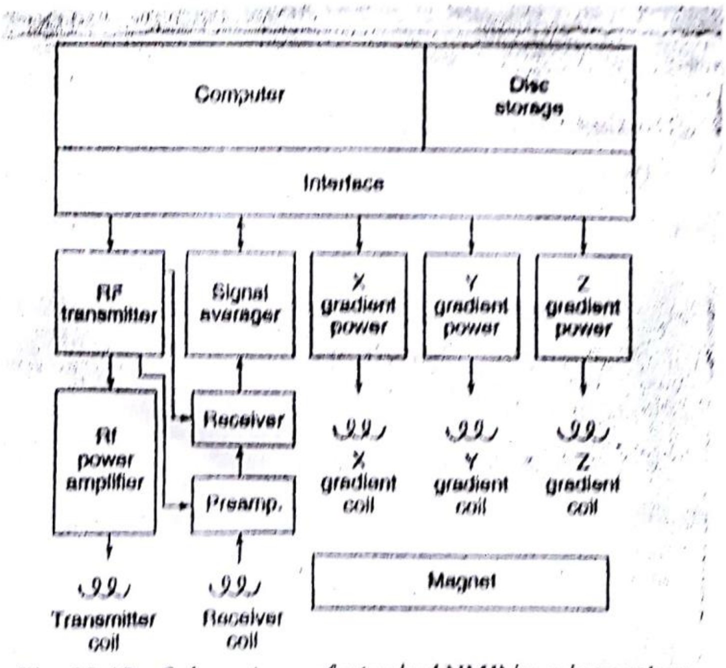
⇒ Magnet : Provides strong uniform, steady mag. field Bo

⇒ RF transmitter ; deliver RF mag field to sample

⇒ gradient s/m ; Provide time varying mag. field

⇒ detection s/m ; Yields the o/p signal.

⇒ Image s/m ; include the computer which reconstruct & display images



➢ Fig. 22.19 *Sub-systems of a typical NMR imaging system*

Properties of X-rays

⇒ Short wave length & high energy
⇒ They can penetrate through materials which readily absorb & reflect visible light.
⇒ X-ray produce secondary radiation in all matters
⇒ They produce ionization in gas.
⇒ X-ray produce flourescence in some material

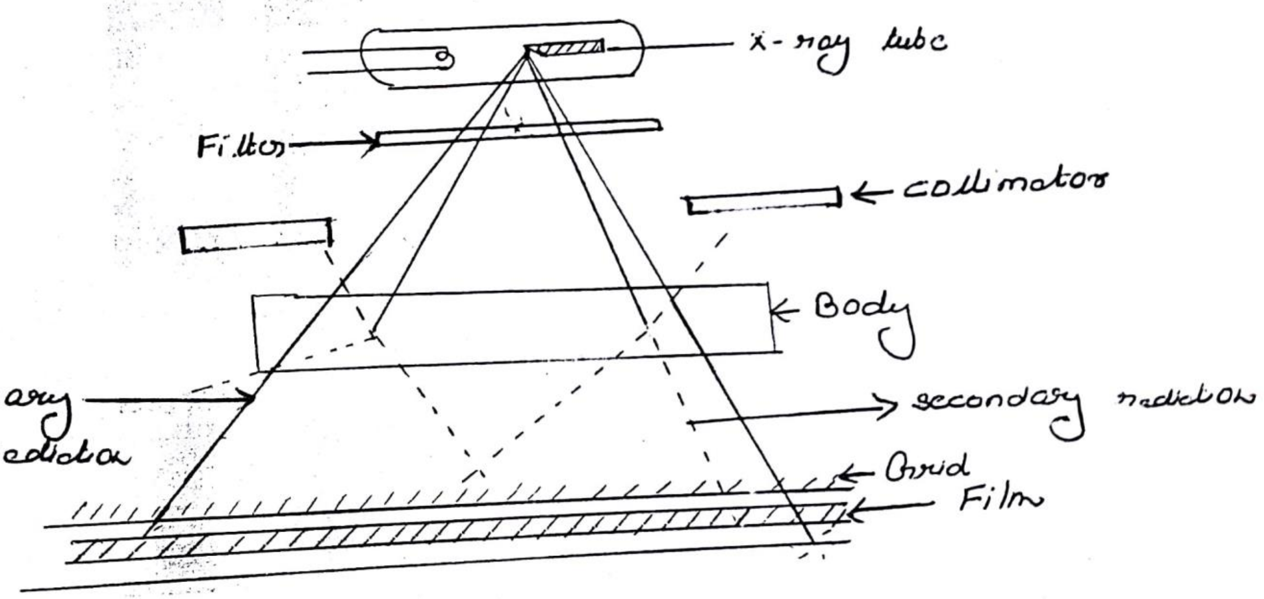
X-rays are generated by a high vaccum, X-ray diode tube in which electrons are accelerated to high velocities.

X-rays are produced in specially constructed glass tube called X-ray tube. Normal tube is a vaccum diode in which electrons are generated by thermionic emission. The electron beam is electrostatically focussed on target anode by cathode cup. This kinetic energy on target cup is converted into X-rays.

X-ray machines are devices that generate exceedingly high frequency, high energy electro magnetic waves that penetrate the body during medical procedures. These machines are used in therapeutic & diagnostic purposes.

Figure shows block diagram of X-ray system machine.

A simple x-ray s/m consists of a high Voltage generator, an x-ray tube, a collimator the object or patient, an intensifying screen & the film. A simple x-ray generator has a line ckt breaker, a variable autotransformer, an exposure timer & contactor, a step-up transformer & rectifier & a filament control for the tube.



The x-ray tube generates x-rays that are restricted by the aperture in the collimator. The filter removes low energy x-rays that would not penetrate the body. Scattered secondary radiation is trapped by the grid, whereas primary radiation strikes the screen phosphor. The resulting light expose the film.

Advantages : 1) used to treat malign tumours.
2) help radiologist to identify cracks.
3) used to locate alien objects

Application of X-rays

1) FLUOROSCOPY

Fluoroscopy is an imaging technique commonly used by physicians to obtain real-time moving images of internal structures of the patient through the use of a fluoroscope. A fluoroscope consists of an X-ray source and fluorescent screen between which a patient is placed.This technology is very helpful to surgeons when performing surgical procedures

Fluoroscopy is used where real-time examination of the patient's body is required. Some of the uses include positioning of orthopedic implants during surgery, catheters and pacemakers, viewing the movement of contrast agents, such as barium, through the body and studying the movement of parts of the body.

As with conventional radiology, an X-ray beam is passed through the body but instead of being registered on film, the image is displayed on a fluorescent screen. Modern versions digitize the image using 'flat panel' detector systems, which reduce the radiation dose required. The image is then intensified digitally and displayed on a screen or recorded for more detailed analysis later.

Contrast agents are used to make organs in the body visible on the images. They can be given by injection into the blood stream or via tubes into internal organs. Barium products, taken orally, are used for examining the gastro-intestinal system. Fluoroscopy is used in many types of examinations and procedures

Fluoroscopy uses a continuous X-ray beam with a special machine called a C-arm. The C-arm can be used to rotate around a person's body to create a sequence of images that are projected onto a fluorescent screen, or television-like monitor.Still images are also captured and stored electronically on a computer.

When used with a contrast material, which clearly defines the area being examined by making it appear bright white, this special X-ray technique makes it possible for the physician to view internal organs and tissues in motion.

2) ANGIOGRAPHY

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

Depending on the type of angiogram, access to the blood vessels is gained most commonly through the femoral artery, to look at the left side of the heart and at the arterial system; or the jugular or femoral vein, to look at the right side of the heart and at the venous system. Using a system of guide wires and catheters, a type of contrast agent (which shows up by absorbing the X-rays), is added to the blood to make it visible on the x-ray images.

The X-ray images taken may either be still, displayed on an image intensifier or film, or motion images. For all structures except the heart, the images are usually taken using a technique called digital subtraction angiography or DSA. Images in this case are usually taken at 2 – 3 frames per second, which allows the interventional radiologist to evaluate the flow of the blood through a vessel or vessels. This technique "subtracts" the bones and other organs so only the vessels filled with contrast agent can be seen. The heart images are taken at 15–30 frames per second, not using a subtraction technique. Because DSA requires the patient to remain motionless, it cannot be used on the heart. Both these techniques enable the interventional radiologist or cardiologist to see stenosis (blockages or narrowings) inside the vessel which may be inhibiting the flow of blood and causing pain

Depending on the type of angiogram, access to the blood vessels is gained most commonly through the femoral artery, to look at the left side of the heart and at the arterial system; or the jugular or femoral vein, to look at the right side of the heart and at the venous system. Using a system of guide wires and catheters, a type of contrast agent (which shows up by absorbing the X-rays), is added to the blood to make it visible on the x-ray images.

3) **ENDOSCOPY**

An ***endoscopy*** (*looking inside*) is used in medicine to look inside the body. The endoscopy procedure uses an endoscope to examine the interior of a hollow organ or cavity of the body. Unlike many othermedical imaging techniques, **endoscopes** are inserted directly into the organ.

There are many types of **endoscopes**. Depending on the site in the body and type of procedure an **endoscopy** may be performed either by a doctor or a surgeon. A patient may be fully conscious oranaesthetised during the procedure. Most often the term ***endoscopy*** s used to refer to an examination of the upper part of thegastrointestinal tract, known as an esophagogastroduodenoscopy

An endoscope can consist of:

- a rigid or flexible tube.
- a light delivery system to illuminate the organ or object under inspection. The light source is normally outside the body and the light is typically directed via an optical fiber system.
- a lens system transmitting the image from the objective lens to the viewer, typically a relay lens system in the case of rigid endoscopes or a bundle of fiberoptics in the case of a fiberscope.
- an eyepiece. Modern instruments may be videoscopes, with no eyepiece. A camera transmits image to a screen for image capture.
- an additional channel to allow entry of medical instruments or manipulators.

4) Diathermy

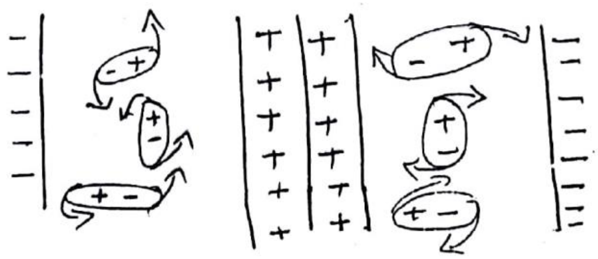
It is a therapeutic treatment commonly Prescribed for muscular & joint associated Pains.

Dia → through

thermy → heat or temperature

It stimulates the circulation, relieve pain, enhance rate of recovery of healing tissue.

Principle :- Before injury, dipole molecules of the body tissues are arranged on the basis of polarity. When the tissues is damaged the dipoles distribution become irregular & deviates from polarity based arrangement. Under the influence of electric field, they rotate according to the polarity of charge in the direction of field lines & get rearranged & tends to acquire its Previous stage of polarity.



It uses an electric current to produce heat deep inside a targeted tissue. As the heat increases, it promotes blood flow. It can also help to improve flexibility in stiff joints & connective tissue.

Advantage: Reduce inflammation, improves circulation Pain relief & accelerate healing.

Short Wave diathermy ⇒ Use high frequency Electromagnetic energy to generate heat.
It may be applied in pulsed or continuous energy waves

Long Wave diathermy ⇒ It is based on capacitor field method. It can work in heavy voltage fluctuation

Ultrasound diathermy ⇒ Uses ultrasound waves to treat deep tissues. Heat is developed by vibration of tissues

Microwave diathermy ⇒ Uses microwaves for heating

Laser diathermy ⇒ Uses lasers for heating

Nuclear medicine uses radioactive material for the diagnosis of disease & for assessment of the patient. Thus it differs from radiography in that the source of gamma rays is not external but rather within the patient. It also differs in a second very important way. The basic imaging technique involves the measurement of a distribution of radioactivity inside the body of the patient. These distributions can be either static or changing in time.

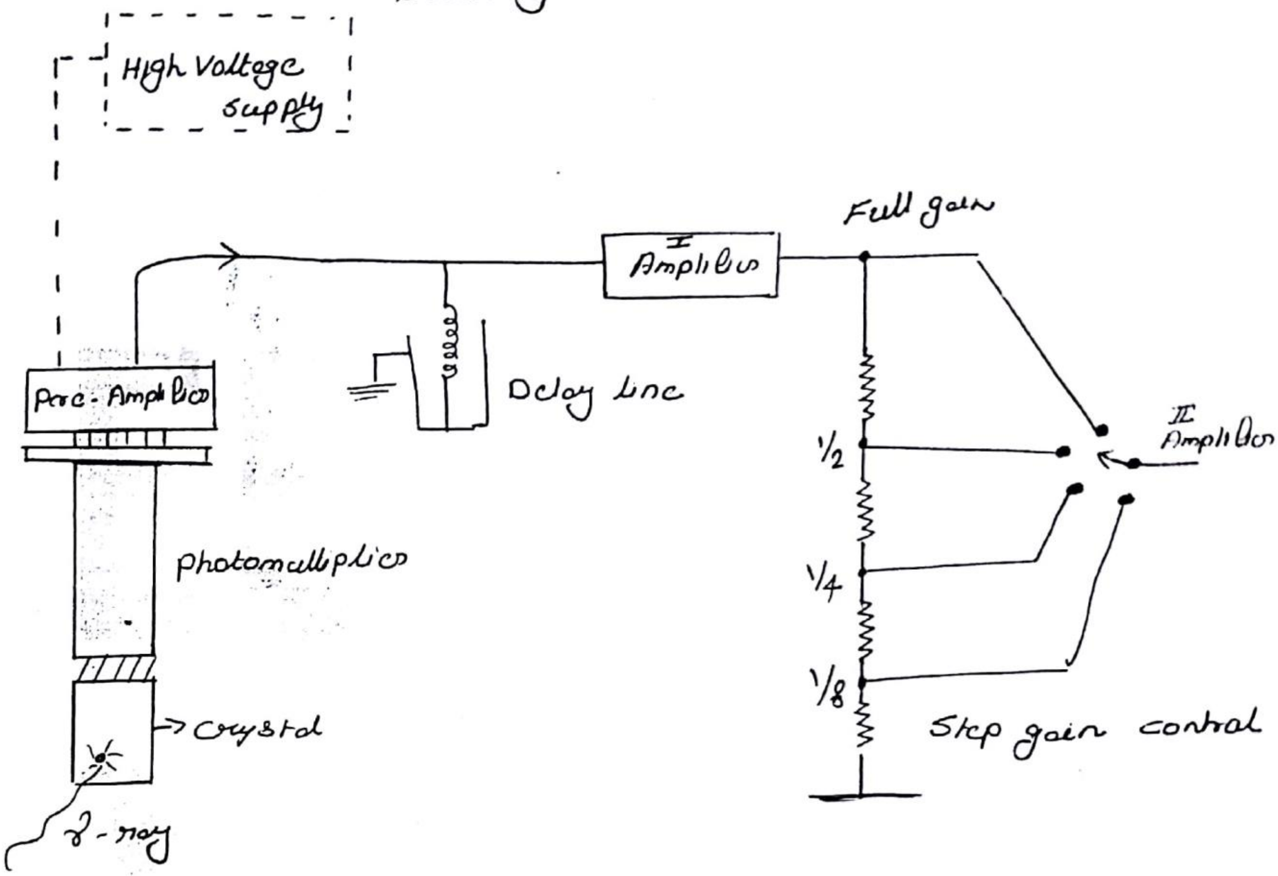
Common to nearly all instruments employed in nuclear medicine imaging is the sodium iodide detector. The detector consists of 3 main components 1) Crystal itself, which scintillates with blue light in linear proportion to the energy a gamma ray loses in it

2) Photomultiplier tube, which converts this light into a proportional electrical signal.

3) Supporting electronics, which amplify & shape this electric signal into usable form

The simplest nuclear medicine procedures do not involve images at all but consists simply of placing such a detector near the surface of patient's skin & counting gamma-ray flux.

The first nuclear-medicine imaging device involves the operator taking such a simple detector & moving it in rectilinear paths relative to patient. The process that involves this rectilinear motion of detector is called scanning



RADIATION THERAPY

The ionizing effect of X-rays is utilized in the treatment of certain diseases, especially of certain tumors. In dermatology very soft X-rays that do not have enough penetration power to enter more deeply into the body are used for treatment of skin. They are called Grenz rays. In the therapy of deep seated tumors, on the other hand, very hard X-rays that are generated with voltages much higher than those for diagnostic X-rays are used some times linear accelerators are used to obtain electrons with very high voltage.

PLETHYSMOGRAPHY

→ Plethysmography is a measurement technique that can be used to measure the volume changes in different parts of the body

→ A plethysmograph is a instrument for measuring changes in volume with in organ or whole body.

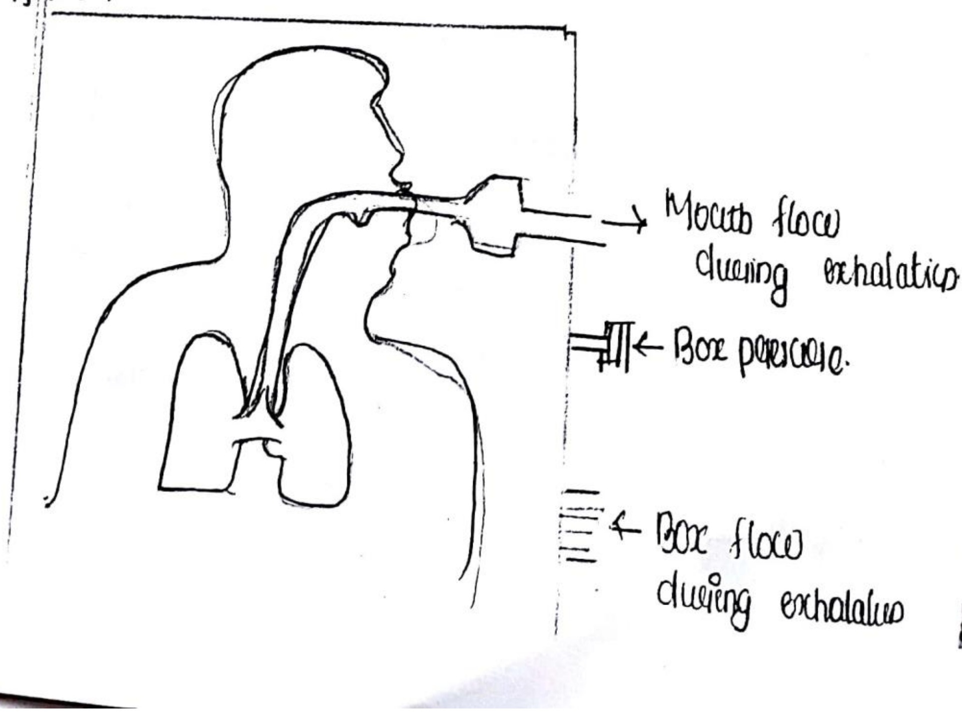
Principles of PPG

→ Most changes in blood flow occur mainly in arterioles (but not in veins)

→ PPG sensors optically detect changes in the blood flow volume via reflection from or transmission through the tissue

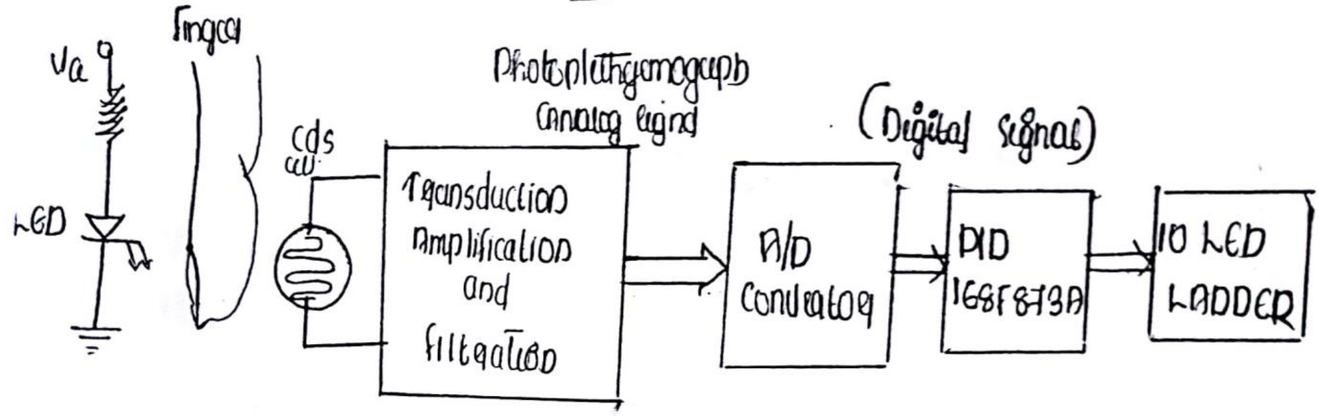
→ the changes in light intensity are associated with small variations in blood perfusion.

