BIO MEDICAL ENGINEERING

1.INTRODUCTION TO BIO MEDICAL ENGINEERING

Development

During 1951-60,many instrument manufacturersentered the fieldof medicalinstrumentation.But development was slow due tohighcostsof development. Thehospitalstaffs wasreluctant to use new equipment. Many times, the medical staff was uncooperative. In view ofthis,someprogressive companies decided to design instrumentationspecifically formedical use insteadofmodifyingtheexistinghardware.

Help was provided by the US government, inparticularbyNASA. Alarge number of physiological parametersneededto be monitored for the

astronauts. Hence,aerospacemedicine programmes were expanded considerably, bothwithinNASAfacilities, and throughgrantstoUniversities andhospital research units.Someof the concepts and features of patient-monitoring systems presently used in hospitals all over the worldis based on astronaut monitoringsystem.Inshort,the engineers and technicians started workingwith medical professionals.

, The biomedical engineering involves communication betweentheengineer andthemedical professional. The language ofthephysician is quite different from thoseof the engineer. The physician must understand enough engineering terminologrforhim todiscuss problems withthe engineer. Theburdenofbridgingthecommunication gapfalls ontheengineer. Theresult isthatthe engineer,mustlearnthedoctor'slanguage, as wellas some anatomyandphysiologr,inorderthatthe two disciplinescan work effectively together.

MAN Instrumentation system

The most indispensable components of Man Instrument system are as follows:

Subject: Subject is the human being on which the measurement is carried out.

Stimulus: In many measurement, the response to some form of external stimulus is required. The instrumentation used to generate and present this stimulus to the subject is a vital part of the man instrument system. The stimulus may be visual (e.g. a flash of light), auditory (e.g. a tone), or direct electrical stimulation of some part of nervous system.

1. Bio-Sensors/Transducers:A bio-sensor is a device that uses a living-organism or biological molecules, especially enzymes or antibodies to detect the presence of chemicals. In man instrument system, ecah transducer is used to produce an electric signal that is an analog of the phenomena being measured. A transducer may measure temperature, pressure or any other variable found in the body but the output is always an electric signal.

2. AMP(Signal Conditioner):It amplifies, modifies the signal obtained from transducer into a suitable form that can be easy to understand and process by the rest of the devices that follows.
3. Display Monitor:It is used to display the result we obatin form the process. Its output is some form of visual, audible or tactile information.
4. Data Processor:It performs the required operation on data.
5. Recorder:It is used to record the signal for possible later use or to transmit it from one location to another, wether across the hall of the hospital or half way around the world.
6. Control feedback:It is used to give feedback to the system for obtaining efficient output.

Block Diagram Of Man Instrument System

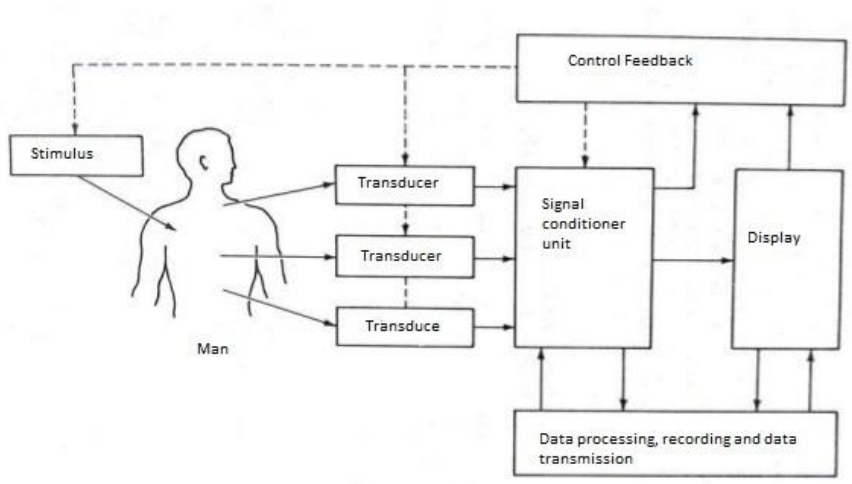


Fig: Components of man-instrument system

Problems encountered in measuring living systems

1. **I**naccessibility of Variables
2. **V**ariability of data
3. **L**ack of knowledge about interrelationships
4. Interaction among **P**hysiological systems

5. Effect of **T**ransducer on measurement
6. **A**rtifacts
7. **E**nergy limitations
8. **S**afety considerations

Physiology of human being

Cardiovascular system

The Cardiovascular System

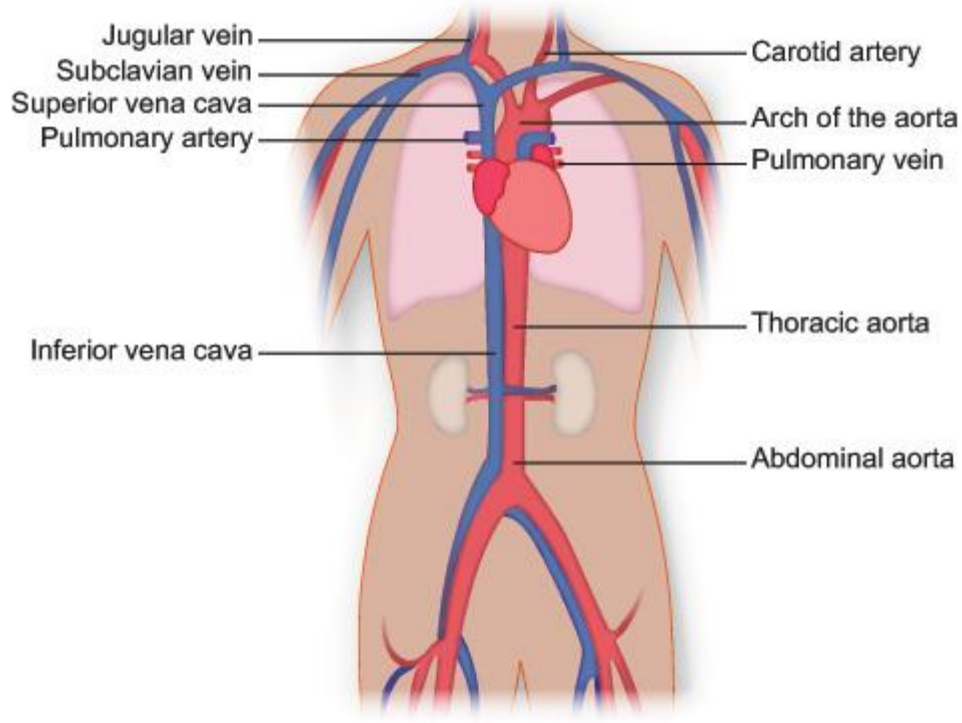
The heart and circulatory system make up your cardiovascular system. Your heart works as a pump that pushes blood to the organs, tissues, and cells of your body. Blood delivers oxygen and nutrients to every cell and removes the carbon dioxide and waste products made by those cells. Blood is carried from your heart to the rest of your body through a complex network of arteries, arterioles, and capillaries. Blood is returned to your heart through venules and veins. If all the vessels of this network were laid end to end, they would extend for about 60,000 miles (more than 96,500 kilometers), which is far enough to circle the planet Earth more than twice!

The one-way system carries blood to all parts of your body. This process of blood flow within your body is called circulation. **Arteries** carry oxygen-rich blood away from your heart, and **veins** carry oxygen-poor blood back to your heart.

In pulmonary circulation, though, the roles are switched. It is the pulmonary artery that brings oxygen-poor blood into your lungs and the pulmonary vein that brings oxygen-rich blood back to your heart.

In the diagram, the vessels that carry oxygen-rich blood are colored red, and the vessels that carry oxygen-poor blood are colored blue.

Twenty major arteries make a path through your tissues, where they branch into smaller vessels called arterioles. Arterioles further branch into capillaries, the true deliverers of oxygen and nutrients to your cells. Most capillaries are thinner than a hair. In fact, many are so tiny only one blood cell can move through them at a time. Once the capillaries deliver oxygen and nutrients and pick up carbon dioxide and other waste, they move the blood back through wider vessels called venules. Venules eventually join to form veins, which deliver the blood back to your heart to pick up oxygen.



Respiratory system

The respiratory system (also referred to as the ventilator system) is a complex biological system comprised of several organs that facilitate the inhalation and exhalation of oxygen and carbon dioxide in living organisms (or, in other words, breathing).

For all air-breathing vertebrates, respiration is handled by the lungs, but these are far from the only components of the respiratory system. In fact, the system is composed of the following biological structures: nose and nasal cavity, mouth, pharynx, larynx, trachea, bronchi and bronchioles, lungs and the muscles of respiration

1. Nose and Nasal Cavity

The nose and nasal cavity constitute the main external opening of the respiratory system. They represent the entryway to the respiratory tract – a passage through the body which air uses for travel in order to reach the lungs. The nose is made out of bone, muscle, cartilage and skin, while the nasal cavity is, more or less, hollow space. Although the nose is typically credited as being the main external breathing apparatus, its role is actually to provide support and protection to the nasal cavity. The cavity is lined with mucus membranes and little hairs that can filter the air before it goes into the respiratory tract. They can trap all harmful particles such as dust, mold and pollen and prevent them from reaching any of the internal

components. At the same time, the cold outside air is warmed up and moisturized before going through the respiratory tract. During exhalation, the warm air that is eliminated returns the heat and moisture back to the nasal cavity, so this forms a continuous process.

2. Oral cavity

The oral cavity, more commonly referred to as the mouth, is the only other external component that is part of the respiratory system. In truth, it does not perform any additional functions compared to the nasal cavity, but it can supplement the air inhaled through the nose or act as an alternative when breathing through the nasal cavity is not possible or exceedingly difficult. Normally, breathing through nose is preferable to breathing through the mouth. Not only does the mouth not possess the ability to warm and moisturize the air coming in, but it also lacks the hairs and mucus membranes to filter out unwanted contaminants. On the plus side, the pathway leading from the mouth is shorter and the diameter is wider, which means that more air can enter the body at the same speed.

3. Pharynx

The pharynx is the next component of the respiratory tract, even though most people refer to it simply as the throat. It resembles a funnel made out of muscles that acts as an intermediary between the nasal cavity and the larynx and esophagus. It is divided into three separate sections: nasopharynx, oropharynx and laryngopharynx. The nasopharynx is the upper region of the structure, which begins at the posterior of the nasal cavity and simply allows air to travel through it and reach the lower sections. The oropharynx does something similar, except it is located at the posterior of the oral cavity. Once the air reaches the laryngopharynx, something called the epiglottis will divert it to the larynx. The epiglottis is a flap that performs a vital task, by switching access between the esophagus and trachea. This ensures that air will travel through the trachea, but that food which is swallowed and travels through the pharynx is diverted to the esophagus.

4. Larynx

The larynx is the next component, but represents only a small section of the respiratory tract that connects the laryngopharynx to the trachea. It is commonly referred to as the voice box, and it is located near the anterior section of the neck, just below the hyoid bone. The aforementioned epiglottis is part of the larynx, as are the thyroid cartilage, the cricoid cartilage and the vocal folds. Both cartilages offer support and protection to other components, such as the vocal folds and the larynx itself. The thyroid cartilage also goes by a more common name – the

Adam's apple – although, contrary to popular belief, it is present in both men and women. It is typically more pronounced in adult males. The vocal folds are mucous membranes that tense up and vibrate in order to create sound, hence the term voice box. The pitch and volume of these sounds can be controlled by modifying the tension and speed of the vocal folds.

5. Trachea

The trachea is a longer section of the respiratory tract, shaped like a tube and approximately 5 inches in length. It has several C-shaped hyaline cartilage rings which are lined with pseudostratified ciliated columnar epithelium. (2) Those rings keep the trachea open for air all the time. They are C-shaped in order to allow the open end to face the esophagus. This allows the esophagus to expand into the area normally occupied by the trachea in order to permit larger chunks of food to pass through. The trachea, more commonly referred to as the windpipe, connects the larynx to the bronchi and also has the role of filtering the air prior to it entering the lungs. The epithelium which lines the cartilage rings produces mucus which traps harmful particles. The cilia then move the mucus upward towards the pharynx, where it is redirected towards the gastrointestinal tract in order for it to be digested.

6. Bronchi

The lower end of the trachea splits the respiratory tract into two branches that are named the primary bronchi. These first run into each of the lungs before further branching off into smaller bronchi. These secondary bronchi continue carrying the air to the lobes of the lungs, then further split into tertiary bronchi. The tertiary bronchi then split into even smaller sections that are spread out throughout the lungs called bronchioles. Each one of these bronchioles continues to split into even smaller parts called terminal bronchioles. At this stage, these tiny bronchioles number in the millions, are less than a millimeter in length, and work to conduct the air to the lungs' alveoli. The larger bronchi contain C-shaped cartilage rings similar to the ones used in the trachea to keep the airway open. As the bronchi get smaller, so do the rings that become progressively more widely spaced. The tiny bronchioles do not have any kind of cartilage and instead rely on muscles and elastin.

This system creates a tree-like pattern, with smaller branches growing from the bigger ones. At the same time, it also ensures that air from the trachea reaches all the regions of the lungs. Besides simply carrying the air, the bronchi and bronchioles also possess mucus and cilia that further refine the air and get rid of any leftover environmental contaminants. The walls of the bronchi and bronchioles are also lined with muscle tissue, which can control the flow of air going into the

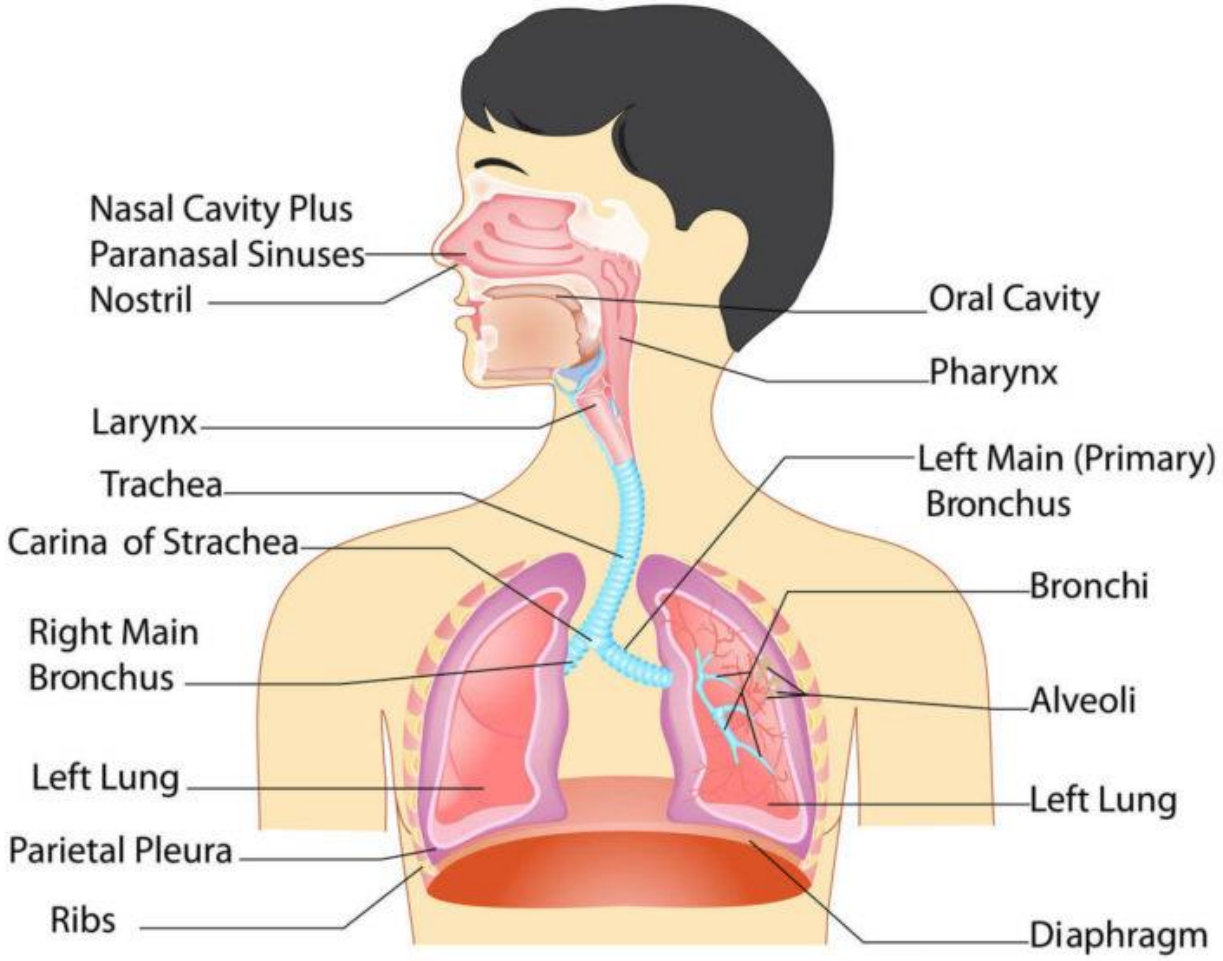
lungs. In certain instances, such as during physical activity, the muscles relax and allow more air to go into the lungs.

7. Lungs

The lungs are two organs located inside the thorax on the left and right sides. They are surrounded by a membrane that provides them with enough space to expand when they fill up with air. Because the left lung is located lateral to the heart, the organs are not identical: the left lung is smaller and has only 2 lobes while the right lung has 3. Inside, the lungs resemble a sponge made of millions and millions of small sacs that are named alveoli. These alveoli are found at the ends of terminal bronchioles and are surrounded by capillaries through which blood passes. Thanks to an epithelium layer covering the alveoli, the air that goes inside them is free to exchange gasses with the blood that goes through the capillaries.

8. Muscles of Respiration

The last component of the respiratory system is a muscle structure known as the muscles of respiration. These muscles surround the lungs and allow the inhalation and exhalation of air. The main muscle in this system is known as the diaphragm, a thin sheet of muscle that constitutes the bottom of the thorax. It pulls in air into the lungs by contracting several inches with each breath. In addition to the diaphragm, multiple intercostal muscles are located between the ribs and they also help compress and expand the lungs.



Nervoussystem

It may seem as if your brain is always on the go. And it is. The brain not only controls what you think and feel, how you learn and remember, and the way you move and talk, but also many things you're less aware of — such as the beating of your heart, the digestion of your food, and yes, even the amount of stress you feel. Like you, your brain is quite the juggler.

Anatomy of the Nervous System

If you think of the brain as a central computer that controls all bodily functions, then the nervous system is like a network that relays messages back and forth from the brain to different parts of the body. It does this via the spinal cord, which runs from the brain down through the back and contains threadlike nerves that branch out to every organ and body part.

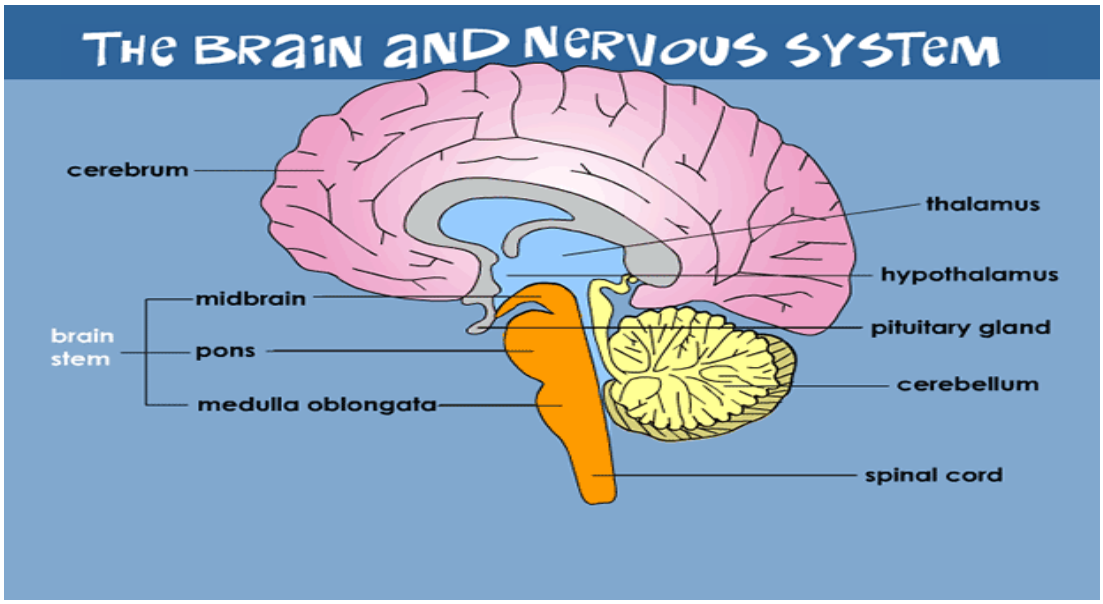
When a message comes into the brain from anywhere in the body, the brain tells the body how to react. For example, if you accidentally touch a hot stove, the nerves in your skin shoot a message of pain to your brain. The brain then sends a

message back telling the muscles in your hand to pull away. Luckily, this neurological relay race takes a lot less time than it just took to read about it.

Considering everything it does, the human brain is incredibly compact, weighing just 3 pounds. Its many folds and grooves, though, provide it with the additional surface area necessary for storing all of the body's important information.

The spinal cord, on the other hand, is a long bundle of nerve tissue about 18 inches long and ¾ inch thick. It extends from the lower part of the brain down through spine. Along the way, various nerves branch out to the entire body. These make up the peripheral nervous system.

Both the brain and the spinal cord are protected by bone: the brain by the bones of the skull, and the spinal cord by a set of ring-shaped bones called vertebrae. They're both cushioned by layers of membranes called meninges as well as a special fluid called cerebrospinal fluid. This fluid helps protect the nerve tissue, keep it healthy, and remove waste products.



Bioelectric potential

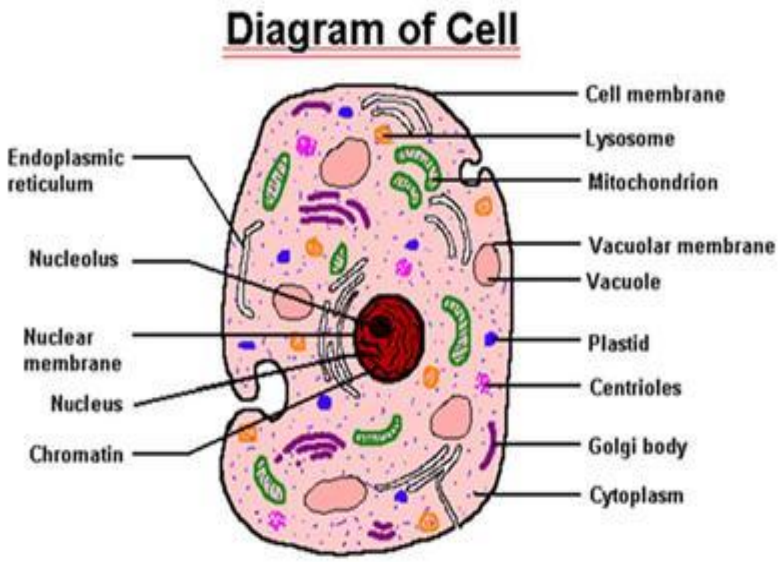
Human cell

A cell is a structure as well as a functional unit of life. Every living thing has cells: bacteria, protozoans, fungi, plants, and animals are the main group of living things. Some organisms are made up of just one cell are called unicellular. (e.g. bacteria and protozoans), but animals, including human beings, are multi-cellular. An adult human body is composed of about 100,000,000,000,000 cells! Each cell has basic requirements to sustain it, and the body's organ systems are largely built around

providing the many trillions of cells with those basic needs (such as oxygen, food, and waste removal).

