

## Unit - III

### SIGNAL CONDITIONING CIRCUITS:

① Need for Bio amplifier - differential bio amplifier - Impedance matching circuit - isolation amplifiers - Power line interference - Right leg driven ECG amplifier, Band Pass filtering.

① \* Need for Bio Amplifier :

\* Modern multi-channel biomedical instruments and recorders are usually modularly designed to meet both existing and anticipated requirements.

\* Conventional pre amplifiers offer a wide range of input sensitivities to cover virtually all signal sources.

\* for biophysical measurements, the amplifiers employed include :

i) ac/dc universal amplifier with special features such as capacity neutralization, current injection, low leakage current and low dc drift or to make extracellular recordings through metal microelectrodes for EMG, EEG, ECG, etc..

ii) an ECG amplifier with full 12 lead selection and patient isolation.

iii) A transducer amplifier suited for bridge measurements on strain gauges, strain gauge based blood pressure transducers, force transducers, resistance temperature devices and direct low level dc input signals.

iv) A dc amplifier used in conjunction with standard thermistor probes for the accurate measurement of temperature within the range of medical applications.

Various types of amplifiers which are generally used are  
as follows:

### Differential Amplifier:

\* It's one which will reject any common mode signal that appears simultaneously at both amplifier input terminals and amplifies only the voltage difference that appears across its input terminals.

\* Most of the amplifiers used for measuring bioelectric signals are of the differential type.

### Ac Coupled Amplifier:

\* Ac Coupled amplifiers have a limited frequency response and are, therefore, used only for special medical applications such as electrocardiograph machine.

\* For electrocardiograms, an Ac amplifier with a sensitivity, giving  $0.5 \text{ mV/cm}$ , and frequency response up to  $1 \text{ kHz}$  and an input impedance of  $2$  to  $5 \text{ MW}$  is used.

\* For such applications as retinography, EEG and EMG more sensitive Ac amplifiers are required, giving a chart sensitivity of  $50 \text{ mV/cm}$  with a high input impedance of over  $10 \text{ MW}$ .

### Carrier Amplifiers:

\* Carrier Amplifiers are used with transducers which require an external source of excitation.

\* They are characterized by high gain, negligible drift, extremely low noise and the ability to operate with resistive, inductive or capacitive type transducers.

\* They essentially contain a carrier oscillator, a bridge balance and calibration circuit, a high gain AC amplifier, a phase-sensitive detector and a DC output amplifier.

### DC Amplifiers:

\* DC Amplifiers are generally of the negative feedback type and are used for medium gain applications down to about 1mV signal levels for full scale.

\* (They are not practical for very low level applications because of DC drift and poor common-mode rejection capabilities)

\* They are usually employed as pen drive amplifiers in direct writing recorders.

### Chopper input DC Amplifiers:

\* Chopper input DC amplifiers are preferred for low level inputs to instrumentation systems.

\* Their high frequency response is limited to about one half of the input chopper frequency.

### Chopper Stabilized DC Amplifiers:

\* Chopper stabilized DC amplifiers are used for low level but preferably wideband applications such as oscilloscopes, tape recorders and light beam oscilloscope recorders.

\* This includes an AC amplifier for signals above about 20Hz, a DC chopper input amplifier for signals from about 20Hz down to DC plus a wideband feedback stabilized DC amplifier.



## DC Bridge Amplifiers:

\* DC Bridge amplifiers are employed with resistive transducers which require an external source of excitation.

\* They can be used as conventional dc high gain amplifiers and offer operating simplicity & high frequency response.

\* These amplifiers are necessary for transducers used to measure temperature and blood pressure.

\* The sensitivity in these cases may be  $50\text{mV/cm}$  with an input impedance of  $50\text{k}\Omega$ .

② Arrangement

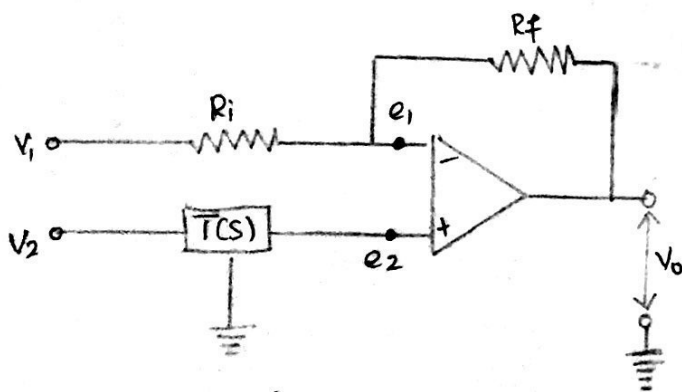
## Differential Bio Amplifier:

Assuming a network with a transfer function  $T(s)$  between  $V_2$  and the noninverting terminal. The voltage existing at the input terminal 2 as

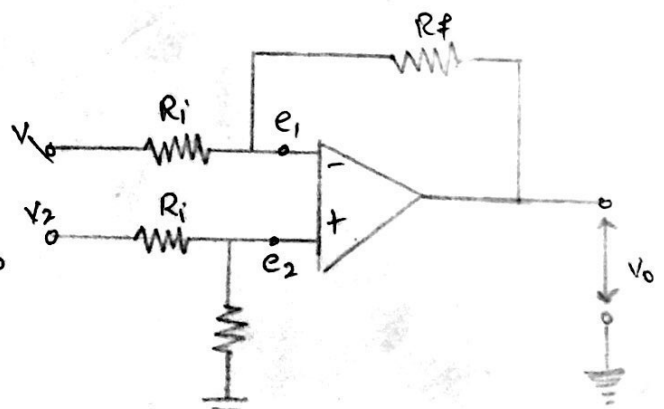
$$e_2 = T(s) V_2.$$

The input current to the ideal amplifier is zero & by the principle of superposition, the voltage existing at the input terminal 1 as.

$$e_1 = \frac{R_f}{R_i + R_f} V_1 + \frac{R_i}{R_f + R_i} V_0.$$



Differential Amplifier



Simple Differential Amplifier.



\* Since the potential difference between the two input terminals of the ideal amplifier is forced to zero by the feedback through  $R_f$ , the voltage  $e_1$  must be equal to  $e_2$ .

$$\therefore -\frac{R_f}{R_i + R_f} V_1 + \frac{R_i}{R_f + R_i} V_0 = T(s) V_2$$

(or)

$$V_0 = \frac{R_f + R_i}{R_i} T(s) V_2 - \frac{R_f}{R_i} V_1$$

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

$$V_0 = \frac{R_f}{R_i} (V_2 - V_1)$$

\* Thus the circuit amplifies the difference of the input signals  $V_1$  and  $V_2$ . There is no virtual ground to the input to the amplifier in this circuit.

\* The feedback in the circuit forces  $e_1$  to be equal to  $e_2$ .

### Different modes of operation of the differential amplifier

#### a) Single ended mode:

\* when either  $V_1$  or  $V_2$  is equal to zero, the operation of the differential amplifier is known as single ended mode of operation.

\* If  $V_1 = 0$  the differential amplifier is operating in the non inverting mode and if  $V_2 = 0$ , it is operating in the inverting mode.

b) Differential mode:

\* In this mode, the two input signals are equal but have opposite polarity at every instant of time.  $\therefore V_1 = -V_2 = V_D$ .

$$V_0 = \frac{R_f}{R_i} (V_2 - V_1) \text{ (or) } V_0 = \frac{2R_f}{R_i} V_D$$

Input signals are called differential mode signals.

c) Common Mode:

\* The input voltages appearing at the input terminals 1 and 2 are identical both in amplitude and phase at every instant of time. These input signals are called common mode signals.

$$V_1 = V_2 = V_{cm}$$

$$\therefore V_0 = 0$$

\* Thus the common mode input signals produce no voltage at the output of the ideal amplifier.

Common Mode Rejection in a differential Amplifier:

\* The ability of the differential amplifier circuit to ignore the common mode inputs like 50Hz interference from mains is known as Common mode Rejection (CMR).

\* CMR is the important characteristics of medical amplifier because it prevents response to stray radiation from the power lines or from other electrical equipment in the vicinity.

(i.e)  $CMRR = \frac{\text{amplification of the differential Voltage}}{\text{amplification of Common mode Voltage}}$

$$= \frac{A_d}{A_c} \frac{|V_{out}| \text{ when } V_2 \text{ is grounded}}{|V_{out}| \text{ when } V_2 = 1}$$

\* A CMRR of 100,000 : 1 means that the common mode signal is discriminated against the differential signal by the ratio of 100,000 to 1

Common mode rejection in dB =  $20 \log_{10} \text{CMRR}$ .

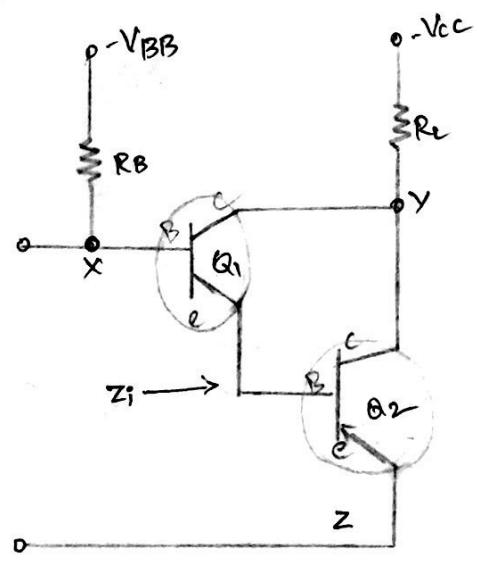
\* Thus a CMRR of 100,000 : 1 can be referred to as a CMRR of 100db.

③ Isolation Amplifiers: Arrangement.

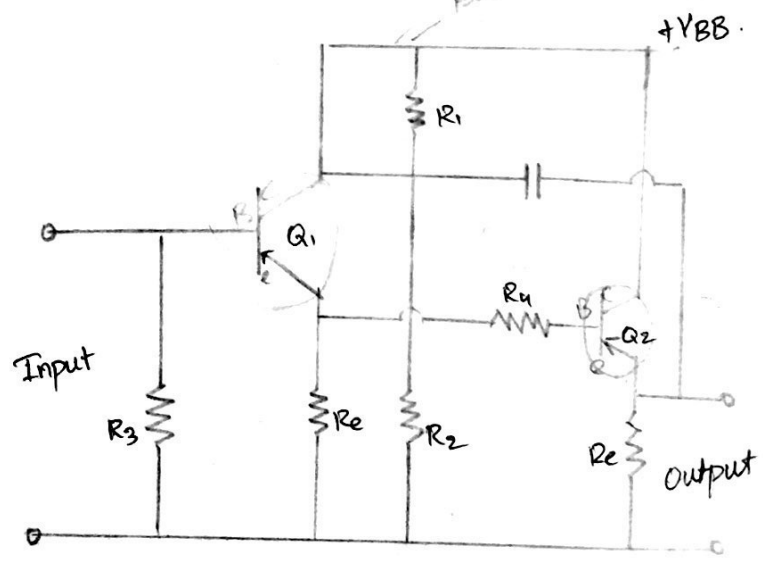
\* Generally isolation amplifiers are called pre-amplifier isolation circuits. They are used to increase the input impedance of monitoring system in order to isolate the patient from the biomedical instrument.

\* The patient must be isolated because of most monitors are line operated.

$Z_i = \beta^2 Z_o$



Darlington Pair



Bootstrapping circuit.

Darlington Pair is an isolation amplifier which provides high input impedance with high current gain.

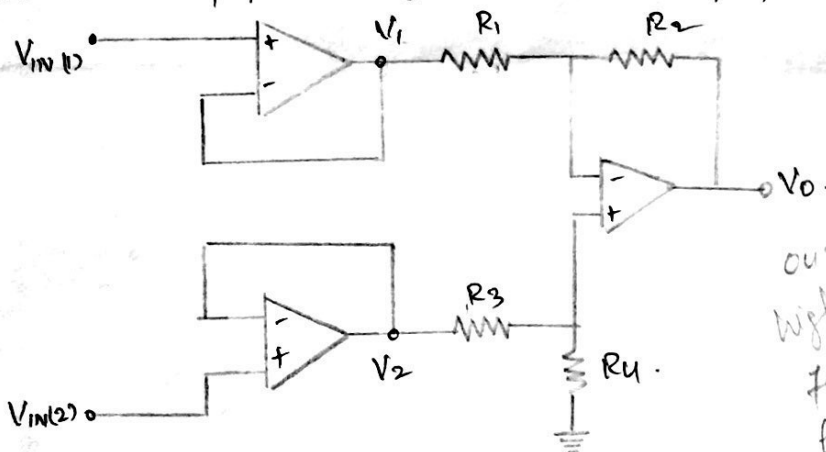
\* Two transistors Q1 & Q2 are connected in common emitter compound connecting circuits.



