BM T61 – DIAGNOSTIC AND THERAPEUTIC EQUIPMENTS

UNIT-1

2 MARKS

1) Explain the principle defibrillator. (April/ May 2018)

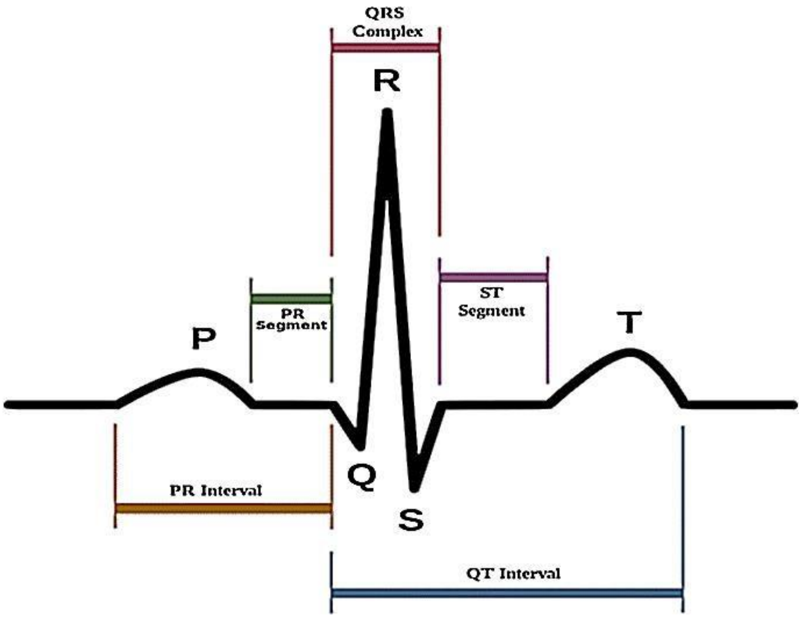
- A defibrillator is a device that delivers direct electrical current across the myocardium to cause synchronous depolarization of the cardiac muscle, with the aim of converting a dysrhythmia into normal sinus **rhythm**.
- **Defibrillation** is a treatment for life-threatening cardiac dysrhythmias, specifically ventricular fibrillation (VF) and non-perfusing ventricular tachycardia (VT).

2) (a) What is pacemaker? (April/ May 2018, May 2017)

(b) Define cardiac pacemaker. (April/ May 2016)

- A pacemaker is a small, battery-operated device. This device senses when your heart is beating irregularly or too slowly. It sends a signal to your heart that makes your heart beat at the correct pace.
- Most pacemakers have 2 parts: (1) The generator contains the battery and the information to control the heartbeat. (2) The leads are wires that connect the heart to the generator and carry the electrical messages to the heart.

3) Draw the ECG waveform. (May 2017)



4) What is normal and abnormal waves? (Nov/ Dec 2017)

NORMAL ECG INTERVALS

The recording of an ECG on a standard paper allows time taken for the various phases of electrical depolarization to be measured, usually in milliseconds. There is a recognized normal range for such 'intervals'.

PR interval: Normal range 120-200 ms.

QRS duration: Normal range up to 120 ms.

QT interval: Normal range upto 440 ms.

ABNORMAL ECG

An abnormal EKG is a normal variation of heart's rhythm. Other time, an abnormal EKG can signal a medical emergency such as a myocardial infaction (heart attack) or dangerous arrhythmia.

5) (a) When do we need Holter Monitor? (Nov/ Dec 2017)

(b) What is the role of Holter Monitor in cardiac care? (Sep 2020)

(c) List out the significance of Holter monitor. (May 2019)

- A Holter monitor is a type of portable Electrocardiogram (ECG).
- A Holter monitor is a medical device that records the heartbeat and checks for unusual signs.
- Doctors may order 24-hour Holter monitoring if they need more information about a person's heart, after having used standard electrocardiography.

6) How to measure heart rate? (April/ May 2016)

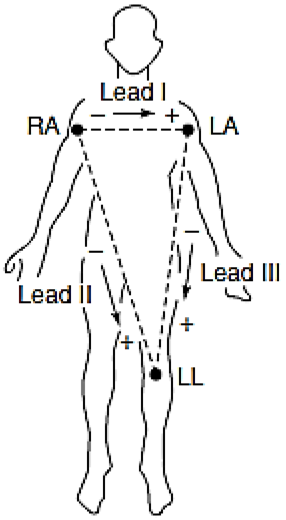
- The number of heartbeat per minute or the number of a cardiac cycle per minute is known as the heart rate which is measured by **stethoscope**.
- Measuring electrical heart information is referred to as **Electrocardiography** (**ECG** or **EKG**).

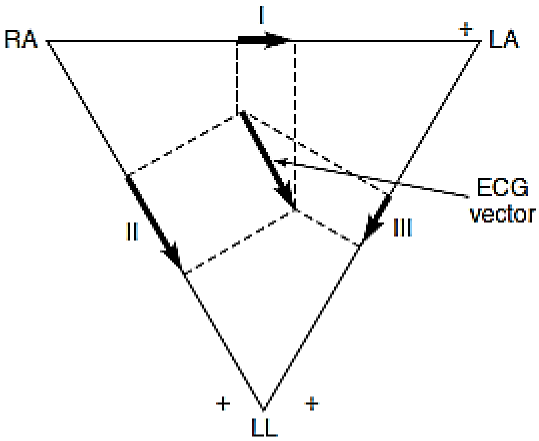
7) Write the physiological nature of ECG waveform. (Nov 2016)

Physiological Nature of ECG Waveform

	Origin	Amplitude mV	Duration Sec.
P Wave	Atrial depolarization or contraction	0.25	0.12 to 0.22 (P-R interval)
R Wave (QRS complex)	Repolarisation of the atria and depolarisation of the ventricles	1.60	0.07 to 0.1
T Wave	Ventricular Repolarisation (Relaxation of myocardium)	0.1 to 0.5	0.05 to 0.15 (S-T interval)
S-T internal	Ventricular contraction		
U Wave	Slow repolarization of the intraventricular (Purkinje fibers) system	< 0.1	0.2 (T-U interval)

8) Draw the Einthoven triangle. (Nov 2016)





The Einthoven triangle for defining ECG leads

9) Distinguish between AC and DC Defibrillator. (May 2019)

AC Defibrillator	DC Defibrillator
An AC defibrillator consists of a step-up transformer with primary and secondary winding, and two switches.	DC defibrillator consists of auto transformer T_1 that acts as primary of the high voltage transformer T_2.
AC DEFIBRILLATOR is the one where AC voltage is stepped down and after rectification it is fed to the surface of the body through electrodes.	In DC DEFIBRILLATOR capacitor is used as a storage element and the power is delivered for the specified period of time

10) What is the velocity of propagation of the action potential in the bundle branches following the AV node? (Nov/ Dec 2018)

- These specialized fibres conduct the impulses at a very rapid velocity (about 2 m/sec).
- The bundle branches the divide into an extensive system of **Purkinje fibres** that conduct the impulses at high velocity (about 4 m/sec) throughout the ventricles.

11) (a) What is Plethysmography? (Nov/ Dec 2018)

(b) Write down the working principle of pulse plethysmography. (Sep 2020)

- Plethysmography is basically used to measure the volume changes in any part of the body that result from the pulsations of blood occurring with each heart beat. These measurements are useful in the diagnosis of arterial obstructions and pulse wave velocity measurements which may lead to determine the heart rate.
- It consists of a rigid cup or chamber placed over any of the body, normally limb or digit, in which the volume changes are to be measured. The cup is tightly sealed to the member and changes in the volume reflect the pressure changes of the air inside the chamber.
- Thus measuring pressure change at constant volume condition or measuring volume change at constant pressure condition, we can do useful measurements.

11 MARKS

1) Explain in detail about the heart rate monitor and Explain with its medical applications. (April/ May 2018)

Heart rate monitor

- A heart rate monitor (HRM) is a personal monitoring device that allows one to measure/display heart rate in real time or record the heart rate for later study. It is largely used to gather heart rate data while performing various types of physical exercise. Measuring electrical heart information is referred to as Electrocardiography (ECG or EKG).
- Medical heart rate monitoring used in hospitals is usually wired and usually multiple sensors are used. Portable medical units are referred to as a Holter monitor. Consumer heart rate monitors are designed for everyday use and thus don't use wires to connect.

Technologies

- X-ray image of a chest strap (left: frontal view; right: side view). Visible is the circuit board, the antenna for data transfer, the battery and the connections to the electrodes in the adjoining belt at picture top and bottom.
- Modern Heart rate monitors commonly use one of two different methods to detect heart rates. Both methods can provide the same basic heart rate data. The original technology is based on electrical sensors and these are still the default used for medical devices. The newer technology is based on optical sensors.

ECG (Electrocardiography) sensors

- They measure the bio-potential generated by electrical signals that control the expansion and contraction of heart chambers.

PPG (Photoplethysmography) sensors

- They use a light-based technology to sense the rate of blood flow as controlled by the heart's pumping action.

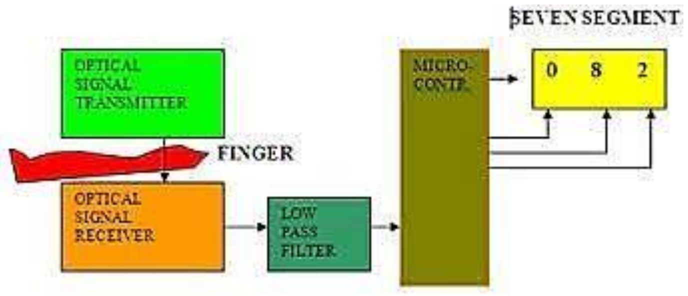
Electrical

- The electrical monitors consist of two elements: a monitor/transmitter, which is worn on a cheast strap, and a receiver. When a heartbeat is detected a radio signal is transmitted, which the receiver uses to display/determine the current heart rate.
- This signal can be a simple radio pulse or a unique coded signal from the chest strap (such as Bluetooth, ANT, or other low-power radio link).
- Newer technology prevents one user's receiver from using signals from other nearby transmitters (known as cross-talk interference) or eavesdropping. Note the older Polar 5.1 kHz radio transmission technology is usable underwater. Both Bluetooth and Ant+ use the 2.4GHZ radio band which cannot send signals underwater.

Optical

- More recent devices use optics to measure heart rate by which measures changes in blood flow by shining a light from an LED through the skin and measuring how it scatters off blood vessels.
- In addition to measuring the heart rate, some devices using this technology are able to measure blood oxygen saturation (SpO2). Some recent optical sensors can also transmit data as mentioned above.
- Newer devices such as cell phones or watches can be used to display and/or collect the information. Some devices can simultaneously monitor heart rate, oxygen saturation, and other parameters. These may include sensors such as accelerometers, gyroscopes, and GPS to detect speed, location and distance.
- In recent years, it has been common for smartwatches to include heart rate monitors, which has greatly increased popularity. Some smart watches, smart bands and cell phones often use PPG sensors.

Heart Rate Monitor Block Diagram



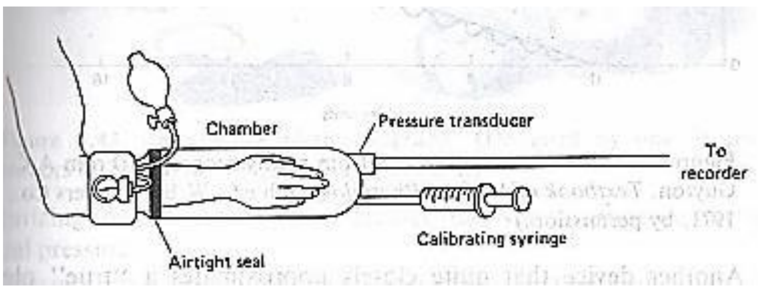
- The heart rate gives a good indication during exercise routines of how effective that routine is improving your health. Once only used by elite athletes, heart rate monitors are now becoming an essential tool for everyone from the casual athlete to the personal trainer.
- Heart monitors provide an easy and scientific measure of the effort you are putting into your workouts. A heart rate monitor is simply a device that takes a sample of heartbeats and computes the beats per minute so that the information can easily be used to track heart condition. Current technology consists of optical and electrical monitors.
- The electrical method provides a bulky strap around one's chest. The optical method does not require the strap and can be used more conveniently than the electrical method.
- There are many constraints in producing a heart monitor. First, the technology used to measure the pulse has to be determined. A cost efficient way of measuring the pulse is the combination of a LED and photo-sensor.
- With the LED technology, ambient light causes excess noise. Therefore, a filter would be needed to attenuate the noise in order that the pulse signal can be extracted. The device must have a display or some way to observe the heart rate. The device should be accurate and easy to use to be attractive to the general public.
- To make an impact on the market, the design must be small, lightweight, durable and affordable. With these constraints noted, one can propose a design to produce a heart monitor.
- Using the design constraints described above, we can now state how we will approach our design. The basis of our design is to construct an efficient and affordable heart monitor.
- A LED and photo-sensor will be used to measure the pulse by measuring the change in blood flow through one of the index fingers. A noise filter will be designed to filter out any unwanted noise and interference from ambient light.
- A micro-controller will be programmed to count the pulse rate and control a LED display to show the pulse rate. The device will operate in the power range of 3 volts to facilitate battery operation.
- With this low power consumption, it will last for a reasonably long time under normal use. The final product will be packaged in a small, lightweight, and durable package that will be approximately 2.5" x 1.7" x 1".

- Heart monitors exist today, so our design is not the first heart monitor to be built. However, our device will apply to all ages of people who want to monitor their heart rate for any reason. It will provide fast and accurate readings.
- Because of its portable size, our design can be used at home or the office or any desired location. Under the time constraints, we will only be able to produce a prototype meeting the general constrains above.
- Many features could be added such as wireless monitoring, ECG technology, and alarm features. Monitoring one’s heart rate is useful not only for a patient but also for normal persons, including athletes, in order to observe the heart rate variations due to stress, exercise and concentration.
- For persons with illness, of course, the heart rate gives a good indication of the intensity and the stress on the heart as well. Normal heart rate for the average individual is known to be 72 beats per minute.

2) With neat block diagram explain the functions of plethysmography. (April/ May 2018)

PLETHYSMOGRAPHY

- Instrument measuring volume changes or providing output that can be related to them are called plethysmographs & the measurement of these volume changes or phenomenon related to them is called plethysmography.
- Such an instrument consists of a rigid cup or chamber placed over the limb or digit in which the volume changes are to be measured.
- The cup is tightly sealed to the member to be measured so that any changes in volume in the limb or digit reflect as pressure changes inside the chamber. Either fluid or air can be used to fill the chamber.



<u>Plethysmography</u>

- Plethysmograph can be designed for constant pressure or constant volume within the chamber. In either case some form of pressure or displacement transducer must be included to respond to pressure changes within the chamber & to provide a signal that can be calibrated to represent the volume of the limb or digit.
- This type of plethysmograph can be used in two ways. If the cuff, placed upstream from the seal, is not inflated, the output signal is simply a sequence of pulsations proportional to the individual volume changes with each heartbeat.
- The plethysmograph illustrated above can be used to measure the total amount of blood flow into the limb or digit being measured. By inflating the cuff to a pressure just above venous pressure, arterial blood can flow past the cuff, but the venous blood cannot leave.
- The result is that the limb or digit increases its volume with each heartbeat by the volume of the blood entering during that beat.

CAPACITANCE PLETHYSMOGRAPH

- Another device quite close to the true plethysmograph is called the **capacitance plethysmograph**. In this device, which is generally used either on arm or leg, the limb in which the volume is being measured becomes one plate of the capacitor.
- The other plate is formed by a fixed screen held at a small distance from the limb by an insulating layer. Pulsations of the blood in the arm or leg cause variations in the capacitance, because the distance between the limb & the fixed screen varies with these pulsations.
- Since the length of the cuff is fixed, the variations in capacitance can be calibrated as volume changes.

PSEUDO PLETHYSMOGRAPH

- Another type is the pseudo plethysmograph, which measures changes in diameter at the cross section of a finger, toe, arm leg or other segment of the body.
- Since volume is related to diameter, this type of device is accurate for many purposes.
- A common method of sensing diameter changes is through use of the mercury strain gauge, which consists of a segment of small diameter elastic tubing, long enough to wrap round the limb or digit being measured.
- When the tube is filled with mercury, it provides a highly compliant strain gauge that changes its resistance with changes in diameter. With each pulsation of the blood that

increases the diameter of the limb or digit, the strain gauge elongates & in stretching becomes thinner thus increasing the resistance.

PHOTOELECTRIC PLETHYSMOGRAPH

- Another type is photoelectric plethysmograph. This device operates on the principle that volume changes in a limb or digit results in changes in optical density through & just beneath the skin over a vascular region.
- A light source in an opaque chamber illuminates the small area of the finger-tip or the other region to which the transducer is applied. Light scattered & transmitted through the capillaries of the region is picked up by the photo cell, which is shielded from all other light.
- As the capillaries fill with blood, the blood density increases thereby reducing the amount of light reaching the photocell. The result causes resistance changes in the photocell that can be measured on a Wheatstone bridge & recorded.

IMPEDANCE PLETHYSMOGRAPH

- The more reliable type is the impedance plethysmograph, in which volume changes in a segment of a limb or digit are reflected as impedance changes.
- The impedance changes are primarily due to the changes in conductivity of the current path with each pulsation of blood. This is done by using either a two or four electrode system. The electrodes are either conductive bands wrapped around the limb or digit to be measured or simple conductive strips of tape attached to the skin.
- In either case, the electrodes contact the skin through a suitable electrolyte jelly or paste to form an electrode interface & to remove the effect of skin resistance. In two electrode system a constant current is forced through the tissue between the two electrodes & the resulting volume changes are measures.
- In the four electrode system, the constant current is forced through two outer or current electrodes & the voltage between the two inner electrodes is measured.
- Several theory explains the actual cause of the measured impedance changes. One is that the presence of blood filling segment of the body lowers the impedance of that segment.
- The second theory is that the increase in diameter due to additional blood in a segment of the body increases the cross sectional area of the segment’s conductive path & thereby lowers the resistance of the path.

RHEOENCEPHALOGRAPHY

- A special form of impedance plethysmography is rheoencephalography, measurement of impedance changes between the electrodes placed on the scalp.
- This technique provides information related to cerebral blood flow & is sometimes used to detect circulatory differences between the two sides of the head.

OCULO PNEUMO PLETHYSMOGRAPHY

- Another special type of plethysmograph is the oculo pneumo plethysmography. This instrument measures every minute volume changes that occur in the eye with each arterial blood pulsation.
- A small eye cup is placed over the sclera of each eye & is connected to a transducer positioned over the patient's head by a short section of flexible tubing. A vaccum, which can be varied from zero to 300mmHg is applied to hold the eye cups in place.
- Pulsations are recorded on two channels of a three channel pen recorder, one for each eye. The third channel is used to record the vacuum.
- By periodically allowing the vaccum to build up to -300mmHg and deplete to zero, the instrument can also be used as recording suction opthalmodynamometer, an instrument used for measuring arterial blood pressure within the eye.

3) Briefly write about (a) Holter cardiography (b) Phonocardiography. (May 2017)

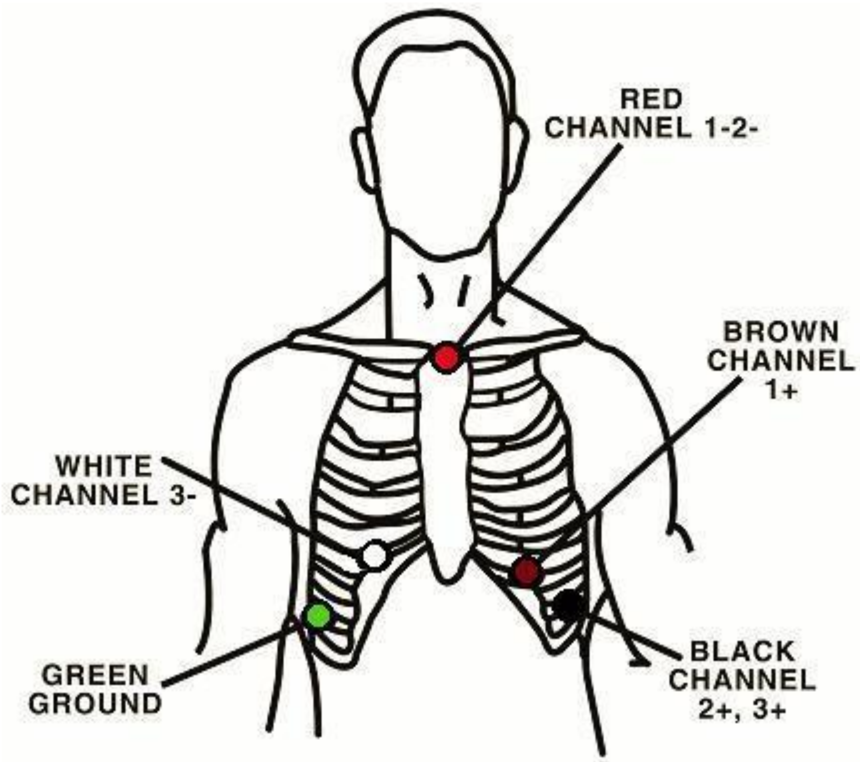
(A) <u>HOLTER CARDIOGRAPHY</u>

- Holter monitoring provides a continuous recording of heart rhythm during normal activity.
- The monitor is usually worn for 24 hours to obtain a recording of a complete day.

Performance of Holter test

- Electrodes (small conducting patches) are placed on the subject's chest and attached to a small recording monitor that the subject can carry in a pocket or in a small pouch worn around in his/her neck. The monitor is battery operated.
- The subject's heart electrical activity is recorded (much like the recording of an ECG), usually for a 24-hour period while the subject keep a diary of his/ her activities.

- The recording is then analyzed, a report of the heart's activity is tabulated, and irregular heart activity is correlated with the subject's activity at the time.



Placement of Electrodes in Holter Monitoring

- It is very important that the subject should accurately record his/ her symptoms and activities so that the doctor can correlate them with his/ her Holter monitor findings.

Preparation for the test

- There is no special preparation for the test. The recording monitor will be started by the health care provider, and the subject will be given instructions on how to replace electrodes should they become loosened.
- Instructions will also be given on how to record activity for the diary.

Need for Holter Monitoring

- Holter monitoring is used to determine how the heart responds to normal activity.
- Other times, Holter monitoring is used include the following:

  - When given cardiac medication
  - After a heart attack
  - To diagnose an abnormal or dangerous heart rhythm

Normal Values

- Normal variations in heart rate occur with activities. No significant alterations in the rhythm or ST elevations occur.

Abnormal results

- Abnormal results may include various arrhythmias. ST segment changes (alterations in the wave form of the electrical conduction pattern of the heart) may indicate that the heart is not receiving enough oxygen and may also correlate with chest pain.
- Additional conditions under which the test may be performed include the following:
    - Atrial fibrillation/flutter
    - Multifocal atrial tachycardia
    - Paroxysmal supraventricular tachycardia
    - Palpitations
    - Fainting

Risks

- There are no risks associated with the test.
- Irritations/ allergens to adhesives

Limitations

- Use of electronic devices interrupt the signal transmission from electrode to holter monitor

Special considerations

- Electrodes must be firmly attached to the chest to permit accurate recording of the heart's activity.
- Avoid magnets, metal detectors, electric blankets, and high-voltage areas while wearing the device.

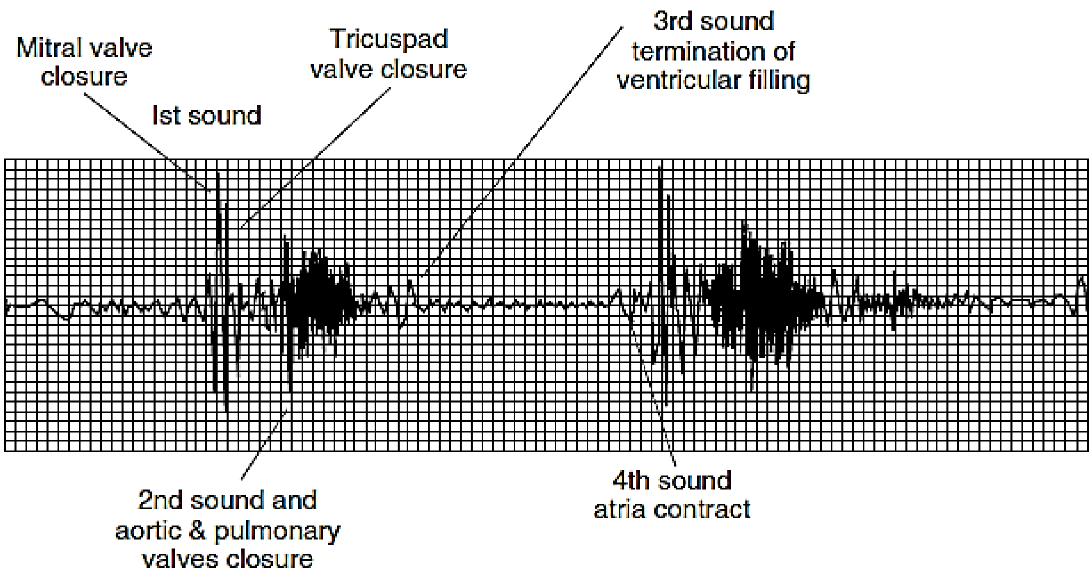
(B) PHONOCARDIOGRAPHY

- The phonocardiograph is an instrument used for recording the sounds connected with the pumping action of the heart. These sounds provide an indication of the heart rate and its rhythmicity.
- They also give useful information regarding effectiveness of blood pumping and valve action. Heart sounds are diagnostically useful. Sounds produced by healthy hearts are

remarkably identical and abnormal sounds always co-relate to specific physical abnormalities.

- From the beginning till today, the principal instrument used for the clinical detection of heart sounds is the acoustical stethoscope.
- An improvement over the acoustal stethoscope, which usually has low fidelity, is the electronic stethoscope consisting of a microphone, an amplifier and a head set.
- Electronic stethoscopes can detect heart sounds which are too low in intensity or too high in frequency to be heard in a purely acoustal instrument.
- The phonocardiographs provide a recording of the waveforms of the heart sounds. These waveforms are diagnostically more important and revealing than the sounds themselves.

