Biomedical Engineering

19BMT202 & BIOMEDICAL SENSORS AND MEASUREMENT

Question Bank

Academic Year 2023-24 (odd semester)

II Year BME

1. Write about stylus

In graph recorders a pen is used for marking the variation in physical quantity, which is called stylus. The stylus moved along the calibrated scale in accordance with input data to get proper record of input data signal.

2. Brief about strip chart recorder

The strip chart recorder often used for the application which require monitoring the quantity.A strip-chart recorder plots one or more parameters as a function of time. A strip is a ribbon of paper moved through the instrument at uniform speed by an electric motor.

3. What is Galvanometer type recorder

It operates on the galvanometer (D'Arsonval) principle. It produces deflection when the current passes through the coil.

What is recorder?
A recorder is a device whose function is to record the value of a quantity as it is being measured. Recording preserves the experimental data in a manageable and usable form.

4. Give the classification the recorders.

1. Graphic Recorder
- (*i*) Strip Chart Recorder
- (*ii*) Circular Chart Recorder
- (*iii*) *X-Y* Recorders
  - (*a*) Analog *X-Y* Recorder
  - (*b*) Digital *X-Y* Recorder

2. Oscillographic Recorder
3. Magnetic Tape Recorder

5. List the various Mechanism for Marking

- Pen and Ink Stylus
- Impact Printing
- Chopper Bar Printing

- Thermal Writing
- Electrical Writing
- Optical Writing

6. List a few applications of biopotential electrode

electrocardiography (ECG), electroencephalography (EEG), electromyography (EMG), and electrooculography (EOG)

7. Recall electrode double layer

At the metal-electrolyte transition, there is a tendency for each electrode to discharge ions into the solution and for ions in the electrolyte to combine with each electrode. The net result is the creation of a charge gradient (difference of potential) at each electrode, the spatial arrangement of which is called the electrical double layer

8. Tell about perfectly Non polarizable electrode

The electrodes in which no net transfer of charge takes place across the metal-electrolyte interface can be termed as perfectly polarized. Those in which unhindered exchange of charge is possible are called non-polarizable or reversible electrodes. The ionic double layer in metals of these electrodes is such that they allow considerable current to flow when a small voltage is applied, thus offering a low resistance.

9. List the key point in Tape Transport Mechanism

(*a*) To handle the tape without straining and wearing it.
(*b*) To guide the tape across magnetic heads with great precision.
(*c*) To maintain uniform and sufficient gap between the tape and heads
(*d*) To maintain proper tension of magnetic tape.

10. Recall the Methods of Recording on Magnetic Tape

1. Direct Recording Method

2. Frequency Modulation Recording

3. Pulse Duration Modulation Recording

11. Define half cell potential

Half-cell potential is the voltage developed at the electrode-electrolyte interface. In a metal – solution interface, electrode potential arises at two conditions i) when ions travel from metal into the solution ii) when ions in solution combine with electrons in the metal they form the atom of metal. Hence, when metal electrode and body fluid interacts electrode discharges ions into solution. At the same instance ions in the electrolyte combine with the electrode. This results in the generation of charge gradient.

12. Tell about perfectly polarizable electrode

The electrodes in which no net transfer of charge takes place across the metal-electrolyte interface can be termed as perfectly polarized. Those in which unhindered exchange of charge is possible are called non-polarizable or reversible electrodes. The ionic double layer in metals of these electrodes is such that they allow considerable current to flow when a small voltage is applied, thus offering a low resistance.

13 .Write about ion sensitive field effect transistors

ISFET (ion sensitive field effect transistors) devices are widely used in biomedical applications, such as the detection of DNA hybridization, biomarker detection from blood, antibody detection, glucose measurement and pH sensing.

14. **Define Bioelectric potentials**

Bioelectric potentials are generated at a cellular level and the source of these potentials is ionic in nature. A cell consists of an ionic conductor separated from the outside environment by a semipermeable membrane which acts as a selective ionic filter to the ions. This means that some ions can pass through the membrane freely where as others cannot do so.

15. Define Depolarization

When the cell is excited or stimulated, the outer side of the cell membrane becomes momentarily negative with respect to the interior. This process is called **depolarization** and the cell potential changes to approximately +20 mV.

16. Define Depolarization

Repolarization then takes place a short time later when the cell regains its normal state in which the inside of the membrane is again negative with respect to the outside. Repolarization is necessary in order to re-establish the resting potential.

