OMD-551

BASICS OF BIOMEDICAL INSTRUMENTATION

Unit -I

Biopotential Generation And Electrode Types.

SYLLABUS :

Origin of biopotential and its propagation. Types of electrodes - surface, needle and micro electrodes and their equivalent circuits. Recording problems - measurement with two electrodes.

Origin of biopotential and its propagation :

Biopotential and its measurement:

Bioelectric potentials are actually ionic voltages produced as a result of the electrochemical activity of certain special types of cells. Through the use of transducers capable of converting ionic potentials into electrical voltages, these natural monitoring signals can be measured.

Body fluids :-

The fluids surrounding the cells of the body are the body fluids. These fluids are conductive

solutions containing charged atoms known as ions. The principal ions are sodium (Na^+), potassium (K^+) and chloride (Cl^-).

Conditions resulting in the inability of the sodium to penetrate the membrane :-

The inability of the sodium to penetrate the membrane results in two conditions,

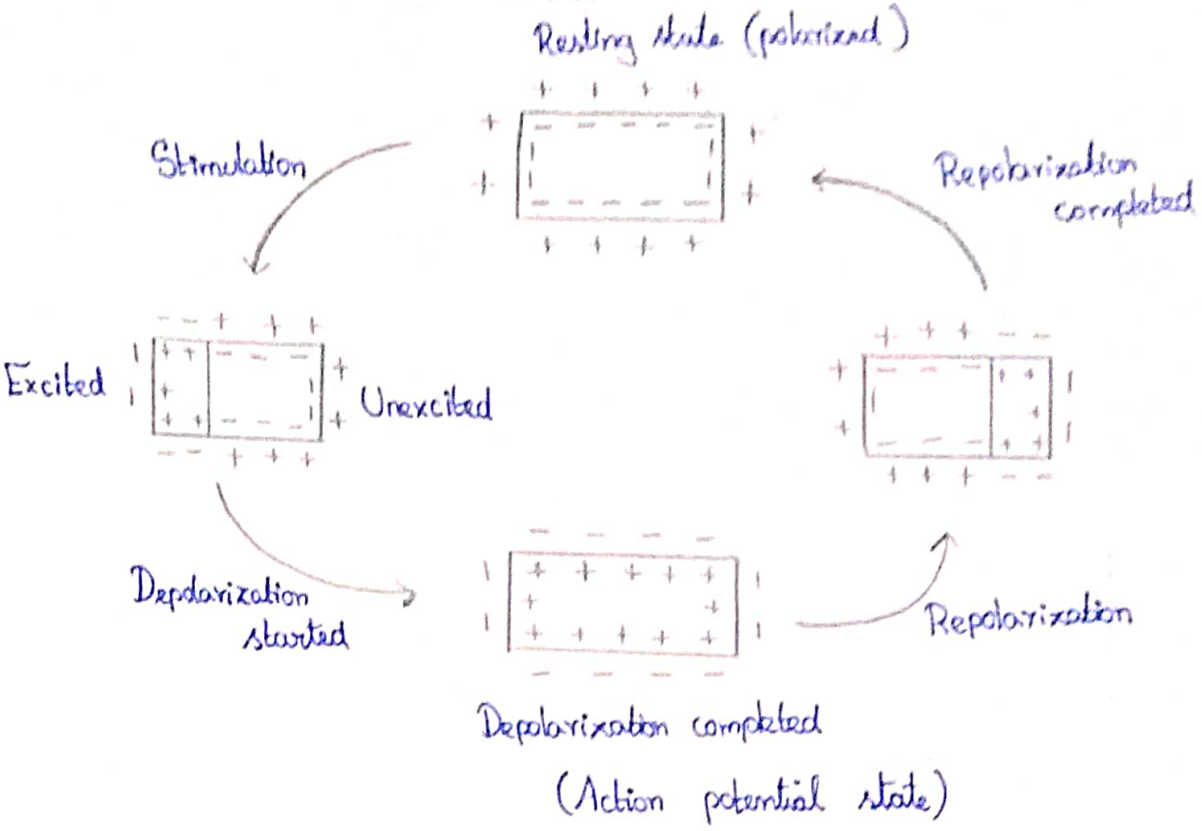
* First, the concentration of sodium ions inside the cell becomes much lower than in the intercellular fluid outside. Since the sodium ions are positive, this would tend to make the outside of the cell more positive than the inside.

* Second, in an attempt to balance the electric charge, additional potassium ions, which are also positive, enter the cell causing a higher concentration of potassium on the inside than on the outside.

Intra cellular and extra cellular fluid :-

The fluid which lies inside the cell membranes is called the intra cellular fluid and the fluid which lies outer the cell membranes is called the extra cellular fluid.

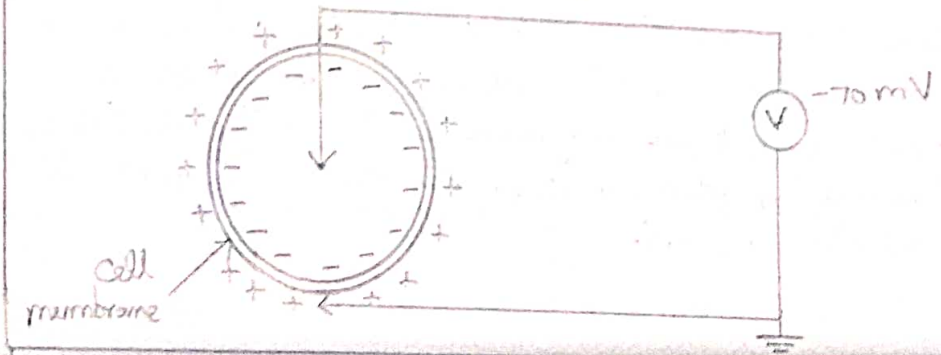
Electrical activity of muscles :



Biopotential states → Resting potential state
Biopotential states → Action potential state

Resting potential :

The charge balanced cannot be achieved, however, 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 caused by different concentration of ions is called as resting potential. The cell in the resting state is said to be polarized.



Polarized cell with its resting potential.

Resting potential equations:

1) $$E_{Na} = \frac{RT}{F} \ln\left\{\frac{Na_o}{Na_I}\right\} = +60 \text{ mV}$$

$$E_K = \frac{RT}{F} \ln\left\{\frac{K_o}{K_I}\right\} = -85 \text{ mV}$$

$$E_{Cl} = \frac{RT}{F} \ln\left\{\frac{Cl_I}{Cl_o}\right\} = -66 \text{ mV}$$

R : Universal Gas constant

F : Faraday constant.

T : Absolute temperature in degree Kelvin

P : Permeability.

K_o, Na_o, Cl_o : ion concentration outside cell.

K_I, Na_I, Cl_I : ion concentration inside cell.

2) Goldman's equation : (Resting potential eqn):

$$E = \frac{RT}{F} \ln\left\{\frac{P_K K_o + P_{Na} Na_o + P_{Cl} Cl_I}{P_K K_I + P_{Na} Na_I + P_{Cl} Cl_o}\right\}$$

N_{atoms} = total charge / electron charge (electrolysis)

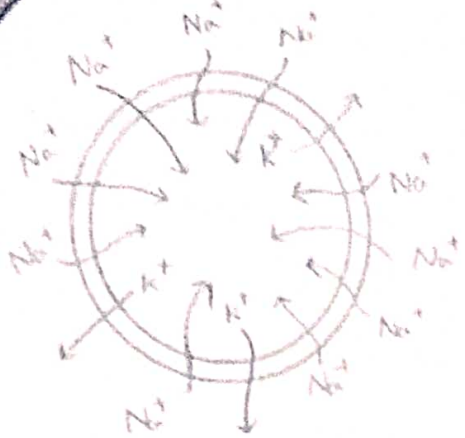
N_{moles} = N_{atoms} / Avagadros Number

Weight (in gram) = Molecular Weight * N_{moles}

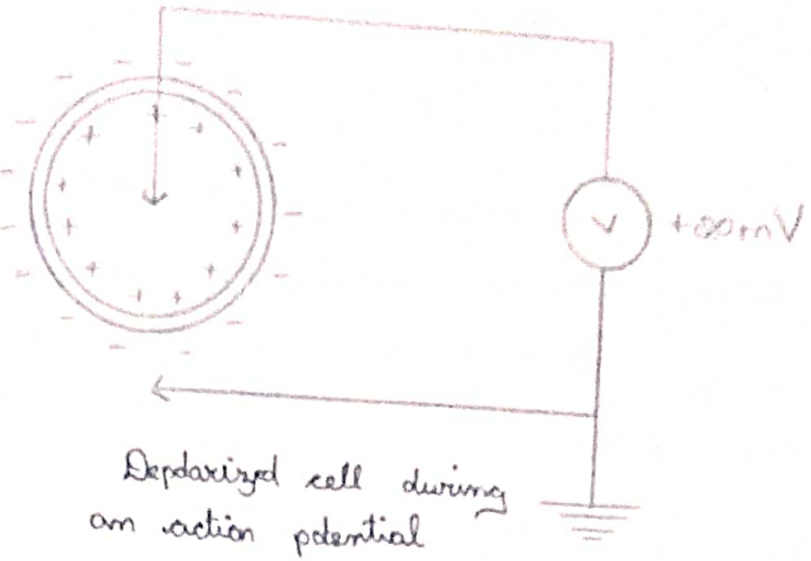
Avagadros Number = 6.03×10^{23} atoms / mole.

Action potential :

The 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 inner side due to the imbalance of potassium ions. This potential is known as action potential and is approximately +40mV.

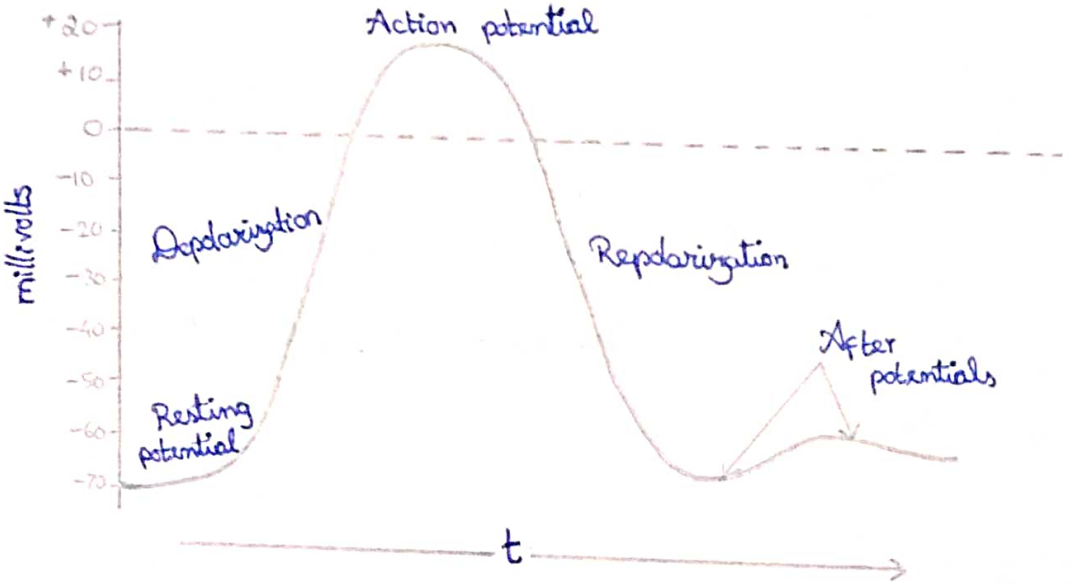


Depolarization of a cell.
Na^+ ions rush into the cell while K^+ ions attempt to leave.



Depolarized cell during an action potential

Waveform of the action potential.
(Time scale varies with type of cell).



Depolarization :

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.

Repolarization :-

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.

Conduction velocity :-

The rate at which an action potential moves along a fibre or propagated from cell to cell is termed as propagate rate or conduction velocity. This velocity varies widely, depending on the type and diameter of the nerve fiber.

All or nothing law :-

Regardless of the method by which a cell is excited or the intensity of the stimulus, the action potential is always the same for any given cell. This is known as all-or-nothing law.

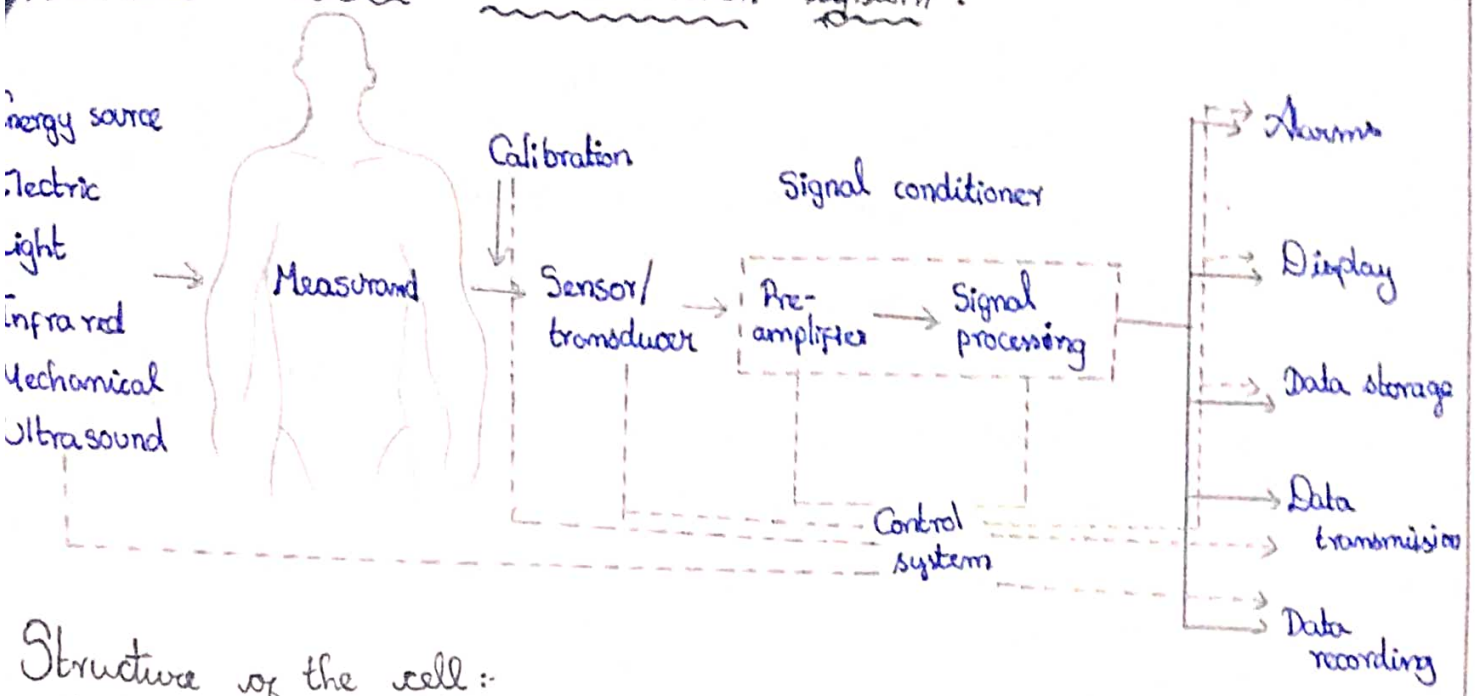
Absolute refractory period :

It is the time duration in which the cell cannot respond to any new stimulus. Generally it is about 1 ms, in nerve cells.

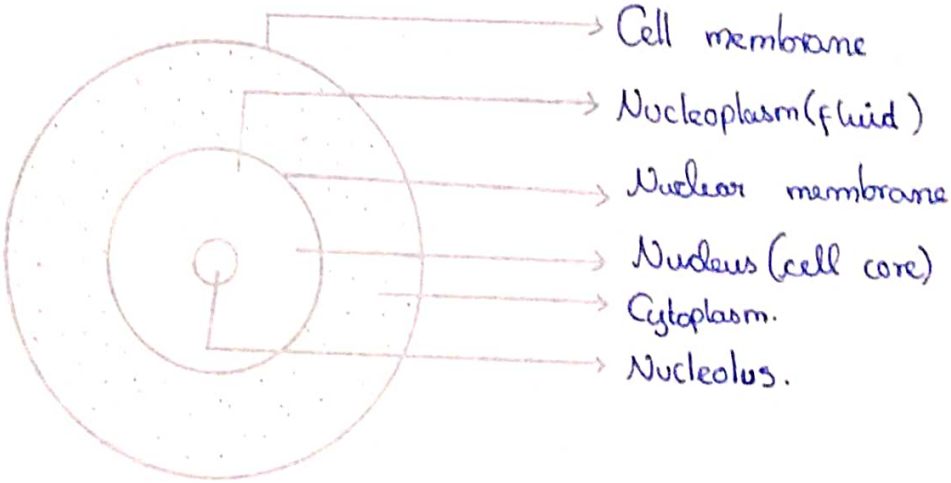
Relative refractory period :-

It is one during which another action potential can be triggered but a higher stimulus is required to reinitiate the action potential and the subsequent contraction of muscles. Generally, the relative refractory period is several millisecond.

Generalized medical instrumentation system :



Structure of the cell :-



ELECTRODES :-

Devices that convert ionic potentials into electronic potentials are called electrodes. Electrodes are generally used to pickup the electric signals of the body.

(or)

It is a transducer/sensor used to capture the biopotential activity.

Electrode potential :-

The interface of metallic ions in solution with their associated metals results in an electrical potential called electrode potential. This potential is a result of the difference in diffusion rates of ions into and out of the metal.

Nernst equation :-

An equation relating the potential across the membrane and the two concentrations of the ion is called the Nernst equation and can be stated as,

$$E = -\frac{RT}{nF} \ln \frac{C_1 f_1}{C_2 f_2}$$

where,

R = gas constant (8.315×10^7 ergs / mole / degree Kelvin)

T = absolute temperature, degrees Kelvin.

n = valence of the ion (the no. of electrons added or removed to ionize the atom)

F = Faraday constant (96,500 coulombs)

C_1, C_2 = two concentrations of the ion on the two sides of the membrane.

f_1, f_2 = respective activity coefficients of the ion on the two sides of the membrane.

Electrode paste :-

The dry outer skin of the body is highly non-conductive and will not establish a good electrical contact with an electrode. The skin should therefore be washed throughly and rubbed briskly to remove some of the outer cells. This area should then be coated with an electrically conductive paste called electrode paste that should be "worked in" by further rubbing.

Electrode offset voltage :-

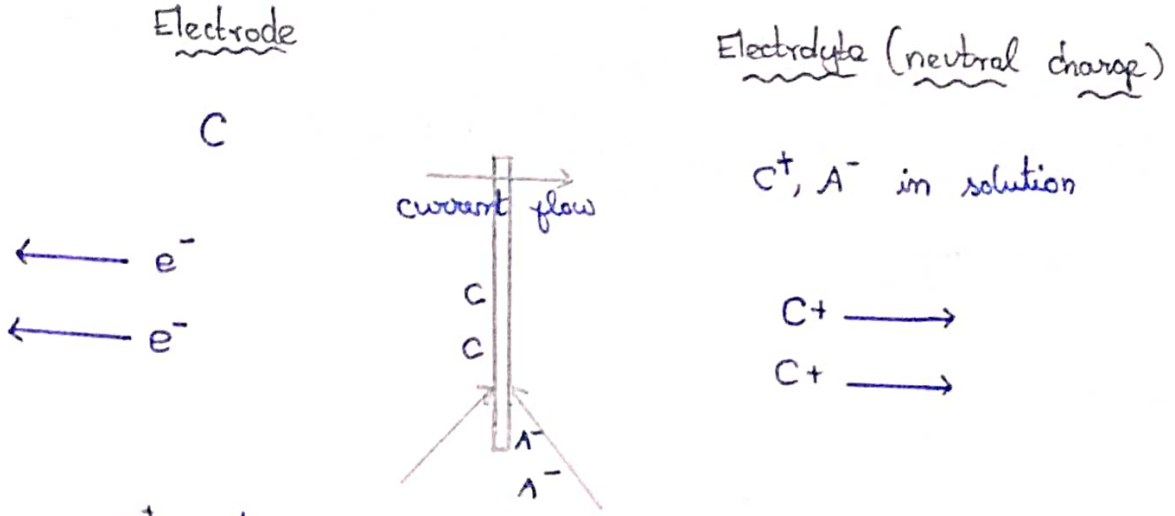
The dc voltage due to the difference in electrode potentials is called electrode offset voltage.

Polarization :

The electrode potential and the impedance are varied by an effect called polarization. Polarization is the result of direct current passing through the metal–electrolyte interface.

Electrode - Electrolyte Interface:

* Fairly common electrode materials : Pt, Carbon, ..., Au, Ag, ...
* Electrode metal is used in conjunction with salt.
* Eg: Ag-AgCl, Pt-Pt black, or polymer coats (eg. Nafion, to improve selectivity).



C^+ - cation
A^- - anion
e^- - electron.

General Ionic equations:-

$$C \leftrightarrow C^{n+} + ne^-$$

$$A^{m-} \leftrightarrow A + me^-$$

Oxidation and Reduction:

Oxidation : Current flow from electrode to electrolyte. (Loss of e^-)

Reduction : Current flow from electrolyte to electrode. (Gain of e^-)

Half cell potential:

A characteristic potential difference established by the electrode and its surrounding electrolyte which depends

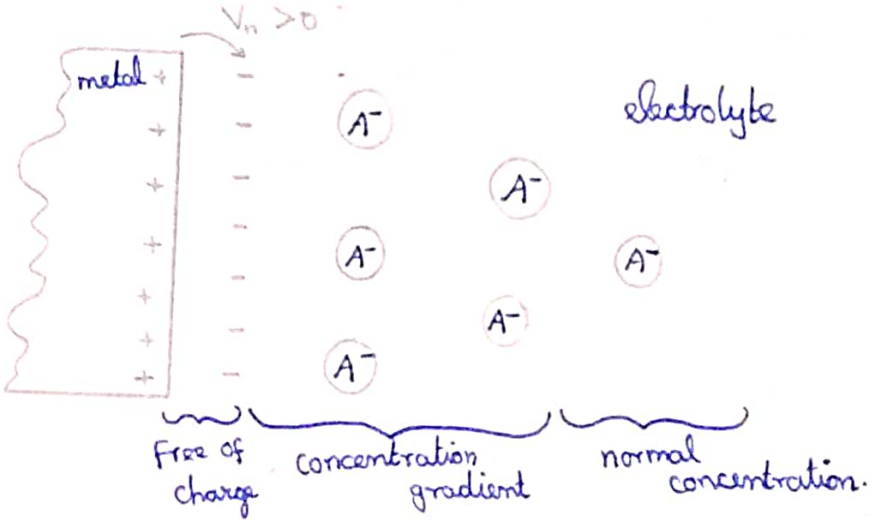
on the metal, concentration of ions in solution and temp; a
(and some second order factors)

Half cell potential can't be measured without a second electrode.

Reason : Charge Separation at Interface :-

Oxidation or reduction reactions at the electrode - electrolyte interface lead to a double charge layer similar to that which exists along electrically active biological cell membrane

Electrode Double layer:



Motion Artifact :

WHAT ?

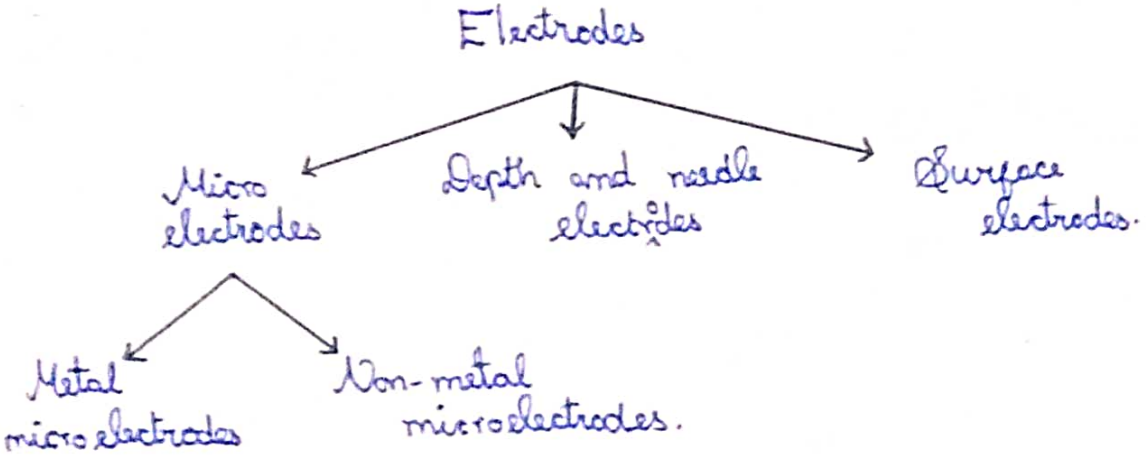
If a pair of electrodes is in an electrolyte and one moves with respect to the other, a potential difference appears across the electrodes known as the motion artifact. This is a source of noise and interference in biopotential measurements.

Motion artifact is minimal for non-polarizable electrodes.

y ?

When the electrodes moves with respect to the electrolyte, the distribution of the double layer of charge on polarizable electrode interface changes. This changes the half cell potential temporarily.

Types of electrodes :-

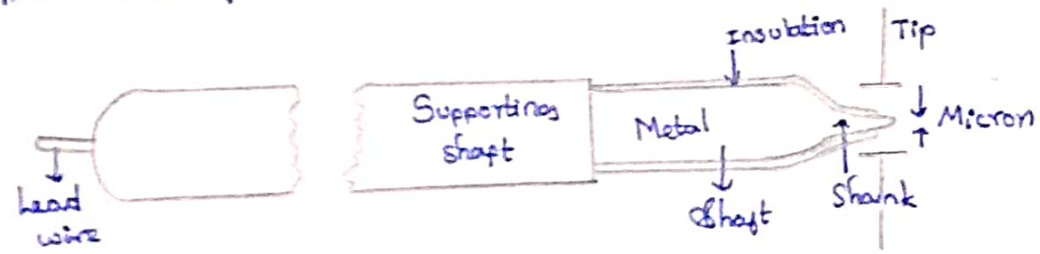


Micro electrodes :

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

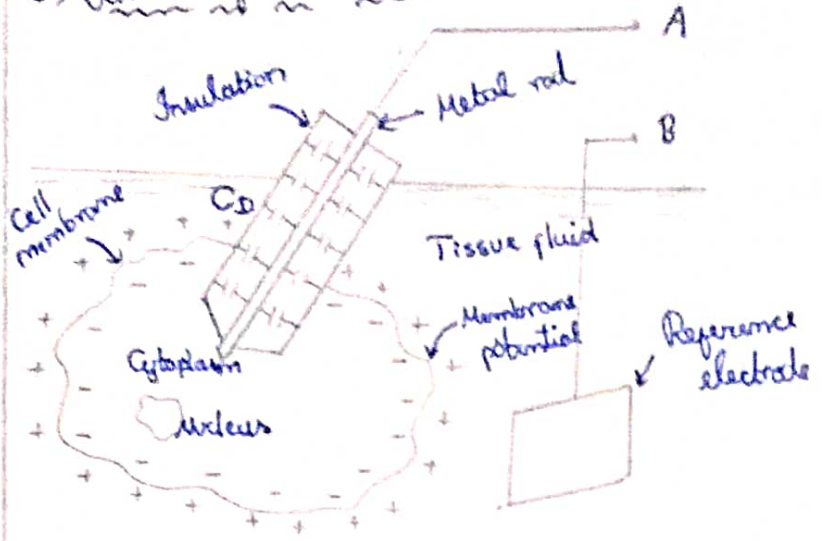
Metal micro electrode:

Electropointing: They are formed by electrolytically etching the (Metal microelectrode)
tip of a fine tungsten or stainless steel wire to a fine point. This technique is known as electropointing.

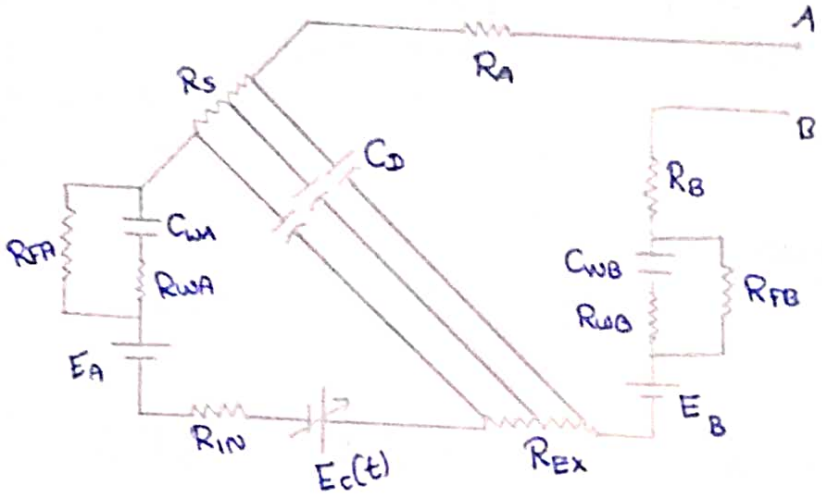


Extracellular recording - typically in brain where you are interested in recording the firing of neurons (spikes).
Use metal electrode + insulation → goes to high impedance amplifier ..... negative capacitance amplifier.

