Biomedical Instrumentation
18EI702
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Scheme of evaluation and Solutions

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Signature of faculty

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Scheme of Evaluation

1.	10 × 1 = 10M	
2(a)	Five problems encountered	5 × 1 = 5M
2(b)	Sketch of respiratory systems	: 2M
	Description	: 3M
3(a)	Definition of action potential	: 1M
	Generation mechanism of action potential	: 4M
3(b)	Definition of bio electric potential	: 1M
	Example of any two bio potentials	: 2 × 2= 4M
4(a)	Any two surface electrodes with description	: 2 × 2= 4M
	Advantages	: 1M
4(b)	Block diagram of electrocardiograph	: 3M
	Operation	: 2M
5(a)	Diagram of Einthoven triangle	: 2M
	Description of significance of vectors	: 3M
5(b)	Five states with resultant EEG	: 5 × 1 = 5M
6(a)	Block diagram	: 3M
	Operation	: 2M
6(b)	Indirect measurement	: 2M
	Direct measurement	: 2M
	Merits and demerits	: 1M
7(a)	Schematic of Ultrasonic flow meter	: 3M
	Working principle	: 2M
7(b)	Definition of cardiac output	: 1M
	Any two methods for measurement	: 2 × 2 = 4M
8(a)	Need of defibrillator	: 1M
	Circuit of Cardiac defibrillator	: 2M
	Operation	: 2M
8(b)	Block diagram of hemodialysis machine	: 3M
	Description of its working	: 2M
9(a)	Block diagram of MRI system	: 3M
	Description of working principle	: 2M
9(b)	Any two method for blood cell counting	: 2 × 2.5 = 5M

Answers

1(a) What is bio electric potential?

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

(b) What are the different types of muscles?

The 3 types of muscle tissue are cardiac, smooth, and skeletal.

(c) Differentiate perfectly polarized electrodes from perfectly non polarized electrodes?

The key difference between polarizable and non polarizable electrode is that polarizable electrodes have a charge separation at the electrode-electrolyte boundary whereas non-polarizable electrodes have no charge separation at this electrode-electrolyte boundary.

The ideal polarizable electrode is characterized by charge separation at the electrode-electrolyte boundary and is electrically equivalent to a capacitor, while the ideal non-polarizable electrode is characterized by no charge separation and is electrically equivalent to a short.

(d) List the different types of electrodes used to measure bio electric potentials?

Biopotential electrodes are classified as

1 . Microelectrodes: Electrodes used to measure bioelectric potentials near or within a single cell.

2. Skin surface electrodes: Electrodes used to measure ECG, EEG, and EMG potentials from the surface of the skin.

3. Needle electrodes: Electrodes used to penetrate the skin to record EEG potentials from a local region of the brain or EMG potentials from a specific group of muscles.

(e) What are the electrodes used for EMG?

Pad electrode and needle type electrode.

(f) What are sensory nerves, motor nerves and mixed nerves?

A nerve contains bundles of nerve fibers, either axons or dendrites, surrounded by connective tissue. Sensory nerves contain only afferent fibers, long dendrites of sensory neurons. Motor nerves have only efferent fibers, long axons of motor neurons. Mixed nerves contain both types of fibers.

(g) What is cardiac output and its normal rate?

Cardiac output is the quantity of blood delivered by the heart to the aorta per minuteand its value is 4 to 6 liters/min.

(h) Write the principle of electromagnetic flow meter?

Magnetic blood flow meters are based on the principle of magnetic induction. When an electrical conductor is moved through a magnetic field, a voltage is induced in the conductor proportional to the velocity of its motion.

(i) What is the use of cardiac 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.

(j) What is meant by Doppler effect?

The Doppler effect (or the Doppler shift) is the change in frequency of a wave in relation to an observer who is moving relative to the wave source

2(a) Write a brief note on problems encountered in measuring a living system?

Inaccessibility of variables to measurement

In some cases, such as in the measurement of dynamic neurochemical activity in the brain, it is impossible to place a suitable transducer in a position to make the measurement.

sometimes the problem stems from the required physical size of the transducer as compared to the space available for measurement.

Where a variable is inaccessible for measurement, an attempt is often made to perform an indirect measurement.

This process involves the measurement of some other related variable that makes possible a usable estimate of the inaccessible variable under certain conditions.

In using indirect measurements, however, one must be constantly aware of the limitations of the substitute variable and must be able to determine when the relationship is not valid.

Variability of data :

Physiological variables can never be viewed as strictly deterministic values but must be represented by some kind of statistical or probabilistic distribution.

In other words, measurements taken under a fixed set of conditions at one time will not necessarily be the same as similar measurements made under the same conditions at another time.

The variability from one subject to another is even greater. Statistical methods must be employed in order to estimate relationships among variables.

Lack of knowledge about interrelationships:

Physiological measurements with large tolerances are often accepted by the physician because of lack of this knowledge and the resultant inability to control variations.

Better understanding of the physiological relationships would also permit more effective use of indirect measurements as substitutes for inaccessible measures and would aid engineers or technicians in their job of coupling the instrumentation to the physiological system

Interaction among Physiological systems:

Because of the large number of feedback loops involved in the major Physiological systems, a severe degree of interaction exists both within a given system and among the major systems.

The result is that stimulation of one part of a given system generally effects all other parts of the system in some way and often affects other systems as well.

Effect of the transducer on the measurement :

In many situations the physical presence of the transducer changes the reading significantly. For example, a large flow transducer placed in a bloodstream partially blocks the vessel and changes the pressure-flow characteristics of the system

Similarly, an attempt to measure the electrochemical potentials generated within an individual cell requires penetration of the cell by a transducer. This penetration can easily kill the cell or damage it so that it can no longer function normally.

Another problem is that the presence of a transducer in one system can affect responses in other systems.

Artifacts :

In medicine and biology, the term artifact refers to any component of a signal that is extraneous to the variable represented by the signal.

Thus, random noise generated within the measuring instrument, electrical interference, cross-talk, and all other unwanted variations in the signal are considered artifacts.

A major source of artifacts in measuring a living system is the movement of the subject, which in turn results in the movement of the measuring device.

Energy limitations :

Many Physiological measurement techniques require that a certain amount of energy be applied to the living system in order to obtain a measurement.

For example, resistance measurements require the flow of electric current through the tissues or blood being measured.

Some transducers generate a small amount of heat due to the current flow. In most cases, this energy level is so low that its effect is insignificant.

However, in dealing with living cells, care must continually be taken to avoid the possibility of energy concentrations that might damage cells or affect the measurements.

Safety considerations :

The methods employed in measuring variables in a living human subject must in no way endanger the life or normal functioning of the subject.

Recent emphasis on hospital safety requires that extra caution must be taken in the design of any measurement system to protect the patient.

The measurement should not cause undue pain, trauma, or discomfort, unless it becomes necessary to endure these conditions in order to save the patient's life.

2(b) With a neat sketch explain the respiratory system?

The respiratory system :

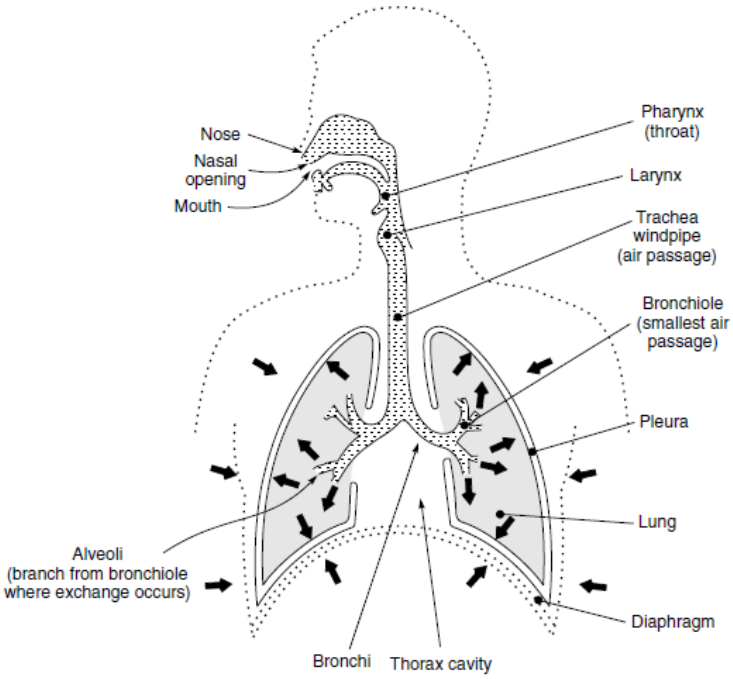


Fig : The respiratory system

The respiratory system is the pneumatic system.