↓ The emitter terminals of transistor  $Q_1$  is directly connected to the base of transistor  $Q_2$ . The collector of both transistor share a common load  $R_L$ . Since the transistor  $Q_2$  is the common leg of the transistor  $Q_1$ .

\* Resistance  $R_B$  is chosen so that both stages are operating in the active region of their collector characteristics X, Y and Z are three external terminals to the two transistors.

Bootstrapping circuit is also used as isolation amplifier. In the cascade emitter follower circuit, a feedback network may be connected between the emitter of the second transistor  $Q_2$  & collector of the first transistor. Isolation Amplifier using operational Amplifier.



our aim is to get high input impedance for differential amp for better isolation.

In the differential amplifier

If  $\frac{R_2}{R_1} = \frac{R_4}{R_3}$  then

$$V_0 = \frac{R_2}{R_1} (V_2 - V_1)$$

### ECG Isolation Amplifier Circuit:

\* It shows block diagram of the transformer.

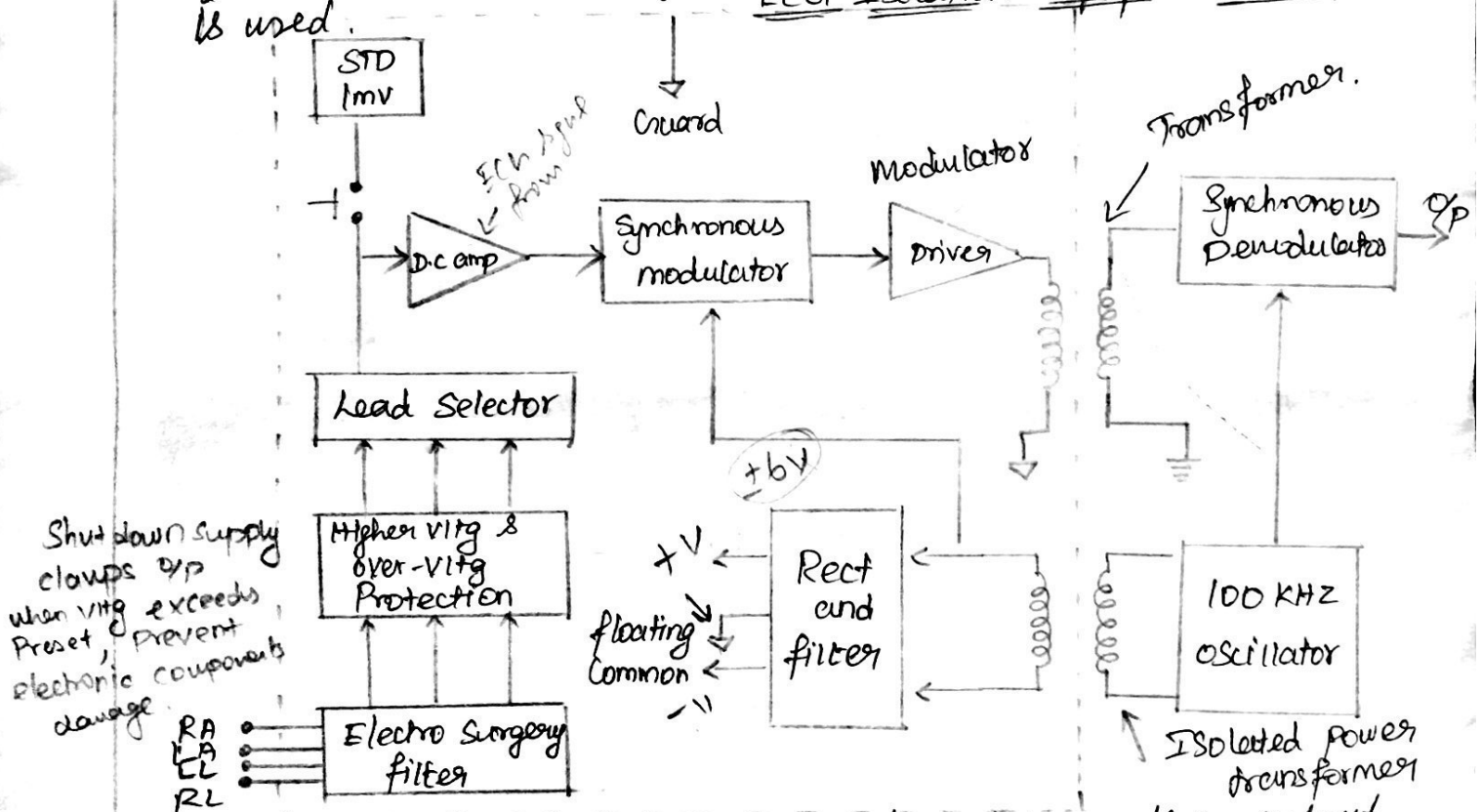
Coupled ECG isolation amplifier circuit. The signals from the different leads are given to the low pass filter having

a cut off frequency about 10kHz.

\* The filter circuit is followed by high voltage and over voltage protection circuits so that the amplifier can withstand large voltages during defibrillation.

↓ The dc amplifiers can also receive a standard dc voltage of 1mv through a push button for calibration.

\* The primary of an isolated low capacitance power transformer along with the rectifier & filter circuits is used.



\* Another transformer is used to deliver the output from the driver of the modulator. The output of the demodulator is used as the input of the power amplifier.

\* The available isolation amplifier having a curve of 115 dB with a common mode impedance as 10<sup>11</sup> ohms.

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Three methods are used in the design of isolation amplifiers

- 1) transformer Isolation
- 2) optical Isolation.
- 3) capacitive Isolation.

(x)

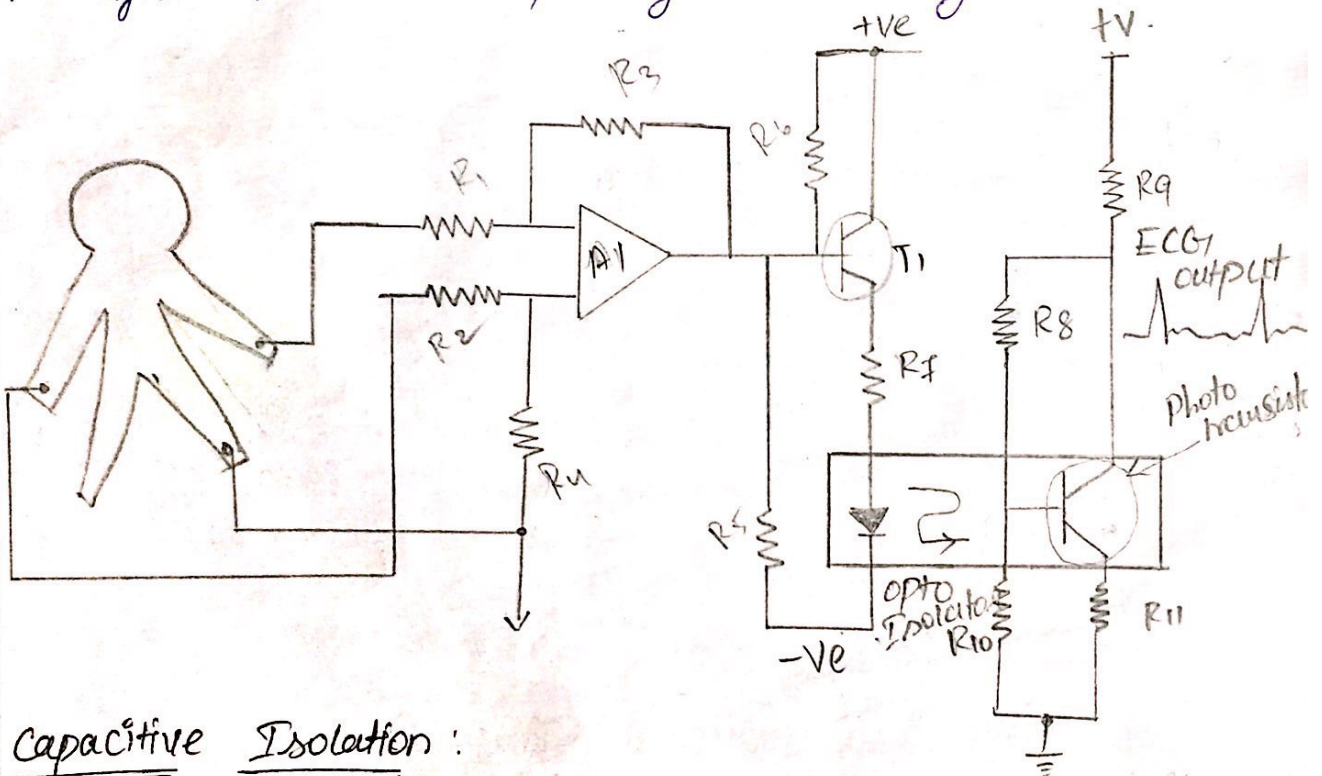
optical Isolation - transfers electrical signals b/w 2 isolated ckt by using light.

\* Isolation could also be achieved by optical means in which the patient is electrically connected with neither the hospital line nor the ground line.

\* The light falls on a phototransistor on the output side, which converts the light signal again into electrical signal.

Separate battery - supplied power to patient ckt  
Hg which converted into light (LED)

\* No modulator/demodulator is needed because the signal transmitted optically all the way.



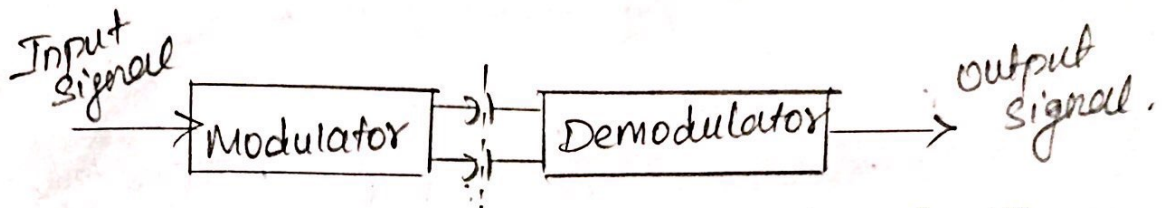
Capacitive Isolation:

\* The capacitive method uses digital encoding of the input voltage and frequency modulation to send the signal across a differential capacitive barrier.



\* Separate power supply is needed on both sides of the barrier.

\* Signals with bandwidth up to 70kHz can be conveniently handled in this arrangement.



Capacitively coupled isolation Amplifier

Relative merits of the three types of isolation techniques are:

\* All three types are in common use, through the transformer isolation amplifier is more popular.

- opto coupled Amplifier uses minimum number of components & is cost effective followed by transformer coupled amplifier,

- Capacitor coupled is most expensive.

\* opto isolated amplifier - lowest isolation voltage (800V continuous) b/w between input & output.

- Transformer coupled 1200V.

- Capacitive Coupled 2200V.

\* Isolation resistance levels order of  $10^{10}$ ,  $10^{12}$  &  $10^{13}\Omega$  for transformer coupled, opto coupled, Capacitance coupled.

\* Circuit stability & linearity - best for capacitance coupled - 0.005%.

- On par for the transformer

- opto-coupled - 0.02%.