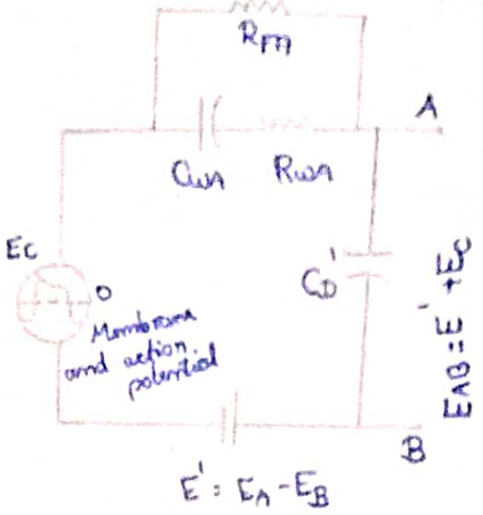
a) Position of the electrodes



b) Electric equivalent of figure a)



c) Approximate equivalent circuit of figure b)

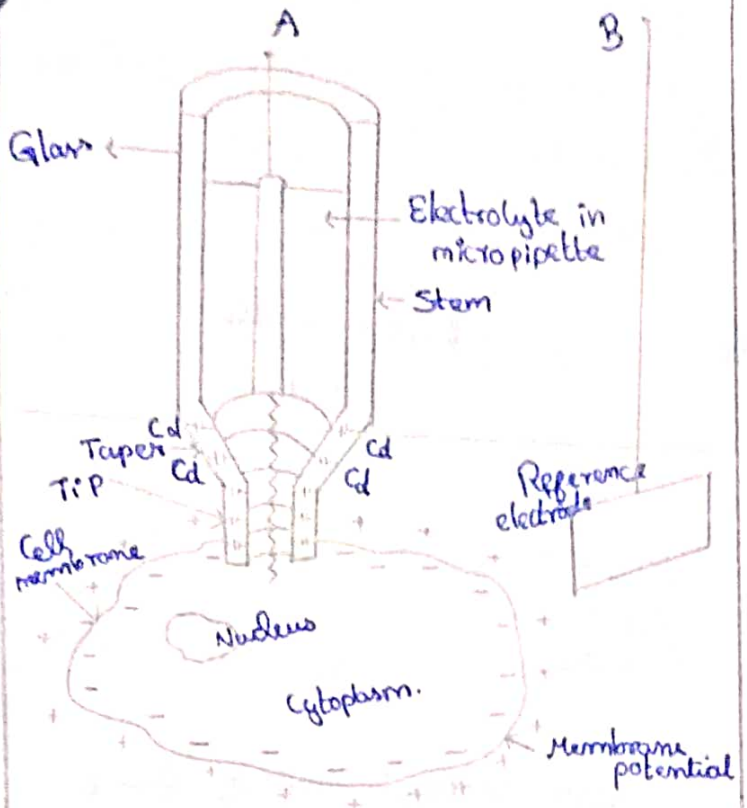


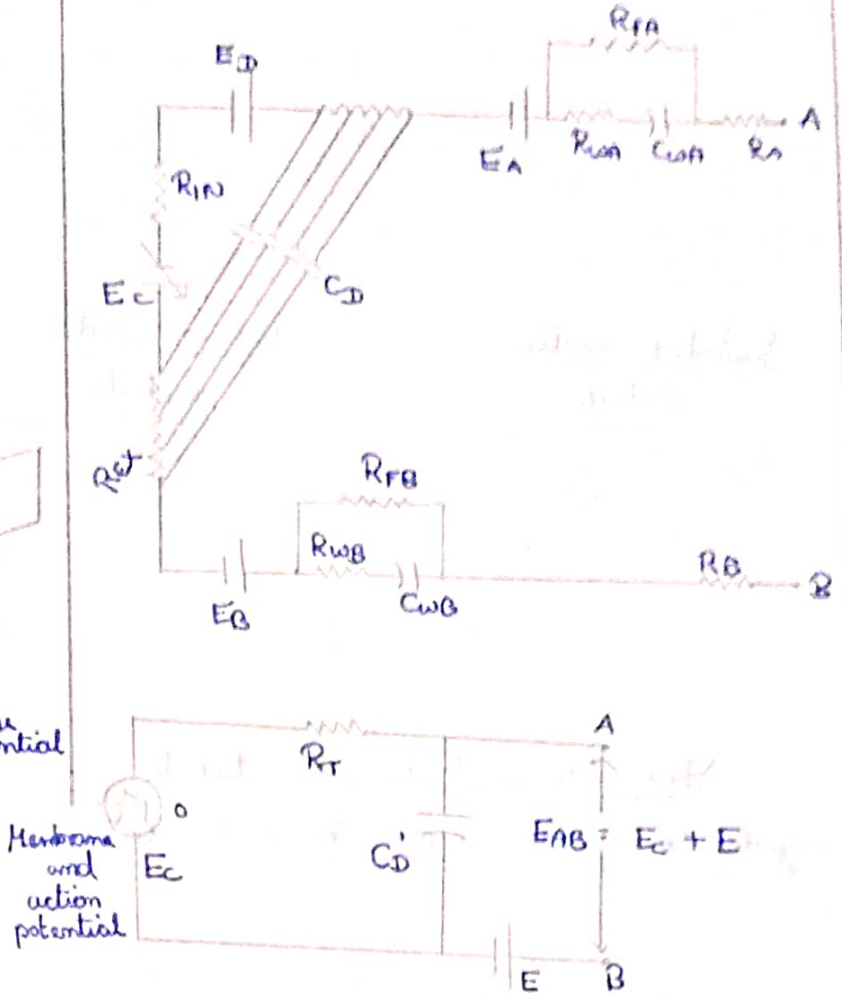
Non-metal micro electrode (Glass micropipet):-

The nonmetallic micropipet consists of a glass micropipet whose tip's diameter is about 1 micrometre. The micropipet is filled with an electrolyte usually 3 M KCl which is compatible with the cellular fluids.

Intracellular recording :- typically for recording from cells, such as cardiac myocyte.

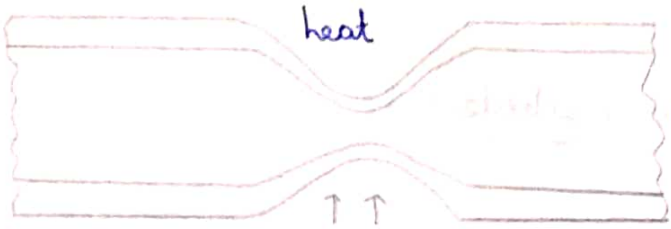
Need high impedance amplifier.... negative capacitance amplifier.



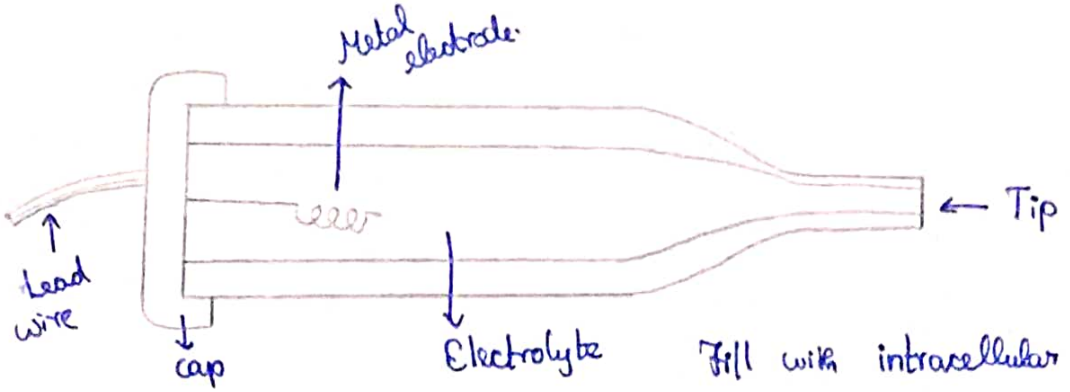


Section of fine-bore glass capillary

Capillary narrowed through heating and stretching



Final structure of glass pipet microelectrode

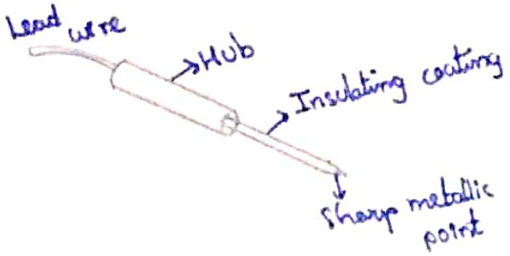


Fill with intracellular fluid or 3M KCl

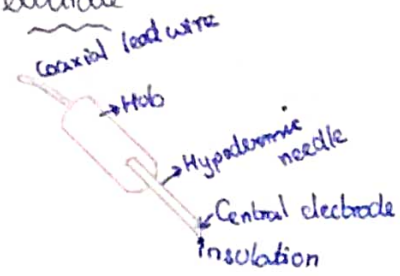
Depth and needle electrodes:

These are used to measure the bioelectric potentials of the highly localized extracellular regions in brain or bioelectric potentials from a specific group of muscles.

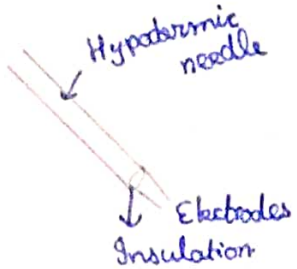
Insulated needle electrode



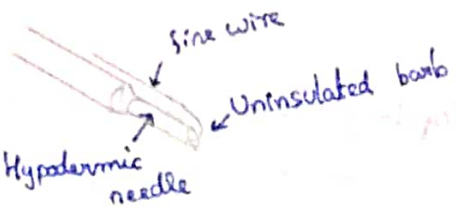
Coaxial needle electrode



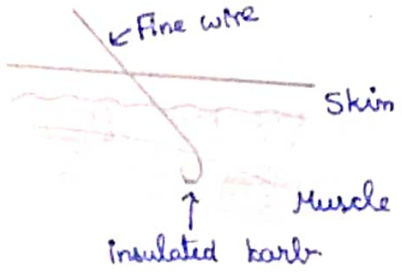
Bipolar needle electrode



Fine-wire electrode connected to hypodermic needle, before being inserted



Cross-sectional view of skin & muscle, showing coiled fine-wire electrode in place

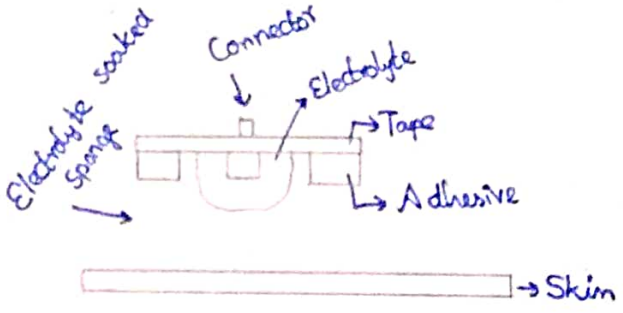


Surface electrode:

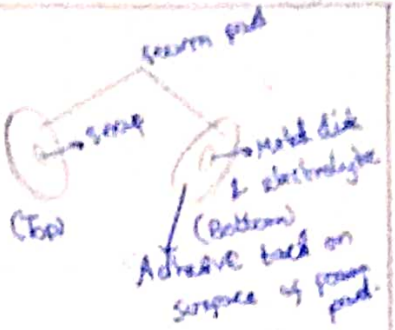
These are used to measure the potentials available from the surface of the skin and are used to sense the potentials from heart, brain and nerves.

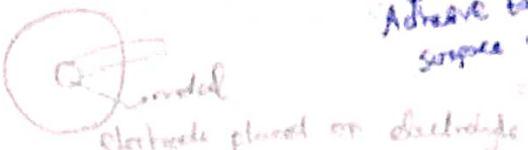
Types:-

* Metal Plate electrodes
* Suction Electrodes
* Heating electrodes
* Flexible electrodes.



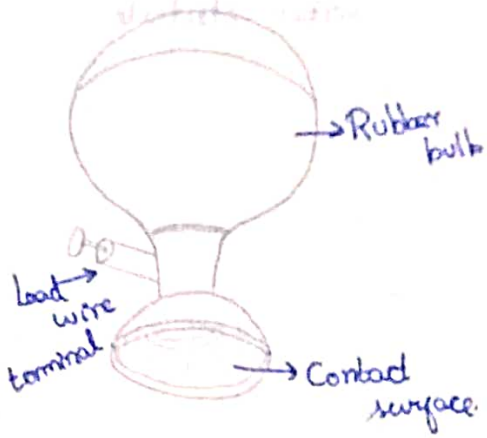
dial Plate electrode:





* ENG, EEG
* smaller diameters
* motion artifacts
* Disposable foam-pad: Cheap!
* Metal disk with stainless steel; platinum or gold coated.
* Large surface: Ancient, therefore still used ECG.

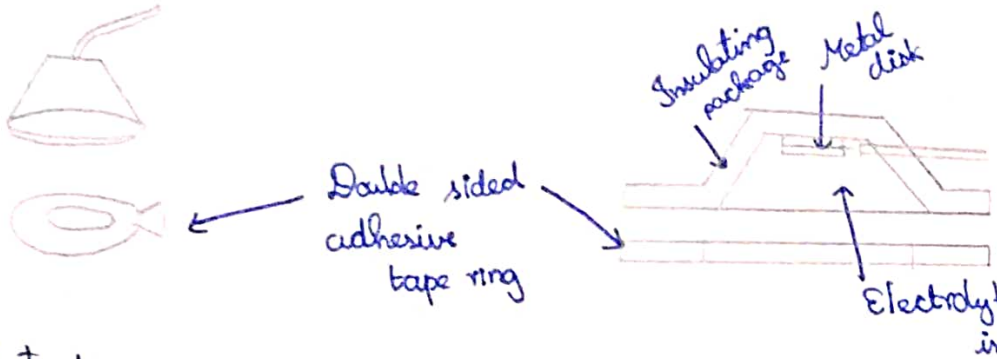
Suction electrode:



* No straps or adhesives required.
* precordial (chest) ECG
* Can only be used for short periods

Floating electrodes:-

* Metal disk is recessed.
* Swimming in the electrolyte gel.
* Not in contact with skin.
* Reduces motion artifact.



Flexible electrode:

* Special case: infants.
* Regularly shaped rigid electrodes may not always work.

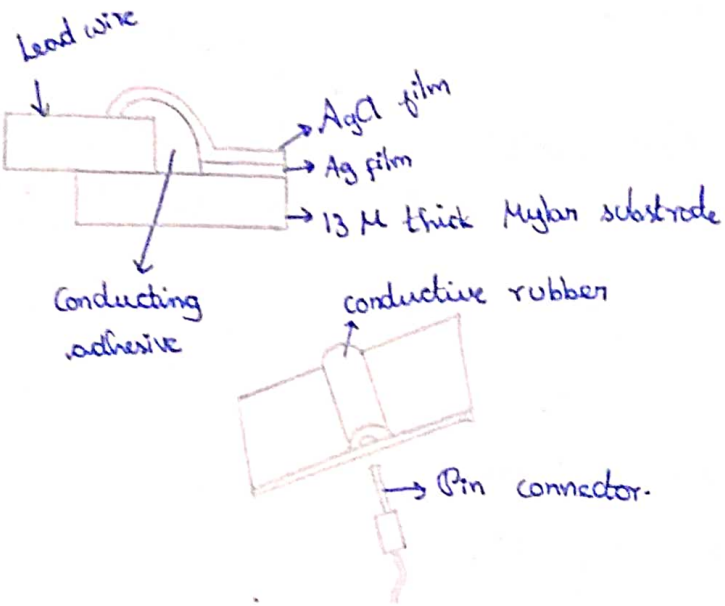
* Material :

  => Polymer or nylon with silver

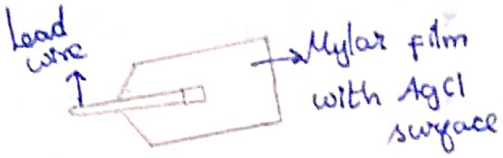
  => Carbon filled silicon rubber (Mylar film)

* Body contours are often irregular.

Carbon filled silicone rubber electrode



Flexible thin-film neonatal electrode



Unit - 2

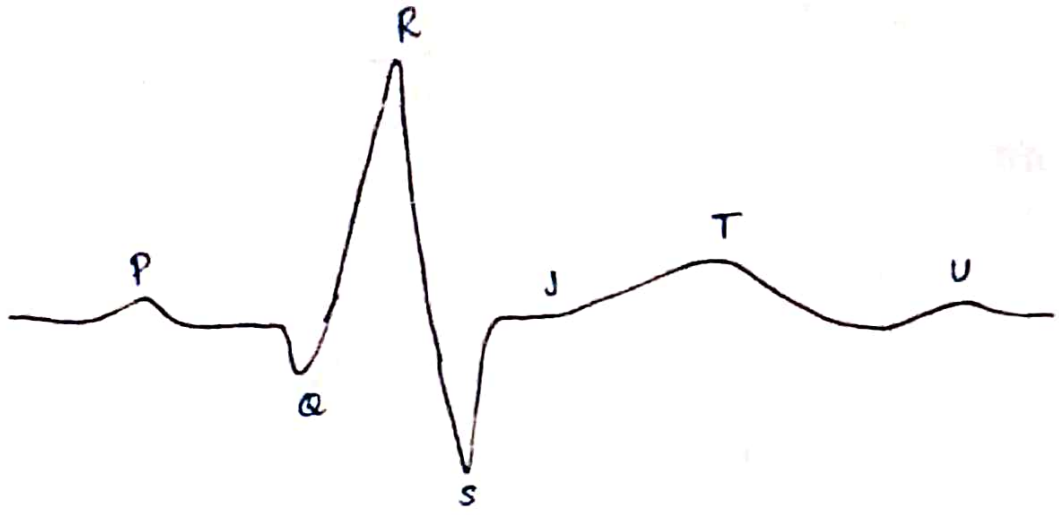
Biopotential Measurements

Bio signals characteristics - frequency and amplitude and amplitude range, ECG - Einthoven's triangle, standard 12 lead system, principles of Vector Cardiography, EEG - 10-20 electrode system, Unipolar, bipolar, and average mode, EMG - Unipolar, and bipolar mode, Recording of ERG, EEG and EMG.

Electrocardiography (ECG) :-

The electrocardiography deals with the study of the electrical activity of the heart muscles. The potentials Orginated in the individual fibres of heart muscles are added to produce the ECG wave form. 'Electrocardiogram' is the recorded ECG wave pattern.

The typical ECG wave consists of P wave, QRS complex and T wave.



The physiological nature of ECG waveform,

	Origin	Amplitude mV	Duration Sec.
P wave	Atrial depolarisation or Contraction	0.25	0.12 to 0.22 (P-R interval)
R wave	Repolarisation of the atria and depolarisation of the Ventricles	1.60	0.07 to 0.1
T wave	Ventricular repolarisation (Relaxation of myocardium)	0.1 to 0.5	0.05 to 0.15 (S-T interval)
S-T Interval	Ventricular Contraction	-	-
U wave	Slow repolarisation of the intraventricular (Purkinje fibres) system	< 0.1	0.2 (T-U interval)

Lead Configuration :-

There are three types of electrode systems. They are,

- Bipolar limb leads (or) standard leads
- Augumented unipolar limb leads
- Chest leads (or) Precordial leads
- Frank lead System (or) Corrected Orthogonal leads.

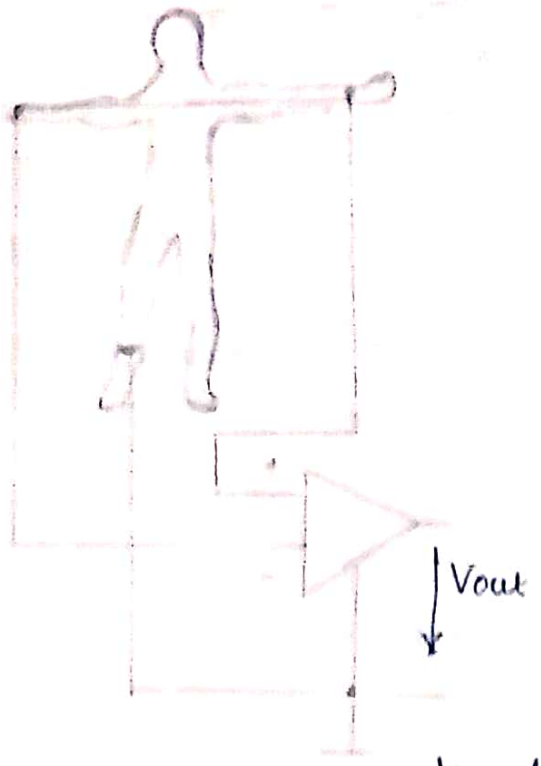
Usually Surface electrodes are used with jelly as electrolyte between skin and electrodes. The potentials generated in the heart are conducted to the body surface. The potential distribution changes in a regular complex manner during each cardiac cycle.

- **Bipolar limb leads - Standard leads I, II & III**

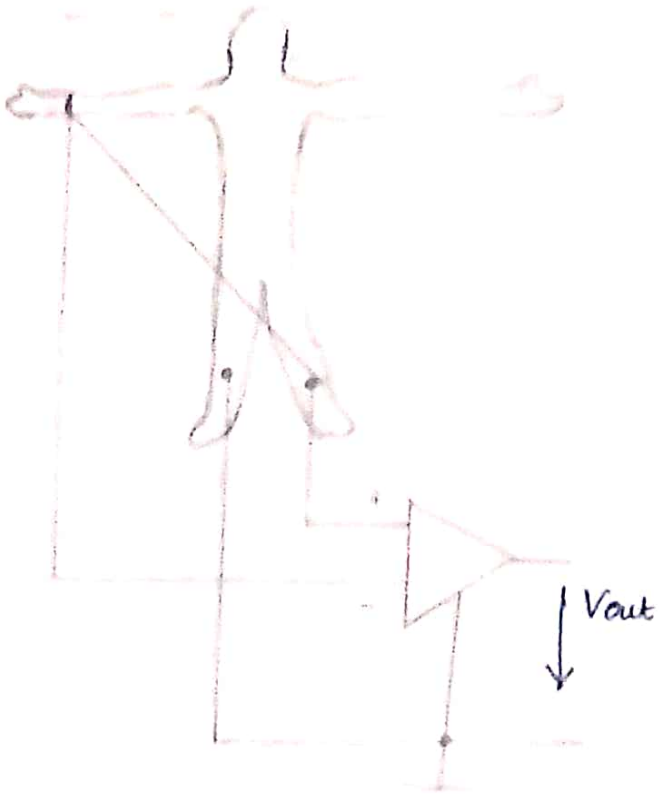
In standard leads, the potentials are tapped from four locations of our body. Usually, the right leg electrode is acting as ground reference electrode.

standard bipolar limb lead positions

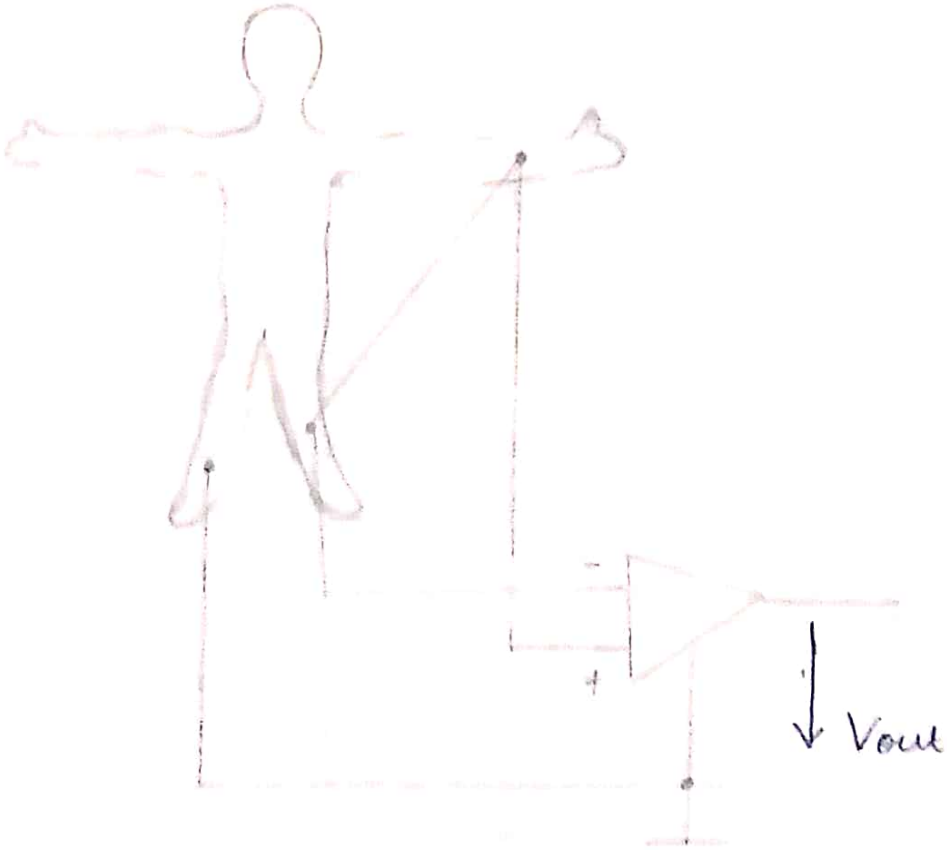
lead I



lead - II



lead - III



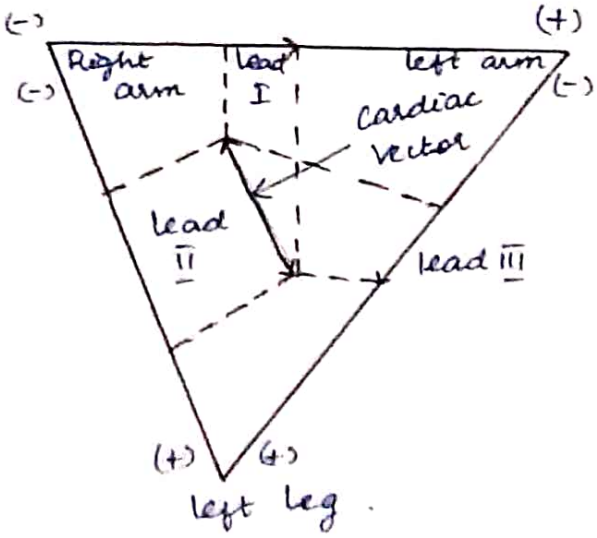
lead - I - given voltage V_I, the voltage drop from the left arm (LA) to the right arm (RA)

lead - II - gives voltage V_{II}, the voltage drop from the left armleg (LL) to the right arm (RA)

lead - III - gives voltage V_{III}, the voltage drop from the left leg (LL) to the left arm (LA).

Einthoven triangle :-

The closed path RA to LA to LL and back to RA is called Einthoven triangle. The vector sum of the projection on all the three sides is equal to zero.

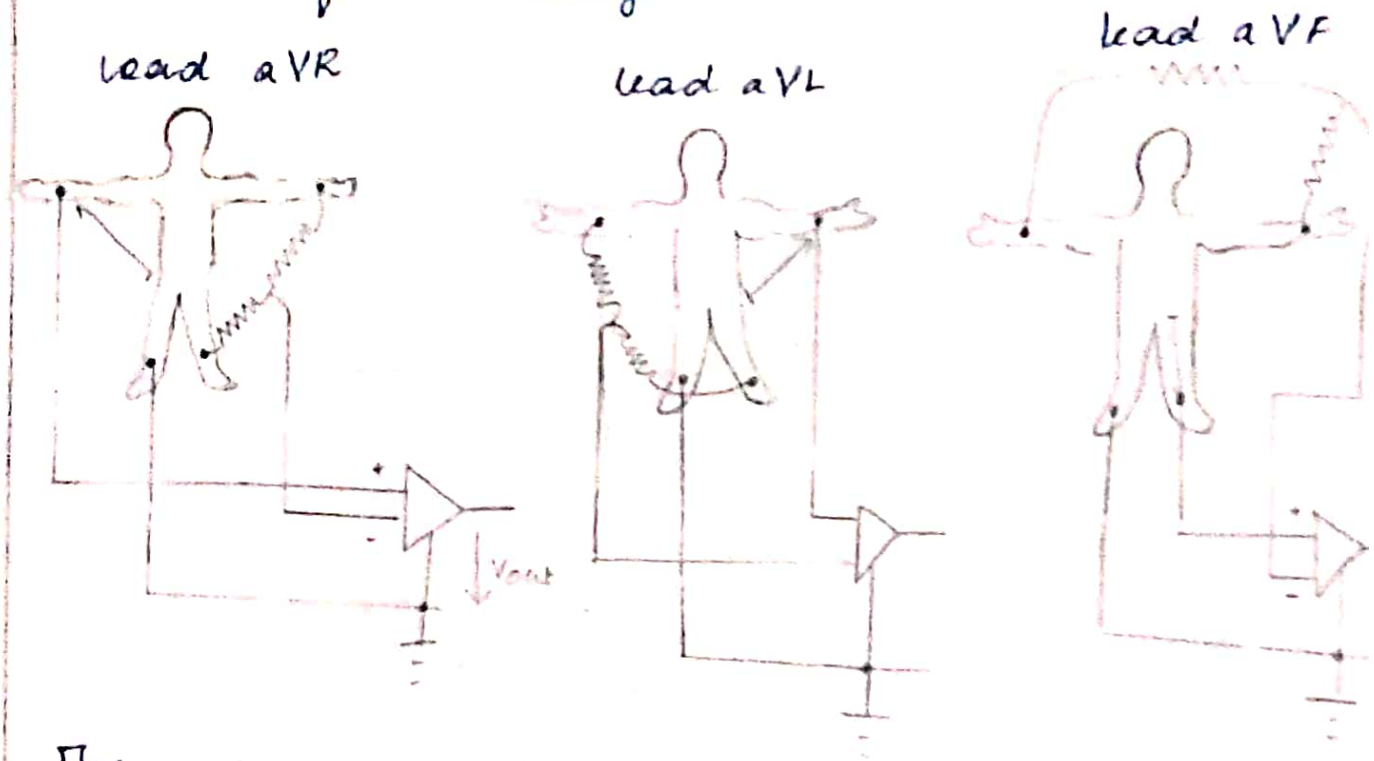


Lead-I	Lead - II	Lead - III	R wave amplitude
V_I	V_{II}	V_{III}	
0.52 (0.07 - 1.18)	0.71 (0.18 - 1.68)	0.38 (0.03 - 1.31)	

Thus, $V_{II} \simeq V_I + V_{III}$

Augumented unipolar limb leads :-

In augumented unipolar lim. lead system, the electro cardiogram is recorded between a single exploratory electrode and central terminal, which ha the a potential corresponding to the center of the body.



The augumented voltages can be written.

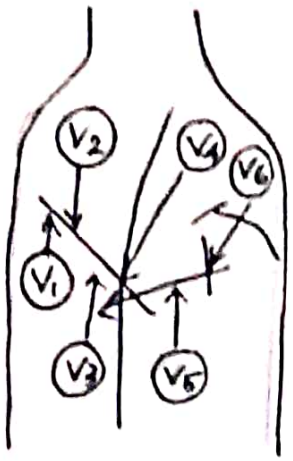
$$aVR = -V_I - \frac{V_{III}}{2}$$

$$aVL = V_I - \frac{V_{II}}{2}$$

$$aVF = V_{II} - \frac{V_I}{2}$$

Unipolar Chest leads :-

In unipolar chest leads, the exploratory electrode is obtained from one of the chest electrodes. The chest electrodes are placed on the six different points on the chest closed to the heart.



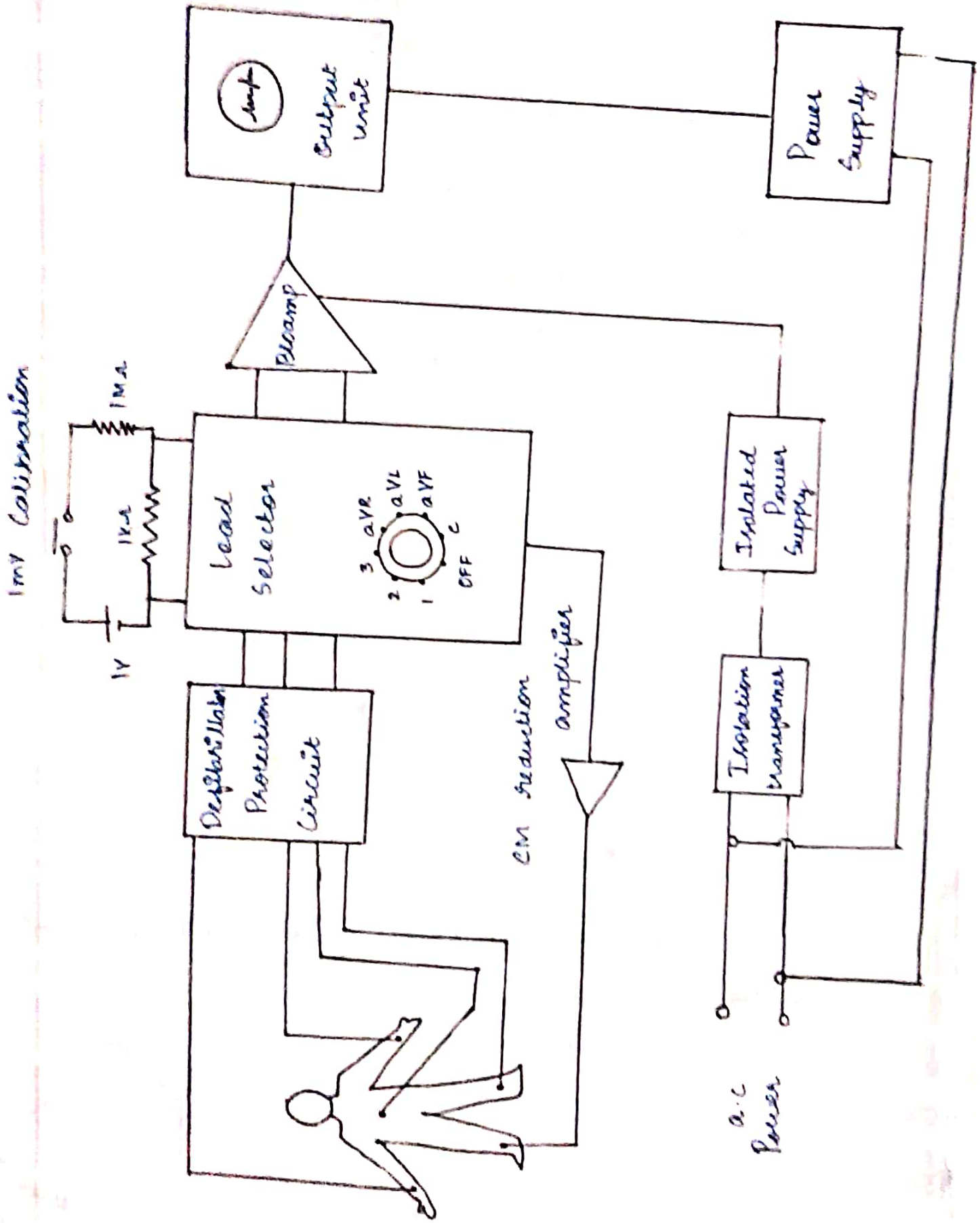
The ECG potentials are measured with colour coded leads according to the convention

White - right arm.
Black - left arm
Green - right leg.
Red - left leg.
Brown - chest.