17. What is Motion artefact

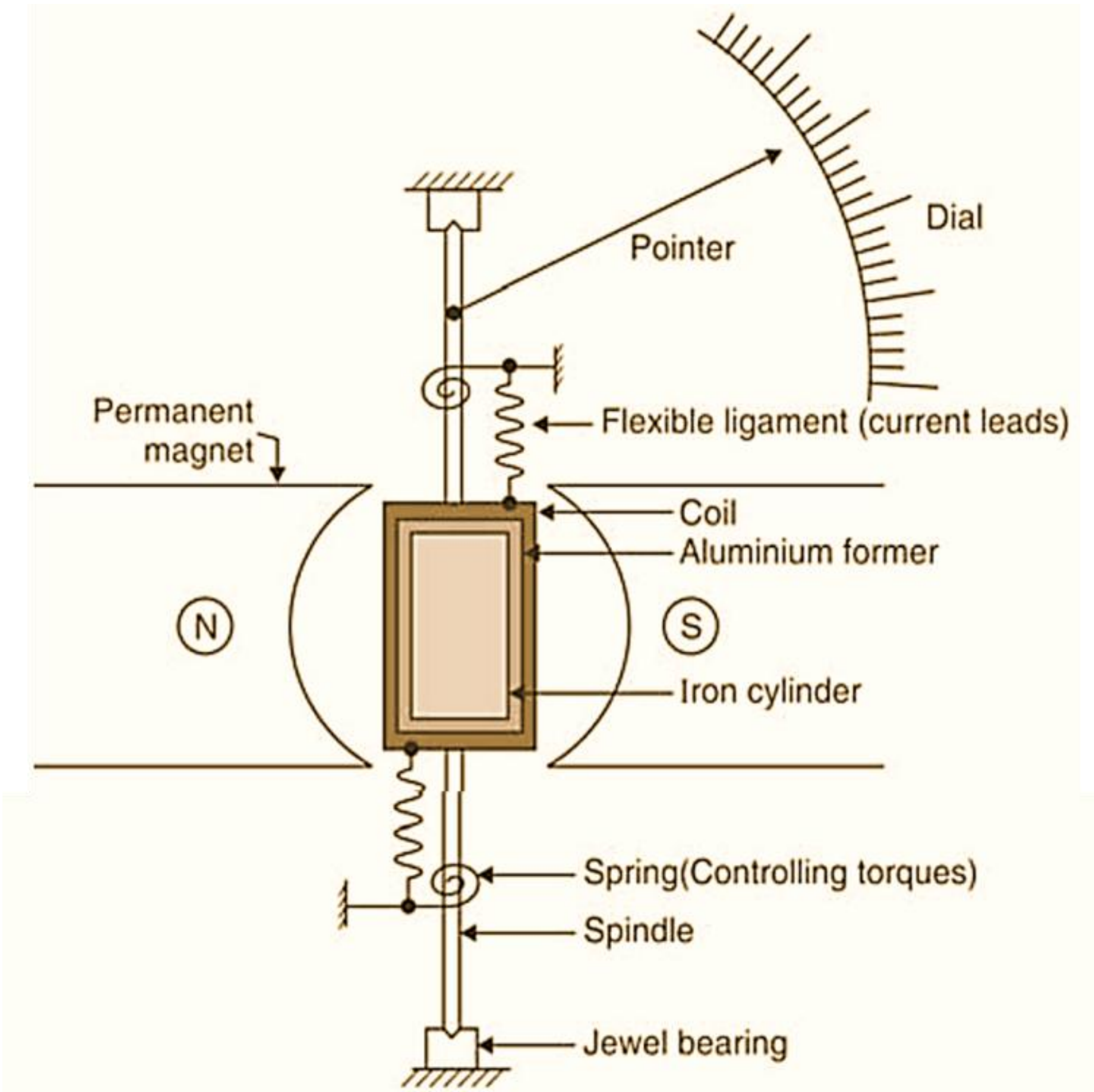
Motion of the subject under measurement creates artefacts which may even mask the desired signal or cause an abrupt shift in the baseline. These artefacts may result in a display being unreadable, a recording instrument exceeding its range, a computer yielding incorrect output or a false alarm being triggered by the monitoring device.

<u>Detailed Question Answers</u>

1. Explain the working principle of PMMC writing system

PMMC Instruments:

- They are also known as d'Arsonval instruments.
- These instruments works on the electromagnetic effect of current.
- A permanent magnet used to produce magnetic flux and coil that carries the current to be measures moves in this field.



Permanent magnet moving coil type (PMMC)

PMMC Instrument Parts, Material and their Functions

Name of part	Material	Function
Permanent magnet	Ferromagnetic	To produce magnetic flux
Iron cylinder	Magnetic	To strengthen magnetic flux linkage
Coil	Copper	To carry current and produce deflection
Former	Aluminium	To support coil and to produce damping torque.
Spindle	Steel	To support the coil and to provide means for rotation.
Flexible ligament	Thin steel strips	To provide connection between meter terminal and coil.
Spring	Phospher bronze	To provide leads for incoming and outgoing connection to coil, To produce controlling torque.
Pointer	Aluminium	To show reading on calibrated scale.

Working principle:

- When a current carrying conductor is placed in a magnetic field, it experiences a force. It is given by expression,

$$F = BIL$$

Where F = Force in Newton,

B = Flux density is tesla,

I = Current is ampere,

L = Length of conductor in meter.

- The current I which is to be measured is passed through the moving coil and experiences a force which is directly proportional to this current.

- Due to this force the coil moves and the pointer attached to it will also move.

The angle through which the pointer moves is proportional to current I

Construction of PMMC instrument:

- A coil of thin wire is mounted on an aluminum frame (spindle) positioned between the poles of a U shaped permanent magnet which is made up of magnetic alloys like alnico.
- The coil is pivoted on the jewelled bearing and thus the coil is free to rotate. The current is fed to the coil through spiral springs which are two in numbers.
- The coil which carries a current, which is to be measured, moves in a strong magnetic field produced by a permanent magnet and a pointer is attached to the spindle which shows the measured value.