An air pump (diaphragm), which alternatively creates negative and positive pressures in a scaled chamber (thoracic cavity), causes air to be sucked into and forced out of a pair of elastic bags (lungs) located within the compartment.

The bags are connected to the outside environment through a passageway (nasal cavities, pharynx, larynx, trachea, bronchi, and bronchioles), which at one point is in common with the tubing that carries liquids and solids to the stomach.

A special valving arrangement interrupts the pneumatic system whenever liquid or solid matter passes through the common region.

The passage way divides to carry air into each of the bags, where in it again sub divides many times to carry air into each of the bags, wherein it again subdivides many times to carry air into and out of each of many tiny air spaces (pulmonary alveoli) within the bags.

The dual air input to the system (nasal cavities) has an alternate vent (the mouth) for use in the event of nasal blockage and for other special purposes.

In the tiny air spaces of the bags is a membrane interface with the body's hydraulic system through which certain gases can diffuse.

Oxygen is taken into the fluid (blood) from the incoming air, and carbon dioxide is transferred from the fluid to the air, which is exhausted by the force of the pneumatic pump.

The pump operates with a two way override.

An automatic control center (respiratory center of the brain) maintains pump operation at a speed that is adequate to supply oxygen and carry off carbon dioxide as required by the system.

Manual control can take over at any time either to accelerate or to inhibit the operation of the pump.

Automatic control will return, however if a condition is created that might endanger the system.

System variables of primary importance are respiratory rate, respiratory air flow, respiratory volume, and concentration of CO2 in the expired air.

This system also has a number of relatively fixed volumes and capacities, such as tidal volume (the volume inspired or expired during each normal breath), inspiratory reserve volume (the additional volume that can be inspired after a normal inspiration), expiratory reserve volume (the additional amount of air that can be forced out of the lungs after normal expiration), residual volume (amount of air remaining in the lungs after all possible air has been forced out), and vital capacity (tidal volume, plus inspiratory reserve volume, plus expiratory reserve volume).

3(a) What is action potential? Explain the propagation of action potential?

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.

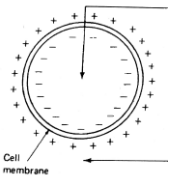


Fig :Cell

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.

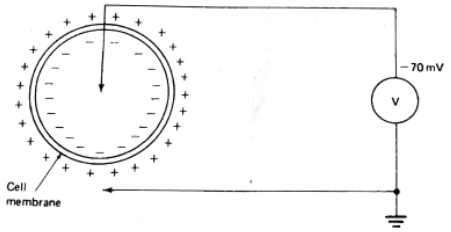


Fig : Polarized cell with its resting potential

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

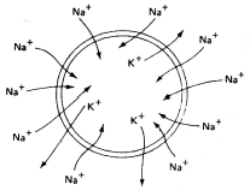


Fig : Depolarization of a cell. Na+ ions rush into the cell while K+ ions attempt to leave

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

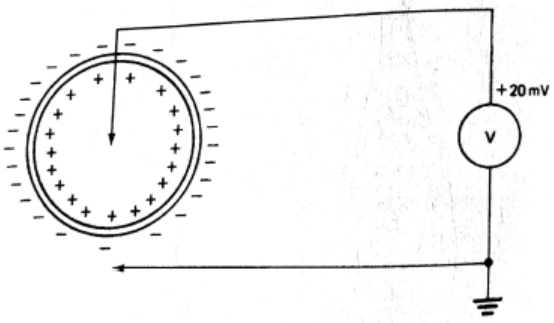


Fig : Depolarized cell during an action potential

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.

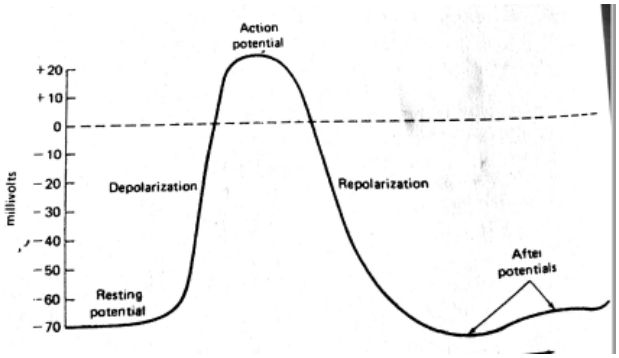


Fig : Waveform of action potential

3(b) Define bio electric potential? Write a brief note on various 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

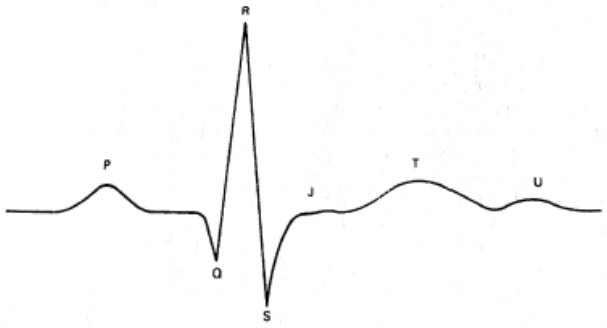


Fig : The electrocardiogram waveform

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.

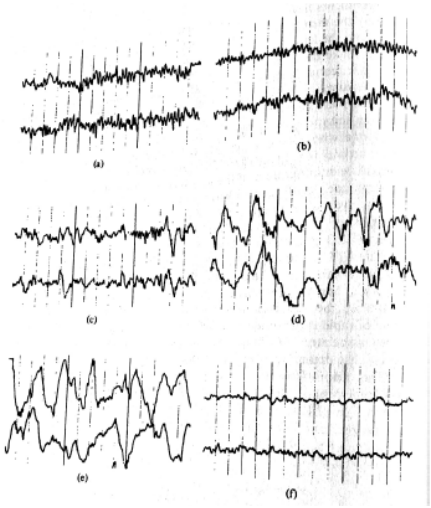
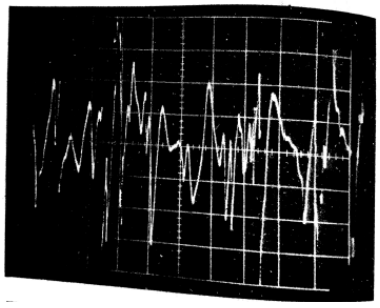


Fig : Typical human EEG patterns for different stages of sleep.
In each case the upper record is from the left frontal region of the brain and the lower tracing is from the right occipital region,
(a)Awake and alert—mixed EEG frequencies (unsynchronized high-frequency EEG)
(b) Stage 1—subject is drowsy 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) Write a short note on different types of surface electrodes? List the advantages of using surface electrodes with EMG?

Body Surface Electrodes

Although any type of surface electrode can be used to sense EGG, EEG, or EMG potentials, the larger electrodes are usually associated with EGG, since localization of the measurement is not important, whereas smaller electrodes are used in EEG and EMG measurements.

The earliest bioelectric potential measurements used immersion electrodes, which were simply buckets of saline solution into which the subject placed his hands and feet, one bucket for each extremity.

As might be expected, this type of electrode (following Figure) presented many difficulties, such as restricted position of the subject and danger of electrolyte spillage.

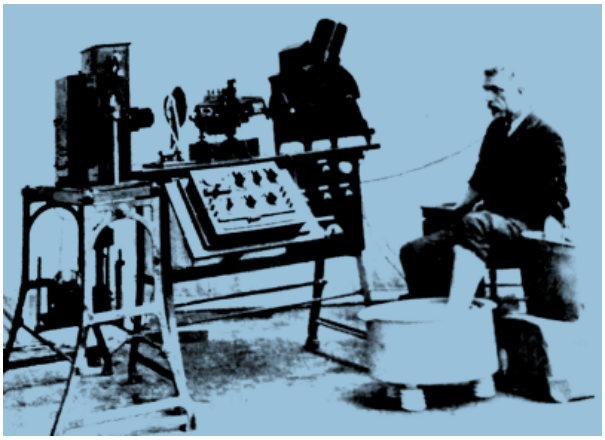


Fig : ECG measurement using immersion electrodes

A great improvement over the immersion electrodes were the plate electrodes, first introduced about 1917. Originally, these electrodes were separated from the subject's skin by cotton or felt pads soaked in a strong saline solution. Later a conductive jelly or paste (an electrolyte) replaced the soaked pads and metal was allowed to contact the skin through a thin coat of jelly. Plate electrodes of this type are still in use today. An example is shown in the following Figure .

