2.2 BLOOD FLOW METER

Blood flow meters are used to monitor the blood flow in various blood vessels and tomeasure cardiac output.

Types

- Electromagnetic blood flow meters
- Ultrasonic blood flow meters
- Laser based blood flow meters

ELECTROMAGNETIC FLOWMETERS

- Electromagnetic blood flow meters measure blood flow in blood vessels
- Consists of a probe connected to a flow sensor box. The bellow Figure 1 shows the Blod flow meter.

Figure 1 Blod flow meter

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

An Electromagnetic Flow Meter is a device capable of measuring the mass flow of a fluid. Unlike the common flow meter you can find on the market it has no moving parts, and for this reason it can be made to withstand any pressure (without leakage) and any fluid (corrosive and non corrosive). This kind of flow meter use a magnet and two electrodes to peek the voltage that appears across the fluid moving in the magnetic field.

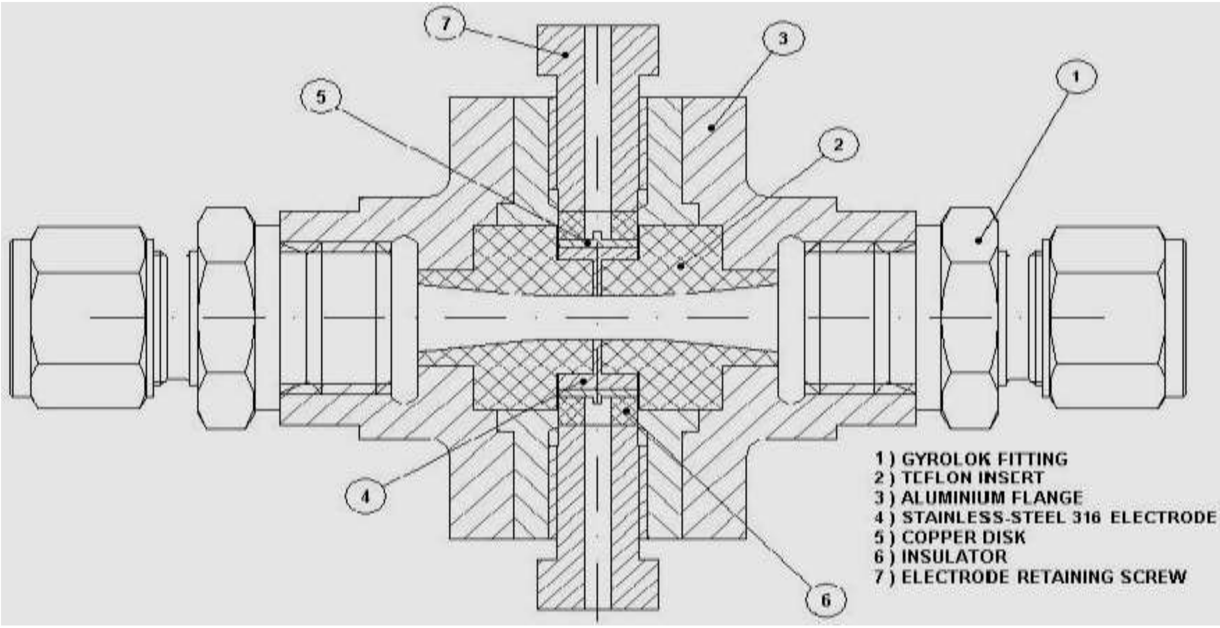


Figure 2 Electromagnetic Flow meter.

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

The above Figure 2 shows the Electromagnetic Flow Meter

The Neumann Law (or Lenz Law) states that if a conductive wire is moving at right angle through a magnetic field, a voltage ***E*** [Volts] will appear at the end of the conductor .

E=B*L*V

Where

B = Magnetic Induction[Weber/m2]

L = Length of the portion of the wire 'wetted' by the magnetic field [m]

V = Velocity of the wire [m/sec]

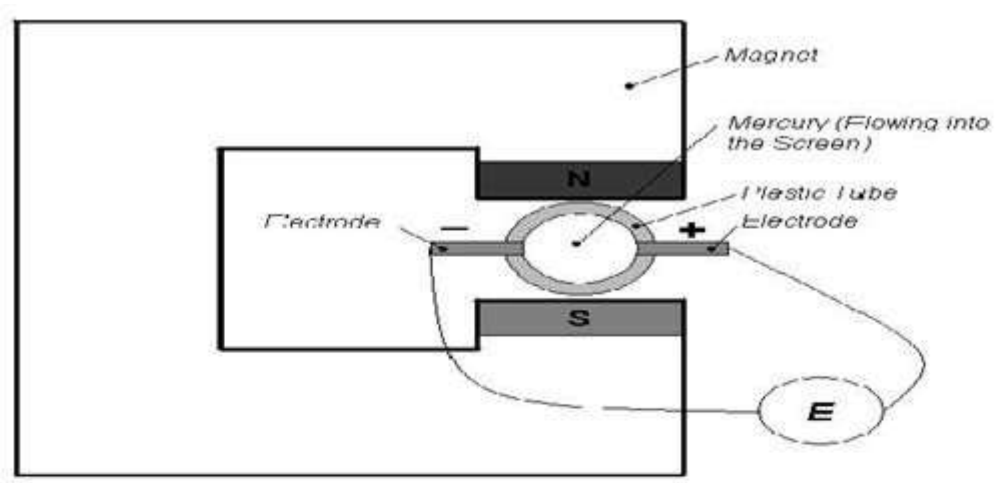


Figure 3 Magnetic Blood flowmeter principle

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

The above fugure 3 represents the principles of Magnetic Blood flow meter. Now imagine you have a plastic tube with two electrodes on the diameter and Mercury flowing into it (fig above). A voltage will appear on the electrodes and it will be

E=B*L*V

As in the previous example (***L*** in this case is the inner diameter of the tube).Mercury as tiny conductive wires next to each other: each wire, moving in the tube, will touch the two electrodes ,and thus you can measure their voltage.

An interesting fact is that if you reverse the flow, you still get a voltage but with reverse polarity (Fig.1). Till now we have talked about a conductive fluid, Mercury, but this stuff will also work with non conductive fluid, provided that you use an alternating magnetic field. Two physicists, Middleman and Cushing, in an unpublished work, stated that when using a non conductive fluid, if the frequency of the alternating magnetic field is ***v*** the voltage at the electrodes will be attenuated by a factor ***a*** so that:

Measuring the flow A perfect axisimmetric construction cannot be achieved and thus some magnetic flux lines will 'wet' the connecting wires to the electrodes. The alternating magnetic field will create an offset voltage in this wire and even if the fluid is not moving, the measured voltage will not be zero.