Deflecting Torque:

- It can be proved that the expression for the deflecting torque is given by,

$T_d = G \times I$ where G = constant

I = Current through the moving coil

Controlling Torque:

- The controlling torque is given by,

$T_c = C.\ \theta$

where C = Control spring constant in N-m/rad

θ = Deflection of coil from zero position

- For steady state, the controlling torque is equal to the deflection torque

$\therefore T_c = T_d$

i.e. $C\theta = GI$

$\therefore \theta \propto I$

- Thus deflection of the pointer is proportional to current passed through the coil.

2. Explain the construction and working principle of magnetic tape recorder

Magnetic Tape Recorder

The recorders discussed earlier are having very poor higher frequency response. They are mostly used for low frequency operation. The magnetic tape recorders are used for high frequency signal recording. The basic components of magnetic tape recorder are given below:

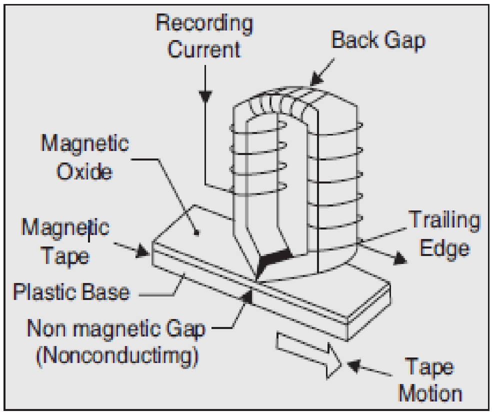


Fig. 11.11. Recording Head

1. Recording Head. The construction of the recording head is shown in Fig. 11.11. Its construction is similar to that of transformer having toroidal core with a coil. The fine air gap of length 5-15 µm is shunted by the passing magnetic tape.

When the current used for recording is passed through the coil wound around magmatic core, it produces magnetic flux. The magnetic tape having iron oxide particles passes the head, the magnetic flux produced gets linked with the iron oxide particles and these particles get magnetized. The state of magnetization of the oxide as it leaves the gap is retained, thus the actual recording takes place at the trailing edge of the gap.

Any signal recorded on the tape appears as a magnetic pattern dispersed in space along the tape, similar to the original coil current variation with time.

2. Magnetic Tape. It is made of a thin sheet of tough, dimensionally stable plastic, one side of which is coated with a magnetic material. Typically the plastic base is polyvinyl chloride (PVC) or polyethylene terephthalate, for example mylar.

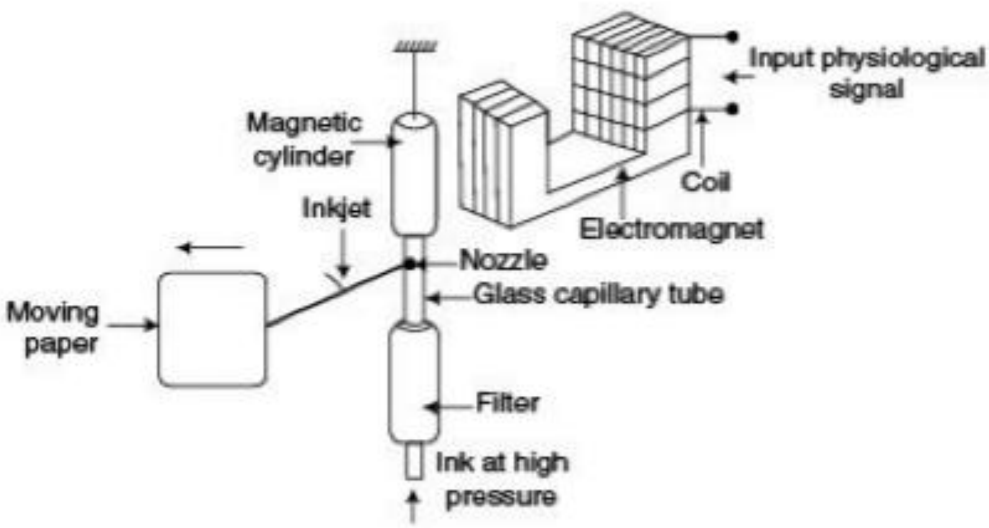
The magnetic coating consists of a dispersion of very small particles of iron oxide (Fe2O3) on a plastic blinder.

3. Reproducing Head. Its function is to detect the stored magnetic pattern and to convert it back to original electrical signal.

3. Explain the construction and working principle of Inkjet recorder

Inkjet Recorder

The principle of working of Inkjet recorder is that a very fine Inkjet is made to move on the paper per the physiological events or signals.



- The recorder has a glass capillary tube placed between the poles of an electromagnet.
- The coil of the electromagnet is connected to the amplified physiological signals.
- The variation of current corresponding to physiological signals in the electromagnetic coil produce a varying magnetic field in it which interacts with the field of the cylindrical magnet attached to the capillary.
- The interaction of the magnetic field deflects the cylindrical magnet and the capillary tube attached with it as per the strength of the physiological signals.
- The capillary tube is supplied with ink at high pressure, and the ink comes out of the nozzle provided on the capillary tube in the form of a jet.
- The waveform is traced on the paper.
- Using more capillaries of different colours, the inkjet recorder can work as a multichannel recorder. The inkjet uses normal paper.
- As it does not have any stylus it can work at much high frequency.

