UNIT I

ELECTRO-PHYSIOLOGY AND BIO-POTENTIAL RECORDING

1.1 THE ORIGIN OF BIO-POTENTIALS:

- Many organs in the human body, such as the heart, brain, muscles, and eyes, manifest their function through electric activity.
- The heart, for example, produces a signal called the electrocardiogram or ECG . The brain produces a signal called an electroencephalogram or EEG The activity of muscles, such as contraction and relaxation, produces an electromyogram or EMG. Eye movement results in a signal called an electrooculogram or EOG and the retina within the eyes produces the electroretinogram or ERG.
- Measurements of these and other electric signals from the body can provide vital clues as to normal or pathological functions of the organs
- The origins of these biopotentials can be traced to the electric activity at the cellular level
- The electric potential across a cell membrane is the result of different ionic concentrations that exist inside and outside the cell.
- The electrochemical concentration gradient across a semipermeable membrane results in the Nernst potential.
- The cell membrane separates high concentrations of potassium ion and low concentrations of sodium ions inside a cell and just the opposite outside a cell.

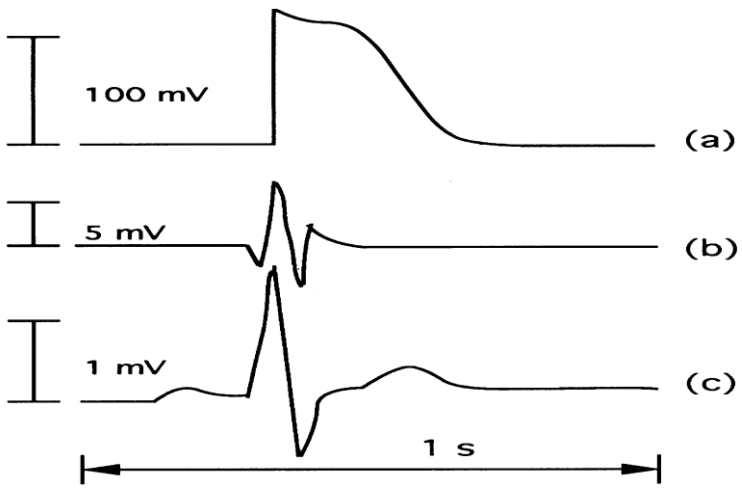


FIGURE:1.1 Schematic showing origins of biopotentials: (a) an action potential from a heart cell (b) the electrogram from the heart surface ; and (c) the ECG signal at the chest

- This difference in ionic concentration across the cell membrane produces the resting potential. Some of the cells in the body are excitable and produce what is called an action potential, which results from a rapid flux of ions across the cell membrane in

response to an electric stimulation or transient change in the electric gradient of the cell .

- The electric excitation of cells generates currents in the surrounding volume conductor manifesting itself as potentials on the body.
- Fig:1.1 illustrates the continum of electrophysiological signals from the (a) heart cells,(b) myocardium (the heart muscle), and (c) the body surface. Each cell in the heart produces a characteristic action potential .
- The activity of cells in the sinoatrial node of the heart produces an excitation that propagates from the atria to the ventricles through well-defined pathways and eventually throughout the heart; this electric excitation produces a synchronous contraction of the heart muscle.
- The associated biopotential is the ECG. Electric excitation of a neuron produces an action potential that travels down its dendrites and axon activity of a massive number of neurons and their interactions within the cortical mantle results in the EEG signal .
- Excitation of neurons transmitted via a nerve to a neuromuscular junction produces stimulation of muscle fibers.
- Constitutive elements of muscle fibers are the single motor units, and their electric activity is called a single motor unit potential.
- The electric activity of large numbers of single motor unit potentials from groups of muscle fibers manifests on the body surface as the EMG.
- Contraction and relaxation of muscles is accompanied by proportionate EMG signals. The retina of the eye is a multilayered and rather regularly structured organ containing cells called rods and cones, cells that sense light and color.
- Motion of the eyeballs inside the conductive contents of the skull alters the electric potentials. Placing the electrode in the vicinity of the eyes picks up the potentials associated with eye movements called EOGs.
- Thus, it is clear that biopotentials at the cellular level play an integral role in the function of various vital organs.

1.2 BIOPOTENTIAL ELECTRODES

Electrodes for biopotential recordings are designed to obtain the signal of interest selectively while reducing the potential to pick up artifact. The design should be pragmatic to reduce cost and allow for good manufacturing and reliable long-term use. These practical considerations determine whether high quality but reusable electrodes made of silver or gold or cheaper disposable electrodes are used .

Silver–Silver Chloride Electrodes

- The classic, high-quality electrode design consists of a highly conductive metal, silver, interfaced to its salt, silver chloride, and connected via an electrolytic gel to the human body .
- Silver–silver chloride–based electrode design is known to produce the lowest and most stable junction potentials.
- Junction potentials are the result of the dissimilar electrolytic interfaces, and are a serious source of electrode-based motion artifacts. Therefore, additionally, an electrolytic gel typically based on sodium or potassium chloride is applied to the electrode.

- A gel concentration in the order of 0.1 *M* results in a good conductivity and low junction potential without causing skin irritation.
- Reusable silver–silver chloride electrodes (Figure 1.2a) are made of silver disks coated electrolytically by silver chloride or alternatively, particles of silver and silver chloride are sintered together to form the metallic structure of the electrode.
- The gel is typically soaked into a foam pad or is applied directly in a pocket produced by the electrode housing.
- The electrode is secured to the skin by means of non allergenic adhesive tape.
- The electrode is connected to the external instrumentation typically via a snap-on connector. Such electrodes are well suited for acute studies or basic research investigations.
- Disposable electrodes are made similarly, although the use of silver may be minimized ,To allow for a secure attachment, a large foam pad attaches the electrode body with adhesive coating on one side (Figure 1.2b). Such electrodes are particularly suited for ambulatory or long term use.

Gold Electrodes

- Gold-plated electrodes (Figure 1.2c), which have the advantages of high conductivity and inertness desirable in reusable electrodes, are commonly used in EEG recordings.
- Small reusable electrodes are designed so that they can be securely attached to the scalp.
- The electrode body is also shaped to make a recessed space for electrolytic gel, which can be applied through a hole in the electrode body .
- The electrodes are attached in hair-free areas by use of a strong adhesive such as colloidon or securely attached with elastic bandages or wire mesh.
- Similar electrodes may also be used for recording EMG, especially when a great deal of motion is expected.
- Disadvantages of using gold electrodes over silver–silver chloride electrodes include greater expense, higher junction potentials, and greater susceptibility to motion artifacts.
- On the other hand, gold electrodes maintain low impedance, are inert and reusable, and are
- good for short-term recordings as long as a highly conductive gel is applied and they are attached securely.

Conductive Polymer Electrodes

- It is often convenient to construct an electrode out of a material that is simultaneously conductive and adhesive.
- Certain polymeric materials have adhesive properties and by attaching monovalent metal
- ions can be made conductive.
- The polymer is attached to a metallic backing made of silver or aluminum foil, which allows electric contact to external instrumentation (Figure 1.2d)

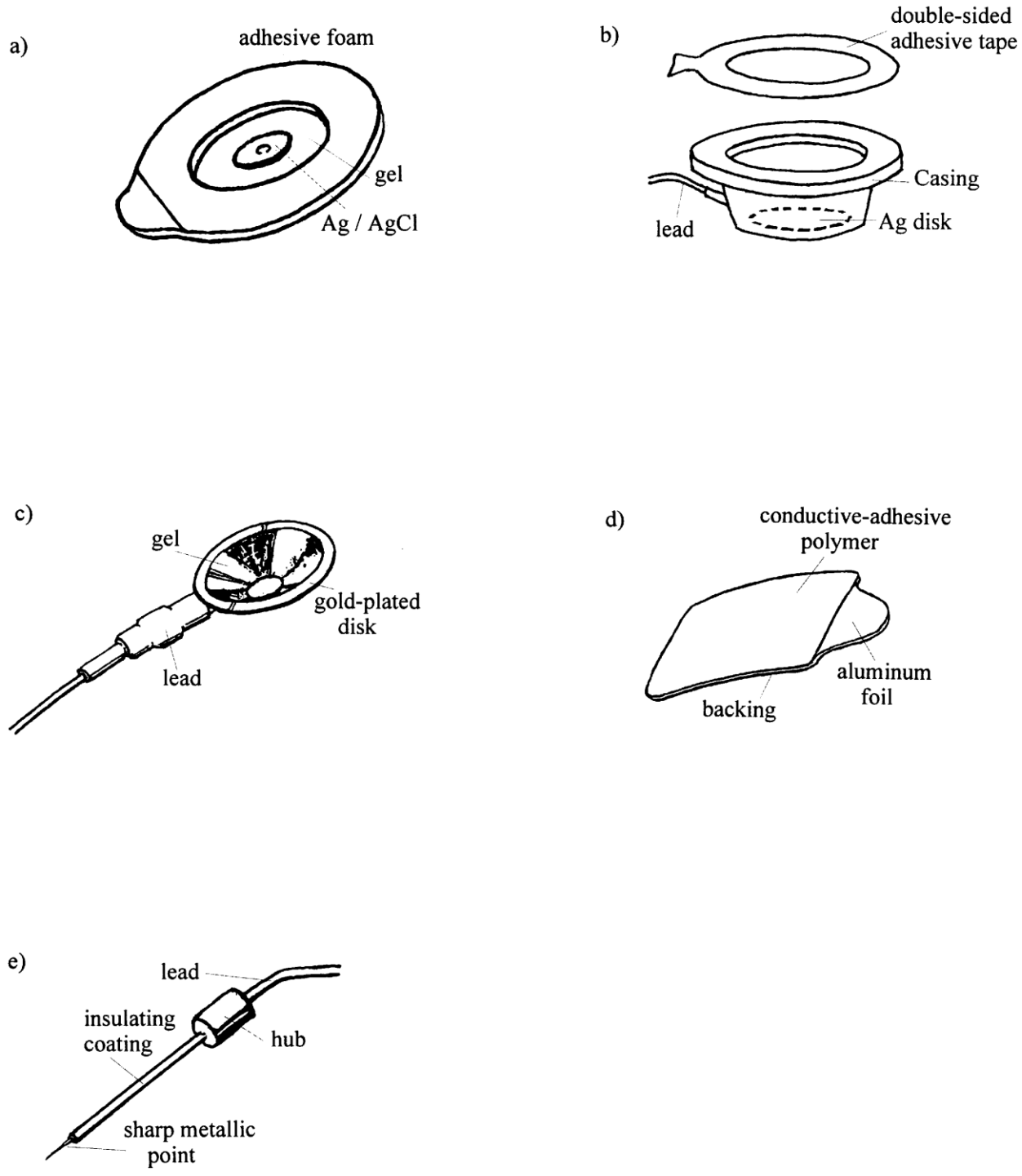


Figure: 1.2 Examples of electrodes used in biopotential recordings: (a) disposable Ag–AgCl electrode, (b) reusableAg–AgCl disk electrode, (c) gold disk electrode, (d) disposable conductive polymer electrode, and (e) needle electrode.

- This electrode does not need additional adhesive or electrolytic gel and hence can be immediately and conveniently used.
- The conductive polymeric electrode performs adequately as long as its relatively higher resistivity and greater likelihood of generating artifacts are acceptable.

- The higher resistivity of the polymer makes these electrodes unsuitable for low-noise measurement.
- The polymer does not attach as effectively to the skin as does the conventional adhesive on disposable ECG electrodes built with a foam base and, furthermore, the potentials generated at the electrode–skin interface are more readily disturbed by motion.
- Nevertheless, when the signal level is high and when restricting the subject movement minimizes artifact, the polymeric electrode offers a relatively inexpensive solution to biopotential recording.

Metal or Carbon Electrodes

- Although other metals such as stainless steel or brass electrodes are used rather infrequently now because high-quality noble metal electrodes or low-cost carbon or polymeric electrodes are so readily available, historically these metallic electrodes were used in laboratory or clinical settings because of their sturdy construction and reusability.
- Electrode gel is applied to the metal electrode which is fastened to the body by means of a rubber band.
- These electrodes have the potential for producing very high levels of artifact and are bulky and awkward to use, but do offer the advantage of being reusable and tend to be inexpensive. Carbon or carbon-impregnated polymer electrodes are also used occasionally.
- These electrodes have a much higher resistivity and are noisier and more susceptible to artifacts, but they are inexpensive, flexible, and reusable and are thus chosen for applications such as electric stimulation or impedance plethysmography.
- For these applications, gel is usually not applied and the electrodes are used in “dry” form for easy attachment and removal.

Needle Electrodes

- Needle electrodes (Figure 1.2e) comprise a small class of invasive electrodes, used when it is absolutely essential to record from the organ itself. The most common application is in recording from muscles or muscle fibers .
- A metallic, typically steel, wire is delivered via a needle inserted at the site of the muscle fiber. The wire is hooked and hence fastens to the muscle fiber, even as the needle is removed.
- Small signals such as motor unit potentials can be recorded in this manner.
- For research applications, similar needle or wire electrodes are sometimes connected directly to the heart muscle. Since such electrodes are noninvasive, their use is limited to only highly specialized and supervised clinical or research applications.

1.3 BIOLOGICAL AMPLIFIERS

- These are very important part of modern medical instrumentation. We need to amplify biopotentials which are generated in the body at low levels with high source impedance.
- Biological amplifiers are required to increase signal strength while maintaining fidelity

Basic Requirements of Biological Amplifiers

Essential functions of a bioamplifier are:

- To take a weak biopotential and increase its amplitude so that it can be processed,recorded or displayed
- To amplify voltage, but it could be considered as a power amplifier as well.To amplify current since in some cases a biopotential amplifier is used to isolate the load from the source current gain only

Input Impedance (Zin)

- All biopotential amplifiers must have **high input impedance** minimize loading (remember the characteristics of biopotential electrodes resulting into loading and distortion if input impedance of the amplifier is not high enough) – typical values of Zin over the frequency range of the measure and = 10 MΩ

Protection & Isolation

- The input circuit of a biopotential amplifier must provide protection to the live measure
- Any potential or current at amplifier's input terminals can affect
- Electric currents produced by the biopotential amplifier can result in microshock and macro shock
- The bioamplifier must have isolation and protection circuitry so that the current through the electrodes can be kept at safe levels and any artifact generated by such current can be minimized

Output Impedance (Zout)

- The output circuit does not present any critical problems, all it needs to do is to drive the load
- Output impedance must be low with respect to the load impedance and it must be capable of satisfying the power requirements of the load

Bandwidth (BW) Frequency response

- The biopotential amplifier must be sensitive to important frequency components of the biosignal
- Since biopotentials are low level signals, it is important to limit bandwidth optimize signal-to-noise ratio

Gain (G)

Biopotential amplifiers have a gain of **1000** or greater

Mode of Operation

- Very frequently biosignals are obtained from bipolar electrodes
- Electrodes symmetrically located with respect to ground need differential amplification
- High CMRR required because:
    1. Common mode signals much greater than the biosignal appear on bipolar electrodes
    2. Symmetry with respect to ground is not perfect (mismatch between electrode impedances)

Calibration Signal

- Medical and clinical equipment require quick calibration. The gain of the biopotential amplifier must be calibrated to provide us with an accurate indication of the signal's amplitude
- Push button to apply standard signal to the input of the biopotential amplifier
- Adjustable gain switch carefully selects calibrated fixed gains.

1.4 ELECTROCARDIOGRAPHY (ECG)

- A very widely used medical instrument, which is utilized to diagnose and monitor cardiac beat abnormalities, is the electrocardiograph.
- It measures the electrical activity of the heart (more precisely biopotential differences arising from the electrical activity of myocardium). We've already talked about the genesis of the ECG signal.
- The ECG machine uses surface electrodes and high input impedance
- Differential amplifiers with good common mode rejection ratio to record the ECG
- Normal ECG amplitude ranges between 0.5-4 mV. Normal frequency content of ECG (for diagnostic purposes) is 0.05-100 Hz. A typical ECG waveform is shown in Fig :3

Significant diagnostic features of the ECG signal are:

- Duration of component parts of the signal
- Polarities and magnitudes
- The details of the ECG signal and the degree of variability in different parts of the ECG signal is shown in fig 3
- The QRS amplitude, polarity, time duration, the RR interval (indicator of heartbeat per min.) and the T-wave amplitude are some very important and distinctive features of the ECG signal.
- The heart rate in BPM = Beats Per Minute) is simply = 60 (RR interval in seconds)

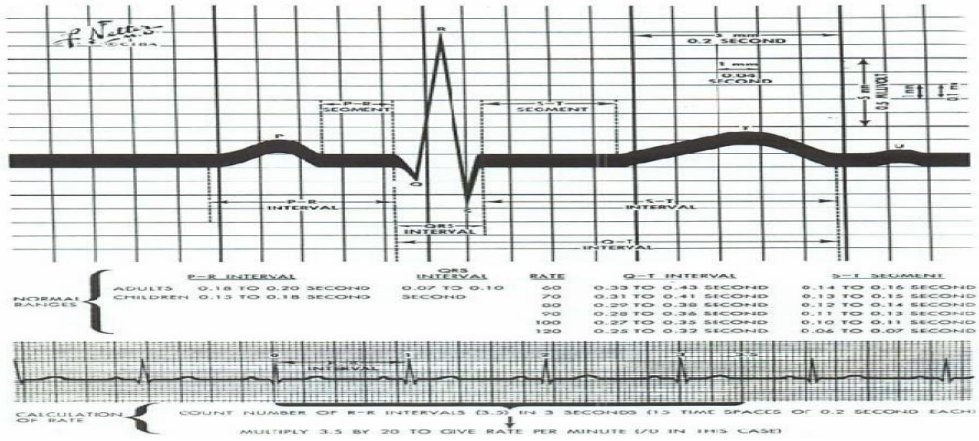


Figure 1.3 ECG Signal

Some ECG waveform abnormalities that may indicate illness are:

- An extended PR interval may be diagnosed as AV node block
- A widening of the QRS complex may indicate conduction problems in the bundle
- An elevated ST segment may indicate occurrence of myocardial Infarction (MI)
- A negative polarity in the T wave may be due to coronary insufficiency

ECG Leads

A Normal ECG recording for the standard lead connections leads I, II and III (Lead II provides the strongest signal)

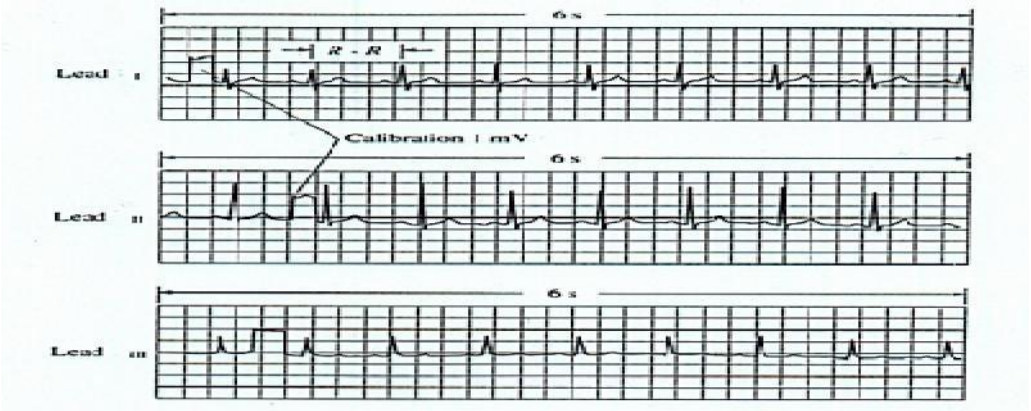


Figure 1.4 Normal ECG waveforms

Obviously, all human hearts are not the same and this results into a high degree of **variability.**

Some abnormalities that may indicate illness:

- An extended P-R interval may be diagnosed as AV node block
- Widening of the QRS complex conduction problems in the bundle of His
- Elevated ST segment may indicate occurrence of MI
- Negative polarity T wave may be due to coronary insufficiency QRS amplitude, polarity, time domain, PR interval (indicator of heat beat per min. & T-wave amplitude are some very important.
- **Distinctive features**.

1. **Loss**

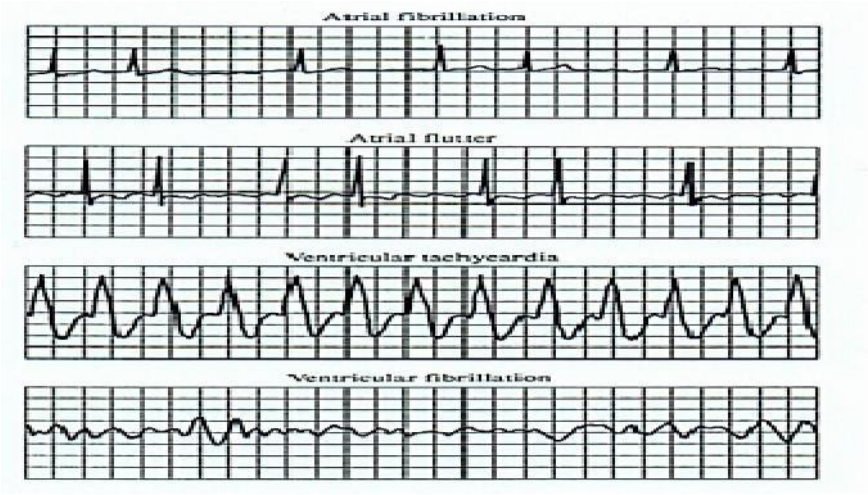


Figure 1.5 ECG Abnormal waveforms

2. Origin of the ECG signal

Standard Limb Leads (I, II, III)

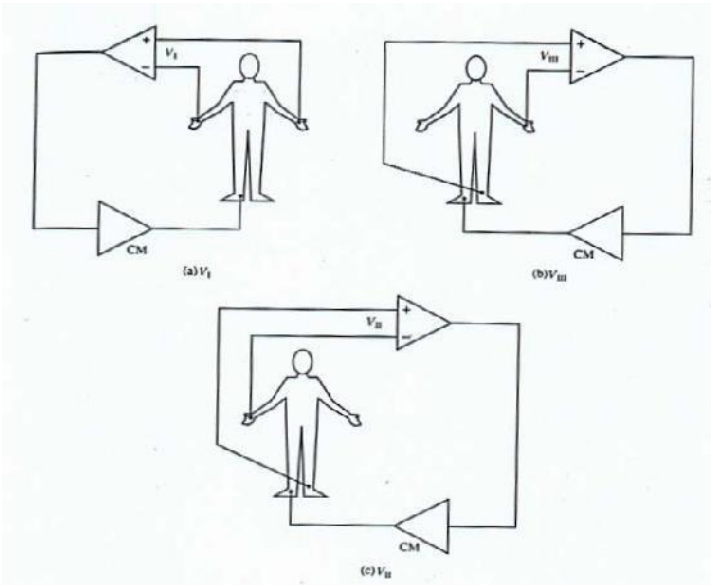


Figure 1.6 origin of ECG Signal

- The lead wires are color-coded according to some conventions. One example is: White – RA (Right Arm), Black – LA (Left Arm), Green – RL (Right Leg), Red – LL (Left Leg), and Brown – C (Chest)

Augmented Limb Leads

- These leads offer a free 50% increase over leads VR, VL, and VF connections (unipolar leads) with respect to Wilson terminal AVR = -I – III/2, AVL = I – II/2, aVF = II – I/2

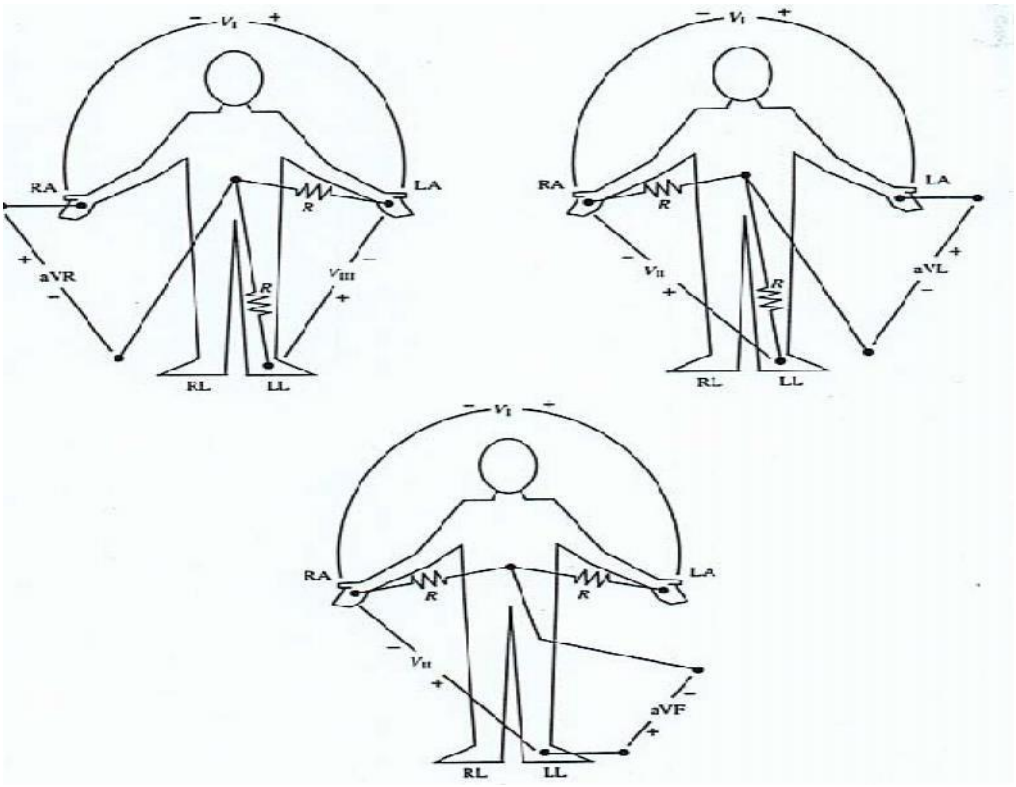


Figure 1.7 Augmented Limb Leads

Each measurement is made from the reflected limb and the average of the other two limbs.

The ECG Machine

Most representative Specs:

- Zin = 10 MΩ
- Frequency response = 0.05 –100 Hz
- Strip Chart Recorder Speed = 25 mm/sec.

• Fast Speed = 100 mm/sec.

Location of the Heart

- The heart is located between the lungs behind the sternum and above the diaphragm.
- It is surrounded by the pericardium.
- Its size is about that of a fist, and its weight is about 250-300 g.
- Its center is located about 1.5 cm to the left of the midsagittal plane.

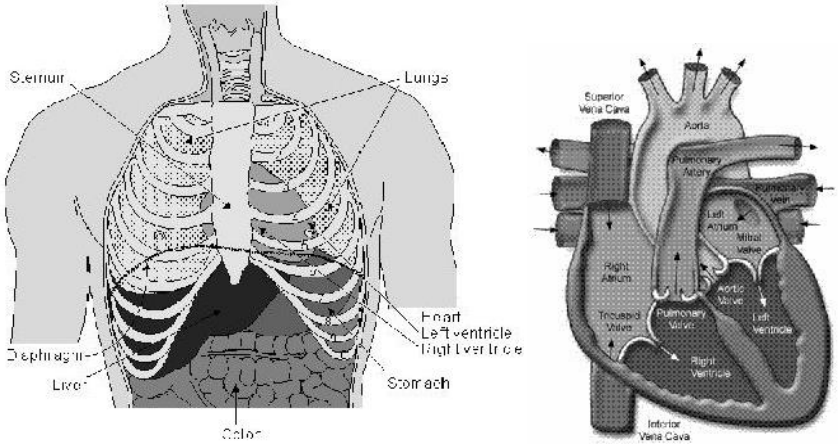


Figure 1.8 Location of Heart

Anatomy of the heart

- The walls of the heart are composed of cardiac muscle, called myocardium.
- It consists of four compartments:
  - the right and left atria and ventricles

The Heart Valves

- The tricuspid valve regulates blood flow between the right atrium and right ventricle
- The pulmonary valve controls blood flow from the right ventricle arteries
- The mitral valve lets oxygen-rich blood from your lungs pass from the left atrium into the left ventricle
- The aortic valve lets oxygen-rich blood pass from the left ventricle into the aorta, then to the body

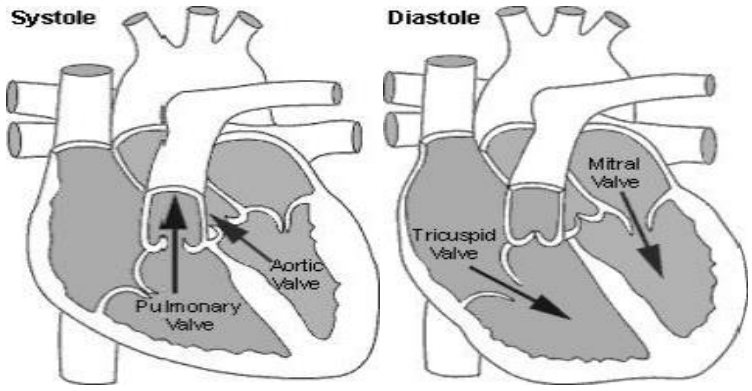


Figure 1.9 Heart Valves

Blood circulation via heart

- The blood returns from the systemic circulation to the right atrium and from there goes through the tricuspid valve to the right ventricle.
- It is ejected from the right ventricle through the pulmonary valve to the lungs.
- Oxygenated blood returns from the lungs to the left atrium, and from there through the mitral valve to the left ventricle.
- Finally blood is pumped through the aortic valve to the aorta and the systemic circulation.

Electrical activation of the heart

- In the heart muscle cell, or *myocyte*, electric activation takes place by means of the same mechanism as in the nerve cell, i.e., from the inflow of Na ions across the cell membrane.
- The amplitude of the action potential is also similar, being 100 mV for both nerve and muscle
- The duration of the cardiac impulse is, however, two orders of magnitude longer than in either nerve cell or sceletal muscle cell.
- As in the nerve cell, repolarization is a consequence of the outflow of K ions.
- The duration of the action impulse is about 300 ms

Mechanical contraction of Cardiac Muscle

- Associated with the electric activation of cardiac muscle cell is its mechanical contraction, which occurs a little later.
- An important distinction between cardiac muscle tissue and skeletal muscle is that in cardiac muscle, activation can propagate from one cell to another in any direction.
- Electrical signal begins in the sinoatrial (SA) node: "natural pacemaker." causes the atria to contract.
- The signal then passes through the atrioventricular (AV) node.
  - sends the signal to the ventricles via the “bundle of His”
  - Causes the ventricles to contract.

The Action Potential

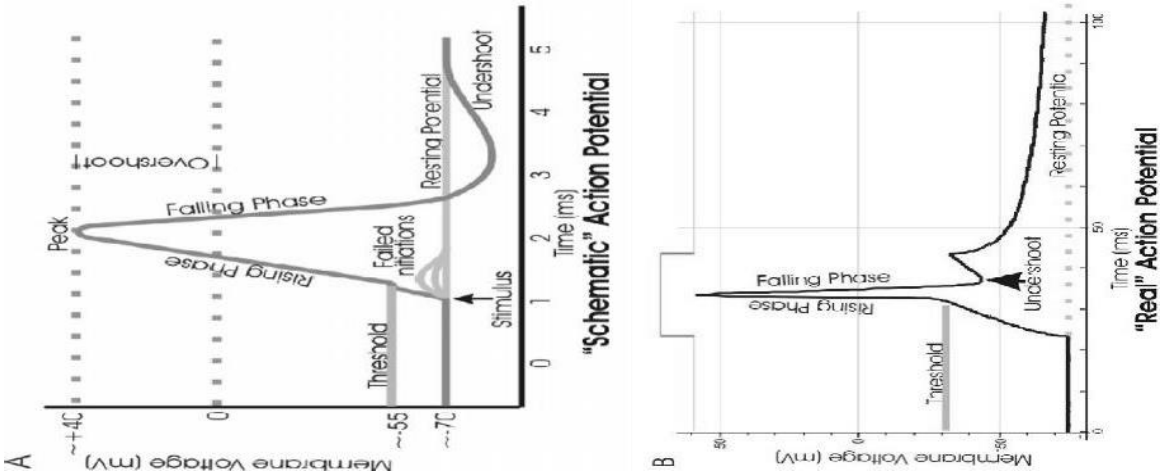


Figure 1.10 Action Potential

Recording an AP requires the isolation of a single cell.

- Microelectrodes (with tips a few μm across) are used to stimulate and record the
  response. A typical AP is 2-4ms long with an amplitude of about 100Mv

1.5 ELECTROENCEPHALOGRAM (EEG)

- EEG is the recorded representation of bioelectric potentials generated by the neuronal activity of the brain.
- Basically, the brain is a gelatinous mass suspend in the meanings, the cerebrospinal fluid, skull and scalp.
- The brain is composed of three major subdivisions:
  1. Cerebellum,
  2. Brainstem
  3. (Medulla, pons, midbrain, diencephalon) and
  4. Cerebrum

The cerebellum is mainly involved with skeletal muscle functions and maintenance of balance. It coordinates smooth and directed movements.

- The brain stem is the stalk of the brain and serves as a relay station for all afferent (sensory) and efferent (motor) nerve fibers between the spinal cord and higher brain canters. It also gives rise to ten of the twelve cranial nerves, which supply the muscles and glands of the head and major organs in the thoracic and abdominal cavities
- Throughout the entire brainstem runs a core of tissue called the reticular formation,

which serves as a highly complex cluster of neurons involved in integration of information from many afferent pathways as well as from numerous other parts of the brain.