There are about 200 different kinds of specialized cells in the human body. When many identical cells are organized together it is called a tissue (such as muscle tissue, nervous tissue, etc). Various tissues organized together for a common purpose are called organs (e.g. the stomach is an organ, and so is the skin, the brain, and the uterus).

Ideas about cell structure have changed considerably over the years. Early biologists saw cells as simple membranous sacs containing fluid and a few floating particles. Today's biologists know that cells are inconceivably more complex than this. Therefore, a strong knowledge of the various cellular organelles and their functions is important to any physiologist. If a person's cells are healthy, then that person is healthy. All physiological processes, disease, growth and development can be described at the cellular level

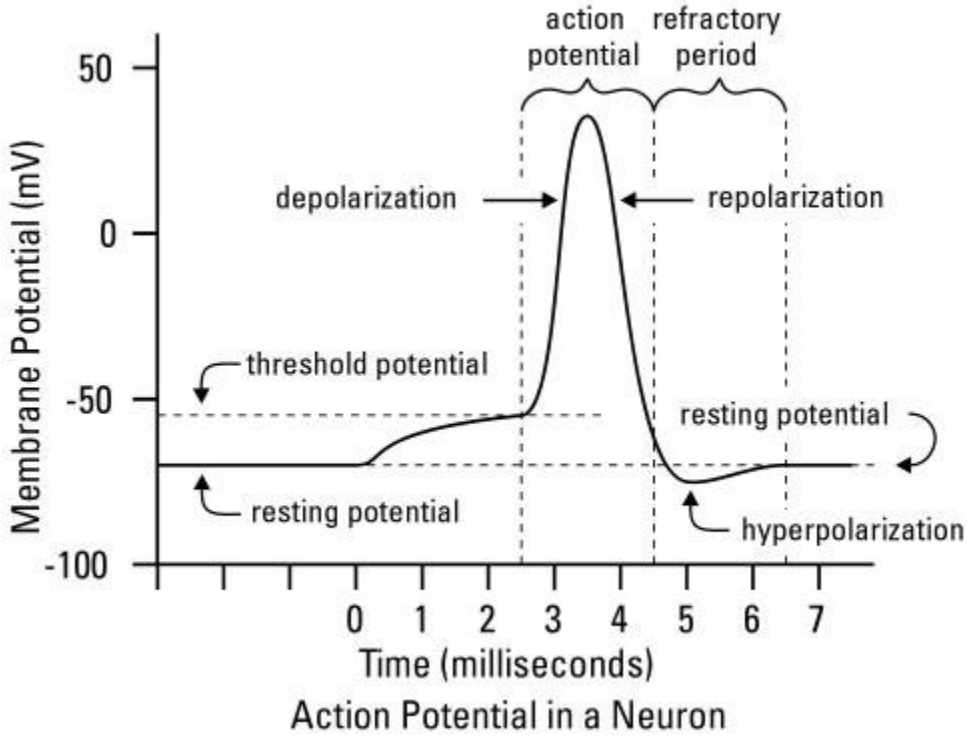


Action and resting potential

In physiology, an **action potential** occurs when the membrane potential of a specific axon location rapidly rises and falls:[1] this depolarisation then causes adjacent locations to similarly depolarise. In the Hodgkin–Huxley membrane capacitance model, the speed of transmission of an action potential was undefined and it was assumed that adjacent areas became depolarised due to released ion interference with neighbouring channels. Measurements of ion diffusion and radii have since shown this not to be possible. Moreover, contradictory measurements of entropy changes and timing disputed the capacitance model as acting alone.

Action potentials occur in several types of animal cells, called excitable cells, which include neurons, muscle cells, and endocrine cells, as well as in some plant cells. In neurons, action potentials play a central role in cell-to-cell communication by providing for (or assisting in, with regard to saltatory conduction) the propagation of signals along the neuron's axon towards boutons at the axon ends which can then connect with other neurons at synapses, or to motor cells or glands. In other types of cells, their main function is to activate intracellular processes. In muscle cells, for example, an action potential is the first step in the chain of events leading to contraction. In beta cells of the pancreas, they provoke release of insulin.[a] Action potentials in neurons are also known as "**nerve impulses**" or "spikes", and the temporal sequence of action potentials generated by a neuron is called its "**spike train**". A neuron that emits an action potential is often said to "fire".

Action potentials are generated by special types of voltage-gated ion channels embedded in a cell's plasma membrane.[b] These channels are shut when the membrane potential is near the (negative) resting potential of the cell, but they rapidly begin to open if the membrane increases to a precisely defined threshold voltage, depolarising the transmembrane potential.[b] When the channels open they allow an inward flow of sodium ions, which changes the electrochemical gradient, which in turn produces a further rise in the membrane potential. This then causes more channels to open, producing a greater electric current across the cell membrane, and so on. The process proceeds explosively until all of the available ion channels are open, resulting in a large upswing in the membrane potential. The rapid influx of sodium ions causes the polarity of the plasma membrane to reverse, and the ion channels then rapidly inactivate. As the sodium channels close, sodium ions can no longer enter the neuron, and then they are actively transported back out of the plasma membrane. Potassium channels are then activated, and there is an outward current of potassium ions, returning the electrochemical gradient to the resting state. After an action potential has occurred, there is a transient negative shift, called the afterhyperpolarization.



Action Potential in a Neuron

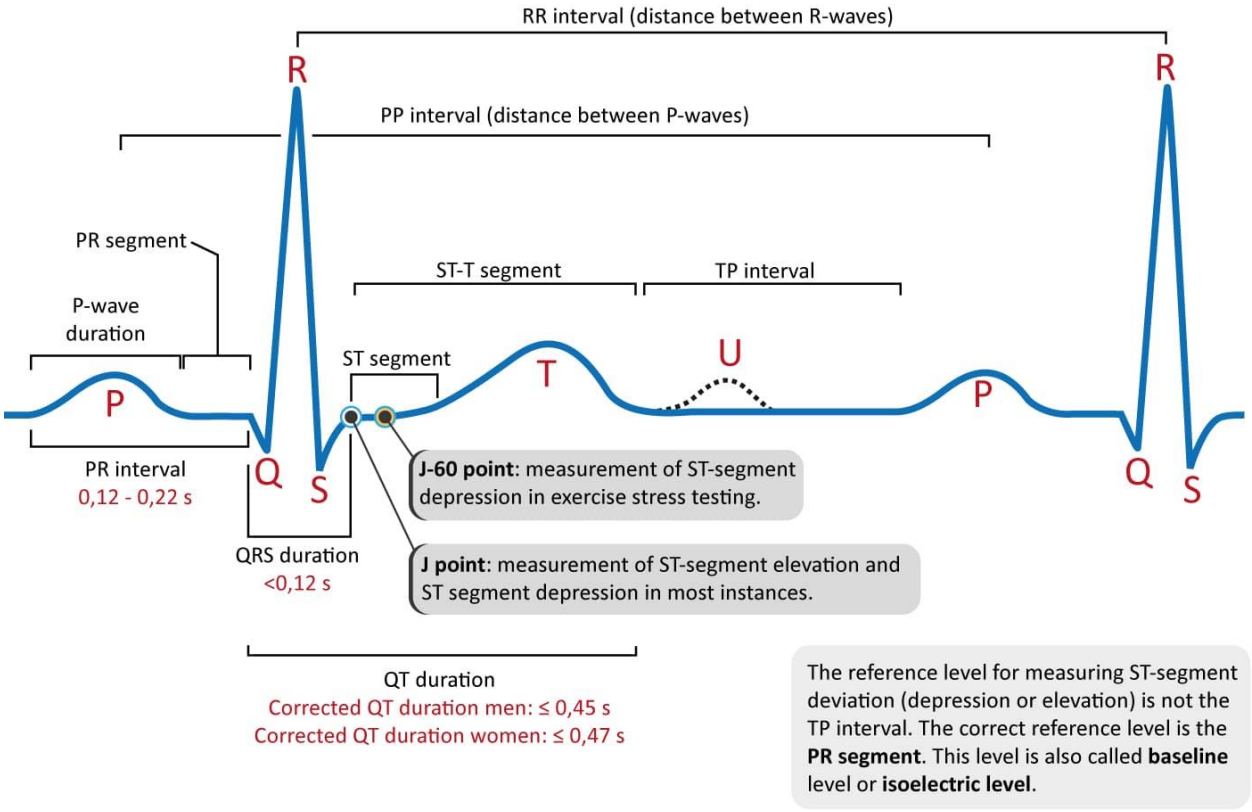
ECG Potential

An ECG is simply a representation of the electrical activity of the heart muscle as it changes with time, usually printed on paper for easier analysis. Like other muscles, cardiac muscle contracts in response to electrical *depolarisation* of the muscle cells. It is the sum of this electrical activity, when amplified and recorded for just a few seconds that we know as an ECG.

Basic Electrophysiology of the Heart

The normal cardiac cycle begins with spontaneous depolarisation of the sinus node, an area of specialised tissue situated in the high right atrium (RA). A wave of electrical depolarisation then spreads through the RA and across the inter-atrial septum into the left atrium (LA).

The atria are separated from the ventricles by an electrically inert fibrous ring, so that in the normal heart the only route of transmission of electrical depolarisation from atria to ventricles is through the atrioventricular (AV) node. The AV node delays the electrical signal for a short time, and then the wave of depolarisation spreads down the interventricular septum (IVS), via the bundle of His and the right and left bundle branches, into the right (RV) and left (LV) ventricles. Hence with normal conduction the two ventricles contract simultaneously, which is important in maximising cardiac efficiency.



EMG potential

The presence of electric potential differences in muscles is the result of motor unit action potentials produced by the central nervous system (CNS). These electric potential differences can be measured using electromyography (EMG) and reported as an EMG amplitude.

EMG amplitude is the sum of the electric potential differences within a muscle relating to all of the active motor units in the vicinity of the electrodes on the skin. An EMG amplitude can therefore be taken as a global measure of motor unit activity during the muscle action being performed.

EMG amplitude can be affected by noise from many sources, including the equipment, background electromagnetic radiation, motion artefacts (movement altering the positions of the electrodes), and the randomness of the motor unit firing patterns.

There are many factors that affect EMG amplitude in addition to the signal from the CNS. These include causative extrinsic factors, such as aspects of the equipment and its placement, and causative intrinsic factors, such as muscle fiber type, blood flow in the muscle, muscle fiber diameter, the depth of the active muscle fibers within the muscle, the amount of non-muscle tissue under the

electrode, crosstalk from other active muscle fibers, and the duration of the intracellular action potential.

In addition to the above factors affecting EMG amplitude, there are determinant factors that are thought to arise primarily from CNS activity. These include both motor unit recruitment and motor unit firing frequency.

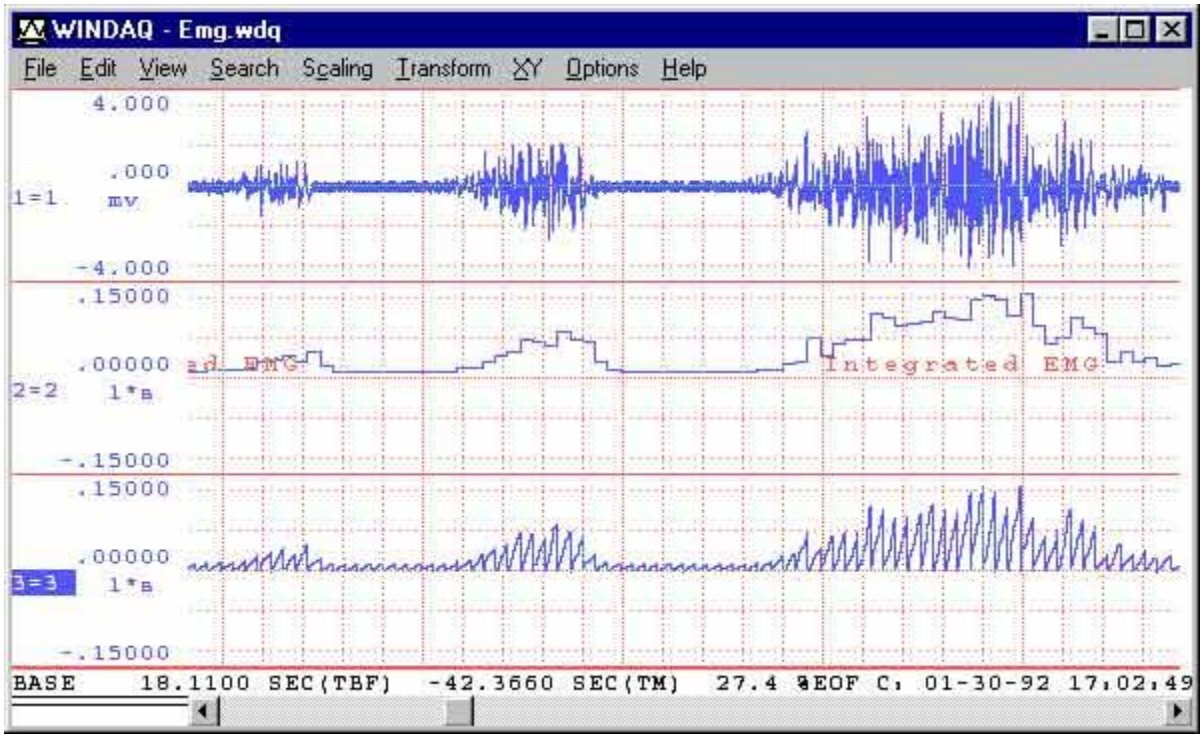
When measuring EMG amplitude, there are several major features that differ between studies, which are: electrode type (surface or fine wire), the normalization option, and the data reduction and processing methods. Researchers are divided over which normalization option is best under which circumstances, and which data reduction and processing methods are most appropriate.

Some researchers have suggested that EMG amplitude can be used as a proxy for voluntary activation. However, this is not appropriate, as voluntary activation requires an assessment of involuntary force production, which EMG does not assess.

Some researchers have suggested that EMG amplitude can be used as a proxy for motor unit recruitment. However, this is not appropriate, as EMG amplitude within muscles is a function of both motor unit recruitment and motor unit firing frequency, as well as many peripheral factors, including intracellular action potential duration.

However, there is a relationship between the EMG amplitude and muscle force when muscle actions are performed without fatigue. Therefore, EMG amplitude is a useful window into the tension in a muscle, which is valuable for comparing exercises or positions. The relationship between EMG amplitude and muscle force is probably non-linear but may depend on which muscle is being measured.

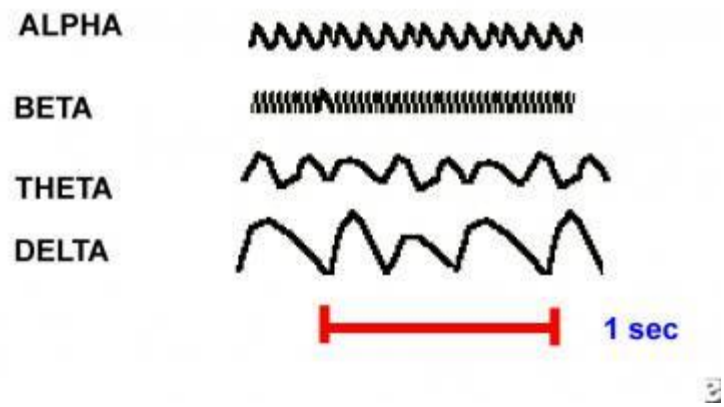
The test-re-test reliability of EMG amplitude can be assessed using either an intra-class correlation coefficient (ICC) or the coefficient of variation (COV). Test-re-test reliability is greater in sub-maximal than maximal muscle actions, when comparing with a single day compared to between days, and when using visual feedback about force levels being produced**.**



EEG Potential

The electroencephalogram (EEG) is the depiction of the electrical activity occurring at the surface of the brain. This activity appears on the screen of the EEG machine as waveforms of varying frequency and amplitude measured in voltage (specifically microvoltages).

EEG waveforms are generally classified according to their frequency, amplitude, and shape, as well as the sites on the scalp at which they are recorded. The most familiar classification uses EEG waveform frequency (eg, alpha, beta, theta, and delta). [1, 2, 3]



Examples of alpha, beta, theta, and delta electroencephalography frequencies.

Information about waveform frequency and shape is combined with the age of the patient, state of alertness or sleep, and location on the scalp to determine significance.

Normal EEG waveforms, like many kinds of waveforms, are defined and described by their frequency, amplitude, and location. [4]

- Frequency (Hertz, Hz) is a key characteristic used to define normal or abnormal EEG rhythms.
- Most waves of 8 Hz and higher frequencies are normal findings in the EEG of an awake adult. Waves with a frequency of 7 Hz or less often are classified as abnormal in awake adults, although they normally can be seen in children or in adults who are asleep. In certain situations, EEG waveforms of an appropriate frequency for age and state of alertness are considered abnormal because they occur at an inappropriate scalp location or demonstrate irregularities in rhythmicity or amplitude. [5]
- Some waves are recognized by their shape, scalp location or distribution, and symmetry. Certain patterns are normal at specific ages or states of alertness and sleep.
- The morphology of a wave may resemble specific shapes, such as vertex (V) waves seen over the vertex of the scalp in stage 2 sleep or triphasic waves that occur in the setting of various encephalopathies.

EOG Potential

Electrophysiological testing of patients with retinal disease began in clinical departments in the late nineteen forties. Under the influence of the Swedish pioneers, Holmgren (1865) and Granit (1933), the electroretinogram was being dissected into component parts and early intraretinal electrode studies were beginning to tell which cells or cell layers gave rise to the various components. A detailed discussion of the electroretinogram, or ERG as it is commonly abbreviated, is found in the accompanying chapter by Ido Perlman. A little after the introduction of the ERG as a test of the state of the patient’s retina, another diagnostic test called the electrooculogram (EOG) was introduced to the clinic (Arden et al., 1962). The EOG had advantages over the ERG in that electrodes did not touch the surface of the eye. The changes in the standing potential across the eyeball were recorded by skin electrodes during simple eye movements and after exposure to periods of light and dark. Over the years ERG recording techniques have become progressively more sophisticated in the clinical setting. With the advent of perimeter, optical coherence tomography (OCT) and pattern ERG techniques, more precise mapping of dysfunctional areas of the retina is now possible. The most recent advance in ERG technology is the multifocal

electroretinogram (mfERG). The mfERG provides a detailed assessment of the health of the central retina.

Where the previous chapter (The electroretinogram: ERG, Ido Perlman) presents the basic science behind the waveforms and components of the massed ERG response, in this chapter the intention is to show the clinical use of the various electrophysiological tests. The chapter is based on experience in the ERG clinic of the Moran Eye Center.

ERG Potential

The global or full-field electroretinogram (ERG) is a mass electrical response of the retina to photic stimulation. The ERG is a test used worldwide to assess the status of the retina in eye diseases in human patients and in laboratory animals used as models of retinal disease.

The basic method of recording the electrical response known as the global or full-field ERG is by stimulating the eye with a bright light source such as a flash produced by LEDs or a strobe lamp. The flash of light elicits a biphasic waveform recordable at the cornea similar to that illustrated below (Fig 1). The two components that are most often measured are the a- and b-waves. The a-wave is the first large negative component, followed by the b-wave which is corneal positive and usually larger in amplitude.

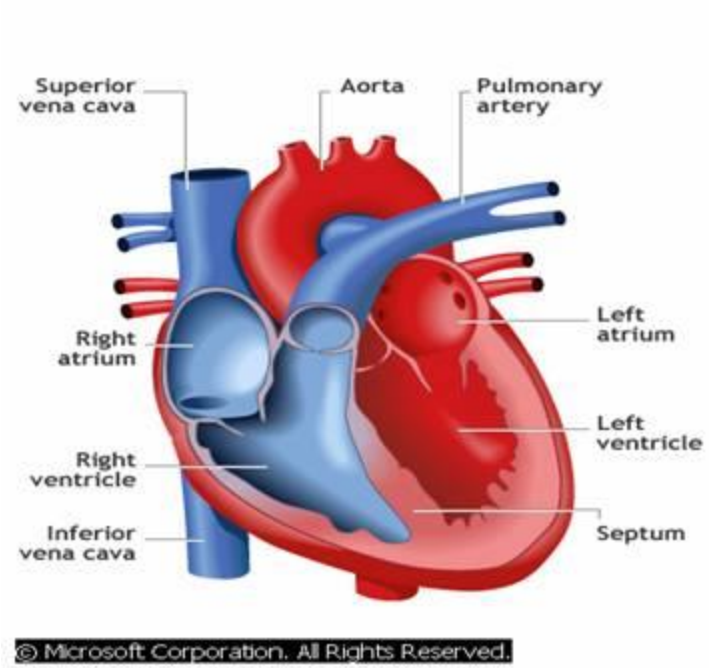
2. CARDIOVASCULAR MEASUREMENT

Introduction

Circulatory System

The circulatory system is made up of the heart, blood and blood vessels known as arteries, capillaries and veins. The heart pumps blood throughout your body through the blood vessels. Blood delivers oxygen and nutrients to cells and carries away carbon dioxide and other waste materials.Did you ever send a valentine with the shape of a heart on it? Did you ever hear someone say, "That came straight from my heart?" People talk about hearts a lot. People have always known that hearts are very important.

You have a heart. Your heart does not look like a valentine heart. Your heart is a pump. When you run very fast, your heart pumps hard and fast. You can feel your heart pumping, or beating.