4. Discuss the Method of Recording on Magnetic Tape

The methods used for magnetic tape recording used for instrumentation purpose are as follows:
1. Direct Recording Method
2. Frequency Modulation Recording
3. Pulse Duration Modulation Recording

1. Direct Recording Method

It is the simplest method of recording and usually requires one tape track for each channel. The signal to be recorded is amplified, mixed with a high frequency bias and fed directly to the recording head as a varying electric current as shown in Fig. 11.13.

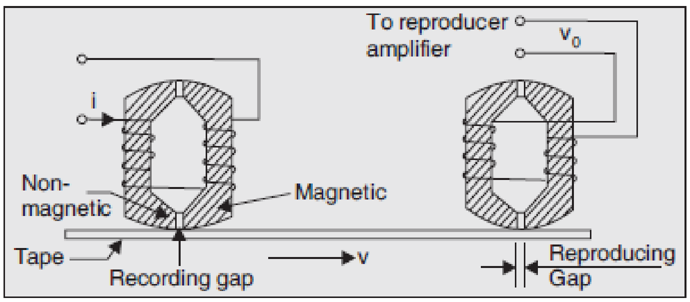


Fig. 11.13.

The input voltage is converted into proportional current and passed through the winding on the recording head. A magnetic flux given by the expression $\phi = K_\phi\, i$ is created at the recording gap and as the tape passes under the gap the oxide particles retain a state of permanent magnetization proportions to the flux existing at the instant the particle leaves the gap. Thus, with a sinusoidal input signal,

$$i = i_o \sin 2\,\pi f t$$

A tape speed of v m/s, the intensity of magnetization along the tape varies sinusoidally with the distance x as,

$$\text{Magnetization, } m = K_m\, K_\phi\, i_o \sin\left(2\pi f\, \frac{x}{v}\right)$$

Thus resulting magnetic field created in the recording gap enables magnetic recording of the input information on a tape that passes under the gap. A dc or high frequency ac is added to the recording signal to improve linearity.

Frequency Modulation Recording

The major disadvantage of direct recording is that it is difficult to record dc signals. This problem is solved with frequency modulation (FM) recording in which accurate dc response is obtained.

Principle of Operation

In FM the carrier frequency is modulated by the input signal. This recorder uses the variation of frequency to carry the required information instead of amplitude. The modulated signal is then recorded using the recording head. The reproducing head reproduces the signal in normal way.

The reproduced signal is passed through FM demodulator, low pass filter to get original signal. Working

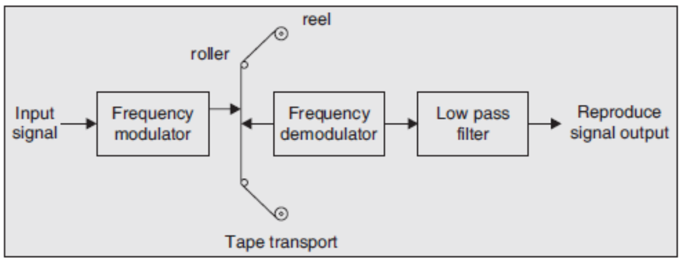


Fig. 11.14. Tape Transport Mechanism

Fig. 11.14 shows the FM recording system. The carrier frequency is called as center frequency fc.

This frequency is modulated by the level of the input signal. The centre frequency is selected with respect to the tape speed and frequency deviation selected for the tape recorders.

When there is no input signal (zero input), the modulation contains only the centre frequency oscillation. The positive input voltage deviates the carrier frequency by specified percentage in one direction. The negative voltage deviates the carrier frequency by specified percentage in other direction.

For dc inputs the modulated output is a signal of constant frequency and for ac inputs the modulated output is a signal of variable frequency. The frequency variation is directly proportional to the amplitude of input signal.

On playback, the output of the reproducing head is demodulated and fed through a low pass filter which removes the carrier and other unwanted frequencies reproduced due to the modulation process. The frequency demodulation converts the difference between centre frequency and the frequency on the tape, to a voltage proportional to the difference in the frequencies. This system can thus record frequencies from dc to several thousand hertz.

Pulse Duration Modulation Recording (PDM) Method

It is also called pulse width modulation. The amplitude and starting time of each pulse of a signal is kept constant while width of pulse is made proportional to amplitude of signal at that instant.

The input signal is converted to a pulse at the sampling instant. The width of each pulse is dependent on the amplitude of the signal at that instant. The sampled signal is recorded at various instants instead of recording instantaneous values continuously. On playback original signal can be obtained by passing recorded signal to appropriate filter.

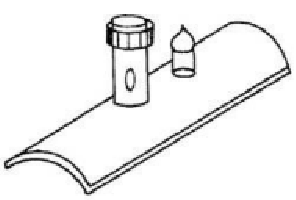
For example if a sine wave is to be recorded, it is sampled and recorded at uniformly spaced discrete intervals in place of continuously recording the instantaneous values. On playback the original sine wave can be reconstructed by passing the discrete readings through an appropriate filter. Its main advantages are high signal-to-noise ratio, high accuracy and capability of recording information from are large number of channels simultaneously.

This recording system is employed in instrumentation systems for special applications such as for simultaneous recording of large number of slowly changing variables.