- The cerebrum consists of the right and left hemispheres. The outer part of the cerebral hemispheres, the cerebral cortex, is a cellular shell 1.5 – 4 mm thick of grey matter.
- The cerebral cortex is highly convoluted and is the most complex integrating center of the nervous system. It brings together basic sensory information into meaningful perceptual images and formulates ultimate decisions for control over the motor systems of the body.
- The cerebral cortex is comprised of two layers: the pale cortex and the neocortex.
- The pale cortex is located on the median surface and the base of the brain and the neocortex is present on the superior and lateral aspects of the cerebral hemispheres.
- The neocortex is composed of six layers and its cells can be categorized as pyramidal and non-pyramidal cells. There are approximately 1010 neurons in the human cerebral cortex, about 75% of, which is pyramidal.
- Pyramidal cells, named originally after their shape, have several characteristics. Their cell bodies are commonly triangular in shape, with the base down and the apex directed toward the cortical (superficial) surface.
- The cell bodies vary in size, from axial dimensions of 15 x 10 μm up to 120 x 90 μm. A typical pyramidal cell consists of a long apical dendrite, about 2 mm long, that ascends from the apex of the cell body and enters the overlaying layers and terminally branches within the outermost layer of the neocortex.
- There is a dominant apical dendrites tree, looking like a forest of similarly oriented, densely packed units in the superficial layers of the neocortex, where extensive branching occurs.

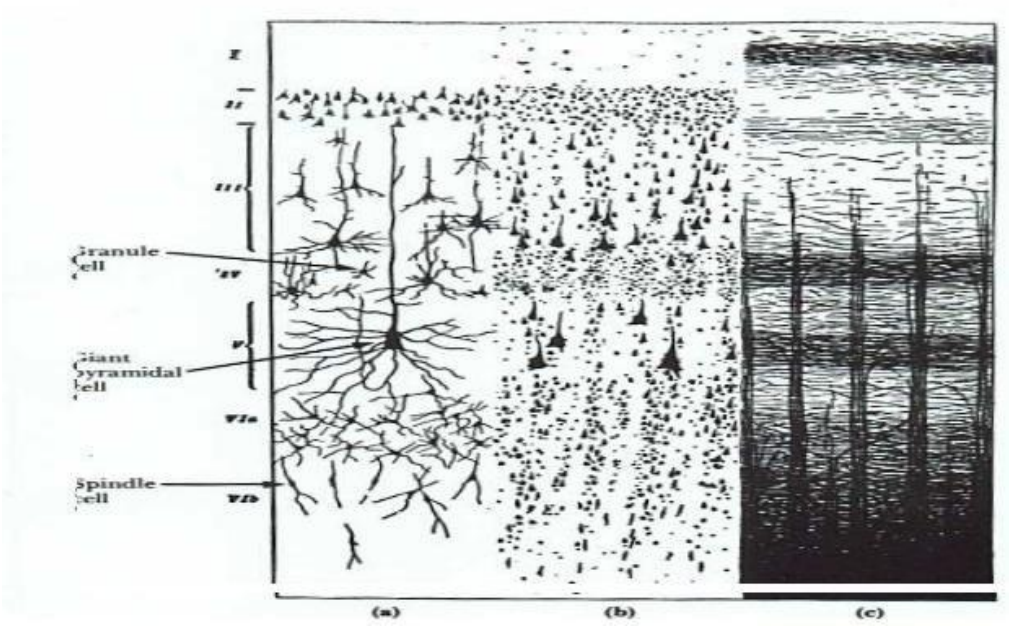


Figure 1.11 EEG

- There is also a basilar dendritic system that extends out spherically from the cell body.

- Pyramidal cells also have an axon that emerges from the cell body and enters the sub cortical white matter.
- The axons of all pyramidal cells terminate in excitatory synapses. The initial segment of pyramidal cells is unmyelinated,as their recurrent branches
- Axons of some pyramidal cells turn back toward the cortical surface to end via their many dendritic branches on the dendrites of other cells.
- It has been shown by electrophysiological studies that under normal circumstances, propagating action potentials in axons do not contribute significantly to surface cortical recordings.
- There reason being that action potentials travel in large number of axons (running in many different directions relative to the surface) in a temporally a synchronized way. Therefore, their net contribution to the surface EEG is minimal and negligible.
- It has been shown that the vertically oriented pyramidal cells with their long apical dendrites running parallel to one another are the major contributors to the electro genesis of the cortical field potentials (EEG signal).

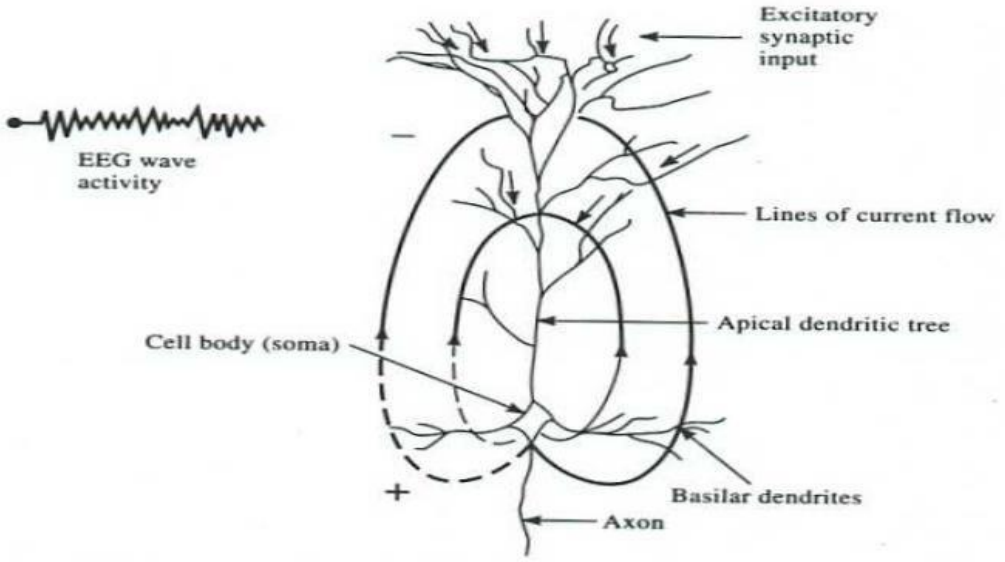


Figure 1.12 Cerebrum

A highly schematic representation of a pyramidal cell and its role in the generation of surface EEG signal. Let's consider a single pyramidal cell, and explain how potential changes in one part of the cell relative to other parts could generate the EEG signal.

- Excitatory synaptic inputs to the branches in the apical dendritic tree of the pyramidal cells cause depolarization of the dendritic membrane.
- This leads into generation of an excitatory postsynaptic potential (EPSP)
- As a result, a radially oriented dipole is set up and sub threshold current flows in a closed path through the cytoplasmic core of the dendrites and cell body of the cell, returning to the synaptic sites via the conducting extracellular medium
- The lines of current flow make the extracellular medium close to the cell body act as a source with + polarity and the upper part of the apical dendritic tree to act as a sink with – polarity.
- This leads into recording a negative potential at the cortical surface
- In case of inhibitory synaptic inputs to the branches in the apical dendritic tree, an

inhibitory postsynaptic potential (IPSP) is generated with a reversal in the polarity of the current dipole, which leads into a generation of a positive cortical recording.

- Therefore, the influence of a particular dendritic postsynaptic potential on the cortical recording depends on its net excitatory or inhibitory effect and on its location relative to the measurement site.

The EEG (electroencephalogram) signal is a recording of the electrical activity of the brain. The EEG signal recorded at the cortex or the scalp is generated by the polled activity of billions of cortical and sub cortical regions. The origin of the EEG signal is based on the electrical activity of the pyramidal cells. The EEG potentials primarily reflect the summated fluctuations of excitatory and inhibitory postsynaptic potentials in the pyramidal cells of the upper layers of the cerebral cortex. For reasons of geometry as well as because of extreme extracellular attenuation, action potentials from firings of pyramidal cells contribute only minimally or not all to the generation of the EEG signal.

- All we need to contend ourselves with at this stages that the EEG or brain waves are summation of neural depolarization sin the brain due to the stimuli from the five senses as well as from thought processes (indeed a very complex source). More on this in physiology in the Nervous System topic.
- EEG potentials have random-appearing waveforms with peak-to-peak amplitudes ranging from less than 10 mV to over 100mV. Required bandwidth is from below 1 Hz to over 100 Hz.

EEG is recorded with 3 types of electrodes:

1. Scalp
2. Cortical Electrocardiogram (recording from surface of cortex)
3. Depth Electrodes recording from depth of brain (thin insulated needles of various designs)

- No matter where the recording is obtained from (scalp, cortex or depth of the brain), the fluctuating potentials represent a superposition of the volume conductor fields produced by a huge variety of active neuronal current-generators.
- On the surface of the brain (i.e. Electrocardiogram), we can record voltages on the order of 10 mV! But, typical EEG electrodes measure the electrical activity propagated through skull bone and is attenuated from 1 to 100 μV.
- EEG potentials vary as a function of position over the surface of the skull, making it necessary to select sets of electrodes grouped around Frontal, Parietal, Temporal and Occipital lobes.

The EEG Signal

- The character of the EEG signal is highly dependent on the degree of the activity of the cerebral cortex, i.e. waves change markedly between states of wakefulness and sleep.
- Much of the time, EEGs are irregular and no general pattern can be observed. Other times, distinct patterns emerge

- The EEG waveform is divided into four wave groups:

    1. The Alpha Waves (α) 8-13 Hz
    2. The Beta Waves (β) 14-30 Hz (The Gamma Waves (γ) 22-30 Hz or higher)
    3. The Theta Waves (θ) 4-7 Hz
    4. The Delta Waves (δ) <3.5 Hz

Note: During periods of mental activity, the waves usually become asynchronous rather than synchronous, so the magnitude of summed potentials decreases in spite of cortical activity.

- In general there is a relationship between cerebral activity and the frequency of the EEG rhythm
- Frequency increases progressively with higher degrees of activity

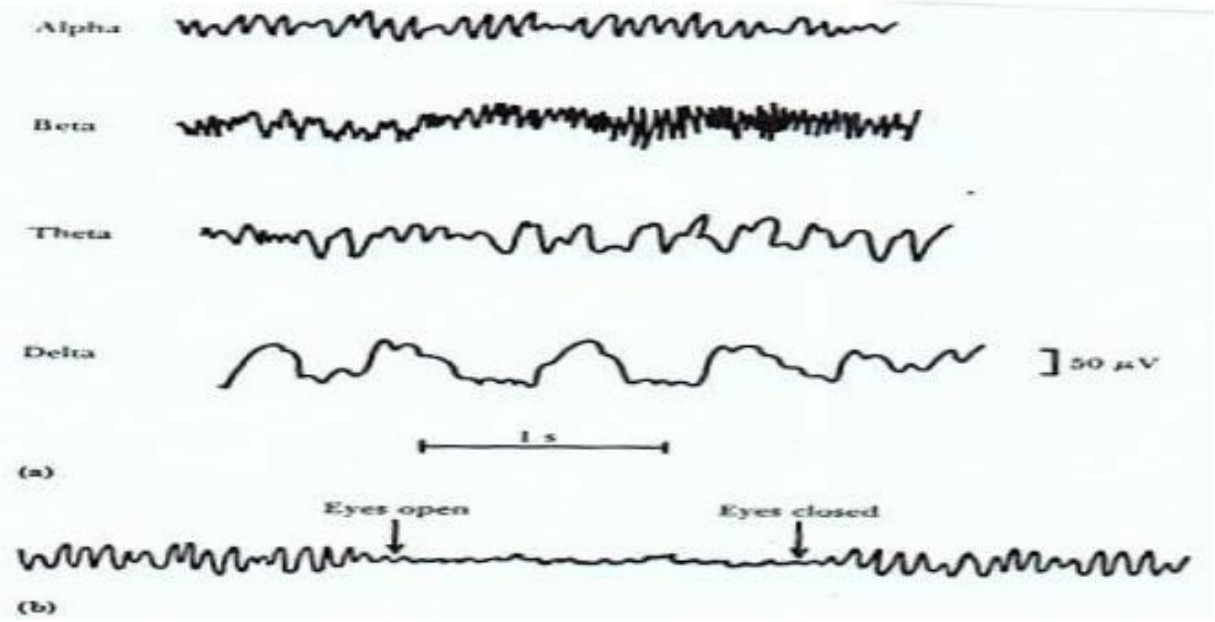


Figure 1.13 EEG waveform

Examples:

- δ-Waves(<3.5 Hz) occur in surgical anesthesia and sleep
- θ-Waves(4-7 Hz) occur in emotional stress and frustration
- α-Waves(8-13 Hz) occur during relaxed states
- β-Waves(14-30 Hz)occur during intense mental activity

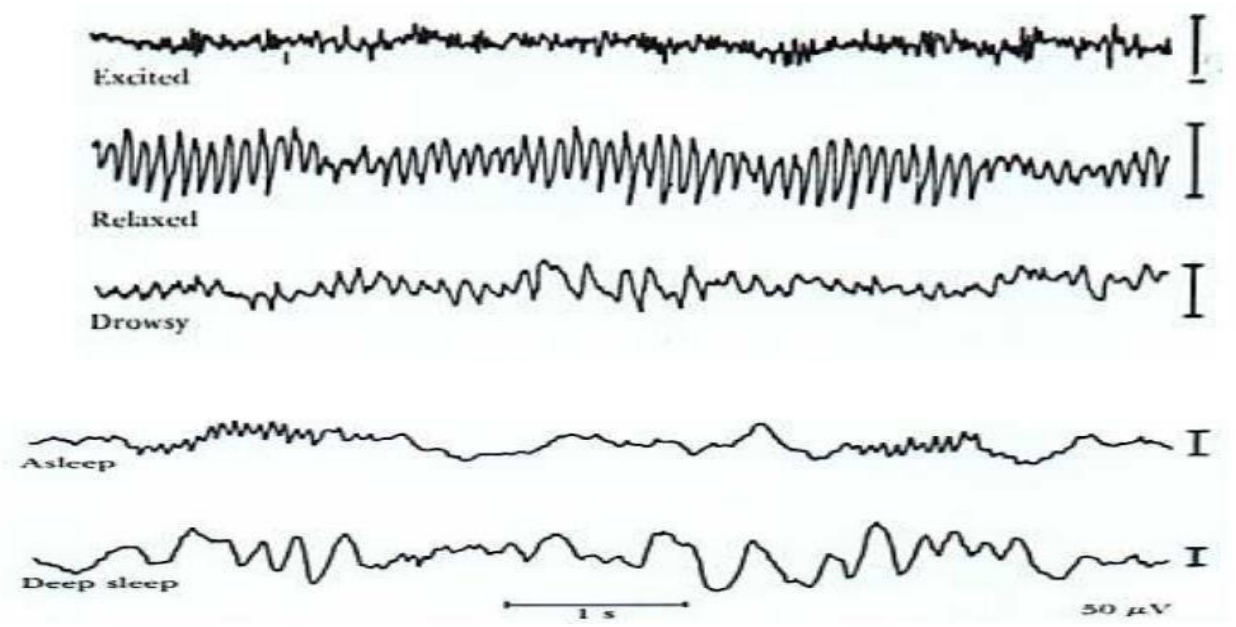


Figure 1.14 Different EEG waveforms

The EEG changes that occur as a human subject goes to sleep.

EEGs in Diagnosis

The purpose of the clinical EEG is to help neurologists diagnose disease. The pathological states most commonly diagnosed using EEG are:

- Brain death (legal death)
- Brain tumors
- Epilepsy
- Multiple Sclerosis
- Sleep Disorder
- Evoked responses (diseases of the audio, visual and tactile senses)
- Modern life sustaining equipment like respirators, kidney dialyzers, ventilators, artificial heart pumps have changes the definition of death
- A sustained absence of EEG signal is a clinical measure of brain death and can be used in deciding whether to transplant a heart, liver, or lung or whether to shut down the life sustaining equipment

Some Representative Abnormal EEGS

Petit mal epilepsy– Minor for of seizure, clouding of consciousness and loss of contact with the environment

Grand mal epilepsy– Sudden loss of consciousness, falling down, tonic contractions (stiffening of muscles) followed by twitching and jerking movements of the limbs

Psychomotor seizures are parietal seizures characterized by: semi-purposeful movements, changes in consciousness, hallucinations and illusions

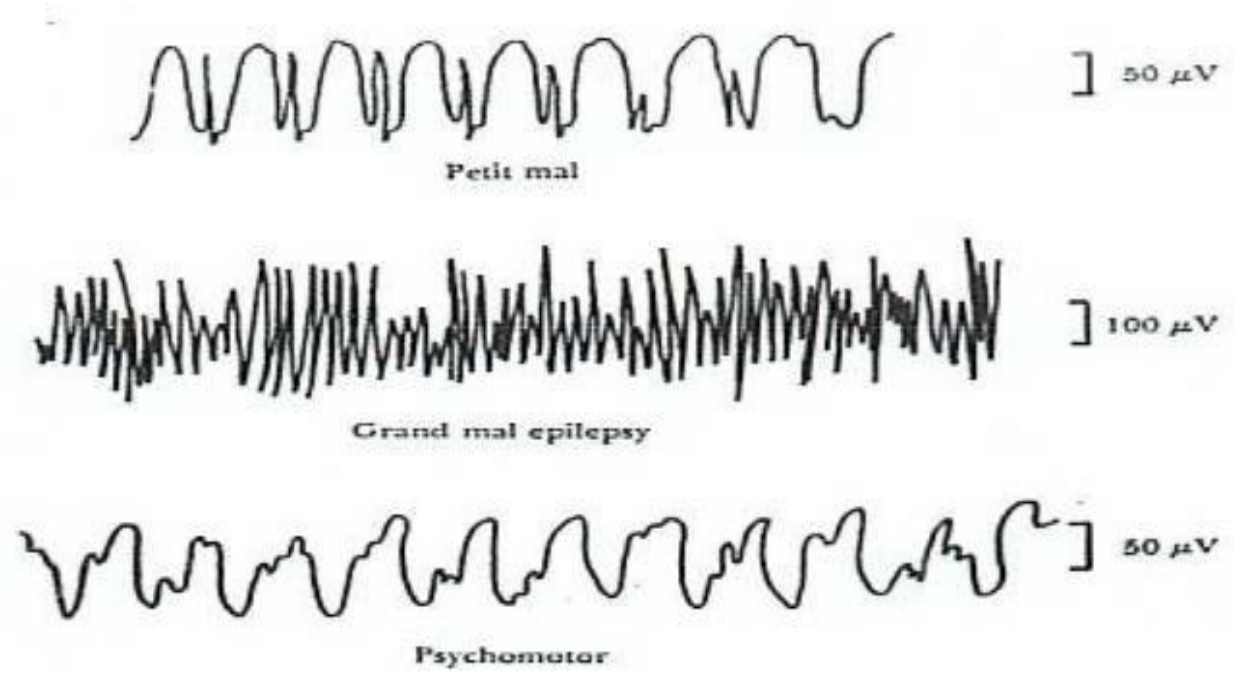


Figure 1.15 Abnormal EEGs

EEG Electrode Positions

- In electroencephalography, the electrodes are placed in an arrangement referred to as the 10-20 system
- This is a placement scheme devised by the International Federation of Societies of Electroencephalography
- The electrodes are placed along a line drawn on the skull from the root of the nose, the nasion, to the classification (bump on the occipital lobe)
- The first mark is placed 10% of the distance along this line and others are arranged at 20% intervals

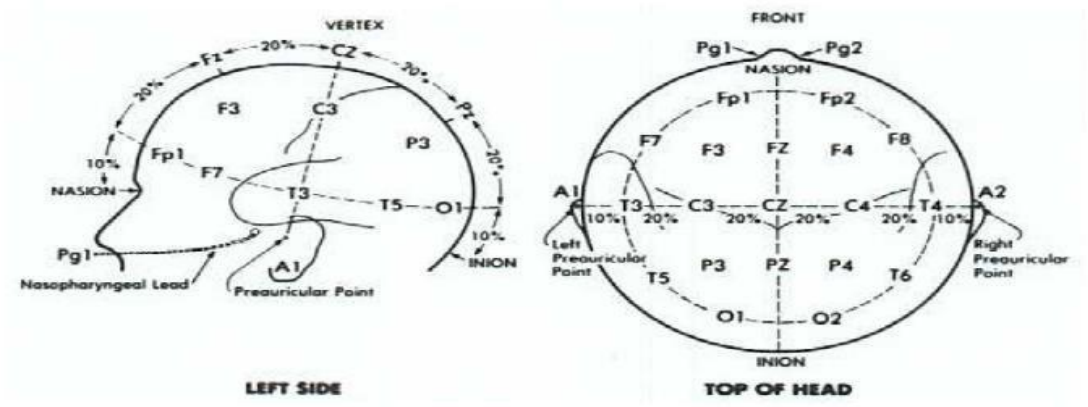


Figure 1.16 EEG Electrode position

1.6 EMG (ELECTRO MYOGRAPH)

It is an instrument used for recording the electrical activity of the muscles to determine whether the muscle is contracting or not. Study of neuromuscular function is also possible by using EMG. Muscular contractions are caused by the depolarization of muscle fibers. Similarly the recording of peripheral nerves action potentials is called as electro neurography.

ELECTRODES USED FOR EMG

Two types of electrodes:

Surface electrodes- Usually this electrode is used for EMG. But by using this electrode, it is not possible to take the deeper potential.

Needle electrodes – These are inserted into tissue or closer to tissue to measure the electrical activity of muscle.

EMG RECORDING SYSTEM

EMG potentials are taken from the tissue by using electrodes. These EMG potentials are given to differential amplifier. This is the high gain amplifier. Its frequency range is given as 10 Hz to 10 KHz.

Bandwidth of EMG is large. CMRR (Common mode Rejection Ratio) of this differential amplifier is 80 to 100 db.Input Impedance of this amplifier is 10 MΩ. Here there is no lead selector switch. Because only two electrodes are available. The output of the differential amplifier is given to loudspeaker system, tape recorder and CRO.

Before giving the output of differential amplifier to loudspeaker, it is given to power amplifier. Power amplifier amplifies the signal that is received by loudspeaker.

The amplified signal from the output of the differential amplifier is displayed by using CRO. Here storage oscilloscope is used. Output cab be displayed and the same can be stored in the CRO. The signal from the differential amplifier is recorded by using tape recorder. It is used for the future purpose.

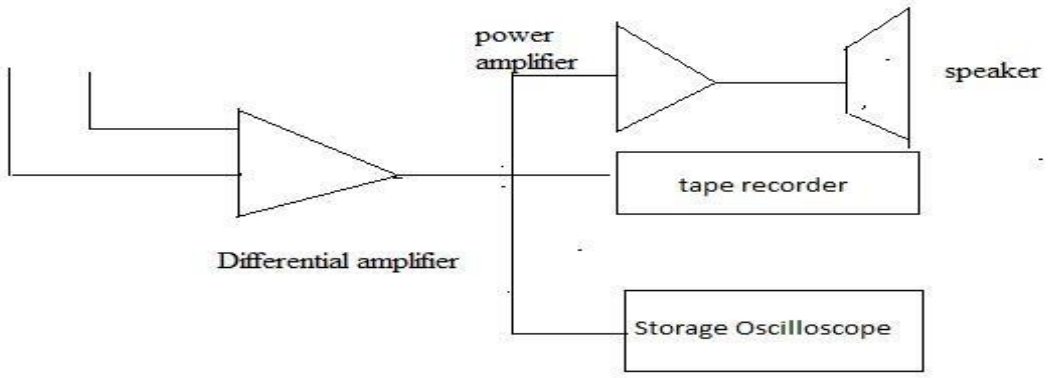


Figure 1.17 EMG Recording System

MEASUREMENT OF CONDUCTION VELOCITY IN MOTOR NERVES

In modern EMG systems, nerve conduction time and nerve velocity are measured. For this measurement, initially nerve is stimulated and EMG is measured.This conduction velocity measurement is used to indicate the location and type of nerve lesion.

Steps involved in measurement of conduction velocity

- Stimulate is applied at point A
- Electrical activity of muscle is measured at point B
- The space between A and B is noted as l_1 meters.
- The time delay between applying stimulus and receiving action potential is known as latency. This time delay is detoned as t_1 second.
- Now change the position of A into C. Now the space is reduced. It is noted as l_2 meters.
- The time delay noted is t_2 second.
- Usually, $l_2 < l_1$ and $t_2 < t_1$.
- Now , the conduction velocity is given as , $V = l_1 - l_2 / t_1 - t_2$.
- Usually V= 50 m/sec.
- If V<40 m/s. It means there is some disorder in nerve conduction.
- Thus conduction velocity is measured in motor nerves.
- Skeletal muscle is organized functionally on the basis of the motor unit.

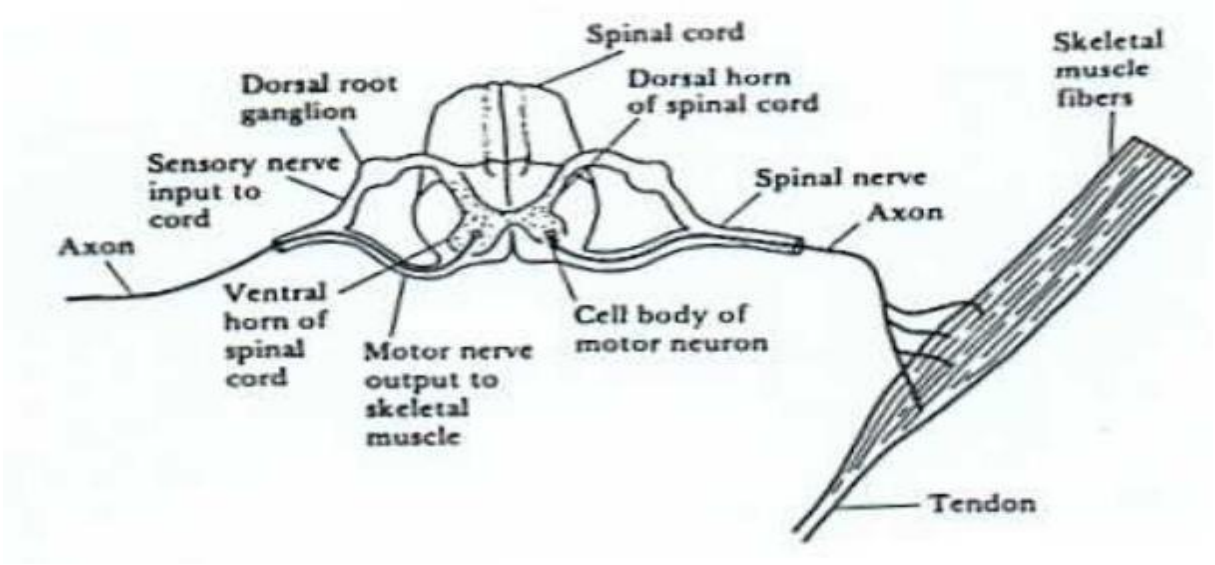


Figure 1.18 Conduction Velocity In Motor Nerves

Single Motor Unit (SMU)

- The motor unit is the smallest unit that can be activated by a volitional effort (all constituent muscle fibers are activated synchronously)
- Single motor unit (SMU) consists of a single motor neuron and the group of skeletal muscles that it innervates
- SMU is a distributed unit bioelectric source in a volume conductor consisting of all other muscle fibers, both active and inactive.
- The evoked extracellular field potential from the active fibers of an SMU has a triphasic form of 3-15 ms duration and 20-2000 μV amplitude depending on the size of SMU
- The figure below shows motor unit potentials from normal muscle under graded levels of contraction. At high levels of activity, many sophisticated motor unit responses give rise to a complicated response (interference pattern)

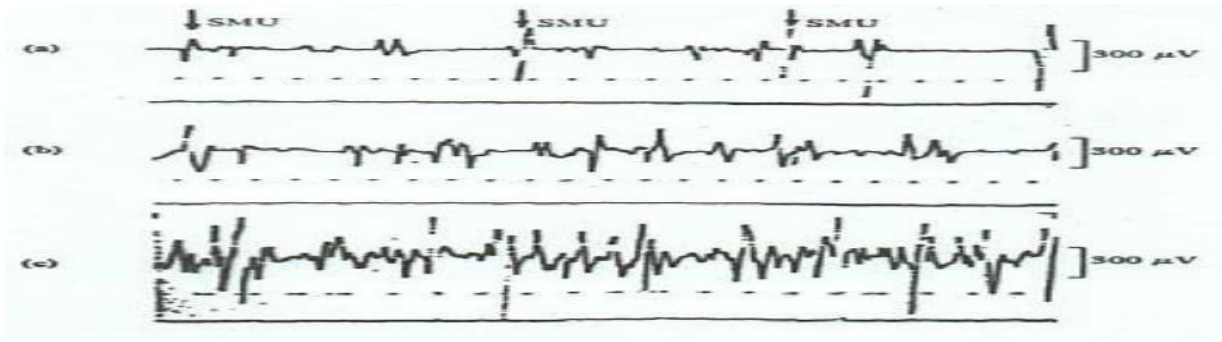


Figure 1.19 EMG Recording

- A variety of electrodes have been developed for EMG recording
- The figure below shows the needle and wire electrodes used in recording the EMG

signal

- The EMG is also of considerable clinical value
- The shape of SMU potentials is modified by disease

The figure below shows the EMG response for a normal subject and one with neuropathy

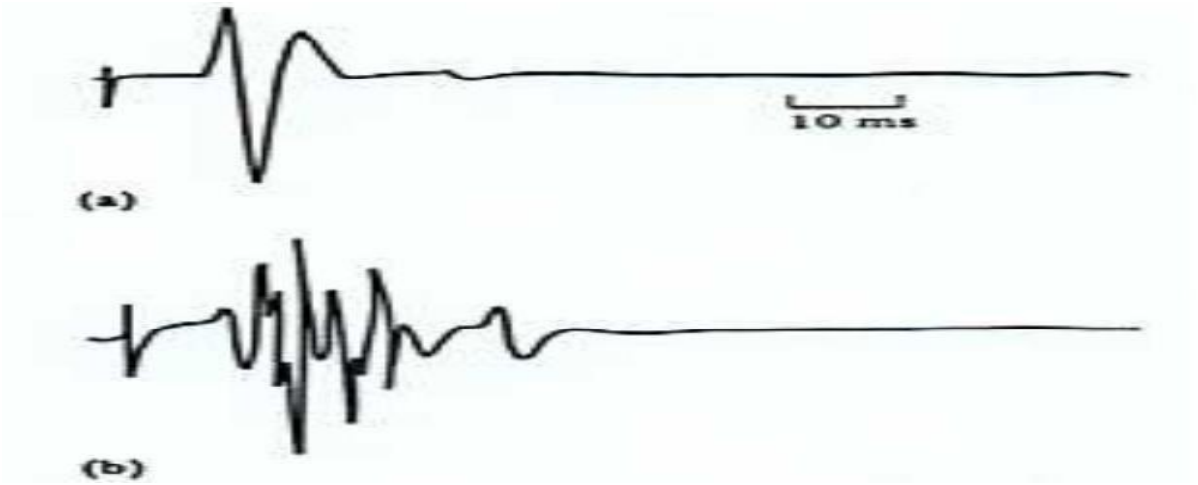


Figure 1.20 EMG response of a normal and an abnormal waveforms

1.7 PCG (PHONO CARDIOGRAM)

The graphical record of heart sound is known as Phono Cardiogram. Here Cardio means the heart. The device which is used to measure heart sound is known as phonocardiograph. Auscultation: The technique of listening sound produced by organs and vessels of the body is known as auscultation.

In PCG, different types of heart sounds are measured. These heart sounds are due to the vibrations set up in the blood inside the heart by the sudden closure of valves. In abnormal heart additional sounds are heard between the normal heart sound. These additional sounds are known as murmurs. Murmers is generally caused by improper opening of the valves or by regurgitation

Applications of EMG:

EMG is used in the field of:

- Electrophysiological testing.
- Clinical neurophysiology.
- Neurology.
- Psychiatry.
-

CLASSIFICATION OF HEART SOUND

It is divided into four types

- ✓ Valve closure sound
- ✓ Ventricular filling sound
- ✓ Valve opening sound

- ✓ Extra cardiac sound

Valve closure sound

This sound occurs at the beginning of systole and at the beginning of diastole.

Ventricular filling sound

This sound is occurred at the time of filling of the ventricles.

Valve opening sound

This sound occurs at the time of opening of atrio- ventricular valves and semi lunar valves.

Extra cardiac sound

This sound occur in mid systole or late systole or early diastole

Systole: The contraction of the heart muscle. The systolic pressure is 120mm of Hg.
Diastole: The relaxation of the heart muscle. The diastolic pressure is 80 mm of Hg.

PCG RECORDING SYSTEM

Microphone is used to convert heart sound into the electrical signals. Certain positions are recommended to pick up the heart sound by using microphone. The electrical signal picked up by the microphone is amplified by the amplifier block. The amplified output is given to filter block.

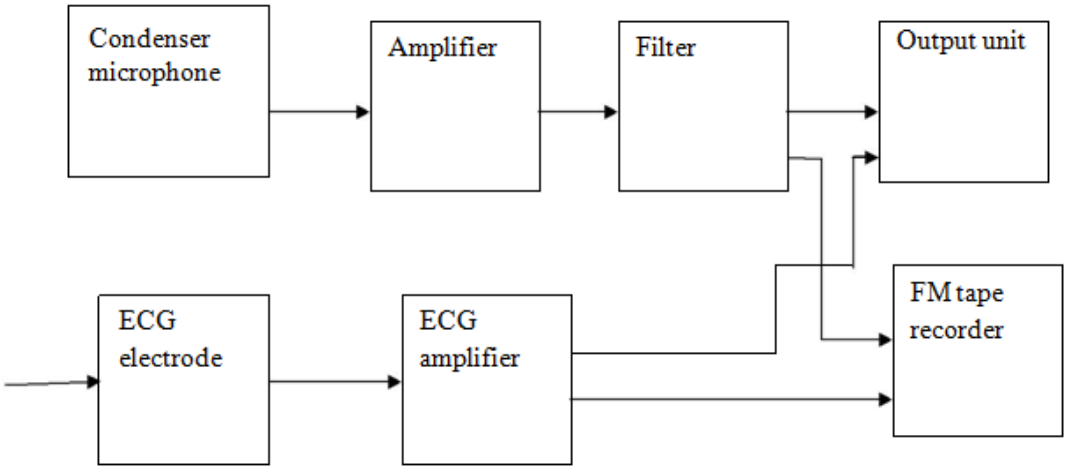


Figure 1.21 Block Diagram of PCG Recording System

In the below high pass filter is used. Its cut of frequency is 1 kHz. Here ECG electrode system and ECG amplifiers are used for reference for PCG. So ECG and PCG outputs are connected to FM tape recorder and output display unit.