Appearence



BLOCK DIAGRAM

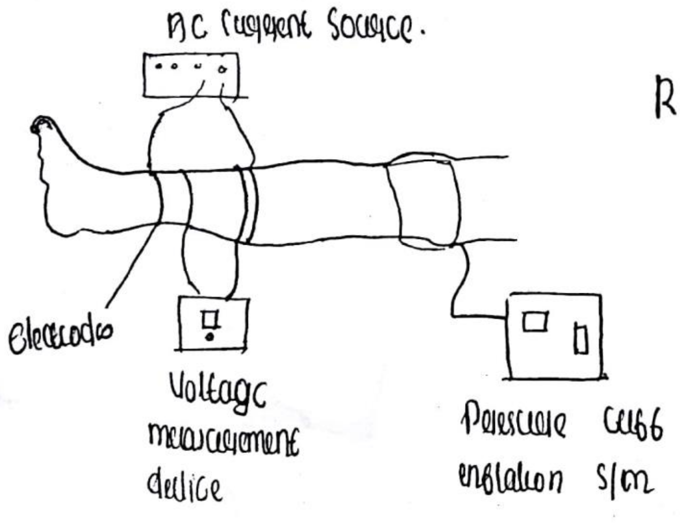
Photoplethysmograph



→ ~~for~~

impedence plethysmograph:

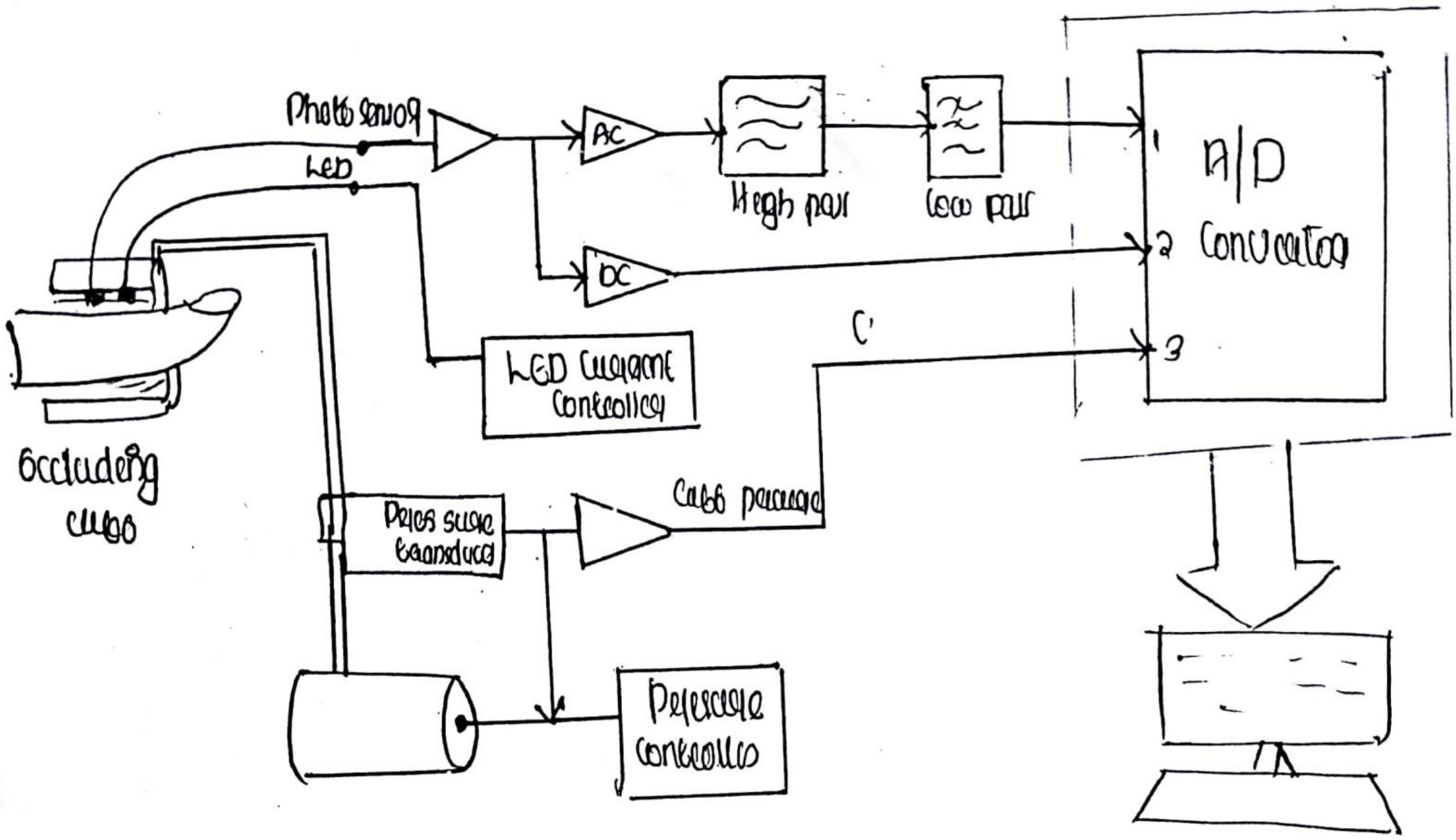
Approach → in this technique of impedence plethysmography, the electrical resistance of the calf is measured to diagnose deep venous thrombosis (blood clotting in the Veins)



$$R = \rho \frac{L}{A} = \rho \frac{L}{V_{calf}/L} = \frac{\rho L^2}{V_{calf}}$$

→ Measuring small changes in resistance reflect changes in the volume of blood, which is good conductor

Block diagram of Plethysmograph



Tests On Blood cells

Module: 6

Blood consists of a fluid, called the plasma in which are suspended 3 different types of blood cells 1) Red blood cells (RBC)

⇒ Responsible for transport of O_2

2) White blood cells (WBC)

⇒ Attack introuding bacteria

3) Blood platelets

⇒ blood clotting.

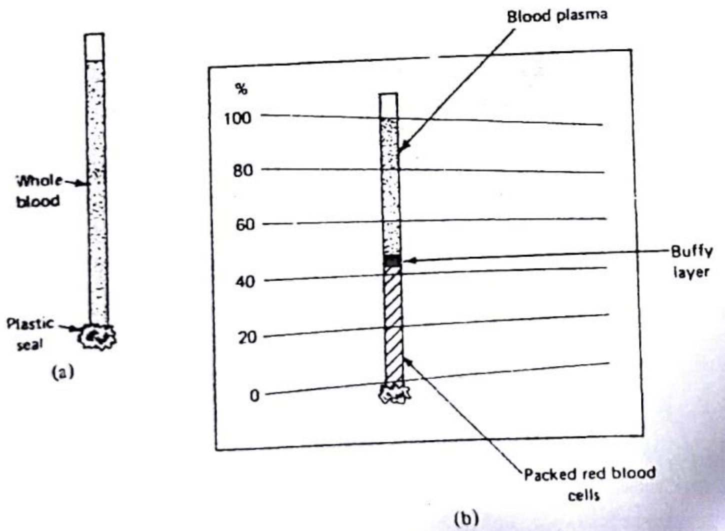


Figure 13.1. Hematocrit determination: (a) blood sample drawn in capillary and sealed with plastic putty; (b) capillary after centrifuging, placed on nomogram to read hematocrit (reading 43%).

The blood sample is taken into a capillary tube & closing one end of tube with a plastic sealing material. The tube is then spun for 3 to 5 minutes to seperate the blood cells from plasma. After stirring a packed column is formed at the bottom of test tube. This column consists of RBC, with the other cells forming a thin buffy layer on the top. The volume of packed RBC at bottom is called hematocrit. Mean cell Volume [MCV] can be calculated by using hematocrit & no: of RBC per cubic millimeter of blood. The active component in RBC is the hemoglobin. Mean cell Hemoglobin concentration [MCHC] can be calculated by using hemoglobin concentration & hematocrit. The hemoglobin concentration can be determined by destroying the membranes of RBC to release hemoglobin & chemically converting hemoglobin into another colored compound (acid hematin). The concentration of new compound can be determined by colorimetry.

Manual blood cell counts are performed by using microscope. For counting RBC, the blood is first diluted 1:100 or 1:200 & a diluent is used to dissolve WBC. For counting WBC, the blood is first diluted 1:10 or 1:20 & a diluent is used to dissolve RBC.

Simple RBC & WBC counts are performed by blood cell counters. The most commonly used device is based on conductivity (Coulter) method. The blood cell counter contains a beaker with diluted blood into which a closed glass tube with a small orifice (1) is placed. The conductance b/w the solution in the glass tube & the solution in beaker is measured with two electrodes (2). The glass tube is connected to suction pump through U-tube filled with mercury (5). The negative pressure generated by pump cause the flow of solution from beaker through orifice. Each time blood cell swept through orifice, the conductance drops & is measured b/w electrodes. The amplitude of conductance is proportional to volume of cell.

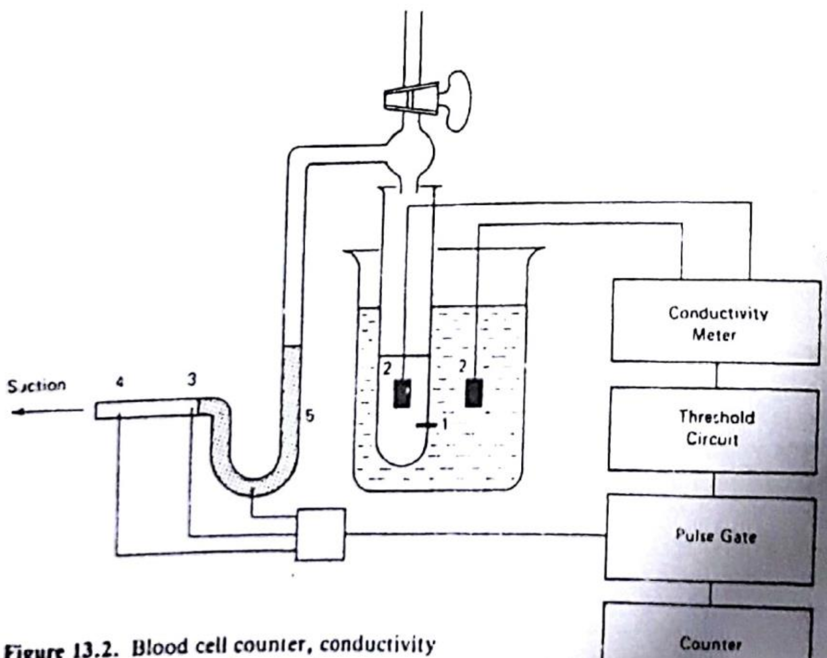


Figure 13.2. Blood cell counter, conductivity (Coulter) method. (Explanation in text.)

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Chemical Tests.

Blood serum is a complex fluid that contains numerous substances in solution. The determination of concentration of these substances is performed by specialized chemical techniques. The way in which this solution absorbs light can be used to determine the concentration of substances.

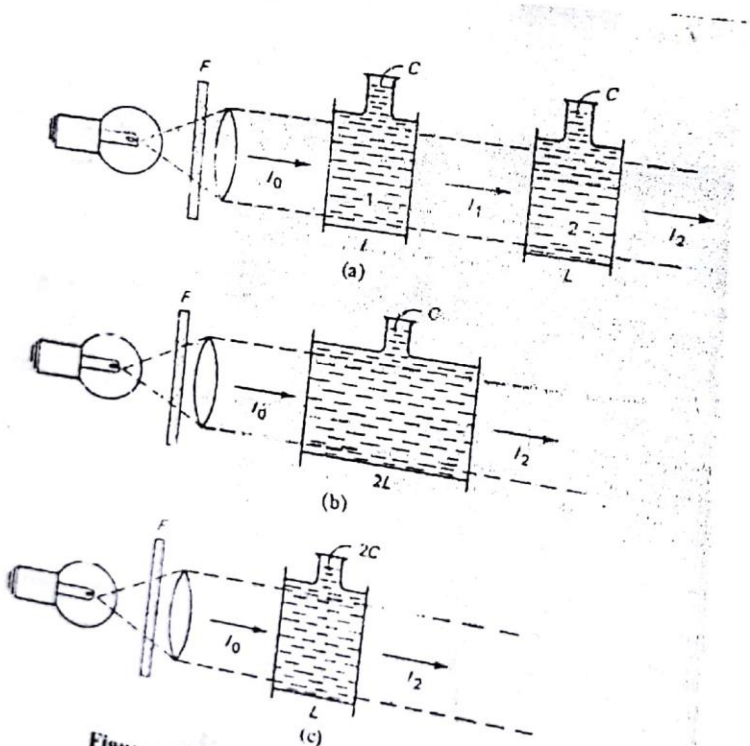


Figure 13.5. Principle of colorimeter analysis. (Explanation in text.)

In fig 13.5 (a), it is assumed that a solution of concentration C is placed in a cuvette having length L. Light of appropriate colour or wavelength is obtained from a lamp through filter F. The light enters cuvette has intensity I_0, a part of which being absorbed in solution & light leaving cuvette has lower intensity I_1.

The transmittance $T = \frac{I_1}{I_2} \times 100\%$

The light intensity I_2 behind second cuvette is

$$\boxed{\begin{aligned} I_2 &= T I_1 \\ I_2 &= T^2 I_0 \end{aligned}}$$

We can express transmittance as a logarithmic measure called absorbance or optical density A

$$\boxed{A = -\log \frac{I_1}{I_0} \quad \text{or} \quad A = \log \frac{1}{T}}$$

If instead of two cuvettes, each with path length L, the one cuvette with path length 2L were used, the absorbance would be same. The absorbance is same if path length is L, but concentration is doubled.

This relation can be expressed by

$$\boxed{A = aCL}$$

$a \Rightarrow$ absorblivity

$C \Rightarrow$ Concentration

$L \rightarrow$ Path length

If A_s = absorbance of Std

A_u = absorbance of unknown solution

C_s = Concen. of Std

C_u = Concen. of unknown solution.

then $C_u = C_s \dfrac{A_u}{A_s}$.

The below fig shows principle of colorimeter or filter photometer for measuring transmittance & absorbance of solutions.

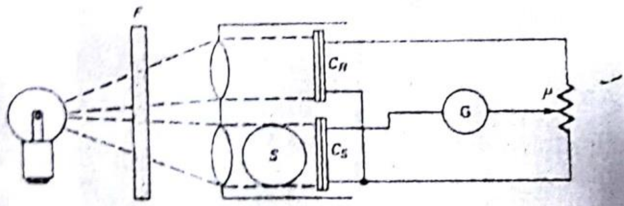


Figure 13.6. Colorimeter (filter-photometer).

A filter F selects suitable wave length light from lamp & is allowed to fall on reference cell CR & sample cell Cs. Without a sample, the o/p of both cells will be same. When a sample is placed in light path, the o/p is reduced, & adjust the potentiometer (P) until galvanometer (G) shows balance. The potentiometer is calibrated in transmittance or absorbance.

Physiological Effects of Electrical Current

Electrical accidents are caused by the interaction of electric current with tissues of the body. For an accident to occur, sufficient magnitude current must flow through the body in such a way that it affects the functions of vital organs. The physiological effect of current depend not only on their magnitude but also on the current pathway through the body, which inturn depends on first & second contact.

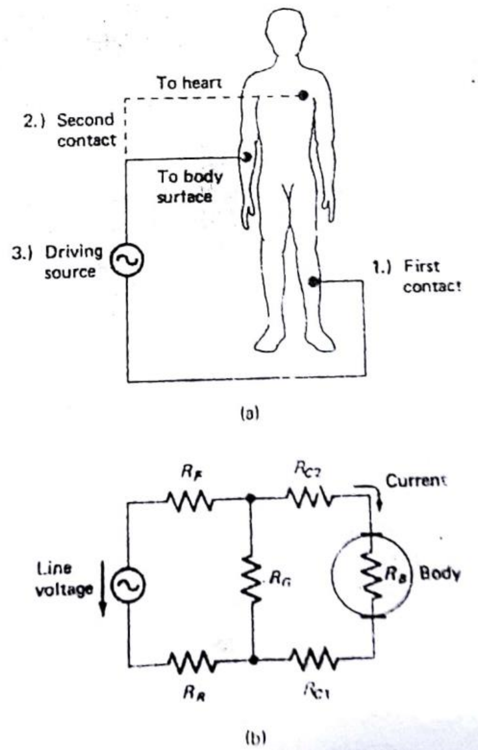


Figure 16.1. The electrical accident. **(a)** The three necessary conditions. **(b)** The generalized model where R_F is the fault or leakage resistance, R_{C1} and R_{C2} are first and second contact resistance, R_B is body resistance and R_R is the ground return resistance.

Scanned by CamScanner

Gross shock : Experienced by the subject by the accidental contact with the electric wiring at any point on the surface of body.

Macroshock : The effect of current applied through the surface contacts.

Microshock : The effect of current applied through the heart.

Basically, electric current can affect the tissue in two different ways. First, the electrical energy dissipated in the tissue resistance can cause a temp. increase. If a high enough temperature is reached, tissue damage can occur. With household currents, electrical burns are usually limited to localized damage. In industrial accidents with high voltage, as well as in lightning accidents, the dissipated electrical energy can be sufficient to cause burns involving larger parts of body.

Respiratory paralysis can also occur if the muscles of thorax are affected by electric current flowing through chest. The organ most susceptible to electric current is the heart; When the current density within the heart exceeds a certain value, extra systolic contraction occurs

If the current density is increased further, the heart activity stops completely but resumes if the current is removed within a short time. An even further increase in current causes heart muscles to go into fibrillation. When fibrillation occurs in ventricles, the heart is unable to pump blood & cause death. It can be converted to regular rhythm by using defibrillators.