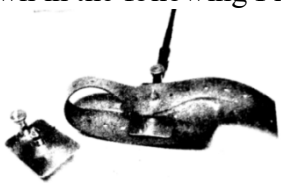


Fig : Metal plate electrode

Another fairly old type of electrode still in use is the suction-cup electrode shown in the following Figure .

Fig : Suction cup electrode

In this type, only the rim actually contacts the skin.

One of the difficulties in using plate electrodes is the possibility of electrode slippage or movement. This also occurs with the suction-cup electrode after a sufficient length of time.

All the preceding electrodes suffer from a common problem. They are all sensitive to movement, some to a greater degree than others. Even the slightest movement changes the thickness of the thin film of electrolyte between metal and skin and thus causes changes in the electrode potential and impedance. In many cases, the potential changes are so severe that they completely block the bioelectric potentials the electrodes attempt to measure.

Later, a new type of electrode, the floating electrode, was introduced in varying forms by several manufacturers. The principle of this electrode is to practically eliminate movement artifact by avoiding any direct contact of the metal with the skin. The only conductive path between metal and skin is the electrolyte paste or jelly, which forms an electrolyte bridge. Even with the electrode surface held at a right angle with the skin surface, performance is not impaired as long as the electrolyte bridge maintains contact with both the skin and the metal. The following Figure shows a cross section of a floating electrode,

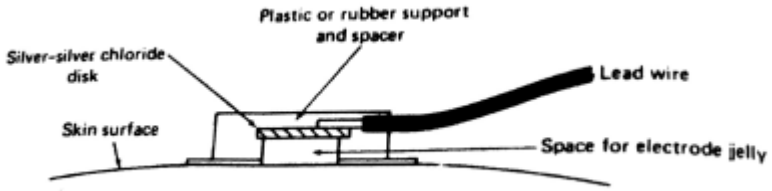


Fig : Diagram of floating type skin surface electrode

and the following Figure shows a commercially available configuration of the floating electrode.

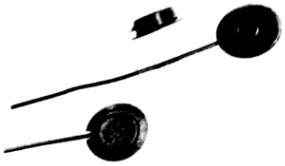


Fig : Floating skin surface electrode

Floating electrodes are generally attached to the skin by means of two sided adhesive collars (or rings), which adhere to both the plastic surface of the electrode and the skin.

Following Figure shows an electrode in position for biopotential measurement.

Fig : Application of floating type skin surface electrode

Various types of disposable electrodes have been introduced in recent years to eliminate the requirement for cleaning and care after each use.
Primarily intended for ECG monitoring, these electrodes can also be used for EEC and EMG as well.

Special types of surface electrodes have been developed for other applications. For example, a special ear-clip electrode (following Figure) was developed for use as a reference electrode for EEG measurements.

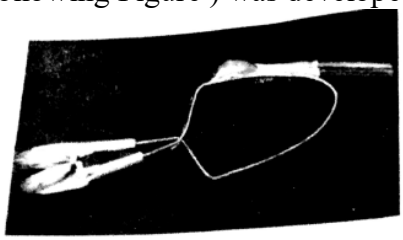


Fig : Ear-clip electrode

Scalp surface electrodes for EEG are usually small disks about 7 mm in diameter or small solder pellets that are placed on the cleaned scalp, using an electrolyte paste.

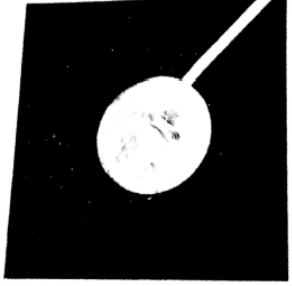


Fig : EEG scalp surface electrode

4(b) With a neat sketch explain the working of Electrocardiograph?
ECG Recorder Principles :

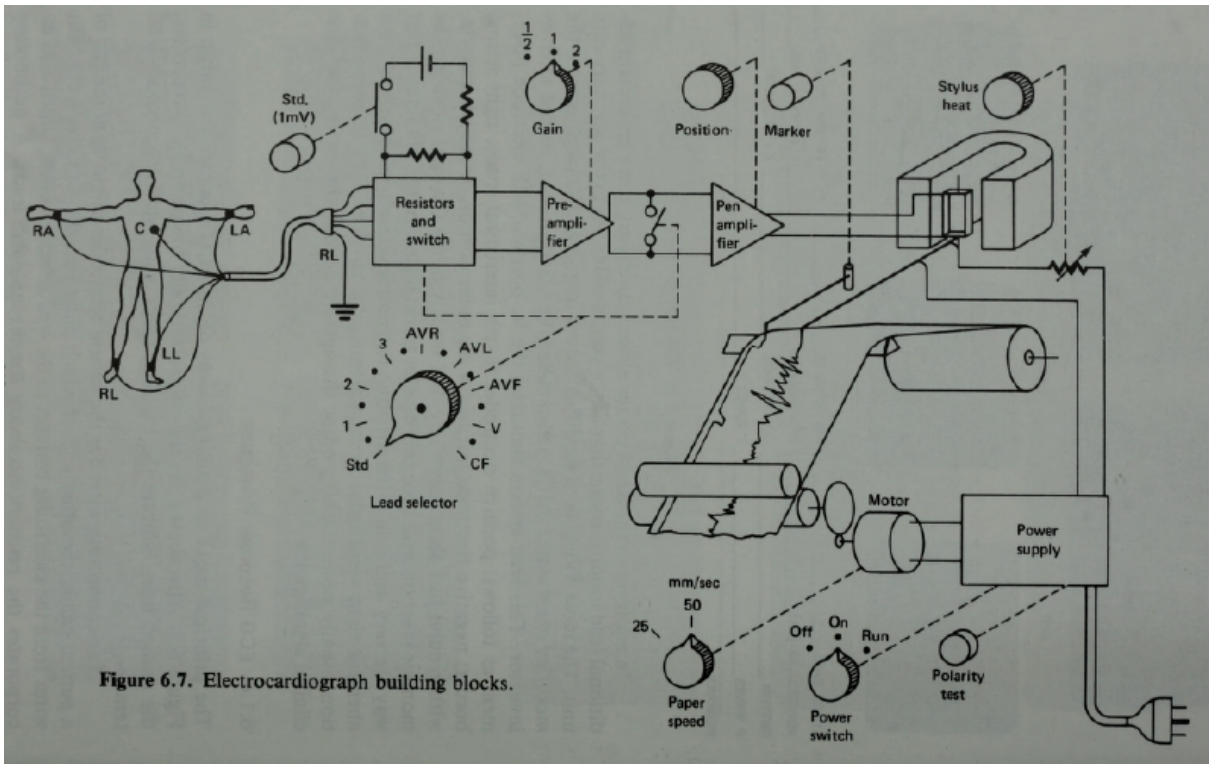


Figure 6.7. Electrocardiograph building blocks.

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 Einthoven Triangle?

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.

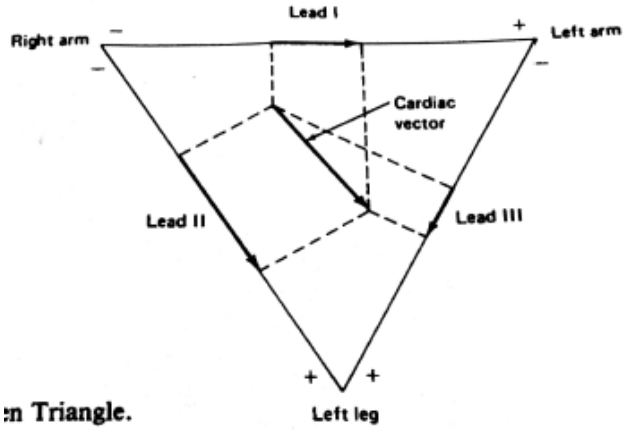
The ECG measured from any of the three basic limb leads is a time-variant single-dimensional component of the vector.

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.

5(b) Discuss how EEG is useful in sleep analysis?

The brain can be regarded as a highly developed biochemical factory. The electrical activity which results from so much of chemical change is known as the electroencephalogram (EEG). It is in a sense a useful by product of nervous action since it allows us to make non mutilating measurements on an organ which does not easily permit any type of external interference.

