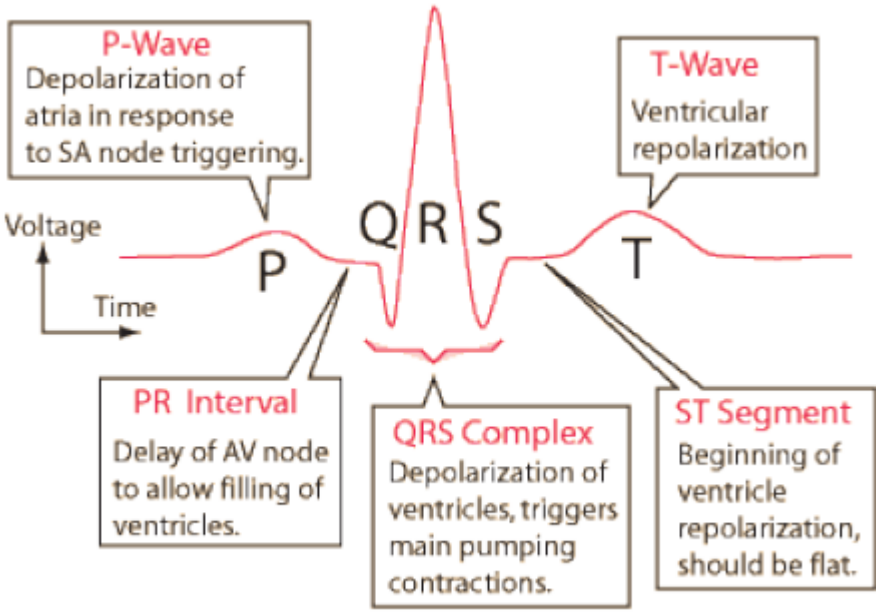
14EI702 (Biomedical Instrumentation)
4/4 B.Tech Degree Examination, January 2021
Scheme of Evaluation and Answers

1 (a)



(b) An in vitro measurement is one performed outside the body

(c) Active transducer does not require external energy for its operation whereas passive transducer require external energy.

(d) Eliminates movement artifacts by avoiding any direct contact of the metal with the skin.

(e) electrode potential is the electromotive force of a galvanic cell built from a standard reference electrode and another electrode to be characterized .

(f) Micro Electrodes are used to measure bioelectric potentials near or within a single cell.

(g) Direct method, Indirect methods : korotkoff method, Rheographic method, Differential auscultatory technique, Oscillometric measurement method.Ultrasonic Doppler shift method.

(h) stethoscope, phonocardiograph.

(i) A plethysmograph is an instrument for measuring changes in volume within an organ or whole body or A true plethysmograph is one that actually responds to changes in volume.

(j) Microscopic method, automatic optical method, electrical conductivity method, Coulter counter.

(k) A device capable of generating artificial pacing impulses and delivering them to the heart is known as a pacemaker system (commonly called a pacemaker) and consists of a pulse generator and appropriate electrodes.

It is used whenever the conduction system fails to transmit the pacing impulses from the atria to the ventricles properly.

(l) MRI is ideal for:

- Diagnosing multiple sclerosis (MS)
- Diagnosing tumors of the pituitary gland and brain
- Diagnosing infections in the brain, spine or joints
- Visualizing torn ligaments in the wrist, knee and ankle
- Visualizing shoulder injuries
- Diagnosing tendonitis
- Evaluating masses in the soft tissues of the body
- Evaluating bone tumors, cysts and bulging or herniated discs in the spine
- Diagnosing strokes in their earliest stages.

2(a)Write a brief note on Man instrument system.

Components of the Man-Instrument system :

A block diagram of the man instrument system is shown in the following figure.

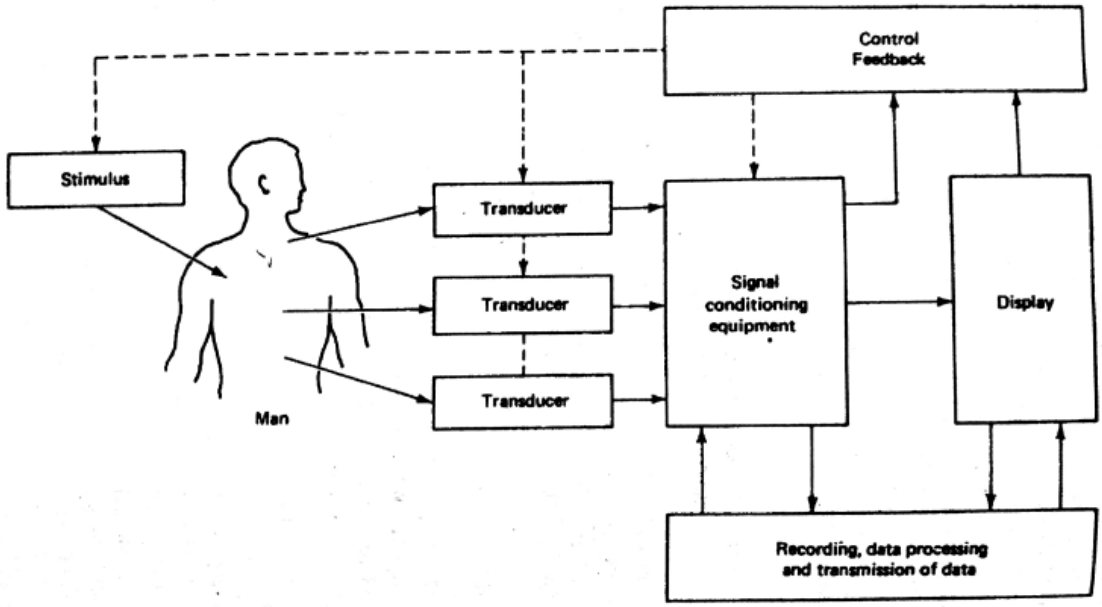


Fig: Block diagram of man-instrument system

The block diagram of man instrument system is shown above.The system components are given below.

The subject :The subject is the human being on whom the measurements are made.

Stimulus:

In many measurements, the response to some form of external stimulus is required.The instrumentation used to generate and present this stimulus to the subject is vital part of man-instrument system whenever responses are measured.The stimulus may be visual (e.g., a flash of light), auditory (e.g., tone), tactile(e.g., a blow of Achilles tendom), or direct electrical stimulation of some part of the nervous system.

The transducer :

A transducer is defined as a device capable of converting one form of energy or signal to another.In the man instrument system, each transducer is used to produce an electrical signal that is an analog of the phenomenon being measured.The transducer may measure temperature, pressure, flow, or any of the other variables that can be found in the body.

Signal conditioning Equipment :

The part of the instrumentation system that amplifies, modifies, or in any other way changes the electrical output of the transducer is called signal conditioning (or sometimes signal-processing). Signal conditioning equipment is also used to combine or relate the outputs of two or more transducers.

Display Equipment :

The display equipment converts the electrical output of the signal conditioning into a form that can be perceived by one of man's senses .Its output is some form of visual, audible, or possibly tactile information. The display equipment may include a graphic pen recorder that produces a permanent record of the data.

Recording, data-processing, and Transmission equipment :

It is often necessary, or at least desirable, to record the measured information for possible later use or to transmit it from one location to another. Equipment for these functions is often a vital part of the man-instrument system.

Control Devices :

Where it is necessary or desirable to have automatic control of the stimulus, transducers, or any other part of the man instrument system, a control system is incorporated.This system usually consists of feedback loop in which part of the output from the signal conditioning or display equipment is used to control the operation of the system in some way.

2(b) Explain the generation of action potential with neat diagram.

In carrying out their various functions, certain systems of the body generate their own monitoring signals, which convey useful information about the functions they represent.

These signals are the bioelectric potentials associated with nerve conduction, brain activity, heartbeat, muscle activity, and so on.

Bioelectric potentials are ionic voltages produced as a result of the electrochemical activity of certain special types of cells.

Resting and Action potentials :

The basic building block of a body is a cell which is isolated from external environment by a semi permeable membrane.

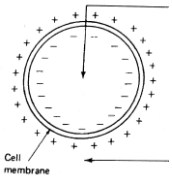


Fig :Cell

Diameter of the cell is 1mm, Thickness of the membrane is 0.01mm

Body is made up of cells, and conducting body fluids consisting Na^+, K^+, Cl^-.

Under normal conditions the membrane allows only K^+ and Cl^- ions and blocks Na^+ ions.

This results in two conditions.

First, the concentration of sodium ions (Na^+) inside the cell becomes much lower than that of the outside of the cell since the sodium ions are positive, this would tend to make the outside of the cell more positive than the inside.

Second, in an attempt to balance the electric charge, additional potassium ions(K+), enter the cell, causing a higher concentration of potassium on the inside than on the outside.

Charge balance cannot be achieved, because of the concentration imbalance of potassium ions. Equilibrium is reached with a potential difference across the membrane, negative on the inside and positive on the outside.

This membrane potential (under normal conditions) is called the resting potential of the cell. It is in the order of - 60 mV to - 100 mV.

The voltage inside the cell w.r.t outside is negative.

