STATE BOARD OF TECHNICAL EDUCATION &TRAINING, TAMILNADU

DIPLOMA IN ENGINEERING/TECHNOLOGY SYLLABUS N SCHEME

Course Name :1040: Electronics and Communication Engineering

Subject Code : 4040620

Semester :VI

Subject title : BIOMEDICAL INSTRUMENTATION

UNIT	TOPIC	Hours
I	Bio-electric potentials, Electrodes and Clinical measurements	14
II	Diagnostic Instruments	15
III	Therapeutic Instruments	16
IV	Biotelemetry and Patient Safety	15
V	Modern Imaging Techniques	13
	Tests and Model Exam	7
	Total	80

UNIT-I :

BIO-ELECTRIC SIGNALS AND ELECTRODES

1.1 ELEMENTARY IDEAS OF CELL STRUCTURE:

The cell is the basic structural and functional unit of life. All organisms are composed of cells. All cells are produced by the division of preexisting cells (i n other words, through reproduction). Each cell contains genetic material that is passed down during this process. All basic chemical and physiological functions- for example, repair, growth, movement, immunity, communication and digestion - are carried out inside of cells. The activities of cells depends on the activities of sub cellular structures within the cell (these sub cellular structures include organelles, the plasma membrane, and, if present, the nucleus) There are millions of living organisms. They are of different shapes and sizes. Their organs also vary in shape, size and number of cells. Human body has trillions of cells which vary in shapes and sizes. Different groups of cells perform a variety of functions. Organisms made of more than one cell are called multi cellular organisms. An organism with billions of cells begins life as a single cell which is the fertilized egg. The fertilized egg cell multiplies and the number of cells increases as development proceeds. A single-celled organism, like amoeba, captures and digests food, respires, excretes, grows and reproduces. Similar functions in multi cellular organisms are carried out by groups of specialized cells forming different tissues. Tissues, in turn, form organs. Generally, cells are rounding, spherical or elongated. Some cells are long and pointed at both ends. They exhibit spindle shape. Cells sometimes are quite long. Some are branched like the nerve cell or a neuron. The nerve cell receives and transfers messages, thereby helping to control and coordinate the working of different parts of the body. The single-celled organisms are called unicellular organisms. A single celled organism performs all the necessary functions that multi cellular organisms perform. 1.1.1 The structure of the cell. Fig.1.1 shows the structure of the cell.

The cell consists of a centrally located Nucleus (cell core) surrounded by the Cytoplasm (cell body). The nucleus is separated from the cytoplasm by a Nuclear membrane and the cytoplasm is separated from the surrounded fluids by a Cell membrane. The different substances that make up the cell are collectively called Protoplasm which is mainly composed of water, electrolytes, proteins, lipids and carbohydrates. Water is the principal fluid medium of the cell and its concentration is in between 70 and 80%. Water serves as a solvent for various chemicals to produce chemical reactions. The Electrolytes present in the cell are Potassium, Magnesium, Phosphate, Sulphate, Bicarbonate and small quantities of Sodium, Calcium and Chloride. The electrolytes provide inorganic chemicals for cellular reaction. Further electrolytes at the cell membrane allow transmission of electrochemical impulses in nerve and muscle fibers and the intracellular electrolytes determine the activity of different enzymatically catalyzed reactions that are necessary for cellular metabolism. Proteins which constitute 10 to 20% of the cell mass are divided into structural proteins and globular proteins (enzymes)

Proteins are used to provide the contractile mechanism of all muscles. Lipids are composed of different types of substances. They are soluble in fat solvents and insoluble in water. Important lipids are phospholipids and cholesterol which are used to form membranous barriers that separate the different intracellular compartments. Carbohydrates play a major role in nutrition of the cell. They are stored in the cell in the form of glycogen which are used to supply the cells‟ energy needs rapidly and are present in the extra cellular fluid in the form of glucose. The cell also contains highly organized physical structures, called Organelles consisting of cell‟s chemical constituents. The Cytoplasm is filled with Cystosol in which the minute band large particles and the organelles are dispersed. Ribosomes are minute granular particles in the Cytosol and are composed of a mixture of Ribonucleic acid (RNA) and proteins and they function in the synthesis of protein in the cells. Lysosomes are vesicular organelles and provide an intracellular digestive system that allows the cell to digest and there by remove unwanted substances and damaged or foreign structures such as bacteria. Mittochondria organelles are called „power houses‟ of the cell.

The cell extract significant amount of energy from the nutrient and oxygen by means the Mittochondria. The Mittochondria contains Deoxy Ribonuicleic Acid(DNA) similar to that found in the nucleus. Nucleus contains large quantities of DNA which are called Genes. Genes first reproduce themselves and after this , the cell splits by a special process called Mitosis to form two daughter cells. Inside the nucles , there is a structure called nucleolus which contains a large amount of RNA and proteins of the type found in ribosomes. The size of the cell is determined by the amount of DNA in the nucleus. The size of the cell is in the range of 5-10 μm. When there are enormous quantities of DNA than normally, the cell size is larger. DNA grows due to the increased production of RNA and cell protein.

Generally Cancer is caused by mutation or abnormal activation of cellular genes that control cell growth and cell mitosis. The probability of mutations can be increased by the following.

1. Exposure of ionizing radiation.

2. Chemical substances.

3. Physical irritants.

4. Hereditary.

5. Viruses.

1.1.2 Transport of ions through cell membrane:

The fluid which lies outside the cell membrane is called the Extra cellular fluid and which lies inside the cell membrane is called Intra cellular fluid. Transport of the substances through the cell membrane occurs by diffusion called passive transport and active transport. When a cell membrane moves molecules or ions uphill against a concentration gradient the process is called active transport. Particularly sodium ion, potassium ions, calcium ions, chloride ions and most of the Amino acids are actively transported through cell membranes. Sodium-potassium pump and the calcium pump are good examples of active transport.

1.2 BIO-POTENTIALS AND THEIR GENERATION :

Bio-electric potentials are actually ionic voltages produced as a result of the migration of ions due to muscular contraction and chemical activity of certain types of cells. These bio electric potentials are also associated with nerve conduction, brain activity, heartbeat, muscle activity and so on. These are generated at cellular level and are the order of a few microvolts. Most of the physiological processes are accompanied with electrical changes.

The human body which is composed of living tissues can be considered as a power station generating multiple electric signals with two internal sources, namely muscles and nerves. Normal muscular contraction is associated with the migration of ions generating potential differences measurable with suitably placed electrodes. Potential differences are also generated by the electrochemical reactions accompanied with the conduction of signals along the nerves to or from the brain.

In general, various sources of bioelectric potentials are

(i) Muscular contraction (ii)Nerve conduction

(iii)Chemical reactions (Acidosis and Alkalosis)

(iv)Heart beat

(v)Brain activity.

1.2.1 Various bio-potentials generated with the point of generation:

Some bio-electric potential obtained from the body are.

(i) ECG (Electrocardiogram): ECG is the bio-potential generated by the muscles of the heart.

(ii) EEG (Electroencephalogram): EEG is the bio-potential generated by the neuronal activity of the brain.

(iii) EMG (Electromyogram): EMG is the bio-potential generated by the muscle activity.

(iv) ERG (Electroretinogram): ERG is the record of the complete pattern of bio potentials obtained from the retina of the eye.

(v) EOG (Electrooculogram):EOG is a measure of the variations in the corneal retinal potential as affected by the position and movement of the eye.

(vi) EGG (Electrogastrogram):EGG is the EMG pattern associated with the peristaltic movement of the gastrointestinal tract .

1.3 RESTING POTENTIAL:

In a resting state, a cell has a negative charge along the inner surface of its membrane and a positive charge along its outer surface. The unequal charge distribution is as a result of certain electro chemical reactions and processes (diffusion and drift) occurring within the living cell .i.e. When the cell is at its resting state the potential measured at cellular level is called resting potential. Fig 1.2 describes resting potential. This resting potential (membrane potential) in various cells ranging from -60 mv to -100 mv. When a section of cell membrane is stimulated by the flow of ionic current or by some form of externally applied energy, the permeability of the membrane changes so that the sodium ions are allowed to enter inside the cell

(a) Movement of Sodium ions

(b) Action potential and Potassium ions. This movement of sodium ions into the cell constitutes an ionic current which further reduces the barrier of the membrane to sodium ions. The net result is an avalanche effect such that sodium ions rush into the cell. Mean while potassium ions are leaving the cell. But are unable to move as rapidly as the sodium ions. Therefore the cell has a slightly positive potential on the inside due to the imbalance of potassium ions.

This positive potential of the cell membrane during excitation is called action potential and is about +20mv. Generally the action of muscles (contraction) generated these potential. By placing suitable electrodes, the action potentials can be recorded. When recorded it can be looked like the following wave pattern shown in fig 1.4

1.4.1 Depolarization and Repolarization:

When a cell is stimulated, an ionic discharge takes place within the cell. This process is called depolarization.After the completion of depolarization, the excited cell regains its original resting state by the process of recharging. This is called repolarization Fig.1.5 shows depolarization and repolarization process. Depolarization and Repolarization process .

PROPAGATION OF ACTION POTENTIAL:

In a tissue the depolarization disturbance of one cell is propagated to the new until the entire tissue depolarizes.The rate at which an action potential moves down a fiber of a nerve cell which is propagated from cell to cell is called the Propagation rate or conduction velocity. The conduction velocity varies in nerves depending on the type and diameter of the nerve fiber and is from 20m to 140m/s. But in heart muscles, it is very slower ranging from 0.2 to 0.4 m/s.

1.6 ELECTRODES:

Electrodes are devices which are used to convert ionic voltages into electronic voltages. Two electrodes can be used as a transducer. Electrode Paste Electrode Paste is an electrically conducting material employed as an interface between the electrode and surface of the body.

1.6.1 Types of electrodes:

A wide variety of electrodes can be used to measure bio-electric events, but nearly all can be classified as belonging to one of the three basic types.

(a) Microelectrodes

(b) Skin surface electrodes

(c) Needle electrodes

1.6.1(a) MICRO ELECTRODES :

Electrodes which are used to measure bio electric potentials near or within a single cell are called micro electrodes. Microelectrodes are generally of two types.

(i) Metal electrode

(ii) Micropipette

i) Metal electrodes:

Metal electrodes are formed by electrolytic ally etching the tip of a fine tungsten or stainless steel wire to the desired size. Then the wire is almost coated to the tip with an insulating material. Fig 1.6 shows a commercial type of metal electrode. Fig.1.6 Metal electrode

ii) Micropipette The micropipette type of microelectrode is a glass micropipette with the tip drawn out to the desired size (usually about 1 micron (1µm) in diameter.) The micropipette is filled with an electrolyte compatible with the cellular fluids. A commercial type of microelectrode is shown in fig 1.7 In this electrode, a thin film of precious metal is bonded to the outside of a drawn glass electrode. All the above types of micro electrodes are used to take measurement within the cell or near the cell.

1.6.1(b) SKIN SURFACE ELECTRODES:

Electrodes which are used to measure ECG, EEG and EMG potentials from the surface of the skin are called skin surface electrodes. The larger electrodes are usually associated with ECG where as smaller electrodes are used in EEG and EMG measurements. Following are various types of surface electrodes.

(i) Metal plate electrodes. (Limb electrodes)

(ii) Suction cup electrodes. (chest electrodes)

(iii) Adhesive tape electrodes.

(iv) Floating electrodes.

(v) Disposable electrodes.

(vi) Ear clip electrodes.

(i) Metal plate electrodes. (Limb electrodes):

Fig 1.8 Metal plate Surface electrode:

Metal plate surface electrode The most common type of electrodes routinely used for recording ECG are rectangular or circular surface (metal plate) electrodes. The material used is German silver, nickel silver or nickel plated steel. They are applied to the surface of the body with electrode jelly. The electrodes are held in position by elastic straps. They are also called limb electrodes as they are most suitable for application on the four limbs of the body. They are reusable and last several years. These are generally preferred for use during surgery and are not suitable for use in long term patient monitoring.

(ii) Suction cup electrodes Suction cup electrode is commonly used to record the uni- polar chest leads which are shown in fig 1.9. The electrode is popular for its practicality, being easily attachable to fleshy parts of the body. Electrode jelly forms the vacuum seal. This electrode suffers by electrode slippage or movement after a sufficient length of time.

(iii) Adhesive tape electrode (Pre-jelled electrodes) The adhesive tape electrodes reduce movement artifact by limiting electrode movement and reducing interface impedance. The pressure of the surface electrode against the skin may squeeze the electrode paste out. To avoid this problem, adhesive tape electrode is used which is shown in fig 1.10.It consists of a light weight adhesive metallic screen backed by a pad for electrode paste. The adhesive backing holds the electrode in place.

(iv)Floating electrodes The principle of this electrode is to practically eliminate movement artifact by avoiding any direct contact of the metal with the skin. Page 14 The floating electrode shown in fig 1.11 consists of a rigid plastic cup which contains the metal electrode and holds the electrode jelly. These are generally attached to the skin by means of two sided adhesive rings which adhere to both the plastic surface of the electrode and the skin. During long term monitoring or exercise testing this electrode is an important part of the system.

(v) Disposable electrodes Various types of disposable electrodes have been introduced in recent years to eliminate the requirement for cleaning and care after each use. In general Disposable electrodes are of the floating type with simple snap connectors by which the leads, which are reusable, are attached.

(vi)Ear clip electrodes A special ear clip electrode developed for use as a reference electrode for EEG measurement.

1.6.1(c)Needle electrodes:

Electrodes for electromyography work are usually of the needle type. Needle electrodes are used in clinical electromyography, neurography and other electrophysiological investigations of the muscle tissues underneath the skin and in the deeper tissues. The material of the needle electrode is generally stainless steel. Needle electrodes are of various types. Some are,

(i) Monopolar

(ii) Bipolar.

(i) Monopolar needle electrode:

The monopolar needle electrode shown in fig 1.13 usually consists of a Teflon coated stainless steel wire which is bare only at the tip.

(ii) Bipolar needle electrode :

A concentric (coaxial) needle electrode contains both the active and reference electrode within the same structure. As shown in fig 1.14. It consists of an insulated wire contained within a hypodermic needle. The inner wire is exposed at the tip and this forms one electrode. This needle electrode looks like a medicine dropper. Some electro-encephalography use small sub dermal needles to penetrate the scalp for EEG measurement. They are not inserted into the brain. They merely penetrate the skin.

1.7 Measurement of Blood Pressure (BP) :

Direct method of Blood Pressure measurement (Percutaneous and cathetherization method) Blood Pressure is an important physiological parameter for indicating the changes in circulation of blood due to;

- Hypertension
- Hypotension
- Strokes
- Shocks
- Trauma
- Emotional stress and strains.

It can be said that the blood pressure is a good indicator of physiological state of a patient.

1.7.1 Methods of BP measurement:

Blood pressure is measured by two methods. (i) Direct method (ii) Indirect method.

1.8 DIRECT METHODS OF MEASURING BLOOD PRESSURE (BP):

They require surgical procedures. The sensing unit is placed near some artery or vein. Following are the direct methods.

(i) Catheterization technique.

(ii) Implanted transducers.

(i) Catheterization methods:

This method requires surgical procedure for the invasion of a needle or catheter into a blood vessel up to the desired position and in some cases right up to the heart. The artery or vein is occluded and a hollow needle is inserted at an angle. The catheter is inserted through hollow needle guide. After positioning the catheter at desired location, the needle guide is taken out very carefully. Local anesthesia is given near the place of insertion. A pressure transducer is placed at the tip of catheter to measure the blood pressure. Strain gauge, LVDT and Semiconductor transducers are used in catheters as pressure sensors which are shown in fig 1.15. By connecting these sensors to a processing unit systolic and diastolic sensors levels can be monitored. Both these methods are used during surgery to get continuous monitoring.

Catheterization methods Implatantable telemetry system for Blood flow

(ii) Implantation technique

For continuous monitoring of Blood pressure for over a long period of time, this method is used. This method requires major surgical operation as the transducer is placed at the site of pressure measurement by opening the body part. Capacitive, inductive, resistive and semiconductor transducers with transmitter unit are used in this method. This is used in animal research and in Biotelemetry applications.

1.9 INDIRECT METHODS OF MEASURING BLOOD PRESSURE (BP):

These are the commonly used non invasive techniques of Blood pressure measurement. They do not require any surgical procedure on the body. Following are the indirect methods of BP measurement

(i) Sphygmomanometer and Stethoscope method.(Auscultatory method)

(ii) Palpatory method (Manual method)

(iii) Ultrasonic method.

(i) Sphygmomanometer method:

(Auscultatory method) This is an indirect method of BP measurement which is widely used in hospitals to find out the systolic and diastolic pressure. This uses a sphygmomanometer consists of a pressure cuff and a mercury manometer to measure the pressure in the cuff and a stethoscope. The cuff consists of a rubber bladder inside an inelastic fabric covering that can be wrapped around the upper arm. The cuff is normally inflated manually with a rubber bulb and deflated slowly through a needle valve. A wall mounted sphygmomanometer is shown in fig 1.15. The sphygmomanometer works on the principle that when the cuff is placed on the upper arm and inflated, arterial blood can flow past the cuff only when the arterial pressure exceeds the pressure in the cuff. Further more, when the cuff is inflated to a pressure that only partially occludes the brachial artery, turbulence is generated in the blood as it spurts through the tiny artery opening during each systole. The sounds generated by this turbulence, Korotkoff sounds, can be heard through a stethoscope placed over the artery downstream from the cuff. This is also known as RIVA-ROCCI Method.

To obtain a blood pressure measurement with a sphygmomanometer and a stethoscope, the pressure cuff on the upper arm is first inflated to a pressure well above the systolic pressure. At this point no sounds can be heard through the stethoscope. The pressure in the cuff is then gradually reduced. As soon as the cuff pressure falls below systolic pressure, small amount of blood spurts is past the cuff and Korotkoff sound begin to be heard through the stethoscope. The pressure of the cuff that is indicated on the manometer when the first Kkorotkoff sound is heard is recorded as the Systolic pressure. As the pressure in the cuff continues to drop, the Korotkoff sound continues until the cuff pressure is no longer sufficient to occlude the vessel during any part of the cycle. Below this pressure the Korotkoff sound disappears, marking the value of the Diastolic pressure.

The difference in pressure between systole and diastole is called pulse pressure and is normally 30 to 50 mmHg. The lower limit of systolic pressure in the normal adults is 105 mmHg and the upper limit at 150 mmHg. In women blood pressure is from 5 to 10mmHg lower than in men. (ii) Palpatory method of BP measurement It is similar to Auscultatory method of BP measurement except that the physician identifies the flow of blood in the artery by feeling the pulse of the patient downstream from the cuff instead of listening for the Korotkoff sounds. Although systolic pressure can easily be measured by the Palpatory method. But diastolic pressure is much more difficult to identify. For this reason, this method is not used. (iii) Ultrasonic method of BP measurement It is an automatic method of BP measurement used in central monitoring system. This method is based on the ultrasonic Doppler Effect. In this an ultrasonic transmitter and receiver are placed near an artery and the control logic incorporated in the instrument analyzes the arterial wall motion signals to detect the systolic and diastolic pressures and displays the corresponding values. Instruments making use of ultrasonic Doppler shift principle for the measurement of BP are based on the detection of the frequency shift ascribed to back scattering from moving blood particles. On the other hand, blood pressure instrument filters out these higher frequency reflections and senses the lower frequency refractions originating from the movement of the relatively slow moving arterial wall. In principle, the instrument consists of four sub systems.

The power supply block converts incoming ac line voltage to several filtered and regulated dc voltage required for the pneumatic subsystem in order to inflate the occlusive cuff around the patient‟s arm. ϖ The control system signals gate on the transmitter in the RF and audio subsystem thereby generating 2 MHz carrier, which is given to the transducer located in the cuff. ϖ The transducer converts RF energy into ultrasonic vibrations, which pass into the patients arm. ϖ The cuff pressure is monitored by the control subsystem and when the pressure reaches the preset level further cup inflation stops. At this time, the RF and audio subsystem are enabled by control subsystem signals and the audio signals representative of any Doppler frequency shift are thus able to enter the control subsystem logic. ϖ The control subsystem signals the pneumatic subsystem to bleed off the cuff pressure at a rate determined by the preset bleed rate. ϖ As Air bleeds from the cuff, the frequency of the returned RF is not appreciably different from the transmitted frequency as long as the bronchial artery remains occluded. Till then, there are no audio signals entering the control subsystem. ϖ As the systolic pressure, the occluded artery snaps open and the arterial blood flow starts. This artery motion results in Doppler shift in the returning ultrasonic vibrations. The converted audio frequency signal is recognized as tentative systolic by the control system. To register four valid artery returns must be recognized. ϖ At diastole, cuff pressure equals or slightly exceeds the arterial wall pressure. As a result, wall snapping ceases and the RF and audio subsystem no longer receive Doppler shifted returns. The reading is registered. ϖ The readings are held fixed until a new measurement is initiated.

1.10 BLOOD FLOW METERS :

An adequate blood supply is necessary for all organs of the body; intact an impaired supply of blood is the cause of various diseases. The ability to measure blood flow in the vessels that supplies a particular organ would therefore be a great help in diagnosing such diseases. Blood flow is the measure of volume of blood passing through a blood vessel in a given unit of time. It is expressed as liters/minute or millimeters/minute. Practically all blood flow meters currently used in clinical and research applications are based on the following principles.

- Electromagnetic induction
- Ultrasonic transmission or reflection.
- Thermal convection
- Radiographic principles.
- Indicator (dye or thermal) dilution.

1.10.1 Electromagnetic blood flow meter:

Blood flow meters which are used during surgery are electromagnetic blood flow meters. The most commonly used instrument for the measurement of blood flow is of the electromagnetic type. With this type of instrument, blood flow can be measured intact blood vessels without cannulation. However, this method requires that the blood vessel be exposed so that the flow head or the measuring probe can be put across it. Principle of operation The operating principle underlying all electromagnetic type flow meters is based on Faraday's law of electromagnetic induction which states that when a conductor is moved at right angles through a magnetic field, an emf is induced in the conductor. Working Page 19 In the electromagnetic blood flow meter, shown in fig 1.18 an electromagnetic assembly provides the magnetic field placed at right angles to the blood vessel in which the flow is to be measured. The blood stream which is the conductor cuts the magnetic field and a voltage is induced in the blood stream. The induced voltage picked up is directly proportional to the strength of the magnetic field, the diameter of the blood vessel and the velocity of blood flow, ie., $e = CHVd$ e – Induced voltage H – Magnetic field strength V – Velocity of blood vessel d – Diameter of the blood vessel. C – Constant of proportionality The induced voltage picked up by the electrodes is amplified and displayed/recorded on a suitable system. The system is calibrated in terms of volume flow as a function of the induced voltage. Basically all modern flow meters consist of a generator of alternating current, a probe assembly, a series of capacitance coupled Amplifiers, a demodulator, a dc amplifier and a suitable recording device. The shape of the energizing current waveform for the electromagnet may be sinusoidal or square.