The Electroencephalogram, as recorded from the surface of the head, consists of rhythmical, slow sinusoidal waveform between 10 μV and 100 μV in amplitude. The electroencephalogram, varies in both form, amplitude and frequency; the basic frequency of around 10 Hz is known as alpha rhythm. When a subject is in deep sleep, the alpha rhythm will disappear and will be replaced by a slower high amplitude signal known as the delta rhythm. The electroencephalogram (EEG) produced by a subject under various conditions is shown in the following figure.

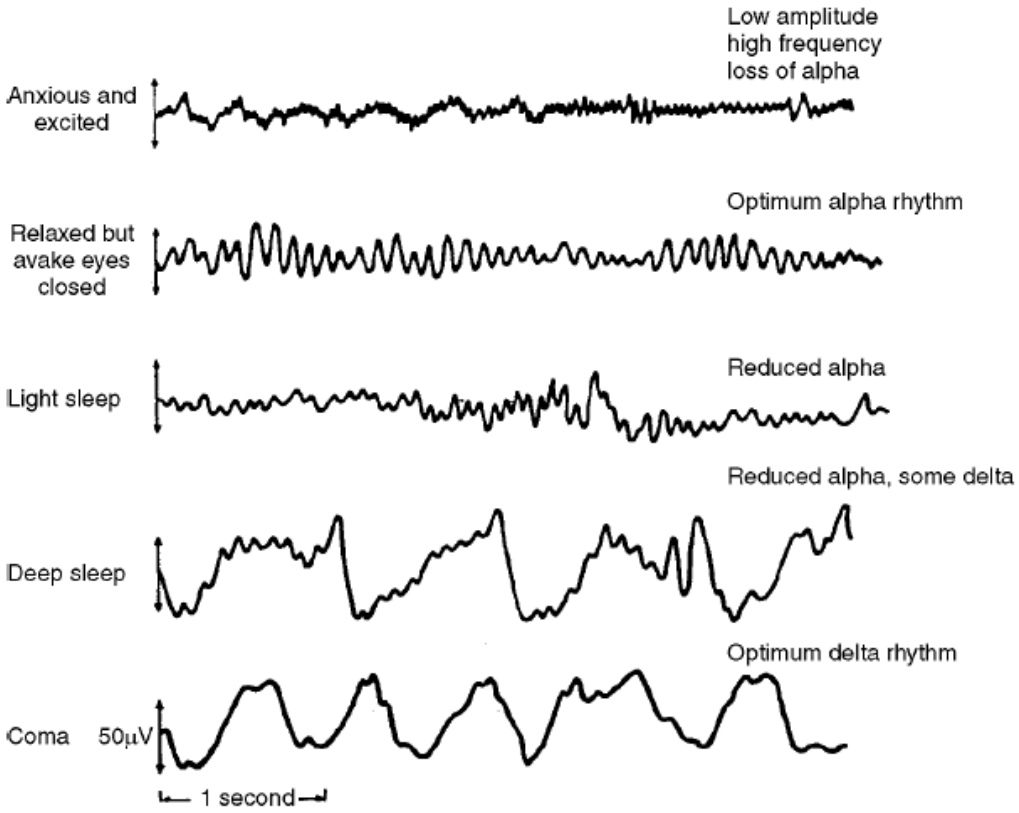
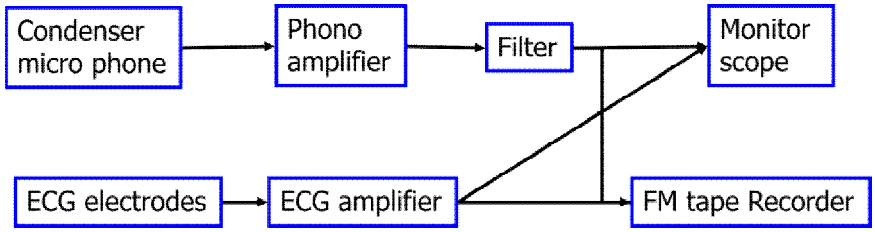


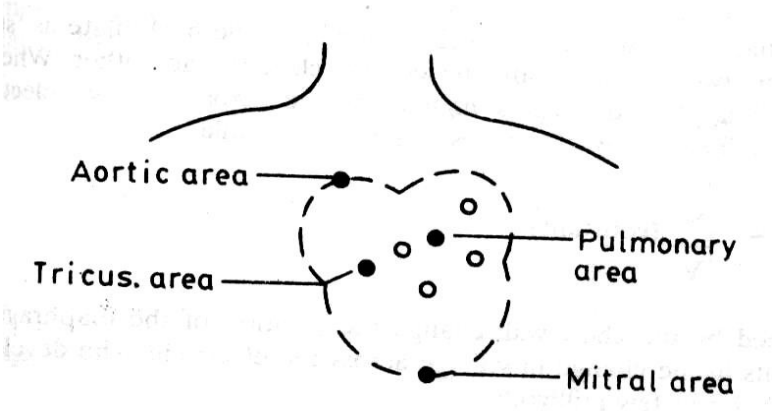
Fig : Shows the physiological states and the resultant electroencephalogram (EEG).

6(a) Explain the measurement of heart sounds with suitable diagram?

- The graphic record of the heart sounds is called "phonogram". Because the sound is from the heart, it is called phonocardiogram.
- The instrument used to measure the heart sounds is called "Phonocardiograph".
- "Phonocardiograph" consists a "photo catheter", a device similar to a conventional catheter, with a microphone at the tip.
- The basic aim of "Phonocardiograph" is to pick-up the different heart sounds, filter out the heart sounds and to display them or record them.



- The heart sounds are converted into electrical signals by means of a heart microphone fastened to the chest wall by an adhesive strip.
- The pick-up successively located at different areas mentioned in the below figure.



- The electrical signals from microphone are amplified by a phonocardiographic pre-amplifier followed by suitable filters and recorder.
- Further the electrodes are also placed on the limbs to pick up the electrical activity of the heart and those signals are amplified and recorded.

This recorded ECG is used as a reference for PC

6(b) List the various methods used in blood pressure measurement? Discuss the merits and demerits of each method?

(i)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.

(ii)Direct methods of monitoring Blood pressure :

The direct method of pressure measurement is used when the highest degree of absolute accuracy, dynamic response and continuous monitoring is required.

For direct measurement, a catheter or a needle type probe is inserted through a vein or artery to the area of interest.

Two types of probes can be used. One type is the **catheter tip probe** in which the sensor is mounted on the tip of the probe and the pressures exerted on it are converted to the proportional electrical signals.

The other is the **fluid-filled catheter type**, which transmits the pressure exerted on its fluid-filled column to an external transducer.

This transducer converts the exerted pressure to electrical signals. The electrical signals can then be amplified and displayed or recorded.

Catheter tip probes provide the maximum dynamic response and avoid acceleration artefacts whereas the fluid-filled catheter type systems require careful adjustment of the catheter dimensions to obtain an optimum dynamic response.

Measurement of blood pressure by the direct method, though an invasive technique, gives not only the systolic, diastolic and mean pressures, but also a visualization of the pulse contour and such information as stroke volume, duration of systole, ejection time and other variables.

Problems of catheter insertion have largely been eliminated and complications have been minimized. This has been due to the development of a simple percutaneous cannulation technique; a continuous flush system that causes minimal signal distortion and simple, stable electronics which the paramedical staff can easily operate.

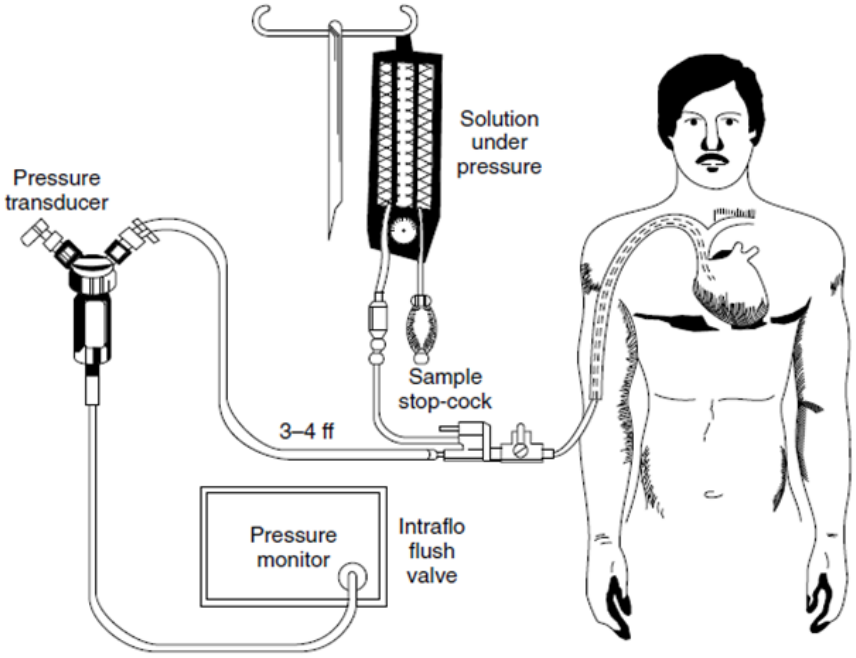


Fig : Typical set up of a pressure measuring system by direct method

A typical set-up of a fluid-filled system for measuring blood pressure shown in the above Fig.