Origin of Heart Sound

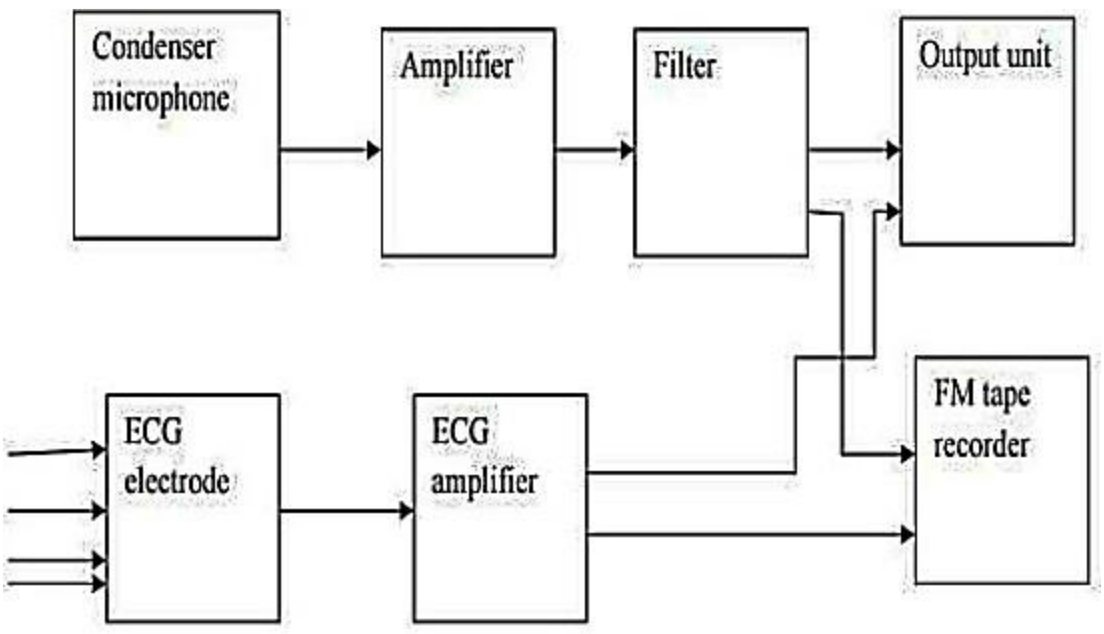


Basic heart sounds in a typical phonocardiogram recording

- The sounds are produced by the mechanical events that occur during the heart cycle. These sounds can be from the movement of the heart wall, closure of walls and turbulence and leakage of blood flow.
- A typical recording of these sounds is illustrated in the following figure. The first sound, which corresponds to the R wave of the ECG, is longer in duration, lower in frequency, and greater in intensity than the second sound.

- The sound is produced principally by closure of the valves between the upper and lower chambers of the heart, i.e. it occurs at the termination of the atrial contraction and at the onset of the ventricular contraction.
- The closure of the mitral and tricuspid valve contributes largely to the first sound. The frequencies of these sounds are generally in the range of 30 to 100 Hz and the duration is between 50 to 100 ms.
- The second sound is higher in pitch than the first, with frequencies above 100 Hz and the duration between 25 to 50 ms.
- This sound is produced by the slight back flow of blood into the heart before the valves close and then by the closure of the valves in the arteries leading out of the ventricles.
- This means that it occurs at the closure of aortic and the pulmonic valves. The heart also produces third and fourth sounds but they are much lower in intensity and are normally inaudible.
- The third sound is produced by the inflow of blood to the ventricles and the fourth sound is produced by the contraction of the atria.
- These sounds are called diastolic sounds and are generally inaudible in the normal adult but are commonly heard among children.

Block Diagram of Phonocardiography



<u>Block Diagram of PCG system</u>

Microphones for Phonocardiography

- Two types of microphones are commonly in use for recording phonocardiograms. They are the contact microphone and the air coupled microphone.
- They are further categorized into crystal type or dynamic type based on their principle of operation. The crystal microphone contains a wafer of piezo-electric material, which generates potentials when subjected to mechanical stresses due to heart sounds.
- They are smaller in size and more sensitive than the dynamic microphone. The dynamic type microphone consists of a moving coil having a fixed magnetic core inside it.
- The coil moves with the heart sounds and produces a voltage because of its interaction with the magnetic flux.
- The phonocardiogram depends extensively on the technical design of the microphone, since it does not transform the acoustic oscillations into electrical potential uniformly for all frequencies.
- Therefore, the heart sound recordings made with a microphone are valid only for that particular type of microphone. As a consequence, microphones of various types cannot, as a rule, be interchanged.

Amplifiers for phonocardiography

- The amplifier used for a phonocardiograph has wide bandwidth with a frequency range of about 20 to 2000 Hz.
- Filters permit selection of suitable frequency bands, so that particular heart sound frequencies can be recorded.
- In general, the high frequency components of cardiovascular sound have a much smaller intensity than the low frequency components and that much information of medical interest is contained in the relatively high frequency part of this spectrum.
- Therefore, high-pass filters are used to separate the louder low frequency components from the soft and interesting high frequency murmurs.
- Experiments have shown that the choice of different filters does not have to be very critical but in general, sets of four or five high-pass filters with different cut-off frequencies and slopes are used in the commercially available instruments.
- PCG amplifiers usually have gain compensation circuits to increase the amplification of high frequency signals, which are usually of low intensity.

- The frequencies at the higher end of the range are of particular significance in research applications.

Filters

- Permit selection of suitable frequency bands
- Avoid aliasing
- Separate louder low frequency signals from lower intensity, much informative high frequency murmurs.

4) (a) Write a detailed note on working principle of Holter moniter. Narrate its applications. (April/ May 2016)

(b) Discuss the Holter monitoring in detail. (Nov 2016)

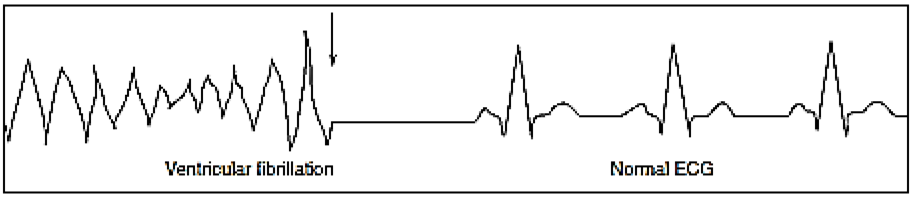
[ANSWER: Refer Q.NO: 3) A)]

5) (a) What is the need of a cardiac defibrillator? Draw the schematic diagram of a d.c defibrillator and explain the function of each components. (Nov/ Dec 2018)

(b) Explain the working of a DC Defibrillator. (May 2017)

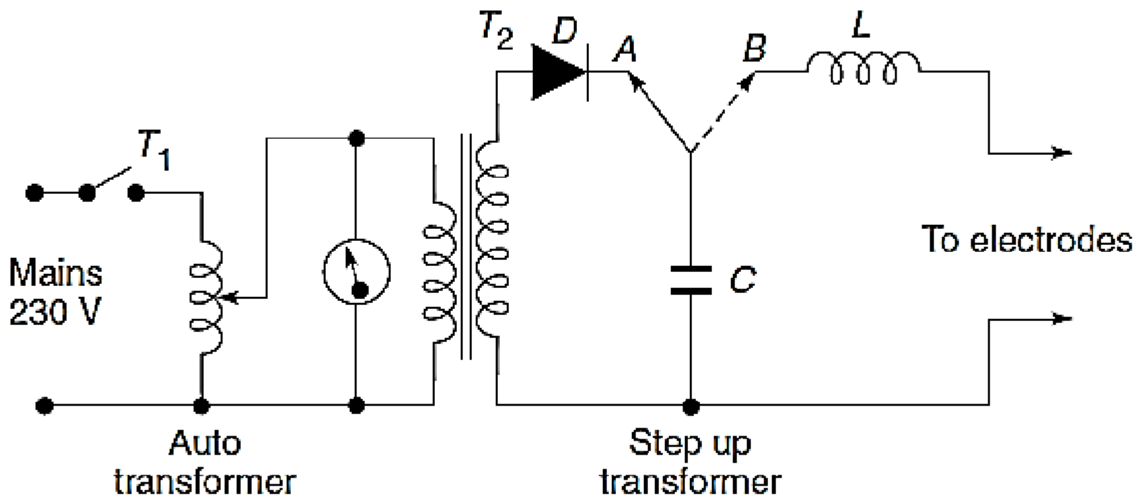
NEED OF CARDIAC DEFIBRILLATOR

- Ventricular fibrillation is a serious cardiac emergency resulting from asynchronous contraction of the heart muscles. This uncoordinated movement of the ventricle walls of the heart may result from coronary occlusion, from electric shock or from abnormalities of body chemistry.
- Because of this irregular contraction of the muscle fibres, the ventricles simply quiver rather than pumping the blood effectively. This results in a steep fall of cardiac output and can prove fatal if adequate steps are not taken promptly.
- In fibrillation, the main problem is that the heart muscle fibres are continuously stimulated by adjacent cells so that there is no synchronised succession of events that follow the heart action. Consequently, control over the normal sequence of cell action cannot be captured by ordinary stimuli.



- The above figure shows the restoration of normal rhythm in fibrillating heart as achieved by direct current shock (arrow) across the chest wall. The horizontal line after the shock shows that the cardiograph was blocked or disconnected for its protection during the period of shock
- Ventricular fibrillation can be converted into a more efficient rhythm (Fig. above) by applying a high energy shock to the heart. This sudden surge across the heart causes all muscle fibres to contract simultaneously.
- Possibly, the fibres may then respond to normal physiological pacemaking pulses. The instrument for administering the shock is called a defibrillator.
- The shock can be delivered to the heart by means of electrodes placed on the chest of the patient (external defibrillation) or the electrodes may be held directly against the heart when the chest is open (internal defibrillation). Higher voltages are required for external defibrillation than for internal defibrillation.

DC DEFIBRILLATOR

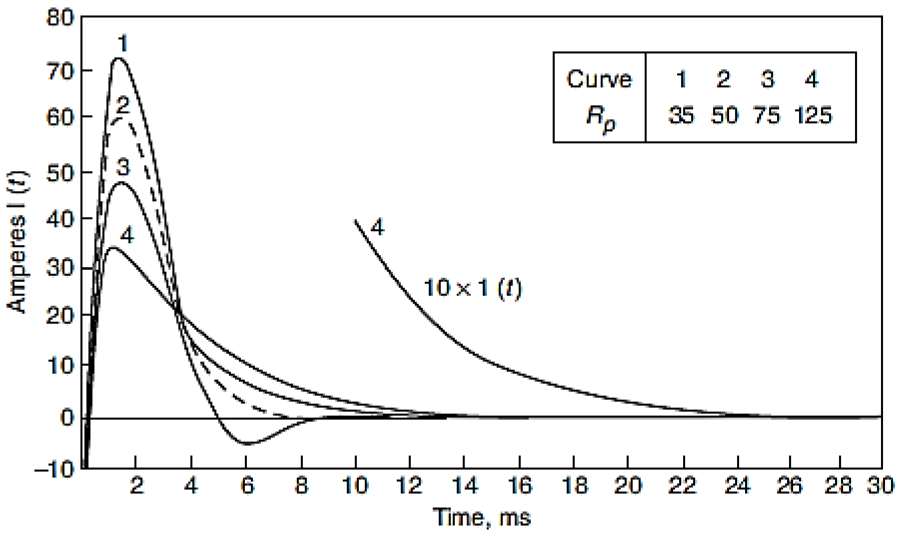


Schematic diagram of DC Defibrillator

- In almost all present-day transthoracic defibrillators, an energy storage capacitor is charged at a relatively slow rate (in the order of seconds) from the AC line by means of a step-up transformer and rectifier arrangement or from a battery and a DC to DC converter arrangement.

- During transthoracic defibrillation, the energy stored in the capacitor is then delivered at a relatively rapid rate (in the order of milliseconds) to the chest of the subject.
- For effective defibrillation, it is advantageous to adopt some shaping of the discharge current pulse.
- The simplest arrangement involves the discharge of capacitor energy through the patient's own resistance (R).
- This yields an exponential discharge typical of an RC circuit. If the discharge is truncated, so that the ratio of the duration of the shock to the time constant of decay of the exponential waveform is small, the pulse of current delivered to the chest has a nearly rectangular shape.
- For a somewhat larger ratio, the pulse of current appears nearly trapezoidal. Rectangular and trapezoidal waveforms have also been found to be effective in the trans-thoracic defibrillation and such waveforms have been employed in defibrillators designed for clinical use.
- The basic circuit diagram of a DC defibrillator is shown in the above figure A variable auto-transformer T1 forms the primary of a high voltage transformer T2.
- The output voltage of the transformer is rectified by a diode rectifier and is connected to a vacuum type high voltage change-over switch.
- In position A, the switch is connected to one end of an oil-filled 16 micro-farad capacitor. In this position, the capacitor charges to a voltage set by the positioning of the auto-transformer.
- When the shock is to be delivered to the patient, a foot switch or a push button mounted on the handle of the electrode is operated.
- The high voltage switch changes over to position 'B' and the capacitor is discharged across the heart through the electrodes.
- In a defibrillator, an enormous voltage (approx. 4000 V) is initially applied to the patient. It has been shown by various investigations that although short-duration pulses (as low as 20 ms), can affect defibrillation, the high current required impairs the contractility of the ventricles.

- This is overcome by inserting a current limiting inductor in series with the patient circuit. The disadvantage of using an inductor is that any practical inductor will have its own resistance and dissipates part of the energy during the discharge process.
- In practice, a 100 mH inductor will have a resistance of about 20 W. The energy delivered to the patient will, therefore, be only 71% of the stored energy.
- The inductor also slows down the discharge from the capacitor by the induced counter voltage. This gives the output pulse a physiologically favourable shape.
- The shape of the waveform that appears across electrodes will depend upon the value of the capacitor and inductor used in the circuit.
- The discharge resistance which the patient represents for the defibrillating pulse may be regarded as purely ohmic resistance of 50 to 100 W approximately for a typical electrode size of 80 cm2.
- The shape of the current/time diagram of the defibrillating pulse remains largely unchanged in the above resistance range, except for a change in amplitude which depends on the resistance. A typical discharge pulse of the defibrillator is shown in figure below.



Current waveform I (t) versus patient impedance Rp for a typical damped sine wave defibrillator (C = 32 uF, L= 35 mH, RC = 67)

- The most common waveform utilized in the RLC circuit employs an under-damped response with a damping factor less than unity.
- This particular waveform is called a 'Lown' waveform. This waveform is more or less of an oscillatory character, with both positive and negative portions.

- The pulse width in this waveform is defined as the time that elapses between the start of the impulse and the moment that the current intensity passes the zero line for the first time and changes direction. The pulse duration is usually kept as 5 ms or 2.5 ms.

Defibrillator Electrodes

- The electrodes for external defibrillation are usually metal discs about 3-5 cm in diameter and are attached to highly insulated handles.
- Most of the conventional electrode systems are circular, a little concave with sharp rims and an insulated back-side. For internal defibrillation when the chest is open, large spoon-shaped electrodes are used.
- Usually, large currents are required in external defibrillation to produce uniform and simultaneous contraction of the heart muscle fibres.
- This current not only causes a violent contraction of the thoracic muscles but may also result in occasional burning of the skin under the electrodes.
- The external electrodes contain safety switches inside the housings and the capacitor is discharged only when the electrodes are making a good and firm contact with the chest of the patient.
- This precludes the possibility of an accidental shock to the operator and the risk of burns to the patient.
- A number of instruments are provided with electrodes which have a spring contact. When these electrodes are adequately pressed on the thorax, the contacts close and the defibrillator is fired. In this way, burns due to poor electrical contact between electrodes and the skin are prevented.
- However, if the operator is not aware of the presence of the spring, there is a risk that the defibrillator is discharged internally after operating the firing control while no energy is delivered to the patient.
- Flat paddle surfaces do not always conform to the body thus reducing contact areas. Proper paddle sizes for different size patients are not quickly and easily available.
- In order to meet these requirements, pre-gelled and self-adhesive electrodes have been introduced.
- Such electrodes are commercially available. Chest wall impedance plays an important part in efficient defibrillation.

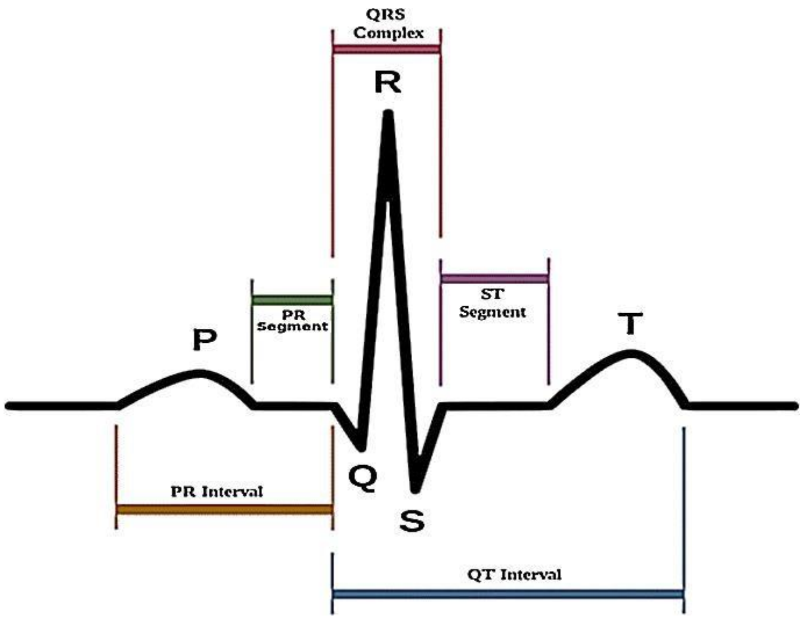
- The factors determining this impedance include the size of the electrodes, paddles, the energy of the discharge, the number and the time interval between previous counter-shocks and the interface material that is used between the paddle electrode and chest wall.
- Electrode gels are usually employed to reduce contact impedance of the interface and for that the impedance of the gel itself must be very low.

6) With neat schematic diagram explain the measurements of electrocardiograph. (Nov/ Dec 2017)

Electrocardiography

- The electrocardiograph (ECG) is an instrument, which records the electrical activity of the heart. Electrical signals from the heart characteristically precede the normal mechanical function and monitoring of these signals has great clinical significance.
- ECG provides valuable information about a wide range of cardiac disorders such as the presence of an inactive part (infarction) or an enlargement (cardiac hypertrophy) of the heart muscle.
- Electrocardiographs are used in catheterization laboratories, coronary care units and for routine diagnostic applications in cardiology.

Typical ECG waveform



Physiological Nature of ECG Waveform

	Origin	Amplitude mV	Duration Sec.
P Wave	Atrial depolarization or contraction	0.25	0.12 to 0.22 (P-R interval)
R Wave (QRS complex)	Repolarisation of the atria and depolarisation of the ventricles	1.60	0.07 to 0.1
T Wave	Ventricular Repolarisation (Relaxation of myocardium)	0.1 to 0.5	0.05 to 0.15 (S-T interval)
S-T internal	Ventricular contraction		
U Wave	Slow repolarization of the intraventricular (Purkinje fibers) system	< 0.1	0.2 (T-U interval)

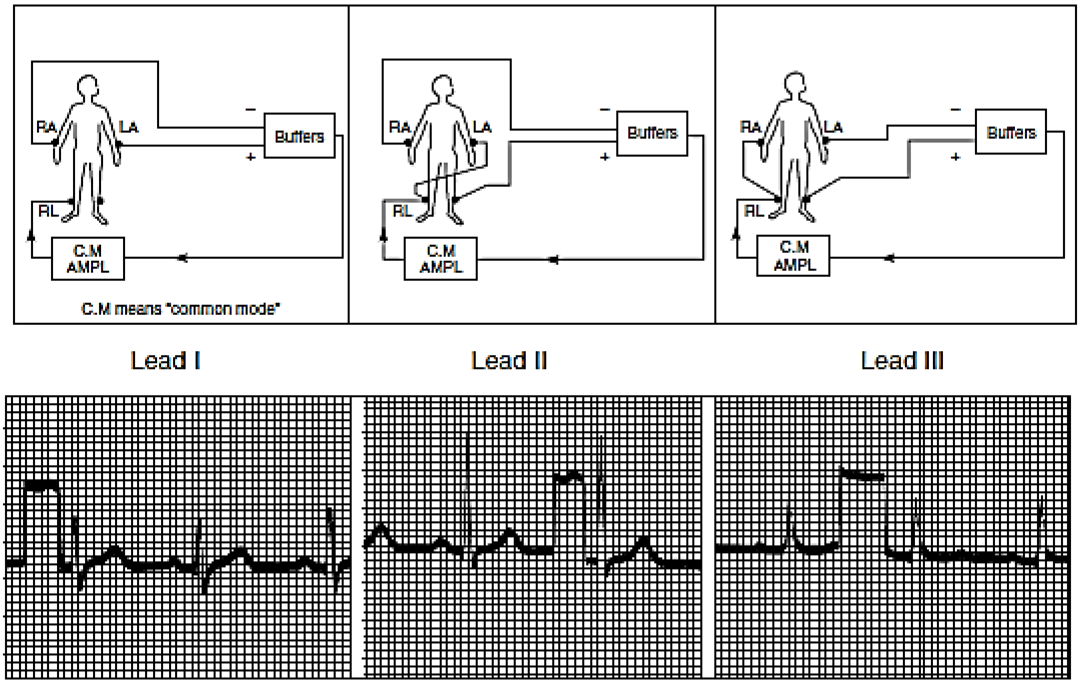
ECG Lead Configuration

- Two electrodes placed over different areas of the heart and connected to the galvanometer will pick up the electrical currents resulting from the potential difference between them.
- For example, if under one electrode a wave of 1 mV and under the second electrode a wave of 0.2 mV occur at the same time, then the two electrodes will record the difference between them, i.e. a wave of 0.8 mV.
- The resulting tracing of voltage difference at any two sites due to electrical activity of the heart is called a “LEAD” (Figs below).

(i) Bipolar Leads

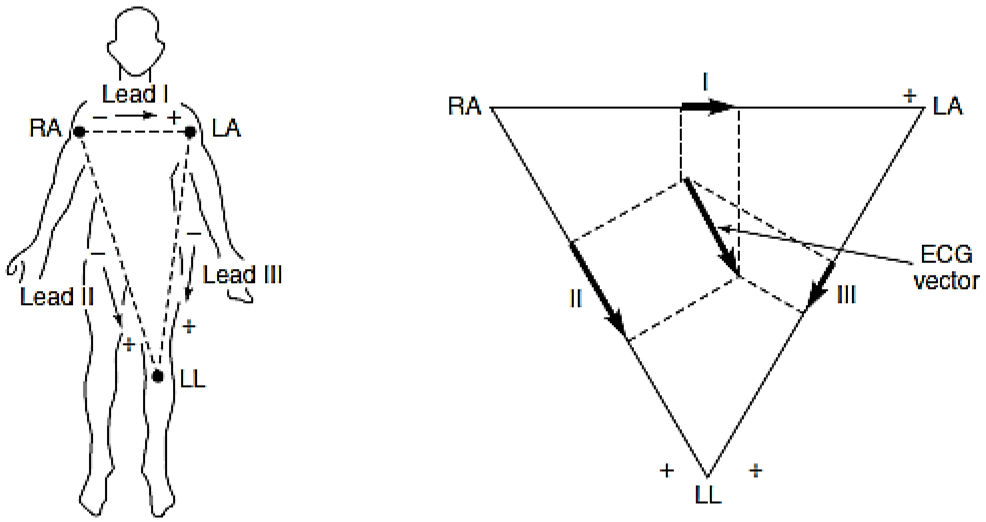
- In bipolar leads, ECG is recorded by using two electrodes such that the final trace corresponds to the difference of electrical potentials existing between them. They are called standard leads and have been universally adopted.
- They are sometimes also referred to as Einthoven leads (Fig. below). In standard lead I, the electrodes are placed on the right and the left arm (RA and LA).

- In lead II, the electrodes are placed on the right arm and the left leg and in lead Ill, they are placed on the left arm and the left leg.
- In all lead connections, the difference of potential measured between two electrodes is always with reference to a third point on the body. This reference point is conventionally taken as the "right leg".



Bipolar Limb Leads

- The records are, therefore, made by using three electrodes at a time, the right leg connection being always present.

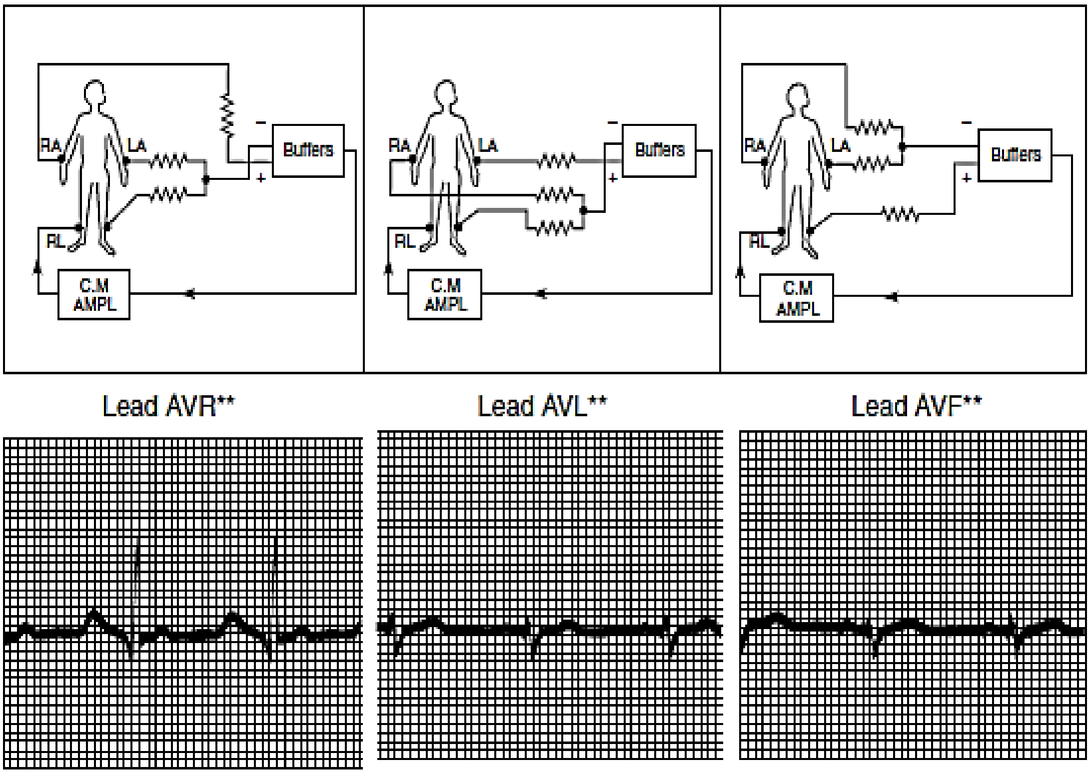


The Einthoven triangle for defining ECG leads

- In defining the bipolar leads, Einthoven postulated that at any given instant of the cardiac cycle, the electrical axis of the heart can be represented as a two dimensional vector.
- The ECG measured from any of the three basic limb leads is a time-variant single-dimensional component of the vector. He proposed that the electric field of the heart could be represented diagrammatically as a triangle, with the heart ideally located at the centre.
- The triangle, known as the "Einthoven triangle", is shown in figure below. The sides of the triangle represent the lines along which the three projections of the ECG vector are measured.
- It was shown that the instantaneous voltage measured from any one of the three limb lead positions is approximately equal to the algebraic sum of the other two or that the vector sum of the projections on all three lines is equal to zero.
- In all the bipolar lead positions, QRS of a normal heart is such that the R wave is positive and is greatest in lead II.