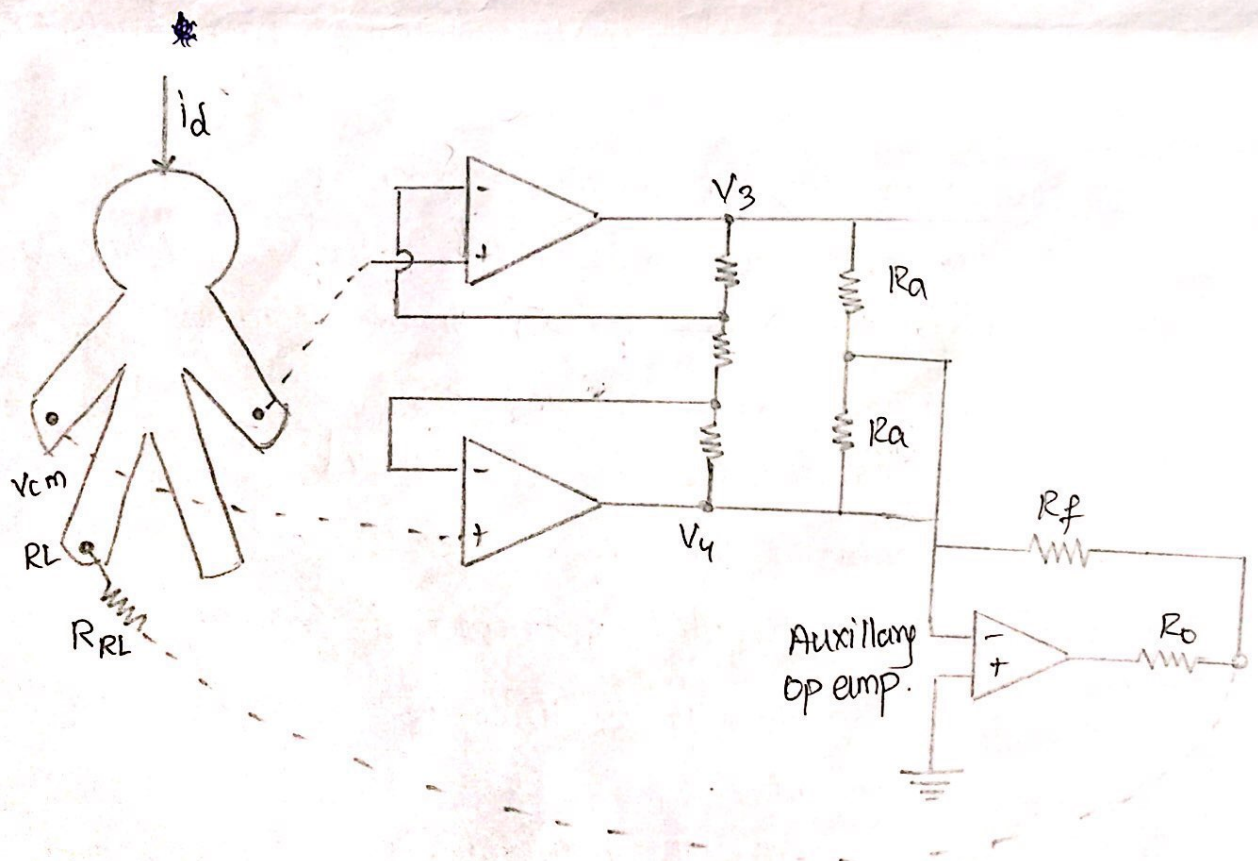


#### ④ Right leg Driven ECG Amplifier!

In many modern electrocardiographic systems, the patient is not grounded at all. Instead the right leg electrode is connected to the output of an auxiliary op amp.

\* The common mode voltage on the body is sensed by two two averaging resistors  $R_a$ , inverted, amplified and fed back to the right leg. This negative feedback drives the common-mode voltage to a low value.

\* The body's displacement current flows not to ground but rather to the op-amp output circuit. This reduces the pickup as far as the ECG Amplifier is concerned and effectively grounds the patient.



\* The circuit can also provide some electric safety. If an abnormally high voltage should appear between the



Patient and ground as a result of electric leakage.

\* This effectively ungrounds the patient, because the amplifier can no longer drive the Right leg. Now the Parallel resistances  $R_i$  and  $R_o$  are between the patient and ground.

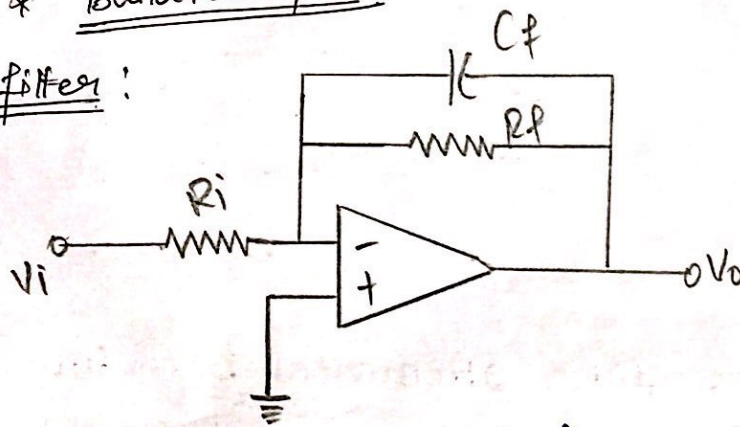
\* They can be several megohms in value - large enough to limit the current. These resistances do not protect the patient, because 120V on the patient would break down the op-amp transistors of the ECG amplifier, and large currents would flow to ground.

### ⑤ Band Pass Filtering :-

The Active filters are

- \* Low - Pass filter
- \* High - Pass filter.
- \* Band Pass filter

#### Low - Pass filter :



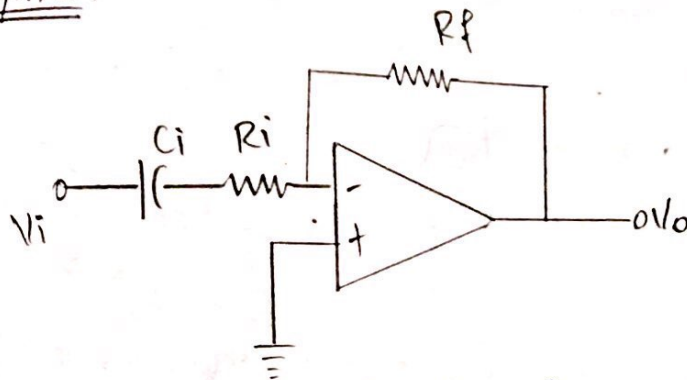
low pass filter attenuates high frequencies.

\* It shows a low-pass filter that is useful for attenuating high frequency noise. A low-pass active filter can be obtained by using the one op-amp circuit.

\* The advantages of this circuit are that it is capable of gain and that it has a very low output impedance.



## High-Pass filter :

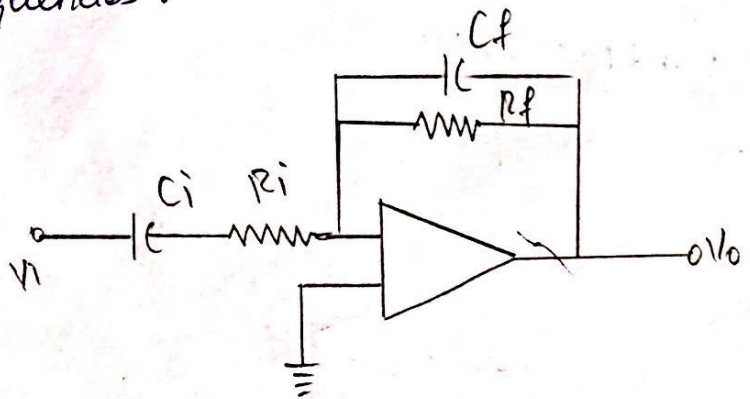


High pass filter attenuates low frequencies and blocks dc

\* It shows a one-op-amp high-pass filter. Such a circuit is useful for amplifying a small ac voltage that rides on top of a large dc voltage, because  $C_i$  blocks the dc.

## Bandpass filter :-

\* A series combination of the low-pass filter and the high-pass filter results in a bandpass filter, which amplifies frequencies over a desired range and attenuates higher and lower frequencies.



A bandpass filter attenuates both low and high frequencies.

\* It shows that the bandpass function can be achieved with one -op-amp. The corner frequencies are defined by the same relations as those for the lowpass and the high-pass filters.

\* This circuit is useful for amplifying a certain band of frequencies, such as those required for recording heart sounds or the electrocardiogram.



## ⑥ Power Line Interference :

### Interference from electric Devices :

\* A major source of interference when one is recording or monitoring the ECG is the electric power system. Besides providing power to the electrocardiograph itself, power lines are connected to other pieces of equipment and appliances.

\* There are also power lines in the walls, floors and ceiling running past the room to other points in the building. These power lines can affect the recording of the ECG and introduce interference at the line frequency in the recorded trace.

\* Such interference appears on the recording as a result of two mechanisms, each operating singly or in some cases both operating together.

\* Electric field coupling between the power lines and electrocardiograph and a patient is a result of electric field. These fields can ~~protect~~ be present even when the apparatus is not turned on because the current is not necessary to establish the electric field.

\* These fields couple into the patient, the lead wires and the electrocardiograph itself.

i) The current through the capacitance  $C_3$  coupling the underground side of the power line & the electrocardiograph itself flow to ground & does not cause interference.



ii)  $c_1$  represents the capacitance between the power line and one of the leads.

iii) current  $i_d$  does not flow into the electrocardiograph because of its high input impedance, but rather through the skin-electrode impedances  $Z_1$  and  $Z_2$  to ground.

The voltage amplified is that appearing between inputs A & B,  $V_A - V_B$ .

$$V_A - V_B = i_{d1} Z_1 - i_{d2} Z_2.$$

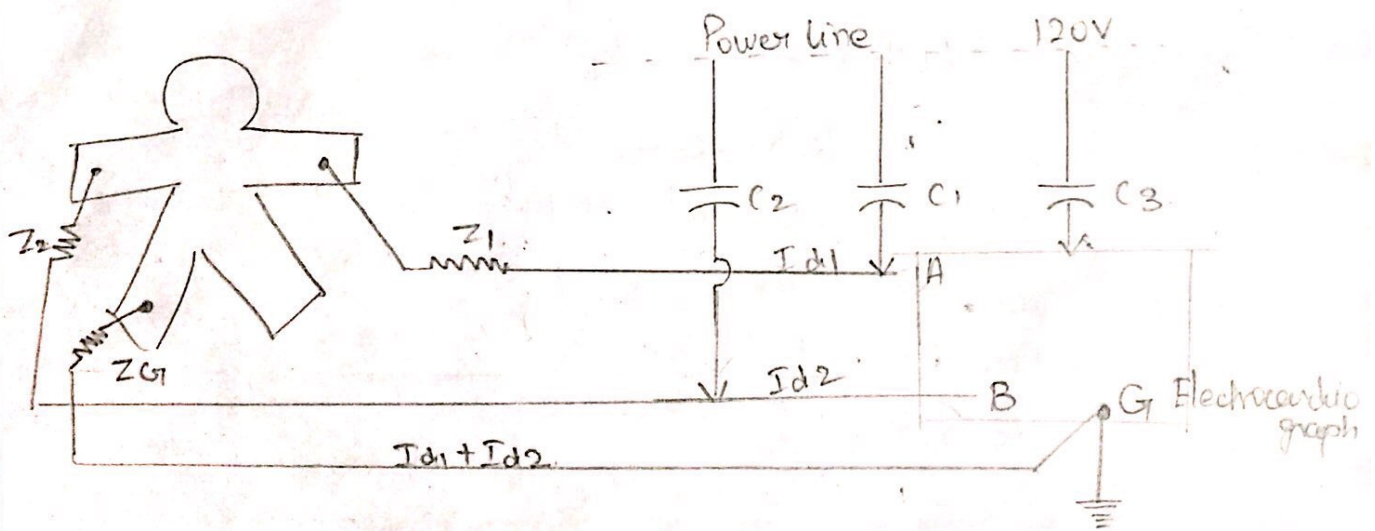
If the two leads run near each other  $i_{d1} \cong i_{d2}$

$$V_A - V_B = i_{d1} (Z_1 - Z_2).$$

Values measured for 9m cables show that  $i_d \cong 6nA$ .