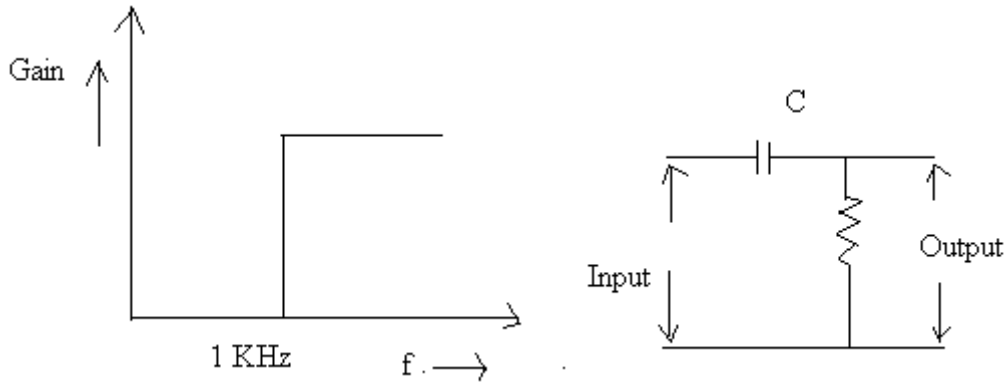


Figure 1.22 Characteristics and Filter circuit

TYPES OF MICROPHONES USED IN PCG

1. Air coupled microphone- Movement of chest is transferred through the air cushion. It provides low mechanical impedance to the chest.
2. Contact microphone – it is directly coupled to the chest wall and provides high impedance, high sensitivity, and low noise. Its light weight is also one of the advantageous factor.

The first heart sound is developed during the opening of aortic valve and during the closing of mitral valve

PCG waveform

Frequency of first heart sound consists of 30 to 45 Hz. Second heart sound is usually higher in pitch than the first. Its frequency range is 50Hz to 70 Hz. Third heart sound is extremely weak vibrate sound is extremely weak vibration. Its frequency is below 600 Hz.

Aortic stenos are murmur occurred when the blood is ejected from the left ventricle through aortic valve due to resistance to ejection, the pressure in the left ventricle increased. So turbulent blood flow occur.This turbulent blood impinging the aortic valve. So intense vibration is produced. It produces loud murmur.

Mitral regurgitation murmur- In this murmur, blood flows in backward direction through the mitral valve during systole.

Aortic regurgitation murmur – During diastole, sound is heard. In diastole blood flows in the backward direction from aorta to left ventricles when valves are damaged, then this sound is heard.

Mitral stenosis murmur – This murmur is produced when blood is passed from left atrium to left ventricle. This sound is very weak.

UNIT II

BIO-CHEMICAL AND NON ELECTRICAL PARAMETER MEASUREMENT

2.1 pH MEASUREMENT

The chemical balance in the body can be determined by the ph value of blood and other body fluids.ph is defined as the hydrogen ion concentration of a fluid. It is the logarithm of the reciprocal value of h+ concentration. The ph equation is given as,

$$Ph= - \log_{10} [H^+] = \log_{10} 1/[H^+]$$

pH is the measure of acid- base balance in a fluid, A neutral solution has the ph value as 7. Solutions with pH value less than 7 are acidic and above 7 are basic. Most of the body fluids are slightly basic in nature.

Construction and working

The ph meter is made up of a thin glass membrane and it allows only the hydrogen ions to pass through it. The glass electrode provides a membrane interface for H+ ions. The glass bulb at the lower end of the ph meter contains a highly acidic buffer solution. The glass tube consists of a sliver-sliver chloride (Ag/Agcl) electrode and the reference electrode which is made up of calomel sliver-sliver chloride(Ag/Agcl) is tan placed in the solution in which ph is being measured.

The potential is measured across the two electrodes. The electrochemical measurement, which should be obtained by each of the electrodes called half- cell. The electrode potential is called as half-cell potential. Here the glass electrode inside the tube constitutes one half –cell and the calomel or reference electrode is considered as the other half-cell.

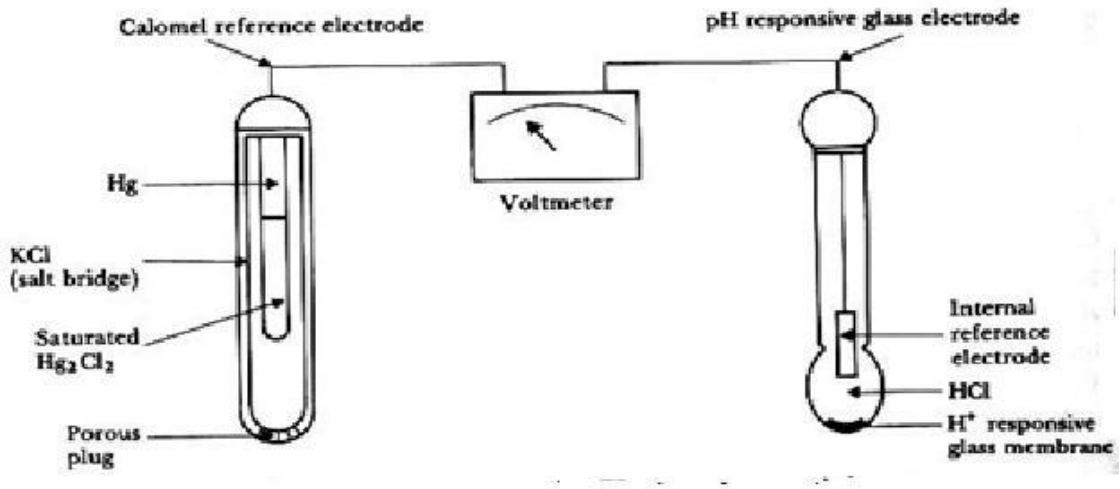


Figure 2.1 pH Electrode

For easier ph measurement combination electrodes are used. In this type both the active glass electrode and reference electrode are present in the same meter. The glass electrodes are suitable only to measure ph values around 7. Since this type of glass electrodes produce considerable errors during the measurement of high Ph values, special type of Ph electrodes are used. After every measurement the pH meter is washed with 20% ammonium biflouride solution, for accurate results. The Ph meter with hydroscopic glass absorbs water readily and provides best pH value.

2.2 PO2 MEASUREMENT

The term po2 is defined as the partial pressure of oxygen respectively. The determination of po2 is one the most important physiological chemical measurement. The effective functioning of both respiratory and cardiovascular system can be by po2 measurement. The partial pressure of a gas is proportional to the quantity of that gas present in the blood.

The platinum wire, which is an active electrode, is embedded in glass for insulation and only its tip is exposed. It is kept in the electrolyte solution in which the oxygen is allowed to diffuse. The reference electrode is made up of silver-silver chloride (Ab/AgCl). A voltage of 0.7 is applied between the platinum wire and the reference electrode. The negative terminal is connected to the active electrode through a micro ammeter and the positive terminal is given to the reference electrode.

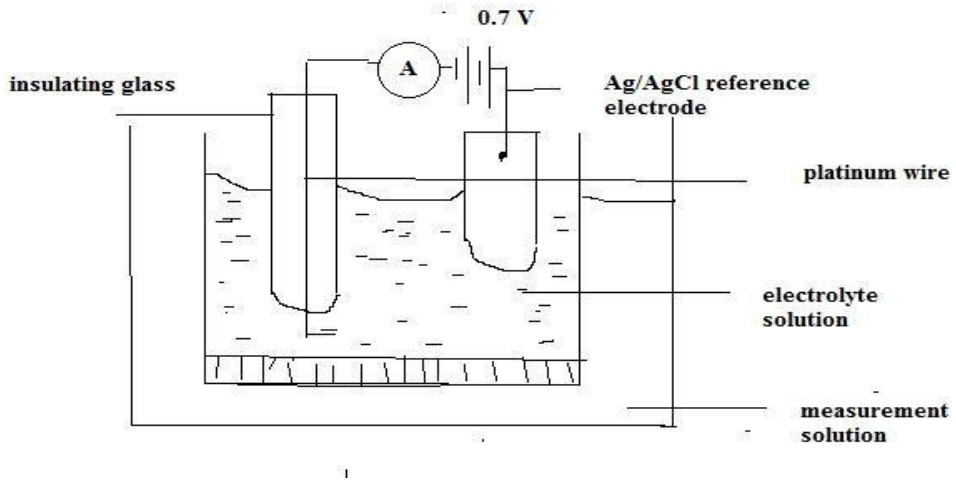


Figure 2.2 PO_2 Electrode

Due to the negative terminal, the oxygen reduction takes place at the platinum cathode. Finally the oxidation reduction current proportional to the partial pressure of oxygen diffused into the electrolyte can be measured in the micro ammeter. The electrolyte is generally scaled in the electrode chamber by means of a membrane through which the oxygen can diffuse from the blood or sample solution.

There are two types of pO_2 measurement. They are

I) Vitro measurement
II) Vivo measurement

In case of dark electrode the platinum cathode and the reference electrode is present in a single unit. This electrode is used for vitro and vivo measurements.

In Vitro Measurements

In this method the blood sample is taken and the measurement for oxygen saturation is made in the laboratory. The electrode is placed in the sample blood solution and the pO_2 value is determined.

In Vivo Measurements

In this method the oxygen saturation is determined while the blood is flowing in the circulatory system. A micro version of the pO_2 electrode is placed at the tip of the catheter so that it can be inserted into various parts of the heart or circulatory system.

The pO_2 measurement also has some disadvantages in it. The reduction process in the platinum cathode removes a finite amount of the oxygen from the cathode. And there is a gradual reduction of current with respect to time. However careful design and proper procedures in modern pO_2 electrodes reduce the errors.

2.3 pCO_2 MEASUREMENT

The term pco2 is defined as the partial pressure of carbon dioxide respectively. The determination of pco2 is one the most important physiological chemical measurement. The effective functioning of both respiratory and cardiovascular system can be by pco2 measurement. The partial pressure of a gas is proportional to the quantity of that gas present in the blood.

The partial pressure of carbon dioxide can be measured with the help of pCO_2 electrodes. Since there is a linear relationship between the logarithm of pCO_2 and pH of a solution. The pCO_2 measurement is made by surrounding a pH electrode with a membrane selectively permeable to CO_2.

The modern improved pCO_2 electrode is called as severinghous electrode. In this electrode the membrane permeable to CO_2 is made up of Teflon which is not permeable to other ions which affects the pH value. The space between the Teflon and glass contains a matrix layer which allows only the CO_2 gas molecules to diffuse through it.

One of the demerits in older CO_2 electrode is, it requires a length of time for the CO_2 molecules to diffuse through the membrane. The modern CO_2 electrode is designed in such a way to overcome this demerit. Here the CO_2 molecules diffuse rapidly through the

membrane and the measurement can be done easily.

2.4 COLORIMETER

- Measures the color concentration of a substance in a solution by detecting the color light intensity passing through a sample containing the substance and a reagent
- Optical color filters are used to detect the color wavelength of interest. E.g., urine passes yellow light and absorbs blue and green
- Laser LEDs are preferred if their wavelength is suitable due monochromatic color.

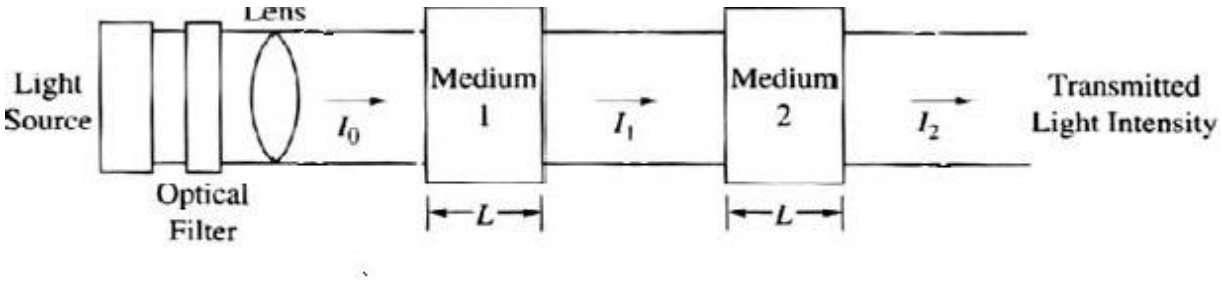


Figure2.3 Colorimeter

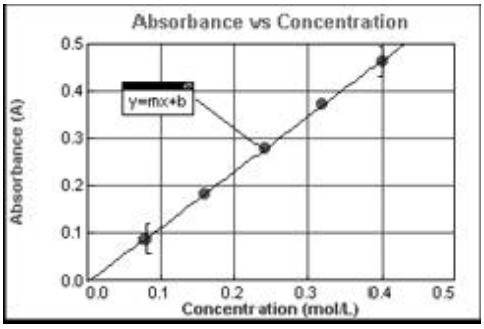


Figure2.4 Concentration vs Absorbance

Transmittance

$T = I_1/I_0 * 100\%$

Absorbance

$A = - \log$

I_1 / I_0

$A = \log$

$1/T$

If the path length or concentration increases, the transmittance decreases and absorbance increases, a phenomenon expressed by Beer's Law.

Absorbtivity related to the nature of the absorbing substance and optical $A = aCL$

wavelength (known for a standard solutionconcentration).

C: Concentration

L: Cuvette path length

2.5 AUTOANALYZER

An auto analyzer sequentially measures blood chemistry through a series of steps of mixing, reagent reaction and colorimetric measurements.

It consists of

- **Sampler:** Aspirates samples, standards, wash solutions into the system
- **Proportioning pump:** Mixes samples with the reagents so that proper chemical color reactions can take place, which are then read by the colorimeter
- **Dialyzer:** separates interfacing substances from the sample by permitting selective passage of sample components through a semi permeable membrane
- **Heating bath:** Controls temperature (typically at 37 °C), as temp is critical in color development
- **Colorimeter:** monitors the changes in optical density of the fluid stream flowing through a tubular flow cell. Color intensities proportional to the substance concentrations are converted to equivalent electrical voltages.
- **Recorder:** Displays the output information in a graphical form.

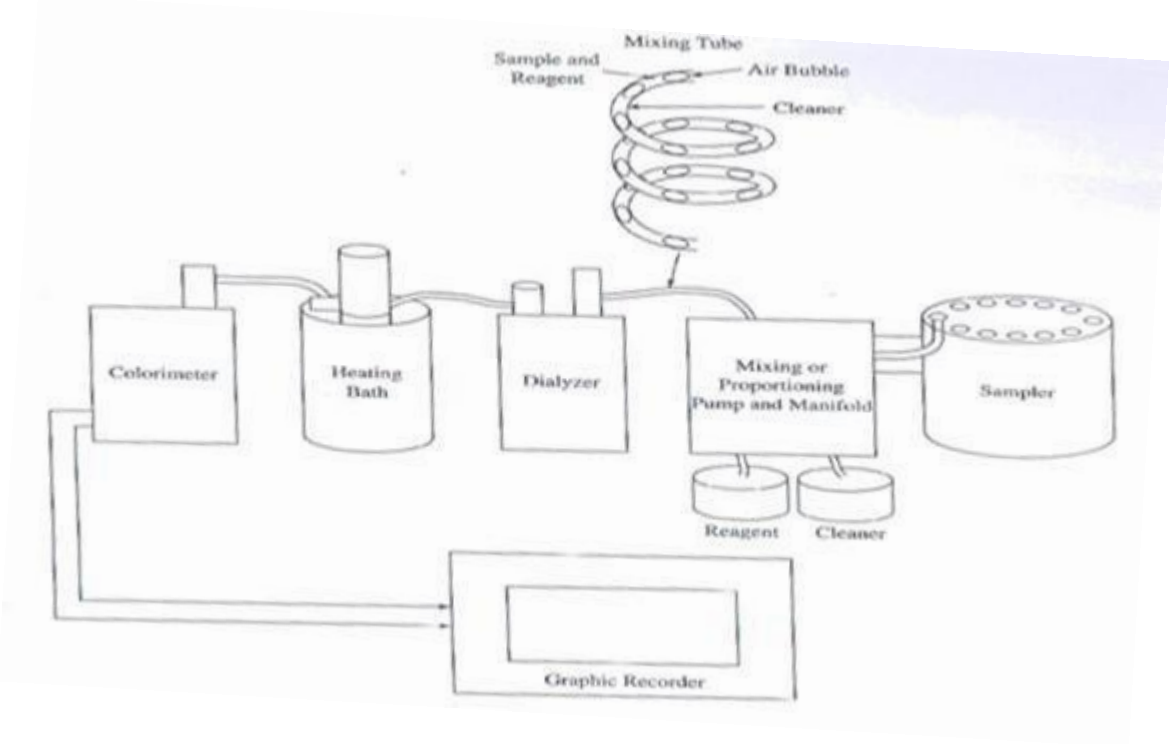


Figure 2.5 Block diagram of Auto Analyzer

2.6 BLOOD FLOW METER

Blood flow meters are used to monitor the blood flow in various blood vessels and to measure cardiac output.

Types

- Electromagnetic blood flow meters
- Ultrasonic blood flow meters
- Laser based blood flow meters

ELECTROMAGNETIC FLOWMETERS

- Electromagnetic blood flow meters measure blood flow in blood vessels
- Consists of a probe connected to a flow sensor box

Figure 2.6 Blood flow meter

An Electromagnetic Flow Meter is a device capable of measuring the mass flow of a fluid. Unlike the common flow meter you can find on the market it has no moving parts, and for this reason it can be made to withstand any pressure (without leakage)and any fluid(corrosive and non corrosive). This kind of flow meter use a magnet and two electrodes to peek the voltage that appears across the fluid moving in the magnetic field.

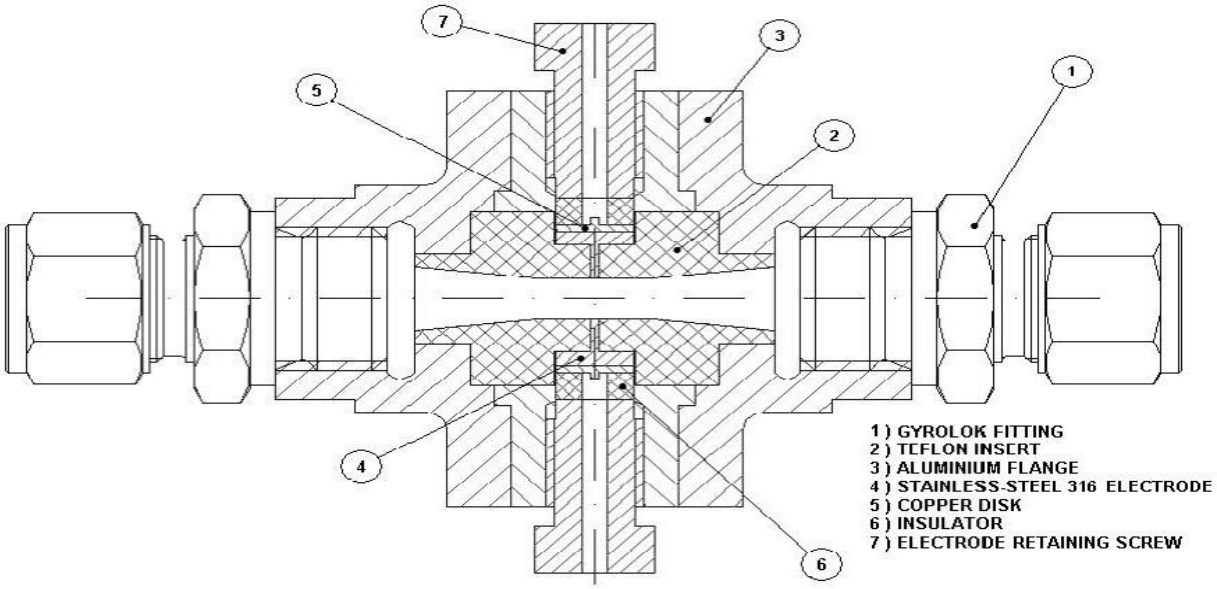


Figure 2.7 Electromagnetic Flowmeter

The Neumann Law (or Lenz Law) states that if a conductive wire is moving at right angle through a magnetic field, a voltage ***E*** [Volts] will appear at the end of the conductor

$$E=B*L*V$$

where

B = Magnetic Induction ***[Weber/m2]***

L=Length of the wire wetted by the magnetic field
V=Velocity of the wire [m/s]

Fig.2

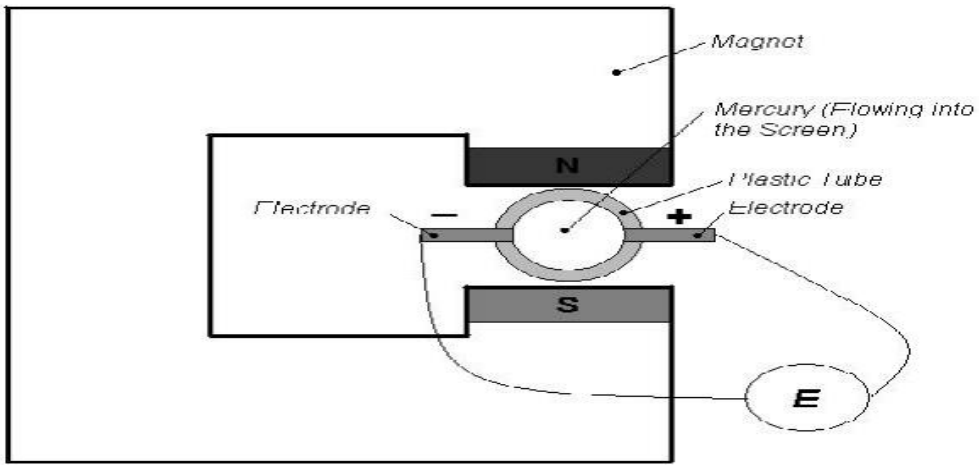


Figure 2.8 Magnetic Blood flowmeter principle

Now imagine you have a plastic tube with two electrodes on the diameter and Mercury flowing into it (fig.2.8). A voltage will appear on the electrodes and it will be

E=B*L*V

Measuring the flow

`A perfect axisimmetric construction cannot be achieved and thus some magnetic flux lines will 'wet' the connecting wires to the electrodes. The alternating magnetic field will create an offset voltage in this wire and even if the fluid is not moving, the measured voltage will not be zero.

ULTRASONIC FLOWMETERS

The blood cells in the fluid scatter the Doppler signal diffusively.In the recent years ultrasound contrast agents have been used in order to increase the echoes. The ultrasound beam is focused by a suitable transducer geometry and a lens.

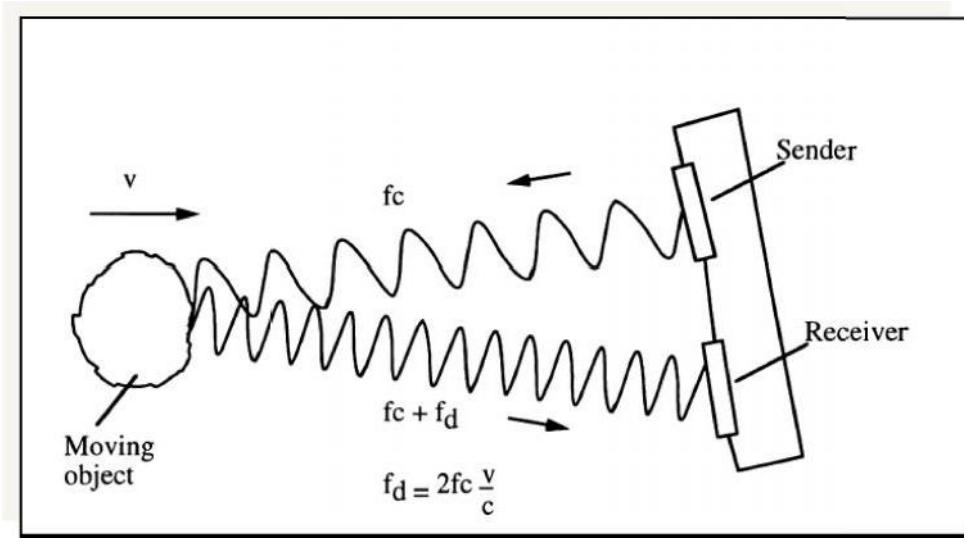


Figure 2.9 Ultrasonic flowmeters

$f_d = 2f_c v/c$

f = 2- 10 MHz

c = 1500 - 1600 m/s (1540 m/s)

f = 1,3 – 13 kHz

In order to know where along the beam the blood flow data is collected, a pulsed Doppler must be used. The flow velocity is obtained from the spectral estimation of the received Doppler signal. The ultrasound Doppler device can be either *a continuous wave* or *a pulsed Doppler*

A Continuous Wave

No minimum range
Simpler hardware
Range ambiguity
Low flow cannot be detected

A Pulsed Doppler

Accuracy
No minimum flow
Minimum range

(Maximum flow) x (range)= limited the power decays exponentially because of the heating of the tissue. The absorption coefficient proportional to frequency the far field operation should be avoided due to beam divergence

$$D_{nf} = D^2 / 4$$

D = Transducer diameter (e.g. 1 – 5 mm) the backscattered power is proportional to *f* .The resolution and SNR are related to the pulse duration. Improving either one of the parameters always affects inversely to the other

LASER DOPPLER FLOWMETRY

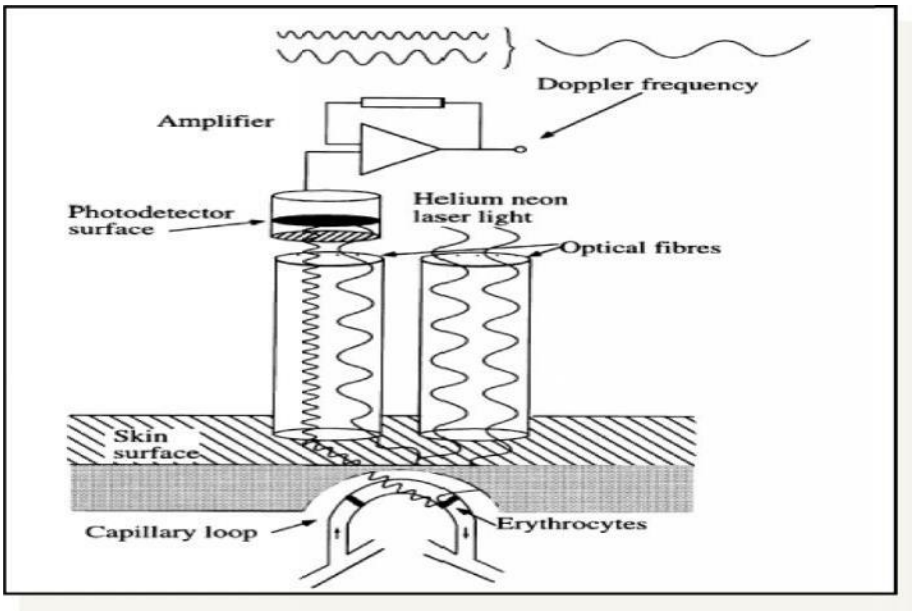


Figure 2.10 Laser Doppler flowmeter

The principle of measurement is same as that with ultrasound Doppler. The laser parameter may have the following properties 5mW; He-Ne laser 632, 8 nm wavelength. The moving RBC cause (30-12000)Hz . The method is used for capillary blood flow measurements.

Indicator Dilution Method

A bolus of indicator, a colored dye *(indocyanine green),* is rapidly injected in to the vessel. The concentration is measured in the downstream The blood is drawn through a colorimetric cuvette and the concentration is measured using the principle of absorption photometry

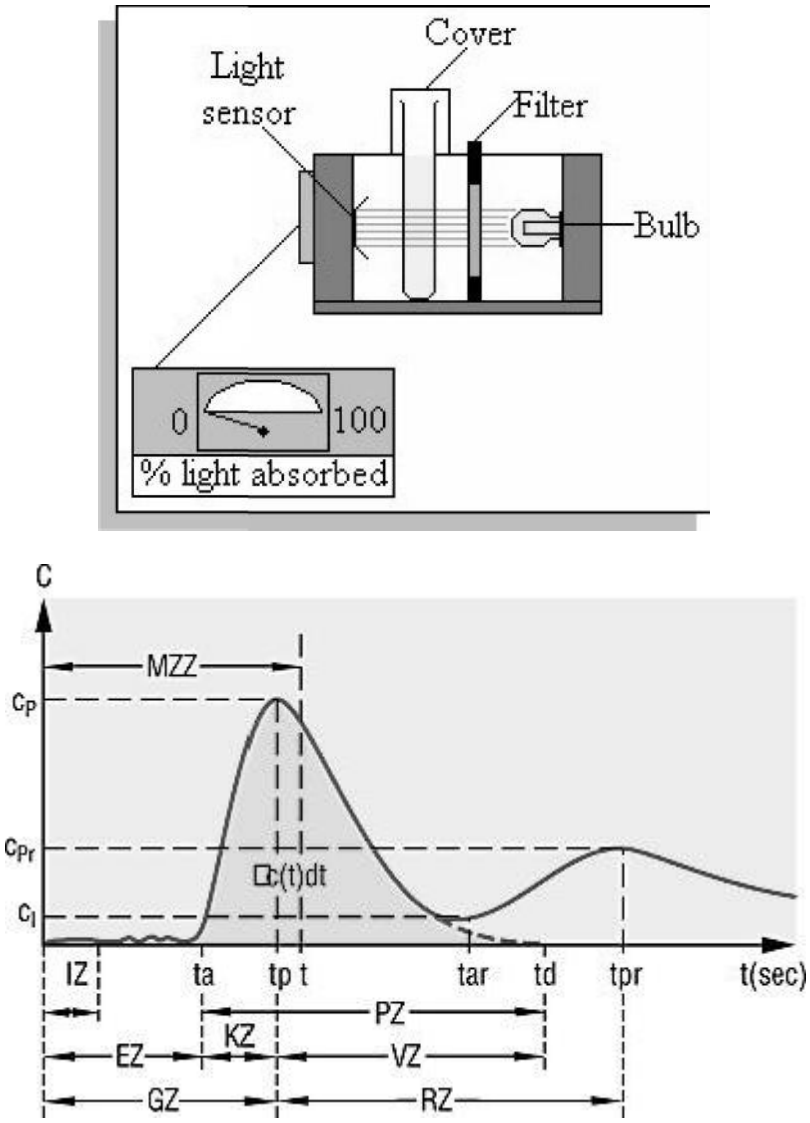


Figure 2.11 Dye Dilution Method

Thermal Dilution Method

A bolus of chilled saline solution is injected into the blood circulation system (right atrium). This causes decrease in the pulmonary artery temperature. An artery puncture is not needed in this technique.Several measurements can be done in relatively short time .A standard technique for measuring cardiac output in critically ill patients.

Photoelectric Method

A beam of IR-light is directed to the part of the tissue which is to be measured for blood flow (e.g. a finger or ear lobe)

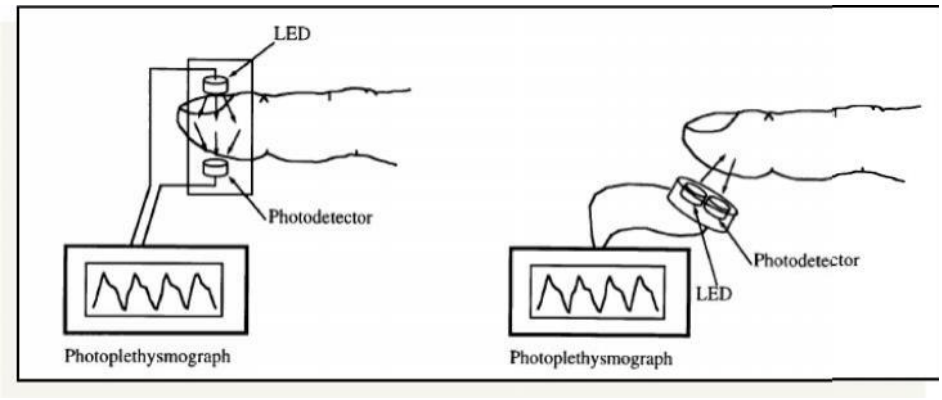


Figure 2.12 Photoelectric Method

The blood flow modulates the attenuated / reflected light which is recorded.The light that is transmitted / reflected is collected with a photodetector.

2.7 CARDIAC OUTPUT

Definition: Volume of blood pumped by the heart

per min CO = SV x HR
Norm ~ 5 l/min
Cardiac index – corrected for body surface area

Affected by :

Met. Rate – pregnancy, hyperthyroid, septic Preload / contractility / afterload

Clinical indicators of CO imprecise

Affected by anaesthetic agents used in everyday practice Provides estimate of:

- whole body perfusion
- oxygen delivery
- left ventricular function Persistently low CO associated with poor out

Methods: Fick method

Dilution techniques – dye / thermal / lithium
Pulse contour analysis- LiDCO & PiCCO
Oesophageal doppler
TOE
Transthoracic impedance plethysmography
Inert gas through flow
Non-invasive cardiac output measurement

Fick Principle: Measure volume displacement 1st proposed 1870 ―the total uptake or release of a substance by an organ is the product of the blood flow through that organ and the arteriovenous concentration difference of the substance. Limited by cumbersome equipment, sampling errors need for invasive monitoring and steady-state haemodynamic and metabolic conditions.

Indicator dilution techniques

An indicator mixed into a unit volume of constantly flowing blood can be used to identify that volume of blood in time, provided the indicator remains in the system between injection and measurement and mixes completely in the blood.

Dye dilution

- Inert dye – indocyanin green
- Injected into pulmonary artery and arterial conc. measured using a calibrated cuvette densitometer
- Plot indicator dilution curve (see diagram) CO derived from area under curve.