(ii) Unipolar Leads (V Leads)

- The standard leads record the difference in electrical potential between two points on the body produced by the heart's action.
- Quite often, this voltage will show smaller changes than either of the potentials and so better sensitivity to be obtained if the potential of a single electrode is recorded.
- Moreover, if the electrode is placed on the chest close to the heart, higher potentials can be detected than normally available at the limbs.
- This lead to the development of unipolar leads introduced by Wilson in 1894. In this arrangement, the electrocardiogram is recorded between a single exploratory electrode and the central terminal, which has a potential corresponding to the centre of the body.
- In practice, the reference electrode or central terminal is obtained by a combination of several electrodes tied together at one point.
- Two types of unipolar leads are employed which are:
    - Limb leads
    - Precordial leads.



Unipolar Limb Lead system

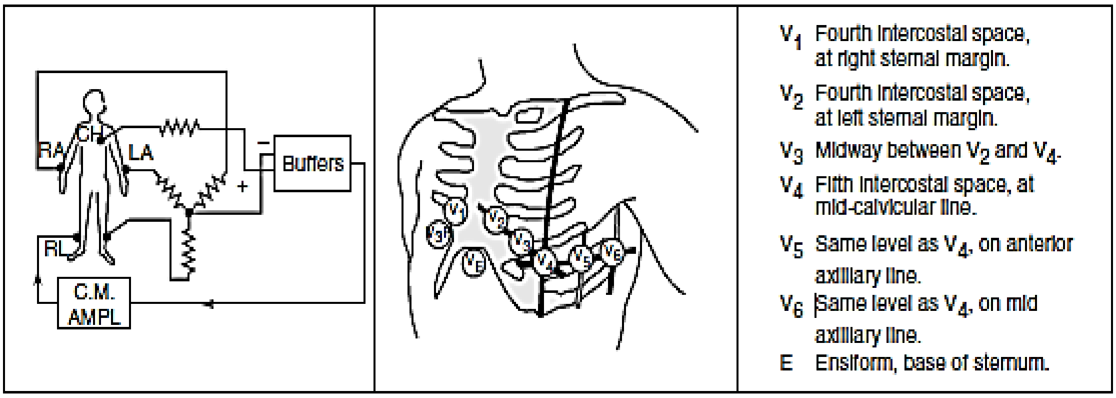
(a) Limb leads

- In unipolar limb leads, two of the limb leads are tied together and recorded with respect to the third limb.
- In the lead identified as AVR, the right arm is recorded with respect to a reference established by joining the left arm and left leg electrodes.
- In the AVL lead, the left arm is recorded with respect to the common junction of the right arm and left leg.
- In the AVF lead, the left leg is recorded with respect to the two arm electrodes tied together.
- They are also called augmented leads or 'averaging leads'. The resistances inserted between the electrodes-machine connections are known as 'averaging resistances'.

(b) Precordial leads

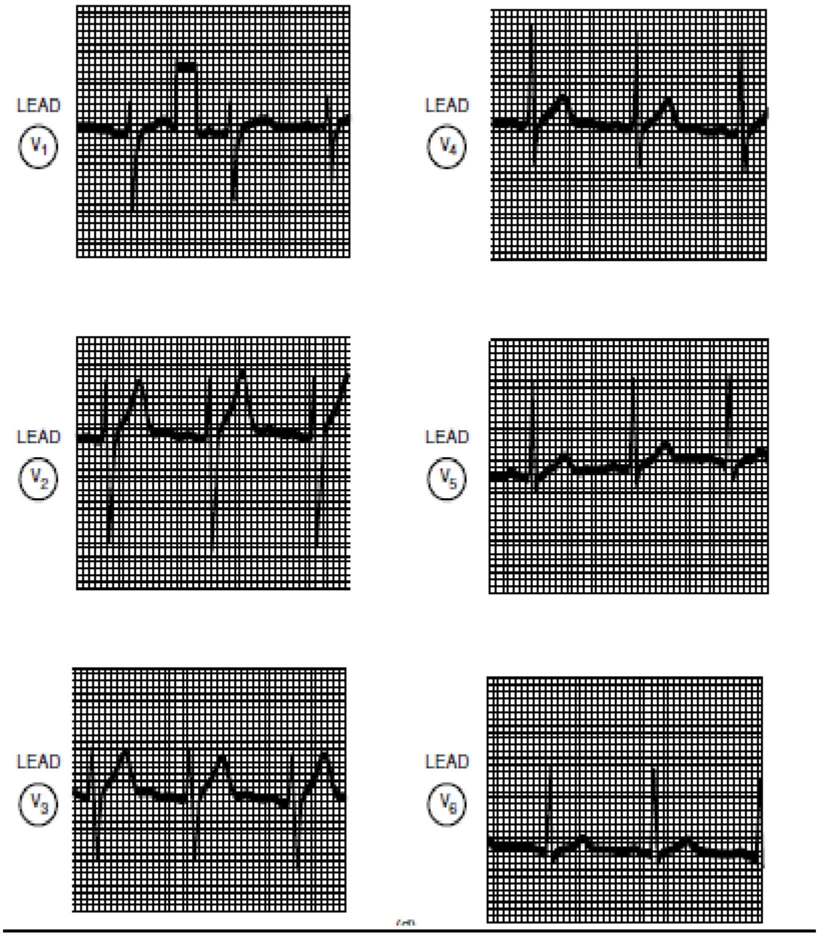
- The second type of unipolar lead is a precordial lead. It employs an exploring electrode to record the potential of the heart action on the chest at six different positions.
- These leads are designated by the capital letter 'V' followed by a subscript numeral, which represents the position of the electrode on the pericardium.

➢ The positions of the chest leads are shown in Fig. below.



Lead V ** CH positions CH positions

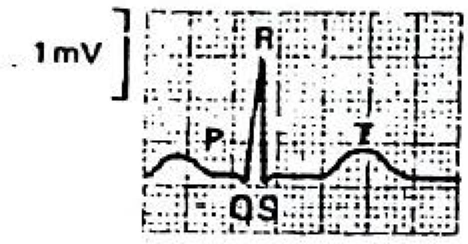
<u>Position of the chest lead in unipolar precordial lead recording</u>



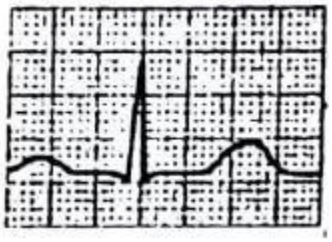
<u>C leads ECG Waveforms</u>

Analysis of ECG recorded signal

1) **Normal ECG Curve**

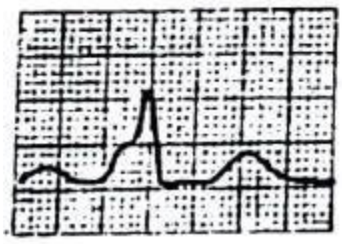


2) **First Degree AV Block**



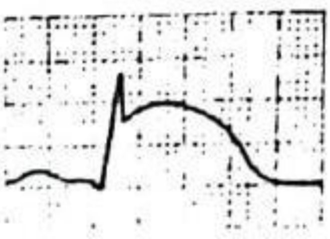
Here PQ segment has prolonged conduction time ie. Greater than 0.22 seconds

3) **Bundle Block**



Here QRS Complex is widened ie. QRS interval is 0.1 Seconds

4) **Myocardial infraction**

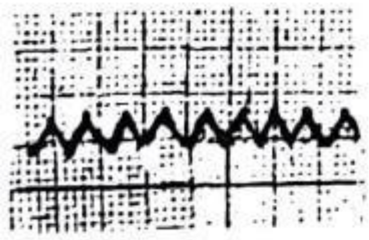


Here ST Segment is elevated

5) Coronary insufficiency

Here ST Segment is depressed and negative T wave is present

6) Ventricular Fibrillation



(Here there is a train of pulses instead of PQRST waves)

Ventricular Fibrillation may lead to death if it not treated properly with defibrillator

7) (a) Explain the working of cardiac pacemaker and discuss its types. (Nov/ Dec 2017)

(b) Discuss the cardiac pacemaker waveforms and its importance. (Nov 2016)

(c) Explain briefly about cardiac pacemaker. (May 2019)

Cardiac Pacemaker

- A pacemaker is a small, battery-operated device. This device senses when your heart is beating irregularly or too slowly. It sends a signal to your heart that makes your heart beat at the correct pace.
- Most pacemakers have 2 parts:

  (i) The generator contains the battery and the information to control the heartbeat.

  (ii) The leads are wires that connect the heart to the generator and carry the electrical messages to the heart.

Types of Pacemaker

- The classification of pacemakers into different types is based on the mode of application of the stimulating pulses to the heart.
- External pacemakers are used when the heart block presents as an emergency and when it is expected to be present for a short time.
- Internal pacemakers are used in cases requiring long-term pacing because of permanent damage that prevents normal self-triggering of the heart.
- In the latter case, the pacemaker itself may be implanted in the body. The patient is able to move about freely and is not tied to any external apparatus.

EXTERNAL PACEMAKER

- External pacemakers are employed to restart the normal rhythm of the heart in cases of cardiac standstill, in situations where short-term pacing is considered adequate, while the patient is in the intensive care unit or is awaiting implantation of a permanent pacemaker.
- Frequently, external pacemakers are used for patients recovering from cardiac surgery to correct temporary conduction disturbances resulting from the surgery. As the patient recovers, normal conduction returns and the use of pacemakers is discontinued.
- The pacing impulse is applied through metal electrodes placed on the surface of the body. Electrode jelly is used for better contact and to avoid burning of the skin underneath.
- An external pacemaker may apply up to 80-mA pulses through 50-cm2 electrode on the chest. This procedure is painful and therefore is used only in an emergency or a temporary situation**.**
- The pulses may be delivered:

(i) Continuously

- When it is felt that the heart rate is below the pre-set value. The impulse frequency is independent of the electrical activity of the heart.

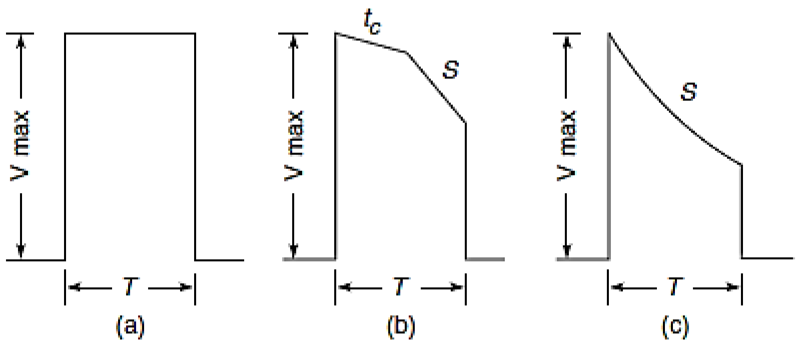
(ii) On demand R-wave synchronous pacing

- Normally the pacemaker is inoperative but it is activated when the heart rate falls below the normal or pre-set value.
- In such a situation, beat to beat examination of the time interval between two R-waves is done.

- When this interval exceeds the pre-set value, the pacemaker comes into operation. This technique eliminates any competition between the heart's own pacemaker and externally applied pacemaker pulses.
- In the R-wave synchronous mode of operation, the external pacemaker can be used to support an implanted unit shortly before re-implantation or shortly after initial implantation to secure pacing.

TYPES OF PACEMAKERS BASED ON THE TYPE OF OUTPUT WAVEFORMS

- There are three types of pacemakers based on the type of output waveform (Fig. below).



Impulses from three different types of pacemakers as seen on oscilloscope (a) constant current type pacemaker, (b) current limited voltage pacemaker, (c) voltage pacemaker

Voltage Pacemakers

- Voltage pacemakers are those in which the current in the circuit is determined by the available voltage during the entire duration of the impulse.
- The voltage output from the pacemaker remains constant and changes of resistance in the circuit will influence only the current.

Current Pacemaker

- In current pacemakers, throughout the impulse, the current in the circuit is determined by the internal resistance of the pacemaker.

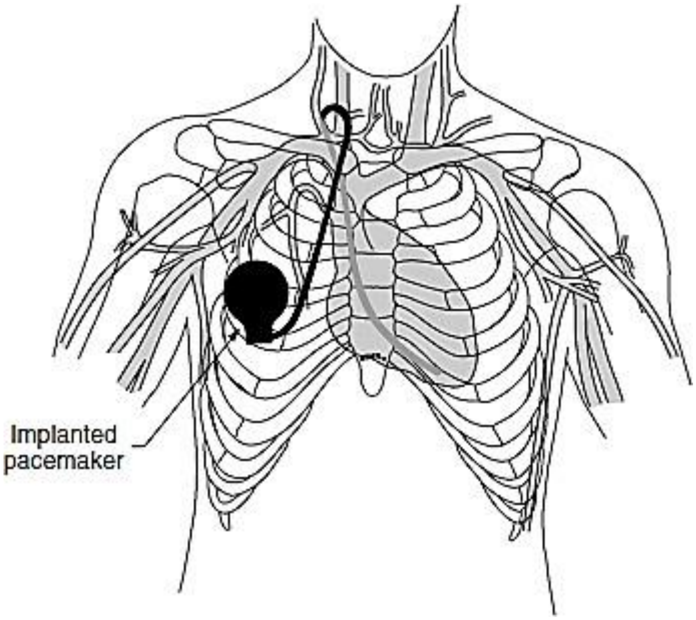
Current Limited Voltage Pacemakers

- This is primarily a voltage circuit, but the maximum current in the circuit is limited, preventing too large a current impulse to circulate when there is a low resistance in the electrode circuit.

- With these pacemakers, during the first part of the impulse, the current in the circuit is determined by the internal resistance of the pacemaker (constant current type) but during the second part of the impulse, the current in the circuit is determined by the voltage available (constant voltage version).

IMPLANTABLE PACEMAKERS

- The implantable pacemaker, alongwith its electrodes, is designed to be entirely implanted beneath the skin. Its output leads are connected directly to the heart muscle (Fig. below).
- The pacemaker is a miniaturized pulse generator and is powered by small batteries. The circuit is so designed that the batteries supply sufficient power for a long period.
- Since the pacemaker is located just beneath the skin, the replacement of the pacemaker unit involving relatively minor surgery has become a routine procedure.



The implantable pacemaker placed in the pectoral region. The lead enters the right external jugular vein immediately superior to the medial-end of the clavicle

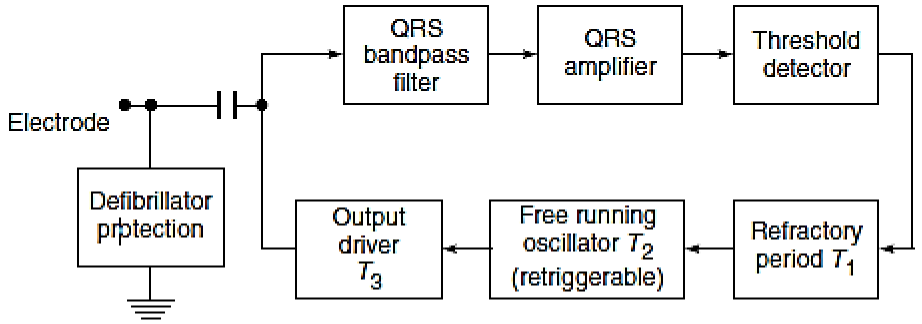
- For any implantable circuit, the basic requirements are:
  (a) The components used in the circuit should be highly reliable;
  (b) The power source should be in a position to supply sufficient power to the circuit over prolonged periods of time;
  (c) The circuit should be covered with a biological inert material so that the implant is not rejected by the body; and

(d) The unit should be covered in such a way that body fluids do not find a way inside the circuit and thus short-circuit the batteries or result in other malfunctioning of the circuit.

[ANSWER: For types of implantable pacemakers refer Q. No: 10]

VENTRICULAR SYNCHRONOUS PACEMAKERS

- The following figure shows a functional block diagram of a ventricular synchronous demand pacemaker.
- The pulse generator has two functions, viz., pacing and sensing. Sensing is accomplished by picking up the ECG signal. In the case of dual-chamber pacing, the P wave is also sensed.
- Once the ECG signal enters the sensing circuit, it is passed through a QRS bandpass filter. This filter is designed to pass signal components in the frequency range of 5-100 Hz, with a centre frequency of 30 Hz.



Block Diagram of Ventricular Synchronous demand Pacemaker

- This is followed by an amplifier and threshold detector which is designed to operate with a detection sensitivity of 1–2 mV.
- Sensitivity of this order ensures reliable detection of cardiac signals sensed on the electrodes which typically have amplitudes in the 1–30 mV range depending on the electrode surface area and the sensing circuit loading impedance.
- A refractory period (T1) is necessarily incorporated to limit the pulse delivery rate, particularly in the presence of electromagnetic interference.
- It is meant to prevent multiple re-triggering of the astable multivibrator following a sensed or paced contraction.
- The free-running multivibrator provides a fixed rate mode with an interval of T2 via the output driver circuit.

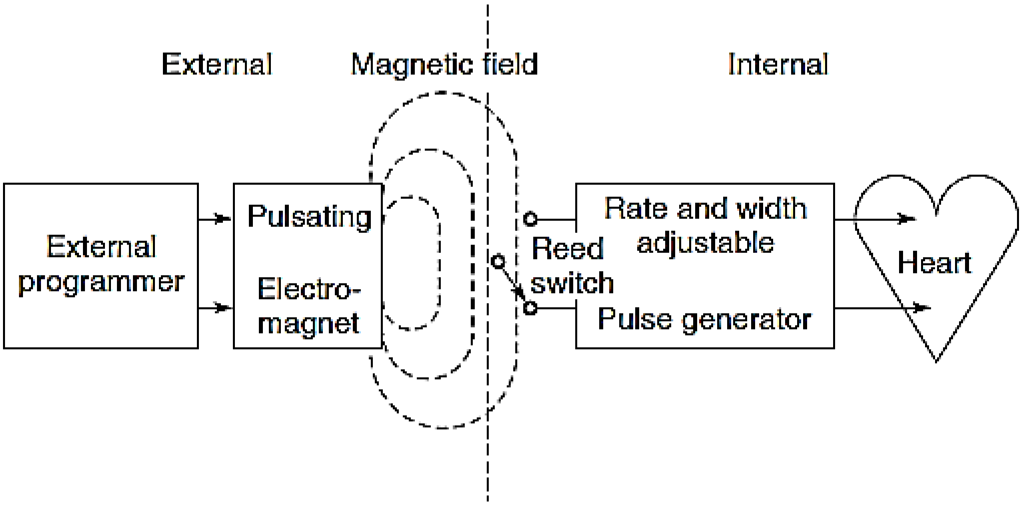
- The output pulses of a length T3 synchronous with input signals that fall outside the sensing refractory period T1are thus delivered at the stimulating electrodes.

PROGRAMMABLE PACEMAKERS

[ANSWER: Refer Q.No. 8)]

8) Explain in detail about the working of implantable programmable pacemaker with neat diagram. (April/ May 2016)

- A programmable pacemaker consists of two parts: the external unit which generates programmed stimuli which is transferred to an internal unit by one of the several communication techniques.
- The following figure shows a functional block diagram of the programming interface.



Functional block diagram of programming interface

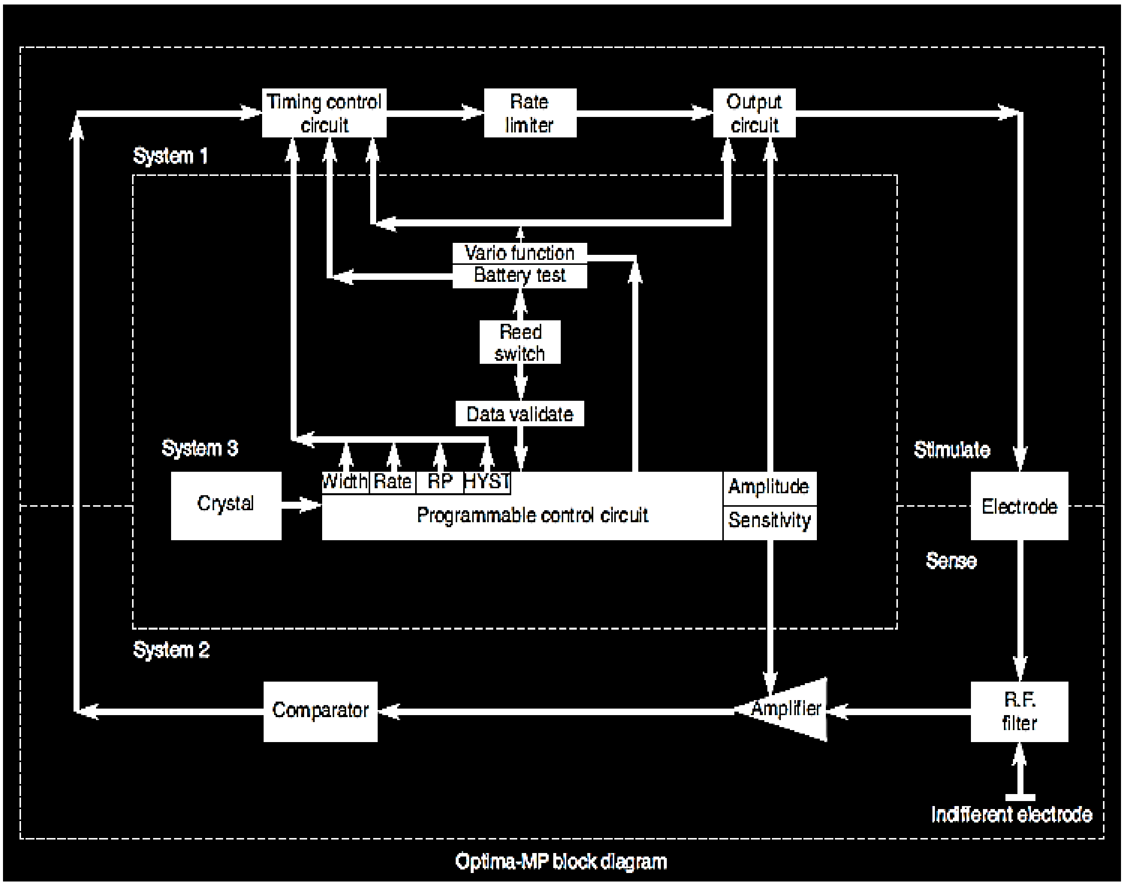
- The commonly used methods of transmitting information are

(i) Magnetic— an electromagnet placed on the surface of the body establishes a magnetic field which penetrates the skin and operates the pacemaker's reed switch.

(ii) Radio-frequency waves—the information can be transmitted over high frequency electromagnetic waves which are received inside the body by an antenna. The antenna is usually in the shape of a coil housed within the pacemaker.

(iii) Acoustic-ultrasonic pressure waves from a suitable transducer placed over the skin, can penetrate the human body.

- They are received by a suitable receiver in the pacemaker which carries out the desired function. Out of all these methods, the magnetic field method is the most widely used because of its simplicity and minimal power requirements.
- An essential requirement of programmable pacemakers is that they should be immune to accidental programming from naturally occurring energy sources.
- To meet this requirement, the information is usually coded and the pacemaker contains a decoding mechanism to recognize proper information.
- This programming security code method makes it practically impossible to reprogram an implantable pacemaker through extraneous random magnetic fields.
- The following figure is a detailed block diagram of the multi-programmable pacemaker.



Block diagram of a multi programmable pulse generator

- It may be considered as being comprised of the three systems. System I controls the main timing functions of the pulse generator and carries the rate limiter, the pulse output circuit and the stimulating function of the electrode.
- Operating as directed by the programmable control circuit, this system generates output pulses at the programmed rate, width and amplitudes unless over-ridden by System 2.

- System 2 carries the sensing and signal discriminating function of the circuit. Comprising the sensing function of the electrode, an RF filter, a signal amplifier and comparator, this system identifies signals of cardiac origin and, where appropriate, sends an inhibit signal to System 1.
- System 3 carries the programmable control circuit, the data validate circuit, the reed switch and the master timing crystal.
- This system effects program recognition, storage, and execution as well as control of the battery and various test sequences.
- Under normal operating conditions, the timing control circuit periodically triggers the output circuit causing the emission, at the programmed rate, of stimulation pulses of programmed pulse width and amplitude.
- The period between each trigger signal is scrutinized by the rate limiter and in the unlikely event of component failure causing a rate increase, the limiter holds the rate of stimulation to less than 180 bpm.
- Upon receipt of inhibit signals from System 2, the timing control circuit compares their time of arrival against the programmed refractory period. Signals arriving within the refractory period are ignored.
- Signals arriving outside the programmed refractory period when zero hysteresis is programmed, reset the timing control circuit thus inhibiting the output circuit.
- When hysteresis is programmed the arrival of a signal outside the refractory period causes resetting of the timing control circuit with the period of escape before the next stimulation of the output circuit becoming the programmed basic interval plus the programmed hysteresis period.
- Should an inhibit signal be received from System 2 during the period, the timing control circuit resets to again offer the increased escape interval.
- A signal detected by the electrode is filtered of high frequency components by the RF filter.
- The signal is then selectively amplified by an amount determined by the programmed sensitivity level and the resultant signal is compared with a preset level at the comparator.
- Signals of either polarity with magnitude greater than the preset level, enable an input signal to be fed to the timing control circuit of System 1.
- Signals below the preset level are ignored. In this way greater assurance is given to inhibitions occurring only with the detection of cardiac signals. System 3, acting on

programming signals transmitted to the reed switch, directs the pulse generator to function as programmed.

