MUTHAYAMMAL ENGINEERING COLLEGE

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

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L-1

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code :BIO MEDICAL ENGINEERING &16BME04
Course Faculty : Dr.G.SUDHA
Unit: I - Physiology and Transducers Date of Lecture:

Topic of Lecture:Cell and its structure - Resting and Action Potential

Introduction :

- Human body is a complex engineering marvel, which contains various types of systems such as electrical, mechanical, hydraulic, pneumatic, chemical and thermal etc.
- Cells have long been recognized as the simplest units of living matter that can maintain life and reproduce themselves. The human body, which is made up of numerous cells, begins as a single, newly fertilized cell.

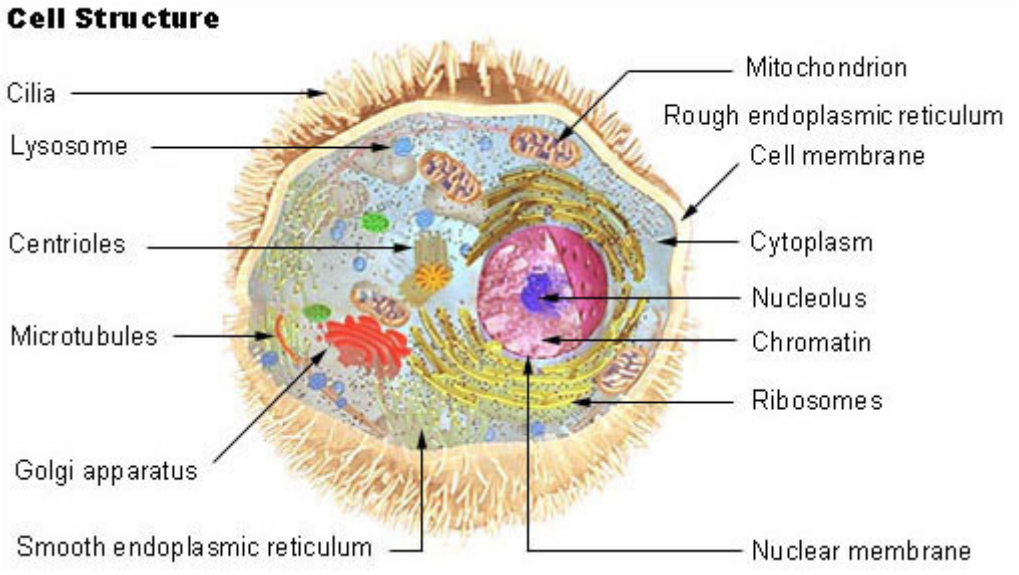
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Temperature measurements

Cell and its structure - Resting and Action Potential

Cell Structure

A cell consists of three parts: the cell membrane, the nucleus, and, between the two, the cytoplasm. Within the cytoplasm lie intricate arrangements of fine fibers and hundreds or even thousands of miniscule but distinct structures called organelles.



Cell membrane

Every cell in the body is enclosed by a cell (Plasma) membrane. The cell membrane separates the material outside the cell, extracellular, from the material inside the cell, intracellular. It maintains the integrity of a cell and controls passage of materials into and out of the cell. All materials within a cell must have access to the cell membrane (the cell's boundary) for the needed exchange.
The cell membrane is a double layer of phospholipid molecules. Proteins in the cell membrane provide structural support, form channels for passage of materials, act as receptor sites, function as carrier molecules, and provide identification markers.

Nucleus and Nucleolus

The nucleus, formed by a nuclear membrane around a fluid nucleoplasm, is the control center of the cell. Threads of chromatin in the nucleus contain deoxyribonucleic acid (DNA), the genetic material of the cell. The nucleolus is a dense region of ribonucleic acid (RNA) in the nucleus and is the site of ribosome formation. The nucleus determines how the cell will function, as well as the basic structure of that cell.

Cytoplasm

The cytoplasm is the gel-like fluid inside the cell. It is the medium for chemical reaction. It provides a platform upon which other organelles can operate within the cell. All of the functions for cell expansion, growth and replication are carried out in the cytoplasm of a cell. Within the cytoplasm, materials move by diffusion, a physical process that can work only for short distances.

Cytoplasmic organelles

Cytoplasmic organelles are "little organs" that are suspended in the cytoplasm of the cell. Each type of organelle has a definite structure and a specific role in the function of the cell. Examples of cytoplasmic organelles are mitochondrion, ribosomes, endoplasmic reticulum, golgi apparatus, and lysosomes.

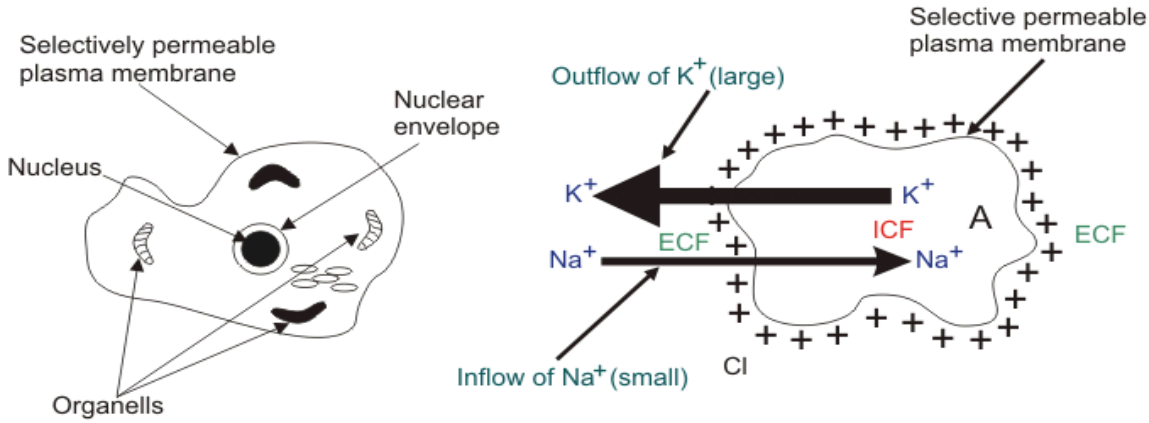
Resting Potential and Action Potential

In a cell membrane, the outside fluid is extra-cellular fluid and inside fluid is intra-cellular fluid. The extra-cellular fluid has a large concentration of sodium ions and chloride ions but less concentration of potassium ions. The intra-cellular fluid has a high concentration of potassium ions than the sodium ions. In our body, neuron sends electrochemical messages, which produces an electrical signal. Chemicals in our body are “electrically charged”, and when they have an electrical charge, they are “ions”. Sodium and Potassium ions have one positive charge. Calcium ions have two positive charges. Chloride ions have one negative charge. The cell membrane is semi-permeable. It allows few ions to pass through and stops passage of other ions.

Resting Potential

Transport of substances across the cell membrane is “diffusion”. Diffusion generates membrane potential. The ions try to balance between inside and outside cell during diffusion. When a cell does not send a signal, it is at “resting state”. At resting state, the inside of the cell is negative when compared to outside of the cell. This permits the entry of potassium (K+) and chloride (CL–) ions and stops Sodium ions (Na+). Since the cell has semi-permeable membrane sodium ion concentration inside the cell is lower than the outside the cell. Na+ ions are positive, so the outside of the cell is positive than the inside. Inside the cell, potassium and chloride ion concentration is more than the outside the cell. Hence, the cell does not meet the charge balance. Yet a potential difference occurs across the cell membrane an equilibrium occurs. The cell membrane is negative inside and positive outside. The difference in ion concentration results in the Resting Membrane Potential of the cell. The value of resting potential is between – 60mV to – 100mV. The value remains constant until an external factor disturbs the cell membrane. At the

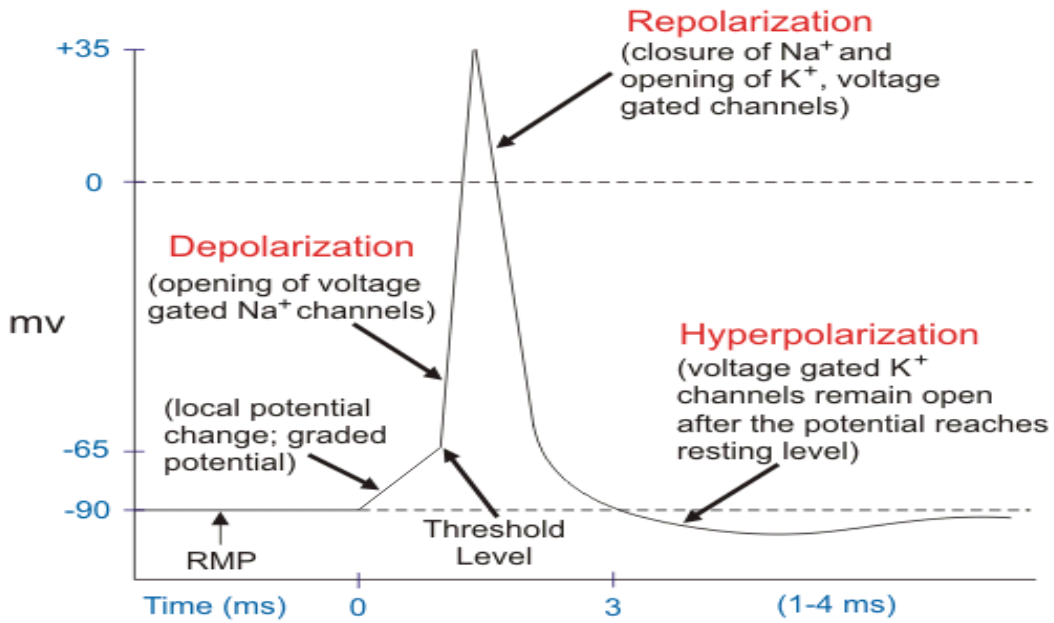
resting state, the cell is polarised.



Consider an example of our blood plasma (serum). If sodium ion concentration increases, renal damage and dehydration occur. If reduced, renal failure and adrenocortical hypofunction occur. If potassium ion concentration increases shock and acidosis occurs. Acidosis is a medical condition where a patient loses his consciousness, tachycardia develops resulting in a decrease in blood pressure. Similarly, an increase in chloride ions produces respiratory problems.

Action Potential

When ionic current or external energy excites the portion of a cell membrane, permeability changes. Now the sodium ions flow inside the cell and generate ionic current. This reduces the membrane barrier. It allows sodium ions to flow into the cell and try to balance with the ions outside. Meanwhile, potassium ions flow outside the cell. Thus, the cell has positive potential inside the cell and negative potential outside the cell due to the imbalance of potassium ions. The positive potential of the cell membrane is Action Membrane Potential. The value of action potential is 20mV. Now the cell is depolarised.



When the sodium ions stop flowing into the cell, ionic currents reduces the barrier to the cell wall membrane. So the cell returns to polarised (original condition). In resting state of the cell, sodium ions rush to outside the cell using Sodium Pump.
In nerve and muscle, cell repolarisation occurs fast after depolarization. Action potential appears as a spike for one millisecond. In heart muscle, an action potential occurs for 150 to 300

milliseconds. Therefore, repolarization occurs slowly in the heart.
Video Content / Details of website for further learning (if any): https://training.seer.cancer.gov/anatomy/cells_tissues_membranes/cells/structure.html https://www.electrical4u.com/action-potential-and-resting-potential/
Important Books/Journals for further learning including the page nos.: Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 32-33

CourseFaculty

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Course Name with Code : BIO MEDICAL ENGINEERING&16BME04

Course Faculty : Dr.G.SUDHA

Unit : I - Physiology and Transducers Date of Lecture:

Topic of Lecture:Nervous system: Functional Organization of the Nervous System - Structure of Nervous System, Neurons - Synapse

Introduction :

- The **nervous system** is a highly complex part of an animal that coordinates its actions and sensory information by transmitting signals to and from different parts of its body.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Temperature measurements

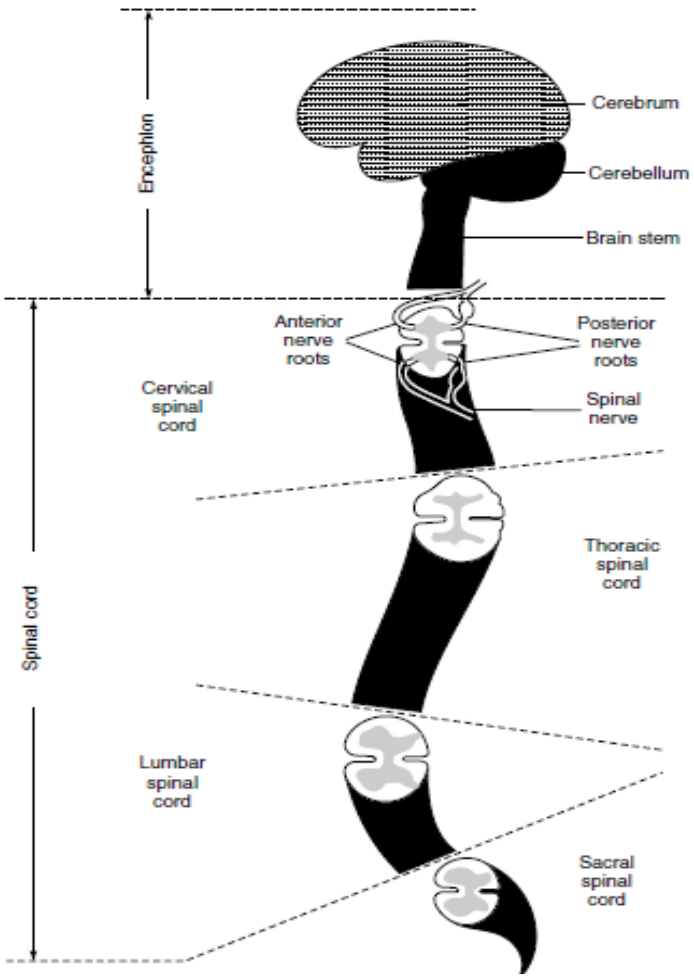
Nervous system: Functional Organization of the Nervous System - Structure of Nervous System, Neurons – Synapse

The nervous system is the control and communication network for the body which coordinates the functions of the various organs.

Rapid communication between the various parts, the effective, integrated activity of different organs and tissues and coordinated contraction of muscle are almost entirely dependent upon the nervous system. It is thus, the most highly developed and complex system in the body.

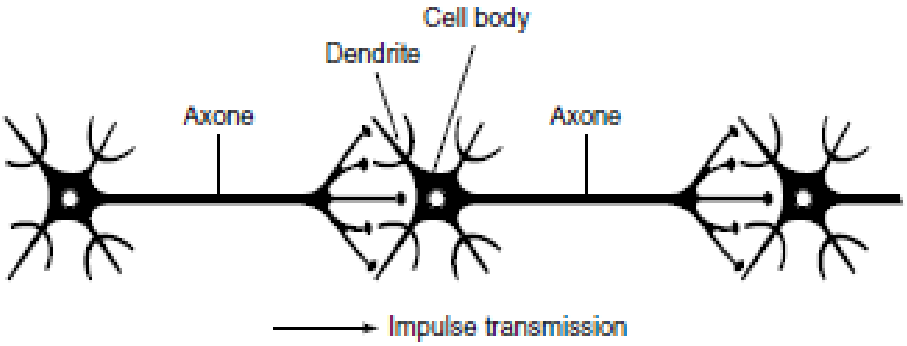
The centre of all these activities is the brain (central information processor) with memory, computational power, decision making capability and a host of input output channels. The nervous system consists of a central and a peripheral part. The central nervous system is made up of the encephalon (brain) and the spinal cord.

The peripheral nervous system comprises all the nerves and groups of neurons outside the brain and the spinal cord. The brain consists of three parts, namely, the *cerebrum*, *cerebellum* and the *brain stem.*



The central nervous system consists of billions of specialized cells about half of which, called neurons, are functionally active as signal transmitters while the other half (supporting cells), maintain and nourish the neurons.

The fundamental property of the neurons is the ability to transmit electrical signals, called nerve impulses, in response to changes in their environment, i.e. stimuli. The central nervous system controls the voluntary muscles of the body and is responsible for all movements and sensations.



The basic functional unit of the nervous system is the neuron. A typical neuron consists of a nucleated cell body and has several processes or branches .

The size and distribution of these branches vary greatly at different sites and in cells with different functions, but the two main kinds are: the axon and the dendrite. The dendrites normally conduct impulses toward the cell body and the axons conduct away from it.

Video Content / Details of website for further learning (if any): https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/overview-of-neuron-structure-and-function
Important Books/Journals for further learning including the page nos.: Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 08-12

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L-3

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING &16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **I - Physiology and Transducers** **Date of Lecture:**

Topic of Lecture:Transmitters and Neural communication

Introduction :

- The process of ionic movement across the membrane occurs in two basic ways. The first process is referred to as passive transport.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Temperature measurements

Transmitters and Neural Communication

Membranes Now that we've considered the structure of the cells of the nervous system it is important to address their principal function, communication. At the neuronal level this communication entails the sending of chemical messengers, called neurotransmitters from one neuron to another.The steps that lead to this process are far from simple and one of the most important factors is the movement of molecules across the neuronal membrane. Referring to the movement of neurotransmitters across the membrane, but the movement of ions that ultimately lead to this basic function of the neuron. The process of ionic movement across the membrane occurs in two basic ways. The first process is referred to as passive transport. In passive transport a substance moves from one area to another (across the neuronal membrane in our discussion below) due to some sort of natural "force".

This process requires no energy expenditure on the part of the cell. One of these forces in neuronal communication is diffusion. An ion that is in high concentration in one area will tend to move, or diffuse, to an area of lower concentration. So, for example, when an ion is in high concentration on one side of a membrane a force will be propelling it to the other side, and, if the membrane is permeable to this ion (i.e., will allow the ion through) the ion will move. A second force that's important in passive transport is electrostatic pressure. Ions, by definition, have a negative or positive charge and, as we all know from playing with magnets, positively charged particles will be attracted by negatively charged particles, repelled by other positively charged particles, and vice-versa.

So, as with diffusion, an ion that is on a side of a membrane where the charge is the same (e.g., positive with positive) will be propelled by a force to the other side, if the membrane is permeable. The second basic type of transport is called active transport, and in active transport an

ion is actively moved ("forced") by some other mechanism against the concentration or electrostatic gradient. So, for example, an ion that is on a side of a membrane that has been drawn by either diffusion or electrostatic pressure, can be moved to the other side via active transport.

This process requires energy on the part of the cell since the ion does not move in this way naturally. As we will see, all of these processes are fundamental in the process of neurotransmitter release, and, ultimately, neural communication. Two other terms that are important for the following discussion are presynaptic and postsynaptic.

The presynaptic membrane is the term used to refer to the membrane from which the neurotransmitter is released, the "sending" neuron. Postsynaptic membrane is the term used to refer to the membrane that receives the message carried by the neurotransmitter, the "receiving" neuron.
Resting PotentialWhen a neuron is not firing it is said to be at rest. Although it is "at rest", it always has the "potential" to fire, and this potential is expressed as the difference in electrical charges across the membrane of the neuron; differences in the electrical charge, that is, between the inside and outside.

This creates a sort of tension, and is maintained by the semi-permeable properties of the membrane, the distribution of negatively and positively charged molecules, and active transport mechanisms, all of which we'll learn about below. Resting potential is the term used to refer to this difference in charge across the membrane. In a neuron at rest this is approximately −70mV (millivolts), which means the inside is 70mV more negative than the outside. This difference is also called polarization, so as the difference grows the membrane is said to be hyperpolarized, and as the number shrinks the neuron is said to be hypopolarized.

It illustrates this difference in charge, and also the molecules that are important in maintaining this charge, and whose movement will be important in changing the charge, which will result in and will propel the release of neurotransmitters. K+ are potassium ions, Na+ are sodium ions, Cl- are chloride ions, and A- are organic anions (negatively charge protein molecules).The Cl- is the only ion that is actually in balance on either side of the membrane in terms of passive transport. That is, the negative charge inside the cell and the concentration of Cl-outside the cell make it so that, even if the membrane was not there the Cl- would not move from one side to the other. The other three ions are "forced" to stay on their sides via membrane permeability and/or active transport. The membrane is impermeable to A-so it cannot cross the membrane. The membrane is also semi-permeable to Na+ andK+, and these two ions are also actively transported via a membrane structure, called the Na+/ K+ pump which constantly moves Na+ ions to the outside of the membrane and K+ ions to the inside.

Ion Positions and Forces in a Neuron at Rest Post Synaptic PotentialThe process of neural communication begins, of course, when a neuron receives a signal from a sending neuron via neurotransmitters.These neurotransmitters affect the postsynaptic membrane via a set of processes, and ultimately result in changes in the permeability of the cell membrane to the important ions mentioned previously. Since all of the ions (besides Cl-) actually are being "forced" to be on one side of the membrane or the other, changes in permeability of the neuron, which happens when ion channelsopen, allows for movement of the ions via diffusion and electrostatic forces, and, consequently causes changes in the charge across the membrane. The membrane releases its neurotransmitter, as we will discuss below, in response to changes in the electrical charge across the membrane.

More specifically, it is due to hypopolarization to the point where the potential reaches approximately −65mV. So, when neurons receive neurotransmitter messages, which result in the eventual movement of ions across the membrane, ions which hyperpolarize the membrane are said to be inhibitory (make the neuron less likely to fire), and those that hypopolarize the membrane are said to be excitatory (make the neuron more likely to fire). An inhibitory signal is

called an inhibitory postsynaptic potential (IPSP), and an excitatory signal is called an excitatory postsynaptic potential (EPSP). It illustrates how this works in terms of ion flow and channels opening. When an excitatory neurotransmitter contacts the postsynaptic membrane, either directly or indirectly, Na+ channels are open. The result is that Na+ enters the cell and the cell depolarizes, thus becoming more likely to fire. When an inhibitory neurotransmitter affects a cell, the eventual result is that K+ and/or Cl-channels open. Of course, if K+ channels open then K+ leaves the cell due to the overwhelming force of electrostatic pressure.

The effect of Cl- in IPSPs is more complex and interesting however, in that Cl- does nothing if the membrane is at rest, since it is in balance as discussed above. However, should a slight excitatory/depolarizing message be received at the same time that Cl- channels are open, then Cl- is like a gatekeeper or guard ready to enter to counteract this charge. Figure 2. Ion Positions and Forces during EPSPs and IPSPsSo, which of these excitatory or inhibitory responses has the final say in whether or not a neuron fires, or more realistically, in the firing rate of a neuron, you might ask? The answer is that none of the signals on their own result in the final decision, but rather it is the combination of signals that matters, a phenomenon known as summation. Neurons synapse on many other neurons simultaneously and are constantly receiving signals, so whether they fire or not is not the result of a single excitatory or inhibitory message, but rather the result of the combination of messages they receive.

Neurotransmitter

Neurotransmitter is released into the synapse, and these neurotransmitters affect the postsynaptic membrane of another neuron and the same process starts all over again. Figure is a schematic illustration of Ca++'s role in neurotransmitter release. the neurotransmitter is released the effect it has on the postsynaptic membrane is very quick, so this brings up an important question. What happens to the neurotransmitter? Well, the nervous system is efficient, and most of the neurotransmitter is recycled in a process called reuptake, in which the neurotransmitter is taken back up into the presynaptic membrane and repackaged, to be released again. In the case of one type of neurotransmitter acetylcholine (Ach), the neurotransmitter is broken down into constituent parts by an enzyme called acetylcholinesterase (AchE), in a process called enzymatic deactivation. There are some other factors that do not directly effect neural firing that nevertheless have an impact on the communication among neurons. First, some synapses actually occur directly on the axon.

These synapses are called axoaxonic, as opposed to the more common synapses on the dendrite (axodendridic) or on the cell body (axosomatic). These synapses have no effect on whether or not a neuron will fire, since as we covered earlier, once an action potential is initiated at the axon hillock it is destined to move to the terminal button.

The axoaxonic synapses actually affect the amount of neurotransmitter released. A message at such a synapse that increases the amount of neurotransmitter released results in what is knows as presynaptic facilitation, and one that decreases the amount of neurotransmitter released results in presynaptic inhibition.

A final factor that we will discuss that indirectly effects communication is the existence of special receptors called autoreceptors. These receptors, which are usually located on the presynaptic membrane are sensitive to neurotransmitters, just like receptors on postsynaptic membranes. However, they do not directly affect neural firing. Interestingly, they are usually sensitive to the neurotransmitter that is being release from the neuron.

Video Content / Details of website for further learning (if any):
http://web.mst.edu/~rhall/neuroscience/01_fundamentals/neural_communication.pdf
Important Books/Journals for further learning including the page nos.:
Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 13

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LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING &16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **I - Physiology and Transducers Date of Lecture:**

Topic of Lecture:Cardiovascular System - Respiratory System

Introduction :

- The **circulatory system**, also called the **cardiovascular system** or the **vascular system**
- The circulatory system includes the lymphatic system, which circulates lymph.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Temperature measurements

Cardiovascular system

The cardiovascular system is a complex closed hydraulic system, which performs the essentialservice of transportation of oxygen, carbon dioxide, numerous chemical compounds and the blood cells. Structurally, the heart is divided into right and left parts. Each part has two chambers called atrium and ventricle. The heart has four valves are The

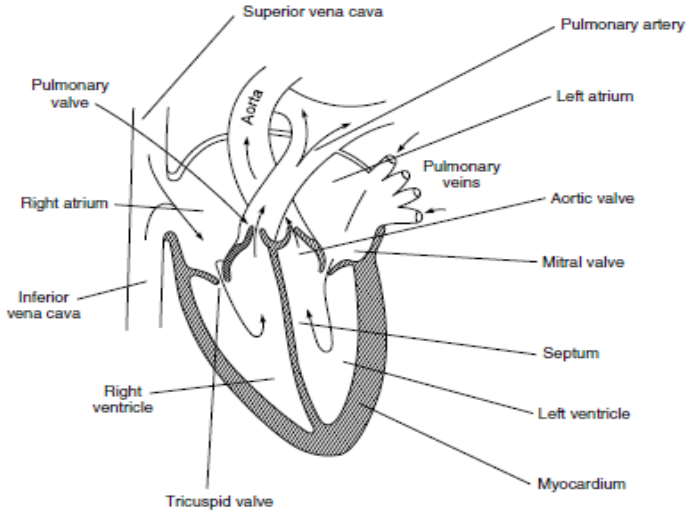
- Tricuspid valve or right atrio-ventricular valve—between right atrium and ventricle. It consists of three flaps or cusps. It prevents backward flow of blood from right ventricle to right atrium.
- Bicuspid Mitral or left atrio-ventricular valve—between left atrium and left ventricle. The valve has two flaps or cusps. It prevents backward flow of blood from left ventricle to atrium.
- Pulmonary valve—at the right ventricle. It consists of three half moon shaped cusps. This does not allow blood to come back to the right ventricle.
- Aortic valve—between left ventricle and aorta. Its construction is like pulmonary valve. This valve prevents the return of blood back to the left ventricle from aorta. The heart wall consists of three layers:

  1.The *pericardium,* which is the outer layer of the heart. It keeps the outer surface moist and prevents friction as the heart beats.

  2.The *myocardium* is the middle layer of the heart. It is the main muscle of the heart, which is made up of short cylindrical fibres. This muscle is automatic in action, contracting and relaxing rythmically throughout life.

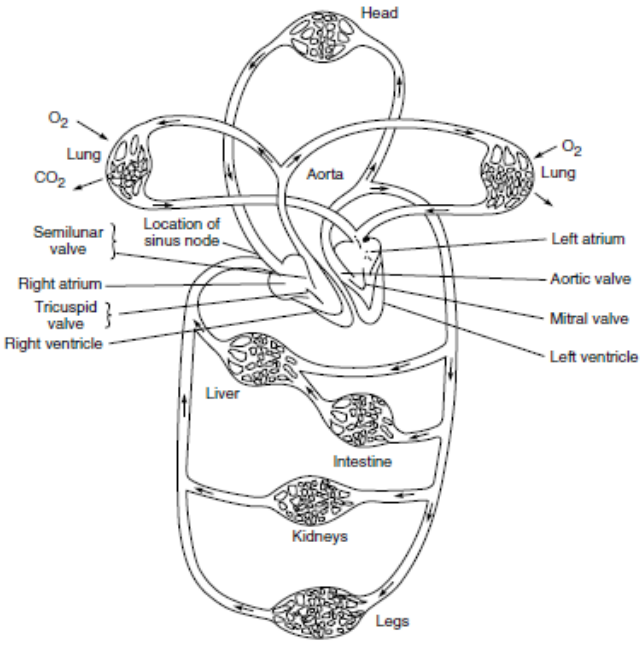
  3.The *endocardium*is the inner layer of the heart. It provides smooth lining for the blood to flow. The blood is carried to the various parts of the body through blood vessels, which are hollow tubes. There are three types of blood vessels. (i) *Arteries*—are thick walled and they carry the oxygenated blood away from the heart. (ii) *Veins*—are thin walled and carry

de-oxygenated blood.



towards the heart. (iii) *Capillaries*—are the smallest and the last level of blood vessels. They are so small that the blood cells, which make blood, actually flow one at a time through them. There are estimated to be over 800,000 km of capillaries in human being, which include all the arteries and veins, which carry blood. From an engineering point of view, the heart which drives the blood through the blood vessels of the circulatory system (Fig. 1.2) consists of four chamber muscular pump that beats about 72 times per minute (on an average for a normal adult), sending blood through every part of the body. The pump acts as two synchronized but functionally isolated two stage pumps. The first stage of each pump (the atrium) collects blood from the hydraulic system and pumps it into the second stage (the ventricle). In this process, the heart pumps the blood through the ***pulmonary circulation***to the lungs and through the ***systemic circulation*** to the other parts of the body.In the pulmonary circulation, the venous (de-oxygenated) blood flows from the right ventricle,through the pulmonary artery, to the lungs, where it is oxygenated and gives off carbon dioxide.

The arterial (oxygenated) blood then flows through the pulmonary veins to the left atrium. In systemic circulation, the blood is forced through blood vessels, which are somewhat elastic. The blood flows from the left atrium to the left ventricle and is pumped through the aorta and its branches, the arteries, out into the body. Through the arterioles (small arteries), the blood isdistributed to the capillaries in the tissues, where it gives up its oxygen and chemical compounds, takes up carbon dioxide and products of combustion. The blood returns to the heart along different routes from different parts of the body. It usually passes from the venous side of the capillaries directly via the venous system to either the superior vena cava or the inferior vena cava, both of which empty into the right atrium. The heart itself issupplied by two small but highly important arteries, the coronary arteries. They branch from the aorta just above the heart. If they are blocked by coronary thrombosis, myocardial infarction follows, often leading to a fatal situation.