Before inserting the catheters into the blood vessel it is important that the fluid-filled system should be thoroughly flushed.

In practice a steady flow of sterile saline is passed through the catheter to prevent blood clotting in it. As air bubbles dampen the frequency response of the system, it should be ensured that the system is free from them.

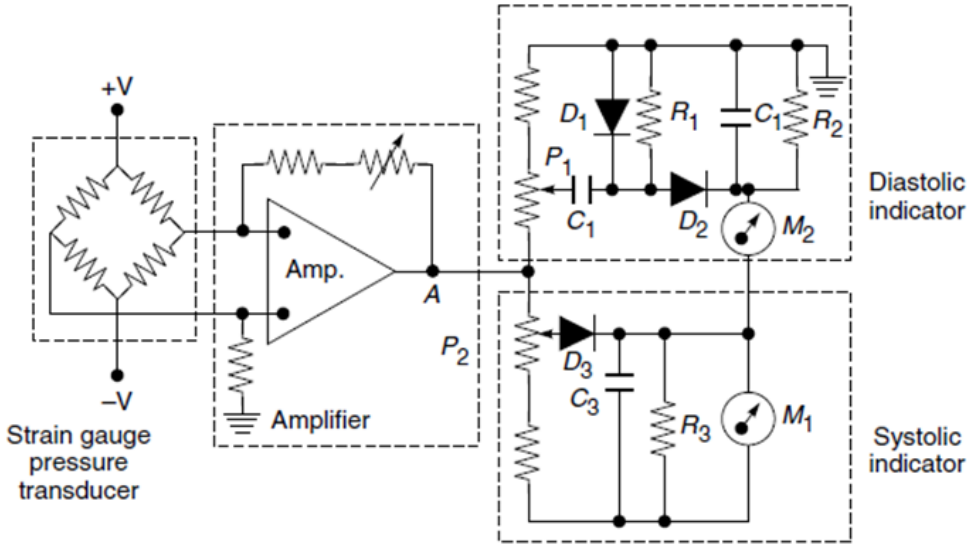


Fig : Circuit diagram for measurement of systolic and diastolic blood pressure

The above Figure shows a simplified circuit diagram commonly used for processing the electrical signals received from the pressure transducer for the measurement of arterial pressure.

The transducer is excited with a 5 V dc excitation. The electrical signals corresponding to the arterial pressure are amplified in an operational amplifier or a carrier amplifier.

The modern preamplifier for processing pressure signals are of the isolated type and therefore comprise of floating and grounded circuits similar to ECG amplifiers.

The excitation for the transducer comes from an amplitude controlled bridge oscillator through an isolating transformer, which provides an interconnection between the floating and grounded circuits.

An additional secondary winding in the transformer is used to obtain isolated power supply for the floating circuits.

The input stage is a differential circuit, which amplifies pressure change, which is sensed in the patient connected circuit.

The gain of the amplifier can be adjusted depending upon the sensitivity of the transducer.

After RF filtering, the signal is transformer-coupled to a synchronized demodulator for removing the carrier frequency from the pressure signal.

For the measurement of systolic pressure, a conventional peak reading type voltmeter is used.

When a positive going pressure pulse appears at *A*, diode *D*3 conducts and charges *C*3 to the peak value of the input signal, which corresponds to the systolic value.

Time constant *R*3*C*3 is chosen in such a way that it gives a steady output to the indicating meter.

The value of diastolic pressure is derived in an indirect way. A clamping circuit consisting of *C*1 and *D*1 is used to develop a voltage equal to the peak-to-peak value of the pulse pressure.

This voltage appears across *R*1. Diode *D*2 would then conduct and charge capacitor *C*2 to the peak value of the pulse signal.

The diastolic pressure is indicated by a second meter *M*2 which shows the difference between the peak systolic minus the peak-to-peak pulse pressure signal. The mean
arterial pressure can also be read by using a smoothing circuit when required.

7(a) Explain how ultrasonic flow meter is used in blood flow measurement?

In an ultrasonic blood flow meter, a beam of ultrasonic energy is used to measure the velocity of flowing blood.

This can be done in two different ways.

In the transit time ultrasonic flow meter, a pulsed beam is directed through a blood vessel at a shallow angle and its transit time is then measured.

When the blood flows in the direction of the energy transmission, the transit time is shortened. If it flows in the opposite direction, the transit time is lengthened.

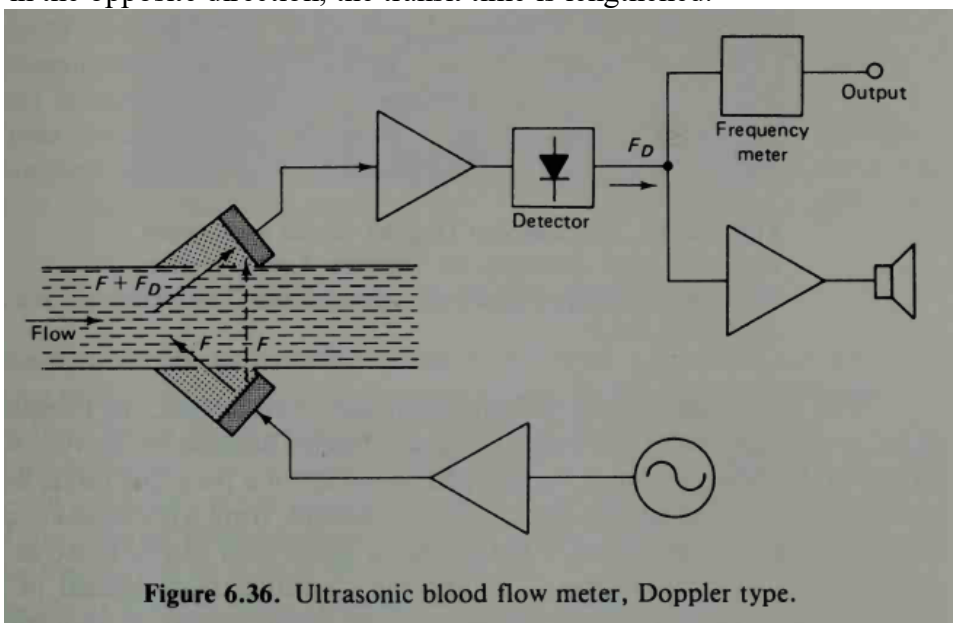


Figure 6.36. Ultrasonic blood flow meter, Doppler type.

Fig : Ultrasonic Blood flow meter, Doppler type

More common are ultrasonic flow meters based on the Doppler principle.

The Doppler effect (or the Doppler shift) is the change in frequency of a wave in relation to an observer who is moving relative to the wave source

An oscillator, operating at a frequency of several megahertz, excites a piezoelectric transducer (usually made of barium titanate).

This transducer is coupled to the wall of an exposed blood vessel and sends an ultrasonic beam with a frequency F into the flowing blood.

A small part of the transmitted energy is scattered back and is received by a second transducer arranged opposite the first one.

Because the scattering occurs mainly as a result of the moving blood cells, the reflected signal has a different frequency due to the Doppler effect.

Its frequency is either $F + F_D$ or $F - F_D$, depending on the direction of the flow.

The Doppler component F_D is directly proportional to the velocity of the flowing blood.

A fraction of the transmitted ultrasonic energy, however, reaches the second transducer directly, with the frequency being unchanged.

After amplification of the composite signal, the Doppler frequency can be obtained at the output of a detector as the difference between the direct and the scattered signal components.