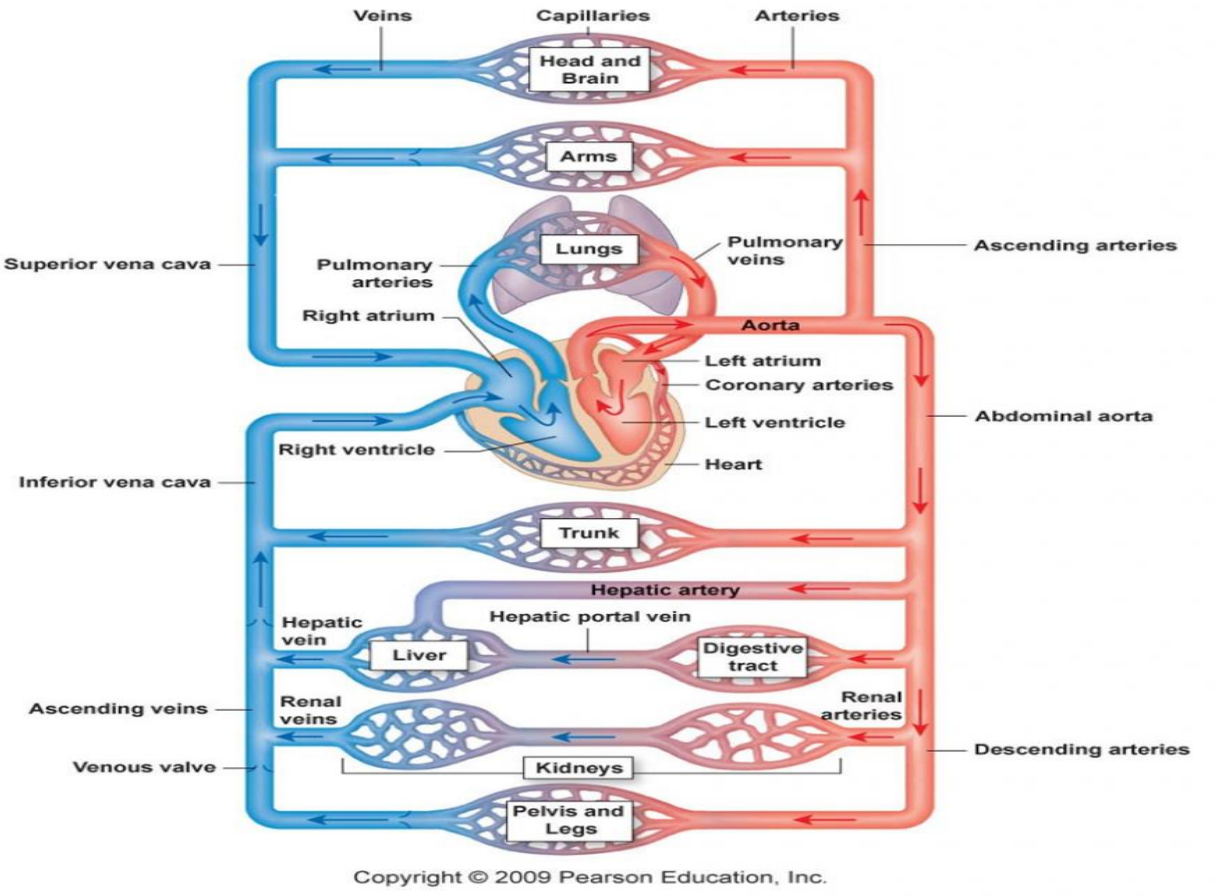
Your heart looks like an upside-down pear. It is about the size of your closed fist. It is almost in the middle of your chest. It is just off to the left side.

Your heart is made of muscle. It is divided into four parts called chambers. The chambers are hollow inside. The two chambers on top are called atria. The chambers on the bottom are called ventricles. Your heart also has four valves that let blood in and out of the chambers.

Tubes called arteries come out of your heart. Tubes called veins go into your heart. Arteries and veins are also called blood vessels.

Your heart pumps blood. Blood comes into the atria or top chambers of your heart. Your ventricles, or bottom chambers, pump blood out to every part of your body.Blood going out of your heart carries food and oxygen. Every part of your body needs food and oxygen for energy. You need energy for your body to work and for you to stay alive. Your heart pumps blood carrying food and oxygen through your arteries. Big arteries carry the blood to your legs and arms. The

arteries get smaller and smaller the farther out they go. Little blood vessels called capillaries take blood to your cells. Everything in your body is made of tiny cells.



Your cells give off waste products when they make energy from food and oxygen. One of these waste products is a gas called carbon dioxide. The blood in your capillaries picks up the waste products. Capillaries connect to bigger veins. The pumping of your heart pushes the blood through your veins.

Your veins carry blood back to your heart. The chambers on the right side of your heart take care of blood coming back through your veins. First, the blood comes into your right atrium, the top chamber. Your right atrium pumps the blood into your right ventricle, the bottom chamber. Your right ventricle pumps the blood through an artery into your lungs.

Your blood has to get rid of carbon dioxide. It has to get a fresh supply of oxygen. Your lungs take care of both jobs. Carbon dioxide from your blood goes into your lungs. Your lungs get rid of the carbon dioxide when you breathe out.

Then you breathe in. Your lungs get oxygen from breathing in air. Your lungs fill up with oxygen. Your blood picks up a new supply of oxygen from your lungs. Now your blood is ready to go out through your arteries to all the parts of your body.

The chambers on the left side of your heart take care of blood going out through your arteries. Special veins send blood from your lungs to your left atrium, or top chamber. The blood goes from the left atrium to the left ventricle. The left ventricle pumps the blood out through your arteries to every part of your body.

Make a fist. Open your fist slightly, and then squeeze it closed. Open and close your fist again and again. This is sort of how your heart pumps blood. The muscles in your heart squeeze the chambers.

To open and close your fist, you have to think about doing it. You don't have to think about squeezing your heart muscles. Your brain tells your heart to pump over and over again. Your heart pumps when you are awake. Your heart pumps when you are asleep. Your heart pumps faster when you run fast. Your body needs more oxygen when you run.

Your heart is better than any pump made. It beats over and over again, day and night. The heart of a 76-year-old person has beaten nearly 2.8 billion times. It has pumped about 179 million quarts (169 million liters) of blood. No one can live if their heart stops beating for more than a few minutes.

Artery, one of the tubular vessels that conveys blood from the heart to the tissues of the body. Two arteries have direct connection with the heart: (1) the aorta, which, with its branches, conveys oxygenated blood from the left ventricle to every part of the body; and (2) the pulmonary artery, which conveys blood

from the right ventricle to the lungs, whence it is returned bearing oxygen to the left side of the heart (*see* Heart: Structure and Function). Arteries in their ultimate minute branchings are connected with the veins by capillaries. They are named usually from the part of the body where they are found, as the brachial (arm) or the metacarpal (wrist) artery; or from the organ which they supply, as the hepatic (liver) or the ovarian artery. The facial artery is the branch of the external carotid artery that passes up over the lower jaw and supplies the superficial portion of the face; the hemorrhoidal arteries are three vessels that supply the lower end of the rectum; the intercostal arteries are the arteries that supply the space between the ribs; the lingual artery is the branch of the external carotid artery that supplies the tongue. The arteries expand and then constrict with each beat of the heart, a rhythmic movement that may be felt as the pulse.

Veins are blood vessels that return blood to the heart from other parts of the body. This false-color electron micrograph shows red blood cells packed into a capillary, the smallest type of blood vessel. Blood flows from the capillaries into veins after oxygen has been exchanged.Capillary, one of the minute blood vessels that form the connection between the arteries and the veins. These tiny vessels vary in diameter from 0.0127 to about 0.2032 mm (0.0005 to about 0.008 in) and are present in great numbers throughout the entire body. The walls of capillaries are exceedingly thin and readily permeable. They are surrounded by lymph, and there is a constant interchange between the substances in the blood within the capillaries and the waste products in the body tissues and lymph outside. This interchange facilitates the processes of nutrition and elimination and enables the exchange of oxygen and carbon dioxide to take place. Lymph capillaries assist the blood capillaries in this process.

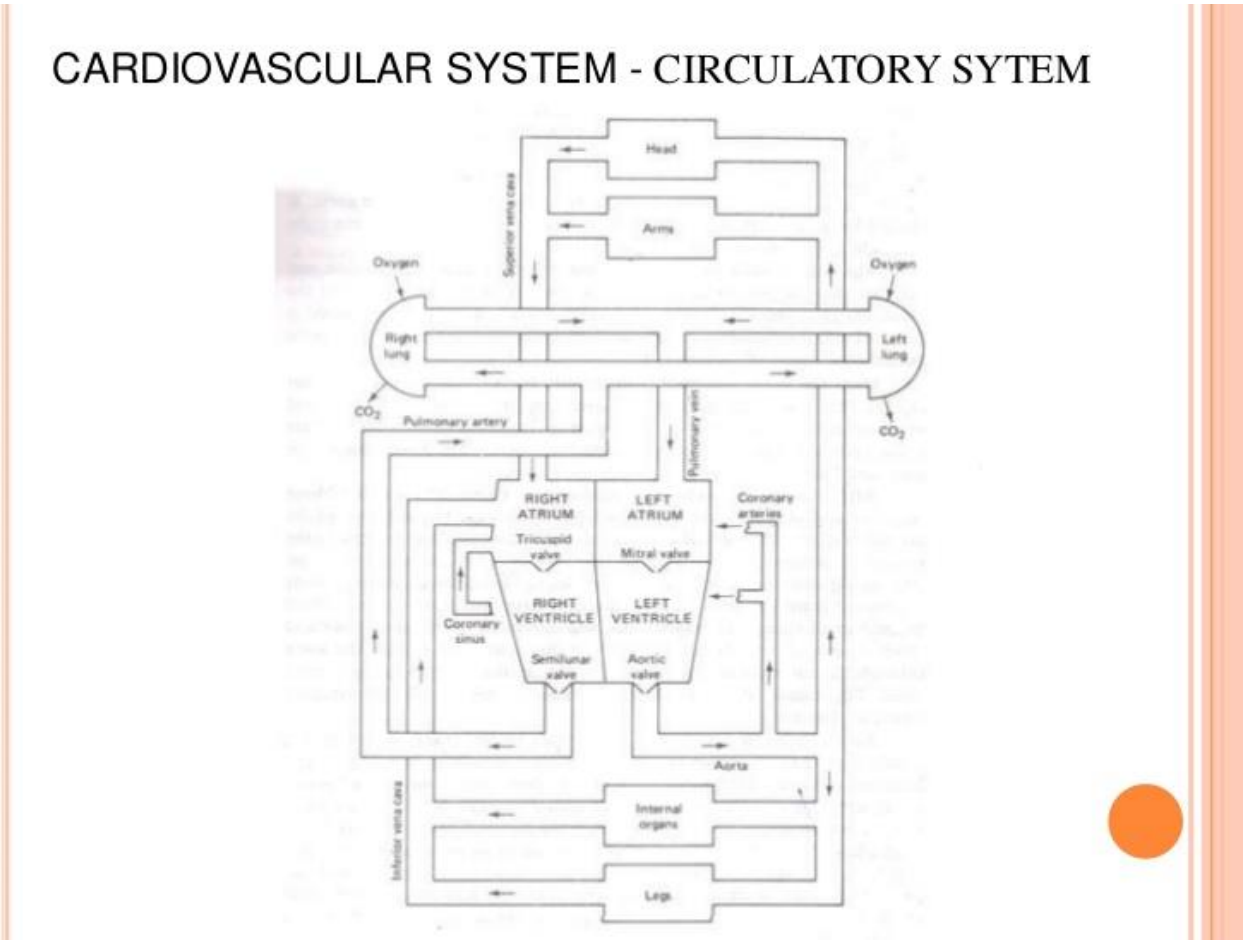


Fig:- Basic analogy of cardiovascular system

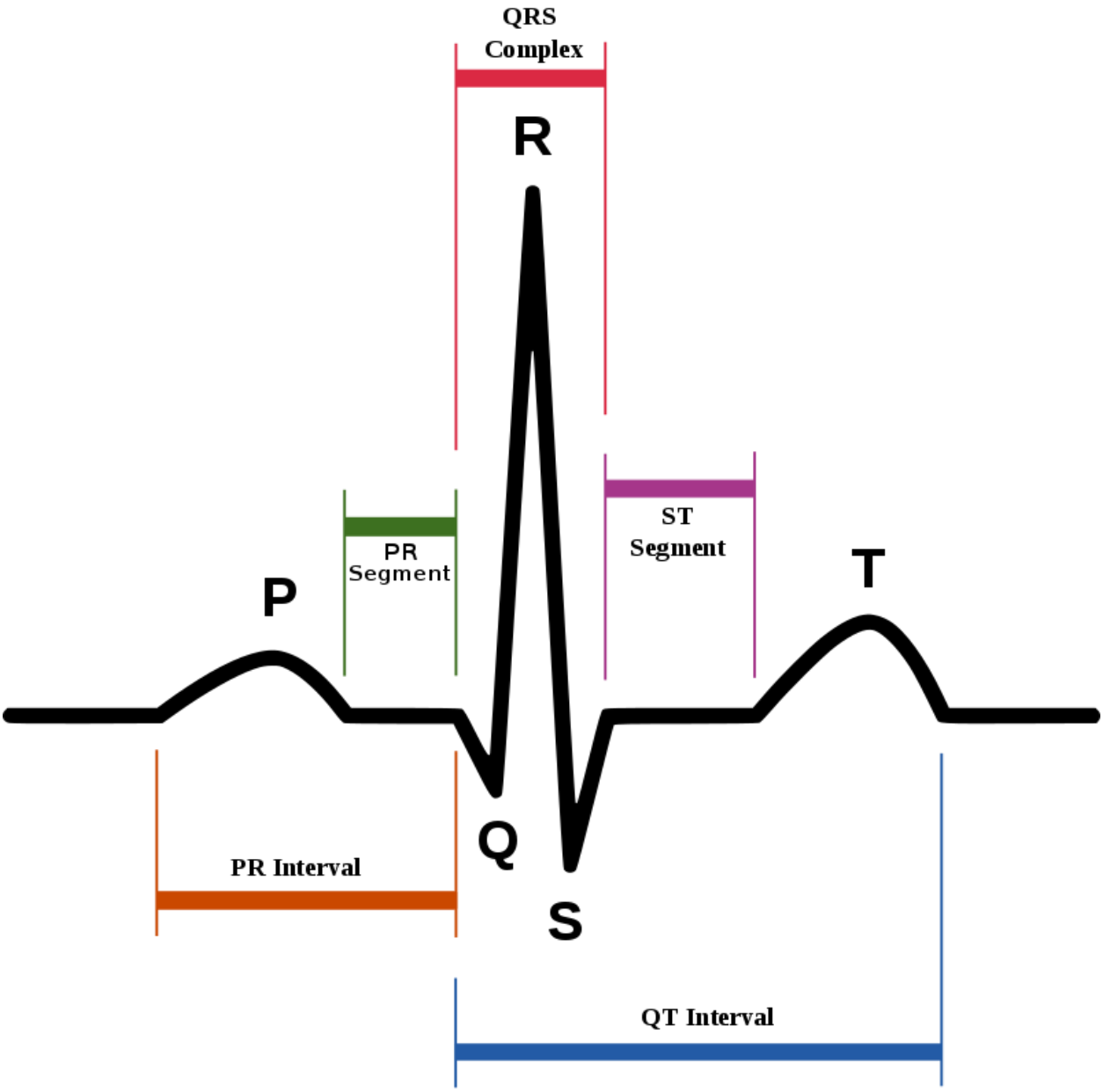
Electrocardiography

Electrocardiography (ECG or EKG[a]) is the process of recording the electrical activity of the heart over a period of time usingelectrodes placed on the skin. These electrodes detect the tiny electrical changes on the skin that arise from the heart muscle'selectrophysiologic pattern of depolarizing and repolarizing during each heartbeat. It is a very commonly performed cardiologytest.

In a conventional 12-lead ECG, ten electrodes are placed on the patient's limbs and on the surface of the chest. The overall magnitude of the heart's electrical potential is then measured from twelve different angles ("leads") and is recorded over a period of time (usually ten seconds). In this way, the overall magnitude and direction of the heart's electrical depolarization is captured at each moment throughout the cardiac

cycle.[4] The graph of voltage versus time produced by this noninvasive medical procedure is referred to as an electrocardiogram.

During each heartbeat, a healthy heart has an orderly progression of depolarization that starts with pacemaker cells in thesinoatrial node, spreads out through the atrium, passes through the atrioventricular node down into the bundle of His and into thePurkinje fibers, spreading down and to the left throughout the ventricles. This orderly pattern of depolarization gives rise to the characteristic ECG tracing. To the trained clinician, an ECG conveys a large amount of information about the structure of the heart and the function of its electrical conduction system. Among other things, an ECG can be used to measure the rate and rhythm of heartbeats, the size and position of the heart chambers, the presence of any damage to the heart's muscle cells or conduction system, the effects of cardiac drugs, and the function of implanted pacemakers.



ECG Amplifiers

The signal acquisition is the first consideration when an HRM is implemented. But the signal is too small and contains a lot of added noise. As we said above the signal extracted from the heart has amplitude of approximately 0.5mV.
Since, it is necessary to amplify the signal and filter the noise, and then extract the QRS complex.
An instrumentation amplifier is usually the very first stage in an instrumentation system. This is because of the very small voltages usually received from the probes need to be amplified significantly to be proceeding stages.
We can summarize the reasons to use instrumentation amplifier:

1- Get differential signal.
2- High input impedance.
3- High CMRR.

Let us take some review about instrumentation amplifier:

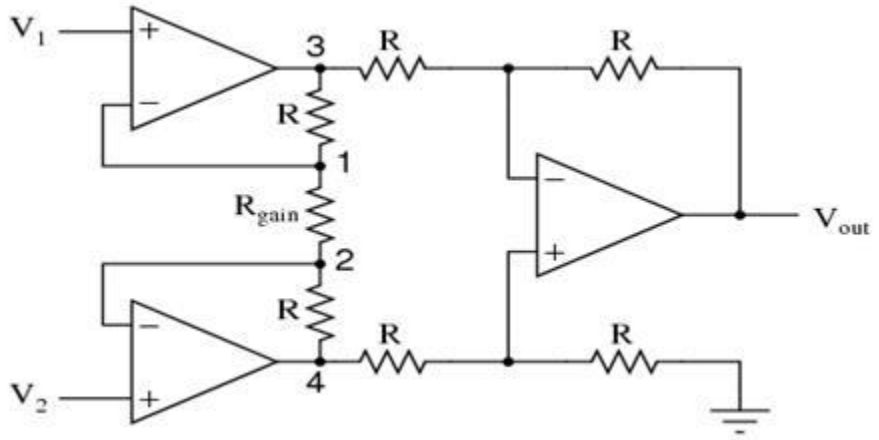


Figure 4: general instrumentation op amp.

This intimidating circuit is constructed from a buffered differential amplifier stage with three new resistors linking the two buffer circuits together. Consider all resistors to be of equal value except for R_{gain}. The negative feedback of the upper-left op-amp causes the voltage at point 1 (top of R_{gain}) to be equal to V_1. Likewise, the voltage at point 2 (bottom of R_{gain}) is held to a value equal to V_2. This establishes a voltage drop across R_{gain} equal to the voltage difference between V_1 and V_2. That voltage drop causes a current through R_{gain}, and since the feedback loops of the two input op-amps draw no current, that same amount of current through R_{gain} must be going through the two "R" resistors above and below it. This produces a voltage drop between points 3 and 4 equal to:

$$V_{3\text{-}4} = (V_2 - V_1)\left(1 + \frac{2R}{R_{gain}}\right)$$

The regular differential amplifier on the right-hand side of the circuit then takes this voltage drop between points 3 and 4, and amplifies it by a gain of 1 (assuming again that all "R" resistors are of equal value). Though this looks like a cumbersome way to build a differential amplifier, it has the distinct advantages of possessing extremely high input impedances on the V_1 and V_2 inputs (because they connect straight into the non inverting inputs of their respective op-amps), and adjustable gain that can be set by a single

resistor. Manipulating the above formula a bit, we have a general expression for overall voltage gain in the instrumentation amplifier:

$$A_V = (1 + \frac{2R}{R_{gain}})$$

2.5 GAIN SELECTION:

The INA128 and INA129 are low power, general purpose instrumentation amplifiers offering excellent accuracy. Their versatile 3-op amp design and small size make them ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth. Even at high gain (200 kHz at G = 100). A single external resistor sets any gain from 1 to10, 000. INA128 provides an industry standard gain. Equation; INA129's gain equation is compatible with the AD620. The INA128/INA129 is laser trimmed for very low offset voltage (50mV), drift (0.5mV/°C) and high common- mode rejection (120dB at G ³ 100). It operates with power supplies as low as ±2.25V, and quiescent. Current is only 700mA—ideal for battery operated systems. Internal input protection can withstand up to±40V without damage. The INA128/INA129 is available in 8-pin plastic DIP, and SO-8 surface-mount packages, specified for the –40°C to +85°C temperature range. The INA128 is also available in dual configuration, the INA2128.

FEATURES:

- LOW OFFSET VOLTAGE: 50mV max.
- LOW DRIFT: 0.5mV/°C max.
- LOW INPUT BIAS CURRENT: 5nA max.
- HIGH CMR: 120dB min.
- INPUTS PROTECTED TO ±40V.
- WIDE SUPPLY RANGE: ±2.25 to ±18V.
- LOW QUIESCENT CURRENT: 700mA.
- 8-PIN PLASTIC DIP, SO-8.

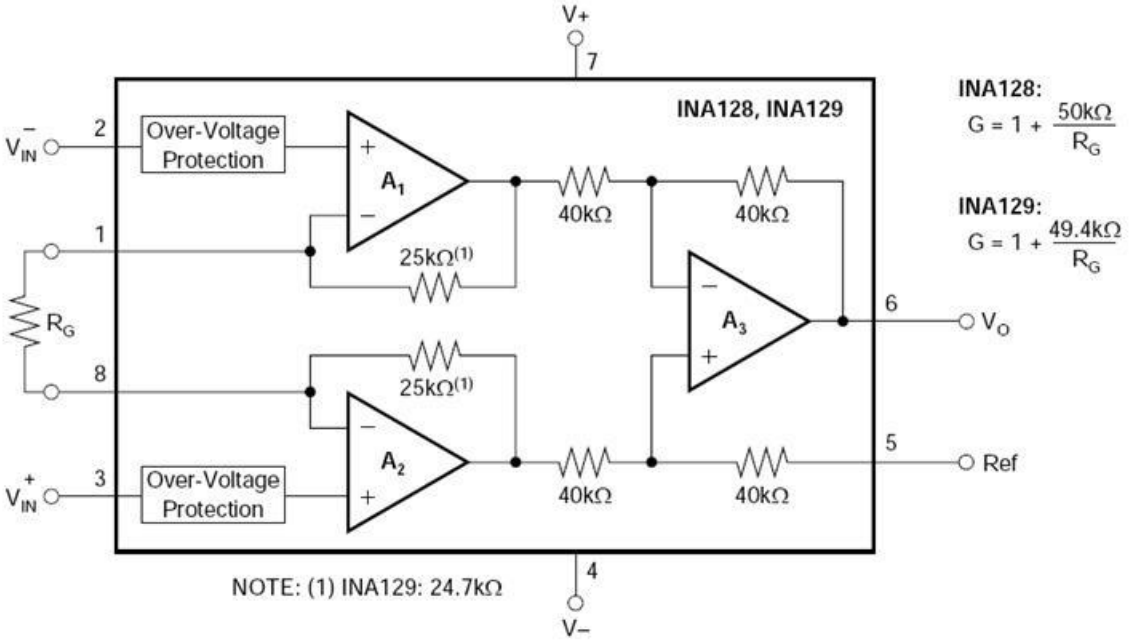


Figure 5: circuit design of INA 128.