ULTRASONIC FLOWMETERS

The blood cells in the fluid scatter the Doppler signal diffusively.In the recent years ultrasound contrast agents have been used in order to increase the echoes.The ultrasound beam is focused by a suitable transducer geometry and a lens.

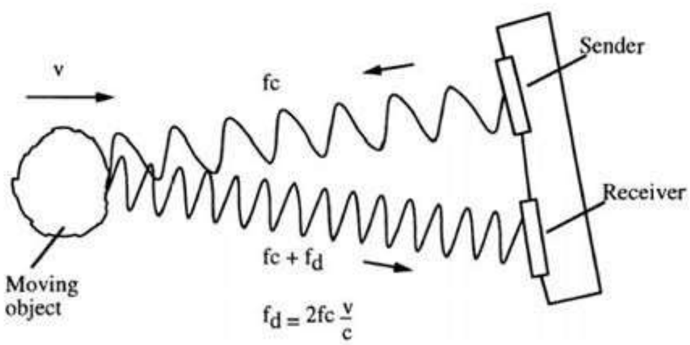


Figure 4 Ultrasonic flowmeters

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

$f_d = 2f_c v/c$

$f = 2\text{- }10\ MHz$

$c = 1500 - 1600$ m/s (1540 m/s)

$f = 1{,}3 – 13\ kHz$

In order to know where along the beam the blood flow data is colledted, a pulsed Doppler must be used. The flow velocity is obtained from the spectral estimation of the received Doppler signal.The ultrasound Doppler device can be either *a continuous wave* or *a pulsed Doppler*

A Continuous Wave

No minimum range

Simpler hardware

Range Ambiguity

Low flow cannot be detected

A Pulsed Doppler

Accuracy

No minimum flow

Minimum range

(Maximum flow) x (range)= limited the power decays exponentially because of the heatingof the tissue. The absorption coefficient ~ proportional to frequency the far field operation shouldbe avoided due to beam divergence.

$$D_{nf} = D^2 / 4\lambda$$

D = Transducer diameter (e.g. 1 – 5 mm) the backscattered power is proportional to f.The resolution and SNR are related to the pulse duration. Improving either one of the parameters always affects inversely to the other.

LASER DOPPLER FLOWMETRY

The principle of measurement is the same as with ultrasound Doppler.The laser parameter may have the following properties:5 mWHe-Ne-laser 632,8 nm wavelength.

The moving red blood cells cause Doppler frequency 30 – 12 000 Hz.The method is used for capillary (microvascular) blood flow measurements

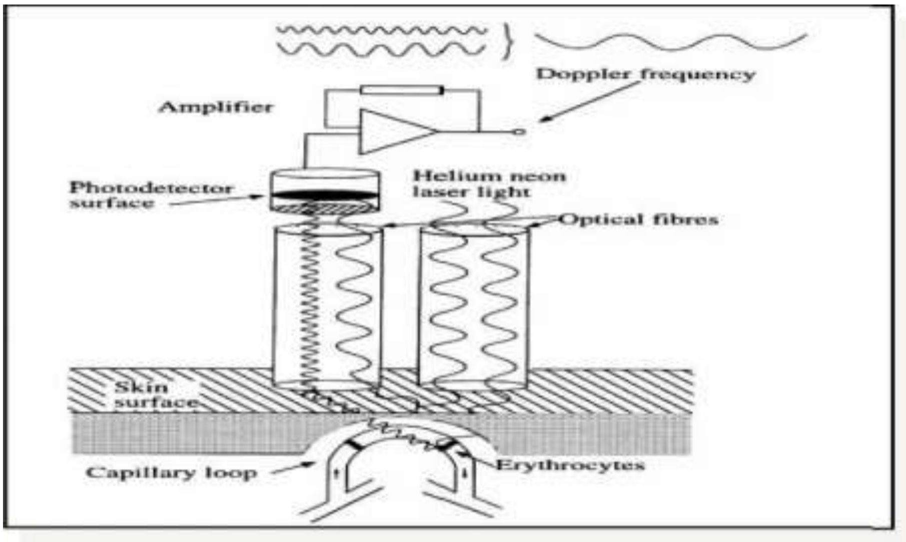


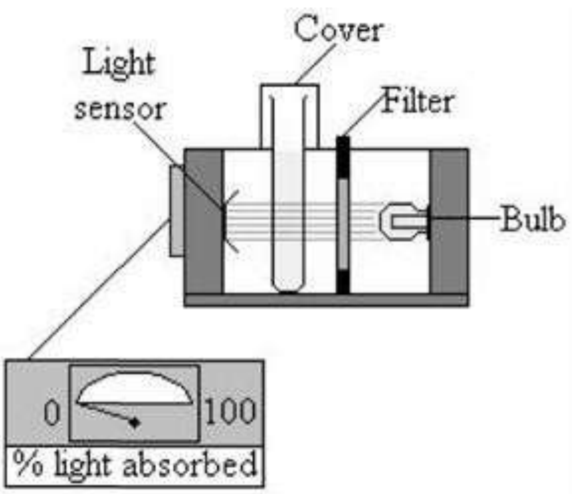
Figure 5 Laser Doppler flowmeter

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

Indicator Dilution Methods

Dye Dilution Method

A bolus of indicator, a colored dye *(indocyanine green)*, is rapidly injected in to the vessel. The concentration is measured in the downstream The blood is drawn through a colorimetric cuvette and the concentration is measured using the principle of absorption photometry