Skin electrode impedances may differ as much as  $20k\Omega$ .

$$V_A - V_B = (6nA) (20k\Omega) = 120\mu V.$$



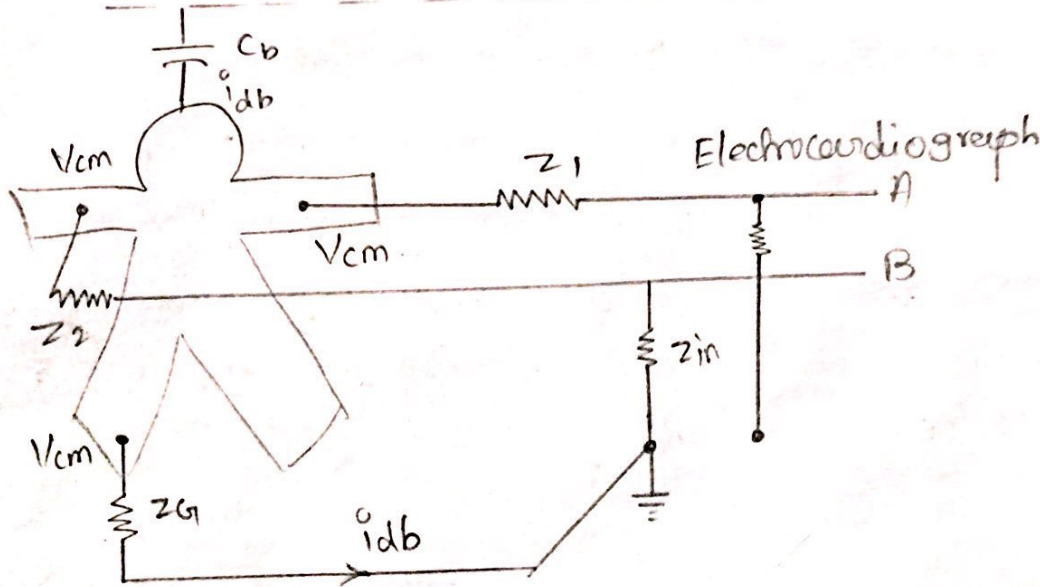
\* It shows that current flows from the Power line into the body. This displacement current  $i_{db}$  flows through the ground impedance  $Z_G$  to ground. The resulting voltage drop causes a common mode voltage  $V_{cm}$  to appear throughout the body.

$$V_{cm} = i_{db} Z_G$$

Substituting typical value yields

$$V_{cm} = (0.2 \mu A) (50 k\Omega) = 10 mV$$

Powerline 120V



\* In poor electrical environment in which  $i_{db} > 1 \mu A$ ,  $V_{cm}$  can be greater than 50 mV.

\* Thus  $V_{cm}$  is decreased because of the attenuator action of the skin electrode impedance and  $Z_{in}$ .

$$V_A - V_B = V_{cm} \left( \frac{Z_{in}}{Z_{in} + Z_1} - \frac{Z_{in}}{Z_{in} + Z_2} \right)$$

Because  $Z_1$  &  $Z_2$  are much less than  $Z_{in}$ ,

$$V_A - V_B = V_{cm} \left( \frac{Z_2 - Z_1}{Z_{in}} \right)$$

Substituting typical value yields,

$$V_A - V_B = (10 mV) \left( \frac{20 k\Omega}{5 M\Omega} \right) = 40 \mu V$$

$$\frac{Z_{in} [Z_{in} + Z_2] - Z_{in} (Z_{in} + Z_1)}{Z_{in}^2 + Z_{in} Z_2 + Z_1 Z_{in} + Z_1 Z_2}$$

$$= \frac{Z_{in}^2 + Z_{in} Z_2 - Z_{in}^2 - Z_{in} Z_1}{Z_{in}^2 + Z_{in} Z_2 + Z_1 Z_{in} + Z_1 Z_2}$$

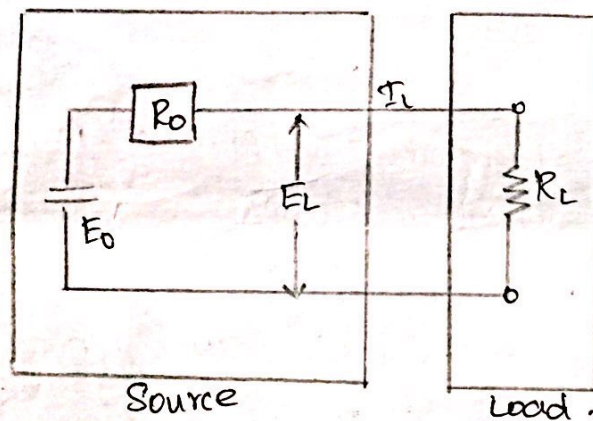
$$= \frac{Z_{in} [Z_2 - Z_1]}{Z_{in}^2 + Z_{in} Z_2 + Z_1 Z_{in} + Z_1 Z_2}$$



## ⑦ Impedance Matching Circuit:

\* In many applications it is desirable to match the impedance of the input device to the output impedance of the signal source instead of making the impedance of the input device either too high or too low.

\* Typical cases of impedance matching are those involving applications of waveform generators like pulse generators and radio frequency generators, which utilize a transmission line to transfer energy from the source to the input device.



$E_0$  = voltage of the source under no load conditions.

$E_L$  = voltage of the source under loaded conditions.

$R_0$  = output resistance of the source.

$R_L$  = input resistance of the load.

$$\text{Power transferred to load is } P = \frac{E_L^2}{R_L} = \frac{E_0^2 R_L}{(R_0 + R_L)^2} \quad \text{--- ①}$$

Maximum power transfer takes place when  $\frac{dP}{dR_L} = 0$ .

Differentiating eq ① & equating it to zero, we get  $R_L = R_0$ .



\* In order to maximum power may be drawn from a source is when the external load resistance matches the internal resistance of the source:

Under condition of maximum power transfer:

$$\text{Power delivered to the load is } P_m = \frac{E_0^2}{4R_0} \quad \text{--- (2)}$$

\* For A.C Circuits: The Internal Impedance of the source and the input impedance may not be pure resistances but are usually complex impedances.

$Z_0$  = output (Internal) impedance of the source.

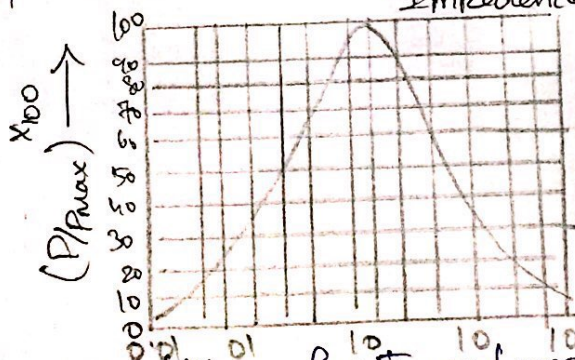
$$= R_0 + jX_0,$$

$Z_L$  = output Impedance of the device =  $R_L + jX_L$ .

\* For maximum power transfer the impedance of the load should be made equal to the Complex Conjugate of the Thevenin equivalent impedance of the source.

$$Z_L = R_L + jX_L = R_0 - jX_0 = Z_0 \quad \text{--- (3)}$$

\* It's clear from eqn (2), if the no load voltage  $E_0$  of the source and its output resistance  $R_0$  are given, the power depends upon the magnitude of the load resistances  $R_L$ .  
Impedance matching Characteristics.

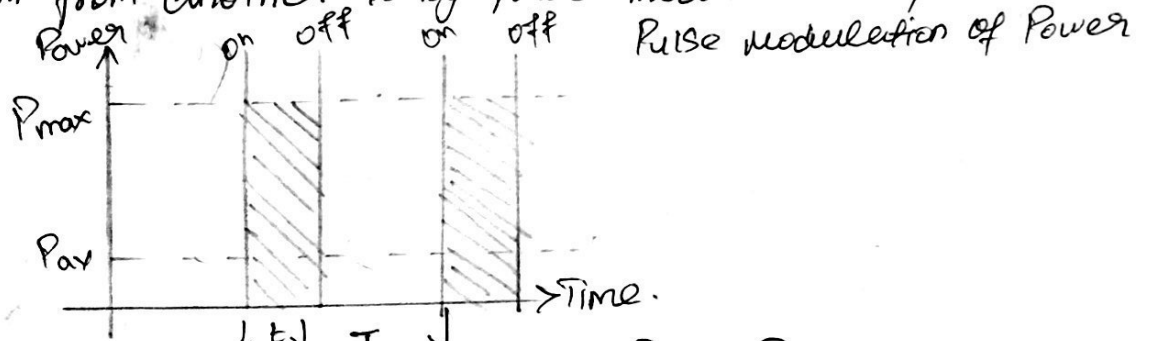


\* The condition for Impedance matching is not critical. It shows the relative amount of power transfer from one system to another for different ratios of  $R_L/R_0$ .

\* It's very often desirable to change or control the amount of Power transferred from one system to another.

\* A disadvantage of this method is considerable loss of power absorbed by the load is low and a very low frequency.

↓ A very efficient way to control power transferred to one system from another is by pulse modulation of Power.



The average Power transfer is  $P_{av} = \frac{P_{max} t}{T}$

$t$  = Pulse width

$T$  = interval between successive pulses.

\* By variation of  $t$  between 0 &  $T$ , the power can be controlled between 0 & the maximum value of Power.

\* Physical advantages like linearity, efficiency or avoidance of loading of previous stage may be more important than the maximum Power transfer.

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## UNIT - V

### BIO CHEMICAL MEASUREMENT

Blood gas analyzers and Non Invasive monitoring, Colorimeter, Sodium potassium Analyser, Spectrophotometer, blood cell counter, Auto Analyzer.

#### ① Blood Gas Analyzers :

Blood gas analysers are mainly used to measure the partial pressures of hydrogen (pH), carbon dioxide ( $pCO_2$ ), and oxygen ( $pO_2$ ) present in human blood. These measurements are very useful to determine the acid base balance in the body.

\* A blood pH below 7.35 indicates respiratory acidosis which indicates the respiratory failure. The respiratory failure can be corrected temporarily using a Ventilator.

Normal blood gas parameters.

| Parameter     | Arterial blood | Venous blood.  |
|---------------|----------------|----------------|
| pH            | 7.37 - 7.44    | 7.35 - 7.45    |
| $PCO_2$ , Men | 34 - 35 mm Hg  | 36 - 50 mm Hg  |
| Women         | 31 - 42 mm Hg  | 34 - 50 mm Hg. |
| $PO_2$        | 75 - 90 mm Hg  | 25 - 40 mm Hg. |

\* Similarly when pH is raised to 7.60 and  $pCO_2$  is reduced to 18 mm Hg, then there is a respiratory alkalosis which can be treated by setting of the Ventilator so as to reduce the ventilation ①



## pH Meter :-

→ According to Goldman equation the electrolyte membrane potentials are proportional to the logarithm of ion concentration and also absolute temperature of the electrolyte.

→ Thus in a solution containing the hydrogen ion, a membrane separating two solutions has a potential proportional to the hydrogen  $[H^+]$  ion concentration.

Thus at a given temperature,  $25^\circ C$

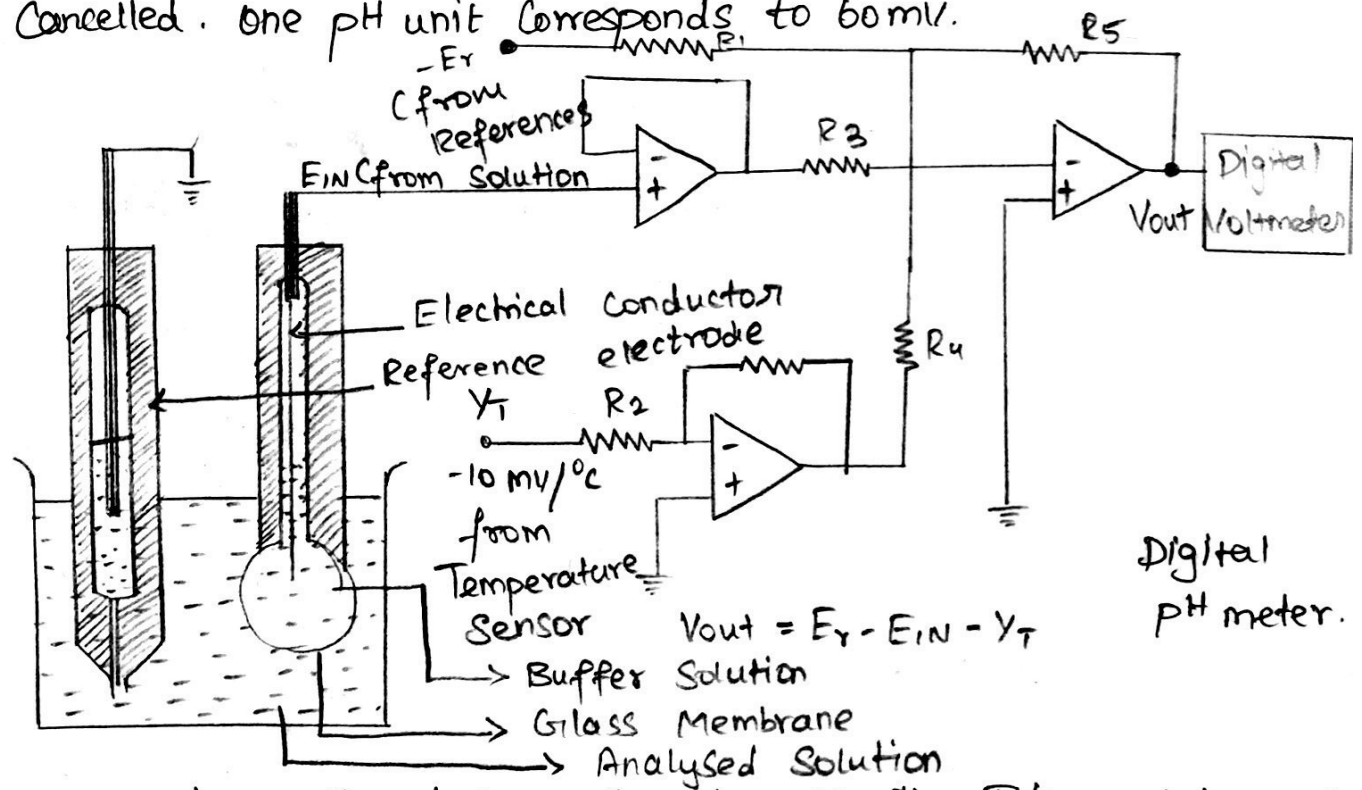
$$V_m = -60 \log [H^+] + c \text{ (in mV)}$$

Where  $c$  is a constant

Since  $pH = -\log [H^+]$ ,

$$V_m = 60 pH + c$$

→ pH meters are calibrated, the effect of constant  $c$ , is cancelled. One pH unit corresponds to 60 mV.