5. Discuss in detail about the various Body Surface Recording Electrodes

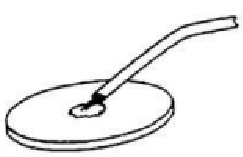
The main design feature of these electrodes which helps in reducing the possibility of artefacts, drift and baseline wandering is the provision of a high-absorbancy buffer layer with isotonic electrolyte. This layer absorbs the effects of movement of the electrode in relationship to the skin, and attempts to maintain the polarization associated with the half-cell potential constant.

1. Metal Plate Electrodes 2. Suction Electrodes 3. Floating Electrodes 4. Flexible Electrodes



Metal-plate electrode used for application to limbs, traditionally made from German-silver (nickel-silver alloy)

(a)

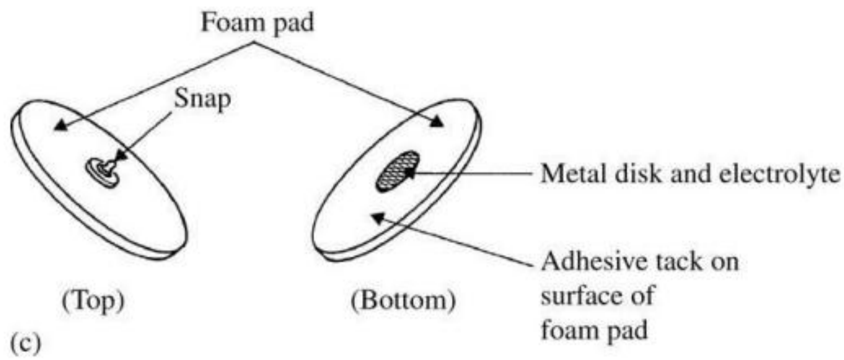


Metal-disk electrode applied with surgical tape.

(b)

- Lead wire soldered or welded on the back surface.
- For ECG application made form disk of Ag with electrolytic deposition of AgCl
- For surface EMG applications made of stainless steel, platinum or gold plated disks to minimize electrolyte chemical reaction.
- Acts as polarizable electrode, and prone to motion artifacts

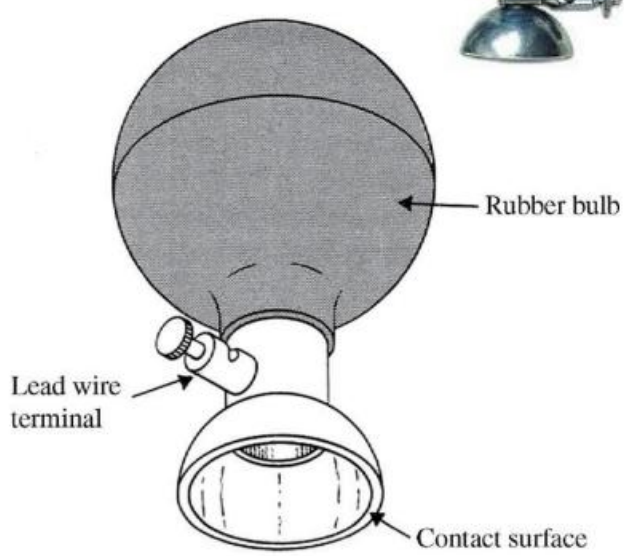
Disposable foam-pad electrodes, often used with ECG monitoring apparatus



- Relatively large disk of plastic foam with silver-plated disk serving as electrode, coated with AgCl
- Layer of electrolyte gel covers the disk
- Electrode side of foam covered with adhesive material
- They are preffered in hospitals due to being easy to apply and disposable.

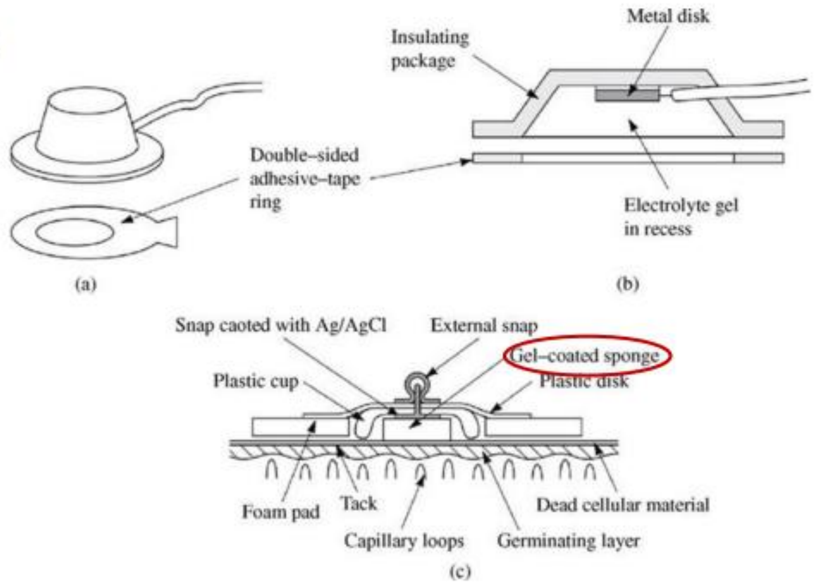
Metallic suction electrode

- A metallic suction electrode is often used as a precordial (chest) electrode on clinical electrocardiographs.
- It requires no straps or adhesives for holding it in place.
- Electrolyte gel is placed on the contacting surface of electrode.
- This electrode can be used only for short periods of time.