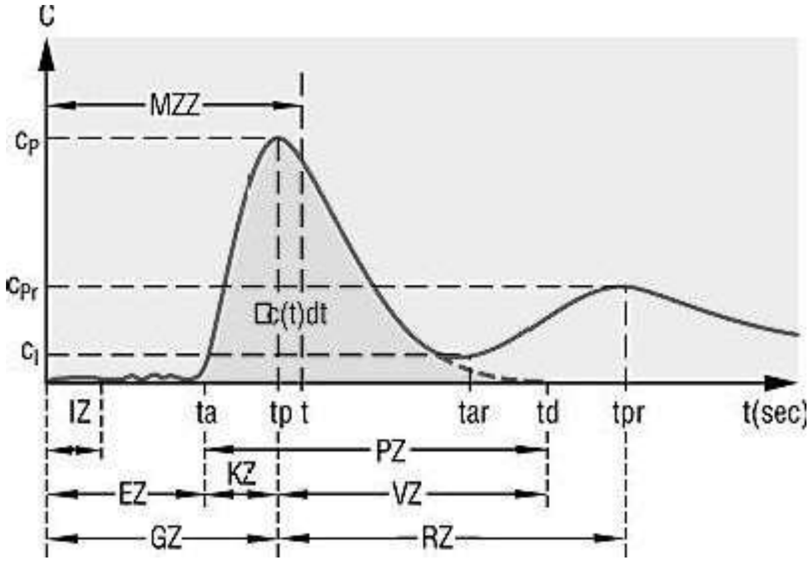


Figure 6 Dye Dilution Method

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

Thermal Dilution Method

A bolus of chilled saline solution is injected into the blood circulation system (right atrium). This causes decrease in the pulmonary artery temperature. An artery puncture is not needed in this technique.Several measurements can be done in relatively short time .A standard technique for measuring cardiac output in critically ill patients

Photoelectric Method

A beam of IR-light is directed to the part of the tissue which is to be measured for bloodflow (e.g. a finger or ear lobe)

The blood flow modulates the attenuated / reflected light which is recorded.The light thatis transmitted / reflected is collected with a photodetector

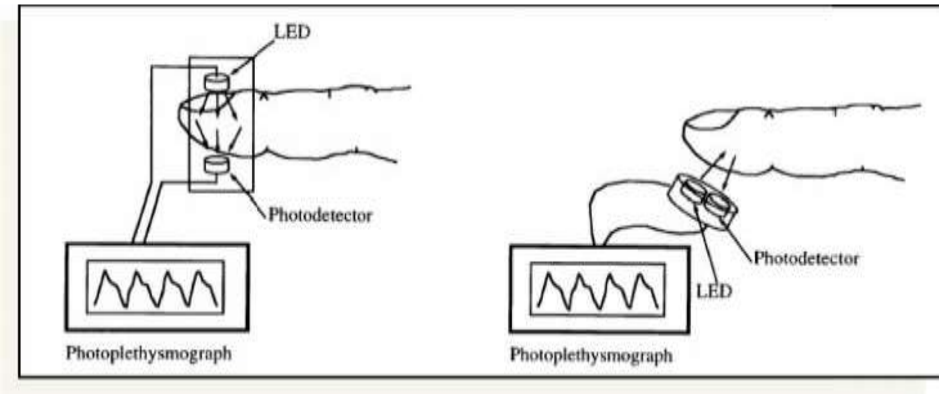


Figure 7 Photoelectric Method

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

Radioisotopes

A rapidly diffusing, inert radioisotope of lipid-soluble gas (Xe or Kr) is injected into the tissue or passively diffused

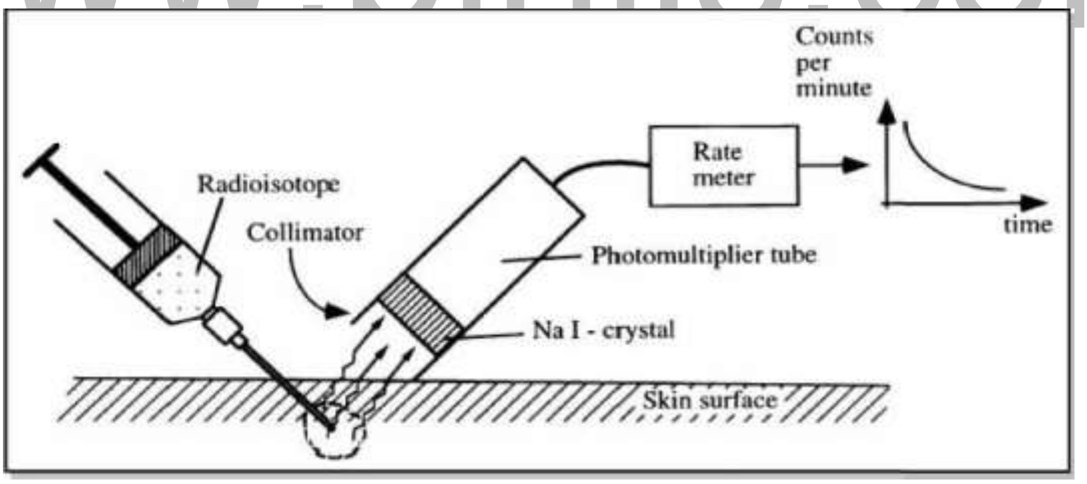


Figure 8 Radioisotopes

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

The elimination of the radioisotope from microcirculatory bed is related to the blood flow.

Thermal Convection Probe

- This is one of the earliest techniques for blood flow measurements

- The rate of heat removal from the tissue under probe is measured
- The concentric rings are isolated thermally & electrically from each other
- The central disk is heated 1 – 2 C over the temperature of tissue.
- A temperature difference of 2- 3 C is established between the disks.The method is not very common due extreme nonlinear properties and difficulties in practical use (e.g. variable thermal characteristics of skin)