- The reed switch by opening and closing in sympathy with magnetic pulses emitted by the programmer, feeds signals to the data validate circuit.
- After first verifying that the reed switch was closed for a minimum period of 300 ms, the data validate circuit checks the speed of arrival of the signals and executes a code validation check.
- Only when all these checks are satisfied is the programmable control circuit directed to store the new code.
- By activating appropriate electronic switches, the programmable control circuit directs Systems 1 and 2 to implement the new program conditions.
- The pulse generator is non-invasively programmable by means of a programmer which emits a magnetic code, which enables the following parameters to be altered:
  - Rate
  - Pulse Width
  - Pulse Amplitude
  - Sensitivity
  - Refractory Period
  - Hysteresis

  All measurements are taken at 37°C with 500W resistive load.
- The programmer contains a microprocessor-based transmitter/receiver that operates by inductively coupling pulse-position modulated, binary coded data from the programmer via the programming wand to the pulse generator.
- The programming information is contained in a 20-bit command code specifying the desired rate, pulse width, pulse amplitude, sensitivity level, mode of operation, a pulse generator model identification code and check codes.
- If an attempt is made intentionally or unintentionally to include in a programming command a parameter that is not a feature of the pulse generator being used, that parameter will simply remain at its nominal value.
- All validly reprogrammed parameters in the command will be implemented. Part of the command code is a check code. If this check code is not correct, the command is rejected by the pulse generator, and no programming occurs.

- The timing of the transmission is precise. Crystal oscillators in both the programmer and the pulse generator control the frequency of data exchanges. Each data bit is transmitted within approximately 1.0 ms.
- The entire command code and its complement are transmitted within approximately 40 ms or 1/25th of a second.
- At present most manufacturers, are offering PC-based programming units rather than dedicated proprietary instruments. These systems are more flexible and more easily updated when new devices are released.
- Also, time-efficient programming plays an important role in the productivity of pacing clinics which may provide follow-up for a very large number of patients per year.

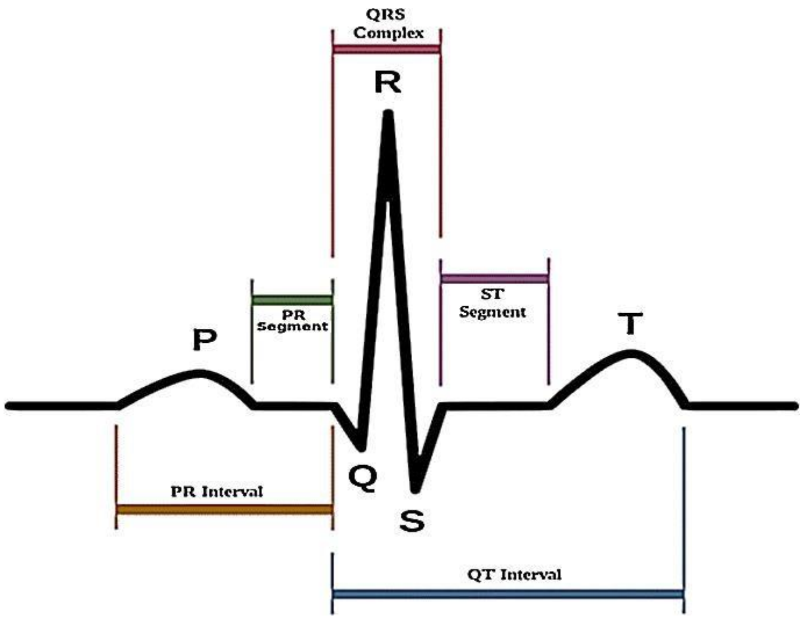
9) (a) Differentiate phonocardiography and plethysmography, (b) Draw and mention the frequency amplitude of normal and abnormal wave form of ECG. (May 2019)

(a) <u>Difference between Phonocardiography and Plethysmography:</u>

PHONOCARDIOGRAPHY	PLETHYSMOGRAPHY
A phonocardiogram is a plot of high-fidelity recording of the sounds and murmurs made by the heart with the help of the machine called the phonocardiograph;	Plethysmography measures changes in volume in different areas of your body. It measures these changes with blood pressure cuffs or other sensors. These are attached to a machine called a plethysmograph.
Thus, phonocardiography is the recording of all the sounds made by the heart during a cardiac cycle.	Thus plethysmography is especially effective in detecting changes caused by blood flow.
Available in both invasive and non-invasive form depending on the use it can be utilized	The test is noninvasive, and it does not use x-rays or injection of dye.

(b) Frequency amplitude of normal and abnormal waveform of ECG:

NORMAL WAVEFORM OF ECG

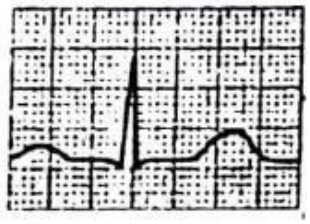


PHYSIOLOGICAL NATURE OF NORMAL ECG WAVEFORM

	Origin	**Amplitude mV**	**Duration Sec.**
P Wave	Atrial depolarization or contraction	0.25	0.12 to 0.22 (P-R interval)
R Wave (QRS complex)	Repolarisation of the atria and depolarisation of the ventricles	1.60	0.07 to 0.1
T Wave	Ventricular Repolarisation (Relaxation of myocardium)	0.1 to 0.5	0.05 to 0.15 (S-T interval)
S-T internal	Ventricular contraction		
U Wave	Slow repolarization of the intraventricular (Purkinje fibers) system	< 0.1	0.2 (T-U interval)

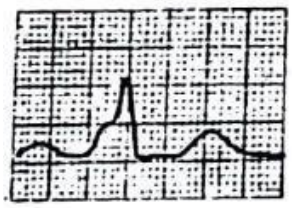
ABNORMAL WAVEFORM OF ECG

1) First Degree AV Block



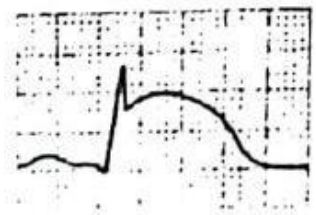
Here PQ segment has prolonged conduction time ie. Greater than 0.22 seconds

2) Bundle Block



Here QRS Complex is widened i.e. QRS interval is 0.1 Seconds

3) Myocardial infraction

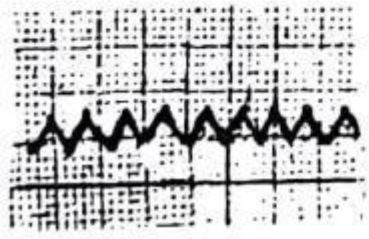


Here ST Segment is elevated

4) Coronary insufficiency

Here ST Segment is depressed and negative T wave is present

5) Ventricular Fibrillation



(Here there is a train of pulses instead of PQRST waves)

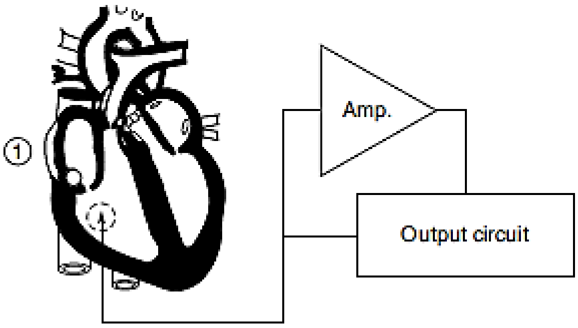
Ventricular Fibrillation may lead to death if it not treated properly with defibrillator

10) What are the different types of implantable pacemakers? Write brief notes on the various pacing modalities of demand pacemaker with clear diagram. (Sep 2020)

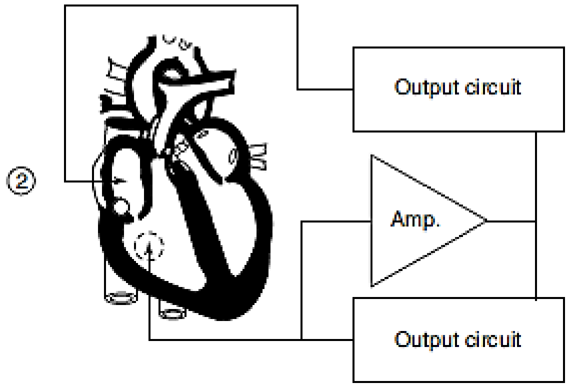
TYPES OF IMPLANTABLE PACEMAKERS:

- Depending upon the clinical requirements, different types of implantable pacemakers (Fig. below) are utilized.
- Besides the fixed rate units, the most widely used (97%) implanted pacemakers are the R-wave controlled units (R-wave inhibited and in some cases R-wave triggered).
- There has been extensive development of other types of pacemakers such as atrial demand, bi-focal demand, and the programmable that enable external programming of such parameters as impulse frequency, impulse duration, output current/voltage and refractory period.

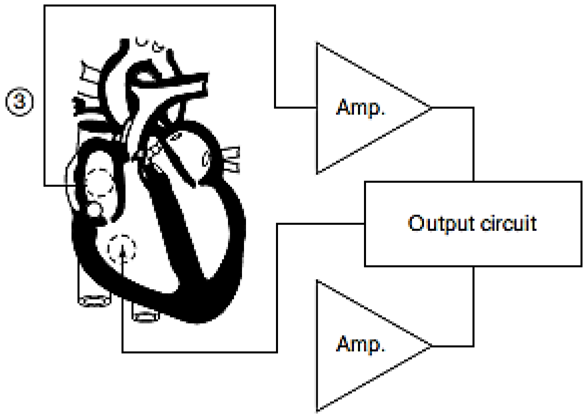
FIGURE: VARIOUS PACING MODALITIES IN DEMAND PACEMAKERS



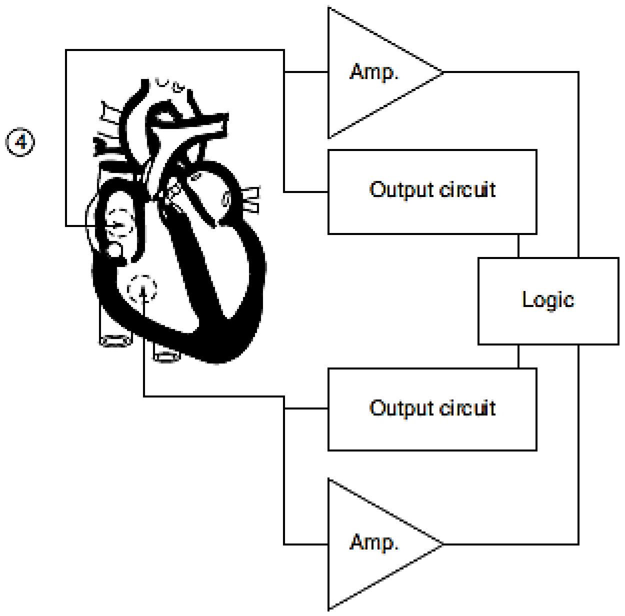
Ventricular demand inhibited VVI
(a)



A-V sequential DVI
(b)



Atrial synchronous (ventricular inhibited)
(c)



Fully automatic DDD
(d)

(i) Fixed Rate Pacemaker

- This type of pacemaker is intended for patients having permanent heart blocks. The rate is pre-set, say at 70 bpm.
- The rate can be varied externally in implanted units by magnetically actuating a built-in relay.
- Since the fixed rate pacemaker functions regardless of the patients' natural heart rhythm, it poses a potential danger because of competition between the patients' rhythm and that of the pacemaker.

(ii)Demand Pacemaker

- These pacemakers have gradually almost replaced the fixed rate pacemakers because they avoid competition between the heart's natural rhythm and the pacemaker rhythm.
- The demand unit functions only when the R-R intervals of the natural rhythm exceed a pre-set limit.

(iii) R wave Triggered Pacemaker

- The ventricular synchronized demand type (R wave triggered) pacemaker is meant for patients who are generally in heart block with occasional sinus rhythm.
- The pacemaker detects ventricular activity (R wave of ECG) and stimulates the ventricles after a very short delay time of some milliseconds.
- If there is sinus rhythm, the stimulating impulse will occur in the ventricular de-polarization. If there is asystole, the unit will stimulate the heart after a pre-set time.

(iv) Ventricular Inhibited or R Wave Blocked Pacemaker

- The ventricular inhibited type (R wave blocked) pacemaker is meant for patients who generally have sinus rhythm with occasional heart block.
- The circuitry detects spontaneous R wave potentials at the electrodes and the pacemaker provides a stimulus to the heart after pre-set asystole.
- However, in the case of ventricular activity, the R-wave does not trigger the output circuit of the pacemaker but blocks the output circuit and no stimulation impulse is given to the heart.

(v)Atrial Triggered Pacemaker

- This is a R wave triggered or atrial triggered pacemaker. The pacemaker detects the atrial de-polarization and starts the pulse forming circuits after a delay so that the impulse to the ventricles is delivered after a suitable PR interval.
- The major advantage of this pacemaker is its ability to provide maximum augmentation of cardiac output at changing atrial rates to meet various physiological requirements.

(vi) Dual Chamber Pacemakers

- These devices are capable of treating the majority of those patients who suffer from diseases of the sino-atrial node by providing atrial stimulation whenever needed.
- In these devices, both the atria and the ventricles are sensed and stimulated as needed while maintaining proper synchronization of the upper and lower chambers.
- Rate–adaptive features available with dual chamber pacemakers include the automatic adjustment of stimulus intensity and gains for the various sensing channels.

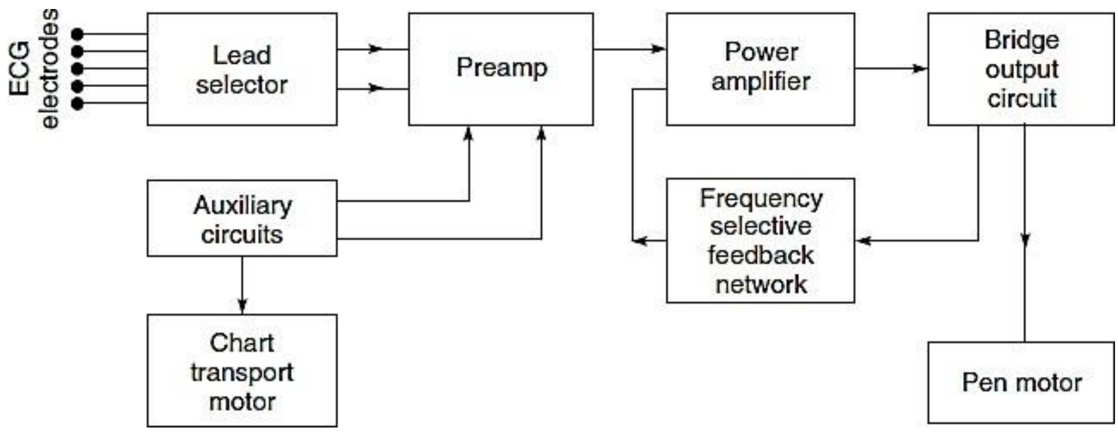
11) Draw the block diagram of an ECG machine and explain about its functioning. (Sep 2020)

Electrocardiograph

- The electrocardiograph (ECG) is an instrument, which records the electrical activity of the heart.
- Electrical signals from the heart characteristically precede the normal mechanical function and monitoring of these signals has great clinical significance.
- ECG provides valuable information about a wide range of cardiac disorders such as the presence of an inactive part (infarction) or an enlargement (cardiac hypertrophy) of the heart muscle.
- Electrocardiographs are used in catheterization laboratories, coronary care units and for routine diagnostic applications in cardiology.
- Although the electric field generated by the heart can be best characterized by vector quantities, it is generally convenient to directly measure only scalar quantities, i.e. a voltage difference of mV order between the given points of the body.

- The diagnostically useful frequency range is usually accepted as 0.05 to 150 Hz. The amplifier and writing part should faithfully reproduce signals in this range. A good low frequency response is essential to ensure stability of the baseline.
- High frequency response is a compromise of several factors like isolation between a useful ECG signal from other signals of biological origin (myographic potentials) and limitations of the direct writing pen recorders due to mass, inertia and friction.
- The interference of nonbiological origin can be handled by using modern differential amplifiers, which are capable of providing excellent rejection capabilities.
- CMRR of the order of 100–120 dB with 5 kW unbalance in the leads is a desirable feature of ECG machines.
- In addition to this, under especially adverse circumstances, it becomes necessary to include a notch filter tuned to 50 Hz to reject hum due to power mains.
- The instability of the baseline, originating from the changes of the contact impedance, demands the application of the automatic baseline stabilizing circuit.
- A minimum of two paper speeds is necessary (25 and 50 mm per sec) for ECG recording.

Block Diagram Description of Electrocardiograph



Block Diagram of an ECG Machine

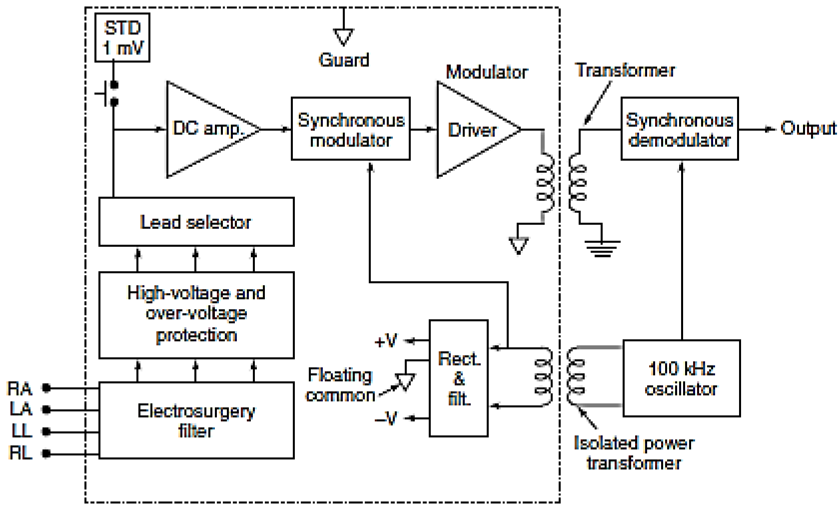
- Figure above shows the block diagram of an electrocardiograph machine. The potentials picked up by the patient electrodes are taken to the lead selector switch.
- In the lead selector, the electrodes are selected two by two according to the lead program. By means of capacitive coupling, the signal is connected symmetrically to the long-tail pair differential preamplifier.

- The preamplifier is usually a three or four stage differential amplifier having a sufficiently large negative current feedback, from the end stage to the first stage, which gives a stabilizing effect.
- The amplified output signal is picked up single-ended and is given to the power amplifier. The power amplifier is generally of the push-pull differentical type.
- The base of one input transistor of this amplifier is driven by the preamplified unsymmetrical signal. The base of the other transistor is driven by the feedback signal resulting from the pen position and connected via frequency selective network.
- The output of the power amplifier is single-ended and is fed to the pen motor, which deflects the writing arm on the paper.
- A direct writing recorder is usually adequate since the ECG signal of interest has limited bandwidth. Frequency selective network is an R–C network, which provides necessary damping of the pen motor and is preset by the manufacturer.
- The auxiliary circuits provide a 1 mV calibration signal and automatic blocking of the amplifier during a change in the position of the lead switch. It may include a speed control circuit for the chart drive motor.
- A'stand by' mode of operation is generally provided on the electrocardiograph. In this mode, the stylus moves in response to input signals, but the paper is stationary.
- This mode allows the operator to adjust the gain and baseline position controls without wasting paper.
- Electrocardiograms are almost invariably recorded on graph paper with horizontal and vertical lines at 1 mm intervals with a thicker line at 5 mm intervals.
- Time measurements and heart rate measurements are made horizontally on the electrocardiogram. For routine work, the paper recording speed is 25 mm/s.
- Amplitude measurements are made vertically in millivolts. The sensitivity of an electrocardiograph is typically set at 10 mm/mV.

Isolated Preamplifier

- It had been traditional for all electrocardiographs to have the right leg (RL) electrode connected to the chassis, and from there to the ground.
- This provided a ready path for any ground seeking current through the patient and presented an electrical hazard.

- As the microshock hazard became better understood, particularly when intracardiac catheters are employed, the necessity of isolating the patient from the ground was stressed.
- The American Heart Association guidelines state that the leakage current should not be greater than 10 microamperes when measured from the patient's leads to the ground or through the main instrument grounding wire with the ground open or intact.
- For this, patient leads would have to be isolated from the ground for all line operated units.
- Figure below shows a block diagram of an isolation preamplifier used in modern electrocardiographs.
- Difference signals obtained from the right arm (RA), left arm (LA) and right leg (RL) is given to a low-pass filter.
- Filtering is required on the input leads to reduce interference caused by electrosurgery and radio frequency emissions and sometimes from the 50 kHz current used for respiration detection.
- The filter usually has a cut off frequency higher than 10 kHz. A multistage filter is needed to achieve a suitable reduction in high frequency signal.



<u>Block diagram of an isolation preamplifier (transformed-coupled) commonly used in modern ECG machines</u>

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

- However, the price of this protection is a relatively high amplifier noise level arising from the high series resistance in each lead.
- The lead selector switch is used to derive the required lead configurations and give it to a dc-coupled amplifier.
- A dc level of 1 mV is obtained by dividing down the power supply, which can be given to this amplifier through a push button for calibration of the amplifier.
- Isolation of the patient circuit is obtained using a low capacitance transformer whose primary winding is driven from a 100 kHz oscillator.
- The transformer secondary is used to obtain an isolated power supply of ±6 V for operating the devices in the isolated portion of the circuit and to drive the synchronous modulator at 100 kHz, which linearly modulates an ECG signal given to it.
- The oscillator frequency of 100 kHz is chosen as a compromise so that reasonable size transformers (higher the frequency the smaller the transformer) could be used and that the switching time is not too fast, so that inexpensive transistors and logic circuitry can be utilized.
- A square wave is utilized to minimize the power requirements of the driven transistors. A synchronous demodulator is chosen to give low noise performance utilizing switching FET’s.
- Isolation of the patient preamplifier can also be obtained using an optical isolator. The high common-mode rejection of the amplifier is obtained by proper shielding.
- The effective capacitance from the input leads to the earth is made negligible. The preamplifier circuitry should is preferably be shielded in a separate case.

BM T61 – DIAGNOSTIC AND THERAPEUTIC EQUIPMENTS

UNIT-2

2 Marks

1. Why EEG recording take more time than other recording system? (May 2019)

- The electrodes are connected with wires to an instrument that amplifies the brain waves and records them on computer equipment.
- Once the electrodes are in place, an EEG typically takes up to 60 minutes.
- Testing for certain conditions require you to sleep during the test. In that case, the test can be longer.

2. Mention the clinical significance of EEG signal? (Nov/Dec 2017) (April/May 2016) (Sep 2020)

- An EEG is used to detect problems in the electrical activity of the brain that may be associated with certain brain disorders.
- The measurements given by an EEG are used to confirm or rule out various conditions, including:
  - seizure disorders (such as epilepsy)
  - head injury
  - encephalitis (inflammation of the brain)
  - brain tumor
  - encephalopathy (disease that causes brain dysfunction)
  - memory problems
  - sleep disorders
  - stroke
  - dementia
- When someone is in a coma, an EEG may be performed to determine the level of brain activity. The test can also be used to monitor activity during brain surgery.

3. State the types of epilepsy (Nov/Dec 2017)

- Experts now divide epilepsy into four basic types based on the seizures you're having:
  - Generalized epilepsy
  - Focal epilepsy
  - Generalized and focal epilepsy
  - Unknown if generalized or focal epilepsy

4. Define epilepsy (April/May 2018) (April/May 2016)

- Epilepsy is a central nervous system (neurological) disorder in which brain activity becomes abnormal, causing seizures or periods of unusual behavior, sensations, and sometimes loss of awareness.
- Anyone can develop epilepsy. Epilepsy affects both males and females of all races, ethnic backgrounds and ages

5. What is EEG signal? (April/May 2018)

- An electroencephalogram (EEG) is a test that detects electrical activity in your brain using small, metal discs (electrodes) attached to your scalp.
- Your brain cells communicate via electrical impulses and are active all the time, even when you're asleep. This activity shows up as wavy lines on an EEG recording.

6. What is 10-20 electrode system? (May 2017)

- The 10-20 System of Electrode Placement is a method used to describe the location of scalp electrodes.
- These scalp electrodes are used to record the electroencephalogram (EEG) using a machine called an electroencephalograph.
- Each point on this figure to the left indicates a possible electrode position.

7. Mention the brain waves with their origin and frequency (May 2017) (Nov 2016) (Nov/Dec 2018)

Waves	Frequency (Hz)	Observation
Delta(δ)	0.5 – 4	These wave occur in deep sleep in premature babies and in very serious organic brain disease
Theta (θ)	4 – 8	These wave occurs during emotional stress in some adults particularly during disappointment and frustration
Alpha(α)	8 – 13	They found in the normal persons when they are awake in a quiet, resting state. During sleep they disappear.
Beta(β)	13- 22	It is observed when the person is alert active, busy, or anxious thinking, active concentration

8. Define evoked potential (Nov 2016) (Nov/Dec 2018)

- The external stimuli are detected by the sense organs which cause changes in the electrical activity of the brain.
- Due to this, potential is developed in the brain as the response to external stimuli like light, sound etc. It is called as evoked potential.

9. What is meant by biofeedback instrumentation? Give some applications of EEG biofeedback study. (Sep 2020)

- Biofeedback instruments are designed to be used in physical therapy, occupational therapy, chiropractic therapy, and in other healthcare or athletic settings.

- The biofeedback therapy has been used to help prevent or treat conditions, including migraine headaches, chronic pain, incontinence, and high blood pressure.

11 MARKS

1. **(a) Explain detail about various evoked potential (May 2019) (April/May 2018) (May 2017)**

   (b) Define evoked potential. Explain auditory evoked potential measurement (Nov/Dec 2017)

EVOKED POTENTIALS

Introduction

- Evoked potentials are electrical activities that occur in the neural pathways and structures as a response to various external stimulations induced by light, sound, electric, smell, or taste.
- Evoked potentials are polyphasic waves that oftenly present with an amplitude between 0.1-20 µA which are formed within 2-500 ms.
- The source of these activities is probably the summation of the action potentials generated by the afferent tracts and the electrical fields or activities of the synaptic discharges or post-synaptic potentials on those tracts.
- Understanding evoked potentials bears importance in terms of controlling the entire pathway from stimulation point to the cortical areas, in other words, to the primary cortex.
- By examining evoked potentials, we can find answers to many questions such as: Does the response against the stimulus reach intended destinations on time? Does the response show any loss of intensity? If there is a problem in the neural parthways, what is its exact location?
- When a person receives a visual stimulus such as a flash light, the EEG (electroencephalogram) record concerning the occipital region (particularly at the O1-P3 and O2-P4 derivations) demonstrates waves that are called “photic driving response” which form within about 150 ms and can be observed after any kind of light stimulation.
- However, most of the responseselicited due to external stimulation are not observed very

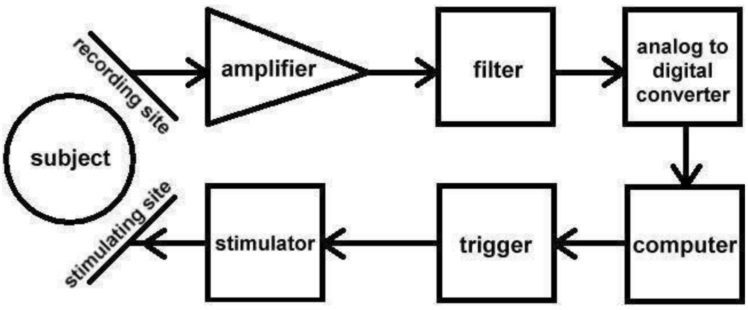
clearly because those tiny little responses that we call “evoked potentials” cannot be seen inEEG signals which may have amplitudes reaching 100 μV.