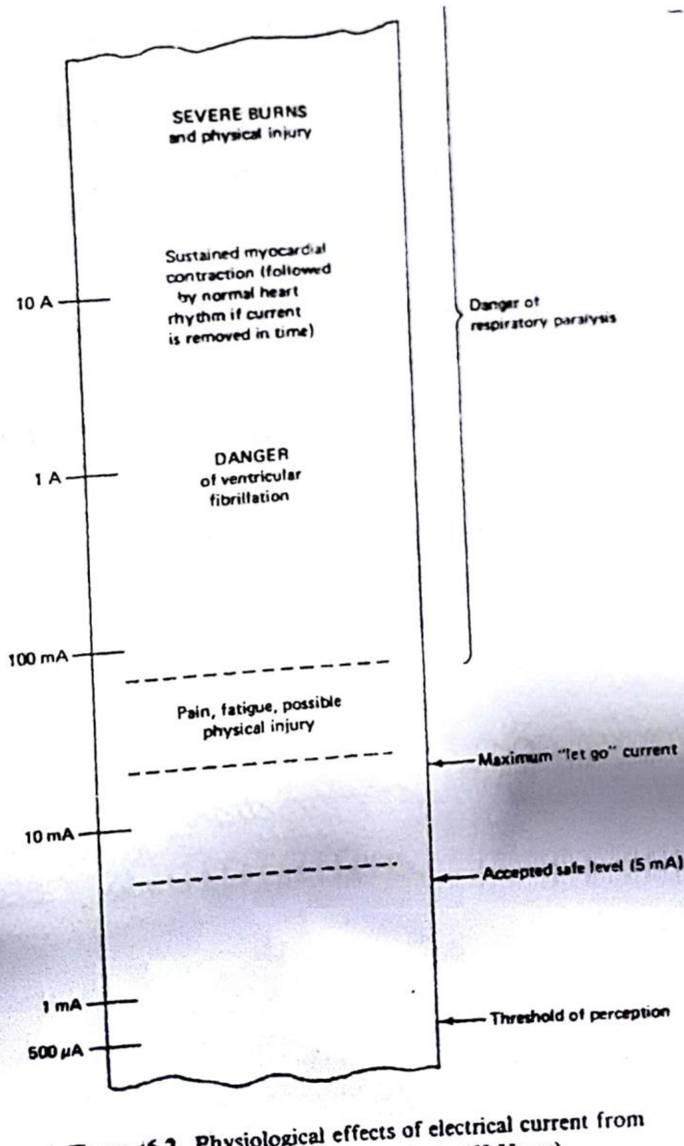


Figure 16.2. Physiological effects of electrical current from 1-second external contact with the body (60 Hz ac).

& resulting effects

Threshold perception : It is 1mA. At this level a tingling sensation is felt.

Let go current : It will not permit the individual to release his grip from the conductor supplying current.

For male : 16 mA

For female : 10.5 mA

Hold-on-type : It is a level above let go current. This current is painful. The subject losses the ability to control his own muscles & unable to release his grip. The current range : 20 – 100 mA.

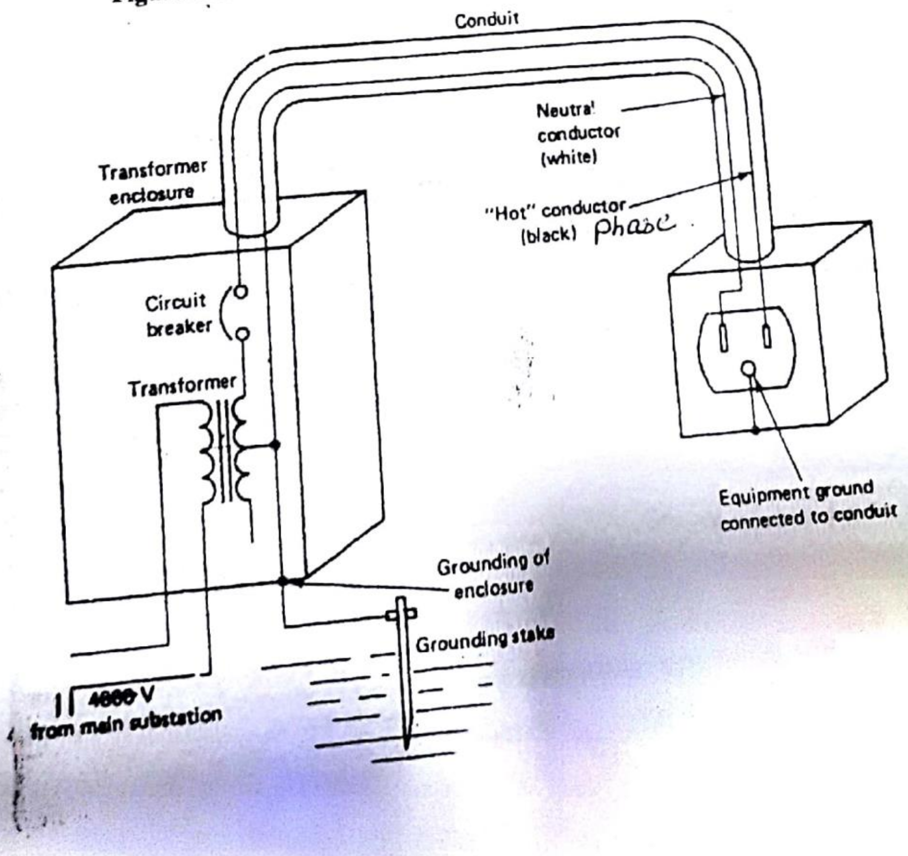
Ventricular Fibrillation : It occurs due to dearrangement of function of heart muscles. It's a serious cardiac emergency

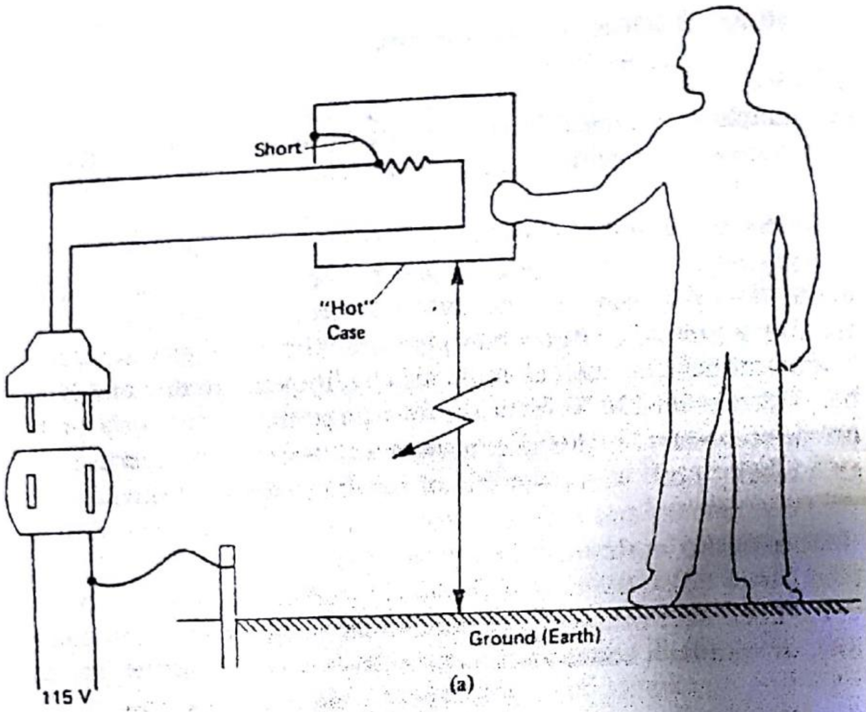
Burns & physical Injury : It's above 6 amp. Causes temporary respiratory paralysis & also serious burns.

Shock Hazards From Electrical Equipment

An example of a typical hospital electric power distribution s/m is shown. From the main hospital substation, the power is distributed to individual buildings at 11 KV, usually through underground cables. A stepdown trf convert 11 KV into 400 V or 230 V.

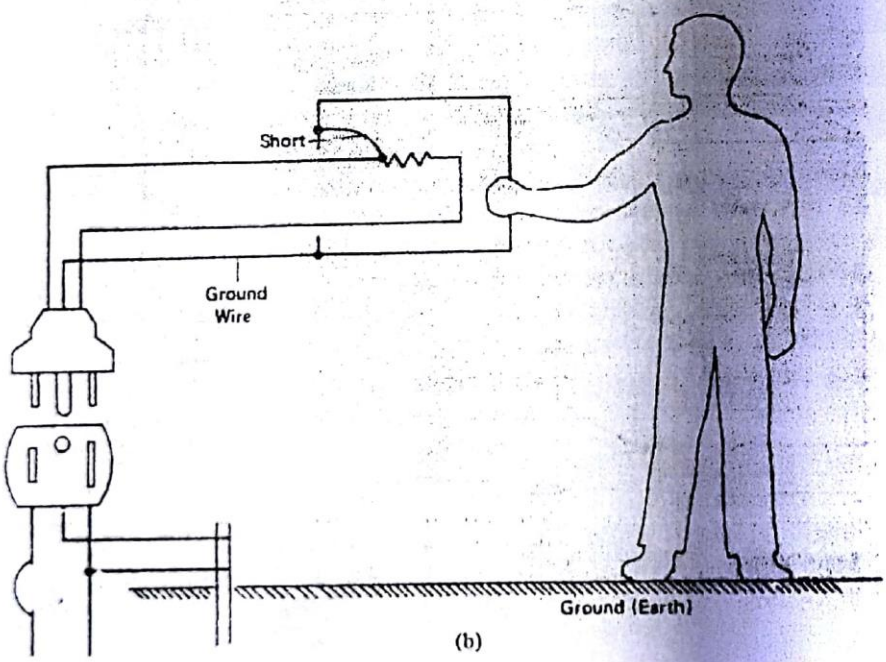
Figure 16.3. Electric power distribution system (simplified).





(a)

Figure 16.4. Ground shock hazards.



(b)

In the design of electrical equipment, great care is taken to prevent personnel from accidentally contacting hot wire by the use of suitable insulating materials & observation of safe distance b/w conductors & equipment case.

Figure shows such an accident. A defect in the equipment has caused a short b/w hot wire & equipment case. When a person makes contact with case, he get shock. Generalized model of electrical accident is shown in fig 16.1 (b).

The fault resistance (R_F) represents short b/w hot wire & case

R_{C1} & R_{C2} ⇒ resistance of first & second contact

R_B ⇒ Body resistance

R_G ⇒ grounding resistance, it is connected parallel to body

R_R ⇒ Return resistance.

An electrical accident can occur when 6 resistances assume any combination of values such that the resulting current through body become dangerous.

Methods Of Accident Prevention

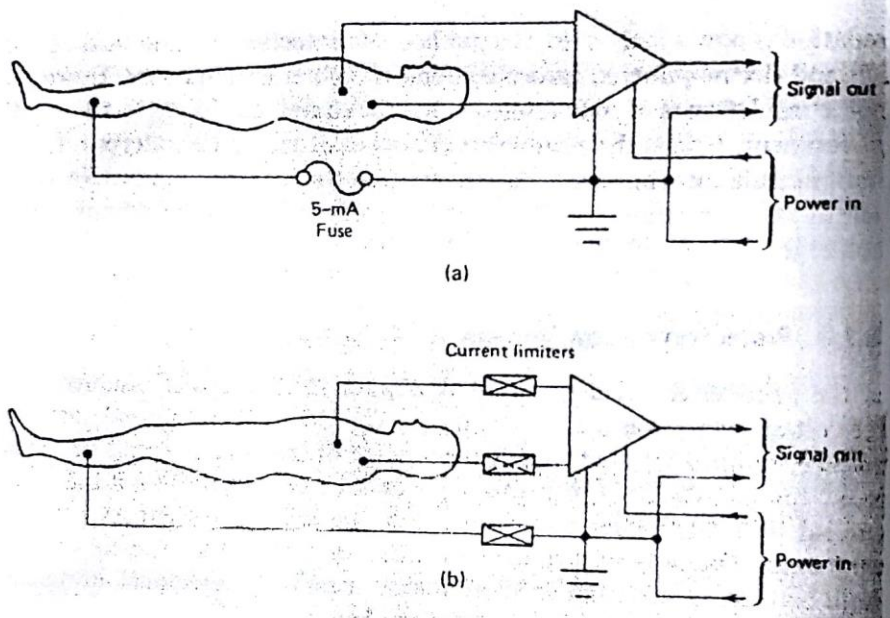


Figure 16.5. Current limiters. (a) Input circuit of older ECG machine or ECG monitor; (b) The same circuit modernized by the addition of current limiters; (c) Electrical characteristics of current limiter.

In order to reduce electrical accidents, a number of protective methods have evolved

The protection method used most frequently are

1) Proper Grounding.

It is illustrated in Fig 16.4(b). The metal case of equipment is connected to ground through seperate wire. If a short occurs, since the case is grounded, the electric current flows through ground wire.

Fig 16.4 (b)

2) Double Insulation

In double insulated equipment the case is made of non conductive material usually plastic. The intention of this method is to assure that R_F is always very large. Double insulated equipment need not be grounded & therefore it is usually equipped with plug that does not have ground. Equipment of this type must be labeled "Double Insulated".

3) Protection by Low Voltage.

If low voltage is applied, the body resistance R_B would be sufficient to limit the body current to a safe value, even if fault occurs.

One way of creating this situation is to operate the equipment from batteries. Normally battery operation is limited to small devices. A low operating Voltage can also be obtained by step-down trf. In addition to lowering the voltage, it also isolate supply voltage from ground.

4) Ground Fault Circuit Interrupter.

Fig 16.5

In the ground fault ckt interrupter, the diff b/w current in hot & neutral wires of the power line is monitored by differential transformer & an electronic amplifier. If this diff exceeds a certain value, usually 5mA, the power is interrupted by circuit breaker. This interruption occurs so rapidly that, even in case of large current flow through the body of a victim, no harmful effects are encountered.

5) Isolation of Patient - Connected Parts.

Many types of medical equipment require that an electrical connection be established to the body of the patient, either to measure electrical potential such as ECG machines. These electrical connections, however, could also serve as a path for dangerous electrical currents.

Modern technology make it possible to design ckts that isolate the patient leads from gnd. This isolation is achieved by isolated i/p amplifier.

6) Isolated Power Distribution System

In an isolated distribution s/m, the power is not supplied from transformer substation directly, but is obtained from seperate isolation transformer for each operating room.

If the equipment in which short occurs is properly grounded, this leakage current will return through the ground connection. As In this case short in faulty equipment effectively grounds one of the conductors of isolated distribution s/m. As a result. the isolated s/m is changed back to grounded distribution s/m & all protection provided by isolated s/m is obviated.

Telemetry

It is an automated communication process by which measurements & other data are collected at remote or inaccessible points & transmitted to receiving equipment for monitoring.

Telemeter is a device used to remotely measure any quality. It consists of sensor, transmission path & a display, recording or control device

Biotelemetry System

It is used for the measurement of biological parameters over a distance.

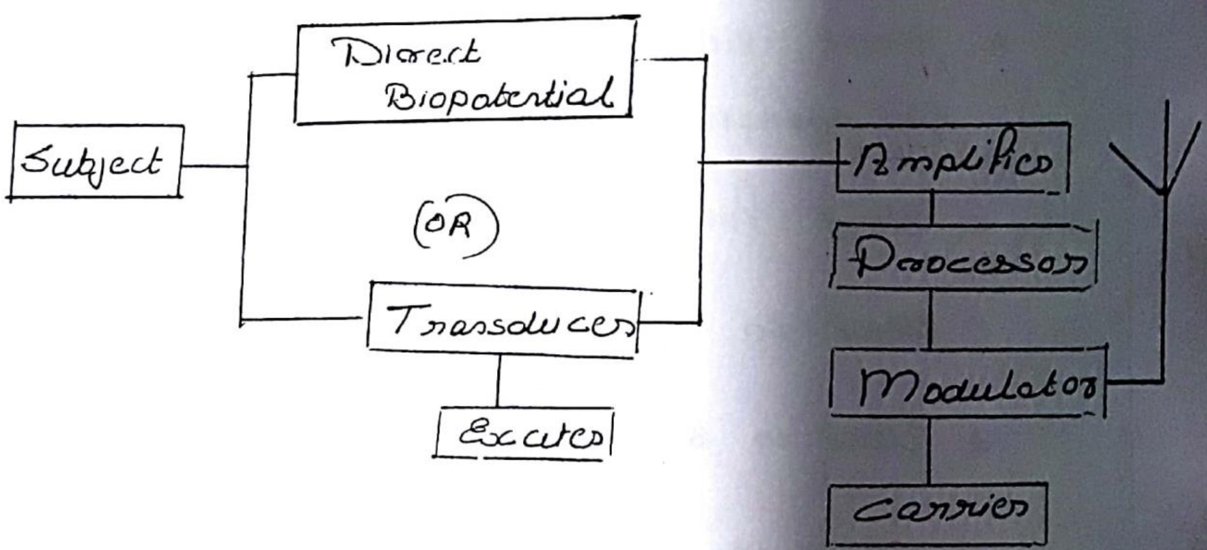
Uses

* Most widespread use of biotelemetry is in the transmission of ECG
* Used for transmission of ECG
* Used in EMG
* Used in studies of mentally disturbed children
* Used in transmitting stimulus signals to patient or object.

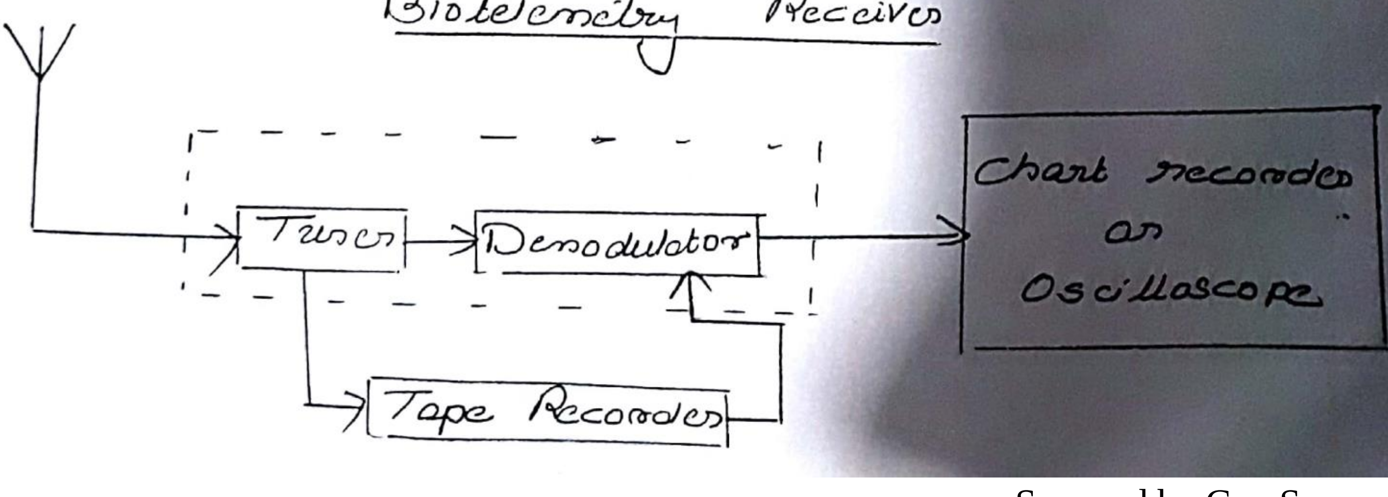
The stages of biotelemetry s/m can be divided into transmitter & receiver functional blocks. Physiological signals obtained from subject by proper transducers. The signal is then passed through a stage of amplification & processing ckt. This stage includes generation of subcarrier & a modulation stage for transmission.