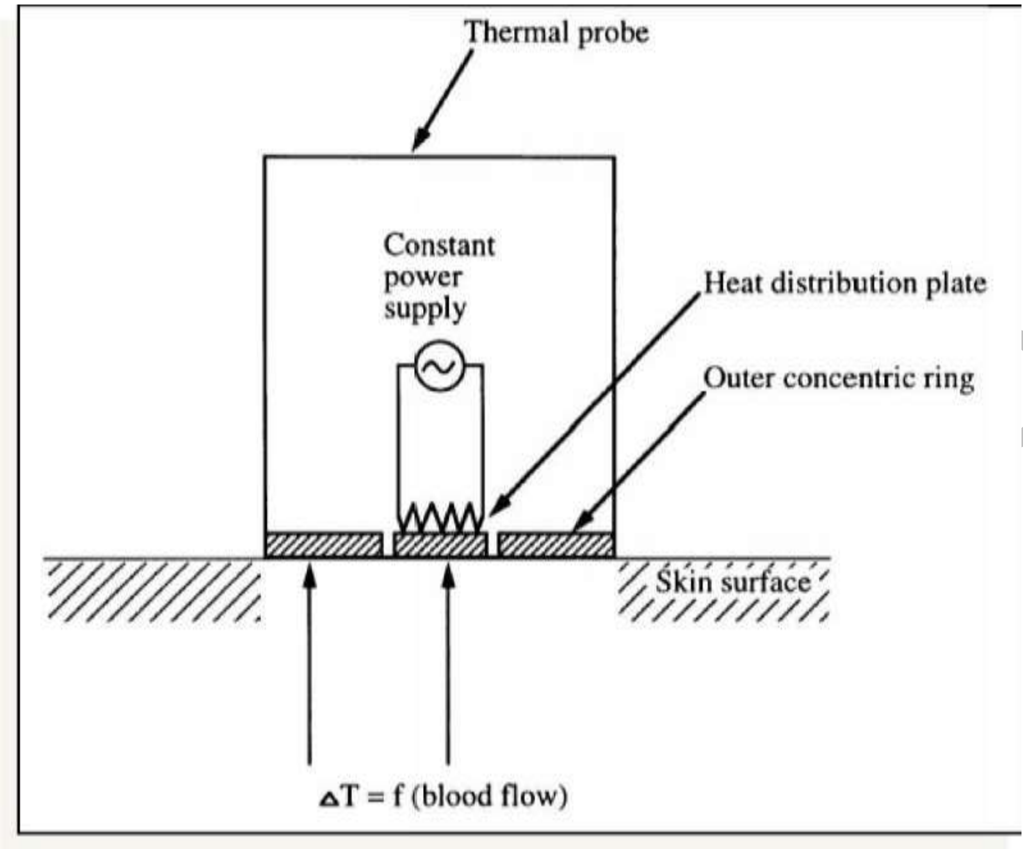


Figure 9 Thermal Convection Probe

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

2.1 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. The ph equation is given as,

$$Ph= - \log_{10} [H^+] = \log_{10} 1/[H^+]$$

pH is the measure of acid- base balance in a fluid, A neutral solution has the ph value as 7. Solutions with pH value less than 7 are acidic and above 7 are basic. Most of the body fluids are slightly basic in nature.

Construction and working

The ph meter is made up of a thin glass membrane and it allows only the hydrogen ionsto 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 sliver-sliver chloride (Ag/Agcl) electrode and the reference electrode which is made up of calomel sliver-sliver chloride(Ag/Agcl) is tan 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. The figure 1 shows the pH 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 biflouride solution, for accurate results. The Ph meter with hydroscopic glass absorbs water readily and provides best pH value.

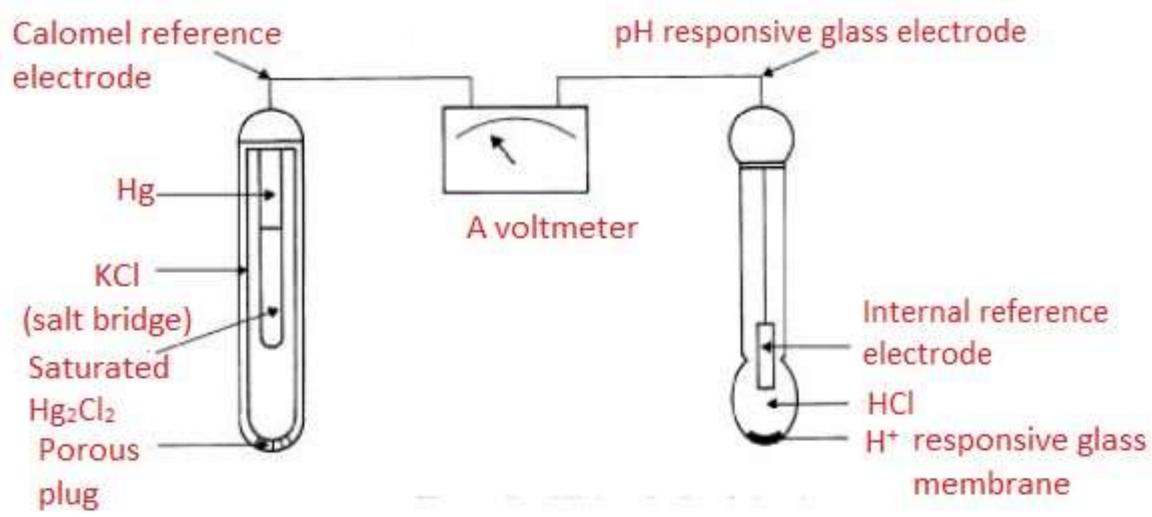


Figure 1 pH Electrode

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

pO_2 MEASUREMENT

The term po2 is defined as the partial pressure of oxygen respectively. The determination of po2 is one the most important physiological chemical measurement. The effective functioning of both respiratory and cardiovascular system can be by po2 measurement. The partial pressure of a gas is proportional to the quantity of that gas present in the blood.

The platinum wire, which is 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 (Ab/AgCl). A voltage of 0.7 is applied between the platinum wire and the reference electrode. The negative terminal isconnected to the active electrode through a micro ammeter and the positive terminal is given to the reference electrode. The bellow figure 2 shows pO2 Electrode.