→ It shows the digital pH meter circuit. It's used to measure pH not only at a given temperature but also at different

temperatures. The pH meter consists of pH electrode which consists of a glass (active) electrode terminal and reference terminal.

→ The Calomel or Silver-Silver chloride electrode in potassium chloride electrolyte is acting as a reference terminal

→ The active terminal is sealed with common glass except for a tip made of pH sensitive glass which consists of hydrated gelatinous glass layer.

The internal resistance of a glass electrode is very high ( $10^7 - 10^{10}$  ohms). There is an external reference voltage, to compensate the various errors and is also added with the output from pH electrode.

To determine the pH at different temperature a voltage from the temperature regulator circuit corresponding to a given temperature is also added with the output from pH electrode. The operational amplifier amplifies these voltages in the required manner and the final output is given to a digital voltmeter.

In the digital voltmeter, the display is obtained in terms of pH as discrete numerals, the digital output may be used for further processing of signals.

### **Non Invasive Monitoring :**

The Invasive techniques to determine arterial blood gases are still widely practised in many clinical situations, it is becoming apparent that simple, real



Time, continuous and non-invasive techniques offer many advantages.

Delays between when the blood sample is drawn and when the blood-gas values are reported average about 30 min. Furthermore, invasive techniques are painful and have associated risks.

Continuous non-invasive monitoring of blood gases, on the other hand makes it possible to recognise changes in tissue oxygenation immediately and to take corrective action before irreversible cell damage occurs.

Various non-invasive techniques for monitoring arterial  $O_2$  and  $CO_2$  have been developed.



## ② Colorimeter :

\* The composition of blood serum is determined by specialised chemical techniques. The different components of biological substances can be determined by measuring how they either absorb or emit visible light.

\* Colorimeters and photometers are used to measure the transmitted and absorbed light as it passes through a sample. The colorimeters use light absorption to determine blood proteins and iron levels.

\* To enhance the colour of these substances in blood serum, it's necessary to mix it with reagents. The basic principle behind these colorimeters is that many chemical compounds in solution appear coloured with the saturation of the colour depending on the concentration of compound.

$$\text{Transmittance, } T = \frac{I_1}{I_0}$$

where  $I_1$  = transmitted light intensity

$I_0$  = Incident light intensity.

$$\text{Absorbance or optical density, } A = -\log \frac{I_1}{I_0} \quad \text{or} \quad \boxed{A = \log \left( \frac{1}{T} \right)}$$

$$\text{Thus } A = a c l$$

where  $a$  = absorptivity which depends on the absorbing substance and optical wavelength at which the measurement is performed.

$C$  = Concentration of the absorbing substance and  
 $l$  = pathlength of the cuvette.

\* Colorimeters can be in the filter photometer or Spectrophotometer, when an interference filter is used to select a given wavelength, it's called filter photometer.

\* when a diffraction grating or prism is used as a monochromator to get different spectral components or wavelengths of interest in the colorimeter, then it's called Spectrophotometer.

\* Fluorescence is an optical phenomenon in which the light of shorter wavelength is incident on a sample and the sample absorbs and reemits light of longer wavelength. The concentration of such chemicals can be determined by fluorimeters.

### FILTER PHOTOMETER (COLORIMETER)

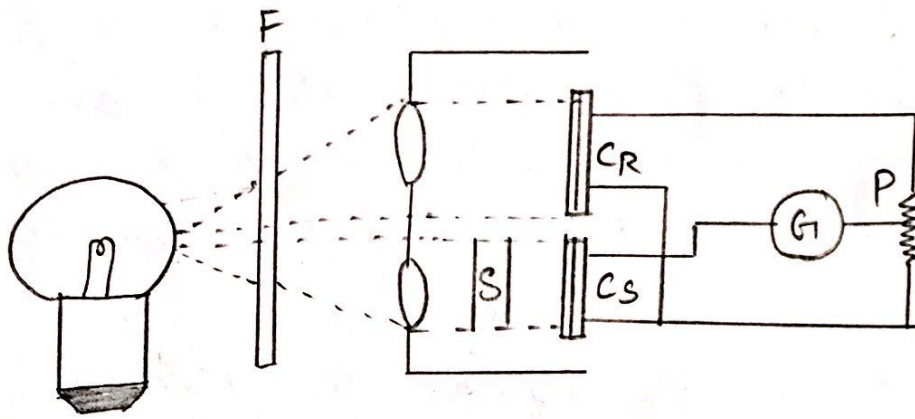
\* A simple filter photometer which is used to measure transmittance. Light from a halogen lamp incident on a filter  $F$ . It transmits only a suitable wavelength range at which the measurement is performed.

\* The divergent transmitted light is converted into two parallel beams by an optical arrangement. one beam falls on a reference Selenium photoelectric cell,  $C_R$  and other beam falls on a Sample Selenium photoelectric cell  $C_S$  after passing through sample in the cuvette.

Without the sample the outputs from photoelectric cells are the same.



## Filter photometer (Colorimeter)



When the sample is placed in the light path, the output of the sample cell is reduced and hence the potentiometer is adjusted such that both the cells  $C_R$  and  $C_S$  give the same output which is indicated by the null deflection in the galvanometer 'G'.

Since the potentiometer is calibrated in terms of transmittance, we can determine the concentration of the given substance in the sample. Generally the potentiometer is calibrated in terms of concentration directly using a standard with known concentration of given substance.

### ③ Spectrophotometer:

When a diffraction grating or prism is used to act as a monochromator to get different spectral components or wavelengths of interest in the colorimeter, then it's called Spectrophotometer.

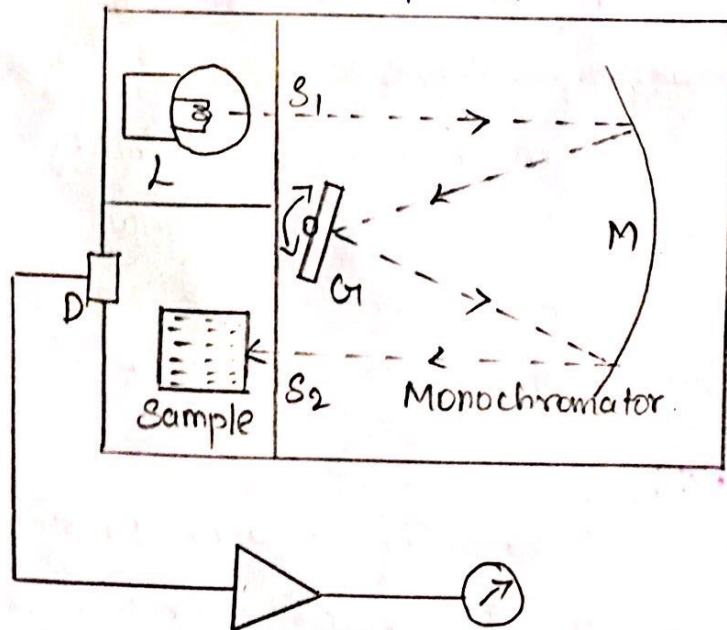
Here a light from a halogen lamp is passed through an entrance slit  $S_1$  and incident on a concave reflector.

④

which focuses the light on a diffraction grating 'G' or a Prism to disperse light. The selective wavelength from the dispersed light. The selective wavelength from the dispersed light is obtained by taking it at the given direction and then it is allowed to incident on the reflector.

\* from the reflector, the light beam is directed to the sample through a narrow exit slit  $S_2$ . A sensitive photodetector D detects the transmitted light and gives an electrical output corresponding to the intensity of the transmitted light.

Spectrophotometer.



The amplifier amplifies the output from the detector and finally the indicator indicates the concentration of the substance. By rotating the grating, the measurements can be made at different wavelengths.



## ④ SODIUM POTASSIUM ANALYZER :

A flame photometer is used to analyse urine or blood in order to determine the concentration of Potassium (K), Sodium (Na), Calcium (Ca) and Lithium (Li). Sometimes Lithium is used ~~to~~ as a calibration substance in the analysis of the other three substances.

\* Using an atomizer, the liquid sample is sprayed into fine droplets by passing oxygen or air past the opening in it. A combustible gas, like acetylene is also added with air.

\* The sample air mixture is burnt out and light is emitted in the flame is passed through a narrow slit and then to diffraction grating. The diffracted colours are incident on various photodiodes.

\* The variations in the intensity of light due to changes in the flow rate of the air. [The concentration of Potassium ions is detected by observing the peak height of the spectral line]

\* For potassium, the wavelength that we are interested is  $4047 \text{ \AA}$  (violet). For Sodium, the interested wavelength is  $5890 \text{ \AA}$  (yellow). For Lithium it is  $6708 \text{ \AA}$  (red). Separate photodetector is used for each channel.

\* The photodetector circuit consists of a reverse biased diode in which current flow increases as the intensity of light incident upon it increases. Calibration potentiometer in each channel is used to calibrate the instrument.

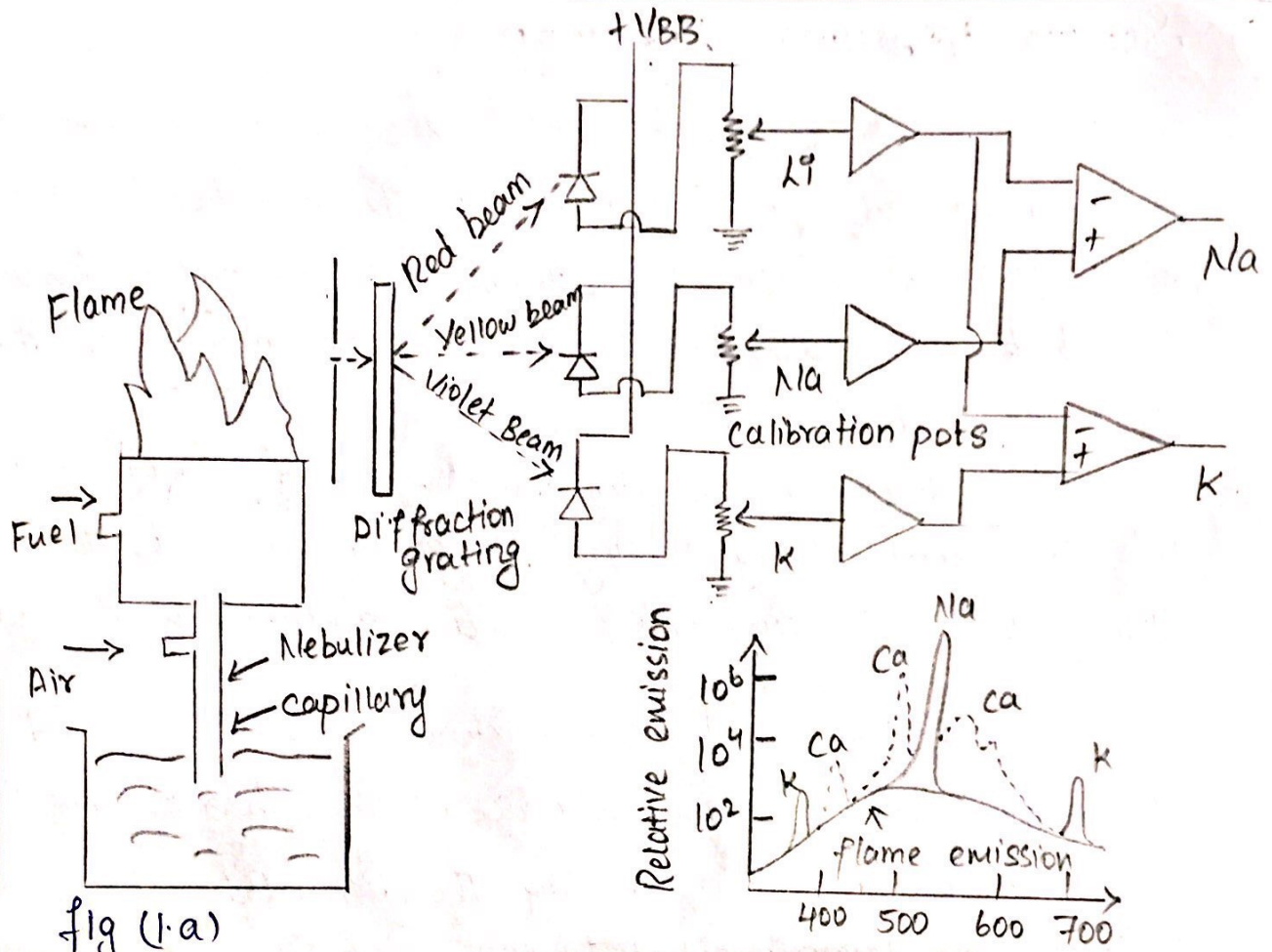


Fig (1.a)

flame photometer and emitted light intensity for different wavelengths.