The receiver consists of tuner to select the transmitting frequency & a demodulator to seperate signal from carrier wave. A device is there to display or recording the signal. The signal can also be stored in modulated state by tape recorder.

Biotelemetry transmitter



Biotelemetry Receiver



⇒ A radio - frequency carrier is a high frequency sinusoidal signal. which is applied to transmitting antenna, is propagated in the form of EM-waves. The distance the signal can be received is called RANGE of the system.

⇒ Various modulation schemes are used → AM (Amp. modu)
→ FM (Freq. modu)

⇒ The equipment capable of receiving transmitted signal & demodulating it to recover information called receiver. By tuning the receiver the signal can be selected & others are rejected.

Application of telemetry in Patient care

* Telemetry of ECG from extended coronary care patients
* Telemetry for ECG measurements during exercise
* Telemetry for emergency patient monitoring
* Use of telephone s/m to transmit biological data

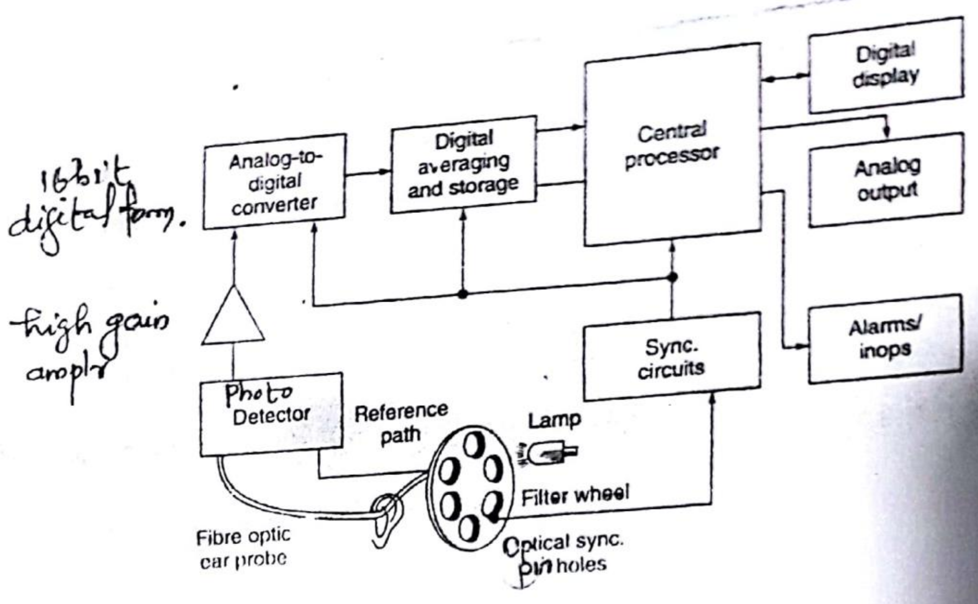
Oxymeters : It is an instrument for measuring the Proportion of oxygenated hemoglobin in the blood or how oxygen the blood is carrying.

Oximetry : It refers to determination of Percentage of oxygen saturation of circulating arterial blood.

$$\text{Oxygen Saturation} = \frac{[HbO_2]}{[HbO_2] + [Hb]}$$

$[HbO_2] \Rightarrow$ concentration of oxygenated hemoglobin

Ear oxymeter



There is a lens system which directs the light through thin film which is mounted on a wheel rotating @ 1300 rpm & it cuts the light beam sequentially. This filtered light beam enters into fibre optic bundle that carriers to the ear & another bundle carries the light beam to detector. The current developed in photo detector is 0.5 nA, it is amplified & converted to 16 bit digital form by ADC. Then it is given to digital averager, which eliminates the noise. Computation of % oxygen saturation is done by 24 bit - algorithmic state m/c. From this

computational section, data is transferred to o/p
card board where it is converted to BCD for
front panel digital display

Disadvantages

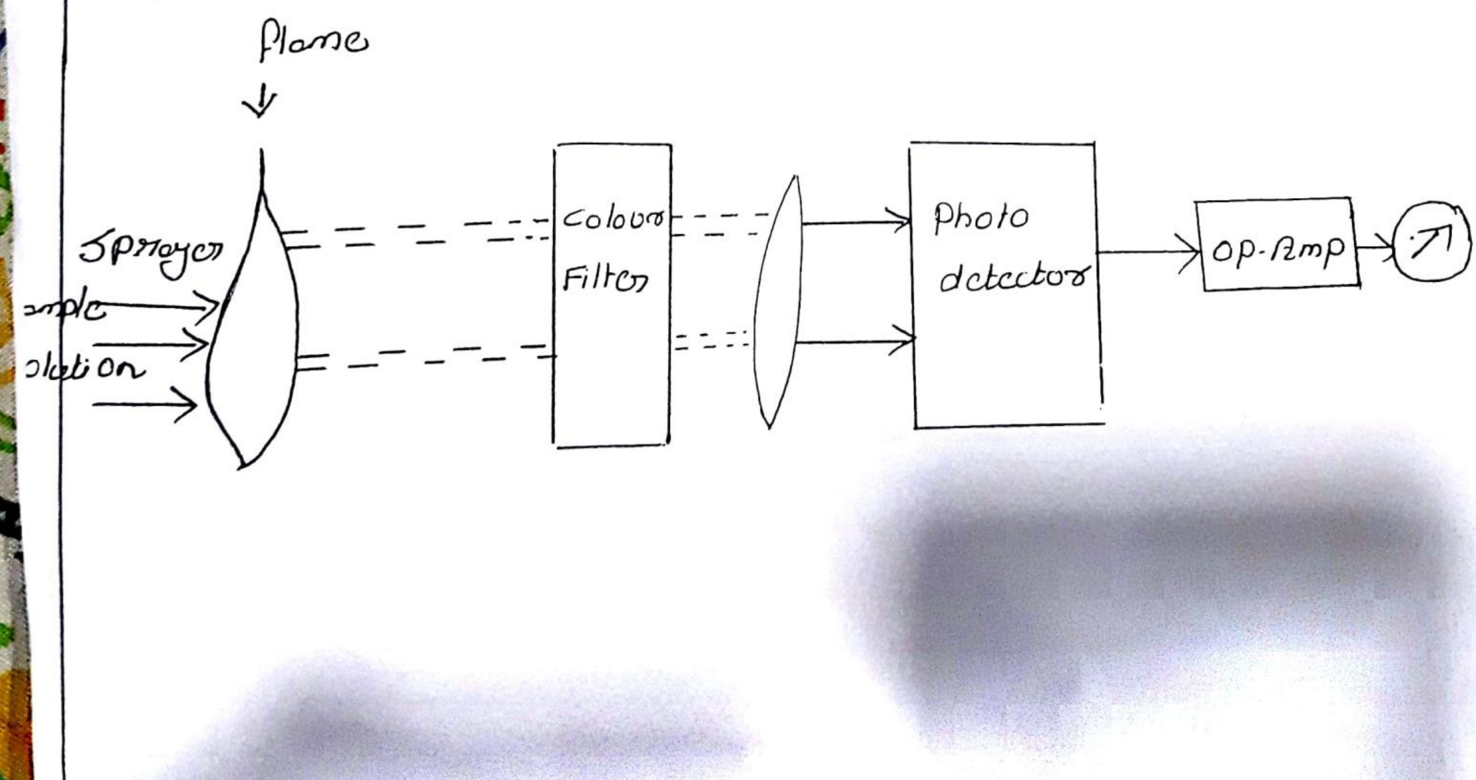
⇒ complex instrument
⇒ Need for pre-calibration
⇒ Ear must be heated to 41 °C

2) Flame Photometer

It is an optical electronic device that measures the colour intensity of substance. It is used to determine Na, K & Ca.

~~The flame photometer has the following parts~~

~~⇒ Emission system consist of~~



Scanned by CamScanner

⇒ A solution of sample to be analyzed is Prepared. A special sprayer is used to introduce this solution in the form of fine spray into the flame of burner.

⇒ Light filters are used to seperate the radiation produced in the flame from emission of other elements

⇒ The intensity of isolated radiation is measured from the current it produces when it falls on the photo cell. Measurement of current is done using galvanometer. This galvanometer reading is proportional to the concentration of elements

3) <u>Blood cell counter</u>

Details in note

4) <u>Colorimeter</u>

Details in note

SYLLUBUS

MODULE-I

Devolopment of biomedical Instrumentation, Biomatrix, Man Instrumentation system components and block diagram. Physiological systems of the body (Brief discussion on heart and cardiovascular system, anatomy of nerves system, physiology of respiratory system), problems encountered in biomedical measurements

Sources of Bioelectric potentials, Resting and action potentials, propagation of action Potentials, eg:- of bio electric potentials (ECG, EEG, EMG, ERG, EOG and EGG)

MODULE-II

Biopotential electrodes, micro electrodes, skin surface electrodes, Needle electrodes Biochemical Transducers, Transducers for biomedical applications.

Electroconduction system of the heart, electrocardiography (Electrodes and leads) Einthoben triangle, ECG readout devices. Block diagram of ECG machine.

MODULE-III

Measurement of blood pressure, Direct and Indirect measurement, Oscillometric measurements, Ultrasonic methods. Measurement of blood flow and cardiac output. PLEthysmography; Two types. photoelectric and Impedance plethysmogra-phy, measurement of heart sound:-

phonocardiography.

MODULE-IV

Cardiac pacemakers :- Internal and external pacemakers, Defibrillators, electro encephalograph, neuronal communication, EEG measurement. Muscle Response (Electromyography EMG) Nerve conduction velocity measurements Measurement of respiratory parameters (spirometer, pneumograph

MODULE-V

Ventilators, Heart-lung machine, Heamodialisis lithotripsy, Infant Incubators

X-ray, Principles of generation, Uses of X-rays, diagonostic still picture, fluroscopy Angiography, Endoscopy, Diathermy.

Basic principles of computer tomography, Magnetic Resonance Imaging System, and Nuclear medicine system and radiation therapy.

Ultrasonic Imaging system ;- Introduction and Basic principle.

MODULE-VI

Instruments for clinical laboratory ; test on blood cells, chemical test.

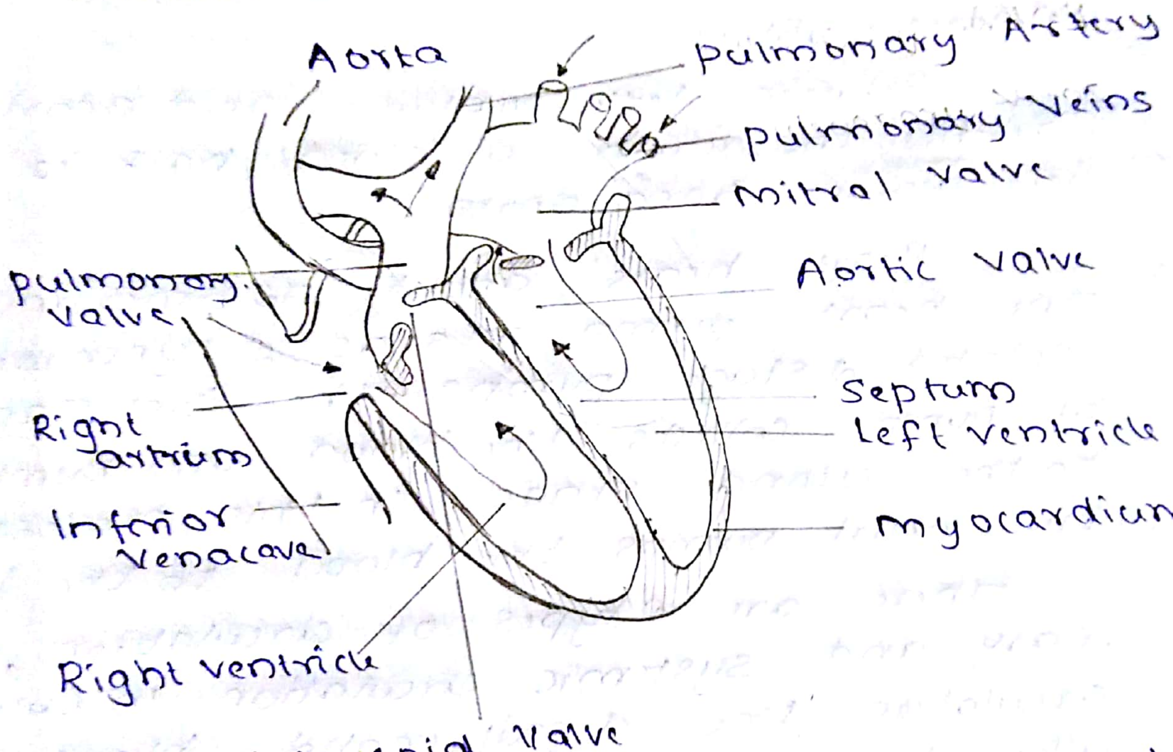
Electrical safety:- physiological effect of electric current, shock hazards from electrical equipment methods of accident prevention, Introduction to Telemedicine.

Text:- J.G Webster, L. Chrombell, R.S Khanpur

MODULE - I

* Physiology of Cardiac System

○ Structure of human heart



The cardiovascular system transports oxygen and different chemical compounds throughout the body. The heart wall consist of 3 layers, pericardium, myocardium and endocardium. In human body there are 3 types of blood vessels, ① Arteries ② veins ③ cappilleries

Structure of heart is divided into right and left part, each part has 2 chambers called atrium and ventricle. The heart has 4 valves ① Tricuspid valve:- between right atrium and ventricle, it prevents the backward flow of blood from right ventricle to right atrium.

② Bicuspid valve or mitral valve:- Between left atrium and left ventricles prevents backword flow of blood from left ventricle to atrium.

3) pulmonary valve:-

It is at right ventricle donnot allow blood to come back to right ventricle

4) Aoertic valves-

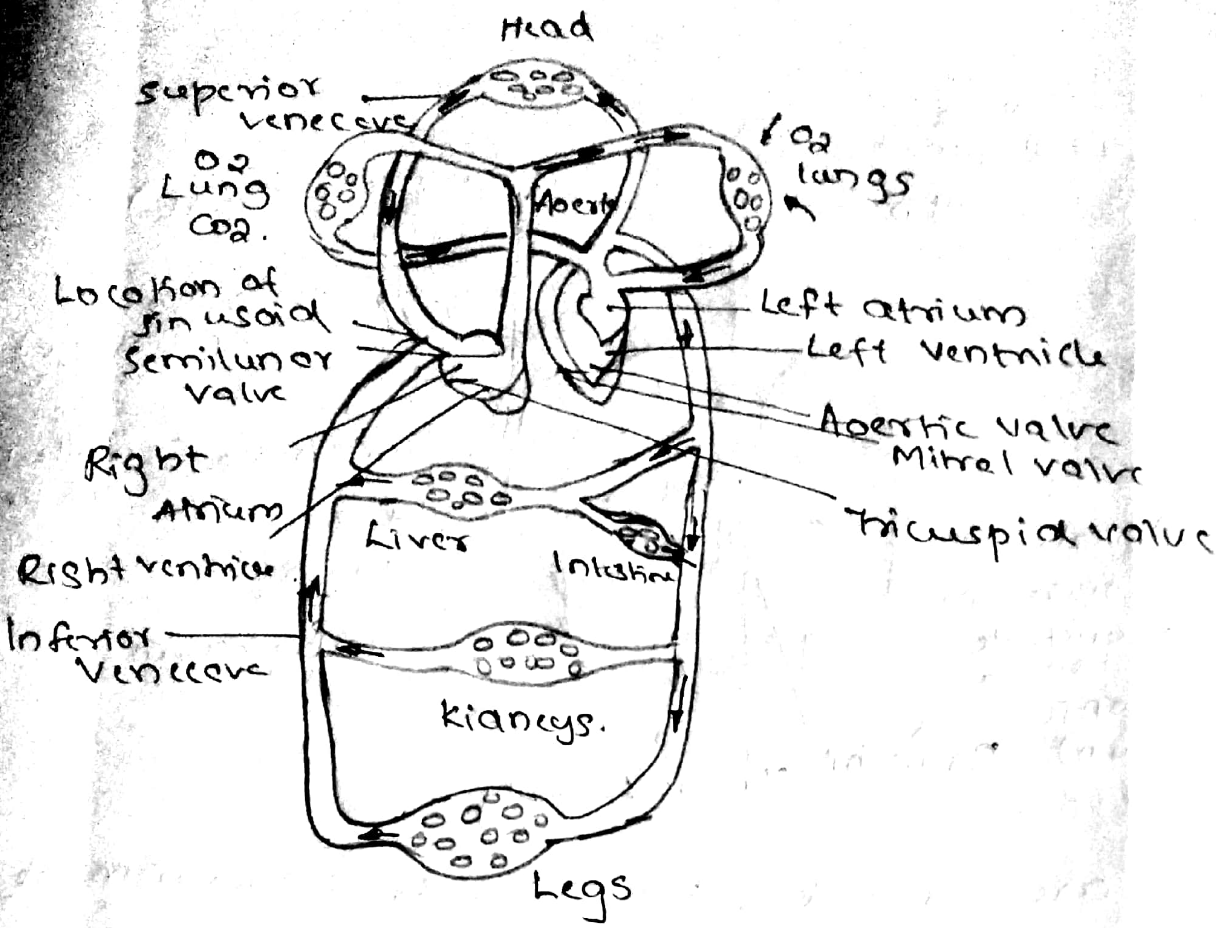
Between left ventricle and aeorta. Prevents the return of blood back to left ventricle atrium from aorta

Heart beats about 72 times/minitue. The heart pump acts as a synchronized isolated 2 stage pumps. The first stage of pump collects the blood and pumps it to the second stage. In this process the heart pumps the blood to the lungs.