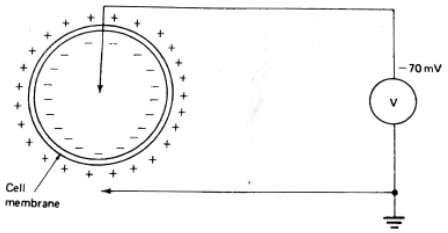


Fig : Polarized cell with its resting potential

When a stimulus is applied to the membrane, it changes its characteristics and allows some of the Na+ ions into the cell.

This movement of sodium ions into the cell constitutes an ionic current flow that further reduces the barrier of the membrane to sodium ions.

The net result is an avalanche effect in which sodium ions rush into the cell to try to reach a balance with the ions outside.

At the same time potassium ions, which were in higher concentration inside the cell during the resting state, try to leave the cell but are unable to move as rapidly as the sodium ions.

As a result, the cell has a slightly positive potential on the inside due to the imbalance of potassium ions.

This potential is known as the action potential and is approximately + 20 mV.

A cell that has been excited and that displays an action potential is said to be depolarized.

The process of changing from the resting state to the action potential is called depolarization.

Following Figure shows the ionic movements associated with depolarization

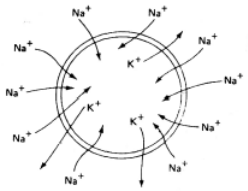


Fig : Depolarization of a cell. Na+ ions rush into the cell while K+ ions attempt to leave

After the application of stimulus the status of the cell is as follows.

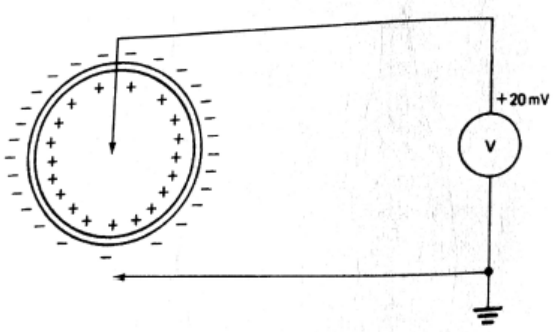


Fig : Depolarized cell during an action potential

The potential generated by the excited cell is called Action Potential.

The process of changing from resting potential to action potential is called Depolarization.

Once the rush of sodium ions through the cell membrane has stopped (a new state of equilibrium is reached), the ionic currents that lowered the barrier to sodium ions are no longer present and the membrane reverts back to its original, selectively permeable condition, wherein the passage of sodium ions from the outside to the inside of the cell is again blocked.

Were this the only effect, however, it would take a long time for a resting potential to develop again. But such is not the case.

By an active process, called a sodium pump, the sodium ions are quickly transported to the outside of the cell, and the cell again becomes polarized and assumes its resting potential. This process is called repolarization

Following Figure shows a typical action-potential waveform, beginning at the resting potential, depolarizing, and returning to the resting potential after repolarization.

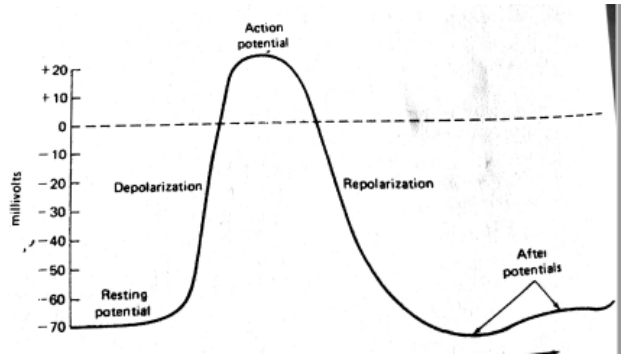


Fig : Waveform of action potential

3(a) Write a short note on physiology of cardiovascular system.

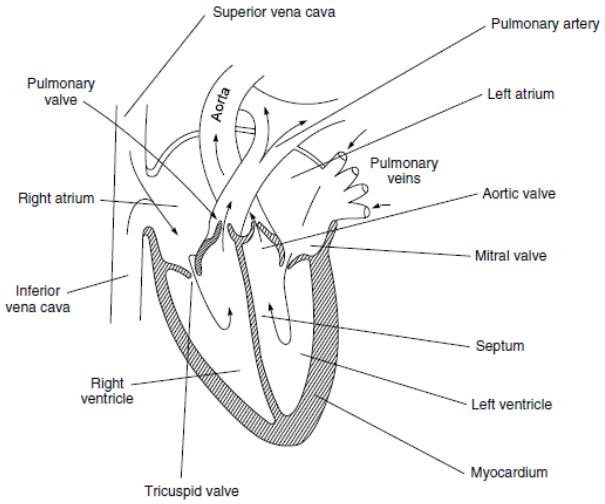


Fig : Structure of the heart

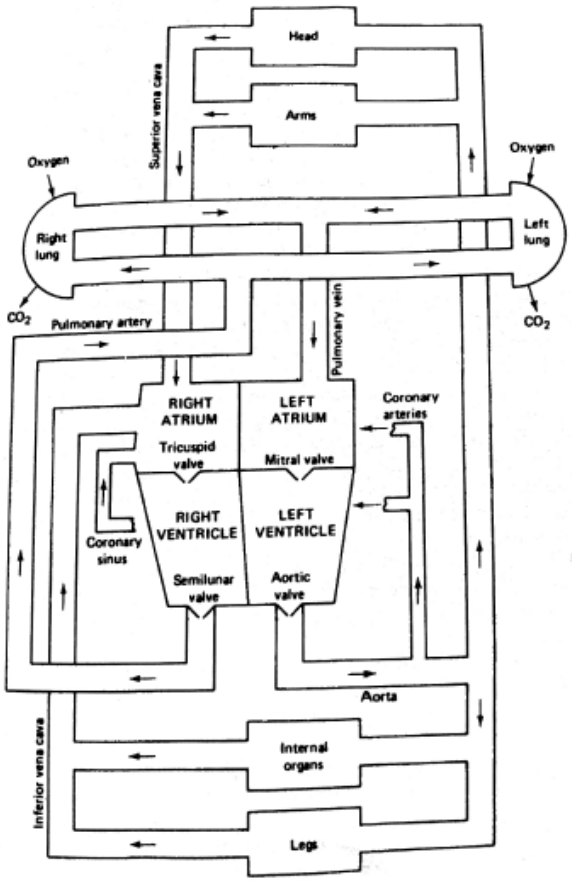


Fig : Block diagram representation of the cardiovascular system

The cardiovascular system can be viewed as a complex, closed hydraulic system with a four chamber pump(the heart), connected to flexible and sometimes elastic tubing (blood vessels).

In some part of the system (arteries, arterioles), the tubing changes its diameter to control the pressure.

Reservoirs in the system (veins) change their volume and characteristics to satisfy certain control requirements, and a system of gates and a variable hydraulic resistances (vascoconstrictors, vasodilators) continually alters the pattern of fluid flow.

The four chamber pump acts as two synchronized but functionally isolated two stage pumps.

The first stage of each pump (the atrium) collects fluid (blood) from the system and pumps it into the second stage (the ventricle).

The action of the second stage is so timed that the fluid is pumped into the system immediately after it has been received from the first stage.

One of the two stage pumps (right side of the heart) collects fluid from the main hydraulic system (systemic circulation) and pumps it through an oxygenation system (the lungs).

The other pump (left side of the heart) receives fluid (blood) from the oxygenation system and pumps it into the main hydraulic system.

The speed of the pump (heart rate) and its efficiency (stroke volume) are constantly changed to meet the overall requirements of the system.

The fluid (blood), which flows in a laminar fashion, acts as a communication and supply network for all parts of the system.

Carriers (red blood cells) of fuel supplies and waste materials are transported to predetermined destinations by the fluid.

The fluid also contains mechanisms for repairing small system punctures and for rejecting foreign elements from the system (platelets and white blood cells, respectively).

Sensors provided to detect changes in the need for supplies, the build up of waste materials, and out-of-tolerance pressures in the system are known as chemoreceptors, P_{co2} sensors, and baroreceptors, respectively.

These and other mechanisms control the pump's speed and efficiency, the fluid flow pattern through the system, tubing diameters, and other factors.

Because part of the system is required to work against gravity at times, special one-way drivers are provided to prevent gravity from pulling fluid against the direction of flow between pump cycles.

The variables of prime importance in this system are the pump (cardiac) output and the pressure, flow rate, and volume of the fluid (blood) at various locations throughout the system.

3(b) Write a detail note on bio electric potentials

In carrying out their various functions, certain systems of the body generate their own monitoring signals, which convey useful information about the functions they represent.

These signals are the bioelectric potentials associated with nerve conduction, brain activity, heartbeat, muscle activity, and so on.

Bioelectric potentials are ionic voltages produced as a result of the electrochemical activity of certain special types of cells.