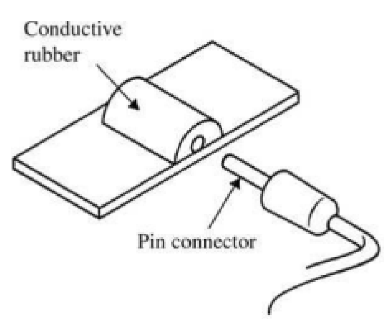
Floating Electrodes

- Mechanical technique to reduce noise. Isolates the electrode-electrolyte interface from motion artifacts.
- Metal disk (actual electrode) is recessed.
- Floating in the electrolyte gel.
- Not directly contact with the skin.
- Reduces motion artifacts.



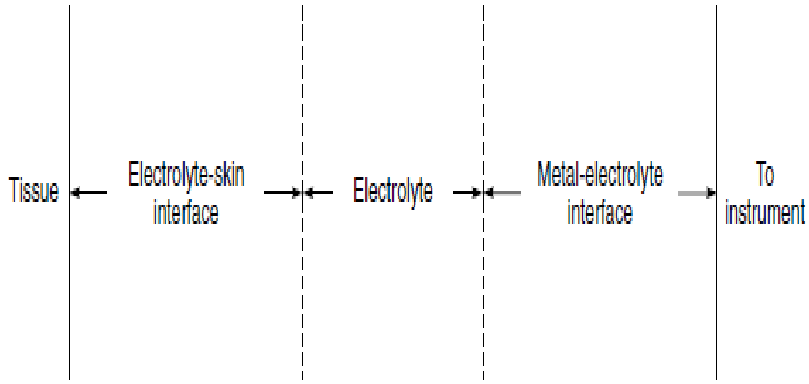
Flexible body-surface electrodes (a) Carbon-filled silicone rubber electrode

- Solid electrodes cannot conform to body-surface topology resulting additional motion artifacts.
- Carbon particles filled in the silicone rubber compound (conductive) in the form of a thin strip or disk is used as the active element of an electrode.
- A pin connector is pushed into the lead connector hole and electrode is usd like a metal plate electrode.
- Applications – monitoring premature infants (2500gr) who are not suitable for using standard electrodes.

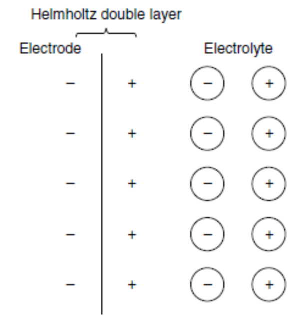


6. Summarize the Electrode-Tissue interface with the important properties of electrode.

In order to avoid movement artefacts and to obtain a clearly established contact (low contact impedance) an electrolyte or electrode paste is usually employed as an interface between the electrode and the surface of the source of the event. Figure 2.7 (a, b) represent the electrode-tissue interface.



➤ Fig. 2.7(a) *Electrode-tissue interface for surface electrodes used with electrode jelly*

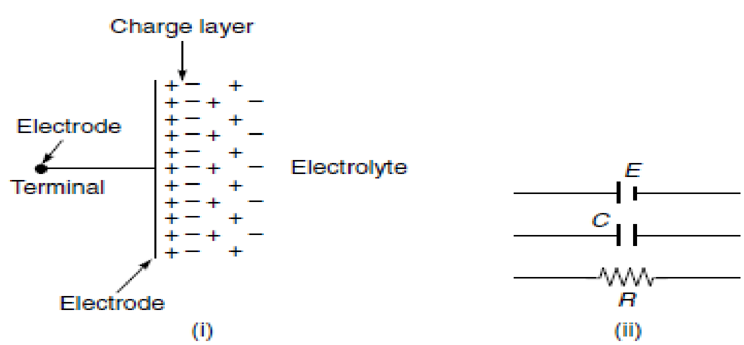


➤ Fig. 2.7(b) *Electrode tissue interface circuit involves transfer of electrons from the metal phase to an ionic carrier in the electrolyte, a charge double layer (capacitance) forms at the interface*

The characteristic of a surface electrode composed of a metal electrode and attached to the surface of the body through an electrolyte (electrode jelly) are dependent upon the conditions at the metal-electrolyte interface, the electrolyte-skin interface and the quality of the electrolyte.

Metal-Electrolyte Interface:

At the metal-electrolyte transition, there is a tendency for each electrode to discharge ions into the solution and for ions in the electrolyte to combine with each electrode. The net result is the creation of a charge gradient (difference of potential) at each electrode, the spatial arrangement of which is called the electrical double layer (Fig. 2.7(c)).



➤ Fig. 2.7(c) *(i) Charge distribution at electrode-electrolyte interface*
(ii) Three components representing the interface

The double layer is known to be present in the region immediately adjacent to the electrode and can be represented, in its simplest form, as two parallel sheets of charge of opposite sign separated by a thin film of dielectric.

Therefore, the metal- electrolyte interface appears to consist of a voltage source in series with a parallel combination of a capacitance and reaction resistance. The voltage developed is called the half-cell potential.