There are 2 types of circulation, pulmonary and systemic circulation. In pulmonary circulation the deoxygenated blood from different part of body is pumped in to right atrium by means of superior and inferior venacava. The deoxygenated blood then enters the right ventricle and through the pulmonary artery it reaches lungs. (In the lungs in systemic circulation, the blood the doxygenated blood is purified by lungs and oxygenated blood return back to left atrium by pulmonary veins. The oxygenated blood reaches left ventricle and this oxygenated blood pumped through different parts of body through aoerta) right atrium by means of superior and Inferior venacava. The deoxygenated blood then enters the right ventricle and through the pulmonary artery it reaches lungs.) (In systmic circulation, the blood ~~the lungs~~ the deoxygenated blood is purified by lungs and oxygenated blood return back to left atrium by pulmonary veins. The oxygenated blood reaches left ventricle and this oxygenated blood pumped through different parts of body through aoerta)

Circulatory System

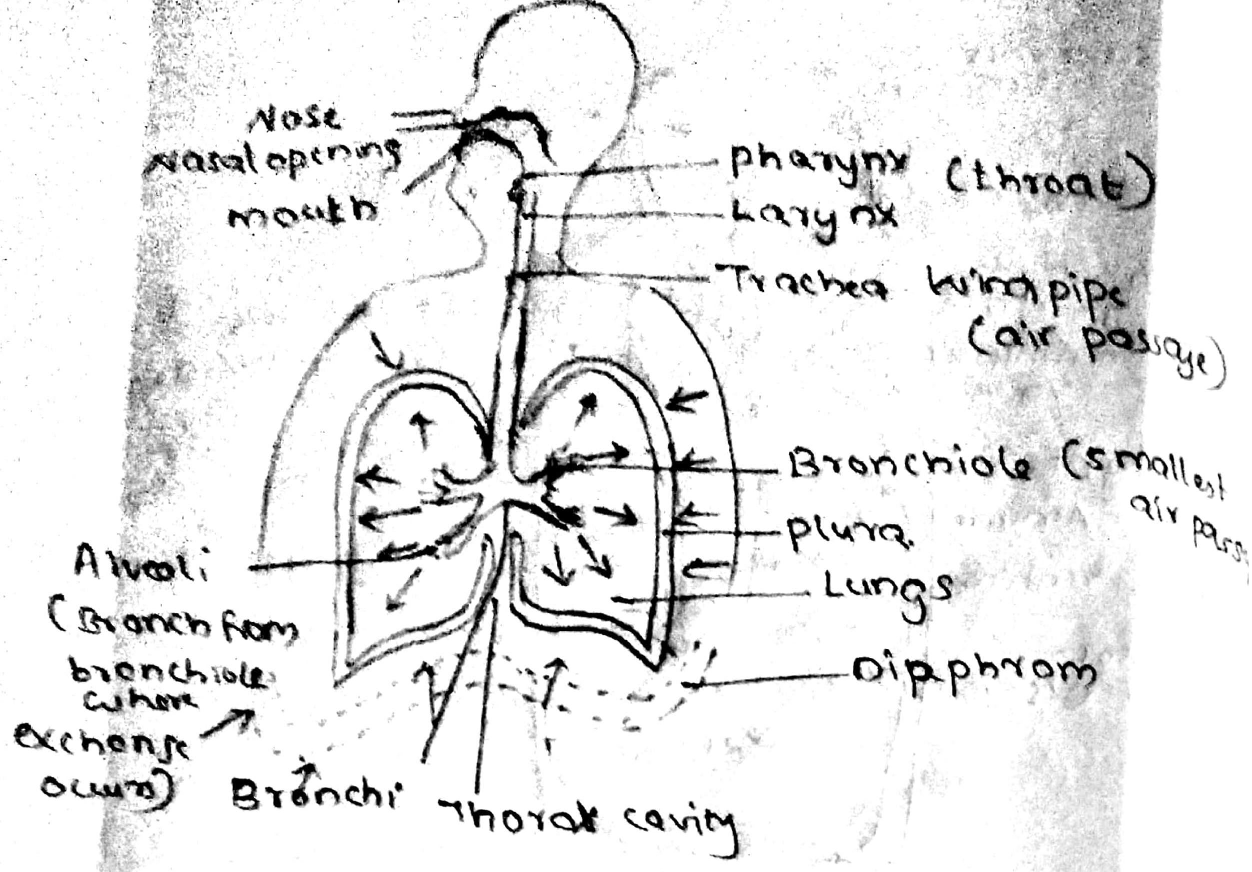
The impure blood from lower and upper organs are pumped into the right atrium by means of Inferior and



superior vencavas. The impure blood then reaches the right ventricle. From the right ventricle, it is pumped to lungs by means of pulmonary artery. Lungs oxygenate the blood and it is pumbed back to left atrium by means of pulmonary vein. The oxygenated blood from left atrium ~~to left~~ reaches the left ventricle and it is pumped to different parts of body through aoerta.

- Respiratory System

It is a pnematic system in which an air pump or diaphram alternatively creates positive and negative pressures and causes air to be suck in to and forced out of a pair of lungs. The lungs



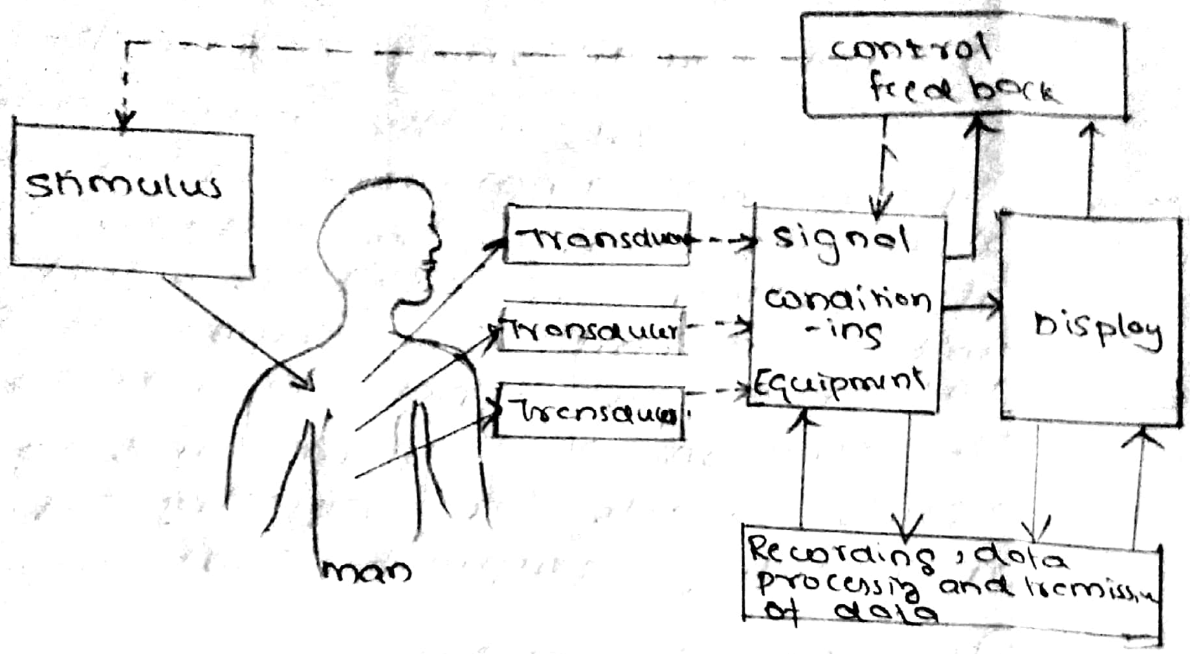
are connected to outside environment through a passage way consisting of pharynx, larynx, Trachea, bronchi and Bronchioles. The passage way divides, to carry air in to each of the lungs where it again subdivides several times to carry air in to and out of each of tiny air spaces within the lungs.

In the tiny air spaces of the lungs, as an interface with the circulatory of body through which certain gases can diffuse. Oxygen is given in to the blood from the incoming air and CO_2 is transferred from the blood in to the air. This is carried out through a process called diffusion (flow from HP point to LP point)

~~Initial~~ In each minute under normal condition, about 250ml of O_2 are taken up and 250ml of CO_2 are given out by

The exchange of gases takesplace in the alveoli at a rate of 15-20 breaths/minute

○ components of man instrument system



A Block diagram of man instrumentation system is as shown. The system consist of

1) subject :-

The suject is the human being on whom the measurements are made. Since it is the subject whose makes this system different from other instrumentation system.

2) Stimulus :-

In many measurements, the response to some form of external stimulus is required. The instrumentation used to generate and present this stimulus to the subject is a vital part of the man instrument system. The stimulus may be visual or auditory or direct electrical stimulation.

3) Transducer :-

Transducer is defined as a device capable of converting one form of energy to another. In the man instrument system the transducer is used to produce electrical signal i.e., analogue in nature. Transducer may measure temperature, pressure, flow etc. and its output is always an electrical signal

4) Signal Conditioning equipment:-

The part of the instrumentation system that amplifies, modifies or in any other way changes the electrical output of transducer is called the signal conditioning unit. In short the purpose of SCE is to process the signal in order to satisfy the functions of systems and to prepare signals suitable for operating the display or recording equipment that follows.

5) Display Equipment:-

The electrical output of SCE must be converted into a form that can be perceived by one of man senses and that can convey the informations obtained by the measurement in a meaningfull way. In the man instrumentation system, the display instrument may be graphic pen Recorder

6) Recording, Data processing & Transmission equipment

It is often necessary to record the measured informations for future use. Equipment for this function is often a vital part of the man instrument system. A graphic pen recorder is actually a display device used to produce a paper record of analogue waveforms, whereas the recording equipment referred to the devices by which data can be recorded for future play back.

Eg: Magnetic tape recorder

7) control feed back:-

It is necessary or desirable to have automatic control of the stimulus, trans--ducer or any other part of the man instrument system. This system consist of feed back loop in which part of the output from the signal conditioning or display equipment is used to control the entire operation of system

Module 2: Cardiovascular Measurement

The heart serves as a pump because of its ability to contract under electrical stimulus. When an electrical triggering is received the heart will contract starting in the atria which will undergo shallow contracting motion. A fraction of a second later, the ventricles also begin to contract from the bottom up. The ventricular contraction is known as systole. The ventricular relaxation is known as diastole.

Electroconduction system of heart

The conduction system of heart consists of sinoatrial node (SA node), bundle of His, atrioventricular (AV) node, the bundle branches and Purkinje fibres.

SA node serves as pacemaker for heart. It is located in the top right atrium near the entry of venacava. It is under the control of CNS and is capable of self excitation.

When SA node discharges a pulse, then electrical current spreads across the atria causing them to contract. Blood in atria is forced by contraction through valves into ventricles at a speed of 30cm/s. There is a band of specialised tissue b/w SA node and AV node called Bundle of His & through this action potential is transmitted at a velocity of 45 cm/s. The internal conduct pathway carries signals to ventricles.

It would not be desirable for ventricles to contract in response to an action potential before the artrial empty their cont. The necessary delay generation is the functi. The action potential reaches AV node. The action potential reaches AV 30 to 50 ms after SA node discharges. Anoth 110 ms will pass before the pulse is transmi from AV node.

The muscle cells of ventricles are actually excited by Purkinje fibres. The ac potential travels along the fibres at the velo of 2 to 4 m/s. The fibres are arranged in 2 bundles - left and right. The action potential traverses the distance between SA and AV n in about 40ms and is delayed in AV node for 110ms so that contraction in lower chamb can be synchronised with emptying of uppe chambers. Conduction to Purkinje fibres takes 60ms.

The action potential generated SA node stimulates muscle fibres of myoc causing them to contract. The contraction so many muscle cells at one time create mass electrical signal that can be detec by electrodes placed on the surface of bo chest. This electrical discharge can be mechanically plotted as a function of time and the resultant waveform is called electrocardiogram (ECG).

The different parts of ECG waveform are designated by letters. P wave indicates atrial contraction, ventricular systole occurs immediately following QRS complex and a refractory period (resting) is indicated by T wave. QRS complex takes 90ms, PR interval is 150-200ms and ST segment is about 50-150ms.

P wave represents depolarization of atrial muscle. QRS complex is obtained as a result of repolarization of atria and depolarization of ventricles which occur almost simultaneously. T wave represents ventricular repolarization whereas u wave if present is the result of after potentials in ventricular muscle. PQ interval represent the time during which excitation wave is delayed in fibres near AV node.

Amplitude

P wave	0.26mV
R wave	1.5mV
Q	25% of R
T	0.1 to 0.5 mV

Duration

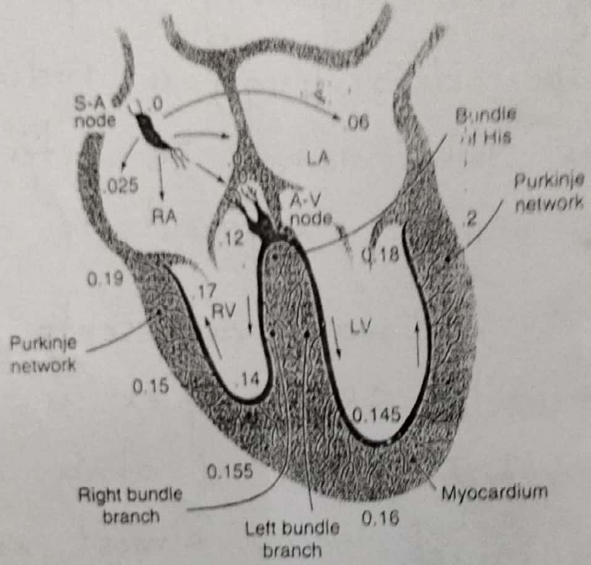
PR - 0.1 to 0.2 s

QT - 0.34 to 0.45 s

ST - 0.05 to 0.15 s.

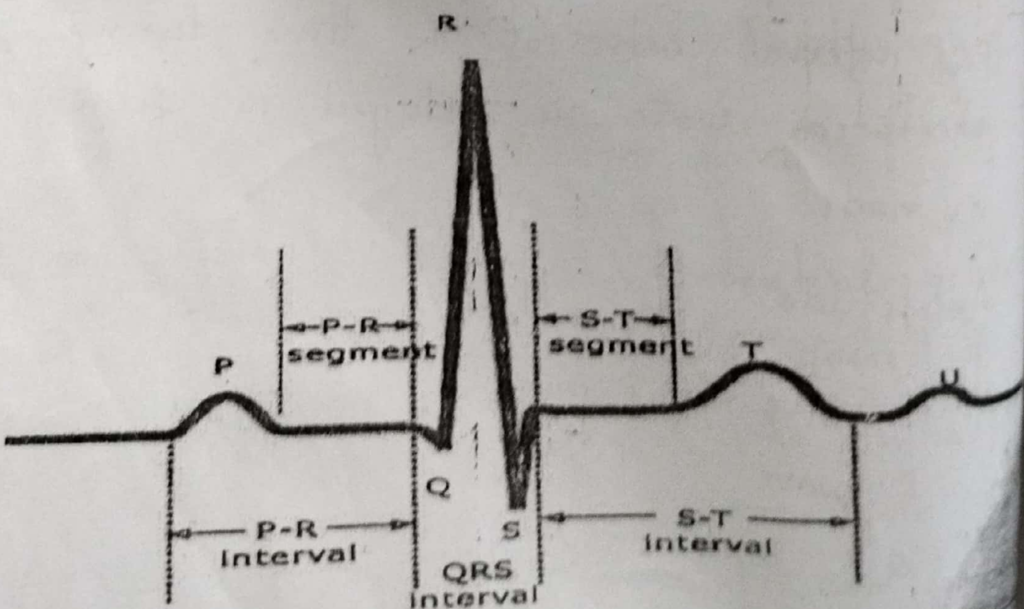
P wave - 0.1 s

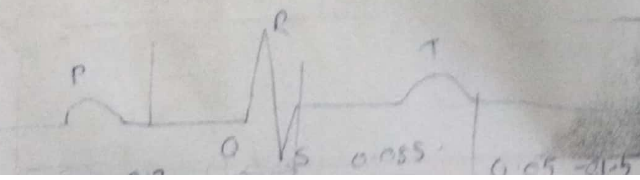
QRS - 0.08 s.



➤ Fig. 2.3 *The position of the sino-atrial node in the heart from where the impulse responsible for the electrical activity of the heart originates. The arrow shows the path of the impulse.*

Note: The numbers like 0.18, 0.145, 0.15, 0.2 ... etc. indicate the time taken for the impulse to travel from the S-A node to various parts of the heart





ECG Leads

Two electrodes placed over different areas of the heart and connected to ~~heart~~ galvanometer will pick up electrical currents resulting from potential difference b/w them. The resulting tracing of voltage difference at any 2 sites due to electrical activity of heart is called a LEAD.

Bipolar leads

In bipolar leads, ECG is recorded by using 2 electrodes such that the final trace corresponds to the difference of electrical potential existing b/w them. They are called standard leads and have been universally adopted. They are also called Einthoven leads.

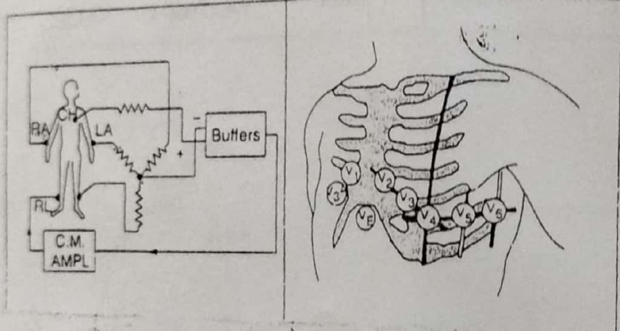
In standard lead I, electrodes are placed on the right arm and left arm and in lead III, then are placed on left arm and left leg. In all lead connections, the difference in potential measured b/w 2 electrodes is always with reference to third point in the body. This reference point is usually taken as 'right leg'. The records are made by using 3 electrodes at a time, right leg connection always being present.

leads or averaging leads.

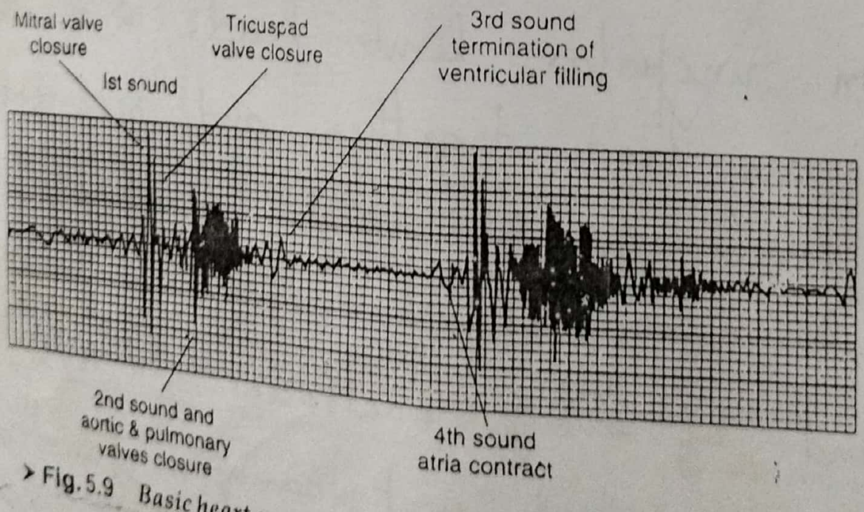
Precordial leads

It employs an extrapolating el[ectrode] to record potential of heart action on chest at 6 different positions. These lead[s are] designated by capital letter 'V' followed [by] subscript numeral which represents the p[osition] of electrode on pericardium.

(c) Unipolar chest leads

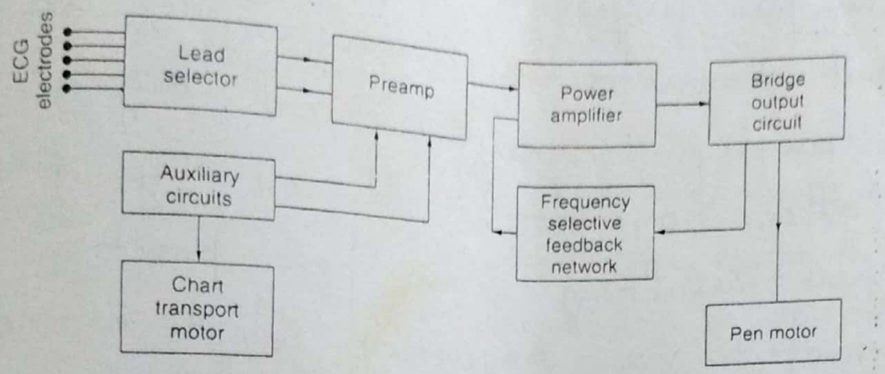


V_1 Fourth intercostal space, at right sternal margin.
V_2 Fourth intercostal space, at left sternal margin.
V_3 Midway between V_2 and V_4.
V_4 Fifth intercostal space, at mid-calvicular line.
V_5 Same level as V_4, on anterior axilliary line.
V_6 Same level as V_4, on mid axilliary line
E: Ensiform, base of sternum.



➤ Fig.5.9 *Basic heart sounds in a typical phonocardiogram recording*

Block diagram of electrocardiograph.