The block diagram of a magnetic blood flow meter is shown in fig 1.19. ϖ The Oscillator, which drives the magnet and provides a control signal for the gate, operates at a frequency of between 60 and 400 Hz. ϖ The use of a gate detector makes the polarity of the output signal reverse when the flow direction reverses. ϖ The frequency response of this type of system is usually high enough to allow the recording of the flow pulses, while the mean or average flow can be derived by use of a low pass filter.

1.10.2 Ultrasonic Blood flow meters:

There are basically two types of ultrasonic blood flow meters.

- The first type is the transit time velocity meter &
- The Doppler shift type

In both these above methods a beam of ultrasonic energy is used to measure the velocity of flowing blood. In transit time ultrasonic flow meter, a pulsed beam is directed through a blood vessel at a shallow angle and its transit time is then measured. When the blood flows in the direction of the energy transmission the transit time is shortened. If it flows in the opposite direction the transit time is lengthened. More common are ultrasonic flow meters based on the Doppler principle. Ultrasonic blood flow meters (Doppler shift velocity meters) It is a non-invasive technique to measure blood velocity in a particular vessel from the surface of the body. It is based on the analysis of echo signals from the erythrocytes in the vascular structures. Because of the Doppler Effect the frequency of these echo signals changes relative to the frequency which the probe transmits.

The Doppler frequency shift is a measure of the size and direction of the flow velocity. This principle is illustrated in the following fig 1.20. An oscillator, operating at a frequency of several Megahertz, excites a piezoelectric transducer. This transducer is coupled to the wall of an exposed blood vessel and sends an ultrasonic beam with a frequency F into the flowing blood. ϖ A small part of the transmitted energy is scattered back and is received by a second transducer arranged opposite the first one. ϖ Because of the scattering occurs mainly as a result of the moving blood cells, the reflected signal has a different frequency due to Doppler Effect. ϖ Its frequency is F+FD or F – FD, depending on the direction of blood flow. ϖ The Doppler component, FD is directly proportional to the velocity of the flowing blood.

A fraction of the transmitted ultrasonic energy, however reaches a second transducer directly with the frequency being unchanged. ϖ After amplification of the composite signal, the Doppler frequency can be obtained at the output of the detector as the difference between the direct and scattered signal component. With blood velocities in the range normally encountered, the Doppler signal is typically in the low audio frequency range. From a loudspeaker or earphone the Doppler signal of the pulsating blood flow can be heard as a characteristic „Swish – Swish". When the transducers are placed in a suitable mount (which defines the area of the blood vessel) a frequency meter used to measure the Doppler frequency can be calibrated directly in flow rate units.

1.11 BLOOD Ph:

pH is a measure of hydrogen ion concentration, expressed logarithmically. It is the negative exponent (log) of the hydrogen ion concentration. i.e., pH = - log10 (H+) The acidity or alkalinity of a solution depends on its concentration of hydrogen ions. Increasing the concentration of hydrogen ions makes a solution more acidic, decreasing the concentration of hydrogen ions makes it more alkaline. Both Acidosis and alkalosis are diseased conditions. Any tendency of the pH of blood to deviate towards three physiological mechanisms. .

pH Measurement of Blood :

- Buffering by chemical means
- Respiration
- Excretion into urine by kidneys.

A sudden change in pH could result in cardiac arrhythmias, ventricular hypotension and even death. This shows the importance of maintenance of physiological neutrality in blood. The blood and tissue fluids contain chemical buffers, which react with added acids and bases and minimize the resultant change in hydrogen ions. Arterial blood has a pH of approximately 7.4 and venous blood has 7.36 of pH. When the pH exceeds 7.45 the body is considered to be in the state of alkalosis. A body pH below 7.35 indicates acidosis.

1.11.1 Measurement of pH Electrochemical:

pH determination utilizes the difference in potential occurring between solutions of different pH separated by a special glass membrane. If the pH of one solution is kept constant, so that the potential varies in accordance with the pH of the other solution, then the system can be used to determine the pH. The device used to effect this measurement is the glass electrode. For making pH measurement, the solution is taken in a beaker. A pair of electrodes, one glass or indicating electrode and the other reference electrode or calomel electrode, are immersed in the solution. The voltage developed across the electrodes is applied to an electronic amplifier, which transmits the amplified signal to the display. The pH meter is usually equipped with controls for calibration and temperature compensation.

1.11.2 Measurement of Blood pH:

Several types of electrodes have been described in literature for the measurement of blood pH. They are all of the glass electrode type but made in different shapes so that they may accept small quantities of blood and yield accurate results. The most common type is the syringe electrode, which is preferred for the convenient of taking small samples of blood. The constructional details of a typical blood pH electrode and the measurement setup used in practice.

Measurement of Blood pH(pH electrode):

The small dead space between the electrode bulb and the inner surface of the syringe barrel is usually filled with dilute heparin solution to prevent blood coagulation Before making measurement, the syringe should be rolled between the hands to ensure thorough mixing. Micro capillary glass electrodes are preferred when it is required to monitor pH continuously for example during surgery. Page 22 Typically a micro electrode for clinical applications requires only 20 – 25 µl of capillary blood for the determination of pH. The electrode is enclosed in a water jacket with circulating water at a constant temperature of 380C. The water contains

1% Nacl for shielding against static interference. The capillary is protected with polyethylene tubing. The internal reference electrode is silver / silver chloride and the calomel reference electrode is connected to a small pool of saturated Kcl, through a porous pin. The potential difference between these active and reference electrodes are given to the amplifier of the pH meter which gives the digital readout of the measured pH value.

1.12 RESPIRATION RATE:

(No. of breathes per minute) The primary function of the respiratory system is to supply oxygen and remove carbon dioxide from the tissues. The action of breathing is controlled by a muscular action causing the volume of the lung to increase and decrease to affect a precise and sensitive control of the tension of carbon dioxide in the arterial blood. Under normal conditions, this is rhythmic action with the result that the respiration rate provides a fairly good idea about the relative respiratory activity. Normal Respiration rate is 12-20 breaths/minute, for normal adults 50-60 breaths/minute for Childs. Several techniques have been developed for the measurement of respiration rate. The choice of a particular method depends mostly upon the ease of application of the transducer and their acceptance by the subject under test.

Some of the commonly used methods for the measurement of respiration rate are explained below.

i. Displacement method

ii. Thermistor method

iii. Impedance Pneumography

iv. CO_2 method of respiration rate measurement.

1.12(i) Displacement method:

The respiratory cycle is accompanied by changes in thoracic volume. These changes can be sensed by means of a displacement transducer incorporating a strain gauge or a variable resistance element. The transducer is held by an elastic band, which goes around the chest. The respiratory movements result in resistance changes of the strain gauge element connected as one arm of a wheat stone bridge circuit. Bridge output varies with chest expansion and yields signals corresponding to respiratory activity.

1.12(ii) Thermistor method:

Since air is warmed during its passage through the lungs and the respiratory tract, there is a detectable difference of temperature between inspired and expired air. The difference of temperature can be best sensed by using a thermistor placed in front of the nostrils by means of a suitable holding device. In case the difference in temperature of the outside air and that of the expired air is small, the thermistor can even be heated initially to an appropriate temperature and the variation of its resistance in synchronism with the respiration rate, as a result of the cooling effect of the air stream can be detected. This can be achieved with thermistor dissipations of about 5 to 25 mw. The thermistor is placed as part of a voltage dividing circuit or in a bridge circuit whose unbalance signal can be amplified to obtain the respiratory activity. This method is found to satisfy the majority of clinical needs for operative and post-operative subjects.

1.12(iii) Impedance Pneumography This is an indirect technique for the measurement of respiration rate using externally applied electrodes on the thorax, the impedance pneumograph measures the rate through the relationship between respiratory depth and thoracic impedance change. Page 23 This method consists in passing a high frequency current through the appropriately placed electrodes on the surface of the body as shown in fig 1.22 and detecting the modulated signal. The signal is modulated by changes in the body impedance accompanying the respiratory cycle. The electrodes used for impedance pneumograph are of the self adhesive type. Contact with the skin is made through the electrode cream layer for minimizing motion artifacts. To avoid the stimulation of sensory receptors, nerves and muscles, currents higher in frequency than 5 kHz must be used for the measurement of physiological events by impedance. Frequencies lower than 5 kHz are particularly hazardous since ventricular fibrillation may be produced with substantial current flow. The impedance based method of measuring respiration rate is commonly employed in patient monitoring systems. The electrodes used for this purpose are the same as those used for ECG measurement. The dynamic measuring range of the amplifier is 0.1 to 3μV with a frequency response of 0.2 to 3 Hz corresponding to respiratory rate of 12 to 180 per minute.

The amplifier produces a respiratory waveform from which respiratory rate is derived. 1.12(iv) CO2 method of respiration rate measurement Respiration rate can also be derived by continuously monitoring the CO2 contained in the subject‟s alveolar air. The measurement is based on the absorption property of infrared rays by certain gases. Suitable filters are required to determine the concentration of specific gases (CO2, CO and NO2) constituting the expired air. When infrared rays are passed through the expired air containing a certain amount of CO2, some of the radiations are absorbed by it. There is a proportional loss of heat energy associated with the rays. The detector changes the loss in heating effect of the rays into an electrical signal. This signal is used to obtain the average respiration rate.

1.13 PULMONARY FUNCTION MEASUREMENT: Measurement of lung volume The mechanics of breathing concern the ability of a person to bring air into his lungs from the outside atmosphere and to exhaust air from the lungs. This ability is affected by the various components of the air passages, the diaphragm, and associated muscles, the rib cage and associated musculature and the characteristics of the lungs themselves. Tests can be performed to assess each of these factors, but no one measurement has been devised that can adequately and completely evaluate the performance of the breathing mechanism. Among the basic tests performed are those to determine the volumes and capacities of the respiratory system.

These are defined as follows Respiratory Volumes Tidal volume (TV): The volume of gas inspired or expired (exchanged with each breath) during normal quiet breathing is known as tidal volume. Fig. 1.2 2 . Measurement of Lung volume (Spirometer) Minute volume (MV): The volume of gas exchanged per minute during quiet breathing. It is equal to the tidal volume multiplied by the breathing rate. Alveolar volume (AV): The volume of fresh air entering the alveolar ventilation = (Breathing rate) x (Tidal volume – Dead space) Inspiratory Reserve volume (IRV): The volume of gas, which can be inspired from a normal end tidal volume. Expiratory Reserve volume (ERV): The volume of gas remaining after a normal expiration less the volume remaining after a forced expiration. Residual volume (RV): The volume of gas remaining in the lungs after a forced expiration Pulmonary function tests are performed for the assessment of lung's ability to act as a mechanical pump for air and the ability of the air to flow with minimum impedance through the conducting airways. These tests are classified into two groups.

(i) Single breath tests and

(ii) Multiple breath tests

There are three types of tests under single breath category. They are, ϖ Tests that measure expired volume only ϖ Tests that measure expired volume in a unit time ϖ Tests that measure expired volume / time. In the class of multiple breath test measurements is the Maximal Voluntary Ventilation (MVV) which is defined as the maximum amount of air that can be moved in a given time period. Here, the patient breaths in and out for 15econds as hard and as fast as he or she can do. The total volume of gas moved by the lungs is recorded. The value is multiplied by 4 to produce the maximum volume that the patient breathed per minute by voluntary effort. A resting person inspires about 0.5 liter of air with each breath, with the normal breathing rate of 12 to 20 breaths per minute. With exercise The volume may increase 8 to 10 times and the breathing rate may reach 40 to 45 breaths per minute. A respiratory disease may be suspected if these volumes, capacities or rates are not in the normal range. 1.13.1 Measurement of lung volume The instrument used to measure lung volume is called a Spiro meter. Basically, the record obtained from this device is called a Spiro gram. Spiro meters are calibrated containers that collect gas and make measurements of lung volume or capacity that can be expired. By adding a time base, flow depended quantities can be measured. Basic Spirometer Fig.1.23 Basic water sealed Spiro meter (Measurement of Lung Volume) Most of the respiratory measurements can be adequately carried out by the classic water sealed Spiro meter shown in fig.1.23 Page 25 This consists of an upright, water filled cylinder containing an inverted counter weighted bell changes the volume of gases trapped inside, and the change in volume is translated into vertical motion, which is recorded on the moving drum of a kymograph. The excursion of the bell will be proportional to the tidal volume. For most purposes, the bell has a capacity of the order of 6 – 8 liters. Unless a special light weight bell is provided the normal Spiro meter is capable of responding fully to slow respiratory rates and not to rapid breathing sometimes encountered after anesthesia. Also, the frequency response of a Spiro meter must be adequate for the measurement of the forced expiratory volume. The Spiro meter is a mechanical integrator, since the input is air flow and the output is volume displacement. An electrical signal proportional to volume displacement can be obtained by using a linear potentiometer connected to the pulley portion of the Spiro meter. The Spiro meter is a heavily damped device so that small changes in inspired and expired air volumes are not recorded. The Spiro meter can be fitted with a linear motion potentiometer, which directly converts Spiro meter volume changes into an electrical signal. The signal may be used to feed a flow – volume differentiator for the evaluation and recording of data. Tests made using the Spiro meter are not analytical. Also, they are not completely objective because the results are dependent on the co-operation of the patient and the coaching efforts of a good respiratory technician. Calculating results manually from the graph of the mechanical volume Spiro meter requires considerable time. Transducers have been designed to transform the movement of the bell, bellows or piston of volume Spiro meters into electrical signals. These are then used to compute the numerical results electronically.

1.14 MEASUREMENT OF HEART RATE:

(Beats/minute) Heart rate is derived by the amplification of the ECG signal and by measuring either the average or instantaneous time intervals between two successive R peaks. Techniques used to calculate heart rate include: ϖ Average Calculation This is the oldest and most popular technique. An average rate (beats/minute) is calculated by counting the number of pulses in a given time. The average method of calculation does not show changes in the time between beats and thus does not represent the true picture of the heart‟s response to exercise, stress and environment. ϖ Beat- to – Beat calculation This is done by measuring the time (T), in seconds between two consecutive pulses, and converting this time into beats/min, using the formula beats/min =60/T . This technique accurately represents the true picture of the heart rate. ϖ Combination of beat – to – beat calculation with Averaging This is based on a four or six beats average. The advantage of this technique over the averaging technique is its similarity with the beat-to-beat monitoring system. The normal heart rate measuring range is 0- 250 beats/min. Limb or chest ECG electrodes are used as sensors. 1.14.1 Average heart rate meters The heart rate meters, which are a part of the patient monitoring systems, are usually of the average reading type. They work on the basis of converting each R wave of the ECG into a pulse of fixed amplitude and duration and then determining the average current from these pulses. Page 26 They incorporate specially designed frequency to a voltage converter circuit to display the average heart rate in terms of beats/minute. 1.14.2 Instantaneous heart rate meters Instantaneous heart rate facilitates detection of Arrhythmias and permits the timely observation of incipient cardiac emergencies. Calculation of heart rate from a patient‟s ECG is based upon the reliable detection of the QRS complex. Most of the instruments are, however quiet sensitive to the muscle noise generated by patient movement. This noise often causes a false high rate that may exceed the high rate alarm. A method to reduce false alarm is by using a QRS matched filter. This filter is a fifteen sample finite impulse-response filter. Whose impulse response shape approximates the shape of a normal QRS complex. The filter therefore would have minimum absolute output when similarly shaped waveforms are input. The output from other parts of the ECG waveform, like a T wave will produce reduced output. Above fig 1.24. shows the block diagram of instantaneous heart rate monitor. The ECG is sampled every 2ms. Fast transition and high amplitude components are attenuated by slew rate limiter which reduces the amplitude of pacemaker artifacts and the probability of counting these artifacts as beats. Two adjacent 2ms samples are averaged and the result is a train of 4ms samples. In order to remove unnecessary high frequency components of the signal, a 30 Hz, infinite impulse response filter is employed. This produces 8ms samples in the process. Any dc offset with the signal is removed by a 1.25 Hz low pass filter. The clamped and filtered ECG waveform is finally passed through a QRS matched filter. The beat detector recognizes QRS complexes in the processed ECG waveform value that has occurred since the last heart beat. If this value exceeds the threshold value, a heart beat is counted. The threshold in this arrangement gets automatically adjusted depending upon the value of the QRS wave amplitude and the interval between the QRS complexes. Following each beat, an inhibitory period of 200ms is introduced during which no beat is detected. This reduces the possibility of the T wave from getting counted.

1.15 MEASUREMENT OF TEMPERATURE: Two basic types of temperature measurements can be obtained from the human body. (i) Systemic (Body) temperature measurements. (ii) Skin temperature measurements. Both provide valuable diagnostic information, although the systemic temperature measurement is much more commonly used. Systemic (Body) temperature is the temperature of the internal regions of the body. This temperature is maintained through a carefully controlled balance between the heat generated by the active regions of the tissue of the body, mainly the muscles and the liver, and the heat lost by the body to the environment. Page 27 Measurement of systemic body temperature is accomplished by temperature sensing devices placed in the mouth, under the armpits, or in the rectum. The normal oral (mouth) temperature of a healthy person is 370 C. (98.60 F) 1.15(i) Measurement of systemic body temperature Since the internal or systemic body temperature is a good indicator of the health of a person measurement of this temperature is considered one of the vital signs of medicine. High degree of accuracy is not always important methods of temperature measurement must be reliable and easy to perform. In case of continuous monitoring, the temperature measurement must not cause discomfort to the patient. When continuous recording of temperature is not required, the mercury thermometer is still the standard method of measurement. Since these are inexpensive, easy to use and sufficiently accurate, they will undoubtedly remain in common use for many years to come. Even so, electronic thermometers are available as replacement of mercury thermometers with disposable tips, these instruments require much less time for a reading and are much easier to read than the conventional thermometer. Where, continuous recording of the temperature is necessary, or where greater accuracy is needed than can be obtained with the mercury thermometer or its electronic counterpart, more sophisticated measuring instruments must be used.

Two types of electronic temperature sensing devices are found in biomedical applications. They are, (i) Thermocouple, a junction of two dissimilar metals that produce an output voltage nearly proportional to the temperature at the junction with respect to a reference junction. (ii) Thermistor, a semi conducting element whose resistance varies with temperature. Both types are available for medical temperature measurement, although thermistors are used more frequently than thermocouples. This preference is primarily because of the sensitivity of the thermistor in the temperature range of interest. Thermistors are variable resistance devices formed into disks, beads, rods or other desired shape. Thermistors decrease their resistance by 4 to 6% per0C. Negative temperature coefficient are widely used in biomedical applications. The most important characteristics is to consider in selecting a probe for a specific biomedical application are the physical configuration of the thermistor probe, the sensitivity of the device, resistance range of the probe. Although the resistance of a thermistor can be measured by use of an ohmmeter, most thermistor thermometers use a Wheatstone bridge to obtain a voltage output proportional to temperature variations.

1.15.2 Skin temperature measurement:

Although the systemic temperature remains very constant throughout the body, the skin temperature can vary several degrees from one point to another. The range is usually from about 30 to 350C. Exposure to ambient temperatures, the covering of fat over capillary areas, and local blood circulation patterns are just a few of the many factors that influence the distribution of temperature over the surface of the body. Often, skin temperature measurements can be used to detect or locate defects in the circulatory system by showing differences the pattern from one side of the body to the other. Skin temperature measurement from specific locations on the body are frequently made by using small, flat thermistor probes taped to the skin. The simultaneous readings from a number of these probes provide a means of measuring changes in the spatial characteristics of the circulatory pattern over a time interval or with a given stimulus. Although the effect is insignificant in most cases, the presence of the thermistor on the skin slightly affects the temperature at the location. Infrared thermometer (Method of measuring skin temperature) The human skin has been found to be an almost perfect emitter of infrared radiation. That is, it is able to emit infrared energy in proportion to the surface temperature at any location of the body. Page 28 Fig. 1.2 5 . Chromatography Fig. 1.2 6 . Output response of Chromatography If a person is allowed to remain in a room at about 21°C without clothing over the area to be measured, a device sensitive to infrared radiation can accurately read the surface temperature. Such a device, called an infrared thermometer can be used to locate breast cancer and other unseen sources of heat.

They can also be used to detect areas of poor circulation and other sources of coolness and to measure skin temperature changes that reflect the effects of circulatory changes in the body. Thermograph An extension of infrared thermometer method of skin temperature measurement is the thermograph. This device is an infrared thermometer incorporated into a scanner so that the entire surface of a body, or some portion of the body, is scanned in much the same way that a television camera scans an image, but much slower. While the scanner scans the body, the infrared energy is measured and used to modulate the intensity of a light beam that produces a map of the infrared energy on photographic paper. This presentation is called a thermo gram. By calibrating the instrument against known temperature sources, the picture can be read quantitatively. Thermo vision A similar device like thermograph is thermo vision. It has a scanner that operates at a rate sufficient high to permit the image to be shown in real time on an oscilloscope. The raster has about 100 vertical lines per frame and the horizontal resolution is also about 100 lines, which seems to be adequate for good representation. The intensity of the measured infrared radiation is reproduced by z-axis modulation (brightness variation) of the oscilloscope beam. One advantage of this system is that certain portions of the gray scale can be enhanced to bring out specific features of the picture. Also, the image can be changed so that warm spots appear dark instead of light as they usually do.

1.16 CHROMATOGRAPHY: Chromatography is a technique used for separating closely related chemical substance and it is based on differences in the migration velocity of the substances between a stationary phase and a mobile phase. The difference in migration velocity is due to a difference in solubility in the two phases. Depending upon the nature of mobile phase, it maybe called liquid chromatography which uses liquid mobile phases or gas chromatography which uses gas mobile phase. Liquid chromatography is used to analyze amino acids and composition of drugs. Gas chromatography is used to analyze steroids which is easily vaporized and aromatic acids. The following fig 1.26. shows the basic principal of chromatography. In this the sample is added with the mobile phase gas or liquid flow. The component in the sample travel with different velocities depending on their solubility in the stationary phase. Fig.1.26 (a) Chromatography Fig.1.26 (b) output response Particularly if the solubility of a component is lower, then it will travel faster. Thus the different components in the sample are separated as a result of their different migration velocities when the mobile phase passes over the stationary phaseThe detector in the outflow detects and displays the various components arriving at different times .