With blood velocities in the range normally encountered, the Doppler signal is typically in the low audio frequency range.

Because of the velocity profile of the flowing blood, the Doppler signal is not a pure sine wave, but has more the form of narrow-band noise.

Therefore, from a loudspeaker or earphone, the Doppler signal of the pulsating blood flow can be heard as a characteristic " swish—swish—."

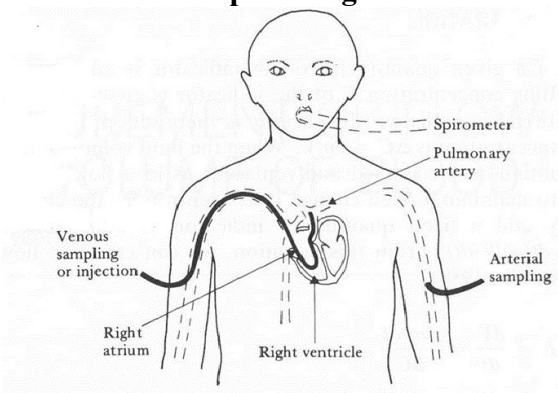
When the transducers are placed in a suitable mount (which defines the area of the blood vessel), a frequency meter used to measure the Doppler frequency can be calibrated directly in flow-rate units.

Unfortunately, Doppler flow meters of this simple design cannot discriminate the direction of flow.

More complicated circuits, however, which use the insertion of two quadrature components of the carrier, are capable of indicating the direction of flow.

7(b) What is cardiac output? Explain the techniques used in measurement of cardiac output?

(i) 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, C_A, 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

(ii)Cardiac output measurement by thermal dilution method :

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

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

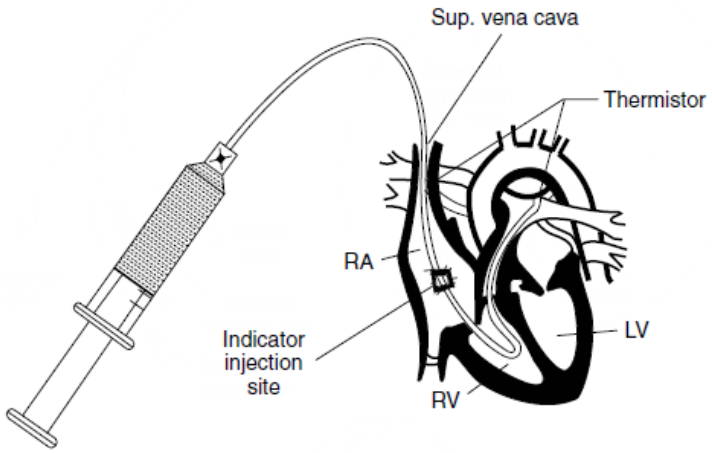


Fig : ***Cardiac output thermal-dilution set-up***

The above Figure shows a typical cardiac output thermal dilution set up.

A solution of 5% Dextrose in water at room temperature is injected as a thermal indicator into the right atrium.

It mixes in the right ventricle, and is detected in the pulmonary artery by means of a thermistor mounted at the tip of a miniature catheter probe.

The injectate temperature is also sensed by a thermistor and the temperature difference between the injectate and the blood circulating in the pulmonary artery is measured.

The reduction in temperature in the pulmonary artery (due to the passage of the Dextrose) is integrated with respect to time and the blood flow in the pulmonary artery is then computed electronically by an analog computer which also applies correction factors.

A meter provides a direct reading of cardiac output after being muted until integration is complete so as to avoid spurious indications during a determination.

8(a) Write a detailed note on cardiac defibrillator?

Defibrillators :

The heart is able to perform its pumping function through precisely synchronized action of the heart muscle fibers.

The rapid spread of action potentials over the surface of the atria causes these two chambers of the heart to contract together and pump blood through the two atrio ventricular valves into the ventricles.

After a critical time delay, the powerful ventricular muscles are synchronously activated to pump blood through the pulmonary and systemic circulatory systems.

A condition in which this necessary synchronism is lost is known as fibrillation.

During fibrillation, the normal rhythmic contractions of either the atria or the ventricles are replaced by rapid irregular twitching of the muscular wall.

Fibrillation of atrial muscles is called atrial fibrillation; fibrillation of the ventricles is known as ventricular fibrillation.

Under conditions of atrial fibrillation, the ventricles can still function normally, but they respond with an irregular rhythm to the non synchronized bombardment of electrical stimulation from the fibrillating atria.

Since most of the blood flow into the ventricles occurs before atrial contraction, there is still blood for the ventricles to pump.

Thus, even with atrial fibrillation circulation is still maintained, although not as efficiently.

The sensation produced, however, by the fibrillating atria and irregular ventricular action can be quite traumatic for the patient.

Ventricular fibrillation is far more dangerous, for under this condition the ventricles are unable to pump blood; and if the fibrillation is not corrected, death will usually occur within a few minutes.

Unfortunately, fibrillation, once begun, is not self-correcting.

Hence, a patient susceptible to ventricular fibrillation must be watched continuously so that the medical staff can respond immediately if an emergency occurs. This is one of the reasons for cardiac monitoring.

Although mechanical methods (heart massage) for defibrillating patients have been tried over the years, the most successful method of defibrillation is the application of an electric shock to the area of the heart.

If sufficient current to stimulate all musculature of the heart simultaneously is applied for a brief period and then released, all the heart muscle fibers enter their refractory periods together, after which normal heart action may resume.

Defibrillation is done by applying a brief (0.25 to 1 sec) burst of 60-Hz ac at an intensity of around 6 A to the chest of the patient through appropriate electrodes.

This application of an electrical shock to resynchronize the heart is sometimes called counter shock.

If the patient does not respond, the burst is repeated until defibrillation occurs. This method of counter shock was known as ac defibrillation.

There are a number of disadvantages in using ac defibrillation, however, successive attempts to correct ventricular fibrillation are often required.

Moreover, ac defibrillation cannot be successfully used to correct atrial defibrillation. In fact, attempts to correct atrial fibrillation by this method often result in the more serious ventricular fibrillation. Thus, ac defibrillation is no longer used.

In dc defibrillation method, a capacitor is charged to a high dc voltage and then rapidly discharged through electrodes across the chest of the patient.

It was found that dc defibrillation is not only more successful than the ac method in correcting ventricular fibrillation, but it can also be used successfully for correcting atrial fibrillation and other types of arrhythmias.

The dc method requires fewer repetitions and is less likely to harm the patient.

A typical dc defibrillator circuit shown in the following Figure.

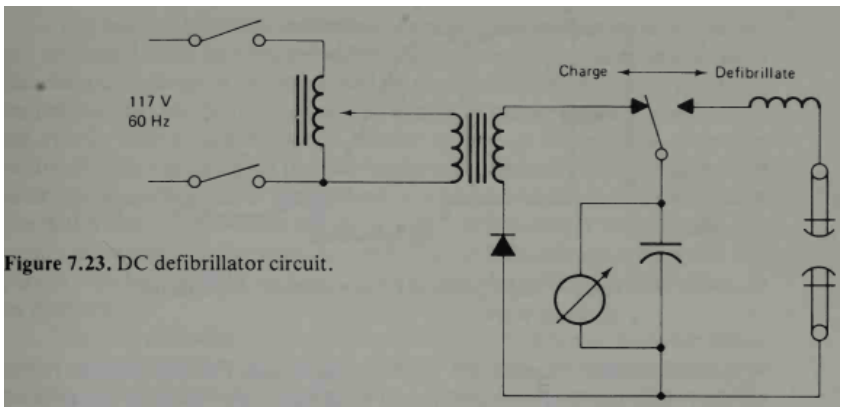


Figure 7.23. DC defibrillator circuit.

Depending on the defibrillator energy setting, the amount of electrical energy discharged by the capacitor may range between 100 and 400 W-sec, or joules.

The duration of the effective portion of the discharge is approximately 5 msec.

The energy delivered is represented by the typical waveform shown in the following Figure as a time plot of the current forced to flow through the thoracic cavity.