➤ Fig. 5.1 *Block diagram of an ECG machine*

The potentials picked up by the patient electrodes are taken to lead selector switch. In lead selector, the electrodes are selected 2 by 2 according to lead program. By means of capacitive coupling, the signal is connected symmetrically to long-tail pair differential pre-amplifier. The pre-amplifier is usually a 3 or 4 stage differential amplifier having a sufficiently large negative current feedback, from end stage to first stage which gives a stabilizing effect.

The amplified output signal is picked up single ended and is given to power amplifier. The power amplifier is generally of push-pull differential type. The base of one input transistor of amplifier is driven by pre-amplified unsymmetrical signal. The base of other transistor is driven by feedback signal resulting from pen position and connected via frequency selective network. The output of power ampr is again single ended and is fed to pen motor which deflects the writing arm on paper.

ECG are recorded on graph paper with horizontal and vertical lines at 1mm intervals with thicker line at 5mm intervals. For routine work, paper recording speed is 25mm/s. Time measurements are made horizontally and amplitude measurements are made vertically in mV. The sensitivity is set at 10mm/mV.

Assignment portion

KC4

Module IV

MODULE 4

CARDIAC PACEMAKERS

- Cardiac pacemaker is an electric stimulator that produces periodic electric pulses that are conducted to electrodes located on the surface of the heart, within heart muscles or within the cavity of the heart or the lining of the heart.
- It is used for the treatment of;
    1. Cardiac rhythm disorders
    2. Abnormalities in SA node, AV node and Purkinje system

TYPES OF PACEMAKERS

- Classification of pacemakers into different types is based on the mode of application
    - External Pacemaker
    - Internal Pacemaker

EXTERNAL PACEMAKER: They are used when heart block presents itself as an emergency and expected to be present for a short time.

INTERNAL PACEMAKER: They are used in cases requiring long term pacing because of permanent damage that prevents normal cardiac operations.

MODES OF OPERATION

- Two modes of operation are possible with both internal and external pacemakers and they are,
    - **Asynchronous:** the fixed rate impulses occur along with natural pacing impulses.
    - **Synchronous:** they are programmed either in demand or synchronized mode.

ASYNCHRONOUS PACEMAKER

- An asynchronous pacemaker is a free running oscillator type.
- The electrical pulses are produced at uniform rate thereby giving a fixed heart rate.

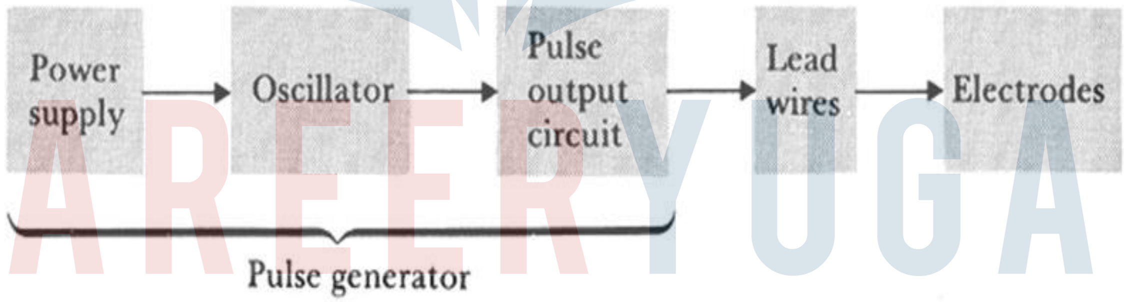


Figure 1: Asynchronous pacemaker – block diagram

POWER SUPPLY:

- It is required to supply energy to the pacemaker
- Primary or secondary batteries are used as power source
- For long life lithium batteries are used
- Sometimes external power sources can be used for implantable pacemakers.

OSCILLATOR:

- The asynchronous pacemakers provide stimulus pulses at a constant rate
- It is either a free running blocking oscillator or a multi-vibrator

PULSE OUTPUT CIRCUIT:

- It consists of a timing circuit to determine when a stimulus should be applied to the heart.

- It produces pulses at a fixed rate between 70 to 90 beats per minute.

LEAD WIRES:

- In most of the cases the generator is positioned at location away from the heart.
- There should be appropriate connection to carry the electric stimuli to the heart and to apply them in the appropriate place.
- So simply lead wires are the connecting electrical wires between the electrodes and the operating device.
- These lead wires being good electrical conductors must also be mechanically strong to with stand of movements and must have a high grade of insulation.
- Thus lead wires are interward helical coils of spring wire alloy moulded in silicon rubber cylinder.

ELECTRODES:

- Electrodes must with stand flexing due to the pumping action of the heart and must remain in place.
- The material chosen is of great importance as it should not have any electrolytic relations with heart tissue and must not cause irritation to the myocardium.
- Materials commonly used are platinum and silver-silver chloride, carbon and titanium.

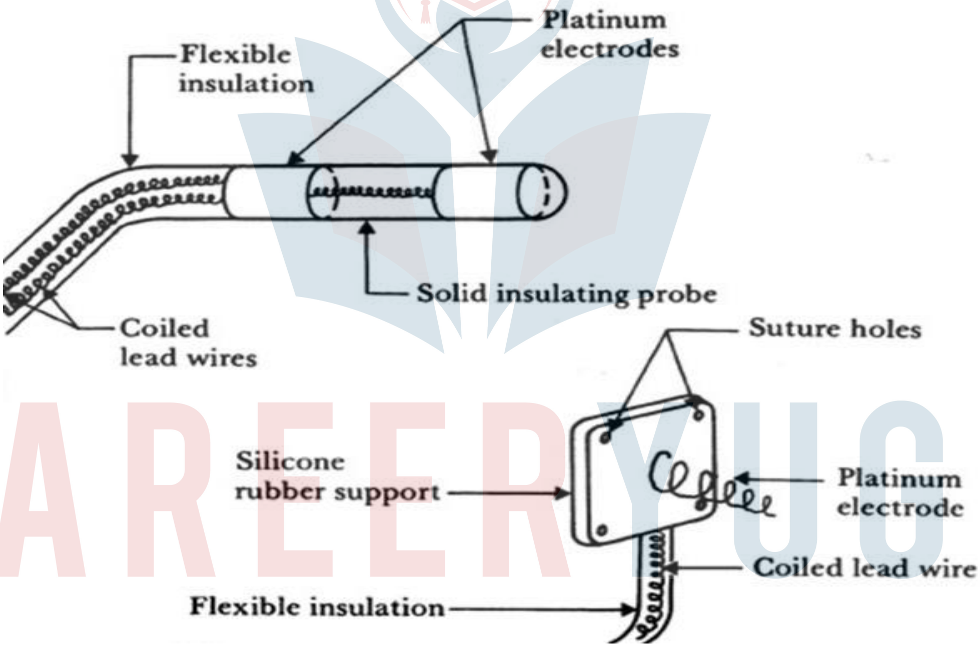


Figure 2: Pacemaker electrodes

SYNCHRONOUS PACEMAKER

- We have two forms of synchronous pacemakers:
    1. Demand Pacemaker
    2. Atrial Synchronous pacemaker
- Most of the patients require pacing intermittently; this is because the patients can establish normal cardiac rhythm between periods of block.
- In this case it is not necessary to stimulate the ventricles continuously as it may cause ventricular fibrillation.
- The pacemaker should not compete with normal pacing of the heart.
- It is also known as **Demand pacemaker**.

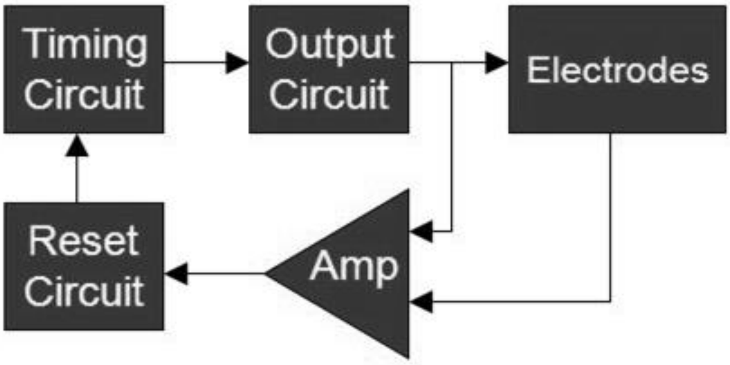


Figure 3: Demand Pacemaker

- It consists of a timing circuit, an output circuit and electrodes along with a feedback path.
- Timing circuit has a fixed rate of 60/80 beats per minute.
- Timing circuit reset itself after each stimulus waits for appropriate time and then generates the next pulse.
- The feedback circuit detects the QRS complex of ECG signal from electrodes and amplifies it.
- The signal is used to reset the timing circuit. It waits for the assigned interval before producing next stimulus.
- If heart beats again, before the stimulus is produced the timing circuit is reset and process repeats itself.

ATRIAL SYNCHRONOUS PACEMAKER

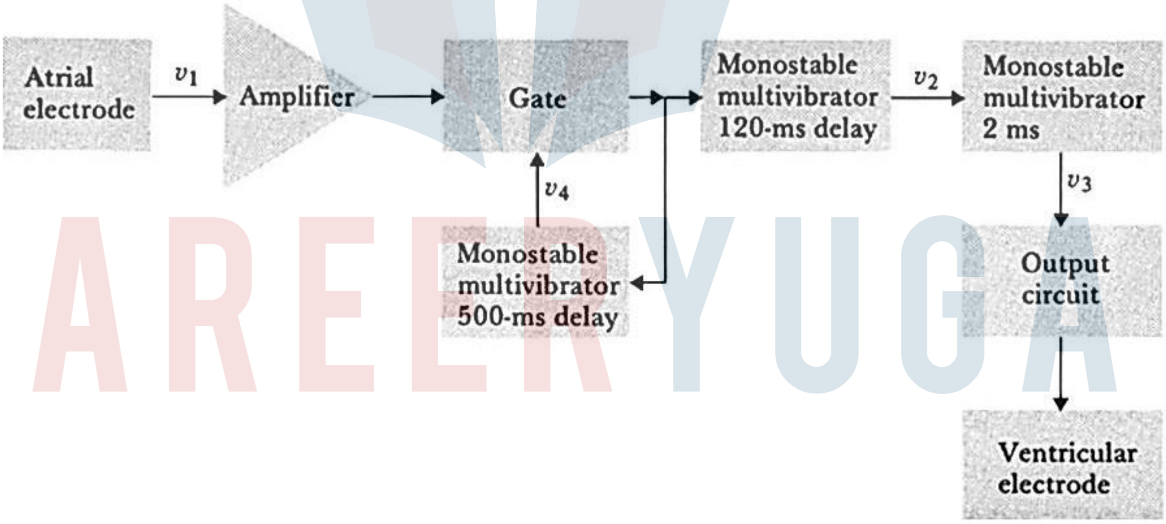


Figure 4: Atrial synchronous pacemaker

- The heart's physiological pacemaker located at SA node, initiate the cardiac cycle by stimulating the atria to contract and then providing stimulus to AV node, which after appropriate delay stimulates ventricles.
- If SA node is able to stimulate the atria, the electric signal corresponding to atrial contraction can be detected by an electrode implanted in atrium and used to trigger the pacemaker in same way that it triggers AV node.
- Voltage is a pulse that corresponds to each beat.
- The atrial signal is then amplified and passed through a gate to a monostable multivibrator giving a pulse V_2 of 120ms duration, the approximate delay of AV node.

- Another monostable multivibrator giving pulse duration of 500ms is also triggered by atrial pulse and it produce V_4 which causes the gate block any signal from atrial electrodes for a period of 500ms following contraction.
- This eliminates any artifact caused by ventricular contraction from stimulating additional ventricular contraction.
- V_2 is used to trigger a monostable multivibrator of 2ms duration.
- Pulse V_2 acts as a delay allowing V_3 to be produced which follows atrial contraction.
- Then V_3 controls an output circuit that applies stimulus to the appropriate ventricular electrodes.

DEFIBRILLATORS

- **CARDIAC FIBRILLATION** is a condition where the individual myocardial cells contact asynchronously and an irregular cardiac rhythm is produced which cause the cardiac output to near zero.
- The fibrillation of atrial muscle is called atrial fibrillation and that of the ventricles is called ventricular fibrillation.
- It must be corrected as soon as possible to avoid irreversible brain damage to the patient and death.
- Electric shock to the heart can be used to re-establish a normal cardiac rhythm.
- Electric machines that produce the energy to carry out this function are known as defibrillators.
- Defibrillator consists of an electric supply unit and two metal electrodes called “Paddles” that are pressed very firmly to the patient’s chest using insulating plastic handles. So the person using them does not get a shock too.
- The important thing is that current should flow through the heart so where the paddles are applied is crucial.
- For getting good electrical contact solid or liquid conducting gel is used.
- There are four basic type:
    1. AC Defibrillator
    2. Capacitive Discharge DC Defibrillator
    3. Capacitive Discharge Delay Line Defibrillator
- Defibrillation by electric shock is carried out either by passing current through electrodes placed directly on heart or by using large area electrodes placed against the anterior thorax.

AC DEFIBRILLATOR

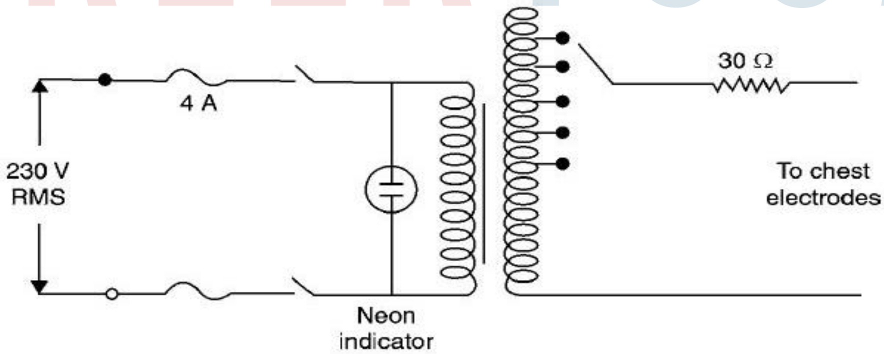


Figure 5: AC Defibrillator

- By construction it consists of a step up transformer with various tapping on the secondary side.
- An electronic timer circuit is connected to the primary of the transformer
- This timer device is a simple capacitor and resistor or mono-stable multivibrator.

- Applying brief 0.25 -1 second burst of 60 Hz AC act as intensity of around 6A.
- It acts as counter shock for resynchronization and repeats until defibrillation occurs.
- It is constructed in such a way that appropriate voltages for internal and external defibrillation are available.
- External defibrillation voltage range: 250 – 750V
- Internal defibrillation voltage range: 60 – 250V
- Large currents are required in external defibrillation to produce uniform and simultaneous contraction of the heart muscle fibers.

CAPACITIVE DISCHARGE DC DEFIBRILLATOR

- The 230 V AC mains supply is connected to variable auto transformer
- The output of this is fed to step up transformer to produce a high voltage
- A half wave rectifier rectifies this high AC voltage to obtain high DC voltage which charges the capacitor C. The voltage to which the Cis charged is determined by the auto-transformer in primary circuit.
- A series resistance R_s limits the charging current to protect the circuit components and an AC voltmeter across the primary is calibrated indicate energy stored in the capacitor.
- With electrodes firmly placed at appropriate position on chest, the clinician discharges the capacitor by changing the switch S from position 1 to 2.
- The capacitor is discharged through electrodes and patient is represented by a resistive load and inductor L.

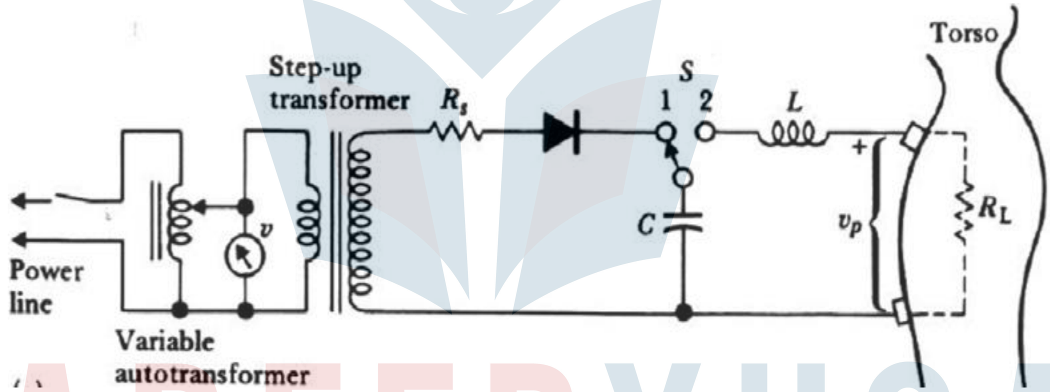


Figure 6: Capacitive Discharge DC Defibrillator

- Inductor L is used to shape the wave in order to eliminate a sharp, undesirable current spike that would otherwise occur at beginning of discharge.
- The energy delivered is represented by typical waveform,

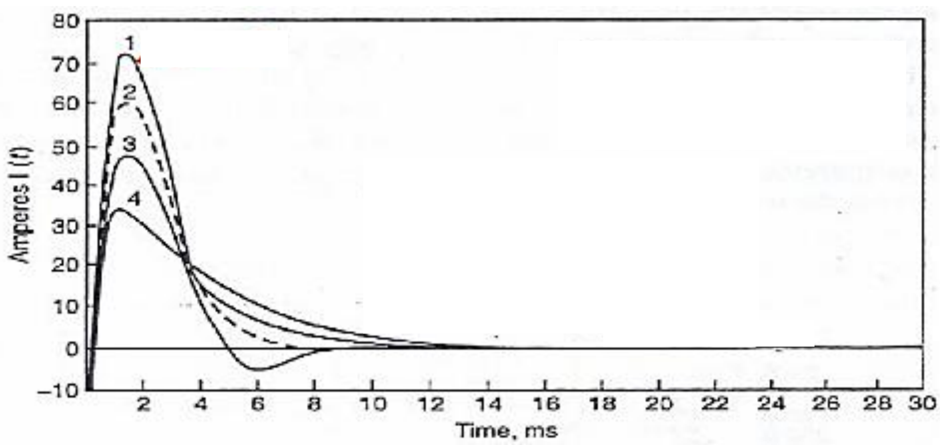


Figure 7: Defibrillator Discharge waveform

- Area under the curve is proportional to energy delivered.
- Once the discharge is completed, the switch automatically returns to position 1 and process can be repeated if necessary.
- Energy stored in capacitor is given by,

  $W = \frac{1}{2} CV^2$

  C= Capacitance

  V= Voltage to which capacitor is discharged

CAPACITIVE DISCHARGE DELAY LINE DEFIBRILLATOR

- Even with dc defibrillation, there is a danger of damage to the myocardium and the chest walls because, peak voltages as high as 6000V may be used.
- To reduce this risk, some defibrillators produce dual-peak waveforms of longer duration at a much lower voltage.
- In this circuit, parallel combination of capacitors C_1 and C_2 stores the same energy as the single capacitor in capacitor discharge type defibrillator.
- But its discharge characteristic is more rectangular in shape at a much lower voltage as shown in second waveform.
- With this type of defibrillation, effective defibrillation can be achieved in adults with lower levels of delivered energy between 50 and 200 watts.