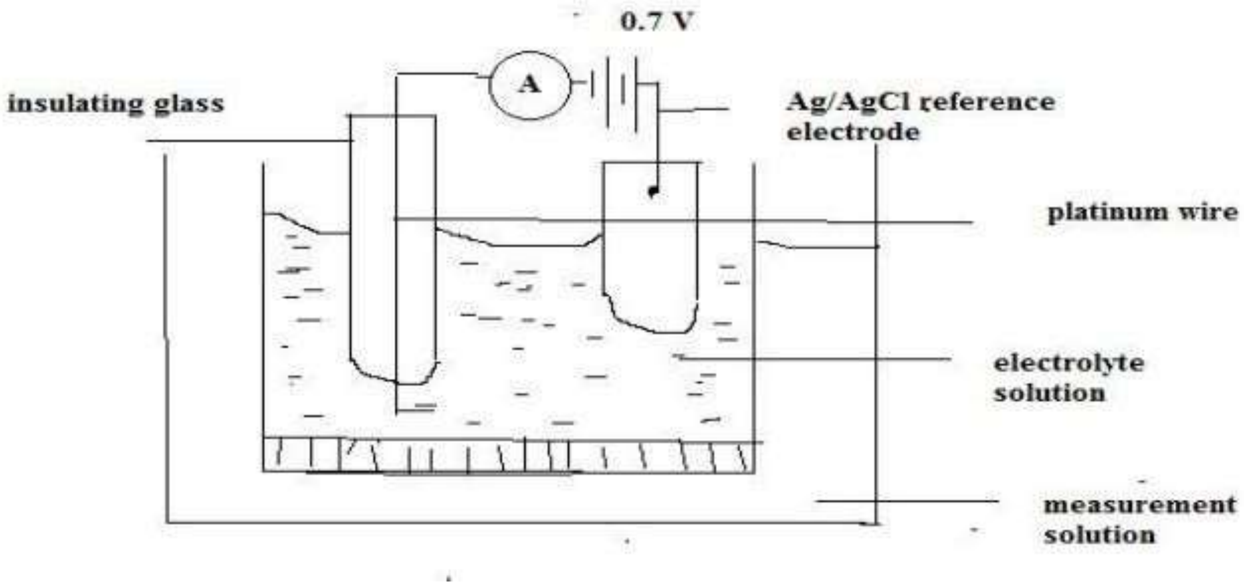


Figure 2 pO_2 Electrode

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

Due to the negative 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 scaled 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

I) Vitro measurement

II) Vivo measurement

In case of dark electrode the platinum cathode and the reference electrode is present in a singleunit. This electrode is used for vitro and vivo measurements.

In Vitro Measurements

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 thatit can be inserted into various parts of the heart or circulatory system.

The pO_2 measurement also has some disadvantages in it. The reduction process in the platinum cathode removes a finite amount of the oxygen from the cathode. And there is a gradualreduction of current with respect to time. However careful design and proper procedures in modern pO_2 electrodes reduce the errors.

pCO_2 MEASUREMENT

The term pco2 is defined as the partial pressure of carbon dioxide respectively. The determination of pco2 is one the most important physiological chemical measurement. The effective functioning of both respiratory and cardiovascular system can be by pco2 measurement. The partial pressure of a gas is proportional to the quantity of that gas present in the blood.

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 older 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.

MEASUREMENT OF $PHCO_3$

- Blood gas analyzers are used to measure the content of pH, pCO and PO_2 from theblood.

Two gases of accurately known O_2 and CO_2 percentages are required for calibrating the analyzer in pO_2 and pCO_2 modes. These gases are used with precision regulators for flow and pressure control.

- Two standard buffers of known pH are required for calibration of the analyzer inthe pH mode.
- Input signal to the calculator is obtained from the outputs of the pH and pCO_2amplifiers
- The outputs are adjusted by multiplying with a constant and are given to an adder circuit. The bellow Figure 3 represents the circuit diagram of computation of bicarbonate.
- The output of adder is passed to antilog generators circuit. Then it is passed toA/D converter for display. Resistance R is used to adjust zero at the output.
- Total CO_2 is calculated by summing the output signals of the calculators and the output of the pCO_2 amplifier

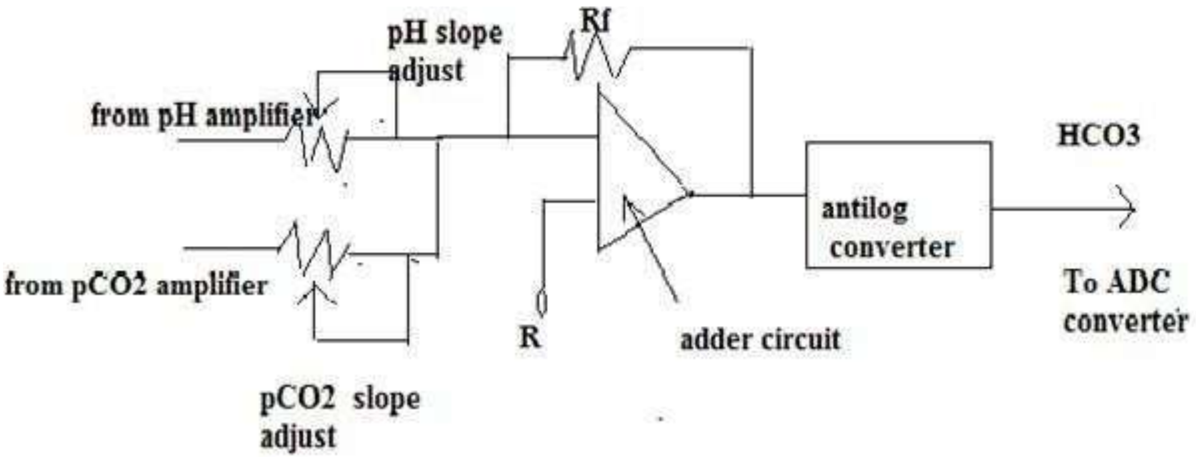


Figure 3 circuit diagram of computation of bicarbonate

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

The base excess calculator consists of three stages.

In the first stage, the output of pH amplifier is inverted in an operational amplifier, whose gain is controlled by a potentiometer. The bellow figure 4 shows the circuit diagram for computation of base excess.

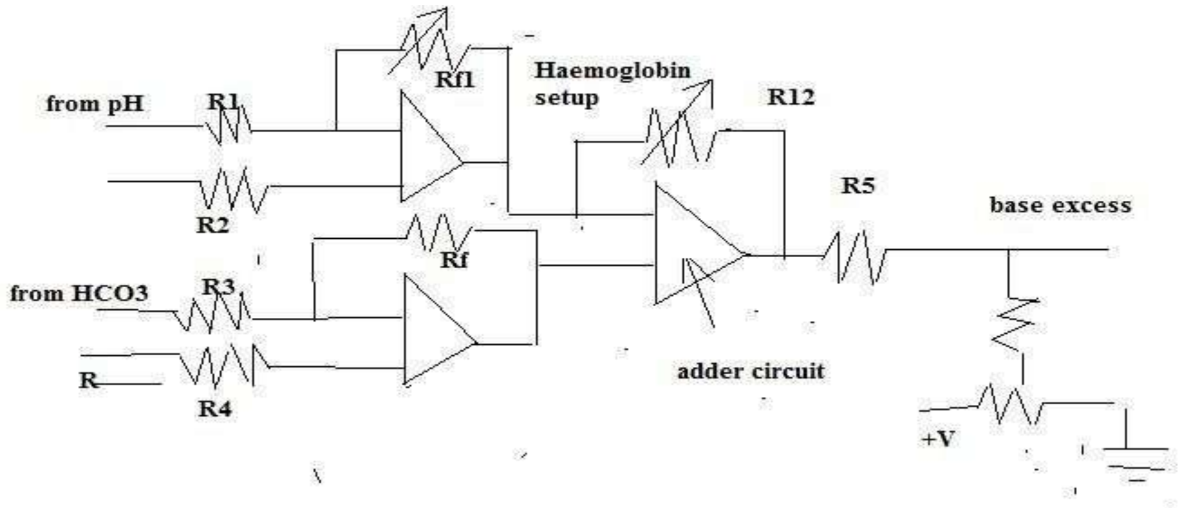


Figure 4 Circuit diagram for computation of base excess

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

The output of HCO_3^- calculator is inverted in the second stage.