Indicator Dilution Curve

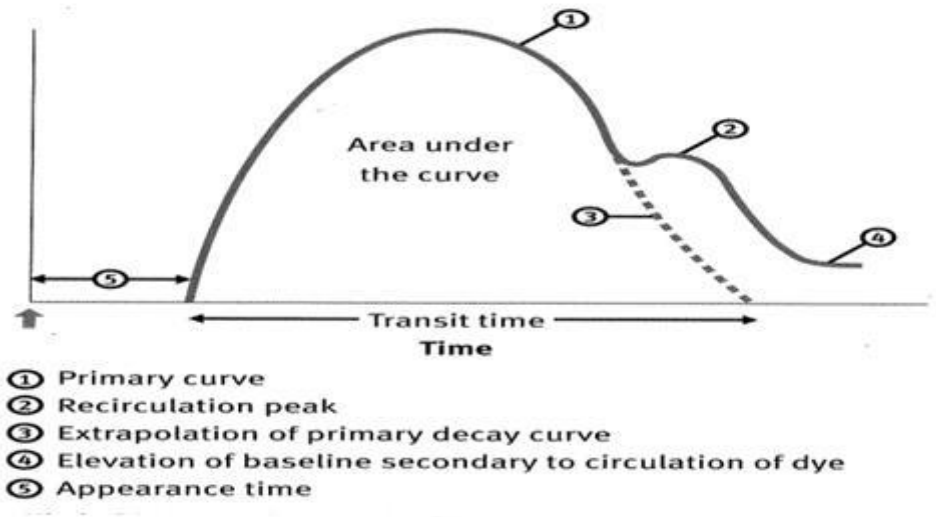


Figure 2.13 Indicator dilution curve

2.8 RESPIRATORY RATE MEASUREMENT

Respiratory system provides a means of acquiring oxygen and eliminating CO_2. Various laws are involved in the understanding of respiratory functions.

Various Gas laws are given below:

1. **BOYLE'S LAW:** It states that at constant temperature, the volume of gas varies inversely with the pressure.

   $V_2/V_1 = P_1/P2$ here temperature T= constant

   V_2= Final volume
   V_1 = Initial volume

P_1 = Original (initial) pressure P_2 = Final pressure

2. **CHARLE'S LAW:** It states that, at constant pressure, the volume of gas isdirectly proportional to the absolute temperature.

$V_2/V_1 = T_2/T_1$ Here pressure P=constant V_2, V1 =Final, initial volume T_1 =original temperature T_2 = Final temperature

3 . **HENRY'S LAW :** It states that, if the temperature is constant, the quantity of a gas that goes into a solution is directly proportional to the partial pressure of that gas . The gas with the greater partial pressure will have more mass in solution.

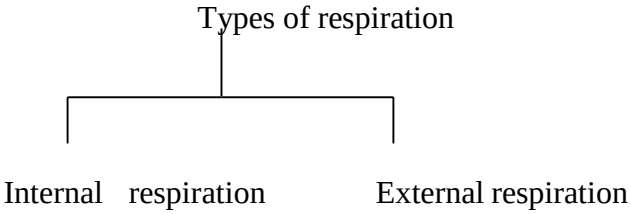
4. **DALTON'S LAW :** It states that, the total pressure exerted by a mixture of gases is equal to the sum of the partial pressures of various gases.

$P_T = P_1 + P_2 + \ldots\ldots\ldots\ldots + P_n$

P_T = total pressure

P_1, P_2, P_3 = partial pressure of various gases

TYPES OF RESPIRATION



Respiration is nothing but the interchange of gases between an organism and the living medium

Internal respiration is the exchange of gases between the blood stream and nearby cells

.**External respiration** is the exchange of gases between the lungs and blood stream .

Lungs Volumes and Capacities (Respiration Parameters) Or (LVC)

Respiration parameters are used to indicate the state of respiratory function , including lung volumes and capacities , airway resistance , lung compliance , etc .

Dead Air

Only a portion of the air entering the respiratory system actually reaches the alveoli . The volume of air that is not available for gas exchange with the blood is known as dead air . The total dead space is less less than 30 percentage of the total volume .

Tidal Volume (TV)

Tidal volume is the depth of breathing or the volume of gas inspired or expired during each respiratory cycle. It is equal to 500 ml for a normal person .

Inspiratory Reserve Volume (IRV)

It is the maximal amount of gas that can be inspired from the end- inspiratory position (Extra inspiration from the high peak tidal volume . It is equal to 3600 ml for a normal person

Expiratory reserve volume (ERV)

It is the maximal amount of gas that can be end expiratory level. It is equal to 1200 ml.

Residual Volume(RV)

It is the amount of gas remaining in the lungs at the end of maximal expiration. It is equal to 1200 ml.

Minute Volume (MV)
It is the volume of air breathed normally for 1 minute.

Total Lung Capacity(TLC)
It is the amount of gas contained in the lungs at the end of maximal inspiration and it is the sum of inspiratory capacity(IC) and functional residual capacity (FRC). TLC is of 6000 ml for a normal person.

Vital Capacity(VC)
It is the maximum amount of gas that can be expelled from the lungs by forceful effort from maximal inspiration. It is 4800 ml for a normal person.

Inspiratory Capacity(IC)
It is the maximum amount of gas that can be inspired from the resting expiratory level and it is the sum of tidal volume and inspiratory reserve volume. It is equal to 3600 ml for a normal person.

Functional Residual Capacity(FRC)

It is the amount of gas remaining in the lungs at the resting expiratory level.

FRC = ERV + RV

Airway resistance

It relates to the ease with air flows through tubular respiratory structures. In smaller tubes, airway resistance is high.

Lung Compliance

It is the ability of the alveoli and lung tissue to expand on inspiration**.**

Lung Elasticity

It is the ability of the lung's elastic tissues to recoil during expiration

Intra thoractic Pressure

It is the positive and negative pressure occur within the thoracic cavity Types of respiration rate measurement

1. Displacement method
2. Thermistor method
3. Impedance pneumography
4. CO_2 method
5. Apnoea detectors

Displacement Method

In this method the transducer is hold by an elastic band which goes around the chest.The respiratory movements results in a corresponding resistance changes of the strain gauge. It is connected as one arm of a wheatstone bridge circuit. Its output varies with chest expansion. This output corresponds to the respiration activity.

Impedance Pneumography

This is the indirect method of measurement . impedance pneumography is based on the fact that , the a.c impedance across the chest of a patient changes as respiration occurs . 50-50KHz a.c signal is produced by oscillator circuit and is given to the chest of the patient through electrodes

.The signal voltage applied to the amplifier (Differential amplifier) block is the voltage drop across the resistance .

The output of the amplifier is given to demodulator and filter block. Hence low pass filter is used to remove the residual carrier signal. The output of the impedance pneumograph contains respirating rate data.

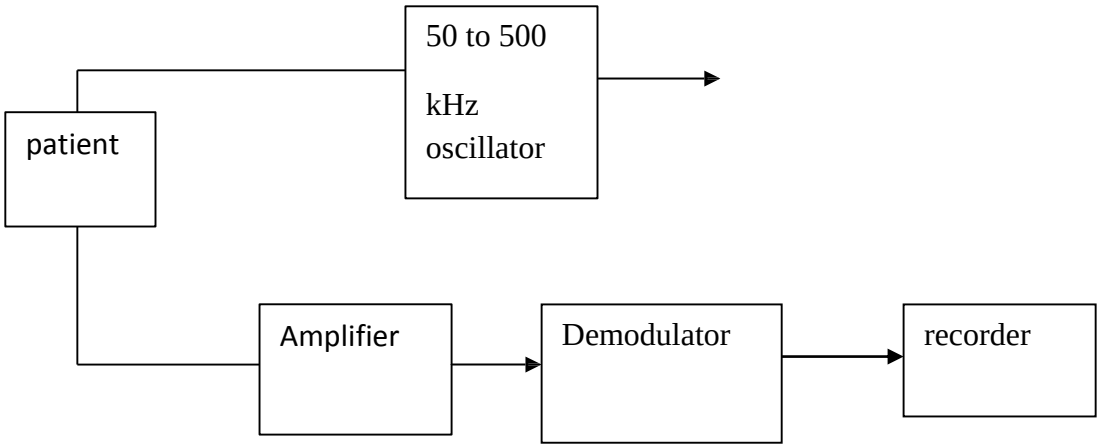


Figure 2.14 Impedance pneumography

$$V = I(R+ R)$$

Where V= Output voltage (V)
I= Current through the chest (A)
R= chest impedance without respiration (R)
R= change of chest impedance due to respiration (Q)

CO_2 Method

Respiration rate can be measured by measuring CO_2 in expired air. This CO_2 method of measurement is based on the absorption property of infrared rays by certain gases .When infrared rays are passed through the expired air which contains certain amount of CO_2, some of radiations are absorbed by it. So, there is loss of heat energy associated with the rays .The detector changes the loss in heating effect of the rays into an electrical signal. It is used to get the average respiration rate. Two infrared sources are available in this set up. The beam from one infrared source falls on the test cuvette side. The beam from another infrared source falls on the reference cuvette side

The detector has two identical portions. These portions are separated by a thin, flexible metal diaphragm. The detector is filled with a sample of pure CO2. Because of the absorption of CO2 in the test cuvette. The beam falling on the test side of the detector is weaker that falling on the reference side. The gas in reference side is heated more than that on the test side. So diaphragm is pushed slightly to the test side of the detector. This diaphragm forms one plate f a capacitor. The a.c signal appears across the detector is amplified and recorded using recorder. The amplified output is integrated. It is used for continuous monitoring the respiration rate.

Apnoea Detectors

Apnoea is the stopping of breathing. It leads to the arrest of the circulation. It can be occurred at the conditions like head injury, drug overdose, etc. It can also occur in premature babies during the first week of life because of their immature nervous system. If apnoea

persists for a prolonged period, then brain functions can be severly damaged. So apnoea patients are closely monitored. Apnoea monitor is used to watch the apnoea patients respiration rate. Apnoea monitor gives audio signals and visual signals, when no inspiration occurs for a particular period of time. Input from the sensor is connected with the amplifier circuit having high input impedance

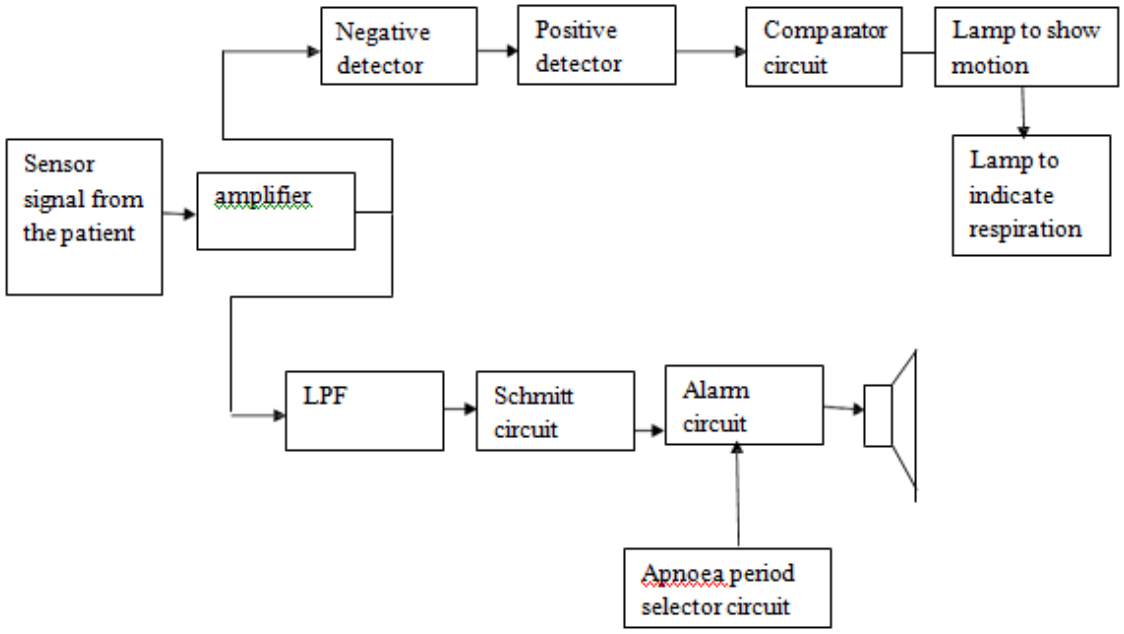


Figure 2.15 Block diagram of apnoea monitor

The output of the amplifier circuit is connected with motion and respiration channel blocks. Motion channel block differentiates motion and the respiration based on the frequency. The frequency below 1.5 Hz is identified as respiration. The frequency above 1.5 Hz is identified as motion. High frequency signal above the threshold is sensed by positive detector.

The frequency below the threshold is sensed by negative detector. The output of the motion channel is connected with comparator circuit. It compares the amplitude of motion and respiration. Based on the output corresponding lamp will glow. In the respiration channel, low pass filter is used to remove high frequency signal. If there is no respiration, then schmid trigger circuit gives the output to switch on the alarm.

Apnoea period selector circuits contain low frequency alarm oscillator and tone oscillator, and audio amplifier. Apnoea period selector circuit drives the alarm circuit. The output of alarm circuit is connected with the speaker. So, where there is no respiration for a period of 10 or 20 sec, then audio signal through the speaker and visual signal through the flash light is delivered**.**

2.9 BLOOD PRESSURE

One of the oldest physiological measurements. Observation of blood pressure allows dynamic tracking of pathology and physiology affecting to the cardiovascular system, which has profound effects to all other organs of the body

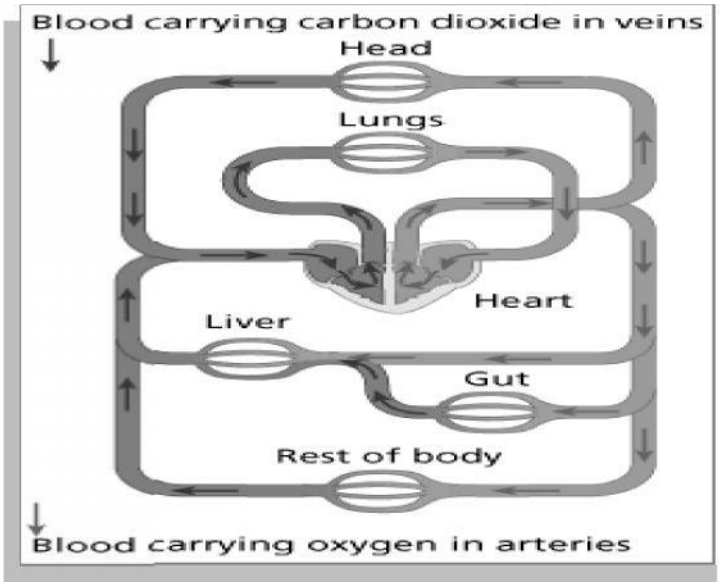


Figure 2.16 Observation of blood pressure

- Originates from the heart
- Commonly refers to arterial blood pressure

Value depends on 3 factors:

- cardiac output diameter of arteries the quantity of blood
- Values should be lower than 120 / 80 mmHg(systolic pressure (SP) / diastolic pressure (DP))
- *High value* increases the risk of heart attack and strokes
- *Low value* increases the risk of lower oxygen perfusion e.g. in brains.

However, the 'normal values' differ from person to another

Pulse Pressure(PP) = SP - DP

Mean pressure (MP)

Average pressure during one cardiac cycle driving force of the peripheral perfusion. an estimate can be done by using an empirical formula:

$$MP = DP+PP/3$$

SP and DP may vary significantly throughout the arterial system but MP is quite uniform (in normal situations)

1. Non-Invasive

Palpatory Method(Riva-Rocci Method)

Auscultatory Method
Ultrasonic Method
Oscillometric Method
Tonometry

2. Invasive

Extravascular Sensor
Intravascular Sensor

INDIRECT METHODS IN BLOOD PRESSURE MEASUREMENTS

Indirect measurement = non-invasive measurement

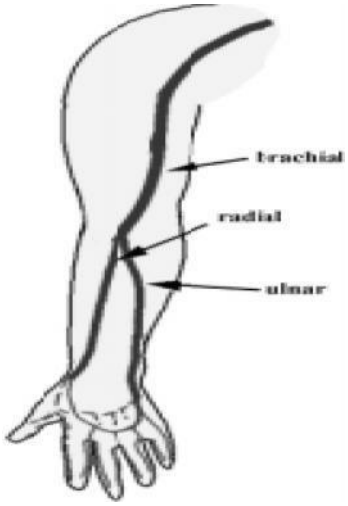


Figure 2.17 Blood pressure measurements

Brachial artery is the most common measurement site

- Close to heart
- Convenient measurement

AUSCULTATORY METHOD

Pulse waves that propagate through the brachial artery, generate Korotkoff sounds. There are 5 distinct phases in the Korotkoff sounds, which define SP and DP The Korotkoff sounds are ausculted with a stethoscope or microphone (automatic measurement

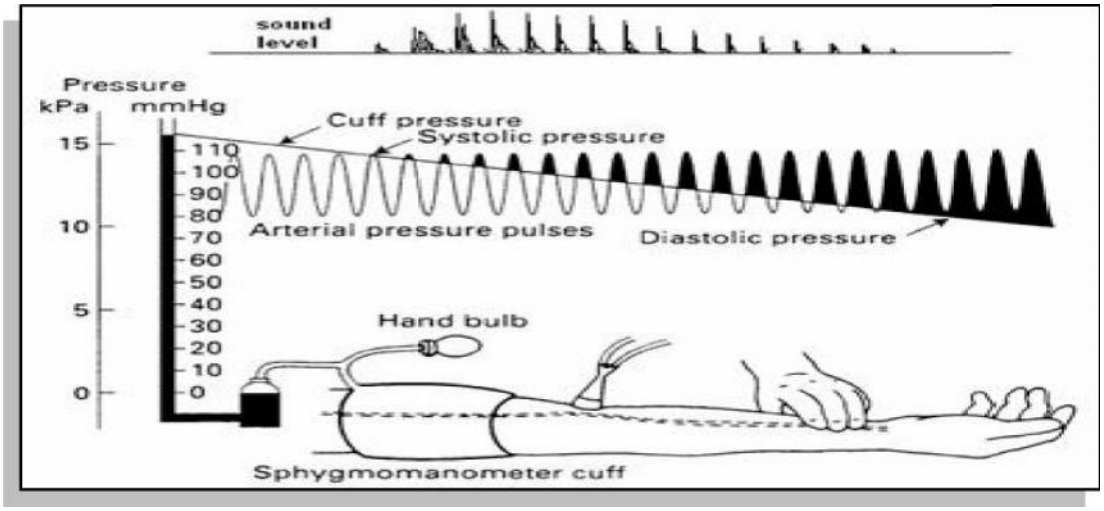


Figure 2.18 Auscultatory Method

The frequency range is 20-300 Hz and the accuracy is +/- 2mmHg (SP) and +/- 4mmHg (DP). Also with this method, several measurements should be done.

Advantages

Auscultatory technique is simple and does not require much equipment

Disadvantages

- Auscultatory tecnique cannot be used in noisy environment The observations differ from observer to another
- A mechanical error might be introduced into the system e.g. mercury leakage, air leakage, obstruction in the cuff etc.
- The observations do not always correspond with intra-arterial pressure
- The technique does not give accurate results for infants and hypotensive patients

ULTRASONIC METHOD

A transcutaneous (through the skin) Doppler sensor is applied here. The motion of blood- vessel walls in various states of occlusion is measured. The vessel opens and closes with each heartbeat when DP < P < SP .The frequency difference between transmitted (8 MHz) and received signal is 40-500 Hz and it is proportional to velocities of the wall motion and the blood. As the cuff pressure is increased, the time between opening and closing decreases until they coincide.

Advantages & Disadvantages

- Can be also used in noisy environment
- Can be used with infants and hypotensive individuals
- Subject's movements change the path from sensor to vessel

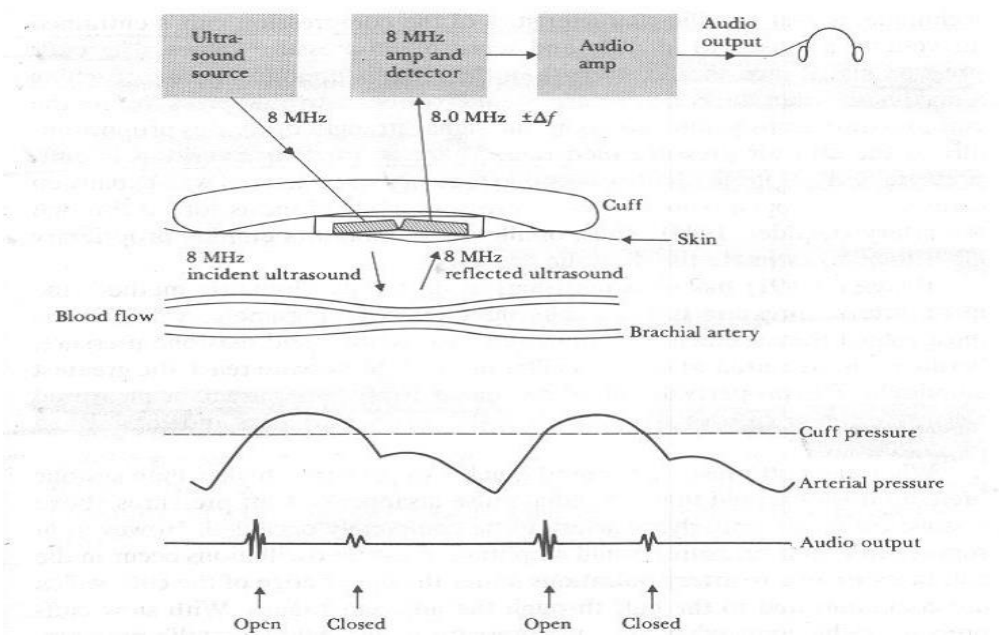


Figure 2.19 Ultrasonic Method

TONOMETRY

Linear array of pressure sensors is pressed against a superficial artery, which is supported from below by a bone (radial artery). A sensor array is used here, because at least one of the pressure sensors must lay directly above the artery .When the blood vessel is partly collapsed, the surrounding pressure equals the artery pressure

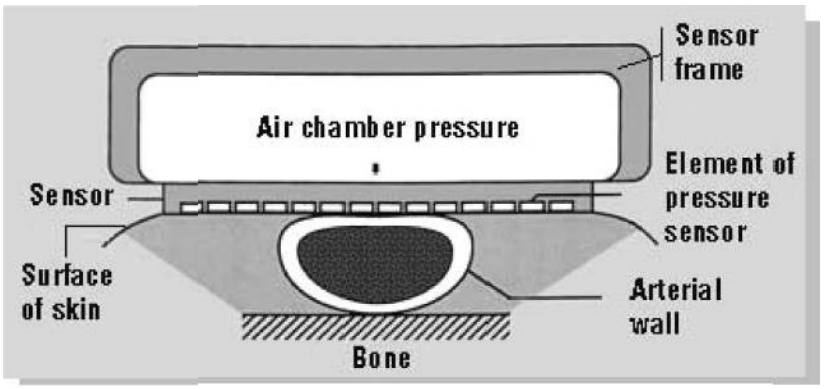


Figure 2.20 Tonometry

The pressure is increased continuously and the measurements are made when the artery is half collapsed. The hold-down pressure varies between individuals and therefore a 'calibration' must be done

Advantages

Can be used for non-invasive, non-painful, continuous measurement

Disadvantages

- Relatively high cost

- The wrist movement and tendons result in measurement inaccuracies

SPHYGMOMANOMETER

- In this method, an occlusive cuff is placed on the arm and inflated to P>SP. Then the cuff is deflated gradually and the blood flow is done.

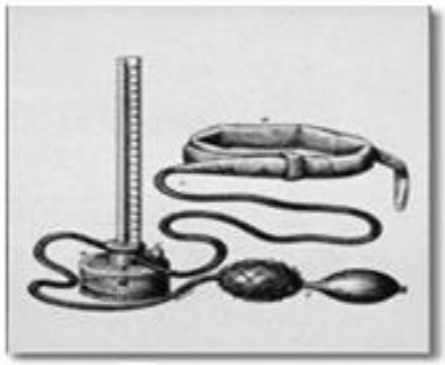


Figure :2.21 Sphygmomanometro

- The occlusive cuff should be of a correct size in order to transmit the pressure to the artery evenly and thus to obtain accurate results .A short cuff requires special attention in placement. Longercuff reduces this problem. The cuff should be placed at the heart level in order to minimize the hydrostatic effects .

DIRECT METHODS IN BLOOD PRESSURE MEASUREMENTS

Direct measurement = Invasive measurement

A vessel is punctured and a catheter (a flexible tube) is guided in The most common sites are brachial and radial arteries but also other sites can be used e.g. femoral artery A division is made into extravascular and intravascular sensor systems .This method is precise but it is also a complex procedure involving many risks Used only when essential to determine the blood pressure continuously and accurately in dynamic circumstances

EXTRAVASCULAR SENSOR

- The sensor is located behind the catheter and the vascular pressure is transmitted via this liquid-filled catheter.
- The actual pressure sensor can be e.g. strain gage,variable inductance,variable capacitance Optoelectronic,piezoelectric, etc…

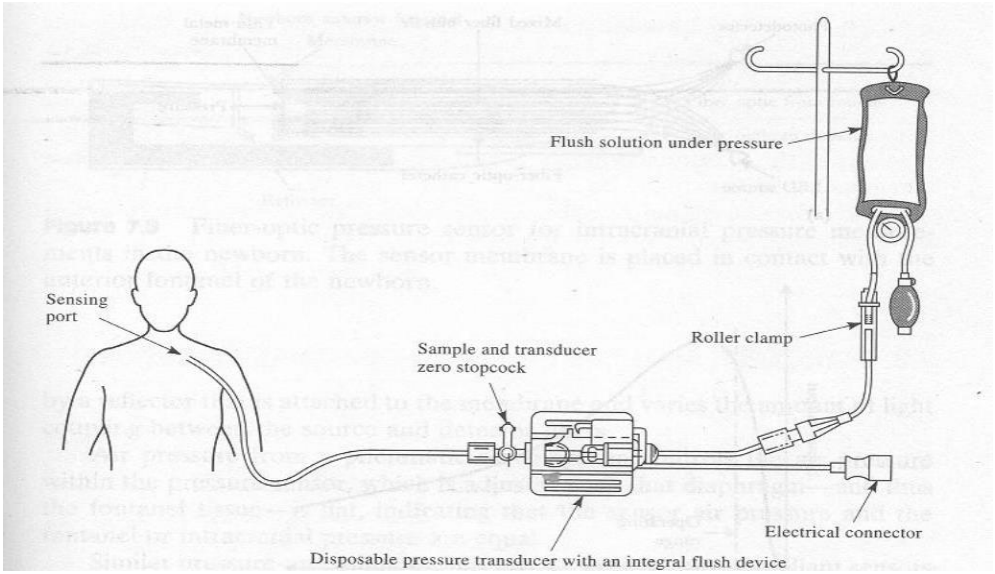


Figure 2.22 Extravascular Sensor

The hydraylic link is the major source of errors. The system's natural frequency may be damped and degraded .

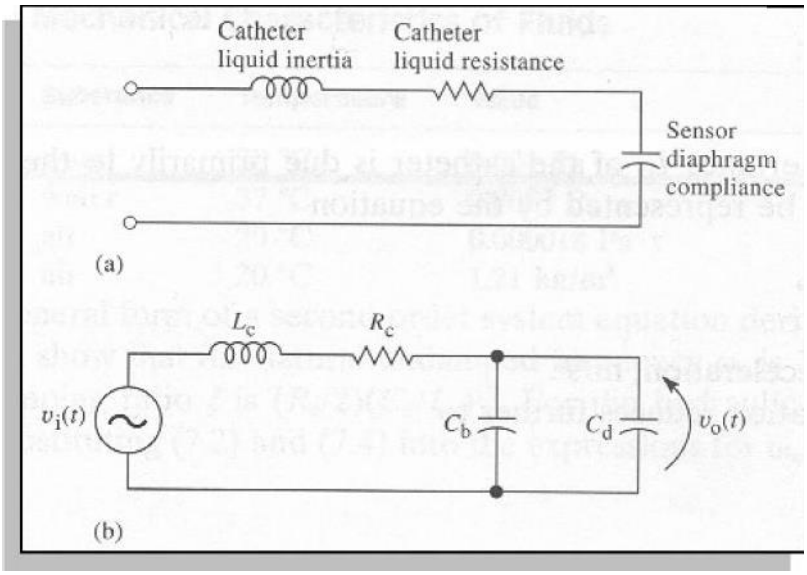


Figure 2.23 Catheter sensor system

The catheter-sensor system must be flushed with saline-heparine solution every few minutes in order to prevent blood from clotting at the tip.

Normally the interesting frequency range is 0 – 100 Hz. If only MP is measured the bandwidth is 20 Hz (harmonics > 10 are ignored)

INTRAVASCULAR SENSOR

sensor is located in the tip of the catheter. This way the hydraulic connection is replaced with an electrical or optical connection .The dispacement of the diaphragm is measured .The frequency response is not limited by the hydraulic properties of the system.

No time delay.
Electrical safety and isolation when using fiber optics
Breaks easily
More expensive

Disposable Sensors

Disposable sensors decrease the risk of patient cross-contamination and reduce the amount of handling by hospital personnel

Cheaper and more reliable than reusable pressure sensors

GENERAL ON SYSTEM PARAMETERS

Even minute air bubbles in catheter have a dramatic effect on frequency response The natural frequency and the length of the catheter have a following relationship:

$$f_n \propto \frac{1}{\sqrt{L}}$$

The catheter diameter has a linear relationship to natural frequency Stiffer catheters have a higher frequency response

2.10 TEMPERATURE MEASUREMENT:

Temperature is one of the inductor of the general well being. Two types of temperature measurements can be obtained from the body. These are

- Systematic temperature
- Surface temperature

Systematic temperature is the temperature of the internal region of the body. Usually, the heat is generated by the active tissues of the body and heat is lost by the body to the environment. But, the temperature of the body is maintained carefully. The normal mouth temperature is 37^0C. the normal underarm temperature is about 1^0C lower than the above temperature. Systemic temperature is measured accurately at tympanic membrane of ear. The brain contains the temperature control centre for the body.

Systemic body temperature measurement

Mercury thermometer is used to measure the systemic temperature. It is inexpensive to use.. when continuous temperature recording is necessary, then, thermocouple or thermistor can be used. In thermocouple, a junction of two dissimilar metals produces an output voltage. This is proportional to the temperature at that junction

Thermistor is a temperature sensing device. Its resistance varies with the temperature. In this thermistor, the relationship between resistance change and temperature is nonlinear. The resistance of the thermistor is given by

$R_t = R_r e^{\beta}(1/T_1 - 1/T_0)$ R_t=resistance at

temperature T_t

R_r = resistance at temperature T_0

T_1 = temperature at which measurement is taken T_0 = reference temperature

B = temperature cosfficient

Special circuits are used to overcome the nonlinear characteristics of thermistors. This special circuit consists of 2 matched thermistors.

Problems associated with thermistor

Self heating is very important problem in thermistor. This problem can be overcome by limiting the current used in measurement. The power dissipation of thermistor is to be maintained in milliwatts range to overcome this problem.

Thermistor probe should be chosen correctly based on

- Resistance range
- Sensitivity

Skin temperature measurement

Skin temperature is not constant throughout the body. It is varied from 30^0C to 35^0C. Various factors affect the skin temperature are given below

- How fat covers over capillary area
- How the skin portion is exposed to ambient temperature
- Blood circulation pattern beneath the skin

Probe used for measurement

A small flat thermistor probe is used to measure the skin temperature.

Infrared thermometer

It is a device used to measure skin surface temperature. It is used to locate breast cancer. It is also used to identify the spots in which blood circulation is poor.

2.11 PULSE MEASUREMENT

When heart muscle contracts , blood is ejected from the ventricles and a pulse of pressure is transmitted through the circulatory system. This pulse can be measured at various points. We can sense the pulse by placing our finger tip over the radial artery in the wrist. This pulse travels at the speed of 5 to 15m per second. Photoelectric method is commonly employed to measure the pulse.

Types:

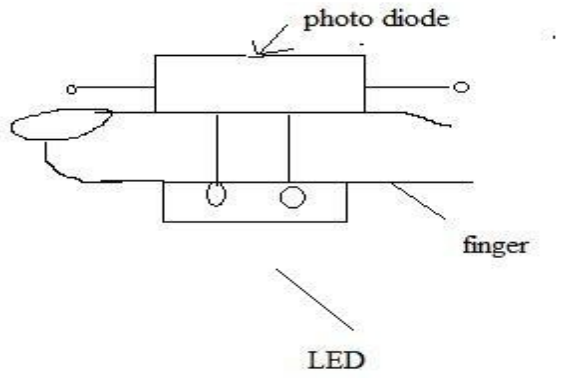
Photoelectric method consists of two types

- Tramsmittance method
- Reflectance method

TRANSMITTANCE METHOD OF PULSE MEASUREMENT

LED and photoresistor are used in this method. These are mounted in a enclosure that

fits over the tip of the finger. Light is produced by the LED. The same light is passed through the finger. For each heart pulse , blood is forced to the extremities and the amount of blood in the finger is increased. So optical density is changed. So, the light transmitted through the finger is decreased. This light is received by the photo resistor. This photo resistor is connecte with the part of voltage divider circuit. The voltage produced by this circuit is directly proportional to the amount of blood flow in the figure. The output ius recorded by using strip chart recorder.



Figuer 2.24 Transmittance Method Of Pulse Measurement

REFLECTANCE METHOD

N reflectance method, LED is placed adjacent to the photoresistor. LED emits the light. This light is reflected form the skin and the tissues falls on the photo resistor. The reflected light varies depending upon the blood flow in the finger. The photo resistor is connected as a part of the voltage divider circuit. The output obtained is directly proportional to the amount of blood in the finger. The output can be recorder using strip chart recorder.