This is internationaly adopted for easy reference.

ECG Recording Setup :-

The important parts of ECG,



Electroencephalography (EEG) :-

Electroencephalography deals with the recording and study of electrical activity of the brain. By means of electrodes attached to the skull of a patient, the brain wave can be picked up and recorded.

Brain waves :-

Alpha waves :-

Frequency : 8 - 13 Hz

Occurence : They found in normal persons when they are awake in a quiet, resting State. They occur normally occupital region. During sleep, these disappear. These have amplitude of 20 - 200 μV with mean of 50 μV.

Betta waves :-

Frequency : 13 - 30 Hz

Occurence : These are recorded from the Parential and frontal regions of the Scalp.

Theta waves :-

Frequency : 4 - 8 Hz

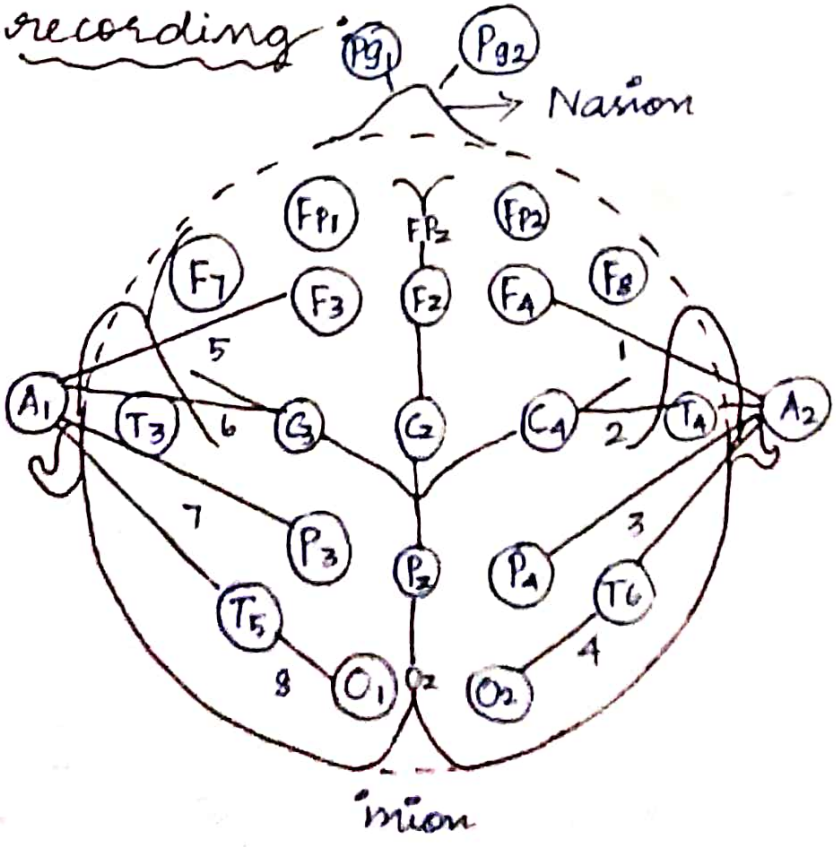
Occurance : These are recorded from the parietal and temporal regions of the scalp of children. These also occur in during emotional stress in some adults.

Delta waves :-

Frequency : 0.5 - 4 Hz.

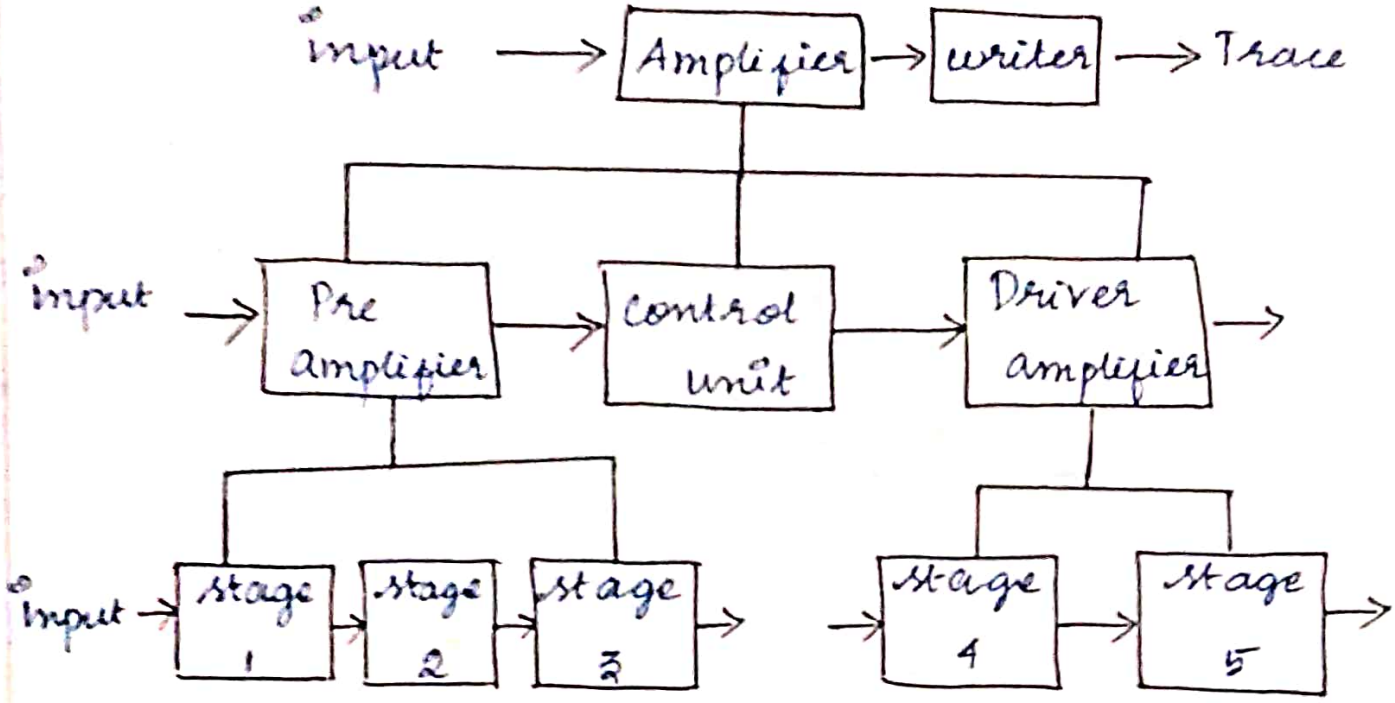
Occurance : These occurs only once in every 2 or 3 seconds. These occurs in deep sleep, in premature babies and in very serious Organic brain diseases.

Placement of electrodes on the scalp for EEG recording :

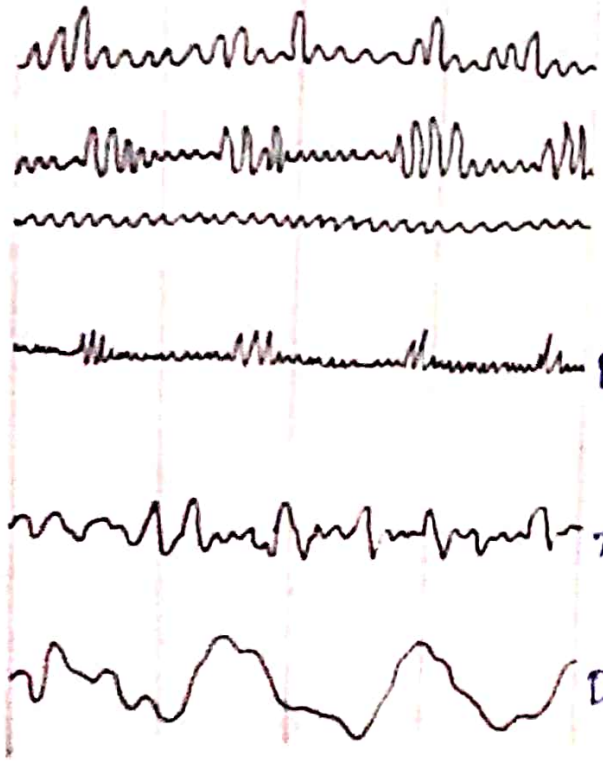


EEG Recording Setup :-

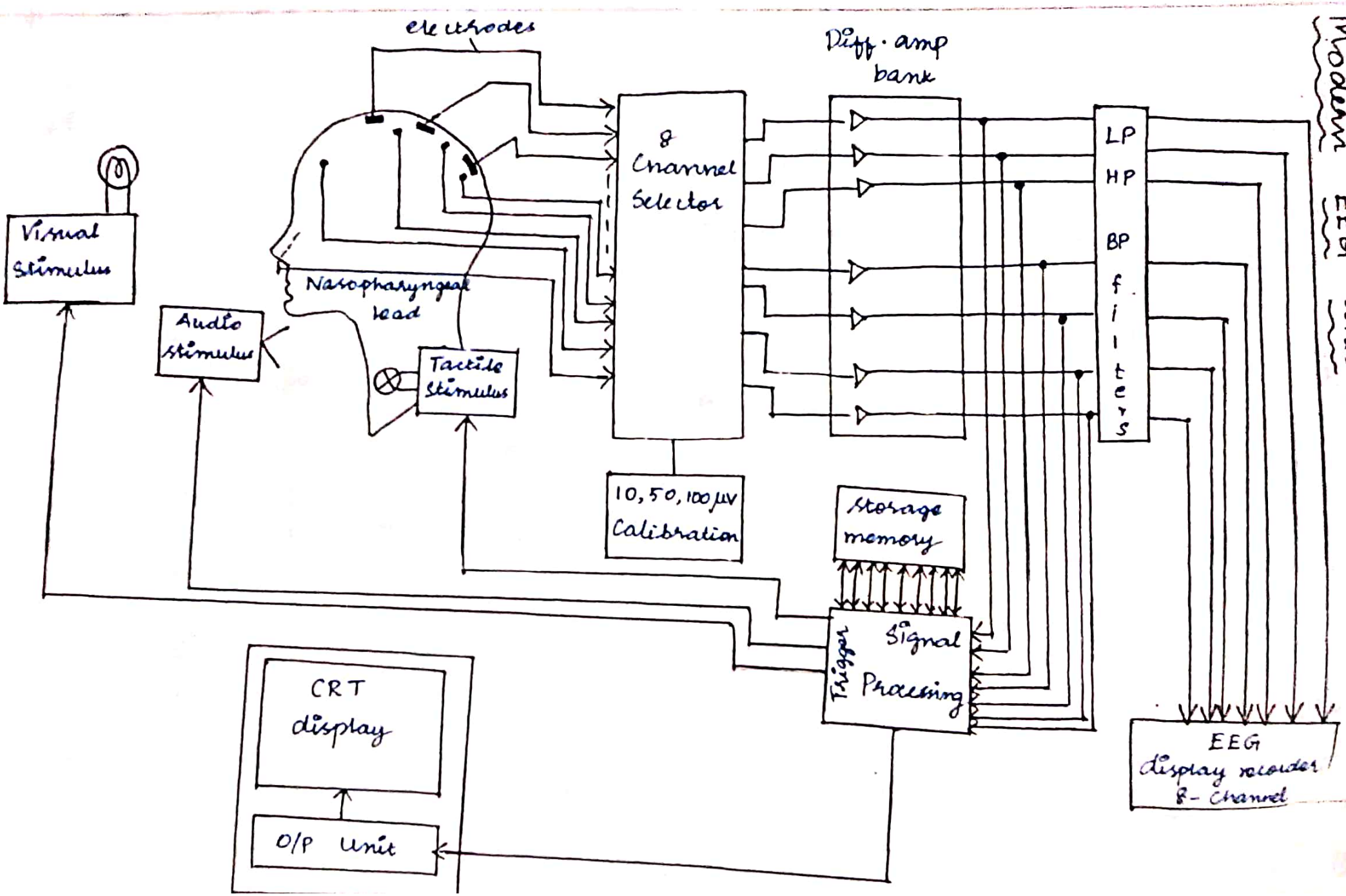
Simple block diagram :-



Brain waves :-



Alpha waves (α)	8-13	normally occipitally.
Beta wave (β)	13-30	normally Parientally and frontall
Theta waves (θ)	4-8	Children sleeping adul
Delta waves (δ)	0.6-4	Premature babies, infant sleeping adults


Modern EEG unit
electrodes
Diff. amp bank
8 Channel Selector
LP
HP
BP
filters
Visual Stimulus
Audio stimulus
Nasopharyngeal lead
Tactile Stimulus
10, 50, 100 μV Calibration
Storage memory
Trigger
Signal Processing
CRT display
O/P Unit
EEG display recorder 8-Channel

Electromyography (EMG) :-

Electromyography is the Science of recording and interpreting the electrical activity of muscle's action potentials. Meanwhile, the recording of the peripheral nerve's action Potentials is called electroneurography.

"Electromyogram is a technique for evaluating and recording the activation signals of muscles"

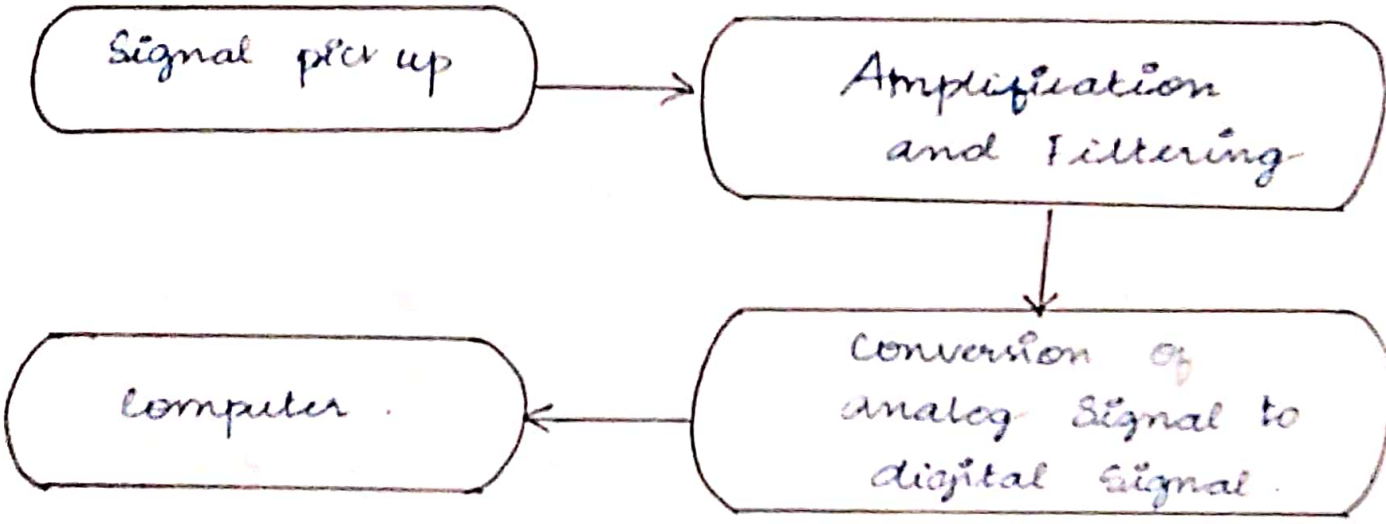
Electrical characteristics :-

- The electrical source is the muscle membrane potential of about -70mV
- Measured EMG Potentials range between <50μV up to 20 to 30 mV, depending on the muscle under observation.
- Typical repetition rate of muscle unit is about 7-20 Hz.
- Damage to motor unites can be excepted at ranges between 450 and 780 mV

Types of electrode :-

* Needle electrodes (intra muscular)
* Surface electrodes (Extra muscular)

EMG Processing :-



EMG condition :-

Muscle Signals are analog in nature.

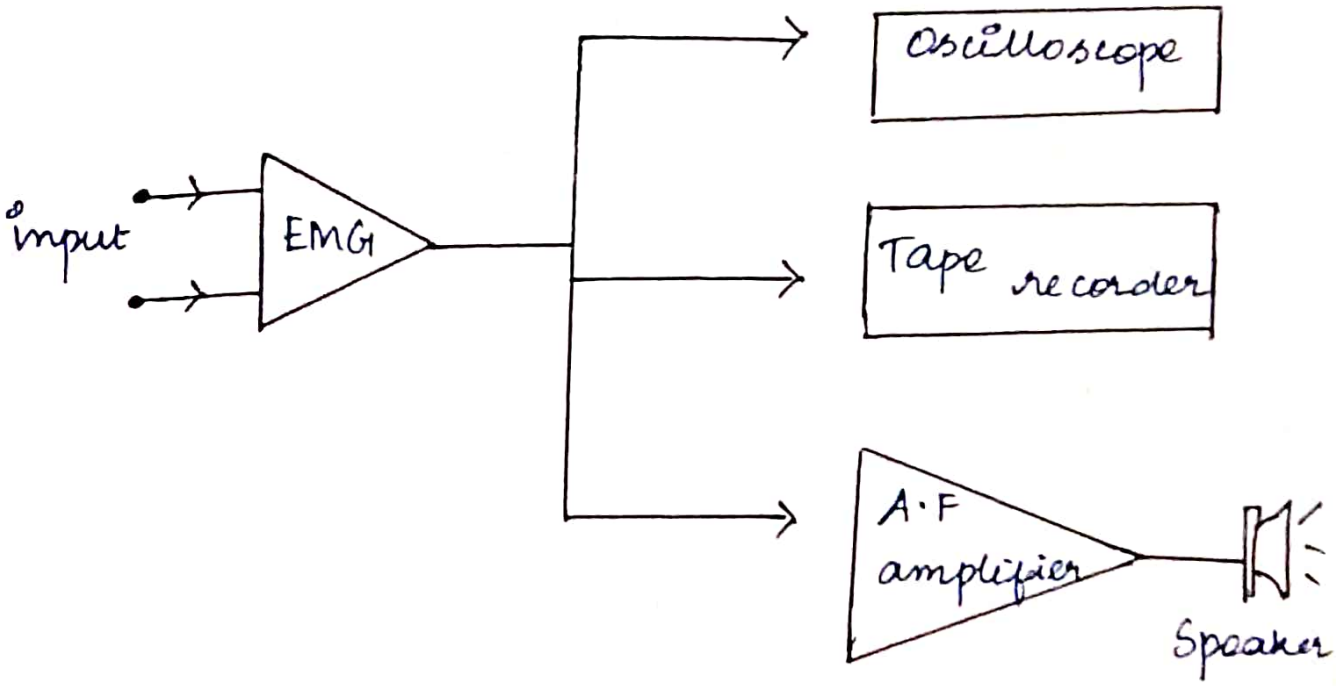
Muscle action potential :- (m.a.p)

Electrode placed on the surface of a muscle or inside the muscle tissue (indwelling electrodes) will record the algebric sum of all muscle action Potential

which are being transmitted along the muscle fibres.

" The electrical signals generated in the muscle fibres are called muscle action Potential ".

Block diagram for EMG recording setup:

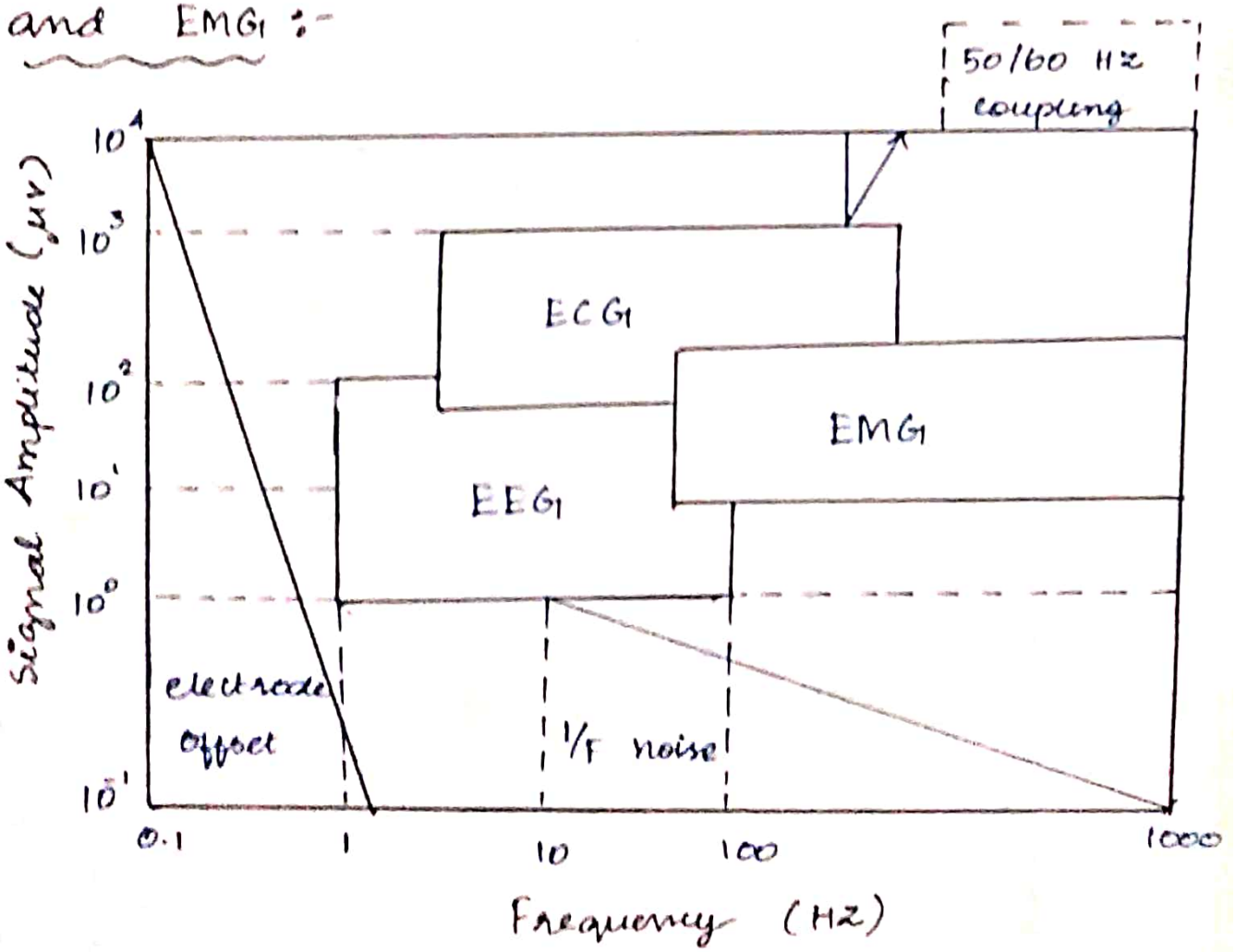


Bio-signal characteristic - Frequency and amplitude :-

Bio potential	Frequency range	Signal amplitude	Electrode
electrocardio-gram (ECG)	0.05 - 150 Hz (diagonistic) 0.5 - 40 Hz (Monitoring)	0.1 - 5 mV	Surface

Electromyogram (EMG)	25 - 5,000 Hz	0.1 - 100 mV	Su ne...
Electroencephalo-gram (EEG)	0.1 - 100 Hz	0.025 - 0.1 mV	Surface
Action potential of neuron	0.10 kHz	50 - 100 mV	Glass Pipette

Frequency and amplitude ranges of ECG, EEG and EMG :-



Input impedance of Bio signal :-

* All biopotential amplifiers must have high input impedance minimize loading - typical values of Z_{in} over frequency range of the measure = 10 MΩ.

Bandwidth :-

Frequency response :-

* The biopotential amplifier must be sensitive to important frequency components of the bio signal.

* Since, biopotential are low level signal, it is important to limit bandwidth optimize signal to noise ratio.

Gain :-

* Bio potential amplifier have a gain of 1000 or greater.

Mode of operation :-

* Very frequently biosignals are obtained from bipolar electrodes.

Output impedance (Z_{out}) :-

* The output circuit does not Present any critical Probelms all it needs

to do is to drive the load.

* output impedance must be low with respect to the load impedance and it must be capable of satisfying the power requirement of the load.

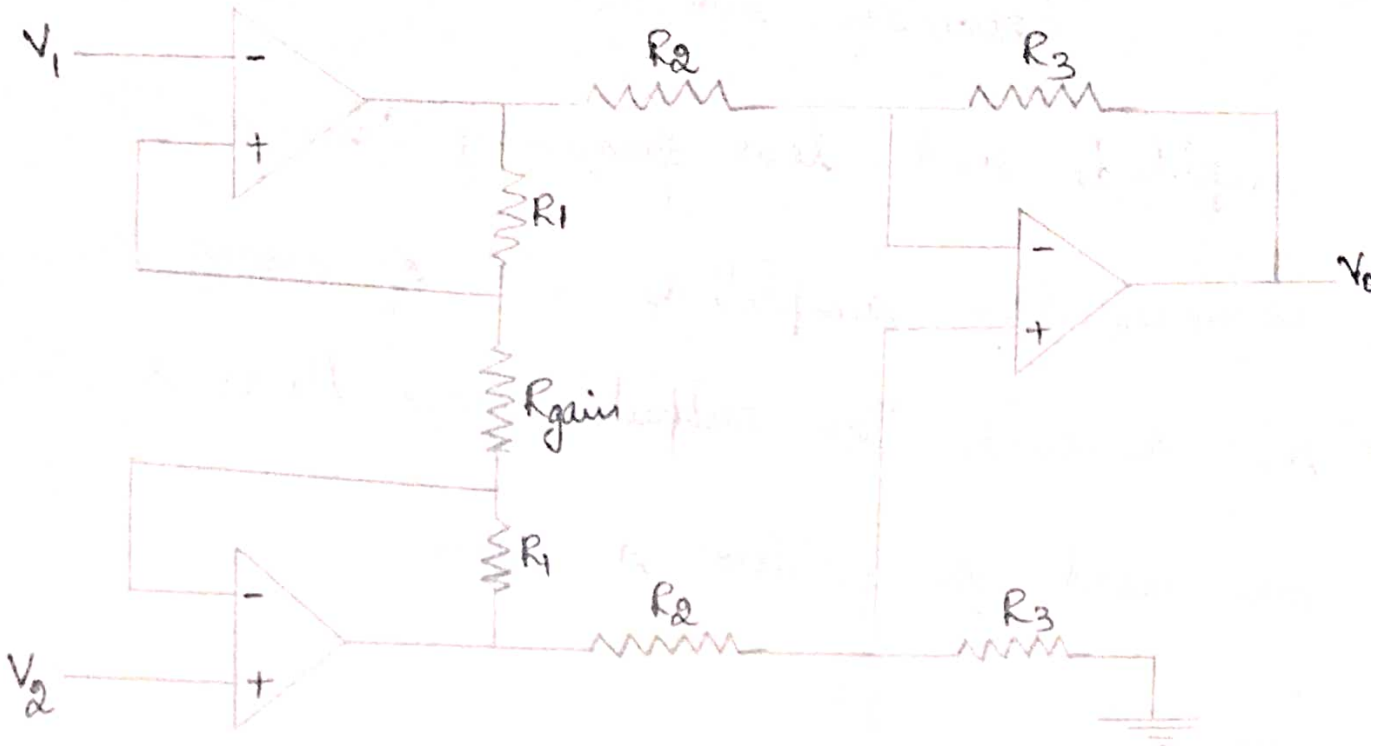
NEED FOR BIOAMPIFIER :

Generally bioelectric signals have low amplitude and low frequency. Therefore to increase the amplitude level of biosignals, amplifier are designed. The outputs from these amplifiers are used for further analysis.

Types of Bioamplifier :

* Differential amplifier
* Operational amplifier
* Instrumentation amplifier
* Chopper amplifier
* Isolation amplifier

DIFFERENTIAL AMPLIFIER



It is an analog circuit with 2 i/p's & 1 o/p in which o/p is ideally proportional to the difference between two voltages.

$$e_2 = T(s) V_2$$

$$e_1 = \frac{R_f}{R_i + R_f} V_1 + \frac{R_i}{R_i + R_f} V_o$$

$$\therefore \frac{R_f}{R_i + R_f} V_i + \frac{R_i}{R_i + R_f} V_o = T(s) V_2$$

$$(\text{or}) \quad V_o = \frac{R_f + R_2}{R_i} T(s) V_2 - \frac{R_f}{R_i} V_1$$

$T(s)$ → Transfer function

If $T(s) = \frac{R_f}{R_i + R_f}$

$$V_o = \frac{R_f}{R_i}(V_2 - V_1)$$

Different modes:

→ Single ended mode:

$$V_1 = 0$$

$$V_2 = 0$$

→ Differential mode:

$$V_1 = -V_2 = V_D$$

$$V_o = \frac{R_f}{R_i}(V_2 - V_1)$$

$$V_o = \frac{2R_f}{R_i} V_D$$

→ Common mode:

$$V_1 = V_2 = V_{CM}$$

$$V_o = 0.$$

Power line Interference :

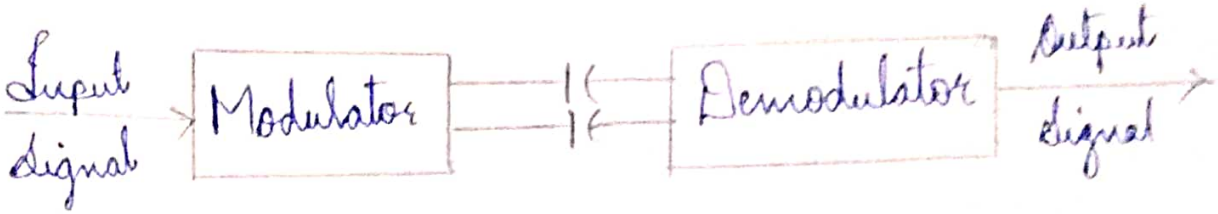
It is due to the stray effect of the alternating current fields due to loops in the patie cable. The 3 main common sources of noise in E filtering system are :-

* Baseline wander
* Power line interference
* Muscle noise

To overcome this the power line inter can be minimized by ;

- Linear filtering
- Non-linear filtering

Isolation Amplifier:



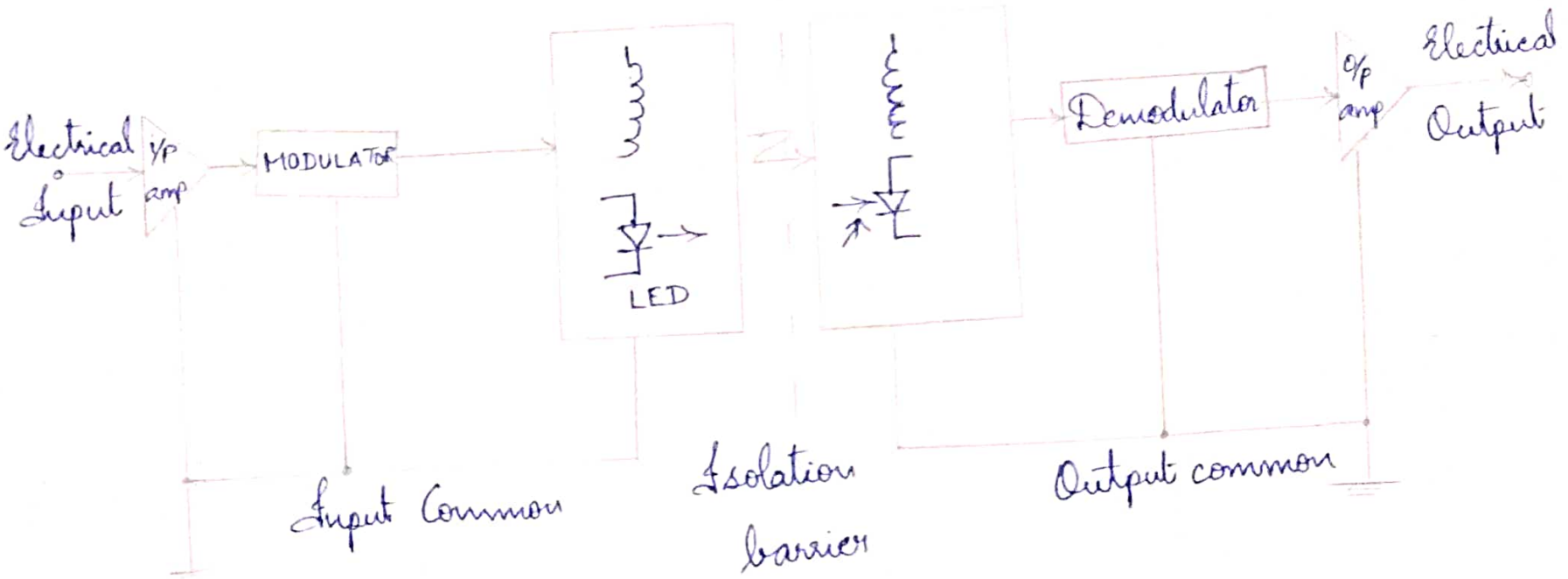
* They are the form of differential amplifiers that allow measurement of small signals in the presence of a high common mode voltage by providing electrical isolation and electrical safety barrier.