1.17 PHOTOMETRY: The composition of blood serum is determined by specialized chemical techniques. The different components of biological substances can be determined by measuring how they either absorb or emit visible light. Photometers are used to measure the transmitted and absorbed light as it passes through a sample. Flame Photometer A flame photometer is used to analyze urine or blood in order to determine the concentration of potassium (k), Sodium (Na), Calcium (Ca) and lithium (Li). Fig.1.27 Flame photometer Sometimes lithium is used as a calibration substance in the analysis of the other these substances. A known amount of lithium is added to the sample and the emitted light intensity of the sample under analysis is measured relative to that of lithium. The fig 1.27 shows the schematic of flame photometer. Using an atomizer, the liquid sample is sprayed into fine droplets by passing oxygen or air past the opening in it. A combustion gas, like acetylene is also added with air. The sample air – mixture is burnt out and the light emitted in the flame is passed through the narrow slit and then to diffraction grating. The diffracted colors are incident on various photodiodes. The variations in the intensity of light due to changes in the flow rate of the air or the changes in the flow rate of the air or the changes in the flow of fuel gas are eliminated by proper electronic monitoring circuit. The concentration of potassium ions is detected by observing the peak height of the spectral lines corresponding to it. For potassium, the wavelength that we are interested is 4047 Å (violet). For sodium, the interested wavelength is 5890 Å (Yellow). For lithium it is 6708 Å (Red). Separate photo-detector is used for each channel. The photo detector circuit consists of a reverse biased diode in which current flow increases as the intensity of light incident light upon it increases. Calibration potentiometer in each channel is used to calibrate the instrument with standard solution whose concentration is known. Assuming the sample is initially not containing any lithium, a known standard amount of lithium is added to the sample. The output of sodium channel and potassium channel are calibrated in terms of difference with the known lithium. For sodium, it can detect up to 0.01 mg/liter. For other ions, the sensitivity is slightly slower.

FLUORESCENCE: Fluorescence is an optical phenomenon in which the light of shorter wavelength is incident on a sample and the sample absorbs and reemits light of longer wavelength. The concentration of such chemicals can be determined by fluorometers. There are filter fluorometers and spectrofluorometers depending on whether filters or monochromators are used to select the emission wavelength respectively. 1.18.1 Fluorometer Fluorometer is an instrument used in the clinical chemistry laboratory to determine the concentration of particular substances in samples of body fluids. Principle of working of Fluorometer The instrument is based on the property of some molecules to emit light in a characteristic spectrum when illuminated by light of another shorter wave length. The fluorescent materials may be in the samples to be analyzed or they may be produced by combination with reagents. The normal layout for the instrument is a slit-lamp light source (often ultraviolet), a filter to make sure that the expected fluorescent spectrum is not present in the illuminating light, and a cuvette containing the sample which is shown in Fig.1.28 Very dilute samples are used since this avoids re-absorption of the light produced. The light emitted is normally detected at right-angles from the incident light through a secondary filter to the photometer. Not many materials exhibit fluorescence, but those that do can be determined by fluorometry, with much great sensitivity than by using a spectrophotometer. Disadvantages of fluorometry The principal disadvantage of fluorometry is the sensitivity of its determinations to temperature and pH of the sample.

UNIT-II BIOMEDICAL RECORDERS

2.1 ELECTROCARDIOGRAPHY (ECG):

Electrocardiography deals with the study of electrical activity of heart muscles. The potentials originated in the individual fibers of heart muscles are added to produce the ECG wave form. 2.1.1 Origin of the Cardiac potential Fig.2.1 shows the Conduction system of heart (Origin of ECG wave) Fig.2.1 Conduction system of heart (Origin of ECG wave) As shown in Fig. 2.1 each action potential in the heart originates at the Sinoatrial (SA) node which is situated in the wall of the right atrium near the entry of the Vena cava. It is called as cardiac pacemaker and generates impulses at the normal rate of the heart, about 70 beats per minute at rest. The action potential contracts the atria muscle and the impulse spreads through the atria wall during a period of about 0.04 seconds to the atrio-ventricular node. The AV node delays the spread of excitation for about 0.11 second. Thu the AV node acts as a delay line to provide timing between the action of the atria and the ventricles. Then a special conduction system carries the action potential to the ventricular muscles. This system consists of a common part (bundle of His), two bundle branches on each of the septum an fine Purkinji fibers. Thus the atria and the ventricles are functionally linked only by the AV node and the conduction system. The AV node delay is provided so that the atrial contraction can complete the ventricular filling before the contraction of ventricles. The heart pumps blood when the heart muscle cells making up the heart wall contract, generating their action potential. This potential creates electrical currents that spread over the heart throughout the body. The spreading electrical currents create differences in electrical potential between various locations in the body, and these potentials can be detected and recorded through surface electrodes attached to the skin. i.e., The waveform produced by the action potentials of heart is called the electrocardiogram (ECG) that is a written record (graph) of the cardiac electrical potential waveform.

2.1.2 Typical ECG waveform The normal wave pattern of the ECG is shown in fig 2.2. Page 36 Fig.2.2 Representation of ECG Wave It shows the details of the electrical activity of the heart. The type of waveform and its variation in different segments depends upon the location of recording electrodes in different state of the heart. The electrical activity in each cycle of cardiac wave can be divided into three main components. 1. Depolarization of atria region. 2. Re polarization of ventricle region. 3. Re polarization of atria and ventricle regions. The depolarization contracts and re polarization relaxes atria and ventricles. 1. The P-wave corresponds to atria depolarization. 2. The QRS complex or R-wave corresponds to ventricular contraction and atria re polarization. 3. The T-wave corresponds to re polarization of ventricles. The re polarization of atrium is slow and prolonged and remains hidden in ventricle depolarization and re polarization. The U-wave is uncertain and may or may not be present in ECG wave. 2.1.3 ECG lead system Different electrode positions and their combinations are used to view the conduction of electrical signal in the heart from different angles and directions. Fig.2.3 Location of electrodes in ECG Measurement

The fig. 2.3 shows the location of electrodes which are used to record ECG. Each pair of electrode position used for recording is called a lead. There are 12 leads in ECG recording system and are divided into; 12 leads: (i) 3 limb leads (Bipolar) (ii) 3 augmented limb leads (iii) 6 Chest leads. In recording ECG, four electrodes are fixed on four locations on limbs at left arm (LA), Right arm (RA), Left Leg (LL) and right leg (RL) and fifth mobile electrode on the chest (V). RL electrode is earthed to provide common ground. Page 37 Fig. 2 .4 . Einthoran Triangle (i) Bipolar limb leads. (Einthoven leads) The bipolar limb leads are those designated as lead I, lead II and lead III and form what is known as Einthoven Triangle. The electrical connection for these three leads is shown in fig 2.3 Fig.2.3 Bipolar limb leads Following are the relationship for various leads. Lead I = LA – RA (Difference between LA and RA) Lead II = LL – RA (Difference between LL and RA) Lead I = LL – LA (Difference between LL and LA) Einthovan Triangle: Einthovan Triangle shown in fig 2.4 shows the mutual relationship between three limb leads lead I, lead II, and lead III of ECG measurement i.e.,) lead II = lead I + lead III Fig.2.4 Einthovan Triangle (ii) Augmented unipolar limb leads These leads examine the composite potential from all three limb leads simultaneously. In all three augmented leads, the signals from two limbs are summed in a resistor network and then applied to the amplifier‟s inverting input, which the signal from the remaining limb electrode is applied to the noninverting input as shown in the following figure 2.5 There is definite relationship between augmented leads and bipolar leads. Page 38 aV leadI leadII aV leadI leadIII aV leadII leadIII R L F = + = + = + 2 2 2 Fig. 2 .5 . Augmented limb lead system Fig. 2 .6 (a). Unipolar chest lead system Fig. 2 .6 (b). Unipolar chest lead system Fig. 2.5 Augmented unipolar limb leads (iii) Unipolar Chest leads The fig 2.6 shows the locations for V1 through V6 Fig.2.6 Unipolar chest lead Page 39 Fig. 2 .7 . Metal plate surface electrode (ECG electrode) The unipolar chest leads (V1 through V6) are measured with the signals from certain specified locations on the chest applied to the amplifier‟s non inverting input, while the RA, LA and LL signals are summed in a resistor network at the amplifier‟s inverting input called the indifferent electrodes. 2.2 ECG ELECTRODES:

A variety of electrodes have been designed for surface acquisition of biomedical signals. Perhaps the oldest forms of ECG electrodes in clinical use are the following. (i) Metal plate or Strap on electrode. (ii) Suction cup electrode (iii) Adhesive or column electrode (i)Metal plate electrodes These electrodes are 1-2 sq. inches. Brass plates that are held in place by rubber straps as shown in fig 2.7. A conductive gel or paste is used to reduce the impedance between the electrode and skin. This device is used as a limb electrode in short term ECG recording. Fig.2.7 Metal plate Surface Electrode (ii)Suction cup electrode This device is used as a chest electrode in short term ECG recording. The electrode is popular for its practicality being attachable to fleshy parts of the body. It is shown in fig 2.8 (iii)Adhesive or column electrode For long term recording or monitoring, such as continuous monitoring of a hospitalized patient in a coronary or intensive care unit, the paste on column electrode or Adhesive electrode is used. It is shown in fig 2.9 The electrode consists ofa silver-silver chloride metal contact button contact at the top of a hollow column that is filled with a conductive gel or paste. This assembly is held in place by an adhesive-coated foam rubber disk.

2.3 ECG AMPLIFIERS:

For electrocardiograms, an ac coupled amplifier with • Sensitivity of 0.5mV/cm • Frequency response of up to 1 kHz • Input impedance of 2 to 5 MΩ is required All the above requirements can be fulfilled by using a differential amplifier at the input stage of an ECG machine which is shown below in Fig.2.10. Page 40 Fig.2.10 shows a single op-amp in differential configuration. The common mode rejection for most Op – amps is typically between 60dB to 90 dB. This may not sufficient to reject common mode noise generally encountered in bio-medical measurements. Also, the input impedance is not very high to handle signals from high impedance sources. Even though it is well suited for most of the bio-medical applications it has the above limitations. But in modern biomedical instrumentation for precision measurement we have to overcome the above limitations. This can be achieved by using instrumentation amplifier. It is basically a precision differential voltage gain device consists of three op-amps as shown in fig-2.11 The instrumentation amplifier offers the following advantages for its applications in the biomedical field. • Extremely high input impedance • Low bias and offset voltage • Less performance deterioration if source impedance changes. • Possibility of independent reference levels for source and amplifier. • Very high CMRR • Low power consumption Good quality instrumentation amplifiers have become available in single IC form such as µA 725, ICL 7605, LH0036 etc.

2.4 ECG RECORDING TECHNIQUES:

The electrocardiograph (ECG) is an instrument, which records the electrical activity of the heart. Fig.2.12 ECG Recorder Page 41 Electrical signals from the heart characteristically precede the normal mechanical function and monitoring of these signals has great clinical significance. ECG provides valuable information about a wide range of cardiac disorders such as the presence of an inactive part (infarction) or an enlargement (cardiac hypertrophy) of the heart muscle. Electrocardiographs are used in catheterization laboratories, coronary care units and for routine diagnostic applications in cardiology. Fig.2.12 shows the block diagram of an electrocardiograph (ECG recorder) machine. An ECG recording unit consists of the following building blocks.

- Lead selector
- Pre-amp stage
- Power Amplifier
- Auxiliary circuits
- Frequency selective feedback network
- Paper (chart) transport mechanism
- Pen motor

Lead selector:

The potentials picked up by the patient electrodes are taken to the lead selector switch. In the lead selector, the electrodes are selected two by two according to the lead program. By means of capacitive coupling, the signal from the lead selector switch is connected symmetrically to the long tail pair differential pre amplifier.

Pre amplifier stage:

The preamplifier is a three or four stage differential amplifier having a sufficiently large negative current feedback from the end stage to the final stage, which gives stabilizing effect. The amplified output signal is picked up single ended and is given to the power amplifier.

Power Amplifier:

The power amplifier is generally of the push pull differential type. The base of one input transistor of this amplifier is driven by preamplifier unsymmetrical signal. The base of the other transistor is driven by the feedback signal resulting from the pen position and connected via a frequency selective network. The output of power amplifier is single ended and is fed to a pen motor, which deflects the writing arm on the paper.

Frequency selective network:

Frequency selective network is an R.C network, which provides necessary damping of the pen motor and is preset by the manufacturer.

Pen motor: The pen motor is driven by a dc driver stage feeding a four transistor output stage operating the galvanometer. A bridge arrangement is preferred because of the low power efficiency of conventional push pull amplifiers.

Auxiliary circuits: The auxiliary circuits provide a 1 mv calibration signal and automatic blocking of the amplifier during a change in the position of the lead switch. It may include a speed control circuit for the chart drive motor. Paper transport mechanism:

A standby mode of operation is generally provided on the electrocardiograph. In this mode, the stylus moves in response to the input signals, but the paper is stationary. This mode allows the operator to adjust the gain and baseline position controls without wasting the paper. Electrocardiographs are almost invariably recorded on a graph paper with horizontal and vertical lines at 1mm intervals with a thicker line at 5 mm intervals. Time measurements and heart rate measurements are made horizontally on the ECG.

For routine work the paper speed is 25mm/s. Amplitude measurements are made vertically in millivolts. The sensitivity of ECG recorder is typically set at 10mm/mv.

2.4.1 Types of ECG Recorders:

There are numerous types of ECG recorders. They are:

1.Galvanometer

2.Potentiometer

3.EM Recorder

4.Jet Recorder

5. Ultra meter

6. CRO Recorder(Computer interface)

7. Digital printer

Many of these are portable units, while others are part of permanent installations.

The following are commonly used types of ECG recorders

- Single channel recorders.
- Abnormal ECG waves
- Three channel recorders.
- Vector cardiographs.
- ECG systems for stress testing (Treadmill).
- ECG for computer processing.
- Continuous ECG recording.

Single channel recorders:

The most frequently used type of ECG recorder is the portable single channel unit. For hospital use this recorder is usually mounted on a cart so that it can be wheeled to the bedside of a patient with relative ease. Three channel recorders: Where large numbers of ECGs are recorded and mounted daily, substantial savings in personal can be achieved by the use of automatic three channel recorders. These devices not only record three leads simultaneously on a three channel recorder, but they also switch automatically to the next group of three leads. An ECG with 12 leads therefore can be recorded automatically as sequence of four groups of three traces.

Vector electrocardiograph: It presents an image of both the magnitude and the special orientation of the heart vector. Electrocardiograph for stress testing: Coronary insufficiency does not manifests itself in the ECG if the recording is taken at rest. So to take ECG under stress this machine is used. Electrocardiograph for computer processing :This technique requires that the ECG signal from the standard leads be transmitted sequentially to the computer by suitable means, together with additional information of the patient. The automatic three channel recorder can frequently adapted for this purpose. Continuous ECG recordings: Because a normal ECG presents only a brief sample of cardiac activity, arrhythmias which occur intermittently or only under certain conditions such as emotional stress are frequently missed.

The technique of continuous recording makes it possible to capture these kinds of arrhythmias. The smallest device of this type can be a worn in a shirt pocket and allowing recording of the ECG at normal daily activity.

2.4.2 Analysis of ECG wave:

(Abnormal ECG waves) Abnormal patterns of ECG may be due to pathological states or on occasion, they may be due to artifacts. To diagnose the presence of undesirable artifacts on the ECG trace, a few recordings are illustrated below. Fig.2.13 Abnormal ECG Waves (a) Interference from the power line Power line frequency, 50 Hz interference is easily recognizable since interfering voltage in the ECG would have a frequency of 50 Hz. This interference may be due to the stray effect of the alternating current on the patient. Other causes of interference are loose contacts on the patient cable as well as dirty electrodes. Page 43 Fig. 2 .13 . Clinical uses of ECG waves When the machine or the patient is not properly grounded power line frequency interference may even completely obscure the ECG waveform as shown in fig 2.13 (a).

The most common cause or 50 Hz interference is the disconnected electrode resulting in a very strong disturbing signal. It is often strong enough to damage the stylus of an unprotected direct writing recorder and therefore needs quick action. (b) Shifting of the baseline: A wandering baseline but otherwise normal ECG trace is usually due to the movement of the patient or electrodes. The baseline shift shown in fig 2.13(b) can be eliminated by ensuring that the patient lies relaxed and the electrodes are properly attached. Baseline wandering is usually observed immediately after application of the electrodes. (c) Muscle tremor: Irregular trembling of the ECG trace without wandering of the baseline occurs when the patient is not relaxed or is cold. It is generally found in the case of older patients.

Muscle tremor signals are especially bothersome on limb leads when a patient moves or the muscles are stretched. For normal routine ECG recordings, the patient must be advised to warm and to relax so that muscle tremor from shivering or tension is eliminated. The most critical component of the ECG recorder is the patient cable. The conventional PVC insulation gets degraded and becomes rigid and breakable because of the ratification of the softener.

Some manufacturer supply a patient cable made of silicon rubber, which provides better elasticity over long periods. 2.4.3 Clinical uses of ECG waves Following waves shown in fig. 2.14 are some types of abnormal ECG waves which are helpful for the physician to diagnose the disease. Prolonged PQ segment conduction time i.e. >0.22sec. Results in first degree AV block. QRS interval is >0.1 sec. results in Bundle block, severe heart attack. ST segment elevated – Results myocardial infarction (dead tissue) caused by blocking of blood circulation Fig.2.14 Clinical uses of ECG Waves Page 44 ST segment is depressed i.e. – negative T wave is present results in coronary insufficiency. Train of pulses instead of PQRST waves results in ventricular fibrillation which may lead to death if it is not properly corrected by defibrillator.

2.5 NERVOUS SYSTEM:

The nervous system is a complex network of nerves and cells that carry messages to and from the brain and spinal cord to various parts of the body. The nervous system includes both the Central nervous system and Peripheral nervous system Fig.2.15 Nervous system and Brain The task of controlling the various functions of the body and coordinating them into an integrated living organism is not simple. Consequently, the nervous system, which is responsible for this task is the most complex of all systems in the body as shown in Fig.2.15 Composed of the brain, numerous sensing devices, and a high speed communication network that links all parts of the body, the nervous system not only influences all the other systems but is also responsible for the behavior of the organism. In this broad sense, behavior includes the ability to learn, remember, acquire a personality and interact with its society and the environment. It is though the nervous system that the organism achieves autonomy and acquires the various traits that characterize it as an individual.

2.5.1 Electroencephalography (EEG):

The record of gross bioelectric potentials generated by neuronal activity in the brain is called electroencephalogram (EEG). The EEG has a very complex pattern which is difficult to recognize as compared to ECG. We know that multifunctional nature of the body requires activation of number of neurons at any instant of time. Depending on the types of neurons and their activities the temporal and spatial summation of neuron potential will be different. Thus this potential will be dependent on the site where the pickup electrode is located. Experiments have shown that the frequency of EEG seems to be affected by mental activity of a person. Further unlike ECG, EEG waves do not have any rhythm. The amplitude of EEG signal is relatively small (about 50 µv) and therefore interference due to external electrical signals often posses serious problems in EEG processing. 2.5.2 EEG Recorder EEG Recorder is an instrument for recording the electrical activity of the brain, by suitably placed surface electrodes on the scalp.The basic block diagram of an EEG recorder with both analog and digital components is shown in fig 2.16. It consists of the following parts.

1. Montage

2. Electrode montage selector

3. Pre amplifier

4. Sensitivity control

5. Filters

6. Writing part

7. Paper Drive

8. Channels

Montage:

A pattern of electrodes on the head and the channels they are connected to is called a montage. Montages are symmetrical. The reference electrode is generally placed on a non active site such as the forehead or ear lobe. EEG electrodes are arranged on the scalp according to a standard known as the 10/20 system. There are 21 electrodes in the 10/20 system. Electrode montage selector: The montage selector on analog EEG machine is large panel containing switches that allow the user to select which electrode pair will have signals subtracted from each other to create an array of channels minus the input from a second electrode. Page 46 Preamplifier: Every channel has an individual multistage, ac coupled, very sensitive amplifier with differential input and adjustable gain in a wide range. Its frequency response can be selected by single stage passive filters. The calibrating signal is used for controlling and documenting the sensitivity of the amplifier channels.