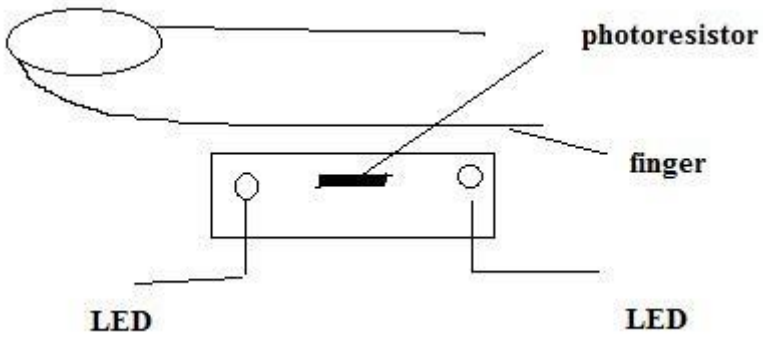


Figure 2.25 Reflectance Method

2.12 BLOOD CELL COUNTER

- The blood cell counter count the number of RBC or WBC per unit of volume of blood using either of two method:
  - Electrical method called aperture impedance change
  - Optical method called flow cytometry

Aperture impedance change

- When blood is diluted in the proper type of solution, the electrical resistivity of blood cells (ρ_c) is higher then the resistivity of the surrounding fluid (ρ_f)
- By contriving a situation in which these resistivities can be differentiated from each other, we can count cells

Blood cell sensing

- The sensor consist of a two-chamber vessel in which the dilute incoming blood is on one side of barrier, and the waste blood to be discarded is on the other
- A hole with a small diameter (50μm) is placed in the partition between the tow halves of the cell
- Ohmmeter measure the change on the resistance when the blood cell pass the aperture

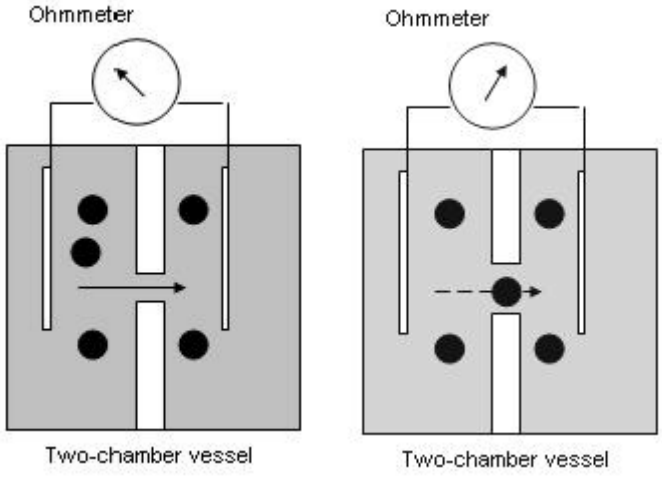


Figure 2.26 Blood cell sensing

COULTER COUNTER

- Constant current source (CCS) and voltage amplifier replace the ohmmeter
- R_A is the resistance of the aperture and will be either high or low, depending on whether or not the blood cell is inside the aperture.
- Amplifier convert the current pulse to voltage pulse

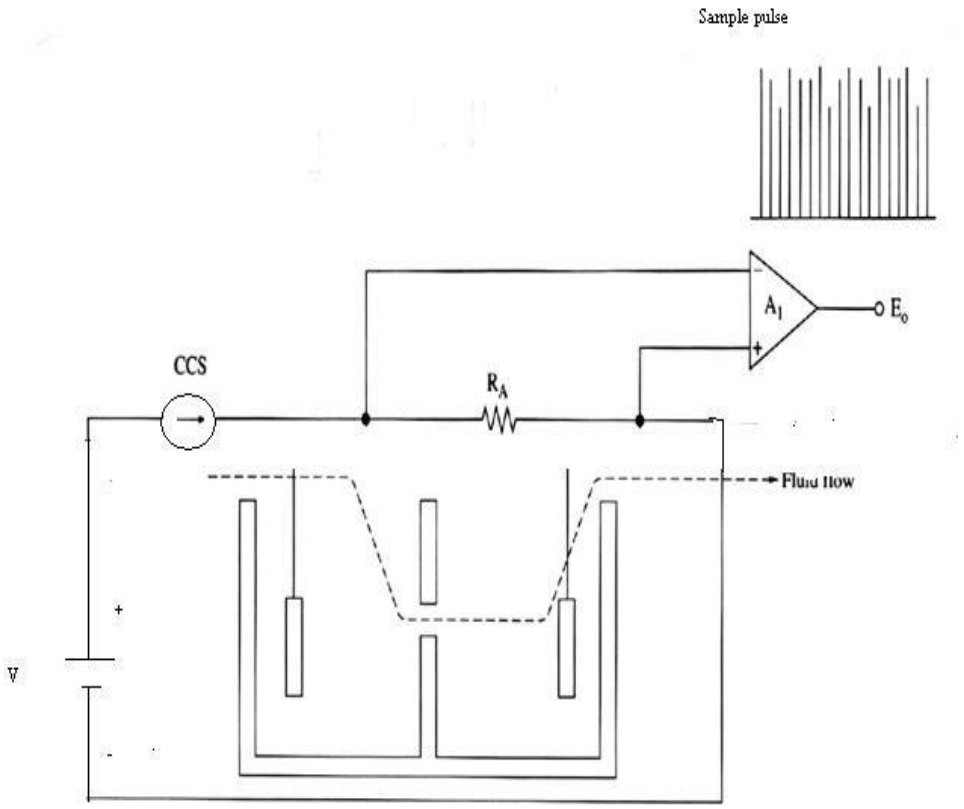


Figure 2.27 Block diagram of Coulter Counter

FLOW CYTOMETRY CELL COUNTERS

Optical flow cytometry sensing

- The optical cytometry sensor consists of a quartz sensing sheath designed with a
  - hydrodynamic focusing region
  - cell path region that passes only a single cell at time.

- Focusing is done by decreasing the diameter of the aperture.
- Light source is (He-Ne) Laser

- Two Photodetectors (photosensors)
  - Photodetector A detects forward scatted light
  - Photodetector B detects orthogonal scatted light

- blood sample enters the analyzer
  - Optical counter → WBC count
  - Colorimeter → hemoglobin
  - Optical flow sensor → RBC count

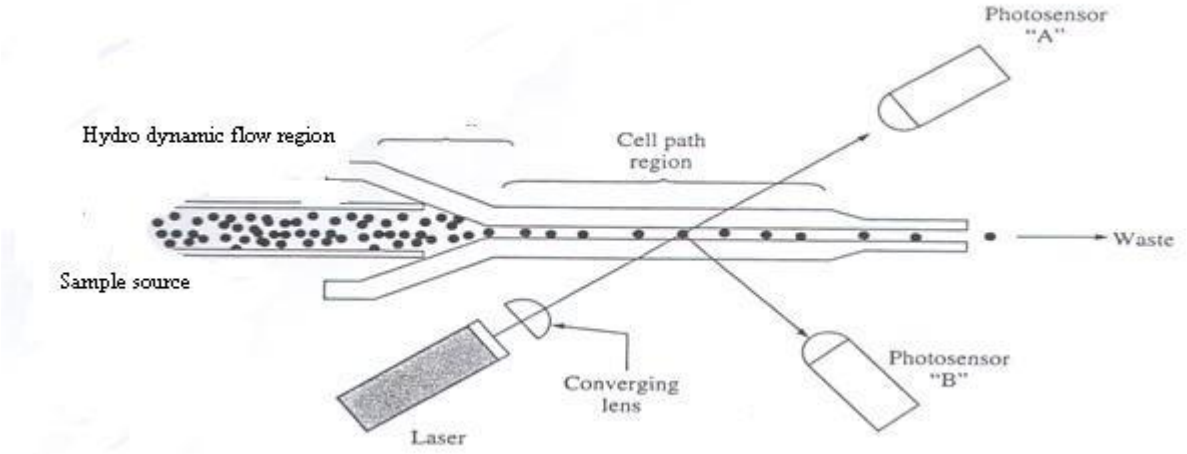


Figure 2.28 Optical flow cytometry

The blood is actually split into different chambers, where in each chamber it is diluted / mixed to differentiate different cell types. WBC and RBC are separated

UNIT III

ASSIST DEVICES

3.1 Cardiac Pacemaker

Definition:

- A device capable of generating artificial pacing impulses and delivering them to heart is known as pacemaker system orpacemaker.

- It consists of a pulse generator and electrodes. Sino Atrial node is responsible for the starting of heart beat, hence it is called as NaturalPacemaker.

Types ofpacemakers:

- Internalpacemaker
- Externalpacemaker

INTERNALPACEMAKER

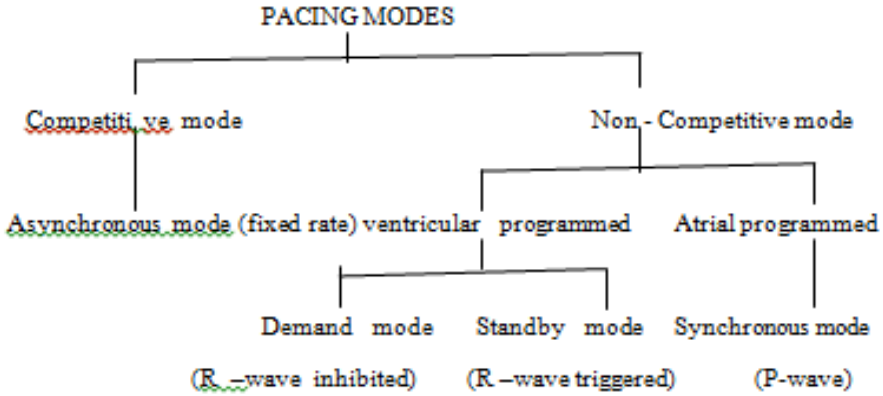
- It is placed inside the body. It may be permanently implanted on the patients whose SA nodes are failed to function or those who suffered from permanent heartblock**.**
- Internal pacemaker systems are implanted with the pulse generator placed in a surgically developed pocket below the right or left clavicle, in left sub costalregion.
- In case of women it is placed beneath the left or right major pectoral'smuscle.
- Internal leads are connected to the electrodes that directly contact the surface of themyocardium**.**
- The exact location of the pulse generator used in the internal pacemaker system depends on the followingfactors.
  - Type and nature of the electrodeused.
  - Nature of the cardiacproblems.
  - Mode of operation of the pacemakersystem.
- There is no external connection for applying power. So the pulse generator should be completely self contained with a battery, which is capable of operating continuously for a specifiedperiod.

EXTERNALPACEMAKER

- It consists of an externally placed pulse generator circuit connected to the electrodes placed on themyocardium.
- Temporary heart irregularities ordisorders.

- Treating the patient fromarrhythmias.
- Treatment of coronary patient and during the cardiacsurgery.
- It consists of pulse generators. They are placed m the body and connected normally to the electrode with the help of wires introduced into the rightventricle.
- The pulse generator may be strapped to the lower arm of thepatient.

TYPES OF PACINGMODES



VENTRICULAR ASYNCHRONOUS PACEMAKER (FIXED RATEPACEMAKER)

- It can be implemented in atrium orventricle.
- Suitable for patients who are suffered by total AV block, atrialarrhythmia.
- It consists of square wave generator and monostablemultivibrator circuit. The periodsquare

  Wave generatorisgiven as .. T.

  $\left(\frac{R3}{2R2+R3}\right)$
- T=-2(RC)ln

Disadvantages:

- Heart beat rate cannot bechanged.
- If it is fixed in atrium, atrium beat at a fixed rate. If ventricle beat at a different rate, and then it leads to a severe problem. Ventricular fibrillation may be occurred.

VENTRICULAR SYNCHRONOUS PACEMAKER (STANDBYPACEMAKER)

- Suitable for the patients who are suffered by short period of AVblock.
- Electrode placed in the right ventricle of heart. This electrode is used to sense the R-wave.
- If ventricular contractions are absent, then the pacemaker provides

the impulses. This type of pacemaker does not compete with the normal heartactivity.

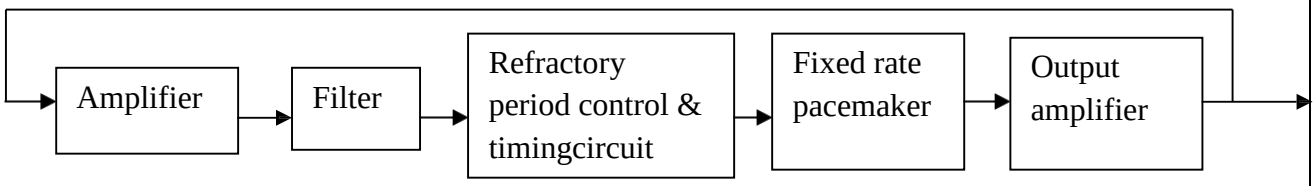


Figure 3.1 Ventricular synchronouspacemaker

- Electrode is used to detect the heart rate and it is given to the amplifier and filter circuit. Because heart rate amplitude is very low. Amplifier is used to amplify the cardiac signal. Filter is used to remove unwanted noisesignal.
- Signal is given to refractory period control and timingcircuit.
- R-wave is below the certain level, at that time only, this pacemaker will deliver thepulses.

Advantages:

- Ventricular fibrillation isavoided.
- When R-wave is normal , then fixed rate pacemaker block is not in ON condition, so power consumption isreduced.

Disadvantages:

- Very sensitive to electromagneticinterferences.
- No synchronization between atrial and ventricularcontraction.

VENTRICULAR INHIBITED PACEMAKER (DEMANDPACEMAKER)

- Comparator determines the pacing rate of the pulsegenerator.
- Output is giventosecondRCnetwork.Thepulsewidthcircuitdeterminesthe duration of the stimulatingpulses.
- Rate limiting circuit disables the comparator for a short interval and limits the pacingrate.
- Output circuit provides a voltage pulse to stimulate theheart.
- Voltage monitor circuit senses the cell depletion and controls the rate slow down circuit and energy compensationcircuit.
- Rate slow down circuit shuts off some current to the basic timing to slow down pulse rate during celldepletion.
- Energy compensation circuit causes the pulse duration unit to increase the battery voltage, when it decreases and it is used to supply the energy toheart.
- Sensing circuit detects a spontaneous R-wave and resets theoscillatortiming capacitor.

- Reversion circuit helps the amplifier to detect spontaneous R wave in the presence of low level continuous waveinterference.

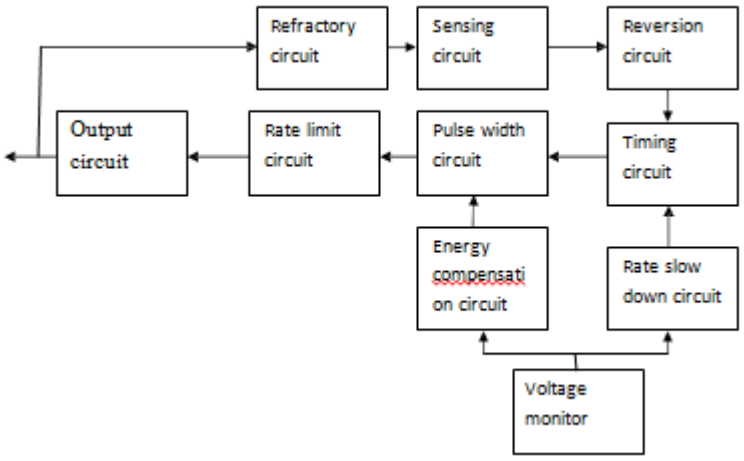


Figure 3.2 Ventricular inhibitedpacemaker

- In the absence of R wave the circuit allows the oscillator to produce pacing pulses at its presentrate.
- The inhibited pacemaker allows the heart to pace at its normal rhythm when it is able todo.
  If the R wave is missing for a preset period of time, then the pacemaker will turn ON and provide the heart a stimulus. Hence it is termed as Demandpacemaker.

ATRIAL SYNCHRONOUSPACEMAKER

- P wave is sensed and picked by the electrode fixed on the atrium. It is given to the amplifiercircuit.
- Amplifier circuit is used to amplify theP-waveform.
- Circuit is used to give the delay 0.12second.

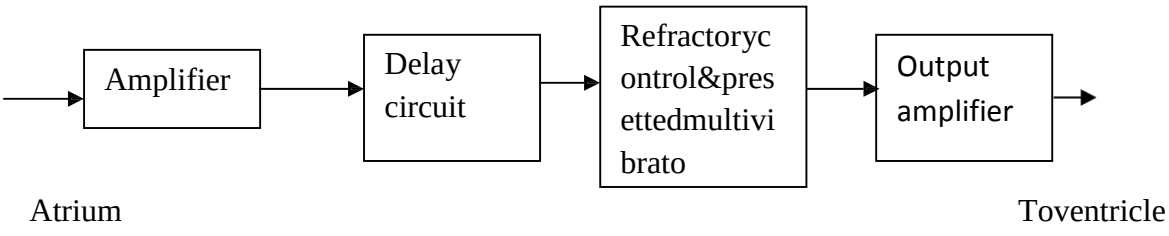


Figure 3.3 Atrial SynchronousPacemaker

- The output of the delay circuit given to refractory control and preset multivibrator block.
- If the P wave amplitude is not in normal value, then fixed rate pacemaker will turn ON. When P-wave amplitude is normal, then fixed rate pacemaker isOFF.
- If fixed rate pacemaker is ON, then the output is given to amplifier. The

amplified signal is given to ventricle throughelectrode.

- Refractory control circuit provide some time delay, because pacemaker pulse is toolarge.

ATRIAL SEQUENTIAL VENTRICULAR INHIBITEDPACEMAKER

- It is used to stimulate both atrial and ventricles. It is a demand pacemaker, so based on the patients need, it provides theimpulses.
- In the modern pacemakers, magnet is placed over the pacemaker on the skin of the patient. This magnet is used to activate the reed switch. This switch, switches the pacemaker into any one of the mode of operation, either to give the impulse for atrial or toventricle.

COMPONENTS OFPACEMAKER

- Pulsegenerator
- Electrodes
- Battery

METHODS OF STIMULATION OFPACEMAKER

- External stimulation- Used to restart the normal rhythm of the heart in case of cardiac standstill.
- Internal stimulation-It prevents normal self triggering of theheart.

3.2 DC DEFIBRILLATION

INTRODUCTION

- To overcome the disadvantage of defibrillation method In 1962,Bernard lawn from Harward school of public health and peter bent of Brigham hospital developed a new method known as dcdefibrillation.
- In this dc defibrillation method , a capacitors charged to a high dc voltage and then rapidly discharged through electrodes across the chest ofpatient.
- DC defibrillation is capable of correcting both the atrial fibrillation and ventricular fibrillation.
- DC method produces some harm to the patient. Depending on the energy setting in the defibrillator , the amount of electrical energy discharged by the capacitor ranges between 100 to 400 joules. Discharge portion is approximately 5ms.
- In discharge waveform ,the peak value ofs current is nearly20 A and the wave is monophasic innature.
- Monophasic means most of the excursion of curve is above the baseline.

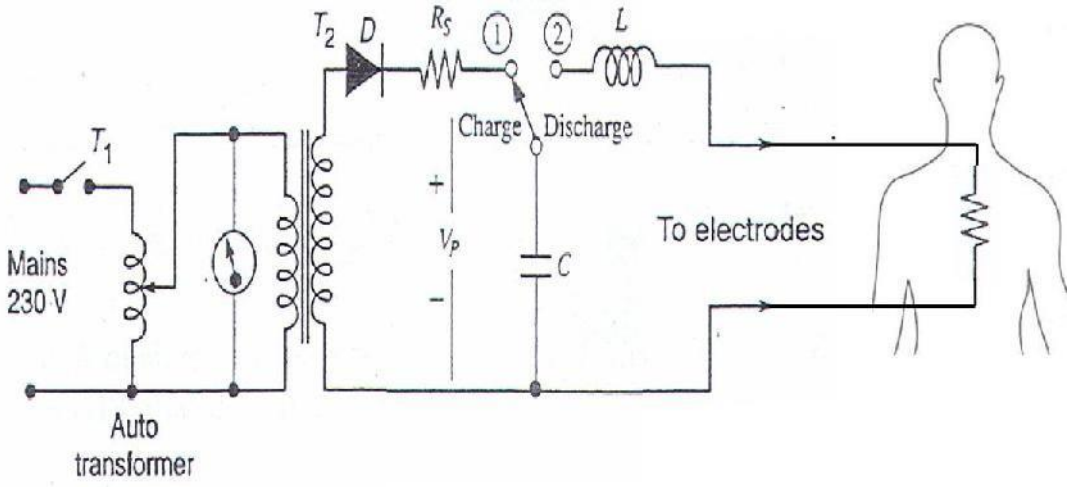


Figure 3.4 DC defibrillatorcircuit

Energy level of a defibrillator can be controlling:The voltage amplitude*VP*of the defibrillator by varying the setting onthevaractor or Duration of the defibrillator pulse. The energy (*WA*) stored in the capacitor *C* and available for the defibrillationis:

Lownwaveform: *Curve 1*shows a typical discharge pulse of defibrillator which called–Lownwaveform.

I rises rapidly to app.

20 A Then I decays to

0 with 5ms

A negative pulse is produced for 1 to 2ms

The pulse width defined as the time that elapses between the start of the impulse and the moment that the current intensity passes the zero line for the first time and changes direction (5 ms or 2.5ms).

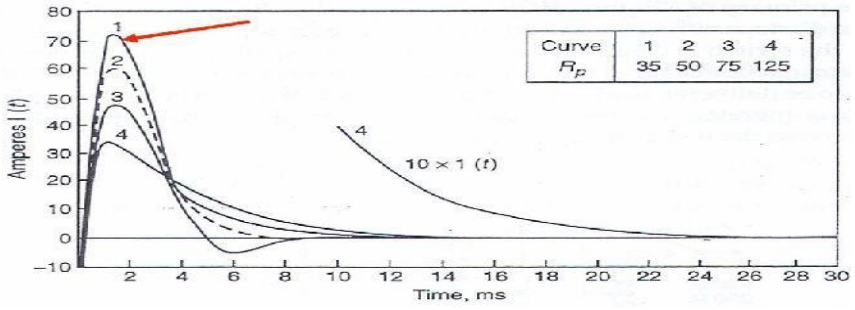


Figure 3.5DC defibrillatorwaveform

DUAL PEAK DCDEFIBRILLATOR

If peak voltage is as high as 6000V is used there is a possibility of damaging myocardium and the chestwalls.

- Produce dual peak wavereform of longer duraoltation at lowervoltage.
- Effective defibrillation is achieved in adults with lower level of deliveredenergy.
- Energy range is between 50 to 200W-sec orjoules.
- Effective defibrillation at the desirable lower voltage levels is also possible with the truncatedwaveform.
- The amplitude of the waveform is relatively constant, but is varied to get required energy.
- Large electrodes are used for the proper delivery of large current through the surface of theskin.
- These electrodes are called as paddles.

EXTERNALDEFIBRILLATOR:

- A unit based on computer technology and designed to analyze the heart rhythm itself, and then advise whether a shock is required.
- It is designed to be used by lay persons, who require littletraining.
- It is usually limited in their interventions to delivering high joule shocks for *VF* and*VT*rhythms
- The automatic units also take time (generally 10-20 seconds) to diagnose the rhythm, where a professional could diagnose and treat the condition far quicker with a manualunit.
- Automated external defibrillators are generally either held by trained personnel who will attend incidents, or are public access units which can be found in places including corporate and government offices, shopping centers, airports, restaurants,
- AEDS require self-adhesive electrodes instead of hand-held paddles for the two followingreasons:
- The ECG signal acquired from self-adhesive electrodes usually contains less noise and has higherquality ⇒ allows faster and more accurate analysis of the ECG⇒bettershockdecisions.Handsoffdefibrillationisasaferprocedurefor the operator, especially if the operator has little or notraining.

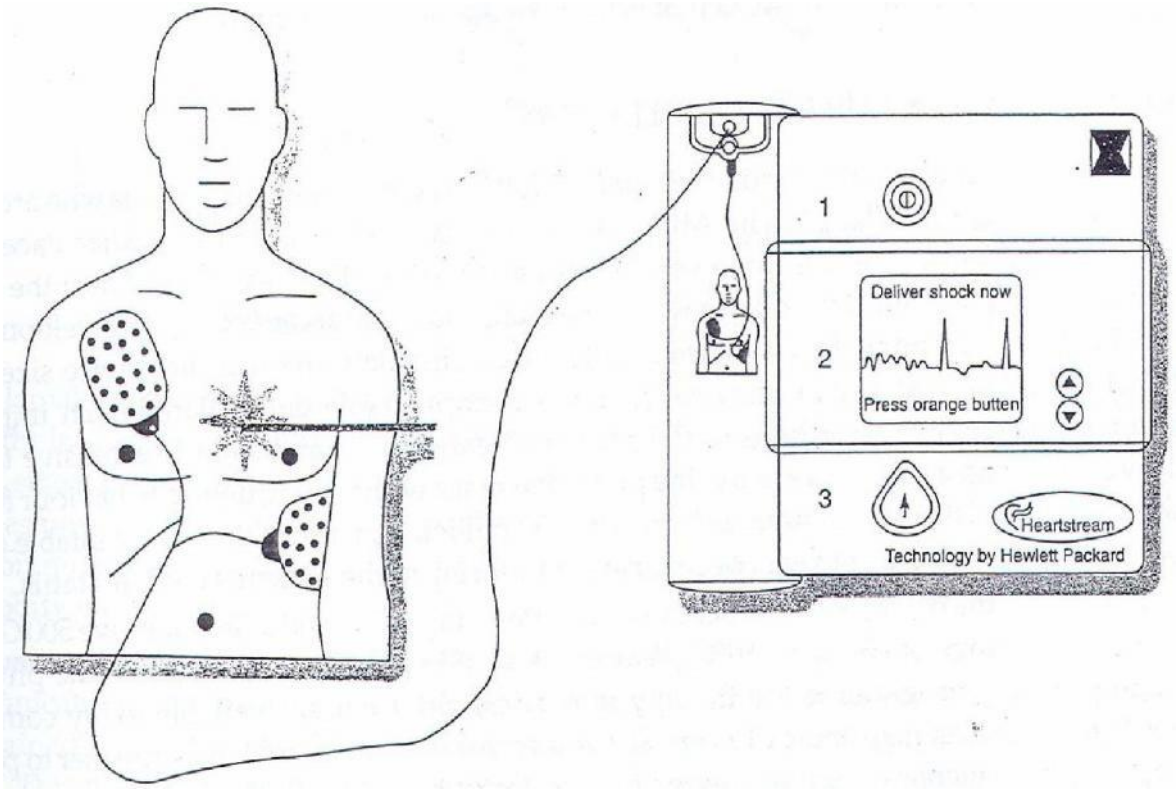


Figure 3.6 ExternalDefibrillator

DC DEFIBRILLATOR WITHSYNCHRONIZER

- Synchronization means, synchronized the working of the heart with the pacemaker. Synchronized DC defibrillator allows the electric shock at the right point on the ECG of thepatient.
- Electric shock is delivered approximately 20 to 30 ms after the peak of R wave of patientsECG.

Working

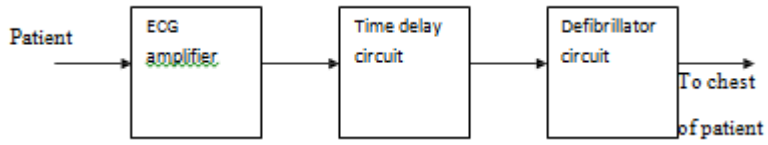


Figure 3.7 Block diagram of DC Defibrillator WithSynchronizer

- ECG waveform is traced from thepatient.
- R-wave in the output of ECG amplifier triggers the time delay circuit .It gives the delayof30msapproximately.Afterthat,defibrillatorcircuitisswitchedON.Sothat,the capacitor discharges the electric shock to the patient'sheart.
- The moment at which electric shock occurs is noted by producing the marker pulse on monitoringdisplay.
- This type of circuit is preferred in cardiacemergencies
- The sudden cardiac arrest can be treated using a defibrillator and 80 percent of the

patients will be cured from the cardiac arrest if the is given within one minute of the attack.

Electrodes used fordefibrillation

- These paddles have metal disks of 8 to 10 cm in diameter for externaluse.
- For internal use smaller paddles are used on infants andchildren.
- For external use, pair of electrodes are firmly pressed against the patientschest.

Need of InsulationHandle

- To prevent the person applying the electrodes from accidential electric shock specially insulated handles are provided in thepaddles.
- When paddles are properly positioned , this prevents the patient from receiving a shock.
- In earlier equipment a foot switch is used instead of thumbswitch.

Need of ThumbSwitch

- There is a possibility of someone accidentally stepping on the foot switch in the excitement of an emergency before the paddles are placed. So thumb switches are mostlypreferred.
-

Charging ofDefibrillators

- In some defibrillators charging is done by means of a charge switch located in the front panel of theunit.
- The charge switch is located in the handle of one of itspaddles.
- In few defibrillators the charging process begins automatically afterdischarge.
-

Types ofElectrodes

Two electrodesare

- Anterior-anterior
- Anterior-posterior

- Anterior-anterior paddles are applied to the chest. Anterior-posterior paddles are applied to both the patients chest wall and back so that energy is delivered through theheart.
- Specially designed pediatric paddles are available with diameter ranging from 2 to 6cm.

Internal paddles can be either gas-sterilized orautoclaved

IndicationMeter

- Most of the defibrillators include a watt second meter to inducate the amount of energy stored in the capacitor beforedischarge.
- The energy indicated on the meter is lost or dissipated as heat in the components inside theunit.

3.3 DIALYSER

A Dialysis Machine is an artificial kidney that treats the blood or persons with

inadequate kidney function.

Dialysis Machines are processor based pieces of equipment incorporating electromechanically controlled extracorporeal blood paths that leverage pumps and semi permeable dialyzer membranes to filter the patient's blood.

From an operational perspective, dialysis equipment need to meet specific safety criteria, one of which is single-fault tolerance. This means that no single point of failure in the pumps, motors, tubes, or electronics will endanger the patient or expose them to a hazardous condition.

This means that there will be several redundant components and circuits, as well as "watchdog" managed disengage mechanisms in the system.

These devices may include both active and passive components such as Control devices, sensors, motors, heaters, pumps, and valve drivers. Often a "Safe Mode" of operation would mean disabling the Arterial blood pump and clamping the venous line to prevent unsafe blood from flowing to the patient.

Typical Electronic Circuits in the Dialysis Machine could be:

Sensor Control Board: Contains Analog to Digital Converters, precision references, Clocks and VCOs as well as instrumentation or operation amplifiers. Although these circuits need to respond quickly, the devices included here are often geared more towards precision than what is considered high speed today.

Part of that is also driven by the need to verify a measurement or alarm signal and coordinating the response across the entire system, versus just reacting to random stimuli. The A/Ds used here would provide high reliability, good noise immunity (note that there are motors and pumps in the system), and good precision.

Arterial And Venous Control Card: These portions of a system may include functions like; Arterial and Venous Pressure Sensors, Blood Pumps, Line Clamps, Level Sensors, blood detection Sensors, and various other monitoring and control features.

Since TI's C2xxx DSPs are targeted at Motor drive and Industrial Sensor applications, they are ideally suited as the microcontroller for these blocks. Providing not only the drive and diagnostic capabilities, but also allowing the implementation of RPM, and motor coil current sensing, as well as reading the pressure transducers. There can also support the redundancy required in the system at a minimal cost impact.

Motor/Pump Drivers: There are a number of motors, pumps, valves and heaters in a Dialysis machine. Each may need a specific drive circuit, where as some may be able to be driven directly for a C2xxx controller. Selecting the right D/A converter and drive amplifier is important to the control of the motor/pump, as well as to the life expectancy of the motor/pump.

Driving any of the values or motors to hard, with signals that are to noisy can cause them to run hot and degrade quickly, as well as impact the overall comfort of the patient connected to the machine.

3.4 HEART LUNG MACHINE

The heart-lung machine is perhaps the most important contribution to the advancement of surgery in the last century.

This apparatus was designed to perform the functions of both the human heart and the lungs allowing surgeons to suspend normal circulation to repair defects in the heart.

The development of a clinically safe and useful machine was the rate-limiting step to the development of modern cardiac surgery.

Since its inception, the heart-lung machine has enabled the surgical treatment of congenital heart defects, coronary heart disease, valvular heart disease, and end-stage heart disease with heart transplantation and mechanical assist devices or artificial hearts.

The heart-lung machine consists of several components that together make up a circuit that diverts blood away from the heart and lungs and returns oxygenated blood to the body.

Commercial investment and production of these components has resulted in wide variability in the design of each, but the overall concept is preserved.

During an operation, a medical specialist known as a perfusionist operates the heart-lung machine. The role of the perfusionist is to maintain the circuit, adjust the flow as necessary, prevent air and particulate emboli from entering the circulation, and maintain the various components of the blood within physiologic parameters.

The heart-lung machine, or perfusion pump, is composed ofa chamber that receives all the blood from the body, which is the responsibility of the right atrium of the heart.

The machine then pumps the blood through an oxygenator, which is the function of the right ventricle. This oxygenator removes the carbon dioxide and adds oxygen to the blood, which is the typical function of the lungs.

The machine then continues by pumping the oxygenated blood back to the body, which is the function of the left atrium and ventricle. This process is possible by a series of tubes that are connected to the patient by a team of surgeons.

The heart-lung machine itself is operated by perfusionists during the surgery. To end an operation, the surgeon gradually lets the patient’s heart resume its normal functions.