Electrolyte-Skin Interface:

An approximation of the electrolyte-skin interface can be had by assuming that the skin acts as a diaphragm arranged between two solutions (electrolyte and body fluids) of different concentrations containing the same ions, which is bound to give potential differences. The simplest equivalent representation could then be described as a voltage source in series with a parallel combination of a capacitance and resistance. The capacitance represents the charge developed at the phase boundary whereas the resistance depends upon the conditions associated with ion-migration along the phase boundaries and inside the diaphragm.

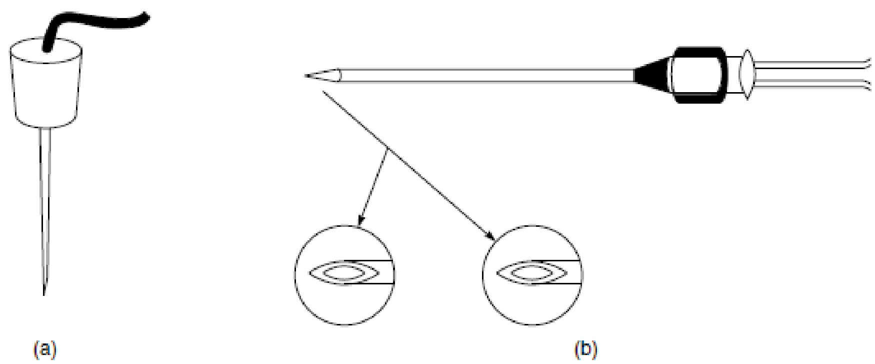
It is further clear that in the measurement of a bioelectric signal, it is essential to minimize potential drops across the electrode impedance. This is achieved by making the skin-contact impedance as low as possible and making the input impedance of the measuring device as high as possible.

7. Distinguish the Internal Electrodes with a neat sketch, based on how they are used to measure the biopotentials

Needle electrodes are used in clinical electromyography, neurography and other electrophysiological investigations of the muscle tissues underneath the skin and in the deeper tissues. The material of the needle electrode is generally stainless steel. In spite of the fact that stainless steel is unfavourable electrode material from the point of view of noise, it is preferred in EMG work due to its mechanical solidity and low price. Needle electrodes are designed to be fully autoclavable and in any case they should be thoroughly sterilized before use.

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

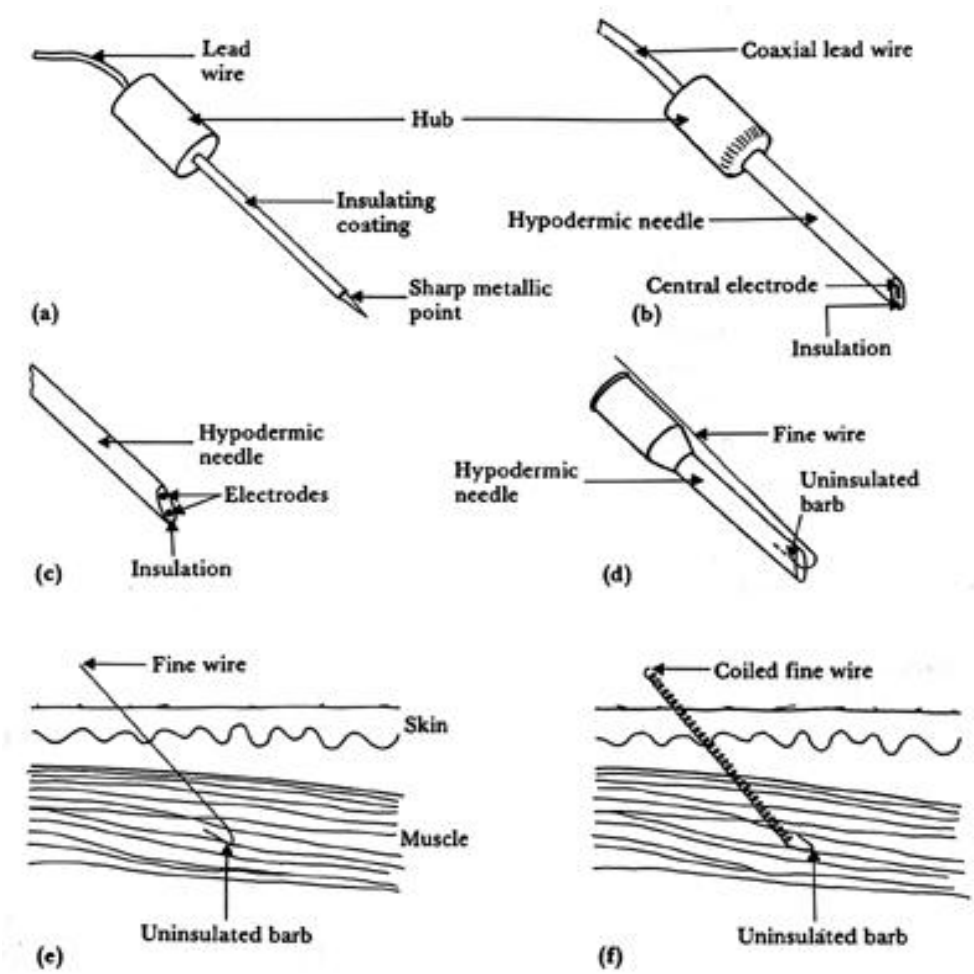
A concentric (coaxial) core needle electrode contains both the active and reference electrode within the same structure. It consists of an insulated wire contained within a hypodermic needle (Fig. 2.22(b)). The inner wire is exposed at the tip and this forms one electrode. The concentric needle is very convenient to use and has very stable electrical characteristics. Care should be taken to maintain the surface electrode in good condition in order to avoid artefacts. Concentric needle electrodes are made by moulding a fine platinum wire into a hypodermic needle having an outside diameter less than 0.6 mm. One end of the needle is bevelled to expose the end of the wire and to provide easy penetration when the needle is inserted. The surface area of the exposed tip of the wire may be less than 0.0005 mm^2.