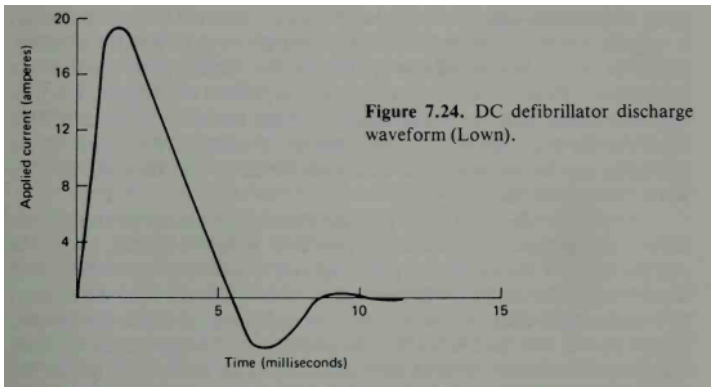


Figure 7.24. DC defibrillator discharge waveform (Lown).

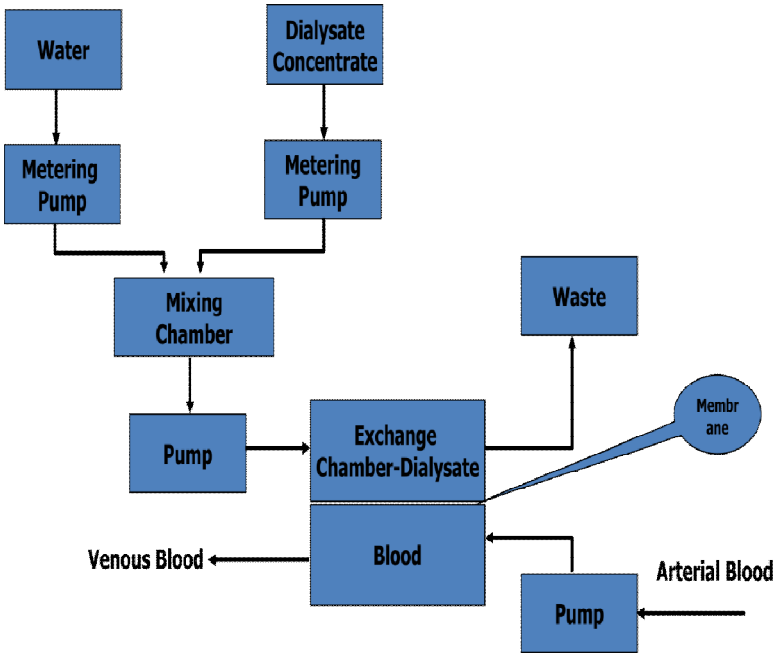
The area under the curve is proportional to the energy delivered.

It can be seen that the peak value of current is nearly 20 A and that the wave is essentially mono phasic, since most of its excursion is above the baseline.

An inductor in the defibrillator is used to shape the wave in order to eliminate a sharp, undesirable current spike that would otherwise occur at the beginning of the discharge.

8(b) With a neat sketch explain the operation of hemodialysis machine?

- There are two basic units haemo dialysis system (i) Exchanger (ii) Dialysate delivery system
- Exchanger:
  1. It consists of dialysis chamber itself, which is a compartment containing the patient's blood
  2. A compartment containing the dialysate
- These two compartments are separated by a semi-permeable membrane which allows the waste products in the blood to diffuse through to the dialysate which carries them away
- We have coil dialyser type, Parallel type, Hollow type exchangers
- The dialysate is made of water with various solutions added
- Metering pumps administer the correct amount of dialysate concentrate and water in to a mixing chamber to produce the dialysate.
- Dialysate is then pumped through a dialysis chamber where it picks up the metabolic waste products



9(a) With a neat sketch explain the MRI system and list the advantages of MRI?

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.

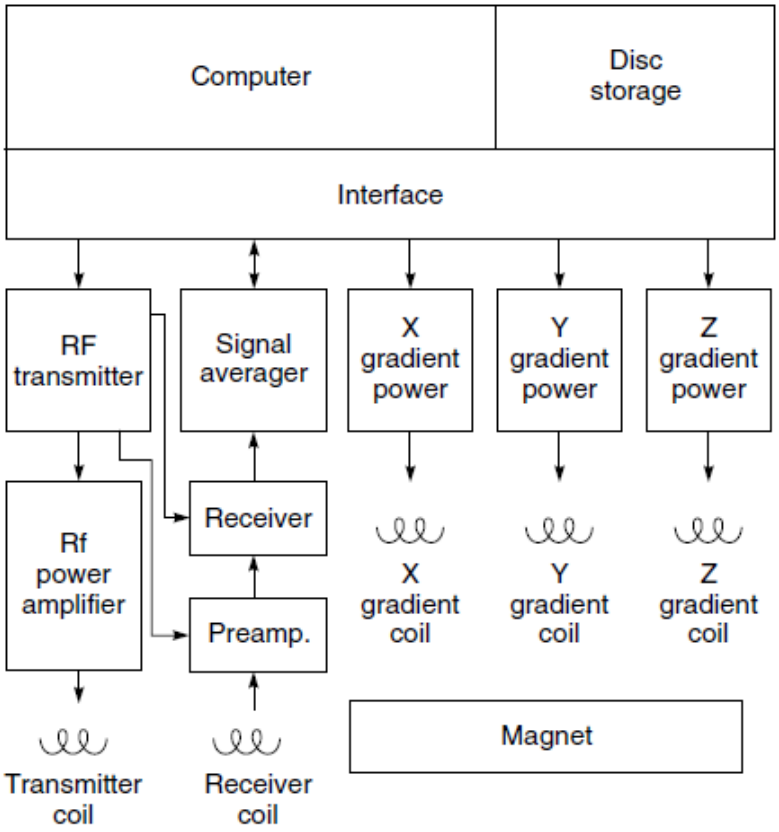


Fig : ***Sub-systems of a typical NMR imaging system***

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.

Nuclear magnetic resonance (NMR) tomography uses magnetic fields and radio frequency signals to obtain anatomical information about the human body as cross-sectional images in any desired direction and can easily discriminate between healthy and diseased tissue.

NMR images are essentially a map of the distribution density of hydrogen nuclei and parameters reflecting their motion, in cellular water and lipids.

The total avoidance of ionizing radiation, its lack of known hazards and the penetration of bone and air without attenuation make it a particularly attractive non-invasive imaging technique.

CT provides details about the bone and tissue structure of an organ whereas NMR highlights the liquid-like areas on those organs and can also be used to detect flowing liquids, like blood.

A conventional X-ray scanner can produce an image only at right angles to the axis of the body, whereas the NMR scanner can produce any desired cross-section, which offers a distinct advantage to and is a big boon for the radiologist.

9(b) Write a short note on blood cell counter?

Methods of cell counting :

(i) Microscopic method :

The most common and routinely applied method of counting blood cells even today, particularly in small laboratories, is the microscopic method in which the diluted sample is visually examined and the cells counted.

Commonly known as the counting chamber technique, it suffers from several common drawbacks : errors in measurement, poor reproducibility of the results, large time required, data gathered by this measurement is not directly suitable for storage or for further processing and evaluation

(ii)Automatic optical method :

The method is based on collecting scattered light from the blood cells and converting it into electrical pulses for counting.

The following Figure shows one type of arrangement for the rapid counting of red and white cells using the optical detection system.

A sample of dilute blood (1:500 for white cells and 1:50,000 for red cells) is taken in a glass container.

It is drawn through a counting chamber in which the blood stream is reduced in cross-section by a concentric high velocity liquid sheath.

A sample optical system provides a dark field illuminated zone on the stream and the light scattered in the forward direction is collected on the cathode of a photomultiplier tube. Pulses are produced in the photomultiplier tube corresponding to each cell.

These signals are amplified in a high input impedance amplifier and fed to an adjustable amplitude discriminator.

The discriminator provides pulses of equal amplitude, which are used to drive a digital display.

Instruments based on this technique take about 30 s for completing the count. An accuracy of 2% is attainable. The instruments require about 1 ml of blood sample.