From our design we choose RG= 1kΩ since the gain we get 51 v/v actually the gain not very large for reason that although the instrumentation amplifier has high common mode rejection ratio but the noise still effect to the output of the circuit according to this equation:

$$\text{Noise signal} = \frac{35\times10^{-9}}{\sqrt{f}} \quad \text{volt / hertz}^{\frac{1}{2}}$$

2.6 filtering stage:

The required band width for ECG signal (0.5 hz- 30 Hz) for normal heart human so we chosen the bandwidth of the circuit near to this range, now if we choose the bandwidth (0.5-120Hz) notching filter required in design to remove 5ohz noise from power line grid .

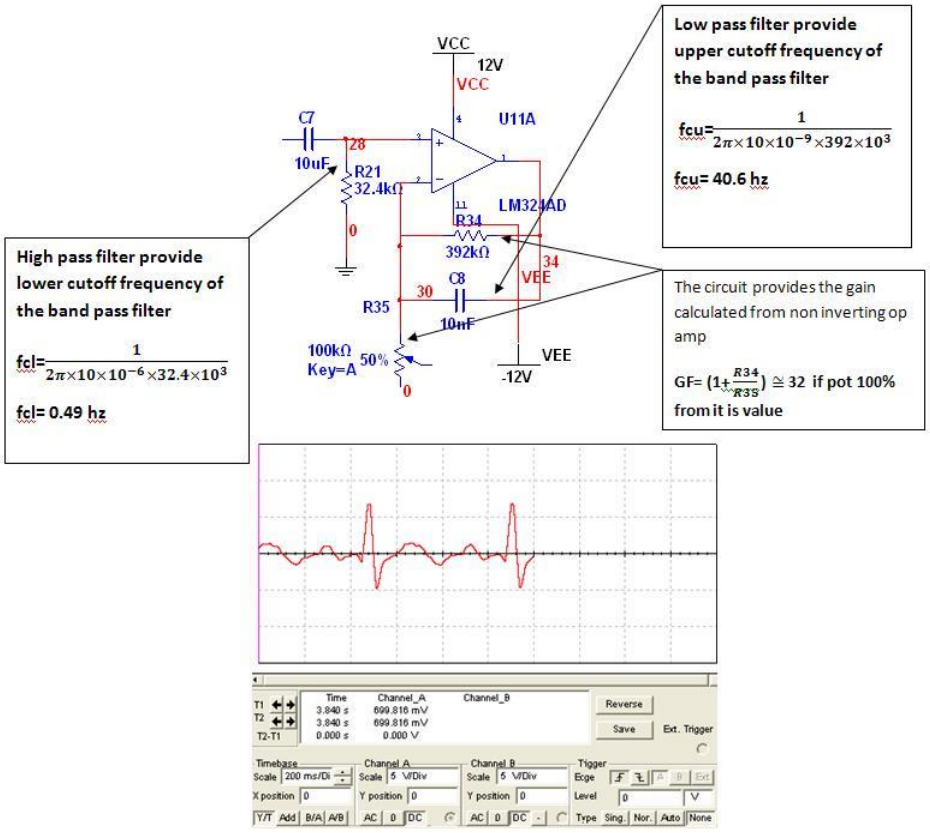
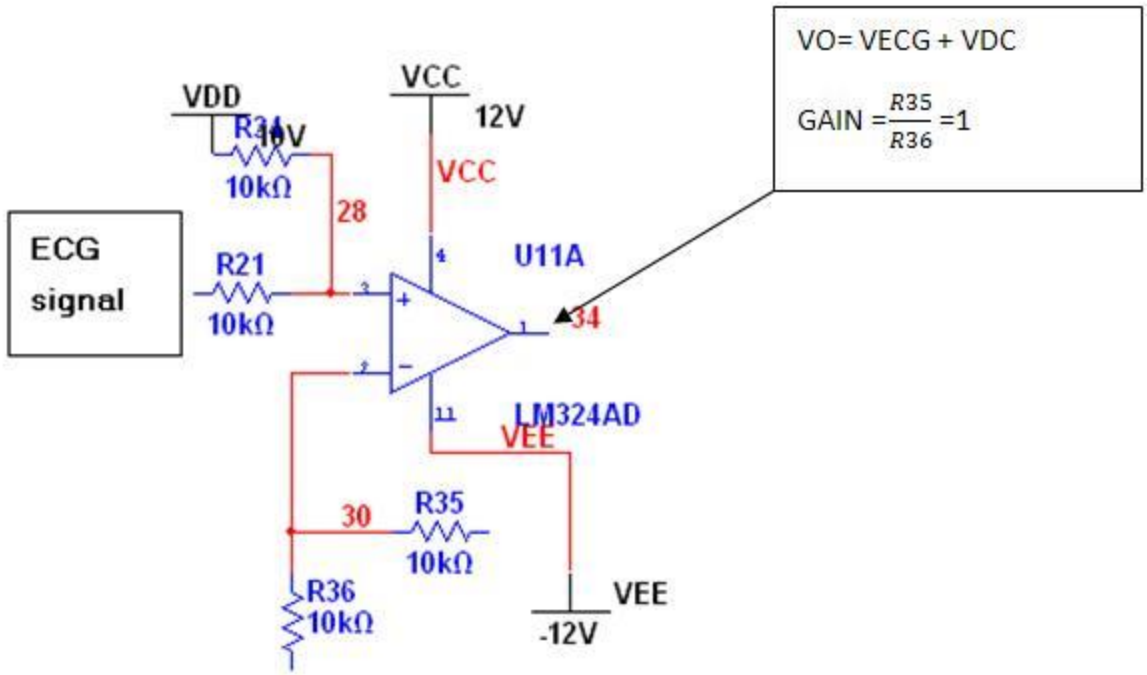


Figure 7: band pass filter.

2.7 dc offset stage:

Actually we use dc offset because some component of (QRSTU) waves in negative portion so if we want to convert our signal to digital form we need to make dc offset or we can use bi polar analog to digital converter.



Electrocardiograph Leads:

ECG leads are the pairs of electrodes across which the electrical potential is measured. There are 12 conventional leads which are divided into frontal plane and horizontal plane leads.

1. Frontal plane leads:

Standard leads I, II, III, and leads aVR, aVL, and aVF.

2. Horizontal plane leads:

Precordial leads V1-V6.

Frontal Plane Leads

Standard Leads:

The electrodes are placed at the extremities, i.e., the right arm, the left arm, and the left leg. The electrical potential recorded from one extremity will be same irrespective of where the electrode is placed on the extremity. If the limbs are amputated, then the electrodes are placed on the amputated

stumps. If the patient is suffering from tremor or shivering, then the electrodes should be placed at the upper end of the limbs.

1. Standard leads I:
Produced by placing the positive electrode on left arm and the negative electrode on the right arm.

2. Standard lead II:
Produced by placing the positive electrode on the left foot and the negative electrode on the right arm.

3. Standard lead III:
Produced by placing the positive electrode on left foot and negative electrode on the left arm. It may be noted that the left foot is always positive and the right arm is always negative as far as the placement of electrodes is concerned. Standard lead II is commonly used for cardiac monitoring as positioning of electrodes most commonly resembles the pathway of current flow in normal atrial and ventricular depolarization.

An imaginary line joining the positive and negative electrodes of a lead is called the axis of the lead. The three lead axes of these three leads form an equilateral triangle with the heart at centre called Einthoven's triangle (Fig. 1.8).

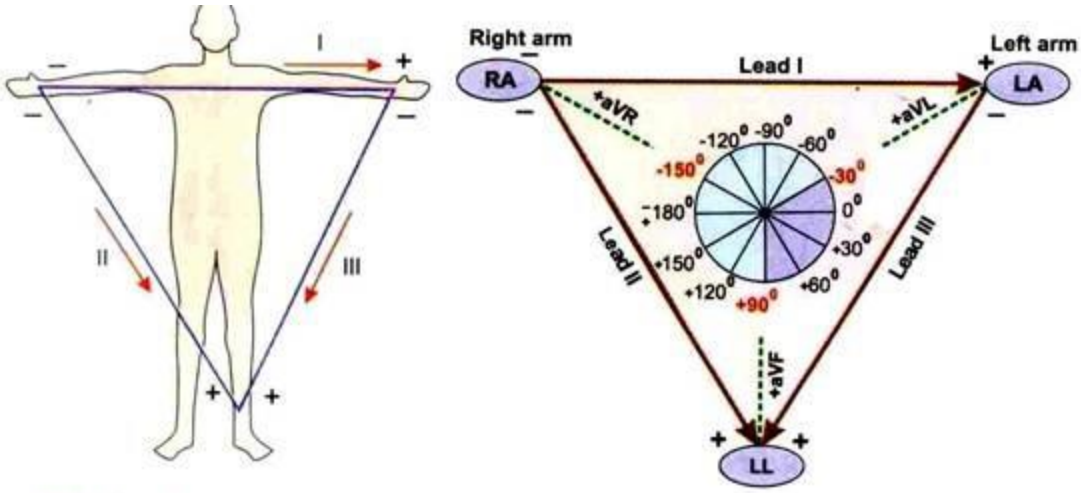


Fig. 1.8 Diagrammatic representation of three lead axes and Einthoven's triangle.

Unipolar Augmented Limb Leads:

According to Einthoven's law, the sum of the potentials of the three lead axes is equal to zero. When these three leads are connected the potential of that terminal is zero. This is the central terminal (indifferent electrode). When this terminal is connected to one pole of the galvanometer, the potential at that pole will be zero.

The electrode (exploring electrode) attached to the other pole of galvanometer will record the potential at any point relative to the indifferent electrode. The voltage at the exploring electrode is augmented by disconnecting the indifferent electrode from the limb which is tested.

1. a VR—Right arm

2. a VL—Left arm

3. a VF—Left foot

The 'a' stands for augmentation, i.e., the voltage is augmented by 50%.

Horizontal Plane Leads:

The chest leads are represented by the letter 'V'. The placement is as follows (Fig. 1.9):

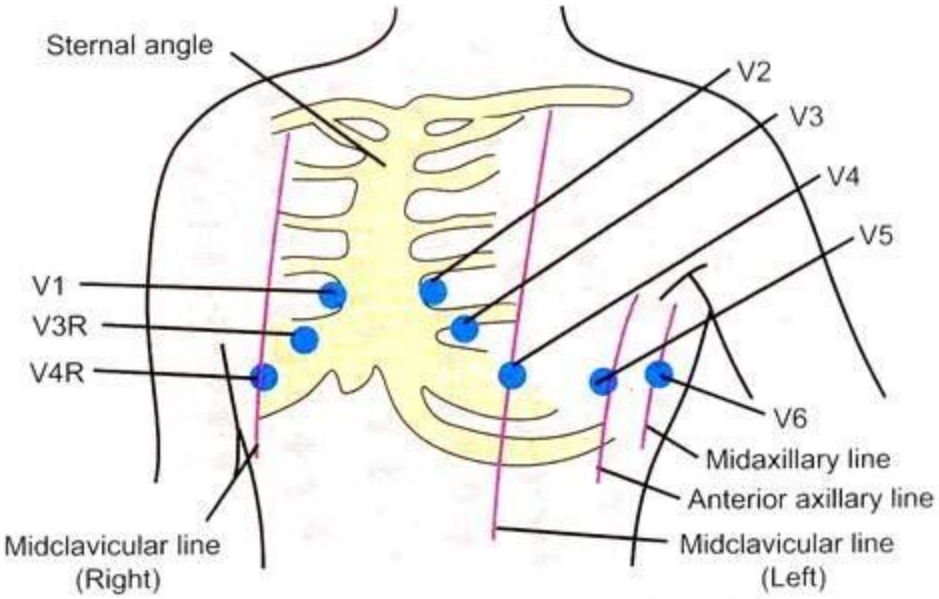


Fig. 1.9 Diagram showing the position of chest leads.

1. VI:

Placed at the 4th inter-costal space immediately to the right of sternum.

2. V2:

Placed at the 4th inter-costal space immediately to the left of sternum.

3. V3:

Placed between leads V2 and V4.

4. V4:

Placed at the 5th inter-costal space on the left midclavicular line.

5. V5:

Placed at the same horizontal level as that of lead V4 on the left anterior axillary line.

6. V6:

Placed at the same horizontal level as that of leads V4 and V5 on the left mid-axillary line.

The placement of leads is summarized in Box 1.2.

Box 1.2 Lead Placement

- Lead I: Left arm positive, right arm negative
- Lead II: Left foot positive, right arm negative
- Lead III: Left foot positive, left arm negative
- aVR: Right arm
- aVL: Left arm
- aVF: Left foot
- V1: Right 4th intercostal space by the side of sternum
- V2: Left 4th intercostal space by the side of sternum
- V3: Between leads V2 and V4
- V4: Left 5th intercostal space on midclavicular line
- V5: Same horizontal plane as lead V4 on anterior axillary line
- V6: Same horizontal plane as lead V4 and V5 on midaxillary line
- V7: Same horizontal plane as lead V4 on posterior axillary line
- V8: Same horizontal plane as lead V4 on posterior scapular line
- V9: Same horizontal plane as lead V4 on posterior left border of spine
- V3R–V9R: Same position as leads V3–V9 but on right side of chest

Recording of ECG:

1. Patient must lie down comfortably and relax. Tell him/her the procedure and you must explain that he will not feel any electric current.

2. Wipe the patient's skin with alcohol and allow it to dry. Then apply the conductive gel and connect the proper electrodes and ensure that they are in good contact with the skin.

3. The patient and the machine must be properly grounded. Any electronic equipment may produce arte-facts and hence should be removed.

4. Calibrate the record (1 mV =10 mm).

5. Record the six standard leads.

6. Record the six chest leads.

BLOOD PRESSURE MEASUREMENT

First, a doctor or other health professional wraps a special cuff around your arm. The cuff has a gauge on it that will read your blood pressure. The doctor then inflates the cuff to squeeze your arm.

After the cuff is inflated, the doctor will slowly let air out. While doing this, he or she will listen to your pulse with a stethoscope and watch the gauge. The gauge uses a scale called “millimeters of mercury” (mmHg) to measure the pressure in your blood vessels.

Another option is to get a blood pressure measurement from the machines available at many pharmacies. There are also home monitoring devices for blood pressure that you can use yourself

Blood pressure is measured using two numbers. The first number, called **systolic** blood pressure, measures the pressure in your blood vessels when your heart beats. The second number, called **diastolic** blood pressure, measures the pressure in your blood vessels when your heart rests between beats.

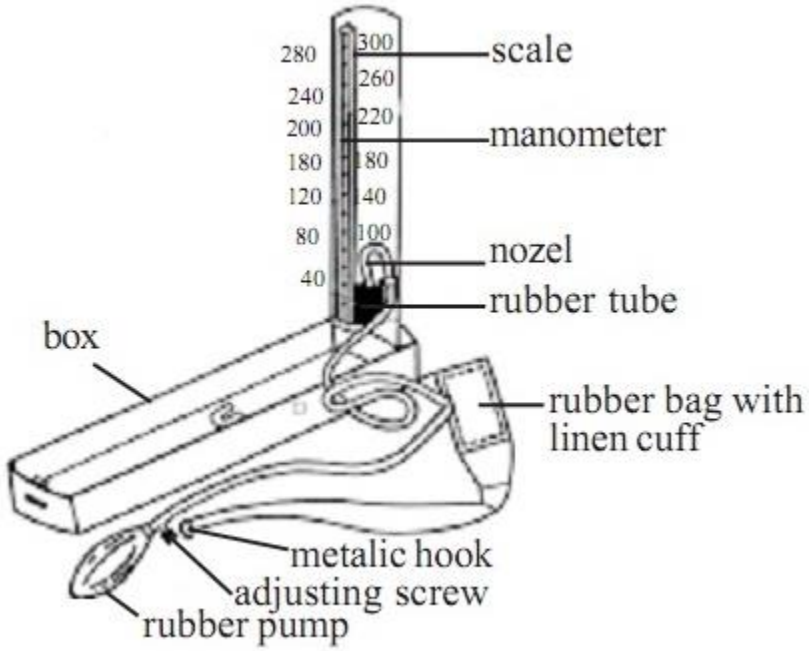
If the measurement reads 120 systolic and 80 diastolic, you would say “120 over 80” or write “120/80 mmHg.”

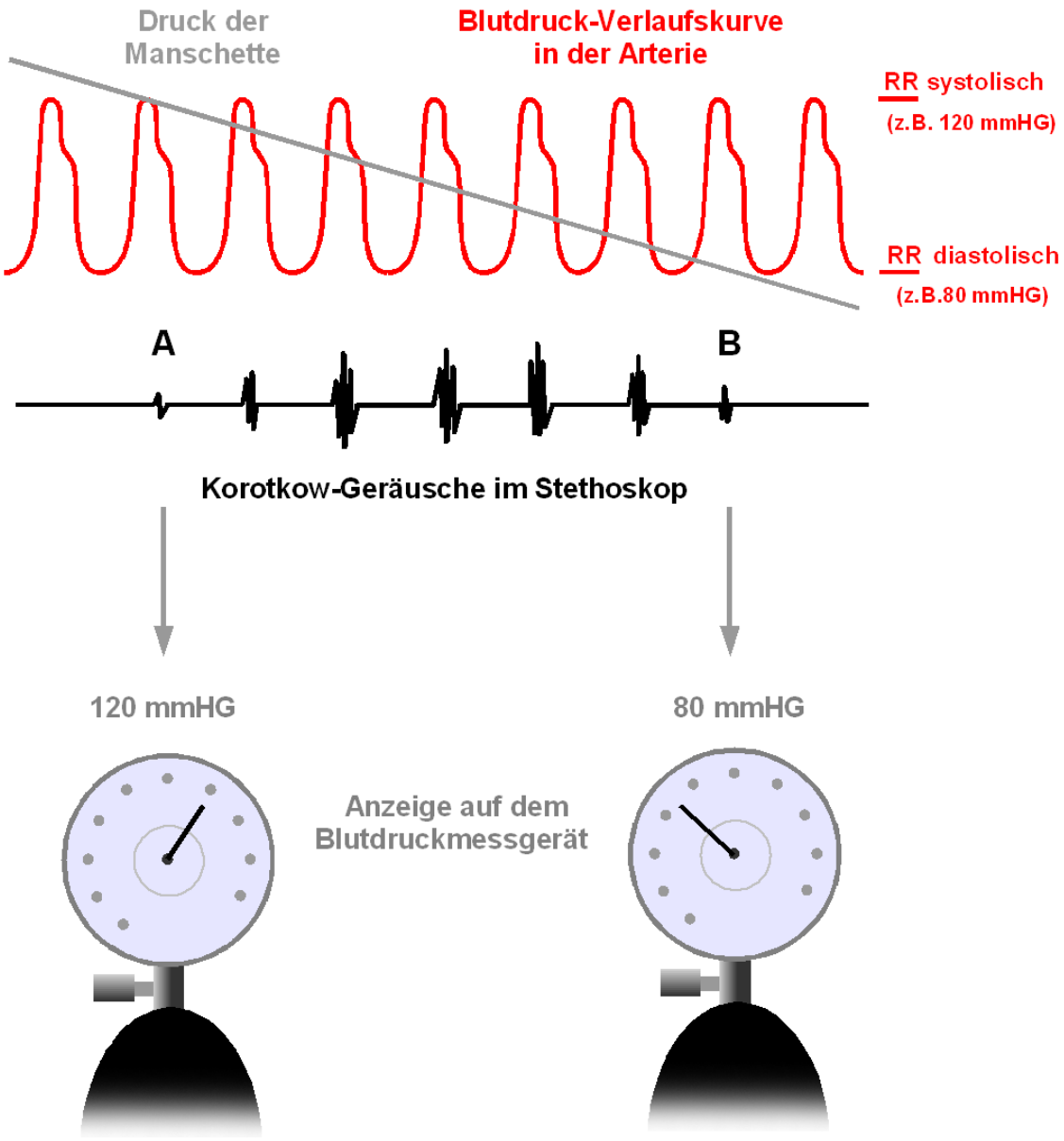
The chart below shows normal, at-risk, and high blood pressure levels. A blood pressure less than 120/80 mmHg is normal. A blood pressure of 140/90 mmHg or more is too high. People with levels in between 120/80

and 140/90 have a condition called prehypertension, which means they are at high risk for high blood pressure.

INDIRECT MEASUREMENT

Sphygmomanometers are used for measuring blood pressure. In our body, pumping blood to all parts of the body is the duty of heart.. The blood pressure measurement is done to check if the **heart and the pipes** which carry the blood are working fine. Blood pressure monitor, blood pressure meter and blood pressure gauge are different names of sphygmomanometer.
Manual and digital sphygmomanometers are in use. In manual type, the equipment consists of an inflatable cuff and a mercury or mechanical manometer. It is used in conjunction with a stethoscope. Expertise of a practitioner is often required for using manual measurement. Digital meters apply oscillometric detection. Measurements are displayed electronically and digital equipment is easy for use. Reading can be taken without training. In manual mode, the pressure in the cuff is increased or decreased manually. But in majority of digital modes, they happen automatically.





The normal reading of **blood pressure** is 120/80. These two numbers indicate what is called the systolic and diastolic pressure. The blood pressure reading is taken by first tying a cuff around the arms. This is to ensure that the cuff is wrapped around roughly at same level as the heart when the person is seated. Now, air is pumped inside the cuff so that it presses on the arm stopping the blood flow. The practitioner listens the heart beat through the stethoscope. As the pressure on the cuff is slowly released, blood starts flowing again. A pounding sound is heard when blood flow starts in the artery. The first reading (120 mm Hg) is the measure of maximum output pressure of the heart and is called the systolic pressure. The other reading (80 mm Hg) that is taken finally is when blood

flows normally or the pressure at which heart pumps when relaxed. This occurs when the cuff pressure is released further and at one point no sound is heard. This is called diastolic pressure. . In the digital mode, inflation and release of air in the cuff and display of readings happen automatically.