A typical value of calibration signal is 50µV/cm. Sensitivity control: The overall sensitivity of an EEG machine is the gain of the amplifier multiplied by the sensitivity of the writer. Thus if the writer sensitivity is 1cm/V, the amplifier must have an overall gain of 20,000 for a 50µV signal. An EEG machine has two gain controls one is continuously variable and it is used to equalize the sensitivity of all channels. The other control operates in steps and is meant to increase or reduce the sensitivity of a channel by known amounts. Filters: Just like in an ECG when recorded by surface electrodes, an EEG may also contain muscle artifacts due to contraction of the scalp and neck muscles, which overlie the brain and skull. These artifacts causing great difficult in both clinical and automated EEG interpretation. These artifacts are generally removed by using low pas filters. Some EEG machine has a notch filter sharply tuned at 50 Hz so as to eliminate mains frequency interference. The high frequency response will be the resultant of the amplifier and writing part. These are removed by HPF Writing Part: The writing part of an EEG machine is usually of the ink type writing recorder. Paper Drive: This is provided by synchronous motor. An accurate and stable paper drive mechanism is necessary and it in normal practice to have several paper speeds available for selection. Speeds of 15, 30 and 60 mm/s are essential. Channels: An EEG is recorded simultaneously from an array of many electrodes. The record can be made from bipolar and monopolar leads. The electrodes are connected to separate amplifiers and writing systems. Commercial EEG machine have up to 32 channels, although 8 or 16 channels are more common. Modern EEG machines are mostly PC based with a Pentium processor, 16 MB RAM, at least a 2 GB hard disk. The system can store up to 40 hours of EEG. 2.5.3 10-20 EEG electrode lead system Spatial nature of EEG signal makes it imperative that the recording sites for this signal on human scalp should be orderized. The system most often used to place electrodes for monitoring the clinical EEG is the International Federation 10-20 system. This system uses certain anatomical landmarks to standardize the placement of EEG electrodes. Traditionally, there are 21 electrodes locations in the 10 -20 system. This system involves placement of electrodes at distances of 10% and 20% and of measured coronal, Saggittal and circumferential areas between landmarks on the cranium which is shown in fig 2.17 Page 47 1. Electrodes are identified according to their position on the head. 2. Fp for frontal – polar, F for frontal, C for central, P for parietal, T – for temporal and o for occipital. 3. Odd numbers refer to electrodes on the left side of the head. 4. Even numbers refer to electrodes on the right side of the head. 5. Z denotes midline electrodes 6. A1 and A2 midline aural i.e. reference ear lobe electrodes 7. Pg1 and Pg2 indicate nasion electrodes also can be used as reference electrodes.EEG can be recorded, 1. Between each of the pairs of locations (Bipolar recording) 2. Between one location and the average of all signals from all locations or 3. Between only one location and a distant reference electrode (usually attached to one or both ear lobes) A1 or A2. (unipolar recording) In the average reference mode, the system reference is formed by connecting all scalp recording locations through equal high resistance to a common point. In a bipolar system, differential measurements are made between successive pairs of electrodes. 2.5.4 EEG recording techniques Varies EEG recording techniques are shown in fig.2.18 (i) Bi-polar mode recording In bipolar recordings the potential difference between 2 electrodes (one may be +ve going and another –ve going) is recorded thro‟ an EEG amplifier which is designed as a diff amplifier (This is also called Pre-Amp). Hence in a 8 machine there will be 8 bipolar recordings done simultaneously on 8 recording strips. (This is an ordinary paper, unlike that of EKG paper) where ink writing is usually done). (ii). Unipolar recording In unipolar recording ear lobe is used as patient earth (O volts) and records against one of the electrodes on the scalp. Hence the difference in potential between the electrodes (as +ve terminal) and the earth point is measured.The Pre-Amps and Power amplifiers and the recorders and the same as discussed with respect to electro book diagram, 8 such identical channels. Page 48 (iii) Average mode recording In this connection a summing network is used as shown in the Figure. This summing network acts as the neutral point against which the potential difference on any of the electrodes fixed on the scalp is recorded. These 3 recording – modes have their own advantages in the clinical studies in the department of neurology. 2.5.5 EEG waves The EEG has a very complex pattern which is difficult to recognize as compared to ECG. Experiments have shown that the frequency of EEG seems to be affected by mental activity of a person. Since the frequency is the most prominent features of an EEG pattern, they are divided into frequency bands. Each band has some specific Greek letter designation as shown in Fig.2.19. Fig.2.19 Types of EEG Waves Accordingly the waves are called as follows and are shown in table below. 2.5.6 Clinical uses of EEG waves (Analysis of EEG waves) Clinically EEG is of immense value in diagnosis of brain lesion, presence of tumor etc. EEG helps physician 1. in diagnosis of epilepsy 2. it allows classification of epileptic seizures Page 49 3. to determine the level of anesthesia in patients undergoing cardiac surgery 4. in case of patients who are difficult to monitor 5. in diagnosis of brain death 6. in diagnosis of brain tumor 7. To diagnose sleep disorders. EEG together with other tests, such as averaged evoked potentials is used to determine hearing and visual problems in the newborn babies. Neurologists rely heavily on EEG‟s as a clinical tool to define patient‟s brain pathology. Following waves shown in fig. 2.20 are some types of abnormal EEG waves which are helpful for the physician to diagnose the disease. Fig.2.20 Clinical uses of EEG Waves (Abnormal EEG Waves) Level of consciousness EEG changes with the level of consciousness. Diminished mental activity usually results in a lower frequency and large amplitude EEG waves. Following are the variation of EEG waves with respect to sleep disorders. Brain Tumors:If the tumor displaces the cortex and if it is large enough, the electrical activity will be absent in the part of hemisphere, since no electrical potentials originated in the tumor itself, an extinguished or damped EEG over a certain part of the cortex can thus be a sign of a brain tumor. If tumors present in the cortex, these can cause near by neurons to generate abnormal electrical activity.

Epilepsy:Epilepsy is a symptom of brain damage. This may due to defects in the birth delivery or head injury during accident or boxing. It may also due to brain tumor. Epilepsy is a disease and is characterized by synchronous discharge of large groups of neurons, often including the whole brain. If High frequency spikes in the EEG wave pattern indicates epilepsy.

2.6 ELECTROMYOGRAPHY (EMG):

Electromyograph is a record of electrical activity of muscles. In fact EMG provides diagnostic information about the system. EMG waves: Like neurons, skeletal muscle fibers generate action potentials when excited by motor neurons via the motor end plates a shown in Fig.2.21 (a). They do not, however, transmit the action potentials to any other muscle fibers or to any neurons. Fig.2.21 (a) Electrical conduction by motor nerves Page 50 Fig. 2 .19 . EMG wave The action potential of an individual muscle fiber is of about the same magnitude as that of a neuron and is not necessarily related to the strength of contraction of the fiber. The measurement of these action potentials, either, directly from the muscle or from the surface of the body, constitutes the Electromyogram. (EMG wave) which is shown in fig 2.21(b) Fig.2.21 (b) EMG wave The amplitude of the EMG signals depends upon various factors, e.g. the type and placement of electrodes used and the degree of muscular exertions. The needle electrode in contact with a single muscle fiber will pickup spike type voltages whereas a surface electrode picks up many overlapping spikes and therefore produces an average voltage effect. A typical EMG signal ranges from 0.1 to 0.5 mv. They may contain frequency components extending up to 10 kHz. Such high frequency signals cannot be recorded on the conventional pen recorders and therefore, they are usually displayed on the CRT screen. 2.6.1 Measurement of Conduction Velocity in Motor Nerves The measurement of conduction velocity in motor nerves is used to indicate the location and type of nerve lesion. Here the nerve function is examined directly at the various segments of the nerve by means of stimulating it with a brief electric shock having a pulse duration of 0.2 – 0.5 milliseconds and measuring the latencies, we can calculate the conduction velocity in that peripheral nerve. Latency is defined as the elapsed time between the stimulating impulse and the muscle action potential. The following fig 2.22 illustrates the measurement procedure. Fig.2.22 Measurement of Conduction Velocity The EMG electrode and stimulating electrodes are placed at two points on the skin separated by a known distance l1. A brief electric pulse is applied thro‟ the stimulating electrode. When the exiting reaches the muscle, this contracts with a short twitch. Since all nerve fibers are stimulated at the same time and the conduction velocity is normally the same in all nerve fibers. The action potential of the muscle is picked up by the EMG electrode and is displayed on the oscilloscope along with the stimulating impulse. The elapsed time „t1‟ (latency) between the stimulating impulse and muscles action potential is measured. Now the two electrodes are repositioned with the distance of separation as l2 meters among the distances l and l2, l2 < l1, the latency is now measured as „t2‟ seconds. Page 51 The conduction velocity in peripheral nerves is normally 50m/s. When we have it below 40ms/ there is some disorder in that nerve conduction. 2.6.2 EMG Recording techniques Electromyograph is an instrument used for recording the electrical activity of the muscles to determine whether the muscle is contracting or not, or for displaying on the CRO. There are two techniques of recording EMG i) Spontaneous Recording This recording is usually done without any stimulation to find out the spontaneous (natural) activities of the skeletal muscles. If the spontaneous activity is not good due to number of reasons (paralysis, polio, hypothyroidism etc.) The second recording will be seen on the oscilloscope. ii) Stimulated Recording In this type of bipolar recordings, the muscles are stimulated and the stimulated recording is seen on the oscilloscope as shown in the diagram. In both the types of recordings it is the action potentials generated in the muscles are summated and presented in a complex waveform. The instrument is useful for making a study of several aspects of neuromuscular function, neuromuscular condition, extent of nerve lesion, reflex responses etc. A typical arrangement for recording of EMG is shown in fig 2.23. The block consists of the following parts. 1. EMG electrodes 2. EMG Amplifier 3. Cathode ray oscilloscope(display) 4. Tape recorder 5. Loud speaker EMG electrodes: EMG is usually recorded by using surface electrodes or needle/wire electrodes. The surface electrodes may be Adhesive or disposable type or the ones which can be used repeatedly. Surface electrodes provide gross indication which is sensitive over a wide area of the superficial muscle; where as needle/wire electrodes pickup the potentials produced by specific muscle or even a single motor unit. The signal then can be amplified. EMG Amplifier: An EMG amplifier is usually an instrumentation amplifier with high gain, high input impedance and high CMRR. The amplifier should have capability to process EMG signal which is about 50 µv to 1mv and of frequency from 10Hz to 3 kHz. Output device (Recording device): Because of high frequency content of an EMG signal, it is not possible to use pen recorder to record the signal pattern. The record is therefore taken either on CRO (Cathode Ray oscilloscope) or tape recorder. In some cases the signal is made audible via loud speaker. An audio amplifier is applied with loudspeaker to drive the loudspeaker. A trained EMG interpreter can diagnose various sounds produced when the muscle potentials are fed to the loudspeaker. Page 52 The tape recorder is included in the system to facilitate playback and study of the EMG sound waves at a later convenient time. The wave form can also be photographed from the CRT screen by using a synchronized camera. 2.6.3 Clinical applications of EMG waves 1. EMG is significant to diagnose the health of muscle. 2. The velocity of action potential in motor and sensory nerves can be determined by recording EMG signal. Such record is of vital importance in diagnosis of nerve damages. 3. EMG made during multiple stimulations is used to determine fatigue characteristic of muscles. 4. EMG is very useful in assistance of patients whose some part of body is not functioning properly. 5. EMG signal generated in the muscle for the control and coordination of the contraction /expression level of muscle.

2.7 ELECTRO-RETINOGRAPHY (ERG) :

It is found that an electrical potential exists between the cornea and the back of the eye. This potential changes when the eye is illuminated. The process of recording the change in potential when light falls on the eye is called electroretinography. The magnitude of the ERG voltage depends upon the intensity and duration of the light falling on the eye. It may be typically about 500µv. The ERG waveform is as shown in fig 2.24. The electrical potential generated in the retina of the eye gives us the ERG wave. The depolarization and re polarization of the retina produces this wave. 2.7.1ERG Recorder A general purpose direct writing recorder may be used for recording electro- retinograms (ERG waves). The following fig 2.25 shows the building block of electro- retinograph (ERG recorder) ERG Electrodes: ERG potentials can be recorded with a pair of electrodes. One of the electrodes is mounted on a contact lens and is in direct contact with the cornea. The other electrode is placed on the skin adjacent to the outer corner of the eye. A reference electrode may be placed on the forehead. The electrodes are usually one cm dia. with silver-silver chloride coated on silver as the base electrode material. Lead selection: In ERG recordings, usually bipolar mode is used which is explained above. Page 53 Bio-Amplifier: A differential amplifier with high gain, high input impedance and high CMRR can be used as Bio-amplifier. ERG is amplified here. Power Amplifier: The power amp is a push pull amplifier which is used to get enough power to drive the stylus of the paper chart recorder. Recorder: The recorder is of the type which is used for ECG applications. It has paper transport mechanism and pen motor. The speed of the pen motor is synchronized with the frequency of the ERG wave form.

2.8 AUDIOMETER :

An audiometer is specialized equipment, which is used for the identification of hearing loss in individuals, and the quantitative determination of the degree and nature of such a loss. It is essentially an oscillator driving a pair of headphones and is calibrated in terms of frequency and acoustic output. Both frequency and output are adjustable over the audio range (20 Hz to 20 kHz). The instrument is also provided with a calibrated noise source and bone conductor vibrator.

2.8.1 Types of Audiometers Audiometers may be divided into two main groups on the basis of the type of stimulus they provide to elicit auditory response. 1. Pure tone audiometer. 2. Speech audiometer. 3. The third type called screening audiometer which uses both types. Pure tone audiometer A pure tone audiometer shown in Fig.2.27 is used primarily to obtain air conduction and bone conduction thresholds of hearing. These thresholds are useful in the diagnosis of hearing loss. Pure tone screening tests are employed extensively in industrial and school hearing conversation programmers. In conventional pure tone audiometry, head phones are worn by the subject and a set of responses is obtained for air conducted sounds directed to each ear in turn. A bone conductor vibrator can then be attached to the head at the centre forehead position to see whether the hearing threshold improves. It does then the disorder is most likely wholly or partly conductive origin. To avoid stimulation of the ear not under test with the vibrator, it can be temporarily made deaf by introducing a suitable masking noise in the non test ear via an earphone. A narrow band noise centered on the pure tone test frequency (125 Hz to 8000Hz) is used for this purpose. Speech audiometers: Speech audiometers are normally used to determine speech reception thresholds for diagnostic purposes and to assess and evaluate the presence of hearing loss. Screening audiometers: Screening audiometers are used to separate two different groups of people. One that can hear as well as or better than a particular standard and that the other cannot hear so well. Application of these instruments are found in industry and evaluate the performance of hearing aids.

2.8.2 Working of Basic Audiometer :

Audiometer is an electronic instrument for measuring human hearing level in terms of loudness and pitch of sound. In audiometers the hearing loss is measured in terms of decibels usually from 10 dB to 100dB. This is also used to detect conductive disorders, partial deafness and also to test the sensitivity of ears for the audible range of frequencies.The basic building block of an audiometer is shown in fig 2.26. It consists of the following parts.

• Tone generator (oscillator) • Speech amplifier

• Power amplifier

• Attenuator control

• Head phone

Tone generator:

Generally pure tone generators generates text tones in octave steps from 125 Hz to 8000 Hz. i.e., 125 Hz, 250Hz, 500Hz, 1000Hz, 2000Hz, 4000Hz & 8000 Hz. The tone generator consists of an LC oscillator in which the inductance and capacitance can be varied precisely and is coupled to a power amplifier. Speech amplifier: The pure tone sine wave is amplified here. The amplified signal is used to drive the power amplifier. Its gain can be controlled. Power Amplifier: The power amplifier delivers power to activate the ear phone or head phone. Attenuator control: The pure tone intensity can be varied from -10dB to 100 dB using the attenuator control. The attenuator used in these instruments is of ladder type of nominal 10Ω impedance. Head phone: Head phones or earphones connected to the outer ear for measuring hearing thresholds Procedure for test Air Conduction Test Fig.2.27 Pure tone screening test. 1. The patient is asked to sit in a room and he will be wearing the head phones in the outer ear as shown in Fig.2.27 2.

The signal from the tone generator is injected into one of the ears. 3. The doctor increases the tone slowly until the patient is able to hear clearly. 4. The doctor, notes down the frequency as well as the level of the volume in dB 5. The volume control is calibrated in decibels and it indicates the hearing loss. The hearing in the other ear during this measurement is often masked by presenting a neutral stimulus. This method is normally used for factory workers. Page 55 Bone Conduction Test In the case of bone conduction measurements the microphones are fitted behind the ear. This is primarily used to test the outer and middle ears and also for people who are suffering from defective diaphragm. The bone conductor is a quartz crystal operating on ultrasonic principle which is used on the mastoid bone to check the blockage of outer and middle ear. The mastoid bone has a direct anatomical connection with the inner ear so that the inner ear and the auditory nerve can be tested. Speech audiometers are normally used to determine speech reception thresholds for diagnostic purposes and to assess and evaluate the performance of hearing aids. In speech audiometers, the tests are carried with spoken voices to prescribe the hearing aids.

2.8.3 Applications of audiometers: 1. To find hearing thresholds. 2. To find conduction deafness. 3. To detect outer ear, middle ear defects 4. To find out hearing losses. 5. To evaluate the effectiveness of ear protectors and noise control measures in the case of industries. 2.8.4 Masking in Audiometer In the presence of monaural and asymmetrical binaural hearing losses, there is a serious difficulty in obtaining accurate measures of hearing for the poorer ear. The answer to the problem is to eliminate response from the better ear by masking, to shift the threshold to a higher level, Permitting greater intensities to be presented to the poorer ear without danger of crossover. If the difference in air conduction acuity between the two ears is 50dB or more, it is advisable to place a masking noise over the better hearing ear while determining depends the threshold in the other. Masking efficiency depends upon the nature of masking sound as well as its intensity. Saw tooth noise and white noise have been most commonly used for masking in clinical audiometry. Narrow band noise can also be used by several investigators in audiometry.

UNIT-III THERAPEUTIC INSTRUMENTS :

3.1 CARDIAC PACEMAKER:

An electronic device which is used to stimulate the heart muscles is called pacemaker. A pacemaker basically consists of two parts i) An electronic unit which generates stimulating impulses of controlled rate and amplitude, known as pulse generator ii) The lead which carries the electrical pulses from the pulse generator to the heart. A variety of pacemakers with various possibilities are commonly available. However, in almost all cases, the waveforms used for pacing are round topped rectangular pulses of 1 -3 ms duration with rates adjustable from 50 -150 pulses per minute (ppm). 3.1.1 Necessity of Pacemakers The muscles of the heart must contract in the correct sequence to allow adequate times for filling and pumping. The timing mechanism depends on the correct action of a natural pacemaker in the heart and the correct delays and distribution of the signal in the muscle and nerves of the heart. In abnormal situations, if this natural pacemaker fails to function or the triggering pulse does not reach the heart muscles, because of blocking by damage tissue, the normal synchronizing of the heart action gets disturbed. When monitored, this manifests itself by decrease in heart rate and changes in ECG waveform. By giving external stimulation pulses to the heart muscles, it is possible to regulate the heart rate. These external stimulation pulses are given by an electronic instrument called pacemaker. 3.1.2 Methods of stimulation or pacing There are two types of Pacing. ϖ External Pacing ϖ Internal Pacing External Pacing External Pacing is employed to restart the rhythm of the heart in case of cardiac stand still. Stand still occurs during open heart surgery or whenever there is a sudden physical shock or accident. Paddle shaped electrodes are applied on the surface of the chest and currents in the range of 20 – 150 mA are employed. Internal Pacing Internal Pacing is employed in cases requiring long term pacing because of permanent damage that prevents normal self triggering of the heart. The electrodes are in the form of wires of Teflon coated stainless steel. The currents in the range of 2 -15 mA are employed. 3.1.3 Types of pacing modes Several Pacing techniques are possible with both internal and external pacemaker. They can be classified as in fig 3.1 Page 60 a) Based on the placement of the pacemaker i) External Pacemaker ii) Internal Pacemaker b) Based on the modes of operation of the pacemaker i) Fixed rate pacemaker (Ventricular Asynchronous) ii) Ventricular synchronous (Stand by a R-wave triggered) iii)Ventricular inhibited (Demand) Pacemaker iv)Atria Synchronous Pacemaker (P-wave Synchronized) v) Programmable Pacemakers vi)A-V sequential inhibited pacemaker .

EXTERNAL PACEMAKERS:

External Pacemakers are the units which are placed on the outside of the body and are normally connected through wires introduced into the right ventricle via a cardiac catheter. External pacemakers are used on patients with temporary heart irregularities, such as those encountered in the coronary patient, including heart blocks. They are also used for temporary management of certain arrhythmias that may occur in patients during critical post operative periods and in patients during cardiac surgery especially if the surgery involves the valves. As the patient recovers, normal conduction returns and the use of pacemaker is discontinued. The pacing impulse is applied through metal electrodes placed on the surface of the body. Electrode jelly is used for better contact and to avoid burning of the skin underneath. An external pacemaker may apply up to 80mA pulses through 50 cm2 electrode on the chest. The procedure is painful and therefore is used only in emergency or in a temporary situation. The pulses may be delivered, (i) Continuously – when it is felt that the heart rate is below the preset value. The impulse frequency is independent of the heart rhythm. (ii) On demand – R wave synchronous pacing – Normally the pacemaker is inoperative but it is activated when the heart rate falls below the normal or preset value. In such a situation, beat to beat examination of the time between two R-waves is done. When this interval exceeds the preset value the pacemaker comes into operation. External pacemakers provide, ϖ Pacing rate adjustable from 30 to 180 pulses per minute ϖ Constant current output from 0.1 to 20 mA ϖ maximum of 18V ϖ Pulse width of is around 2 ms ϖ maximum sensitivity is 1.5 mV ϖ Common mode rejection of 50 Hz or 60 Hz mains frequency.

3.3 IMPLANTABLE (INTERNAL) PACEMAKERS:

The implanted pacemaker, along with its electrode, is designed to be entirely implanted beneath the skin. Its output leads are connected directly to the heart muscles. The pacemaker is a miniaturized pulse generator and is battery powered. The circuit is so designed that the batteries supply sufficient power for a long period. Since the pacemaker is located just beneath the skin, the replacement of the pacemaker unit involving relatively minor surgery has become routine procedure. For any implantable pacemaker, the basic requirements are, • The components should be highly reliable • The power source should supply sufficient power over prolonged period of time. • The circuit should be covered with a biological inert material Page 61 (a) Ventricular demand inhibited : VVI (b) A-V Sequential DVI (c) Synchronous, VD T/I (Atrial Ventricular inhibited) (d) Fully automatic DDD Fig. 3 .2 . Pacing modalities • The unit should be in such a way that body fluids should not enter into the pacemaker 3.3.1 Types of implantable pacemaker Depending upon the clinical requirements, different types of implantable pacemakers are utilized. i) Fixed rate pacemakers ii) Demand pacemakers: a. R-wave triggered b. R-wave inhibited c. Atria triggered d. Dual chamber pacemakers (i) Fixed rate pacemakers This type of pacemaker is intended for patients having permanent heart blocks. The rate is preset, say at 70 bpm. The rate can be varied externally in implanted units by magnetically actuating a built in relay. Since the fixed rate pacemaker functions regardless of the patient‟s natural because of competition between the patient‟s rhythm and that of the pacemaker. (ii) Demand Pacemakers These pacemakers have almost gradually replaced the fixed rate pacemakers because they avoid competition between the hearts natural rhythm and the pacemaker rhythm. The demand unit functions only when the R-R intervals of the natural rhythm exceed a pre-set limit.