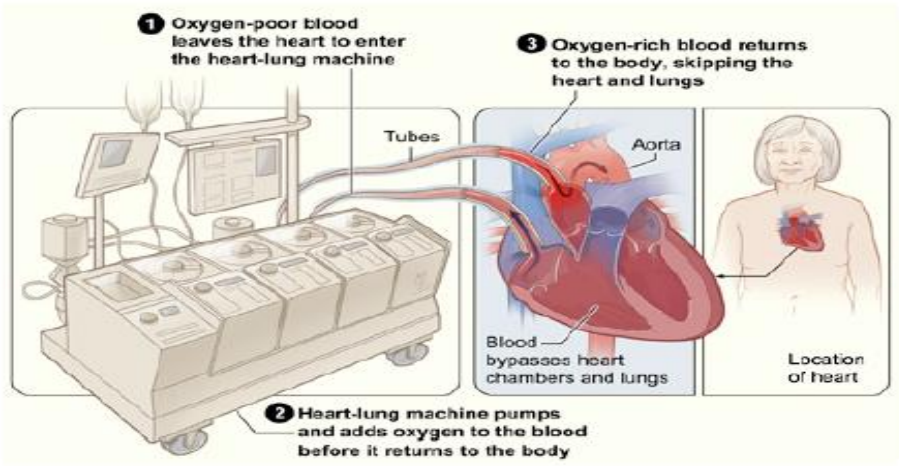


Figure 3.8 Heart lung machine

- The result of the heart-lung pump is the ability of a surgeontoperform an open-heart surgery in a blood-free zone whilethe heart is not beating.
- Such a procedure, called cardiopulmonary bypass, allows for supporting the circulation of the blood when operations require the opening of the heart's chambers.
- CPB can also be used to induce total body hypothermia, where the body can be maintained for up to 45 minutes without perfusion (blood flow).
- If blood flow were to be stopped at normal body temperature, permanent brain damage will occur in just a few minutes, followed by almost certain death shortly after.
- The heart-lung machine also allows for medications andanesthetics to be administered directly into the blood, simply by adding them to the blood in the heart-lung reservoir, arriving immediately to the patient.

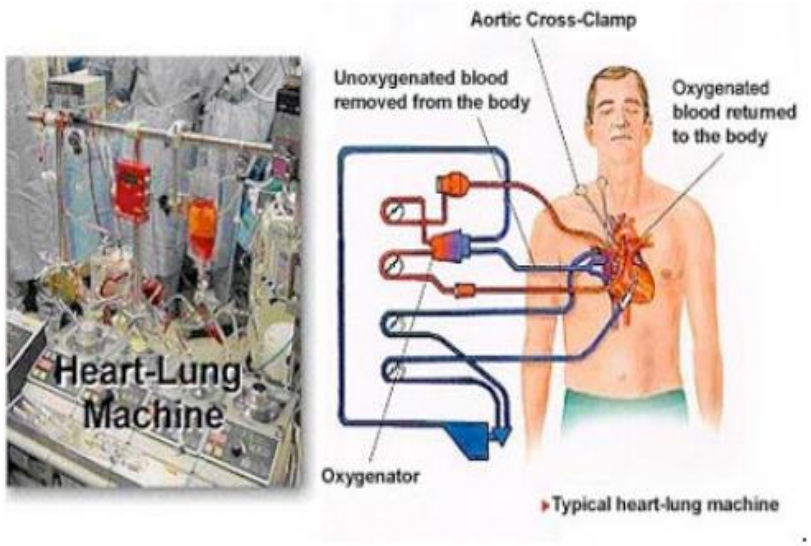


Figure 3.8 Heart lung Machine Interfacing with Human

Advantage

- The clear advantage to the heart-lung machine is being ableto allow doctors to operate in a blood-free area.
- This should contribute to less surgical error.

Disadvantage

- The disadvantage is thatbrain damage can still occur, particularly a syndrome knownas “pumphead”.
- The effects can include defects to attention, concentration, short term memory, and fine motor function.
- In the future, the heart-lung pump will hopefully become portable, allowing for paramedics to aid heart attack patients on the scene, for instance. Also, the device will be further developed to allow for less brain damage after the surgery.

UNIT IV

PHYSICAL MEDICINE AND BIOTELEMETRY

4.1 DIATHERMIES

Definition: Diathermy is the treatment process by which cutting, coagulation of tissues are obtained.

Advantages:

- Treatment can be controlled easily.
- Use of appropriate electrodes permit the heat to be localized only in the region tobe treated.
- Amount of heat that is to be delivered can be adjusted accurately.
- Inter lying tissues, muscles, bones, internal organs, etc, can be provided with heat by using high frequency

Physiologic Responses To Diathermy

- Not capable of producing depolarization and contraction of muscles
- Wavelengths too short

Physiologic Effects Are Those of Heat In General

- Tissue temperature increase
- Increased blood flow (vasodilation)
- Increased venous and lymphatic flow
- Increased metabolism
- Changes in physical properties of tissues
- Muscle relaxation
- Analgesia

Diathermy Heating

Doses are not precisely controlled thus the amount of heating cannot be accurately measured

Heating= Current^2 X Resistance

Types of diathermy

- Shortwave diathermy

- Ultrasonic diathermy
- Microwave diathermy
- Surgical diathermy

SHORTWAVE DIATHERMY

- Power supply powers radio frequency oscillator (RFO)
- RFO provides stable drift-free oscillations at given frequency
- Power amplifier generate power to drive electrodes
- Output resonant tank tunes in the patient for maximum power transfer

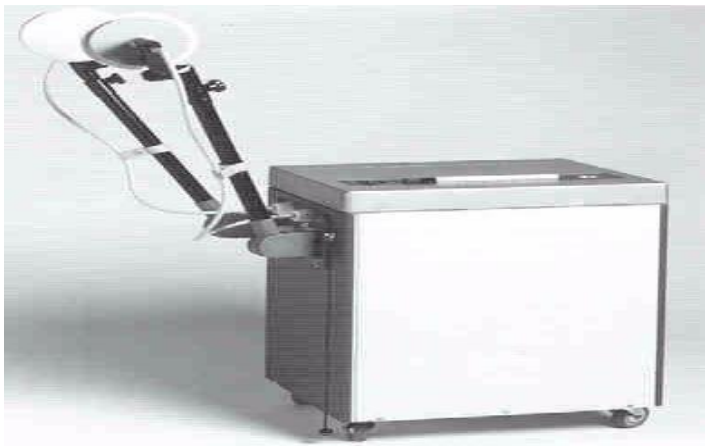


Figure4.1 Short wave diathermy unit

- Power output should provide energy to raise tissue temp to therapeutic range (40-45 deg c) (80-120 watts)
- Should exceed sar-specific absorption rate (rate of energy absorbed /unit area of tissue mass)
- Generates both an electrical and a magnetic field

SWD Electrodes

- Capacitor electrodes
- Inductor electrodes
- Selection of appropriate electrodes can influence the treatment

Capacitor Electrodes

- Create stronger electrical field than magnetic field
- Ions will be attracted or repelled depending on the charge of the pole

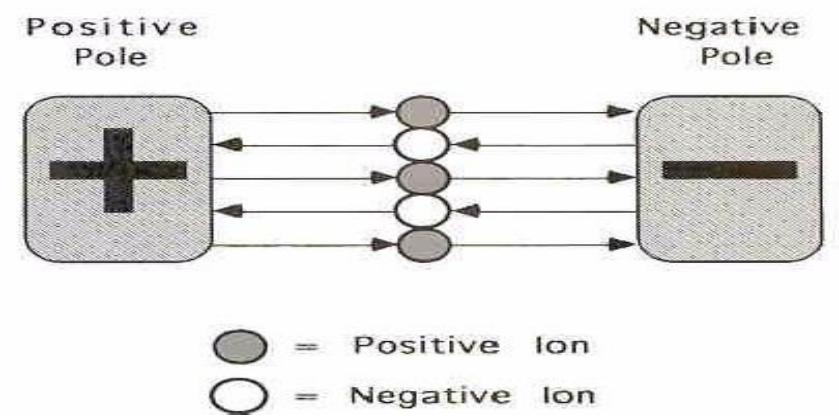


Figure 4.2 Capacitor Electrodes

- Electrical field is the lines of force exerted on charged ions that cause movement from one pole to another
- Center has higher current density than periphery
- Patient is between electrodes and becomes part of circuit
- Tissue is between electrodes in a series circuit arrangement
- The tissue that offers the greatest resistance to current flow develops the most heat
- Fat tissue resists current flow
- Thus fat is heated in an electrical field
- Typical with capacitor electrodes

Air Space Plates

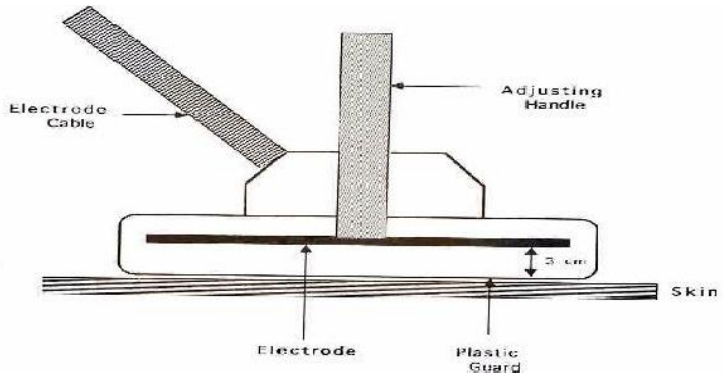


Figure 4.3 Air Space plates

- Two metal plates surrounded by plastic guard
- Can be moved 3cm within guard
- Produce high-frequency oscillating current
- When overheated discharges to plate of lower potential
- Area to be treated is pllaced between electrodes becoming part of circuit
- Sensation of heat in direct proportion to distance of electrode from skin
- Closer plate generates more surface heat

- Parts of body low in subcutaneous fat best treated

Pad Electrodes

- Greater electrical field
- Patient part of circuit
- Must have uniform contact (toweling)
- Spacing equal to cross-sectional diameter of pads
- Part to be treated should be centered
- Increasing the spacing will increase the depth of penetration but will decrease the current density

Induction Electrodes

Creates a stronger magnetic field than electrical field. A cable or coil is wrapped circumferentially around an extremity or coiled within an electrode

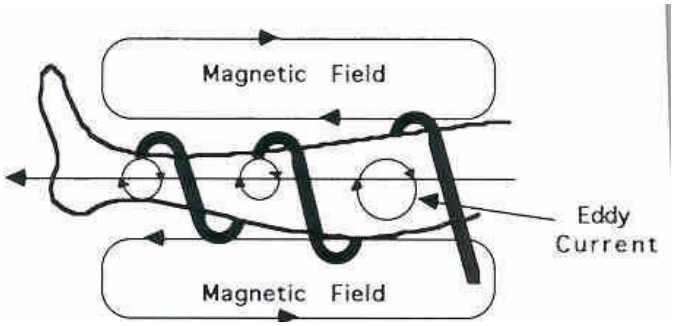


Figure4.4 Induction Electrode

- Passing current through a coiled cable creates a magnetic field by inducing eddy currents (small circular electrical fields) that generate heat
- Patient in a magnetic field not part of a circuit
- Tissues in a parallel arrangement
- Greatest current flow through tissue with least resistance
- Tissue high in electrolytic content respond best to a magnetic field

Cable Electrode

Two arrangements
Pancake coils
Wraparound coils
Toweling is essential
Pancake coil must have 6" in center then 5-10cm spacing between turns

Drum Electrode

One or more monopolar coils rigidly fixed in a housing unit May use more than one drum depending on area treated.

Toweling important.

ULTRASONIC DIATHERMY

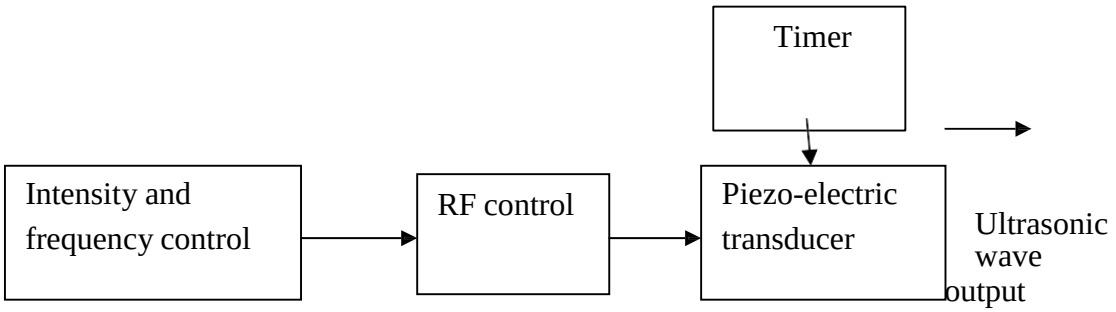


Figure 4.5 Block diagram of Ultrasonic diathermy

- It is used for curing the diseases of peripheral nervous system, skeletal muscle system and skin ulcers.
- It is adopted when the short wave treatment has failed and it helps to achieve the localization of heart to the affected part.
- The heating effect is produced in the tissues by the absorption of ultrasonic energy. The absorption effect is similar to that of a micro massage.
- It is better than the manual massage because the micro massage provides a greater depth of massage without causing any pain to the patient.
- Piezo-electric transducer is excited by the high frequency alternating current produced by the Rf oscillator.
- Ultrasonic wave from the piezo electric transducer is used for the purpose of treatment.
- It can be applied in continuous mode or pulse mode.
- Frequency range of 800 KHz to 1MHz is suitable for the ultrasonic method of treatment

MICROWAVE DIATHERMY

- In this method the tissues are heated by the absorption of microwave energy. The frequency used is about 2450 MHz.
- Better results are obtained by the microwave method and it is more advantageous than the short wave method.
- There is no pad electrodes and flexible cable.
- Microwave is transmitted into body and treat directly from the direction of unit.
- Microwaves are produced with the help of magnetron
- Proper cooling arrangements are made for the purpose of cooling the magnetron

Precautions

- Necessary precautions should be taken during this method of treatment
- Excessive dosage causes skin burns and the skin should be dry as the waves are rapidly absorbed by water.

Disadvantages

- Patients with implanted pacemaker should not undergo this treatment
- There are possibilities of over heating
- Care should be taken while the treatment is made near the eyes**.**

4.2 SURGICAL DIATHERMY

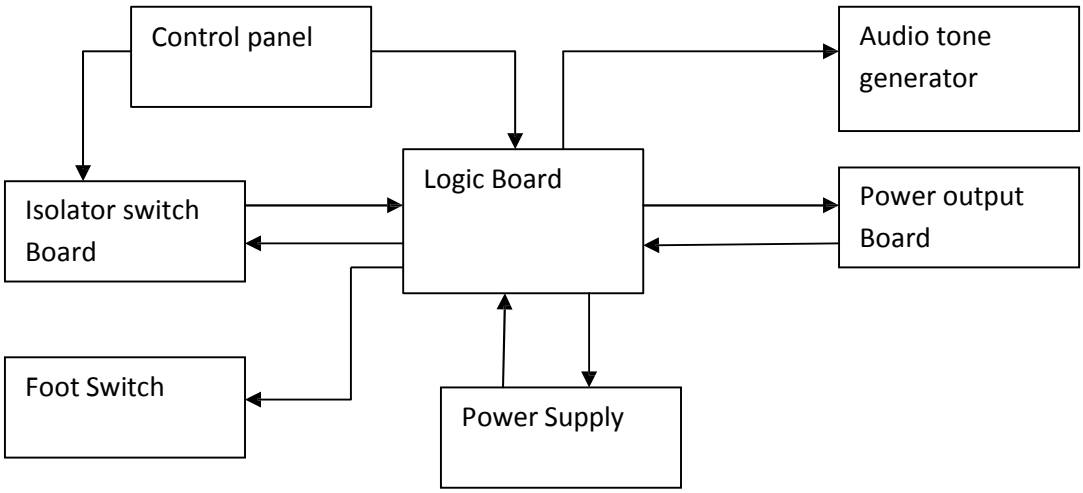


Figure 4.6 Block diagram of electrosurgical diathermy

- Logic board is the main part of the unit which produces the necessary waveforms for cutting, coagulation and hemostasis modes of operation.
- An astable multivibrator generates 500 kHz square pulses. The output from this oscillator is divided into a number of frequencies using binary counters.
- These frequencies are used as system timing signals, A frequency of 250 KHz provides a split phase signal to drive output stages on the power output board.
- Frequency of 250 Hz is used for cutting , after the high power amplification by push pull amplifier.
- The output of the push pull amplifier is given to a transformer so that the voltage is stepped up and the output signal from the unit is well isolated.
- The isolator switch provides an isolated switching control between the active hand switch and the rest of the unit.

4.3 TELEMETRY PRINCIPLES & BIO TELEMETRY

Telemetry is a technology that allows remote measurement and reporting of information. The word is derived from Greek roots *tele* = remote, and *metron* = measure. Systems that need external instructions and data to operate require the counterpart of telemetry, telecommand.

Although the term commonly refers to wireless data transfer mechanisms (e.g. using radio or infrared systems), it also encompasses data transferred over other media, such as a telephone or computer network, optical link or other wired communications. Many modern telemetry systems take advantage of the low cost and ubiquity of GSM networks by using SMS to receive and transmit telemetry data.

- Telemetry is the measurement of biological parameters over long distance.
- For conveying biological information from a living organism and its environment to a different location where this can be recorded.
- This involves radio frequency signal as a carrier for modulation, referred to as radio telemetry.

ELEMENTS OF BIOTELEMETRY

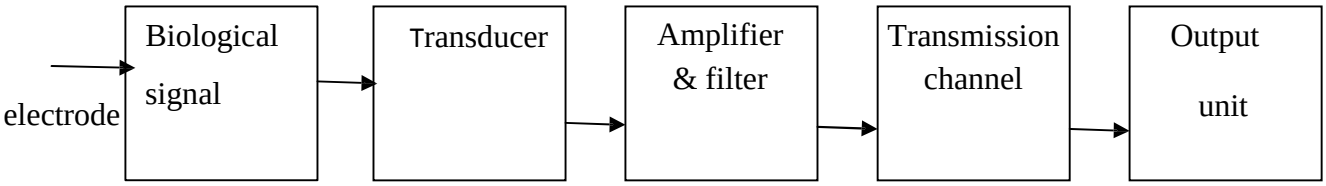


Figure 4.7 Block diagram of bio telemetry system

ECG,EEG,EMG- Electrodes act as transducer
For measuring temperatures-Thermisto is used as transducer
For measuring blood pressure-strain gauge is used as transducer
For measuring stomach pH-glass electrode is used as transducer.

DESIGN OF BIO TELEMETRY

- Telemetry system should be selected to transmit the bio –electric Signal with maximum fidelity and simplicity.
- The system should not affect the living system by any interference.
- Smaller in size light in weight.
- It should have more stability and reliability.
- The power consumption at the transmitter and receiver should be small.
- It should reject common mode interference rejection.
- Miniatured radio telemetry system should be used to reduce noise.

RADIO TELEMETRY SYSTEMS

- Single channel telemetry system
- Multi channel telemetry system

SINGLE CHANNEL TELEMETRY SYSTEM

- For a single channel telemetry system, a miniature battery operated radio transmitter is connected to the electrodes of the patients.
- The transmitter broadcasts the biopotential to a remote place in which the receiver detects the radio signal and recovers signal for further processing.
- The receiving system can be located in a room separately from the patients.
- The only risk is shock to the patient.

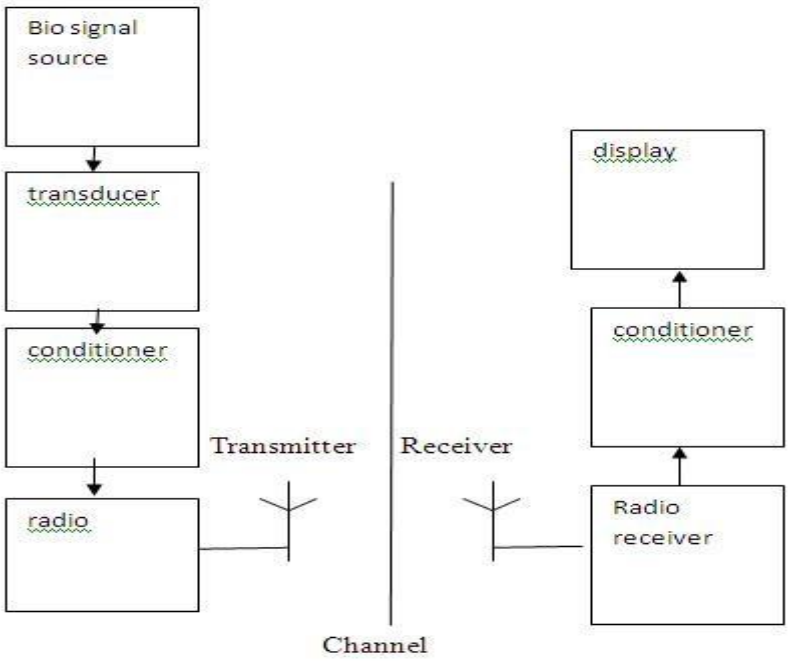


Figure 4.8 Block diagram of Single Channel Telemetry System

- Biosignal from the patient is converted into electrical signals by the transducer.
- They are amplified and filtered at the conditioner. Further they are frequency modulated or pulse modulated.Frequency modulation provides the high noise interference rejection and high stability.
- The biosignals are amplified to radio frequency range of few hundred KHz to about 300 KHz and then they are transmitted by transmitter antenna.s
- At radio receiver the corresponding frequency are received and then they are demodulated, amplified and displayed.

Transmission of bioelectric variables:

- Active measurements
- Passive measurements

Tunnel diode FM transmitter

- The tunnel diodes exhibit a specific characteristics known as negative resistance. They have extremely low values of inductance an capacitance.
- It is used for the transmission of EMG,ECG, respiration rates.
- Tunnel diodes are used as active devices and this circuit has higher fidelity and sensitivity.
- Total weight is 1.44 gm with battery and the size is small.
- Varactor diode is basically a reverse biased PN junction which utilizes the inherent capacitance of depletion layer.
- Varactor diodes are voltage capacitors used for frequency modulation.
- The signal is transmitted through the inductor L of the tank circuit of RF oscillator.

Advantages:

- All the signal can be transmitted by using the circuit.
- No shielded room is needed.
- Interference is much reduced.

Radio telemetry with sub carrier sytem:

Transmitter side:

- When the position of transmitter to the body or other conduction object change, the carrier frequency and amplitude will change due to the loading change of the carrier frequency resonant circuit.
- If the signal has a frequency different from the loading effect ,they can be separated by filters. .Otherwise the real signal will be distorted by loading effect.
- To avoid this loading effect the sub carrier system is needed. The signal is modulated on a sub carrier to convert the signal frequency to the neighbourhood of the sub carrier frequency.
- Then the RF carrier is modulated by this sub carrier carrying the signal.
    - The 20 KHz sub carrier signal is given to amplitude modulator.
    - The signals are amplified and forwarded to the transmitter.

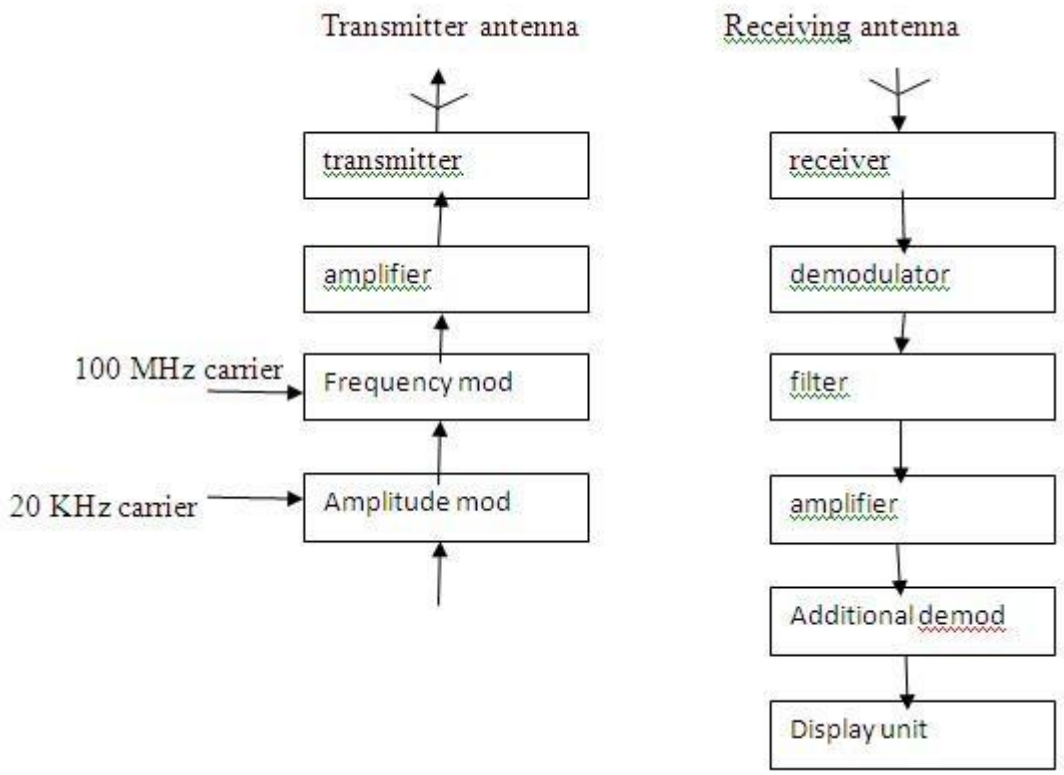


Figure 4.9 Bio telemetry using sub carrier system

Receiver side:

- At the receiver end the receiver detects the RF and recovers the sub carrier carrying the signal.
- At the receiver side, the signals are passed to demodulator, demodulated signal is filtered, amplified by amplifier and then they are given to additional demodulator. It is used to convert the signal from the modulated sub carrier system an to get the original signal.
- Finally the signal is displayed**.**

MULTI CHANNEL TELEMETRY SYSTEM:

- For most biomedical applications, simultaneous recording of Bio signals are required for correlation study.
- Each signal is in need of one channel. When the number of channels is more than the two or three, the simultaneous operation of the several single channel is difficult. At that time multiple channel telemetry system is adopted**.**

Two types of multiplexing:

I) FDM
II) TDM

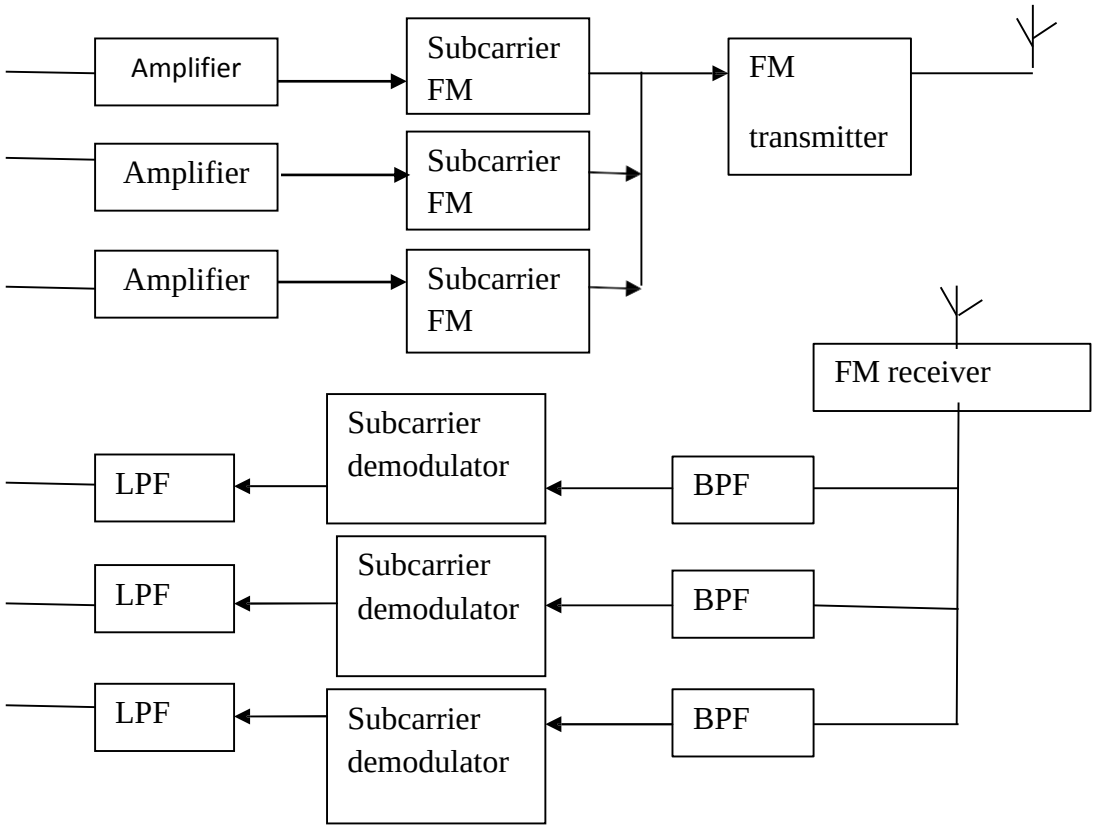


Figure 4.10 Frequency Division Multiplex System

- Each signal is frequency modulated on a sub carrier frequency.
- Modulated sub carrier frequencies are combined to modulate the RF carrier.
- At receiver the modulated sub carrier can be separated by the proper band pass filter.
- Then the each signals are demodulated by using specified frequency.
- Frequency of the sub carrier has to be carefully selected to avoid interference.
- The low pass filter are used to extract the signals without any noise. Finally the output unit displays the original signal.

Time division multiplex telemetry system:

- Most biomedical signals have low frequency bandwidth requirement, we can use time division multiple system by time sharing scheme.
- Transmission channel is connected to each signal channel input for a short time to sample and transmit that signal.
- Transmitter is switched to the next input signal channel in a definite sequence.
- All the channels have been scanned once, a cycle is completed and the next cycle will start. Scanning follows a order from signal 1 to signal 3.
- At the receiver the process is reversed. The sequentially arranged, signal pulses are

given to the individual channels by using gate signal generator.

- If the number of scanning cycles per second is large and if the transmitter and the receiver are synchronized, the signal in each channel at the receiver side can be recovered. But the scanning frequency has to satisfy the following condition.

$$f_{scan} = 2f_{max}$$

The maximum number of channels practically allowed is smaller than the calculated value of n to avoid the interference between channels.

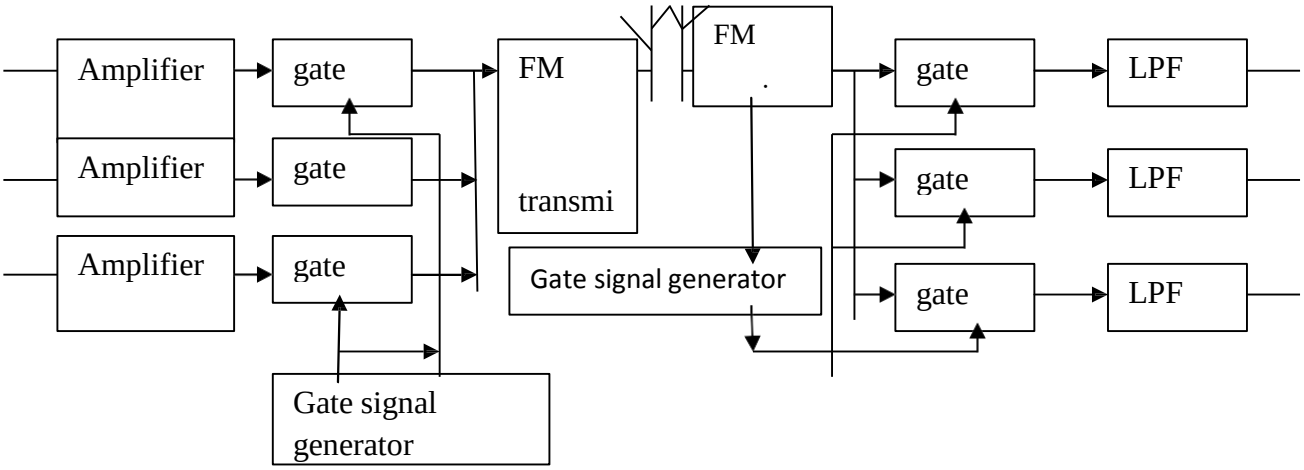


Figure 4.11 Time Division Multiplex System

Advantages of biotelemetry:

- Used to record the biosignals over long periods.
- Patient is not disturbed during recording
- For future reference or to study the treatment effect
- Monitor the athletes running a race.
- For monitoring the persons who are in action the biotelemetry is an ideal one.
- For recording on animals, particularly for research , the biotelemetry is greatly used.

Applications

Motorracing

- Telemetry is a key factor in modern motor racing, allowing race engineers to interpret the vast amount of data collected during a test or race, and use that to properly tune the car for optimum performance. Systems used in some series, namely Formula One, have become advanced to the point where the potential lap time of the car can be calculated and this is what the driver is expected to meet. Some examples of useful measurements on a race car include accelerations (G forces) in 3 axis, temperature readings, wheel speed, and the displacement of the suspension. In Formula 1, the driver inputs are also recorded so that the team can assess driver performance and, in the case of an accident, the FIA can determine or rule out driver error as a possible cause.

- Later developments saw two way telemetry, that allowed the engineers the ability to update calibrations on the car in real time, possibly while it is out on the track. In Formula 1, two-way telemetry surfaced in the early nineties from TAG electronics, and consisted of a message display on the dashboard which the team could update. Its development continued until May 2001, at which point it was first allowed on the cars.

- By 2002 the teams were able to change engine mapping and deactivate particular engine sensors from the pits while the car was on track. For the 2003 season, the FIA banned two-way telemetry from Formula 1, however the technology still exists and could eventually find its way into other forms of racing or road cars.

- In addition to that telemetry has also been applied to the use of Yacht racing. The technology was applied to the Oracle's USA-76.

Agriculture

- Most activities related to healthy crops and good yields depend on timely availability of weather and soil data. Therefore, wireless weather stations play a major role in disease prevention and precision irrigation. These stations transmit major parameters needed for good decisions to a base station: air temperature and relative humidity, precipitation and leaf wetness (for disease prediction models), solar radiation and wind speed (to calculate evapotranspiration), water deficit stress (WDS) leaf sensors and soil moisture, crucial to understand the progress of water into soil and roots for irrigation decisions.

- Because local micro-climates can vary significantly, such data needs to come from right within the crop. Monitoring stations usually transmit data back by terrestrial radio though occasionally satellite systems are used. Solar power is often employed to make the station independent from local infrastructure.

Water Management

- Telemetry has become indispensable for water management applications, including water quality and stream gauging functions. Major applications include AMR (automatic meter reading), groundwater monitoring, leak detection in distribution pipelines and equipment surveillance. Having data available in almost real time allows quick reactions to occurrences in the field.