DIRECT MEASUREMENT

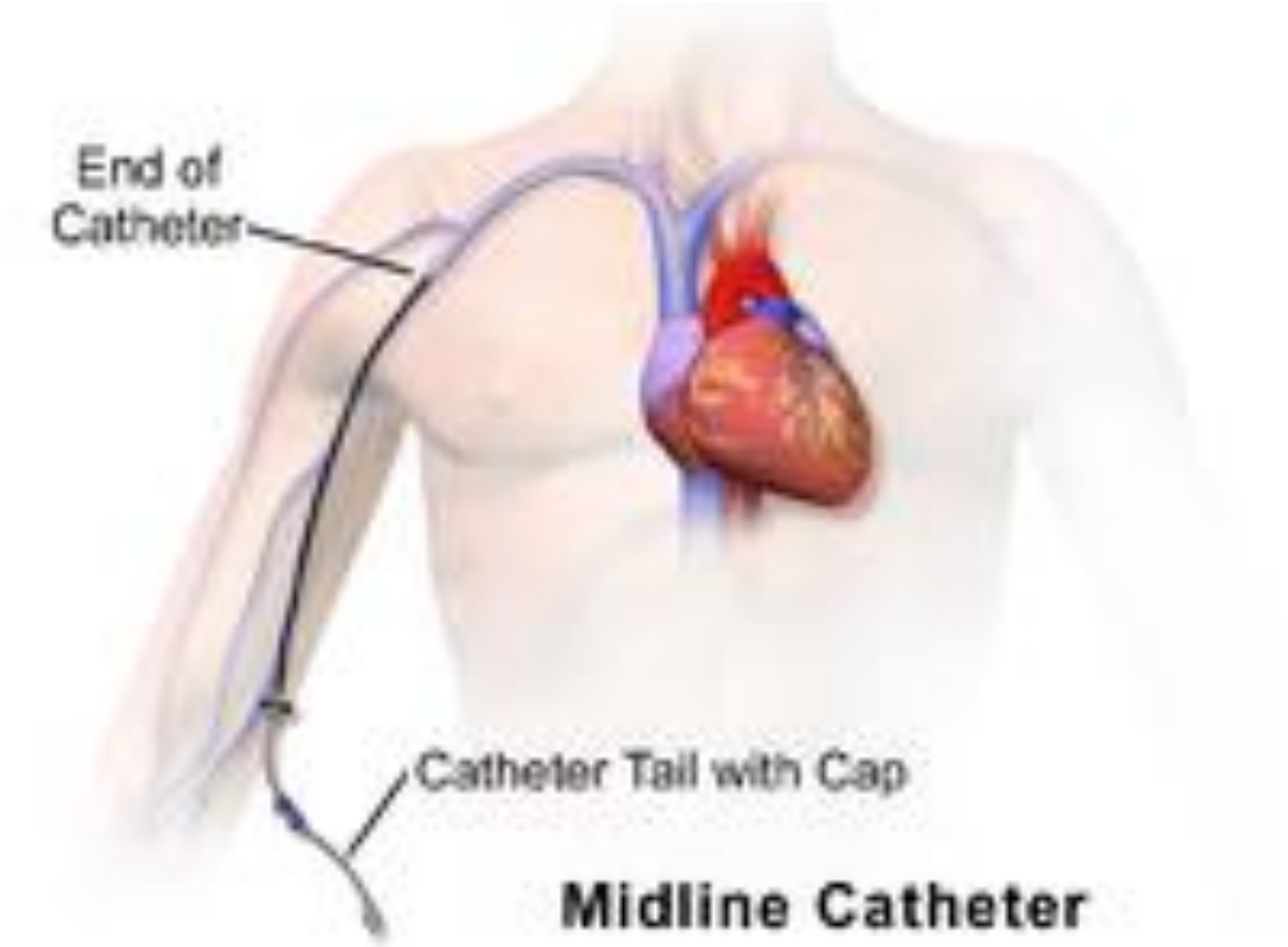
The blood pressure is measured using one of the following methods

i) Percutaneous method

ii) Catheterization

iii)Implantation of a transducer in a vessel or heart

Direct blood pressure measurement requires placing a catheter into an artery by percutaneous or cut-down methods. Although this technique requires a skilled technician or anesthetist, the arterial blood pressure readings obtained with direct measurement are more accurate and continuous compared with indirect methods. The most commonly used arteries for percutaneous catheterization in dogs and cats are the dorsal pedal (metatarsal) artery or the lingual artery. Once the catheter has been placed, it can be attached to a commercial transducer and recording system, which allows for continuous systolic, mean, and diastolic pressure readings.



Cardiac catheterization" is a general term for a group of procedures that are performed using this method, such as coronary angiography and left ventricle angiography. Once the catheter is in place, it can be used to perform a number of procedures including, coronary angioplasty, balloon septostomy, electrophysiology study or catheter ablation.

Procedures can be diagnostic or therapeutic. For example, coronary angiography is a diagnostic procedure that allows the interventional cardiologist to visualize the coronary vessels. Percutaneous coronary intervention, however, involves the use of mechanical stents to increase blood flow to previously blocked (or occluded) vessels. Other common diagnostic procedures include measuring pressures throughout the four chambers of the heart and evaluating pressure differences across the major heart valves. Interventional cardiologists can also use cardiac catheterization to estimate the cardiac output, the amount of blood pumped by the heart per minute.[1] Cardiac catheterization can be used as part of a therapeutic regimen to improve outcomes for survivors of out-of-hospital

cardiac arrestCardiac catheterization requires the use of fluoroscopy to visualize the path of the catheter as it enters the heart or as it enters the coronary arteries. The coronary arteries are known as "epicardial vessels" as they are located in the epicardium, the outermost layer of the heart.[3] Fluoroscopy can be conceptually described as continuous x-rays. The use of fluoroscopy requires radiopaque contrast, which in rare cases can lead to contrast-induced kidney injury (see Contrast-induced nephropathy). Patients are constantly exposed to low doses of ionizing radiation during procedures. Ideal table positioning between the x-ray source and receiver, and radiation monitoring via thermoluminescent dosimetry, are two main ways of reducing a person's exposure to radiation.[4] People with certain comorbidities (people who have more than one condition at the same time) have a higher risk of adverse events during the cardiac catheterization procedure.[4] These comorbidity conditions include, aortic aneurysm, aortic stenosis,

Blood flow measurement

The measurement of blood flow is important to the understanding and management of cardiovascular disease. The development of new imaging methods has allowed detailed quantification of *in vivo* blood flow that has traditionally been difficult. Both invasive and oninvasive methods have been used to measure blood flow, and this chapter outlines the main techniques of blood flow measurement for cardiovascular research and practical clinical applications. A brief history and the basic principles of each of the methods are presented along with their relative merits and potential pitfalls. Recent development of noninvasive imaging techniques has allowed detailed depiction and quantification of *in vivo* flow patterns, the main focus of this chapter is therefore directed towards Doppler ultrasound and cardiovascular magnetic resonance (CMR). The future trend of combining different imaging modalities for investigating the relationships between morphological structure and the hemodynamic properties of flow is also outlined.

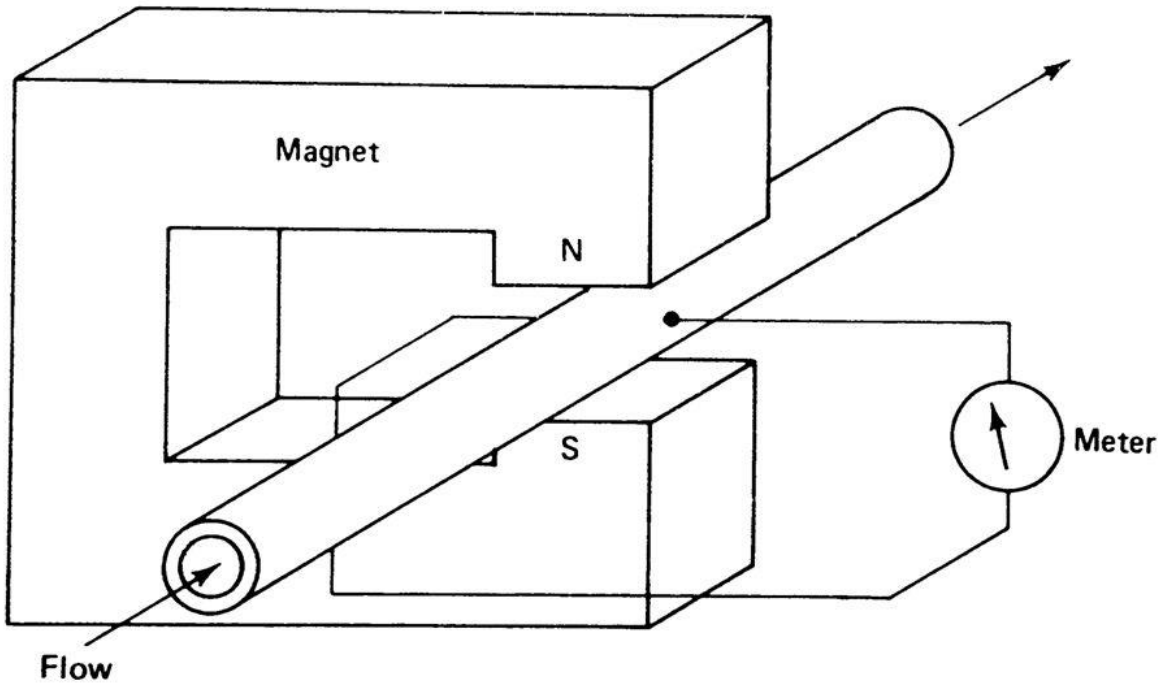
All blood flow meters used in clinical and research applications are

1. Electro magnetic induction
2. Ultrasound transmission and reflection

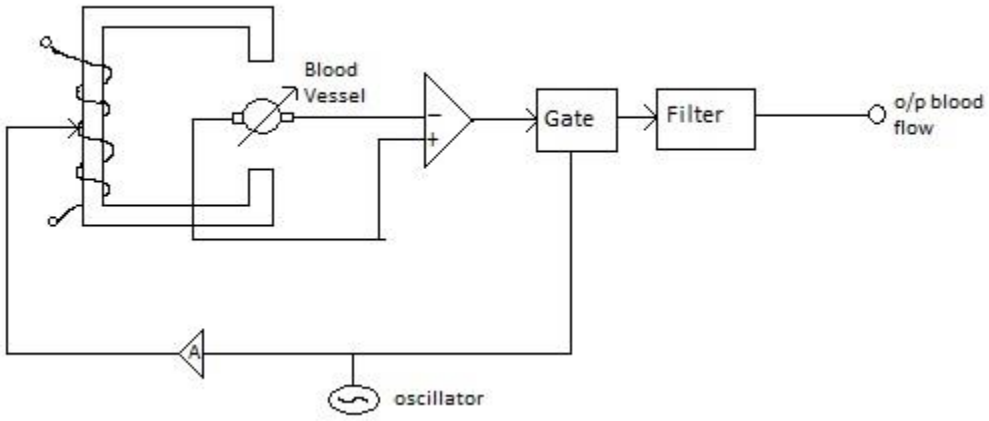
3. Thermal convection
4. Radiographic principle
5. Indicator or Thermal dilution

Magnetic Induction

The magnetic flow meter works on the principle of EMF (Electromotive Force), induced in a moving liquid under the influence of a magnetic field. Magnetic flow meters are popularly used across industries like power generation, oil and gas, material processing and so on. In this article, measurement of blood flow rate in large blood vessels using electromagnetic (EM) flow meter is discussed. The technique is non-invasive since the magnetic field can be generated by coils external to the body and the induced EMF can be measured in a capacitive manner by noncontact electrodes. A possible limitation of the technique is the movement of blood vessels due to the patient's bodily functions like respiration. In this study using a finite element (F.E.) modeling approach (COMSOL Multiphysics tool), an investigation was carried out to check the effect of blood vessel movement on blood flow measurement. The induced EMF and hence the flow meter sensitivity (induced EMF/average velocity), under vessel displaced condition has been compared against that under vessel undisplaced or original condition.



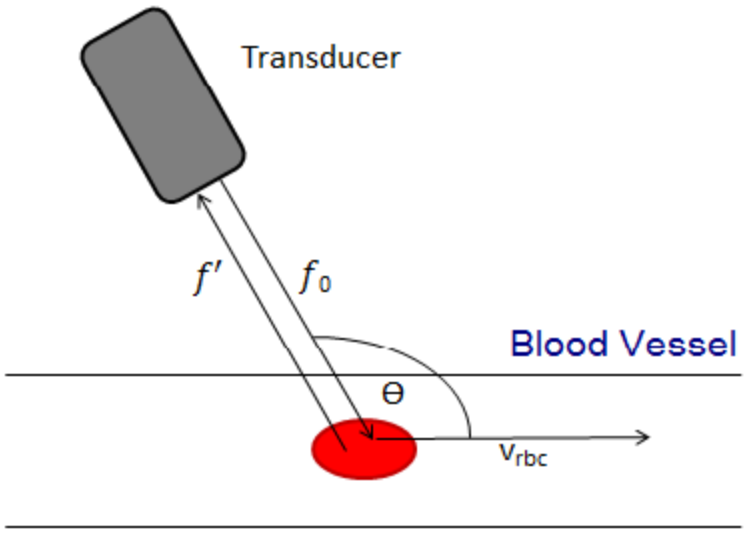
For the fluid flow calculations, a uniform inlet velocity was imposed across the pipe inlet and ambient pressure was imposed at the outlet. No slip boundary condition (u = 0) was imposed at the pipe walls. The velocity value chosen ensured that the fluid flow within the pipe is laminar. The central portion of the pipe, where we are interested, was enclosed in an air domain (Fig 2a).



A magnetically insulated boundary condition was imposed at the wall of the air domain. The pipe wall was considered electrically insulated and blood vessel properties were assigned to it. An initial vertical displacement of 0.5 cm was given to the blood vessel towards the top coil, to simulate breathing effects.

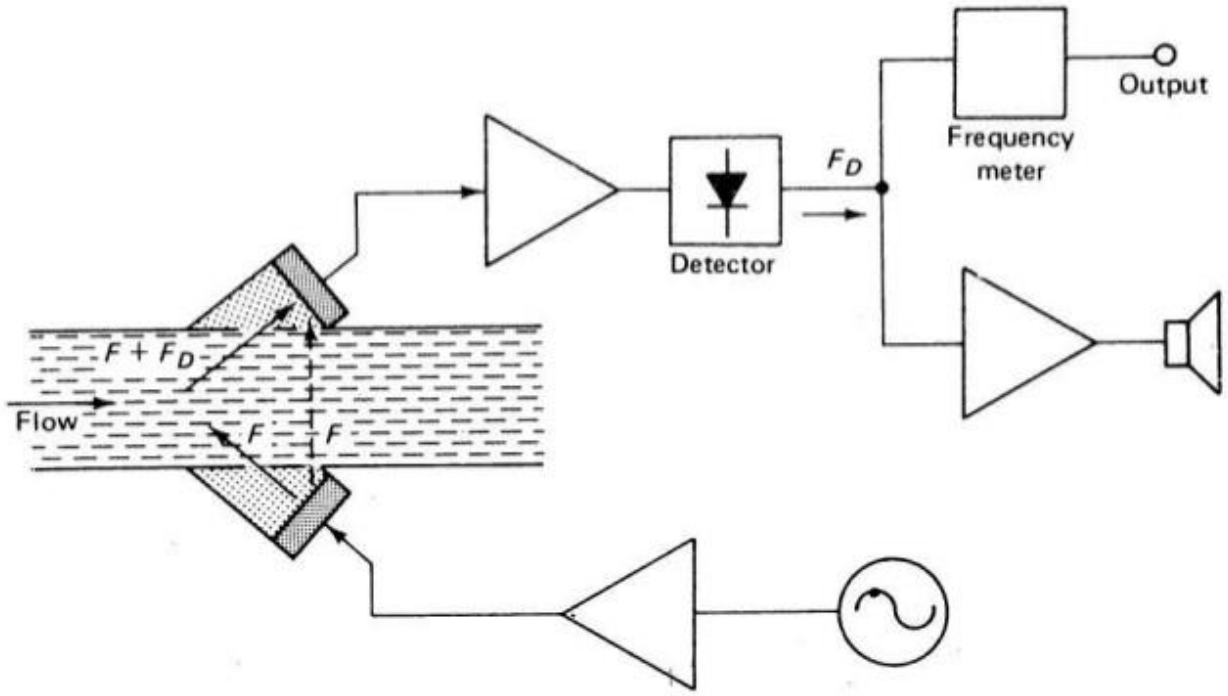
Ultrasound blood flow meter

Doppler ultrasound has now developed to the point where the rate of flow of blood in a given vessel can be measured with appropriate instrumentation. The theoretical basis of Doppler flow measurement is reviewed in this paper, with particular emphasis on the potential and actual sources of error. Three distinct approaches are identified, and the strengths and weaknesses of each discussed. The separate errors involved in estimating the vessel cross-sectional area, the angle of approach, and the Doppler shift are analyzed, together with the question of the uniformity of scattering from the blood. In vivo and in vitro tests of the accuracy obtained using a number of Doppler flow measuring instruments are then reviewed. It is concluded that the Doppler methods are capable of good absolute accuracy when suitably designed equipment is used in appropriate situations, with systematic errors of 6% of less. There are, however, considerable random errors, attributable primarily to errors in measuring the cross-sectional area and the angle of approach. Repeating the measurement of flow several times and averaging the results can reduce these random errors to an acceptable level.



One of the strengths of ultrasound imaging compared to other imaging modalities such as MRI or CT is its ability to provide bedside measurements of blood and tissue velocities. Information of blood velocities is used to identify abnormal blood flows related to pathology, such as the jet flow pattern resulting from a heart valve leakage, or the filling properties of the heart.Today, Doppler ultrasound measurement is an integral part of clinical scanner systems. Conventional blood flow imaging modalities include *spectral Doppler* where the complete spectrum of velocities within one specific region is displayed, *color-Doppler* where the mean blood velocity in a 2D or 3D image region is displayed. In the current workflow, spectral-Doppler is used quantitatively, while color-Doppler is used qualitatively. Current methods suffer from several limitations that hinder its use in the clinic, related to data acquisition, processing, and workflow. We are continuously working to improve the technology and methods to measure the properties of vascular and cardiac blood flows. Our aim is to provide a single imaging modality capable of providing accurate and robust 2D and 3D quantitative information of blood velocities without the need for image interpretation.

Doppler Type Ultrasonic Flow Meters



Thermal convection measurement

A catheter-type flowmeter for continuous blood-velocity measurements is described. The new device is based on the thermal method: a constant amount of electrically produced heat is partly dissipated by convection into the bloodstream. The resulting equilibrium for each value of blood velocity determines the temperature of the heat-dissipating body. This temperature is accurately measured by means of thermistors. Linearisation of the hyperbolic blood-velocity thermistor-resistance relationship is performed by means of an appropriate antilogarithmic amplifier.

Radiographic method

TO HAVE a complete understanding of coronary artery disease, a clinician must be able to evaluate coronary anatomy, ventricular function, and coronary blood flow. Selective coronary arteriography and left ventriculography remain the standard means for obtaining information on the first two factors. Although visual analysis of percent diameter coronary stenosis suffers from significant intraobserver and interobserver variability, quantitative analysis of arteriographic images provides accurate and objective measurements of arterial geometry. The third factor, coronary blood flow, is rarely measured directly. Most often, alterations in blood flow are inferred clinically from the coronary anatomy. This inference is based on the close correlation between percent diameter stenosis and coronary flow reserve found in experimental animals, coronary flow reserve being defined as the ratio of maximal hyperemic-to-baseline blood flow in a coronary artery.' Contrary to these experimental observations are data suggesting that human coronary flow reserve correlates poorly with percent diameter stenosis and only moderately with absolute measurements of stenosis geometry-' Recent developments in radiographic technology have therefore rekindled an interest in measuring coronary blood flow and flow reserve in the catheterization laboratory, with the intention of providing an independent means for their assessment. Results of preliminary trials suggest that this is possible, although contrast media cannot be used to measure coronary blood flow by traditional approaches. Early data also suggest that many factors in addition to epicardial arterial stenosis need to be considered in the clinical interpretation of blood flow parameters

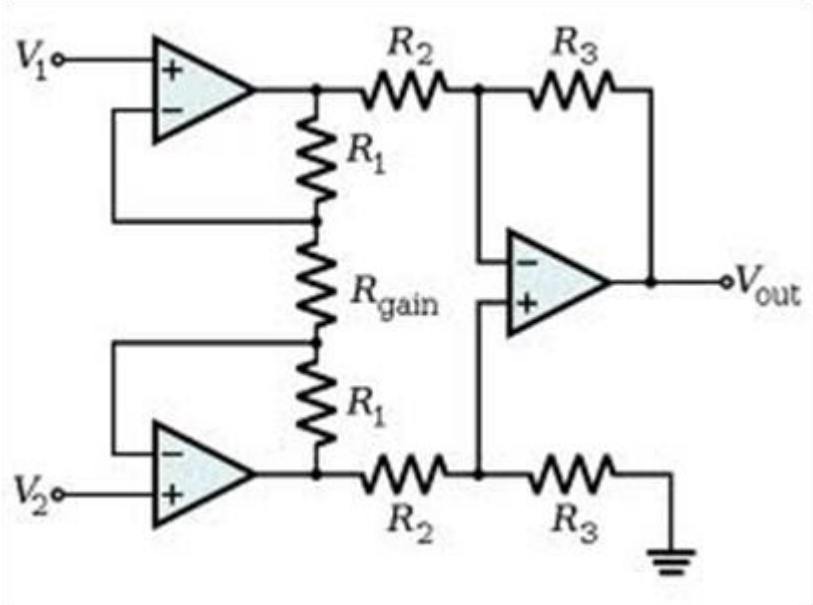
4. Monitors and Recorders

Bio potential amplifier

Amplifiers are an important part of modern instrumentation systems for measuring biopotentials. Such measurements involve voltages that often are at low levels, have high source impedances, or both. Amplifiers are required to increase signal strength while maintaining high fidelity. Amplifiers that have been designed specifically for this type of processing of biopotentials are known as biopotential amplifiers. In this chapter we examine some of the basic features of biopotential amplifiers and also look at specialized systems.

The essential function of a biopotential amplifier is to take a weak electric signal of biological origin and increase its amplitude so that it can be further processed, recorded, or displayed. Usually such amplifiers are in the form of voltage amplifiers, because they are capable of increasing the voltage level of a signal. Nonetheless, voltage amplifiers also serve to increase power levels, so they can be considered power amplifiers as well. In some cases, biopotential amplifiers are used to isolate the load from the source. In this situation, the amplifiers provide only current gain, leaving the voltage levels essentially unchanged.

Figure below show the basic Biopotential amplifier circuit diagram



The gain of the circuit is

$$\frac{V_{\text{out}}}{V_2 - V_1} = \left(1 + \frac{2R_1}{R_{\text{gain}}}\right)\frac{R_3}{R_2}$$

The rightmost amplifier, along with the resistors labeled R_2 and R_3 is just the standard differential amplifier circuit, with gain = R_3 / R_2 and differential input resistance = $2 \cdot R_2$. The two amplifiers on the left are the buffers. With R_{gain} removed (open circuited), they are simple unity gain buffers; the circuit will work in that state, with gain simply equal to R_3 / R_2 and high input impedance because of the buffers.