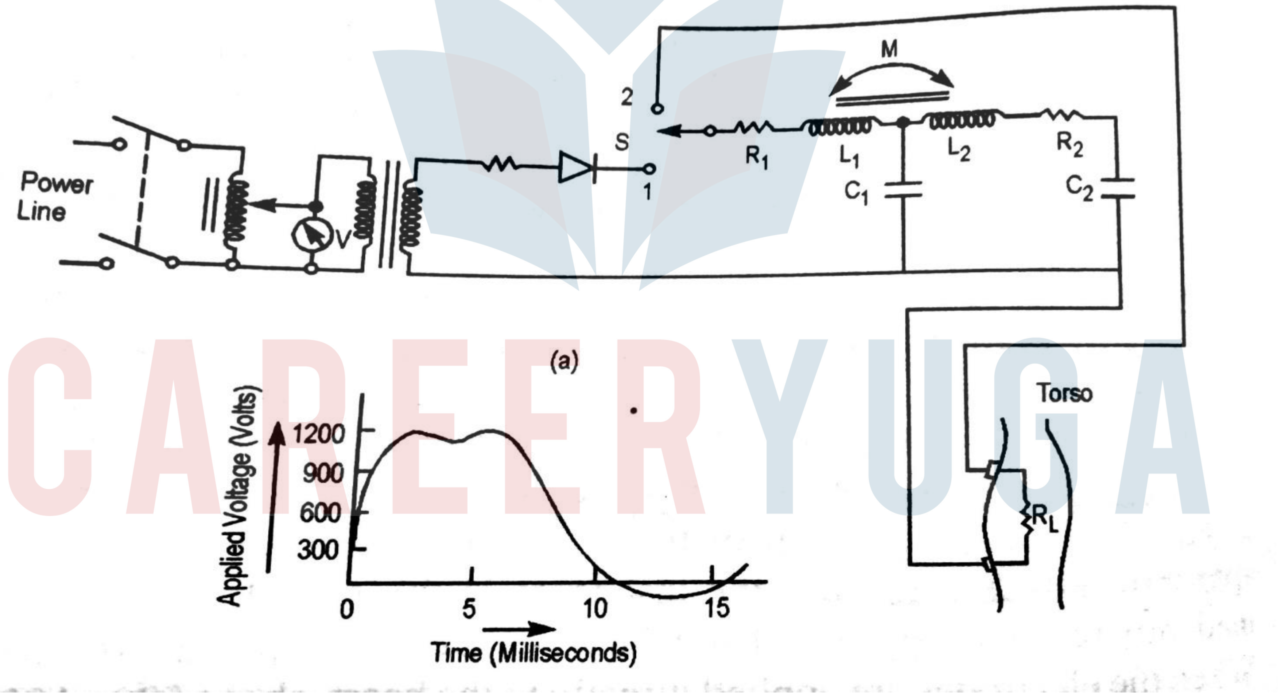


Figure 8: Capacitive discharge delay line defibrillator

ELECTRO ENCEPHALOGRAM

- Electroencephalography (encephalon = brain), or EEG, is the physiological method of choice to record all of the electrical activity generated by the brain from electrodes placed on the scalp surface.
- The EEG has a very complex pattern, which is much more difficult to recognize than the ECG.
- The waveform varies greatly with the location of the measuring electrodes on the surface of the scalp.

NEURONAL COMMUNICATION

Functions of the Nervous System:

1. Gathers information from both inside and outside the body - Sensory Function
2. Transmits information to the processing areas of the brain and spine
3. Processes the information in the brain and spine – Integration Function
4. Sends information to the muscles, glands, and organs so they can respond appropriately – Motor Function

- It controls and coordinates all essential functions of the body including all other body systems allowing the body to maintain homeostasis or its delicate balance.
- The Nervous System is divided into Two Main Divisions: **Central Nervous System (CNS)** and the **Peripheral Nervous System (PNS)**

Divisions of the Nervous system:

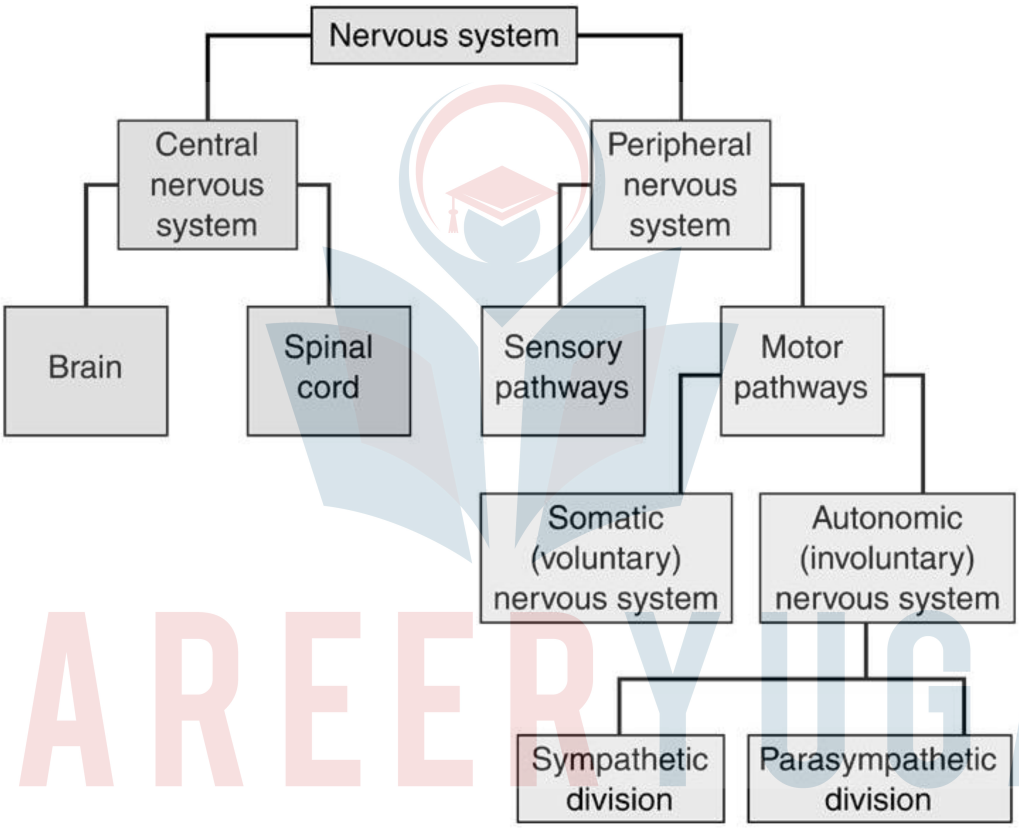


Figure 9: Divisions of nervous system

Basic Cells of the Nervous System:

Neuron

- Basic functional cell of nervous system
- Transmits impulses (up to 250 mph)

Parts of a Neuron

- **Dendrite** – receive stimulus and carries it impulses toward the cell body
- **Cell Body with nucleus** – nucleus and most of cytoplasm
- **Axon** – fiber which carries impulses away from cell body
- **Schwann Cells**- cells which produce myelin or fat layer in the Peripheral Nervous System

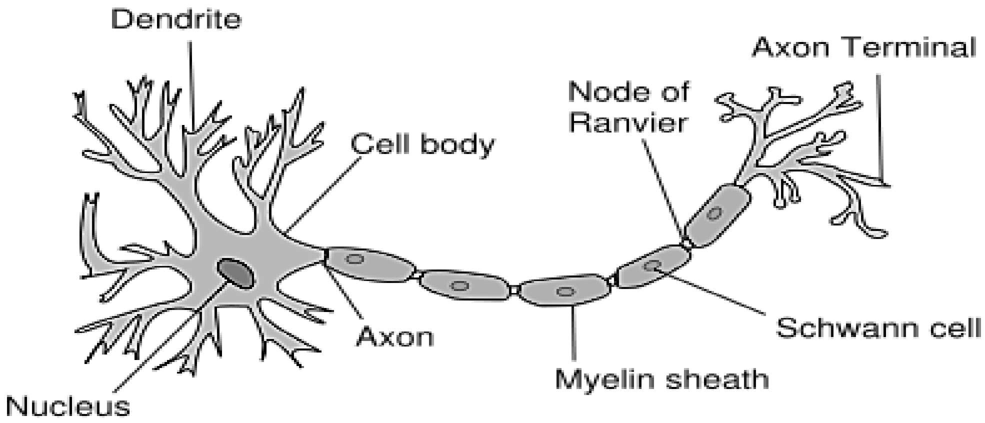


Figure 10: Structure of a neuron

- **Myelin sheath** – dense lipid layer which insulates the axon – makes the axon look gray
- **Node of Ranvier** – gaps or nodes in the myelin sheath
- Impulses travel from dendrite to cell body to axon

Three types of Neurons:
- **Sensory neurons** – bring messages to CNS
- **Motor neurons** - carry messages from CNS
- **Interneurons** – between sensory & motor neurons in the CNS

BRAIN WAVES

- At the root of all our thoughts, emotions and behaviours is the communication between neurons within our brains.
- Brainwaves are produced by synchronised electrical pulses from masses of neurons communicating with each other.
- Brainwaves are detected using sensors placed on the scalp. They are divided into bandwidths to describe their functions.
- It is a handy analogy to think of brainwaves as musical notes - the low frequency waves are like a deeply penetrating drum beat, while the higher frequency brainwaves are more like a subtle high pitched flute.
- Our brainwaves change according to what we're doing and feeling.
- When slower brainwaves are dominant we can feel tired, slow or dreamy.
- The higher frequencies are dominant when we feel wired, or hyper-alert.
- Brainwave speed is measured in Hertz (cycles per second) and they are divided into bands delineating slow, moderate, and fast waves.
- When our brainwaves are out of balance, there will be corresponding problems in our emotional or neuro-physical health.

INFRA-LOW (<0.5 HZ)

- Infra-Low brainwaves are thought to be the basic cortical rhythms that underlie our higher brain functions.
- Very little is known about infra-low brainwaves.
- Their slow nature makes them difficult to detect and accurately measure, so few studies have been done.

DELTA WAVES (0.5 TO 3 HZ)

- Delta Waves, the slowest but loudest brainwaves.
- Delta brainwaves are slow, loud brainwaves (low frequency and deeply penetrating, like a drum beat).

- They are generated in deepest meditation and dreamless sleep.

THETA WAVES (3 TO 8 HZ)

- Theta brain waves occur in sleep and are also dominant in deep meditation.
- Theta is our gateway to learning, memory, and intuition.
- In theta we are in a dream, imagery, intuition and information beyond our normal conscious awareness.
- It's where we hold our 'stuff', our fears, troubled history, and nightmares.

ALPHA WAVES (8 TO 12 HZ)

- Alpha brainwaves are dominant during quietly flowing thoughts, and in some meditative states.
- Alpha is 'the power of now', being here, in the present.
- Alpha is the resting state for the brain.
- Alpha waves aid overall mental coordination, calmness, alertness, mind/body integration and learning.

BETA WAVES (12 TO 38 HZ)

- Beta brainwaves dominate our normal waking state of consciousness when attention is directed towards cognitive tasks and the outside world.
- Beta is a 'fast' activity, present when we are alert, attentive, engaged in problem solving, judgment, decision making, or focused mental activity.
- Beta brainwaves are further divided into three bands;
- **Lo-Beta (Beta1, 12-15Hz)**
- **Beta (Beta2, 15-22Hz)**
- **Hi-Beta (Beta3, 22-38Hz)**

GAMMA WAVES (38 TO 42 HZ)

- Gamma brainwaves are the fastest of brain waves (high frequency, like a flute), and relate to simultaneous processing of information from different brain areas.
- Gamma brainwaves pass information rapidly and quietly.

EEG MEASUREMENT

TYPES OF ELECTRODES IN EEG

- Several types of electrodes may be used to record EEG.
- These include:
    1. Peel electrodes
    2. Stick electrodes
    3. Silver plated cup electrodes
    4. Needle electrodes
- EEG electrodes are smaller in size than ECG electrodes.
- They may be applied separately to the scalp or may be mounted in special bands, which can be placed on the patient's head.
- In either case, electrode jelly or paste is used to improve the electrical contact.
- If the electrodes are intended to be used under the skin of the scalp, needle electrodes are used.
- EEG electrodes give high skin contact impedance as compared to ECG electrodes.
- Good electrode impedance should be generally below 5 kilohms.
- Impedance between a pair of electrodes must also be balanced or the difference between them should be less than 2 kilohms.

- EEG preamplifiers are generally designed to have a very high value of input impedance to take care of high electrode impedance.
- EEG may be recorded by picking up the voltage difference between an active electrode on the scalp with respect to a reference electrode on the ear lobe or any other part of the body.
- This type of recording is called **‘monopolar’** recording.
- However, **‘bipolar’** recording is more popular wherein the voltage difference between two scalp electrodes is recorded.
- Such recordings are done with multi-channel electroencephalographs.
- EEG signals picked up by the surface electrodes are usually small as compared with the ECG signals.
- They may be several hundred microvolts, but 50 microvolts peak-to-peak is the most typical.
- The brainwaves, unlike the electrical activity of the heart, do not represent the same pattern over and over again.
- Therefore, brain recordings are made over a much longer interval of time in order to be able to detect any kind of abnormalities.

PLACEMENT OF ELECTRODES IN EEG

- The 10/20 system or international 10/20 system is an internationally recognized method to describe the location of the scalp electrodes.
- The system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex.
- The numbers ‘10’ and ‘20’ refer to the fact that the distance between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull.
- Each site has a letter to identify the lobe and a number to identify the hemisphere location.

ELECTRODE	LOBE
F	Frontal
T	Temporal
C	Central
P	Parietal
O	Occipital

- No central lobe exists; the ‘C’ letter is used for identification purposes only.
- The ‘z’ (zero) refers to an electrode placed on the mid line.
- Even numbers (2, 4, 6, 8) refer to electrode positions on the right hemisphere.
- Odd numbers (3, 5, 7, 9) refer to electrode positions on the left hemisphere.

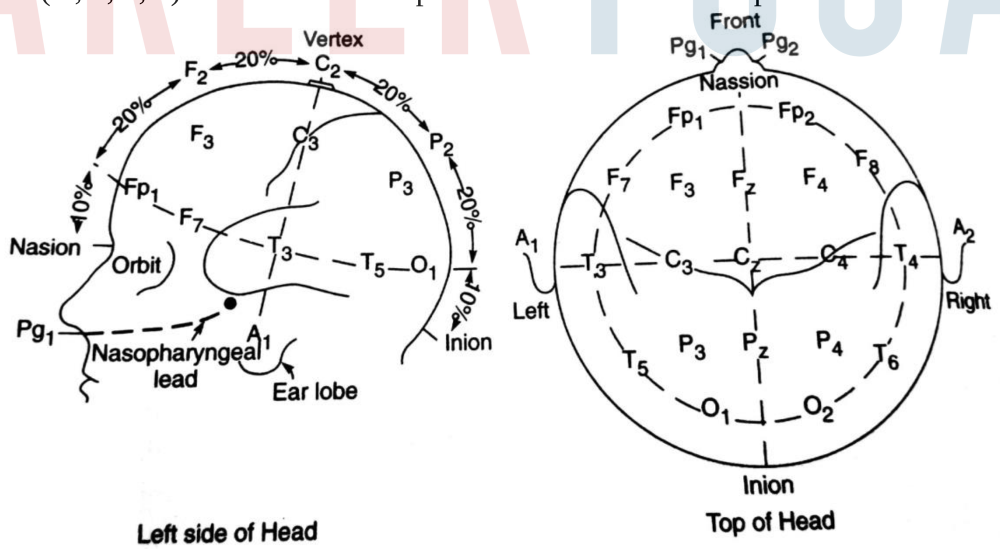


Figure 11: System of placement of electrodes

EEG RECORDING

- The basic block diagram of an EEG machine with both analog and digital components is shown in figure given below.

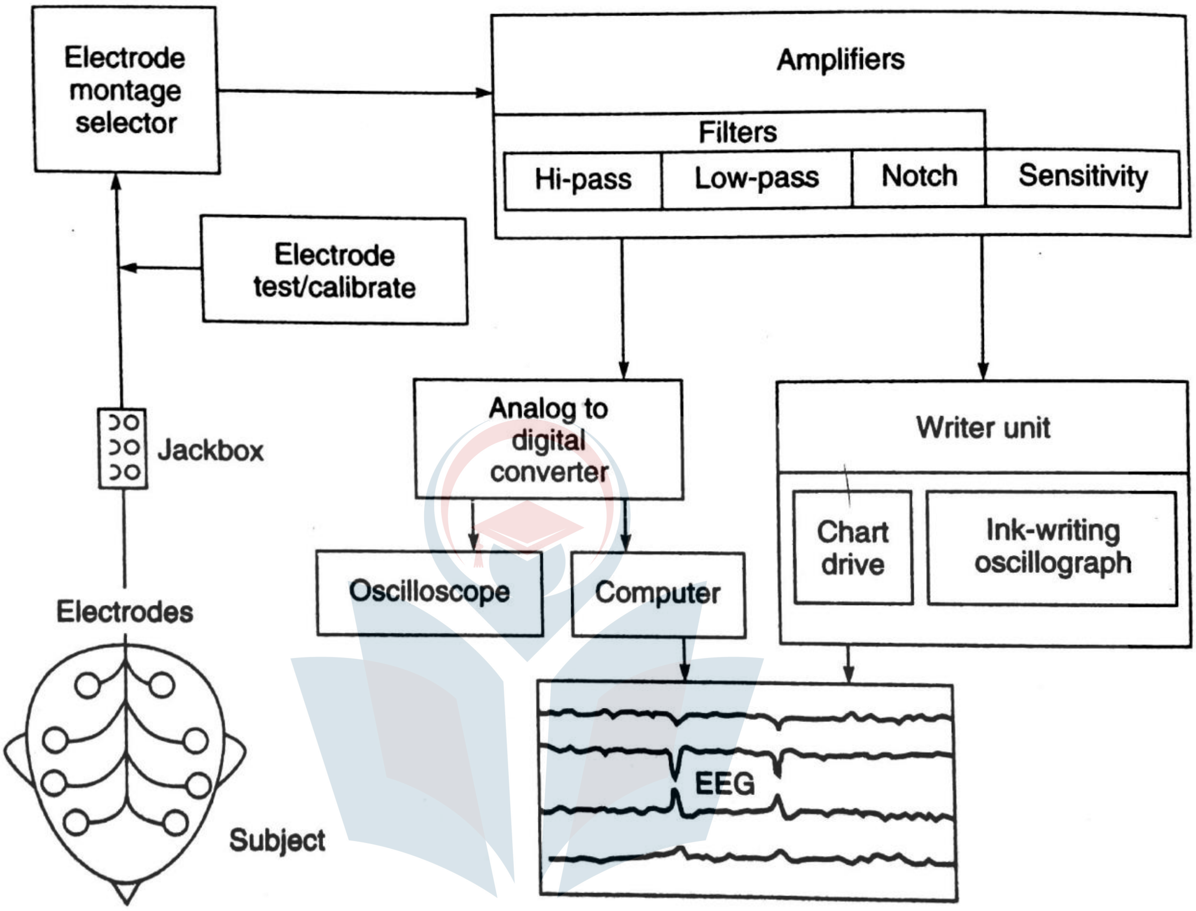


Figure 12: Schematic diagram of an EEG machine

MONTAGES

- A pattern of electrodes on the head and the channels they are connected to is called a montage.
- Montages are always symmetrical.
- The reference electrode is generally placed on a non-active site such as the forehead or earlobe.
- EEG electrodes are arranged on the scalp according to a standard known as the 10/20 system, adopted by the American EEG Society.