3.4 Various pacing modalities in demand pacemakers (Implantable pacemakers):

Depending upon the clinical requirements, different types of implantable pacemakers are utilized as shown in Fig.3.2 Fig.3.2 pacing techniques Page 62 3.4.1 R-wave triggered (Ventricular synchronize demand Pacemaker) The ventricular synchronized demand type pacemaker is meant for patients who are generally in heart blocks with occasional sinus rhythm. The pacemaker detects ventricular activity (R-wave of ECG) and stimulates the ventricles after a very short delay time of some milliseconds. If there is a sinus rhythm the stimulating impulse will occur in the ventricular depolarization. If there is a systole, the unit will stimulate the heart after a preset time. Fig 3.3 shows the block diagram of R-wave triggered demand pacemaker. Fig.3.3 R-wave triggered demand pacemaker. The pulse generator has two functions, viz pacing and sensing. Sensing is accomplished by picking ECG signals. In the case of dual chamber pacing, P-wave is also sensed. The sensing path contains the parts, ϖ QRS BPF ϖ QRS Amplifier ϖ Threshold detector The stimulating path contains the parts, ϖ Refractory period T1 ϖ Free running oscillator T2 ϖ Output driver T3 Working ϖ Once the ECG signal enters the sensing circuit, it is passed through QRS BPF. This filter is designed to pass signals in the frequency range of 5 -100 Hz, with a centre frequency of 30Hz. ϖ This is followed by an amplifier and threshold detector which is designed to operate with a detection sensitivity of 1-2 mV i.e., cardiac signals have amplitudes in the 1 -30 mV range depending on the electrode surface area. ϖ A refractory period (T1) is necessarily incorporated to limit the pulse delivery rate, particularly in the presence of electromagnetic interference. ϖ The free running multi-vibrator provides a fixed rate mode with an interval of T2 via the output driver circuit. ϖ The output pulses of a length T3 synchronous with input signals that fall outside the sensing refractory period T1 are thus delivered at the stimulating electrode. ϖ Most of the commercial pacemakers employ a single defibrillation protection circuit that minimizes the detection of high level, high frequency, and pulsed electromagnetic interference artifacts. ϖ Two types of stimuli are produced by the output circuit of the pacemaker. These are the constant voltage and constant current type. ϖ Constant voltage pulses are typically in the range of 5V with a duration of 500 to 600 ms. ϖ Constant current pulses are typically in the range of 8-10mA with pulse duration of 1.0 to 1.2 ms. 3.4.2 Ventricular inhibited or R-wave blocked Pacemaker (demand pacemaker) Page 63 Fig.3.4 Ventricular inhibited or R-wave blocked Pacemaker The ventricular inhibited type pacemaker is meant for patients who generally have sinus rhythm with occasional heart block. The circuitry detects spontaneous R-wave potentials at the electrodes and the pacemaker provides a stimulus to the heart after a pre-set a systole. However, in the case of ventricular activity, the R-wave does not trigger the output circuit of the pacemaker but blocks the output circuit and no stimulation pulse is given to the heart. Fig 3.4 shows in block schematic of ventricular inhibited or R-wave blocked pacemaker. The circuit consists of sensing, stimulation as well as controlling actions. Stimulating Path ϖ The timing circuit which consists of an R-C network a reference voltage source and a comparator determines the pacing rate of the pulse generator. ϖ Its output feeds into a second RC network, the pulse width circuit, which determines the stimulating pulse duration. ϖ A third RC network, the rate limiting circuit, disables the comparator for a preset interval and thus limits the pacing rate to a maximum of 120 pulses per minute for most signal component failures. ϖ The output circuit provides a voltage pulse to stimulate the heart. ϖ The voltage monitor circuit senses cell depletion and signals the rate slow down circuit and energy compensation circuit. ϖ The rate slow down circuit shuts off some of the current to the basic timing network to cause the rate to slow down 8+3 OR 8-3 Beats per minute when cell depletion has occurred. ϖ The energy compensation circuit causes the pulse duration to increase as the battery voltage decreases, to maintain nearly constant stimulation energy to the heart. Sensing circuit ϖ There is a feedback loop from the output circuit to the refractory circuit, which provides a period of time following an output pulse or a sensed R-wave during which the amplifier will not respond the outside signals. ϖ The sensing circuit detects a spontaneous R-wave and resets the oscillator timing capacitor. ϖ The reversion circuit allows the amplifier to detect a spontaneous R-wave in the presence of low level continuous wave interference. ϖ In the absence of an R-wave, this circuit allows the oscillator to pace at its preset rate 71 beats per minute.

3.5 PROGRAMMABLE PACEMAKER:

Some times the rate of the internal pacemakers can be varied by external stimulation. For this programmed pacemakers are used. A programmable pacemaker consists of two parts as shown in fig 3.5. Page 64 Fig.3.5 Programmabl Fig. 3 .5 . Programmable Pacemaker e Pacemaker i) The external unit which generates programmed stimuli which is transferred to (ii) an internal unit by one of the several communication techniques. Using external programmer the parameters of the internal pulse generator i.e., pulse rate, pulse width etc. can be varied by the following communication techniques. The commonly used methods of transmitting information are

(i) Magnetic – an electromagnet placed on the surface of the body establishes a magnetic field which penetrates the skin and operates the pacemaker‟s reed switch as shown in fig 3.5.

(ii) Radio frequency waves – the information can be transmitted over high frequency electromagnetic waves which are received inside the body by an antenna. The antenna is usually in the shape of a coil housed within the pacemaker.

(iii) Acoustic – ultrasonic pressure waves from a suitable transducer placed over the skin can penetrate the human body. They are received by a suitable receiver in the pacemaker which carries out the desired function. Out of all these methods, the magnetic field method is the most widely used because of its simplicity and minimal power requirements.

An essential requirement of programmable pacemakers is that they should be immune to accidental programming from naturally occurring energy sources. To meet this requirement, the information is usually coded and the pacemaker contains a decoding mechanism to recognize proper information. This programming security code method makes it practically impossible to reprogram an implantable pacemaker through extraneous random magnetic fields.

3.6 CARDIAC DEFIBRILLATORS:

A defibrillator is a device that delivers electric shock to the heart muscle undergoing a fatal arrhythmia. Necessity of Defibrillators Heart diseases, electrolyte disturbances, or electric shock, can cause the normally coordinated action of the ventricular heart muscle to be disrupted. The uncoordinated contractions of different parts of the ventricles are called ventricular fibrillation which may lead to death within a few minutes. The most effective treatment for this is to pass a short pulse of electrical current through the ventricles. This is done after open heart surgery by applying electrodes directly to the heart. In all other situations (external defibrillation) electrodes are applied to the chest and a large current (e.g. 50 A for 5 ms) is required for this. The instrument for applying the electric shock is called defibrillator.

Classification of defibrillators Based on the placement of defibrillator electrodes, defibrillators can be classified into two types.

i) External defibrillator

ii) Internal defibrillator

Depending upon the signal (voltage or current) applied; the defibrillators can be classified as i) AC defibrillator ii) DC defibrillator iii) Synchronized defibrillator iv) Square pulse defibrillator v) Double square pulse defibrillator vi) Biphasic DC defibrillator Page 65 3.6.1 AC defibrillators The earliest and the simplest type of defibrillator is AC defibrillator. It is constructed in such a way that appropriate voltages for internal and external defibrillation are available. Fig.3.6 AC

Defibrillator:

The above fig 3.6. shows the basic circuit of AC defibrillator ϖ It consists of a step-up transformer with various taping on the secondary side. ϖ An electronic timer circuit is connected to the primary of the transformer. ϖ This timer connects the output to the electrodes for a preset time. ϖ The timing device may be a simple capacitor and resistor network or a monostable multivibrator circuit which is triggered by a foot switch or push switch. ϖ The duration of counter shock may vary from 0.1 second to 1 second, depending upon the voltage to be applied. ϖ For reasons of safety, the secondary coil of the transformer should be isolated from earth so that there is no shock risk to anyone touching an earthed object. ϖ The electrodes for external defibrillation are usually copper disc about 3.5cm in diameter and are attached to high insulated handle. ϖ For internal fibrillation when the chest is open, large spoon like electrode is used. ϖ The voltages used range from 250V to about 750V ϖThe current of some 2.5A to 7.5 amps is passed during the period of counter shock. ϖFor internal fibrillation, much lower voltages are used. When the heart is exposed, the voltages commonly used are from 60 to 250 V. Disadvantages of AC defibrillator.

In AC defibrillation, if the patient does not respond, the burst is repeated until defibrillation occurs. ϖ AC defibrillation cannot be successfully used to correct atrial defibrillation. ϖ Infact, attempts to correct atrial fibrillation by this method often result in ventricular fibrillation. ϖ Large currents are required in external defibrillation to produce uniform and simultaneous contraction of muscle fibres. ϖ Large currents causes violent contraction of thoracic muscles results in occasional burning of the skin under the electrodes. For the above disadvantages, AC defibrillators are not used now a days.

3.6.2 DC defibrillators:

Ventricular fibrillation can be terminated by passing a high energy shock by discharging a capacitor either through the chest of the patient or directly through the exposed heart. The instrument used for doing above process is called as DC defibrillator.

DC Defibrillator :

The circuit diagram of dc defibrillator is shown in fig 3.7. ϖ A variable auto-transformer T1 forms the primary of high voltage transformer T2 ϖ The output voltage of the transformer T2 is rectified by a diode rectifier and is connected to a vacuum type high voltage charge over switch. ϖ In position A the switch is connected to one end of an oil filled capacitor having capacity of 16µF. In this position, the capacitor charges to a voltage, set by the positioning of the auto transformer. ϖ During the delivery of the shock to the patient, a foot switch or a push button switch mounted on the handle of the electrode is operated, so that the high voltage switch changes over to position B and the capacitor is discharged across the heart through the electrodes.

An inductor L is placed in one of the electrode leads so that the discharge from the capacitor is slowed down by the inductor counter voltage. This gives the output pulse in a physiologically favorable shape in order to eliminate a sharp undesirable current spike. ϖ The shape of the waveform that appears aeries the electrodes will depend upon the value of capacitor and inductor used in this circuit. ϖ The amplitude depends on its discharge resistance ϖ The success of defibrillation depends upon the energy stored in the capacitor and not with the value of voltage used. It is for this reason that the output of a dc defibrillator is always calibrated in terms of watts – second or joules as a measure of electrical energy stored in the capacitor. ϖ The instrument usually provides output from 0-400 joules.

This range is sufficient for both internal and external defibrillation. Thus if C = 16μF and the voltage used is 6000V, then the energy stored in the capacitor is = 288 joules or Watts-second. ϖFor internal defibrillation 100 joules are required where for external defibrillation 400 joules are required. ϖThe discharge duration is in the range of 5 ms to 10 ms.

3.7 HEART LUNG MACHINE:

Necessity of Heart lung machine The heart is unable to maintain circulation during surgery to either itself or the great vessels from the heart. During these types of surgical procedures perfusion of body tissues with blood is maintained by an extracorporeal i.e., outside the body pump called heart lung machine. Further this is also used to provide circulatory assistance to support a faulty heart. While doing open heart surgery, it is necessary to bypass the heart to enable the surgeon to work in a bloodless field under direct vision.

The heart lung machine replaces the function of the heart and lungs there by providing the rest of the body with a continuous supply of oxygenated blood while the heart is stopped. It is properly called a cardiopulmonary bypass machine.

The machine consists of, i) A number of pumps ii) An oxygenator (As gas exchanger) iii) A heat exchanger to control blood temperature iv) Filters v) A bubble trap. E = CV = × × × × – 1 2 1 2 16 10 6000 6000 2 6 / / Page 67 Fig.3.8 Heart Lung Machine Working ϖ Usually two cannulae are inserted into the right side of the heart to collect the returning venous blood. ϖ Extra corporeal circulation can be possible by replacing lungs and heart by the oxygenators and blood pumps respectively. ϖ The collected venous blood is directed into a receiving reservoir by gravity drainage. ϖ The accumulated blood from the operating field is also collected and passed into the receiving reservoir by suction devices. From here, the blood is passed on to the settling reservoir or debubbling chamber and then it is passed into oxygenator. ϖ In oxygenator the blood is exposed to an atmosphere rich in oxygen. ϖ From the oxygenator, a pump raises the pressure of the blood to the mean atrial pressure from which it flows into an atrial heat exchanger.

The heat exchanger reduces the body temperature to 280C during the operation but the blood is rewarmed towards the end. ϖ Afterwards the heart may restart spontaneously or electrical defibrillation may be required. ϖ The pumps are usually roller pumps and the oxygenator may be a bubble type or a membrane type. ϖThe blood passes through a filter to prevent the possibilities of particles or bubble returning to the body. ϖThe time during which the heart can be bypassed is limited to only 10 minutes at normal body temperature. ϖ To increase the time available for the operation, hypothermia is used that is, cooling of the whole body and the heart then can tolerate nearly 20 minutes without blood flow. ϖThe total time of extracorporeal circulation is restricted to a few hours because of the hemolysis of red cells.

3.8 DIALYSIS:

Both acute and chronic renal failure can be treated successfully by dialysis. Dialysis is a process by which the waste products in the blood are removed and restoration of normal pH value of the blood is obtained by an artificial kidney machine called dialyser. In dialysis, there are three physical processes called, i) Diffusion ii) Osmosis iii) Ultra filtration are used to remove the waste products.

3.8.1 Need for Artificial kidney machine (Dialyser):

The advanced renal failure may be due to,

i) Inflammation of the kidneys

ii) Obstruction of urine by stone or tumors

iii) Poisoning by organic and inorganic chemicals.

Intermittent treatment with a mechanical device called artificial kidney will reduce accumulation of waste products and water in the body.

3.8.2 Types of Dialysis:

There are two types of dialysis

i) Extra corporeal dialysis called haemo-dialysis

ii) Intra corporeal dialysis called peritoneal dialysis.

Extra Corporeal Dialysis In extra corporeal dialysis (haemo-dialysis) blood is purified by an artificial kidney (a hemodialyzer) where waste products diffuse through a semi permeable membrane which is continuously rinsed by a dialyzing solution (dialysate) Intra corporeal dialysis In intra corporeal dialysis, a membrane in the body is used for diffusion in clinical applications, the peritoneal cavity is employed. The method is known as peritoneal dialysis. Substances diffuse through the membrane from higher concentration to lower concentration. Waste products are transferred to the dialysate until equilibrium is reached.

Similarly, if the concentration is higher in the dialysate, lower molecular weight substances diffuse from this into the blood (Reverse osmosis) When equilibrium is corrected to achieve the normal ion concentration.

. 3.9 HEMODIALYSIS :

ϖ In this, blood is purified by an artificial kidney machine called hemodialyzer in which the blood is taken out from the body and waste products diffuse through a semi permeable membrane which is continuously rinsed by a dialyzing solution called dialysate. ϖ In this method, since the blood is taken out of the body for dialysis this is also called extra orporeal dialysis. Fig 3.9 shows the block schematic of hemodialyser.

Hemodialyser ϖ For short term use, a double lumen catheter is inserted into the formal vein. ϖ For long term use in arterio-venous shunt a permanent connection between an artery and vein is used. ϖ The catheter is inserted below the skin in the hand by a minor operation, are used to take blood from the artery to the dialyzing unit. ϖ There should be perfect protection against bacterial infection. ϖ By this way the arterio-venous shunt can be used for 2 years. ϖ The arterio-venous shunt is opened and connected to the dialyser ϖ Using a blood pump, the blood is pumped into a number of planar sheets of cellophane which pressed together in a frame. ϖ Blood flows in alternate spaces and the dialysate flows in the others as shown in

When the volume of blood flow through the spaces is very small, then the arterial pressure is enough to maintain the flow in the dialyzing unit where the blood pump is not necessary. ϖ The dialysate is an electrolyte. Through the cellophane sheets, urea, creatinine, uric acid and phosphate are diffused from blood to dialysate (dextrose and salts of Ca, Mg, K and Na) and ultra filtration takes place. ϖ There is a blood leak detector to detect the rupture of a membrane. ϖ Further there are pressure monitoring meters at the input and output. A thermostat control is provided to maintain the blood at 370C is necessary.

3.10 PERITONEAL DIALYSIS:

In peritoneal dialysis, the peritoneal membrane is used as a dialysis membrane. A catheter is inserted in the abdomen through a puncture just below the navel. A sterile dialysate about 1.5 to 2 litres is allowed to flow into the peritoneal cavity. The diffusion takes place in 10 – 30 minutes and the dialysate is ahen removed from the cavity. This procedure is repeated 20 to 30 times to remove all the waste products from the blood. The above procedure is done in an automatic manner using electronic control circuitry as shown in the fig 3.10. ϖ First the dialysate is pumped into the abdominal cavity through volume recording pump. ϖ The dialysate is kept at 370C by thermostatic control ϖ Here the thermistor is used as a sensing device.

When the dialysate volume is about 2 litres, a timing circuit will first deliver a signal to drop the dialysate flow into the abdomen. ϖ Next the timing circuit allows the diffusion time upto 30 minutes. Page 70 Fig.3.10 Peritoneal Dialysis ϖ

After that it runs the sucking pump so that the dialysate in the abdominal cavity is pumped and sent out through the drain. ϖ Once again the volume of the outgoing dialysate is measured. ϖ When the volume of the dialysate is less than 2 litres then the working of the suction pump is stopped and fresh dialysate is allowed one again to enter into the abdominal cavity through the volume recording pump. ϖ Thus the above procedure is repeated 20 to 30 times. If the volume of the sucked dialysate is less than 2 litres after the diffusion is over, then an alarm circuit will work. Immediately the patient should consult the doctor.

3.11 ENDOSCOPY:

Direct visualization of a diseased area inside the body can be achieved by using a telescope or tube passed through a natural orifice or through a small incision in the skin. This may be rigid employing a series of lenses, or flexible employing optic fibers to convey the illuminating light and to convey the image to the eyepiece. This is called endoscopy. Thus endoscope is an instrument to inspect or view the body cavities which are not visible to the naked eye normally. The Broncho fiberoscopes, gastrointestinal fiber scopes and Laparoscopes are the important endoscopes used in hospitals for examination, treatment of disease and surgery. Working Usually in each endoscope, there are two fiber bundles. One is used to illuminate the inner structure of the object. The other is used to collect the reflected light from that area and from we can view the inner structure of the object. The endoscope is often fitted with smell forceps for taking samples of tissues biopsy specimens – for microscopic examinations in cases of suspected tumor.

The body cavities can be inspected either through existing orifices in the body or through passages created with a sharp instrument so that the endoscope can be inserted. The body cavity is filled with air or saline so as to keep the walls distended and to improve optical transmission. The light is guided through the glass fibers by total internal reflection. A typical glass fiber consists of central core glass having high refractive index surrounded by a cladding made of a glass or slightly lower refractive index. For a wider field of view and better quality in image, a telescope system is added in the internal part of the endoscope. In endoscope, at the object end there is an assembly of objective lens and prism and at the viewing end, there is an eye lens. Endoscopic pictures can be recorded with color film and video tape recorders. Endoscopic laser coagulator Fig.3.11 shows the schematic diagram of gastric optical (endoscopic laser) coagulator using Argon ion laser as high energy optical source and Endoscope as the delivery unit. It is known that argon ion lasers are very useful in the coagulation of blood vessels since it green light is highly absorbed by the red blood vessels and hemoglobin. The absorption of green light results in the photo coagulation of the blood protein and micro hemostasis. Further it is more advantageous to use argon ion laser for the photo coagulation of retina because of its smaller beam diameter and ability to do coagulation without affecting the surrounding healthy tissue. Fig.3.11 Endoscopic laser coagulator To control the gastric hemorrhage photo coagulation technique is adopted. With the help of fiber optic endoscope, the output from the argon ion laser is delivered to the required pot to arrest the gastric bleeding. We can move the laser beam in any direction with the flexible endoscope. The argon ion laser gives output of 13 watts in the form of continuous waves. Using an endoscope the beam can be delivered To the required site as well as it can view for proper alignment. The diameter of the quartz fiber endoscope is about 2 mm.

3.11.2Different types of commonly available endoscopes (Applications of endoscopes) S.No Type Range of use Diagnostic problem (or) operation 1. Bronchoscope Trachea larger airways Foreign body infections 2. Cardioscope Heart cavities Valvular defects 3. Cystoscope Urinary bladder Tumors, inflammation, stones. 4. Gastroscope Stomach Gastritis, gastric ulcer, tumors 5. Laproscope Abdominal cavity Tumors, family planning operation 6. Opthalmoscope Eye fundus State of vessels in high blood pressure, retinal detachment 7. Otoscope Tympanic membrane Infections, perforations of ear drum.

3.12 PHYSIOTHERAPY EQUIPMENT:

The treatment of disease, injury, or deformity by physical method such as massage, heat treatment, and exercise rather than by drugs or surgery is termed as Physiotherapy. Equipments which are used for Physiotherapy are called as Physiotherapy equipments. There is variety of physiotherapy equipments.

3.13 DIATHERMY:

Diathermy is electrically induced heat or the use of high-frequency electromagnetic currents as a form of physical or occupational therapy and in surgical procedures. Diathermy is commonly used for muscle relaxation, and to induce deep heating in tissue for therapeutic purposes in medicine. It is used in physical therapy and occupational therapy to deliver moderate heat directly to pathologic lesions in the deeper tissues of the body.

Types of Diathermy :

Diathermy is produced by three techniques:

i) Ultrasound (ultrasonic diathermy)

ii) Short-wave radio frequencies in the range 1–100 MHz (shortwave diathermy)

iii) Microwaves typically in the 915 MHz or 2.45 GHz bands (microwave diathermy) The methods differing mainly in their penetration capability.

3.13.1 SHORT WAVE DIATHERMY:

Short wave diathermy machines use two condenser plates that are placed on either side of the body part to be treated. Another mode of application is by induction coils that are pliable and can be molded to fit the part of the body under treatment as shown in Fig.3.13 (a)

(a) Methods of applying electrodes in Short wave Diathermy Fig.3.13 (b) Block diagram of Short wave Diathermy unit .

In this method the output of the RF Oscillator is applied to the pair of patient electrodes. ϖ The RF energy heats the tissues and promotes the healing of injured tissues and inflammations. ϖ The power delivered by the unit is about 500 watts. There are several provisions to regulate the intensity of current passed through the patient circuit. ϖ The electrode or pads are not directly contact with the skin. ϖ Usually layers of towel are interposed between the metal and the surface of the body. The pads are placed so that the portion of the body to be treated is sandwiched between them. The pads are forming capacitor plates and the body tissues between the pads act as dielectric. Thus the whole arrangement forms a capacitor.

When the RF current is applied to the pads, the dielectric loss of the capacitor produces heat in the intervening tissues. ϖ This method is called a condenser or capacitor method. ϖ In inductive method a flexible cable is coiled around the knee or arm or any other part of body as shown in Fig.3.13(a) Applications of Shortwave Diathermy 1. Short wave diathermy usually is prescribed for treatment of deep muscles and joints that are covered with a heavy soft-tissue mass, for example, the hip. 2. In some instances short wave diathermy may be applied to localize deep inflammatory processes, as in pelvic inflammatory disease. 3. Short wave diathermy can also be used for hyperthermia therapy, as an adjuvant to radiation in cancer treatment

MICROWAVE DIATHERMY:

Microwave Diathermy consists in irradiating the tissue of the patient's body with very short wireless waves having frequency in the microwave region.

• Microwaves are a form of electromagnetic radiation with a frequency range of 300-3000 Hz and a wavelength varying from 10mm to 1m.