The buffer gain could be increased by putting resistors between the buffer inverting inputs and ground to shunt away some of the negative feedback; however, the single resistor R_{gain} between the two inverting inputs is a much more elegant method: it increases the differential-mode gain of the buffer pair while leaving the common-mode gain equal to 1. This increases the common-mode rejection ratio (CMRR) of the circuit and also enables the buffers to handle much larger common-mode signals without clipping than would be the case if they were separate and had the same gain. Another benefit of the method is that it boosts the gain using a single resistor rather than a pair, thus avoiding a resistor-matching problem (although the two R_1s need to be matched), and very conveniently allowing the gain of the circuit to be changed by changing the value of a single resistor. A set of switch-selectable resistors or even a potentiometer can be used for R_{gain}, providing easy changes to the gain of the circuit, without the complexity of having to switch matched pairs of resistors.

To be useful biologically, all biopotential amplifiers must meet certain basic requirements. They must have high input impedance, so that they provide minimal loading of the signal being measured. The characteristics of biopotential electrodes can be affected by the electric load they see, which, combined with excessive loading, can result in distortion of the signal. Loading effects are minimized by making the amplifier input impedance as high as possible, thereby reducing this distortion. Modern biopotential amplifiers have input impedances of at least 10 megaohm.

The input circuit of a biopotential amplifier must also provide protection to the organism being studied. Any current or potential appearing across the amplifier input terminals that is produced by the amplifier is capable of affecting the biological potential being measured. In clinical systems, electric currents from the

input terminals of a biopotential amplifier can result microshocks or macroshocks in the patient being studied—a situation that can have grave consequences. To avoid these problems, the amplifier should have isolation and protection circuitry, so that the current through the electrode circuit can be kept at safe levels and any artifact generated by such current can be minimized.

The output circuit of a biopotential amplifier does not present so many critical problems as the input circuit. Its principal function is to drive the amplifier load, usually an indicating or recording device, in such a way as to maintain maximal fidelity and range in this readout. Therefore, the output impedance of the amplifier must be low with respect to the load impedance, and the amplifier must be capable of supplying the power required by the load.

Biopotential amplifiers must operate in that portion of the frequency spectrum in which the biopotentials that they amplify exist. Because of the low level of such signals, it is important to limit the bandwidth of the amplifier so that it is just great enough to process the signal adequately. In this way, we can obtain optimal signal-to-noise ratios (SNRs). Biopotential signals usually have amplitudes of the order of a few millivolts or less. Such signals must be amplified to levels compatible with recording and display devices. This means that most biopotential amplifiers must have high gains—of the order of 1000 or greater.

Monitors

A computer monitor, technically termed as visual display unit is an output device that presents the information from the CPU on the screen working as an interface between CPU and the user. A cable connects the monitor to a video adaptor or video card which is set up on the motherboard of the computer. The CPU (Central Processing Unit) sends instruction to the video adaptor telling what needs to be displayed on the screen. The video adaptor converts the instructions into a set of corresponding signals and sends to the monitor. Monitor contains a circuitry that generates the picture on the screen from the set of signals.

History

The first monitor dates long back in history. In the early stages of its evolution they were known as Terminals,  which were the boxy Video Display Terminals (VDTs). VDTs were monochrome monitors which used CRT (Cathode Ray Tube) technology. They were capable of working with any type of computer by connecting through a serial interface.

IBM's CRT - IBM launched its first computer also known as a 'three piece computer' in 1981. It had three different units – CPU, monitor and keyboard separately. By 1984, IBM introduced the new CRT monitor with enhanced Color Graphics Adaptor (CGA) with 16 colors and a resolution of 640 x 350 pixels. In 1987 IBM started offering the Video Graphics Array as part of its new PCs which allowed 256 different colors and a resolution of 640 x 480 pixels.

XGA and UXGA – A new technology named Enhanced Graphics Array or XGA was introduced in 1990 which allowed 16.8 million colors with a resolution of 800 x 600 pixels. The new monitors were now offering true colors that matched the human eye (human eye can detect 10 million different colors). Later the technology extended as UXGA, Ultra Extended Graphics Array which allowed 1600 x 1200 pixels.

In the 90s the LCD monitors came in the scene and gradually started competing with the CRT monitors. By the end of the 20th century, the CRT era was declining with the increasing popularity of Liquid Crystal Technology (LCD). This technology produces sharper images than the CRT monitors and the LCD monitors are significantly thinner having lower radiation emissions.

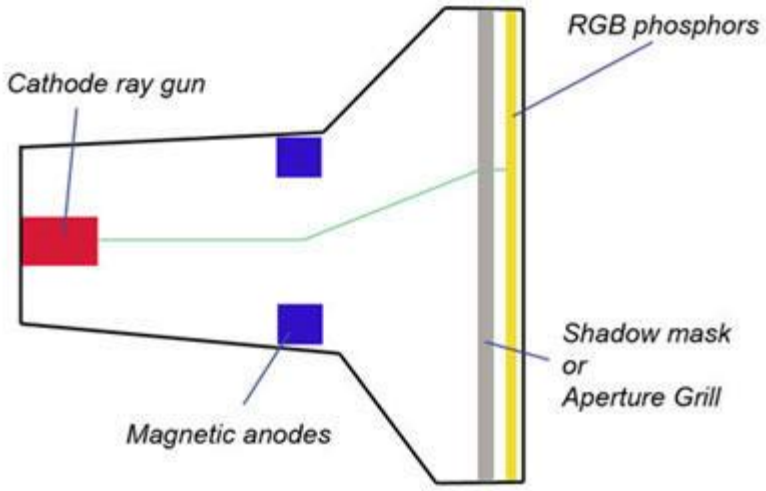
Few years' back, LED displays came in the scene and they are gradually making its space in the market. LED technology has various advantages over LCD technology like better image quality, low power consumption, etc.

Display Technologies

Since the beginning of computer era, there have been a number of technologies used for the display of output. The major technologies are CRT, LCD, Plasma, LED and OLED displays.

1. Cathode Ray Tube (CRT) Monitors

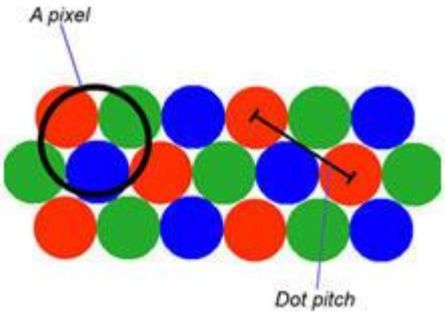
These monitors employ the CRT technology to create a display. The CRT (also known as picture tube) receives



the signals through a cable and the signal is decoded by the display controller which finally appears on a phosphor screen. The detailed working is as following:

As shown in the image CRTs have a conical shape and there is an electron gun or cathode ray gun at the back end of the monitor and a phosphor screen in the front. The electron gun fires a stream of electrons towards the display screen through a vacuum tube. This stream of electrons is also known as cathode rays. At the middle of the monitor, there are magnetic anodes which are magnetized in accordance with the instruction from the display controller. When electrons (cathode rays) pass through the magnetic anodes, they are pushed or pulled in one direction or other depending on the magnetic field on the anodes. This directs the electrons towards the correct part of phosphor coating inside the display glass. When electrons strikes the phosphor coated screen passing through a mesh (shadow mask or aperture grill), the phosphor lights up making a displayable dot on the computer screen. There are three different colored phosphors (Red, Green and Blue) for each pixel and the color of the pixel depends on the phosphor on which the electrons strike.

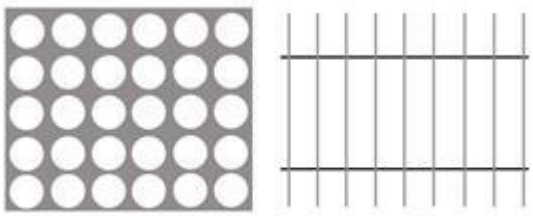
This image shows the color combination schematic for phosphor particles. The



monitor that has a single electron gun has three different phosphors for each pixel. A cathode ray strikes to one or more of these phosphors and the corresponding colored pixel appear on the screen. However high quality monitors use individual electron gun for each color which improves the image quality. Distance for two same colored phosphors (for single electron gun monitors) is known as dot pitch. Lesser the dot pitch higher is the quality of monitors.

Aperture Grille v/s Shadow Mask

CRTs incorporate a metal sheet behind the display screen which affects the pixels



Shadow mask and Aperture Grill

on the screen as well as brightness on the screen. Shadow mask is an obsolete technology in which there is a metal sheet with millions of holes to pass electrons in order to hit the phosphor coating. The shadow mask covers the entire screen thereby protecting the phosphors from stray ions (due to vacuum) and also limits the strength of the rays reducing the brightness on the monitor.

Aperture grille is a mesh of wires rather than any metal sheet with holes in it. Although the grill is fragile, it allows a brighter display.

RECORDERS

In any instrumentation system one of the important consideration is the method by which the data acquired is recorded. The recording method should be consistent with the typical system. If the signal is analogue and the analogue output is available for recording then we need an

analogue recorder to record the event. On the other hand, if the system has a digital output then digital recor:ding system to needed.
/Thus there are two types of recorders are used:
(a) Analogue Recorders.
(b) Digital Recorders.
Analogue Recorders are of various types. They can be broadly classified as under:
(z) Graphic Recorders.
(irJ Osicllographic Recorders.
(ifiJ Magnetic Tape Recorders.
The Graphic Recorders are devices which display and store a pen and ink record of some physical event. The basic element of a recorder include a chart for displaying and storing the recorded information, a chart drive for driving paper with known speed and a suitable coupling for connecting the source of information. The graphic recorders can be further classified as follows:
(a) Strip Chart Recorders:
A strip chart recorder records one or more variables with respect to time.
. Strip Chart Recorder
Strip chart recorders use a long roll or strip of paper to archive data points over a timed interval. Using data acquired by one or more sensors, strip chart use one or more pens to plot the data linearly as the chart passes at a uniform speed. The benefits of strip chart recorders includes the ease of operation, the hardcopy it produces, and real-time output.

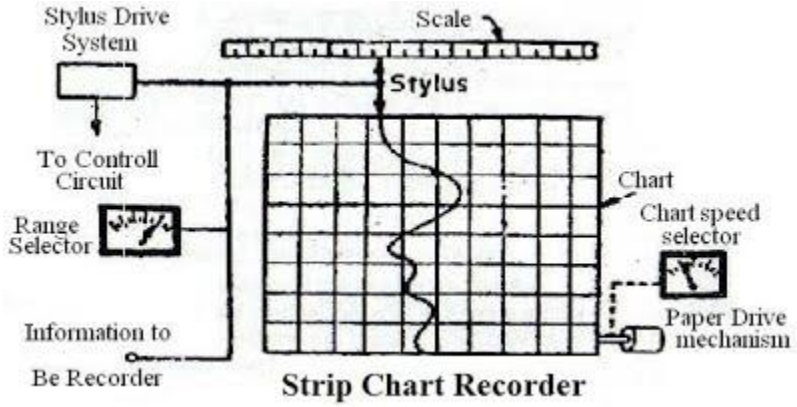
Common applications for strip chart recorders include temperature and humidity measurements, flow rates, pH, pressure, as well as a host of other process measurements. Strip chart recorders are especially well suited for recording continuous processes. Strip chart recorders are available in single or multichannel styles and in various configurations. Many recorders can also record information in a digital format for download to a computer. Strip chart recorders require the correct charts and pens to work correctly.

Strip Chart Recorder Technology

Generally speaking, strip chart recorders simply render data. The data itself is produced by application specific sensors that attach to the recorder. Sensor types include temperature (thermocouple, thermistor, RTD), strain gauge or bridge, current, humidity, level, pressure, pH, as well as many others.

Sensors can be either active or passive devices. Passive sensors, like thermocouples, do not require an outside power supply to generate a signal. Active sensors, on the other hand, do require a power supply to generate a signal. Power to active sensors is often provided by the recorder and is referred to as the excitation source. Signal excitation can either be a voltage or current output.

As the recorder receives a digital signal, analog signal or sensor input, the chart paper (for chart or strip recorders) is driven past the pen (or pens) at a steady rate by the drive mechanism. The pen assemblies typically use a galvanometer or potentiometer to drive the marking device.



The ink is supplied to the stylus from a refillable reservoir by capillary action. Modern technology has replaced these pens by disposable fibre tip pens. In addition, multichannel operation can be performed, i.e. at any instant, a maximum of six pens can be used to record data. When using multiple pens, staggering of the pens are necessary to avoid mechanical interference.

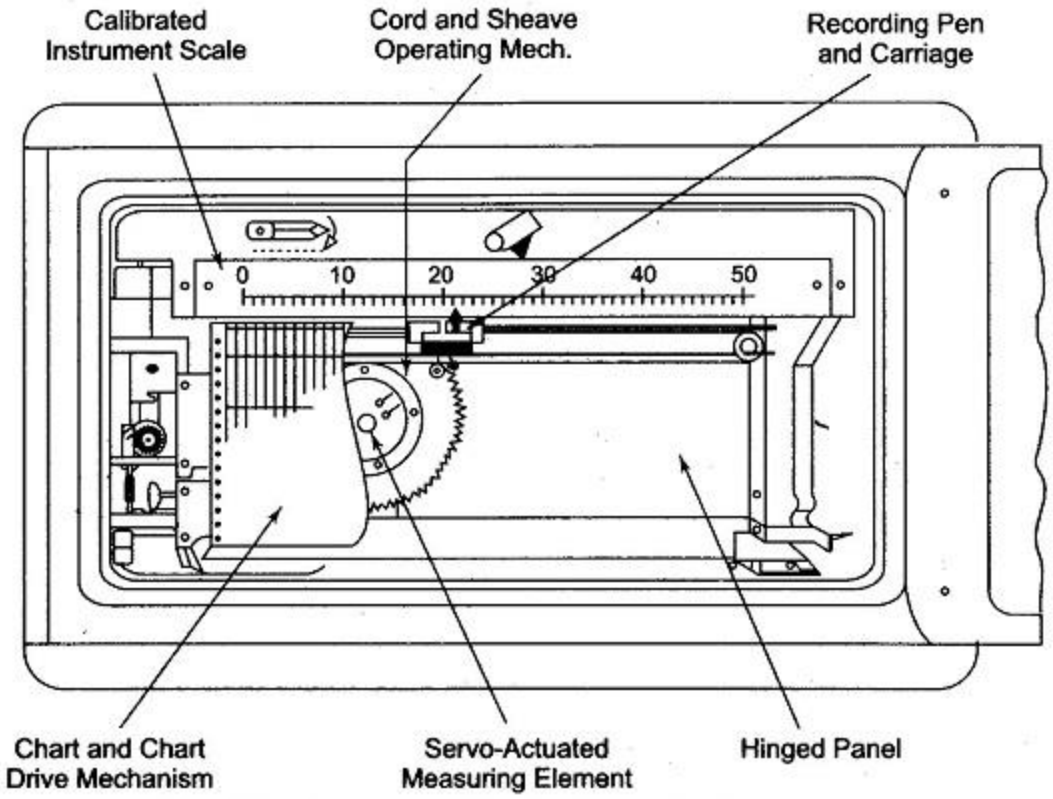


Fig. 12.1(b) Assembly of a Single Pen Servo Operated Strip Chart Recorder

2.Impact Printing

The original impact system consisted of a carbon ribbon placed between the pointer mechanism and paper, which provided the ink for recording data. The mark was made on the paper by pressing the pointer mechanism on it. The advantage of impact printing over the pen and ink method is that, it can record data on up to 20 variables simultaneously. This is achieved with the help of a wheel with an associated ink pad which provides the ink for the symbol on the wheel. The wheel is moved across the paper in response to the variable being recorded.

In some mechanisms, pressure sensitive paper is used. The markings on the paper are done with chopper bar, which applies the pressure on the paper. The frequency of the chopper bar is once per second.

3.Thermal Writing

In this system, a special movable pen which is thermally heated by passing an electric current through it is used. This system requires a thermally sensitive paper which changes its colour on application of heat.

4.Electric Writing

This technique is based on the principle of electrostatics.

In this method, a special chart paper is used. This paper consists of a paper base coated with a layer of coloured dye (black, blue or red), which in turn is coated with a thin surface of aluminium.

The stylus (pen) consists of a tungsten wire moving over the aluminium surface. Markings on the paper are achieved by applying a potential of 35 V to the stylus. This causes an electric discharge which removes the aluminium, revealing the coloured dye.

5.Optical Writing

In this technique of writing, a special photo sensitive chart paper, sensitive to ultra violet light is used. This technique is mostly used in galvanometer system.

Ultra violet light is used to reduce unwanted effects from ambient light. The paper can be developed in daylight or under artificial light without the need for special chemicals, which is not possible if ordinary light is used.

Most recorders use a pointer attached to the stylus. This pointer moves over a calibrated scale giving the instantaneous value of the quantity being recorded.

- **Paper drive system:** The paper drive system should move the paper at a uniform speed. A spring wound mechanism may be used in most A synchronous motor is used for driving the paper.
- **Chart speed:** Chart speed is a term used to express the rate at which the recording paper in a strip chart recorder moves. It is expressed in in/s or mm/s and is determined by mechanical gear trains. If the chart speed is known, the period of the recorded signal can be calculated as

$$\text{Period} = \frac{\text{time}}{\text{cycle}} = \frac{\text{time base}}{\text{chart speed}}$$

and frequency can be determined as $f = 1/\text{period}$

The recording pen is connected to an ink reservoir through a narrow bore tube. Gravity and capillary action establish a flow of ink from the reservoir through the tubing and into the hollow of the pen.

Galvanometer type recorders are well suited for low frequency ac inputs obtained from quantities varying slowly at frequencies of upto 100 c/s, or in special cases up to 1000 c/s.

Because of the compact nature of the galvanometer unit (or pen motor) this type of recorder is particularly suitable for multiple channel operation. Hence it finds extensive use in the simultaneous recording of a large number of varying transducers outputs.

This recorder uses a curvilinear system of tracing. The time lines on the chart must be arcs of radius R (where R is the length of the pointer), and the galvanometer shaft must be located exactly at the center of curvature of a time line arc. Improper positioning of the galvanometer or misalignment of the chart paper in the recorder can give a distorted response, i.e. having a negative rise time or a long rise time. One method of avoiding the distorted appearance of recordings in curvilinear coordinates is to produce the recording in rectangular coordinates. In this design, the chart paper is pulled over a sharp edge that defines the locus of the point of contact between the paper and the recording stylus. The stylus is rigidly attached to the galvanometer coil and wipes over the sharp edge as the coil rotates.

In one of the recorders, the paper used is usually heat sensitive, and the stylus is equipped with a heated tip long enough to guarantee a hot point of contact with the paper, regardless of the stylus position on the chart. Alternatively the paper can be electrically sensitive, in which case the stylus tip would serve to carry current into the paper at the point of contact.

The recorders can work on ranges ranging from a few mA/mV to several mA/mV. These moving galvanometer type recorders are comparatively inexpensive instruments, having a narrow bandwidth of 0 — 10 Hz. They have a sensitivity of about 0.4 V/mm, or from a chart of 100 mm width a full scale deflection of 40 mV is obtained.

In most instruments, the speed of the paper through the recorder is determined by the gear ratio of the driving mechanism. If it is desired to change the speed of the paper, one or more gears must be changed.

Paper speed is an important consideration for several reasons.

1. If the paper moves too slowly, the recorded signal variations are bunched up and difficult to read.
2. If the paper moves too fast, the recorded waveform will be so spread out that greater lengths of paper will be required to record the variations of the signal. It also makes the task of reading and interpreting the waveforms more difficult.
3. Also, the operator can determine the frequency components of the recorded waveform, if he knows how fast the paper has moved past the pen position. The paper is usually printed with coordinates, such as graph

Some recorders contain a timing mechanism that prints a series of small dots along the edge of the paper chart, as the paper moves through the recorder. This time marker produces one mark per second.

These types of recorders are mostly used as optical recorders, and contain a light source provided by either an ultra violet or tungsten lamp.

A small mirror is connected to the galvanometer movement and the light beam is focussed on this mirror, as shown in Fig. 12.2(b).

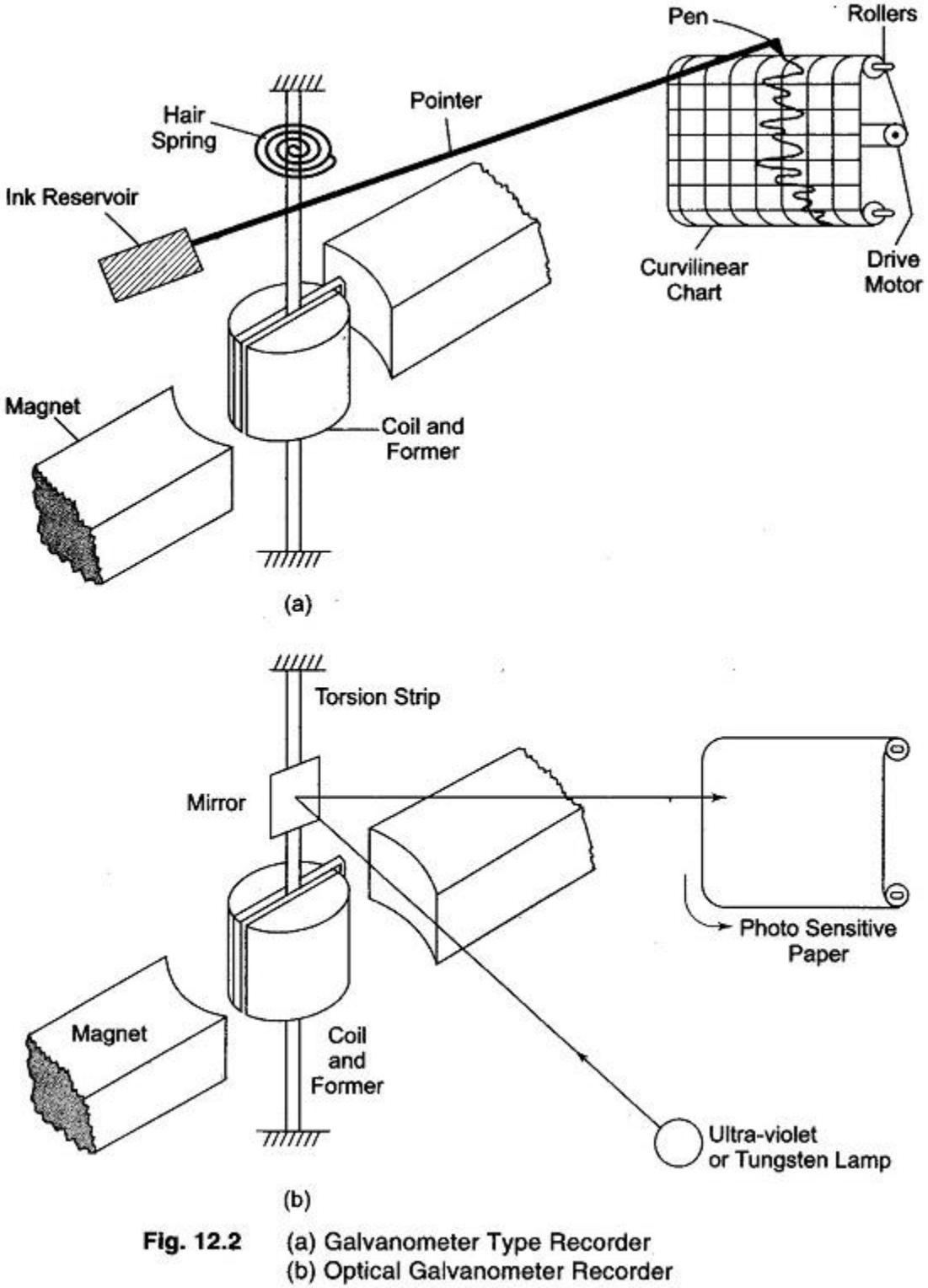


Fig. 12.2 (a) Galvanometer Type Recorder
(b) Optical Galvanometer Recorder

The beam reflected from the mirror is focussed into a spot on a light sensitive paper.