- Moreover, there are non-neural activities that suppress those signals such as EEG: ECG(electrocardiogram), EMG (electromyogram), and other biologicsignals.
- In addition, when the noises of the electronic devices and theenvironment are also considered, the difficulty of isolating evoked potentials can be figured out more easily.
- Currently, there are two methods used for eliminating those external interferences and both of them should beused in combination: “filtration” and “averaging”.
- Today, novelties in the electronics and computerized devices present us these advantages: High-quality amplifiers, smaller devices, perfect averaging techniques, multichannel capability, quality filtration options (digital filter, adaptive filter, spectral analysis etc.), capability of recordingin any kind of environment (eg. operating room, bedside, or noisy environments), routine use of evoked potential recording systems in clinics.
- The three major types of evoked potentials used in clinical studies are visualevoked potentials (VEP), brainstem auditory evoked potentials (BAEP), and somatosensory evoked potentials (SSEP).

Recording system

Electrodes

- In evoked potential recordings, Ag/AgCl or gold-plated surface electrodes with a hole are used.
- Needle electrodes should not be employed because they produce many artifacts and have high electrode-skin impedance (5000–7000 Ω).

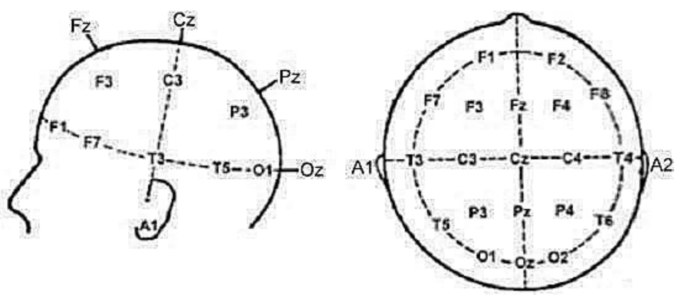


Block diagram of the recording system

- The electrode-skin impedance in surface electrodes is lower than 5000 Ω, within a range of 2000–3000 Ω (under intensive care settings or in comatose patients and during intraoperative use, needle electrodes or disposable electrodes can be employed for following the evoked potentials).

- Nonetheless, surface electrodes and needle electrodes do not have any difference with regard to recording quality of evoked potentials, both in terms of amplitude and waveform.
- In addition to the use of chloride gel in all electrodes, collodion is applied on hairy skin areas (for fixation purposes in long recordings).
- Prior to the placement of the electrodes, the related skin surface should be cleaned with alcohol or acetone in order to adequately reduce the electrode- skin impedance.
- In case of need, abrasive gels can be applied for thispurpose.
- During recording, bipolar electrodes are preferred because lowest noise level can be achieved only by them. As the distance between the bipolar electrodes increase, signals grow more strong, however, the noise increases by the same rate, as well.
- Stimulus electrodes are also bipolar and the distance between them should be 35 mm with the active electrode placed distally.
- The electrode configuration and system of a classic 10/20 electrode EEG recording system, shown in the Figure 2, are used in evoked potentialrecordings, as well.
- However, if needed, the electrode configuration of a 32- electrode EEG recording system can also be employed. (F: Frontal region, C: Central region, T: Temporal region, P: Parietal region, O: Occipital region, A1 and A2: Ear lobes, Fz, Cz, Pz, Oz: Midline electrodes, The odd numbered electrodes are always placed on the left.)

International 10/20 EEG electrode positioning system



General principles

Before the test

- The patient should wash his/her hair on the evening before the test or a couple of hours inadvance.

- Substances such as perfume, lotion, or cream should not be applied prior to the test.
- Any accessories such as an auditory device, glasses, or lense should be brought to the clinic.
- The patient should dress in a comfortable way and clothes with a turtle neck orbra should not be worn.
- Drugs or foods containing caffeine should not be taken.
- The people that will undergo visual evoked potential test, should not use sedatives.

During the test

1. In somatosensory, dermatomal, and auditory evoked potential tests, patient is told that thetest could take a while and that he/she would take a nap during the test.
2. In somatosensory evoked potential test, the patient should be informed that a tingling can befelt in the stimulation points and flexion may be observed in the thumbs and toes.
3. The patient should be informed that there is no limitation of drug, food, or activity after thetest.
4. Skin surfaces that will receive the electrodes should be rubbed with alcohol and acetone, andsmoothened if required to.
5. In presence of muscular noise during the auditory evoked potential test and if the patient cannot sleep, then sedation with chloride hydrate or diazepam should be performed.
6. Prior to the visual evoked potential test, the visual acuity and pupil width should becontrolled in both eyes of the patient.

After the test

- There is no limitation of drug, food, or acitivity.

Types of Evoked Potential

- An evoked potential is an electrical potential recorded from the nervous system, which is responding to a stimulus and is used for a neurophysiological examination.
- It can be recorded from the somatosensory cortex or directly through the scalp. These

electric potentials in the nervous system are produced by systematic stimulation of a sensory organ or a peripheral nerve, mainly by sight, sound or touch.

- These stimuli evoke electrical signals that travel along the nerves and through the spinal cord to special areas in the brain.
- There they lead to potential differences in the cerebral cortex, which can be recorded by placing electrodes on the respected area.
- Evoked potentials are time-locked to the beginning of stimulation and consist of series of waves characteristic to the stimulus modality.
- Evoked potentials are mainly used in the neurological field. They help to detect neurological diseases as nerve damages, spinous cord dysfunctions or a demyelinating disease as multiple sclerosis.
- There are three main types of evoked potential tests:
  - Visual evoked potentials (VEP): You sit in front of a screen and watch an alternatingcheckerboard pattern.
  - Brainstem auditory evoked potentials (BAEP): You hear a series of clicks in each ear.
  - Sensoryevoked potentials (SEP): You get short electrical pulses on one of your arms or legs.
- A fourth type of test, motor evoked potentials, can find damage along nerves in the brain and spinalcord that make your body move. However, doctors don't usually use this test to diagnose MultipleSclerosis.

Visual evoked potentials (VEP)

- Visual evoked potentials are used to examine the optical nerves and the visual pathway. Visual stimulation can have various types, for example the flashing light on a monitor. Using VEPs sight disorders can be detected as well than optic nerve damage.
- A typical disorder detected by VEP is the optic neuritis, an inflammation of the optic nerve, mainly caused by multiple sclerosis. The velocity of the transmission of the impulse to the convertion of the impulse in the brain is measured.

Brainstem auditory evoked potentials (BAEP)

- Auditory evoked potentials are evoked by acoustic stimuli like a speech sound transmitted by earphones.
- Brainstem auditory evoked potentials are helpful in the diagnose of a hearing ability and detection of brainstem tumors and multiple sclerosis.

- Even silent lesions (disease without symptoms) can be detected by BAEPs, although BAEPs are less sensitive and specific than SSEPs.
- The velocity of the transmission of the impulse is measured in the acoustic system of the brainstem.

Somatosensory evoked potentials (SSEP)

- SSEPs are providing an evaluation of the central somatosensory pathway and the peripheral sensible nerves.
- The stimulation occurs transcutaneously, usually by an electric stimulus. The velocity of the transmission of the impulse to the brain or the spinal cord is measured.
- SSEPs are used for the detection of cervical myelopathy (spinous cord dysfunction). Somatosensory evokedpotentials are also used during surgery to examine neurological dysfunction in order to avoid risking brain damage.
- SSEPs additionally help in the prognosis of the comatose state of patients.

Motor evoked potentials (MEP)

- For motor evoked potentials no sensory organ is stimulated, but the motor cortex itself either directly or through transcranial magnetic stimulation (TMS).
- For the TMS procedure a magnetic field generator is placed near the head and via electromagnetic induction the brain receives electric currents. MEPs are mainly used intraoperatively to monitor the intactness of the motor system.
- MEPs are also used to measure the transmittance between the brain and a muscle at a disorder of cranial nerves or the spinal cord.

Conclusion:

- Evoked potential studies are considered to be safe procedures. They are objective and very sensitive compared to other neurological examinations and can be also used for comatose or anaesthetised patients.
- Especially in the diagnose of a developing multiple sclerosis evoked potentials still play a major role.
- The main disadvantage of evoked potentials is the lack of being disease specific. VEPs can be for example abnormal in optic neuritis as well as in an ocular disease.
- The use of evoked potentials has been reduced in the last years due to progressive advances in imaging technology, especially magnetic resonance imaging (MRI) and is now oftenused only complementar

2. (a) Enumerate the clinical significance of EEG and also explain the multi channel EEG system (May 2019) (May 2017) (Nov/Dec 2017) (April/May 2016)

(b) Explain the block diagram of an eight channel EEG system (Nov/Dec 2018)

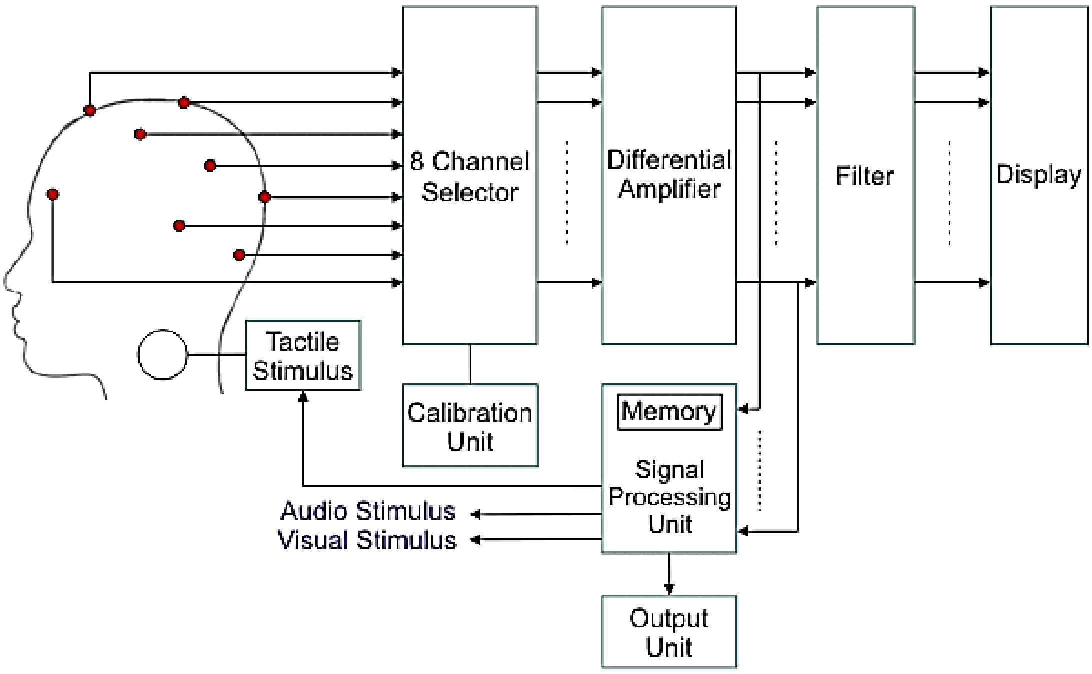
(c) Describe about the parts of an EEG machine with the schematic diagram and explain its functioning (Sep 2020)

ELECTRPHALOGRAPH (EEG)

- Electroencephalograph is an instrument for recording the electrical activity of the brain, by suitably placing surface electrodes on the scalp. EEG, describing the general function of the brain activity, is the superimposed wave of neuron potentials operating in a non-synchronized manner in the physical sense.
- Its stochastic nature originates just from this, and the prominent signal groups can be empirically connected to diagnostic conclusions.
- Monitoring the electroencephalogram has proven to be an effective method of diagnosing many neurological illnesses and diseases, such as epilepsy, tumour, cerebrovascular lesions, ischemia and problems associated with trauma.
- It is also effectively used in the operating room to facilitate anaesthetics and to establish the integrity of the anaesthetized patient's nervous system.
- This has become possible with the advent of small, computer-based EEG analyzers.
- Consequently, routine EEG monitoring in the operating room and intensive care units is becoming popular.
- Several types of electrodes may be used to record EEG.
- These include:
    - Peel and Stick electrodes
    - Silver plated cup electrodes
    - Needle electrodes.
- EEG electrodes are smaller in size than ECG electrodes.
- They may be applied separately to the scalp or may be mounted in special bands, which can be placed on the patient's head.
- In either case, electrode jelly or paste is used to improve the electrical contact.
- If the electrodes are intended to be used under the skin of the scalp, needle electrodes are used.

- They offer the advantage of reducing movement artefacts.
- EEG electrodes give high skin contact impedance as compared to ECG electrodes. Good electrode impedance should be generally below 5 kilohms.
- Impedance between a pair of electrodes must also be balanced or the difference between them should be less than 2 kilohms.
- EEG preamplifiers are generally designed to have a very high value of input impedance to take care of high electrode impedance.
- EEG may be recorded by picking up the voltage difference between an active electrode on the scalp with respect to a reference electrode on the ear lobe or any other part of the body.
- This type of recording is called ‘monopolar’ recording. However, ‘bipolar’ recording is more popular wherein the voltage difference between two scalp electrodes is recorded.
- Such recordings are done with multi-channel electroencephalographs.
- EEG signals picked up by the surface electrodes are usually small as compared with the ECG signals.
- They may be several hundred microvolts, but 50 microvolts peak-to-peak is the most typical.
- The brain waves, unlike the electrical activity of the heart, do not represent the same pattern over and over again.
- Therefore, brain recordings are made over a much longer interval of time in order to be able to detect any kind of abnormalities.

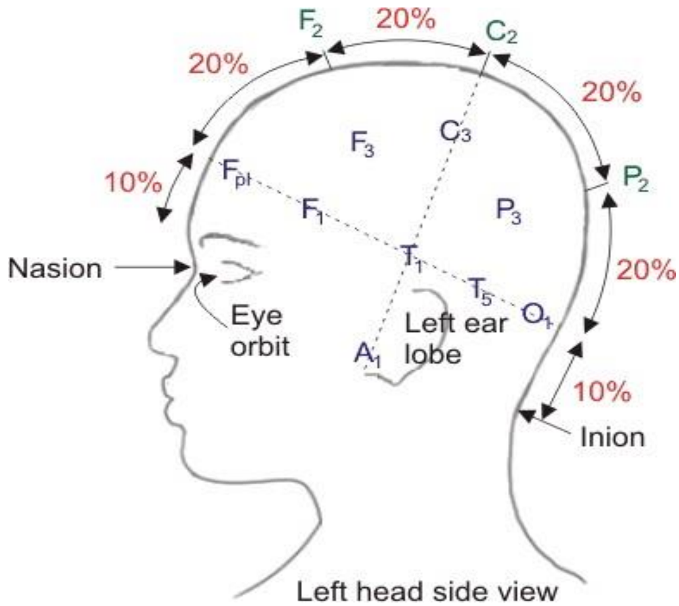
EEG RECORDING SETUP



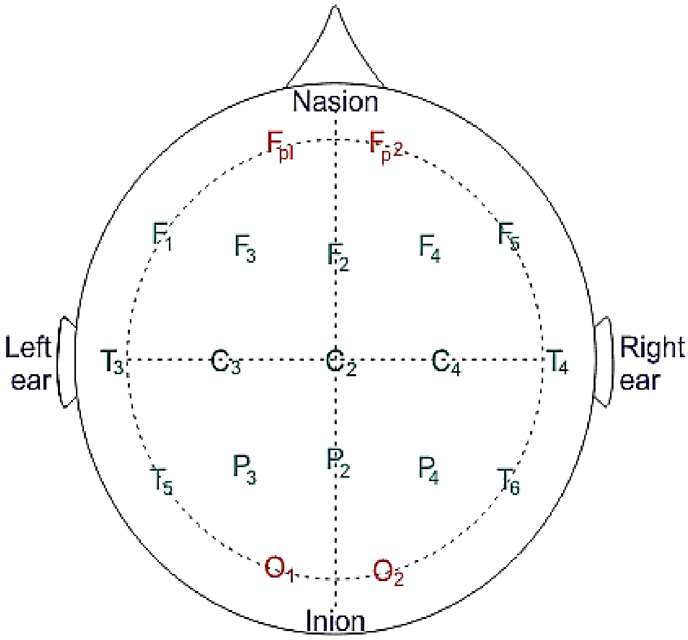
SCHEMATIC DIAGRAM OF EEG

- Here 21-electrode system is used. Electrodes are connected to 8-channel selector. Output from 8-channel connector goes to the differential amplifier bank.
- Differential amplifier is made of preamplifiers that are used to reduce noise. 50 Hz noise is created due to A.C interference that can be reduced using differential amplifier.
- The output obtained from differential amplifier is connected with signal processing unit. After further processing, the display unit displays the data.
- This system helps to record the potentials generated from the sensory parts of the brain. To achieve this, output unit is connected with audio stimulus, visual stimulus and touch stimulus. It can also measure the time delay between stimulus and response from brain.
- In addition, we have a filter bank consisting of low pass filters, high pass filters and band pass filters. They help to remove noise from the brain waves.
- For the output recording, we can use either pen recorder or CRO. Three modes namely Unipolar, Average mode and bipolar recording are used to measure EEG.

EEG LEAD SYSTEM



- International Federation of EEG society has suggested 10 – 20 electrode placement system for EEG recording.
- Silver / silver chloride electrodes are used as surface electrodes in this setup. On the scalp, distances between two electrodes are given as 10% and 20% of the distance between specified points.
- Nasion and Inion are the two reference points near the ear lobes of the human. Over the head, the distance between nasion and inion are divided into 5 points.
- The nasion – inion distance via the vertex is measured and three electrodes are placed as 1 in frontal, 1 in central and 1 in parietal.
- They are placed at a distance of 10%, 20%, 20%, 20%, 20% and 10% of this length. Now, similarly nasion – inion distance is measured along the temporal lobes and five electrode are placed as two in frontal, 2 in temporal and 1 in occipital lobes respectively.
- They are also placed at a distance of 10%, 20%, 20%, 20%, 20% and 10% of this length on either side.
- Lastly, on the peripheries of the circle remaining six electrodes are fixed as 2 in frontal, 2 in central and 2 in parietal.
- So, in the setup totally 19 electrode are placed on the brain scalp and one electrode which acts as reference is placed at the ear lobe. This is popularly known as 10 – 20 EEG system.



MEDICAL USE

- EEG is one of the main diagnostic tests for epilepsy. A routine clinical EEG recording typically lasts 20–30 minutes (plus preparation time).
- It is a test that detects electrical activity in the brain using small, metal discs (electrodes) attached to the scalp.
- Routinely, EEG is used in clinical circumstances to determine changes in brain activity that might be useful in diagnosing brain disorders, especially epilepsy or another seizure disorder.
- An EEG might also be helpful for diagnosing or treating the following disorders:

- Brain tumor
- Brain damage from head injury
- Brain dysfunction that can have a variety of causes (encephalopathy)
- Inflammation of the brain (encephalitis)
- Stroke
- Sleep disorders

ADVANTAGES

- Hardware costs are significantly lower than those of most other techniques
- EEG prevents limited availability of technologists to provide immediate care in high traffic hospitals.
- EEG is silent, which allows for better study of the responses to auditory stimuli.
- EEG does not aggravate claustrophobia, unlike fMRI, PET, MRS, SPECT, and sometimes MEG
- EEG does not involve exposure to radioligands, unlike positron emission tomography.
- ERP studies can be conducted with relatively simple paradigms, compared with IE block-design fMRI studies
- Extremely uninvasive, unlike Electrocorticography, which actually requires electrodes to be placed on the surface of the brain.

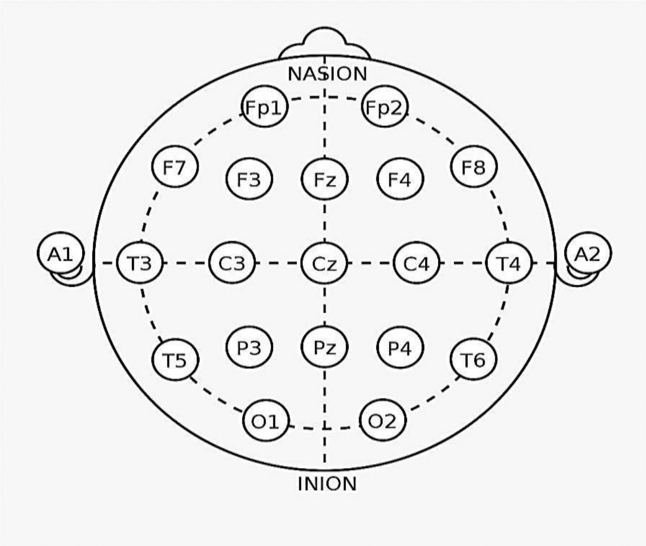
DISADVANTAGE

- Low spatial resolution on the scalp.
- EEG poorly measures neural activity that occurs below the upper layers of the brain (the cortex).
- Unlike PET and MRS, cannot identify specific locations in the brain at which various neurotransmitters, drugs, etc. can be found
- Signal-to-noise ratio is poor
- Often takes a long time to connect a subject to EEG, as it requires precise placement of dozens of electrodes around the head and the use of various gels, saline solutions, and/or pastes to maintain good conductivity

3. Discuss in detail about the 10 – 20 lead system of EEG signal with its significance(April/May 2018)

10-20 LEAD SYSTEM

- The 10–20 system or International 10–20 system is an internationally recognized method to describe and apply the location of scalp electrodes in the context of an EEG exam, polysomnograph sleep study, or voluntary lab research.
- This method was developed to maintain standardized testing methods ensuring that a subject's study outcomes (clinical or research) could be compiled, reproduced, and effectively analyzed and compared using the scientific method.
- The system is based on the relationship between the location of an electrode and the underlying area of the brain, specifically the cerebral cortex.
- During sleep and wake cycles, the brain produces different, objectively recognized and distinguishable electrical patterns, which can be detected by electrodes on the skin.
- (These patterns might vary, and can be affected by multiple extrinsic factors, i.e. age, prescription drugs, somatic diagnoses, hx of neurologic insults/injury/trauma, and substance abuse).
- The "10" and "20" refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front–back or right–left distance of the skull. For example, a measurement is taken across the top of the head, from the nasion to inion.
- Most other common measurements ('landmarking methods') start at one ear and end at the other, normally over the top of the head. Specific anatomical locations of the ear used include the tragus, the auricle and the mastoid.

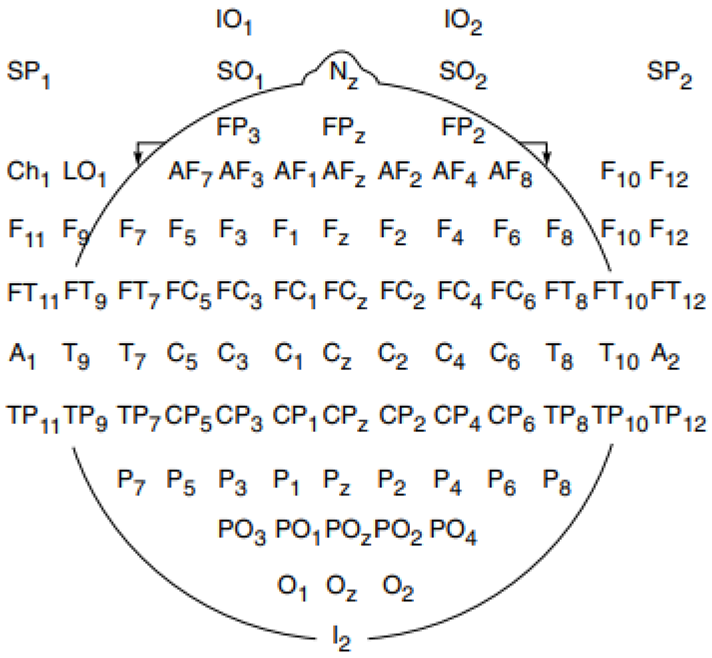


LOCATION OF 10-20 SYSTEM OF EEG RECORDING

ELECTRODE LABLEING

- Each electrode placement site has a letter to identify the lobe, or area of the brain it is reading from: pre-frontal (Fp), frontal (F), temporal (T), parietal (P), occipital (O), and central (C).
- Note that there is no "central lobe"; due to their placement, and depending on the individual, the "C" electrodes can exhibit/represent EEG activity more typical of frontal, temporal, and some parietal-occipital activity, and are always utilized in polysomnography sleep studies for the purpose of determining stages of sleep.
- There are also (Z) sites: A "Z" (zero) refers to an electrode placed on the midline sagittal plane of the skull, (FpZ, Fz, Cz, Oz) and is present mostly for reference/measurement points.
- These electrodes will not necessarily reflect or amplify lateral hemispheric cortical activity as they are placed over the corpus callosum, and do not represent either hemisphere adequately.
- "Z" electrodes are often utilized as 'grounds' or 'references,' especially in polysomnography sleep studies, and diagnostic/clinical EEG montages meant to represent/diagnose epileptiform seizure activity, or possible clinical brain death.
- Note that the required number of EEG electrodes, and their careful, measured placement, increases with each clinical requirement and modality.

- Even-numbered electrodes (2,4,6,8) refer to electrode placement on the right side of the head, whereas odd numbers (1,3,5,7) refer to those on the left; this applies to both EEG and EOG (electrooculogram measurements of eyes) electrodes, as well as ECG (electrocardiography measurements of the heart) electrode placement.
- Chin, or EMG (electromyogram) electrodes are more commonly just referred to with "right," "left," and "reference," or "common," as there are usually only three placed, and they can be differentially referenced from the EEG and EOG reference sites.
- The "A" (sometimes referred to as "M" for mastoid process) refers to the prominent bone process usually found just behind the outer ear (less prominent in children and some adults).
- In basic polysomnography, F3, F4, Fz, Cz, C3, C4, O1, O2, A1, A2 (M1, M2), are used. Cz and Fz are 'ground' or 'common' reference points for all EEG and EOG electrodes, and A1-A2 are used for contralateral referencing of all EEG electrodes.
- This EEG montage may be extended to utilize T3-T4, P3-P4, as well as others, if an extended or "seizure montage" is called for.



Pictorial representation of closely spaced electrodes

MEASUREMENT

- Specific anatomical landmarks are used for the essential measuring and positioning of the EEG electrodes.
- These are found with a tape measure, and often marked with a grease pencil, or "China marker."