• The most commonly used microwave frequency for therapeutic heating is 2450 MHz corresponding to 12.25 cm.

• The heating effect is produced by the absorption of the microwaves in the region of the body under treatment. The schematic diagram of Microwave diathermy unit

The essential parts of a microwave diathermy unit are shown in Fig.3.14. ϖ The main supply voltage is applied to an interference suppression filter. This filter helps to bypass the high frequency pickup generated by the Magnetron. Page 74 ϖ A fan motor is directly connected to the main supply. The fan is used to cool the Magnetron. The Delay circuit: It is necessary for the magnetron to warm up for 3 to 4 minute before power may derive from it. Delay circuit is incorporated in the apparatus which connects the anode supply to the magnetron only after the elapse of this time. The Magnetron circuit: The Magnetron filament heating voltage is obtained directly from a separate secondary winding of the transformer.

The filament cathode circuit contains interference suppression filters. The anode supply to the Magnetron can be AC or DC. A DC voltage is obtained from the full wave rectifier followed by a voltage doubler. A high wattage variable resistance is connected in series which controls the current applied to the anode of the magnetron. Safety circuits: There are chances of magnetron being damaged due to excessive flow of current. It is protected by inserting a fuse (500 mA) in the anode supply circuit of the magnetron. Protection of the patient the radiator is ensured by the automatic selection of the control range depending on the type of the radiator used. Excessive dosage can cause skin burns and in all cases, the sensation experienced by the patient is the primary guide for application. The skin should be dry as these waves are rapidly absorbed by water. Duration of irradiation generally range from 10 to 25 minutes. Applications of Microwave diathermy i. Microwave diathermy is used in the management of superficial tumors with conventional radiotherapy and chemotherapy. ii. Hyperthermia has been used in oncology for more than 35 years, in addition to radiotherapy, in the management of different tumors. iii. In 1994, hyperthermia was introduced in several countries of the European Union as a modality for use in physical medicine and sports traumatology. iv. Its use has been successfully extended to physical medicine and sports traumatology in Central and Southern Europe. Demerits of Microwave diathermy Microwaves cannot be used in high dosage on edematous tissue, over wet dressings, or near metallic implants in the body because of the danger of local burns. 3.13.3 Ultrasonic diathermy Ultrasound diathermy employs high-frequency acoustic vibrations which, when propelled through the tissues, are converted into heat. FIig.3.15 Block diagram/Circuit diagram of Ultrasonic Diathermy unit Fig.3.15shows the block/circuit diagram of Ultrasonic diathermy unit Page 75 ϖ The heart of the system is a timed oscillator which generates high-frequency electrical oscillations of required frequency.

The oscillator output is given to a power amplifier which drives the piezo-electric crystal to generate ultrasound waves. ϖ Power amplification is achieved by replacing the transistor in typical LC tuned Colpitts oscillator by four power transistors in bridge configuration. ϖ The delivery of ultrasound power to the patient is to be done for a given time to switch on the circuit. The timer can be a mechanical spring loaded type or an electronic one, allowing Time settings from 0 to 30 minutes. The output of the oscillator can be controlled by either of the following two methods. 1. Using a transformer with a primary winding having multi- tapped windings and switching the same as per requirement. 2. Controlling the firing angle of a triac placed in the primary circuit of the transformer, and there by varying the output of the transformer.The power output in case of triac controlled machines can be continuously varied from 0 to 3 watts/cm2 . The machine can be operated in continuous or pulsed mode.A full -wave rectifier comes in the circuit for continuous mode of operation.

Dosage control: The dosage can be controlled by varying any of the Following variables.

• Frequency of Ultrasound

• Intensity of ultrasound

• Duration of the exposure

The probe can be put in direct with the body of the patient through a couplant provided the part to be treated is sufficiently smooth and uninjured. In case of long area is to be, the probe is moved up and down , and for mall areas it is given a circular motion to obtain a uniform distribution of ultrasonic energy.

Applications of Ultrasonic diathermy:

Therapeutic applications of Ultrasonic diathermy are,

1. in the treatment of diseases of peripheral nervous system (neuritis)

2. in the treatment of skeletal muscle system (arthritis)

3. in the treatment of skin (ulcer)

3.14 VENTILATOR:

In medical work this term usually refers to a breathing machine for providing assisted or artificial ventilation of the lungs. It can thus mean a resuscitator for emergency use, a body respirator, or lung ventilator. In any form its function is to assist or take over from the spontaneous respiratory effort of the patient. .

3.14.1Types of Ventilators:

There are two types,

1. Anaesthisia ventilator (used to give regular assisted breathing during operation)

2. Intensive care ventilator (used to deliver air to the patient when the patient tries to inhale)

3.14.2 Modern Ventilators:

More modern ventilators use pressures greater than atmospheric pressures to ventilate the lungs; they are known as positive-pressure ventilators. .Positive-pressure ventilators generate the inspiratory flow by applying a positive pressure (greater than the atmospheric pressure) to the airways. Figure 3.16 shows a simplified block diagram of a positive – pressure ventilator.

.Positive-pressure ventilators

• In this during inspiration, the inspiratory flow delivery system creates a positive pressure in the tubes connected to the patient airway, called patient circuit, and the exhalation control system closes a valve at the outlet of the tubing to the atmosphere.

• When the ventilator switches to exhalation, the inspiratory flow delivery system stops the positive pressure and the exhalation system opens the valve to allow the patient‟s exhaled breath to flow to the atmosphere Almost all modern ventilators use microprocessor instrumentation. Fig.3.17 shows the simplified block diagram of a control structure for mandatory and spontaneous breath delivery system of a microprocessor based Modern ventilator machine.

Modern ventilator ϖ Compressed air and oxygen are normally stored in high pressure tanks (s1400 kPa) that are attached to the inlets of the ventilator. In some ventilators, an air compressor is used in place of a compressed air tank. ϖ The primary mission of the device is to enrich the inspiratory air flow with the proper level of oxygen and to deliver a tidal volume according to the therapist‟s specifications. ϖ The air and oxygen valves are placed in closed feedback loops with the air and oxygen flow sensors.

The microprocessor controls each the valves to deliver the desired inspiratory air and oxygen flows for mandatory and spontaneous ventilation. ϖ During inhalation, the exhalation valve is closed to direct all the delivered flows to the lungs. When exhalation starts, the microprocessor actuates the exhalation valve to achieve the desired PEEP level. ϖ The airway pressure sensor, shown on the right side of Fig.3.17 generates the feedback signal necessary for maintaining the desired PEEP (in both mandatory and spontaneous modes) and airway pressure support level during spontaneous breath delivery. Mandatory Volume Controlled Inspiratory Flow Delivery ϖ In a microprocessor-controlled ventilator, the electronically actuated valves open from a closed position to allow the flow of blended gases to the patient.

The control of flow through each valve depends on the therapist‟s specification for the mandatory breath. That is, the clinician must specify the following parameters for delivery of CMV breaths:

(1) respiration rate;

(2) flow waveform;

(3) tidal volume;

(4) oxygen concentration (of the delivered breath);

(5) peak flow; and

(6) PEEP, as shown in the lower left side .

It is noted that the PEEP selected by the therapist in the mandatory mode is only used for control of exhalation flow. ϖ The microprocessor utilizes the first five of the above parameters to compute the total desired inspiratory flow trajectory. Applications of Ventilator These are used during; ϖ anaesthesia (where muscle relaxants impair natural breathing), ϖ in intensive care for life support, and ϖ during emergency resuscitation

UNIT-IV BIO-TELEMETRY AND PATIENT SAFETY

4.1 Introduction :

Bio-telemetry is the measurement of biological parameters of man or animal under normal conditions and in natural surroundings without any discomfort to the person or animal under investigation over a distance. The means of transmitting data from the point of generation to the point of reception can take many forms. Certain type of application of biotelemetry utilizes.

i) The telephone lines which need hardware conditions between transmitter & receiver.

ii) Radio links (wireless) which need not any hardware connection between transmitter & receiver. 4.2 Physiological Parameters (biological sources) Adaptable to biotelemetry system. (i) Bio electrical variables such as ECG, EEG, EMG (ii) Physiological variable like a) Blood pressure b) Pulse pressure c) Temperature d) Respiration rate e) pH f) Blood flow

4.3 Components of Biotelemetry system for land line telemetry:

The components of land line telemetry are, (i)Electrodes or transducers (ii)Amplifier & filter (iii)Transmission wire (iv)Readout device a) Video recorder b) Tape recorder c) CRO d) x – y recorder e) Loudspeaker. Components of radio telemetry system 1. Electrodes or transducers 2. Processor (Amplifier) 3. Modulator 4. Carrier generator 5. Tuner 6. Demodulator 7. Tape recorder 8. Chart recorder 9. Oscilloscope 4.4 Applications (Advantages) of Biotelemetry in patient care 1. For monitoring patient in a hospital from a remote location 2. For monitoring astronauts in space. 3. For monitoring patient who are on the job or home 4. Make research on untrained, unanaesthetized animals in their natural habitual. 5. For monitoring patient in an ambulance on other locations away from the hospital. 6. Used in studies of mentally disturbed children 7. Used for transmission of ECG or medical data through telephone link. 8. For isolation of an electrically susceptible patient from power line operated ECG equal to Page 81 protect him from accidental shock. 9. For tracing acidity or pressure through implantation techniques.

4.5 Elements of Biotelemetry System through landline Fig.4.1Block diagram of Elements of a Biotelemetry system The essential blocks of a bio-telemetry system using transmission and reception through land lines are shown in fig 4.1. Physiological signals are obtained from the subject by means of appropriate electrodes or transducers. The signal is then passed through a stage of amplification. The signal conditioner amplifies and modifies this signal for effective transmission. The transmission link connects the signal input blocks to the readout devices as shown in the fig 4.1. 4.6 Elements of Biotelemetry System through Radio waves (Using AM or FM Modulation) Fig 4.2 shows the block diagram of a typical radio telemetry system using AM or FM modulation. Fig.4.2 (a) AM or FM transmitter in Biotelemetry system Transmitter ϖPhysiological signals are obtained from the subject by means of electrodes or transducers. ϖThe signal is then passed through conditioner for amplification and further processing (Filtering) is done by radio transmitters. ϖThe processed signal is then transmitted thro‟ the transmitting antenna. ϖThe radio transmitter consists of generation of carrier and modulator blocks. The radio frequency (carrier) used in this system varies from a few hundred KHz to about 300 MHz. Beyond this frequency range, the attenuation due to subject body becomes excessive. ϖ When we go to higher frequencies, the transmitter should be small and the man made noise should be small. So we must take care of design of high frequency transmitter into small one with higher fidelity. Page 82 Further amplitude modulation is not adopted because when relative motion occurs between transmitter and receiver, the signal amplitude will be varied and thus introduces serious error. Thus we adopt either frequency modulation or pulse modulation technique to transmit the bio signals. Receiver Fig.4.2 (b) AM or FM Receiver in Biotelemetry system Fig.4.2 (c) AM and FM Wave Receiver ϖThe receiver consists of tuner to select transmitting frequency, ϖ a demodulator to separate the signal from the carrier wave and ϖ a means of displaying or recording the signal. ϖ The signal can also be stored in the modulated state by the use of a tape recorder. 4.7 Requirements of subcarrier single channel and multi channel Biotelemetry system

- When the relative position of transmitter to the body or other conduction object changes, the carrier frequency and amplitude will change. This is due to the loading change of the carrier frequency resonant circuit. This effect is not distinguishable from the signal at the receiving end.

- 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 the loading effect. To avoid this loading effect, the subcarrier system is needed. For most bio-medical experiments, it is desirable to have simultaneous recordings of several signals for correlation study. Each signal requires a telemetry channel. When the number of channels is more than two or three, the simultaneous operation of the several single channel units is difficult. At that time, multiple channel (multiplex) telemetry system is adopted. Page 83 4.8 Radio telemetry with subcarrier (Single channel telemetry System) Fig.4.3 shows the block diagram of single channel telemetry with subcarrier system suitable for transmission of electrocardiogram. This system consists of two main parts: (i) The telemetry transmitter which consists of ECG Amplifier, Subcarrier (AM) modulator and a UHF (FM) transmitter along with a dry cell battery. (ii)The telemetry receiver which consists of a high frequency unit and a demodulator, to which an ECG can be connected to record, a cardio scope to display and a magnetic tape recorder to store ECG.

A heart rate meter with an alarm facility can be provided to monitor continuously beat to beat heart rate of the subject. Fig.4.3 Block diagram of a single channel telemetry system The testee should be able to carry on with his normal activities whilst carrying the instrument without the lightest discomfort. He should be able to forget their presence after some minutes of application ϖ Motion artifacts and muscle potential interference should be kept minimum. ϖ The battery life should be long enough so that a complete experimental procedure may be carried out. 4.9 Multi Channel Telemetry Systems When the number of channels is more than two or three, the simultaneous operation of the several single channel units is difficult. At that time, multiple channel (multiplex) telemetry system shown in Fig.4.4 is adopted. There are two types of multi channel telemetry systems:

1. Frequency division multiplex 2. Time division multiplex Frequency Division Multiplex System ϖ In the transmitter side each signal I frequency modulated on a subcarrier frequency. Then these modulated subcarrier frequencies are combined to modulate the main RF carrier. ϖ At the receiver side, the modulated subcarriers will be separated by the proper band pas filters after the first discrimination. Page 84 ϖ The individual signal is recovered from these modulated subcarriers by the second set of discriminators. ϖ The frequency of the subcarrier has to be carefully selected to avoid interference. ϖ The low pass filters are used to extract the signals without any noise. Fig.4.4 Multi channel telemetry system Time Division Multiplex System ϖ In the transmitter side since most biomedical signals have low frequency bandwidth requirements, we can use time division multiplex system by

the time sharing method. ϖ The transmission channel is connected to each single-channel input for a short time to sample and transmit that signal.

Then the transmitter is switched to the next signal channel in a definite sequence. ϖ When all the channel have been scanned once a cycle is completed and the next cycle will start. The operation is repeated again. ϖ In the receiver side, the process is reversed. The sequentially arranged signal pulses are distributed to the individual channels by a synchronized switching circuit. ϖ 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 without noticeable distortion. 4.10 Telemedicine: Introduction Telemedicine is the application of telecommunications and computer technology to deliver health care from one location to another. Page 85 In other words, telemedicine involves the use of modern information technology to deliver timely health services to those in need by the electronic transmission of the necessary expertise and information among geographically dispersed parties including physicians and patents, to result in improved patient care and management, resource distribution efficiency and potentially cost – effectiveness. From a technology stand point, telemedicine technology includes hardware, software, medical equipment and communication links. The technology infra structure is a telecommunication network with input and output devices at each connected locations. 4.10.1 Telemedicine applications The greater current applications are found in radiology, pathology, cardiology and medical education. Tele-radiology: Radio logical images such as x-ray, CT, or MRI images can be transferred from one location to another location for expert interpretation and consultation. The process involves image acquisition and digitization. Tele-pathology: To obtain an expert opinion on the microscopic images of pathology slides and biopsy reports from specialists. Tele-cardiology: Tele cardiology relates to the transmission of ECG, echocardiography, color Doppler, etc In addition, telemedicine is being advantageously used for Tele education: Delivery of medical education programmes to the physicians and paramedics located at smaller towns who are professionally isolated from major medical centers. Teleconsultation: Specialists, doctors can be consulted either by a patient directly or by the local medical staff through telemedicine technology. Depending upon the level of interaction required, the telecommunication infrastructure requirements also varies from a normal telephone line, low bit rate image transmission, real time video transfer to video conferencing. 4.10.2 Telemedicine concept :

1. Store and forward Concept involves compilation and storing of information relating to audio, video images and clips, ECGs etc.

2. The store information in the digital form is sent to the expert for review, interpretation and advice at his /her convenience.

3. The experts opinion can be transmitted back without any immediate compulsion on the consultant‟s time during his/her busy professional schedule. Real time involves real-time exchange of information between the two centers simultaneously and communicating interactively. It may include video conferencing, interviewing and examining the patients, transmission of images of various anatomic sites, auscultation of the heart and lung sounds and a review of various images.

4.10.3 Essential parameters for telemedicine:

Telemedicine systems are based on multimedia computing, which not only support live multi way conversations between physicians, patients and specialists but can also facilitate off – line consultations among health-care team members. It is however, advisable to create a detailed electronic patient record so that necessary information can be accessed, when desired.

The following components relating to a patient are considered essential from the point of view of telemedicine.

1. Patient Data : Name, age, occupation, sex, address, telephone no/:, registration number etc./:

2. Patient history: Personal and family history and diagnostic reports.

3. Clinical information: Direct observations obtained from senses.

4.Investigations: Biochemical test results.

5. Data and reports: MRI, CT, ECG, Spirogram etc reports.

In addition, there is a need to have video conferencing facility for on line consultations.

4.10.4Working of Telemedicine Technology :

The principle and various sub-systems used in a telemedicine set-up. Transmission of Medical Images: One of the most important aspects of telemedicine is the acquisition and transmission of medical images such as X-rays, CT, MRI, histopathology slides, etc. These images are first required to be converted into digital form. The usual types of diagnostic images used in telemedicine include: 1. Images stored on traditional film or print media (e.g.-ray film) and converted into digital format by direct imaging or scanning in a raster sequence under controlled lighting conditions. CCD (charge coupled devices) and laser-based scanners are commercially available for digitizing the film recorded X-ray images. A typical 11-by-17 inch chest film requires at least 2000 by 2000 pixels and an optical dynamic range of at least 4000 to (12-bits) to represent the image adequately. Page 87 2. Computer-generated images (e.g. ultrasound, CT) available in standard video format (NTSC), computer format (SVGA), or computer-file format (TIF). In modern digital radiography systems, the X-ray image is stored in the computer in the digital format. Being a filmless system, it does not require any further digitization. Transmission of Video Images Telemedicine applications generally require video and individual still-frame images for interactive visual communication and medical diagnosis. Images are obtained from direct visualization by a video camera and a lens system for direct observation (e.g. a skin lesion) or an optical adapter to a conventional scope (e.g. laparoscope, microscope, otoscope) that provides magnification or remote access using fiber optics. The most commonly used digital camera is based on the use of charge coupled device (CCD).

Incident light exposes an array of discrete light-sensitive regions called pixels, which accumulate electric charge in proportion to light intensity. After a specific integration time, the accumulated charges in the pixels are sequentially converted into conventional analog intensity and color signals. Single CCD cameras offer 450 TVL (Television Lines) or higher resolution while high quality 3-chip CCD cameras offer 700 TVL or higher resolution. Video is captured one frame at a time typically in a 640 by 480 pixel format, with an intensity scale typically consisting of eight bits for monochrome and 24 bits for color (8-bit each for red, green and blue). Other formats exist for high-resolution cameras; a 1024 by 1024 pixel format at 8, 10 or 12 bits per pixel can be achieved with a capture time, which depends in part on the time needed to integrate a sufficient number of photons from dark areas of the image. Transmission of Digital Audio Audio channels are usually provided for diagnostic instruments such as an electronic stethoscope or Doppler ultrasound. To reproduce heart and lung sounds accurately, an electronic stethoscope must have a uniform frequency response from 20 Hz to 2 kHz, while Doppler ultrasound requires a uniform frequency response from 100 Hz to 10kHz. Audio used for conversation and medical diagnosis in a telemedicine system must be digitized and compressed before it can be combined with digital video and other information. Typical audio compression algorithms operate at data rates from 16 Kbps to 64 Kbps. Medical diagnostic applications which require fidelity at higher audio frequencies will require higher data rates; 120 Kbps is sufficient to reproduce the full auditory frequency spectrum from 20 Hz to 20 kHz over a dynamic range of 90 dB which is adequate for the normal physiologic hearing range. Video Conferencing One of the essential components in a telemedicine system is the video conferencing facility, which permits real-time transmission of both audio and video information.

4.11 Physiological Effects of (Low frequency or 50 Hz commercial frequency) :

Electric current Most of the electrical accidents involve a current pathway through the victim from one upper limb to the feet or to the opposite upper limb as shown in fig 4.6. At commercial frequencies (50 Hz or 60 Hz) the body acts as a volume conductor Electrical current passing through the human body has three primary effects

• Injury to tissue

• Uncontrollable muscular contraction or unconsciousness

• Fibrillation of the heart. All the above effects are because of the cellular potentials of muscles and nerves of the body. i.e.) It is the electrical stimulation of the muscle and nerve cells. All the above effects are purely depend on the current pathway through the body, body resistance, weight, contact area frequency, duration and magnitude of the current. The permissible current magnitude can be determined by one‟s let go current.

Physiological effects due to low frequency current are listed below Type of current Current range (mA) Physiological effect Threshold of perception 1 – 5 Tingling sensation Pain 5 – 8 Intense painful sensation Let go 8 – 20 Threshold of involuntary muscular contraction Paralysis > 20 Respiratory paralysis and pain Fibrillation 80 – 100 Ventricular fibrillation of the heart Defibrillation 1000 – 10,000 (1A – 10A) Sustained myocardial contraction. Threshold of Perception: It states that it is a level of current at which tingling sensation is felt by the subject, when there is a contact with an electrical object. It may vary from individual to individual. The lowest threshold could be 0.5 mA when the skin is moistioned at 50Hz. Threshold for dc current are 2 to 10mA. Let go current :As the magnitude of the alternating current is increased, the sensation of tingling gives way to the contraction of muscle.The muscular contractions increase as the current is increased and finally a value of current is reached at which the subject cannot release his grip on the current carrying conductor. The maximum current at which the subject is still capable of releasing the conductor is called let go current. The safe let go current for men is 9mA and for women is 6 mA.

Physical injury and pain At current levels higher than the let go current, the subject loses the ability to control his own muscle actions and he is unable to release his grip on the electrical conductor. Such currents are very painful and hard to bear. This type of accident is (painful) called the „hold on type‟ accident and is caused by currents in the range of 20 – 100 mA. Ventricular fibrillation If the current comes is contact with intact skin and passes through the trunk at about 100mA and above, there is a likelihood of pulling the heart into ventricular fibrillation. In this condition, the rhythmic action of the heart ceases, pumping action stops and the pulse disappears.

Ventricular fibrillation occurs due to the derangement of function of the heart muscles rather than any actual physical damage to it. It proves fatal unless corrected within minutes. Physical injury and burns At currents in the range of 6 amperes and above, there is a danger of temporary respiratory paralysis and also of serious burns. Resistive heating causes burns, usually on the skin at the entry points, because skin resistance is high. Voltages higher than 230V can puncture the skin. The brain and other nervous system loose all functions when high current pass through them. Sustained myocardial contraction At currents in the range of 1 to 6A the entire heart muscle contracts. Although the heart stops beating while the current is applied, it may revert to a normal rhythm if the current is discontinued in time, just as in defibrillation.