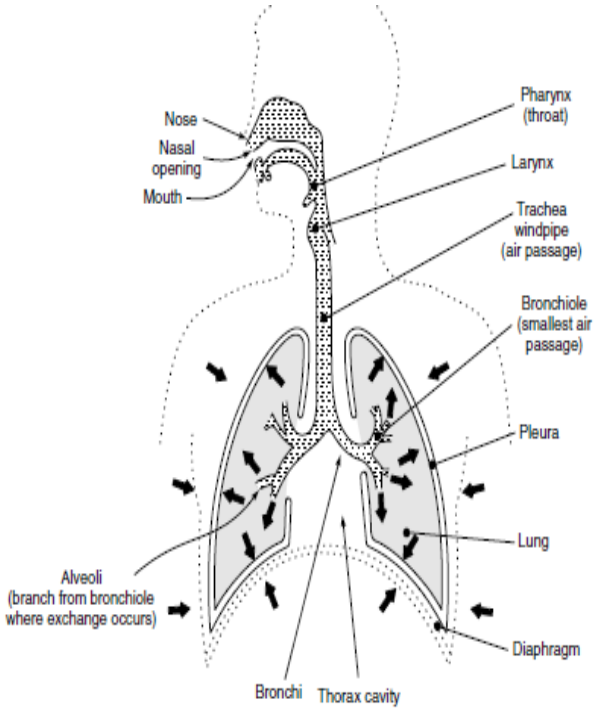
The heart rate is partly controlled by autonomic nervous system and partly by harmone action. These control the heart pump's speed, efficiency and the fluid flow pattern through the system. The circulatory system is the transport system of the body by which food, oxygen, water and other essentials are transported to the tissue cells and their waste products are transported away. This happens through a diffusion process in which nourishment from the blood cell diffuses through the capillary wall into interstitial fluid. Similarly, carbon dioxide and some waste products from the interstitial fluid diffuses through the capillary wall into the blood cell. The condition of the cardiovascular system is examined by haemodynamic measurements and by recording the electrical activity of the heart muscle (electrocardiography) and listening to the heart sounds (phonocardiography). For assessing the performance of the heart as a pump,measurement of the cardiac output (amount of blood pumped by the heart per unit time), bloodpressure, blood flow rate and blood volume are made at various locations throughout thecirculatory system.

Rrespiratory system

The respiratory system in the human body is a pneumatic system in which an air pump (diaphragm) alternately creates negative and positive pressures in a sealed chamber (thoracic cavity) and causes air to be sucked into and forced out of a pair of elastic bags (lungs).

The lungs are connected to the outside environment through a passage way comprising nasal cavities, each of the lungs wherein it again subdivides several times to carry air into and out of each of the many tiny air spaces (alveoli) within the lungs. In the tiny air spaces of the lungs is a membrane interface with the hydraulic system of the body through which certain gases can defuse. Oxygen is taken into the blood from the incoming air and carbon dioxide is transferred from the blood to the air under the control of the pneumatic pump. Thus, the blood circulation forms the link in the supply of oxygen to the tissues and in the removal of gaseous waste products of metabolism. The movement of gases between blood and the alveolar air is basically due to constant molecular movement or diffusion from points of higher pressure to points of lower pressure.

An automatic respiratory control centre in the brain maintains heart pump operation at a speed that is adequate to supply oxygen and take away carbon dioxide as required by the system. In each minute, under normal conditions, about 250 ml of oxygen are taken up and 250 ml of CO2 are given out by the body and these are the amounts of the two gases, which enter and leave the blood in the lungs. Similar exchanges occur in reverse in the tissues where oxygen is given up and CO2 is removed. The exact amount of CO2 expired depends upon the metabolism, the acid-base balance and the pattern of espiration.



The exchange of gases takes place in the alveoli and can be achieved by the normal 15-20 breaths/min, each one involving about 500 ml of air. The respiratory system variables which are important for assessing the proper functioning of the system are respiratory rate, respiratory air flow, respiratory volume and concentration of CO2 in the expired air. The system also requires measurements to be made of certain volumes and capacities such as the tidal volume, vital capacity, residual volume, inspiratory reserve volume and expiratory reserve volume.

Video Content / Details of website for further learning (if any):

https://opentextbc.ca/biology/chapter/11-3-circulatory-and-respiratory-systems/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No :04-08

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LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : BIO MEDICAL ENGINEERING &16BME04

Course Faculty : Dr.G.SUDHA

Unit : I - Physiology and Transducers Date of Lecture:

Topic of Lecture:Basic Components of a Biomedical System

Introduction :

- Biomedical Systems offered centralized cardiac safety, medical imaging and respiratory services in drug development and also collected, analyzed and distributed electronic patient-reported outcome in multiple modalities across all phases of clinical research.

Prerequisite knowledge for Complete understanding and learning of Topic:

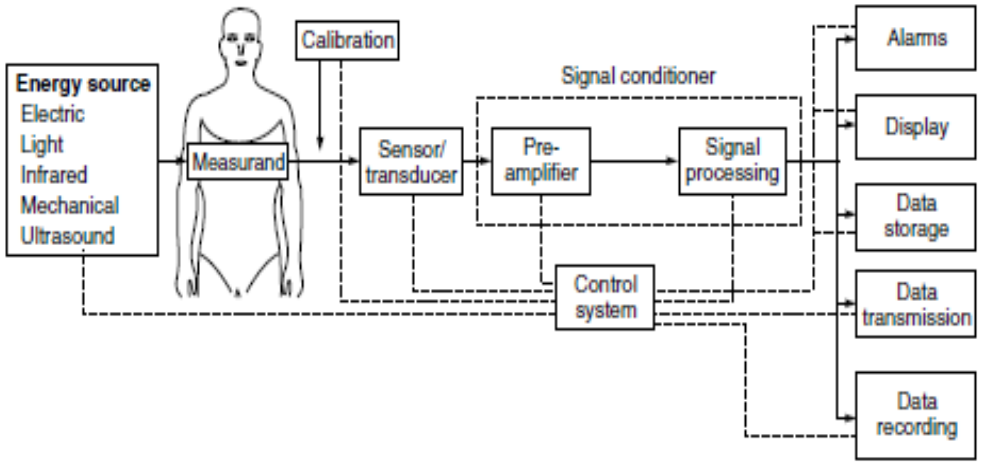
- Basic components of a biomedical system
- Temperature measurements

Basic Components of a Biomedical System

The basic four basic functional components:

Measurand: The physical quantity or condition that the instrumentation system measures is called the *measurand*. The source for the measurand is the human body which generates a variety of signals. The measurand may be on the surface of the body (electrocardiogram potential) or it may be blood pressure in the chambers of the heart.

Transducer/Sensor:A transducer is a device that converts one form of energy to another. Because of the familiar advantages of electric and electronic methods of measurement, it is the usual practice to convert into electrical quantities all non-electrical phenomenon associated with the measurand with the help of a transducer. For example: a piezo-electric crystal converts mechanical vibrations into an electrical signal and therefore, is a transducer. The primary function of the transducer is to provide a usable output in response to the measurand which may be a specific physical quantity, property or condition. In practice, two or more transducers may be used simultaneously to make measurements of a number of physiological parameters.Another term 'sensor' is also used in medical instrumentation systems. Basically, a sensorconverts a physical measurand to an electrical signal. The sensor should be minimally invasive and interface with the living system with minimum extraction of energy.



Signal Conditioner: Converts the output of the transducer into an electrical quantity suitable for operation of the display or recording system. Signal conditioners may vary in complexity from a simple resistance network or impedance matching device to multi-stage amplifiers and other complex electronic circuitry. Signal conditioning usually include functions such as amplification, filtering (analog or digital) analog-to-digital and digital-to-analog conversion or signal transmission circuitry. They help in increasing the sensitivity of instruments by amplification of the original signal or its transduced form.

Display System: Provides a visible representation of the quantity as a displacement on a scale, or on the chart of a recorder, or on the screen of a cathode ray tube or in numerical form. Although, most of the displays are in the visual form, other forms of displays such as audible signals from alarm or foetal Doppler ultrasonic signals are also used. In addition of the above, the processed signal after signal conditioning may be passed on to:

Alarm System—with upper and lower adjustable thresholds to indicate when the measurand goesbeyond preset limits.

Data Storage—to maintain the data for future reference. It may be a hard copy on a paper or on magnetic or semiconductor memories.

Data Transmission—using standard interface connections so that information obtained may be carried to other parts of an integrated system or to transmit it from one location to another.

In most of the medical instrumentation systems, some form of *calibration* is necessary at regular intervals during their operation. The calibration signal is usually applied to the sensor input or as early in the signal conditioning chain as possible.

Video Content / Details of website for further learning (if any):

http://iirc.khu.ac.kr/uploads/6/3/4/3/63434825/ch01webster.pdf

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 14-16

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L-6

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING &19BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **I - Physiology and Transducers Date of Lecture:**

Topic of Lecture:Transducers - Selection Criteria

Introduction :

- A **transducer** is a device that converts energy from one form to another. Usually a transducer converts a signal in one form of energy to a signal in another.
- Transducers are often employed at the boundaries of automation, measurement, and control systems, where electrical signals are converted to and from other physical

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Temperature measurements

The following factors are to be considered while selecting a transducer for applications,

- **Operating Principle :** The transducers are selected on the basis of operating principle it may be resistive, inductive, capacitive, optical etc.
- **Operating range :** The range of transducer should be appropriate for measurement to get a good resolution.
- **Accuracy :** The accuracy should be as high as possible or as per the measurement.
- **Range :** The transducer can give good result within its specified range, so select transducer as per the operating range.
- **Sensitivity :** The transducer should be more sensitive to produce the output or sensitivity should be as per requirement.
- **Loading effect :** The transducer's input impedance should be high and output impedance should be low to avoid loading effect.
- **Errors :** The error produced by the transducer should be low as possible.
- **Environmental compatibility :** The transducer should maintain input and output characteristic for the selected environmental condition.

Video Content / Details of website for further learning (if any):
https://www.polytechnichub.com/selection-criteria-transducer/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 16-17

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L-7

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code :**BIO MEDICAL ENGINEERING &16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **I - Physiology and Transducers Date of Lecture:**

Topic of Lecture:Piezo Electric, Ultrasonic Transducers

Introduction :

- A transducer can be anything that converts one form of energy to another. The piezoelectric **material** is one kind of transducers.
- When we squeeze this piezoelectric material or apply any force or pressure, the transducer converts this energy into voltage. This voltage is a function of the force or pressure applied to it.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Temperature measurements

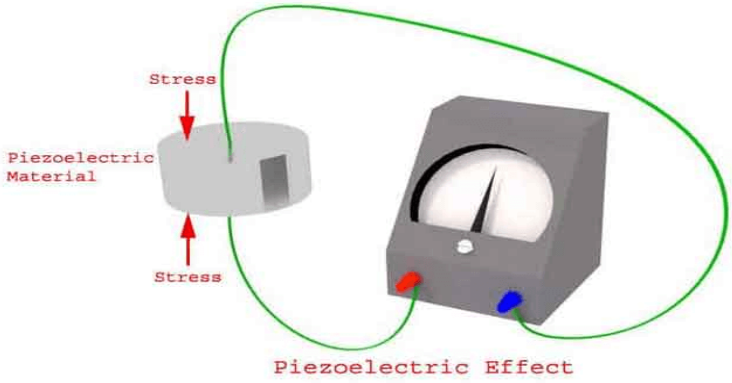
Piezoelectric Transducer and Ultrasonic Transducers

Piezoelectric Transducer

A **piezoelectric transducer** (also known as a piezoelectric sensor) is a device that uses the piezoelectric effect to measure changes in acceleration, pressure, strain, temperature or force by converting this energy into an electrical charge.

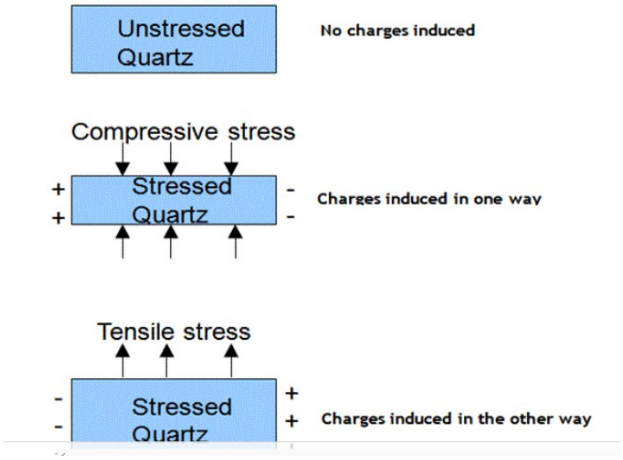
A transducer can be anything that converts one form of energy to another. The piezoelectric **material** is one kind of transducers. When we squeeze this piezoelectric material or apply any force or pressure, the transducer converts this energy into voltage. This voltage is a function of the force or pressure applied to it.

The electric voltage produced by a piezoelectric transducer can be easily measured by the voltage measuring instruments. Since this voltage will be a function of the force or pressure applied to it, we can infer what the force/pressure was by the voltage reading. In this way, physical quantities like mechanical stress or force can be measured directly by using a piezoelectric transducer.



The Piezoelectric Ultrasonic Transducer working Principle

It produces frequencies that are far above that which can be heard by the human ear. It expands and contracts rapidly when subjected to any voltage. It is typically used in a vacuum cleaner.



Piezo Buzzer

A buzzer is anything that produces sound. They are driven by the oscillating electronic circuit. A piezoelectric element may be driven by an oscillating electronic circuit or another audio signal source, driven with a piezoelectric audio amplifier. A blick, a ring, or a beep are commonly sued sound to indicate that a button has been pressed.

A piezoelectric buzzer (or piezoelectric beeper) depends on acoustic cavity resonance (or Helmholtz resonance) to produce an audible beep.

Piezoelectric Transducer Advantages

The advantages of piezoelectric transducers are:

1. No need for an external force
2. Easy to handle and use as it has small dimensions
3. High-frequency response it means the parameters change very rapidly

Piezoelectric Transducer Disadvantages

The disadvantages of piezoelectric transducers are:

1. It is not suitable for measurement in static condition
2. It is affected by temperatures
3. The output is low so some external circuit is attached to it

4. It is very difficult to give the desired shape to this material and also desired strength

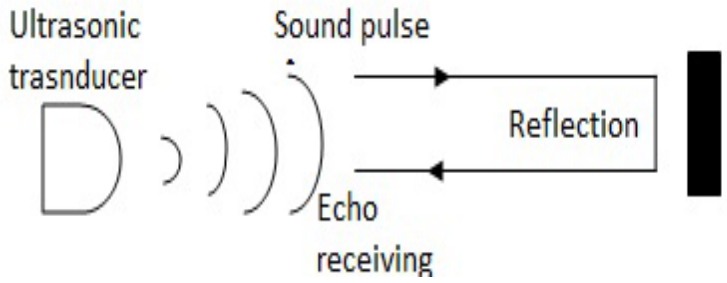
Ultrasonic Transducer

The ultrasonic transducer is one type of sound-related sensor. These transducers send the electrical signals to the object and once the signal strikes the object then it reverts to the transducer. In this process, this transducer measures the distance of the object not by the intensity of the sound. These transducers use ultrasonic waves for the measurement of a few parameters. It has a wide range of applications in various fields. The frequency range of ultrasonic waves is above 20 kHz. These are mainly used in measuring distance applications. The following image indicates the ultrasonic transducer.

These transducers can be defined as a transducer which is used to convert one type of energy to ultrasonic vibration. By these ultrasonic vibrations, this transducer measures the distance of the object. These are available in two types like active and passive

Ultrasonic Transducer Working Principle

When an electrical signal is applied to this transducer, it vibrates around the specific frequency range and generates a sound wave. These sound waves travel and whenever any obstacle comes, these sound waves will reflect the transducer inform of echo. And at the end of the transducer, this echo converts into an electrical signal. Here, the transducer calculates the time interval between the sending of the sound wave to the receiving the echo signal. The ultrasonic sensor sends the ultrasonic pulse at 40 kHz which travels through the air. These transducers are better than the infrared sensors because these ultrasonic transducer/sensors are not affected by the smoke, black materials, etc. Ultrasonic sensors exhibit excellence in suppressing background interference.



Ultrasonic transducers are mainly used for finding the distance by using ultrasonic waves. The distance can be measured by the following formula.

$$D = ½ * T * C$$

D indicates the distance

T indicates the time difference between sending and reception of ultrasonic waves

Video Content / Details of website for further learning (if any): https://www.electrical4u.com/piezoelectric-transducer/
Important Books/Journals for further learning including the page nos.: Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 75-76 , 145-146

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L-8

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code :**BIO MEDICAL ENGINEERING &16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **I - Physiology and Transducers Date of Lecture:**

Topic of Lecture:Temperature Measurements

Introduction :

- Temperature is the measure of heat in the body. Temperature characterizes the body as hot or cold. The SI unit used to measure the temperature in Kelvin(K). The other scales used to measure the temperature are Celsius or Fahrenheit.

Prerequisite knowledge for Complete understanding and learning of Topic:

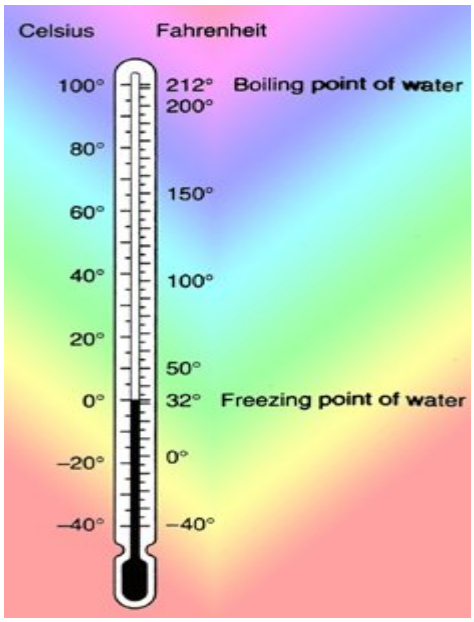
- Basic components of a biomedical system
- Temperature measurements

Temperature Measurements

The transducer normally used for temperature measurement in a patient monitoring system is athermistor. Changes in resistance of the thermistor with changes in temperature are measured in a bridge circuit and indicated on a calibrated meter. The measuring range is 30–42°C.Many devices have been invented to accurately measure temperature. It all started with the establishment of a temperature scale. This scale transformed the measurement of temperature into meaningful numbers.

In the early years of the eighteenth century, Gabriel Fahrenheit (1686-1736) created the Fahrenheit scale. He set the freezing point of water at 32 degrees and the boiling point at 212 degrees. These two points formed the anchors for his scale. Later in that century, around 1743, Anders Celsius (1701-1744) invented the Celsius scale. Using the same anchor points, he determined the freezing temperature for water to be 0 degree and the boiling temperature 100 degrees. The Celsius scale is known as a Universal System Unit. It is used throughout science and in most countries.

There is a limit to how cold something can be. The Kelvin scale is designed to go to zero at this minimum temperature. The relationships between the different temperature scales are:



At a temperature of Absolute Zero there is no motion and no heat. Absolute zero is where all atomic and molecular motion stops and is the lowest temperature possible. Absolute Zero occurs at 0 degrees Kelvin or -273.15 degrees Celsius or at -460 degrees Fahrenheit. All objects emit thermal energy or heat unless they have a temperature of absolute zero.

$^{o}K = 273.15 + {}^{o}C$ $^{o}C = (5/9)*(^{o}F-32)$ $^{o}F = (9/5)*{}^{o}C+32$

Video Content / Details of website for further learning (if any):

http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/measure.html

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 232

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L-9

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code :**BIO MEDICAL ENGINEERING &16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **I - Physiology and Transducers Date of Lecture:**

Topic of Lecture:Fibre Optic Temperature Sensors

Introduction :

- The group of sensors known as fiber optic thermometers generally refer to those devices measuring higher temperatures wherein blackbody radiation physics are utilized.
- Lower temperature targets--say from -100°C to 400°C--can be measured by activating various sensing materials such as phosphors, semiconductors or liquid crystals with fiber optic links offering the environmental and remoteness advantages.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Temperature measurements

Fibre Optic Temperature Sensors

The development of optical fibres has given rise to a number of transducers which find applications in the medical field. The ability of these fibres to transmit light over great distances with low power loss and the interaction of light with a measured system provide the basis of these sensing devices. These sensors are electrically passive and consequently immune to electromagnetic disturbances. They are geometrically flexible and corrosion resistant. They can be miniaturized and are most suitable for telemetry applications.

The optical transducers are based on glass or plastic fibres, about 100 to 250 mm in diameter, as found in fibre-optic communication systems. The initial optical fibre had poor transmission characteristics, but within a decade, fibre losses were reduced from 1000 db/km in 1966 to below 1 db/km

Advantages of Fibre Optic Temperature Sensors

·Optical fibre sensors are non-electrical and hence are free from electrical interference usually associated with electronically based sensors.

· They are immune from cross-talk.

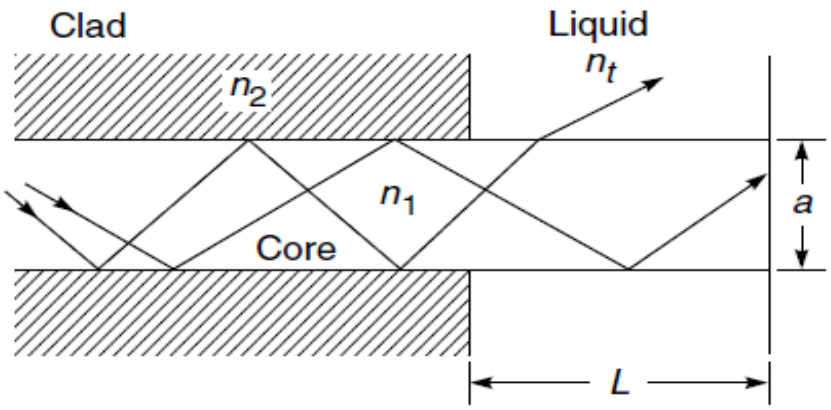
· There is a high degree of mechanical flexibility associated with the fibre optic and this combined with its reduced size, allows access to otherwise inaccessible areas of the body.

· They are suitable for telemetry applications as bulk of the instrumentation can be at a reasonable distance from the patient.

· These sensors do not involve any electrical connection to the patient body, thereby ensuring patient safety.
· More than one chemical species can be measured with a single sensor by employing more than one probe detection wavelength offering substantial economic advantage.
· These devices are intrinsically safe, involving low optical power–generally a few milliwatts.
· The sensors are capable of observing a sample in its dynamic environment, no matter how distant, difficult to reach or hostile the environment.
·The cost is low enough to make the sensors disposable for many applications.

The production of localized and controlled hyperthermia (elevated temperatures in the range of 42–45°C or higher) for cancer treatment by electromagnetic energy, either in the radio frequency or microwave frequency range, poses a difficult temperature measurement problem.

Traditional temperature sensors, such as thermistors or thermocouples, have metallic components and connecting wires which perturb the incident electromagnetic (EM) fields and may even cause localized heating spots and the temperature readings may be erratic due to interference. This problem is overcome by using temperature sensors based on fibre-optics. These devices utilise externally induced changes in the transmission characteristics of the optical fibres and offer typical advantages of optical fibres such as flexibility, small dimensions and immunity from EM interference.



One of the simplest types of temperature sensors consists of a layer of liquid crystal at the end of optical fibres, giving a variation in light scattering with temperature at a particular wavelength. Figure shows ray-path configuration of a temperature sensor which utilizes a silica-core silicon-clad fibre, with an unclad terminal portion immersed in a liquid which replaces the clad.

A temperature rise causes a reduction in the refractive index of the liquid clad fibre section. Therefore, the light travelling from the silicon-clad fibre to the liquidclad fibre undergoes an attenuation which decreases by increasing temperature. The light from an 860 nm light-emitting diode (LED) is coupled into the fibre.

The light reflected backwards is sent along the same fibres and the light amplitude modulation induced by the thermo-sensitive clading applied on the distal end of the fibre is detected and processed. The constructed a miniature temperature probe for medical use with a 0.8 mm external diameter and 0.5 mm internal diameter. The sensitivity achieved was 0.1°C in the temperature interval 20–50°C.

Video Content / Details of website for further learning (if any): https://www.omega.co.uk/prodinfo/fibre-optics.html
Important Books/Journals for further learning including the page nos.: Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 101-104

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LECTURE HANDOUTS

BME

IV/VII/A

C Course Name with Code : **BIO MEDICAL ENGINEERING &16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **II - ELECTRO – PHYSIOLOGICAL MEASUREMENTS**

Date of Lecture:

Topic of Lecture: Electrodes - Limb electrodes-floating electrodes - pregelled disposable electrodes

Introduction :

- Electrodes are devices that convert ionic potentials into electronic potentials. The type of electrode used for the measurements depends on the anatomical location of the bioelectric event to be measured. In order to process the signal in electronic circuits, it will be better to convert ionic conduction into electronic conduction.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Electrode measurements

Heart is an electrical field; arms and legs are a linear extension of this field

• ECG is a recording of the electrical activity of the heart over a period of time

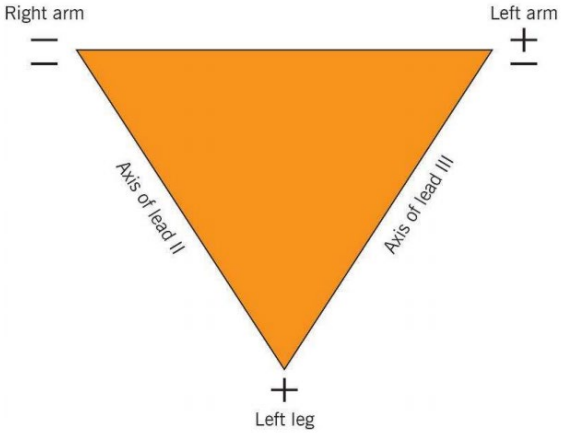
• Detected by electrodes attached to the surface of the skin and recorded and displayed by a device external to the body

• Changes in electrical activity may indicate arrhythmias, cardiac ischemia, or electrolyte imbalances

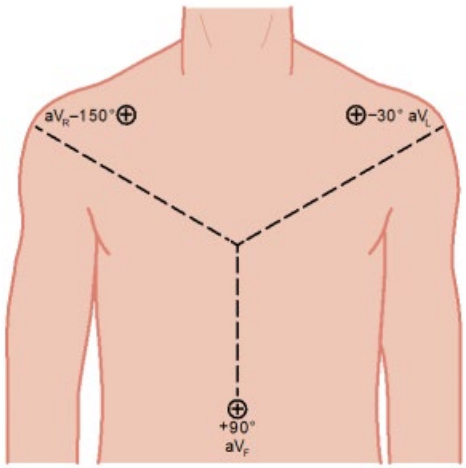
12 Lead ECG System

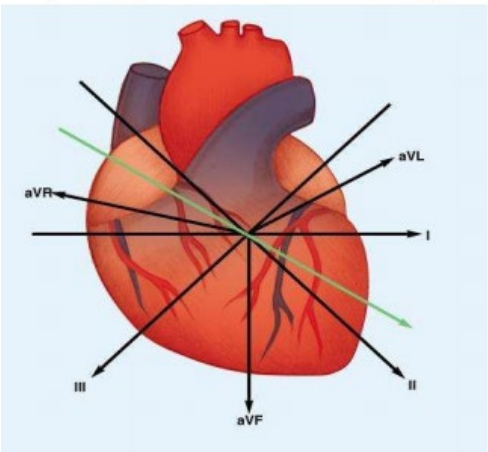
3 limb leads (bipolar)
• 3 augmented limb leads (unipolar)
• 6 precordial leads
Leads I, II, and III
• Two electrodes (+ and -) equidistant from heart • Records electricity flow from negative to positive electrode
• A wave of depolarization moving toward a positive electrode produces a positive deflection on the ECG
• Depolarization moving away from a positive electrode records a negative deflection

• Lead axis is the direction of electrical depolarization

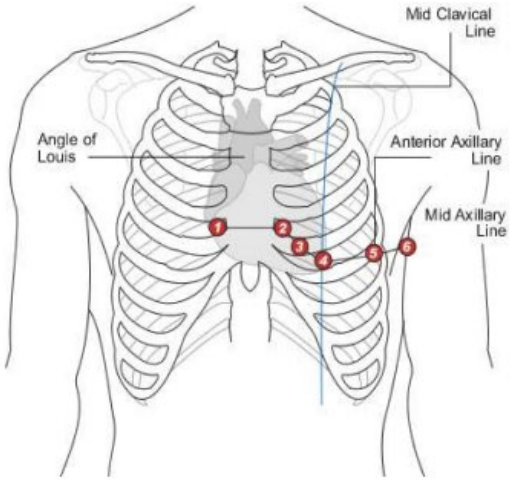


Leads aVR, aVL, aVF
• Letter a refers to augmented
• Letter V refers to voltage
• Letters R, L, and F refer to where positive electrode is placed (right arm, left arm and left leg)
• Records electricity flow from center of heart toward positive electrodes



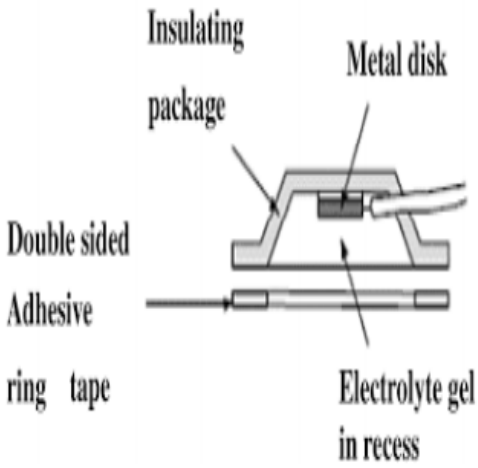


6 precordial leads (V1 – V6)
• Letter V refers to unipolar
• Numbers 1-6 are codes for locations on precordium P
V1 and V2 are on either side of sternum at 4th ICS
• V4 is midclavicular line, 5th ICS
• V3 is halfway between V2 and V4
• V6 is at midaxillary line, 5th ICS
• V5 is halfway between V4 and V6, 5th ICS



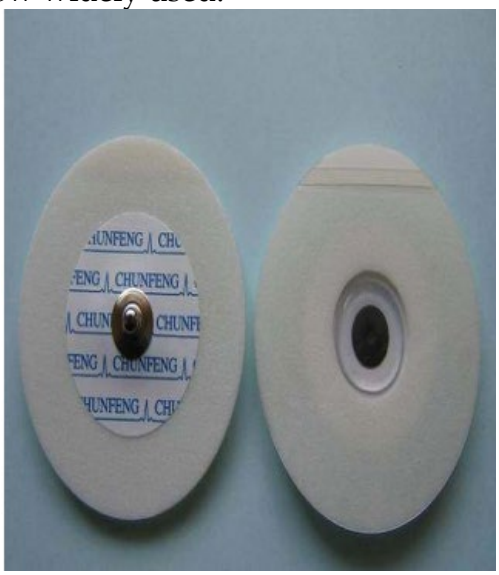
These types of electrodes can eliminate the movement errors (called artifacts) which is a main problem with plate electrodes.

- This is done by avoiding any direct contact of the metal with the skin.
- So the main advantage of floating electrodes is mechanical reliability.
- Here the conductive path between the metal and the skin is the electrolyte paste or jelly.



Normally plate electrodes, floating electrodes etc can be used more than one time.