* Amplifiers with internal transformers eliminate external isolated power supply.

* They are used in medical instruments to ensure isolation of a patient from power supply leakage current.

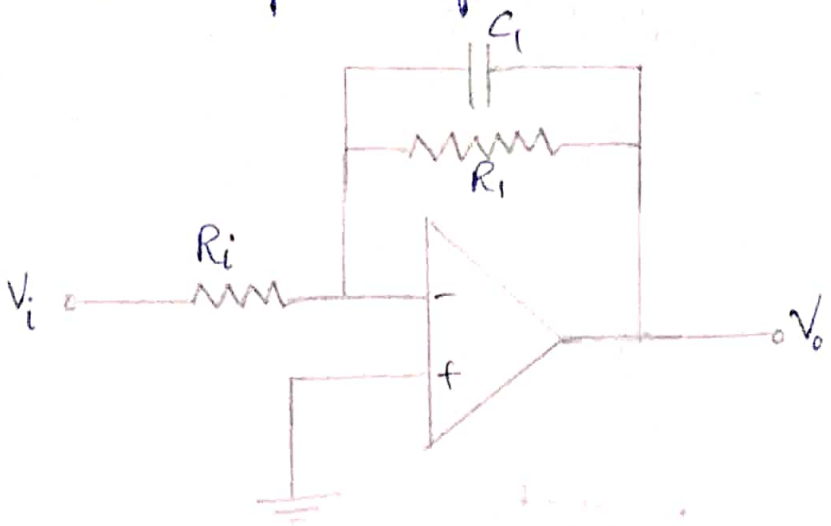
$$V_0 = \frac{G}{R_{G1} + R_{G2} + R_{IN}} \left[V_D + \frac{V_{CM}}{CMRR} \right] + \frac{V_{ISO}}{IMRR}$$

Isolation Amplifier

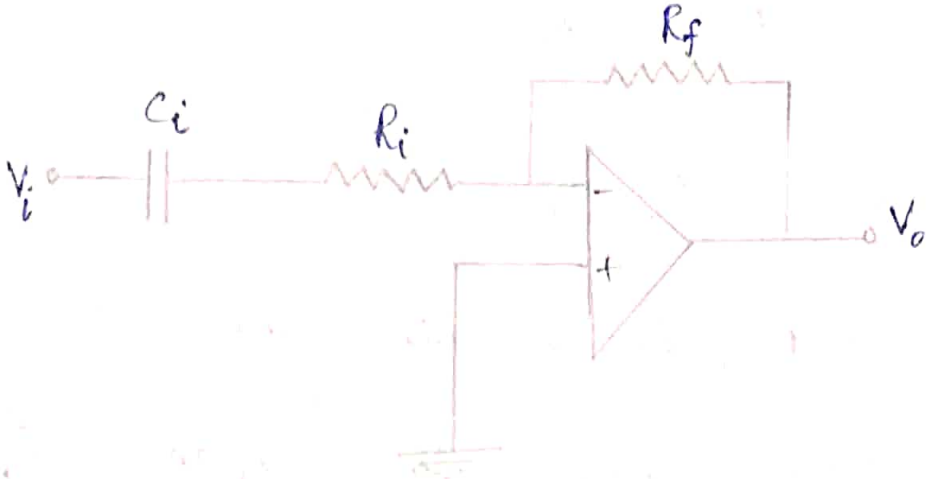


Bandpass filtering:

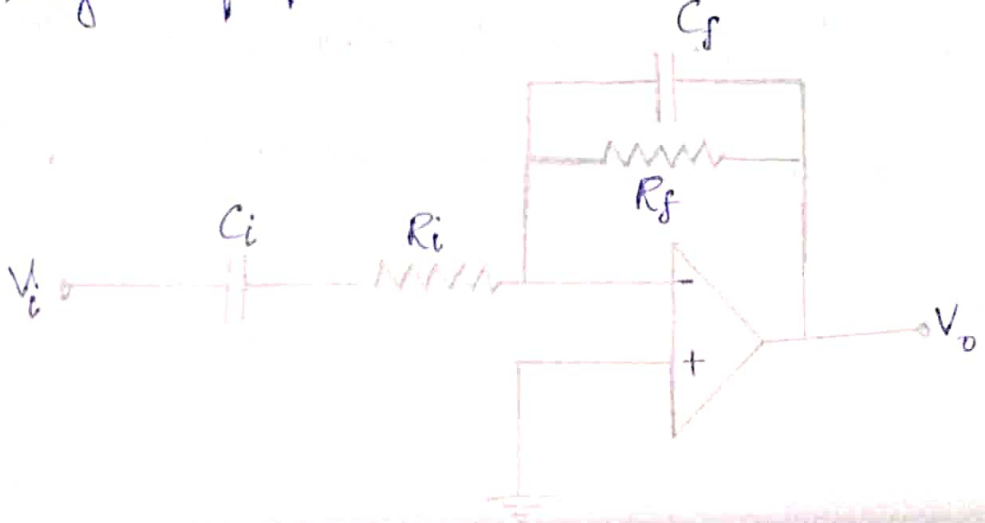
A lowpass filter alternates high frequencies



A high pass filter alternates low frequencies



A bandpass filter alternates both low and high frequencies.



$$\frac{V_o(j\omega)}{V_i(j\omega)} = \frac{Z_f}{Z_i} = \frac{R_f / j\omega C_f}{\left|\left(\frac{1}{j\omega C_f}\right)\right| + R_f}{R_i}$$

$$= \frac{R_f}{\left(\frac{1}{j\omega C_f R_f}\right) R_i}$$

$$= \frac{R_f}{R_i} \cdot \frac{1}{1 + j\omega\tau}$$

Where $\tau = C_f \cdot R_f$

For $\omega << \frac{1}{\tau}$, the circuit behaves as an inverting amplifier, because the impedance of C_f large compared with R_f.

For $\omega >> \frac{1}{C}$ the circuit behaves as an integrator, because C_f is the dominant feedba impedence.

UNIT - 4

Measurement of Non-electrical parameters

Temperature, respiration rate and pulse rate measurements. Blood pressure : indirect methods - Auscultary Method, direct method : electronic manometer, systolic, diastolic pressure, Blood flow and cardiac output measurement : Indicator dilution - and dye dilution method, ultrasound blood flow measurement.

Temperature Measurement

Temperature is one of the indicator of the general well being. Two types of temperature measurements can be obtained from the body. there are systemic temperature and surface temperature

Systemic temperature is the temperature of the internal regions of the body usually. the heat is generated by the active tissues of the body and heat is lost by the body to the environment. But, the temperature of the body

Types of Temperature Measurements:

i) Thermometer

ii) Thermocouple

iii) Thermistor

Thermometer:

Thermometer instrument for measuring the temp of the system. Temperature measurement is important to a wide range of activitys, including manufacturing scientific reasearch and medical practice.

A thermometer has two important elements.

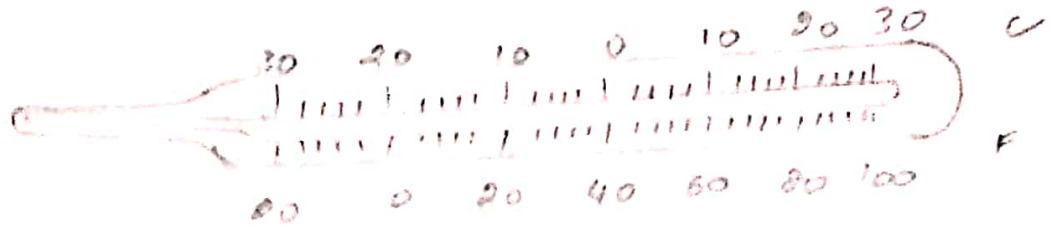
1. A temp- sensor in which some change occurs with a change temp.

2. Some means of converting this change into a numerical value.

Working:

A thermometer has a glass tube sealed at both ends and is partly filled with a liquid like mercury or alcohol. As the temp around the thermometer bulb heats up the liquid in the glass tube. When it is hot. The liquid inside the thermometer will

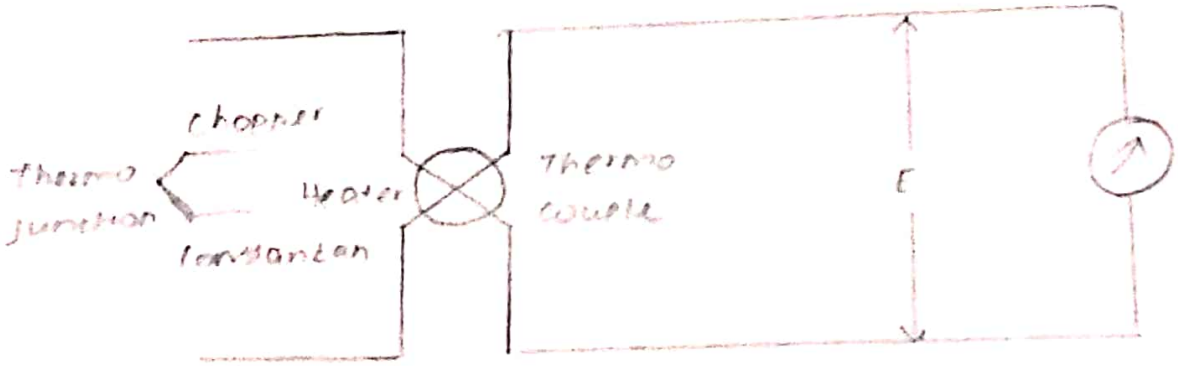
expand and rise in the tube.



Thermo couples:

When two metals having different work functions are placed together than heated by using a heater, a voltage is genetated at the junction which is nearly proportional to the temperature.

This junction is called termo couple. This principle is used to convert heat energy to electrical energy.



Thermo couple

Construction:

A termo couple can be formed by joining the two dissimilas metals such as platinum - Thodium, Chromel Alumel, copper - constantan and constantan at their ends. one method is to weld the wires together.

This produces brittle joint

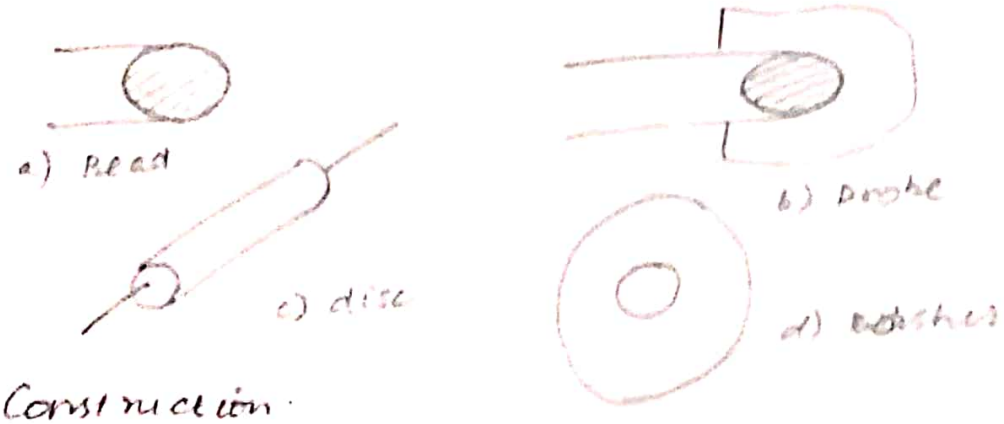
Thermistors:

Thermistors is a construction of term "thermal resistors".

Thermistors are generally composed of semi conductor materials.

Although positive temperature coefficient of unit are values available most termistors have a negative coefficient of temperature i.e. their resistance decreases with increases of temperature.

The negative temperature coefficient of resistance can be as large as several percent per degree celcius.



Construction:

Thermistors are manufactured from the oxides of metals like manganese, Nickel cobalt, copper, iron, zinc.

The electrical terminals are embedded before sintering or locked after words.

They are available in variety of size and shapes.

TYPES OF RESPIRATION RATE MEASUREMENT

The primary function the respiratory system is supply oxygen and to remove carbon dioxide from the tissues

various techniques used for this measurement

i) Displacement method

ii) Thermistor method

iii) Impedance Pneumography

iv) CO_2 method

① displacement method

In this method, the transducer is held by an elastic band which goes around the chest.

The respiratory movements result in corresponding resistance changes the strain gauge.

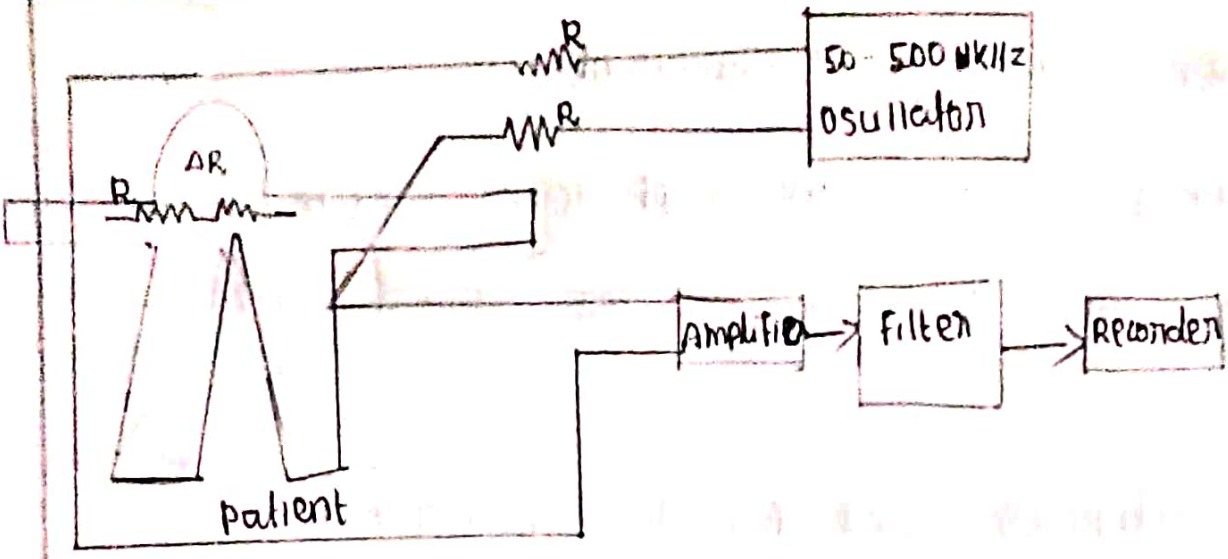
This output corresponds the respiration activity

ii) Thermistor method

Generally there is temperature difference between expired and inspired air

This temperature is sensed by placing thermistor in Front of nostrils

Thermistor is connected with the bridge circuit



iii) Impedance Pneumography

* This is the indirect method of measurement

* Impedance pneumograph is based the fact that ac impedance across chest a patient as respiration occurs.

The signal voltage applied the amplifier block is voltage drop across resistance

$$V = I(R \pm \Delta R)$$

V = output voltage

I = current through the chest (A)

R = chest impedance without respiration

ΔR = change of chest impedance due to respiration

The output the amplifier is given to demodulator and filter block

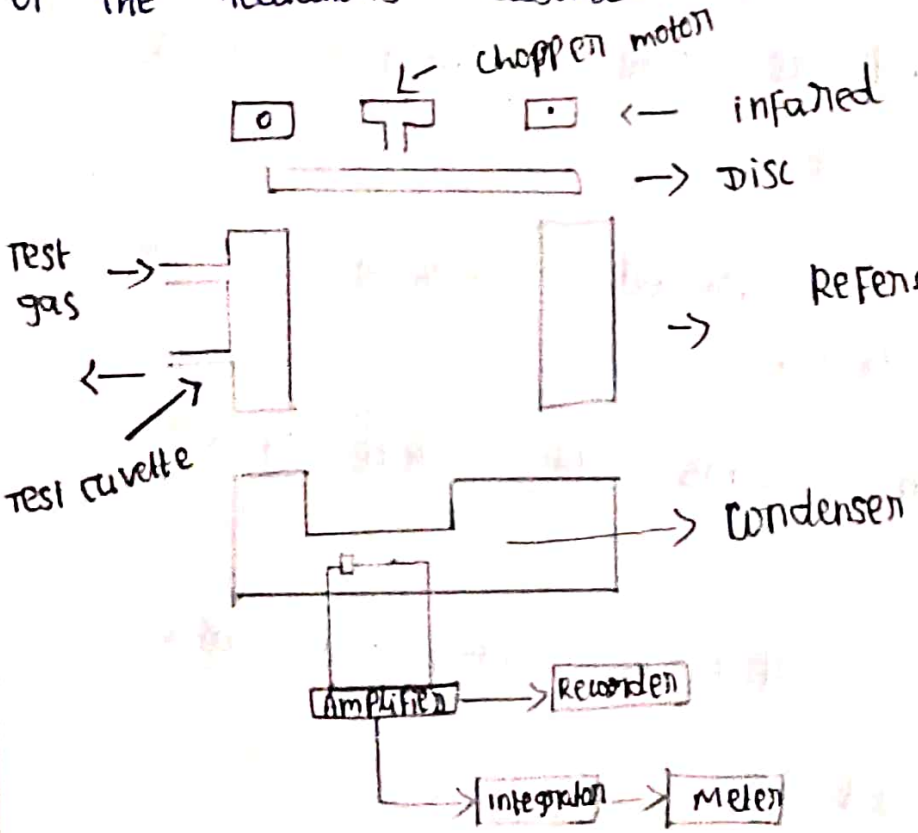
The output of the impedance contains respiratory rate data

(iv) CO_2 Method

Respiration rate can be measured by measuring CO_2 in expired air

It is based on the absorption property IR rays by certain gases

When IR rays are passed through the expired air which contain certain amount of CO_2 by some of the mediations absorbed by it



CO_2 method of respiration rate measurement

Two infrared sources available in this set up

The beam from one infrared source falls on the test cuvette side

The beam from infrared source falls on the reference cuvette

The detector has two identical portions These portions by flexible metal diaphragm

The gas is reference side is heated more than that on the test side

So diaphragm is pushed slightly to the test side of the detector

The diaphram forms one plate of a capacitor

The amplified output is integrated and shown in the method

It is used for continuous monitoring the respiration rate

Pulse measurements

Each time the heart muscle contracts blood is ejected from the ventricles and a pulse of pressure is transmitted through the circulatory system. This pressure pulse travelling through the vessels causes vessels wall displacement which is measurable various points the peripheral circulatory system

The pulse pressure and waveform are indicators for blood pressure and flow instruments used to detect the arterial pulse and pulse pressure waveforms in the extremities are called plethysmographs

The larger and more right the artery walls the greater the velocity. The velocity is 10-15 times faster than blood flow and is relatively independent it.

Types of pulse rate measurement

The methods used for detection of pulse changes due to blood flow are:

- Electrical impedance changes
- Strain gauge or microphone
- Optical changes

i) Electrical Impedance Method

An electric impedance method measures the impedance change between two electrodes caused by the change in blood volume between them.

ii) Mechanical Method

The mechanical method involves the use of a strain gauge connected a rubber-band placed around a limb or finger.

Expansion the band due to change in blood volume causes change in resistance the strain gauge In another a sensitive crystal microphone is placed the skins surface to pick up the pulsation.

Photo Electric method

The most commonly used method to measure pulsatile blood volume is by the Photoelectric method. Two methods are common:

(i) Reflection method

(ii) Transmittance method

i) Reflection method

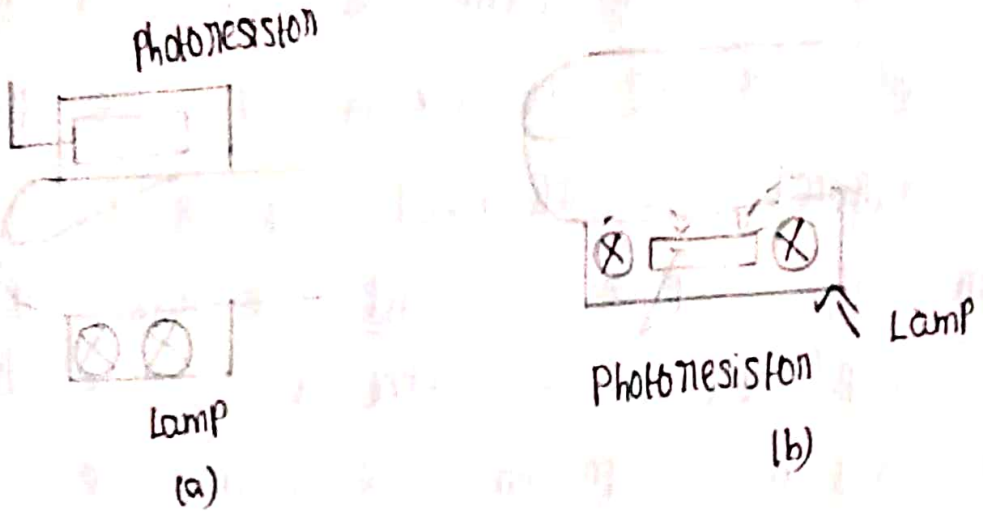
The arrangement used in the reflectance method of photoelectric plethysmography. The photoresistor this case is placed adjacent the exciter lamp part of the light rays emitted by the LED is reflected and scattered from the skin and the tissues and falls on the photoresistor. The quantity of light reflected is determined by the blood saturation the capillaries and therefore the voltage drop across the connected as a voltage divider vary in proportion the volume the blood vessels.

ii) Transmittance method

In the transmittance method a light emitting diode and photoresistor are mounted in enclosure that fits over the tip the patient's finger light is transmitted through finger resistance the light reaching it.

With each contraction of the heart blood is forced the extremities and the amount of blood in finger increases.

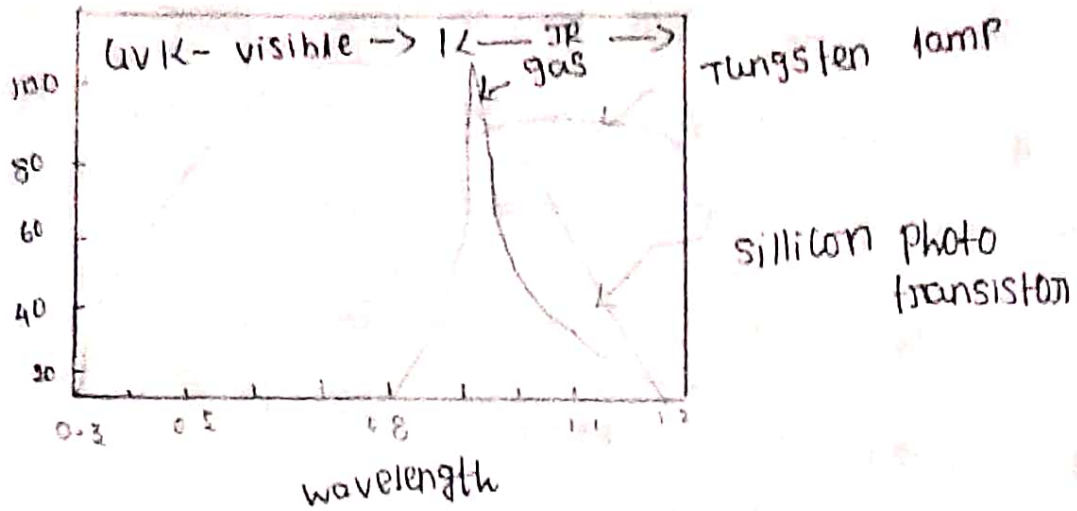
If optical density the result that the % light transmission through the finger reduces and the resistance of photoresistor increases accordingly. can be displayed on an oscilloscope or recorded on a strip chart recoded on a strip chart recorder



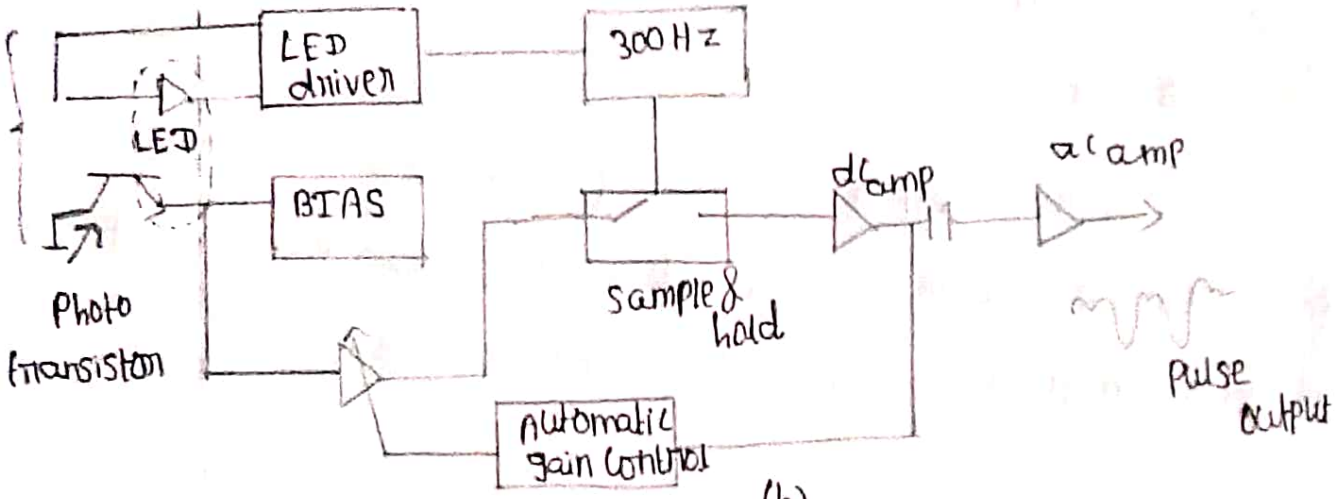
ii) Optical changes

The LED Phototransistor photo plethysmograph transducer consist of A Ga-As infamed emitting diode and a photo transmitter in a compact package measuring 6.25 x 4.5 x 4.75 mm

The peak spectral emission LED at 0.94 µm with 0.707 peak band width 0.04 µm



(a)



(b)

Isolation

For pulse rate measurement a photoelectric transducer suitable for use on the finger or ear lobe is used

The signal from the photocell amplified and filtered the time interval two successive pulse is measured. The measuring range is 20 50 bpm.

The circuit consists of two parts a LED oscillator and driven 300 Hz, 50 µs light pulses to the finger probe attached to the patient

The electrical signal obtained from the phototransistor is amplified its peak valve is sampled and filtered

An automatic gain control circuit ajusts amplifier gain a constant average pulse height at the output

This signal is transmitted across the isolation barrier demodulated low pass filtered and transmitted on the CPU board.

Blood Pressure Measurements

Blood pressure is the most often measured and the most intensively studied Parameter in medical and physiological Practical. The determination of only its maximum and minimum levels during each cardiac cycle suplemented by information about other physiological parameters is an invaluable diagnostic due to assess the vascular condition. and certain other aspects of cardiac performance.

Pressure measurements are a vital indication in the successful treatment and and management of critically ill patients in an intensive cardiac care or of patients undergoing cardiac catheterization. The tremendous research and development for an automatic blood pressure

monitor has resulted in several methods
but only very few have been commercialized
due to certain practical difficulties

Blood is pumped by the left side of the heart into the aorta, which supplies it to the arterial circuit. Due to the load resistance of the arterioles and Precapillaries, it loses most of its pressure and returns to the heart at a low Pressure via highly distensible veins

The right of the heart pumps it to the pulmonary circuit, which operates at a lower pressure. The heart supplies blood to both circuits as simultaneous intermittent flow pulses of variable rate and volume. The maximum pressure reached during cardiac rejection is called

called systolic pressure and the minimum Pressure occuring at the end of a ventricular relaxation is termed as diastolic pressure. The mean arterial pressure over one cardiac cycle is approximated by adding one-third of the pulse pressure to the diastolic Pressure. All blood pressure measurements are made with refference to the atmospheric Pressure. Typical hemodynamic pressure values

The normal values in the basic circulatory system are as follows.

Arterial system 30-300 mmHg.

Venous system 5-15 mmHg

Pulmonary system 6-25 mm Hg

The most frequently monitored pressures which have clinical usefullness in medium

and long term patient monitoring, are the arterial pressure and the venous pressu

$P = F/A$, P = pressure (in pascal)

F = Force (in Newton) , A = Area (in m^2)

pressure is increased by increasing the applied force or by decreasing the area.

Hydrostatic pressure.

If the force in a system under pressure is not varied. then the pressure is known as hydrostatic pressure.

Hydrodynamic pressure.

If the force in a system under Pressure is varied, then the pressure is known as hydrodynamic pressure.

Procedure to use sphygmomanometer

★ The cuff is wrapped around the patient upper arm at a point about midway between the elbow and shoulder.

★ The stethoscope is placed over an artery distal to the cuff.

★ The cuff is inflated, so the pressure inside the flated bladder is increased a point greater than the anticipated systolic pressure.

★ This pressure compreses the artery against the underlying bone. so blood is stoped in the vessel

★ Then the doctor slowly reduces the pressure in the cuff and he watches the mercury column when the systole Pressure exeeds the cuff pressure, then the doctor can hear some canashing.