4.11.1 Let go current Let-go current is the minimum current to produce muscular contraction. (or) The maximum current at which a person is still capable of releasing a conductor by using muscles directly stimulated by the current is called „ let-go‟ current. (or) the maximum current level of a person can tolerate and still voluntarily let go of the conductor is called his let-go-current. Let go current for men is about 16mA. And for women is about 10.5mA. Between 5Hz to 100Hz, the value of let go current is low, above 200Hz, the let-go current is directly proportional to the log frequency. Let-go current also depends on weight and time of passage of current thro‟ the body i.e., let-go current varies inversely with the weight and square root of the current passage time in the case of adults. Currents only slightly in excess of one‟s let go current are said to freeze the victim to the circuit.

4.12 Electrical Shock :

Electrical shock is an unwanted physiological response to current. The electric shock may be macro or micro depending on the current pathway. If the flow of current is from arm to arm, then it produces macro shock. If the flow of current is directly through the heart, then it produces micro shock. Micro shock is more hazardous than macro shock. Anyway both are fatal if one receives the current greater than 5 mA.

Causes for shock hazard Electric shock results from,

• Improper grounding

• Broken ground wire

• ungrounded equipment

• Leakage current

- Operational error (or) human error
- Simultaneous use of other equipment on the patient.
- High frequency currents from therapeutic equipments and surgical units.
- Amplifiers used in the input circuit of ECG, EEG or EMG machines.
- Power failure
- Static electricity

4.12.1 Micro shock:

A physiological response to a current applied to the surface of the heart that results in unwanted stimulation like muscle contraction or tissue injury is called micro shock. Micro shock is most often caused when currents in excess of 10µA flow through an insulated catheter to the heart. Micro shock can cause a heart fibrillation and can result in a patient‟s death. The international electro technical commission‟s recommendations covering the safety aspects of electrical equipment for medical equipments stipulate that the current that flows continuously through the heart shall not exceed 10µA for a frequency range of 0 to 1kHZ (refer fig 4.7(b))

4.12.2Macro shock (Gross shock):

A physiological response to a current applied to the surface of the body that produces unwanted or unnecessary stimulation like muscle contractions or tissue injury is called macro shock. Currents in the range of 1-5mA are harmless. Greater than 100 mA is lethal, greater than 10A is fatal. All hospital patients, medical attendants, employees and visitors are exposed to macro shocks from defective devices and biomedical equipments. (a) Macro shock (b) Micro shock The international electro technical commission therefore recommends that for medical equipments the current flowing continuously through the body should not exceed 100µA within a frequency range of 0 to 1 kHz. (refer fig 4.7) 4.13 Leakage current Leakage current by definition is an inherent flow of non-functional current from the live electrical parts of an instrument to the accessible metal parts. Leakage currents usually flow through the third wire connection to the ground. They occur by the presence of insulation impedance which consists of two parts – resistance and capacitance. Instruments are generally designed so that leakage current flows to the instrument case and then to the ground via the three wire power cord provided with the instruments.

The third or the grounding wire effectively drains off leakage current to the earth. Then there will no longer be any danger for the patient or the operator. However, when the earth connection is interrupted, the leakage current can become a real danger to the patient or the operator. Types of leakage currents (Causes for leakage current) Leakage currents are divided according to the currents path into the following types. 1. Enclosure leakage current 2. Earth leakage current 3. Patient leakage current. 1. Enclosure leakage current: The enclosure leakage current is the current which flows, in normal condition, from the enclosure through a person in contact with an accessible part of the enclosure to earth or another part of the enclosure. 2. Earth leakage current: The earth leakage current is the current which flows in normal condition, to earth from the mains part of an apparatus via the earth conductor. 3. Patient leakage current: The patient leakage current is the current which flows, in normal conditions through the patient from or the applied part of the patient circuits. In almost all equipments leakage currents do flow to the ground from the ac supply operating the device. This current may not prove hazardous if there is a good grounding system to drain it away. Lethal effects of leakage current ϖ Long continued currents in excess of one‟s let go current passing through the chest may produce collapse, unconsciousness and death. ϖ Ventricular fibrillation is probably the most common cause of death. ie) when fibrillation takes place, the rhythmic pumping action of the heart ceases and death follows rapidly. ϖ Current flowing through the nerve centers controlling breathing may produce respiratory paralysis. ϖ Cardiac arrest may be caused by relatively high currents flowing in the region of the heart. Page 91 ϖ Relative high currents may produce total damage to central nervous system. ϖ Leakage currents may produce deep burns and raise body temperature.

4.14 Shock Hazards (Situations of Shock Hazards):

Many devices have a metal chassis and cabinet that can be touched by the medical attendants and patients. If they are not grounded, then an insulation failure or short circuit results and leads to macro shock or micro shock. If a patient is ill, unconscious, anaesthetized or strapped on the rotating table, a tingling effect on the skin reveals that the patient is receiving a shock. Such patients must be isolated or insulated from electrical circuits. All hospital patients are exposed to macro shocks from defective electric devices such as lamps, bed adjusting motors, defective ECG machine in operation after well prepared electrodes are applied to the patients body. Micro shock is much more serious hazard than macro shock. Most of the accidents occur due to improper grounding and leakage current. The leakage current flow is due to (Causes for leakage current) 1. ungrounded equipment 2. Broken ground wire 3. unequal ground potential There are two types of shock hazards. i) Micro shock ii) Macro shock.

4.14.1 Micro shock hazard:

Micro shock hazard due to path of leakage current in the case of discontinuous ground (broken ground wire) Fig.4.8 Situation of Micro Shock hazard Consider electrical equipment connected to the power line which is shown in fig.4.8. A leakage current of 100°A can be assumed to be flowing in the ground wire. If the chassis of this equipment is connected to the patient who is grounded, then very little of this current will flow through him. Let us further assume that the patient offers a resistance of 1000° to the ground and the ground connection from the instrument has 1° of series resistance the current division shall be such that only 0.1°A of current shock pass through the patient, the rest will flow to the ground if by chance the ground connection breaks as shown in fig, the full leakage current will flow through the patient. This is very hazardous situation particularly if the current goes through internal electrodes in the vicinity of the patient‟s heart.

14.2 Macro shock hazard:

Macro shock hazards occur more with two wire systems than with three wire systems. Fig 4.9 shows such a macro shock hazard. With two wire system, it is always dangerous to get between the both „H‟ (Hot or phase) and „N‟ – neutral wires. If the patient touches H and N wires simultaneously with two limbs, then the currents are flowing directly through vital organs of circulation and respiration because N-wires are internally connected to ground, touching H and G wires can produce macro shock. Such a scenario of macro shock hazard is shown in fig. above. Here since the patient‟s foot is touched with ground and upper arm is touched the hot case, the current passes through upper to foot make a macro shock. Fig.4.9 Macro shock hazard

4.15 Methods of accident prevention:

In order to reduce the likelihood of electrical accidents, a number of protective methods have evolved. Some are, required in areas that are generally hazardous, and still others have been developed essentially for use in hospitals. They are safety analyzers & safety instruments, i.e.)

1. Mechanical testing of electrical outlets

2. Tests of the grounding system in patient care

3. Testing of Biomedical equipment (chassis leakage current measurement)

4. Ground continuity test

5. Grounding (Equi-potential grounding).

6. Double insulation

7. Protection by low voltage

8. Ground fault circuit interrupter.

9. Isolation of patient connected parts

10. Isolated power distribution system

leakage current measurement Leakage current is mostly measured from the equipment case to the ground with an QC micrometer, while the equipment is plugged in through an adapter that interrupt the ground wire, forcing the leakage current to flow through the measuring instrument. The measurement is made with the power on an off, preferably with both normal and reverse polarity on the power conductors. This helps to assess the possible hazard arising from the outlet, which is improperly wired. Leakage currents from the chassis should not exceed 500 µA for equipment not intended to come into contact with patients and should not exceed 100µA for equipment that is likely to come in contact with the patients. These are limits on RMS currents from DC to 1 kHz. Fig.4.10 Leakage current measurement Fig.4.10 (a) shows the principle of a leakage current meter. Fig. 4.10

(b) shows a scheme for the measurement of enclosure leakage current using a leakage current meter. The capacitor is employed to initiate the sensitivity of the heart as a function of the frequency. The measurement of enclosure leakage current should be made with a disconnected and connected ground wire.The patient leakage current is determined by connecting the measuring instrument between earth and one of the patient leads. The leakage current in patient leads must be limited to 50µA and for isolated patients; it should be less than 10µA.

4.15.2 Ground continuity test:

The integrity of the ground wire circuit is usually checked with an ohmmeter while the equipment is unplugged. This test helps to detect complete failure. The resistance between the ground pin of the plug and the equipment chassis exposed metal objects should not exceed 0.15µA during the life of the equipment. 4.15.3 Grounding The protection method used most frequently is proper grounding of equipment. The principle of this method is to make the grounding resistance RG in figure 4.11(a) small enough that for all possible values of the fault resistance RF, the majority of the fault current bypasses the body of the victim and the body current remains at a safe level even if contact and body resistances are small. The practical implementation of this method is shown in figure 4.11 (b), where the metal case of the equipment is connected to ground by a separate wire. Fig.4.11 Grounding Page 94 In cord-connected electrical equipment this ground connection is established by the third, round, or Ushaped contact in the plug. If a short occurs in a device whose case has been grounded in this way, the electric current flows through the short to the case and returns to the substation through the ground wire. Ideally, the short circuit will result in sufficient current to cause the circuit breaker to trip immediately. This action would remove the power from the faulty piece of equipment and thus limit the hazard. 4.15.4 Equi-potential grounding The protection method used most frequently is proper grounding of equipment. The principle of this method is to make the grounding resistance small enough that for all possible values of the fault resistance, the majority of the current bypasses the body of the victim and the body current remains at a safe level even if contact and body resistance are small. The practical implementation of this method is shown in fig.4.12 This special grounding system is called equi-potential rounding. Because it keeps all metallic objects in the area that could . FIG.4.12 Equi- potential grounding possibly come in contact with staff or patients at the same electrical potential. This system protects the patient and staff by shunting all leakage currents to ground

4.15.5 Double Insulation:

In double-insulated equipment the case is made of nonconductive material, usually a suitable plastic. If accessible metal parts are used, they are attached to the conductive main body of the equipment through a separate (protective) layer of insulation in addition to the (functional) insulation that separates this body from the electrical parts. The intention of this method is to assure that the fault resistance RF is always very large. Doubleinsulated equipment need not be grounded, and therefore it is usually equipped with a plug that does not have a ground pin. Equipment of this type must be labeled “Double Insulated.”

Double insulation is now widely used as a method of protection in hand-held power tools and electric-powered garden equipment such as lawn mowers. However, double insulation is of only limited value for equipment found in a hospital environment. Unless the equipment is also designed to be waterproof, the double insulation can easily be rendered ineffective if a conductive fluid such as saline or urine is spilled over the equipment or if the equipment is submerged in such a fluid.

4.15.6 Protection by Low Voltage In the generalized accident model of figure 4.11 (b) it was assumed that the voltage source was the line voltage (115 or 230 V AC). If, instead, another voltage source were used, and if the voltage of this source could be made small enough, the body resistance RB would be sufficient to limit the body current to a safe value, even if the fault and contact resistances become very small. One way of creating this situation is to operate the equipment from batteries. Aside from its lower voltage there is the additional advantage that battery-operated equipment does not have to be grounded. Normally, battery operation is limited to small devices such as flashlights and razors, but occasionally equipment as large as portable X-ray machines may use this method of protection. A low operating voltage can also be obtained by means of a step-down transformer. In addition to lowering the voltage the transformer provides isolation of the supply voltage from ground. Where power requirements are small, the transformer can be made an integral part of the line plug, a design now frequently employed in small electronic equipment as well as in such medical devices as ophthalmoscopes and endoscopes.

4.15.7 Ground Fault Interrupter (GFI):

GFI is an automatic switch that disconnects power if excessive leakage current is present. Statistical evidence indicates that most electrical accidents are of the type in which the body of the victim provides a conductive path to ground. Normally all current that enters a device through the hot wire returns through the neutral wire. However, in case of such an accident, part of the current actually returns through the body of the victim and through ground. Fig. 4.13 Ground Fault Interrupter (GFI) In the ground fault interrupter shown in fig.4.13, the difference between the currents in the hot and neutral wires of the power line is monitored by a differential transformer and an electronic amplifier. If this difference exceeds a certain value, usually 5mA, the power is interrupted by a circuit breaker. The GFI consists of a magnetic coil on which the hot lead (H) and the neutral (N) are wound with the same number of turns, but in opposite directions when the system is normal, IN is equal to IH and the magnetic flux, in the coil due to these currents cancels, under this condition the sensing coil does not have a voltage induced in it. However, when the hot lead faults, or is touched by a person, the fault current IF is shunted ground. Then we have IN = IH – IF and IH is not equal to IN. Under this fault condition corresponding fluxes in the coil are unequal and a net flux exists in the coil. This induces a voltage in the sensing amplifier. If the current exceed 2mA for 0.2 seconds, the relay opens the line and prevents a macro shock from injury the person as well as preventing further damage to the equipment. The GFI can be conveniently mounted in the power receptacle. It is required in wet areas. The interruption occurs so rapidly that even in the case of large current flow through the body of the victim, no harmful effects are encountered.

4.15.8 Isolation of Patient-Connected Parts Many types of medical equipment require that an electrical connection be established to the body of the patient, either to measure electrical potentials, such as in ECG machines, or to apply electrical signals, such as in electrical pacemakers. These electrical connections, however, could also serve as a path for dangerous electrical currents should the equipment malfunction. For example, in older ECG machines and patient monitors, it was common practice to connect one of the patient leads (the RL lead) to a power-line ground. This effectively grounded the patient and established one of the two connections necessary for an electrical accident. Modern technology makes it possible to design circuits that isolate the patient leads from ground. For patient leads that connect to an amplifier, this isolation is most commonly achieved by the use of an isolated input amplifier, as shown in fig.4.14. Fig.4.14 Isolation of Patient connected parts This type of amplifier is completely isolated from the rest of the equipment, with the power provided through a low-capacitance transformer. A second transformer is used to couple the amplified signal to the rest of the equipment. Because signal transformers are difficult to design for the frequency range of biological signals, a modulation scheme is normally employed.

The amplifier shown in the fig.4.14 uses amplitude modulation of the carrier signal used to provide power for the isolated amplifier. Other designs use frequency modulation. Occasionally, isolation protection is provided by connecting a current limiter into each patient lead. The characteristics of these devices are shown in figure 4.14. For low currents these devices act as resistors, but when a certain current level is approached they change their characteristics and prevent the current from exceeding a predetermined limit. Although current limiters are less desirable than isolated amplifiers, they are nevertheless used where many patient leads have to be protected, such as in EEG machines. 4.15.9 Isolated Power Distribution Systems In an isolated distribution system, the power is not supplied from the transformer substation directly, but is obtained from a separate isolation transformer for each operating room. This transformer, together with the associated circuit breaker and the line isolation monitor described below, is mounted in a separate enclosure, either in the operating room or adjacent to it. The panel of such an installation is shown in

Isolated Power Distribution Systems If a short between the case and one of the two wires occurs in a piece of equipment powered from an isolated system, the result will be quite different from that of the grounded system described earlier. Even if the case of the equipment is not grounded properly, someone touching the equipment and a grounded object simultaneously will not receive a shock, for neither of the power conductors is connected to a ground. 4.16 Safety aspects in electro surgical units, burns and High frequency current hazard and explosion hazard. Burns Fire may results from heat produced by over loaded, incorrectly wired, or improperly maintained equipment or power system. Explosion

• Explosion may result from electrical contact sparks that ignite a variety of explosive gases, such as ether or cyclo-prophane anesthetic

. • Damage to equipment and buildings may results from explosion, fire or electrical overload. Above these shock hazards are prevented by using line isolation systems. 4.16.1

Prevention of shock hazard in Electro surgical units In these systems, power isolation transformers produce. Isolated systems by breaking direct electrical connection to neutral ground. The power used inside the electrical equipment is not effectively referenced to ground. This hazards since contact with either side of the isolation transformer secondary and ground produces no shock. Patient isolation through a driven (RL) amplifier amounts to reducing possible current paths through the patient. Power isolation transformer is designed toward reducing differential voltages to 5 mv between the catheter and equipment chassis or earth ground. These devices are used in the operating room as a safety aspect in electro surgical units. If the standard patient resistance of 500Ω is used, no more than 10μA will flow. Fig. 4.16 shows a short circuit with a power isolation transformer. Here Neutral return wire is shorted with grounded case. Even though it is shorted only a small amount of current will flow through neutral return. This is because the resistance of transformer secondary is higher than the ground resistance. Page 98 Fig.4.16 Prevention of shock hazard in Electro surgical units

4.16.2 Prevention of shock hazard due to burns and explosion Isolation transformer systems were designed to prevent heating and sparking due to the hot-wire shorting to the metal case. This caused explosion of flammable anesthetic gases, such as ether. To understand this phenomenon, consider a ground-referenced (non-isolated) system and an ECG monitor. If the hot-wire shorts to the metal case in a two-wire system, the floating case (not grounded) becomes 120V with respect to ground. The fuse does not blow, and this is a very serious macroshock or microshock hazard. For this reason, two-wire systems are never used in hospital. If the hot wire shorts to metal case in a three-wire system. The grounded case passes a large current (15 – 30 A) until the fuse blows. This disconnects the power from the equipment and removes the shock hazard. However, this large current causes heating and may jump small gaps to cause sparking. At levels near the floor, where anesthetic gases collect, this can cause explosion. In a non-grounded (isolated) system, if the hot-wire (either isolation transformer secondary wire) shorts to the grounded metal case, no large current flows through the case. Only leakage current flows (a few mill-ampere) and sparking is non-existent. This system protects against explosion and corrosive action is taken when the line isolation monitor sounds (loud buzzer) or monitor leakage meter reads in the red (2-3 mA). The line isolation monitor (LIM) is a device that continuously monitors the impedance of either isolated power line to ground.

The effect is to monitor leakage current. This device is used with power isolation transformer systems. Fig.4.17 Prevention of shock hazard due to burns and explosion Fig.4.17 shows a power LIM system with fault detector. Page 99 Essentially there are several ways in which one could be shocked by touching one power line and ground, one metal chassis and ground, and two metal chassis. For example, if the patient touches two metal chassis (A and B), both of which are grounded, and the insulation on the device B breaks down, the patient can be protected by the LIM system which is shown in Fig.4.20 Only 2μA will flow through the 500Ω patient and 998μA through the ground wire as a result of the LIM (alarm) limit of 1mA total fault current.

4.17 Safety codes for electro medical equipment Various countries have laid down codes of practice for equipment intended to be used in hospitals. The International electro-technical commission (IEC) has brought out a fairly voluminous document, the IEC 601 (general requirements for the safety of medical electrical equipment), to provide a universal standard for manufactures of electro-medical equipment as well as a reference manual on good safety practice. Bases on the IEC document, the Bureau of Indian Standards (BIS) has issued the IS: 8607 standard to cover general and safety requirements of electro-medical equipment.

4.18 Precautions to minimize electric shock hazards:

1. In the vicinity of the patient, use only apparatus appliances with three wire power cords.

2. Provide isolated input circuits on monitoring equipment

3. Have periodic checks ground wire continuity of all equipment

4. No other apparatus should be put where the patient monitoring equipment is connected.

5. Staff should be trained to recognize potentially hazardous conditions.

6. Connectors and probes should be standardized

7. The functional controls should be clearly marked.

8. A potential difference of not more than 5 mv should just between ground point at outlet and the ground points at any of the other outlet.

UNIT-V MODERN IMAGING TECHNIQUES:

5.1 Lasers:

The term „Laser" has been coined by taking the first letters of the expression "Light Amplification by Stimulated Emission of Radiation". It is an extension of maser (microwave amplification by stimulated emission of radiation) to the optical region of the electromagnetic spectrum. It is a generator of light. But its light is quite unlike the output of conventional source of light.

5.1.1 Laser beam properties:

The Laser beam has,

- High radiance
- Spatial
- Temporal
- Coherence
- Mono chromaticity
- Directionality
- Pure wavelength
- Easy accessibility

i) Transparency

ii)Absorption

iii) High density

iv) Low dispersion

v) High penetration power

vi) Intense heat

vii) Ionizing radiation

The above mentioned properties make the laser a unique light probe of non-invasive applications.

5.1.2 Laser Principle and Laser operation The laser action depends upon the phenomenon of stimulated emission shown in Fig 5.1. Consider a single atom A in an excited state which can come back to its normal or ground state by emitting a „photon" or a light quantum whose frequency is related to the excitation energy E . \ This corresponds to the phenomenon known as spontaneous emission fig 5.1 (a). If during the period, the atom is still excited, it can be stimulated to emit if it is struck by an outside photon fig 5.1(b) Since most atoms are in the ground state, their absorption is generally far more likely than emission. However, if population inversion could be obtained (with more atoms in the excited state) an incident – photon could trigger stimulated emission causing an avalanche of coherent photons.

To achieve this, it is necessary to have an active medium in which atoms are kept in an excited state and stimulation by an outside photon to emit light in a particular direction. The process by means of which a medium is activated is called „pumping".

This entails injecting an electromagnetic energy into the medium at a wavelength different from the stimulating wavelength (Refer fig 5.2) The active medium is usually enclosed in a resonator box with highly reflecting walls. The photons released by the stimulated emission undergo multiple reflections and result in a coherent wave of growing strength. The laser output is obtained if the resonator box is transparent to the emitted laser beam. The incident wave could continue to grow as long as the scattering is few and population inversion is maintained. 5.1.3 Population inversion Population of atoms in higher energy level is normally smaller than the lower (ground) energy level in an atomic system. But, when an atom is excited, at one particular time after receiving the excitation, the outer most orbits will be more populated than the inner orbit. This is called population inversion which is shown in fig 5.3

Population inversion can be done by pumping the matter by photons of appropriate energy giving by pumping source (light) or by an applied electric field Because of population inversion, simultaneously many of the electrons jump from outer to inner orbit producing almost the same frequency of light. Hence a monochromatic beam of light is possible. In the presence of population inversion, the two processes spontaneous emission and stimulated emission are taken place.