Nasion to Inion

- The nasion is the distinctly depressed area between the eyes, just above the bridge of the nose, and the inion, is the crest point of back of the skull, often indicated by a bump (the prominent occipital ridge, can usually be located with mild palpation).
- Marks for the Z electrodes are made between these points along the midline, at intervals of 10%, 20%, 20%, 20%, 20% and 10%.

Preauricular to preauricular (or tragus to tragus: the tragus refers to the small portion of cartilage projecting anteriorly to the pinna)

- The preauricural point is in front of each ear, and can be more easily located with mild palpation, and if necessary, requesting patient to open mouth slightly.
- The T3, C3, Cz, C4, and T4 electrodes are placed at marks made at intervals of 10%, 20%, 20%, 20%, 20% and 10%, respectively, measured across the top of the head.
- Skull circumference is measured just above the ears (T3 and T4), just above the bridge of the nose (at Fpz), and just above the occipital point (at Oz). The Fp2, F8, T4, T6, and O2 electrodes are placed at intervals of 5%, 10%, 10%, 10%, 10%, and 5%, respectively, measured above the right ear, from front (Fpz) to back (Oz).
- The same is done for the odd-numbered electrodes on the left side, to complete the full circumference.
- Measurement methods for placement of the F3, F4, P3, and P4 points differ. If measured front-to-back (Fp1-F3-C3-P3-O1 and Fp2-F4-C4-P4-O2 montages), they can be 25% "up" from the front and back points (Fp1, Fp2, O1, and O2).
- If measured side-to-side (F7-F3-Fz-F4-F8 and T5-P3-Pz-P4-T6 montages), they can be 25% "up" from the side points (F7, F8, T5, and T6).
- If measured diagonally, from Nasion to Inion through the C3 and C4 points, they will be 20% in front of and behind the C3 and C4 points.
- Each of these measurement methods results in different nominal electrode placements.

- When placing the A (or M) electrodes, palpation is often necessary to determine the most pronounced point of the mastoid process behind either ear; failure to do so, and to place the reference electrodes too low (posterior to the ear pinna, proximal to the throat) may result in "EKG artifact" in the EEGs and EOGs, due to artifact from the carotid arteries.
- EKG artifact can be reduced with post-filtering of signals, or by "jumping" (co-referencing) of A/M reference electrodes, if replacement of reference electrodes is not possible, ameliorative, or if other clinical considerations prevent otherwise good placement (such as congenital malformation, or post-surgical considerations such as Cochlear Implants).

HIGH RESOLUTION SYSTEM

- When recording a more detailed EEG with more electrodes, extra electrodes are added using *the 10% division*, which fills in intermediate sites halfway between those of the existing 10–20 system.
- This new electrode-naming-system is more complicated giving rise to the Modified Combinatorial Nomenclature (MCN).
- This MCN system uses 1, 3, 5, 7, 9 for the left hemisphere which represents 10%, 20%, 30%, 40%, 50% of the inion-to-nasion distance respectively.
- The introduction of extra letter codes allows the naming of intermediate electrode sites. Note that these new letter codes do not necessarily refer to an area on the underlying cerebral cortex.
- The new letter codes of the MCN for intermediate electrode places are:

- AF – between Fp and F
- FC – between F and C
- FT – between F and T
- CP – between C and P
- TP – between T and P
- PO – between P and O

- Also, the MCN system renames four electrodes of the 10–20 system:

- T3 is now T7
- T4 is now T8
- T5 is now P7
- T6 is now P8

- A higher-resolution nomenclature has been suggested and called the "5% system" or the "10–5 system"

4. (a) Describe in principles of visual auditory machine. Add a note on its applications (April/May 2016)

(b) Draw and explain the operation of EEG system and visual-auditory evoked system with its block diagram (Nov/Dec 2018)

EVOKED POTENTIAL

- An **evoked potential** or **evoked response** is an electrical potential in a specific pattern recorded from a specific part of the nervous system, especially the brain, of a human or other animals following presentation of a stimulus such as a light flash or a pure tone.
- Different types of potentials result from stimuli of different modalities and types. EP is distinct from spontaneous potentials as detected by electroencephalography (EEG), electromyography (EMG), or other electrophysiologic recording method.
- Such potentials are useful for electrodiagnosis and monitoring that include detections of disease and drug-related sensory dysfunction and intraoperative monitoring of sensory pathway integrity.
- Evoked potential amplitudes tend to be low, ranging from less than a microvolt to several microvolts, compared to tens of microvolts for EEG, millivolts for EMG, and often close to 20 millivolts for ECG.
- To resolve these low-amplitude potentials against the background of ongoing EEG, ECG, EMG, and other biological signals and ambient noise, signal averaging is usually required.
- The signal is time-locked to the stimulus and most of the noise occurs randomly, allowing the noise to be averaged out with averaging of repeated responses.
- Signals can be recorded from cerebral cortex, brain stem, spinal cord, peripheral nerves and muscles. Usually the term "evoked potential" is reserved for responses involving either recording from, or stimulation of, central nervous system structures.

- Thus evoked compound motor action potentials (CMAP) or sensory nerve action potentials (SNAP) as used in nerve conduction studies (NCS) are generally not thought of as evoked potentials, though they do meet the above definition.
- Evoked potential is different from event-related potential (ERP), although the terms are sometimes used synonymously, because ERP has higher latency, and is associated with higher cognitive processing.
- Evoked potentials are mainly classified by the type of stimulus: somatosensory, auditory, visual. But they could be also classified according to stimulus frequency, wave latencies, potential origin, location, and derivation.

Visual evoked potential

- Visual evoked potential (VEP) is an evoked potential elicited by presenting light flash or pattern stimulus which can be used to confirm damage to visual pathway including retina, optic nerve, optic chiasm, optic radiations, and occipital cortex.
- One application is in measuring infant's visual acuity. Electrodes are placed on infant's head over visual cortex and a gray field is presented alternately with a checkerboard or grating pattern.
- If the checker's boxes or stripes are large enough to be detected, VEP is generated; otherwise, none is generated. It's an objective way to measure infant's visual acuity.
- VEP can be sensitive to visual dysfunctions that may not be found with just physical examinations or MRI, even if it cannot indicate etiologies.
- VEP may be abnormal in optic neuritis, optic neuropathy, demyelinating disease, multiple sclerosis, Friedreich's ataxia, vitamin B12 deficiency, neurosyphilis, migraine, ischemic disease, tumor compressing the optic nerve, ocular hypertension, glaucoma, diabetes, toxic amblyopia, aluminum neurotoxicity, manganese intoxication, retrobulbar neuritis, and brain injury.
- It can be used to examine infant's visual impairment for abnormal visual pathways which may be due to delayed maturation.
- The P100 component of VEP response, which is the positive peak with the delay about 100 ms, has a major clinical importance. The visual pathway dysfunction anterior to the optic chiasm maybe where VEPs are most useful.
- For example, patients with acute severe optic neuritis often lose the P100 response or have highly attenuated responses.

- Clinical recovery and visual improvement come with P100 restoration but with an abnormal increased latency that continues indefinitely, and hence, it may be useful as an indicator of previous or subclinical optic neuritis.
- In 1934, Adrian and Matthew noticed potential changes of the occipital EEG can be observed under stimulation of light. Ciganek developed the first nomenclature for occipital EEG components in 1961.
- During that same year, Hirsch and colleagues recorded a visual evoked potential (VEP) on the occipital lobe (externally and internally), and they discovered amplitudes recorded along the calcarine fissure were the largest.
- In 1965, Spehlmann used a checkerboard stimulation to describe human VEPs. An attempt to localize structures in the primary visual pathway was completed by Szikla and colleagues. Halliday and colleagues completed the first clinical investigations using VEP by recording delayed VEPs in a patient with retrobulbar neuritis in 1972.
- A wide variety of extensive research to improve procedures and theories has been conducted from the 1970s to today and the method has also been described in animals.

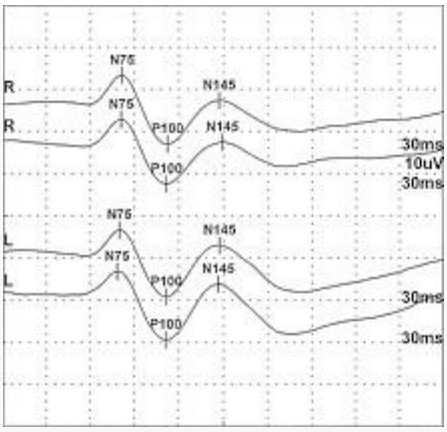
VEP Stimuli

- The diffuse-light flash stimulus is rarely used nowadays due to the high variability within and across subjects. However, it is beneficial to use this type of stimulus when testing infants, animals or individuals with poor visual acuity.
- The checkerboard and grating patterns use light and dark squares and stripes, respectively. These squares and stripes are equal in size and are presented, one image at a time, via a computer screen.

VEP Electrode Placement

- Electrode placement is extremely important to elicit a good VEP response free of artifact. In a typical (one channel) setup, one electrode is placed 2.5 cm above the inion and a reference electrode is placed at Fz.
- For a more detailed response, two additional electrodes can be placed 2.5 cm to the right and left of Oz.

VEP Waves



Normal visual evoked potential

- The VEP nomenclature is determined by using capital letters stating whether the peak is positive (P) or negative (N) followed by a number which indicates the average peak latency for that particular wave.
- For example, P100 is a wave with a positive peak at approximately 100 ms following stimulus onset. The average amplitude for VEP waves usually falls between 5 and 20 microvolts.
- Normal values are depending on used stimulation hardware (flash stimulus vs. cathode ray tube or liquid crystal display, checkerboard field size, etc.).

Types of VEP

- Some specific VEPs are:

  - Monocular pattern reversal (most common)
  - Sweep visual evoked potential
  - Binocular visual evoked potential
  - Chromatic visual evoked potential
  - Hemi-field visual evoked potential
  - Flash visual evoked potential
  - LED Goggle visual evoked potential
  - Motion visual evoked potential
  - Multifocal visual evoked potential
  - Multi-channel visual evoked potential
  - Multi-frequency visual evoked potential
  - Stereo-elicited visual evoked potential

- Steady state visually evoked potential

5. Explain the working of AEP (Auditory Evoked Potential) monitor to measure individual's level of consciousness during general anaesthesia (Sep 2020)

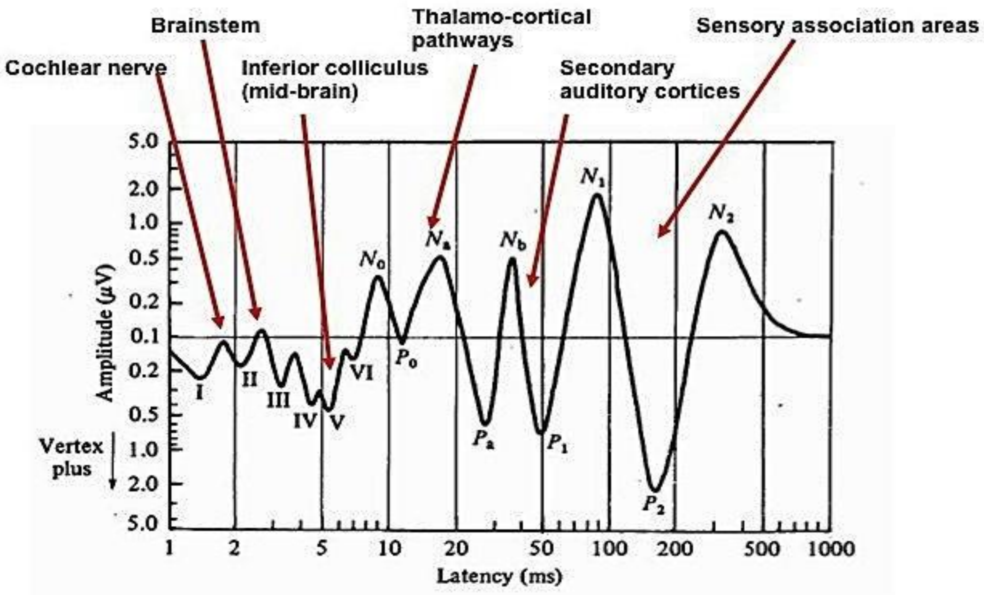
EVOKED POTENTIAL

- An **evoked potential** or **evoked response** is an electrical potential in a specific pattern recorded from a specific part of the nervous system, especially the brain, of a human or other animals following presentation of a stimulus such as a light flash or a pure tone.
- Different types of potentials result from stimuli of different modalities and types.
- EP is distinct from spontaneous potentials as detected by electroencephalography (EEG), electromyography (EMG), or other electrophysiologic recording method.
- Such potentials are useful for electrodiagnosis and monitoring that include detections of disease and drug-related sensory dysfunction and intraoperative monitoring of sensory pathway integrity.
- Evoked potential amplitudes tend to be low, ranging from less than a microvolt to several microvolts, compared to tens of microvolts for EEG, millivolts for EMG, and often close to 20 millivolts for ECG.
- To resolve these low-amplitude potentials against the background of ongoing EEG, ECG, EMG, and other biological signals and ambient noise, signal averaging is usually required.
- The signal is time-locked to the stimulus and most of the noise occurs randomly, allowing the noise to be averaged out with averaging of repeated responses.
- Signals can be recorded from cerebral cortex, brain stem, spinal cord, peripheral nerves and muscles. Usually the term "evoked potential" is reserved for responses involving either recording from, or stimulation of, central nervous system structures.
- Thus evoked compound motor action potentials (CMAP) or sensory nerve action potentials (SNAP) as used in nerve conduction studies (NCS) are generally not thought of as evoked potentials, though they do meet the above definition.
- Evoked potential is different from event-related potential (ERP), although the terms are sometimes used synonymously, because ERP has higher latency, and is associated with higher cognitive processing.

- Evoked potentials are mainly classified by the type of stimulus: somatosensory, auditory, visual. But they could be also classified according to stimulus frequency, wave latencies, potential origin, location, and derivation.

Auditory evoked potential

- Auditory evoked potentials (AEP) can be used to trace the signal generated by a sound through the ascending auditory pathway.
- The evoked potential is generated in the cochlea, goes through the cochlear nerve, through the cochlear nucleus, superior olivary complex, lateral lemniscus, to the inferior colliculus in the midbrain, on to the medial geniculate body, and finally to the cortex.
- Auditory evoked potentials (AEPs) are a subclass of event-related potentials (ERPs). ERPs are brain responses that are time-locked to some "event", such as a sensory stimulus, a mental event (such as recognition of a target stimulus), or the omission of a stimulus.
- For AEPs, the "event" is a sound. AEPs (and ERPs) are very small electrical voltage potentials originating from the brain recorded from the scalp in response to an auditory stimulus, such as different tones, speech sounds, etc.
- Brainstem auditory evoked potentials are small AEPs that are recorded in response to an auditory stimulus from electrodes placed on the scalp.
- AEPs serve for assessment of the functioning of the auditory system and neuroplasticity. They can be used to diagnose learning disabilities in children, aiding in the development of tailored educational programs for those with hearing and or cognition problems.



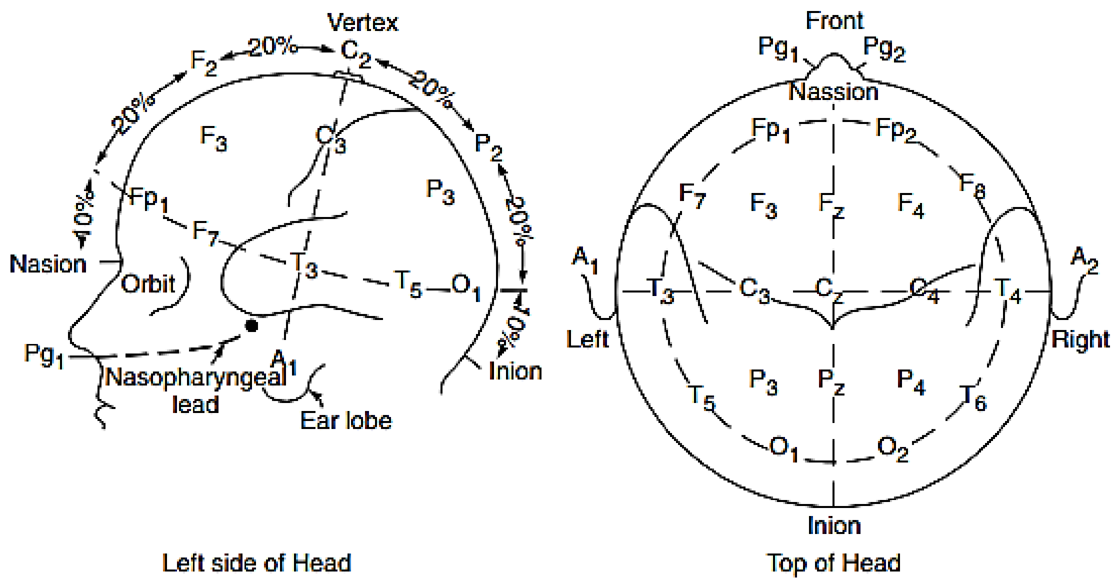
Auditory Evoked Potential

6. Explain montage system in detail (Nov 2016)

[Refer Q: 3 for continuation]

Montages

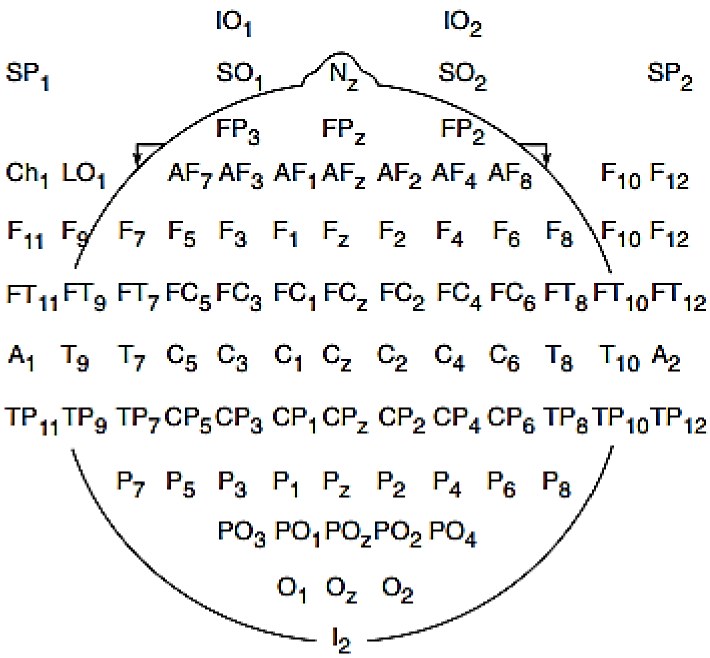
- A pattern of electrodes on the head and the channels they are connected to is called a montage.
- Montages are always symmetrical. The reference electrode is generally placed on a nonactive site such as the forehead or earlobe.
- EEG electrodes are arranged on the scalp according to a standard known as the 10/20 system, adopted by the American EEG Society (Barlow et al, 1974).
- Traditionally, there are 21 electrode locations in the 10/20 system. This system involves placement of electrodes at distances of 10% and 20% of measured coronal, sagittal and circumferential arcs between landmarks on the cranium.
- Electrodes are identified according to their position on the head: Fpfor frontal-polar, F for frontal, C for central, P for parietal, T for temporal and O for occipital. Odd numbers refer to electrodes on the left side of the head and even numbers represent those on the right while Z denotes midline electrodes.
- One electrode is labelled isoground and placed at a relatively neutral site on the head, usually the midline forehead. A new montage convention has recently been introduced in which electrodes are spaced at 5% distances along the cranium.
- These electrodes are called closely spaced electrodes and have their own naming convention.



10-20 system of placement of electrodes

Electrode Montage Selector

- EEG signals are transmitted from the electrodes to the head box, which is labelled according to the 10–20 system, and then to the montage selector.
- The montage selector on analog EEG machine is a large panel containing switches that allow the user to select which electrode pair will have signals subtracted from each other to create an array of channels of output called a montage.
- Each channel is created in the form of the input from one electrode minus the input from a second electrode.
- Montages are either bipolar (made by the subtraction of signals from adjacent electrode pairs) or referential (made by subtracting the potential of a common reference electrode from each electrode on the head).
- In order to minimize noise, a separate reference is often chosen for each side of the head e.g. the ipsilateral ear.
- Bipolar and referential montages contain the same basic information that is transformable into either format by simple substration as long as all the electrodes, including reference, are included in both montages and linked to one common reference.
- Many modern digital EEG machines record information referentially, allowing easy conversion to several different bipolar montages.
- The advantage of recording EEG in several montages is that each montage displays different spatial characteristics of the same data.



Pictorial representation of closely spaced electrodes

7. Discuss the origin of brain waves (Nov 2016)

ANATOMY OF BRAIN

- The brain is an amazing three-pound organ that controls all functions of the body, interprets information from the outside world, and embodies the essence of the mind and soul.
- Intelligence, creativity, emotion, and memory are a few of the many things governed by the brain. Protected within the skull, the brain is composed of the cerebrum, cerebellum, and brainstem.
- The brain receives information through our five senses: sight, smell, touch, taste, and hearing - often many at one time.
- It assembles the messages in a way that has meaning for us, and can store that information in our memory.
- The brain controls our thoughts, memory and speech, movement of the arms and legs, and the function of many organs within our body.
- The central nervous system (CNS) is composed of the brain and spinal cord. The peripheral nervous system (PNS) is composed of spinal nerves that branch from the spinal cord and cranial nerves that branch from the brain.

BRAIN

- The brain is composed of the cerebrum, cerebellum, and brainstem

Cerebrum

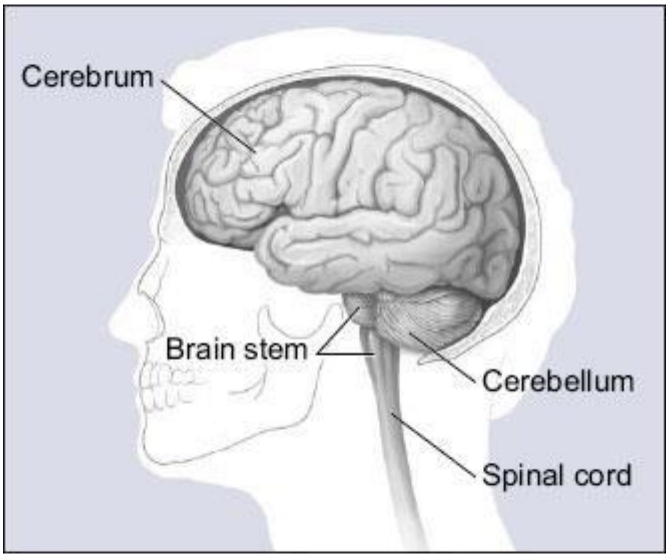
- It is the largest part of the brain and is composed of right and left hemispheres.
- It performs higher functions like interpreting touch, vision and hearing, as well as speech, reasoning, emotions, learning, and fine control of movement.

Cerebellum

- It is located under the cerebrum.
- Its function is to coordinate muscle movements, maintain posture, and balance.

Brainstem

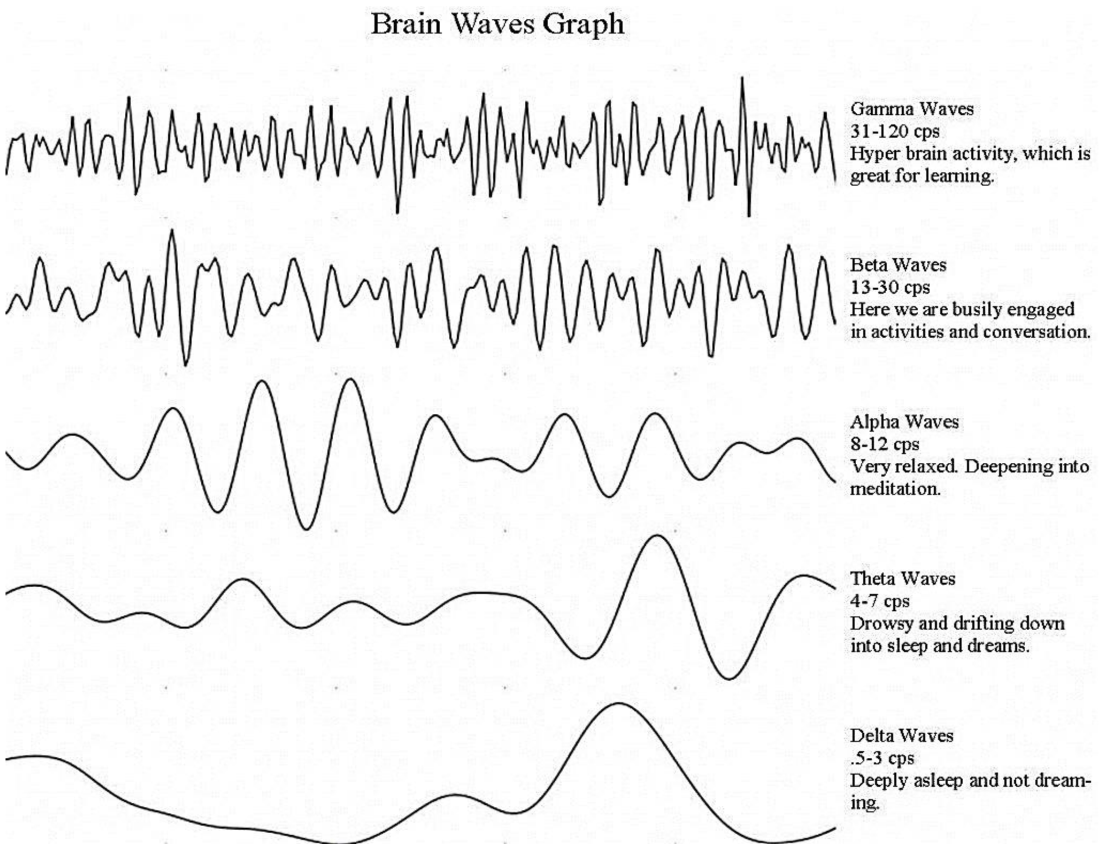
- It acts as a relay center connecting the cerebrum and cerebellum to the spinal cord.
- It performs many automatic functions such as breathing, heart rate, body temperature, wake and sleep cycles, digestion, sneezing, coughing, vomiting, and swallowing.



Electroencephalography (EEG)

- EEG is the measurement of differences in electrical potential (voltage) between points on the scalp.
- These voltages differences are the result of ionic current flow within neurons, and glial cells, in the brain.