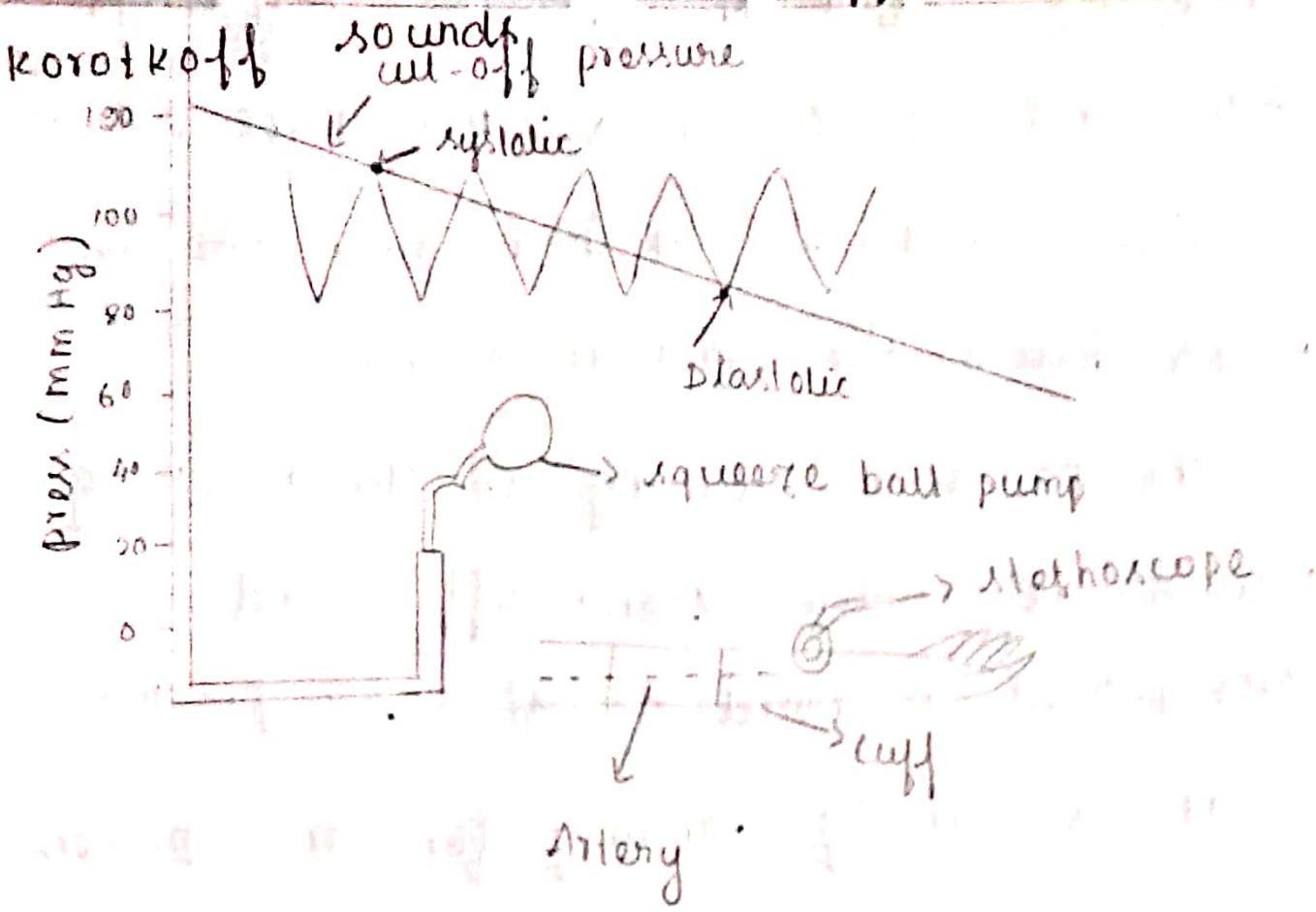
Types of blood pressure measurement.

1. Direct Method
2. Indirect Method
3. Auscultatory Method.

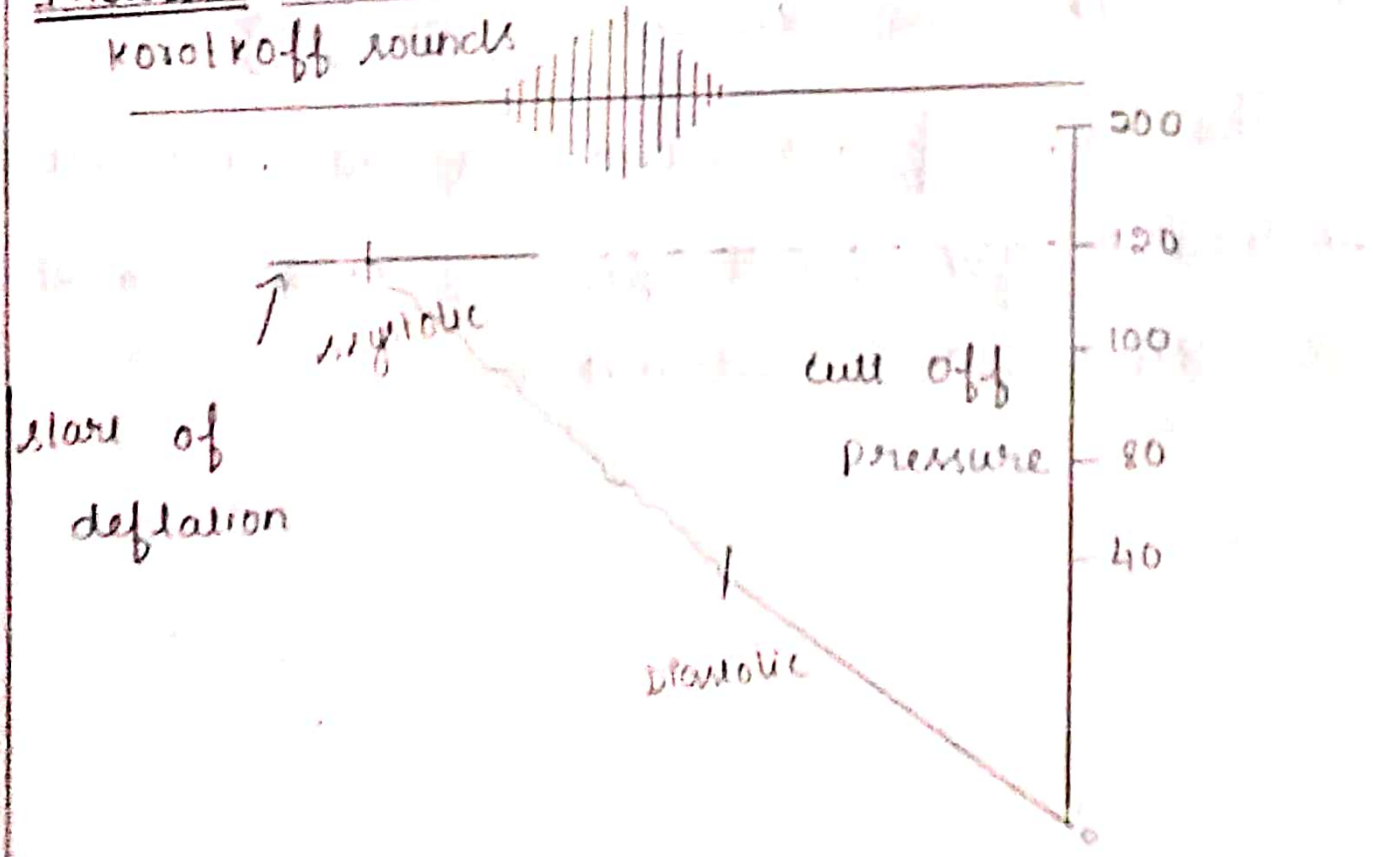
(i) Indirect Method of BP Measurement.

* In this method sphygmomanometer is used to measure blood pressure indirectly
* Sphygmomanometer consists of inflatable rubber bladder which is known as cuff. rubber squeeze ball pump and valve assembly.
* Pressure is measured using manometer with mercury column.

Pressure measurement with cuff placement and korotkoff sound



Indirect Method blood pressure measurements



snapping sound through the stethoscope This sound is known as korotkoff sound

This sound is vanished when the pressu drops below the diastolic pressure.

The pressure reading in the mercury column at which koorotkoff sound is disappeared is noted as diastolic pressure

It is usually 80mmHg for normal persons

This sound is disappeared at some point. This is known as muffing

The use of this sound as the indirect indicator for blood pressure measurement is known as auscultation.

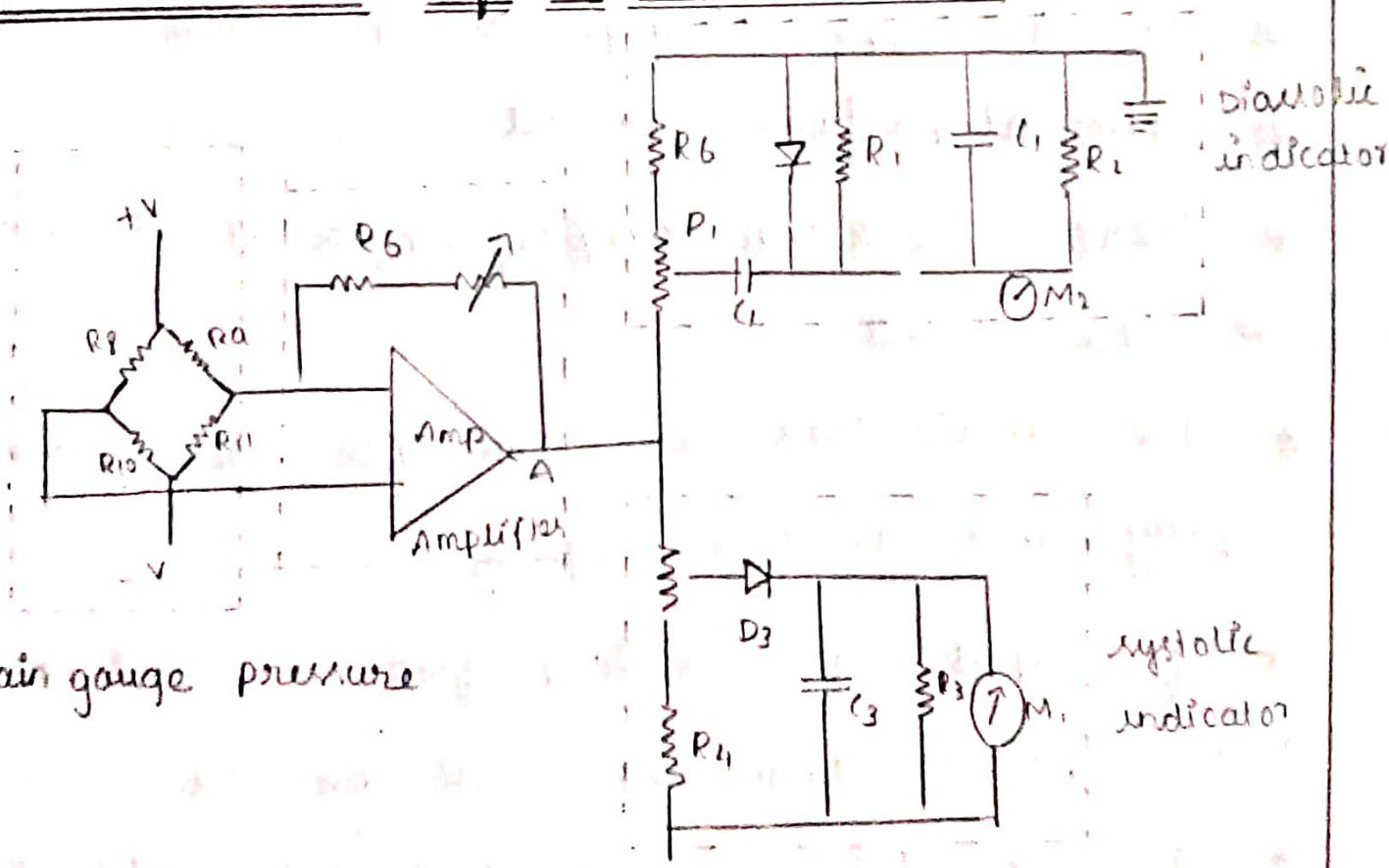
Advantages.

* This method is very simple, It is a painless technique. There is no harardous surgical procedure involved.

Disadvantages.

* The effective result depends on the fact that how accurately the doctor read the pressure values when korotkoff sound is heard.

ii) Direct method of BP measurement



Strain gauge pressure

Working

★ Blood is taken from the vessel using the catheter tip probe

★ Pressure created is transmitted to the pressu transducer

★ The output of transducer is given to pressu monitor

★ Because transducer converts pressure into electrical signals. It is displayed in the mon

★ Initially, strain guage pressure transduc is used. The change in pressure given to the amplifier circuit

★ Here isolation amplifier as in ECG syst can be used

★ Two indicators are available for systole display and diastole display

★ If output of the amplifier is positive going pulse. then D_3 will be ON

★ so capacitor C_3 is charging upto the Peak value. Here R_3 and C_3 combination

used to get sometimes constant valve which is used for stable display

★ Diastole circuit shows reading in indirect way

★ clamping circuit is available C_1 and D_1 are used to develop the voltage which is equal to the peak to peak valve of the pressure pulse

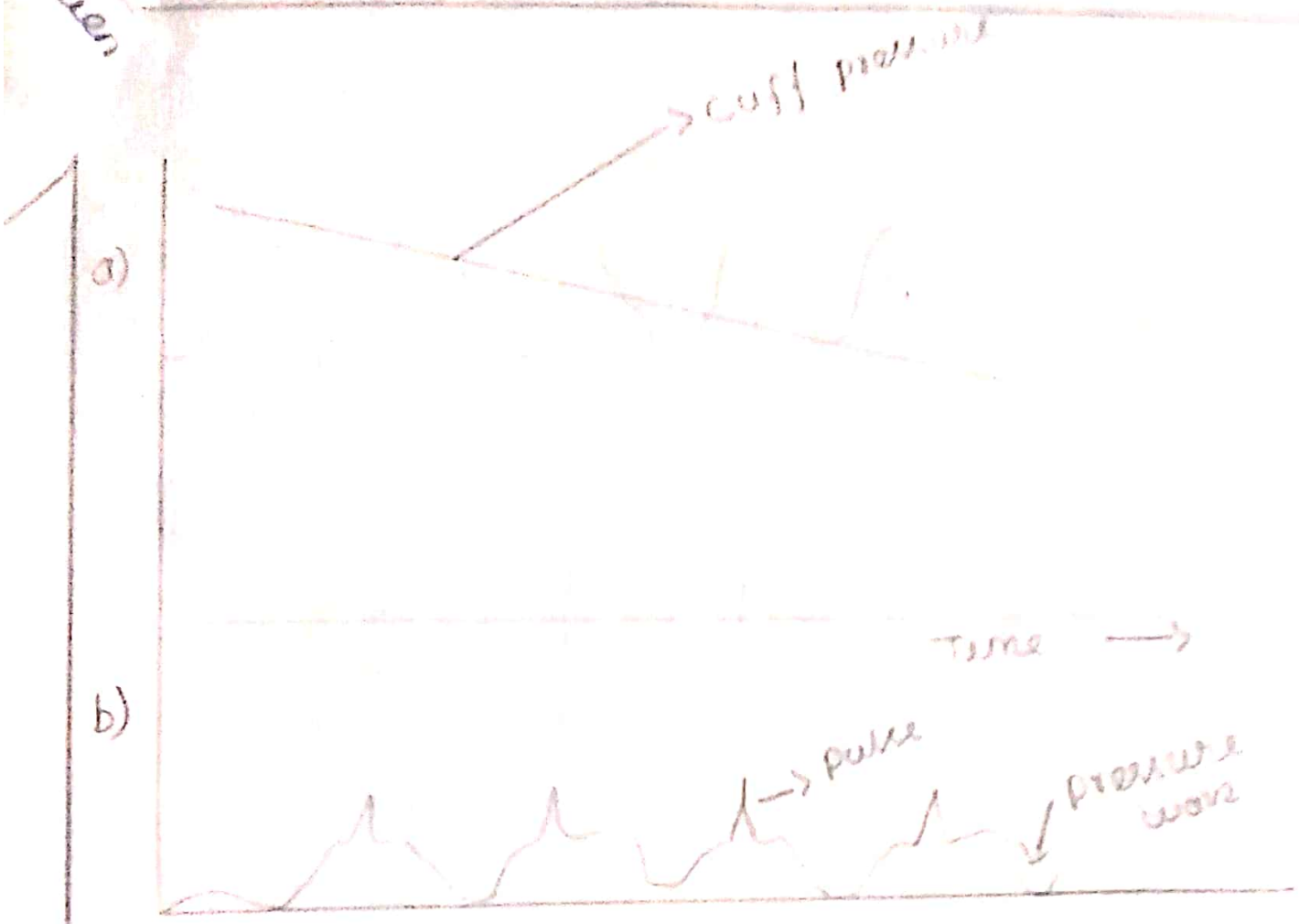
★ The voltage approached across R_1 Resistor. Then D_2 diode is ON

M_2 reading = Peak systolic valve - Peak to peak pulse pressure valve.

iii) Ausculatory Method

The differential ausculatory technique is a non-invasive method for accurately measuring blood pressure A special cuff-mounted sensor consisting of a pair of pressure sensitive elements, isolates the signal created each time the atory is forced

open. 4 illustrates how high frequ
pulses are created each time the
intra-arterial pressure exceeded the
cuff pressure. As long as the cuff
Pressure in the artery. the artery
is held closed, and no pulse is general
However, as soon as the pressure intra
arterial pressure rises to a value, which
momentarily exceeds the cuff pressure
the artery 'snaps' open, and a pulse
is created. Once artery is open, blood
flows through it giving rise to the
low frequency pressure wave signal whic
lasts untill the arterial pressure again
drops below the cuff pressure. The
Process is repeated until the cuff pressur
drops to a value below the
diastolic.



a) systolic pressure b) signal detected by sensor

Fig: Diagram showing relationship between cuff pressure and intra-arterial Pressure (b) signal created by the relative Pressure changes.

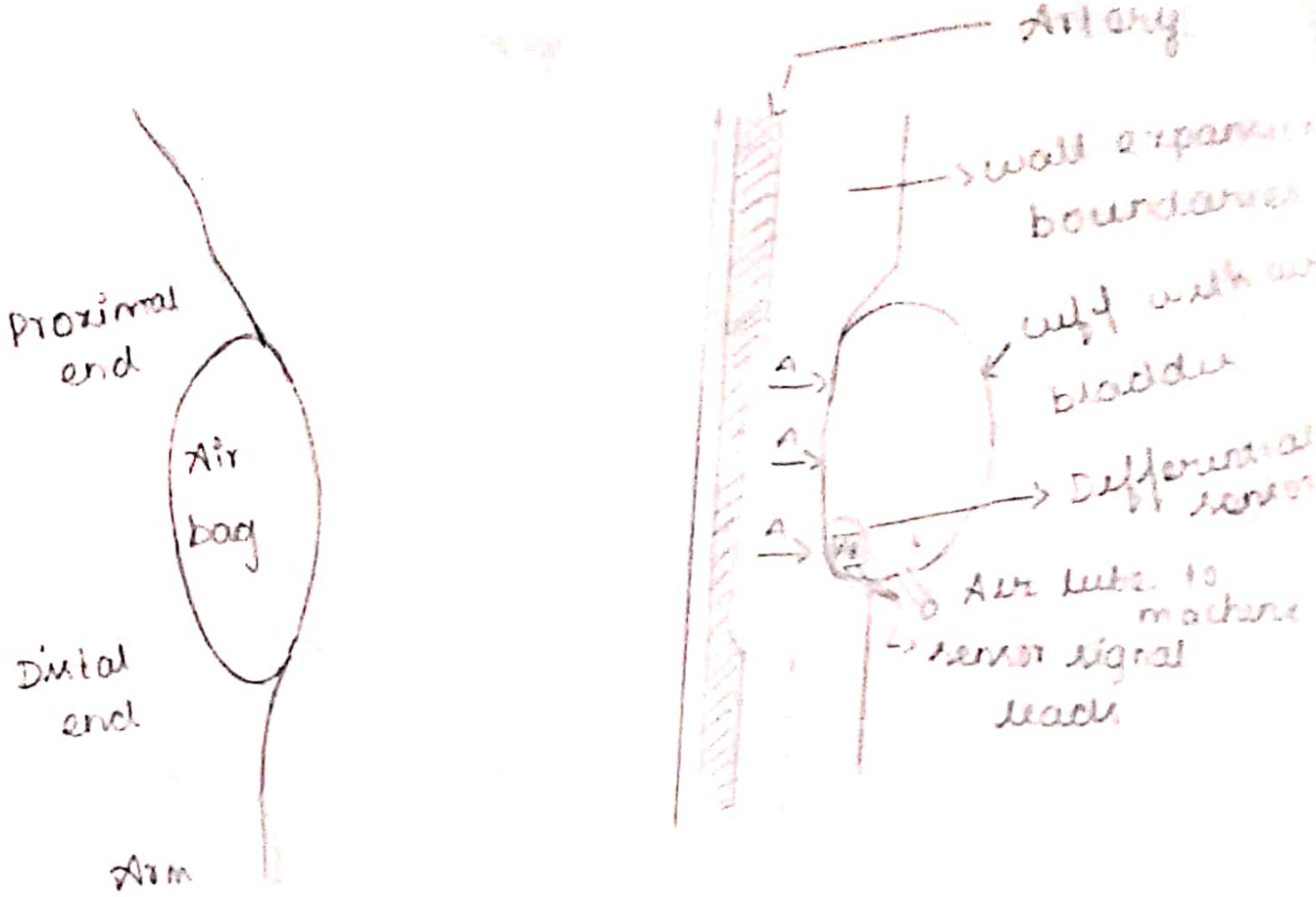


Fig : cut away view showing signal detection.

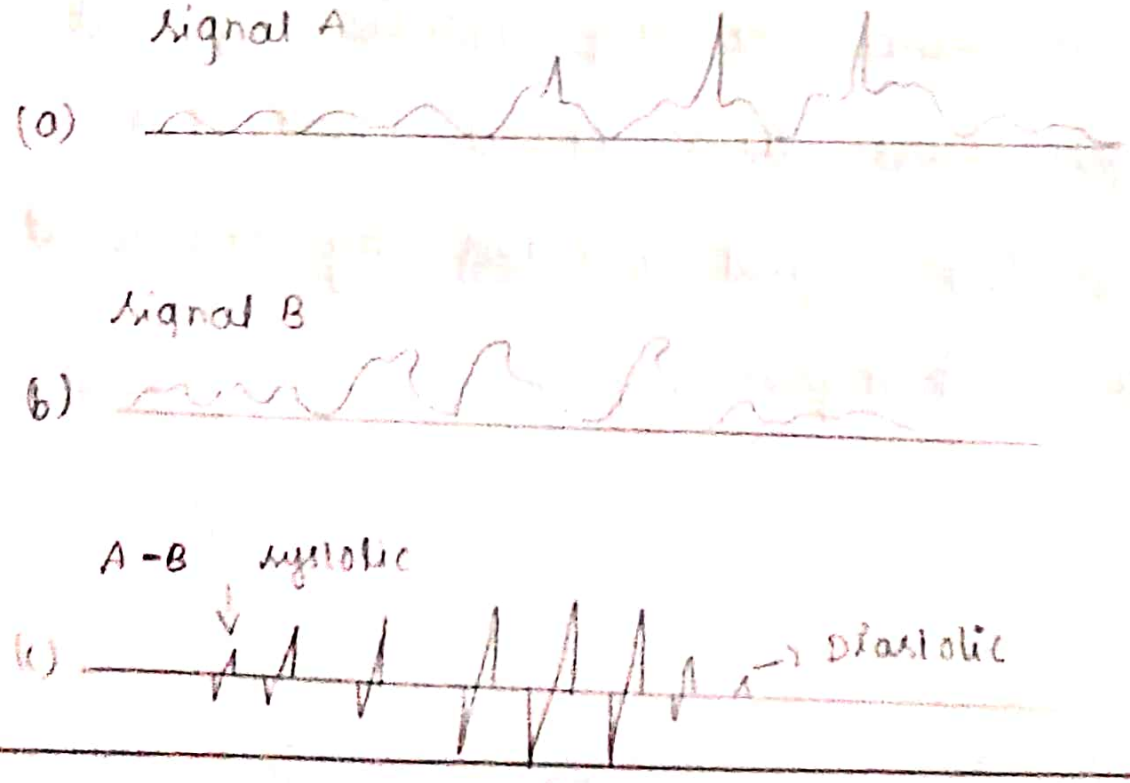


figure is a cut away view of an arm with a cuff partially occluding the brachial artery. Each time the artery opens figure created. Note that this signal consists of a slowly rising. low frequency component with a fast pulse superimposed on it. This signal is transmitted to the side of the sensor facing the air bag as denoted by the arrows marked B. since most artifact signals (unwanted signals due to motion etc) fall in a frequency range below 10 Hz they are also transmitted to both sides of the sensor.

The systolic pressure is determined as the pressure at which the first opening of the artery occurs as shown by the first pulse fig. because this pulse is created the first time the artery is forced open by intra-arterial

pressure similarly. diastolic value is determined as the pressure at which the differential signal essentially dis appears. became this corresponds to the last time the artery is forced open The differential sensor wave subtracts the side B signal from the ~~end~~ side A signal thereby cancelling out the pressure wave component and the motion artifact signals and the higher frequency korotkoff signals are isolated

CARDIAC OUTPUT MEASUREMENTS:

* Cardiac output is the amount of delivered by the heart to the aorta per minute.

* For normal adult, the cardiac output is 4-6 litres/min.

* The decrease in cardiac output is due low blood pressure, reduced tissue oxygenation, poor renal function, shock and acidosis.

Types of cardiac output Measurement:

The cardiac output is measured by using three methods.

i) Fick's method

ii) Indicator dilution method.

iii) Measurement of cardiac output by impedance change.

iv) Thermodilution method.

i) Fick's method:

In this method, the cardiac output is determined by the analysis of gas-keep of the organism.

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

Let, $I = C_A Q - C_V Q$.

$I \rightarrow$ amount of infused or removed oxygen per unit time.

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

where,

$Q \rightarrow$ cardiac output in terms of litre/min.

$C_A \rightarrow$ concentration of oxygen in arterial blood

$C_V \rightarrow$ concentration of oxygen in venous blood,

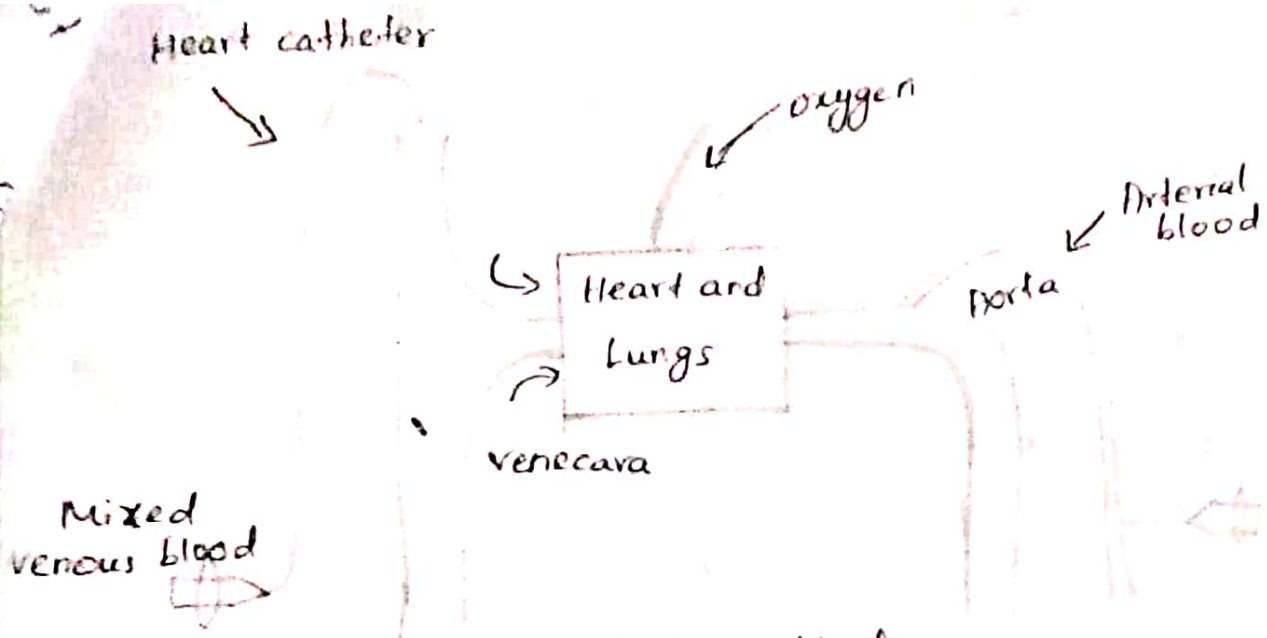


Fig. Fick's method.

ii) Indicator dilution method:

* In this method, a known amount of dye or radioisotope is used as an indicator in the blood circulation and then measuring the concentration of the indicator with respect to time, we can estimate the volume flow of the blood.

* Let an increment of volume dv passes the sampling time dt.

Let the mass of an indicator in dv: dM

∴ The concentration of an indicator, $D = \frac{dM}{dv}$

$$\frac{dM}{dt} = C \frac{dv}{dt}$$

But $\frac{dv}{dt} = Q$, in the cardiac output,

$$\therefore \frac{dM}{dt} = Q C dt$$

Integrating over the time, $M = \int_0^t Q C dt$

considering the flow as constant, $M = Q \int_0^t C dt$

$$Q = \frac{M}{\int_0^t C \, dt}$$

where, $Q \rightarrow$ cardiac output

$$Q \rightarrow \frac{M}{\text{Area of the curve.}}$$

iii) Thermo dilution method:

* 10ml of 5% dextrose in water of room temperature is injected as a thermal indicator into the right atrium.

* After mixing, it is detected in the pulmonary artery by thermistor

the temperature difference between the injected temperature and the circulating blood temperature is measured.

* Amplifier block is used to remove the non-linearity of the thermistor.