➤ Fig. 2.22 (a) *Needle type EMG electrode*
(b) *Hypodermic needle type EMG electrode*

Multi-element needle electrodes are used to pick up the signals from individual fibres of muscle tissue. Special needles are available using 25-micron diameter electrode surfaces and having up to 14 pickup surfaces down the side of one needle. From the point of view of construction, needle electrodes are the simplest. However, edging of the needle point to the suitable angle, providing a proper plastic coating, making them resistant against thermal and chemical stresses and ensuring histological suitability is a difficult manufacturing process.

For the measurement of potentials from a specific part of the brain, longer needles are actually inserted into the brain. The needles are precisely located by means of a map or atlas of the brain. Generally, a special instrument called a stereotaxic instrument is used to hold the subject's head and guide the placement of electrodes. Often, these electrodes are implanted to permit repeated measurements over an extended period of time.



(a) Insulated needle electrode. (b) Coaxial needle electrode. (c) Bipolar coaxial electrode. (d) Fine-wire electrode connected to hypodermic needle, before being inserted. (e) Cross-sectional view of skin and muscle, showing coiled fine-wire electrode in place.

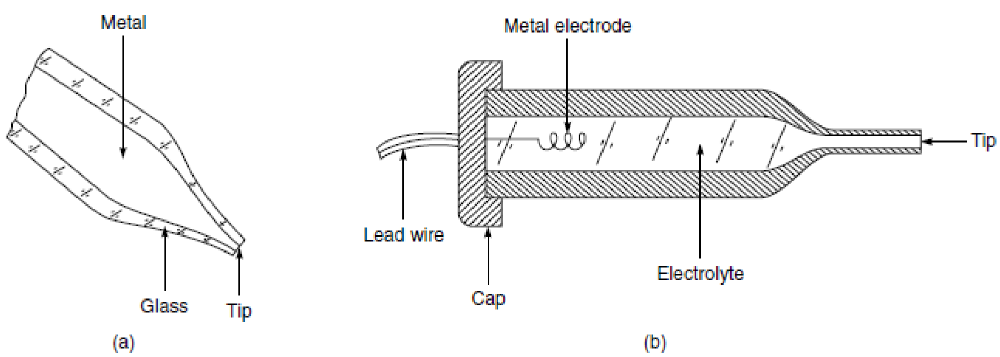
8. How potential difference across cell membrane is measured? Identify the suitable electrodes and explain in detail about each of them

Microelectrodes

To study the electrical activity of individual cells, microelectrodes are employed. This type of electrode is small enough with respect to the size of the cell in which it is inserted so that penetration by the electrode does not damage the cell. The size of an intracellular microelectrode is dictated by the size of the cell and the ability of its enveloping membrane to tolerate penetration by the microelectrode tip. Single-living cells are rarely larger than 0.5 mm (500 microns) and are usually less than one-tenth of this size. Typical microelectrodes have tip dimensions ranging from 0.5 to 5 microns. The tips of these electrodes have to be sufficiently strong to be introduced through layers of tissues without breaking.

Two types of microelectrodes are generally used: metallic (Fig. 2.25(a)) and glass microcapillaries (Fig. 2.25(b)). Metallic electrodes are formed from a fine needle of a suitable metal drawn to a fine tip. On the other hand, glass electrodes are drawn from Pyrex glass of special grade. These microcapillaries are usually filled with an electrolyte.

The metal microelectrodes are used in direct contact with the biological tissue and, therefore, have a lower resistance. However, they polarize with smaller amplifier input currents. Hence, they tend to develop unstable electrode offset potentials and are therefore not preferred for steady state potential measurements. On the other hand, in case of glass microelectrodes, improved stability can be obtained by properly choosing the metal and the electrolyte so that the small current passing through their junction may not be able to modify the electrical properties of the electrodes. Also, the glass microelectrode has a substantial current carrying capacity because of the large surface contact area between the metal and the electrolyte.



➤ Fig. 2.25 (a) *Microelectrodes—metal microelectrodes*
(b) *Microelectrodes—micropipette or micro capillaries electrode*

The microelectrodes have very high impedance as compared to conventional electrodes used for recording ECG, EEG, etc. The high impedance of a metal microelectrode is due to the characteristics of the small area metal-electrolyte interface.

Reference:

1. https://mece493.cankaya.edu.tr/uploads/files/Electrodes.pdf

2. Handbook of Biomedical Instrumentation by R S Khandpur, McGraw Hill Education 3rd Edition, 2014.