- The measured scalp voltages are primarily in the 200nV-200uV amplitude range, 0.01 Hz – 100 Hz frequency range, and are typically simultaneously recorded at multiple sites on the scalp.
- The EEG is usually collected using the 10-20 electrode montage. This arrangement of electrodes typically references left or right hemisphere electrodes to the left or right earlobe (or mastoid), respectively.
- However, a wide range of signal referencing methods are used depending on the situational requirements.
- An EEG recording can be short or long-term. Shorter-term, signal-averaged, EEG measurements are typically used to evaluate precognitive and cognitive processes with respect to specific stimuli.
- These EEG signals have relatively low amplitude levels, typically 200nV – 2uV, so signal averaging methods are required to discern these signals from background concurrent EEG sources.
- Longer-term, non-signal-averaged, EEG measurements are used to discern the subject's, real-time, conscious state.
- Different and observable wave rhythms are evident during such recordings.
- Commonly observed rhythms include
    - Delta
    - Theta
    - Alpha
    - Beta and
    - Gamma waves.
- These waves can be continuously recorded and are in the range of 2uV – 200uV.



Delta waves (0.5-4 Hz)

- They are considered slow rhythms and tend to be the highest in amplitude. Delta waves are normally the dominant rhythm in infants.
- Delta waves are found in sleeping adults and consistent Delta is considered abnormal in conscious adults.
- Delta waves are low-frequency EEG patterns that increase during sleep in the normal adult. Although Delta waves are generally prominent during sleep, there are cases when Delta rhythms are recorded from awake individuals.
- Delta waves may increase during difficult mental activities requiring concentration and other continuous-attention tasks.
- Delta rhythms depend on activity of motivational systems, in the brain, and participate in the identification of prominent phenomena.
- The presence and amplitude of Delta rhythms are highly variable within and between individuals.

Theta waves (4-8 Hz)

- They are considered slow rhythms. Theta waves are normal in children up to 13 years old. Theta waves are found in sleeping adults and consistent Theta is considered abnormal in conscious adults.
- Theta rhythms are low-frequency EEG patterns that increase during sleep in the normal adult. Although Theta rhythms are generally prominent during sleep, there are cases when theta rhythms are recorded from awake individuals.
- Theta rhythms are involved in memory and emotional regulation. Theta waves will spike during emotional responses to frustrating events or situations.
- Theta waves are associated with the inhibition of elicited responses, in that Theta activity has been found to temporarily increase when a person is actively trying to repress a behavioral response.
- The presence and amplitude of theta rhythms are highly variable within and between individuals.

Alpha waves (8-13 Hz)

- They are considered moderate rhythms and usually seen in the occipital regions of the head and are higher in amplitude on the dominant side.
- Alpha waves appear when relaxing and closing the eyes. Alpha waves are suppressed when opening the eyes or coming to an alert state.
- Alpha waves are the primary rhythm observed in relaxed adults and are present during most of life after 13 years old.
- Each region of the brain has a characteristic Alpha rhythm amplitude and the largest Alpha waves are from the occipital and parietal regions of the cerebral cortex.
- Alpha rhythms correlate with inhibitory processes in the brain. Reduced Alpha wave occurrence and amplitude, in relation to Delta-Theta activity, is associated with reduced inhibitory control over behavior.

Beta waves (13-30 Hz)

- They are considered fast rhythms. Beta waves are typically observed on both sides of the head and are most evident frontally (executive function).

- Beta waves may be substantially reduced in areas of cortical damage. Beta waves are considered normal and are the dominant rhythm in patients whose eyes are open or are otherwise attentive to external stimuli or exerting specific mental effort.
- Beta rhythms also occur during rapid eye movement (REM) sleep. In this situation, the typical Alpha rhythm is suppressed and supplanted by Beta waves.
- This replacement of Alpha rhythm is called desynchronization, or “Alpha block”, because it represents a change in the synchronized activity of neural systems in the brain.
- It is thought that Beta waves represents arousal of the cortex to a higher state of alertness and may also be associated with memory retrieval.

Gamma waves (30-100 Hz)

- They are considered fast rhythms. Gamma waves are present during mixed sensory processing, such as perceptual tasks that combine hearing and seeing.

- Gamma waves are also evident during short-term memory matching of recognized sights, sounds or sensations.

- A reduction in Gamma wave activity might be associated with cognitive decline, especially when compared to Theta wave activity levels.

Long-term EEG signal characteristics

- Long-term EEG signal characteristics are related to consciousness. As conscious activity increases, the dominant EEG rhythms shift to higher frequencies.

- When asleep, with the exception of REM, the dominant EEG rhythms move to lower frequencies. In deep sleep, the EEG is characterized by low frequency Delta waves.

Short-term EEG measurements

- Short-term EEG measurements are typically focused on the nature of cognition. These types of recordings are typically performed in synchrony with well-controlled, environmental, stimuli. Signal-averaging measurements, of this type, are known as Event Related Potentials (ERPs).

- There are a range of ERP signals, stretching between 50ms to many seconds, with respect to the occurrence of the event.

- ERPs require signal averaging methods, to be observed, because their amplitude levels (0.2-2uV) are usually lower than the ambient EEG signal level.

EEG can be useful to

- Determine coma and brain death
- Evaluate inhibitory control over behavior
- Establish brain / computer interfaces
- Monitor sleep physiology
- Test afferent pathways via evoked potentials
- Establish biofeedback situations
- Evaluate anaesthesia depth
- Locate seizure origin
- Test drug effects for convulsion and seizure
- Assist in cortical excision (surgery) of epileptic locus
- Monitor human and animal brain development

BM T61 – DIAGNOSTIC AND THERAPEUTIC EQUIPMENTS

UNIT-3

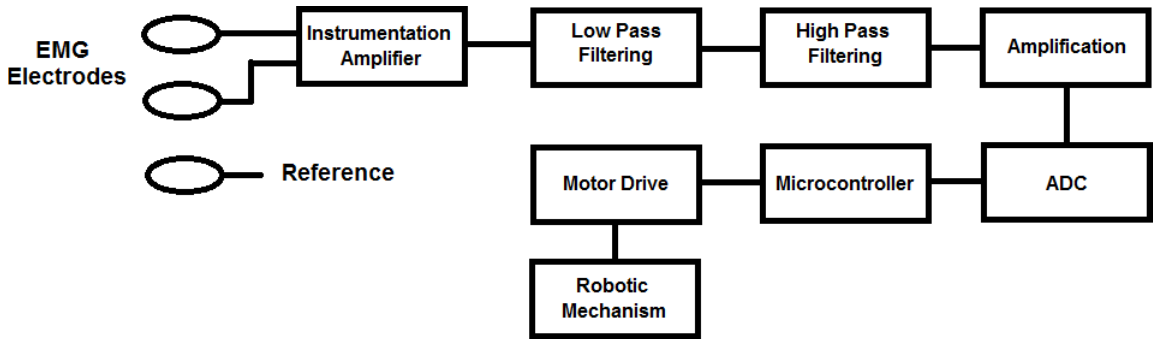
2 MARKS:

1. Write down the characteristics muscle fatigue.(April/May2018)

Muscle fatigue can present as a:

- Loss of force or power output
- Slowing of relaxation
- Changes in contractile characteristics and
- Alterations in electrical properties.

2. Draw the block diagram for EMG signal acquisition.(April/May2018)



3. Differentiate the A mode and M-mode display of ultrasound.(April/May2018)

A-MODE	M-MODE
• One dimensional ultrasound image	• Both one and two dimensional.(two dimensional is an advancement)
• Amplitude modulation	• Time Motion mode or TM mode
• It is the display of amplitude spikes of different height	• It is the display of an image that is used for analysing moving body parts
• Not applicable to a regional anaesthesia	• Use in regional anaesthesia is negligible

4. Write the principle of dialysis.(April/May2018)

Dialysis works on the principles of the diffusion of solutes and ultrafiltration of fluid across a semi-permeable membrane. Diffusion is a property of substances in water; substances in water tend to move from an area of high concentration to an area of low concentration.

5. Define latency.(May2017)

Latency is the delay between a user's action and a web application's response to that action, often referred to in networking terms as the total round trip time it takes for a data packet to travel.

While according to science, The time between onset of a stimulus and peak of the ensuing action potential.

6. What is nerve stimulators used for?(May2017)

It is a battery-operated device that some people **use** to treat pain.

- Endometriosis.
- Arthritis.
- Sports injuries.
- Multiple sclerosis.
- Fibromyalgia.
- Painful diabetic neuropathy.
- Spinal cord injury.

7. What is fatigue?(April/May2016)

Fatigue is a term used to describe an overall feeling of tiredness or lack of energy. It isn't the same as simply feeling drowsy or sleepy. When you're **fatigued**, you have no motivation and no energy. Being sleepy may be a symptom of **fatigue**, but it's not the same thing.

8. Write a short note on muscle stimulators.(April/May2016)

Muscle stimulators employ the sinusoidal output. The sensory nerves are stimulated in a fashion that disrupts pain perception through gate control or opiate system mechanisms. The **stimulation** of the motor nerves elicits **muscular** contractions.

9. a) Enlist the type of electrodes used for electro diagnostic application.(November 2016)

b) Mention the types of electrodes used for EMG.(September 2020)

There are two main **types** of **EMG electrodes**: surface (or skin **electrodes**) and inserted **electrodes**. Inserted **electrodes** have further two **types**: needle and fine wire **electrodes**. The three **electrodes** (needle, fine wire and surface)

10. Write a note on nerve stimulators.(November 2016)

A **nerve stimulator works** by masking pain signals before they reach the brain. A **stimulator** device delivers electric pulses to electrodes placed over the spinal cord. Modified by the pulses, the pain signals are either not perceived or are replaced by a tingling feeling.

11. a)What is muscle fatigue?(May 2019)

b) What is meant by muscle fatigue? List the causes for fatigue. (November/December2018)

Muscle fatigue is the decline in ability of **muscles** to generate force. It can be a result of vigorous exercise but abnormal **fatigue** may be caused by barriers to or interference with the different stages of **muscle** contraction.

Fatigue can result from:

- Physical exertion.
- Lack of physical activity.
- Lack of sleep.
- Being overweight or obese.
- Periods of emotional stress.
- Boredom.
- Grief.
- Taking certain medications, such as antidepressants or sedatives.

12. Define nerve conduction velocity and also mention the value for normal person. (May2019)

A **nerve conduction velocity** (NCV) test — also called a **nerve conduction** study (NCS) — measures how fast an electrical impulse moves through your **nerve**. NCV can identify **nerve** damage. During the test, your **nerve** is stimulated, usually with electrode patches attached to your skin. **Normal** impulses in peripheral **nerves** of the legs travel at 40–45 m/s, and 50–65 m/s in peripheral **nerves** of the arms. Largely generalized, **normal conduction velocities** for any given **nerve** will be in the **range of** 50–60 m/s.

- **Median Sensory:** 45–70 m/s
- **Ulnar Sensory:** 48–74 m/s
- **Sural Sensory:** 46–64 m/s
- **Ulnar Motor:** 49+ m/s

13. What is muscle twitching?(November/December2018)

Muscle twitches can happen for lots of reasons, like stress, too much caffeine, a poor diet, exercise, or as a side effect of some medicines. Lots of people get **twitches** in the eyelid, thumb, or calf **muscles**. These types of **twitches** usually go away after a few days. They're often related to stress or anxiety.

14. What is nerve conduction velocity? (November/December2017)

A **nerve conduction velocity** (NCV) test — also called a **nerve conduction** study (NCS) — measures how fast an electrical impulse moves through your **nerve**. NCV can identify **nerve** damage. During the test, your **nerve** is stimulated, usually with electrode patches attached to your skin.

15. Differentiate muscular stimulator & nerve stimulator(November/December2017)

TENS	EMS
Uses steady current to stimulate nerves	Uses a cycle of impulses to cause muscle contractions
Primary use is to relieve pain	Primary use is for physical therapy of muscle tissue
Blocks pain signals from reaching the brain	Prevents wastage or damaging of muscles due to injuries
Temporary pain reduction	Reduces muscle atrophy
Low penetration value and temporary benefits	Deep penetration value and permanent results
Helps body produce more natural pain-relieving substances	Helps increase blood flow, range of motion, and increases muscle
Relieves both chronic and acute pain	Relieves muscle pain from spastic muscles, tight or sore muscles
Used for: • Arthritis • Back pain • Carpal tunnel syndrome • Foot pain • Labor pain • Multiple sclerosis • Sciatica	Used for: • Muscle strengthening • Rehabilitation purposes • Prevent disuse muscle atrophy • Increase blood circulation • Relaxation of muscles • Cosmetic muscle toning

16. Write down the principle used for the measurement of nerve conduction velocity and define latency.(September 2020)

The **nerve conduction velocity** (**speed**) is then calculated by **measuring** the distance between electrodes and the time it takes for electrical impulses to travel between electrodes. A related procedure that may be performed is electromyography (EMG).

Latency is the delay between a user's action and a web application's response to that action, often referred to in networking terms as the total round trip time it takes for a data packet to travel.While according to science, The time between onset of a stimulus and peak of the ensuing action potential.

11 MARKS:

1. Draw the EMG waveform and differentiate between muscle stimulator and nerve stimulation.(April/May2018)

TENS	EMS
• TENS stimulates the nerves – the logic is that these stimulatory actions prevents pain signals from	• EMS accelerates contraction of muscles – by mimicking the action potential that comes from the

reaching the brain.	central nervous system
• TENS devices offer a wider range of signals with respect to frequency, pulses and intensities.	• EMS devices offer limited signals and thus narrower functions in this regard
• TENS therapy, offers short-term pain relief. TENS is not painful and is an efficient and effective therapy to mask pain like diabetic neuropathy. TENS therapy also encourages the production of endorphins, which act as body's natural painkillers.Electrical stimulation from TENS also improves circulation locally. It can also either minimize or completely put an end to muscle spasms.	• In medicine, Electrical muscle stimulation is used for rehabilitation purposes. It should never be utilized as a replacement for training.
It is also used for; • Arthritis relief • Relieves acute, chronic, and psychogenic pain • Bursitis • Tendonitis • Osteoarthritis • Nerve pain • Shoulder pain • Migraines and Headaches • Sciatic pain relief •	Some of the uses of EMS are: • It aids in muscle strengthening when in pain or injured • Electrical muscle stimulation can help activate fatigued muscles, with no risk to the athlete. • Electrical muscle stimulation is an extremely useful tool to assist a healthy or injured athlete, in conjunction with tactical and proven concords. • EMS also offers the added benefit of pain reduction for patients who are not willing or are not able to

	take oral pain reduction medications or any anti-inflammatory tablets or liquid drugs. • EMS benefits also include Muscle Atrophy, Osteoarthritis, Pressure Sore Prevention, muscle re-education, massaging of sore muscles.
• TENS generates stimulatory actions in nerves to block pain and relax muscles consequence. TENS provides immediate painrelief.	• EMS stimulates muscles cells. An EMS unit is usually appropriate before and after physical exercise or any workout sessions or can also be used on the advice of a physiotherapist in case you are rebuilding your muscles that have suffered atrophy. EMS offers long range treatment for muscle development.
• Low penetration value and temporary benefits	• Deep penetration value and permanent results

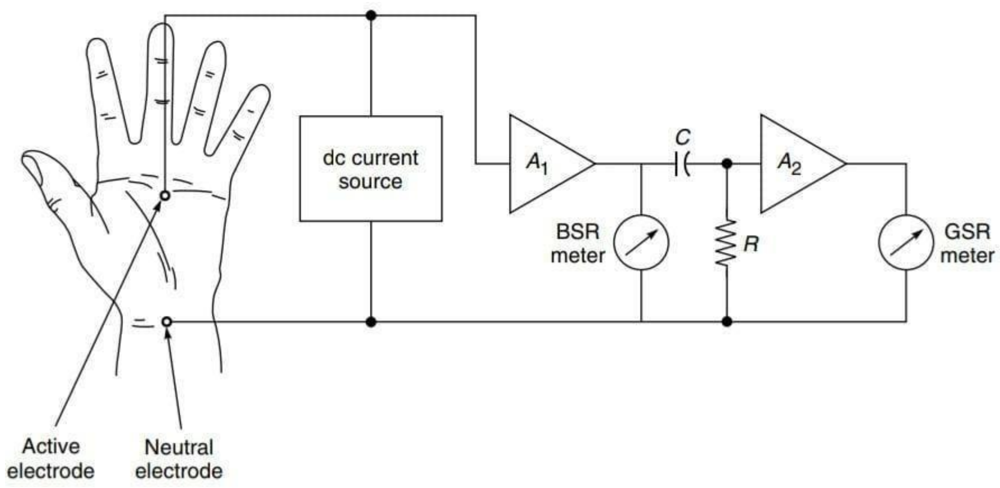
2. a) Explain in detail about EMG bio feedback instrumentation.(April/May2018)

b) List out the function of muscle stimulator and explain the EMG biofeedback system(May 2019)

- Feedback is a common engineering term and refers to its function to control a process. When this concept is applied to biological processes within the body, it is known as biofeedback.
- Here again, biofeedback is a means for gaining control of the body processes to create a specially required psychological state so as to increase relaxation, relieve pain and develop healthier and more comfortable life patterns.

- The technique involves the measurement of a variable produced by the body process and compares it with a reference value.
- Based on the difference between the measured and reference value, action is taken to bring the variable to the reference value.
- Many different physiological processes have been evaluated for possible control by biofeedback methods. However, the following four neural functions are commonly employed:
  - Emotions or Electrodermal Activity (Galvanic skin response measurements)
  - Muscle tension or EMG (Electromyograph measurements)
  - Temperature/sympathetic pattern (Thermistor readings)
  - Pulse (Heart rate monitoring)

Electrodermal activity is measured in two ways: BSR (basal skin response) and GSR (galvanic skin response) is a measure of the average activity of the sweat glands and is a measure of the phasic activity (the high and low points) of these glands. BSR gives the baseline value of the skin resistance where as GSR is due to the activity of the sweat glands.



3. Describe in detail about the echoencephalogram with a neat diagram.(April/May2018)

- Electroencephalograph is an instrument for recording the electrical activity of the brain, by suitably placing surface electrodes on the scalp.
- EEG, describing the general function of the brain activity, is the superimposed wave of neuron potentials operating in a non-synchronized manner in the physical sense.

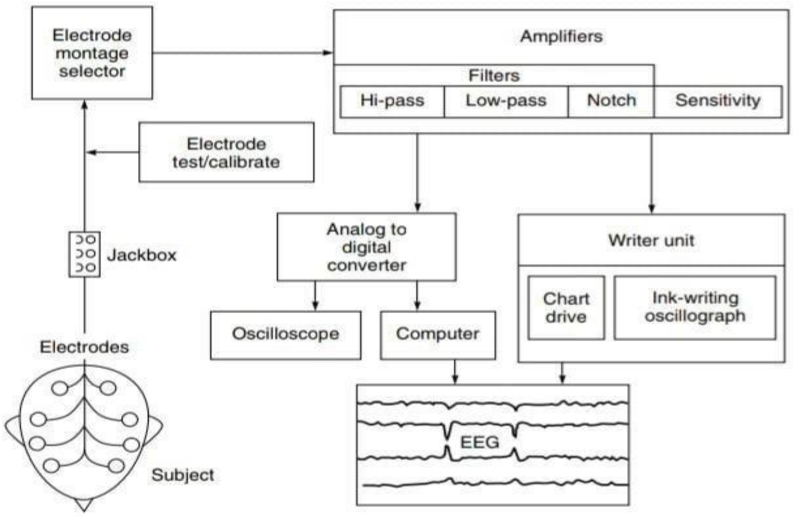
Its stochastic nature originates just from this, and the prominent signal groups can be empirically connected to diagnostic conclusions.

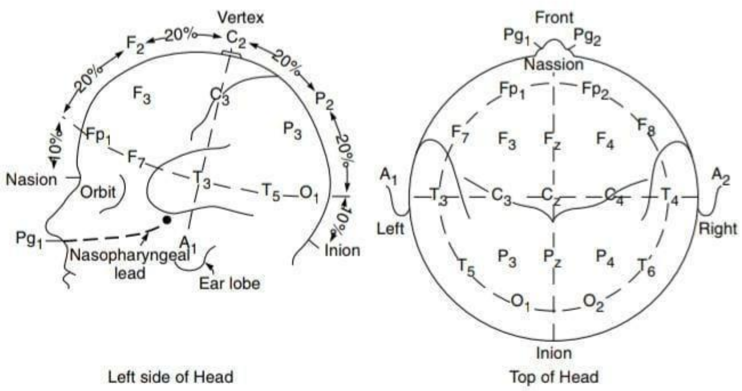
- Monitoring the electroencephalogram has proven to be an effective method of diagnosing many neurological illnesses and diseases, such as epilepsy, tumour, cerebrovascular lesions, ischemia and problems associated with trauma.
- It is also effectively used in the operating room to facilitate anaesthetics and to establish the integrity of the anaesthetized patient's nervous system.
- This has become possible with the advent of small, computer-based EEG analyzers. Consequently, routine EEG monitoring in the operating room and intensive care units is becoming popular.
- Several types of electrodes may be used to record EEG. These include: Peel and Stick electrodes, Silver plated cup electrodes and Needle electrodes.
- EEG signals picked up by the surface electrodes are usually small as compared with the ECG signals. They may be several hundred microvolts, but 50 microvolts peak-to-peak is the most typical.
- The brain waves, unlike the electrical activity of the heart, do not represent the same pattern over and over again. Therefore, brain recordings are made over a much longer interval of time in order to be able to detect any kind of abnormalities.
- Several types of electrodes may be used to record EEG. These include: Peel and Stick electrodes, Silver plated cup electrodes and Needle electrodes.
- EEG electrodes are smaller in size than ECG electrodes. They may be applied separately to the scalp or may be mounted in special bands, which can be placed on the patient's head. In either case, electrode jelly or paste is used to improve the electrical contact.
- If the electrodes are intended to be used under the skin of the scalp, needle electrodes are used. They offer the advantage of reducing movement artefacts. EEG electrodes give high skin contact impedance as compared to ECG electrodes.
- Good electrode impedance should be generally below 5 kilohms. Impedance between a pair of electrodes must also be balanced or the difference between them should be less than 2 kilohms. EEG preamplifiers are generally designed to have a very high value of input impedance to take care of high electrode impedance.

- EEG may be recorded by picking up the voltage difference between an active electrode on the scalp with respect to a reference electrode on the ear lobe or any other part of the body. This type of recording is called ‘monopolar’ recording.
- However, ‘bipolar’ recording is more popular wherein the voltage difference between two scalp electrodes is recorded. Such recordings are done with multi-channel electroencephalographs.

BLOCK DIAGRAM:

- Montages: A pattern of electrodes on the head and the channels they are connected to is called a montage. Montages are always symmetrical. The reference electrode is generally placed on a non- active site such as the forehead or earlobe. EEG electrodes are arranged on the scalp according to a standard known as the 10/20 system.





: *10-20 system of placement of electrodes*

- Electrode Montage Selector: EEG signals are transmitted from the electrodes to the head box, which is labelled according to the 10–20 system, and then to the montage selector.
- Preamplifier: Every channel has an individual, multistage, ac coupled, very sensitive amplifier with differential input and adjustable gain in a wide range. Its frequency response can be selected by single-stage passive filters.
- Sensitivity Control: The overall sensitivity of an EEG machine is the gain of the amplifier multiplied by the sensitivity of the writer.
- Filters: Just like in an ECG when recorded by surface electrodes, an EEG may also contain muscle artefacts due to contraction of the scalp and neck muscles, which overlie the brain and skull. The artefacts are large and sharp, in contrast to the ECG, causing great difficulty in both clinical and automated EEG interpretation.
- Noise: EEG amplifiers are selected for minimum noise level, which is expressed in terms of an equivalent input voltage. Two microvolts is often stated as the acceptable figure for EEG recording.
- Writing Part: The writing part of an EEG machine is usually of the ink type direct writing recorder.
- Paper Drive: This is provided by a synchronous motor. An accurate and stable paper drive mechanism is necessary and it is normal practice to have several paper speeds available for selection.
- Channels:An electroencephalogram is recorded simultaneously from an array of many electrodes. The record can be made from bipolar or monopolar leads.

4. Discuss in detail about the application of ultrasound in obsterics and gynecology.(April/May2018)

- The introduction of ultrasound to obstetrics and gynecology has made tremendous impact to patient care as it allowed imaging of the fetus and placenta in obstetrics and maternal internal organs in gynecology with such clarity to allow advanced diagnosis and also to guide various life saving interventions.
- Understanding the physical principles of ultrasound is essential for a basic knowledge of instrument control and also for understanding safety and bioeffects of this technology. In this chapter, we present the basic concepts of the physical

principles of ultrasound, define important terminology, review the safety and bioeffects and report on ultrasound statements of national and international organizations.

- Sound is a mechanical wave that travels in a medium in a longitudinal and straight-line fashion. When a sound travels through a medium, the molecules of that medium are alternately compressed (squeezed) and rarefied (stretched).
- Sound cannot travel in a vacuum; it requires a medium for transmission, as the sound wave is a mechanical energy that is transmitted from one molecule to another. It is important to note that the molecules do not move as the sound wave passes through them, they oscillate back and forth, forming zones of compression and rarefaction in the medium. Seven acoustic parameters describe the characteristics of a sound wave.
- Ultrasound waves are generated from tiny piezoelectric crystals packed within the ultrasound transducers. When an alternate current is applied to these crystals, they contract and expand at the same frequency at which the current changes polarity and generate an ultrasound beam.
- The ultrasound beam traverses into the body at the same frequency generated. Conversely, when the ultrasound beam returns to the transducer, these crystals change in shape and this minor change in shape generate a tiny electric current that is amplified by the ultrasound machine to generate an ultrasound image on the monitor.
- The piezoelectric crystals within the transducer therefore transform electric energy into mechanical energy (ultrasound) and vice-versa. One crystal is not sufficient to produce an ultrasound beam for clinical imaging and modern transducers have large number of crystals arranged into parallel rows .
- Each crystal can nevertheless be stimulated individually. The crystals are protected by a rubber covering that helps decrease the resistance to sound transmission (impedance) from the crystals to the body.
- The high frequency sound generated by a transducer do not travel well through air, so in order to facilitate their transfer from the transducer to the skin of the patient, a watery gel is applied that couples the transducer to the skin and permits the sound to go back and forth.
- Ultrasound is therefore generated inside transducers by tiny crystals that convert electric current to ultrasound and convert returning ultrasound beams from the body

into electric currents. Modern transducers have crystals made of synthetic plumbium zirconium titanate (PZT).