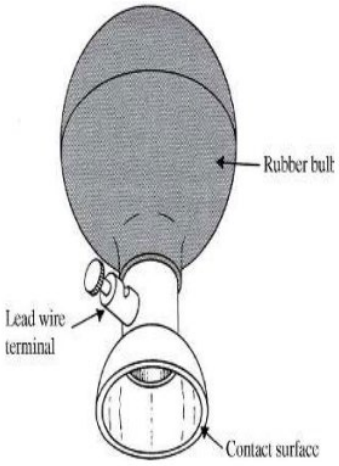
- This requires the cleaning and cares after each use.
- We can use disposable electrodes which can be used only once and be disposed after the use.
- These types of electrodes are now widely used.



These type of electrodes are well suited for the attachment to flat surfaces of body and to regions where the underlying tissue is soft, due to the presence of contact surface.

- An advantage of these type of electrodes is that it has a small surface area.

• These types of electrodes are mainly used for the measurement of ECG.
• Suction electrodes used a plastic syringe barrel to house suction tubing and input cables to an AC amplifier



These type of electrodes are widely used in the measurement of EEG exclusively.
• Scalp electrodes can provide EEG easily by placing it over bare head. A typical ear clip electrode is shown in figure below.
• The most common method for EEG measurement is 10 – 20 electrode placement system and here we use scalp electrode usually.
• They can avoid measurement errors and movement errors. During labour internal monitoring may be needed and is usually in the form of an electrode placed under the baby's scalp.
• It is called fetal scalp electrode which is used to monitor baby's heartbeat while still in uterus
These type of electrodes are widely used in the measurement of EEG exclusively.
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• They can avoid measurement errors and movement errors. During labour internal monitoring may be needed and is usually in the form of an electrode placed under the baby's scalp.
• It is called fetal scalp electrode which is used to monitor baby's heartbeat while still in uterus

Our pre-gelled disposable electrodes have a round contact and are suitable for short-term recordings such as surface EMG, ECG, EOG, etc. The small vinyl area allows close electrode placement where necessary, and a slightly less firm adhesive allows easy removal. The electrodes come pre-gelled and some chloride salt content for quick, accurate acquisitions. These disposable snap electrodes provide the same signal measurements as reusable electrodes, with added convenience and hygiene. Each electrode (peel-and-stick) is pre-gelled and designed for one use only. The electrodes do not contain any latex.

General-purpose and economical
Standard snap connection
Ag/AgCl contact (11 mm diameter)
Electrolyte: wet liguid gel (7% chloride salt)
Moderate adhesive
Size: 35 mm vinyl backing

Use disposable snap electrodes with any snap-on leads (i.e. press stud leads, ECG clip on cables) specified for snap electrodes. For best performance, use shielded leads for recording electrodes and an unshielded lead for the ground electrode.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=hn1JvLq8uJ4
http://www.fis.uc.pt/data/20062007/apontamentos/apnt_134_5.pdf

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 50-55

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LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **II - ELECTRO – PHYSIOLOGICAL MEASUREMENTS**

Date of Lecture:

Topic of Lecture: Micro- Needle and Surface Electrodes

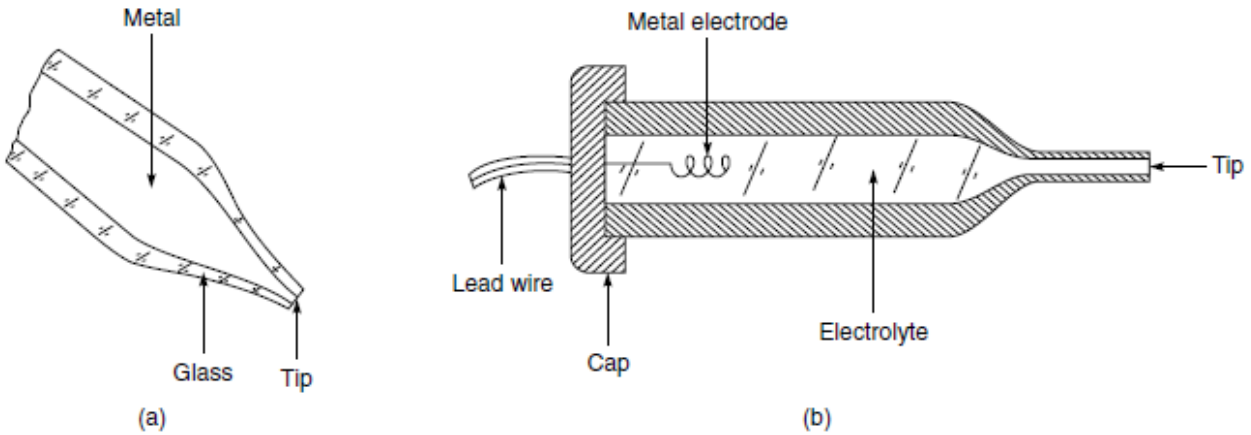
Introduction :

The electrical activity of individual cells, microelectrodes is employed. This type of electrode is small enough with respect to the size of the cell in which it is inserted so that penetration by the electrode does not damage the cell. .

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Cells measurements and Acquiring Bio signals

Micro Electrode



The size of an intracellular microelectrode is dictated by the size of the cell and the ability of its enveloping membrane to tolerate penetration by the microelectrode tip. Single-living cells are rarely larger than 0.5 mm (500 microns) and are usually less than one-tenth of this size.

Typical microelectrodes have tip dimensions ranging from 0.5 to 5 microns. The tips of these electrodes have to be sufficiently strong to be introduced through layers of tissues without breaking.

Two types of microelectrodes are generally used: metallic Fig,a and glass micro capillaries (Fig. (b)). Metallic electrodes are formed from a fine needle of a suitable metal drawn to a fine tip. On the

other hand, glass electrodes are drawn from Pyrex glass of special grade. These micro capillaries are usually filled with an electrolyte. The metal microelectrodes are used in direct contact with the biological tissue and, therefore, have a lower resistance.

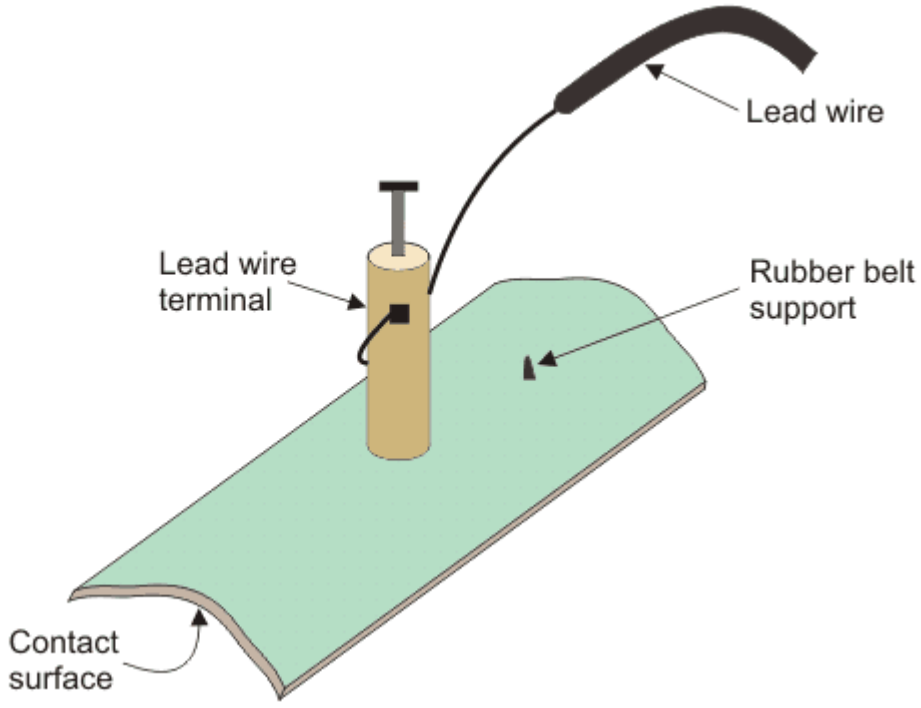
However, they polarize with smaller amplifier input currents. Hence, they tend to develop unstable electrode offset potentials and are therefore not preferred for steady state potential measurements. On the other hand, in case of glass microelectrodes, improved stability can be obtained by properly choosing the metal and the electrolyte so that the small current passing through their junction may not be able to modify the electrical properties of the electrodes. Also, the glass microelectrode has a substantial current carrying capacity because of the large surface contact area between the metal and the electrolyte.

Surface electrode measures the potential available from the surface of the skin. It senses the signal from heart, brain and nerves. Larger surface electrodes sense the ECG signals. Smaller surface electrodes sense the EMG and EEG signals. The types of surface electrodes are as follows.

Metal Plate Electrodes

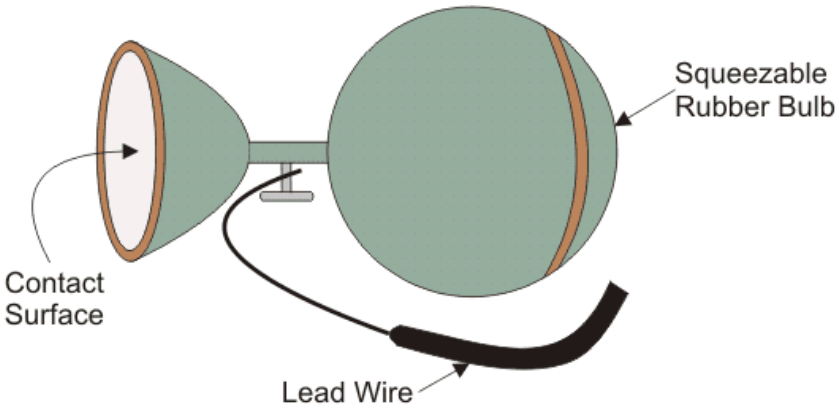
ECG measurement technique uses either rectangular or circular shaped plate electrodes made of nickel, silver or German silver materials. It has a smaller contact area and do not seal completely on the patient. Electrodes are pasted on the skin using electrolyte paste. The electrode slippage and plate displacement are the two major disadvantages of this electrode type. They are very sensitive, leading to measurement errors.

Since it is suitable for application on four limbs of the body, they called limb electrodes. During surgical procedure since patient's legs are immobile, limb electrodes are preferred. Chest electrodes interfere with the surgery, so not used for ECG measurement. At the same time for a long-term patient monitoring limb-electrodes are not used.



Suction Cup Electrodes or Welsh Cup Electrodes

To measure ECG from various positions on the chest, Suction cup electrodes are used. It suits well to attach electrodes on flat surface of the body and on soft tissue regions. They have a good contact surface. Physically they are large but the skin contacts only the electrode rim. It has high contact impedance. They have a plastic syringe barrel, suction tube and cables. Recently, due to infection and cleaning procedures, these electrodes are not used.



Video Content / Details of website for further learning (if any):
https://www.electrical4u.com/surface-electrodes/
https://www.youtube.com/watch?v=49CWbXNJ3WE

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 63-65

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L12

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **II - ELECTRO – PHYSIOLOGICAL MEASUREMENTS**

Date of Lecture:

Topic of Lecture: Amplifiers: Preamplifiers- differential amplifiers

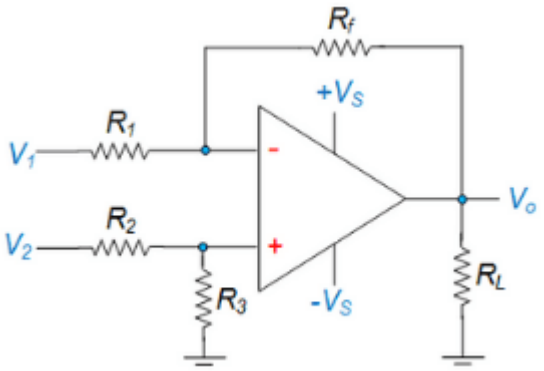
Introduction :

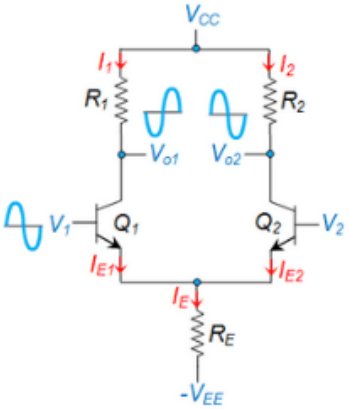
- Generally, biological/bioelectric signals have low amplitude and low frequency. Therefore, to increase the amplitude level of biosignals amplifiers are designed.
- The outputs from these amplifiers are used for further analysis and they appear as ECG, EMG, or any bioelectric waveforms. Such amplifiers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

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Amplifier

Differential Amplifier:





A differential amplifier (also known as a difference amplifier) is a type of electronic amplifier that amplifies the difference between two input voltages but suppresses any voltage common to the two inputs. A differential amplifier is an analog circuit with two inputs (V1 and V2) and one output (V0) in which the output is ideally proportional to the difference between the two voltages.

The formula for a simple differential amplifier can be expressed:

Differential Amplifier formula

$$V_0 = A_d(V_1 - V_2)$$

Where

V0 is the output voltage
V1 and V2 are the input voltages
Ad is the gain of the amplifier (i.e. the differential amplifier gain)

From the formula above, you can see that when V1 = V2, V0 is equal to zero, and hence the output voltage is suppressed. But any difference between inputs V1 and V2 is multiplied (i.e. amplified) by the differential amplifier gain Ad.

This is why the differential amplifier is also known as a difference amplifier – the difference between the input voltages is amplified.

A differential amplifier circuits can be of two types:

BJT Differential Amplifier – This is a differential amplifier built using transistors, either Bipolar Junction Transistors (BJTs) or Field Effect Transistors (FETs)
Opamp Differential amplifiers built using Operational Amplifiers

Pre Amplifier:
A preamplifier is an electronic amplifier that converts a weak electrical signal into an output signal strong enough to be noise-tolerant and strong enough for further processing, or for sending to a power amplifier and a loudspeaker.
Without this, the final signal would be noisy or distorted. They are typically used to amplify signals from analog sensors such as microphones and pickups. Because of this, the preamplifier is often placed close to the sensor to reduce the effects of noise and interference.

Video Content / Details of website for further learning (if any):
https://www.electrical4u.com/differential-amplifier/
https://www.youtube.com/watch?v=tC43ztgutwo

Important Books/Journals for further learning including the page nos.:
Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 114-119

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LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **II - ELECTRO – PHYSIOLOGICAL MEASUREMENTS**

Date of Lecture:

Topic of Lecture: Chopper amplifiers -Isolation amplifier

Introduction :

The chopper amplifier is a useful device in the field of medical electronics as it gives another solution to the problem of achieving adequate low frequency response while avoiding the drift problem inherent in direct coupled amplifiers.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Pre amplifier

Chopper Amplifier:

This type of amplifier makes use of a chopping device, which converts a slowly varying direct current to an alternating form with amplitude proportional to the input direct current and with phase dependent on the polarity of the original signal.

The alternating voltage is then amplified by a conventional ac amplifier whose output is rectified back to get an amplified direct current. A chopper amplifier is an excellent device for signals of narrow bandwidth and reduces the drift problem.

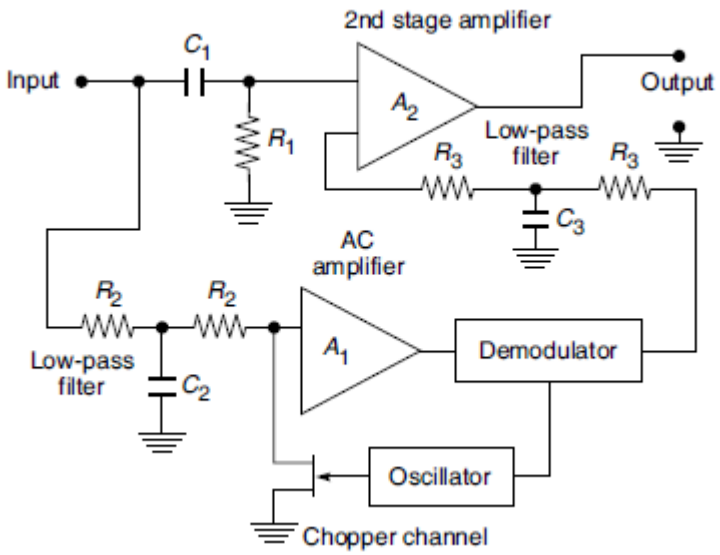
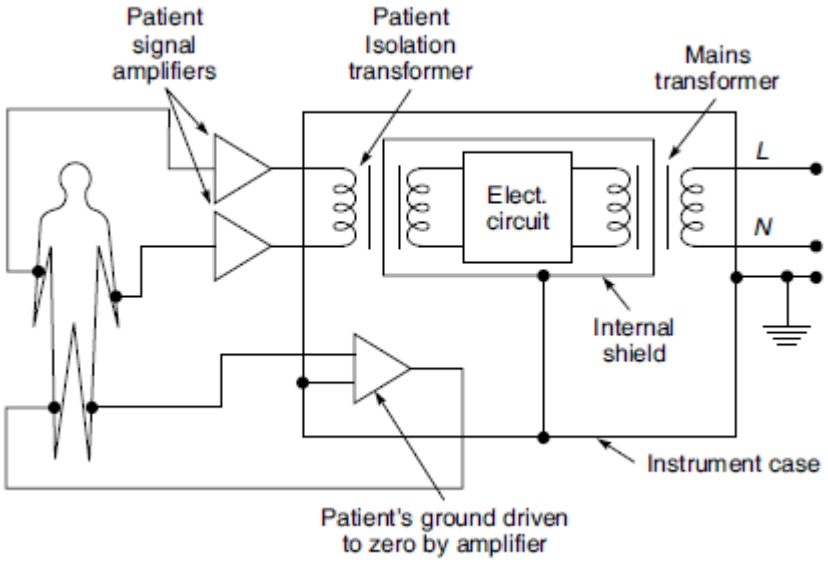


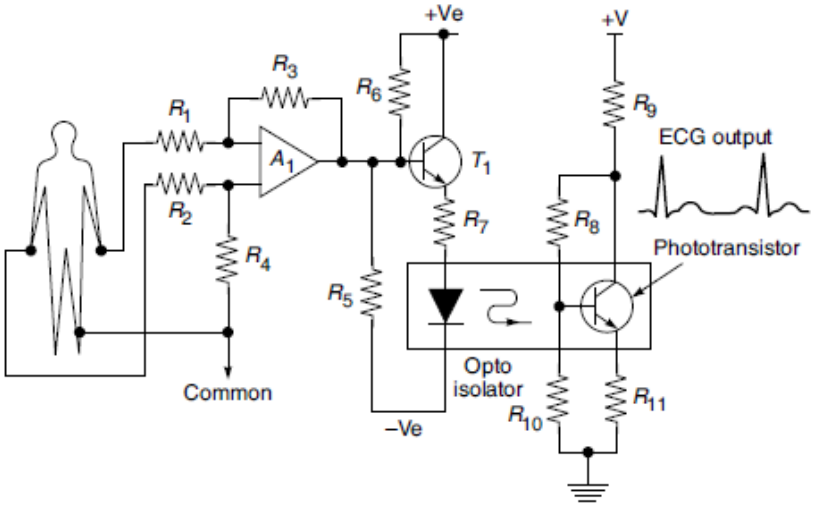
Figure shows a simplified block diagram of a single-ended chopper stabilized amplifier. The amplifier achieves its ultra low dc offset voltage and bias current by chopping the low frequency

components of the input signal, amplifying this chopped signal in an ac amplifier (A1) and then demodulating the output of the ac amplifier. The low frequency components are derived from the input signal by passing it through the low-pass filter, consisting of R2, C2 and R2.
The chopping signal is generated by the oscillator. The filtered output is then further amplified in a second stage of dc amplification (A2). High frequency signals, which are filtered out at the input of the chopper channel, are coupled directly into the second stage amplifier. The result of this technique is to reduce the dc offsets and drift of the second amplifier by a factor equal to the gain of the chopper channel. The ac amplifier introduces no offsets.
Minor offsets and bias currents exist due to imperfect chopping, but these are extremely small. The amplifier modules contain the chopper channel, including switches and switch-driving oscillator built on the module; only the dc power is supplied externally.
Due to the extremely low dc offset and dc drift associated with the chopper-stabilized amplifier, the signal resolution is limited only by the noise present in the circuit. Thus, it is desirable to design the feedback networks and external wiring to minimize the total circuit noise.
When the full bandwidth of the amplifier is not required, it is advisable that a feedback capacitor be used to limit the overall bandwidth and eliminate as much high frequency noise as possible.

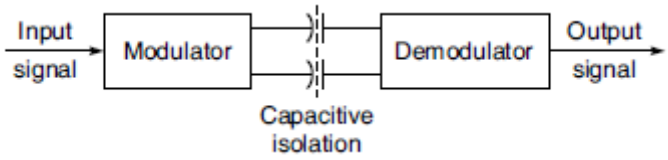
Isolation Amplifier:
Isolation amplifiers are commonly used for providing protection against leakage currents. They break the ohmic continuity of electric signals between the input and output of the amplifier.
The isolation includes different supply voltage sources and different grounds on each side of the isolation barrier. Three methods are used in the design of isolation amplifiers: (i) transformer isolation (ii) optical isolation (iii) capacitive isolation.
The transformer approach is shown in Fig. It uses either a frequency-modulated or a pulsewidth-modulated carrier signal with small signal bandwidths up to 30 kHz to carry the signal.
It uses an internal dc–to-dc converter comprising of a 20 kHz oscillator, transformer, rectifier and filter to supply isolated power.



Isolation could also be achieved by optical means in which the patient is electrically connected with neither the hospital line nor the ground line.
A separate battery operated circuit supplies
power to the patient circuit and the signal of interest is converted into light by a light source (LED).
This light falls on a phototransistor on the output side, which converts the light signal again into an electrical signal (Fig. 4.9), having its original frequency, amplitude and linearity.
No modulator/demodulator is needed because the signal is transmitted optically all the way.



The capacitive method uses digital encoding of the input voltage and frequency modulation to send the signal across a differential capacitive barrier. Separate power supply is needed on both sides of the barrier. Signals with bandwidths up to 70 kHz can be conveniently handled in this arrangement.



Video Content / Details of website for further learning (if any):

https://www.electrical4u.com/chopper-amplifier/
https://www.youtube.com/watch?v=tC43ztgutwo

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No :121 - 124

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LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **II - ELECTRO – PHYSIOLOGICAL MEASUREMENTS**

Date of Lecture:

Topic of Lecture: Physiological measurements-ECG

Introduction :

An electrocardiogram (ECG or EKG) records the electrical signal from your heart to check for different heart conditions. Electrodes are placed on your chest to record your heart's electrical signals, which cause your heart to beat. The signals are shown as waves on an attached computer monitor or printer.

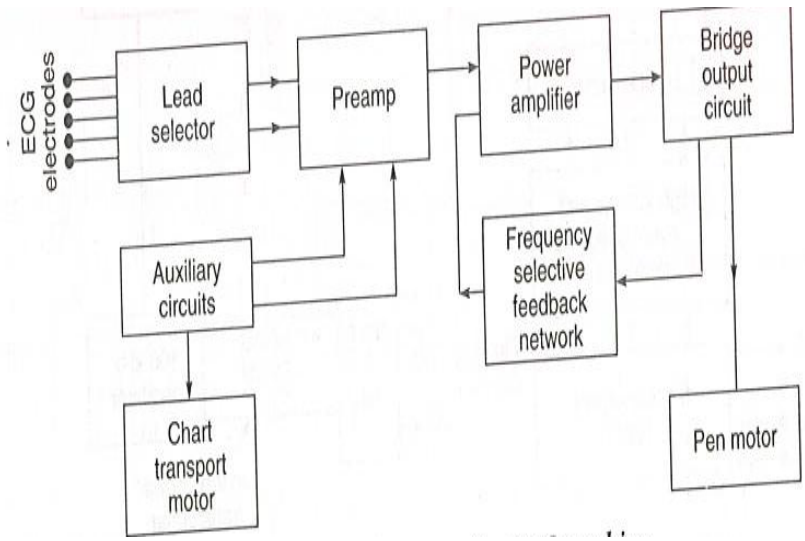
Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Bio Signal

Physiological measurements-ECG

- It records the electrical avtivity of heart.
- It provides valuable information about wide range of cardiac disordersas presence of inactive (infarction) or enlargement (cardiac hyperophy)
- Electric field generated by heart can be characteristed by voltage difference in mV.frequency range of 0.05 to 150 hz.CMMR=100-120db
-

Block diagram of ECG machine

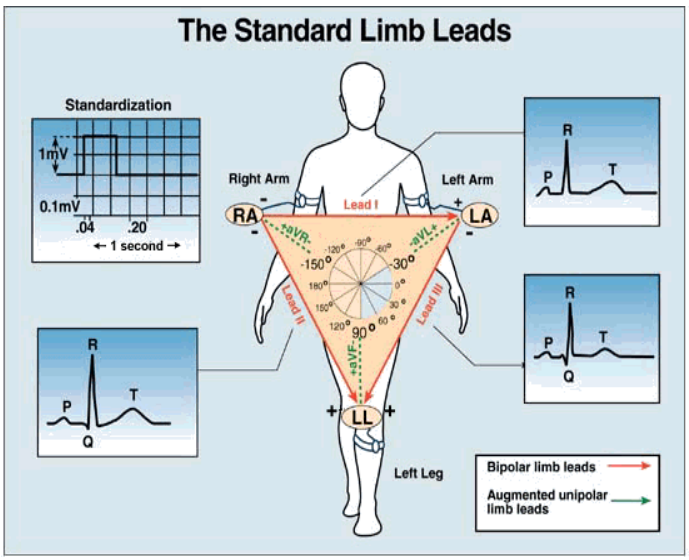


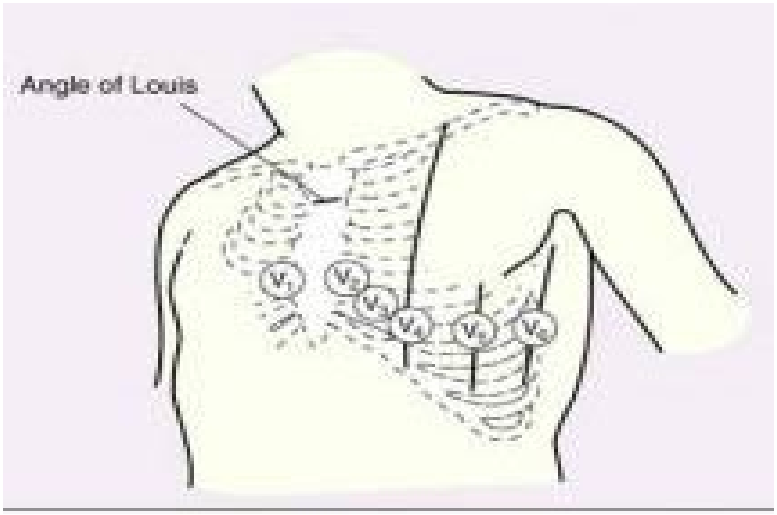
Potiential picked up by the patient electrodes are taken to the leads sector switch. The signal is connected symmetrically to the long tail pair differential amplifiers differential amplifiers has negative feedback. The amplified o/p is given to power amplifiers Feedback is obtained from selective feedback network. The o/p is single ended and feed to pen motor which deflects the writing arm on the paper. Instead of preamplifier isolated preamplifier is used.

Types of unipolar leads

Limb leads :
Two of the limb leads are tied together and recorded with respect to third limb. In the lead identified AVR the right arm is recorded with respect to reference by joining the left arm and left leg electrodes.
Augumented leads or averaging leads :
In the AVL lead, the left arm is recorded w.r.t to common junction of the right arm and left leg. In AVF lead, the left leg is recorded w.r.t two arm electrodes tied together.
The resistance inserted between electrode –machine connections are called averaging resistance.

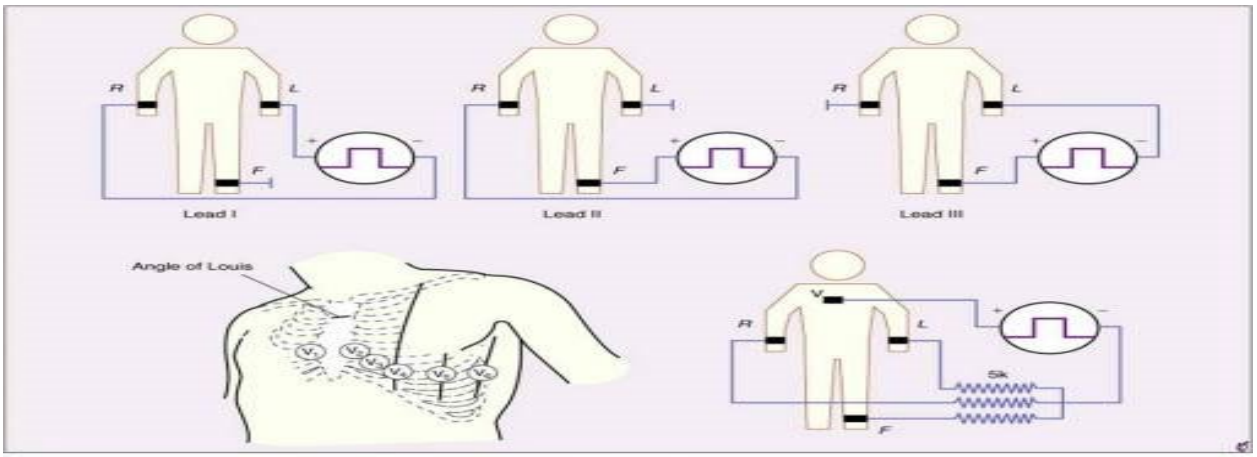
Einthoven Triangle





V1 – fourth intercostals space of right sternal margin
V2 – fourth intercostals space of left sternal margin
V3 – Midway between V2 and V4
V4 – fifth intercostals space at mid-clavicular line
V5 – Same level as V4 on anterior auxiliary line
V0 – Same level as V4 on mid auxiliary line

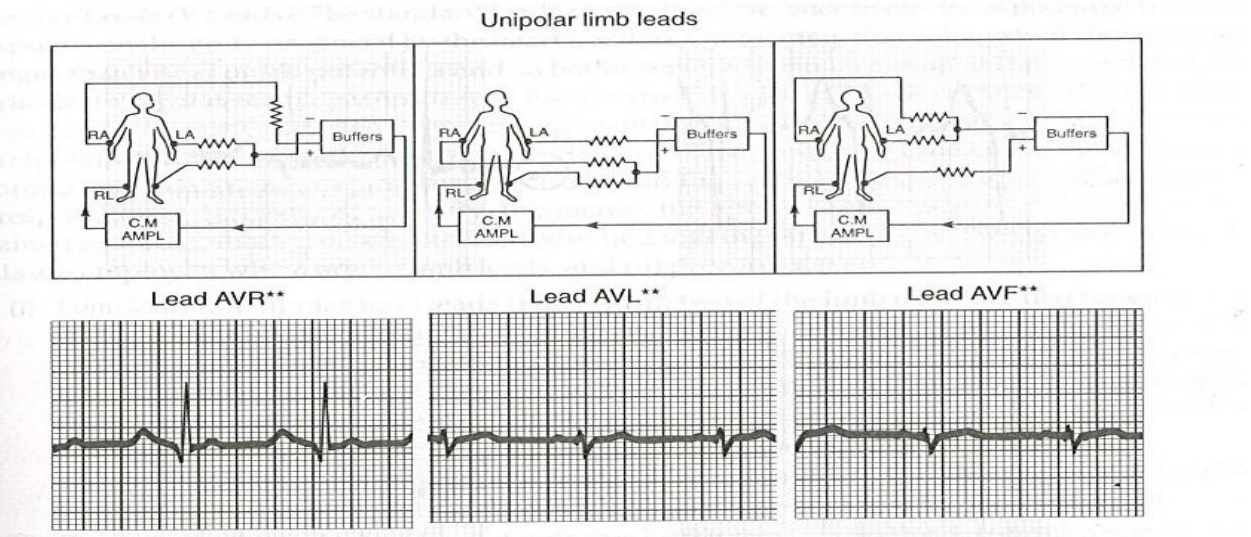
ECG Leads- bipolar limb leads



Lead Position I : voltage drop V1 from left LA to RA
Lead Position II : voltage drop V2 from left LL to RA
Lead Position III : voltage drop V3 from left LL to LA

In all lead connections ,the difference of potential measured between two electrodes is always with reference to a third point on the bThird point is conventionally taken as RL.