Origin and characteristics of ECG, EEG, EMG bio potentials

	ECG	**EEG**	**EMG**
Origin	Heart Muscle	Neuronal activity of the Brain	Skin Muscles
Frequency range	0.05 to 100Hz	0.1 to 100Hz	5 to 2000Hz
Voltage range	10 to 500µV	2 to 200µV	20 to 5000µV
Electrodes used	Surface	Surface & Needle	Surface & Needle

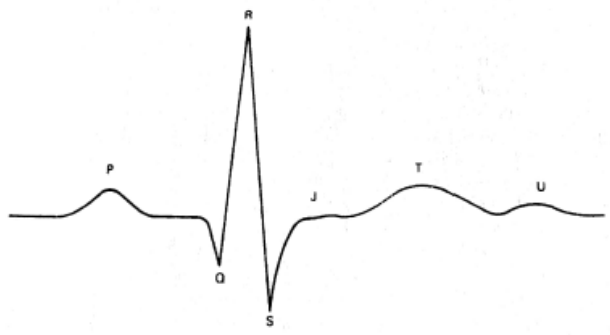


Fig : The electrocardiogram waveform

The Electroencephalogram (EEG) :

EEG frequency bands or rhythms are classified approximately as follows:

Below 3.5 Hz	delta
From 3.5 Hz to about 8 Hz	theta
From about 8 Hz to about 13 Hz	alpha
Above 13 Hz	beta

The waveforms associated with the different stages of sleep are shown in the below Figure.

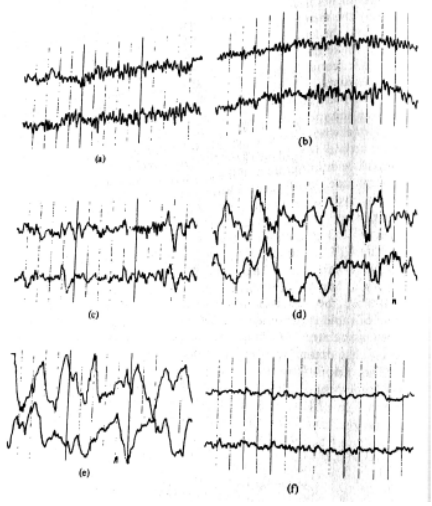
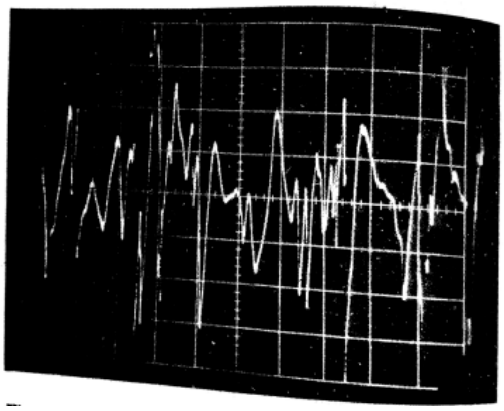


Fig : Typical human EEG patterns for different stages of sleep.

In each case the upper record is from the left frontal region of the brain and the lower tracing is from the right occipital region,
(a)Awake and alert—mixed EEG frequencies (unsynchronized high-frequency EEG)
(b) Stage 1—subject is drowsy and produces large amount of alpha waves; (produces a large amount of rhythmic activity in the range 8 to 13 Hz)
(c) Stage 2—light sleep; (the amplitude and frequency of the waveform decrease)
(e) Stage 4—deeper slow wave sleep;(even slower and higher-amplitude waves)
(f) Paradoxical or rapid eye movement (REM) sleep (unsynchronized high frequency EEG pattern for a time and then returns to the low-frequency sleep pattern)

Electromyogram (EMG)



4(a) Discuss various types of needle electrodes used in biomedical instrumentation

Needle electrodes come in various forms. The monopolar needle electrode usually consists of a Teflon coated stainless steel wire which is bare only at the tip. It is found that after the needle has been used a number of times, the Teflon coating will recede, increasing the tip area. The needle must be discarded when this occurs. Bipolar (double coaxial) needle electrodes contain two insulated wires within a metal cannula. The two wires are bared at the tip and provide the contacts to the patient. The cannula acts as the ground. Bipolar electrodes are electrically symmetrical and have no polarity sense.

A concentric (coaxial) core needle electrode contains both the active and reference electrode within the same structure. It consists of an insulated wire contained within a hypodermic needle (Fig.b). The inner wire is exposed at the tip and this forms one electrode. The concentric needle is very convenient to use and has very stable electrical characteristics. Care should be taken to maintain the surface electrode in good condition in order to avoid artefacts. Concentric needle electrodes are made by moulding a fine platinum wire into a hypodermic needle having an outside diameter less than 0.6 mm. One end of the needle is bevelled to expose the end of the wire and to provide easy penetration when the needle is inserted. The surface area of the exposed tip of the wire may be less than 0.0005 mm2.

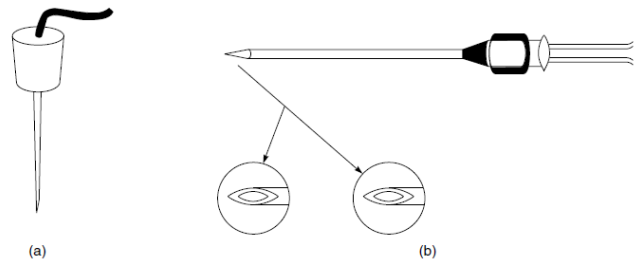


Fig (a) Needle type EMG electrode (b) Hypodermic needle type EMG electrode

Multi-element needle electrodes are used to pick up the signals from individual fibres of muscle tissue. Special needles are available using 25-micron diameter electrode surfaces and having up to 14 pick up surfaces down the side of one needle. From the point of view of construction, needle electrodes are the simplest. However, edging of the needle point to the suitable angle, providing a proper plastic coating, making them resistant against thermal and chemical stresses and ensuring histological suitability is a difficult manufacturing process. For the measurement of potentials from a specific part of the brain, longer needles are actually inserted into the brain. The needles are precisely located by means of a map or atlas of the brain. Generally, a special instrument called a stereotaxic instrument is used to hold the subject's head and guide the placement of electrodes. Often, these electrodes are implanted to permit repeated measurements over an extended period of time.

4(b) Write a brief note on different types of ECG recorders

ECG Recorder Principles :

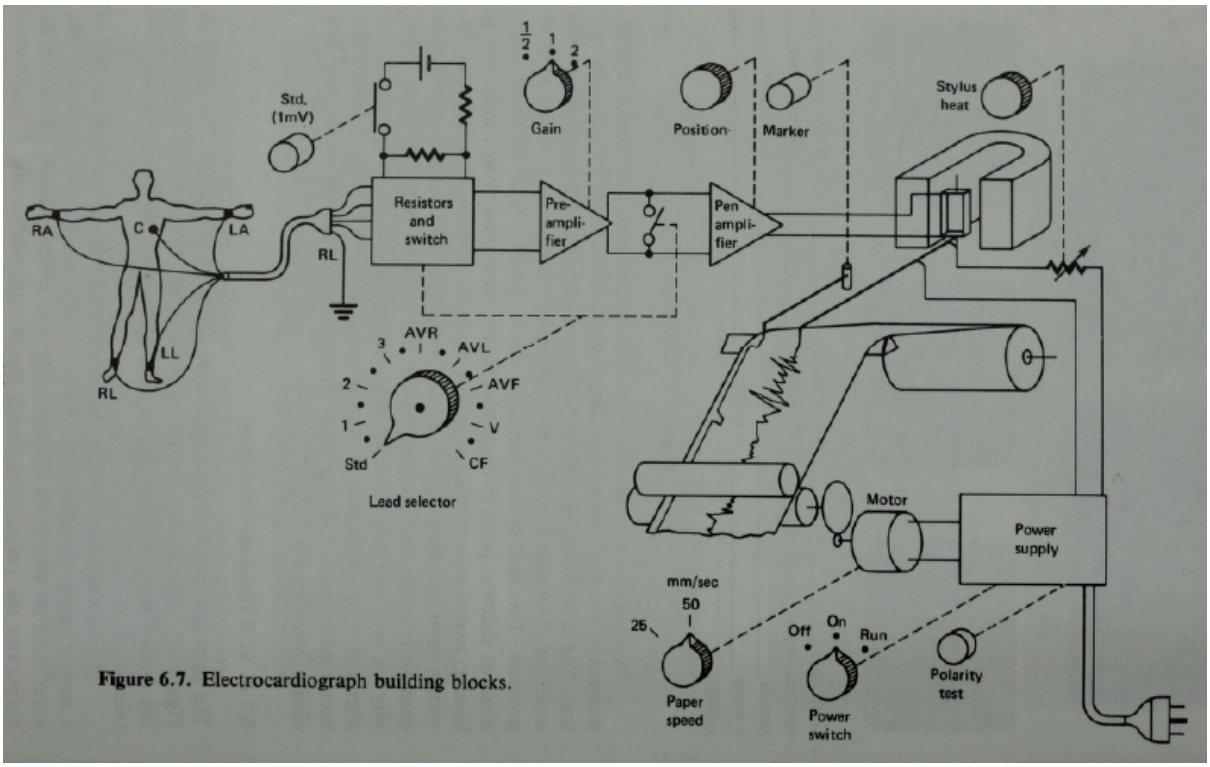


Figure 6.7. Electrocardiograph building blocks.