Defense, space and resource exploration systems

- Telemetry is an enabling technology for large complex systems such as missiles, RPVs, spacecraft, oil rigs and chemical plants because it allows automatic

monitoring, alerting, and record-keeping necessary for safe, efficient operations.

- Space agencies as NASA, ESA,and other agencies use telemetry/telecommand systems to collect data from operating spacecraft and satellites.
- Telemetry is vital in the development phase of missiles, satellites and aircraft

because the system might be destroyed after/during the test. Engineers need critical system parameters to analyze (and improve) the performance of the system. Without telemetry, these data would often be unavailable

Rocketry

- In rocketry, telemetry equipment forms an integral part of the rocket range assets used to monitor the progress of a rocket launch. Some special problems are the extreme environment (temperature, accelerations, vibrations...), the energy supply, the precise alignment of the antenna and (at long distances, e.g. in spaceflight) the signal travel time.

Flight Test

- Flight test programs typically telemeter data collected from on-board flight test instrumentation over a PCM/RF link.This data is analyzed in real-time for safety reasons and to provide feedback to the test pilot. Particular challenges for telemetering this data includes fading, multipath propagation and the Doppler effect. The bandwidth of the telemetry link is often insufficient to transfer all the data acquired and therefore only a limited set is sent to the ground for real-time processing while an on-board recorder ensures the full dataset is available for post flight analysis.

Enemy Intelligence

- Telemetry was a vital source of intelligence for the US and UK when Soviet missiles were tested. For this purpose, the US operated a listening post in Iran. Eventually, the Russians discovered this kind of US intelligence gathering and encrypted their telemetry signals of missile tests. Telemetry was a vital source for the Soviets who would operate listening ships in Cardigan Bay to eavesdrop on the UK missile tests carried out there.

ENERGY MONITORING

- In factories, buildings, and houses, energy consumption of systems such as HVAC are monitored at multiple locations, together with the related parameters (e.g. temperature) via wireless telemetry to one central location. The information is collected and processed enabling intelligent decisions regarding the most efficient use of energy to be implemented. Such systems also facilitate predictive maintenance.

4.4 RADIO PILLS

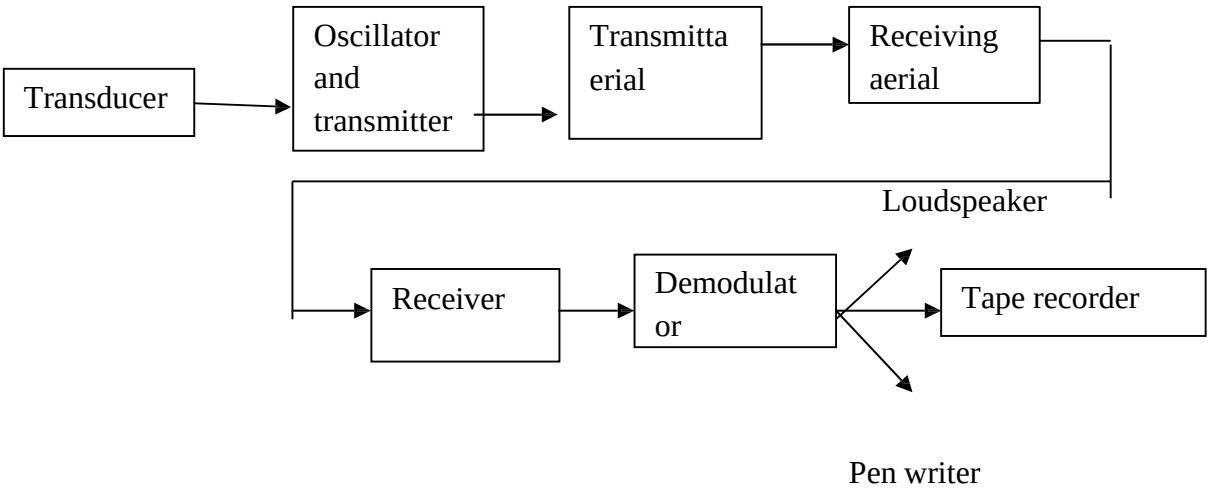


Figure 4.12Block diagram of Radio Pills

It contains transducer sensitive to pH, temperature and pressure. It is used for telemetring continuous informations about one or various variables from lumen of the gut. Temperature sensitive pills are designed by the medical research council's bioengineering lab

4.5 ELECTRICAL SAFETY OF MEDICAL EQUIPMENT

The patient in hospital is the center of care, but he is also helpless in the center of potential dangers, which are in the industry, long time ago, as such identified (i.e. chemicals, electricity, radiation).Safety in hospital means firstly patient safety, but it means also safety of operators and others. Electrical safety is a very important element in hospital safety. The electrical safety of the medical equipment in hospital is the most important of it.

Medical. Enggineering. & El. Safety

Assurance the highest possible level of med. Equipment safety in hospital is one of the most important tasks of the med. / clinical engineer.The med. / clinical engineer, therefore, must be aware of and very familiar with the issues of the electrical safety of the medical equipment in hospital. Electrical Safety means electrical shock protection.

The Mechanism of the El. Shock

El. Shock occurs when a victim is a part of an electrical circuit (an element closing it), in which an electrical current can flow and has the ability to harm the victim or even cause death (electrocution).That means consequently that there must be a simultaneous two-points contact of the victim with the electrical shock circuit.

El. Shock = Closing the El. Shock Circuit

El. Power Distribution System

For technical reasons, neutral point (and consequently the neutral line) is deliberately connected to earth. It is this connection that makes the electrical service a "grounded system".Understanding this is the key for understanding the mechanism of electric shock and electrocution.The voltage between the two power-carrying wires (Phase (P) & Neutral (N) or "hot & cold") is also present between Phase and Ground (which is not considered as power- carrying wire) and every thing connected to earth.

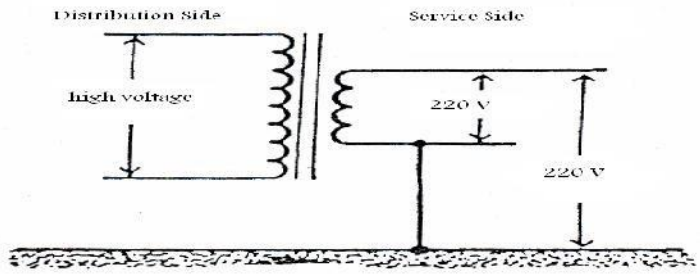


Figure 4.13Power distribution system

Two Kinds of Grounding / Earthing

Grounding of Electrical Systems:

Connecting N-line of the service side to earth due to technical reason and for protection of systems and plants (removing the floating high voltage in the secondary (service) side of the distribution transformer).

Protective Grounding:

Connecting conducting parts, which are not intended for carrying current in normal circumstances (enclosures; switch-, fuse-, outlet- metal boxes; etc.) via 3rd conductor (which, in normal situations, does not carry current) to earth.

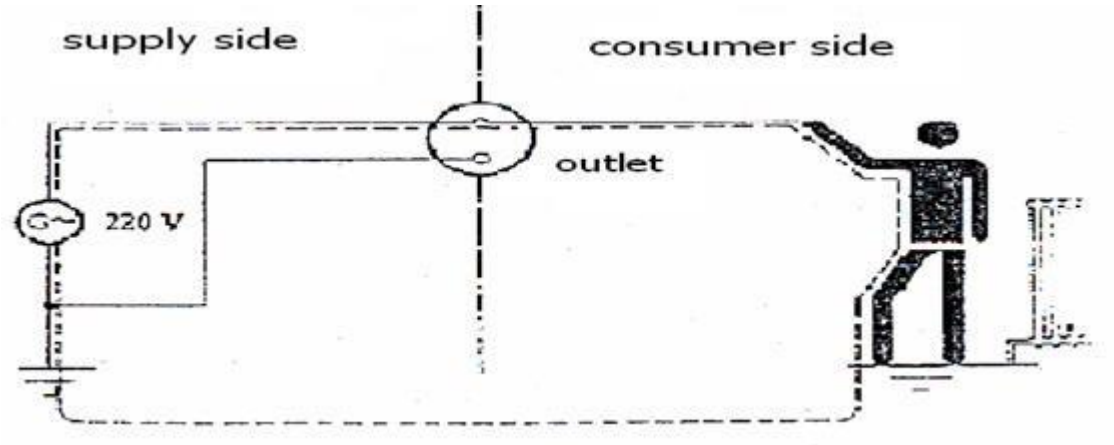


Figure4.14 Basic shock circuit

Leakage Currents: Caused by stray capacitances, which are always present between conducting surfaces.

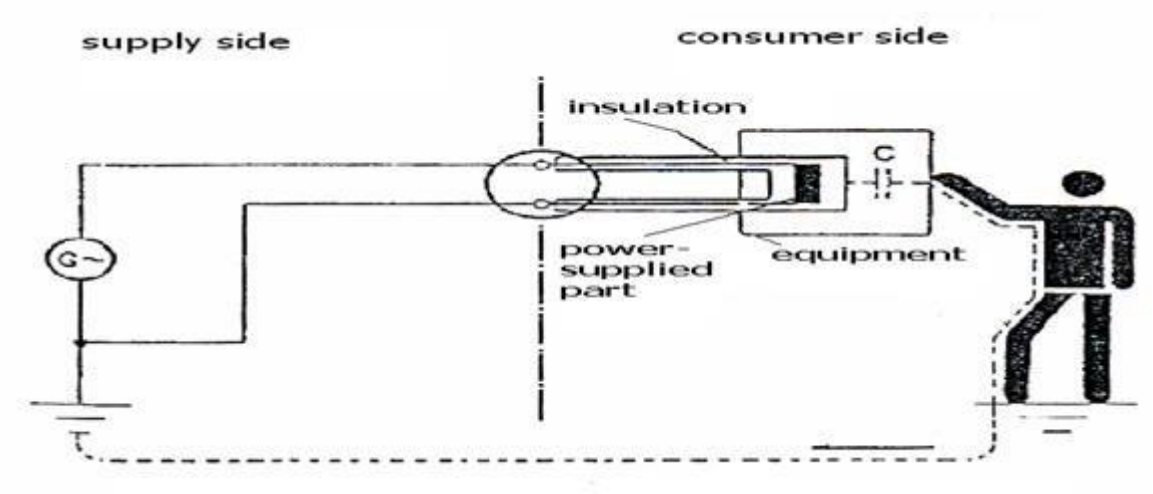


Figure 4.15 Stray capacitance and leakage current

Leakage Current & Fault Current

Due to the relatively low values of the stray capacitances and frequency, the resulting el. Pathway is very high resistive , and hence, the resulting leakage currents are very low.Distinguishing between leakage and fault current depends on the internal resistance of the source in relation to the load in a given circuit.

MACRO-SHOCK:

External or touch - current shock (voltage applied externally, current pass through the skin in and out

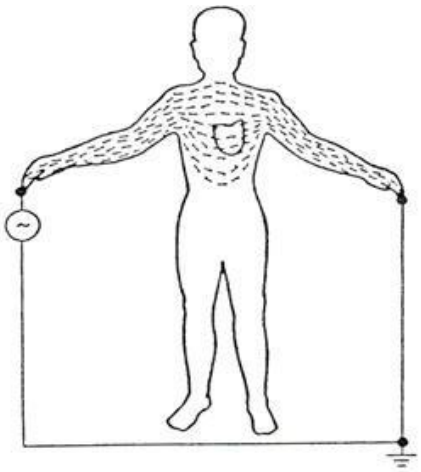


Figure 4.16 Macro shock

MICRO-SHOCK

Current affect heart directly (through pacemaker leads or catheter) Currents less than (100) micro-Ampere have the potential to cause VF (it is possible from (25) micro-Ampere up).

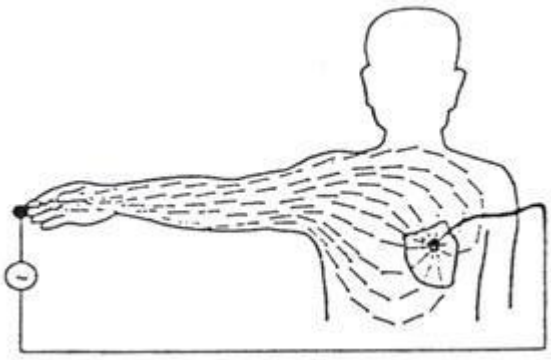


Figure 4.17Micro shock

Methods of Protection Against El. Shock

- Over-current protection (indirect protection).
- Protective earthing (grounding).

- Double insulation.
- Low voltage power supply.
- Differential circuit breaker (Ground Fault Circuit Interrupter GFCI) .
- Isolated power system (IPS).

Protective Earthing

Simple, efficient, and inexpensive, but it is not "fail-safe" (i.e. if it fails, equipment does
not go in a safe mode (alarm, power interruption for example)).

Double insulation

All surfaces which can be contacted are made of non- conductive materials, or all voltage carrying parts are double insulated. Equipment protected this way are referred to as class II, and need not to be earthed.

Low Voltage Supply

- Referred to as class III.
- Supply voltage less than 50 Volt.
- Equipment need not to be earthed.
- For wet areas: voltage less than 25 Volt.
- If skin immersed in water: voltage less than 12 Volt.
- If supply is via transformer, then primary and secondary must be galvanically separated.

Differential Circuit Breaker &GFCI

If difference between currents in "hot" and neutral wires is more than 6 mA, the circuit
breaker is activated within 5 ms.

Isolated Power System (IPS) & Isolation Transformer

Isolation transformer is used to omit the ground connection so that the el. System on
service side is no more "ground seeking

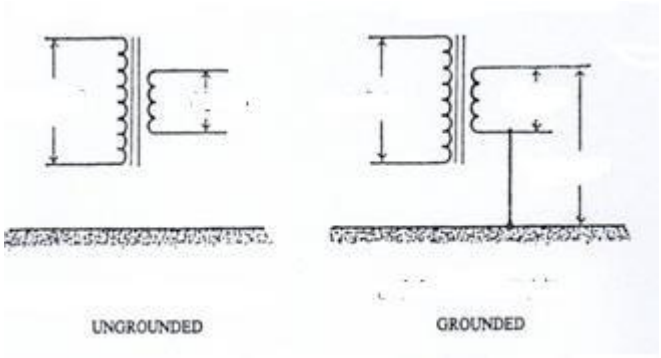


Figure 4.18 Isolation Transformer

- IPS & Line Isolation Monitor (LIM)
- IPS are not 100% isolated. It has certain "resistance" to earth (caused by stray capacitances).
- LIM measure this resistance.The monitored value in LIM represent a virtual current which would flow if a short-circuit occurred between a power carrying line and earth (prognostic value, worst case condition).
- LIM gives audio-visual alarm if the a.m. prognostic value exceeds 5 mA (USA standard).
- The 5 mA could be annoying, but it is normally not dangerous.
- Grounding of the equipment is independent of the power system (isolated or not).

IPS Applications

- IPS is a protection against macro-shock. It is not (and has never been) a protection against micro-shock (even if it makes the related safety level higher).
- IPS is necessary for operation theatres (OT), but is not necessary (and not required) for ICU.

Hazard due to ungrounded lamp

(lamp failure → lamp metal cover carries voltage → patient connected to grounded equipment touches cover → current path through patient to earth)

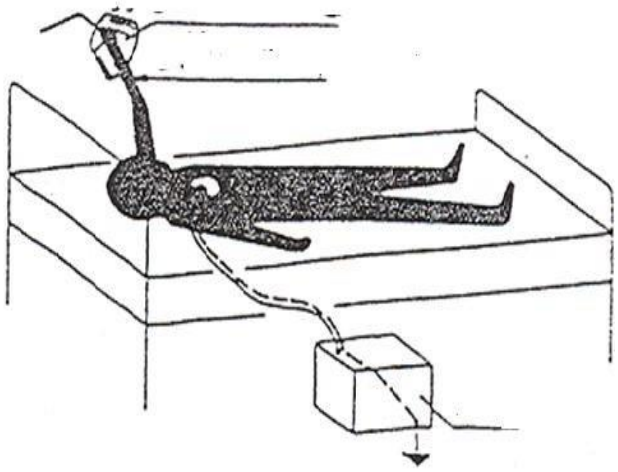


Figure 4.19 Hazard due to ungrounded lamp

Protection through non-conductive signal transfer (lamp failure → lamp metal cover carries voltage → patient connected to grounded equipment (but here via battery operated amplifier which is connected to equipment via glass fiber) touches cover → no current path through patient to earth).

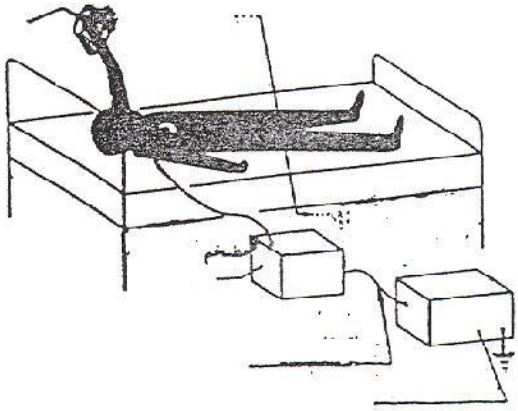


Figure 4.20 Hazard due to lamp failure

Hazards due to using open sockets (extensions)

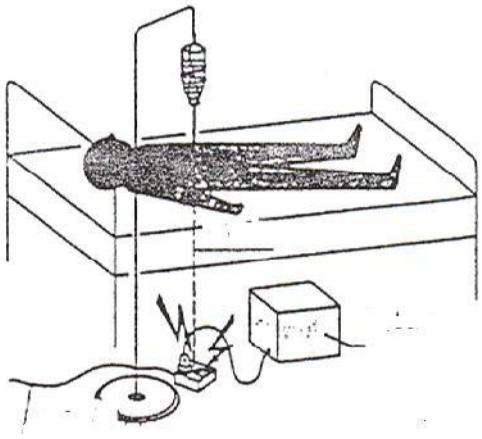


Figure 4.21 Hazards due to using open sockets

If patient connected to more than one equipment , and the equipment are powered from a socket-block, then the connection of the patient with the ground must be through one wire only.

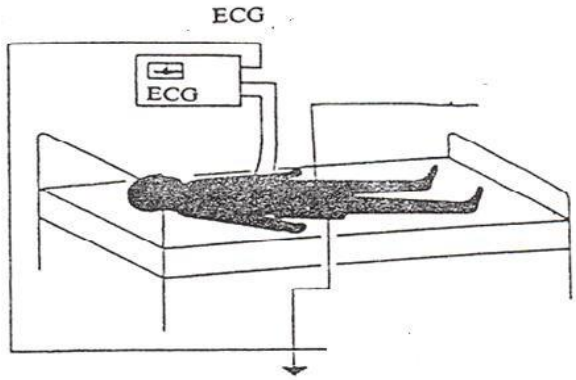


Figure 4.22 Connection of the patient with the ground be through one wire

Rules for Med. Equipment Electrical Safety

- Equipment connected to a patient to be powered from one socket, or a block of sockets having the same protective grounding point.
- All metal subjects in the vicinity of the patient to be grounded one at a time with the same protective ground point.
- Patient to be connected to the common ground through only one grounding pole.
- Isolation amplifiers to be used for measurements if possible.
- If possible, avoid using material which can be charged electro-statically .
- Deal carefully with electric wires and sockets and let it be checked periodically. Do not use extension cables. Do not use faulty cables / plugs and ask for

replacement.

- If an equipment has a failure, which can cause electric shock, it has to be taken out of service immediately. Reversing the plug (this “advice” is heard often) , which might lead to eliminate the shock, is a wrong action / behavior.
- If, by touching the metallic surface of an equipment, you sensed an electric prickle (even a light one), then plug off the equipment immediately and ask for check. This equipment is either badly earthed or not earthed at all.
- Do not use any medical equipment you do not know the basics of its operation and did not read its instruction manual carefully

UNIT V

RECENT TRENDS IN MEDICAL INSRUMENTATION

5.1 THERMOGRAPH

Thermograph, thermal imaging, or thermal video, is a type of infrared imaging. Thermo graphic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 900–14,000 nanometers or 0.9–14 μ m) and produce images of that radiation. Since infrared radiation is emitted by all objects based on their temperatures, according to the black body radiation law, thermograph makes it possible to see one's environment with or without visible illumination.

The amount of radiation emitted by an object increases with temperature, therefore thermograph allows one to see variations in temperature (hence the name). When viewed by thermo graphic camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day or night. As a result, thermograph's extensive use can historically be ascribed to the military and security services. Thermal imaging photography finds many other uses. For example, firefighters use it to see through smoke, find persons, and localize the base of a fire.

With thermal imaging, power lines maintenance technicians locate overheating joints and parts, a telltale sign of their failure, to eliminate potential hazards. Where thermal insulation becomes faulty, building construction technicians can see heat leaks to improve the efficiencies of cooling or heating air-conditioning.

Thermal imaging cameras are also installed in some luxury cars to aid the driver, the first being the 2000 Cadillac Deville. Some physiological activities, particularly responses, in human beings and other warm-blooded animals can also be monitored with thermo graphic imaging. The appearance and operation of a modern thermo graphic camera is often similar to a camcorder. Enabling the user to see in the infrared spectrum is a function so useful that ability to record their output is often optional. A recording module is therefore not always built-in.Instead of CCD sensors, most thermal imaging cameras use CMOS Focal Plane Array (FPA). The most common types are InSb, InGaAs, HgCdTe and QWIP FPA.

The newest technologies are using low cost and uncooled microbolometers FPA sensors. Their resolution is considerably lower than of optical cameras, mostly 160x120 or 320x240 pixels, up to 640x512 for the most expensive models. Thermo graphic cameras are much more expensive than their visible-spectrum counterparts, and higher-end models are often export- restricted. Older bolometer or more sensitive models as require cryogenic cooling, usually by a miniature Stirling cycle refrigerator or liquid nitrogen.

Methods of Thermography

Infrared thermography
Liquid crystal thermography
Microwave thermography**.**

INFRARED THERMOGRAPHY

Infrared thermography is the science of acquisition and analysis of thermal information by using non contact thermal imaging devices.Human skin emits infrared radiation as an exponential function of its absolute temperature and the emissive properties of the skin temperature.

The maximum wavelength λ_{max} = 10 μ m and range from 4 to 40μm.The thermal picture is usually displayed on a TV tube may be photographed to provide a permanent record.

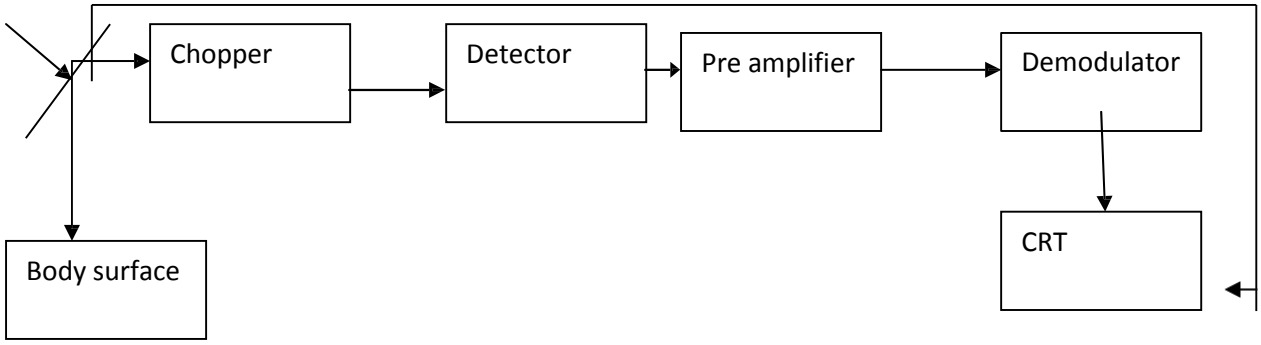


Figure 5.1 Block diagram of Infrared thermograph

Every thermo graphic equipment is provided with a special infrared camera that scales the object. The camera contains an optical system in the form of an oscillating plane mirror which scans the field of view at a very high speed horizontally and vertically and focuses the collected infrared radiations onto chopper.

The chopper disc interrupts the infrared beam so that a.c signals are produced. Then they are given to detector. The detector is infrared radiation detector. The detected output by detector is amplified and led to phase sensitive.

LIQUID CRYSTAL THERMOGRAPHY

Liquid crystals are a class of compounds which exhibit colour temperature sensitivity in the cholestric phase. Scattering effects with the material give rise to iridescent colours, the dominant wavelength being influenced by very small changes in temperature.

The high temperature sensitivity makes cholesteric liquid crystals useful for thermal mapping.In this technique, the temperature sensitive plate consists of a blackened thin flim support into which encapsulated liquid crystals cemented to a pseudo solid powder (with particle sizes between 10 to 30) have been incorporated.

Thermal contact between the skin surface and plate produces a color change in the encapsulated liquid crystals; red for relatively low temperatures through the visual spectrum to violet for high temperatures. But in infrared thermograms, the violet colour is used to identify the low temperature regions and the bright colour or red is used to identify the temperature regions.

If we want to study a breast's temperature distribution, several different plates are necessary to cover a breast temperature range from 28^0C to36^0C. Each plate covers a range of temperature 3^0C. A record of the liquid crystal image may be obtained by colour photography. The response time varies according to the thickness of plate (ranges from 0.06mm to 0.3 mm) and is 20 to 40 seconds.

MICROWAVE THERMOGRAPHY

Eventhough we get microwave emissions from the skin surface, that intensity is very small when we compare with Infra red radiation intensity . (10 wavelenght emission intensity is 10^8 times greater than 10 cm wavelength emission intensity). But using modern microwave radiometers one can detect temperature change of 0.1K. since body tissues are partially transparent to microwave radiations which orginates from a tissue volume extending from the skin surface to a depth of several centimeters. Microwave radiometers consisting of matched antennae placed in contact with the skin surface for use at 1.3 G Hz and 3.3 G Hz have been used to sense subcutaneous temperature.

The present day thermographic systems, using Infrared radiation, only give a temperature map of the skin due to low penetration depth of the short wavelength of the infrared component of the emitted radiation. Using a microwave receiver with a frequency response from 1.7 GHz to 2.5 GHz a penetration depth of 1 cm in tissue and 8 cm in fat and bone can be obtained.

A severe problem is the unknown emissivity of the body surface for microwaves, as part of the radiation is reflected back into the body.In a conventional radiometer this gives rise to a measurement error proportional to the temperature difference between the body

surface and the applied antenna. This error lies in the order of 1-2 K which is too high for medical applications.

The problem has been solved iv an elegant way by adding artificial microwave noise from the antenna,thus providing a radiation balace between the receiver and body surface. With this a temperature sensitivity of 0.1 K could be obtained. Based on the transducer attachment on the skin surface, we can classify the thermography into contact thermography and tele- thermography.

Advantages of Thermography

- Get a visual picture so that you can compare temperatures over a large area
- It is real time capable of catching moving targets
- Able to find deteriorating components prior to failure
- Measurement in areas inaccessible or hazardous for other methods
- It is a non-destructive test method

Limitations & disadvantages of thermography

- Quality cameras are expensive and are easily damaged
- Images can be hard to interpret accurately even with experience
- Accurate temperature measurements are very hard to make because of emissivities
- Most cameras have ±2% or worse accuracy (not as accurate as contact)
- Training and staying proficient in IR scanning is time consuming Ability to only measure surface areas

Applications

- Healthy Cases
- Tumors Infla mation
- Diseases of peripheral Vessels
- Burns and Perniones
- Skin Grafts and Organ Transplantation
- Collagen diseases
- Orthopedic Diseases
- Brain and Nervous Diseases
- Examination of Placenta Attachment

5.2 ENDOSCOPY UNIT

HISTORY

The first endoscope, of a kind, was developed in 1806 by Philip Bozzini with his introduction of a Lichtleiter (light conductor) for the examinations of the canals and cavities of the human body. However, the Vienna Medical Society disapproved of such curiosity. An endoscope was first introduced into a human in 1822 by William Beaumont, an army

surgeon at Mackinac Island, MichiganThe use of electric light was a major step in the improvement of endoscopy. The first such lights were external. Later, smaller bulbs became available making internal light possible, for instance in a hysteroscope by Charles David in 1908Hans Christian Jacobaeus has been given credit for early endoscopic explorations of the abdomen and the thorax with laparoscopy (1912) and thoracoscopy (1910).Laparoscopy was used in the diagnosis of liver and gallbladder disease by Heinz Kalk in the 1930. Hope reported in 1937 on the use of laparoscopy to diagnose ectopic pregnancyIn 1944, Raoul Palmer placed his patients in the Trendelenburg position after gaseous distention of the abdomen and thus was able to reliably perform gynecologic laparoscopy

The first gastrocamera was released in 1950 by Olympus Optical Co., Ltd. The device took pictures on monochromatic film using a small light bulb that was triggered manually. The device was of limited use, however, because it did not implement real-time optical capability. Olympus continued its development of endoscopes by incorporating fiber optics in the early 1960s, leading to the first useful endoscopes. In 1964, it released a gastrocamera guided by a fiberscope. A few articles claim that Dr.Basil Hirschowitz of Univ.Of Michigan,Ann Arbor discussed the endoscope in early 50's.

As endoscopic technology improved, so did the methods of gastrointestinal endoscopy. Owing primarily to the efforts of Dr. Hiromi Shinya in the late 1960s, GI endoscopy developed into what is more recognizable as today's colonoscopy. While many doctors experimented with techniques to take advantage of the new iterations of endoscopes, Dr. Shinya focused on techniques that would allow for successful operation of the endoscope by an individual, rejecting the common practice at the time of utilizing two people. Consequently, many of the fundamental methods and procedures of modern colonoscopy were developed by Dr. Shinya.

By 1980, laparoscopy training was required by gynecologists to perform tubal ligation procedures and diagnostic evaluations of the pelvis. The first laparoscopic cholecystectomy was performed in 1984 and the first video-laparoscopic cholecystectomy in 1987. During the 1990s, laparoscopic surgery was extended to the appendix, spleen, colon, stomach, kidney, and liver . Wireless capsule endoscopy or Capsule Endoscopy is now approved in all the countries including Japan where government reimbusement will be available from Oct.2007.Capsule Endoscopy increases detection of Small Bowel tumors where traditional Endoscopy is not very efficient.

Endoscopy

An endoscopy is a test that looks inside the body. The endoscope is a long flexible tube that can be swallowed. It has a camera and light inside it. Some doctors call it a telescope.Most likely to have an endoscopy to look at the inside of

Gullet (oesophagus)

Stomach

Duodenum - the first part of the small bowel that attaches to the stomach Large

bowel (colon)

There is more detailed information about having a colonoscopy in the bowel cancer section of CancerHelp UK. Below is information about having other types of endoscopy.

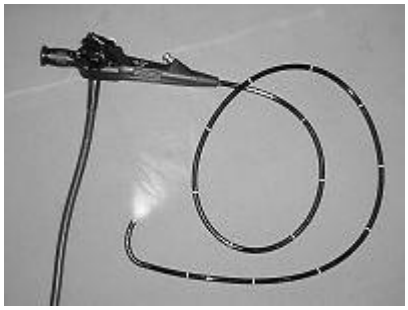


Figure 5.2 A flexible endoscope

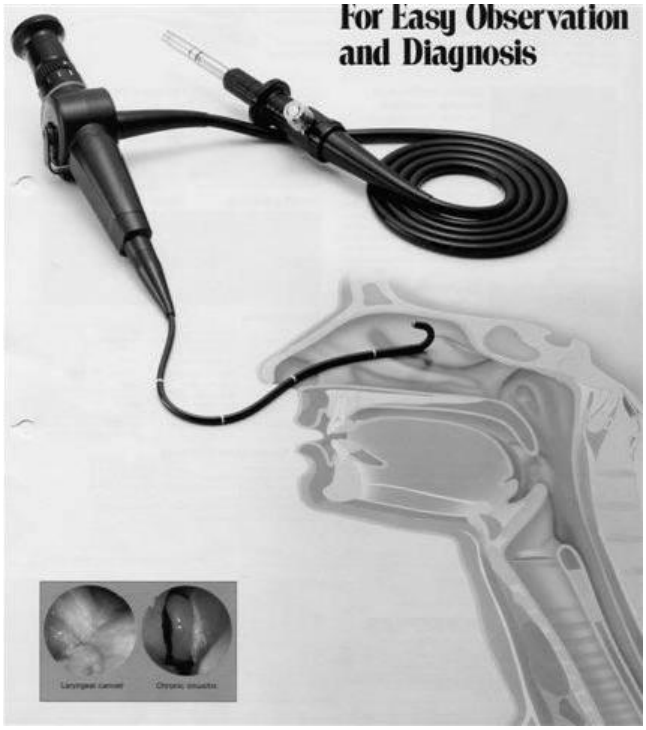


Figure 5.3 Observation using Endoscopy

Reflected light rays are collected by CCD(Charge coupled device) and electrical signals are produced, which are fed to the video monitor to get image.Thorough one channel of endoscope water and air is conducted to wash and dry the surgical site.The endoscope also has a channel through which surgeons can manipulate tiny instruments, such as forceps, surgical scissors, and suction devices.

A variety of instruments can be fitted to the endoscope for different purposes.A surgeon introduces the endoscope into the body either through a body opening, such as the mouth or the anus, or through a small incision in the skin.The endoscope gives visual

evidence of the problem,
such as ulceration or inflammation It can be used to collect a sample of tissue; remove
problematic tissue, such as polypss.It is used to take photograph of the hollow internal organs

Depending on the body part, each type of endoscopy has its own special term, such as
laparoscopy (abdomen, uterus, fallopian tube),
laryngoscopy (vocal cords),
bronchoscopy (lungs),
colonoscopy (colon),
arthroscopy (joint)
Gastroscopy (Stomach).