Augmented Unipolar Limb leads



The ECG measured from any of the three basic limb leads is a time-varient single dimentional component of the vector. Electric field of the heart could be represented as triangle called Einthoven triangle . The sides of triangle represent the lines along which the three projections of ECG vector measured. **The instantaneous voltage measured from any one of the three limb lead position is approximately equal to the algebric sum of the other two that the vector sum of the projections on all three lines is equal to zero.**

Video Content / Details of website for further learning (if any):

https://www.heart.org/en/health-topics/heart-attack/diagnosing-a-heart-attack/electrocardiogram-ecg-or-ekg
https://www.healio.com/cardiology/learn-the-heart/ecg-review/ecg-interpretation-tutorial/introduction-to-the-ecg

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No :36-38

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LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **II - ELECRTO - PHYSIOLOGICAL MEASUREMENTS**

Date of Lecture:

Topic of Lecture: EEG, EMG, ERG

Introduction :

An **electroencephalogram** (**EEG**) is a test used to evaluate the electrical activity in the brain. Brain cells communicate with each other through electrical impulses. An **EEG** can be used to help detect potential problems associated with this activity.

Electromyography (EMG) is an electrodiagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an electromyograph to produce a record called an electromyogram.

Electroretinography (ERG) is an eye test that detects function of the retina (the light-detecting portion of the eye). The retina is comprised of layers of specialized cells, including photoreceptors (rods and cones), that detect light and ganglion cells that transmit images to the brain.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Bio signal

Electroencephalograph(EEG)

Brain consist of

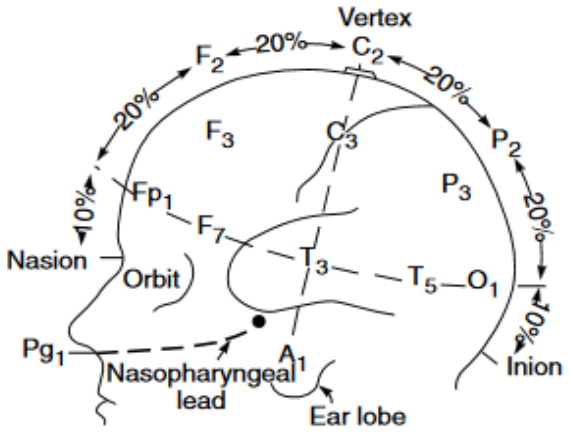
Cerebrum - 9-12 billion neurons .
Frontal Lobe – responsible for intelligence
Pariental Lobe – for eye movement
Temporal Lobe – storage process for long term memory
Occipital Lobe – Responsible for vision of eye
Cerebellum – to main body balance
Medulla Oblongata – breathing , heart rate ,kidney function
Spinal Card – it activates motor nerves.

Placement of Electrodes in EEG Management

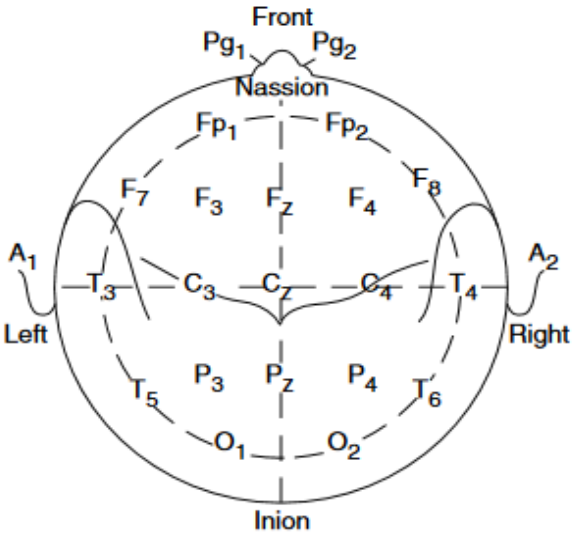
Anterior – Posterior (Front – Back) Measurement
Frontal Pole (FP) : 10% of Nasion- Inion distance above Nasion
Frontal (F) : 20% of Nasion- Inion distance from FP

Central (C) : 20% of Nasion- Inion distance from F
Parental (P) : 20% of Nasion- Inion distance from C
Occipital (O) : 10% of 20% of Nasion- Inion distance from Inion

Lateral Measurements (21 Electrode System)



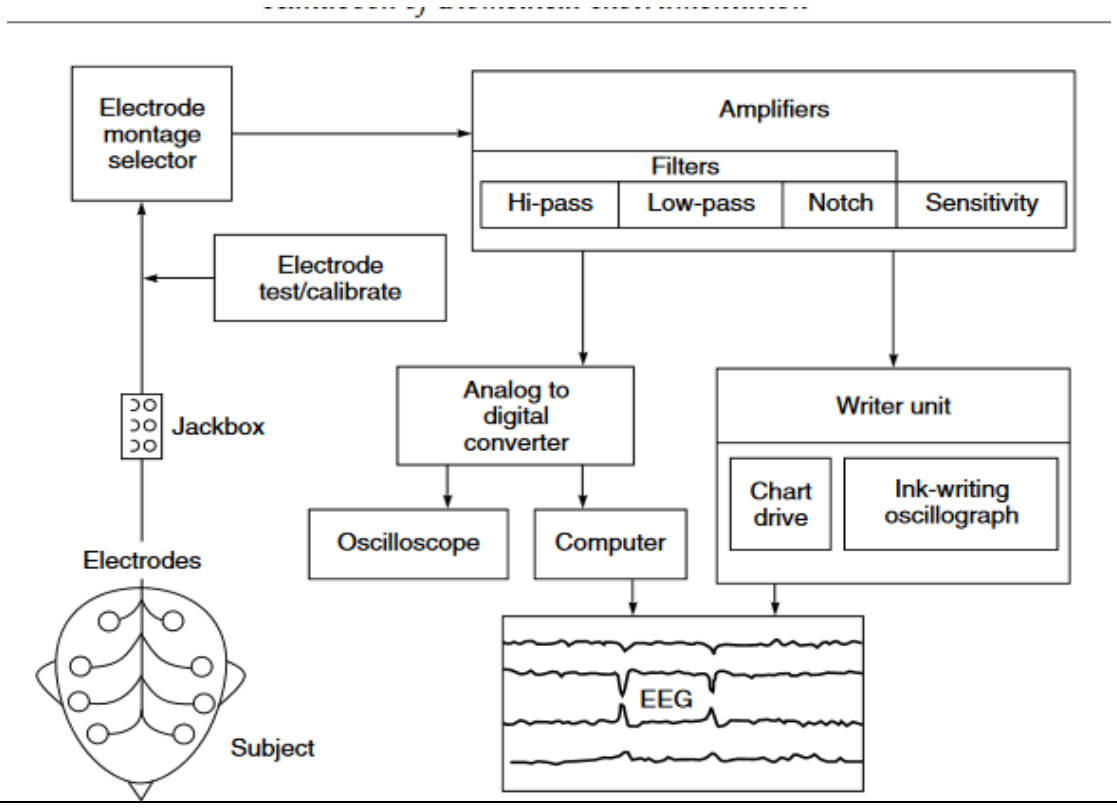
Left side of Head



Top of Head

1.Temporal Points (T) : 10% of the distance from the pre-auricular point (from left ear to right ear
2.Central Points (C) : 20% of the same distance

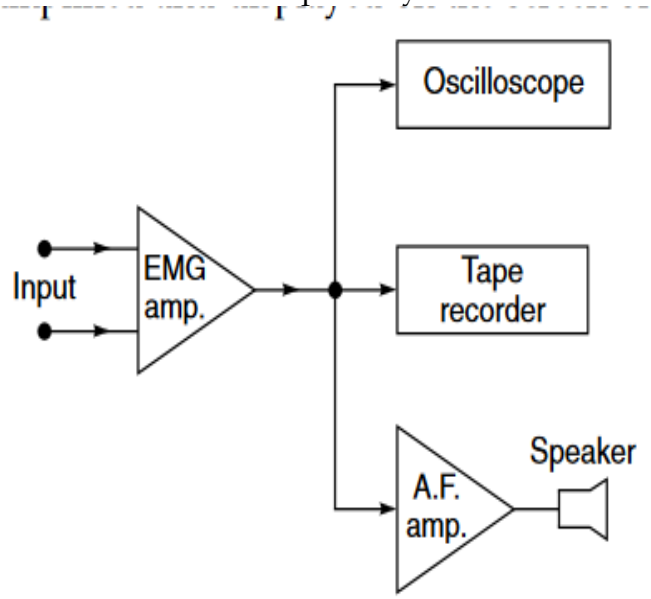
FP1 , FP2 = Frontal Pole Points
F3 ,F4 = Frontal Points
T3,T4,T5,T6 = Temporal Points
O1,O2 = occipital Points
C3,C4,Cz = Central Points
A1,A2 = Pre-Auricular Points



Electromyograph

Electromyograph is an instrument used for recording the electrical activity of the muscles todetermine whether the muscle is contracting or not; or for displaying on the CRO and loudspeakerthe action potentials spontaneously present in a muscle or those induced by voluntary contrac-tions as a means of detecting the nature and location of motor unit lesions; or for recording theelectrical activity evoked in a muscle by the stimulation of its nerve. The instrument is useful formaking a study of several aspects of neuromuscular function, neuromuscular condition, extent ofnerve lesion, reflex responses, etc.EMG measurements are also important for the myoelectric control of prosthetic devices (artificiallimbs).

This use involves picking up EMG signals from the muscles at the terminated nerve endingsof the remaining limb and using the signals to activate a mechanical arm. This is the mostdemanding requirement from an EMG since on it depends the working of the prosthetic device.EMG is usually recorded by using surface electrodes or more often by using needle electrodes,which are inserted directly into the muscle. The surface electrodes may be disposable, adhesivetypes or the ones which can be used repeatedly.



A ground electrode is necessary for providing acommon reference for measurement. These electrodes pick up the potentials produced by thecontracting muscle fibres. The signal can then be amplified and displayed on the screen of acathode ray tube. It is also applied to an audio-amplifier connected to a loudspeaker. A trainedEMG interpreter can diagnose various musculardisorders by listening to the sounds producedwhen the muscle potentials are fed to the loud-speaker. The block diagram (Fig. 5.15) shows atypical set-up for EMG recordings. The oscillo-scope displays EMG waveforms. The taperecorder is included in the system to facilitateplayback and study of the EMG sound waveformsat a later convenient time. The waveform canalso be photographed from the CRT screen byusing a synchronized camera.The amplitude of the EMG.

Electroretinography

It is found that an electrical potential exists between the cornea and the back of the eye. Thispotential changes when the eye is illuminated. The process of recording the change in potentialwhen light falls on the eye is called electroretinography. ERG potentials can be recorded with apair of electrodes. One of the electrodes is mounted on a contact lens and is in direct contact withthe cornea. The other electrode is placed on the skin adjacent to the outer corner of the eye. Areference electrode may be placed on the forehead.

A general purpose direct writing recorder maybe used for recording electroretinograms.The magnitude of the ERG voltage depends upon the intensity and duration of the light fallingon the eye. It may be typically about 500 mV.

Video Content / Details of website for further learning (if any):
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1455479/
https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/electromyography-emg

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No :170-175

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LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **II - ELECRTO - PHYSIOLOGICAL MEASUREMENTS**

Date of Lecture:

Topic of Lecture: Lead systems and recording methods

Introduction :

The Standard 12 Lead ECG. The standard 12-lead electrocardiogram is a representation of the heart's electrical activity recorded from electrodes on the body surface. This section describes the basic components of the ECG and the lead system used to record the ECG tracings.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Bio signal

Lead systems and recording methods

Bioelectric signal have to be picked up from the surface of the body to put into amplifier to record or display.

It transfer from ionic conduction in the tissue to the electric conduction .

Two types :

1.Practice-surface electrode

2.deep- seated electrodes

Types of electrodes

1.Silver – Silver Chloride Electrodes

2.Electrodes for ECG

3. Electrodes for EEG

4. Electrodes for EMG

5.Micro Electrodes

1.Silver – Silver Chloride Electrodes

It is prepared by electrolysis.

Two Silver discs suspended in a saline solution.

The positive pole of a dc supply is connected to the disc to be chlorinated and negative pole goes to the other disc.1ma/cm2 current passed through the electrode.

2.Electrodes for ECG

1.Limb Electrodes
2.Floating Electrodes
3.Pregelled Disposable Electrodes
4.Pasteless Electrodes
5.Air-Jet Electrodes

3..Electrodes for EMG

It is needle electrode.
It is used in clinical electromyography, neurography, electrophysiological investigation of tissues, muscles.
4. Microelectrodes

It is made up of 10um diameter.
It has good stainless steel wire.
The metal electrolyte interface is between the metal film and electrolyte.
The tips of these electrodes have to be sufficiently strong to be introduced through layers of tissues without breaking.

Video Content / Details of website for further learning (if any):
https://www.cardiosecur.com/magazine/specialist-articles-on-the-heart/lead-systems-how-an-ecg-works
https://www.electrical4u.com/ecg-lead-system-configuration/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No :171-173

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

IQAC

L17

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **II - ELECRTO - PHYSIOLOGICAL MEASUREMENTS**

Date of Lecture:

Topic of Lecture: Typical waveforms

Introduction :

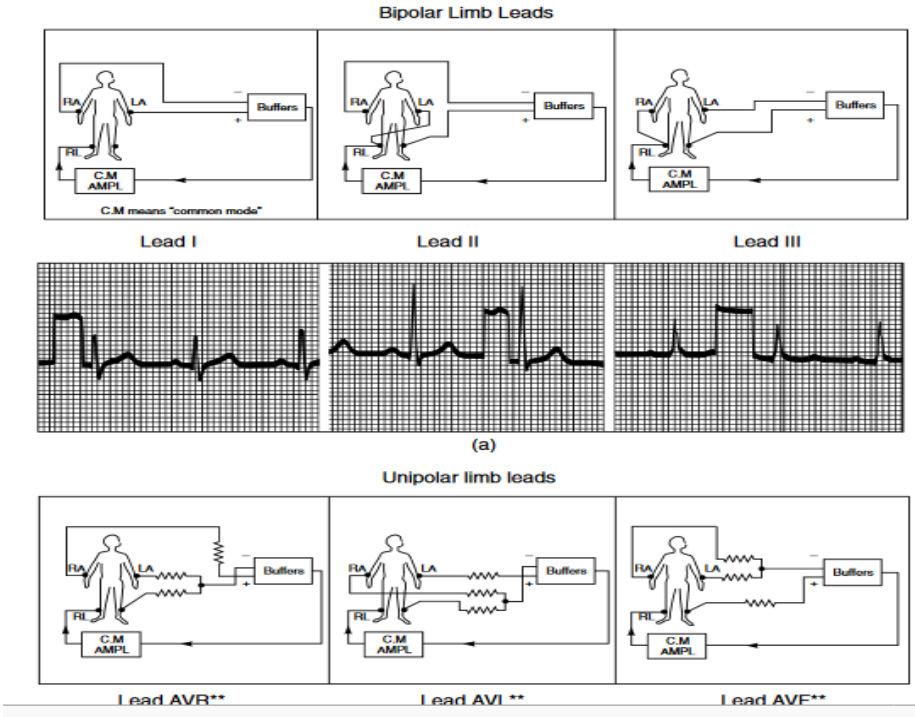
The Standard 12 Lead ECG. The standard 12-lead electrocardiogram is a representation of the heart's electrical activity recorded from electrodes on the body surface. This section describes the basic components of the ECG and the lead system used to record the ECG tracings.

Prerequisite knowledge for Complete understanding and learning of Topic:

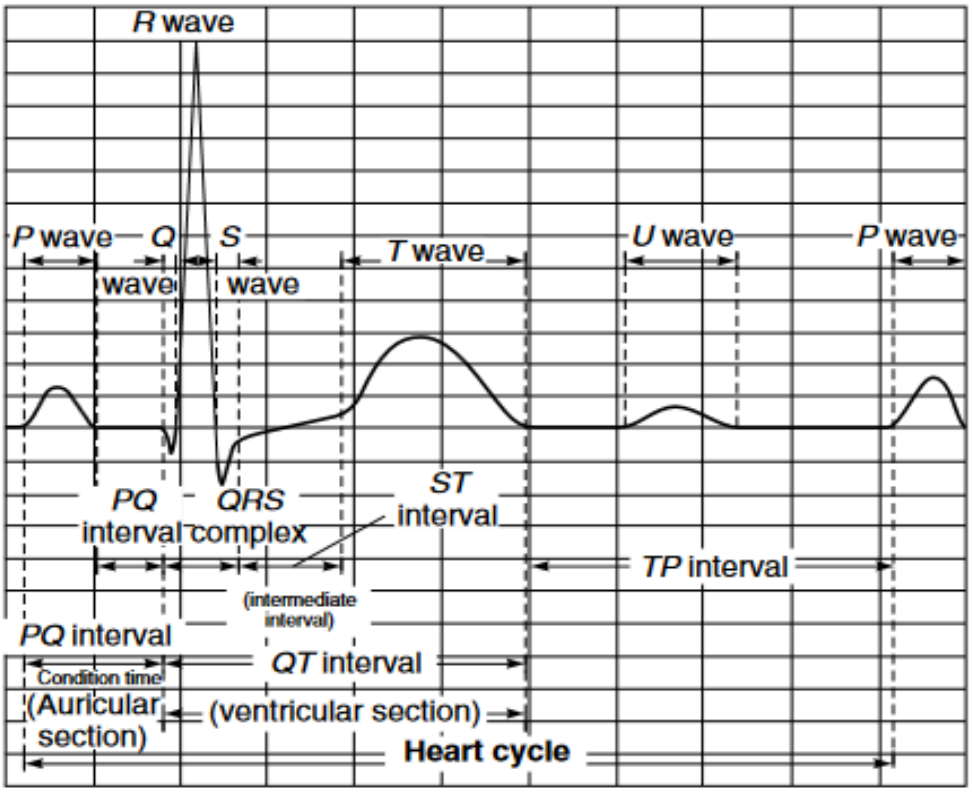
- Basic components of a biomedical system
- Bio signal

Typical waveforms

ECG Leads wave form :



PQRST Waveform



Video Content / Details of website for further learning (if any):
https://ecgwaves.com/topic/ekg-ecg-leads-electrodes-systems-limb-chest-precordial/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5067828/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No :38-40

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L18

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **II - ELECRTO - PHYSIOLOGICAL MEASUREMENTS**

Date of Lecture:

Topic of Lecture: Electrical safety in medical environment: shock hazards-leakage current.

Introduction :

Electrical safety is Microshock hazards as Leakage currents:- Small currents (usually on μA) that flow between any adjacent insulated conductors that are at different potentials.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic components of a biomedical system
- Bio signal

Electrical safety in medical environment: shock hazards-leakage current.

People responsible for acts of omission and operation¬ Natural and unnatural disasters surroundings, gravity, mechanical stress ¬ Sound and electricity ¬ Waste products ¬ fire, air, earth, water, chemicals, drugs, microorganisms ¬Electrical safety Medical procedures usually expose the patient to more hazards than the typical home or workplace, because :-

1. In medical environments the skin and mucous membranes are frequently penetrated or altered.

2. There are many sources of potentially hazardous substances and energy forms that could injure either the patient or the medical staff.

These sources of hazards include:-

The magnitude of the current is equal to the applied voltage divided by the sum of the series impedances of the body tissues and the two interfaces at the entry points Three phenomena can occur when electric current flows through biological tissue:

(1) Electric stimulation of excitable tissue (nerve and muscle)

(2) Resistive heating of tissue

(3) Electrochemical burns and tissue damage for direct current and very high voltages psychophysical and physiological effects of electrical current in humans:-

70 kg AWGNo.8copperwires¬ For a physiological effect to occur, the body must become part of an electric circuit. Current must enter the body at one point and leave at some other point ¬ Physiological effects of electricity psychophysical and physiological effects of electrical current in humans:- Threshold of perception = the minimal current that an individual can detect. This threshold varies considerably among individuals and with the measurement conditions (wet or dry skin) Thresholds for dc current range from 2 to 10 mA, and slight warming of the skin is perceived (realized)

Ventricular fibrillation Ventricular fibrillation:- Is a rapid and disorganized cardiac rhythm. If

the magnitude of the current is sufficient to excite only part of the heart muscle and disrupted the heart rate The heart rate can rise to 300 beats/min The fibrillation does not stop when the current that triggered it is removed. Ventricular fibrillation is the major cause of death due to electric shock. The threshold for ventricular fibrillation for an average-sized human varies from about 75 to 400 mA .
Threshold and let-go variability For men:- The mean value for the threshold of perception is 1.1 mA. let-go currents of 16 mA For women:- the estimated mean is 0.7 mA. The minimal threshold of perception is 500 mA. let-go currents of 10.5 mA

Let-go current versus frequency of the current The minimal let-go currents occur for commercial power-line frequencies of 50 to 60 Hz For frequencies below 10 Hz, let-go currents rise, probably because the muscles can partially relax during part of each cycle At frequencies above several hundred hertz, the let-go currents rise again. Let-go current versus frequency

Body weight and fibrillation, duration of the current Several studies using animals of various sizes have shown that the fibrillation threshold increases with body weight Fibrillating current increases from 50 mA rms for 6 kg dogs to 130 mA rms for 24 kg dogs.

Point of entry (macroshock and microshock) Macroshock:- When current is applied at two points on the surface of the body, only a small fraction of the total current flows through the heart (macroshock). The magnitude of current needed to fibrillate the heart is far greater when the current is applied on the surface of the body than it would be if the current were applied directly to the heart Microshock:- All the current applied through an intracardiac catheter flows through the heart small currents called microshocks can induce Ventricle fibrillation Current of about 20 μA can cause microshock . The widely accepted safety limit to prevent microshocks is 10 mA.

Microshocks can occur if sufficient potentials exist between exposed conductive surfaces in the patients' environment THE maximal potentials permitted between any two exposed conductive surfaces in the vicinity of the patient are specified by the 2006 NEC, General-care areas, 500 mV under normal operation 2. Critical-care areas, 40 mV under normal operation Things must be done:-
1. All exposed conductive surfaces in the vicinity of the patient must be grounded at a single patient grounding point.
2. Periodic testing for continuity between the patient ground and all grounded surfaces is required
3. Each patient-bed location in general- care areas must have at least four single or two duplex receptacles ,the receptacle must be grounded
4. At least two branch circuits with separate automatic overcurrent devices must supply the location of each patient bed.
5. For critical-care areas at least six single or three duplex receptacles are required for each location of a patient bed.
Electric faults in equipment Many devices have a metal chassis and cabinet that medical personnel and patients may touch If the chassis and cabinet are not grounded, If a person touches the chassis and any grounded object, a macroshock results
Electric faults in equipment Macroshock due to a ground fault from hot line to equipment cases ungrounded case sun grounded cases.
Microshock hazards Leakage currents:- Small currents (usually on μA) that flow between any adjacent insulated conductors that are at different potentials The leakage current in line operated equipment flows through: 1. The stray capacitance between the two conductors. 2. Resistive leakage current flows through insulation, dust, and moisture. If the ground wire is broken, then the chassis potential rises above ground, and a patient who touches the chassis and has a grounded electric connection to the heart may receive a micro shock.

Conductive paths to the heart A patient is in danger of microshock only when there is some electric connection to the heart. The following clinical devices make patients susceptible to

microshock:- 1. Epicardial or endocardial electrodes of externalized temporary cardiac pacemakers 2. Electrodes for intracardiac electrogram measuring and stimulation devices 3. Liquid-filled catheters placed in the heart.
There are two fundamental methods of protecting patients against shock:-
1. The patient should be completely isolated and insulated from all grounded objects.
2. All sources of electric current and all conductive surfaces within reach of the patient can be maintained at the same potential, which is not necessarily ground potential Protection: power distribution Grounding system:- A grounding system protects patients by keeping all conductive surfaces and receptacle grounds in the patient's environment at the same potential The grounding system has
1. a patient-equipment grounding point
2. a reference grounding point
3. and connectionsProtection: power distribution The patient equipment grounding point is connected individually to all :- receptacle grounds Metal beds Metal door and window frames Water pipes Any other conductive surface. These connections should not exceed resistance of 0.15 Ω The difference in potential between receptacle grounds and conductive surfaces should not exceed 40 mVGround-fault circuit interrupters (GFCI) GFCI disconnect the source of electric power when a ground fault greater than about 6 mA occurs In electric equipment that has negligible leakage current, the current in the hot conductor is equal to the current in the neutral conductor.
Protection(equipment design) Leakage current inside the chassis can be reduced by :-
1. Using layouts and insulating materials that minimize the capacitance between all hot conductors and the chassis
2. Maximizing the impedance from patient leads to hot conductors 3. Maximizing the impedance from patient leads to chassis groundDouble insulation protects against both macroshock and microshock.
Reinforced insulation is defined in standards as being a single layer of insulation offering the same degree of protection against electric shock as double insulation Supplementary Insulation: independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.⎫Double-insulated equipment

Video Content / Details of website for further learning (if any):
https://www.slideshare.net/YassirAliHassan/electrical-safety-41590043
http://www.ece.ucy.ac.cy/courses/ece473x665/slides/8.pdf

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No :700-705

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LECTURE HANDOUTS

L 19

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **III – Non – Electrical Parameter Measurements**

Date of Lecture:

Topic of Lecture: Measurement of blood pressure

Introduction : Blood pressure is the most often measured and the most intensively studied parameter in medical and physiological practice.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements

Detailed content of the Lecture:

Blood Pressure Measurement:

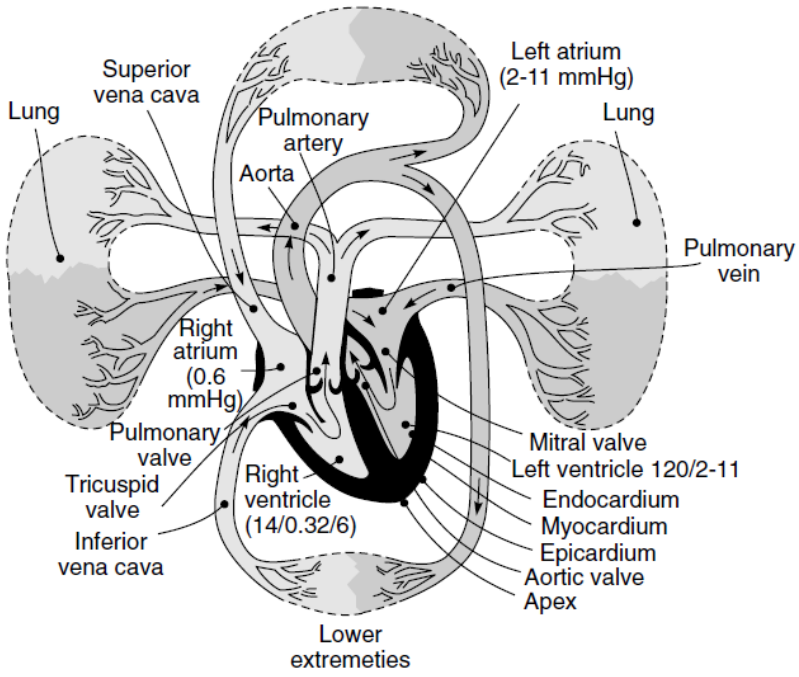
Blood pressure is the most often measured and the most intensively studied parameter in medical and physiological practice. The determination of only its maximum and minimum levels during each cardiac cycle supplemented by information about other physiological parameters is an invaluable diagnostic aid to assess the vascular condition and certain other aspects of cardiac performance. Pressure measurements are a vital indication in the successful treatment and management of critically ill patients in an intensive cardiac care or of patients undergoing cardiac catheterization. The tremendous research and development for an automatic blood pressure monitor has resulted in several methods but only very few have been commercialized due to certain practical difficulties.

Blood is pumped by the left side of the heart into the aorta, which supplies it to the arterial circuit. Due to the load resistance of the arterioles and precapillaries, it loses most of its pressure and returns to the heart at a low pressure via highly distensible veins. The right side of the heart pumps it to the pulmonary circuit, which operates at a lower pressure. The heart supplies blood to both circuits as simultaneous intermittent flow pulses of variable rate and volume. The maximum pressure reached during cardiac ejection is called systolic pressure and the minimum pressure occurring at the end of a ventricular relaxation is termed as diastolic pressure. The mean arterial pressure over one cardiac cycle is approximated by adding one-third of the pulse pressure (difference between systolic and diastolic values) to the diastolic pressure. All blood pressure measurements are made with reference to the atmospheric pressure.

Typical haemodynamic pressure values are shown in Fig. 6.18. The nominal values in the basic

circulatory system are as follows:

- Arterial system 30–300 mmHg
- Venous system 5–15 mmHg
- Pulmonary system 6–25 mmHg

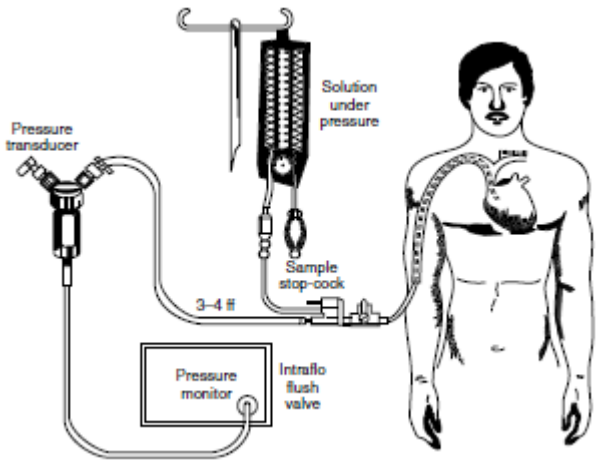


The equivalent reading at heart level is thus:

mmHg reading = (mm above or below heart level) / 12.9

1. Direct Methods of Monitoring Blood Pressure

The direct method of pressure measurement is used when the highest degree of absolute accuracy, dynamic response and continuous monitoring is required. The method is also used to measure the pressure in deep regions inaccessible by indirect means.