As the current passes through the coil, the mirror deflects. The movement of the light beam is affected by the deflection of the small mirror, and the spot on the paper also varies for the same reason, thus tracing the waveform on the paper.

POTENTIOMETRIC RECORDERS

Potentiometric recorders have much better specifications than galvanometric recorders, with a typical inaccuracy of š0.1% of full scale and measurement resolution of 0.2% f.s. being achievable. Such instruments employ a servo system, as shown in Figure 11.8, in which the pen is driven by a servomotor, and a potentiometer on the pen feeds back a signal proportional to pen position. This position signal is compared with the measured signal, and the difference is applied as an error signal that drives the motor. However, a consequence of this electromechanical balancing mechanism is to give the instrument a slow response time in the range 0.2–2.0 seconds. This means that potentiometric recorders are only suitable for measuring d.c. and slowly time-varying signals. In addition, this type of recorder is susceptible to commutator problems when a standard d.c. motor is used in the servo system. However, the use of brushless servo motors in many recent models overcomes this problem. Newer models also often use a non-contacting ultrasonic sensor to provide feedback on pen position in place of a Measurement and Instrumentation Principles 207 Servomotor and gearbox Measured Error signal Pen position signal Potentiometer Pen position

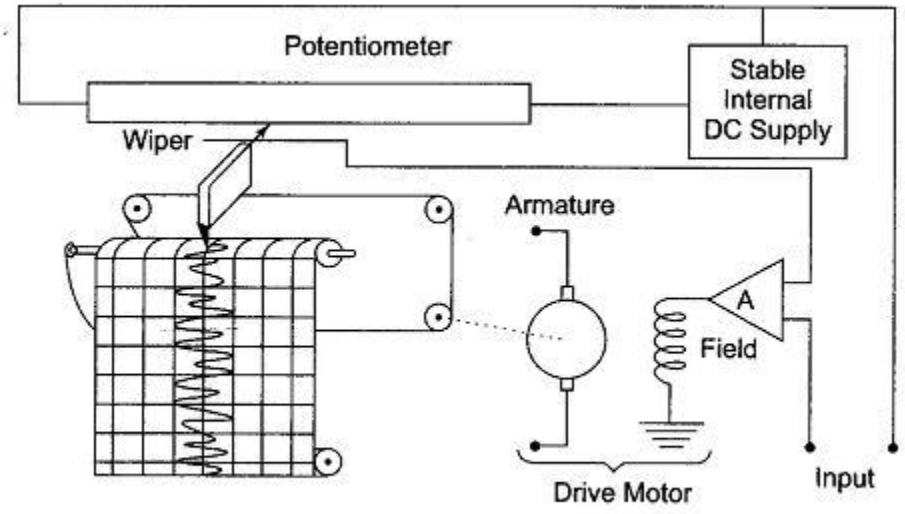
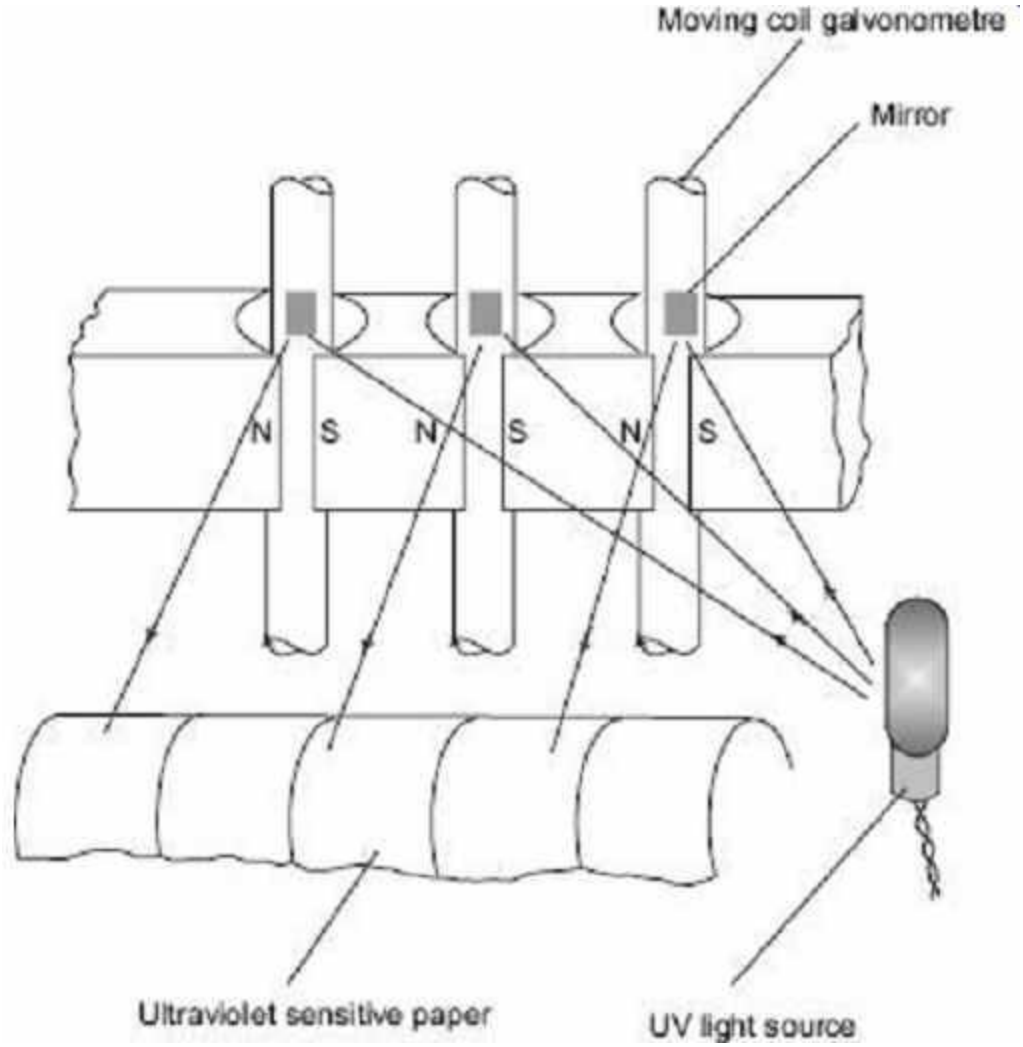


Fig. 12.4 Block Diagram of Self-Balancing Potentiometer Recorder

ULTRAVIOLET RECORDER

A number of situations may cause deviations from Beer's law, such as high concentration or mixtures of
compounds which absorb at the wavelength of interest. From an instrumental standpoint, the primary

causes are stray light and excessive spectral bandwidth. Stray light refers to any light reaching the detector
other than light from the desired pass-band which has passed through sample. Sources of stray light may
include room light leaking into the detection chamber, scatter from the cuvette, and undesired fluorescence.
A typical spectrophotometer consists of a light source, some form of wavelength selection, and a
detector for measuring the light transmitted through the samples. There is no single light source that
covers the entire visible and UV spectrum. The source most commonly used for the visible part of the
spectrum is the tungsten-halogen lamp, which provides continuous radiation over the range of 360 to
950 nm. The deuterium lamp has become the standard for much UV work. It covers the range from
220–360 nm. Instruments which cover the entire UV/visible range use both lamps with a means for
switching from one lamp to the other at a wavelength of approximately 360 nm .
Wavelength selection is accomplished with filters, prisms, and diffraction gratings. Specially designed
interference filters can provide bandwidths as small as 5 nm. These are useful for instruments which do
not need to scan a range of wavelengths. Prisms produce a nonlinear dispersion of wavelengths with the
longer wavelengths closer together than the shorter ones. Since the light must pass through the prism
material, they must be made of quartz for UV work. Diffraction gratings are surfaces with 1000–3000
grooves/mm cut into them. They may be transmissive or reflective; the reflective ones are more popular
since there is no attenuation of light by the material. They produce a linear dispersion. By proper selection
of slit widths, pass bands of 0.1 nm are commonly achieved.



INKJET PRINTER

Fluorometers and spectrofluorometers are very similar to photometers and spectrophotometers but with two major differences. Fluorometers and spectrofluorometers use two monochrometers, one for excitation light and one for emitted light. By proper selection of the bandpass regions, all the light used to excite the sample can be blocked from the detector, assuring that the detector sees only fluorescence. The other difference is that the detector is aligned off-axis, commonly at 90°, from the excitation source. At this angle, scatter is minimal, which helps ensure a dark background for the measured fluorescence. Some spectrofluorometers use polarization filters both on the input and output light beams, which allows for fluorescence polarization studies . An intense light source in the visible-to-UV range is desirable. A common source is the xenon or mercury arc lamps, which provide a continuum of radiation over this range.Atomic absorption spectroscopy is based on the fact that just as metal elements have unique emission lines, they have identical absorption lines when in a gaseous or dissociated state. The atomic absorption

spectrometer takes advantage of these physical characteristics in a clever manner, producing an instrument with approximately 100 times the sensitivity of a flame photometer for similar elements. The sample is aspirated into a flame, where the majority of the atoms of the element being measured remain in the ground state, where they are capable of absorbing light at their characteristic wavelengths. An intense source of exactly these wavelengths is produced by a hollow cathode lamp. These lamps are constructed so that the cathode is made from the element to be measured, and the lamps are filled with a low pressure of argon or neon gas. When a current is passed through the lamp, metal atoms are sputtered off the cathode and collide with the argon or neon in the tube, producing emission of the characteristic wavelengths.A monochromator and photodetector complete the system.
Light reaching the detector is a combination of that which is emitted by the sample (undesirable) and light from the hollow cathode lamp which was not absorbed by the sample in the flame (desirable). By pulsing the light from the lamp either by directly pulsing the lamp or with a chopper, and using a detector which is sensitive to ac signals and insensitive to dc signals, the undesirable emission signal is eliminated. Each element to be measured requires a lamp with that element present in the cathode. Multielement lamps have been developed to minimize the number of lamps required. Atomic absorption spectrophotometers may be either single beam or double beam; the double-beam instruments have greater stability.

LASER PRINTER

A laser printer is a popular type of personal computer printer that uses a non-impact (keys don't strike the paper), photocopier technology. When a document is sent to the printer, a laser beam "draws" the document on a selenium-coated drum using electrical charges. After the drum is charged, it is rolled in toner, a dry powder type of ink. The toner adheres to the charged image on the drum. The toner is transferred onto a piece of paper and fused to the paper with heat and pressure. After the document is printed, the electrical charge is removed from the drum and the excess toner is collected. Most laser printers print only in monochrome. A color laser printer is up to 10 times more expensive than a monochrome laser printer.

IBM introduced the first laser printer in 1975 for use with its mainframe computers. In 1984, Hewlett-Packard revolutionized laser-printing technology with its first LaserJet, a compact, fast, and reliable printer that personal computer users could afford. Since then, laser printers have decreased further in price and increased in quality. Hewlett Packard continues to be the leading manufacturer with competitors including Lexmark, Okidata, and Xerox.

The laser printer is different from an inkjet printer in a number of ways. The toner or ink in a laser printer is dry. In an inkjet, it is wet. Over time, an inkjet printer is about ten times more expensive to operate than a laser printer because ink needs replenishing more frequently. The printed paper from an inkjet printer will smear if wet, but a laser-printed document will not. Both types of printer operate quietly and allow fonts to be added by using font cartridges or installing soft fonts. If your printing needs are minimal, an inkjet printer is sufficient. But if your printing volume is high, consider buying a laser printer.When buying a laser printer, these are some important features to consider Personal laser printers are sufficient for printing an average of 200 pages per week. These are low-end and cost $200 and up. They can print up to eight ppm (pages per minute). A workgroup printer is needed if an average of 1000 pages per week is needed. These print up to 24 ppm and cost $1000 to $6000 and more. Production printers are needed for printing 50,000 or more pages per week. These are quite expensive and are used by commercial publishers. They can print up to 700 ppm and cost $100,000 and up. They can print 24 hours a day, seven days a week

SHOCK HAZARDS

if electrical systems are not properly wired to remove dangerous voltage, persons can be subjected to electric shock, which can result in injury or death. The National Safety Council estimates that approximately 300 people in the United States die each year because of an electric shock from 120 or 277V circuits. People become injured and death occurs when voltage pushes electrons through the human body, particularly through the heart. An electrical shock from as little as 50V alternating current for as little as one second can disrupt the hearts rhythm resulting in death in a matter of minutes from ventricular fibrillation.

Micro shock and macro shock

Mains power station supplied at high voltage to substation. Transformer converts voltage to standard output 240 V. Active and Neutral lines supplied to hospital switch and to operating suite. Neutral line is earthed at the substation.

The third horizontal plug at the wall is also earthed locally at the hospital.

Equipment with metal casing or exposed metal components must be connected to the hospital earth.

If a person touches a live wire, their footwear provides the pathway for current to form an earthed circuit back to the substation. If the person is wearing anti-static footwear, this may resist the closing of the circuit and prevent a high current passing through the person causing burns or shock.

The direct application of current to the heart causing or increasing the risk of ventricular fibrillation and or death.

The current can be either AC or DC, and is usually of low voltage, but because it is focused directly on the heart muscle it need only be greater than 50 microAmps at 50 Hz.

Technically, microshock can only occur if there is an electrode or conducting device within or very close to the heart such as in cardiac pacemakers, percutaneous catheterization, temporary pacing or it has been proposed that esophageal temperature probes could also cause microshock.

The current required is low due to 'current density'

A large current from a mains power supply returning to earth via a grounded subject. Distributes the current throughout the whole body so has a lower 'current' density.

Current depends on resistance, or impedance, of the person (can range from 1000 to 1,000,000 Ohm's).

1 mA causes tingling
100 mA - 4 A causes muscle contraction to ventricular fibrillation
> 4 A can cause severe burns.

A shock from mains electricity of 240 V in a person with the lowest possible

impedence (1000 Ohm) would give a maximum shock of 240 mA as per Ohm's law (Current = Volt/Resistance).

List the Types of Medical

METHODS OF ACClDENT PREVENTION

Diagonstic Techniques

Diagnostic techniques involve measurements to help in detection of some malfunction of the system of the body. Such instrumentation may also be called troubleshooting equipment. The diagnostic equipments and their underlying principles related with ultrasonic, X-ray, Radio-isotopic, cAT scan, Emission computerized Tomography and MRI techniques are discussed here. These techniques of diagnostic does not involve getting inside the body physically or invading it, therefore, these are known as Non-invasive diagnostic techniques. The non-invasive diagnostic techniques are not traumatic for the patient and do not have any determinental side effects on the patient. The non-invasion techniques are very sophisticated which offer accurate results without invasion of the body" Usual method of blood pressure measurement is non-invasive which has been around for years.

ULTRASONIC PRINCIPLE

Ultrasonic detection is most commonly used in industrial applications to detect hidden tracks, discontinuities in metals, composites, plastics, ceramics, and for water level detection. For this purpose the laws of physics which are indicating the propagation of sound waves through solid materials have been used since ultrasonic sensors using sound instead of light for detection.

Sound is a mechanical wave travelling through the mediums, which may be a solid, or liquid or gas. Sound waves can travel through the mediums with specific velocity depends on the medium of propagation. The sound waves which are having high frequency reflect from boundaries and produces distinctive echo patterns.Sound waves are having specific frequencies or number of oscillations per second. Humans can detect sounds in a frequency range from about 20Hz to 20 KHz. However the frequency range normally employed in ultrasonic detection is 100 KHz to

50MHz. The velocity of ultrasound at a particular time and temperature is constant in a medium.

W = C/F (or) W = CT

Where W = Wave length

C = Velocity of sound in a medium

F = Frequency of wave

T=Time Period

The most common methods of ultrasonic examination utilize either longitudinal waves or shear waves. The longitudinal wave is a compression wave in which the particle motion is in the same direction of the propagation wave. The shear wave is a wave motion in which the particle motion is perpendicular to the direction of propagation. Ultrasonic detection introduces high frequency sound waves into a test object to obtain information about the object without altering or damaging it in any way. Two values are measured in ultrasonic detection.

The amount of time, taking for the sound to travel through the medium and amplitude of the received signal. Based on velocity and time thickness can be calculated.

Thickness of material = Material sound velocity X Time of Fight

Transducers for Wave Propagation and particle detection

For sending sound waves and receiving echo, ultrasonic sensors, normally called transceivers or transducers will be used. They work on a principle similar to radar that will convert electrical energy into mechanical energy in the form of sound, and vice versa.

The commonly used transducers are contact transducers, angle beam transducers, delay line transducers, immersion transducers, and dual element transducers. Contact transducers are typically used for locating voids and cracks to the outside surface of a part as well as measuring thickness. Angle beam transducers use the principle of reflection and mode conversion to produce refracted shear or longitudinal waves in the test material.

Delay line transducers are single element longitudinal wave transducers used in conjunction with a replaceable delay line. One of the reasons for choosing delay line transducer is that near surface resolution can be improved. The delay allows the element to stop vibrating before a return signal from the reflector can be received.

The major advantages offered by immersion transducers over contact transducers are Uniform coupling reduces sensitivity variations, Reduction in scan time, and increases sensitivity to small reflectors.

Operation of ultrasonic sensors:

When an electrical pulse of high voltage is applied to the ultrasonic transducer it vibrates across a specific spectrum of frequencies and generates a burst of sound waves. Whenever any obstacle comes ahead of the ultrasonic sensor the sound waves will reflect back in the form of echo and generates an electric pulse. It calculates the time taken between sending sound waves and receiving echo. The echo patterns will be compared with the patterns of sound waves to determine detected signal’s condition.

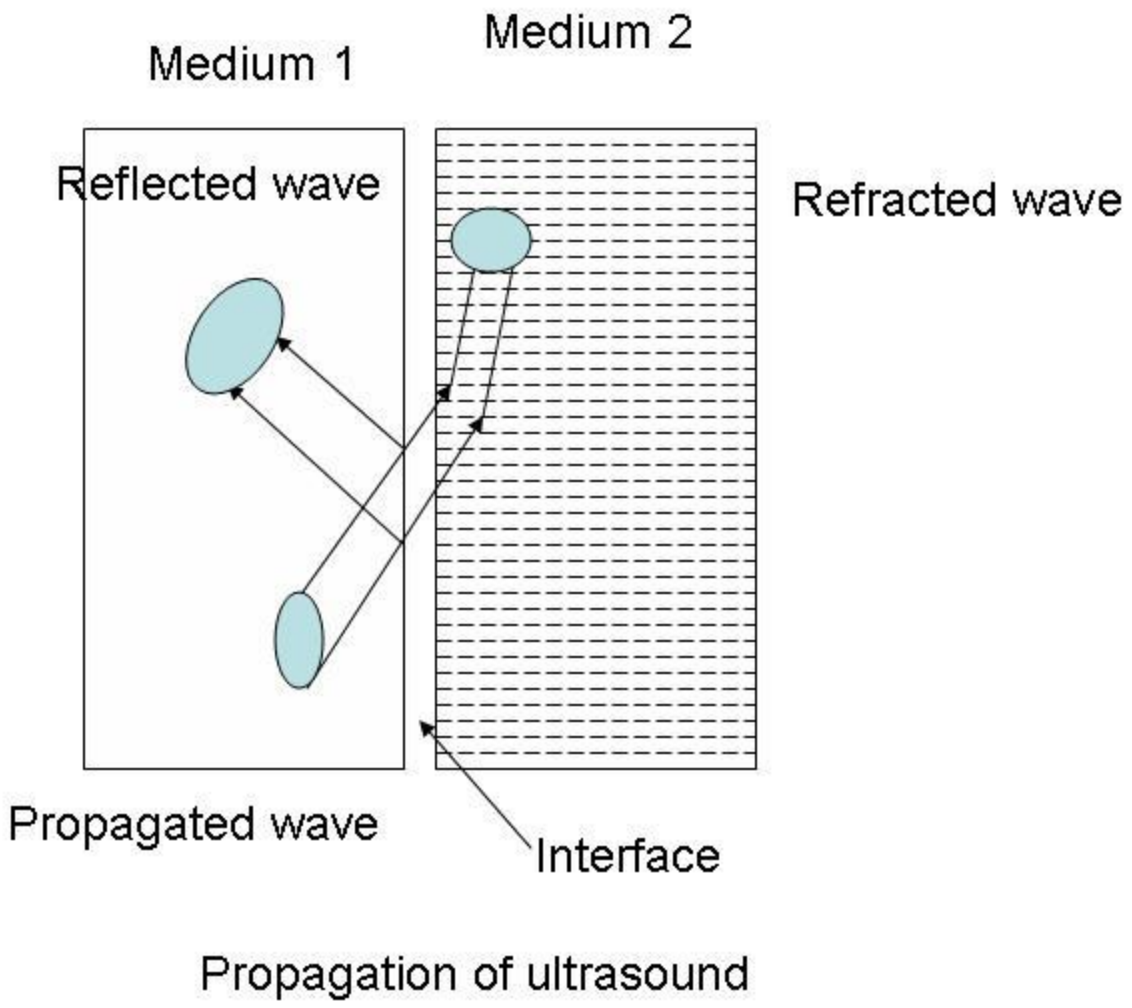


Fig:-ultrasound principle

	mm/μs	m/s
Air	330	0.33
Lung	500	0.5
Fat	1450	1.45
Soft tissue	1540	1.54
Bone	4000	4

C (human soft tissue) = 1540 m/s or 1.54 mm/μs

Types or modes of ultrasonics waves:

Ultrasonic waves can propagate through a medium as stress or strain waves depending upon the elastic properties of medium. Based on particle displacement of the media, ultrasonic waves are are classified into four types or modes:

(i) **Longitudinal or Compressional or Pressure ultrasonic Waves.** In the longitudinal waves particles of medium vibrate back and forth parallel to the direction of propagation of wave. These waves propagate through the medium as a series of alternate compression and rarefaction. These waves are most widely used in the ultrasonic inspection of materials. This mode is exhibited when medium of propagation has no boundaries i.e. it has infinite span. Due to propagation of these waves both pressure and density of medium fluctuate periodically.

(ii) **Transverse or Shear ultrasonic Waves.** In the transeverse waves particles of the medium vibrate perpendicular to the direction of waves propagation. In this case the medium undergoes shear deformations periodically. These waves can propagate through this rods.