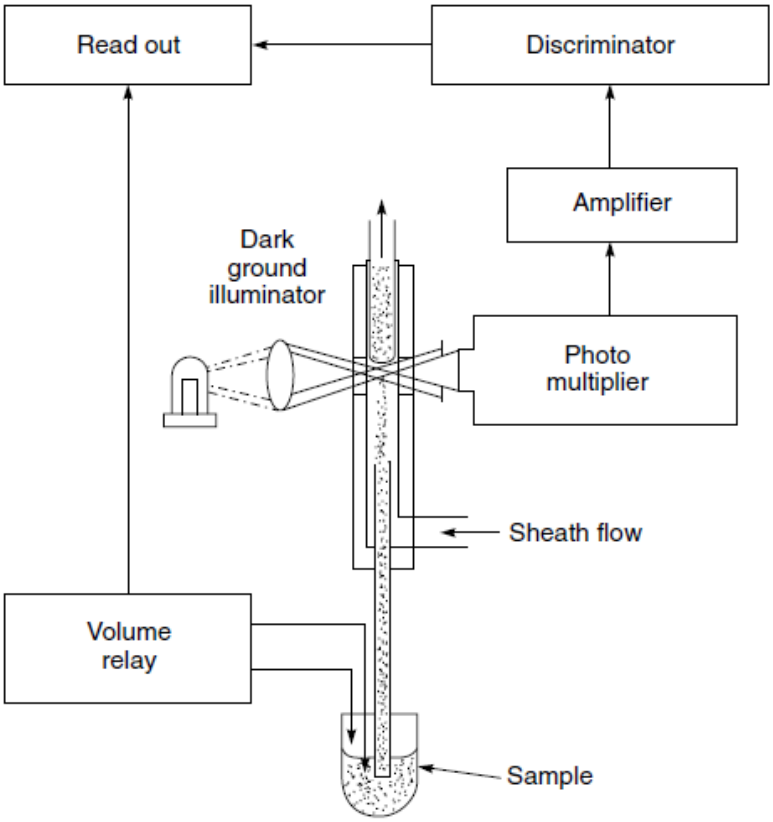


Fig : Optical method of counting cells

(iii) Electrical conductivity method :

Blood cell counters, operating on the principle of conductivity change, which occurs each time a cell passes through an orifice, are generally known as Coulter Counters.

The method was patented by Coulter in 1956 and it forms the basis of several particle counting instruments manufactured by a number of firms throughout the world.

The technique is extremely useful for determining the number and size of the particles suspended in an electrically conductive liquid.

The underlying principle of the measurement is that blood is a poor conductor of electricity whereas certain diluents are good conductors.

For a cell count, therefore, blood is diluted and the suspension is drawn through a small orifice.

By means of a constant current source, a direct current is maintained between two electrodes located on either side of the orifice.

As a blood cell is carried through the orifice, it displaces some of the conductive fluid and increases the electrical resistance between the electrodes.

A voltage pulse of magnitude proportional to the particle volume is thus produced. The resulting series of pulses are electronically amplified, scaled and displayed on a suitable display.

The instrument based on the Coulter principle works most satisfactorily when the average diameter of the particles ranges between 2 to 40% of the diameter of the measuring hole.

Therefore, the following condition must be met for the measuring range:

$$D/50 \leq d \leq D/2$$

where d = maximum particle size

D = diameter of the measuring aperture

Coulter counters :

The following Figure shows a block diagram showing the principle of a Coulter counter.

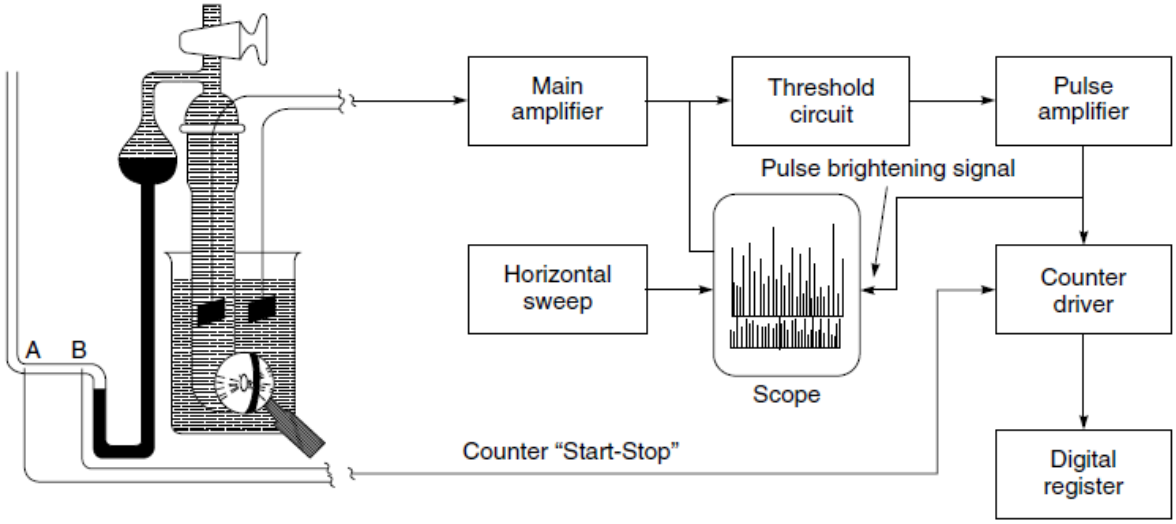


Fig : Principle of Coulter counter

A platinum electrode is placed inside the orifice tube and a second electrode is submerged into the beaker containing the cell dilution, creating an electrical circuit between the two electrodes.

Current will flow from one electrode to the other through the orifice.

When the cell suspension is drawn through the orifice, cells will displace their own volume of electrolyte and cause a resistance change, which is converted to a voltage change, and is amplified and displayed.

In practice, the cell suspension is drawn through the orifice by means of a mercury manometer.

This manometer includes two platinum wire contacts (A and B) set through the glass walls.

Contact A will start the count and contact B will stop it when precisely 0.5 ml of the dilution has passed through the orifice tube.

Thus, it provides a count of the number of particles in a fixed volume of suspension. The following Figure shows the sequence of building up the pulse in terms of increase in resistance at different positions of the cell with respect to the orifice.

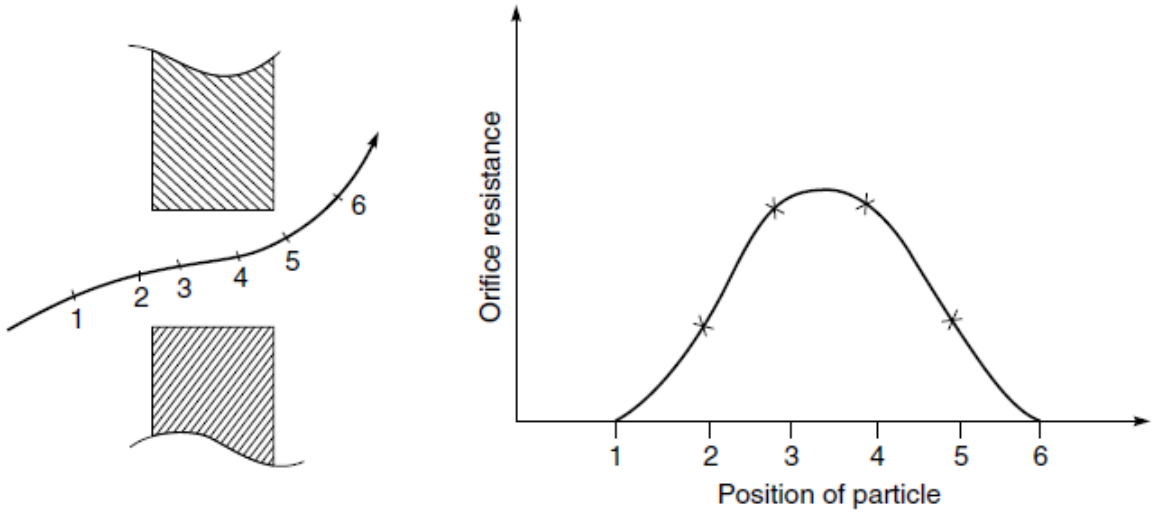


Fig : The sequence of building up the pulse in terms of increase in resistance at different positions the cell has with respect to the orifice

To enable the instrument to count only those pulses, which fall within certain preset size limits, the threshold facility is required.

The threshold is also necessary to enable the instrument to ignore any electronic noise, which may be present in the system.

The lower threshold sets an overall voltage level, which must be exceeded by a pulse before it can be counted.

The upper threshold will not allow pulses to be counted which exceed its preset level.

The Coulter counters are usually provided with an oscilloscope monitor to display the pulse information, which has passed through the amplifier, and acts as a visible check on the counting process indicating instantaneously any malfunctions such as a blocked orifice.

In particular, it provides information regarding (i) relative cell size, (ii) relative cell size distribution, (iii) settings of the threshold level control, and (iv) means to check the performance of the instrument for reliability of counts.

The voltage pulses produced each time a cell passes through the orifice are displayed on the oscilloscope screen as a pattern of vertical spikes.