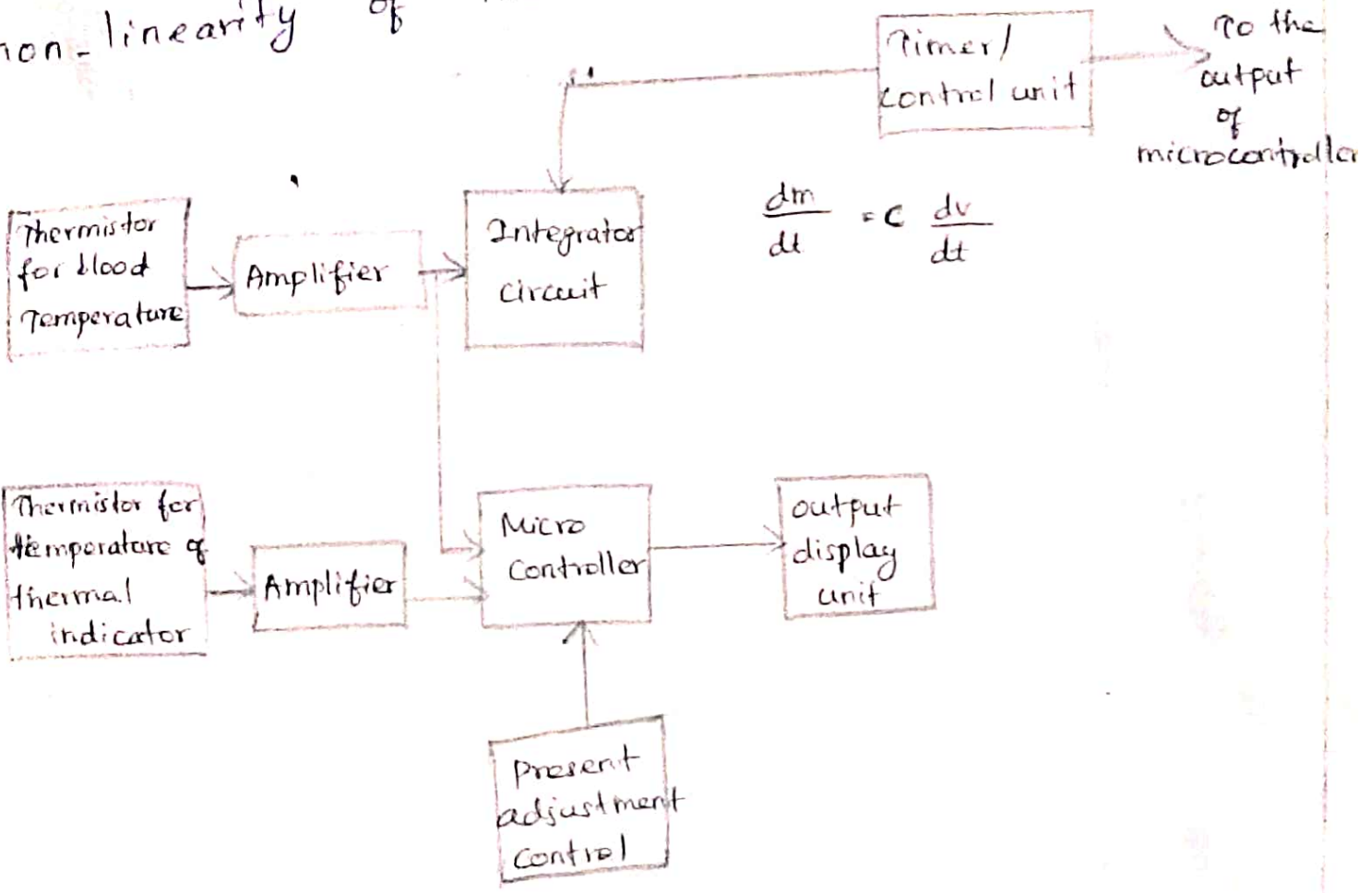


Fig. Thermal dilution method.

iv) Measurement of cardiac output by impedance change:

* The cardiac output can be determined electronically by the impedance method.

* Four electrodes are placed surrounding thorax.

* Electrode pair 1 and 4 are used as current electrodes.

* Electrode pair 2 and 3 are used to pick up the voltage across the thorax.

Let ρ → Resistivity of the patient's haemotocrit

A → cross-sectional area of the thorax.

L → seperation length between the potential electrodes 2 and 3.

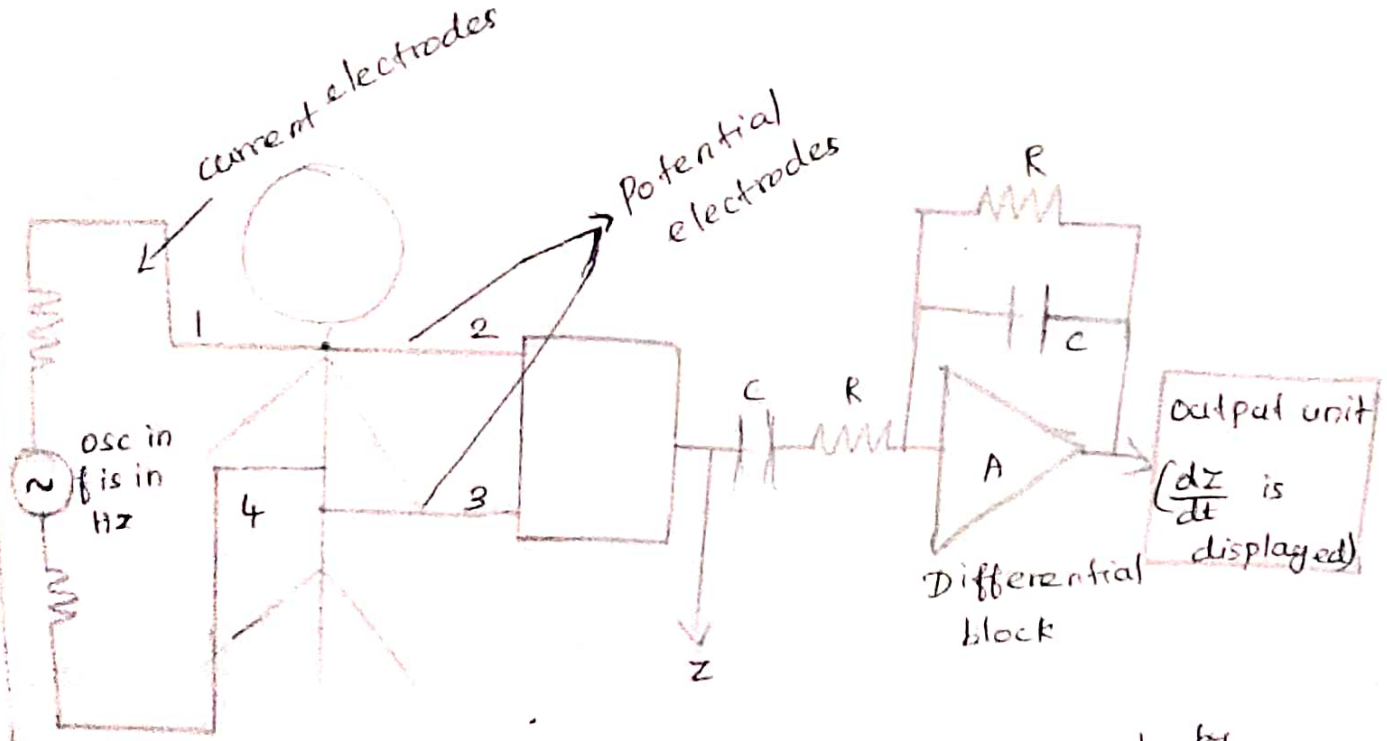


Fig. cardiac output measurement by Impedance change

* The resistance of the thorax is

$$R = \rho L / A$$

$$R = \frac{\rho L^2}{AL} = \frac{\rho L^2}{V}$$

$$V = \frac{\rho L^2}{R}$$

V → volume of the thorax.

* During ejection of stroke volume, the change in volume is dv corresponding decrease in resistance is dR.

* Differentiating the expression for V,

$$dv = -\rho \cdot \frac{L^2}{R^2} dR.$$

* Since a.c excitation is used, impedance z is used instead of R.

$$dv = -\rho \frac{L^2}{Z^2} dz.$$

* By determining dv the cardiac output can be measured by multiplying dv with heart beat rate per minute.

Blood Flow Measurements

Blood flow is one of the most important physiological parameters and also one of the most difficult to measure accurately. This is because instruments for measuring the flow through blood vessels within the body have to meet certain specification

eg Sensitivity and stability requirements depends upon the magnitude of flow, location and diameter of the individual vessels.

The circulatory system of human helps in the bloodflow throughout the body during the process. adequate amount of blood should be applied for the organs to perform their function Improper blood supply results in the case of various diseases Hence the diseases can be diagonised by measuring the rate of blood flow in the vessel

The rate of flow of blood in a vessel is given as the volume of the blood that passes through the vessel in a given unit of time The ancient methods like turbine flowmeter and the rotameter are not suitable Hence

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The rate of flow of blood in a vessel is given as the volume of the blood that passes through the vessel in a given unit of time. The anvent methods like turbine flowmeter and the rotameter are not suitable. Hence

modern methods are adopted for blood flow measurement.

Types of Blood flow measurement

There are 5 types of Blood flow measurements.

(i) Electromagnetic blood flow meter.
(ii) Thermal convention method.
(iii) Radiographic method.
(iv) Indicator Dilution method.
(v) Ultrasonic blood flow meters.

Electromagnetic blood flow meter

This induced voltage is picked up by two electrodes incorporated in the magnetic assembly. The magnitude of the voltage picked up is directly propotional to the strength of the magnetic field, the diameter of the blood vessel and the velocity of blood flow.

i.e, $e = CHVd$

Where $e \rightarrow$ induced voltage. $d \rightarrow$ Diameter of blood vessel.
$H \rightarrow$ strength of mag. field. $c \rightarrow$ Constant.
$V \rightarrow$ velocity of blood flow

If the strength of the magnetic field and the diameter of the blood vessel remain unchanged then the induced voltage will be a linear function of the blood flow velocity

Therefore $e = C_1 V$

$C_1 = CHV$

Further the flow rate through a tube is given by

$Q = VA$

$V = Q/A$.

$A \rightarrow$ Area of cross section of tube

$e = C_1 \times Q/A = C_2 \times Q$

where, $C_2 = C_1/A$.

$e = C_2 \times Q$ it shows that induced voltage is directly proportional to the flow rate through blood vessel.

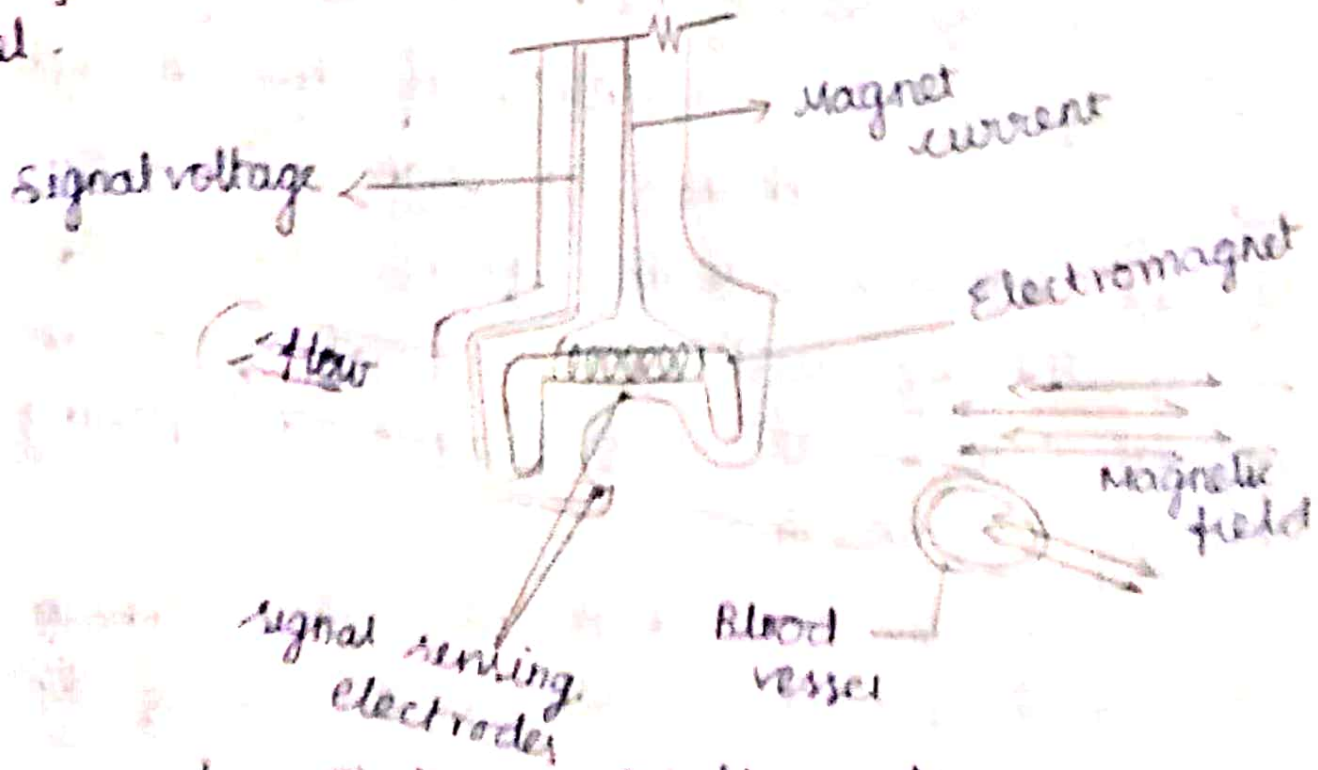


fig. Electromagnetic flow meter

The induced voltage picked up by the electrodes is amplified and displayed / recorded on a suitable system The system is calibrated interms of volume flow as a function of the induced voltage. The diameter of the blood vessel is held constant by the circumference of the hole in the probe that surrounds it

Dye Dilution Method :-

The most commonly used indicator substance is a dye. The dye is prefferred because of its property of absorbing light in the 80nm region of the spectrum where both reduced and oxygenated haemoglobin have the same optical absorption.

The dye dilution method entails injecting a bolus of a known quantity of dye through a central venous catheter. The change in concentration of the indicator resulting from mixing with blood is detected by withdrawing blood from an arterial catheter at a fixed rate and passing it through a densitometer.

This device measures the optical density of the blood to determine the concentration of the

indicator

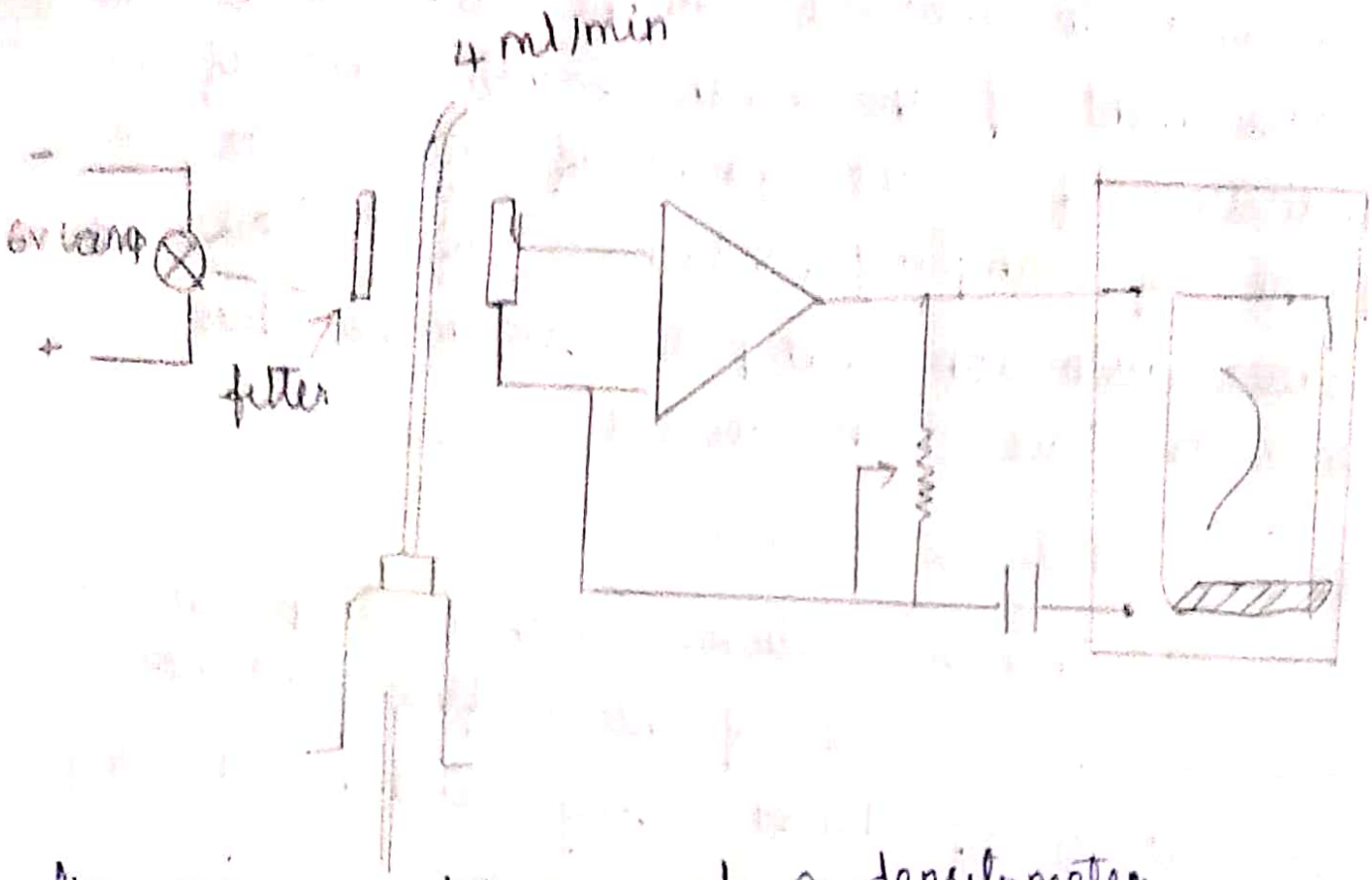


fig. Diagrammatic rep of a densitometer.

First, the velocity of flow within the catheter is not uniform, which causes the dye to mix within the tube as it travels downstream. The mixing is a function of the flow rate and volume of the sampling system, the viscosity of the sampled fluid and the shape of the configuration of the sampling tube. The second source of distortion is the measuring instrument itself, which may not have response characteristics fast enough to record instantaneous dye concentration as it actually occurs in the lumen. Distortion is very

important when the indicator dilution method is used to measure volume since it is the measurement of the mean transit time of an indicator from the point of injection to the point of sampling, which is of interest. To reduce distortion, computer software based corrections have been devised.

Indicator Dilution Method:

The indicator dilution method helps in the determination of rate of blood flow and not the velocity of blood. Any substance having no toxic side effects can be used as an indicator if it readily mixes with blood and its concentration can be easily determined after mixing. The principle is used in the indicator dilution method. Here the substance used should be stable and should not be retained in the body. The most frequently used indicator is isotonic saline.

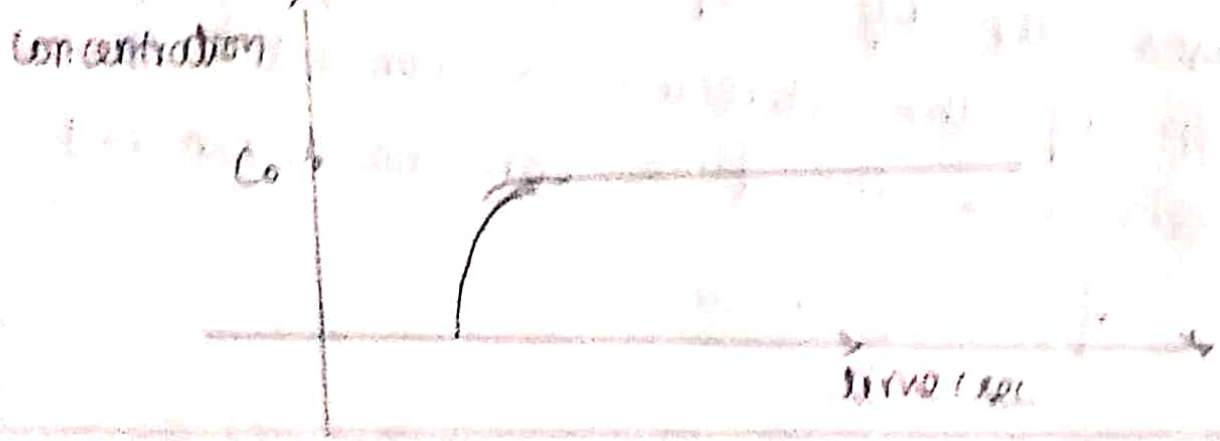
(i) open circulation method.
(ii) closed circulation method.

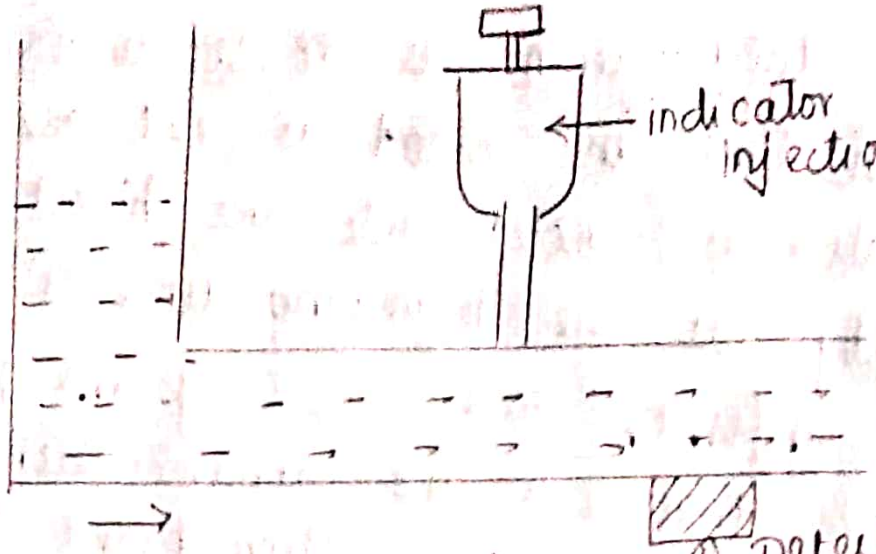
Open circulation method:

The measurement is made under the assumption that the blood is not recirculated. The indicator is injected into the blood flow continuously at the beginning time 't' with a constant infusion rate of I grams per minute. A detector measures the concentration of the downstream from the injection point. The o/p of the detector is connected to the recorder. and here at a certain time after injection the concentration of the indicator increases and finally reaches a constant value C_o mg per litre. The flow can be determined with the help of injection rate I and the measured concentration C_o

Rate of flow (liters per minute)

$$= \frac{I \text{ (mg per minute)}}{C_o \text{ (mg per litre)}}$$





(ii) closed circulation method :-

This method states that when a dye or isotope is used as an indicator, the concentration does not assume a steady state instead increases in steps whenever the recirculated indicator again passes the detector. This method is based on the assumption that the blood is being recirculate

Here at first, the indicator is injected & its concentration is measured with the help of detector. and when the indicator is again recirculated the concentration increases step by step as shown in graph. The o/p of the detector is connected to the recorder & the flow can be determined.

$$f_1 = \frac{C - V_{1050}}{C}$$

Where $f \rightarrow$ transmitted frequency

$c \rightarrow$ velocity of sound

$\theta \rightarrow$ angle of inclination of the incident wave to the direction of blood.

$v \rightarrow$ velocity of blood cells.

Assuming that the incident & scattered radiation are both inclined at θ

$$f_2 = f_1 \left[\frac{c}{c + v\cos\theta} \right]$$

The resultant Doppler shift,

$$\Delta f = f - f_2 = f - f_1 \left[\frac{c}{c + v\cos\theta} \right]$$

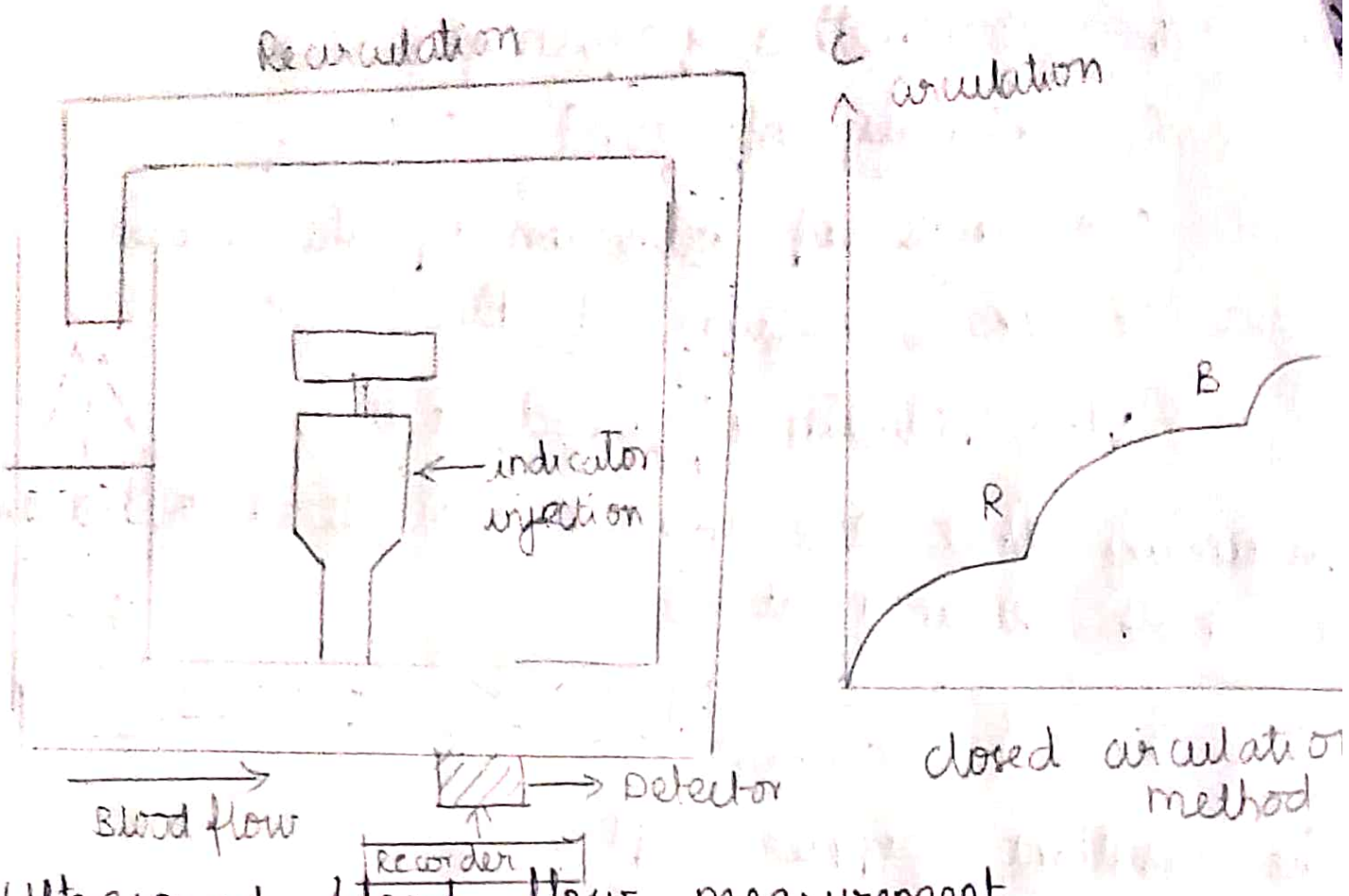
$$= f \left[1 - \frac{c - v\cos\theta}{c + v\cos\theta} \right]$$

since $c > v$

$$\Delta f = \frac{2 f v \cos\theta}{c}$$

$$v = \frac{\Delta f \cdot c}{2 f \cos\theta}$$

However, due to the seperation of the transmitter and receiver, the Doppler shift fqys are not zero. In such cases, the position at which the minimum Doppler shift fqys are present is taken for the probe to be at right angles.



Ultrasound blood flow measurement

In ultrasonic blood flow meter, the velocity of the flowing blood can be determined with a beam of ultrasonic flow meter and Doppler type ultrasonic flow meter.

Two types:

1. Transit time type
2. Doppler-shift flow velocity type.

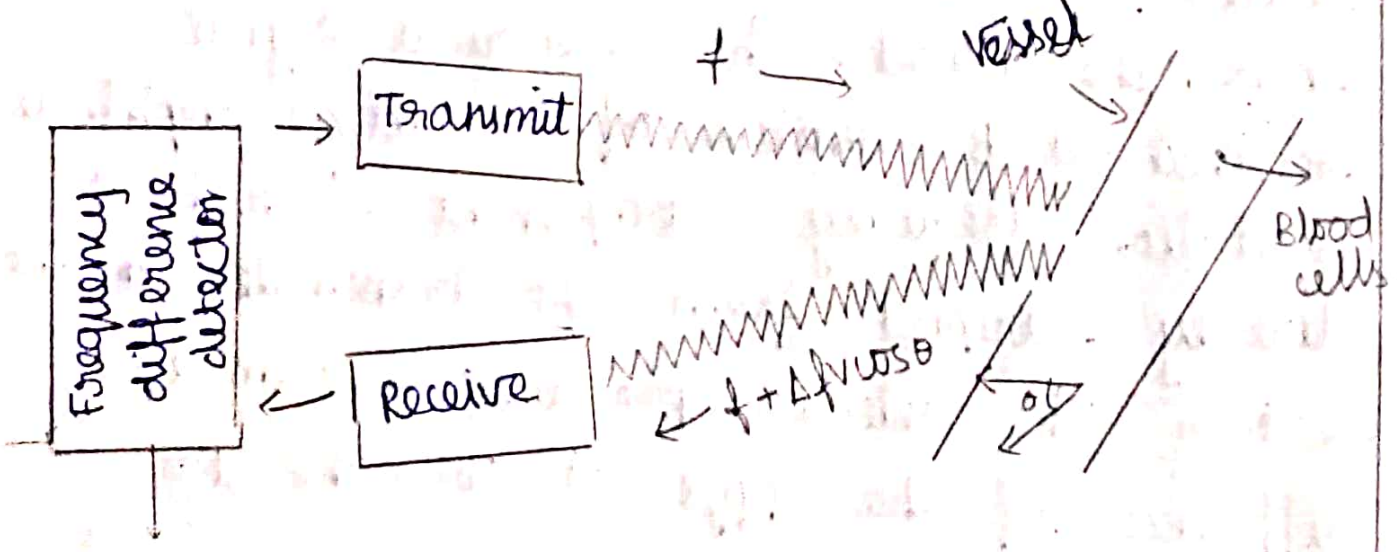
Transit time Type:

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

flow is in opposite direction, the time value is greater.

Doppler-shift flow velocity Type

It is a non-invasive technique to measure blood velocity in a particular vessel from the surface of the body. It is based on the analysis of echo signals from the erythrocytes in the vascular structures. Bcoz of the Doppler Effect, the fqy of these echo s/ls changes. relative to the fqy which the probe transmits. The Doppler frequency is a measure of the size and direction of the flow velocity. The principle is illustrated in fig.



The incident ultrasound is scattered by the blood cells and the scattered wave is rejected received by the second transducer The frequency shift due to the moving scatters is propotional to the scatters.

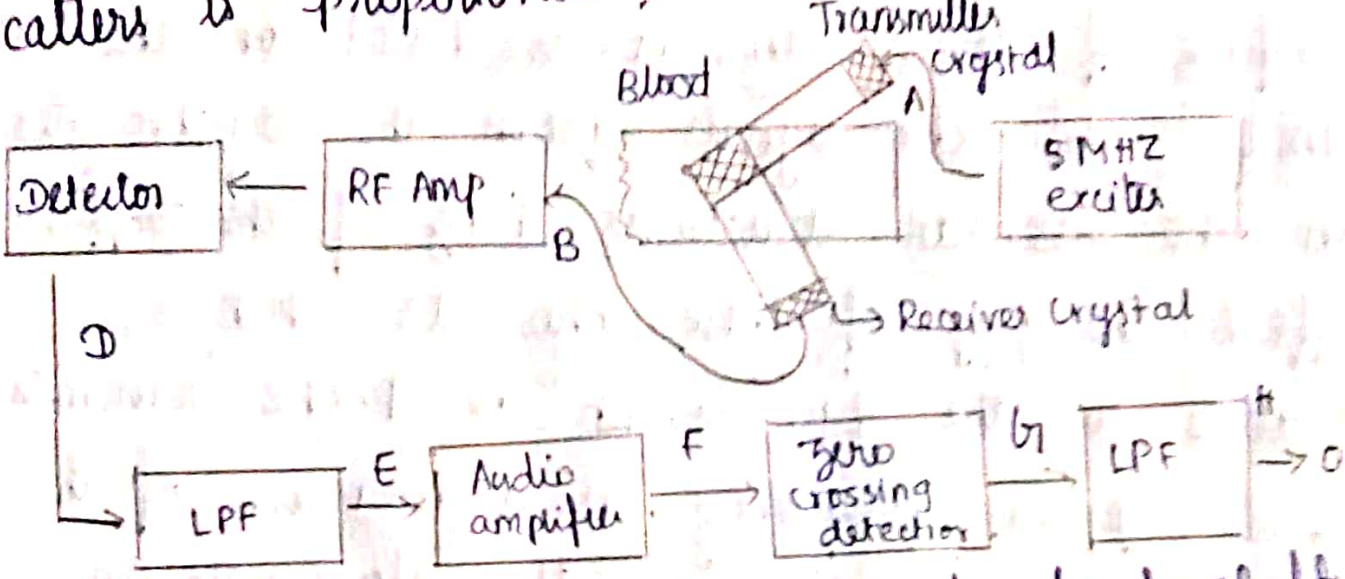


Fig shows the block diagram of doppler shift flow meter.