Central venous pressure (CVP) measurements made with needle cannulation techniques prove extremely useful in the management of acute circulatory failure and in the maintenance of blood volume in difficult fluid balance problems.

2 Indirect Methods of Blood Pressure Measurement

The classical method of making an indirect measurement of blood pressure is by the use of a cuff over the limb containing the artery. This technique was introduced by Riva-Rocci for the determination of systolic and diastolic pressures. Initially, the pressure in the cuff is raised to a level well above the systolic pressure so that the flow of blood is completely terminated. Pressure

in the cuff is then released at a particular rate. When it reaches a level, which is below the systolic pressure, a brief flow occurs. If the cuff pressure is allowed to fall further, just below the diastolic pressure value, the flow becomes normal and uninterrupted.

a. Automatic Blood Pressure Measuring Apparatus using Korotkoff's Method
b. The Rheographic Method
c. Differential Auscultatory Technique
d. Oscillometric Measurement Method
e. Ultrasonic Doppler Shift Method

Video Content / Details of website for further learning (if any):

Can be added as link
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3639494/
https://extranet.who.int/rhl/resources/videos/blood-pressure-measurement

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 208 to 232

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LECTURE HANDOUTS

L 20

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **III – Non – Electrical Parameter Measurements**

Date of Lecture:

Topic of Lecture: Cardiac output

Introduction : Cardiac output is the quantity of blood delivered by the heart to the aorta per minute. It is a major determinant of oxygen delivery to the tissues.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements
3. Blood Pressure measurements

Detailed content of the Lecture:

Cardiac output measurement

Cardiac output is the quantity of blood delivered by the heart to the aorta per minute. It is a major determinant of oxygen delivery to the tissues.

Methods of cardiac measurement are listed below:

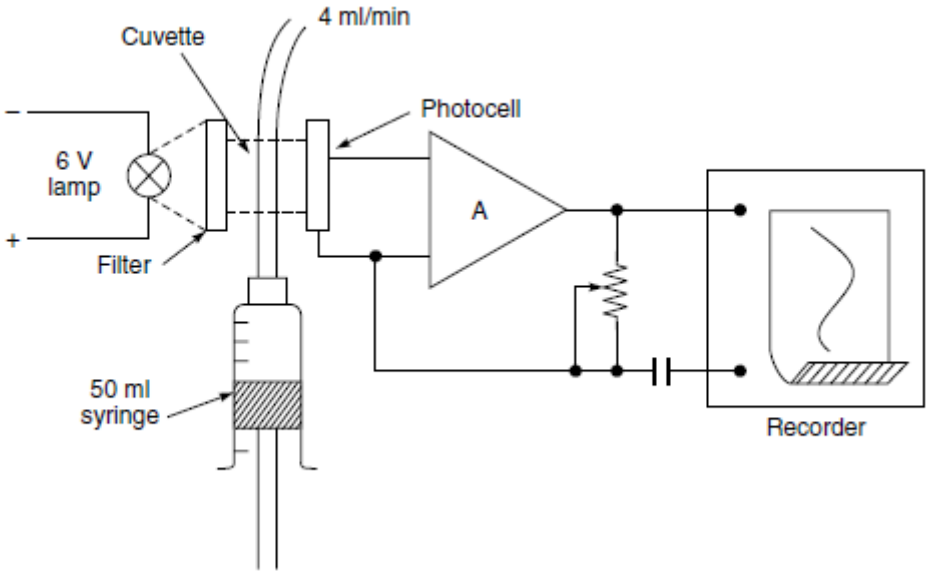
Indicator Dilution Method

Indicator dilution principle states that if we introduce into or remove from a stream of fluid a known amount of indicator and measure the concentration difference upstream and downstream of the injection (or withdrawal) site, we can estimate the volume flow of the fluid.

For calculating the cardiac output from the dilution curve, assume that
M = quantity of the injected indicator in mg
Q = cardiac output
then
Q = ((M* 60) /area under the curve) * (l/min)

Dye Dilution Method

This dye is preferred because of its property of absorbing light in the 800 nm region of the spectrum where both reduced and oxygenated haemoglobin have the same optical absorption. While using some of a the blue dyes, it was nBMEssary to have the patient breathe oxygen. The concentration of cardiogreen can be measured with the help of infra-red photocell transducer. Dye cuvettes of as small volume as 0.01 ml are available.



Thermal Dilution Techniques

A thermal indicator of known volume introduced into either the right or left atrium will produce a resultant temperature change in the pulmonary artery or in the aorta respectively, the integral of which is inversely proportional to the cardiac output.

$$\text{Cardiac output} = \frac{\text{"a constant"} \times (\text{blood temp.} - \text{injectate temp.})}{\text{area under dilution curve}}$$

Measurement of Continuous Cardiac Output Derived from the Aortic Pressure Waveform

The method is based on the analysis of the aortic pressure wave, and estimates the left ventricular stroke volume from the pulse contour. The analysis of the pressure wave depends on simple hydraulic relationships between flow, pressure and time.

During the ejection phase flow is ejected into the aorta, the total amount depending on the driving pressure, on the duration of the ejection period and on the impedance to flow in the aorta.

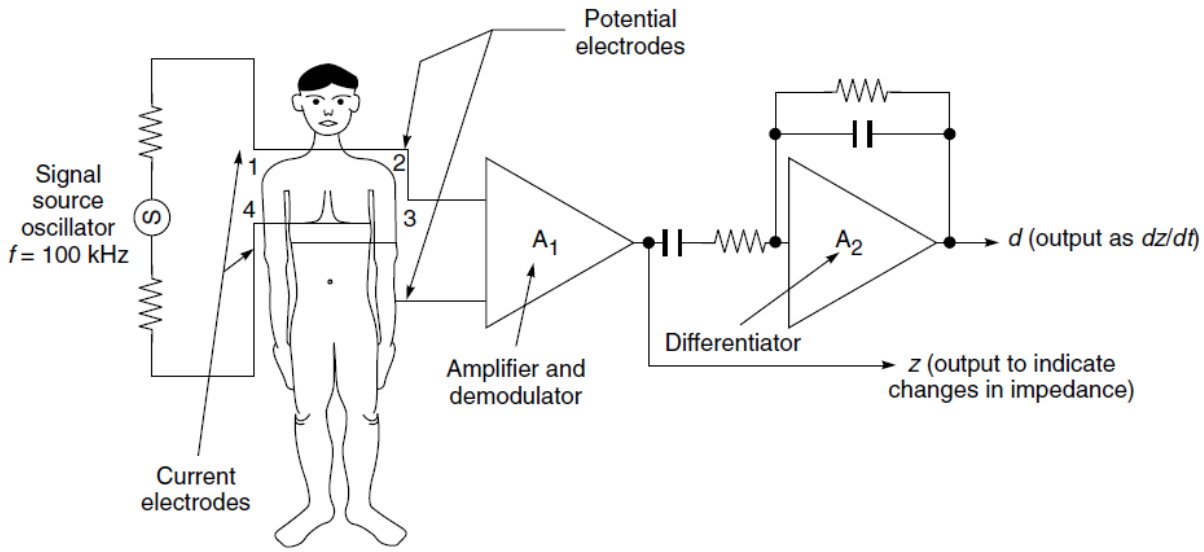
$$\text{Stroke volume (SV)} = \frac{A}{Z_{ao}} \ (\text{cm}^3)$$

$$\text{Heart rate} = \frac{60}{T} \ (\text{bpm})$$

$$\text{Cardiac output} = \frac{(SV) \times (HR)}{1000} = \frac{60 \cdot A}{1000 \cdot Z_{ao} T} \ (\text{l/min})$$

Impedance Technique

The technique used for the measurement of cardiac output by the impedance method is illustrated in Fig.



Ultrasound Method

Ultrasound can be used to measure the velocity of blood flow in the ascending aorta by the application of the Doppler principle (Huntsman et al, 1983). If the area of cross-section of the aorta is known or can be measured, the blood flow rate can be calculated as follows:

Blood flow = velocity (cm/sec) x area (cm2)
= cm3/sec = ml/sec x L/100 ml x 60 sec/min
= L/min

Cardiac output measurement devices based on ultrasound actually measure the stroke volume during the cardiac cycle as per the relationship given below:

$$SV = CSA \times \int^{VET} V(t)\,dt$$

where SV = stroke volume
CSA = cross-sectional area of the aorta
VET = ventricular ejection time
V = blood velocity

Video Content / Details of website for further learning (if any):

Can be added as link
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3045542/
https://www.youtube.com/watch?v=0O3FfHPE9PU

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 344 to 357

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LECTURE HANDOUTS

L 21

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **III – Non – Electrical Parameter Measurements**

Date of Lecture:

Topic of Lecture: Heart rate-Heart sounds

Introduction : 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.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements

Detailed content of the Lecture:

Measurement of Heart Rate

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:

• ***Average calculation*** This is the oldest and most popular technique. An average rate (beats/ min) 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.

• ***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.

• ***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 techniques 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. **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

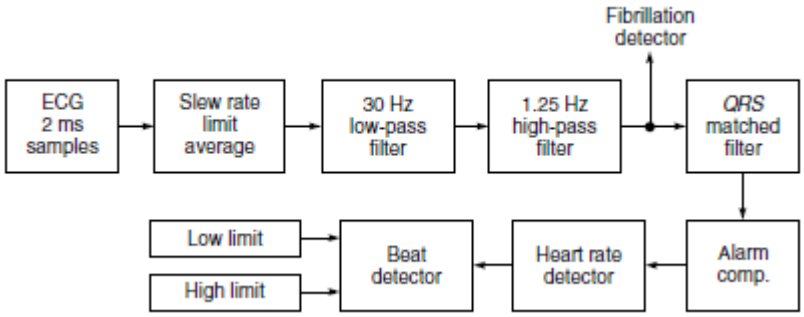
of fixed amplitude and duration and then determining the average current from these pulses. They incorporate specially designed frequency to a voltage converter circuit to display the average heart rate in terms of beats per minute.

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 QRScomplex (Thakor, et al 1983).

Most of the instruments are, however, quite sensitive to the muscle noise (artefact) 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, as suggested by Hanna (1980). This filter is a fifteen sample finiteimpulse- response-filter whose impulse response shape approximates the shape of a normal QRS complex.

The filter, therefore, would have maximum 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.



Video Content / Details of website for further learning (if any):

Can be added as link

https://www.healthline.com/health/how-to-check-heart-rate#target-heart-rates
https://valencell.com/blog/2018/02/can-heart-rate-sensor-today/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 202 to 204

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LECTURE HANDOUTS

L 22

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **III – Non – Electrical Parameter Measurements**

Date of Lecture:

Topic of Lecture: Pulmonary function measurements

Introduction : The primary functions of the respiratory system are 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 effect a precise and sensitive control of the tension of carbon dioxide in the arterial blood.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements

Detailed content of the Lecture:

Measurement of Respiratory Rate

The primary functions of the respiratory system are 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 effect a precise and sensitive control of the tension of carbon dioxide in the arterial blood.

Under normal circumstances, this is rhythmic action with the result that the respiration rate provides a fairly good idea about the relative respiratory activity. Several techniques have been developed for the measurement of the 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.

1. **Displacement Method**

The respiratory cycle is accompanied by changes in the 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 Wheatstone bridge circuit. Bridge output varies with chest expansion and yields signals corresponding to respiratory activity.

2. **Thermistor Method**

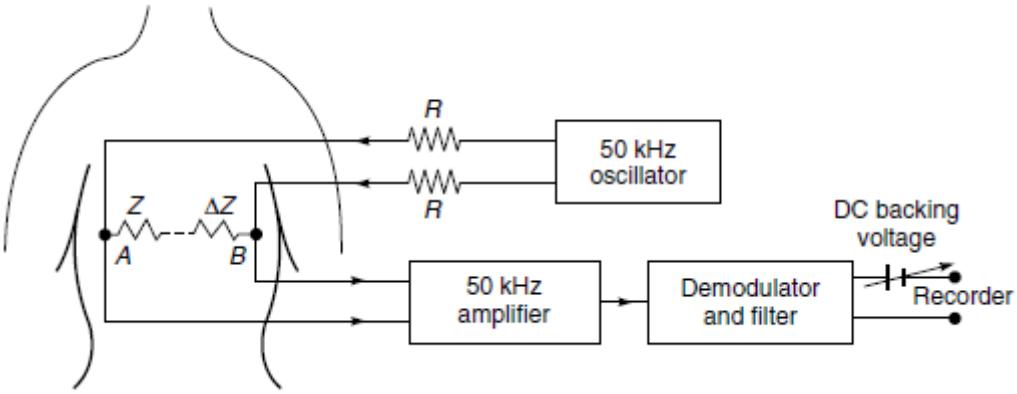
Since air is warmed during its passage through the lungs and the respiratory tract, there is a detectable difference of temperature between inspired and expired air. This difference of temperature can be best sensed by using a thermistor placed in front of the nostrils by means of a suitable holding device.

In case the difference in temperature of the outside air and that of the expired air is small, the thermistor can even be initially heated 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.

3. **Impedance Pneumography**

This is an indirect technique for the measurement of respiration rate. Using externally applied electrodes on the thorax, the impedance pneumograph measures rate through the relationship between respiratory depth and thoracic impedance change. The technique avoids encumbering the subject with masks, tubes, flowmeters or spirometers, does not impede respiration and has minimal effect on the psychological state of the subject.

Impedance method for measuring respiration rate consists in passing a high frequency current through the appropriately placed electrodes on the surface of the body (Figure) and detecting the modulated signal.



4. **CO2 Method of Respiration Rate Measurement**

Respiration rate can also be derived by continuously monitoring the CO2 contained in the subject's alveolar air. Measurement of CO2 in expired air is otherwise useful in several ways; for example, for originally setting up the respirator and in making adjustments to it afterwards, supervising patients suffering from respiratory paralysis, and other cases where there is respiratory involvement.

5. **Apnoea Detectors**

Apnoea is the cessation of breathing which may prBMEde the arrest of the heart and circulation in several clinical situations such as head injury, drug overdose, anaesthetic complications and obstructive respiratory diseases. Apnoea may also occur in premature babies during the first weeks of life because of their immature nervous system.

If apnoea persists for a prolonged period, brain function can be severely damaged. Therefore, apnoeic patients require close and constant observation of their respiratory activity. Apnoea monitors are particularly useful for monitoring the respiratory activity of premature infants.

Video Content / Details of website for further learning (if any): **Can be added as link** https://emedicine.medscape.com/article/303239-overview https://www.youtube.com/watch?v=WyhOJR8btCs
Important Books/Journals for further learning including the page nos.: **Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 232 to 238**

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LECTURE HANDOUTS

L 23

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **III – Non – Electrical Parameter Measurements**

Date of Lecture:

Topic of Lecture: Spirometer -Photo Plethysmography

Introduction : The instrument used to measure lung capacity and volume is called a spirometer. Basically, the record obtained from this device is called a spirogram.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements

Detailed content of the Lecture:

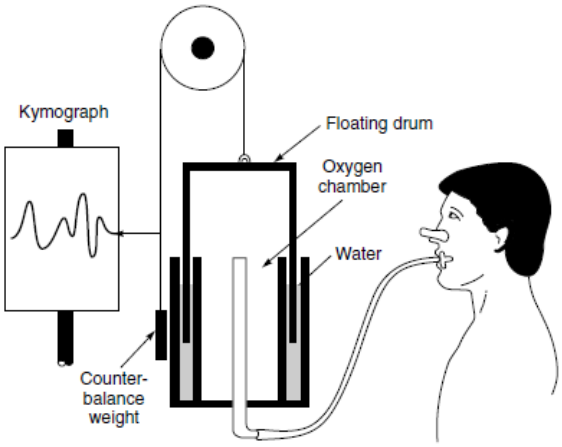
SPIROMETRY

The instrument used to measure lung capacity and volume is called a spirometer. Basically, the record obtained from this device is called a spirogram. Spirometers are calibrated containers that collect gas and make measurements of lung volume or capacity that can be expired. By adding a time base, flow–dependent quantities can be measured.

1. Basic Spirometer

Most of the respiratory measurements can be adequately carried out by the classic water-sealed spirometer (Figure). This consists of an upright, water filled cylinder containing an inverted counter weighted bell. Breathing into the 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 l. Unless a special light weight bell is provided, the normal spirometer is only capable of responding fully to slow respiratory rates and not to rapid breathing, sometimes encountered after anaesthesia. Also, the frequency response of a spirometer must be adequate for the measurement of the forced expiratory volume.



2. Wedge Spirometer

A wedge spirometer consists of two square pans, parallel to each other and hinged along one edge. The first pan is permanently attached to the wedge casting stand and contains a pair of 5 cm inlet tubes. The other pan swings freely along its hinge with respect to the fixed pan.

A space existing between the two pans is sealed airtight with vinyl bellows. The bellows is extremely flexible in the direction of pan motion but it offers high resistance to 'ballooning' or inward and outward expansion from the spirometer. As a result, when a pressure gradient exists between the interior of the wedge and the atmosphere, there will only be a negligible distortion of the bellows.

3. Ultrasonic Spirometer

Ultrasonic spirometers depend, for their action on transmitting ultrasound between a pair of transducers and measuring changes in transit time caused by the velocity of the intervening fluid medium (McShane, 1974). They employ piezo-electric transducers and are operated at their characteristic resonant frequency for their highest efficiency. Gas flowmeters generally operate in the range from about 40 to 200 kHz. At frequencies higher than 200 kHz, absorption losses in the gas are very high whereas sounds below 40 kHz are audible and can be irritating.

Video Content / Details of website for further learning (if any):

Can be added as link
https://www.healthline.com/health/spirometry#preparation
https://www.nhs.uk/conditions/spirometry/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 362 to 368

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LECTURE HANDOUTS

L 24

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **III – Non – Electrical Parameter Measurements**

Date of Lecture:

Topic of Lecture: Body Plethysmography-Blood Gas analyzers

Introduction : Blood gas analyzers are used to measure the pH, partial pressure of carbon dioxide (pCO_2) and partial pressure of oxygen (pO_2) of the body fluids with special reference to the human blood.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements

Detailed content of the Lecture:

Blood Gas Analyzers

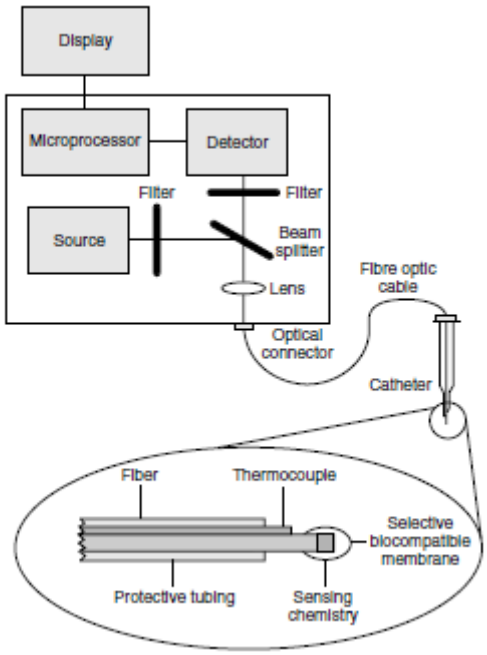
Blood gas analyzers are used to measure the pH, partial pressure of carbon dioxide (pCO_2) and partial pressure of oxygen (pO_2) of the body fluids with special reference to the human blood.

The measurements of these parameters are essential to determine the acid-base balance in the body. A sudden change in the pH and pCO2 could result in cardiac arrhythmias, ventricular hypotension and even death. This shows the importance of the maintenance of physiological neutrality in blood, and consequently the crucial role that the blood gas analyzers play in clinical medicine.

1. Fiber-optic Based Blood Gas Sensors

For in vivo measurements and for reliably analyzing blood gases, a small, stable, accurate and biocompatible sensor is required which could be inserted in the blood flow of an artery (Miller, 1993) through an arterial cannula and remain in place for several days.

In addition, it has to be low cost so that it could be used as a disposable item. Advances in fiber-optics and the development of pH and oxygen sensitive dyes have made such a sensor possible. Blood gas analyzers based on such sensors are now commercially available.



Video Content / Details of website for further learning (if any):

Can be added as link
https://www.sciencedirect.com/topics/nursing-and-health-professions/blood-gas-analyzer
https://www.radiometer.com/en/knowledge-center/guide-to-blood-gas-analysis

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 433

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LECTURE HANDOUTS

L 25

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **III – Non – Electrical Parameter Measurements**

Date of Lecture:

Topic of Lecture: pH of blood -measurement of blood pCO2, pO2

Introduction : Blood gas analyzers are used to measure the pH, partial pressure of carbon dioxide (pCO_2) and partial pressure of oxygen (pO_2) of the body fluids with special reference to the human blood.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements
3. Blood Gas Analyzers

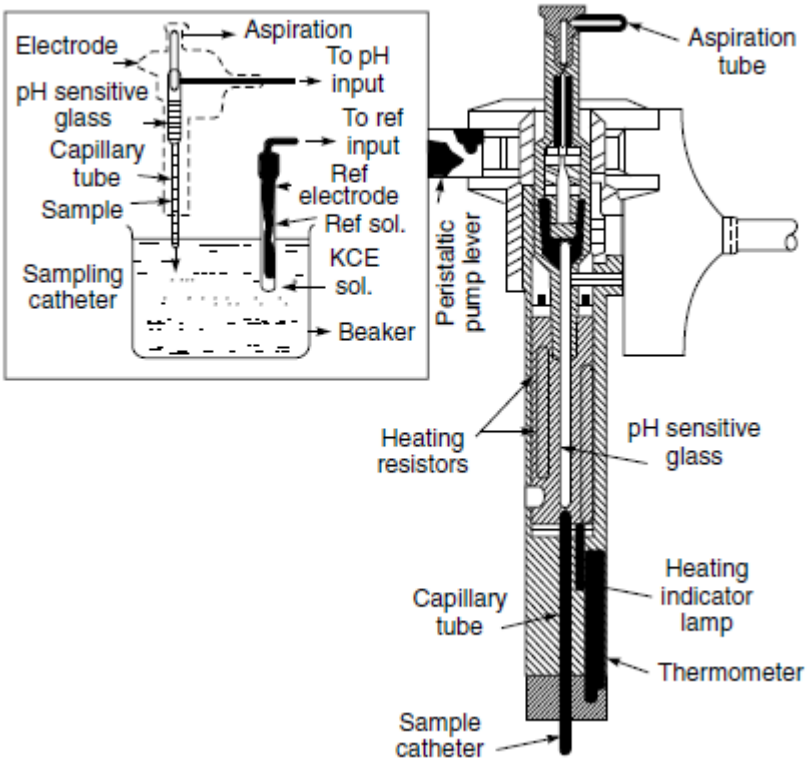
Detailed content of the Lecture:

1. **Blood pH Measurement**

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. The amount of hydrogen ions generally encountered in solutions of interest is extremely small and, therefore, the figure is usually represented in the more convenient system of pH notation. pH is thus a measure of hydrogen ion concentration, expressed logarithmically. Specifically, it is the negative exponent (log) of the hydrogen ion concentration.

pH Measurement For making pH measurements, the solution is taken in a beaker. A pair of electrodes: one glass or indicating electrode and the other reference 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.

The glass electrode exhibits a high electrical resistance, of the order of' 100–1000 MW. The emf measurement, therefore, nBMEssitates the use of measuring circuits with high input impedance. Further, the high resistance of glass electrodes render them highly susceptible to capacitive pickup from ac mains. In order to minimize such effects, it is advisable to screen the electrode cable. The screen is usually grounded to the case of the measuring instrument.



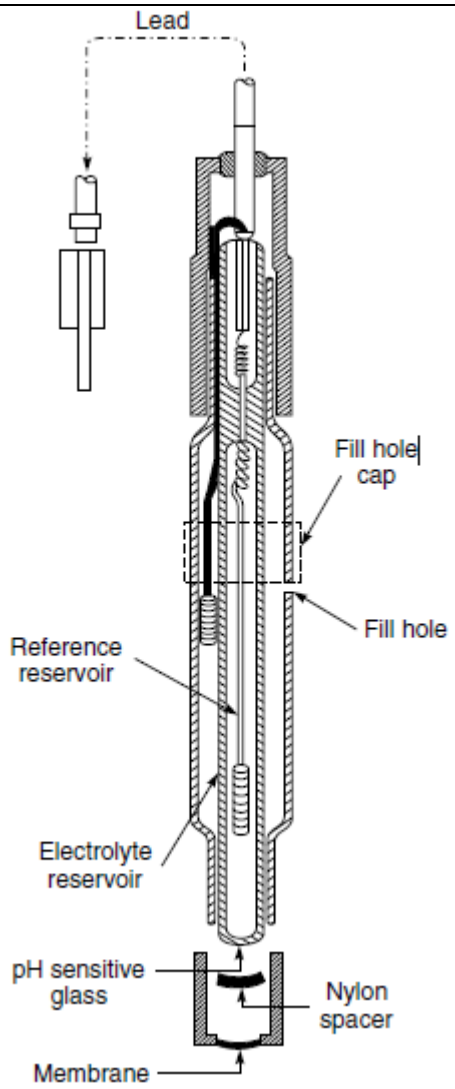
2. **Measurement of Blood PCO2**

The blood pCO2 is the partial pressure of carbon dioxide of blood taken anaerobically. It is expressed in mmHg and is related to the percentage CO2 as follows:
pCO2 = Barometric pressure – water vapour pressure x ((%CO2)/100)

The basic construction of the electrode was modified by Severinghaus and Bradley (1958) to a degree that made it suitable for routine laboratory use. In the construction worked out by them, the water layer was replaced by a thin film of an aqueous sodium bicarbonate (NaHCO3) solution.

The rubber membrane was also replaced by a thin Teflon membrane, which is permeable to CO2 but not to any other ions, which might alter the pH of the bicarbonate solution. The CO2 from the blood diffuses into the bicarbonate solution. There will be a drop in pH due to CO2 reacting with water forming carbonic acid. The pH falls by almost one pH unit for a ten-fold increase in the CO2 tension of the sample. Hence, the pH change is a linear function of the logarithm of the CO2 tension.

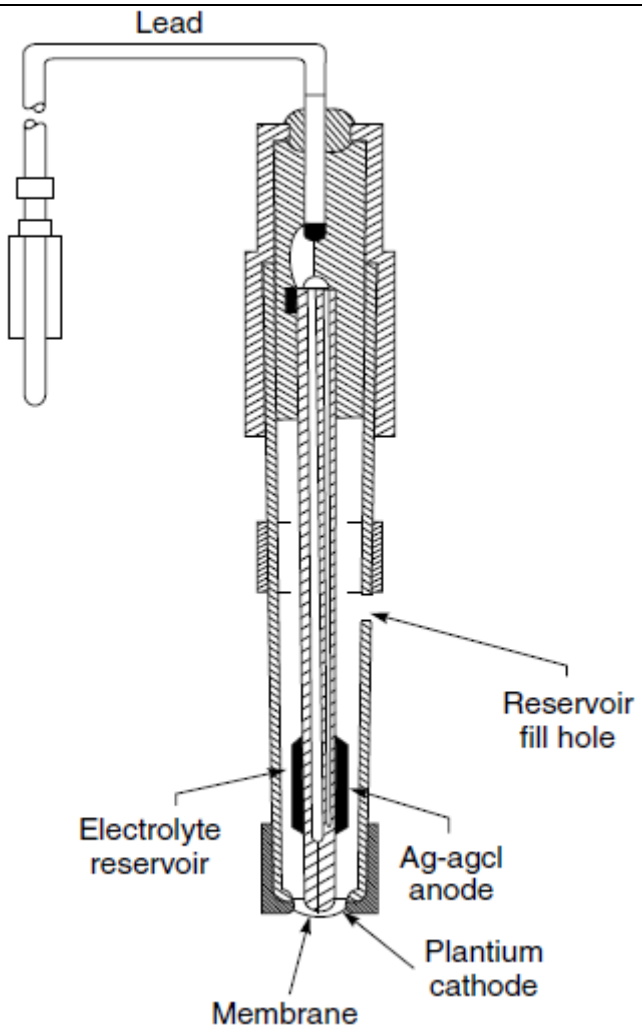
The optimum sensitivity in terms of pH change for a given change in CO2 tension is obtained by using a bicarbonate solution of concentration of about 0.01 mole/l. The electrode is calibrated with the known concentration of CO2. The response time of the CO2 electrode is of the order of 0.5 to 3 min. This electrode was twice as sensitive and drifted much less than the Stow's electrode. Figure shows the construction of a typical pCO2 electrode.



3. **Blood pO2 Measurement**

The partial pressure of oxygen in the blood or plasma indicates the extent of oxygen exchange between the lungs and the blood, and normally, the ability of the blood to adequately perfuse the body tissues with oxygen. The partial pressure of oxygen is usually measured with a polarographic electrode.

There is a characteristic polarizing voltage at which any element in solution is predominantly reduced and in the case of oxygen, it is 0.6 to 0.9 V. In this voltage range, it is observed that the current flowing in the electrochemical cell is proportional to the oxygen concentration in the solution. Most of the modern blood gas analyzers utilize an oxygen electrode first described by Clark (1956) for measuring oxygen partial pressure. This type of electrode consists of a platinum cathode, a silver/silver chloride anode in an electrolyte filling solution and a polypropylene membrane. The electrode is of a single unit construction and contains the reference electrode also in its assembly. Figure shows the construction of a typical Clark-type oxygen electrode. The entire unit is separated from the solution under measurement by the polypropylene membrane.



Video Content / Details of website for further learning (if any):

Can be added as link
https://www.sciencedirect.com/science/article/abs/pii/S0007193517321942

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 421 to 430

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LECTURE HANDOUTS

L 26

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **III – Non – Electrical Parameter Measurements**

Date of Lecture:

Topic of Lecture: Finger-tip oxymeter

Introduction : Pulse oximetry is based on the concept that arterial oxygen saturation determinations can be made using two wavelengths, provided the measurements are made on the pulsatile part of the waveform.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements

Detailed content of the Lecture:

Pulse Oximeter

Pulse oximetry is based on the concept that arterial oxygen saturation determinations can be made using two wavelengths, provided the measurements are made on the pulsatile part of the waveform.

The two wavelengths assume that only two absorbers are present; namely oxyhaemoglobin (HbO_2) and reduced haemoglobin (Hb). These observations, proven by clinical experience, are based on the following:

(i) Light passing through the ear or finger will be absorbed by skin pigments, tissue, cartilage, bone, arterial blood, venous blood.

(ii) The absorbances are additive and obey the Beer-Lambert law

(iii) Most of the absorbances are fixed and do not change with time. Even blood in the capillaries and veins under steady state metabolic circumstances is constant in composition and flow, at least over short periods of time.

(iv) Only the blood flow in the arteries and arterioles is pulsatile.

Therefore, only measuring the changing signal, measures only the absorbance due to arterial blood and makes possible the determination of arterial oxygen saturation (SaO_2). This is uninfluenced by all the other absorbers which are simply part of the constant background signal.