Fig : Electrocardiograph building blocks.

The building blocks of an ECG recorder along with the front panel controls are shown in the above fig.

The wires from the electrodes connect to the lead selector switch, which also incorporates the resistors necessary for the unipolar leads.

A pushbutton allows the insertion of a standardization voltage of 1 mV to standardize or calibrate the recorder.

From the lead selector switch the ECG signal goes to a preamplifier, a differential amplifier with high common-mode rejection.

By means of standardization adjustment, the sensitivity of the ECG recorder can be set so that the standardization voltage of 1 mV causes a pen deflection of 10 mm.

The preamplifier is followed by a dc amplifier called the pen amplifier, which provides the power to drive the pen motor that records the actual ECG trace.

All modern ECG recorders use heat-sensitive paper, and the pen is actually an electrically heated stylus, the temperature of which can be adjusted with a stylus heat control for optimal recording trace.

5(a) Write a short note on electromyographic measurements.

Myography :

Myography is a study of muscular contraction and a myograph is an apparatus for recoding the mechanical effects of a muscular contraction.

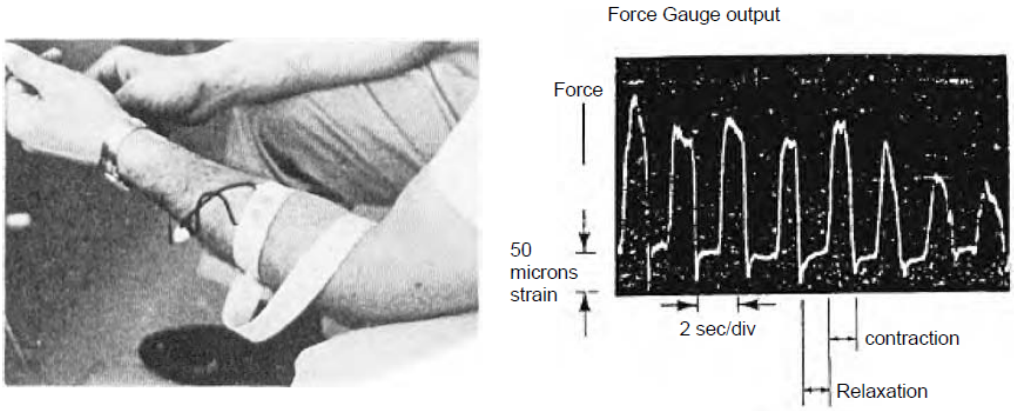


Fig : Shows how a myograph with a strainage is used.

A myograph may simply consist of a displacement transducer or a force transducer mechanically coupled to the muscle under investigation. As shown is the above Fig., an elastic strip is paced around the muscle concerned and a strain gauge is bonded to this elastic strip. Muscular contraction causes a tension increase in the elastic strip with resulting resistance change in the strain gauge. The muscular contraction may be initiated voluntarily or produced by electrical stimulation. The output form a recording system, a series of muscular contractions over a 20sec. period is also shown in the above figure

Electromyography :

The myography records are for the study of muscular contraction, the EMG records the electric effects of such a contraction. Muscular contraction is caused by depolarization of the muscle fibers. The depolarization produces action potentials as discussed in earlier chapters. This muscular action potential is known as the electromyogram or EMG. An electromyogram will be produced in a muscle where the muscle contraction is caused either by voluntarily muscle action or by electrical stimulation of the muscle.

Electromyography with Voluntary Muscular Action

A typical system of recording the electromyography produced by voluntary muscle action is shown in the following Fig.

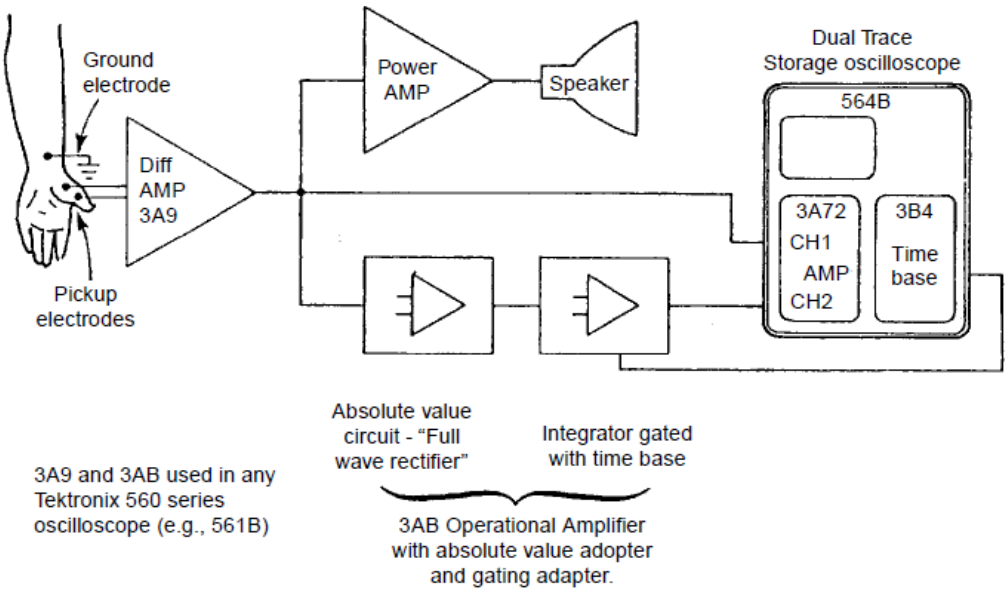


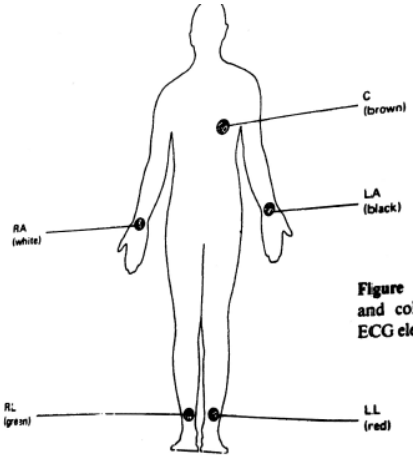
Fig : Shows an electromyograph system

The muscle action potential is picked up by a needle electrodes inserted into the muscle or by surface electrodes placed over the muscle concerned . Then the signal is amplified by a suitable differential amplifier. The EMG can then be detected audibly by using a speaker in conjunction with an audio amplifier. The EMG may also be displayed directly on an oscilloscope or this may be converted to an absolute integral and then displayed on an oscilloscopes.

5(b) Write a brief note on various types of ECG lead configurations

Electrodes :

The placement of the electrodes, as well as the color code used to identify each electrode, is shown in the following Figure.



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ECG el

Fig : Abbreviations and color codes used for ECG electrodes

Plate electrodes are used for the electrodes at the extremities and suction type electrode is used as chest electrode (the other name of chest electrode is precordial electrode).

Leads :

In the normal electrode placement shown in the above Figure, four electrodes are used to record the electrocardiogram.

The electrode on the right leg is only for ground reference.

Because the input of the ECG recorder has only two terminals, a selection must be made among the available active electrodes.

The 12 standard leads used most frequently are shown in the following Figure.

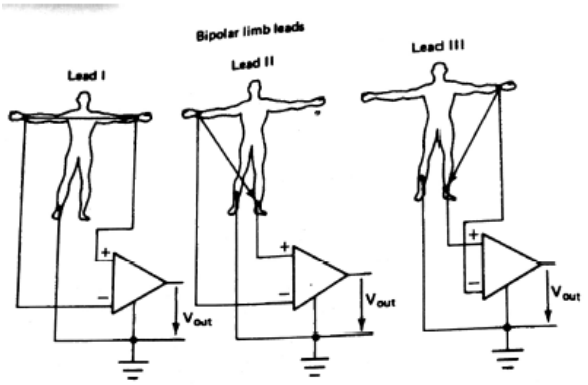
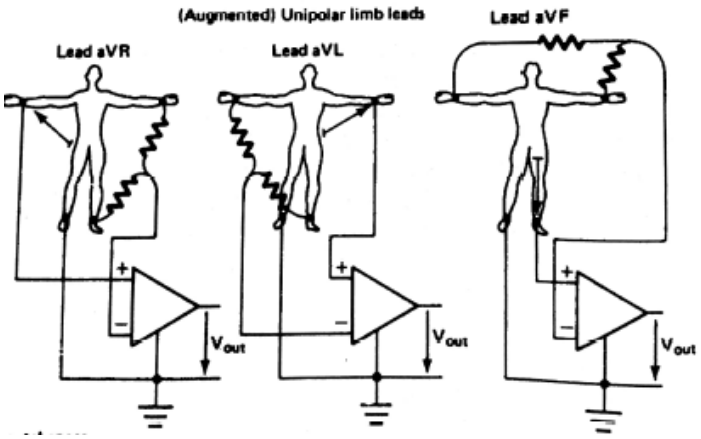
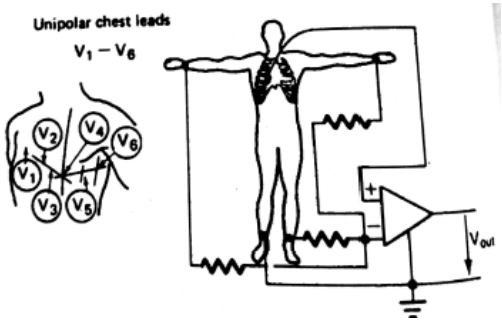


Fig (a) : ECG lead configurations - Bipolar limb leads



Fig(b) : ECG lead configurations - (Augmented)Unipolar limb leads



Fig(c) : ECG lead configurations - Unipolar chest leads

Bipolar Leads:

In bipolar leads, ECG is recorded by using two electrodes such that the final trace corresponds to the difference of electrical potentials existing between them. They are called standard leads and have been universally adopted. They are sometimes also referred to as Einthoven leads.