Components

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 to the viewer from the fiberscope
- An additional channel to allow entry of medical instruments or manipulators

Uses

Endoscopy can involve

- The gastrointestinal tract (GI tract):
- esophagus, stomach and duodenum (esophagogastroduodenoscopy)
- colon (colonoscopy,proctosigmoidoscopy)
- The respiratory tract
- The nose (rhinoscopy)
- The lower respiratory tract (bronchoscopy)
- The urinary tract (cystoscopy)
- The female reproductive system
- The cervix (colposcopy)
- The uterus (hysteroscopy)
- The Fallopian tubes (Falloscopy)
- Normally closed body cavities (through a small incision):
- The abdominal or pelvic cavity (laparoscopy)
- The interior of a joint (arthroscopy)
- Organs of the chest (thoracoscopy and mediastinoscopy)
- During pregnancy
- The amnion (amnioscopy)
- The fetus (fetoscopy)
- Plastic Surgery
- Panendoscopy (or triple endoscopy)

- Combines laryngoscopy, esophagoscopy, and bronchoscopy

Non-medical uses for endoscopy

The planning and architectural community have found the endoscope useful for pre-visualization of scale models of proposed buildings and cities (architectural endoscopy) Internal inspection of complex technical systems (borescope) Endoscopes are also a tool helpful in the examination of improvised explosive devices by bomb disposal personnel. The FBI uses endoscopes for conducting surveillance via tight spaces.

Risks

- Infection
- Punctured organs
- Allergic reactions due to Contrast agents or dyes (such as those used in a CT scan)
- Over-sedation

Recent developments

With the application of robotic systems, telesurgery was introduced as the surgeon could operate from a site physically removed from the patient. The first transatlantic surgery has been called the Lindbergh Operation.

Upper Endoscopy

Upper endoscopy enables the physician to look inside the esophagus, stomach, and duodenum (first part of the small intestine). The procedure might be used to discover the reason for swallowing difficulties, nausea, vomiting, reflux, bleeding, indigestion, abdominal pain, or chest pain. Upper endoscopy is also called EGD, which stands for esophagogastroduodenoscopy (eh- SAH-fuh-goh-GAS-troh-doo-AH-duh-NAH-skuh-pee).

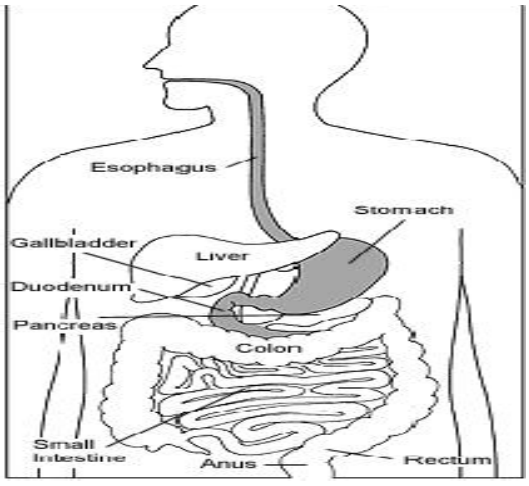


Figure5.4 Upper Endoscopy

For the procedure you will swallow a thin, flexible, lighted tube called an endoscope (EN- doh-skope). Right before the procedure the physician will spray your throat with a numbing agent that may help prevent gagging. You may also receive pain medicine and a sedative to help you relax during the exam. The endoscope transmits an image of the inside of the esophagus, stomach, and duodenum, so the physician can carefully examine the lining of these organs. The scope also blows air into the stomach; this expands the folds of tissue and makes it easier for the physician to examine the stomach.

The physician can see abnormalities, like inflammation or bleeding, through the endoscope that don't show up well on x rays. The physician can also insert instruments into the scope to treat bleeding abnormalities or remove samples of tissue (biopsy) for further tests.Possible complications of upper endoscopy include bleeding and puncture of the stomach lining. However, such complications are rare. Most people will probably have nothing more than a mild sore throat after the procedure.The procedure takes 20 to 30 minutes. Because you will be sedated, you will need to rest at the endoscopy facility for 1 to 2 hours until the medication wears off.

Preparation

Stomach and duodenum must be empty for the procedure to be thorough and safe, will not be able to eat or drink anything for at least 6 hours beforehand. Also, must arrange for someone to take home—will not be allowed to drive because of the sedatives. Physician may give other special instructions.

Need of Endoscopy

Endoscopy allows physicians to peer through the body's passageways. Endoscopy is the examination and inspection of the interior of body organs, joints or cavities through an endoscope. An endoscope is a device that uses fiber optics and powerful lens systems to provide lighting and visualization of the interior of a joint. The portion of the endoscope inserted into the body may be rigid or flexible, depending upon the medical procedure.

An endoscope uses two fiber optic lines. A "light fiber" carries light into the body cavity and an "image fiber" carries the image of the body cavity back to the physician's viewing lens. There is also a separate port to allow for administration of drugs, suction, and irrigation. This port may also be used to introduce small folding instruments such as forceps, scissors, brushes, snares and baskets for tissue excision (removal), sampling, or other diagnostic and therapeutic work. Endoscopes may be used in conjunction with a camera or video recorder to document images of the inside of the joint or chronicle an endoscopic procedure. New endoscopes have digital capabilities for manipulating and enhancing the video images

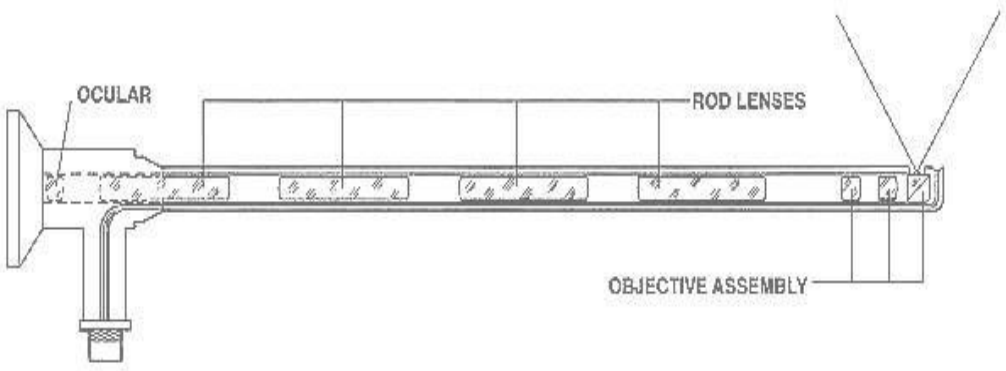


Figure 5.5 Rigid endoscope

This figure shows a rigid endoscope used for arthroscopy. The "image fiber" leads from the ocular (eye piece) to the inserted end of the scope. The "light fiber" is below and leads from the light source to the working end of the endoscope.

Types of Endoscopy

Fiber optic endoscopes now have widespread use in medicine and guide a myriad of diagnostic and therapeutic procedures including

Arthroscopy: Examination of joints for diagnosis and treatment (arthroscopic surgery)

Bronchoscopy: Examination of the trachea and lung's bronchial trees to reveal abscesses, bronchitis, carcinoma, tumors, tuberculosis, alveolitis, infection, inflammation

Colonoscopy: Examination of the inside of the colon and large intestine to detect polyps, tumors, ulceration, inflammation, colitis diverticula, Chrohn's disease, and discovery and removal of foreign bodies.

Colposcopy: Direct visualization of the vagina and cervix to detect cancer, inflammation, and other conditions.

Cystoscopy: Examination of the bladder, urethra, urinary tract, uteral orifices, and prostate (men) with insertion of the endoscope through the urethra.

ERCP (endoscopic retrograde cholangio-pancreatography) uses endoscopic guidance to place a catheter for x-ray fluorosocopy with contrast enhancement. This technique is used to examine the liver's biliary tree, the gallbladder, the pancreatic duct and other anatomy to check for stones, other obstructions and disease. X-ray contrast is introduced into these ducts via catheter and fluoroscopic x-ray images are taken to show any abnormality or blockage. If disease is detected, it can sometimes be treated at the same time or biopsy can be performed to test for cancer or other pathology. ERCP can detect biliary cirrhosis,.cancer of the bile ducts, pancreatic cysts, pseudocysts, pancreatic tumors, chronic

pancreatitis and other conditions such as gallbladder stones.

EGD (Esophogealgastroduodensoscopy): visual examination of the upper gastro-intestinal (GI) tract. (also referred to as gastroscopy) to reveal hemorrhage, hiatal hernia, inflammation of the esophagus, gastric ulcers.

Endoscopic biopsy is the removal of tissue specimens for pathologic examination and analysis.

Gastroscopy: examination of the lining of the esophagus, stomach, and duodenum. Gastroscopy is often used to diagnose ulcers and other sources of bleeding and to guide biopsy of suspect GI cancers.

Laparoscopy: visualization of the stomach, liver and other abdominal organs including the female reproductive organs, for example, the fallopian tubes.

Laryngoscopy: examination of the larynx (voice box).

Proctoscopy, sigmoidoscopy, proctosigmoidoscopy: examination of the rectum and sigmoid colon.

Thoracoscopy: examination of the pleura (sac that covers the lungs), pleural spaces, mediastinum, and pericardium.

Endoscopy Equipment

Endoscopes have many practical needs. And H.M.B. Endoscopy Products (Hollywood, Florida) has been providing endoscopic equipment and educating people on the use of endoscopes for more than 17 years..

Figure 5.6 Endoscopic Equipment

In the simplest terms, Endoscopy equipment consists of instruments that can look at the inside of many different organs — these are small, flexible or rigid tubes with a light or lenses on the end that can look into the esophagus, stomach and colon — and in more general terms endoscopy equipment can help doctors look deep inside body structures and hollow organs. An endoscope and related endoscope products and equipment are usually composed of three components:

An optic system that allows the doctor to look through the scope into the organ or cavity, or to attach a video camera to the scope

A fiberoptic cable to light up the bodily area

A lumen (e.g. the bore of a tube, like a needle or catheter) to take tissue samples of the area being viewed

5.3 LASERS IN MEDICINE

LASERS (Light Amplification by Stimulated Emission of Radiation)

Characteristics of laser sources

•Tissue optical properties
•Laser/tissue interactions
•Some diagnostic applications

Components of a Laser

- Lasing Medium: provides appropriate transition and determines wavelength.
- Pump: provides energy necessary for population inversion.
  E.g. electric discharge, flashlamp, another laser.
- Cavity: provides opportunity for amplification and produces a directional beam.

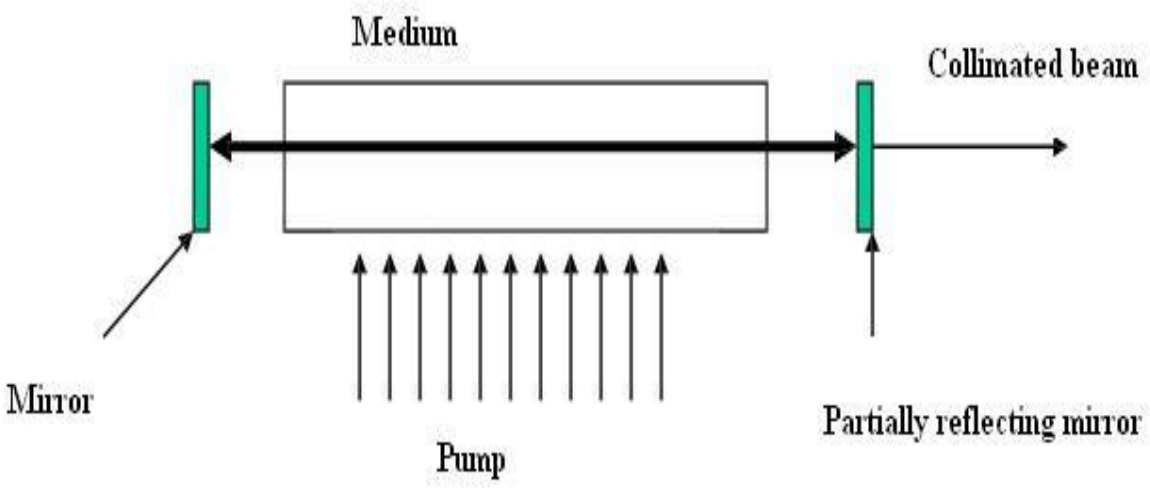


Figure 5.7 Components of Laser

Useful Characteristics of Output Beam

- Coherence
- Collimation
- Monochromaticity
- Wide range of pulse structure
- High power

Optical Properties of Tissues Scattering

- Elastic (i.e. no energy loss), although Doppler shift and Raman shift have been exploited for diagnostic information.
- Mean free path for scattering is typically 100 microns.
- Scattering is forward peaked, typically the average cosine of the scattering angle is > 0.9 (for isotropic scatt
- Scattering coefficient decreases slowly as a function of wavelength.

Absorption

Depends on concentration and absorption spectra of specific molecules in the tissue. Highly dependent on wavelength. UV - high absorption by proteins.Visible - can identify specific features of absorption by hemoglobin, melanin, and other pigments.700 - 900 nm - the "optical window" where tissue absorption is low, maximum light penetration in tissue.IR - absorption is mainly due to water, highest at 2.95 microns.

The beam is incident on tissue at two different wavelengths:300 nm and 700 nm. At 300 nm the "effective" scattering coefficient is 1 mm-1 and the absorption coefficient is 10 mm-1. At 700 nm, let us assume the scattering is the same but the absorption coefficient is only 0.005 mm-1.

Mechanisms of interaction

In order for light to affect tissue, absorption must take place. The rate at which energy is deposited in the tissue is given by the product of the fluence rate (W cm^{-2}) and the linear absorption coefficient (cm^{-1}). The rate of energy absorption largely determines whether photochemical, thermal, or photomechanical effects are dominant.

Photochemical

Initial absorption by specific molecules If photon energy is high enough (UV, excimer laser), direct bond- breaking is possible. Alternatively, the molecule can be raised to an excited state from which a variety of chemical reactions are possible such as the generation of free radicals and reactive oxygen species.

Photomechanical

For very high rates of energy deposition, shock waves can be generated in the tissue by mechanisms such as bubble expansion/collapse or plasma formation. The mechanical properties of the tissue govern the propagation of these waves and their biological effect.

Tissue can be ablated (i.e. physically removed from the surface, torn or, in the case of "brittle" tissue, shattered. Interestingly, these two quantities span many orders of magnitude but their product (the light fluence), varies over a much smaller range. This emphasizes the point that is is the rate of energy absorption that determines the nature of the light-tissue interaction.

Selected Applications of Lasers in Medicine Diagnostic: Goal is to learn something about the tissue

Therapeutic: Goal is to modify the tissue, e.g. kill malignant cells

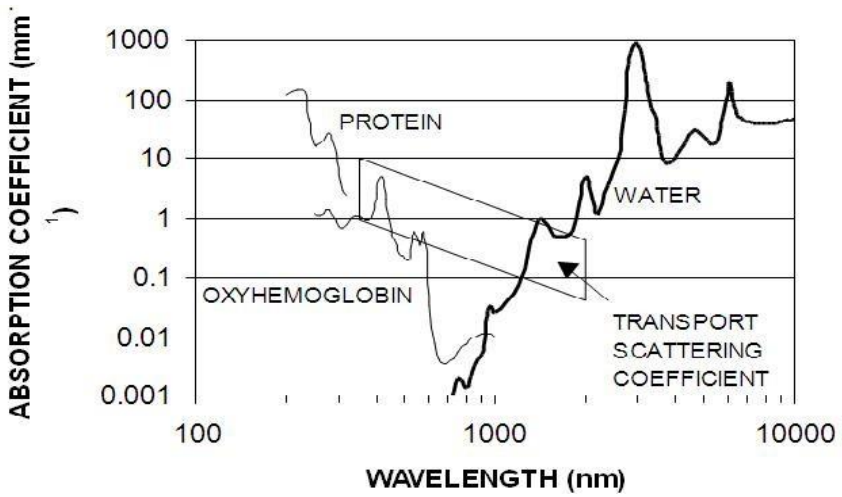


Figure 5.8 Aborption vs wavelength

Distribution of Light in Tissue

The quantity we are usually interested in is the fluence rate. This is defined as the ratio of total power incident on an infinitesimal sphere to the cross sectional area of that sphere. The SI unit is W m-2. It is a measure of how many photons are available per unit volume in the tissue.The fluence rate distribution in tissue is highly dependent on the absorption and scattering coefficents of the tissue.

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Selected Applications of Lasers in Medicine Diagnostic:

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Optical spectroscopy

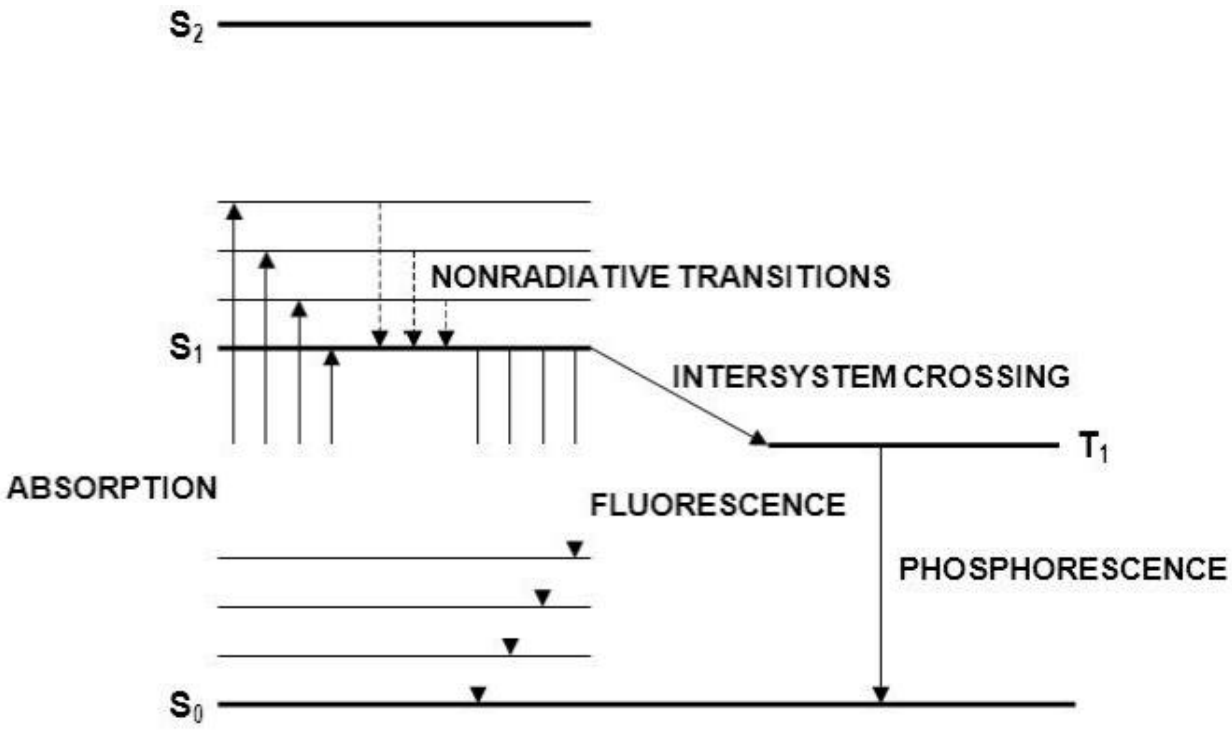

Figure 5.9 Optical Spectroscopy

Endogenous absorbers: Hemoglobin, proteins, melanin, water

Endogenous fluorophores: Collagen, elastin, NADH

Fluorescence Spectroscopy: Noninvasive tissue characterization to replace or guide

physical biopsy, e.g. early diagnosis of lung cancer

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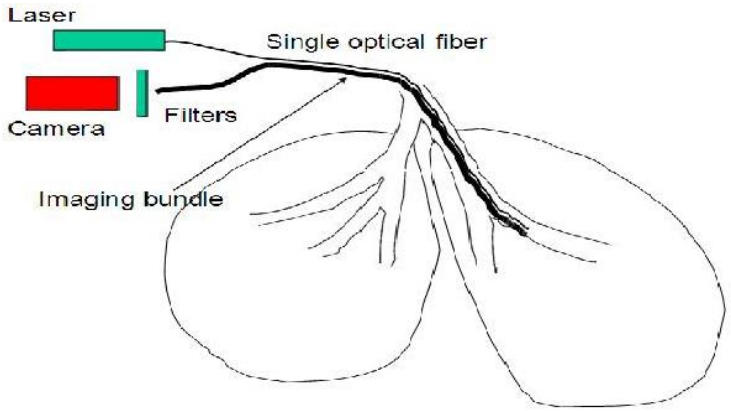

Figure 5.10 Diagnosis of lung cancer

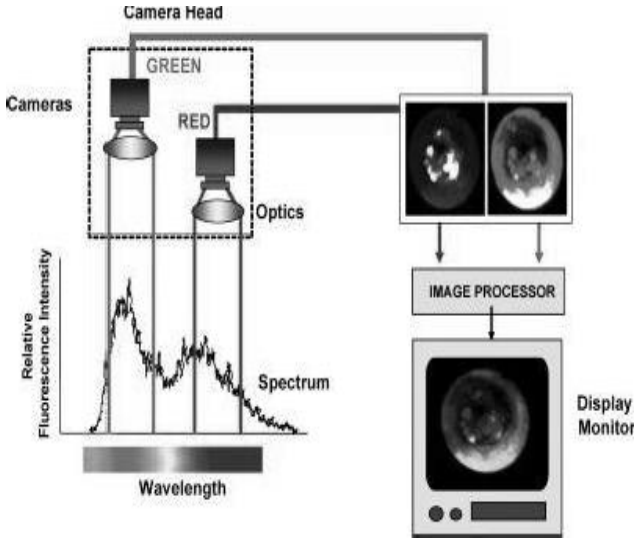

Figure 5.11 Fluorescence Spectroscopy

Images are acquired at the two wavelengths shown, and a ratio image is computed and displayed to the physician in real time. This application uses coherence and collimation of the laser to achieve efficient coupling to the fiber and endoscopic light delivery. In addition, the choice of laser (HeCd) provides optical power at the optimum wavelength for fluorescence excitation.

Photodynamic Therapy

Use chemical reactions initiated by light absorption to kill cells. Original application in oncology but is applicable to other diseases, including age-related macular degeneration caused by a proliferation of new blood vessels in the retina.

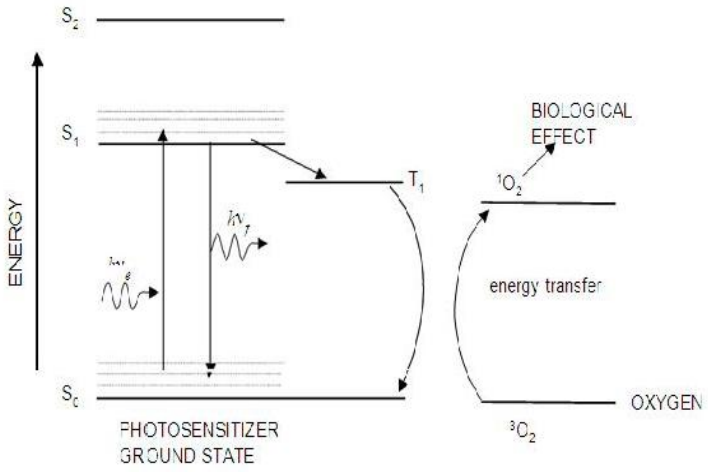

Figure5.12 Photodynamic Therapy

Process:

1. Inject photosensitizer or apply topically.
2. Possibly wait for biodistribution.
3. Irradiate with light of appropriate wavelength

Recent advances:

- Long wavelength photosensitizers.
- Reliable clinical diode lasers.
- Better targetting of photosensitizers

Selective Destruction of Blood Vessels

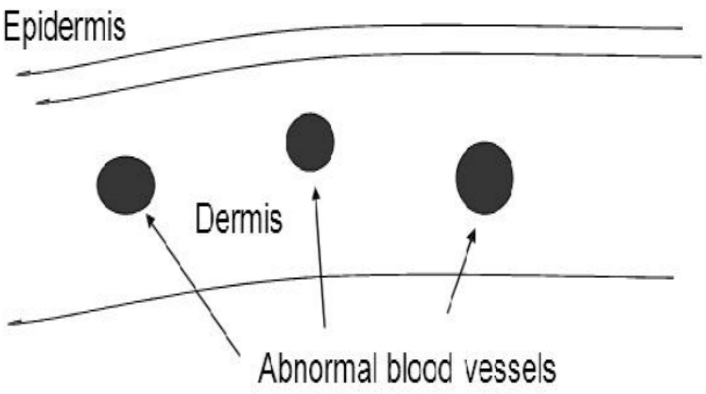

Figure5.13 Selective Destruction of Blood Vessels

Port Wine Stain: Congenital hypervascularization of the dermis.Could just ablate the epidermis and dermis but this would result in unacceptable scarring. Instead, develop a strategy to target the blood vessels:

Wavelength;

The vessels are filled with hemoglobin - most of it oxygenated. Oxyhemoglobin has a strong absorption peak at 577 nm.

Thermal confinement:

Use a pulsed laser to heat the blood in a time short compared with the "thermal relaxation time of the vessel.

Solution:

Pulsed dye laser (ms pulses) tuned to 577 nm.

5.4 CRYOGENIC APPLICATION

Cryogenics – the study and use of materials at extremely low temperatures .Inputs from three major disciplines, namely PHYSICS , MECHANICAL ENGINEERING, CHEMICAL ENGINEERING. Such low temperatures cause changes in the physical properties of materials that allow them to be used in unusual engineering, industrial, and medical applications

For example, in the cryogenic temperature range, air becomes a liquid—or even a solid—and living tissue freezes instantly

- Cryobiology: Branch of biology involving the study of the effects of low temperatures on organisms
- Cryosurgery: Branch of surgery applying very low temperatures (down to -196 °C) to destroy malignant tissue, e.g. cancer cells.
- Cryonics: The emerging medical technology of cryopreserving humans and animals with the intention of future revival.
- Cryoelectronics: Field of research regarding superconductivity at low temperatures.
- Cryotronics: Practical application of cryoelectronics.

TYPES OF CRYOGENIC TREATMENT

- SHALLOW CRYOGENICS, the objects are cooled down to temperature of approximately -85^{o}C
- FLOODING, first the object is taken to -85oC, then the chamber is flooded with liquid nitrogen to reduce the temperature furthur
- DEEP CRYOGENICS TREATMENT, Subjects the objects to the temperature of approximately -185^{o}C

ABSOLUTE ZERO

Absolute zero is a temperature marked by a 0 entropy configuration. It is the coldest temperature theoretically possible and cannot be reached by artificial or natural means

PRODUCTION OF LOW TEMPERATURE

- HEAT CONDUCTION: When bodies are in contact, heat flows from the body with the higher temperature to the body with a lower temperature. Can occur between any and all forms of matter. It is essential in the production of cryogenic temperatures and environments.
- EVAPORATIVE COOLING: Humans lose heat by this mechanism. Atoms and molecules in the gaseous state are moving faster than the atoms and molecules in the liquid state. Adding heat energy to the particles in a liquid makes them gaseous
- THE JOULE-THOMSON EFFECT: Allowing a gas to expand very rapidly causes its temperature to drop dramatically. Reducing the pressure on a gas accomplishes the same effect. Ordinary house hold refrigerators and air conditioners operate on this principle.

APPLICATION OF CRYOGENICS

- Aerospace-cryogenic engines
- Medical Field
- Manufacturing field
- Electronics Field
- Fuels research
- Miscellaneous uses

CRYOGENIC ENGINES IN AEROSPACE

First operational Cryogenic Rocket Engine is 1961 NASA designed RL-10 LOX LH2 rocket engine The second-stage Pratt & Whitney RL10B-2 engine is based on the 30-year heritage of the reliable RL10 engine At Mahendragiri in Tamil Nadu, is the LPSC. The system involves materials working at 23K and pumps at speeds of 40,000 rpm. Complex metering, monitoring, integrating technologies involved. The engines required to fire for 700 seconds during the final stage of a launch providing 7 tones of thrust Engine works on 'Staged Combustion Cycle' with an integrated turbo pump running at 42,000rpm. Also equipped with two steering engines developing a thrust of 2 kN each to enable three-axis control of the launch vehicle during the mission Closed loop control of both thrust and mixture ratio, which ensures optimum propellant utilization for the mission

CRYOSURGERY

Cryosurgery- Use of extreme cold produced by liquid nitrogen (or argon gas) to destroy abnormal tissue. Used to treat external tumors, such as those on the skin. For internal tumors, liquid nitrogen is circulated through a hollow instrument called a Cryoprobe. Used since many years in the treatment of skin cancer

CRYOGENICS IN MANUFACTURING FIELD

Cryogenic treatment works on Reamers, Tool bits, Tool punches, Carbide Drills, Carbide Cutters, Milling Cutters, Files, Knives, Reciprocating Blades, Dies and cutting tools
Stress relieved ferrous and non ferrous castings and forgings for enhanced dimensional stability and surface finish

CRYOGENICS IN ELECTRONICS FIELD

Super conducting electronic devices like SQUID (Super conducting quantum interference device) are used in sensitive digital magnetometers and voltmeters Zero friction bearings use magnetic field instead of oil or air, derived from the Meissner Effect associated with super conductivity. Super conducting electric motors are constructed approaching zero electric loses
Nuclear Magnetic Resonance Spectroscopy (NMR)

Most common method to determine the physical and chemical properties of atoms by detecting the radio frequency absorbed and subsequent relaxation of nuclei in a magnetic field. Strong magnetic fields are generated by supercooling electromagnets. Liquid helium(BP 4K) is used to cool the inner coils. Cheap metallic superconductors can be used for the coil wiring. So-called high-temperature superconducting compounds can be made to superconduct with the use of liquid nitrogen(BP 77K)

Magnetic Resonance Imaging (MRI) :

Complex application of NMR where geometry of the resonances is deconvoluted and used to image objects by detecting the relaxation of protons that have been perturbed by a radio-frequency pulse in the strong magnetic field. Mostly used in health applications

Electric Power Transmission:

Superconductors could be used to increase power throughput. Require cryogenic liquids such as nitrogen or helium to cool special alloy-containing cables to increase power transmission. Field is the subject of an agreement within the International Energy Agency.

Frozen Food:

Transportation of large masses of frozen food. Food is freezed in war zones, earthquake hit regions, etc. Cryogenic food freezing is also helpful for large scale food processing industries.

5.5 INTRODUCTION TO TELEMEDICINE

- Telemedicine is the use of medical information exchanged from one site to another through electronic communications to improve a patient's clinical health status. Telemedicine includes a growing variety of applications and services using two-way video, e-mail, smart phones, wireless tools, and other forms of telecommunications technology.

- Starting out over forty years ago with demonstrations of hospitals extending care to patients in remote areas, the use of telemedicine has spread rapidly and is now becoming integrated into

the ongoing operations of hospitals, specialty departments, home-health agencies, private physician offices, as well as consumers' homes and workplaces.

- Telemedicine is not a separate medical specialty. Products and services related to telemedicine are often part of a larger investment by health-care institutions in either information technology or the delivery of clinical care. Even in the reimbursement fee structure, there is usually no distinction made between services provided on-site and those provided through telemedicine and often no separate coding required for billing of remote services. Patient consultations through videoconferencing, transmission of still images, e-health including patient portals, remote monitoring of vital signs, continuing medical education, consumer-focused wireless applications and nursing call centers, among other applications, are all considered part of telemedicine and telehealth.

Services Provided Telemedicine

- Sometimes telemedicine is best understood in terms of the services provided and the mechanisms used to provide those services. Here are some examples:

- Primary care and specialist referral services may involve a primary care or allied health professional providing a consultation with a patient or a specialist assisting the primary care physician in rendering a diagnosis. This may involve the use of live interactive video or the use of store-and-forward transmission of diagnostic images, vital signs, and/or video clips along with patient data.

- Remote patient monitoring, including home telehealth, uses devices to remotely collect and send data to a home-health agency or a remote diagnostic testing facility (RDTF) for interpretation. Such applications might include a specific vital sign, such as blood glucose or heart ECG, or a variety of indicators for homebound patients. Such services may supplement the use of visiting nurses.

- Consumer medical and health information includes the use of the Internet and wireless devices for patients to obtain specialized health information and access online discussion groups that provide peer-to-peer support.

- Medical education provides continuing medical education credits for health professionals and special medical education seminars for targeted groups in remote locations.

Delivery Mechanisms

- Networked programs link tertiary care hospitals and clinics with outlying clinics and community health centers in rural or suburban areas. The links may use dedicated high-speed lines or the Internet for telecommunication links between sites. American Telemedicine Association (ATA) estimates the number of existing telemedicine networks in the United States at roughly 200, providing connectivity to over 3,000 sites.

- Point-to-point connections using private high-speed networks are used by hospitals and clinics that deliver services directly or outsource specialty services to independent medical service providers. Such outsourced services include radiology, stroke assessment, mental health, and intensive care (ICU) services.

- Monitoring center links are used for cardiac, pulmonary or fetal monitoring, and home care services. Often normal land-line or wireless connections are used to communicate directly between the patient and the center, although some systems use the Internet.

- Web-based e-health patient service sites provide direct patient outreach and services over the Internet. Under telemedicine, these include those sites that provide direct patient care.

Benefits of Telemedicine

Telemedicine has been growing rapidly because it offers four fundamental benefits:

- Improved Access—For over 40 years, telemedicine has been used to bring health-care services to patients in distant locations. Not only does telemedicine improve access to patients, it also allows physicians and health-care facilities to expand their reach beyond their office walls. Given the provider shortages throughout the world—in both rural and urban areas—telemedicine has a unique capacity to increase service to millions of new patients.

- Cost Efficiencies—Reducing or containing the cost of healthcare is one of the most important reasons for funding and adopting telehealth technologies. Telemedicine has been shown to reduce the cost of healthcare and increase efficiency through better management of chronic diseases, shared staffing, reduced travel times, and fewer or shorter hospital stays.

- Improved Quality—Studies have consistently shown that the quality of health-care services delivered through telemedicine is as good as that given in traditional in-person consultations. In some specialties, particularly in mental health and ICU care, telemedicine delivers a superior product with greater outcomes and patient satisfaction.

- Patient Demand—Consumers want telemedicine. The greatest impact of telemedicine is on the patient, their family, and their community. Using telemedicine technologies reduces travel time and related stresses for the patient. Over the past 15 years, study after study has documented patient satisfaction and support for telemedical services. Such services offer patients access to providers that might not be available otherwise, as well as medical services without the need to travel long distances.