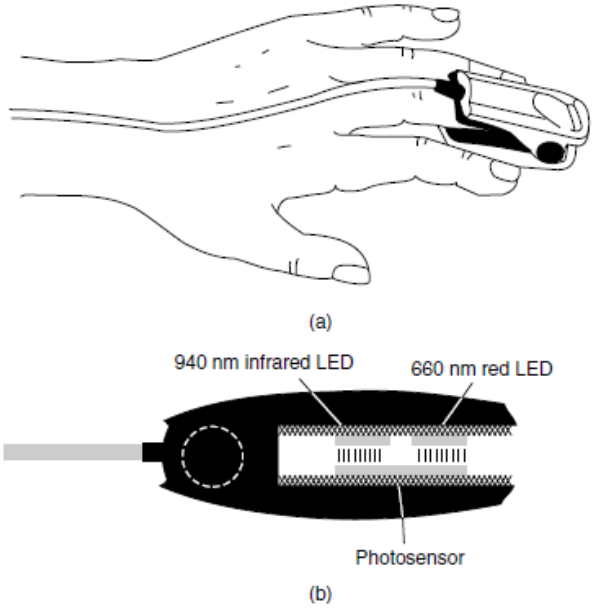
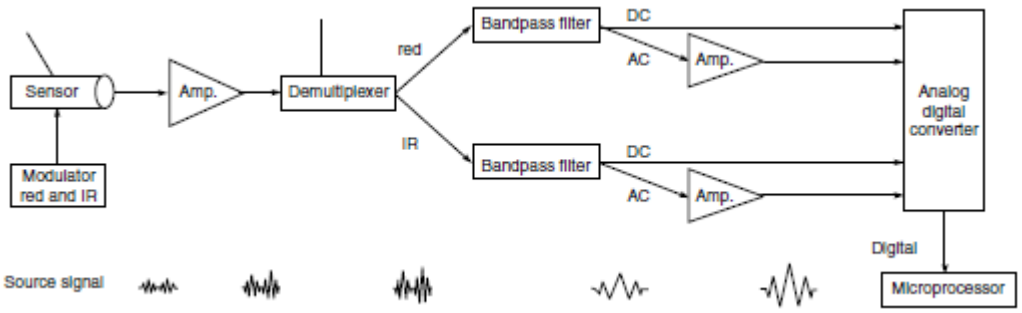


Figure (a) shows a typical finger tip oximeter probe in use whereas Fig.(b) shows the construction of a typical pulse oximeter probe. This has two LEDs (light emitting diodes), one that transmits infrared light at a wavelength of approximately 940 nm and the other transmitting light at approximately 660 nm. The absorption of these select wavelengths of light through living tissues is significantly different for oxygenated haemoglobin (HbO2) and reduced haemoglobin (Hb). The absorption of these selected wavelengths of light passing through living tissue is measured with a photosensor.



Video Content / Details of website for further learning (if any):

Can be added as link
https://www.healthline.com/health/pulse-oximetry#takeaway
https://www.youtube.com/watch?v=-wsLjj78DXY

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 318 to 322

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LECTURE HANDOUTS

L 27

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **III – Non – Electrical Parameter Measurements**

Date of Lecture:

Topic of Lecture: ESR, GSR measurements

Introduction : An erythrocyte sedimentation rate (ESR) is a type of blood test that measures how quickly erythrocytes (red blood cells) settle at the bottom of a test tube that contains a blood sample. The Galvanic Skin Response (GSR), also named Electrodermal Activity (EDA) and Skin Conductance (SC), is the measure of the continuous variations in the electrical characteristics of the skin, i.e. for instance the conductance, caused by the variation of the human body sweating.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements

Detailed content of the Lecture:

Erythrocyte Sedimentation Rate (ESR)

What is an erythrocyte sedimentation rate (ESR)?

An erythrocyte sedimentation rate (ESR) is a type of blood test that measures how quickly erythrocytes (red blood cells) settle at the bottom of a test tube that contains a blood sample. Normally, red blood cells settle relatively slowly. A faster-than-normal rate may indicate inflammation in the body. Inflammation is part of your immune response system. It can be a reaction to an infection or injury. Inflammation may also be a sign of a chronic disease, an immune disorder, or other medical condition.

What is it used for?

An ESR test can help determine if you have a condition that causes inflammation. These include arthritis, vasculitis, or inflammatory bowel disease. An ESR may also be used to monitor an existing condition.

Why do I need an ESR?

Your health care provider may order an ESR if you have symptoms of an inflammatory disorder. These include:

Headaches

Fever
Weight loss
Joint stiffness
Neck or shoulder pain
Loss of appetite
Anemia

What happens during an ESR?

A health care professional will take a blood sample from a vein in your arm, using a small needle. After the needle is inserted, a small amount of blood will be collected into a test tube or vial. You may feel a little sting when the needle goes in or out. This usually takes less than five minutes.

GSR Measurement

The Galvanic Skin Response (GSR), also named Electrodermal Activity (EDA) and Skin Conductance (SC), is the measure of the continuous variations in the electrical characteristics of the skin, i.e. for instance the conductance, caused by the variation of the human body sweating. The traditional theory of the GSR analysis is based on the assumption that skin resistance varies with the state of sweat glands in the skin. Human body sweating is regulated by the Autonomic Nervous System (ANS).

In particular, if the sympathetic branch (SNS) of the autonomic nervous system is highly aroused, then sweat gland activity also increases, which in turn increases skin conductance, and viceversa. In this way, skin conductance can be a measure of the human Sympathetic Nervous System responses. Such system is directly involved in the emotional behavioural regualation in the humans.

GSR sensors

Let's get practical with some good news: The observation of electrodermal phenomena requires only very basic equipment. However, there are a few things to keep in mind when it comes to choosing the right gear and applying it correctly.

With minimal preparation times and cleanup, skin conductivity is recorded **non-invasively** using two electrodes placed on the skin. This renders GSR measurements a lot more **comfortable for respondents** compared to other neuro-methods such as fMRI or EEG, where longer preparation and calibration phases are quite common (and sometimes a true hassle).

Generally, GSR sensors have a 1 cm^2 measurement site made of Ag/AgCl (silver/silver-chloride) and are placed either in reusable snap-on Velcro straps or in a patch sticker. While the former can be applied as-is, the patch sticker requires to use conductive gel in order to improve the conductivity between skin and electrode.

GSR devices

In case you are thinking bulky equipment, think again. In fact, GSR devices are quite the opposite.

They typically consist of **two electrodes**, an **amplifier** (to boost signal amplitude), and a **digitizer** (to transfer the analog raw signal into binary data streams). Wireless GSR devices further contain data transmission modules for communication with the recording computer (using the Bluetooth protocol, for example). Principally, GSR devices offer different sensor placement options. While some devices allow arbitrary sensor placements in any of the locations we have already mentioned, other devices have GSR electrodes rigidly mounted in wristbands or elastic straps.

There is **no "one fits all" solution –** it very much depends on your research question and the specific requirements of your study which sensor to pick in order to obtain the most appropriate GSR data.

However, irrespective of which GSR sensor you go for, it is always good advice to **assess the quality of the GSR signal** in the live viewer before you start the recording.

Video Content / Details of website for further learning (if any):

Can be added as link
https://medlineplus.gov/lab-tests/erythrocyte-sedimentation-rate-esr/
https://www.brainsigns.com/en/science/s2/technologies/gsr

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 184, 314, 331

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LECTURE HANDOUTS

L 28

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **IV – Medical Imaging and Biotelemetry**

Date of Lecture:

Topic of Lecture: Radio graphic and fluoroscopic techniques

Introduction: In both radiography and fluoroscopy, there are definite advantages of having a digital image stored in a computer. This allows image processing for better displayed images, the use of lower doses, avoiding repeat radiography and opening up of the possibility of digital storage with a PACS (Picture Archieving and Communication System) or remote image viewing via tele-radiology.

Prerequisite knowledge for Complete understanding and learning of Topic:

3. X-Ray
4. Temperature measurements

Detailed content of the Lecture:

Radiographic and fluoroscopic techniques:

In both radiography and fluoroscopy, there are definite advantages of having a digital image stored in a computer. This allows image processing for better displayed images, the use of lower doses, avoiding repeat radiography and opening up of the possibility of digital storage with a PACS (Picture Archieving and Communication System) or remote image viewing via tele-radiology.

Digitally formatted images would permit digital storage, retrieval, transfer and display of X-ray images with vast possibilities of image-related processing and manipulations, as each function can be individually optimized (Schittenhelm, 1986).

Digital X-ray imaging systems consist of the following two parts:
(i) X-ray imaging transducer or data collection; and
(ii) Data display, storage and processing.

The digitally compatible X-ray imaging transducers can be divided into the following two categories:
(i) Image intensifier TV system; and
(ii) Radiographic (film replacement) systems.

The application of X-ray image intensifier TV systems in digital X-ray imaging evolved from their use in angiography. Angiography is a diagnostic and rapidly developing therapeutic modality concerned with diseases of the circulatory system. The procedure is carried out by using a contrast material to opacify vascular structures because the radiographic contrast of blood is essentially the same as that of soft tissue. Contrast material is an iodine-containing compound which is injected through a catheter (diameter ranging from 1 to 3 mm). Radiographic images of the contrast filled vessels can be viewed on a TV screen or are recorded by using either film or video.

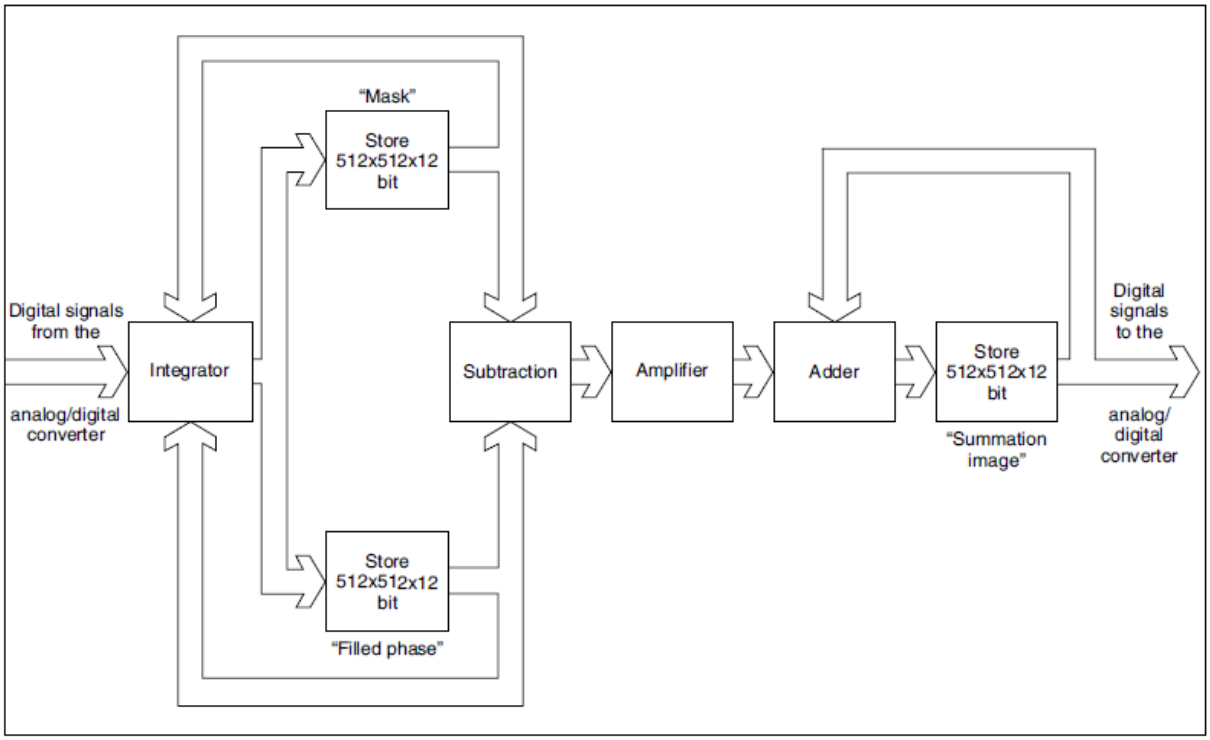

Figure shows a digital subtraction angiography system based on the use of image intensifier. The output of the video camera, which is in the analog form, is first digitized in an analog to digital converter and fed into two semiconductor memories.

Video Content / Details of website for further learning (if any):

Can be added as link
https://www.youtube.com/watch?v=ygCoqY9Zhe4
https://www.uclahealth.org/radiology/x-ray-fluoro-radiography

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 533 to 537

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LECTURE HANDOUTS

L 29

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **IV – Medical Imaging and Biotelemetry**

Date of Lecture:

Topic of Lecture: Computer tomography

Introduction: Computed tomography enabled radiologists to distinguish, for the first time, between different types of brain tissue, and even between normal and coagulated blood. With CT images, radiologists could easily visualize the ventricles of the brain and repositories of the cerebro-spinal fluid.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements
3. X-Ray

Detailed content of the Lecture:

Computer tomography:

Computed tomography enabled radiologists to distinguish, for the first time, between different types of brain tissue, and even between normal and coagulated blood. With CT images, radiologists could easily visualize the ventricles of the brain and repositories of the cerebro-spinal fluid.

The desirability of having body scanners was soon realized. The examination of the body sections, however, represents widely differing problems. Some of these problems include the movement of organs, the patient's respiratory action, the broader range of tissue densities encountered and the wide range of body sizes that have to be accommodated.

Basic Principle

Computed tomography differs from conventional X-ray techniques in that the pictures displayed are not photographs but are reconstructed from a large number of absorption profiles taken at regular angular intervals around a slice, with each profile being made up from a parallel set of absorption values through the object.

In computed tomography, X-rays from a finely collimated source are made to pass through a slice of the object or patient from a variety of directions. For directions along which the path

length through-tissue is longer, fewer X-rays are transmitted as compared to directions where there is less tissue attenuating the X-ray beam. In addition to the length of the tissue traversed, structures in the patient such as bone, may attenuate X-rays more than a similar volume of less dense soft tissue.

In principle, computed tomography involves the determination of attenuation characteristics for each small volume of tissue in the patient slice, which constitute the transmitted radiation intensity recorded from various irradiation directions. It is these calculated tissue attenuation characteristics that actually compose the CT image.

For a monochromatic X-ray beam, the tissue attenuation characteristics can be described by

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

I_o = Incident radiation intensity

I_t = Transmitted intensity

x = Thickness of tissue

μ = Characteristic attenuation coefficient of tissue

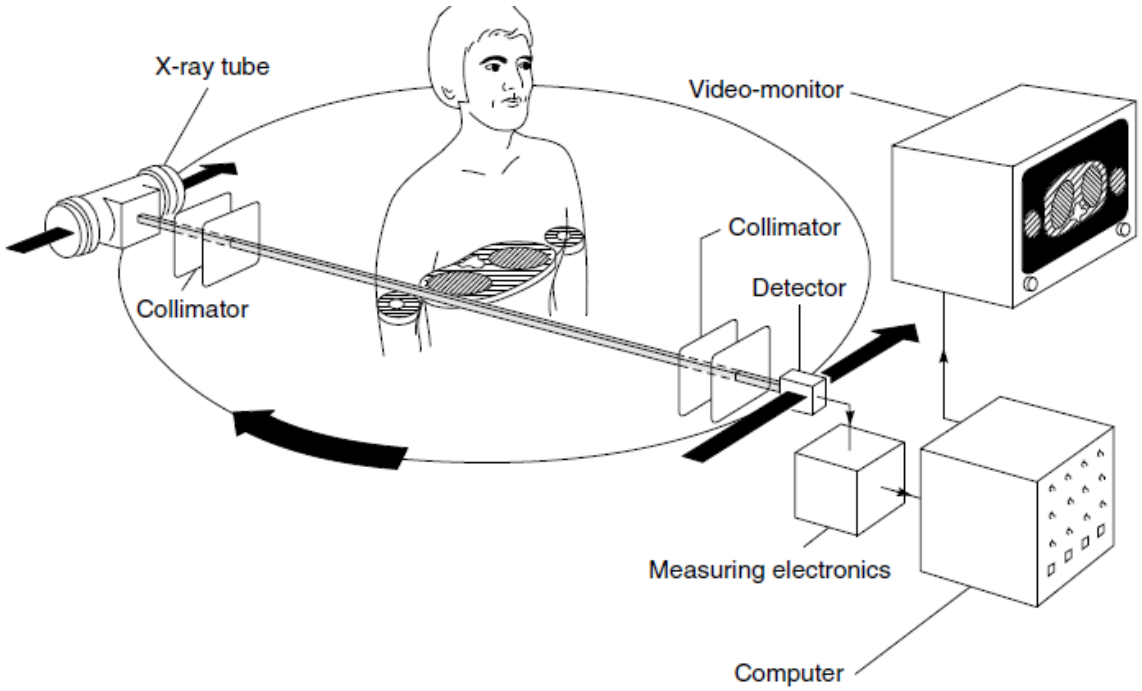

Fig. shows The technique of producing CT images. The X-ray tube and the detector are rigidly coupled to each other. The system executes translational and rotational movement and transradiates the patient from various angular projections. With the aid of collimators, pencil thin beam of X-ray is produced.

A detector converts the X-radiation into an electrical signal. Measuring electronics then amplify the electrical signals and convert them into digital values. A computer then processes these values and computes them into a matrix-line density distribution pattern which is reproduced on a video monitor as a pattern of gray shade.

Video Content / Details of website for further learning (if any):

Can be added as link

https://www.nibib.nih.gov/science-education/science-topics/computed-tomography-ct

https://radiology.ucsf.edu/patient-care/services/ct

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 538 to 545

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LECTURE HANDOUTS

L 30

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**
Course Faculty : **Dr.G.SUDHA**
Unit : **IV – Medical Imaging and Biotelemetry**
Date of Lecture:

Topic of Lecture: Magnetic Resonance Imaging

Introduction: Nuclear magnetic resonance (NMR) tomography has emerged as a powerful imaging technique in the medical field because of its high resolution capability and potential for chemical specific imaging.

Prerequisite knowledge for Complete understanding and learning of Topic:

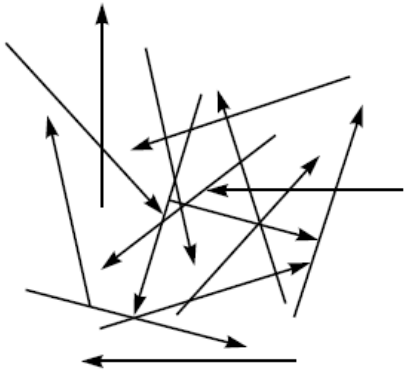
1. Basic components of a biomedical system
2. Temperature measurements
3. X-Ray,
4. Computer Tomography

Detailed content of the Lecture:

Magnetic Resonance Imaging:

Principles of NMR Imaging Systems

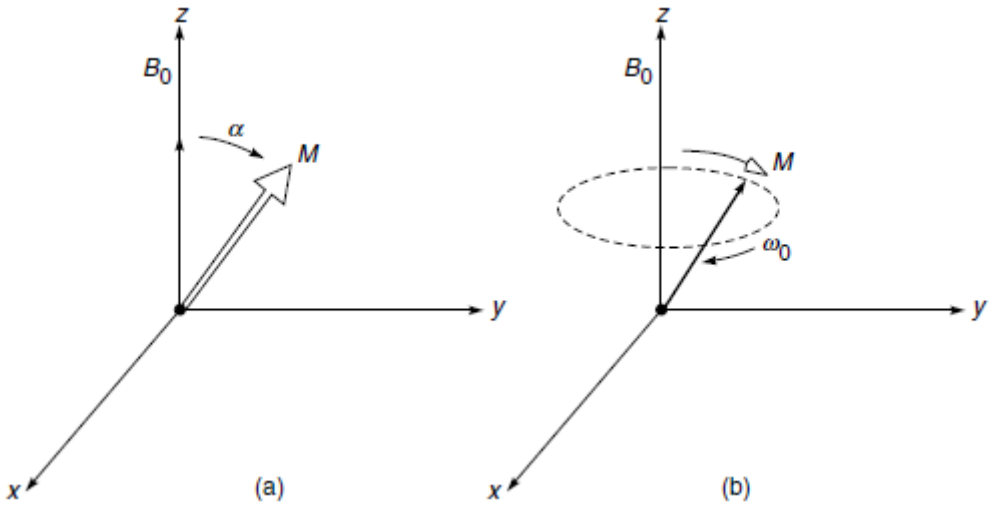
Magnetic Moment: All materials contain nuclei that are either protons or neutrons or a combination of both (Show, 1971). Nuclei containing an odd number of protons or neutrons or both in combination, possess a nuclear 'spin' and a magnetic moment which has both magnitude and direction. In body tissue or any other specimen, the magnetic moments of the nuclei making up the tissue are randomly aligned (Fig. 1) and have zero net magnetization (M = 0).



Free Induction Decay (FID): In NMR, at room temperature, there are more protons in a low energy state than in a high energy state. The excited proton tends to return or relax to its low-energy state with

spontaneous decay and re-emissions of energy at a later time 't' in the form of radio wave photons. This decay is exponential in nature and produces a "free induction decay" (FID) signal that is the fundamental form of the nuclear signal obtainable from an NMR system.

Excitation: If the material or tissue is now subjected to another magnetic field, say a bar magnet placed along the Y-axis, this would cause net magnetization to shift slightly from the Z-axis (B_0 magnetic field direction), through an angle x (Fig. 2).



(a) The magnetic moment is flipped from its equilibrium by the application of another magnetic field
(b) It then precesses about the external field direction at a high angular frequency which is proportional to the field strength

Video Content / Details of website for further learning (if any):

Can be added as link
https://www.nibib.nih.gov/science-education/science-topics/magnetic-resonance-imaging-mri
https://www.radiologyinfo.org/en/info.cfm?pg=safety-mr

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 590 to 622

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LECTURE HANDOUTS

L 31

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **IV – Medical Imaging and Biotelemetry**

Date of Lecture:

Topic of Lecture: Ultrasonography-A mode, B mode, M mode

Introduction : Ultrasonic waves are sound waves associated with frequencies above the audible range and generally extend upward from 20 kHz.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements
3. CT Scan
4. X-Ray

Detailed content of the Lecture:

Ultrasonic:

Ultrasonic waves are sound waves associated with frequencies above the audible range and generally extend upward from 20 kHz. These waves exhibit the same physical properties as the audible sound waves but they are particularly preferred in situations favoured by one or more of
the following reasons:

• Ultrasonic waves can be easily focussed, i.e., they are directional and beams can be obtained with very little spreading.

• They are inaudible and are suitable for applications where it is not advantageous to employ audible frequencies.

• By using high frequency ultrasonic waves which are associated with shorter wavelengths, it is possible to investigate the properties of very small structures. It is particularly true in the detection of defects where the wavelengths utilized should be of the same order as the dimensions of the defect.

• Information obtained by ultrasound, particularly in dynamic studies, cannot be acquired by any other more convenient technique.

A – Mode

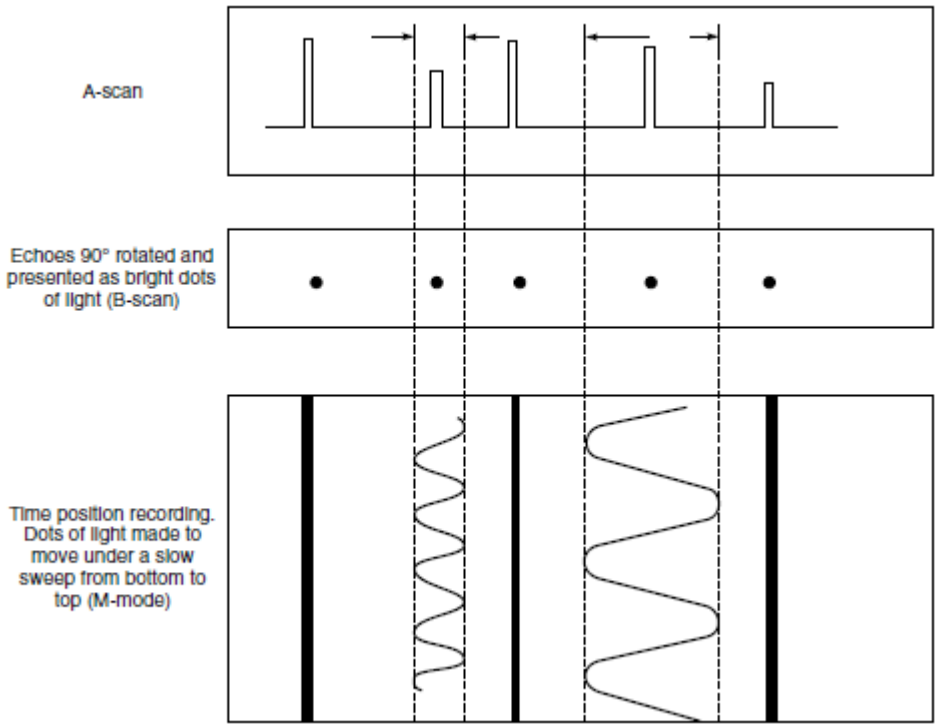
This type of scan offers only one-dimensional information. The echo signals are applied to the Y-deflecting plates of the CRT so that they are displayed as vertical blips as the beam is swept across the CRT. The height of the vertical blip corresponds to the strength of the echo and its position from left to right across the CRT face corresponds to the depth of its point of origin from the transducer.

M – Mode (Echocardiograph)

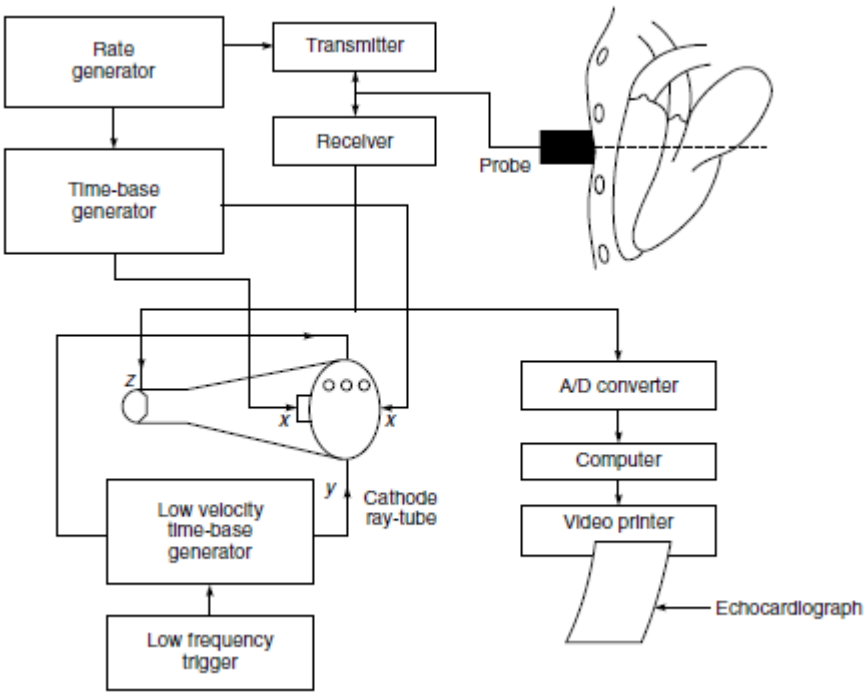
Echocardiograph is a widely used and valuable instrument for carrying out cardiac examination and assessment of many congenital and acquired cardiac diseases. By using this instrument it is possible to detect intra-cardiac structures.

When an ECG trace is super-imposed on the ultrasonic display, the movement of structures detected ultrasonically can be conveniently correlated with known events in the cardiac cycle. Phonocardiogram is also often recorded simultaneously.

The echocardiogram is currently the best method for the diagnosis of mitral stenosis. Echocardiography is also often used for the study of the aortic valve, tricuspid valve and pulmonary valve. Another very important use is in the detection of peri-cardial effusion, which is the abnormal collection of fluid between the heart and the peri-cardial sac**.**



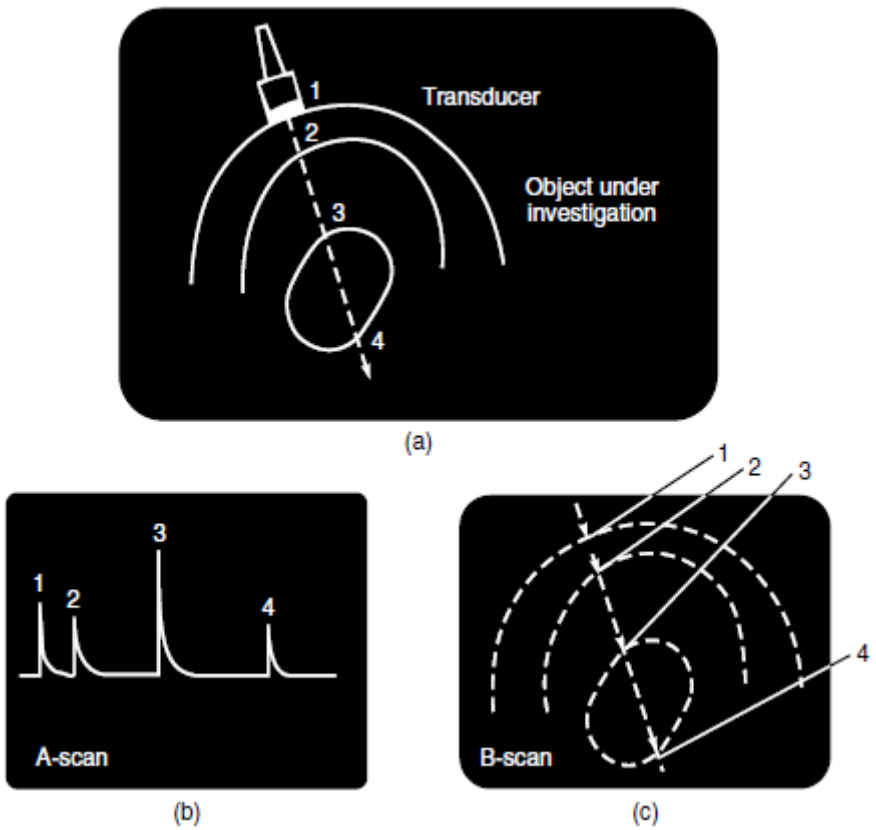
Principle of time-motion (M-mode) display



Block diagram of an echocardiograph circuit

B – Mode

A pictorial display can be conceived as a means of simultaneously presenting the echo information as well as information about the position of the probe and the direction of propagation of the sound. This is achieved in the B-scan display which results from brightness modulation with amplitude of the echoes obtained for various probe positions and orientations to produce a cross-sectional image of the object integrated by a storage display from individual scans.



Difference between A-scan and B-scan displays

The above figure represents the difference between A-scan and B-scan. Figure (a) is a hypothetical body with the probe placed upon its surface. The probe is positioned in such a way that it transmits a beam obliquely inwards. The beam encounters three interfaces in its travel.