In defining the bipolar leads, Einthoven postulated that at any given instant of the cardiac cycle, the electrical axis of the heart can be represented as a two dimensional vector.

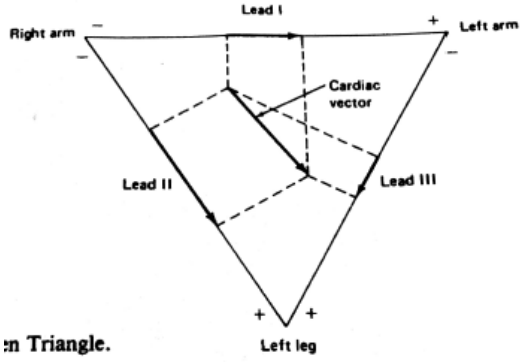
The ECG measured from any of the three basic limb leads is a time-variant single-dimensional component of the vector.

He proposed that the electric field of the heart could be represented diagrammatically as a triangle, with the heart ideally located at the centre.

The triangle, known as the "*Einthoven triangle*". The sides of the triangle represent the lines along which the three projections of the ECG vector are measured.

It was shown that the instantaneous voltage measured from any one of the three limb lead positions is approximately equal to the algebraic sum of the other two or that the vector sum of the projections on all three lines is equal to zero.

In all the bipolar lead positions, *QRS* of a normal heart is such that the *R* wave is positive and is greatest in lead II.



:n Triangle.

Fig : The Einthoven Triangle.

Unipolar Leads (V Leads):

The standard leads record the difference in electrical potential between two points on the body produced by the heart's action.

Unipolar leads were introduced by Wilson in 1894.

Two types of unipolar leads are employed which are: (i) limb leads, and (ii) precordial leads.

(i) ***Limb leads :***

In unipolar limb leads, two of the limb leads are tied together and recorded with respect to the third limb.

In the lead identified as AVR, the right arm is recorded with respect to a reference established by joining the left arm and left leg electrodes.

In the AVL lead, the left arm is recorded with respect to the common junction of the right arm and left leg.

In the AVF lead, the left leg is recorded with respect to the two arm electrodes tied together. They are also called augmented leads or 'averaging leads'.

The resistances inserted between the electrodes-machine connections are known as 'averaging resistances'.

(ii) ***Precordial leads :***

The second type of unipolar lead is a precordial lead. It employs an exploring electrode to record the potential of the heart action on the chest at six different positions.

These leads are designated by the capital letter 'V' followed by a subscript numeral, which represents the position of the electrode on the pericardium.

The positions of the chest leads are shown in the above figure.

6(a) With a neat sketch, explain the blood pressure measurement using Electrophygmomanometer.

The sphygmomanometer consists of an inflatable pressure cuff and a mercury or aneroid manometer to measure the pressure in the cuff.

The cuff consists of a rubber bladder inside an inelastic fabric covering that can be wrapped around the upper arm and fastened with either hooks or a Velcro fastener.

The cuff is normally inflated manually with a rubber bulb and deflated slowly through a needle valve.

The sphygmomanometer works on the principle that when the cuff is placed on the upper arm and inflated, arterial blood can flow past the cuff only when the arterial pressure exceeds the pressure in the cuff.

Furthermore, when the cuff is inflated to a pressure that only partially occludes the brachial artery, turbulence is generated in the blood as it spurts through the tiny arterial opening during each systole.

The sounds generated by this turbulence, Korotkoff sounds, can be heard through a stethoscope placed over the artery downstream from the cuff.

To obtain a blood pressure measurement with a sphygmomanometer and a stethoscope, the pressure cuff on the upper arm is first inflated to a pressure well above systolic pressure.

At this point no sounds can be heard through the stethoscope, which is placed over the brachial artery, for that artery has been collapsed by the pressure of the cuff.

The pressure in the cuff is then gradually reduced.

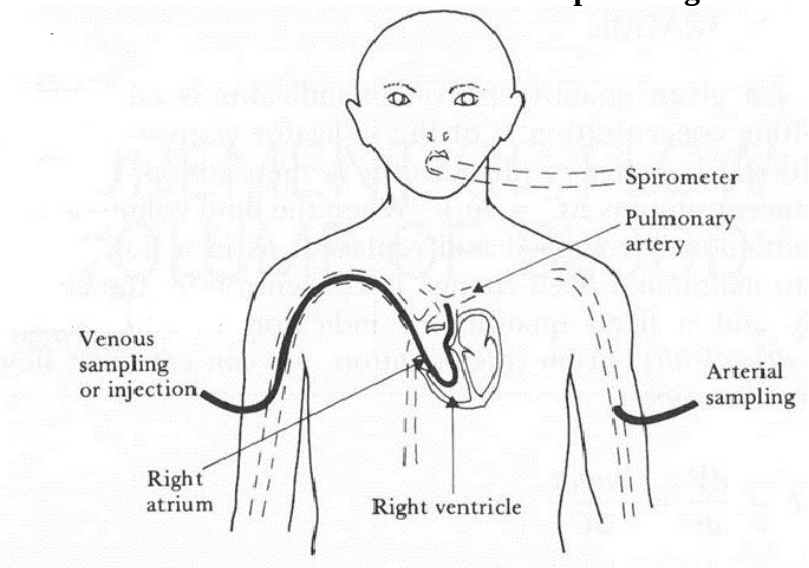
As soon as cuff pressure falls below systolic pressure, small amounts of blood spurt past the cuff and Korotkoff sounds begin to be heard through the stethoscope.

The pressure of the cuff that is indicated on the manometer when the first Korotkoff sound is heard is recorded as the systolic blood pressure.

As the pressure in the cuff continues to drop, the Korotkoff sounds continue until the cuff pressure is no longer sufficient to occlude the vessel during any part of the cycle. Below this pressure the Korotkoff sounds disappear, marking the value of the diastolic pressure.

This familiar method of locating the systolic and diastolic pressure values by listening to the Korotkoff sounds is called the auscultatory method of sphygmomanometry.

6(b) Explain in detail about measurement of cardiac output using Fick's method



This method is based on the determination of Cardiac output by the analysis of the gas keeping of the organism.

The Cardiac output can be calculated by continuously infusing O_2 in to the blood or removing it from the blood and measuring the amount of O_2 in the blood before and after its passage.

Let us take I be the amount of infused or removed O_2 per unit time and is equal to the difference between the amounts in the blood arriving at and departing from the site of measurement.

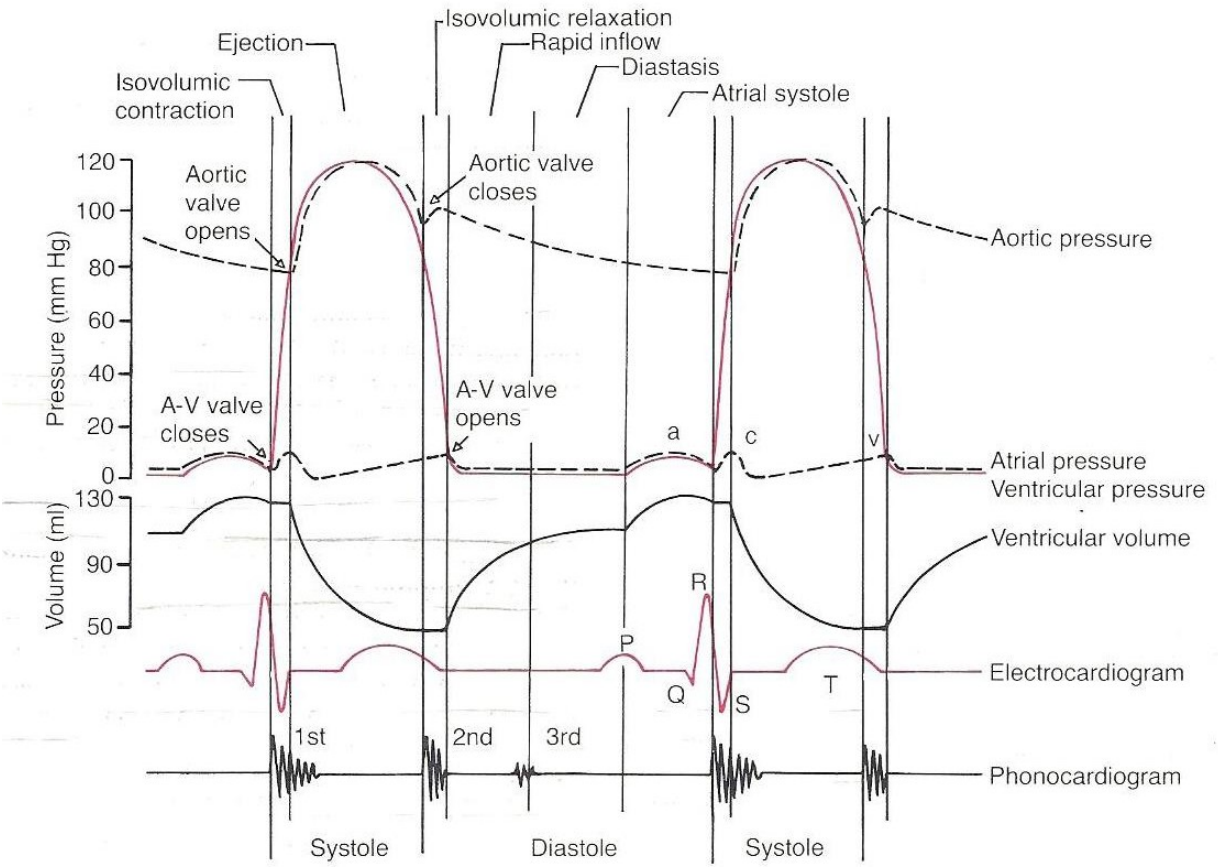
$$I = C_A Q - C_V Q \Rightarrow Q = \frac{I}{C_A - C_V}$$