ELECTRODE MONTAGE SELECTOR

- EEG signals are transmitted from the electrodes to the head box, which is labelled according to the 10-20 system, and then to the montage selector.
- The montage selector on analog EEG machine is a large panel containing switches that allow the user to select which electrode pair will have signals subtracted from each other to create an array of channels of output called montage.
- Each channel is created in the form of the input from one electrode minus the input from a second electrode.
- The advantage of recording EEG in several montages is that each montage displays different spatial characteristics of the same data.

PREAMPLIFIER

- Every channel has an individual, multistage, ac coupled, very sensitive amplifier with differential input and adjustable gain in a wide range.
- Its frequency response can be selected by single-stage passive filters.
- The preamplifier used in electroencephalographs must have high gain and low noise characteristics because the EEG potentials are small in amplitude.
- In addition, the amplifier must have very high common-mode rejection to minimize stray interference signals from power lines and other electrical equipment.

SENSITIVITY CONTROL

- The overall sensitivity of an EEG machine is the gain of the amplifier multiplied by the sensitivity of the writer.
- Thus, if the writer sensitivity is 1 cm/V, the amplifier must have an overall gain of 20,000 for a 50 µV signal.
- The various stages are capacitor coupled.
- An EEG machine has two types of gain controls.
- One is continuously variable and it is used to equalize the sensitivities of all channels.
- The other control operates in steps and is meant to increase or reduce the sensitivity of a channel by known amounts.

FILTERS

- Low pass filters and high pass filters are used to eliminate or remove the additional unwanted bio-electrical signals from the muscles nearer to the EEG electrodes.
- Some EEG machines have a notch filter sharply tuned at 50 Hz so as to eliminate mains frequency interference.

WRITING PART

- The writing part of an EEG machine is usually of the ink type direct writing recorder.
- The best types of pen motors used in EEG machines have a frequency response of about 90 Hz.

CHANNELS

- An electroencephalogram is recoded simultaneously from an array of many electrodes.
- The record can be made from bipolar or monopolar leads.
- The electrodes are connected to separate amplifiers and writing systems.
- Commercial EEG machines have up to 32 channels, although 8 or 16 channels are more common.

MUSCLE RESPONSE-ELECTROMYOGRAM

- Electromyography is the science of recording and interpreting the electrical activity of muscle's action potentials.
- The recoding of the peripheral nerve's action potentials is called electroneurography.
- The electrical activity of the underlying muscle can be measured by placing surface electrodes on the skin.
- To record the action potentials of individual motor neurons in a muscle, the needle electrode is inserted into the muscle.
- Thus EMG indicates the amount of activity of a given muscle or a group of muscles.
- The action potentials occur both positive and negative polarities at a given pair of electrodes; so they may add or cancel each other.
- Thus EMG appears, very much like a random noise wave form.
- The contraction of a muscle produces action potentials.
- In a relaxed muscle, there is no action potential

ELECTROMYOGRAM MEASUREMENTS

- EMG is usually recorded by using surface electrodes or more often by using needle electrodes, which are inserted directly into the muscle.
- The surface electrode may be disposable, adhesive types.
- A ground electrode is necessary for providing a common reference for measurement.
- These electrodes pick up the potentials produced by the contracting muscle fibers.
- The signal can then be amplified and displayed on the screen of a cathode ray tube.
- It is also applied to an audio amplifier connected to a loudspeaker.
- A trained EMG interpreter can diagnose various muscular disorders by listening to the sounds produced when the muscle potentials are fed to the loudspeaker.

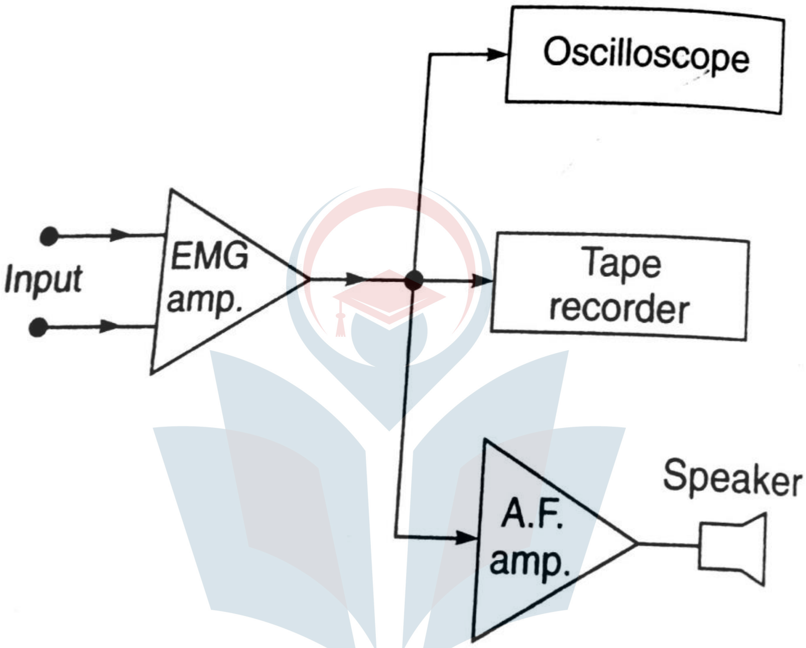
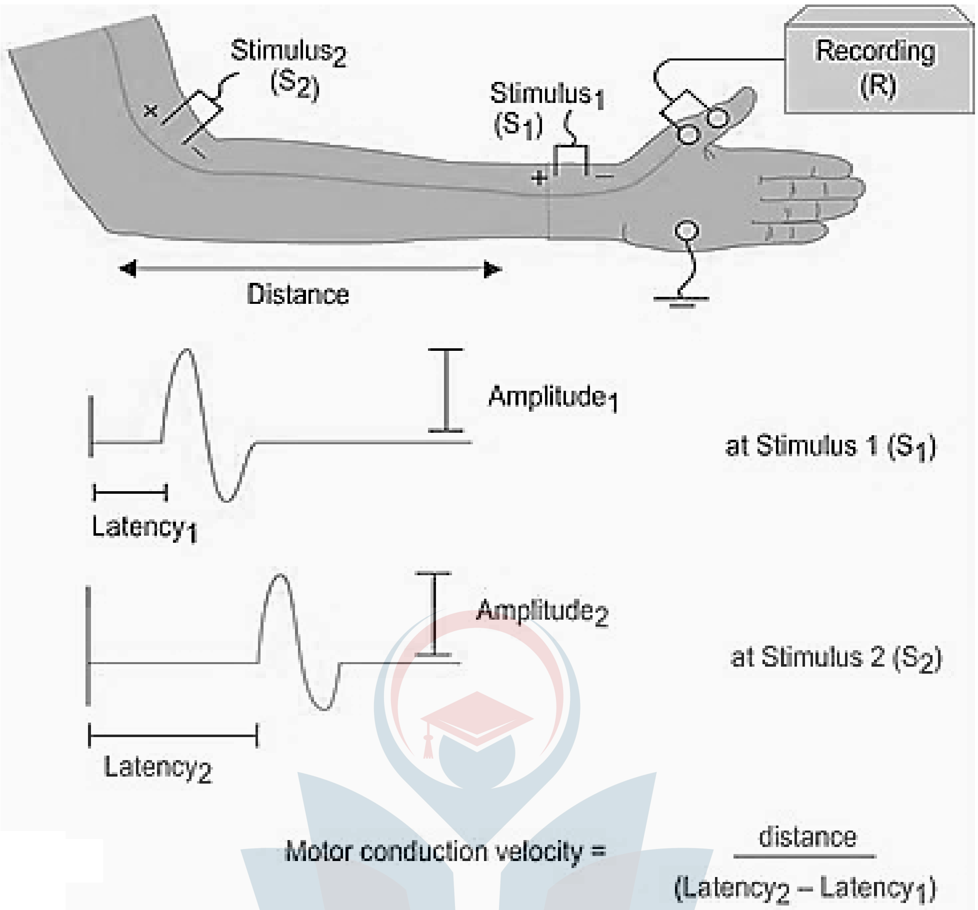


Figure 13: Block diagram of a typical setup for EMG recording

- The block diagram shows a typical setup for EMG recordings.
- The oscilloscope displays EMG waveforms.
- The tape recorder is included in the system to facilitate playback and study of the EMG sound waveforms at a later convenient time.
- The waveform can also be photographed from the CRT screen by using a synchronized camera.
- The amplitude of the EMG signals depends upon various factors, such as type and placement of electrodes used and the degree of muscular exertions.

NERVE CONDUCTION VELOCITY MEASUREMENTS

- The measurement of conduction velocity in motor nerves is used to indicate the location and type of the nerve damages.
- Here the nerve function is examined directly at the various segments of the nerve by means of stimulating it with a brief electric shock having pulse duration of 0.2 to 0.5 milliseconds and measuring the latencies, we can calculate the conduction velocity in that nerve.
- Latency is defined as the elapsed time between the stimulating impulse and the muscle’s action potential.



RESPIRATORY PARAMETERS

- **Tidal Volume (TV):** The volume of gas inspired or expired during normal quiet breathing, is known as tidal volume.
- **Minute Volume (MV):** The volume of gas exchanged per minute during quiet breathing.it is equal to the tidal volume multiplied by the breathing rate.
- **Alveolar Ventilation (AV):** The volume of fresh air entering the alveoli with each breath.
  AV = (Breathing rate) x (Tidal volume – Dead space)
- **Inspiratory Reserve Volume (IRV):** The volume of gas, which can be inspired from a normal end-tidal volume.
  IRV = VC – (TV + FRC)
- **Expiratory Reserve Volume (ERV):** The volume of gas remaining after a normal expiration less the volume remaining after a forced expiration.
  ERV = FRC – RV
- **Residual Volume:** The volume of gas remaining in the lungs after a forced expiration.
- **Functional Residual Capacity (FRC):** The volume of gas remaining in the lungs after normal expiration.
- **Total Lung Capacity (TLC):** the volume of gas in the lungs at the point of maximal inspiration.
  TLC = VC + RV
- **Vital Capacity (VC):** The greatest volume of gas that can be inspired by voluntary effort after maximum expiration, irrespective of time.
- **Inspiratory Capacity (IC):** The maximum volume that can be inspired from the resting end expiratory position.
- **Dead Space:** Dead space is the functional volume of the lung that does not participate in gas exchange.

- **Compliance (C):** Change in lung volume resulting from unit change in trans-pulmonary pressure (P_L).
- **Chest-Wall Compliance (C_{cw}):** Change in volume across the chest wall resulting from unit change in trans-chest wall pressure.
- **Elastance (E):** Reciprocal of compliance. Units are cmH_2O/litre.
- **Forced Vital Capacity (FVC):** This is the total amount of air that can be forcibly expired as quickly as possible after taking the deepest possible breath.

SPIROMETER

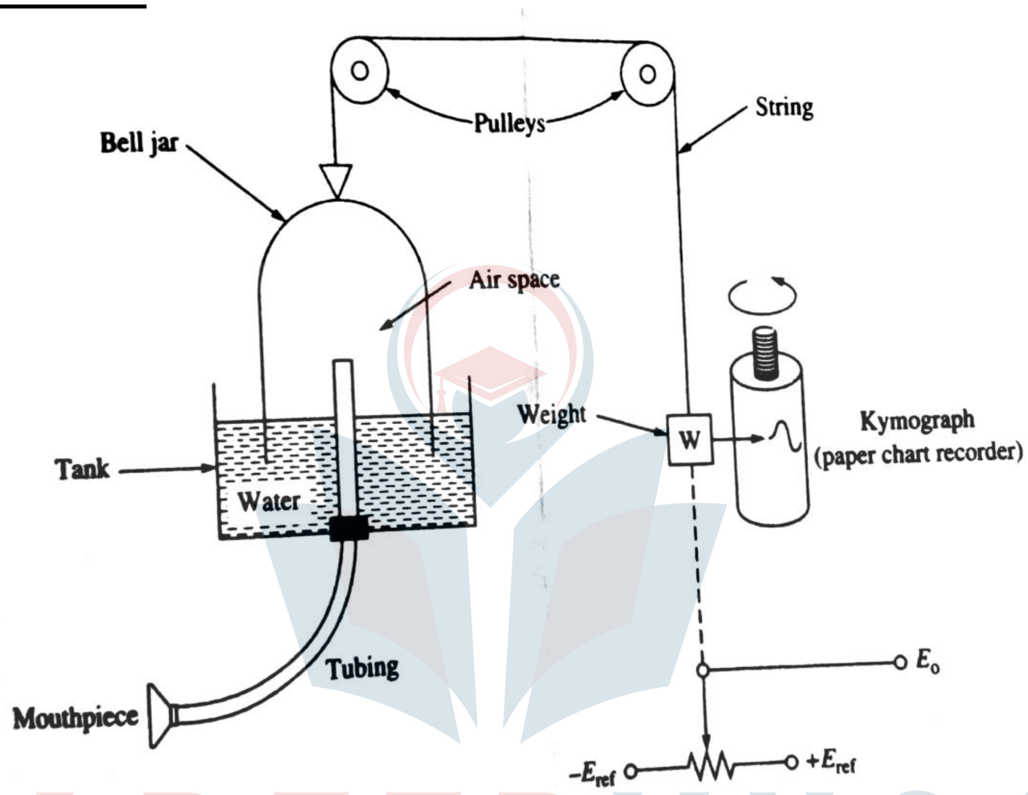


Figure 14: Spirometer

- This instrument uses a bell jar, suspended from above, in a tank of water.
- An air hose leads from mouthpiece to the space inside of the bell above the water level.
- A weight is suspended from the string that holds the bell in such a way that it places a tension force on the string that exactly balances the weight of the bell at atmospheric pressure.
- When no one is breathing into the mouthpiece, therefore, the bell will be at rest with a fixed volume above the water level.
- But when the subject exhales, the pressure inside the bell increases above atmospheric pressure, causing the bell to rise.
- Similarly, when the patient inhales, the pressure inside the bell decreases.
- The bell will rise when the pressure increases and drop when the pressure decreases.
- The change in bell pressure changes the volume inside the bell, which also causes the position of the counterweight to change.
- We may record the volume changes on a piece of graph paper by attaching a pen to the counterweight or tension string.
- The chart recorder is a rotatory drum model called a kymograpgh.
- It rotates slowly at speed between 30 and 2000 mm/min.

PNEUMOGRAPH

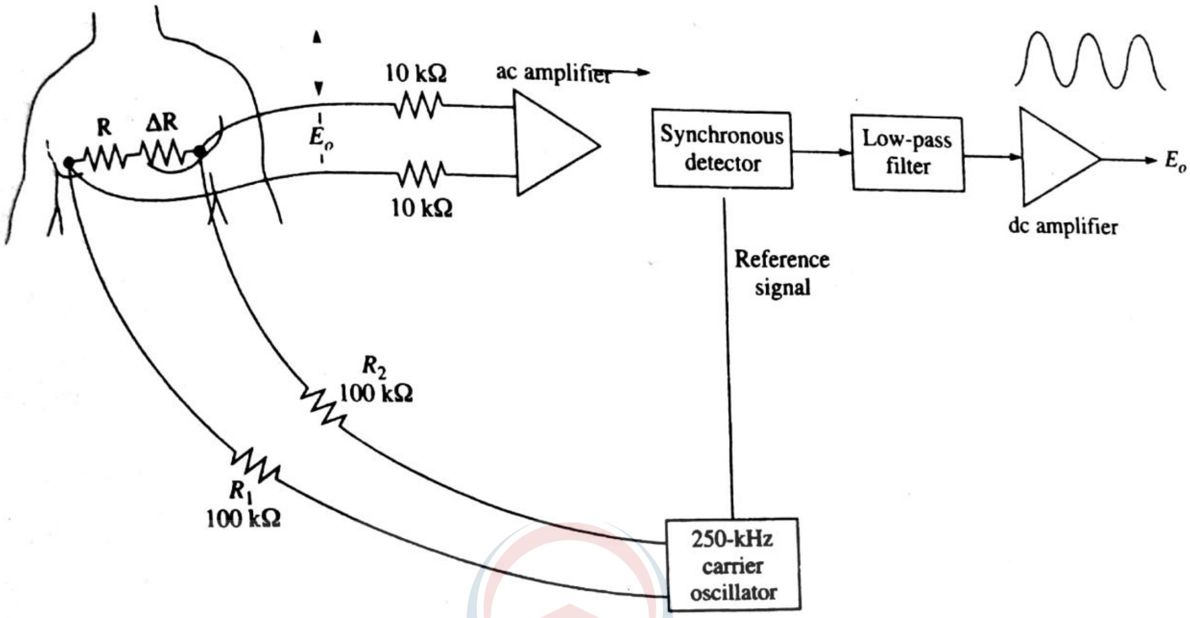


Figure 15: Impedance pneumograph-Block diagram

- An impedance pneumograph is based on the fact that the ac impedance across the chest of a subject changes as respiration occurs.
- Figure 15 shows the block diagram for an impedance pneumograph.
- A low voltage, 50 to 500 KHz ac signal is applied to the chest of the patient through surface electrodes of the same type as used in ECG monitoring.
- In fact, many of these monitors are also ECG monitors, using a common set of electrodes and a single pair of lead wires.
- High value fixed resistors connected in series with each electrode create a constant ac current source.
- The signal voltage applied to the differential ac amplifier is the voltage drop across the resistance, representing the patient's thoracic impedance. (figure 16)

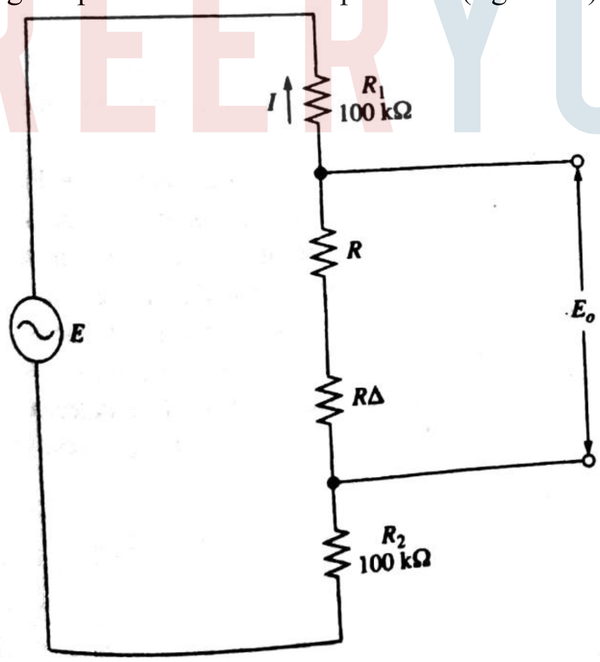


Figure 16: Equivalent circuit-Pneumograph

$$E_0 = I(R \pm \Delta R)$$

- Where,

  E_0 is the output potential in volts (V)
  I is the current through the chest in amperes (A)
  R is the chest impedance, without respiration, in ohms (Ω)
  ΔR is the change of chest impedance caused by respiration, in ohms (Ω)
- The current passed through the patient's chest is very small and is nearly constant without respiration because the source voltage E is constant and the term ΔR is very small with respect to the sum $R_1 + R_2 + R$.
- The signal E_0 is amplified and then applied to a synchronous amplitude modulation (AM) detector; the respiration waveform is contained within amplitude variations in E_0 caused ΔR.
- A low pass filter following the detector removes residual carrier signal, and a dc amplifier scales the output waveform to the level required by the display device.

END OF MODULE 4