The piezo-electric crystal A is electrically excited to generate ultrasonic waves, which enter the blood. The electrical signal received at B consists of a large amplitude excitation frequency component, which is directly coupled from the transmitter to the receiver. The detector produces a sum of difference of the fqys at D. The LPF

selects the difference fqy, resulting in audio fqys at E. Each time the audio wave crosses the zero axis, a pulse appears at G. The filtered output level at H will be proportional to the blood velocity. The following two pitfalls are encountered in Doppler ultrasonic blood flow meters. The High fqy response is usually inadequate which introduces a non-linearity into input-output calibration curve. Also the low fqy gain is normally too high, resulting in wall-motion artifacts.

OMD-551

Basics of Biomedical Instrumentation

Unit-V

Bio-chemical Measurement

Syllabus:

Blood gas analyzers and non-Invasive monitoring, Colorimeter, Sodium potassium Analyser, Spectrophotometer, blood cell counter, auto analyser (simplified schematic description).

Blood Gas Analyzers.

Blood gas analyzers are used to measure the PH, partial pressure of carbon dioxide (PCO_2) and PO_2 of the body fluids with special reference to the human blood. A sudden change in the PH and PCO_2 could result in cardiac arrhythmias, ventricular hypotension and even death.

Types of blood gas measurement

i) Acid-base balance
ii) Blood PH measurement
iii) Blood PCO_2 measurement
iv) Blood PO_2 measurement

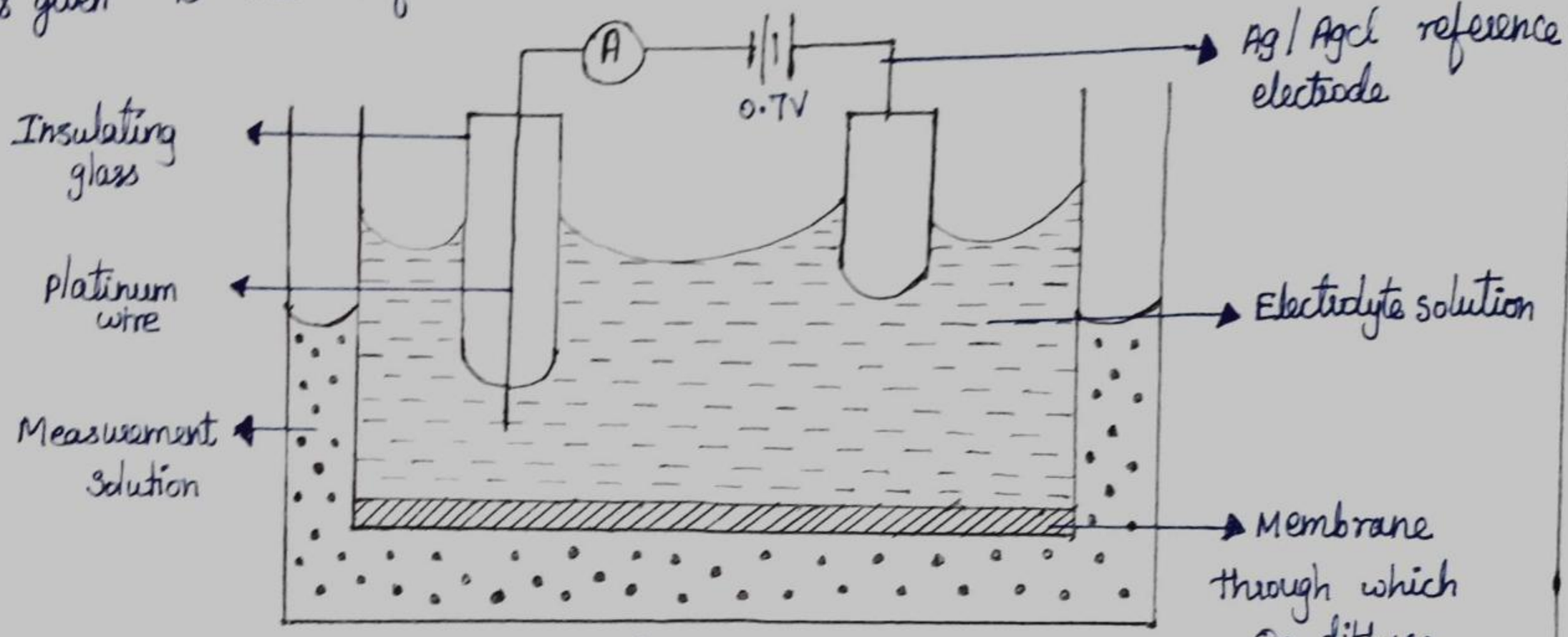
i) PO_2 measurement

The term PO_2 is defined as the partial pressure of oxygen respectively. The partial pressure of a gas is proportional to the quantity of that gas present in the blood.

The platinum wire, which is in an active electrode is embedded in glass for insulation and only its tip is exposed.

It is kept in the electrolyte solution in which the oxygen is allowed to diffuse. The reference electrode is made up of silver-silver chloride (Ag/Ag Cl).

A voltage of 0.7 is applied between the platinum wire and the reference electrode. The -ve terminal is connected to the active electrode through a micro ammeter and the +ve terminal is given to the reference electrode.



Due to the -ve terminal, the oxygen reduction takes place at the platinum cathode. Finally the oxidation reduction current proportional to the partial pressure of oxygen diffused into the electrolyte can be measured in the micro ammeter. The electrolyte is generally sealed in the electrode chamber by means of a membrane through which the oxygen can diffuse from the blood or sample solution. There are two types of PO_2 measurement. They are

1. Vitro measurement
2. Vivo measurement

In Vitro measurement

In this method the blood sample is taken and the measurement for oxygen saturation is made in the laboratory. The electrode is placed in the sample blood solution and the PO_2 value is determined.

In vivo measurements

In this method the oxygen saturation is determined while the blood is flowing in the circulatory system. A micro version of the PO_2 electrode is placed at the tip of the catheter so that it can be inserted into various parts of the heart or circulatory system.

Disadvantages:

The reduction process in the platinum cathode removes a finite amount of the oxygen from the cathode. And there is a gradual reduction of current with respect to time. However careful design and proper procedures in modern PO_2 electrodes reduce the errors.

pH measurement

The chemical balance in the body can be determined by the pH value of blood and other body fluids. pH is defined as the hydrogen ion concentration of a fluid. It is the logarithm of the reciprocal value of H^+ concentration.

$$pH = -\log_{10}[H+] = \log_{10}\frac{1}{[H+]}$$

pH < 7 - acidic solution

pH > 7 - basic solution

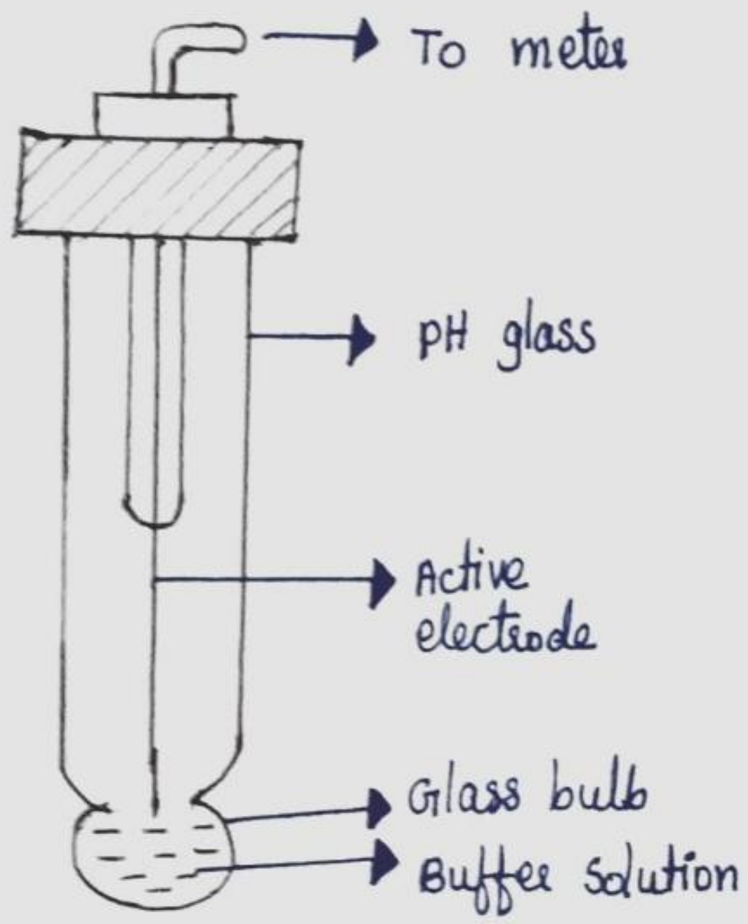
pH = 7 - neutral solution

Construction and working

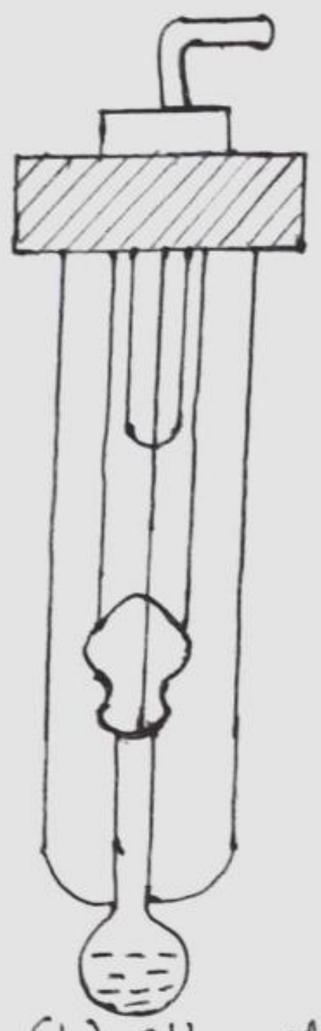
The pH meter is made up of a thin glass membrane and it allows only the hydrogen ions to pass through it. The glass electrode provides a membrane interface for H+ ions. The glass bulb at the lower end of the pH meter contains a highly acidic

buffer solution. The glass tube consists of a silver - silver chloride electrode and the reference electrode which is made up of calomel Ag/AgCl is then placed in the solution in which pH is being measured.

The potential is measured across the two electrodes. The electrochemical measurement, which should be obtained by each of the electrodes called half-cell. The electrode potential is called as half-cell potential. Here the glass electrode inside the tube constitutes one half-cell and the calomel or reference electrode is considered as the other half-cell.



(a) pH meter



(b) pH meter with combination electrode

For easier pH measurement combination electrodes are used. In this type both the active glass electrode and reference electrode are present in the same meter. The glass electrodes are suitable only to measure pH values around 7. Since this type of glass electrodes produce considerable errors during the measurement of high pH values, special type of pH electrodes are used. After every measurement the pH meter is washed with 20% ammonium bifluoride solution, for accurate results.

PCO_2 measurement :

The term pCO_2 is defined as the partial pressure of carbon dioxide respectively. The determination of pCO_2 is one of the most important physiological chemical measurement.

The partial pressure of carbon dioxide can be measured with the help of pCO_2 electrodes. Since there is a linear relationship between the logarithm of pCO_2 and pH of a solution. The pCO_2 measurement is made by surrounding a pH electrode with a membrane selectively permeable to CO_2.

The modern improved pCO_2 electrode is called as severinghous electrode. In this electrode the membrane permeable to CO_2 is made up of Teflon which is not permeable to other ions which affects the pH value. The space between the Teflon and glass contains a matrix layer which allows only the CO_2 gas molecules to diffuse through it.

One of the demerits in order CO_2 electrode is, it requires a length of time for the CO_2 molecules to diffuse through the membrane. The modern CO_2 electrode is designed in such a way to overcome this demerit. Here the CO_2 molecules diffuse rapidly through the membrane and the measurement can be done easily.

Non - Invasive Blood Gas Monitoring

Blood gas determination can provide valuable information about the efficiency of pulmonary gas exchange, the adequacy of alveolar ventilation, blood gas transport and tissue oxygenation.

Although invasive techniques to determine arterial blood gases are till widely practiced in many clinical situation it is becoming appasent that simple, real time, continuous and non-Invasive techniques offer many advantages.

Advantages:

* Intermittent blood sampling provides historical data valid only at the time the sample was drawn.
* Delay between when the blood samples is drawn.
* when the blood gas values are reported average about 30 min.

Disadvantages:

* These limitations are particularly serious in critically in patients for close monitoring of arterial blood gases.
* painful and have associated risks.
* Irreversible cell damage occurs.

Skin characteristics

skin layers i) stratum corneum ii) epidermis iii) dermis

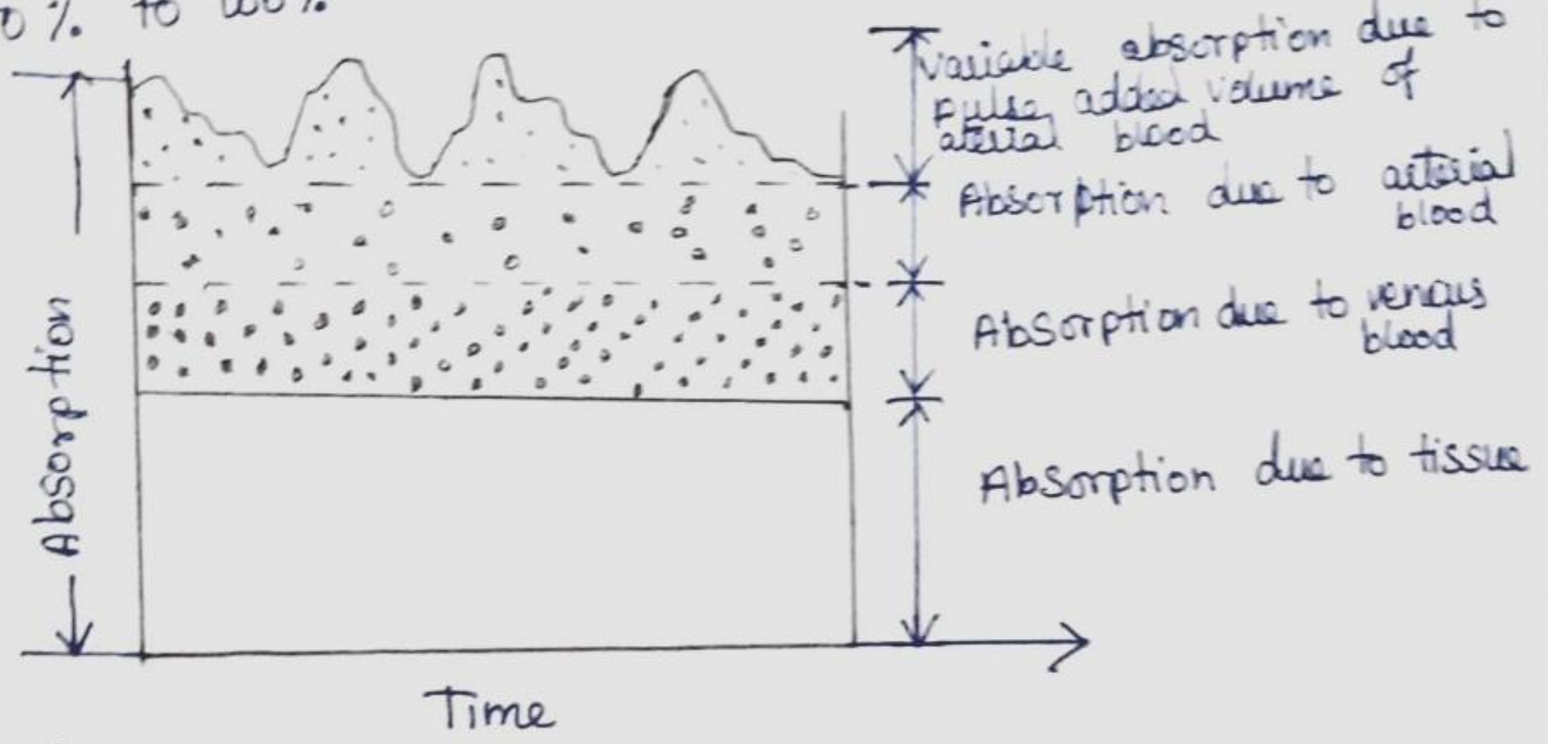
The stratum corneum is the non-living, out layer of the skin. It is composed of a supple, protective layer of dehydrated cells.

The non-vascular epidermis layer is a living tissue underneath the stratum corneum. It consists of proteins, lipids, and the melanin forming cells that gives skin its color. Average thickness is 0.1 to 0.2mm.

Dense connective tissue, hair follicles, sweat glands, nerve endings, fat cells and a profuse approximately 200 to 400 μm in length provide nutrients for the upper layers of the skin. Blood is supplied to those capillaries by arterioles that form of a flat network parallel to the surface of the skin below the dermis.

pulse oximetry

This instrument determines SO_2 by analyzing the time varying, or ac, components of the light transmitted through the skin during the systolic phase of the blood flow in the tissue. This approach achieves measurements of the arterial oxygen with only two wavelengths (660 and 940nm, for instance). The dc component of the transmitted light, which represents light absorption by the skin pigments and other tissues, is used to normalize the ac signals. A transcutaneous reflectance oximeter based on a similar photoplethysmographic technique has been developed. Non-invasive measurements of SO_2 can be made with 2.5% accuracy of saturation values from 50% to 100%.



Transcutaneous SO_2 sensor

The basic transcutaneous SO_2 sensor for both the transmission and the reflective mode, make use of a light source and a photodiode. In the transmission mode, the face each other and a segment of the body is interposed. In the reflection mode, the light source and photodiode are mounted adjacent to each other on the surface of the body.

The transmission sensor are placed on the finger tips, toes, ear lobes, or nose. A pair of red and infrared light-emitting diodes are used for the light source, with peak emission wavelengths of 660 nm

(red) and 940 nm (infrared). These detect signals are processed, in the form of transmission photoplethysmograms, by the oximeter, which determines the SO_2.

$tcpO_2$ monitoring

This is similar in ~~to the~~ principle to the conventional in vitro pO_2 determination. A clark electrode is used in a sensor unit that is placed in contact with the skin.

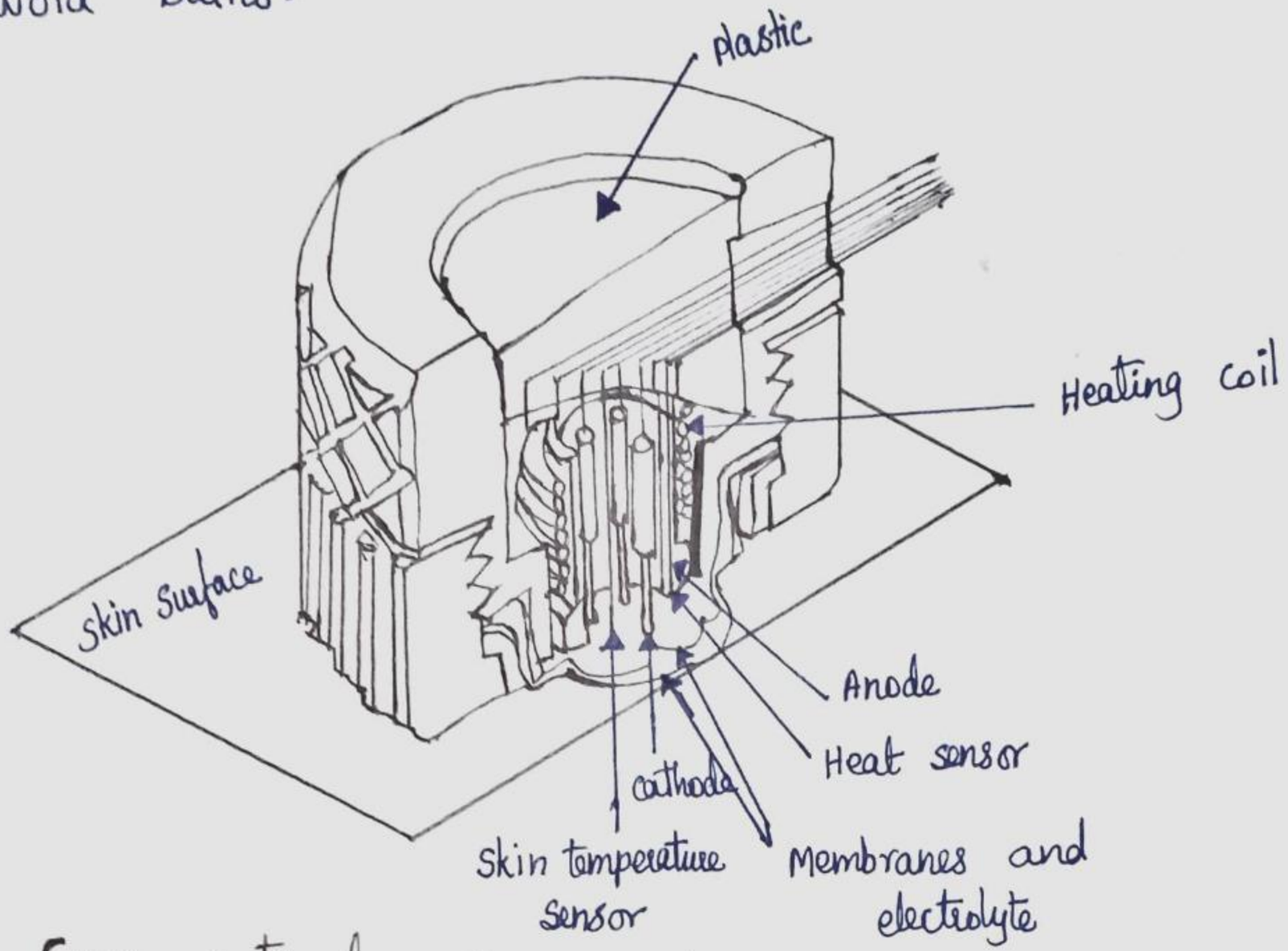
2 known gas mixtures are required to calibrate the sensor, because the relationship between O_2 dependent current and PO_2 is linear. Two calibration procedures are commonly used. One employs two precision medical gas mixtures, such as nitrogen and oxygen. The other employs sodium sulfite, which is a "zero O_2 solution", and ambient air. ~~Room~~.

Transcutaneous pO_2 Sensor

In this sensor three-sealed pt cathodes are separately connected via current amplifier to an Ag/AgCl anode during storage, is used to provide a medium in which the chemical reactions can occur. Under normal physiological condition. The PO_2 at the skin surface is essentially atmospheric regardless of the PO_2 is the underlying tissue.

Hyperemia can be induced by the administration of certain drugs, by the heating or abrasion of the skin, or by the application of nicotinic acid cream. Because heating gives the most readily controllable and consistent effect, a heating element and a thermistor sensor are used to control the sink temperature beneath the $tcpO_2$ sensor. Sufficient arterialization results when

the skin is heated to temperatures between 43°C and 44°C. These temperatures cause minimal skin damage, but with neonates it is necessary to reposition the sensor frequently to avoid burns.



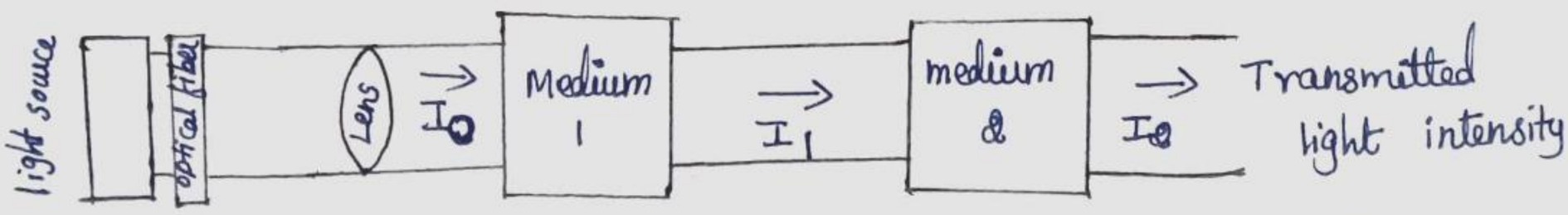
Cross-sectional view of transcutaneous oxygen sensor.
· Heating promotes arterialization

Colorimeters

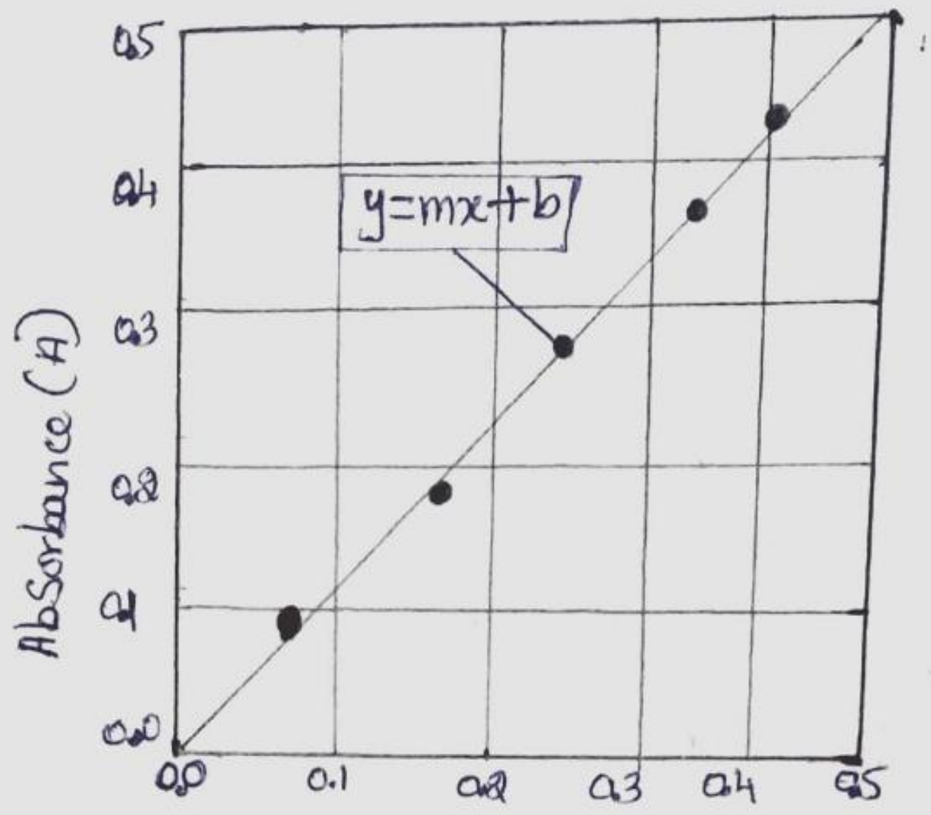
Measures the color concentration of a substance in a solution by detecting the color light intensity passing through a sample containing the substance and a reagent.

Optical color filters are used to detect the color wavelength of interest. E.g., urine passes yellow light and absorbs blue and green.

Laser LEDs are preferred if their wavelength is suitable due to purity of the monochromatic color.



Absorbance Vs concentration



Transmittance

$$T = \frac{I_1}{I_0} * 100\%$$

Absorbance

$$A = -\log \frac{I_1}{I_0}$$

$$A = \log \frac{1}{T}$$

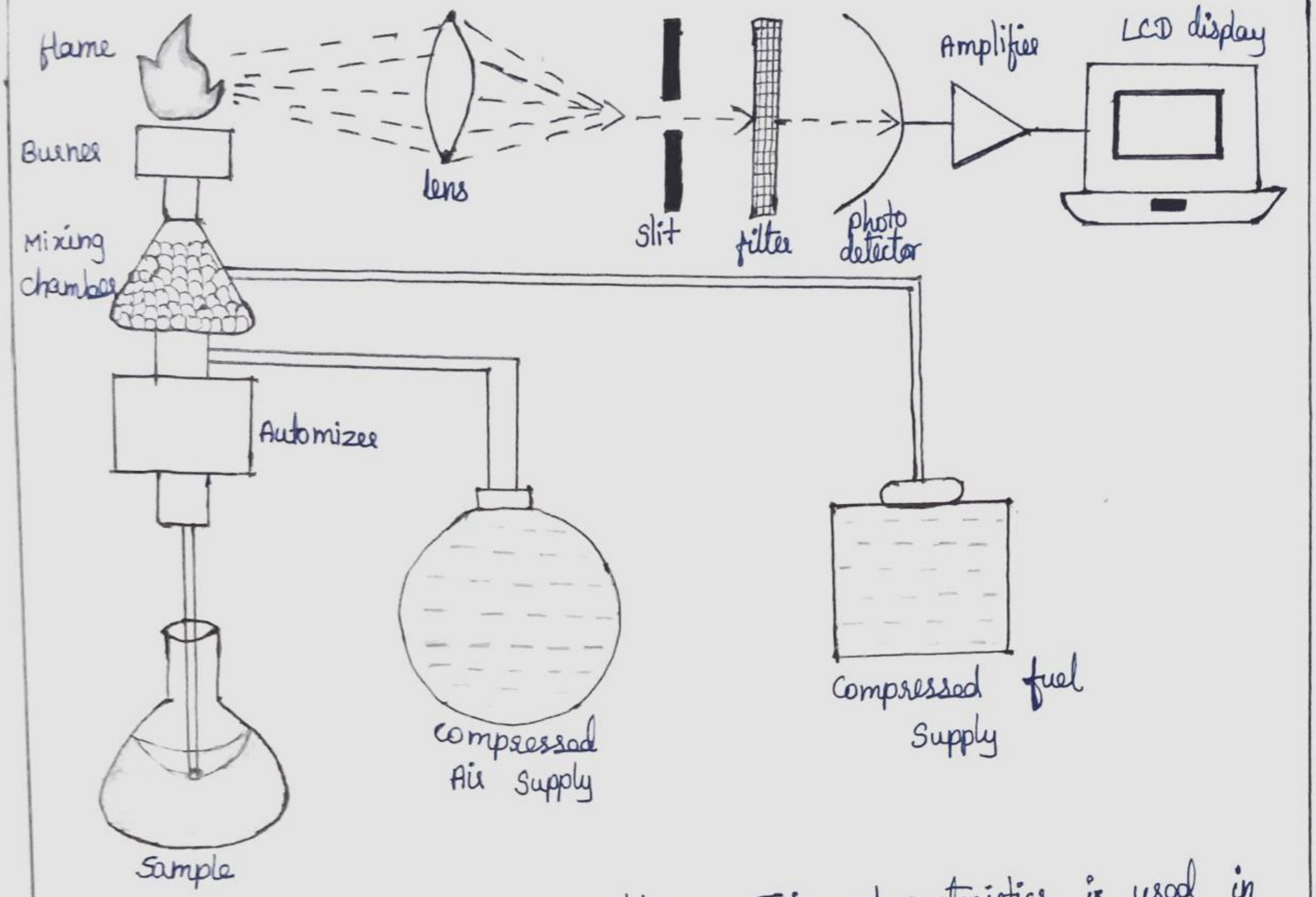
If the path length or concentration increases, the transmittance decreases and absorbance increases, a phenomenon expressed by Beer's law. Absorbtivity related to the nature of the $A = aCL$ absorbing substance and optical wavelength (known for a standard solution concentration).