Here Q is the cardiac output, CA, CV concentrations of O_2 in terms of milliliters of O_2 per liter of blood in the arterial blood and mixed venous blood. I is the volume of O_2 uptake by ventilation.

The O_2 concentration of mixed venous blood is measured by taking samples from a central vein through a cardiac catheter.

For analysis of arterial blood, samples are taken from an artery in the fore arm. Complicated procedure, Difficult to repeat and Catheterization required

7(a) Write a short note on measurement of heart sounds.



Heart sounds:

1. Heart sounds are acoustic phenomenon resulting from the vibrations of the cardiac structures.
2. Generally the heart sounds are due to the closing and opening of the valves.

Heart sounds classification:

- First heart sound
- Second heart sound
- Third heart sound
- Fourth heart sound

First Heart sound:

Origin: It is produced by a sudden closure of the mitral and tricuspid valves associated with myocardial contraction.

Timing: The low frequency vibrations occur approximately 0.05sec after the onset of the "QRS" complex of the ECG.

Duration: The first heart sound lasts for 0.1 to 0.12 sec

Second heart sound:

Origin: Due to the vibration setup by the closure of semi lunar valves i.e. the closure of aortic and pulmonary valves.

Timing: The second heart sound starts approximately 0.03-0.05sec after the end of "T" wave of the ECG.

Duration: This lasts for 0.08-0.14sec.

Third heart sound:

Origin: The third heart sound arises as the ventricles relax and internal pressure drops well below the pressure in atrium.

Timing: This starts at 0.12-0.18sec after the onset of the 2nd heart sound.

Fourth Heart sound:

Origin: Due to atrial contraction.

Timing: The fourth heart sound starts approximately 0.12-0.18sec after the onset of the P-wave.

Duration: The sound lasts for 0.03-0.06sec.

7(b)Explain the blood flow measurement by thermal convection method.

Blood Flow measurement by thermal convection :

A hot object in a colder-flowing medium is cooled by thermal convection.

The rate of cooling is proportional to the rate of the flow of the medium.

This principle, often used to measure gas flow, has also been applied to the measurement of blood velocity.

In one application, a thermistor in the bloodstream is kept at a constant temperature by a servo system.

The electrical energy required to maintain this constant temperature is a measure of the flow rate.

In another method an electric heater is placed between two thermocouples or thermistors that are located some distance apart along the axis of the vessel.

The temperature difference between the upstream and the downstream sensor is a measure of the blood velocity.

A device of the latter type is sometimes called a thermostromuhr (literally, from the German"heat current clock").

Thermal convection methods for blood flow determination, although among the oldest ones used for this purpose, have now been widely replaced by the other methods described in this chapter.

8(a)With a neat sketch explain the operation of Internal Pacemaker.

A device capable of generating artificial pacing impulses and delivering them to the heart is known as a pacemaker system (commonly called a pacemaker) and consists of a pulse generator and appropriate electrodes.

Pacemakers are available in a variety of forms.

Internal pacemakers may be permanently implanted in patients whose SA nodes have failed to function properly or who suffer from permanent heart block because of a heart attack.

An internal pacemaker is defined as one in which the entire system is inside the body. In contrast, an external pacemaker usually consists of an externally worn pulse generator connected to electrodes located on or within the myocardium.

External pacemakers are used on patients with temporary heart irregularities, such as those encountered in the coronary patient, including heart blocks.

They are also used for temporary management of certain arrhythmias that may occur in patients during critical postoperative periods and in patients during cardiac surgery, especially if the surgery involves the valves or septum.

Internal pacemaker systems are implanted with the pulse generator placed in a surgically formed pocket below the right or left clavicle, in the left subcostal area, or, in women, beneath the left or right major pectoralis muscle.

Internal leads connect to electrodes that directly contact the inside of the right ventricle or the surface of the myocardium (see following Figure).

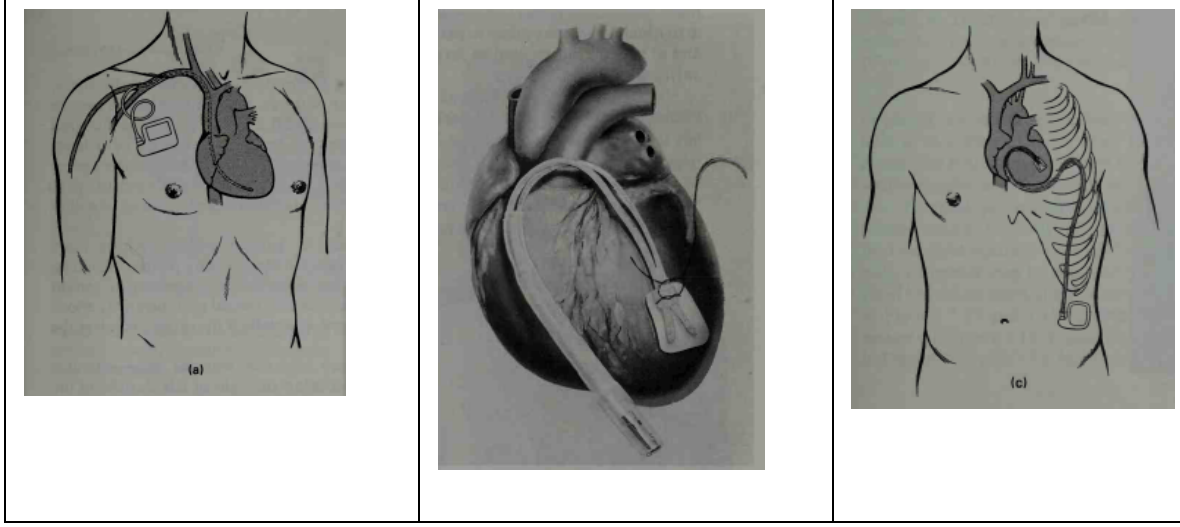


Figure (a) Implanted standby pacemaker with catheter electrodes inserted through the right cephalic vein,
(b) Pacing electrodes attached to the myocardium;
(c) Myocardial electrodes with pacemaker generator implanted in abdomen

The exact location of the pulse generator depends primarily on the type of electrode used, the nature of the cardiac dysfunction, and the method (mode) of pacing that may be prescribed.

Pacing electrodes and modes are described later in this chapter. Since there are no external connections for applying power, the pulse generator must be completely self-contained, with a power source capable of continuously operating the unit for a period of years.

8(b)Explain the measurement of blood PO2 and PCO2.

Measurement of Blood PCO_2 :

The blood pCO2 is the partial pressure of carbon dioxide of blood taken anaerobically. It is expressed in mmHg and is related to the percentage CO2 as follows:

$$pCO_2 = \text{Barometric pressure} - \text{water vapour pressure} \times \frac{\%\ CO_2}{100}$$

At 37°C, the water vapour pressure is 47 mmHg, so at 750 mm barometric pressure, 5.7% CO2corresponds to a pCO2 of 40 mm.

All modern blood gas analyzers make use of a pCO2 electrode of the type described by Stow *et al* (1957).

It basically consists of a pH sensitive glass electrode having a rubber membrane stretched over it, with a thin layer of water separating the membrane from the electrode surface.

The technique is based on the fact that the dissolved CO2 changes the pH of an aqueous solution.

The CO2 from the blood sample defuses through the membrane to form H_2CO_3, which dissociates into(H^+) and (HCO^{-3}) ions. The resultant change in pH is thus a function of the $C0_2$ concentration in the sample.

The emf generated was found to give a linear relationship between the pH and the negative logarithm of pCO2. Although the electrode could not provide sensitivity and stability required for clinical applications, it made way for realizing a direct method for the measurement of pCO_2.