A-scan representation of this structure consists of vertical peaks (2, 3, 4) received as echoes at the receiving crystal in response to the transmitted pulse (1). The same structure in B-scan appears as light dots whose position is related to the echoing interface within the body.

In order to record cross-sectional pictures of internal structures, the ultrasonic probe is mounted on a mechanical scanner which allows movement in two directions and which links the direction and position of a B-scope time base on a CRT to those of the ultrasonic beam within the patient.

Video Content / Details of website for further learning (if any):

Can be added as link
https://www.sciencedirect.com/topics/computer-science/ultrasound
https://www.youtube.com/watch?v=CZil8XFY9nM

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 623 to 646

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LECTURE HANDOUTS

L 32

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **IV – Medical Imaging and Biotelemetry**

Date of Lecture:

Topic of Lecture: Endoscopy

Introduction : An endoscopy is a procedure where organs inside your body are looked at using an instrument called an endoscope.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements

Detailed content of the Lecture:

Endoscopy:

An endoscopy is a procedure where organs inside your body are looked at using an instrument called an endoscope.

An endoscope is a long, thin, flexible tube that has a light and camera at one end. Images of the inside of your body are shown on a television screen.

Endoscopes can be put into the body through the mouth and down the throat, or through the bottom. An endoscope can also be put inside the body through a small cut (incision) made in the skin when keyhole surgery is being done.

When an endoscopy is used

An endoscopy can be used to:

- investigate unusual symptoms
- help perform certain types of surgery

An endoscope can also be used to remove a small sample of tissue to be looked at more closely. This is called a biopsy.

Video Content / Details of website for further learning (if any): **Can be added as link** https://www.nhs.uk/conditions/endoscopy/ https://www.nhs.uk/conditions/endoscopy/
Important Books/Journals for further learning including the page nos.: **Bio-medical Instrumentation, Anuradha Agencies, 2003, by M.Arumugam Page No: 10.12 to 10.15**

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LECTURE HANDOUTS

L 33

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **IV – Medical Imaging and Biotelemetry**

Date of Lecture:

Topic of Lecture: Thermography

Introduction : The medical thermograph is a sensitive infrared camera which presents a video image of the temperature distribution over the surface of the skin. This image enables temperature differences to be seen instantaneously, providing fairly good evidence of any abnormality.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements
3. CT
4. X-Ray
5. Endoscopy

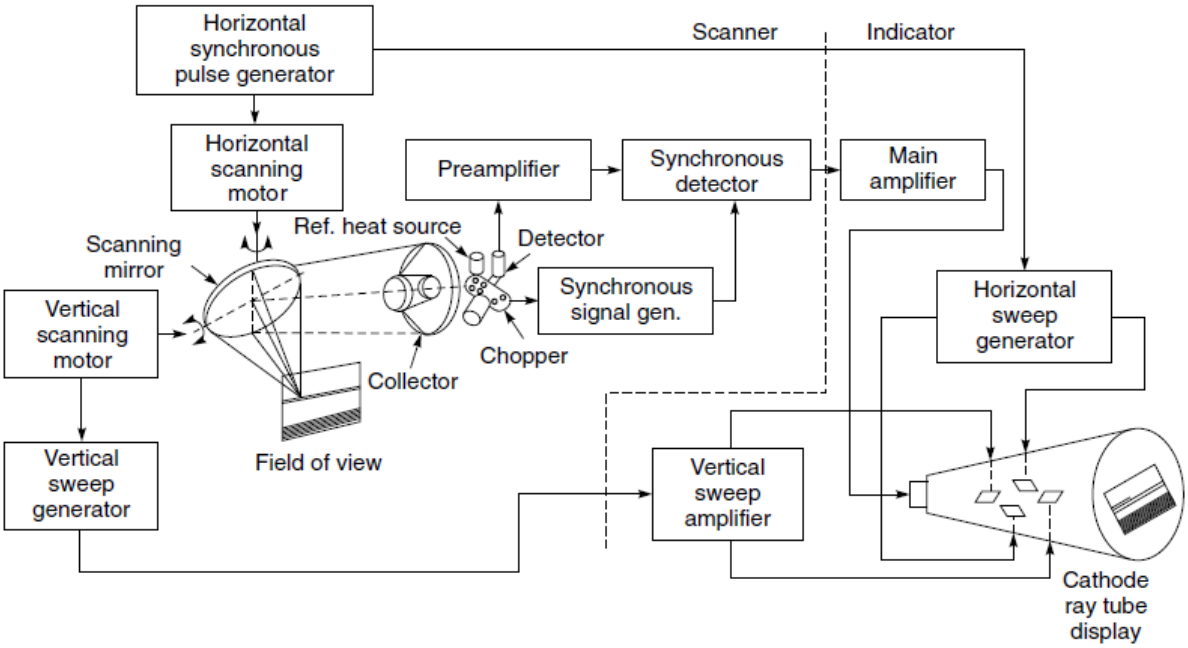
Detailed content of the Lecture:

Thermography:

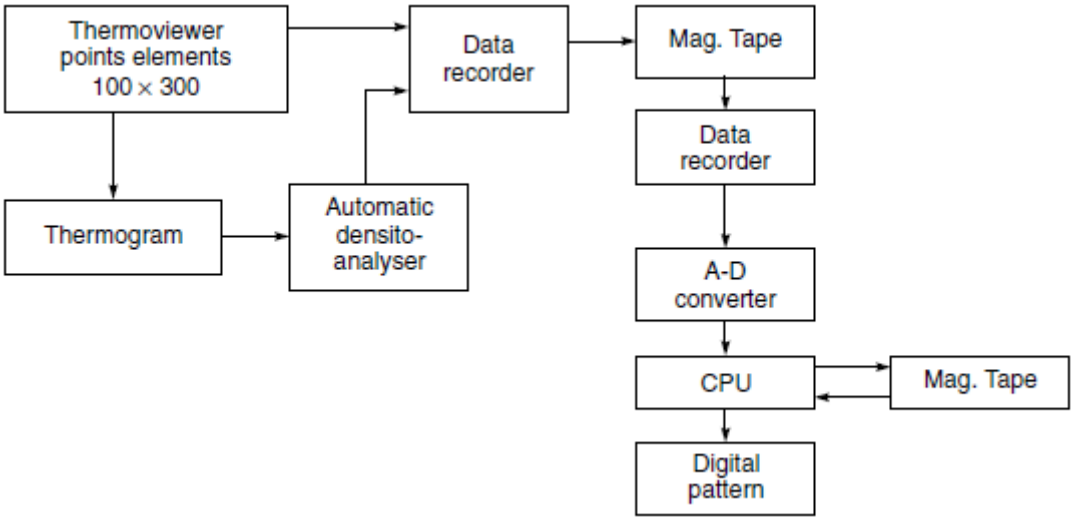
The medical thermograph is a sensitive infrared camera which presents a video image of the temperature distribution over the surface of the skin. This image enables temperature differences to be seen instantaneously, providing fairly good evidence of any abnormality.

Thermographic Equipment:

Thermographic cameras incorporate scanning systems which enable the infrared radiation emitted from the surface of the skin within the field of view to be focused on to an infrared detector. Most systems have a wide range of absolute temperature sensitivity ranging from 1 to 50°C.



Digitizing Thermal Images: A direct CRT display of a thermogram permits only about 8 shades of gray to be distinguished between black and white, and a photographic record from a CRT face provides a permanent record of only 5 or 6 shades.



Video Content / Details of website for further learning (if any):

Can be added as link
https://www.healthline.com/health/breast-cancer/thermography
https://www.youtube.com/watch?v=4xulzkBOFKI

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 670 to 684

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LECTURE HANDOUTS

L 34

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **IV – Medical Imaging and Biotelemetry**

Date of Lecture:

Topic of Lecture: Different types of biotelemetry systems and patient monitoring

Introduction : Wireless bio-telemetry has made possible the study of active subjects under conditions that so far prohibited measurements.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements
3. Modulation systems
4. CT

Detailed content of the Lecture:

Biotelemetry:

Wireless bio-telemetry has made possible the study of active subjects under conditions that so far prohibited measurements.

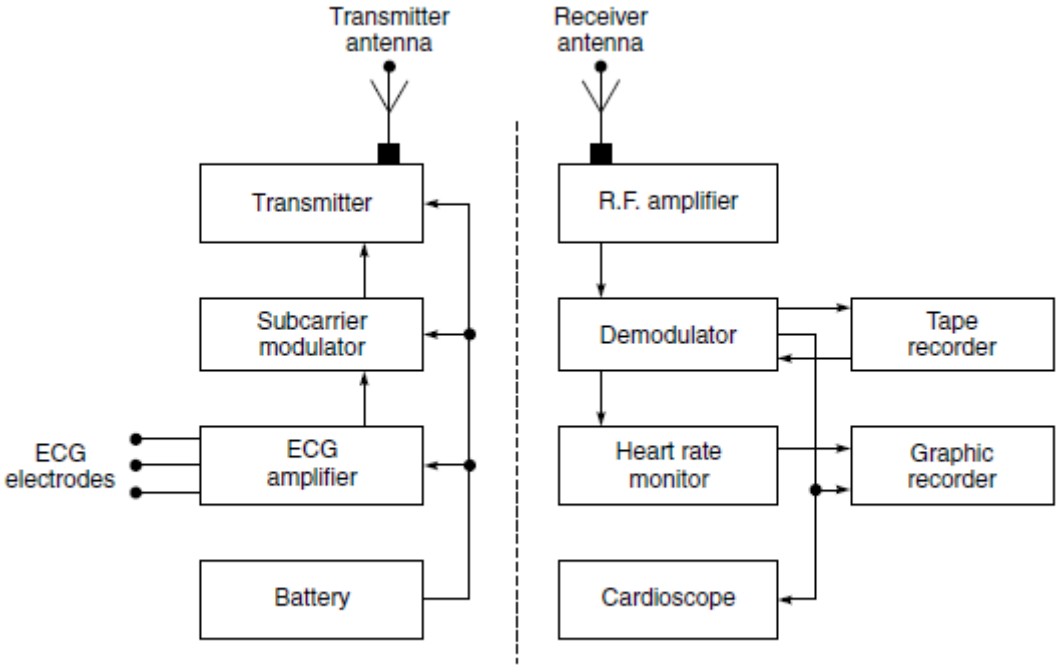
Using wireless telemetry, physiological signals can be obtained from swimmers, riders, athletes, pilots or manual labourers. Telemetric surveillance is most convenient during transportation within the hospital area as well for the continuous monitoring of patients sent to other wards or clinics for check-up or therapy.

Single channel Telemetry systems:

In a majority of the situations requiring monitoring of the patients by wireless telemetry, the parameter which is most commonly studied is the electrocardiogram. It is known that the display of the ECG and cardiac rate gives sufficient information on the loading of the cardiovascular system of the active subjects.

1. **ECG Telemetry system**
   - TheTelemetry Transmitter which consists of an ECG amplifier, a sub-carrier oscillator and a UHF transmitter along with dry cell batteries.

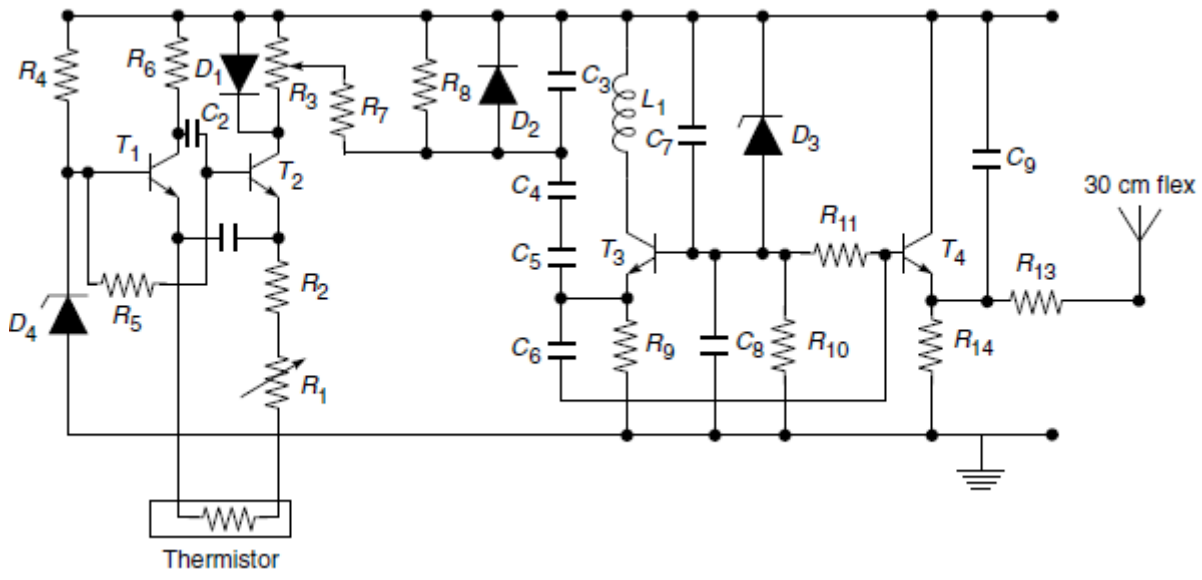
• Telemetry Receiver consists of a high frequency unit and a demodulator, to which an electrocardiograph can be connected to record, a cardioscope to display and a magnetic tape recorder to store the ECG. A heart rate meter with an alarm facility can be provided to continuously monitor the beat-to-beat heart rate of the subject.



Block diagram of a single channel telemetry system

2. Temperature Telemetry system

Systems for the transmission of alternating potentials representing such parameters as ECG, EEG and EMG are relatively easy to construct. Telemetry systems which are sufficiently stable to telemeter direct current outputs from temperature, pressure or other similar transducers continuously for long periods present greater design problems.



Multi – channel Telemetry systems:

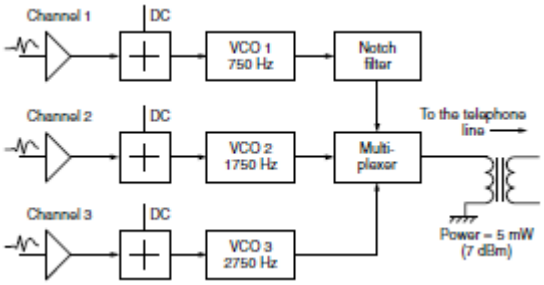
Multi-channel telemetry is particularly useful in athletic training programs as it offers the possibility of simultaneously surveying several physiological parameters of the person being

monitored.

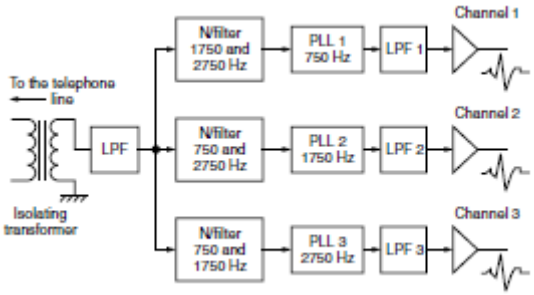
1. **Telemetry of ECG and Respiration**
2. **Obstetrical Telemetry System**
3. **Telemetry in Operating Rooms**
4. **Sports Physiology Studies through Telemetry**

Patient Monitoring:

Single and multi-channel systems for the transmission of electrocardiograms have been widely employed as remote diagnostic aids for cardiac patients recovering at home and for pacemaker performance follow up. There is however, an increasing need for multi-channel parameter monitoring, especially the simultaneous transmission of ECG, blood pressure, respiration and also temperature.



Block diagram of the three channel telephone transmitter



Block diagram of the three channel telephone receiver

Video Content / Details of website for further learning (if any):

Can be added as link
https://electricalvoice.com/biotelemetry-system/
http://www.jetmedical.com/different-types-of-patient-monitoring-systems/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 283 to 303

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LECTURE HANDOUTS

L 35

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **IV – Medical Imaging and Biotelemetry**

Date of Lecture:

Topic of Lecture: Wireless Telemetry, Single channel, Multi channel

Introduction : Wireless bio-telemetry has made possible the study of active subjects under conditions that so far prohibited measurements.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements
3. Modulation systems
4. CT

Detailed content of the Lecture:

Wireless biotelemetry:

Wireless bio-telemetry has made possible the study of active subjects under conditions that so far prohibited measurements.

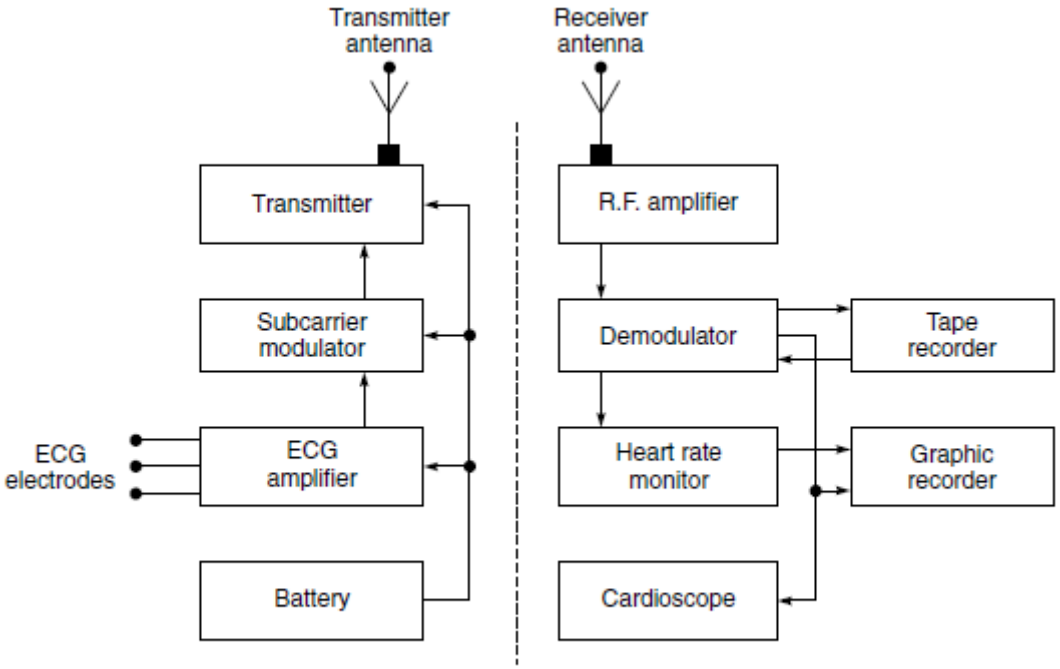
Using wireless telemetry, physiological signals can be obtained from swimmers, riders, athletes, pilots or manual labourers. Telemetric surveillance is most convenient during transportation within the hospital area as well for the continuous monitoring of patients sent to other wards or clinics for check-up or therapy.

Single channel Telemetry systems:

In a majority of the situations requiring monitoring of the patients by wireless telemetry, the parameter which is most commonly studied is the electrocardiogram. It is known that the display of the ECG and cardiac rate gives sufficient information on the loading of the cardiovascular system of the active subjects.

1. **ECG Telemetry system**
   - TheTelemetry Transmitter which consists of an ECG amplifier, a sub-carrier oscillator and a UHF transmitter along with dry cell batteries.

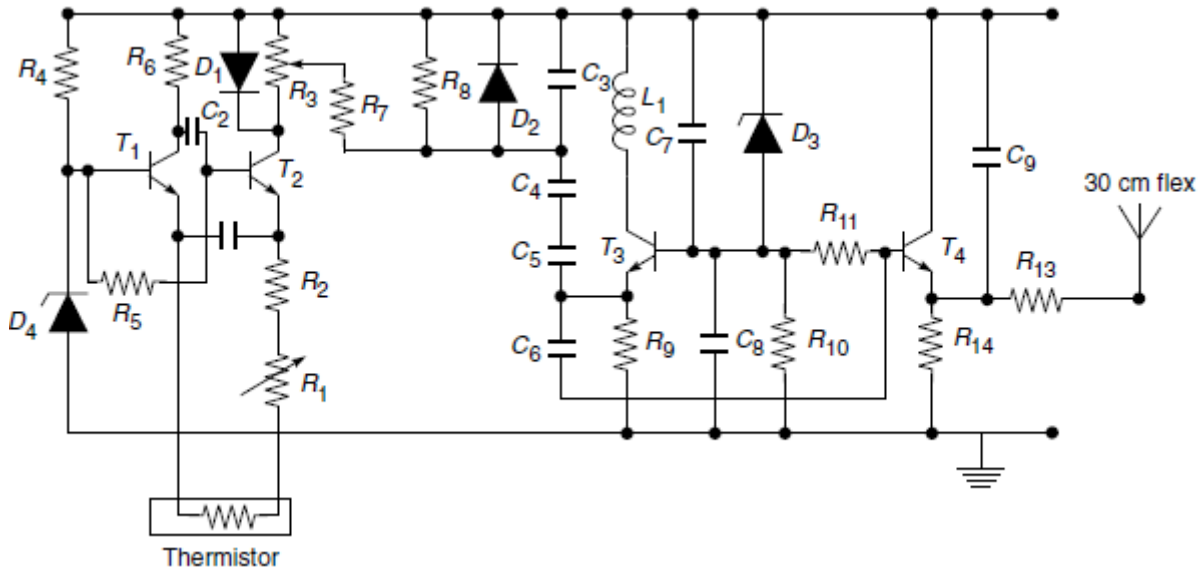
• Telemetry Receiver consists of a high frequency unit and a demodulator, to which an electrocardiograph can be connected to record, a cardioscope to display and a magnetic tape recorder to store the ECG. A heart rate meter with an alarm facility can be provided to continuously monitor the beat-to-beat heart rate of the subject.



Block diagram of a single channel telemetry system

2. Temperature Telemetry system

Systems for the transmission of alternating potentials representing such parameters as ECG, EEG and EMG are relatively easy to construct. Telemetry systems which are sufficiently stable to telemeter direct current outputs from temperature, pressure or other similar transducers continuously for long periods present greater design problems.



Multi – channel Telemetry systems:

Multi-channel telemetry is particularly useful in athletic training programs as it offers the possibility of simultaneously surveying several physiological parameters of the person being monitored.

1. **Telemetry of ECG and Respiration**
2. **Obstetrical Telemetry System**
3. **Telemetry in Operating Rooms**
4. **Sports Physiology Studies through Telemetry**

Video Content / Details of website for further learning (if any):

Can be added as link
http://www.accumetrix.com/Multi-Channel-Telemetry
https://www.brainkart.com/article/Bio-Telemetry_11874/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 283 to 296

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LECTURE HANDOUTS

L 36

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **IV – Medical Imaging and Biotelemetry**

Date of Lecture:

Topic of Lecture: Multi patient and implantable telemetry systems

Introduction : When a patient's condition has stabilized within a few days, it is necessary that he is monitored during the early stages of increased activity and exertion to determine if his heart has sufficiently recovered.

Prerequisite knowledge for Complete understanding and learning of Topic:

1. Basic components of a biomedical system
2. Temperature measurements
3. Modulation systems
4. CT

Detailed content of the Lecture:

Multi-Patient Telemetry:

The establishments of instrumented coronary care units have resulted in substantial reduction in the mortality rates of hospitalized patients. When a patient's condition has stabilized within a few days, it is necessary that he is monitored during the early stages of increased activity and exertion to determine if his heart has sufficiently recovered.

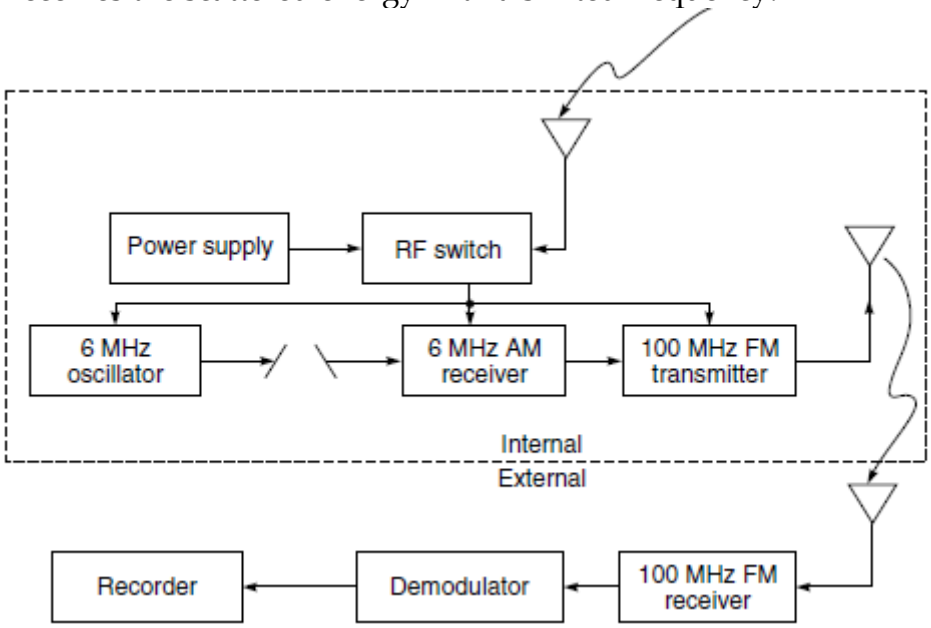
Implantable Telemetry Systems:

Implantable telemetry systems allow the measurement of multiple physiological variables over long periods of time without any attachment of wires, restraint or anaesthesia to the monitored subjects. Above all, no sensors need to be attached even to the body surface.

Most of the work in implantable telemetry has been used exclusively in animal research. Single or multi-channel systems have been used successfully to monitor ECG, EEG, blood pressure, blood flow, temperature, etc. For a multi-channel operation, a time-multiplex system is used to handle from 3 to 10 channels.

1. **Implantable Telemetry system for Blood Pressure and Blood Flow**
   In this method, blood velocity information is converted to an electrical signal by means of two ultrasonic transducers which are mounted in a rigid cuff surrounding the

vessel. One of the transducers is driven by a high frequency power source and the second receives the scattered energy with a shifted frequency.



Video Content / Details of website for further learning (if any):

Can be added as link
https://www.accessengineeringlibrary.com/content/book/9789339205430/chapter/chapter11
http://www.implantable-device.com/category/therapies/telemetry/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No: 296 to 300

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L37

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **V - Assisting and Therapeutic Equipments**

Date of Lecture:

Topic of Lecture: Pacemakers-External and internal pacemakers

Introduction :

- A **pacemaker** is a small device that's placed in the chest or abdomen to help control abnormal heart rhythms. This device uses electrical pulses to prompt the heart to beat at a normal rate.
- **Pacemakers** are used to treat arrhythmias (ah-RITH-me-ahs). Arrhythmias are problems with the rate or rhythm of the heartbeat.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Principles and operations of Therapeutic equipments

Pacemakers-External and internal pacemakers

Need For Pacemakers:

The rhythmic beating of the heart is due to the triggering pulses that originate in an area of specialized tissue in the right atrium of the heart. This area is known as the sino-atrial node. In abnormal situations, if this natural pacemaker ceases to function or becomes unreliable or if the triggering pulse does not reach the heart muscle because of blocking by the damaged tissues, the natural and normal synchronization of the heart action gets disturbed. When monitored, this manifests itself through a decrease in the heart rate and changes in the electrocardiogram (ECG) waveform. By giving external electrical stimulation impulses to the heart muscle, it is possible to regulate the heart rate. These impulses are given by an electronic instrument called a '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, and (ii) the lead which carries the electrical pulses from the pulse generator to the heart. The lead includes the termination which connects to the pulse generator and the insulated conductors, which interface with electrodes and terminate within the heart.

Types Of Pacemakers:

The classification of pacemakers into different types is based on the mode of application of the stimulating pulses to the heart. External pacemakers are used when the heart block presents as an emergency and when it is expected to be present for a short time. Internal pacemakers are used in cases requiring long-term pacing because of permanent damage that prevents normal self triggering of the heart. In the latter case, the pacemaker itself may be implanted in the body. The patient is able to move about freely and is not tied to any external apparatus.

External Pacemakers:

External pacemakers are employed to restart the normal rhythm of the heart in cases of cardiac standstill, in situations where short-term pacing is considered adequate, while the patient is in the intensive care unit or is awaiting implantation of a permanent pacemaker. Frequently, external pacemakers are used for patients recovering from cardiac surgery to correct temporary conduction disturbances resulting from the surgery.

As the patient recovers, normal conduction returns and the use of pacemakers 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 80-mA pulses through 50-cm2 electrode on the chest. This procedure is painful and therefore is used only in an emergency or a temporary situation.

Internal Pacemakers:

The implantable pacemaker, along with its electrodes, is designed to be entirely implanted beneath the skin. Its output leads are connected directly to the heart muscle . The pacemaker is a miniaturized pulse generator and is powered by small batteries. 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 a routine procedure.

Video Content / Details of website for further learning (if any):

https://youtu.be/53_jyoA47Fk

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 687-692

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L38

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **V - Assisting and Therapeutic Equipments**

Date of Lecture:

Topic of Lecture: Defibrillators-DC defibrillator, implantable defibrillators

Introduction :

The **nervous system** is a highly complex part of an animal that coordinates its actions and sensory information by transmitting signals to and from different parts of its body.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Principles and operations of Therapeutic equipments

Need for defibrillators:

Ventricular fibrillation is a serious cardiac emergency resulting from asynchronous contraction of the heart muscles. This uncoordinated movement of the ventricle walls of the heart may result from coronary occlusion, from electric shock or from abnormalities of body chemistry. Because of this irregular contraction of the muscle fibres, the ventricles simply quiver rather than pumping the blood effectively.

This results in a steep fall of cardiac output and can prove fatal if adequate steps are not taken promptly. In fibrillation, the main problem is that the heart muscle fibres are continuously stimulated by adjacent cells so that there is no synchronised succession of events that follow the heart action. Consequently, control over the normal sequence of cell action cannot be captured by ordinary stimuli.

Ventricular fibrillation can be converted into a more efficient rhythm by applying a high energy shock to the heart. This sudden surge across the heart causes all muscle fibres to contract simultaneously. Possibly, the fibres may then respond to normal physiological pacemaking pulses. The instrument for administering the shock is called a defibrillator.

DC Defibrillator:

In almost all present-day transthoracic defibrillators, an energy storage capacitor is charged (Lown et al., 1962) at a relatively slow rate (in the order of seconds) from the AC line by means of a step-up transformer and rectifier arrangement or from a battery and a DC to DC converter arrangement. During transthoracic defibrillation, the energy stored in the capacitor is then

delivered at a relatively rapid rate (in the order of milliseconds) to the chest of the subject. For effective defibrillation, it is advantageous to adopt some shaping of the discharge current pulse. The simplest arrangement involves the discharge of capacitor energy through the patient's own resistance (R). This yields an exponential discharge typical of an RC circuit.

If the discharge is truncated, so that the ratio of the duration of the shock to the time constant of decay of the exponential waveform is small, the pulse of current delivered to the chest has a nearly rectangular shape. For a somewhat larger ratio, the pulse of current appears nearly trapezoidal. Rectangular and trapezoidal waveforms have also been found to be effective in the trans-thoracic defibrillation and such waveforms have been employed in defibrillators designed for clinical use (Schuder et al. 1980).