5.1.4 Types of Laser

1. Argon

2. Helium neon

3. Krypton

4. Ruby

5. CO_2

6. Nd-yag

5.2 CO_2 Laser:

CO_2 laser is a mixture of carbon-dioxide, nitrogen and helium with the CO_2 as the active, energy emitting gas. The CO_2 laser has a high conversion efficiency of 15% it operates with a simple cooling system of tap water and is relatively in expensive. The beam can be reflected or focused by appropriate Page 106 mirrors and lenses. The normal operation of the laser is multimode. However, by inserting an annular diaphragm into the resonator, a single mode can be obtained and the focal spot reduced to about 0.5mm.

The operating microscope can be used in conjunction with CO2 laser as an aid to visualization of tissue undergoing treatment. The above fig 5.4 shows block diagram of CO2 laser. The laser head contains the CO2 laser which produces the invisible infrared (10.6 micron) beam used for surgery. A continuously adjustable power up to 25W is available. A helium-Neon laser provides a visible red (-.8 mW, 63280A) aiming beam. This beam provides accurate visualization of the operating area for precise laser removal of pathologic tissue.

5.3 Nd-Yag Laser (Neodymium doped -1/Hrium aluminium garnet) Nd-Yag laser is very similar to the ruby laser in construction. (For diagram refer ruby laser. Note: Here Ruby Rod is replaced by Nd-Yas laser rod). These lasers have become very popular in recent years because of their very high output energies, repetition rate and wavelength. The active element is Nd-Yag crystal optically pumped by two krypton are lamps. Wave length (WL) of emission is 1.06 μm Fig 5.5 shows block schematic of Nd-Yag Laser. Working principle In a typical pulsed laser system a high voltages transformer (4000 – 10000V) is connected to a bank of capacitors and pulse forming inductances. This network is further connected to a Xenon flash lamp (as shown in fig) which may be straight or helical. Neodymium has a four level transition. It is thus easier to achieve a population inversion in Nd-Yag because it is measured relative to another excited state instead of the ground state as in ruby laser. The laser arrangement consists of a Nd-yag rod placed within a elliptical cavity. Pumping of the laser rod is generally by pulsed or continuous discharge tube where as pumping at low levels of CW power output is achieved by flash lamps. Page 107 The oscillator is often Q-switched to obtain very high, reproducible peak powers that can be effectively doubled, tripled and quadrupled in frequency. The pulse widths and repetition rates are typically 10-20ns and 10HZ respectively A typical commercially available Nd-yag laser consists of a power supply and laser head fitted with light guide and focusing hand piece. The system operates on 380V, 20A, 3 phase supply. The power supply unit contains the thyristor control for the lamp current and a control circuit for automatic switching and monitoring the laser. Due to high power requirements, the lamp fittings and the Yag crystal are cooled by a single cooling system safeguarded by flow monitors and magnetic valves. Approximately 10.1 per minute water at a pressure of 3.5 bar is required for cooling with these inputs, maximum power output available out of the light guide is approximately 70W. 5.4 Applications of Laser in medical field

Types of Laser Wave length mm Medium Power watts Type of beam Applied field Argon 0.49 (visible) Gas 5 Continuous pulsed Neurosurgery, ophthalmology, gynecology, dermatology, biological research. Helium neon 0.63 (visible) Gas 0.1 Continuous Diagnostic applications like study of light, Permeability of blood containing tissues. Krypton 0.35 (ultraviolet) Gas 5 Continuous Ophthalmology and for general diagnostic use. Ruby 0.69 (visible) Solid 5 Pulsed Ophthalmology, Dermatology. CO2 10.6 (Infrared) Gas 200 Continuous Neurosurgery, general surgery, dermatology, gynecology. Nd-yag 1.06 (Infrared) Gas 50 Q-switched Neurosurgery, dermatology, gynecology. Excimers ArF 193 (ultraviolet) gas 30 pulsed Surgery KrF 249 (ultraviolet) gas 45 pulsed Surgery Xecl 308 (ultraviolet) gas 30 pulsed Surgery XeF 350 (ultraviolet) gas 20 pulsed Surgery Page 108 Lasers are presently used for a variety of applications in the medical field for diagnostic and therapeutic purposes. The information contained in laser light reflected or scattered by structures can be detected and analyzed for diagnostic purposes. The most widespread medical application for laser technology in medicine has occurred in ophthalmology. This is due to the easy accessibility of the human eye, its transparency and the absorption properties of intense tissues. Lasers are in routine clinical use for many therapeutic and diagnostic purposes and their application has become the standard of care in the treatment of many eye diseases.

The following table shows the typical laser characteristics and their medical applications. There is variety of laser applications in medical field. Here we give few of them as an extension of the above tabular column. a) Photo thermal applications Laser heating of tissue is used for two distinct surgical functions, cutting as a scalped and photocoagulation. The first medical application of laser was in ophthalmology. Ophthalmologists use them to treat variety of eye problems, including retinal bleeding, the excessive growth of blood vessels in the eye caused by diabetes and also for “spot welding” – reattaching retinas that have become partly detached from the back surface of the eye, the choroids. b) Application in Dentistry Lasers could be used to drill holes in tooth; the dept is governed by the pumping energy used to produce the laser.

The beam destroys by vaporization the decayed dark spots while leaving the good parts of the teeth alone. By way of advantage, it may be said that no noticeable vibration to the patients, no extended heating, no anesthetic and no pain. c)

Dermatology Laser could be used in treating skin diseases. Laser has been used as a catering tool (to sear out affected part of skin by thermal treatment). For the local treatment of the skin growth and blemishes considerable energy may be transmitted through the skin to internal selectively with deeper different biological structures. d) In cancer and tumor Laser beam can remove cancer cells accurately. It was found that two to four weeks after exposure to laser beam the cancer growth disappeared or diminished. 5.5 X – ray imaging X – rays X- rays are electromagnetic waves that have a much shorter wavelength than radio waves or visible light. Their wavelength can vary between approximately 10-8 and10-10cm corresponding to a frequency between 1010 and 1014 MHz. X-rays were discovered by Roentgen in 1895. X-rays can penetrate body tissues and affect photographic plates and fluorescent screens. The ability of these rays to penetrate matter depends on their wavelength.

5.5.1 Properties of x-rays :

1. X-rays can penetrate matter

2. X-rays can be absorbed by denser medium like bones.

3. X-rays can be transmitted by opaque medium like soft tissues, muscles.

4. X-rays can produce luminescence when they strike Fluorescent screens.

5. X-rays affect photographic emulsions.

6. X-rays produce ionization in gases and influence the electrical properties of liquids and solids.

7. X-rays produce secondary radiation in all matters through which they pass.

8. X-rays have shorter wavelength & high energy.

9. X-rays are potentially danger.

10 . X-rays propagate with a speed of 3 x 1010 cm/s and are unaffected by electric and magnetic fields.

5.5.2 Generation of X-rays. :

(Principle of X-ray apparatus) X-rays are generated when fast moving electrons are suddenly stopped by impinging on a target. The energy possessed by the electrons appears from the site of collision as a parcel of energy in the form of highly penetrating electromagnetic waves (X-rays) of many different wavelengths. X-rays are produced in a specially constructed glass tube, shown in fig 5.10 which basically comprises.

- A source for the production of electrons
- An energy source to accelerate the electrons
- A free electron path
- A means of focusing the electron beam and
- A device to stop the electrons.

The intensity of X-rays depends on the current through the tube. This can be varied by varying the filament current, which in turns control cathode temperature. The wavelength of the X-rays depends on the target material (anode) and the velocity of electrons hitting the target. It can be varied by varying the target voltage of the tube. X-ray equipment for diagnostic purposes uses target voltage in the range of 30 to 100 kV, while the current is in the range of several hundred mill amperes.

5.5.3 Working of X – ray apparatus (machine) In the basic X-ray machines, following components are there

1. High voltage source
2. X-ray tube
3. X-ray tube filament supply
4. Temperature control circuit
5. Timer circuits

Working ϖ High voltage is produced by a step – up transformer whose primary is connected to an autotransformer ϖ Secondary is connected to anode after rectification. ϖ The primary voltage is measured with the help of voltmeter calibrated directly in kilovolts with respect to secondary. ϖ Milliamp here meter is connected in series with rectifier to measure the current. ϖ Milliamp here - second is also measured to know the energy. ϖ Kilovolt selector and exposure switches are there to select the voltage as well as to give the exposure. ϖ The exposure timing is controlled by using a timing circuit. ϖ There is a circuit to control the heating of X-ray filament. ϖ Filament temperature is measured in terms of tube current, therefore milliamp here control is provided. The information contained in X- ray beam is converted into a visible image with either a fluorescent screen or on a photographic film.

Most – X-ray images are made on special film coated on both sides with light sensitive emulsion. Real time visualization is possible in fluoroscopy which can be used to study the dynamic behavior of the body organ. To improve the quality of images, exposure to be increased which possess radiation hazards. In the new systems, image intensified tubes are used. There tubes convert X-ray to visible light. In cine technique, the image tube and an optical system are used. A 16 or 35 mm motion camera is used to record the output of image intensifier tube. Close circuit television (CCTV) is another procedure to present the diagnosis of disorder of the patient.

5.5.4 Applications of X- rays.:

Low energy X-rays are used in hospitals to study and diagnose disorders of internal organs of body. They are used to diagnose,

1. lung and heart disorders

2. gall bladder stone

3. ulcers

4. Tumors etc.

High energy X- rays are used in,

1. treatment of cancer and

2. Other malignant and infectious diseases.

5.6 Special techniques in X-ray imaging:

Various techniques which use X-ray imaging are

1. Fluoroscopy

2. Angiography

3. Tomography (CAT and CT scan)

5.6.1 Tomography :

Tomography is a term derived from the Greek, meaning to write a slice or section and is well understood in radiographic circles. In the ordinary X-ray image, all the tissue layers traversed by the X-ray beam are visualized. When it is desired to eliminate all image shadows except those originating from a particular plane in the patient, tomography can be applied. The principle of tomography is to produce intentional movement un sharpness in all planes except the one to be visualized.

This is accomplished by moving the X-ray tube and film during the exposure about an axis located in that particular plane. Computerized Axial Tomography (CAT) A highly acclaimed application of the digital computer to clinical medicine is computerized axial tomography (CAT). This procedure, which combines X-ray imaging with computer techniques, permits visualization of internal organs and body structures with greater definition and clarity than could ever be attained by conventional methods. The principle of obtaining X-ray images from a number of vantage points is used in computerized axial tomography, but in a different way. As the name implies, the vantage points for axial tomography are taken around the axis of the body. Instead of sending X rays through the entire portion of the body to be visualized, a very narrow pencil-like X-ray beam scans a single slice perpendicular to the body‟s axis.

By scanning two or more such slices, a three-dimensional representation can be produced.Rather than obtaining an image on an X-ray film, the intensity of the X-rays, after penetrating the boby is measured by means of one or more sodium iodide, xenon, or calcium chloride crystal detectors, which scintillate in proportion to the intensity. The scintillation light is measured by Photomultiplier tubes. In the original computerized axial tomography (CAT) scanners, the source of the pencil-like beam was mechanically moved across the region of the slice, as shown in Fig 5.13. At the same time, the detector moved linearly in parallel with the source to receive a signal whose variations with respect to time represented the density pattern across the slice from one vantage point. The mechanism containing the source and detector were then rotated about the axis of the body to a new vantage point, from which another scan of the slice was made. Scans were taken from 180 such vantage points, 10 apart. Data from each scan were fed into a computer, which combined the density pattern and reconstructed the anatomical density of the two-dimensional slice. By repeating this process for several slices, a detailed three-dimensional representation could be obtained.

The early instruments usually scanned two slices at a time, this process requiring about 5 minutes. Computer Tomography (CT) scans Computer tomography is a diagnostic imaging technique in which anatomical information of a patient is digitally reconstructed on a screen from X-ray data by scanning an area in many directions. System components of CT scanner All CT systems consists of four subsystems which are shown in Fig.5.14 (b) i) Scanning system – takes suitable readings for a picture to be reconstructed. This includes X-ray source and detectors. ii) Processing unit coverts these readings into intelligible pictures information iii) Viewing part – presents the information‟s in visual form and includes other manipulative aids to assist diagnosis. iv) Storage unit – enables the information to be stored for subsequent analysis. Page 112 Block Explanation (working) ϖ The X-ray source and detectors are mounted opposite each other in a rigid gantry with the patient lying in between and by moving one or both of these around and across the relevant sections the measurements are made. ϖ The patient lie on a motorized coach as shown in fig.5.8 and is moved into the aperture of the gantry. ϖ The location to be accurately determined by means of a narrow strip of light that falls on the body from the gantry and illuminates the section to be examined. ϖ The X-rays pass through the patient and are partially absorbed and the remaining X-ray photons impinge upon several of as many as 1000 radiation detectors fixed around the circumference of gantry. ϖ The timing, anode voltage (kV) and beam current (mA) are controlled through a control bus. ϖ The high dc supply drives the X-ray tube that can be mechanically rotated along the circumference of the gantry. ϖ From the keyboard mounted in the operating console the patient name, the name of the hospital etc. are fed into the system and setting for X-ray parameter for the scan are made. ϖ The detectors absorb the X-ray photons and emit the energy as visible light. This is converted to electrons by photo multiplier tubes and amplified. ϖ After initial processing the final image is put on the system disc. This allows direct viewing on the operators console.

5.7 Ultrasonics Ultrasonic waves: (Ultrasound) Ultrasonic waves are the non audible sound waves whose frequencies are greater than 20 KHz. The frequency range of ultrasonic waves in medical field is from 1 to 15 MHz.

5.7.1 Applications of ultrasonic waves in medical field:

1. used in diagnostic and therapeutic applications.

2. used in cardiology (Echocardiography)

3. used in gynecology (Doppler scan)

4. used in abdominal imaging

5. used in brain studies

6. used in eye analysis

7. used in blood flow measurement

8. used in blood pressure measurement

5.7.2 Principle of ultrasonic imaging :

When certain solid materials are deformed, they generate within them an electric charge. This effect is reversible in that if a charge is applied, the material will mechanically deformed in response. These actions are given the name „Piezo-electric effect‟. This electro-mechanical conversion is applied in medical field for diagnosis. Generation of ultrasonic waves. When a high frequency RF input is given to electrical axis of The crystal as shown in fig 5.6, then along the mechanical axis Of the crystal, the crystal expands and contracts periodically, particularlywhen the natural frequency of the crystal is equal to RF input frequency, ultrasonic resonant vibrations are obtained. Since the crystal is used to convert mechanical vibrations into electric charges or vice versa this arrangement is called as ultrasonic transducer.

5.7.3 Ultrasonic Imaging :

The most widely used applications of ultrasound in diagnostic medicine involve the non-invasive imaging of internal organs or structures of the body. Such imaging can provide valuable information regarding the size, location, displacement, or velocity of a given structure without the necessity of surgery or the use of potentially harmful radiation. Tumors and other regions of an organ that differs in density from surrounding tissues can be detected. Imaging systems, generally utilize the pulsed ultrasound or pulsed Doppler mode. Instrumentation must include an electrical signal source capable of driving the transmitter, which consists of a piezoelectric crystal. The same crystal can be used for receiving echoes or a second crystal may be used After amplification, the received information is displayed in one of the several display modes.

Various modes of ultrasonic imaging 1. A scan display: This is the simplest form of display in which each transmitted pulse triggers the sweep of an oscilloscope. That pulse and the returning echoes are displayed as vertical deflections of the trace. The sweep is calibrated in units of distance. An example of an A-scan display is that of echoencephalogram. (Brain study). 2. M – Scan display: As in the A – scan display, each transmitted pulse triggers the oscilloscope sweep, however, the received pulses are used to brighten the trace rather than control the vertical deflection. The quiescent brightness level is set below the visibility threshold so that only the echoes, which appear as dots with brightness proportional to the intensity of each echo, can be seen.

For the M-scan, the transducer is held stationary so that the movement of the dots along the sweep represents movement of the received targets. An example of M-scan recording is the echocardiogram. 3. B – Scan display: While the M- scan is used to display the movement of the targets with respect to time, the B – scan presents a two dimensional image of stationary organ or body structure. As in the M-scan, the brightness of the oscilloscope or light pen beam is controlled by returning echoes, however in the B – scan the transducer is moved with respect to the body while the vertical deflection is made to correspond to the movement of the transducer.

5.8 Ultrasonic Imaging Techniques:

5.8.1. Pulse – echo system Many medical applications employ pulse waves for ultrasonic imaging. In fact, the majority of modern ultrasonic diagnostic instrumentation is based on the pulse echo technique which is shown in Fig.5.7. The pulse echo technique basically consists of transmitting a train of short duration ultrasonic pulses into the body and detecting the energy reflected by a surface or boundary separating the two media of different, the presence of discontinuity can be conveniently established and its position located if the velocity of travel of ultrasound in the medium is known.

Also, it is possible to determine the magnitude of the discontinuity and to access its physical size. The basic layout of the apparatus based on the pulse echo technique 1. The transmitter generates a train of short duration pulses at repetition frequency determined by the PRF generator.

2. There are converted into corresponding pulses of ultrasonic waves by a piezo-electric crystal acting as the transmitting transducer.

3. The echoes from the target or discontinuity are picked up by the same transducer and amplified suitable for display on a cathode ray tube.

4. The X plates of the CRT are driven by the time base which starts at the instant when the transmitter radiates a pulse.

5. In this way, the position of the echo along the trace is proportional to the time taken for a pulse to travel from the transmitter to the discontinuity and back again. 6. Knowing the velocity of the ultrasonic waves and the speed of the horizontal movement of the trace on the CRT, the distance of the target from the transmitting end can be estimated.

5.8.2. Echocardiography:

The major application in cardiovascular diagnosis is the echocardiogram, which utilizes M – scan technique of ultrasonic imaging. In the echocardiogram movements of the valves and other structures of the heart are displayed as a function of time and usually in conjunction with an electrocardiogram. Echocardiography has been extremely useful in diagnosing many cardiac abnormalities. Echocardiography is a widely used and valuable instrument for carrying cardiac examinations. By using the instrument it is possible to detect intra – cardiac structures.

The fig 5.8 shows the block diagram of an echocardiograph several circuit blocks are common to the general echo measuring instrument, except for the addition of a slow sweep circuit and recording arrangement. ϖ For echocardiography, the transducer is placed between the third and fourth ribs on the outer chest wall where there is no lung between the skin and the heart. ϖ From this probe a low intensity ultrasonic beam is directed towards the heart and echo signals are obtained. Page 115 ϖ The probe position is manipulated to obtain echoes from areas of interest in the heart.

The system operates on the principle of reflected ultrasound and senses flow velocity within a small 2 x 4 mm tear drop shaped volume, referred to as the sample volume. ϖ The sample volume is especially selectable within the heart and the great vessels by means of a depth control setting and is subject to a variety of components of blood flow velocity.

A growing number of routine examinations and the possibility of extracting more quantitative data from the echocardiogram have necessitated the development of a computer system for semi automated analysis of M-mode echocardiogram. ϖ The routine programme generally aims at the measurements which can be sub divided into three groups, i) Ventricular dimensions ii) aorta and left atrium dimensions iii) mitral valve measurements Each group of measurements is preceded by a calibration so that it is possible to use different recordings of the measurement structures from each group.

Applications of Echocardiography :

It is widely used for cardiac examinations like

1. Measurement of ventricular dimensions

2. Aorta and left atrium dimensions

3. Measurement of mitral valve

4. Detection of intra – cardiac structures

5. Study of aortic valve, tricuspid valve and pulmonary valve.

6. Detection of abnormal fluid collection

7. Sensing of flow velocity

8. Finding of volume of blood in the chambers.

5.9 Angiography:

Angiography is a diagnostic and rapidly developing therapeutic modality concerned with diseases of the circulatory system. It is a special X-ray imaging technique in which better contrast can be obtained. In this, the outlines of the blood vessels are made visible by injecting a contrast medium which is normally water soluble organic compound of iodine and is readily excreted by the body, directly into an artery or vein in the region to be investigated. Injection is made through a catheter placed in the blood vessel. Meanwhile using fluoroscopic technique, combined with the television system, the function of various organs.

Thus angiocardiography is related with the study of moving heart using angiographic X-ray pictures as shown in Fig.5.9. Similarly there is cerebral angiography (brain), brochography (lungs) nephro angiography (kidneys) etc. 5.10 Magnetic Resonance Imaging System (MRI scan or NMR scan) Magnetic Resonance Imaging is a representation of the spatial distribution of the NMR (Nuclear Magnetic Resonance) signal intensity in heterogeneous specimens like the different part of the human body. This technique makes use of RF region of the electromagnetic spectra to provide an image. In this technique, first the patient is placed in an external magnetic field which causes the magnetization of protons of hydrogen atoms in his body.

Due to magnetization there protons align and process about the external magnetic field. Now a radio frequency pulse at resonance frequency is transmitted into the patient the individual proton responds by emitting a radio frequency signal. This is called nuclear magnetic resonance signal. These emitted signals by the protons, during their return form higher nuclear energy states to ground states, are picked up by the RF coils and processed by computers using Fourier transforming techniques to produce an image. Page 117 The basic components of a MRI system are shown in fig.5.10 ϖ There is a magnet which provides strong, uniform, steady magnetic field Bo.

Different gradient coil system produce a time varying controlled spatial non uniform magnetic fields in different directions. ϖ The patient is kept in this gradient field space. ϖ There are also transmitter and receiving RF coils surrounding the site on which the image is to be constructed. ϖ There is a superposition of a linear magnetic gradient on to the uniform magnetic field applied to the patient. ϖ When this superposition takes place, the resonance frequencies of the processing nuclei will depend primarily on the positions along the directions of the magnetic field gradient. ϖ This produces one dimension projection of the structure of the three dimensional object. ϖ By taking series of these projections at different gradient orientations using X,Y and Z gradient coils a two or three dimensional image can be obtained ϖ The slice of the image depends upon the gradient of the magnetic field. ϖ The gradient magnetic field is controlled by computer and that field can be positioned in three invariant planes(x, y and z) ϖ The transmitter provides the RF signal pulses. ϖ The received nuclear magnetic resonance signal is picked up by the receiver coil and is fed into the receiver for signal processing. ϖ By two dimensional Fourier transformations, the image is constructed by the computer and is displayed on the television screen.

MRI has the following advantages over other imaging modalities.

1. Superior contrast resolution

2. Direct multiplanner imaging, slices in the sagittal, coronal and oblique directions can be obtained directly.

3. There is total absence of harmful radiations like X-rays, r- rays, positions. etc. Hence making it as a non invasive imaging technique.