The basic construction of the electrode was modified by Severinghaus and Bradley (1958) to a degree that made it suitable for routine laboratory use.

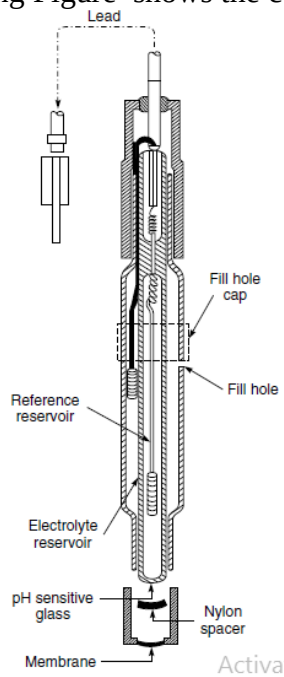
In the construction worked out by them, the water layer was replaced by a thin film of an aqueous sodium bicarbonate ($NaHCO_3$) solution.

The rubber membrane was also replaced by a thin Teflon membrane, which is permeable to CO_2 but not to any other ions, which might alter the pH of the bicarbonate solution.

The CO_2 from the blood diffuses into the bicarbonate solution. There will be a drop in pH due to CO_2 reacting with water forming carbonic acid.

The pH falls by almost one pH unit for a ten-fold increase in the CO_2 tension of the sample.

Hence, the pH change is a linear function of the logarithm of the CO_2 tension. Following Figure shows the construction of a typical pCO2 electrode.



Activate Fig : Construction of pCO2 electrode

Blood pO2 Measurement :

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

The partial pressure of oxygen is usually measured with a polarographic electrode. There is a characteristic polarizing voltage at which any element in solution is predominantly reduced and in the case of oxygen, it is 0.6 to 0.9 V.

In this voltage range, it is observed that the current flowing in the electrochemical cell is proportional to the oxygen concentration in the solution.

Most of the modern blood gas analyzers utilize an oxygen electrode first described by Clark (1956) for measuring oxygen partial pressure.

This type of electrode consists of a platinum cathode, a silver/silver chloride anode in an electrolyte filling solution and a polypropylene membrane.

The electrode is of a single unit construction and contains the reference electrode also in its assembly.

Following Figure shows the construction of a typical Clark-type oxygen electrode.

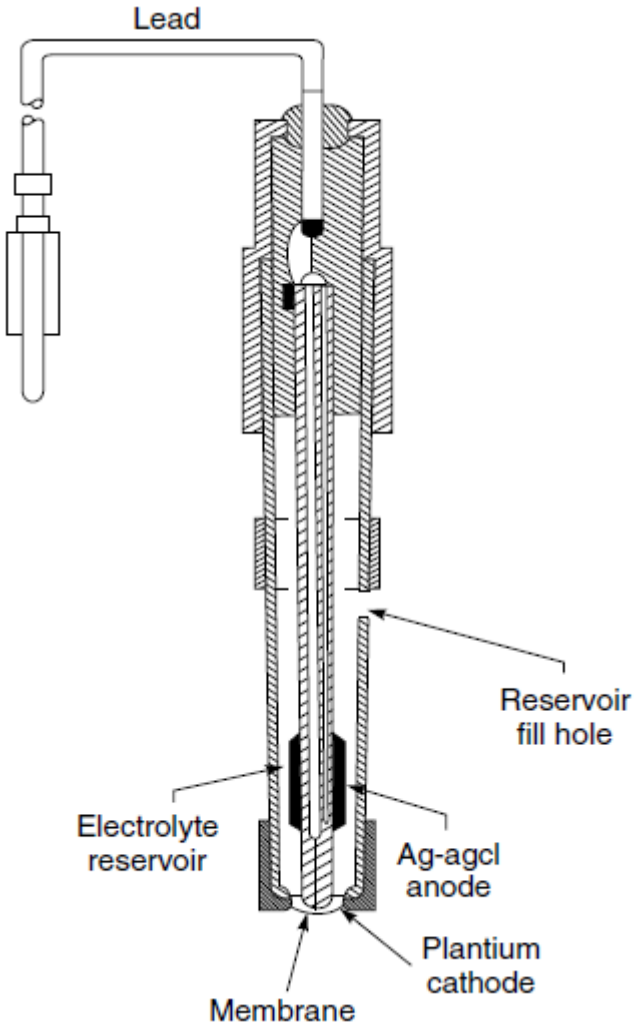


Fig : Construction of pO_2 electrode

The entire unit is separated from the solution under measurement by the polypropylene membrane.

Oxygen from the blood diffuses across the membrane into the electrolyte filling solution and is reduced at the cathode.

The circuit is completed at the anode, where silver is oxidized, and the magnitude of the resulting current indicates the partial pressure of oxygen.

The reactions occurring at the anode and cathode are:

Cathode reaction:

$$O_2 + 2H_2O + 4e^- \rightarrow 4\,OH^-$$

Anode reaction:

$$4Ag \rightarrow 4Ag^+ + 4e^-$$

The Clark electrode for measuring pO2 has been extensively studied and utilized. It is found to be of particular advantage for measuring blood samples. The principal advantages are:

i. sample size required for the measurement can be extremely small
ii. the current produced due to pO2 at the electrode is linearly related to the partial pressure of oxygen
iii. the electrode can be made small enough to measure oxygen concentration in highly localized areas

the response time is very low, so the measurements can be made in seconds.

9(a) Write a short notes on Blood gas electrodes.

Electrodes for Blood pH Measurement:

Several types of electrodes have been described in literature for the measurement of blood pH.

They are all of the glass electrode type but made in different shapes so that they may accept small quantities of blood and yield accurate results.

The most common type is the syringe electrode, which is preferred for the convenience of taking small samples of blood anaerobically.

The small ‘dead space’ between the electrode bulb and the inner surface of the syringe barrel is usually filled with dilute heparin solution to prevent blood coagulation.

Before making measurements, the syringe should be rolled between the hands to ensure thorough mixing.

Microcapillary glass electrodes are preferred when it is required to monitor pH continuously: for example during surgery. These types of electrodes are especially useful when a very small volume of the sample is to be analyzed.

Typically, a micro-electrode for clinical applications requires only 20–25 ml of capillary blood for the determination of pH.

The electrode is enclosed in a water jacket with circulating water at a constant temperature of 38°C.

The water contains 1% NACI for shielding against static interference.

The capillary is protected with a polyethylene tubing.

The internal reference electrode is silver/silver chloride and the calomel reference electrode is connected to a small pool of saturated KCI, through a porous pin.

An accuracy of 0.001 pH can be obtained with this electrode against a constant buffer.

Following Figure shows the constructional details of a typical blood pH electrode and the measurement set-up used in practice.