A variable auto-transformer T1 forms the primary of a high voltage transformer T2. The output voltage of the transformer is rectified by a diode rectifier and is connected to a vacuum type high voltage change-over switch. In position A, the switch is connected to one end of an oil-filled 16 micro-farad capacitor. In this position, the capacitor charges to a voltage set by the positioning of the auto-transformer. When the shock is to be delivered to the patient, a foot switch or a push button mounted on the handle of the electrode is operated. The high voltage switch changes over to position 'B' and the capacitor is discharged across the heart through the electrodes.

Implantable Defibrillator:

The use of automatic implantable defibrillators (AID) is recommended for patients who are at high risk for ventricular fibrillation. The AID was commercially introduced by Cardiac Pacemakers (CPI), USA in 1985, following three years of clinical testing (Thomas, 1988). Once the clinical benefit of the implantable defibrillator was proven and clinically accepted, rapid developments in technology were facilitated by the use of integrated circuits to reduce the device size, while enhancing functionality of the device.

A modern implantable defibrillator is an implanted computer which stores recordings of the patient's heart signals and collects extensive therapy history and diagnostic data files to aid the physician in individualizing device behaviour for each patient. Less than 70 cc's in volume and with over 30 million transistors, these implantable devices draw less than 20 mA during years of constant monitoring of the patient's cardiac status. Additionally, the device is hermetically sealed, bio-compatible, and able to survive 500 G's over a temperature range of –30°C to 60°C (Warren et al, 1996).

These devices allow the physician to non-invasively programme the therapy rate threshold. Devices available today combine a defibrillator to deliver high energy to very fast and erratic heart rates, with a pacemaker to provide therapies to both increased and decreased heart rates. Other additions to these devices are more sophisticated algorithms for rhythm classification (Warren et al, 1996), and storage of patient's heart signals. An implantable defibrillator is continuously monitors a patient's heart rhythm. If the device detects fibrillation, the capacitors with in the device are charged up to 750 V.

The capacitors are then discharged into the heart which mostly represents a resistive load of 50 W and to bring the heart into normal rhythm. This may require delivery of more than one high energy pulse. However, most devices limit the number of high energy shocks to 4 or 5 during any single arrhythmic episode. The shock duration for efficient defibrillation is approximately 4-8 ms which results in the delivery of approximately 30 –35 J at 750 volts.

Video Content / Details of website for further learning (if any):
https://youtu.be/WJfNaEYui8Y
Important Books/Journals for further learning including the page nos.:
Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 714-722

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L39

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **V - Assisting and Therapeutic Equipments**

Date of Lecture:

Topic of Lecture: Ventilators -Nerve and muscle stimulators

Introduction :

A **ventilator** is a machine that provides mechanical ventilation by moving breathable air into and out of the lungs, to deliver breaths to a patient who is physically unable to breathe, or breathing insufficiently. Modern ventilators are computerized microprocessor-controlled machines, but patients can also be ventilated with a simple, hand-operated bag valve mask

Prerequisite knowledge for Complete understanding and learning of Topic:

- Principles and operations of Therapeutic equipments

Ventilators:

When artificial ventilation needs to be maintained for a long time, a ventilator is used. Ventilators are also used during anaesthesia and are designed to match human breathing waveform/ pattern. These are sophisticated equipment with a large number of controls which assist in maintaining proper and regulated breathing activity. For short-term or emergency use, resuscitators are employed.

These depend upon mechanical cycle operation and are generally light-weight and portable. The main function of a respirator is to ventilate the lungs in a manner as close to natural respiration as possible. Since natural inspiration is a result of negative pressure in the pleural cavity generated by the movement of the diaphragm, ventilators were initially designed to create the same effect. These ventilators are called negative-pressure ventilators.

In this design, the flow of air to the lungs is facilitated by generating a negative-pressure around the patient's thoracic cage. The negative-pressure moves the thoracic walls outward, expanding the intra-thoracic volume and dropping the pressure inside the lungs, resulting in a pressure gradient between the atmosphere and the lungs which causes the flow of atmospheric air into the lungs.

The inspiratory and expiratory phases of the respiration are controlled by cycling the pressure inside the body chamber. However, because of several engineering problems impeding the

implementation of the concept and the difficulty of accessing the patient for care and monitoring, negative pressure ventilators have not become really popular.

Nerve Stimulators:
Electrical nerve stimulation is a procedure that uses an electrical current to treat chronic pain. Peripheral nerve stimulation (PNS) and spinal cord stimulation (SCS) are two types of electrical nerve stimulation. In either, a small pulse generator sends electrical pulses to the nerves (in peripheral nerve stimulation) or to the spinal cord (in spinal cord stimulation). These pulses interfere with the nerve impulses that make you feel pain.

Nerve stimulation is done in two steps. To see if it will help your pain, your doctor will first insert a temporary electrode through the skin (percutaneously) to give the treatment a trial run. The electrode is connected to a stimulator that the patient can control. If the trial is successful, your doctor can implant a permanent stimulator under your skin. This is typically done using a local anesthetic and a sedative. The stimulator itself is implanted under the skin and the small coated wires (leads) are inserted under the skin to the point where they are either connected to nerves or inserted into the spinal canal.

Muscle stimulators:

Electrical muscle stimulation (**EMS**), also known as **neuromuscular electrical stimulation** (**NMES**) or **electromyostimulation**, is the elicitation of muscle contraction using electric impulses. EMS has received an increasing amount of attention in the last few years for many reasons: it can be utilized as a strength training tool for healthy subjects and athletes; it could be used as a rehabilitation and preventive tool for partially or totally immobilized patients; it could be utilized as a testing tool for evaluating the neural and/or muscular function in vivo; it could be used as a post-exercise recovery tool for athletes.

The impulses are generated by a device and are delivered through electrodes on the skin near to the muscles being stimulated. The electrodes are generally pads that adhere to the skin. The impulses mimic the action potential that comes from the central nervous system, causing the muscles to contract. The use of EMS has been cited by sports scientists as a complementary technique for sports training, and published research is available on the results obtained.

Video Content / Details of website for further learning (if any):

https://youtu.be/V8VIw0fk4X0

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 840-848

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L40

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **V - Assisting and Therapeutic Equipments**

Date of Lecture:

Topic of Lecture: TENS-Surgical diathermy machine

Introduction :

Transcutaneous electrical nerve stimulation (**TENS**) is a therapy that uses low voltage electrical current to provide pain relief. A **TENS** unit consists of a battery-powered device that delivers electrical impulses through electrodes placed on the surface of your skin

Prerequisite knowledge for Complete understanding and learning of Topic:

- Principles and operations of Therapeutic equipments

TENS:

Pain is man's oldest enemy and for centuries, medicine has searched for an innocuous, nondestructive, non-invasive, well-tolerated and effective way of relieving pain that is both efficient and practical. In the past few years, several workers have reported their success in using electrical impulses to block the pathways of the transmission of pain. The impulses are produced in a batterypowered pulse-generator to which a pair of electrode-tipped wires can be attached.

Applied to the skin overlying any painful area of the body, these electrodes provide continuous, mild electrical stimulation. These signals seem to jam the pain signals travelling along the nerve pathways before they can reach the brain. The result is analgesia, often for hours after stimulation ends. The pain control is explained by:

• The Gate Control Theory which suggests that by electrically stimulating sensory nerve receptors, a gate mechanism is closed in a segment of the spinal cord, preventing paincarrying messages from reaching the brain and blocking the perception of pain; and

• The Endorsphin Release Theory which suggests that electrical impulses stimulate the production of endorphin and enkaphalins in the body. These natural, morphine-like substances block pain messages from reaching the brain, in a similar fashion to conventional drug therapy, but without the danger of dependence or other side-effects.

The electrical impulses required for electrotherapy to treat the pain are provided by an instrument called TENS (Transcutaneous Electrical Nerve Stimulator). Investigations on a great variety of electrical impulse parameters have indicated that two waveforms, the square wave and the spike wave are optimally and equally effective in relieving pain. Most stimulators feature

adjustable settings to control the amplitude (intensity) of stimulation by controlling voltage, current and the width (duration) of each pulse. Electrodes are placed at specific sites on the body for treatment of pain. The current travels through the electrodes and into the skin stimulating specific nerve pathways to produce a tingling or massaging sensation that reduces the perception of pain.

Typically, the stimulator is based around a 500 ms spike pulse, having an adjustable amplitude of 0 to 75 mA and an adjustable frequency of 12 to 100 pulses per second. Instruments having similar specifications except that they produce square waveform, have a pulse frequency range of 20–200 Hz, pulse width from 0.1 to 1.0 ms and pulse amplitude of 0–120 V with maximum output current as 25 mA.

The instrument powered by three standard flashlight batteries of 1.5 V each gives about 100 hours of continuous operation. Transcutaneous or skin surface application of electrical stimulus is accomplished by application of the conducting pads to various triggerzone areas, acupuncture sites or even peripheral nerves. Skin irritation at the site of electrode application is diminished by the use of carbonized rubber electrodes applied with a tincture of Benzoin interface.

The skin electrode system must be designed so as to minimize impedance variations with motion, to conform to the body surface to provide uniform impedance across the surface of the electrode and to have an adequate surface area.

The adequate surface area can be determined keeping in view the peak square-wave current at the threshold of thermal damage as a function of the electrode surface area. The thermal damage threshold varies widely with skin impedance, which is a function of skin preparation.

Transcutaneous electrical nerve stimulation (TENS) electrodes are commonly moulded from an elastomer such as silicon rubber, loaded with carbon particles to provide conductance. Conformability is achieved by making the electrode thin. Useful carbon-loaded silicon rubbers have a minimum resistivity near 10 W cm.

A thin electrode may exhibit an impedance which is not negligible as compared to the impedance of the interface and tissue under it. Thus, the design of an electrode with the required conformability and current distributing properties becomes a compromise in electrode geometry and material properties. The frequency-dependence of the electrode performance also has to be considered since the impedance between the electrode and subcutaneous contains capacitance.

Surgical Diathermy :

The term ‘diathermy’ means ‘through heating’ or producing deep heating directly in the tissues of the body. Externally applied sources of heat like hot towels, infrared lamps and electric heating pads often produce discomfort and skin burns long before adequate heat has penetrated to the deeper tissues. But with the diathermy technique, the subject’s body becomes a part of the electrical circuit and the heat is produced within the body and not transferred through the skin (Yang and Wang, 1979).

Basically, a surgical diathermy machine consists of a high frequency power oscillator. The earlier types of diathermy machines consisted of spark-gap oscillators whereas the current practice is to use thermionic valves or solid-state oscillators. A majority of the earlier units have access to both these power sources, viz. an RF generator and a spark-gap generator. The RF generator provides an un damped high frequency current (typically 1.75 MHz) which is suitable for making clean cuttings.

The spark-gap generator produces damped high frequency current which is specifically suitable for the coagulation of all kinds of tissues. The mixing of both these currents signifies one of the

most important possibilities for use in electro-surgery. By blending the currents of the tube and spark-gap generator, the degree of coagulation of wound edges may be chosen according to the requirements.

Video Content / Details of website for further learning (if any):

https://youtu.be/zNBVQPvlX6g

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No :779-780,731-732

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L41

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **V - Assisting and Therapeutic Equipments**

Date of Lecture:

Topic of Lecture: Safety aspects in Electro surgical units

Introduction :

The risks associated with electro-surgery fall into four main categories viz. burns, electrical interference with the heart muscles (ventricular fibrillation), the danger of explosions caused by sparks and electrical interference with pacemakers and other medical electronic equipment

Prerequisite knowledge for Complete understanding and learning of Topic:

- Principles and operations of Therapeutic equipments

Safety Aspects in Electro surgical Units:

Burns:The predominant hazard associated with electro-surgical units is burns caused by excess current density at a rate other than that at which it is meant to be present. The burn usually occurs at the dispersive electrode because of failure to achieve adequate contact. The injury can also occur because an unintended current pathway may be created. In the latter case, the lesion usually occurs at a point where the patient is inadvertently touching a grounded object and contact is made over a small area of skin. The risk of burns also exists in the presence of moisture, i.e., the accumulation of prepping agents, blood or other fluids around the indifferent electrode can give rise to small, highly conductive areas. Burns resulting from small conductive areas between the limbs can be prevented by means of dry cloth placed between them. During surgery, the output power of the electro-surgical unit should not be increased if the desired surgical effect is not obtained.

Abnormal power settings indicate that something is wrong and that the fault must be identified. In particular, the indifferent electrode and all cables and connectors should be thoroughly checked. It is advisable to carry out surgical work with the power setting as low as possible, to reduce the risk of burns. Besides this, the active electrode, when not in use, should be placed well clear of the patient. This is to avoid its activation in case the foot switch is inadvertently pressed. High Frequency Current Hazards: Another serious hazard associated with the use of surgical diathermy machines is the possible electrocution of the patient from faulty mains operated equipment, when one side of an electrical circuit is connected to earth.

In order to provide protection against mains current electrocution, a capacitor (RF earthed) is generally included between the indifferent lead and earth. The output configuration plays an

important role in the RF current circuit. There are three technical approaches. In the earthed output system, the indifferent electrode is connected conductively to protective earth .

The earth referenced system uses a capacitor to connect the indifferent electrode to earth .In the isolated system, the return electrode is floating, i.e., there is no intentional connection to earth . The value of the capacitor is such that while providing a very low impedance to the high frequency diathermy current, it offers a higher impedance to the mains frequency.

This approach also offers only a partial solution to a complex problem. Modern solid-state machines usually have RF isolated patient circuits. This implies that ideally RF current may take only one path, i.e. from active electrode through the patient to the indifferent electrode. Since there is no earth connection, there is no propensity for the RF current to take any earth pathways which may unintentionally develop.

However, due to RF leakage pathways inherent in the equipment and leads, no machine can be considered as completely isolated. The degree of RF leakage current is thus a measure of the degree of isolation of a particular machine. The lower the leakage current, the better the isolation. With the current technology, RF leakage figures of around 100 mA are generally achieved.

Video Content / Details of website for further learning (if any):

https://youtu.be/AgwE6MHCuZU

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 739-740

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L42

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **V - Assisting and Therapeutic Equipments**

Date of Lecture:

Topic of Lecture: Heart Lung machine

Introduction :

A Cardiopulmonary bypass (CPB) is a technique in which a machine temporarily takes over the function of the heart and lungs during surgery, maintaining the circulation of blood and the oxygen content of the patient's body

Prerequisite knowledge for Complete understanding and learning of Topic:

- Principles and operations of Therapeutic equipments

The CPB pump itself is often referred to as a heart–lung machine or "the pump". Cardiopulmonary bypass pumps are operated by perfusionists. CPB is a form of extracorporeal circulation. Extracorporeal membrane oxygenation is generally used for longer-term treatment.

CPB mechanically circulates and oxygenates blood for the body while bypassing the heart and lungs. It uses a heart–lung machine to maintain perfusion to other body organs and tissues while the surgeon works in a bloodless surgical field. The surgeon places a cannula in the right atrium, vena cava, or femoral vein to withdraw blood from the body. Venous blood is removed from the body by the cannula and then filtered, cooled or warmed, and oxygenated before it is returned to the body by a mechanical pump. The cannula used to return oxygenated blood is usually inserted in the ascending aorta, but it may be inserted in the femoral artery, axillary artery, or brachiocephalic artery (among others).

The patient is administered heparin to prevent clotting, and protamine sulfate is given after to reverse effects of heparin. During the procedure, hypothermia may be maintained; body temperature is usually kept at 28 °C to 32 °C (82.4–89.6 °F). The blood is cooled during CPB and returned to the body. The cooled blood slows the body's basal metabolic rate, decreasing its demand for oxygen. Cooled blood usually has a higher viscosity, but the crystalloid solution used to prime the bypass tubing dilutes the blood.

USES:

Cardiopulmonary bypass is commonly used in operations involving the heart. The technique allows the surgical team to oxygenate and circulate the patient's blood, thus allowing the surgeon

to operate on the heart In many operations, such as coronary artery bypass grafting (CABG), the heart is arrested (i.e., stopped) because of the difficulty of operating on the beating heart. Operations requiring the opening of the chambers of the heart, for example, mitral valve repair or replacement, requires the use of CPB to avoid engulfing air systemically and to provide a bloodless field to increase visibility for the surgeon. The machine pumps the blood and, using an oxygenator, allows red blood cells to pick up oxygen, as well as allowing carbon dioxide levels to decrease.[3] This mimics the function of the heart and the lungs, respectively.

CPB can be used for the induction of total body hypothermia, a state in which the body can be maintained for up to 45 minutes without perfusion (blood flow).[1] If blood flow is stopped at normal body temperature, permanent brain damage normally occurs in three to four minutes – death may follow shortly afterward. Similarly, CPB can be used to rewarm individuals suffering from hypothermia. This rewarming method of using CPB is successful if the core temperature of the patient is above 16 °C.

Extracorporeal membrane oxygenation (ECMO) is a simplified version of the heart lung machine that includes a centrifugal pump and an oxygenator to temporarily take over the function of heart and/or the lungs. ECMO is useful in post cardiac surgery patients with cardiac or pulmonary dysfunction, in patients with acute pulmonary failure, massive pulmonary embolisms, lung trauma from infections, and a range of other problems that impair cardiac or pulmonary function. ECMO gives the heart and/or lungs time to repair or recover but it's only a temporary solution. Patients with terminal conditions, cancer, severe nervous system damage, uncontrolled sepsis and other conditions may not be candidates for ECMO.

Video Content / Details of website for further learning (if any):

https://youtu.be/Cp59BCMVHHc

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 747

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L43

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **V - Assisting and Therapeutic Equipments**

Date of Lecture:

Topic of Lecture: Audiometers

Introduction :

An audiometer is a 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.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Principles and operations of Therapeutic equipments

Audiometers

Audiometers may be divided into two main groups on the basis of the type of stimulus they provide to elicit auditory response: pure-tone audiometers and speech audiometers. A pure-tone audiometer is used primarily to obtain air-conduction and bone-conduction thresholds of hearing.

These thresholds are helpful in the diagnosis of hearing loss. Pure-tone screening tests are employed extensively in industrial and school hearing conservation programmes. Speech audiometers are normally used to determine speech reception thresholds for diagnostic purposes and to assess and evaluate the performance of hearing aids.

Screening audiometers are used to separate two groups of people. One that can hear as well as or better than a particular standard and the other that cannot hear so well. Applications of these instruments are found in industry, schools and military service. An important application of audiometers is in industry. They help to assess the hearing function of personnel at different stages of their detection of changes in auditory acuity, identify noise susceptible persons and evaluate the effectiveness of ear protectors and noise control measures.

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. If it does, then the disorder is most likely wholly or partly

conductive in 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 centred on the pure-tone test frequency or a wide-band white noise is used for this purpose. The problem of how to recognize the need for masking and then applying the correct intensity poses a considerable difficulty.

General Requirements for audiometer:

Modern audiometers are solid-state instruments covering a frequency range from approximately 100 to 10,000 Hz. Some instruments produce this range in discrete octave or semi-octave steps or intervals, while others provide for continuously variable frequency over their designed range. The frequency must remain sensibly constant at a value within 1–3% of the indicated value. Where automatic recording facilities include a continuous sweep frequency, the rate of change is normally kept as one octave per minute.

If an automatic recording audiometer provides fixed frequencies, then a minimum period of 30 s must be allowed at each frequency. The test frequencies should have sufficient purity of tone or approximation to the ideal sine wave form to ensure response only to the desired fundamental frequency. The maximum harmonic distortion in pure-tone air conduction audiometry is specified as 2% for the second and third harmonic and much less at higher order harmonics. The total harmonic distortion should not be more than 3%. The intensity range of most audiometers starts from approximately 15 dB above normal to 95 dB below normal over a frequency range from approximately 500 to 4000 Hz. The intensity range is somewhat less for frequencies below 500 Hz and above 4000 Hz.

For example, the threshold of feeling is stimulated at an intensity level approximately 120 dB above the normal threshold of audibility from about 500 to 4000 Hz, but at 64 Hz the threshold of feeling is stimulated by sound pressures approximately 65 dB above the normal threshold value. The attenuation dials on the audiometers provide variable intensity or volume controls. They are calibrated in decibels usually in discrete steps, which differ by 5 dB in intensity from step to step.

Auditory acuity for each frequency is thus measured in dB above or below the normal hearingzero dB reference level for that frequency. This level is the minimal intensity at which each given frequency can be perceived by the normal ear in a noise free environment and is experimentally determined by averaging the results of measurement on a large number of normal individuals between 18 and 25 years of age.

Audiometers usually have two channels with single pure-tone generators. The first channel has pure-tone or speech output while the second channel has nominal masking. The pure-tone and speech can be switched to both channels for special tests. Channel two can have either wide or narrow-band masking. Each channel has an accurate independent attenuator output and the transducers are switched to each attenuator as required.

Video Content / Details of website for further learning (if any):
https://youtu.be/8G7m5vHa1_E

Important Books/Journals for further learning including the page nos.:
Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 469-472

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L44

LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **V - Assisting and Therapeutic Equipments**

Date of Lecture:

Topic of Lecture: Dialyzers

Introduction :

The dialyzer is the part in the artificial kidney system in which the treatment actually takes place and where the blood is freed from the waste products. It is the meeting point of two circuits, one in which the blood circulates and the other in which dialysis fluid flows.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Principles and operations of Therapeutic equipments

Dialyzers:

Intermittent treatment with a mechanical device like the artificial kidney (dialyzer) will reduce the accumulation of waste products and water and thus the blood concentrations of the toxic substances are returned to normal levels. By effectively removing these materials from the blood, the dialyzer temporarily replaces the function of the natural kidneys and is able to keep the patient close to normal condition.

Essentially, an artificial kidney is a dialyzing unit which operates outside the patient's own body. It receives the patient's blood from the cannulated artery via a plastic tubing. The dialysate is an electrolyte solution of suitable composition and the dialysis takes place across a membrane of cellophane. The return of the dialyzed blood is by another plastic tube to an appropriate vein. The dialyzing membrane has perforations which are extremely small and are invisible to the naked eye. Waste products in the blood are able to pass through these minute perforations into the dialysate fluid from where they are immediately washed away.

The perforations in the dialysis membrane have an average diameter of 50 Å with an estimated range of 30 Å to 90 Å . The waste products pass through the membrane because of the existence of a concentration gradient across the membrane. The dialysate fluid is free of waste product molecules and, therefore, those in the blood would tend to distribute themselves evenly throughout the blood and the dialysate. This movement of waste product molecules from the blood to the dialysate results in cleaning of the blood.

The volume of body fluid cannot be controlled by dialysis. Instead, ultra-filtration across the

membrane is employed. For this, a positive pressure is applied to the blood compartment or a negative pressure established in the dialysate compartment. Either way, fluid—both water and electrolytes—will move from the blood compartment to the dialysate, which is subsequently discarded.

The degree of ultra-filtration depends both on the pressure difference across the membrane and the ultra-filtration characteristics of the membrane. The artificial kidney is thus simply a membrane separation device that serves as a mass exchanger during clinical use. It is unable to perform any of the synthetic or metabolic functions of the normal kidney and, therefore, cannot correct abnormalities that result from the loss of these functions.

The only use of the artificial kidney in replacing renal function, therefore, is the transfer of noxious substances from the blood to the dialysate, so that they might be eliminated from the body. The physical processes by which solutes move across the dialysis membrane are discussed by Henderson (1976). The application of repeated dialysis as a definitive treatment of the permanent loss of kidney function requires a simple method for obtaining repeated access to the patient's circulation over a period of years. This is achieved either by the Scribner Teflon-Silastic arterio-venous shunt or by using a subcutaneous arterio-venous fistula, surgically created by anastomosis of the radial artery to an adjacent branch of the cephalic vein in the forearm.

The fistula can then be used for dialysis by insertion of wide-bore needles through the skin into the veins. The fistulas have proved to be essentially non-clotting, rarely become infected and help to keep the patient free from an external device between dialyses. The maximum number of dialyses are performed for the treatment of chronic renal failure. This is maintenance dialysis, replacing the excretory functions of the kidney for the duration of the patient's life, or until he receives a transplant. Acute renal failure is the next major indication. Dialysis for acute renal failure is necessarily undertaken only for a few days or weeks until the patient's own kidneys recover.

Dialyzers, in routine clinical use, may be classified according to three basic design considerations: coil, parallel plate and hollow fibre type. Each type of dialyzer has certain optimum operating requirements. The rate of clearance of substances such as urea, creatinine, etc. from the blood during passage through an artificial kidney is dependent upon the rate of the blood flow. As the flow rate falls, there is a disproportionate fall in clearance. At high flow rates, there is little advantage in further augmentation of the blood flow. The rate and pattern of the dialysate flow also influence overall performance in respect of clearance of waste products. Almost all commercial dialyzers use cellulosic type membranes, the most common being Cuprophan (cupro-ammonium regenerated cellulose).

The removal of waste products during dialysis is proportional to the concentration gradient across the membrane. In order to effect the maximum gradient, the concentration of waste products in the dialysate should be maintained at zero. This is achieved in most currently employed machines by using the dialysate only once and then discarding it. In addition, counter-current flow through the artificial kidney is used so that the dialysate enters the kidney at the blood exit-end where blood concentration of waste products is at the lowest level.

It is desirable for the resistance to blood flow in the dialyzer to be as low as possible, eliminating the need to employ a blood pump. In addition, the design of the blood compartment should be such that all the blood can be easily and completely returned to the patient at the end of dialysis. The design must effect an optimum, thin film of blood going through the dialyzer without streaming under perfused areas of membrane surface. Similarly, there must be optimum mixing in the dialysate compartment, effected via the membrane support structure.

Video Content / Details of website for further learning (if any):
https://youtu.be/Yq6TrHJDO2A
Important Books/Journals for further learning including the page nos.:
Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 788-790

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MUTHAYAMMAL ENGINEERING COLLEGE

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LECTURE HANDOUTS

BME

IV/VII/A

Course Name with Code : **BIO MEDICAL ENGINEERING & 16BME04**

Course Faculty : **Dr.G.SUDHA**

Unit : **V - Assisting and Therapeutic Equipments**

Date of Lecture:

Topic of Lecture: Lithotripsy

Introduction :

Lithotripsy is a procedure that uses shock waves to break up stones in the kidney and parts of the ureter (tube that carries urine from your kidneys to your bladder). After the procedure, the tiny pieces of stones pass out of your body in your urine.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Principles and operations of Therapeutic equipments

Lithotripsy :

Stone diseases of the urinary and biliary tract are rather common. They can cause very intense pain and may ultimately lead to renal failure through infection of the urinary tract. Many forms of treatment have been tried with surgery and interventional techniques, greatly increasing the success of treatment and reducing the risks in the process.

Surgery is resorted to when stones are unlikely to pass out and when infection and pain cannot be controlled. The form of surgical intervention choosen would depend upon the type, size and site of the stone. The search for less invasive and more efficient methods has concentrated on the use of mechanical and acoustic energy for the destruction of concrement and has resulted in the establishment of various forms of lithotripsy (Greek for “stone grinding”).

The first machine from Dornier medical systems, pioneers in the field of lithotripsy consists of a large tub of warm water with the underwater electrode (spark plug) in the ellipsoidal reflector at the base of the tub. The water provides an acoustic coupling to the patient so that acoustic waves generated in the water penetrate the tissue and are not reflected from the skin. Since a single acoustic wave generated by the lithotriptor is of high amplitude compared with those used in normal medical diagnostic ultrasound, it propagates in a characteristic way.

The shock-wave is produced when an electrical discharge occurs between two electrodes in water

The energy deposited in the water from the electrical discharge produces a bubble of very hot, rapidly expanding plasma which subsequently collapses after emitting a shock-wave. This wave, which expands out from the electrode gap, is focused using a hollow, hemi-ellipsoidal brass reflector. Since an ellipse has two foci, a spherical wave initiated at one of the foci will be focused after reflection at the second.

The point of shock-wave generation is at point P1 of an ellipsoid, half of which constitutes the reflector at the base of the water bath tub. Through the focusing of the shockwaves, the energy is concentrated at the second focus P2 of the ellipsoid, where the volume of the shock-wave energy corresponds to that of a fingertip, approximately 15mm3. In the Dornier machine, this point is about 15 cm above the upper edge of the ellipsoid. The patient is moved, partially submerged in the bath tub, on a hydraulically operated gantry until the stone is accurately positioned at the second focus of the ellipsoid by using bi-planar fluoroscopy.

The positioning system of the Dornier lithotripter uses two independent X-ray systems with separate axes. The orthogonal X-ray beams, from X-ray tubes positioned under the bath tub, are viewed by two image intensifiers, resting on the patient's lower abdomen, and the resulting images are displayed on two monitors. The crossing point of the X-ray beam axes is the second focus of the shock-wave reflector, the stone is correctly centred when it appears at the same position on both monitors which is indicated by cross-wires of each X-ray system.

The stone is possibly broken up by stress and shear forces generated in it by a series of shockwaves, though other mechanisms may also be involved including a phenomenon known as 'cavitation'. Kidney stones can generally support a compression stress up to about 8 MPa (megapascal) and a tensile stress up to about 0.6 MPa.

The peak positive pressure (compression) in water due to a single shock-wave has been measured at around 40 MPa at the focus. This is followed rapidly, in about 5 seconds, by a peak negative pressure (de-compression) of approximately 10 MPa. Although it is not possible to measure the pressures in tissue, yet it is expected that these peak pressures will be at least 50% smaller due to the attenuation of the wave produced by the tissue.

It is therefore likely that part of the stone will be fragmented by compression as the wave enters the stone. Pressure waves of less than about 8 MPa will be able to travel in the stone and may subsequently be internally reflected on meeting an interface between stone and tissue.

A reflection of this type leads to tension within the stone and its consequent fragmentation. The size of fragments resulting from internal reflections is closely related to the decay constant of the pressure waveform; the fragments being smaller for a faster fall-off in pressure after the peak pressure. An internally reflected wave of peak positive pressure, 8 MPa, with an exponential pressure decay with a time constant of 2 ms, will give fragments of the order of 1 mm in thickness.

It is possible to estimate the velocity of the fragments due to the same pressure waveform and this is found to be of the order of 1 m/s. Clearly, there may be some advantage in keeping the time constant of the pressure waveform small (<2 ms) to reduce both the energy and size of stone fragments. It is possible that considerably smaller peak pressures may be useful in breaking up the stone simply by tension produced in the stone by internal reflection of a suitable pressure

wave, though this would probably require the use of multiple shock-waves.

Extracorporeal shock wave lithotripsy (ESWL) is the most common type of lithotripsy. "Extracorporeal" means outside the body. High-energy shock waves, also called sound waves, guided by x-ray or ultrasound, will pass through your body until they hit the kidney stones. If you are awake, you may feel a tapping feeling when this starts. The waves break the stones into tiny pieces.

The lithotripsy procedure should take about 45 minutes to 1 hour.

A tube called a stent may be placed through your back or bladder into your kidney. This tube will drain urine from your kidney until all the small pieces of stone pass out of your body. This may be done before or after your lithotripsy treatment.

Video Content / Details of website for further learning (if any):

https://youtu.be/3KnPA4k9jo4

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 811-817

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