C : concentration

L : Cuvette path length

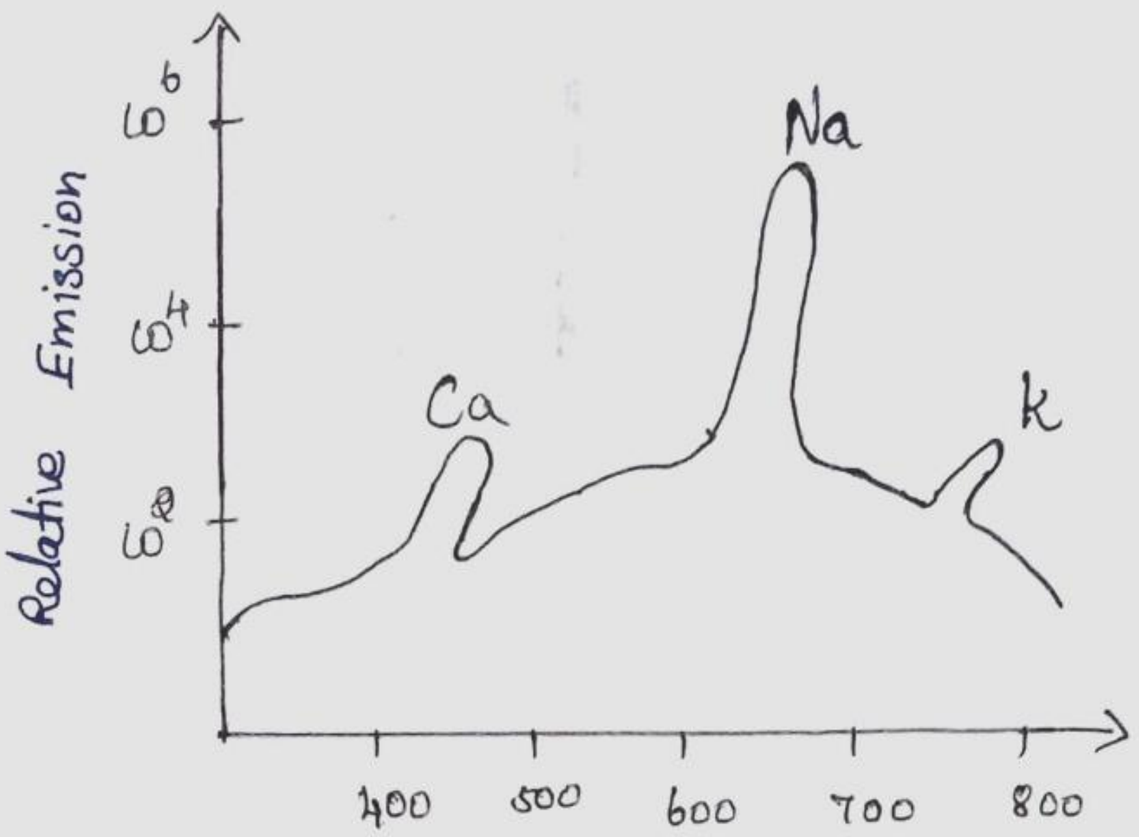
Sodium and potassium analyzer (or) Flame photometer

A flame photometer is used in order to determine the concentration of potassium (K), sodium (Na), Calcium (Ca) and lithium. It is used in the analysis of blood or urine. Here lithium is used as calibration substance. A colourless flame appers flow yellow for sodium and violet for potassium. When these solutions are



aspiration into the flame. This characteristics is used in flame photometer.

In this method, fine droplets of the sample is aspirated into a gas flame that burns in a chimney. A known amount of lithium salt is added to the sample, as a refesence. As a result, red light is emitted by the lithium and yellow and violet beam are emitted due to sodium and potassium respectively. These diffracted colours are made to incident on photodiodes. These photodetector circuit consists of a reverse biased diode in which the current flow incases and the intensity of incident light increases. A calibration potentio -meter is used in every channel. Since the lithium is used as a standard reference, the output of sodium and potassium channel are calibrated in terms of differences with the known lithium. The output can be compared with spectral illustration.



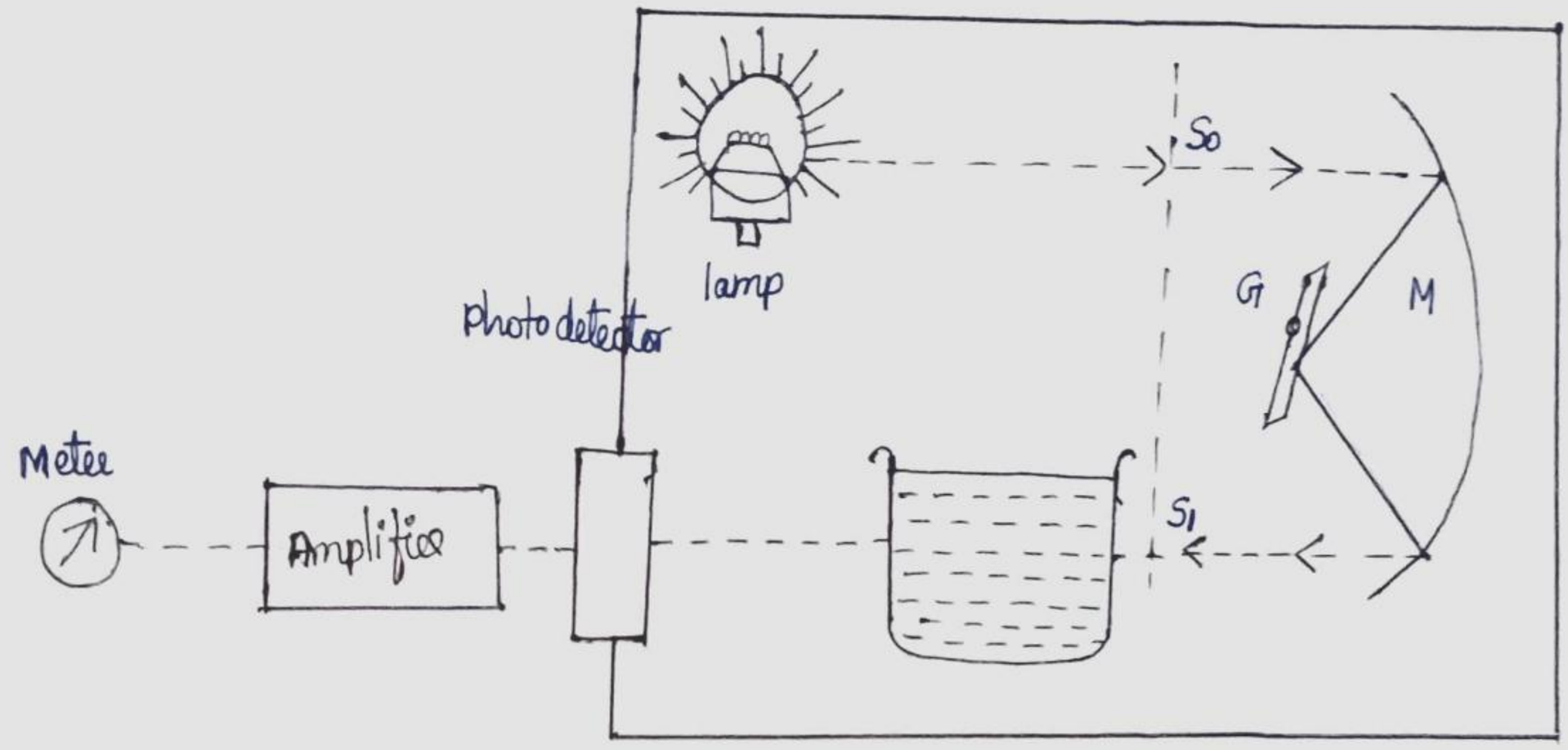
Spectrophotometer

A Spectrophotometer is an instrument which isolates monochroma-tic radiation in a more efficient and versatile manner than colour filters used in filter photometers. In these instruments, light from the source is made into a parallel beam and passed to prism or diffraction grating, where light of different wavelength is dispersed at different angles.

Block diagram of Spectrophotometer:

In spectrophotometer, selection filter of colorimeter is replaced by a monochromotor.

Monochromotor uses a diffraction grating (G) or a prism to disperse light from the lamp. Light falls through the slit so into its spectral components. Split S_1 is used for selecting a narrow band of the Spectrum which is used to measure the absorption of a sample in the cuvette. The light from the cuvette is given to photodetector. It converts light into correct only electrical signal. This electrical signal is amplified by using an amplifier. The output from the amplifier is given to meter which shows absorbance. Light absorption is varied when the wavelength is varied. Mirror M is used to reduct the size of the instrument.



So , S_1 = Split

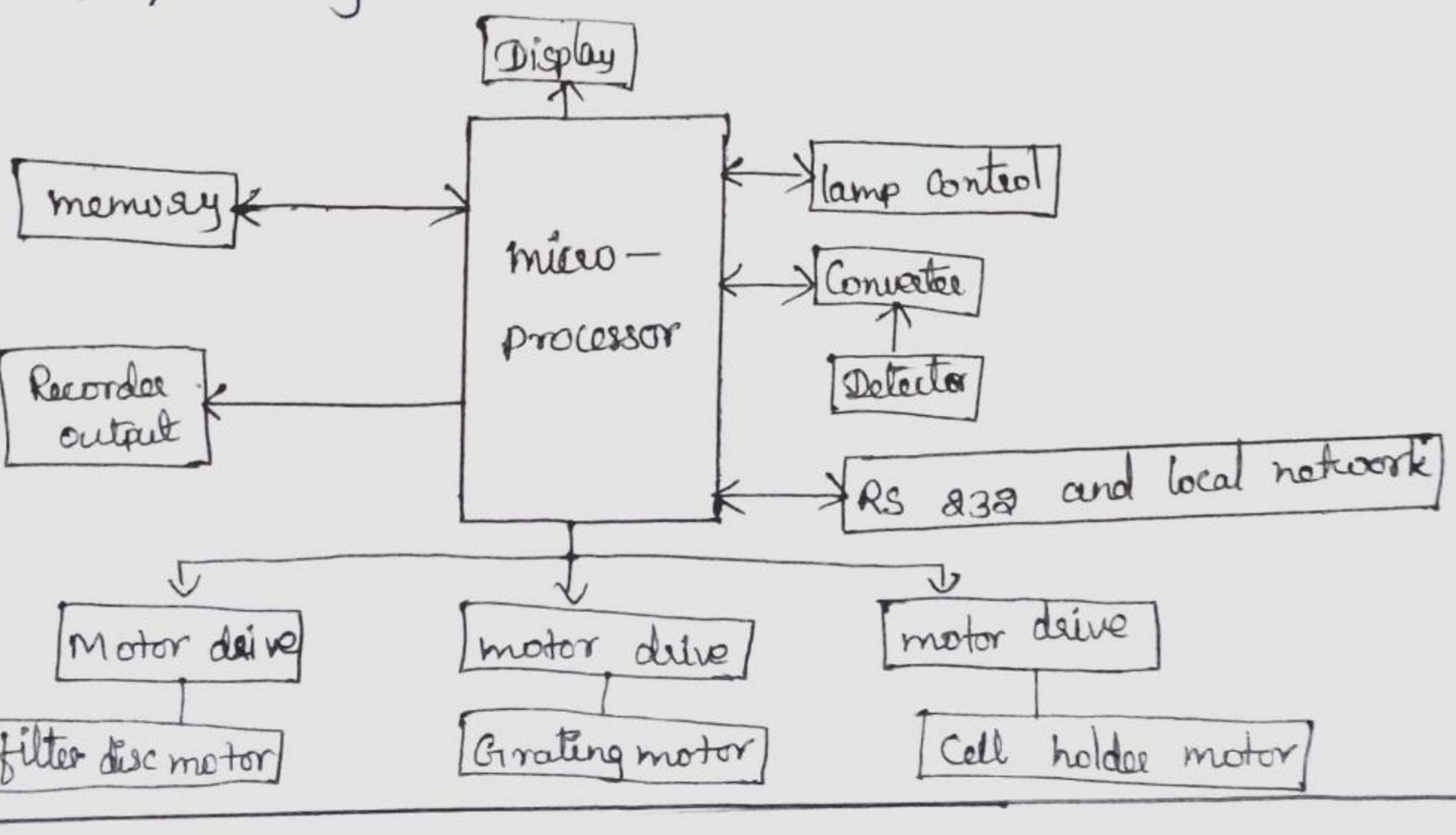
M = mirror

G = Grating

Microprocessor based Spectrophotometer :

A microprocessor, in a spectrophotometer, could be used for the following functions:

* Control functions: Wavelength scanning, automatic light source selection, control of slitwidth, detector sensitivity, etc.
* Signal processing functions: Baseline correction, signal smoothing, calculation of %T, absorbance and concentration, derivative, etc.
* Communication functions: keyboard entry, menu-driven operations, data presentation, warning display, communication with external systems, etc.



Any filters introduced at appropriate points and sample and reference cells are correctly managed in the sample area. Output in the desired form (transmittance, absorbance, concentration, etc.) is presented along with the sample identification. Secondary routines such as wavelength calibration and self-tests become available on demand.

For wavelength scanning, a stepper motor is used, which ensures accurate and fast scanning.

The signal from the photodetector is amplified in a preamplifier and converted into digital form in an A-D converter. The signals are differentiated into Sample signal S, reference signal R and zero signal Z and stored in the memory. From these values, the microprocessor calculates the transmittance $T = (S-Z/R-Z)$ and absorbance $= -\log T$. In order to obtain R or S values within a specified range, the microprocessor provides control signals for slit-width and high voltage for the photomultiplier.

The digital output from the microprocessor is converted into analog form with a D-A converter and given to an X-Y recorder as the Y-axis signal, whereas the wavelength forms the X-axis, to obtain absorption or reflected spectra.

Blood cell counter

Types of blood cells:

i) Red blood cells (RBC)
ii) White blood cells (WBC)
iii) Blood platelets (Thrombocytes)

i) Red blood cells

* They are round disks with a diameter of about 8 μm.
* One cubic millimeter of blood contains about 4.5 to 5.5 million RBC's.
* It binds the oxygen molecules to the haemoglobin and transports oxygen through the blood.

ii) white blood cells [WBC] :

i) It has an average diameter of 10 μm.

ii) It has cell nucleus.

iii) One cubic multimeter of blood Contains 6000 to 10000 WBC's.

iv) It helps to maintain the immune system of the body and fight against the anti-bodies.

iii) Blood platelets :

i) They have the diameter about 2 to 4 μm.

ii) One cubic millimeter of blood contains 200,00-8,00,000 number of platelets.

iii) The blood clothing mechanism prevents the loss of blood during.

Types of blood cell Counter

i) Hematocrit determination

ii) manuel method

iii) Conductivity method

iv) Laser based cell Counter

i) Hematocrit determination

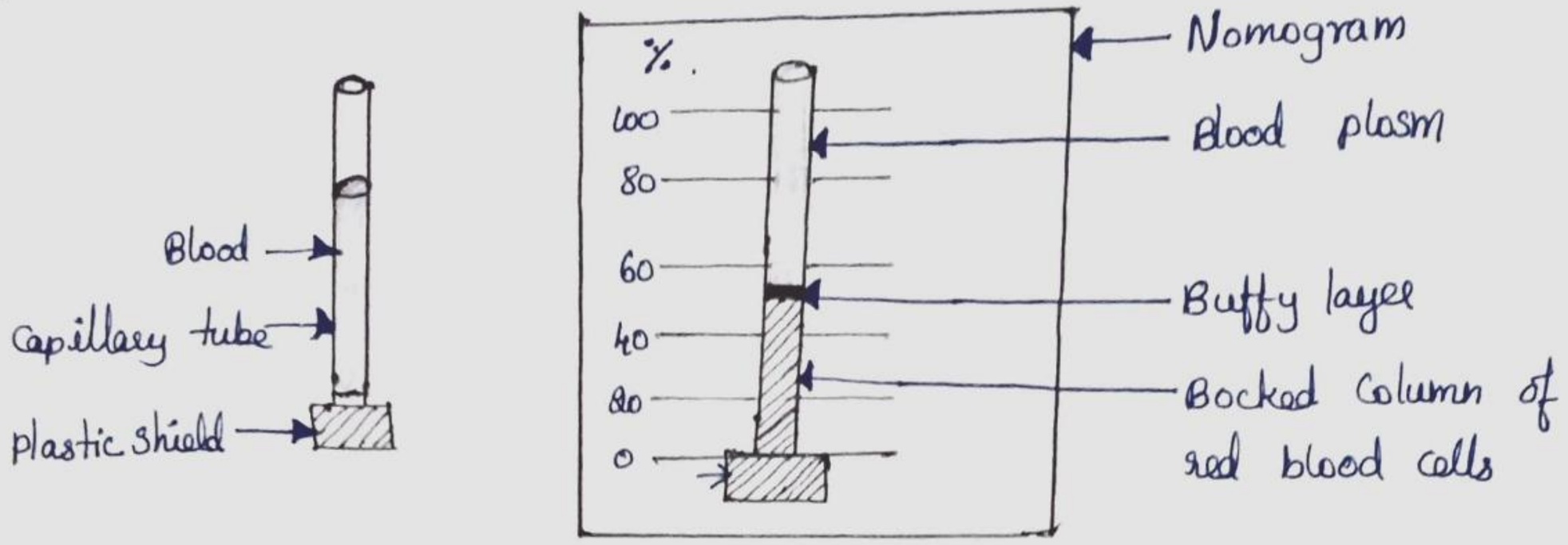
To determine the relative proportion of blood cells in a given volume of blood hematocrit or packaged cell volume is used.

A blood sample is tracker into a capillary tube and one end of the tube in sealed with plastic material. The tube is then spun (rotated) with the help of a high speed centrifuge to separate the blood cells from plasma. From the tube, the blood and the cell volumes can be compared by measuring the length of the columns.

This is made with the help of nomogram/graph to show the readings). When the capillary tube is lined up with the blood column, the nomogram gives the direct reading of the hematocrit.

The red blood cells have high electrical resistivity that the

blood plasma. Hence they settles at the bottom of the capillary tube. The haemoglobin concentration can be determined by destroying the membranes of the RBC. And then the haemoglobin is extracted.



ii) Manual method :

Blood cell Counts by manual method is performed by a microscope. At first the blood is diluted in the ratio of 1:100 or 1:200 for counting RBC's and in the ratio of 1:10 or 1:20 for WBC's The diluted blood is then bought to the counting chamber of 0.1 mm drop which is divided into a number of squares. It is magnified about 500 times and the number of cells present in particular square can be determined.

iii) Conductivity method (Coulter method) :

The sample solution is added to an electrolyte solution which is drawn through a small orifice.

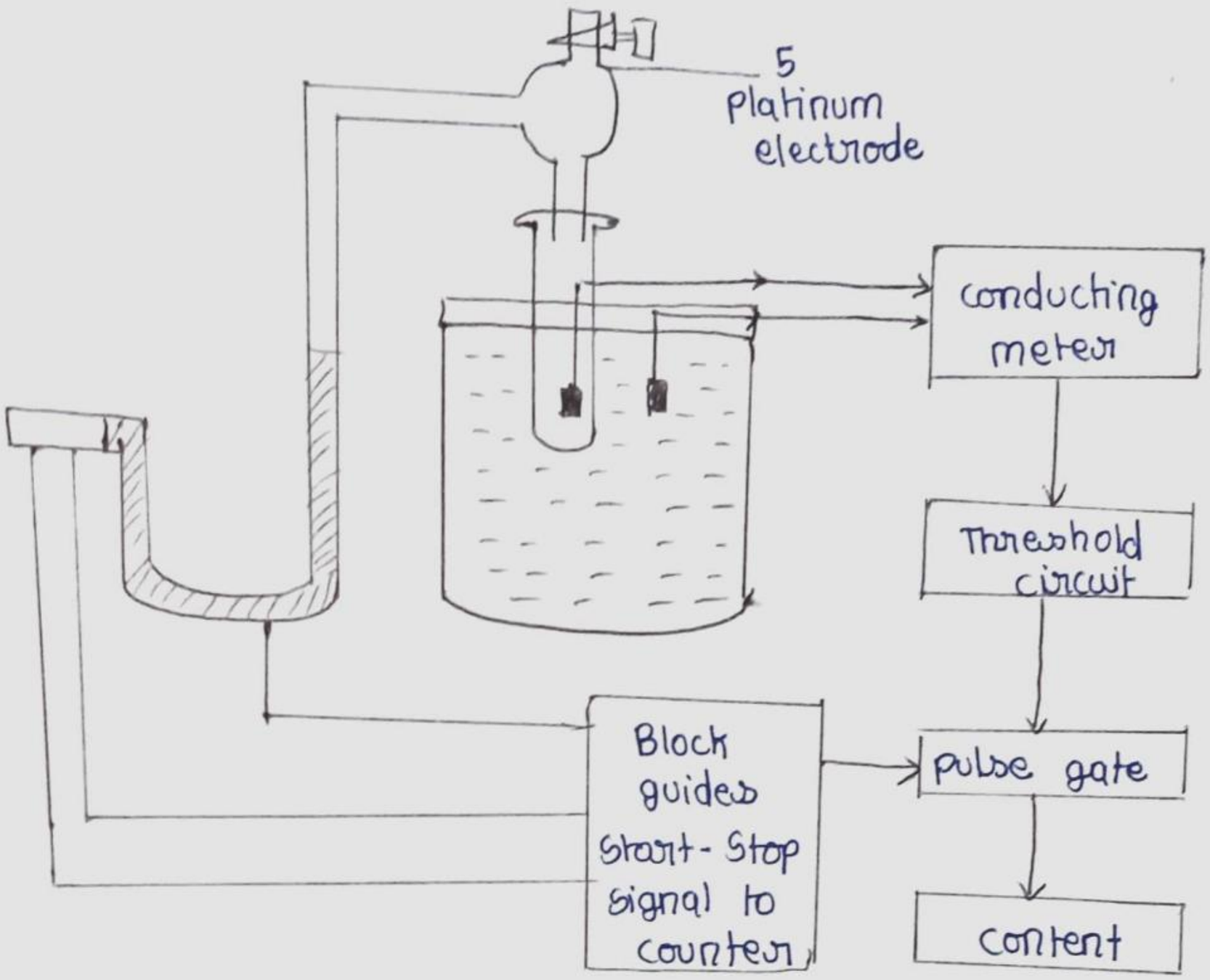
As particle passes through the orifice it displaces its own volume of electrolyte.

particle detected by the increases in electrical resistance.

Voltage pulses are proportional to the particle size.

particles below 0.2 μm can also be detected.

A number of pulses is equal to the number of cells counted and the strength of the signal (pulse hight) is directly proportional to the cell volume.

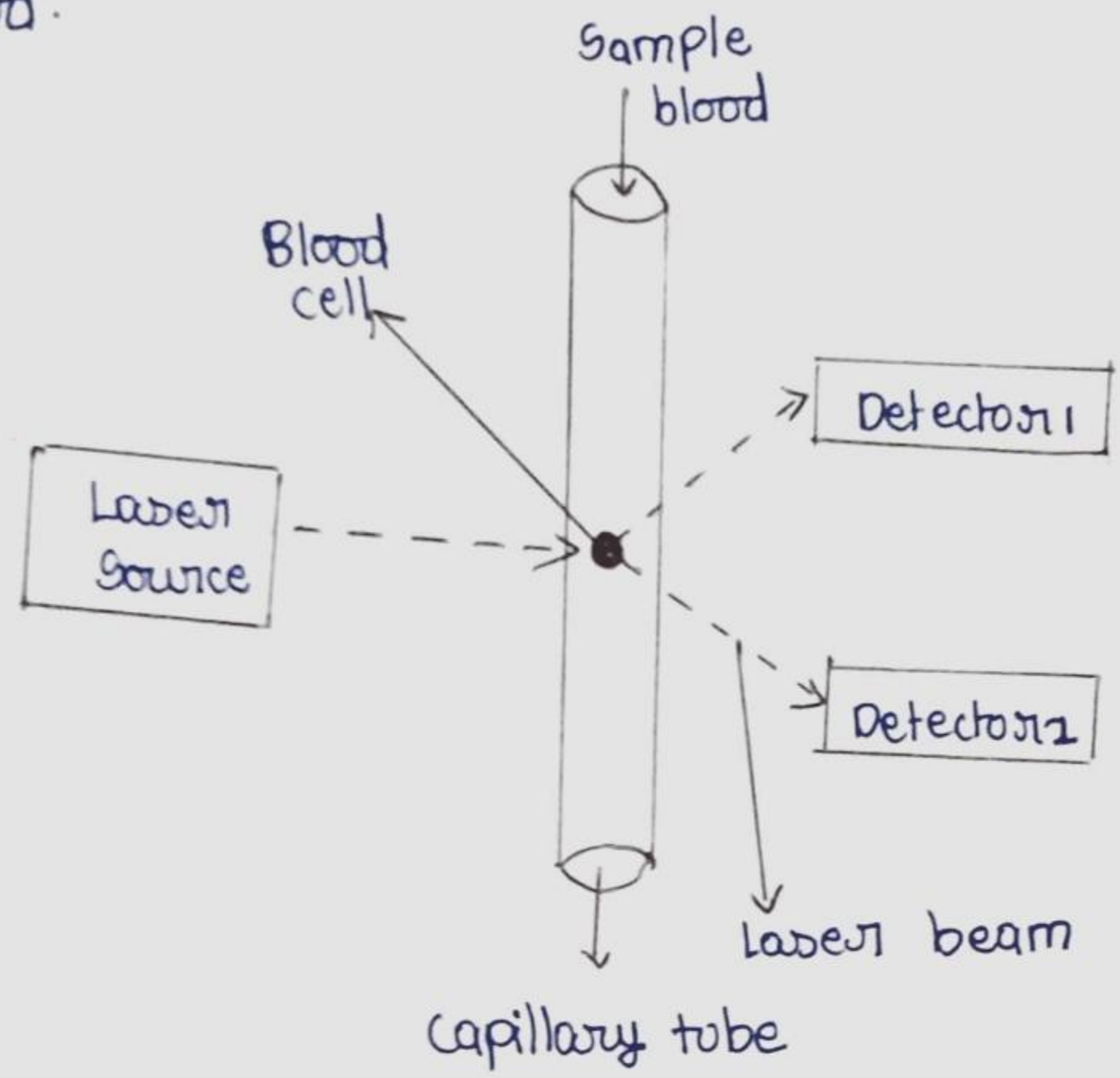


conductivity method

1. Surface
2. Electrode
3. First contact
4. Second contact
5. Section pump
6. Suction

Laser baser cell counting

This mordern techniques is used to determine the numbers of RBC's WBC's and platelets. This cell volume of the red blood cell and the haemoglobin concentration can also be obtained by this method.



Laser Based cell Counting

The principle used in this laser based blood cell counting is the angle of scattering light is different for different size blood cells. The blood is diluted and parsed through the capillary tube. The laser light is parsed through the glass tube and the blood cells in the tube scatter the light. The scattering angles of platelets and RBC are different.

They are detected by two different photodetectors the detectors are given the digital voltmeter which gives the density of blood cells and platelets. Lysing agent is used to destroy the RBCs and the WBC number can be determined. The haemoglobin concentration in the RBCs also can be measured by this method.

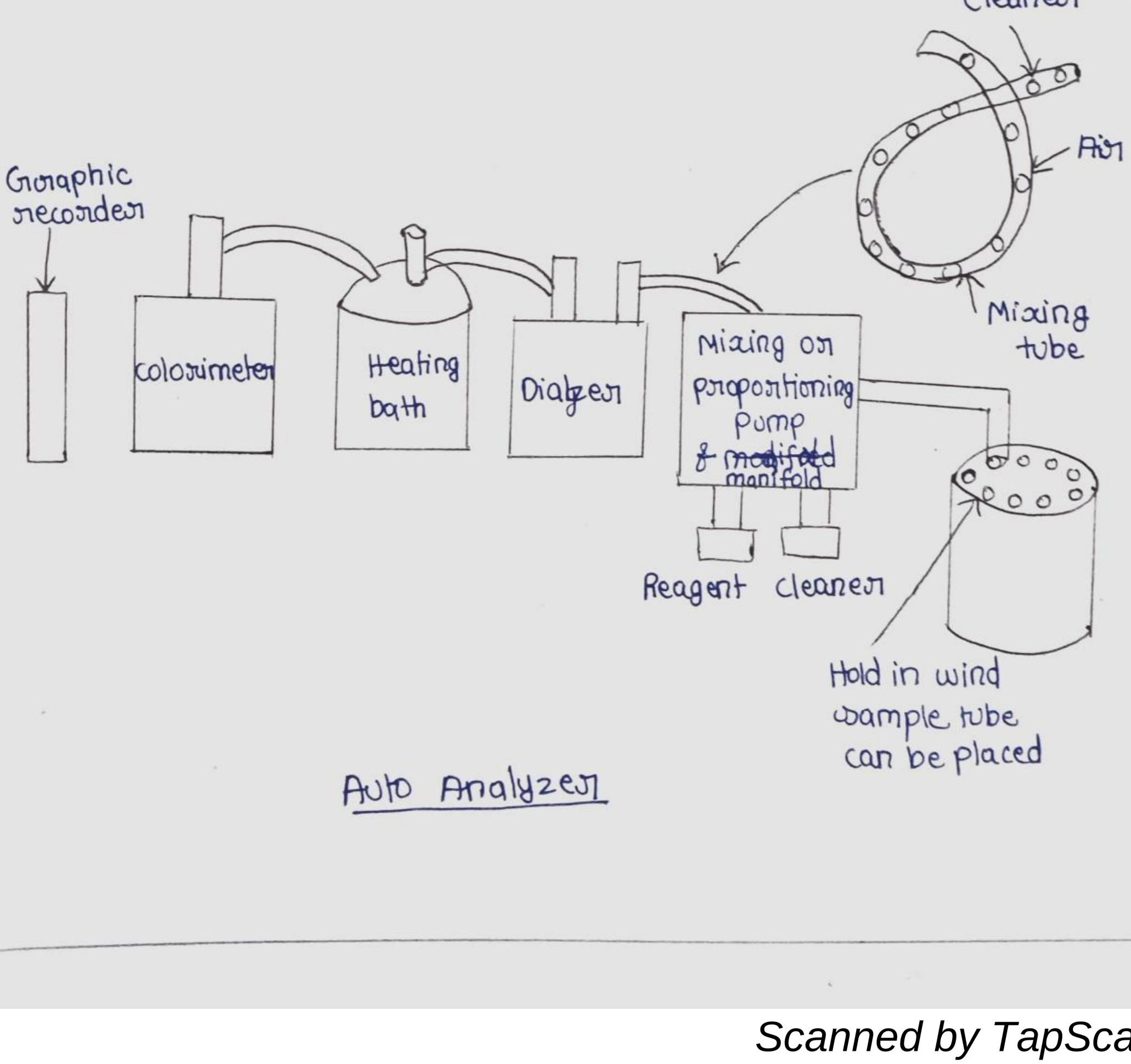
Auto Analyser

An auto analyzer sequentially measures blood chemistry through a series of steps of mixing reagent reaction and calorimeteric measurements.

It consist of

- Sampler : Aspirates samples, standards, wash solution into the system.
- Proportioning pump: Mixes samples with the reagent so that proper chemical color reaction can take place, which are then read by the colorimeter.
- Dialyzer : Seperates interfacing substances from the sample by premitting selective passage of sample components through a semi-permeable membrane.

- Heating bath : Controls temperature (typically at 37°C) as temp is critical in color development
- Colorimeter : monitors the change in optical density of the fluid stream flowing through a tubular flow cell. Color intensities is proportional to the substance concentrations are converted to equivalent electrical voltages.
- Recorder : Displays the output information in a graphical form.



Auto Analyzer