The third stage is a summing amplifier A_3 whose output is given to A/D converter, that gives adigital read out.

ELECTROPHORESIS

In clinical laboratories, various devices are used based on the electrophoretic principle.

These devices are used for the following applications.

- To measure the quantity of protein in plasma, urine, etc.
- To separate enzymes into their components is enzymes.
- To identify antibodies.

Basic principle

Electrophoresis is defined as the movement of a solid phase with respect to a liquid. The buffer solution is used to carry the current and to maintain the pH value of the solution as a constant one during the migration.

In this title, zone electrophoresis is explained. In this technique, the sample is applied to the medium and under the effect of the electric field, group of particles that are similar in charge, size, and shape migrate at the same rate. So the particles are separated into zones.

Factors Affect the Speed of MigrationMagnitude of charge:

The mobility of a given particle is directly related to the net magnitude of the particles charge. Mobility is defined as, the distance in cm, a particle moves in unit time per unit field strength.

Ionic Strength of Buffer

If the buffer is more concentrated then the migration of the particles is slow. Because, if greater the proportion of buffer ions present, then greater the proportion of the current they carry.

Temperature:

Mobility is directly related to temperature. Heat is produced when the current flows through the resistance of the medium. So, the temperature of the medium is increased and resistance is decreased. Finally, the rate of migration is increased.

The water is evaporated from the surface of the medium due to heat. So, the concentration of particle is increased. Finally the rate of migration is increased. When the gel is used as a medium; this heat will create a problem. So, for this medium, constant current sources are used tominimize the heat production.

Time: The distance of migration is related to the time period during which electrophoresis takesplace.

Types of Support Media:

Cellulose acetate, starch gel and sucrose are used as support media in various electrophoretic applications. We can see the cellulose acetate electrophoresis in the following sections**.**

Cellulose Acetate Electrophoresis

Cellulose acetate strip is saturated with the buffer solution and placed in the membrane holder. It is otherwise known as bridge. The two ends of the bridge are placed in the cuvette in which buffer solution is available.

The sample for each test is placed on the strip at a marked location. Then, the constant electric potential(250 V) is applied across the strip 4 – 6 mA of initial current is obtained **.**After 15-20mins, the electric voltage is removed, then, migrated protein band is stained with buffer and it is dried in preparation for densitometry.

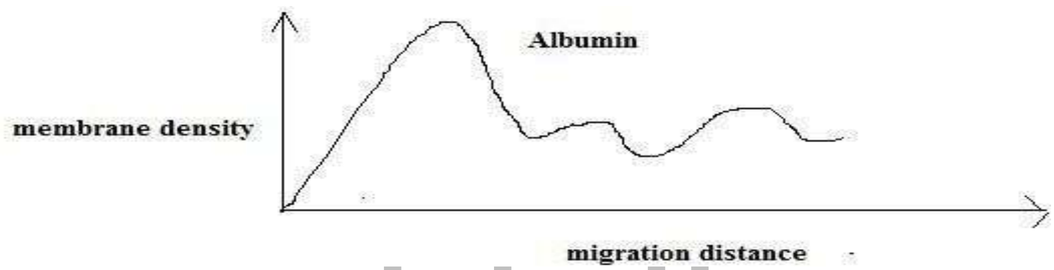


Figure 5 Pattern

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

The membrane is placed in the holder of densitometer. The path of the migration ofone of the specimen is scanned. The low voltage output is amplified and recorded using x-y recorder. The bellow figure 6 shows the cellulose acetate electrophoresis

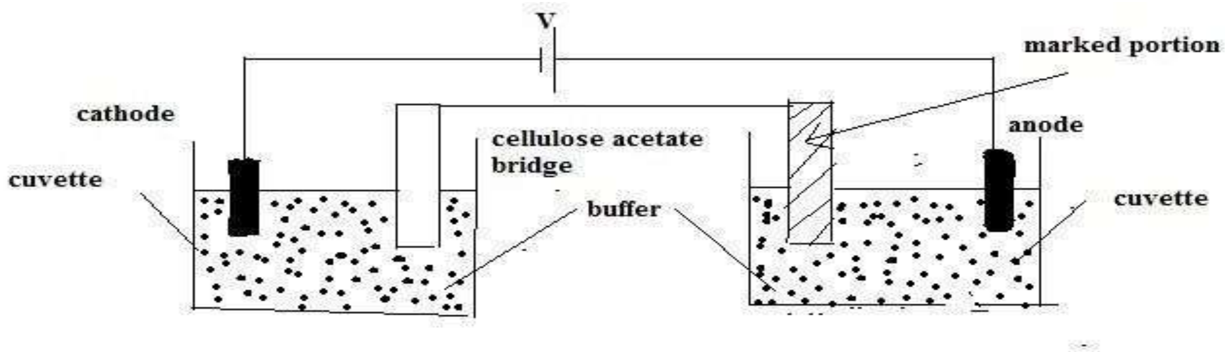


Figure 6 Cellulose acetate electrophoresis

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

2.1.1 COLORIMETER

- Measures the color concentration of a substance in a solution by detecting the color lightintensity 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. The figure 7 shows the colorimeter.
- Laser LEDs are preferred if their wavelength is suitable due to purity of the monochromatic color.