\* Assuming the sample is initially not containing any lithium, a known standard amount of lithium is added to the sample. The output of Sodium channel and Potassium channel are calibrated in terms of differences with the known lithium.

✦ For Sodium, it can detect upto 0.01mg/litre, for other ions its sensitivity is slightly lower. It has so many advantages like fast response, high accuracy and lesser cost.



## ⑤ BLOOD CELL COUNTER

The blood cells have important functions in our body. The red blood cell is used for the transport of oxygen and carbon dioxide. The white blood cell are part of the body's defenses against infections and foreign substances. The platelets are involved in the clotting of blood. The red blood cells in the blood consist of hemoglobin.

\* When the body produces too many red blood cells, the amount of hemoglobin in the blood increases and a chronic disease called polycythemia or dehydration is produced. When the hemoglobin in the blood decreases, anemia is produced. The anemia produces headache and giddiness.

\* The amount of hemoglobin is normally 130-170 g/l for men and 120-160 g/l for women. To determine relative proportion of blood cells in a given volume of blood, hematocrit or packed cell volume is used.

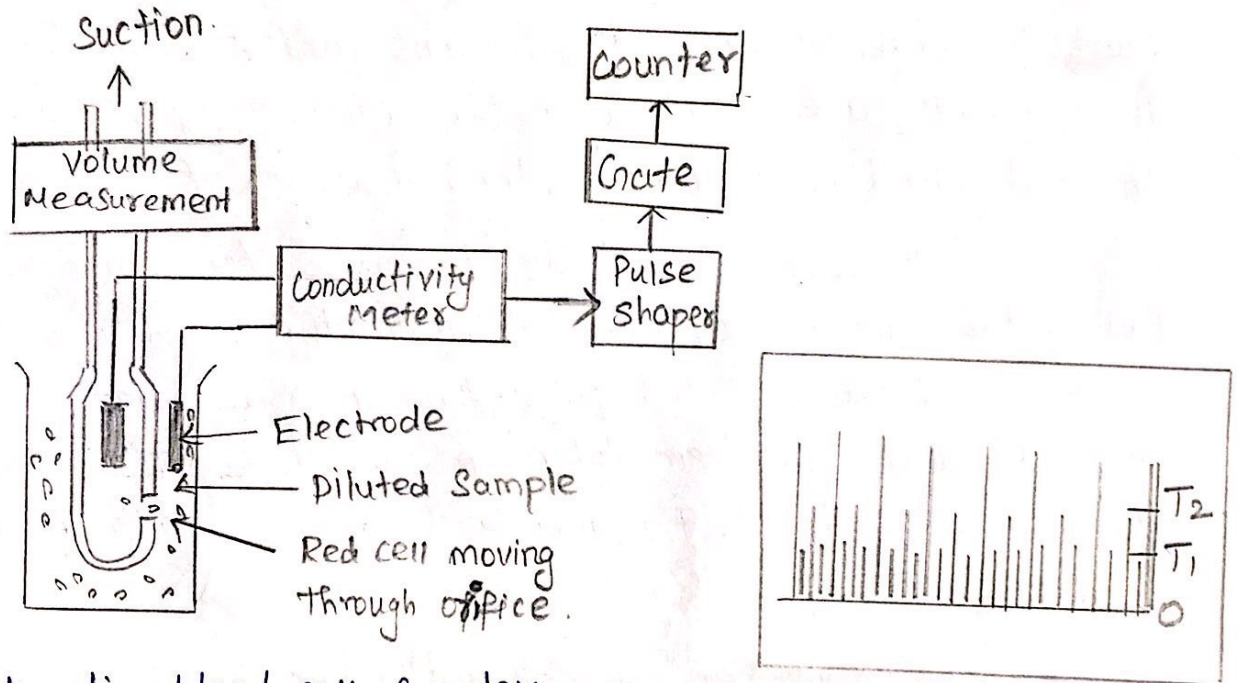
\* The blood sample is placed in a test tube which is spun so that the cells are packed at the bottom under centrifugal force provided by the centrifuge.

\* Normal range of packed cell volume for men is 42% - 54% and for women is 37% - 47%. The number of red blood cells is also counted using microscope. Since, the density of red blood cells is so large, the microscopic counting is time consuming.



\* Automatic red blood cell counters are used.

The method is based on the fact that red cells have a higher electrical resistivity than the saline solution.



Automatic blood cell counter  
fig(1.1.a)

Counter display of  
Impulses.  
fig(1.1.b)

\* It shows the automatic blood cell counter using electronic circuitry. A diluted blood sample is drawn through a small orifice having diameter less than  $100\mu\text{m}$  by means of a suction pump. The electrodes are placed such that one is in the surrounding sample chamber and other in the suctioned blood.

\* The electrodes are attached with the conductivity bridge such that their resistance forms one arm of bridge.

\* After suctioning of blood, each red cell moving through orifice will produce a sudden increase in resistance, such that resistance of the arm is now equal to  $(R + AR)$  or  $R_{out}$ .



Assuming equal resistances  $R$  are placed in other arms, the bridge output voltage,

$$V_{out} = \left[ \frac{R_{out}}{R_{out} + R} - \frac{1}{2} \right] V_{BB}$$

$$= \frac{\Delta R}{4R + 2\Delta R} V_{BB} \left[ \frac{R + \Delta R}{R + \Delta R + R} - \frac{1}{2} \right]$$

$$= \frac{\Delta R}{4R + 2\Delta R} V_{BB} \left[ \frac{R + \Delta R - 2R + \Delta R}{2(R + \Delta R)} \right]$$

$$= \frac{\Delta R}{4R + 2\Delta R} V_{BB} \left[ \frac{-R + 2\Delta R}{2(R + \Delta R)} \right]$$

Since  $\Delta R \ll R$ ,

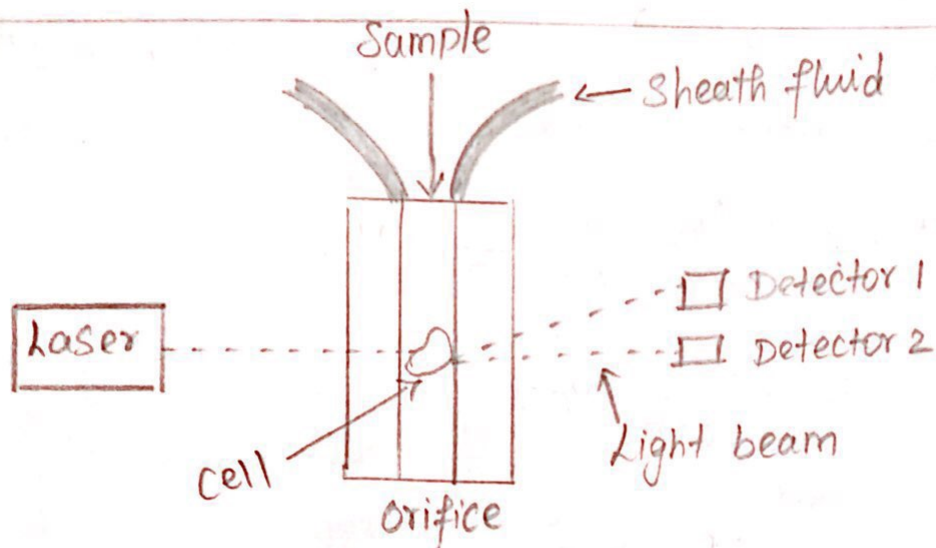
$V_{BB}$  = constant excitation voltage of the bridge.

$V_{out}$  is directly proportional to  $\Delta R$ .

Fig 1.6 shows the counter display in terms of impulses. The impulses having highest peaks are fewest in number. These are due to WBC's which make highest resistance change in the orifice. The RBC's are represented by the peaks between threshold  $T_2$  and  $T_1$ .

\* The threshold is first set to zero and the counter output is given by the total number of particles (WBCs + RBCs + platelets) per litre.

\* The threshold is set to  $T_1$  and now the counter gives the total number of RBC's and WBC's per litre. After that the threshold is set to  $T_2$  and the counter reads just the total number of WBC's, per litre.



Principle of laser based blood cell counting.

This is a modern technique which gives the number of RBCs, WBCs and platelets, hematocrit, mean cell volume of red blood cell and concentration of hemoglobin.

The basic principle behind this technique is that the angle of scattered light intensity is different for different sized particles. Thus the blood cells are illuminated by the laser light & scatter light.

The scattering angles of platelets & red blood cells having large difference, so that scattered light from these two types of cells are directed into two different photo detectors.

The output of the photodetector is given properly calibrated digital voltmeter. To separate WBCs from RBCs, it's necessary to destroy the RBCs with lysing agent.



## ⑥ Auto Analyzer :

\* The first automatic analyzer that found wide acceptance and that is still used at most hospitals in the "Auto Analyzer". The basic method used in Auto analyzer departs in several respects from that of standard manual methods

\* The Sampler feeds the samples into the analyzer in a true sequence. A proportioning pump which is basically a simple peristaltic pump works simultaneously on a number of tube with certain ratios of diameters, is used to meter the sample and the reagent.

\* Mixing is achieved by injection the air bubbles. The mixture is incubated while flowing through heated coils. The air bubbles are removed and solution finally flow through the cuvette of the colorimeter.

\* An electronic ratio recorder compares the output of the reference and sample photocells. The recording shows the individual samples as peaks of continuous transmittance or absorbance recording.