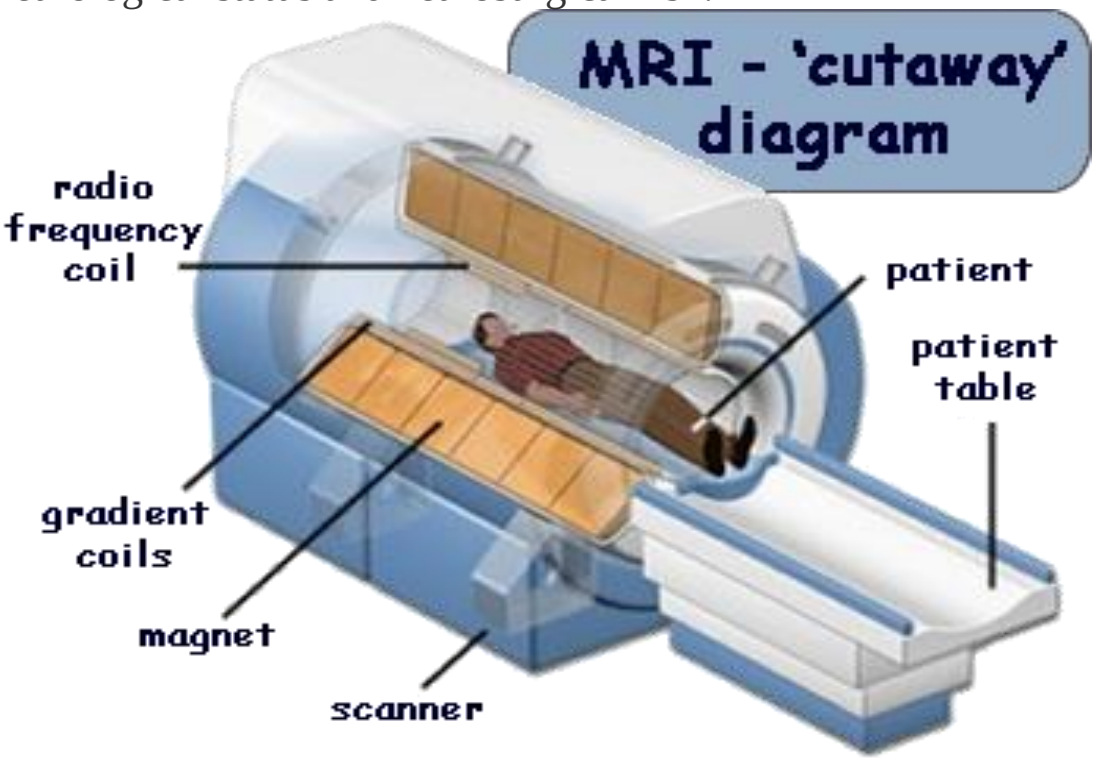
(iii) **Surface or Rayleigh Waves.** The surface waves travel along the flat or curved surface of thick solids without influencing the bulk of medium below the surface. The depth to which these waves propagate below the surface with considerable intensity is approximately equal to wavelength of the wave.Practically all of its energy is attenuated within this depth. These waves are used to detect cracks or flaws on or near the surface of test objects. During the propagation of surface waves, the particles of medium describe elliptical orbits.

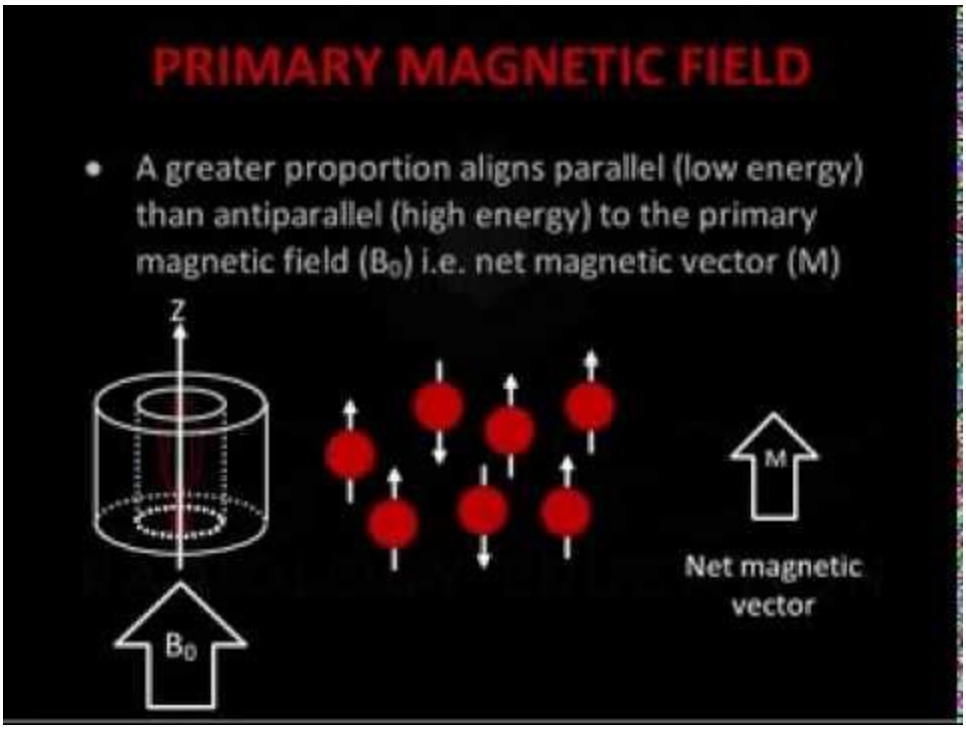
MRI

MRI is a non-invasive imaging technology that produces three dimensional detailed anatomical images without the use of damaging radiation. It is often used for disease detection, diagnosis, and treatment monitoring. It is based on sophisticated technology that excites and detects the change in the direction of the rotational axis of protons found in the water that makes up living tissues MRIs employ powerful magnets which produce a strong magnetic field that forces protons in the body to align with that field. When a radiofrequency current is then pulsed through the patient, the protons are stimulated, and spin out of equilibrium, straining against the pull of the magnetic field. When the radiofrequency field is turned off, the MRI sensors are able to detect the energy released as the protons realign with the magnetic field. The time it takes for the protons to realign with the magnetic field, as well as the amount of energy released, changes depending on the environment and the chemical nature of the molecules. Physicians are able to tell the difference between various types of tissues based on these magnetic properties. MRI scanners are particularly well suited to image the non-bony parts or soft tissues of the body. They differ from computed tomography (CT), in that they do not use the damaging ionizing radiation of x-rays. The brain, spinal cord and nerves, as well as muscles, ligaments, and tendons are seen much more clearly with MRI than with regular x-rays and CT; for this reason MRI is often used to image knee and shoulder injuries.

In the brain, MRI can differentiate between white matter and grey matter and can also be used to diagnose aneurysms and tumors. Because MRI

does not use x-rays or other radiation, it is the imaging modality of choice when frequent imaging is required for diagnosis or therapy, especially in the brain. However, MRI is more expensive than x-ray imaging or CT scanning.
One kind of specialized MRI is functional Magnetic Resonance Imaging (fMRI.) This is used to observe brain structures and determine which areas of the brain "activate" (consume more oxygen) during various cognitive tasks. It is used to advance the understanding of brain organization and offers a potential new standard for assessing neurological status and neurosurgical risk.





Magnetic resonance imaging (MRI) uses the body's natural magnetic properties to produce detailed images from any part of the body. For imaging purposes the hydrogen nucleus (a single proton) is used because of its abundance in water and fat.The hydrogen proton can be likened to the planet earth, spinning on its axis, with a north-south pole. In this respect it behaves like a small bar magnet. Under normal circumstances, these hydrogen proton “bar magnets” spin in the body with their axes randomly aligned.When the body is placed in a strong magnetic field, such as an MRI scanner, the protons' axes all line up. This uniform alignment creates a magnetic vector oriented along the axis of the MRI scanner. MRI scanners come in different field strengths, usually between 0.5 and 1.5 tesla.When additional energy (in the form of a radio wave) is added to the magnetic field, the magnetic vector is deflected. The radio wave frequency (RF) that causes the hydrogen nuclei to resonate is dependent on the element sought (hydrogen in this case) and the strength of the magnetic field.The strength of the magnetic field can be altered electronically from head to toe using a series of gradient electric coils, and, by altering the local magnetic field by these small increments, different slices of the body will resonate as different frequencies are

applied.When the radiofrequency source is switched off the magnetic vector returns to its resting state, and this causes a signal (also a radio wave) to be emitted. It is this signal which is used to create the MR images. Receiver coils are used around the body part in question to act as aerials to improve the detection of the emitted signal. The intensity of the received signal is then plotted on a grey scale and cross sectional images are built up.

Multiple transmitted radiofrequency pulses can be used in sequence to emphasise particular tissues or abnormalities. A different emphasis occurs because different tissues relax at different rates when the transmitted radiofrequency pulse is switched off. The time taken for the protons to fully relax is measured in two ways. The first is the time taken for the magnetic vector to return to its resting state and the second is the time needed for the axial spin to return to its resting state. The first is called T1 relaxation, the second is called T2 relaxation.An MR examination is thus made up of a series of pulse sequences. Different tissues (such as fat and water) have different relaxation times and can be identified separately. By using a “fat suppression” pulse sequence, for example, the signal from fat will be removed, leaving only the signal from any abnormalities lying within it.Most diseases manifest themselves by an increase in water content, so MRI is a sensitive test for the detection of disease. The exact nature of the pathology can be more difficult to ascertain: for example, infection and tumour can in some cases look similar. A careful analysis of the images by a radiologist will often yield the correct answer.There are no known biological hazards of MRI because, unlike x ray and computed tomography, MRI uses radiation in the radiofrequency range which is found all around us and does not damage tissue as it passes through.Pacemakers, metal clips, and metal valves can be dangerous in MRI scanners because of potential movement within a magnetic field. Metal joint prostheses are less of a problem, although there may be some distortion of the image close to the metal. MRI departments always check for implanted metal and can advise on their safety. Safety information is also available on the internet on

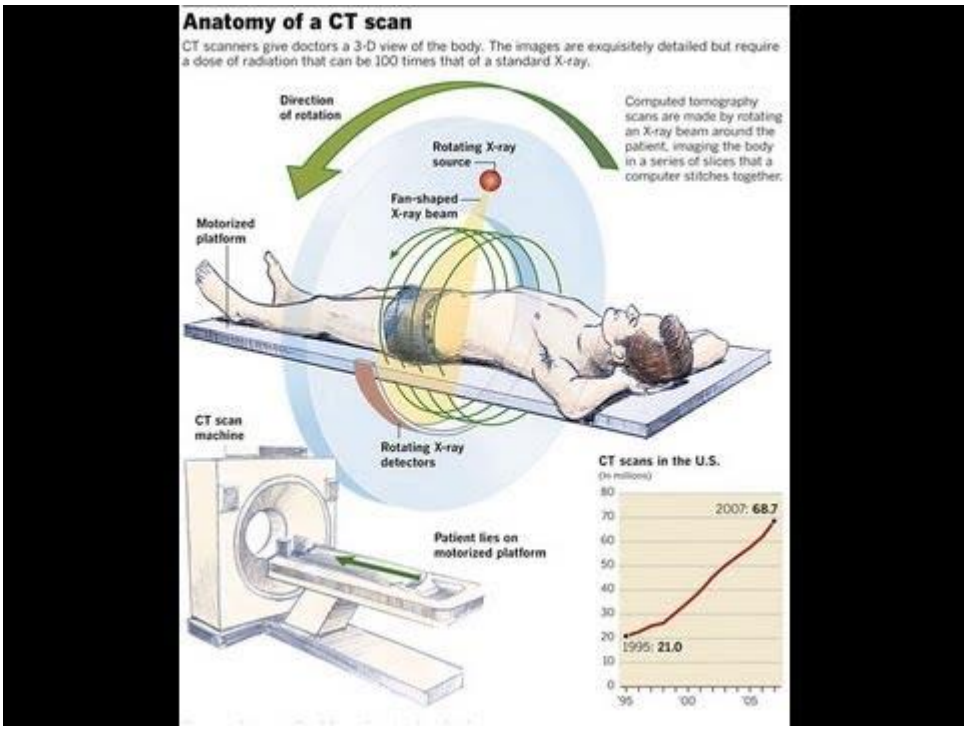
Ct scan

Computed Tomography is based on the x-ray principal: as x-rays pass through the body, they are absorbed or attenuated (weakened) at differing levels creating a matrix or profile of x-ray beams of different strength. This x-ray profile is registered on film, thus creating an image. In the case of CT, the film is replaced by a banana shaped detector which measures the x-ray profile.

in many ways CT scanning works very much like other x-ray examinations. Different body parts absorb the x-rays in varying degrees. It is this crucial difference in absorption that allows the body parts to be distinguished from one another on an x-ray film or CT electronic image.

In a conventional x-ray exam, a small amount of radiation is aimed at and passes through the part of the body being examined, recording an image on a special electronic image recording plate. Bones appear white on the x-ray; soft tissue, such as organs like the heart or liver, shows up in shades of gray, and air appears black.

With CT scanning, numerous x-ray beams and a set of electronic x-ray detectors rotate around you, measuring the amount of radiation being absorbed throughout your body. Sometimes, the examination table will move during the scan, so that the x-ray beam follows a spiral path. A special computer program processes this large volume of data to create two-dimensional cross-sectional images of your body, which are then displayed on a monitor. CT imaging is sometimes compared to looking into a loaf of bread by cutting the loaf into thin slices. When the image slices are reassembled by computer software, the result is a very detailed multidimensional view of the body's

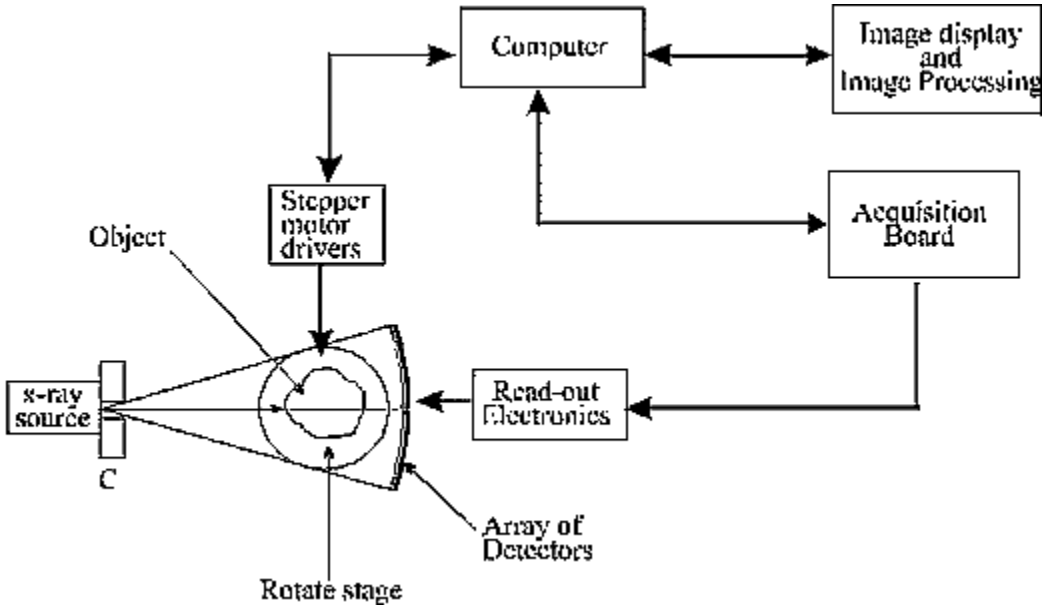


.

Refinements in detector technology allow nearly all CT scanners to obtain multiple slices in a single rotation. These scanners, called multislice CT or multidetector CT, allow thinner slices to be obtained in a shorter period of time, resulting in more detail and additional view capabilities.

CT exams are generally painless, fast and easy. With multidetector CT, the amount of time that the patient needs to lie still is reduced.Though the scanning itself causes no pain, there may be some discomfort from having to remain still for several minutes and with placement of an IV. If you have a hard time staying still, are very nervous or anxious or have chronic pain, you may find a CT exam to be stressful. The technologist or nurse, under the direction of a physician, may offer you some medication to help you tolerate the CT scanning procedure.For exams (excluding head and neck) your head will remain outside the hole in the center of the scanner. The scanner is approximately 24 inches wide, therefore, your entire body will be "inside" the scanner at one time such as with MRI.If an intravenous contrast material is used, you will feel a pin prick when the needle is inserted into your vein. You will likely have a warm, flushed sensation during the injection of the contrast materials and a metallic taste in your mouth that lasts for at most a minute or two. You may experience a sensation like you have to urinate; however, this is actually a contrast effect and subsides quickly.

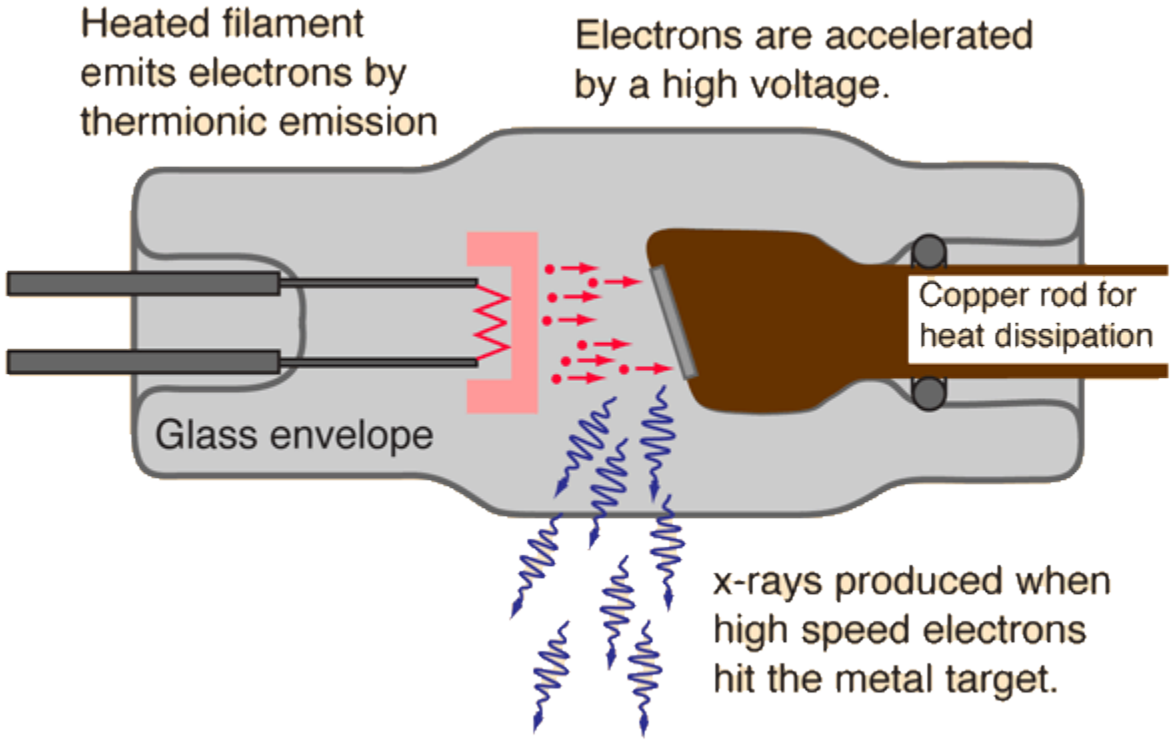
If the contrast material is swallowed, you may find the taste mildly unpleasant; however, most patients can easily tolerate it. You can expect to experience a sense of abdominal fullness and an increasing need to expel the liquid if your contrast material is given by enema. In this case, be patient, as the mild discomfort will not last long.When you enter the CT scanner, special light lines may be seen projected onto your body, and are used to ensure that you are properly positioned. With modern CT scanners, you will hear only slight buzzing, clicking and whirring sounds as the CT scanner's internal parts, not usually visible to you, revolve around you during the imaging process.You will be alone in the exam room during the CT scan, unless there are special circumstances. For example, sometimes a parent wearing a lead shield may stay in the room with their child. However, the technologist will always be able to see, hear and speak with you through a built-in intercom system.



X-RAY

As previously mentioned, xrays from nature come from extraterrestial sources, such as distant suns and stars, however these xrays simply contribute to background radiation that is all around us. The ground and soil are also sources of natural background radiation. Depending on where a person lives will determine how much exposure they will receive from natural background radiation sources, however this type of exposure is typically not dangerous. Medical x-rays come from a machine that is designed to emit radiation on command. The history of how x-rays were discovered is interesting. In the late 1800's

there were many scientists of that era hat were experimenting with electricity which at that time was a new phenomena. One particular experiment involved the behavior of electricity in a vacuum.
The experiments that scientists were conducting involved a bulb like device called a Crooks tube which is illustrated here. You will notice that the tube has two electrodes; an anode which is electrically positive and a cathode which is negative. The idea here was to pass electricity from the cathode to the anode. Because electricity is comprised of electrons flowing in a conductor, what they did in this case they made the electrons stream across the space between the cathode to the anode. If there is air in the tube, this means that any electrons that are streaming across the space between the cathode and anode will most likely collide with the atoms whatever gas is in the tube. These collisions will reduce the efficiency of transmitting the electricity (current) and this is why they tried to remove as much of the air as they could in the Crookes tube. One thing that they did not know at the time, whenever the electrons streamed across the distance between the cathode and anode, the electrons would accelerate to a very high velocity. The electrons that were streaming across the space between the cathode and anode were called “cathode rays”. This velocity was controlled by the voltage applied to the Crookes tube. The higher the voltage, the greater the velocity of the electron stream. Little did the scientists know that when the electrons arrived at the anode as well as the surrounding glass tube, collisions between the high speed electrons and the atomic structure of the anode metal and glass would take place. It is these interactions that that are responsible for the production of xrays as well as a “glowing effect” in the glass tube that was often observed when the tube was energized.



As you can see radiation can come from a variety of sources. These are: X-rays from extraterrestial origins, natural background radiation, and radiation from x-ray equipment. Radiation from x-ray equipment started not long after Roentgen’s discovery however, it took many years before the equipment achieved the level of reliability, safety, and dependability that we know today. So far, we have seen how x rays can interact with matter after they leave the x-ray tube, but we have not yet seen how they are actually produced in the x-ray tube. In this photograph, you can see the technologist adjusting the x-ray tube. She has her hands on part of the system that actually “shapes” the beam of

radiation to the size that is needed. The device that limits the beam to a specific size is called the collimator. The collimator has a series of metal leaves that overlap to different sizes. The technologist can adjust the field of radiation to whatever size image receptor (film) is being used. Collimators can also function automatically in that when the film is positioned in the table film tray, the collimator can sense the dimensions of the image receptor and limit the beam to that size. This is known as PBL or positive beam limitation.