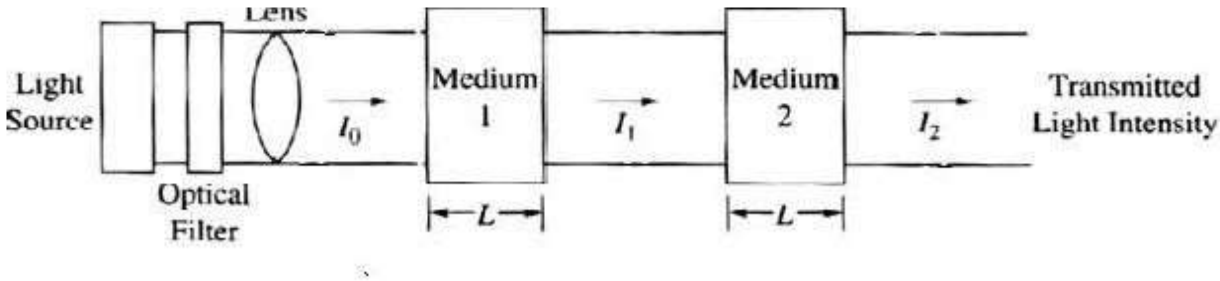


Figure 7 Colorimeter

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

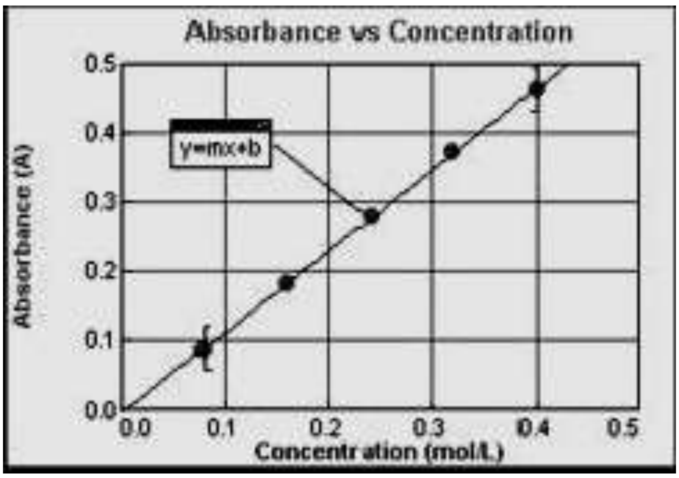


Figure 8 Concentration vs Absorbance

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

Transmittance

$T = I_1/I_0 * 100\%$

Absorbance

$A = -\log I_1/I_0$

$A = \log 1/T$

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

PHOTOMETER

FLAME PHOTOMETER

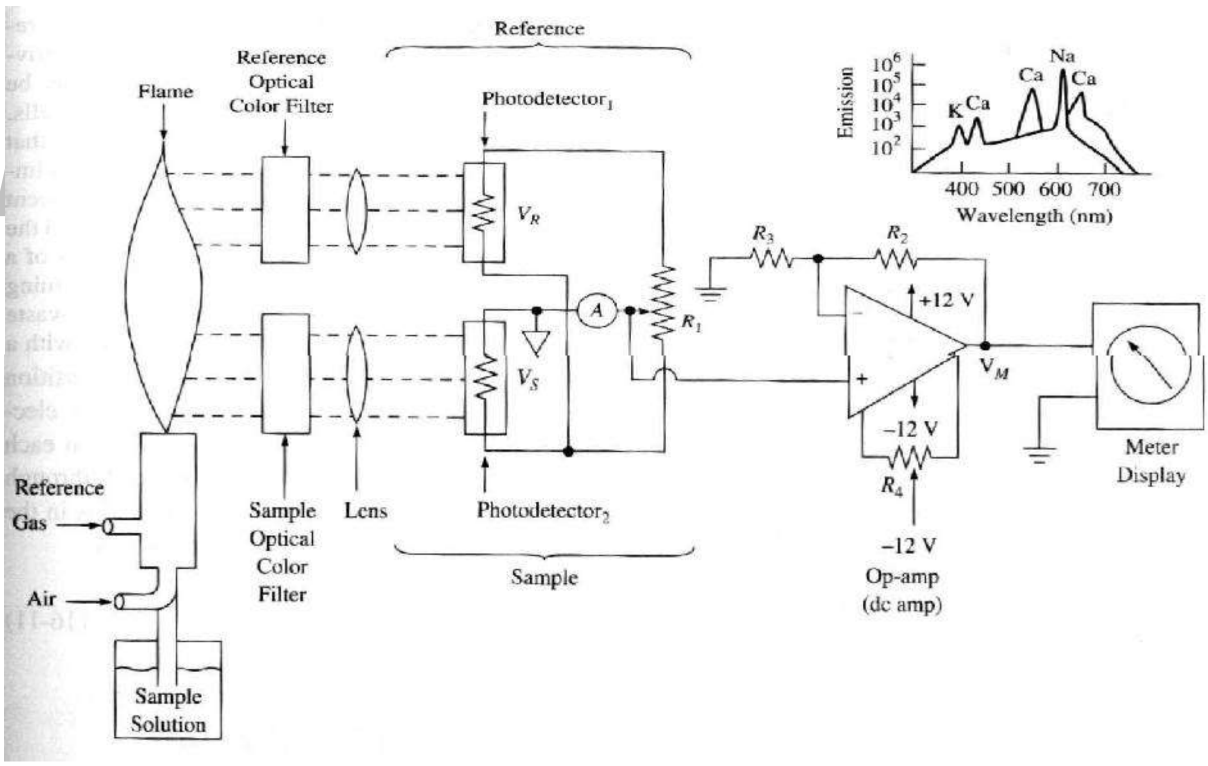


Figure 9 Flame Photometer

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

Measures the color intensity of a flame supported by O2 and a specific substance. Sample's emission of light is measured (rather than the absorbance of light).Typically used to determine the conc. of pure metals and/or Na^+, K^+, Li^+ and Ca^{++}. The above figure 9 shows the flame photometer.

In this method, fine droplets of the sample is aspirated into gas flame that burns in a chimney. A known amount of lithium salt is added to the sample, as a reference. 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. The photo detector circuits consists of a reverse biased diode in which the current flow increases as intensity of incident light increases. A calibration potentiometer is used in every channel. Since the lithiumis 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 the spectral illustration.

SPECTROPHOTOMETER

The general name given to the group of instruments whose principle of operation is based on the fact that substances of clinical interest selectively absorb or emit EM energy (light) at different wavelengths. The bellow figure 10 shows the spectrophotometer.

- Depending on the substance being measured, the wavelength used is typically in theultraviolet (200-400 nm), visible (400-700nm) or infrared (700 to 800 nm) range.
- Spectrophotometer can be used to determine the entity of an unknown substance, or theconcentration of a number of known substances.
- The type of source / filters used typically determines the type of the spectrophotometer.
- Rays of light bend around sharp corners, where the amount of bending depends on the wavelength! This results in separation of light into a spectrum at each line.
- In spectrophotometer, selection filter of colorimeter is replaced by a monochromator. Monochromatic uses a diffraction grating G to disperse light from the

lamp. Light falls through the slit S_0 into its spectral components.