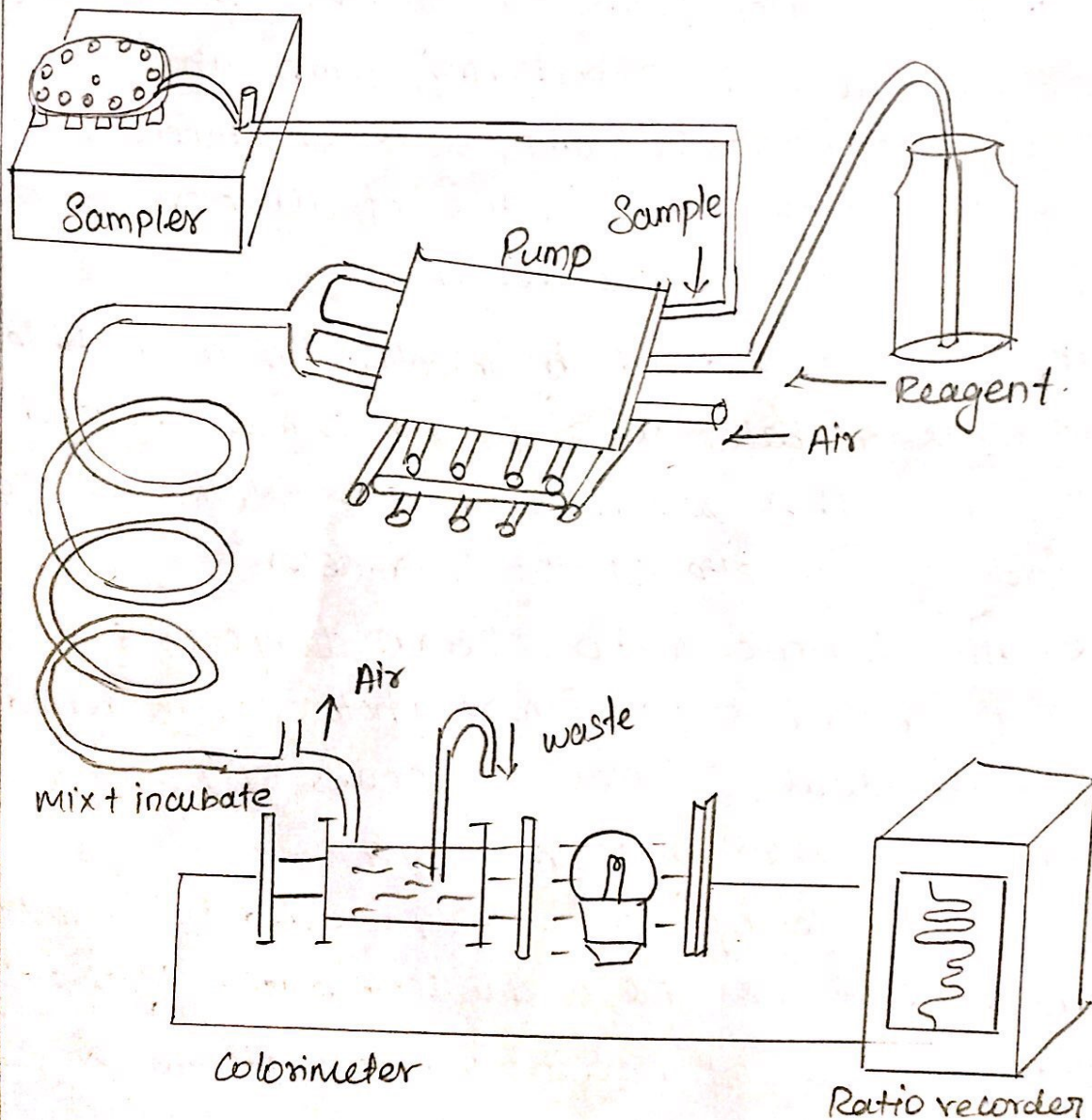
\* The samples of "run" are preceded by a number of standards that cover the useful concentration of the test.

\* The removal of protein from the plasma is achieved in the continuous flow method with a dialyzer.

\* The smallest model of Autoanalyzer performs a single test at rate upto 120 samples per hour.

\* Large latex models perform upto 12 different test on each of 90 samples per hour.

\* The continuous flow analyzer was first to find wide acceptance, numerous other analyzers that use discrete samples are now available.



Continuous flow Analyzer (Simplified)

\* All automatic analyzers of this type use syringe type pumps to dispense the sample and to add the reagents. After incubation the sample is aspirated into colorimeter.



Cuvette, where its absorbance is measured.

\* Discrete sample analyzer as well as continuous flow analyzer require that all reagents be available in proper dilution.

\* Many modern automatic analyzers utilize electronic data processing by built-in mini- or microcomputers to calibrate the system. They also convert absorbance measurements into concentration values and print out the results.

S. B. P. R.  
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N. M. J.  
Verified By

D. P. S. R.  
Approved By





## MEASUREMENT OF RESPIRATION RATE

The primary functions of the respiratory system are to supply oxygen and carbon dioxide from the tissues. The action of breathing is controlled by a muscular action causing the volume of the lungs to increase and decrease to effect a precise and sensitive control of the tension of carbon dioxide in the arterial blood.

Some of the commonly used methods for the measurement of respiration rate are explained below,

### Displacement Method:

\* The respiratory cycle is accompanied by changes in the thoracic volume. These changes can be sensed by means of displacement transducers incorporating a strain gauge or a variable resistance element.

\* The transducer is held by an elastic band, which goes around the chest.

\* Changes in the chest circumference can also be detected by a rubber tube filled with mercury. With the expansion of the chest during an inspiratory phase, the rubber tube increases in length and thus the resistance of mercury from one end of this tube to the other changes.

### Thermistor Method:

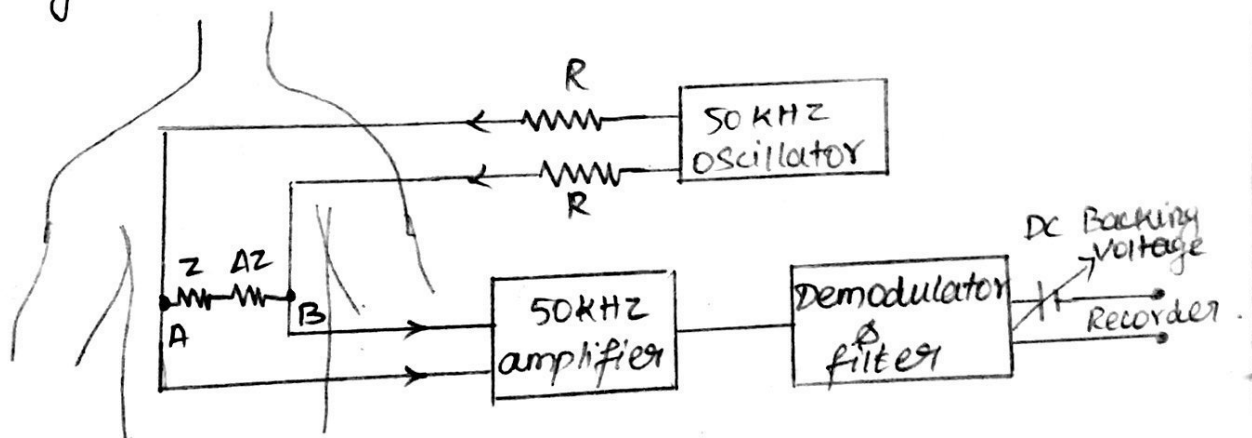
Air is warmed during its passage through the lungs and respiratory tract, there is a detectable difference of temperature between inspired and expired air.

This difference of temperature can be sensed by using thermistor placed in front of the nostrils by means of suitable holding device.

\* The thermistor is placed as a part of voltage dividing circuit or in a bridge circuit whose unbalance signal can be amplified to obtain respiratory activity. This method is simple and works well. This method is found to satisfy the majority of clinical needs including operative and post-operative subjects.

### Impedance Pneumography :-

This is an indirect technique for the measurement of respiration rate. The electrodes on the thorax, the impedance pneumograph measures rate through the relationship between respiratory depth and thoracic changes.



\* The two electrode impedance pneumograph is convenient for use with quiet subjects. Movement artefacts are produced due to changes in the electrode contact.



Impedance, These artefacts can be significantly reduced by using a four electrode impedance pneumograph. The output from the oscillator is applied to the two outer electrodes. By doing, the main oscillator current does not flow through the contact impedance of the measuring electrodes.

\* Some of the physiological quantities which have been measured and recorded by the impedance method include respiration, blood flow, stroke volume, autonomous nervous system. The impedance method of measuring respiration rate is commonly employed in patient monitoring systems.

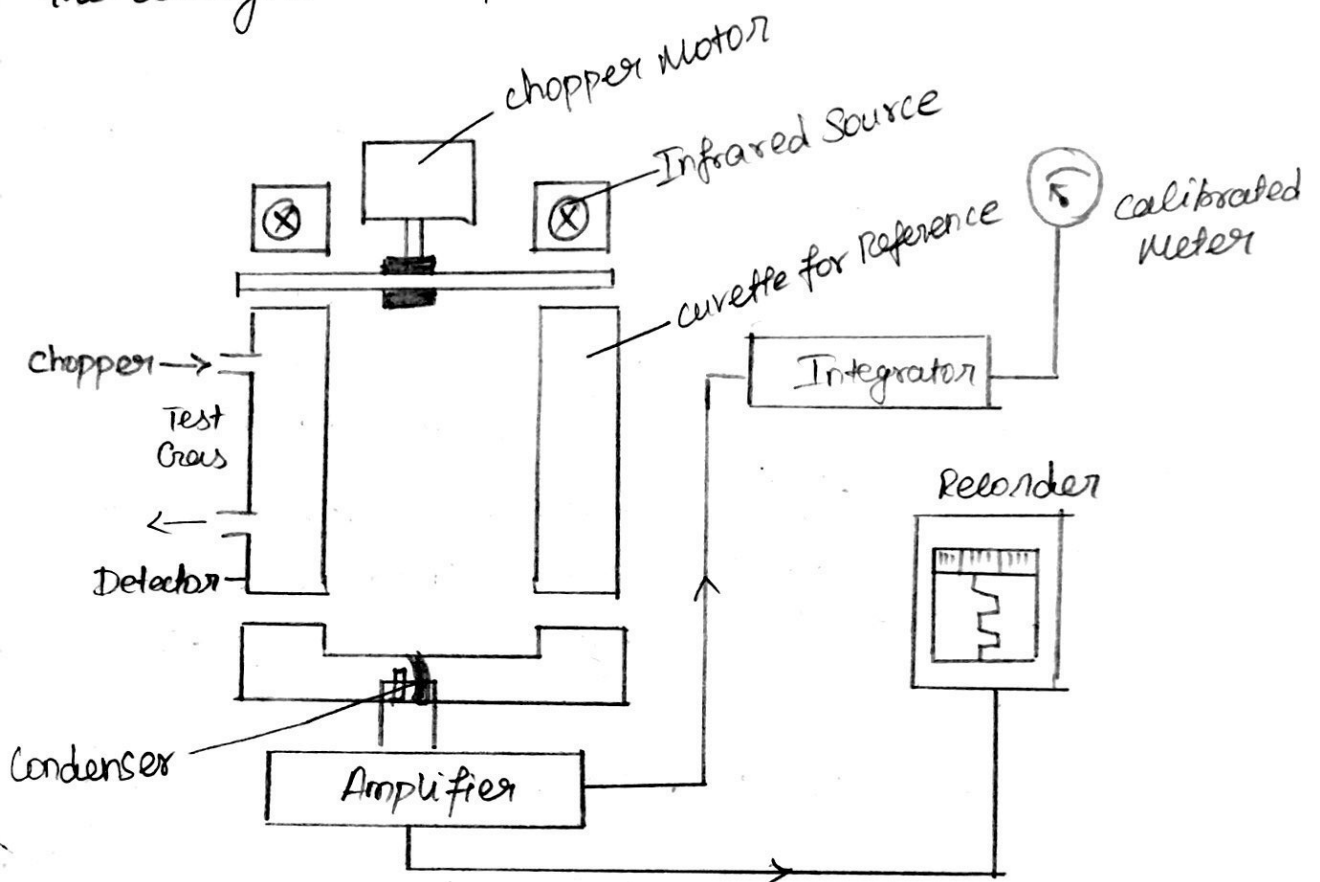
### CO<sub>2</sub> Method of Respiration rate Measurement

The measurement is based on the absorption property of infrared rays by certain gases. Suitable filters are required to determine the concentration of specific gases (like CO<sub>2</sub>, CO and NO<sub>2</sub>) constituting the expired air.

\* It shows the arrangement for the detection of CO<sub>2</sub> in expired air. The detector has two identical portions separated by a thin, flexible metal diaphragm. The detector is filled with sample of pure CO<sub>2</sub>. Because of the absorption of CO<sub>2</sub> in the analysis cell, the beam falling on the test side of the detector is weaker than that falling on reference side.

\* The gas in the reference side would, therefore, be heated more than that on the analysis side.

\* As a result, the diaphragm is pushed slightly to the analysis side of the detector.



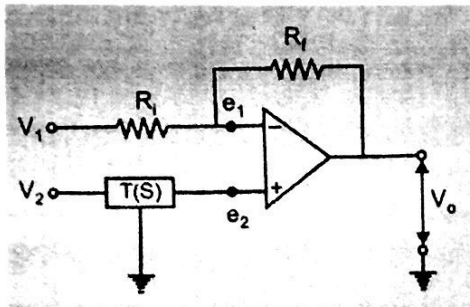
Schematic diagram for detection of  $\text{CO}_2$  in the expired air for continuous monitoring of respiration rate.