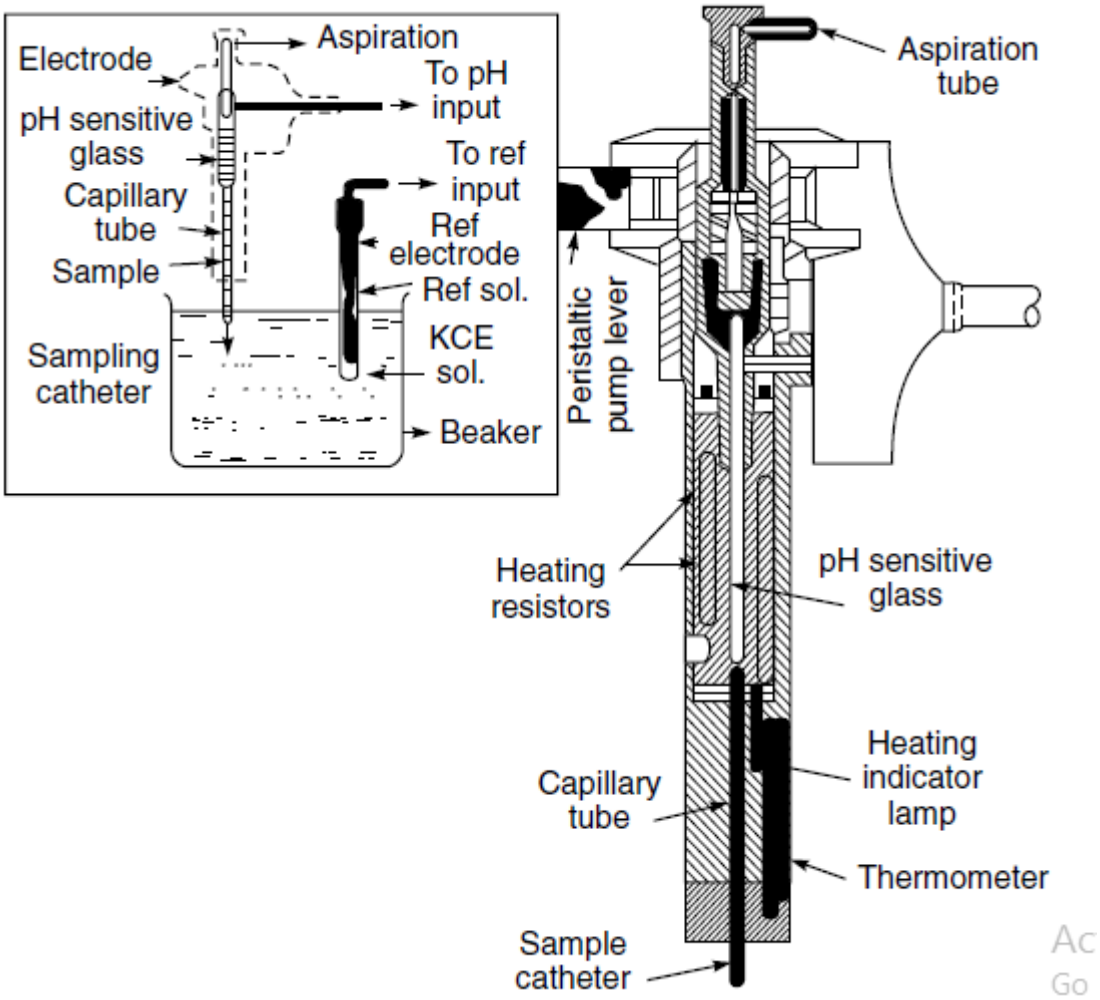


Fig : Microcapillary electrode for measurement of blood pH

Quite often, combination electrodes comprising both measuring and reference electrodes offer single-probe convenience for all pH measurements. Several instruments offer the ability to measure pH in small containers with as little as 250 ml of the sample.

Effect of Blood on Electrodes :

Glass electrodes deteriorate if allowed to remain in contact with blood for a long time. This results in a change of the emf-pH slope. The poisoning effect appears to be due to protein deposition. Therefore, as a precautionary measure, in an apparatus where blood necessarily remains in contact around the electrode for long periods (more than 20 min.), the response must be checked frequently against buffer solutions. The poisoning effect can be reduced by putting the electrode in pepsin and 0.1 N HCI, followed by careful wiping with a tissue paper.

The pH of blood is found to change linearly with temperature in the range of 18° to 38°C. The temperature coefficient for the pH of blood is 0.0147 pH unit per degree centigrade. This necessitates the use of a highly accurate temperature controlled bath to keep the electrodes with the blood sample at 37°C ± 0.01°C.

Another important point to be kept in mind while making blood pH measurements is that because of the possible individual variations in the temperature coefficient of blood pH, the method of measuring at some temperature other than 37°C followed by correction is not recommended. It is advisable to keep both the glass as well as the reference electrode at the temperature of measurement.

9(b) Explain the building blocks of Magnetic Resonance Imaging system.

The basic components of an NMR imaging system are shown in the following Fig. These are:
• *A magnet,* which provides a strong uniform, steady, magnet field *B*0;
• *An RF transmitter,* which delivers radio-frequency magnetic field to the sample;
• *A gradient system,* which produces time-varying magnetic fields of controlled spatial nonuniformity;
• *A detection system,* which yields the output signal; and
• *An imager system,* including the computer, which reconstructs and displays the images.

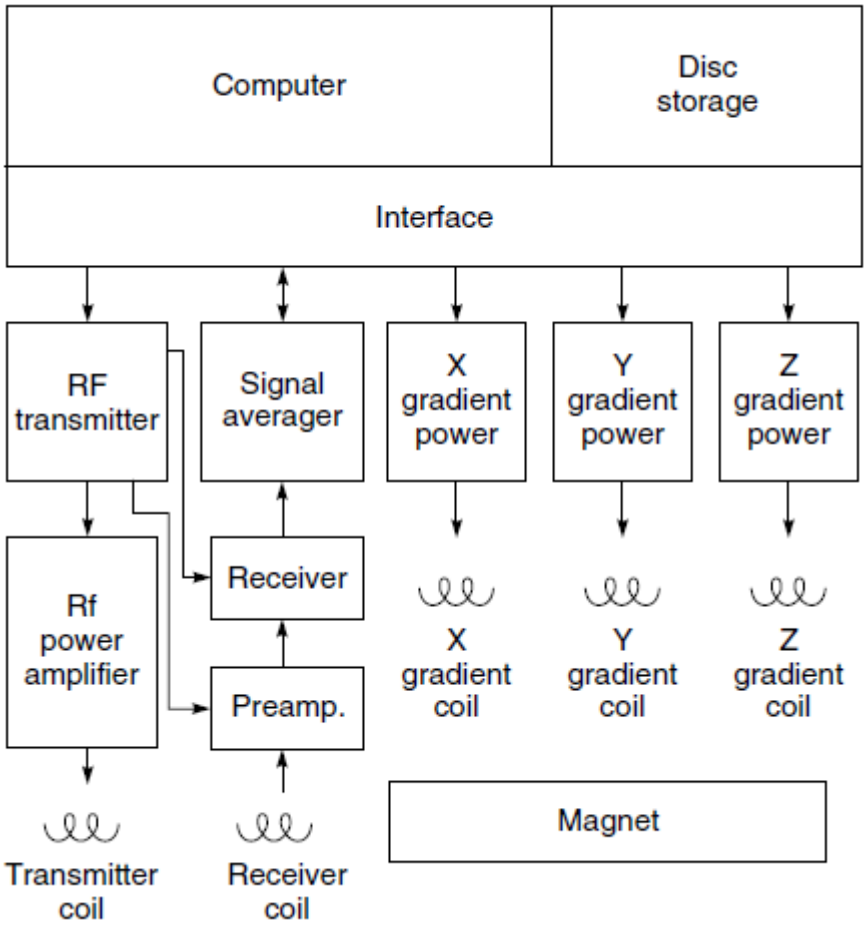


Fig : ***Sub-systems of a typical NMR imaging system***

The imaging sequencing in the system is provided by a computer. Functions such as gates and envelopes for the NMR pulses, blanking for the pre-amplifier and RF power amplifier and voltage waveforms for the gradient magnetic fields are all under software control. The computer also performs the various data processing tasks including the Fourier transformation, image reconstruction, data filtering, image display and storage. Therefore, the computer must have sufficient memory and speed to handle large image arrays and data processing, in addition to interfacing facilities.

The Magnet: In magnetic resonance tomography, the base field must be extremely uniform in space and constant in time as its purpose is to align the nuclear magnets parallel to each other in the volume to be examined. Also, the signal-to-noise ratio increases approximately linearly with the magnetic field strength of the basic field, therefore, it must be as large as possible. Four factors characterize the performance of the magnets used in MR systems; viz., field strength, temporal stability, homogeneity and bore size. The effect of the magnetic field

strength has been elaborated earlier. The temporal stability is important since instabilities of the field adversely affect resolution.

The gross non homogeneities result in image distortion while the bore diameter limits the size of the dimension of the specimen that can be imaged. Such a magnetic field can be produced by means of four different ways, viz., permanent magnets, electromagnets, resistive magnets and super-conducting magnets. In case of the permanent magnet, the patient is placed in the gap between a pair of permanently magnetized pole faces. Permanent magnet materials normally used in MRI scanners include high carbon iron alloys such as alnico or neodymium iron (alloy of neodymium, boron and iron) and ceramics such as barium ferrite. Although permanent magnets have the advantages of producing a relatively small fringing field and do not require power supplies, they tend to be very heavy (up to 100 tons) and produce relatively low fields of the order of 0.3 T or less. Electromagnets make use of soft magnetic materials such as pole faces which become magnetized only when electric current is passed through the coils wound around them. Electromagnets obviously require external electrical power supply. On cost considerations, the earlier NMR imaging systems were equipped with resistive magnets. Resistive magnets make use of large current-carrying coils of aluminium strips or copper tubes. In these magnets, the electrical power requirement increases proportionately to the square of the field strength which becomes prohibitively high as the field strength increases. Moreover, the total power in the coils is converted into heat which must be dissipated by liquid cooling. For instance, at 0.2 T, the power requirement is nearly 70 kW (Oppelt, 1984) and a substantial increase of field strength above 0.2 T in resistive magnets is thus technically limited. At present, resistive magnets are seldom used except for very low field strength applications, generally limited to 0.02 to 0.06 T.

RF Transmitter System: In order to activate the nuclei so that they emit a useful signal, energy must be transmitted into the sample. This is what the transmitter does. The system consists of an RF transmitter, RF power amplifier and RF transmitting coils. The RF transmitter consists of an RF crystal oscillator at the Larmor frequency. The RF voltage is gated with the pulse envelopes from the computer interface to generate RF pulses that excite the resonance. These pulses are amplified to levels varying from 100 W to several kW depending on the imaging method and are fed to the transmitter coil. The higher power levels are necessary for the large sample volumes encountered in whole body experiments.
The RF coils can be either a single coil serving as both transmitter and receiver or two separate coils that are electrically orthogonal. The latter configuration has the advantage of reduced pulse breakthrough into the receiver during the pulse. In both cases, all coils generate RF fields orthogonal to the direction of the main magnetic field. Saddle-and solenoidal-shaped RF coils are typical geometries for the RF coils. The coils are tuned to the NMR frequency and are usually isolated from the remainder of the system by enclosure in an RF shielding cage.