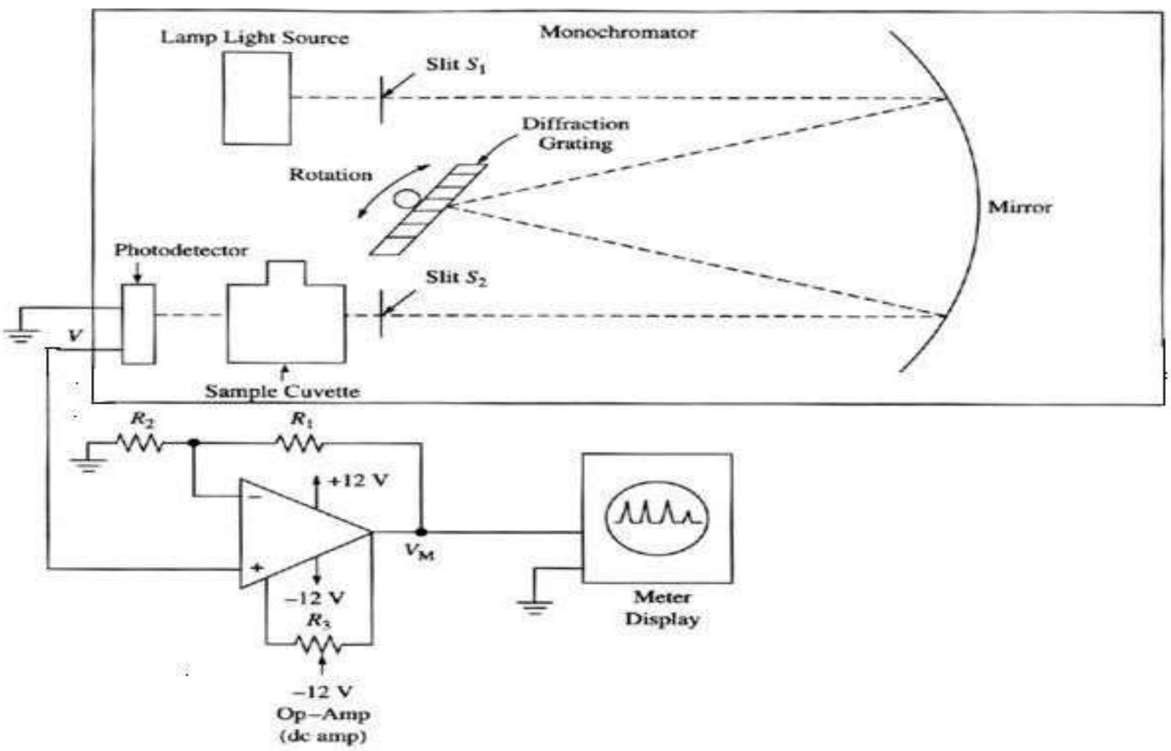


Figure 10 Spectrophotometer

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

AUTOANALYZER

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

It consists of

- **Sampler:** Aspirates samples, standards, wash solutions into the system
- **Proportioning pump:** Mixes samples with the reagents so that proper chemical color reactions can take place, which are then read by the colorimeter
- **Dialyzer:** separates interfacing substances from the sample by permitting 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 changes in optical density of the fluid stream flowing through a tubular flow cell. Color intensities proportional to the substance concentrations are converted to equivalent electrical voltages.
- **Recorder:** Displays the output information in a graphical form.
- lit 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 bellow figure 11 shows the block diagram of autoanalyzer. The light from the cuvette is given to photo detector. It converts light into a 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 reduce the size of the instruments.

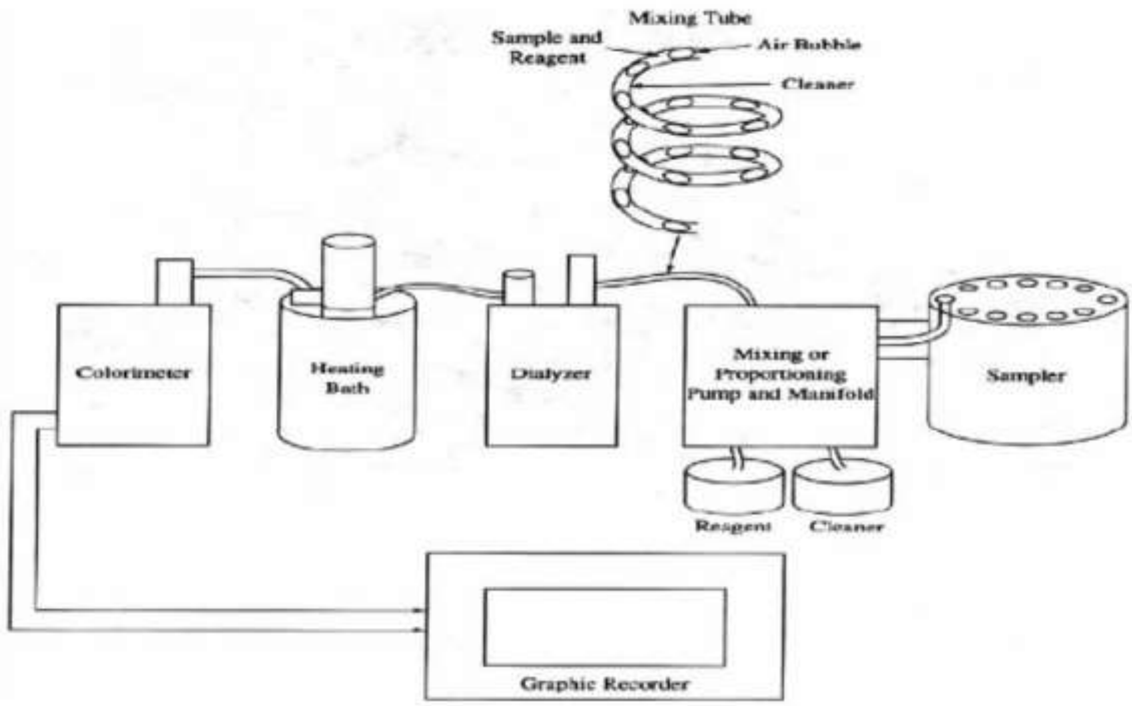


Figure 11 Block diagram of Autoanalyzer

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]