UNIT - III  
QUESTION BANK

1. Explain the special features of isolation amplifier. (A/M12,10)  
**Isolation amplifiers** are used in medical instruments to ensure **isolation** of a patient from power supply leakage current. ...  
These **amplifiers** are also used for amplifying low-level signals in multi-channel applications. They can also eliminate measurement errors caused by ground loops.
2. Write down the conditions for design of biomedical pre amplifiers.(A/M10)  
The properties desired in a bioelectric amplifier are:
  - The single-ended output, often differential input.
  - High common mode rejection ratio (CMRR).
  - Extremely high-input impedance.
  - Variable gain adequate to do the job intended.
  - Frequency response suitable for the application. In the case of a universal bioelectric amplifier, the response should be variable through switch selection.
  - Zero suppression.
3. What is the need for band pass filter in bio amplifier circuits?(A/M10)  
Band pass filters may be used to pass a larger range of frequencies(i.e. 0-100Hz EEG activity), frequencies either side of this band are not passed.
4. Differentiate between single ended bioamplifier and differential bio amplifier?(A/M17)  
Both these types of amplifier are powered in the same way, but the differential amplifier, amplifies the difference between its two inputs, whereas the single ended amplifier, amplifies the difference between its single input and ground.  
The receiving circuit responds to the electrical **difference between** the two signals, rather than the **difference between a single** wire and ground.  
The opposite technique is called **single-ended signaling**. **Differential** pairs are usually found on printed circuit boards, in twisted-pair and ribbon cables, and in connectors.
5. What is meant by Bandpass filtering?(A/M12)  
A series combination of **the low pass filter and the high pass filter** results in a **band pass filter** which amplifies frequencies over a desired range and attenuates higher and lower frequencies.
6. Why do we require isolation amplifier in biomedical instrumentation?(A/M12)  
**Isolation amplifiers** are a form of differential **amplifier** that allows measurement of small signals in the presence of a high common mode voltage by providing electrical **isolation** and an electrical safety barrier. They can also eliminate measurement errors caused by ground loops.
7. What is power line interference?(N/D17)  
**ECG** is a biomedical signal which gives electrical activity of heart. This **ECG** signal is corrupted by various noises like **power line interference**, baseline wandering, channel **noise**, contact **noise**, muscle artifacts etc. Frequency range of **ECG** signal is nearly same as the frequency of **power line interference**.
8. Draw a circuit of differential amplifier using op amps?(N/D17)

Differential amplifier is one which will reject any common mode signal that appears simultaneously at both amplifier input terminals and amplifies only the voltage difference that appears across its input terminals.



9. State the requirements of amplifiers used in biomedical instrumentation?(N/D18)

Low internal noise .

High Input Impedance .

Bandwidth ranging from 0.16–250 Hz.

Bandwidth cutoffs (>18 dB/octave).

Notch filter (50 or 60 Hz)

Common mode rejection ratio (CMRR > 107 dB)

10. What is the need for Bandpass filter in bio amplifier circuits?(N/D18)

These BioAmplifiers are designed for a wide range of applications including EMG, ECG, EEG, and others. They have a built-in bandpass filter network, a 60 (or 50) Hz notch filter that can be bypassed, and a coupler filter between the preamp and main amplifier sections.

11. What is DC amplifiers?

DC amplifiers are generally of the negative feedback type and are used for medium gain applications down to about 1 mV signal levels for full scale.

12. What is the potential difference between the two input terminals present in differential amplifier?

The potential difference between the two input terminals of the ideal amplifier is forced to zero by the feedback through  $R_f$ , the voltage  $e_1$  must be equal to  $e_2$

$$\frac{R_f}{R_i + R_f} V_1 + \frac{R_i}{R_f + R_i} V_0 = T(S) V_2 \quad (0V)$$

$$V_0 = \frac{R_f + R_i}{R_i} T(S) V_2 - \frac{R_f}{R_i} V_1 \rightarrow \text{If } T(S) = \frac{R_f}{R_f + R_i}, V_0 = \frac{R_f}{R_i} (V_2 - V_1)$$

13. What are the different modes of operation in differential amplifier?

Single ended mode

Differential mode and



Common mode

14. Define differential mode in differential amplifier.

In this mode, the two input signals are equal but have opposite polarity at every instant of time.

$\therefore V_1 = -V_2 = V_D$   
We have seen that  
 $V_o = \frac{R_f}{R_i} (V_2 - V_1)$  (or)  $V_o = \frac{2 R_f}{R_i} V_D$

C

Input signals are called **differential mode** signals.

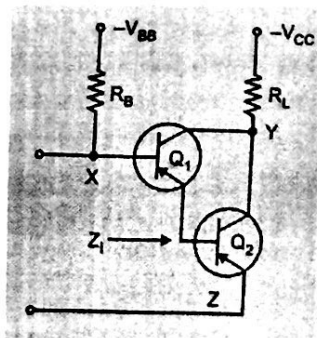
15. Define CMR in differential amplifier?

The ability of the differential amplifier circuit to ignore the common mode inputs like 50Hz interference from the mains is known as **Common Mode Rejection (CMR)**.

$CMRR = \frac{\text{Amplification of differential voltage}}{\text{Amplification of common mode voltage}}$

16. Draw the circuit of darlington pair in isolation amplifier?

**Darlington pair** is an isolation amplifier which provides high input impedance with high current gain.



17. What are the methods used in the design of isolation amplifier?

Three methods are used in the design of isolation amplifiers:

- Transformer isolation
- Optical isolation
- Capacitive isolation.

18. Write the merits of three types in isolation techniques?

All three types are in common use, though the transformer isolation amplifier is more popular.

Opto-coupled amplifier uses a minimum number of components and is cost effective, followed by the transformer coupled amplifier.

The capacitor coupled amplifier is the most expensive.

19. Define pulse modulation of power.

A very efficient way to control power transferred to one system from another is by pulse modulation of power

The average power transfer is  $P_{av} = P_{max}/T$

$t =$  Pulse Width

$T =$  interval between successive pulses

20. State the advantages and disadvantages of pulse modulation of power

Physical advantages like linearity, efficiency or avoidance of loading of previous stage may be more important than the maximum power transfer

A disadvantage of this method is considerable loss of power and a very low frequency.

*D. D. 17/19/19*



## UNIT - V QUESTION BANK.

1. What are the gases to be analyzed in blood? (N/D-17)

Blood gas analyzers are mainly used to measure the Partial pressures of hydrogen ( $pH$ ), Carbon dioxide ( $pCO_2$ ), and oxygen ( $pO_2$ ) present in human blood. These measurements are very useful to determine the acid base balance in the body.

2. How pH sensor works? (N/D-17).

pH probe measures the potential difference generated by the solution by measuring the difference in hydrogen ion concentration and displays the pH as output.

3. Why it is necessary to maintain acid-base balance in the human body? Indicate the normal blood pH value (N/D-18)

Blood gas analyzers are mainly used to measure the partial pressure of  $pH$ ,  $pCO_2$ , and  $pO_2$  present in human blood. These measurements are very useful to determine the acid base balance in the body.

Normal pH value in arterial blood & venous blood.

| Parameter | Arterial blood | Venous blood. |
|-----------|----------------|---------------|
| pH        | 7.37 - 7.44    | 7.35 - 7.45   |

4. Mention the purpose of using  $pCO_2$  in Bio medical Instrumentation. (N/D-18)

The  $pCO_2$  of arterial blood is also increased to quantify. The respiratory failure can be corrected temporarily using a Ventilator.

Similarly when pH is raised to 7.60 and  $PCO_2$  is reduced to 18mm Hg, then there is respiratory alkalosis which can be treated by setting the ventilator so as to reduce the ventilation.

5. What is an auto analyzer? Mention its advantages and disadvantages. (N/D-18), (N/D-10)

An auto analyzer is a medical laboratory instrument designed to measure different chemicals and other characteristics in a number of biological samples quickly with minimal human assistance.

| Advantages  | Dis Advantages.  |
|---|--|
| i) Simpler<br>ii) Dialyzer<br>iii) constant temperature<br>iv) flow through colorimeter<br>v) Recorder. | i) Prohibited cost<br>ii) The usual hazards of any complicated equipment.<br>iii) "Carry-over" errors. |

6. What are photometers? (N/D-10, 12).

Colorimeter can be in the filter photometer or Spectro photometer, when an interference filter is used to select a given wavelength. It's used to measure the transmitted and absorbed light as it passes through the sample.

7. Mention the uses of gas analyzers? (N/D-12).

Chemical process analysis and control

Metallurgical process gas monitoring.

Atmosphere measurements in hardening gas applications.



Ambient air monitoring in chemical plants.  
Continuous Emissions Monitoring Systems (CEMS).

8. Define pH meter?

According to Nernst equation the electrolyte membrane potentials are proportional to the logarithm of ion concentration and also absolute temperature of electrolyte.

$$V_m = -60 \log [H^+] + C \quad \therefore C = \text{constant}$$

$$pH = -\log [H^+]$$

$$\boxed{V_m = 60pH + C}$$

9. What are the basic principle used in colorimeters?

The basic principle behind these colorimeter is that many chemical compounds in solution appear coloured with the saturation of colour depending on the concentration of compound.

$$\boxed{A = \epsilon c l}$$

10. What is meant by Spectrophotometer? (AM-10), (12).

When a diffraction grating or prism is used as a monochromator to get different spectral components or wavelength of interest in the colorimeter, then it's called Spectrophotometer.

11. Define flame photometer?

A flame photometer is used to analyse urine or blood in order to determine the concentration of Potassium (K), Sodium (Na), Calcium (Ca) and Lithium (Li).



12. What are the wavelengths interested in K, Na and Li?  
For potassium, the wavelength that we are interested is  $4047 \text{ \AA}$  (violet). For sodium, the interested wavelength is  $5890 \text{ \AA}$  (yellow). For lithium it is  $6708 \text{ \AA}$  (red).

13. Mention the advantages of flame photometer?

- i) Fast Response
- ii) High accuracy.
- iii) lesser cost of equipment.

14. Define polycythemia.

When a body produces too many red blood cells, the amount of hemoglobin in the blood increases and chronic disease called polycythemia or dehydration.

15. Define ~~by~~ Blood cell counter?

The blood cells have important functions in our body. The RBC is used for transport of oxygen and  $\text{CO}_2$ . The WBC are part of the body defenses against infection and foreign substances.

16. What is the normal range of packed cell for men and women?

Normal range of packed cell volume for men is  $42\% - 54\%$  and for women is  $37\% - 47\%$ .

17. Calculate the bridge output voltage present in equal resistances  $R$ .

Each red cell moving through orifice will produce a sudden increase in resistance such that the resistance of arm is now equal to  $(R + \Delta R)$  or  $R_{out}$ .

$$V_{out} = \left[ \frac{R_{out}}{R_{out} + R} - \frac{1}{2} \right] V_{BB} = \frac{\Delta R}{4R + 2\Delta R} V_{BB}$$

(or) 
$$V_{out} = \frac{\Delta R}{4R} V_{BB} \quad \therefore \Delta R \ll R.$$

18. What is the principle used in laser based blood cell counting?

The basic principle behind this technique is that angle of scattered light intensity is different for different size particles.

19. Explain the counter display of impulses present in Blood Cell counter.

The RBC's are represented by the peaks between threshold  $T_2$  and  $T_1$ .

The threshold is first set to zero and the counter output is given by total number of particles (WBC's + RBC's + Platelets).

The threshold is set to  $T_1$ , now the counter gives total no of RBC's & WBC's per litre.

The threshold is set to  $T_2$ , the counter reads just the total no of WBC's per litre.



20. What is a continuous flow analyzer?

Continuous flow analyzer is an automated chemical analyzer in which the samples and reagents are pumped continuously through a system of modules interconnected by tubing.

21. Write the normal blood gas parameters?

| Parameter            | Arterial blood | Venous blood  |
|----------------------|----------------|---------------|
| pH                   | 7.37 - 7.44    | 7.35 - 7.45   |
| PCO <sub>2</sub> Men | 34 - 35 mm Hg  | 36 - 50 mm Hg |
| Women                | 31 - 42 mm Hg  | 34 - 50 mm Hg |
| PO <sub>2</sub>      | 75 - 90 mm Hg  | 25 - 40 mm Hg |

22. What is meant by fluorescence?

Fluorescence is an optical phenomenon in which the light of shorter wavelength is incident on a sample and the sample absorbs and re-emits light of longer wavelengths.

D. D. D. 16/10/19