5. a) What is EMG?Briefly explain about the recording set up of the same.(May2017)

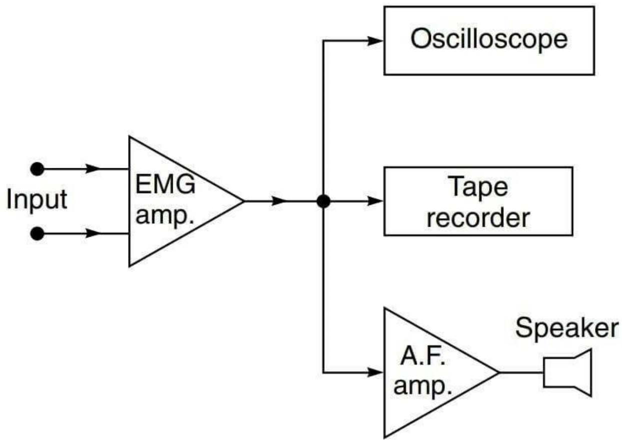
b) Discuss EMG recording system in detail.(November 2016)

c)Analyse the EMG waves taken from a normal person and also explain the generation of those waves.(May 2019)

d)Describe the recording set up used in EMG.(November/December2018, November/December2017)

- Electromyograph is an instrument used for recording the electrical activity of the muscles to determine whether the muscle is contracting or not; or for displaying on the CRO and loudspeaker the action potentials spontaneously present in a muscle or those induced by voluntary contrac- tions as a means of detecting the nature and location of motor unit lesions; or for recording the electrical activity evoked in a muscle by the stimulation of its nerve.
- The instrument is useful for making a study of several aspects of neuromuscular function, neuromuscular condition, extent of nerve lesion, reflex responses, etc.
- EMG measurements are also important for the myoelectric control of prosthetic devices (artificial limbs).
- This use involves picking up EMG signals from the muscles at the terminated nerve endings of the remaining limb and using the signals to activate a mechanical arm. This is the most demanding requirement from an EMG since on it depends the working of the prosthetic device.
- EMG is usually recorded by using surface electrodes or more often by using needle electrodes, which are inserted directly into the muscle. The surface electrodes may be disposable, adhesive types or the ones which can be used repeatedly.
- A ground electrode is necessary for providing a common reference for measurement. These electrodes pick up the potentials produced by the contracting muscle fibres. The signal can then be amplified and displayed on the screen of a cathode ray tube.

- It is also applied to an audio- amplifier connected to a loudspeaker. A trained EMG interpreter can diagnose various muscular disorders by listening to the sounds produced when the muscle potentials are fed to the loud- speaker.
- The block diagram shows a typical set-up for EMG recordings. The oscillo- scope displays EMG waveforms. The tape recorder is included in the system to facilitate playback and study of the EMG sound waveforms at a later convenient time. The waveform can also be photographed from the CRT screen by using a synchronized camera.



- The amplitude of the EMG signals depends upon various factors, e.g. the type and placement of electrodes used and the degree of muscular exertions. The needle electrode in contact with a single muscle fibre will pick up spike type voltages whereas a surface electrode picks up many overlapping spikes and therefore produces an average voltage effect.
- A typical EMG signal ranges from 0.1 to 0.5 mV. They may contain frequency components extending up to 10 kHz. Such high frequency signals cannot be recorded on the conventional pen recorders and therefore, they are usually displayed on the CRT screen.

6. With neat diagram, describe the method of measuring the nerve conducting velocity.(May2017)

Also called an **electroneurography**, **EneG**, or **nerve conduction study**, a **nerve conduction velocity (NCV) test** is a measurement of the speed of conduction of an electrical impulse through a nerve. NCV can determine nerve damage and destruction.

A nerve conduction study (NCS) is a test commonly used to evaluate the function, especially the ability of electrical conduction, of the motor and sensory nerves of the human body. Nerve conduction velocity (NCV) is a common measurement made during this test.

During the test, flat electrodes are placed on the skin at intervals over the nerve that is being examined. A low intensity electric current is introduced to stimulate the nerves thus generating nerve impulses.

The Nerve Impulse

The nerve impulse is a wave of cell depolarisation immediately followed by a wave of repolarisation, collectively called an action potential, occurring on the plasma membrane of a

What abnormal results mean is that most often, abnormal results are caused by some sort of neuropathy (nerve damage or destruction) including:

- Demyelination (destruction of the myelin sheath)
- Conduction block (the impulse is blocked somewhere along the nerve pathway)
- Axonopathy (damage to the nerve axon)

Some of the associated diseases or conditions include:

- Alcoholic neuropathy
- Diabetic neuropathy
- Nerve effects of uremia (from kidney failure)
- Traumatic injury to a nerve
- Guillain-Barre syndrome

Some of the common disorders which can be diagnosed by nerve conduction studies include:

- Peripheral neuropathy
- Carpal tunnel syndrome
- Ulnar neuropathy
- Guillain-Barré syndrome etc,…

The nerve conduction study consists of the following components:

- Motor NCS
- Sensory NCS
- F-wave study
- H-reflex study

Patient risk

Nerve conduction studies are very helpful to diagnose certain diseases of the nerves of the body. The test is not invasive, but can be a little painful due to the electrical shocks. However, the shocks are associated with such a low amount of electrical current that they are not dangerous to anyone. Patients with a permanent pacemaker or other such implanted stimulators such as deep brain stimulators or Spinal Cord Stimulators must tell the examiner prior to the study. This does not prevent the study, but special precautions are taken.

7. Explain in detail about the peripheral nerve stimulator and its application in pain relief. (April/May2016)

- Electrical nerve stimulation is a procedure that uses an electrical current to treat chronic pain. Peripheral nerve stimulation (PNS) and spinal cord stimulation (SCS) are two types of electrical nerve stimulation.
- In either, a small pulse generator sends electrical pulses to the nerves (in peripheral nerve stimulation) or to the spinal cord (in spinal cord stimulation). These pulses interfere with the nerve impulses that make you feel pain.

Post treatment care:

You will have a small incision that you should keep clean and dry until it heals.

This treatment may be done for people with severe, chronic pain who have:

- Failed back surgery syndrome.
- Severe nerve-related pain or numbness.
- Chronic pain syndromes, such as complex regional pain syndrome.

Electrical nerve stimulation is typically considered investigational for various other conditions, includingmultiple sclerosis, paraplegia, and intractable angina.

- Nerve stimulation is done in two steps. To see if it will help your pain, your doctor will first insert a temporary electrode through the skin (percutaneously) to give the treatment a trial run. The electrode is connected to a stimulator that the patient can control.
- If the trial is successful, your doctor can implant a permanent stimulator under your skin. This is typically done using a local anesthetic and a sedative.
- The stimulator itself is implanted under the skin and the small coated wires (leads) are inserted under the skin to the point where they are either connected to nerves or inserted into the spinal canal.
- After this outpatient procedure is complete, you and your doctor determine the best pulse strength. You are then told how to use the stimulator at home.
- A typical schedule for spinal cord stimulation is to use it for 1 or 2 hours, 3 or 4 times a day.
- When in use, electrical nerve stimulation creates a tingling feeling.

Working :

- There isn't a lot of evidence to show how well spinal cord stimulation works. It seems to help certain types of chronic pain, such as failed back surgery syndrome and complex regional pain syndrome.
- Spinal cord stimulation may also help chronic low back pain.
- Some researchers have reported that more than half of people receiving spinal cord stimulation for chronic low back and leg pain, ischemic leg pain (for example, from peripheral arterial disease), or complex regional pain syndrome have pain reduction or relief.
- There is some evidence that peripheral nerve stimulation helps certain types of chronic pain, such as peripheral nerve pain and pain after surgery.
- Studies so far have been small.
- Initial pain relief is often followed by a gradual decline in effectiveness. Apparently, this is caused by the body's increasing tolerance to the treatment.

Risks

Possible risks related to electrical nerve stimulation include:

- Scar tissue (fibrosis) developing around the electrode.
- Pain gradually moving beyond the reach of the nerve stimulator.

- Breakage of an electrode or hardware failure.
- Infection.
- Leakage of spinal fluid during spinal cord stimulation.
- Headache from spinal cord stimulation.
- Bladder problems in spinal cord stimulation.
- Getting used to the stimulation, making it less effective.

- Some people who have an implanted stimulator may not be able to have a magnetic resonance imaging (MRI)test. If you have an appointment for an MRI, be sure to take the device card that was given to you when you got your implanted stimulator.
- The imaging staff will know if it is safe for you to have an MRI.
- There is still not strong proof that electrical nerve stimulation works. Better research is needed. Treatment success varies widely and is influenced by the cause of pain.
- Electrical nerve stimulation may be recommended for some people who have certain types of chronic pain.

8. Describe in detail about the various types of aneasthetic machines.(April/May2016)

The types of **Modern Anesthesia Machine** are as follows:

(1) Air anesthesia machine

- The air anesthesia machine is a semi-open anesthesia device. It mainly consists of a liquid medicine tank, an ether regulating switch, folding bellows, and a suction and exhalation one-way valve and a bellows.
- The device is lightly applicable and can directly use air and oxygen as a carrier gas to assist in breathing and control breathing to meet various surgical requirements.
- The working principle is that the patient connects the air anesthesia machine to the closed mask or the tracheal tube after completing the anesthesia induction.
- When inhaling, the anesthetic mixture enters the patient through the open inspiratory flap; when exhaled, the expiratory flap opens, and the inspiratory flap closes, expelling the exhaled gas. Folding bellows can be used when assisting or controlling breathing.

- Press down during inhalation and pull up when exhaling to ensure adequate ventilation. At the same time, according to actual needs, adjust the ether switch to maintain a stable anesthesia level.
- The shortcoming of this device is that the concentration of ether is low, and it can only be used as anesthetic maintenance, and the consumption of ether is large, which is likely to cause environmental pollution.

(2) DC anesthesia machine

- The direct current anesthesia machine consists of high-pressure oxygen, pressure reducer, flow meter, and anesthetic liquid evaporator. The device can only provide oxygen and adjust the concentration of anesthetic gas to be inhaled.
- There must be other devices in series with the output site for anesthesia.The exhaled gas is re-used through the exhalation flap into the CO_2 absorber.

(3) Closed Anesthesia Machine

- The device supplies the patient with a low-flow anesthetic mixture and a one-way activity through the outgassing flap (door).
- The exhaled gas is re-used through the exhalation flap into the CO_2 absorber. Its structure is mainly composed of oxygen supply and nitrous oxide device, gas flow meter, evaporator, CO_2 absorber; one-way valve, breathing tube, outgassing valve, storage airbag and so on.
- Modern anesthesia machines are also equipped with ventilator airway pressure, expiratory flow, end-tidal CO_2 concentration, inhalation anesthetic concentration, oxygen concentration monitor, hypoxic alarm and hypoxic-nitrous oxide automatic protection device.

9.Define latency. How will you measure the conduction velocity in peripheral nerves?(November 2016)

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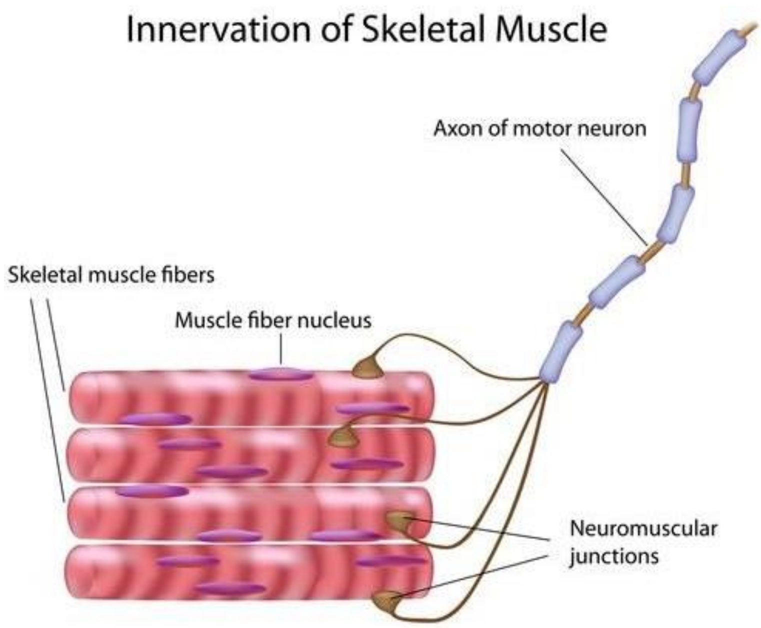
- Breakage of an electrode or hardware failure.
- Infection.
- Leakage of spinal fluid during spinal cord stimulation.
- Headache from spinal cord stimulation.
- Bladder problems in spinal cord stimulation.

- Getting used to the stimulation, making it less effective.

- Some people who have an implanted stimulator may not be able to have a magnetic resonance imaging (MRI)test. If you have an appointment for an MRI, be sure to take the device card that was given to you when you got your implanted stimulator. The imaging staff will know if it is safe for you to have an MRI.
- There is still not strong proof that electrical nerve stimulation works. Better research is needed. Treatment success varies widely and is influenced by the cause of pain.
- Electrical nerve stimulation may be recommended for some people who have certain types of chronic pain.

10. Describe the sliding theory of contraction of skeletal muscle.(November/December2018)

- It starts with a signal from the nervous system. So it starts with a signal from your brain. The signal goes through your nervous system to your muscle. Your muscle contracts, and your bones move. And all this happens incredibly fast.

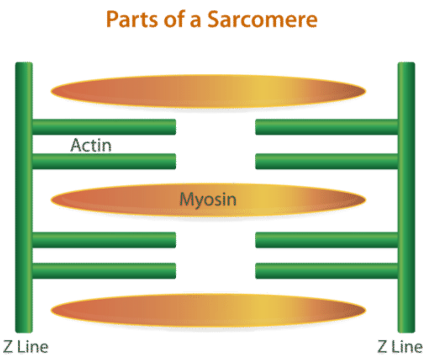


Muscle Contraction

- Muscle contraction occurs when muscle fibers get shorter. Literally, the muscle fibers get smaller in size. To understand how this happens, you need to know more about the structure of muscle fibers.

Structure of Muscle Fibers

- Each muscle fiber contains hundreds of organelles called **myofibrils**. Each myofibril is made up of two types of protein filaments: **actin** filaments, which are thinner, and **myosin** filaments, which are thicker.
- Actin filaments are anchored to structures called **Z lines** (Figure 13.13.2). The region between two Z lines is called a **sarcomere**. Within a sarcomere, myosin filaments overlap the actin filaments. The myosin filaments have tiny structures called **cross bridges** that can attach to actin filaments.



Sliding Filament Theory

- The most widely accepted theory explaining how muscle fibers contract is called the **sliding filament theory**. According to this theory, myosin filaments use energy from ATP to "walk" along the actin filaments with their cross bridges.
- This pulls the actin filaments closer together. The movement of the actin filaments also pulls the Z lines closer together, thus shortening the sarcomere.
- When all of the sarcomeres in a muscle fiber shorten, the fiber contracts. A muscle fiber either contracts fully or it doesn't contract at all. The number of fibers that contract determines the strength of the muscular force. When more fibers contract at the same time, the force is greater.

Muscles and Nerves

- Muscles cannot contract on their own. They need a stimulus from a nerve cell to "tell" them to contract. Let's say you decide to raise your hand in class.
- Your brain sends electrical messages to nerve cells, called **motor neurons**, in your arm and shoulder.
- The motor neurons, in turn, stimulate muscle fibers in your arm and shoulder to contract, causing your arm to rise. Involuntary contractions of cardiac and smooth muscles are also controlled by nerves.

11.Discuss the different types of current waveforms used in muscle stimulator with its clinical application. (November/December2017)

Muscle Stimulator:

- **Electronic muscle stimulation (EMS)** may help you to strengthen weak muscles. There are several theories on how EMS may assist muscle strengthening.
- There are three basic **waveforms used** in commercial therapeutic electrical **stimulation** units: direct **current**, alternating **current**, **and** pulsed **current**.
- One potential reason is that when you maximally contract a muscle, at best, only 30% of all your muscle fibres are in a state of contraction.
- The remaining 70% are dormant and awaiting recruitment when the contracting fibres fatigue. With EMS you can potentially electrically stimulate these resting muscle fibres to improve their strength.
- Clinically, EMS appears to be more effective when the muscles are very weak and you have difficulty performing normal anti-gravity exercises.

Benefits of Electric Muscle Stimulation

Electric muscle stimulation (EMS) can help treat musculoskeletal injuries or ailments.

EMS is a common and effective way to:

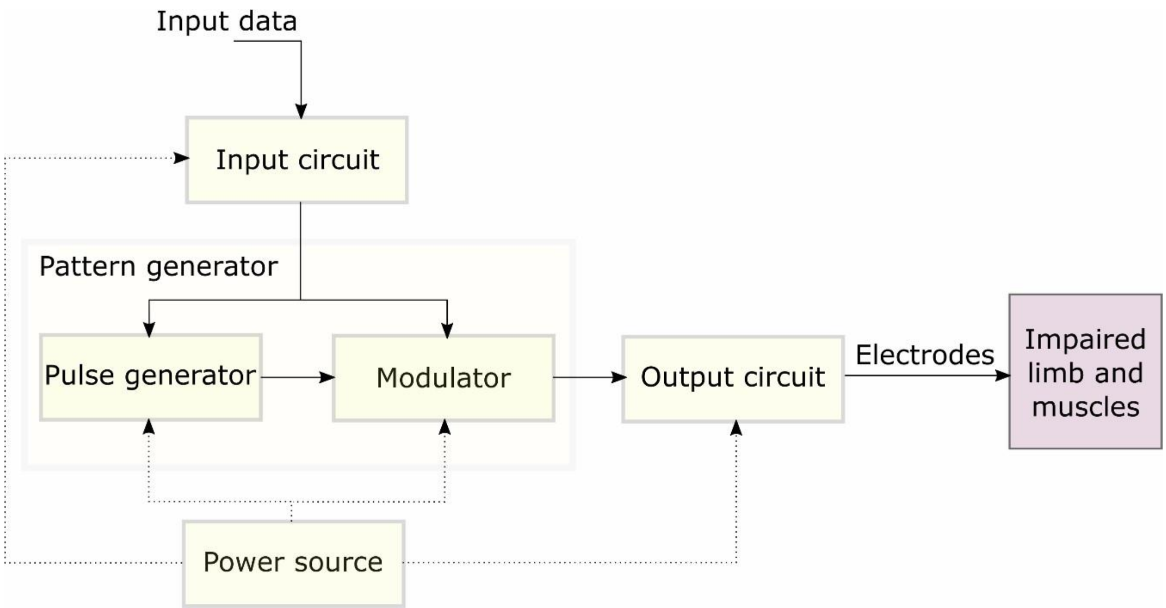
- Relieve discomfort and pain
- Reduce muscle spasms
- Restore muscle tone
- Rehabilitate parts of the body

How Electric Stimulation Works

- Electric stimulation works by attaching stick-on pieces of equipment to the skin and using the control unit to transmit currents to targeted muscle groups. The control unit is where the timer, sensory knobs and other devices are located to produce the electric current.
- Two lead wires and two to four neurostimulation electrodes are the tools that are attached to the skin to transmit the current. The machine may cause a number of unique sensations when turned on and applied to a specific muscle group.

How Electric Stimulation Feels

- Some patients report feeling pins and needles, muscle twitching and/or a dull tingling. These sensations usually only last during the treatment, but there are times patients will feel them up to 30 minutes after the therapy session.



Added Benefits of EMS

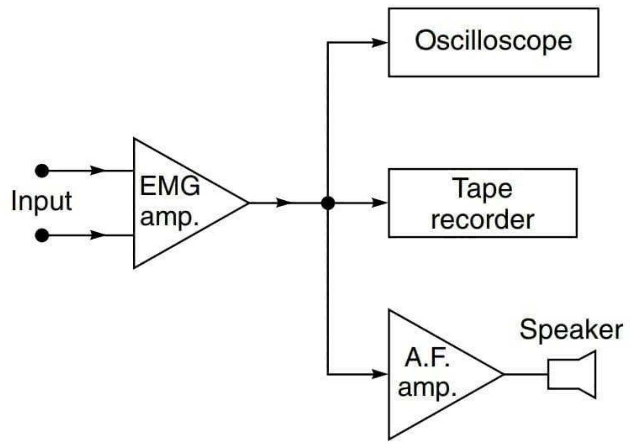
- There are many benefits to this kind of therapy. To start, it can help reduce edema (swelling) and expedite the healing process of injured or damaged tissue. Electric muscle stimulation can also help reduce chronic pain. Other benefits include:
  - May improve joint pain and swelling
  - Prevents and reveres muscle atrophy (loss of muscle mass/tissue)
  - Enhances rehabilitation of muscles
  - Increases range of motion for tense muscles or tendons
  - Reduces stress and discomfort
  - Improves blood flow and circulation

12. Explain the EMG biofeedback instrumentation using measurement and record of basal skin resistance(BSR) and Galvanic skin response(GSR)(September 2020)

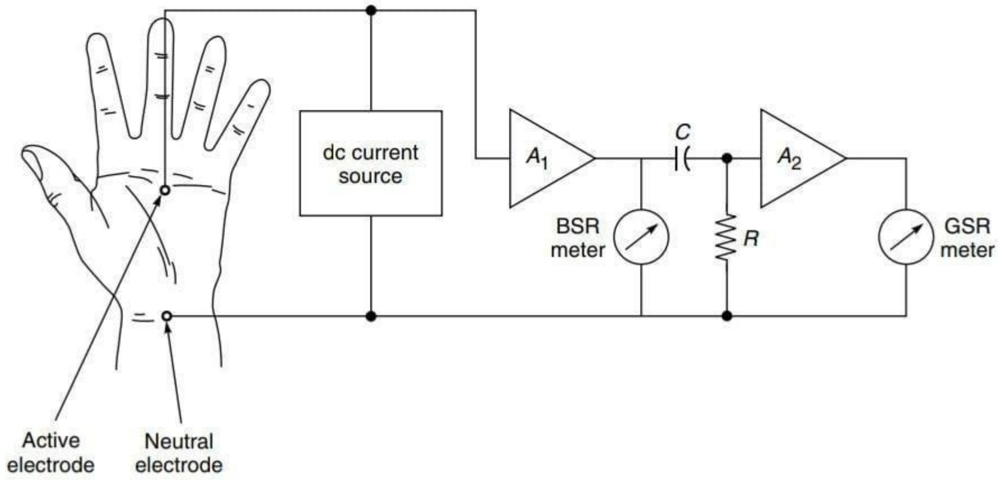
- Electromyograph is an instrument used for recording the electrical activity of the muscles to determine whether the muscle is contracting or not; or for displaying on the CRO and loudspeaker the action potentials spontaneously present in a muscle or those induced by voluntary contrac- tions as a means of detecting the nature and location of motor unit lesions; or for recording the electrical activity evoked in a muscle by the stimulation of its nerve.
- The instrument is useful for making a study of several aspects of neuromuscular function, neuromuscular condition, extent of nerve lesion, reflex responses, etc.
- EMG measurements are also important for the myoelectric control of prosthetic devices (artificial limbs).
- This use involves picking up EMG signals from the muscles at the terminated nerve endings of the remaining limb and using the signals to activate a mechanical arm.
- This is the most demanding requirement from an EMG since on it depends the working of the prosthetic device.
- EMG is usually recorded by using surface electrodes or more often by using needle electrodes, which are inserted directly into the muscle.
- The surface electrodes may be disposable, adhesive types or the ones which can be used repeatedly. A ground electrode is necessary for providing a common reference for measurement. These electrodes pick up the potentials produced by the contracting

muscle fibres. The signal can then be amplified and displayed on the screen of a cathode ray tube. It is also applied to an audio- amplifier connected to a loudspeaker.

- A trained EMG interpreter can diagnose various muscular disorders by listening to the sounds produced when the muscle potentials are fed to the loud- speaker. The block diagram shows a typical set-up for EMG recordings.
- The oscillo- scope displays EMG waveforms. The tape recorder is included in the system to facilitate playback and study of the EMG sound waveforms at a later convenient time. The waveform can also be photographed from the CRT screen by using a synchronized camera.



- Electrodermal activity is measured in two ways: BSR (basal skin response) and GSR (galvanic skin response) is a measure of the average activity of the sweat glands and is a measure of the phasic activity (the high and low points) of these glands.
- BSR gives the baseline value of the skin resistance where as GSR is due to the activity of the sweat glands. The GSR is measured most conveniently at the palms of the hand, where the body has the highest concentration of sweat glands. The measurement is made using a dc current source.
- Silver-silver electrodes are used to measure and record the BSR and GSR. The figure shows the arrangement for measuring these parameters. The BSR output is connected to an RC network with a time constant of 3 to 5 seconds which enables the measurement of GSR as a change of the skin resistance.

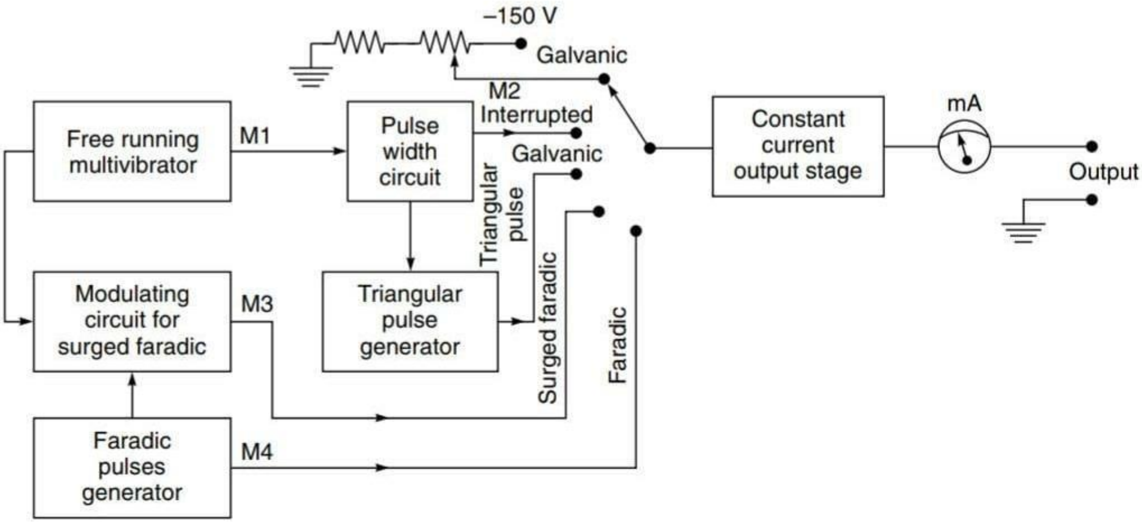


- Biofeedback instrumentation for the measurement of EMG, temperature and pulse/heart rate is not different from other instruments used for the measurement of physiological variables. Transducers and amplifiers are employed to measure the variable that is to be controlled by the feedback process.
- The magnitude of the measured variable or changes in the magnitude are converted into a suitable visual or auditory stimulus that is presented to the subject. Based on the stimulus, the subject learns to control the abnormal conditions.
- Reports have appeared in literature regarding applications of biofeedback to control migraine headaches, to slow down heart rate, etc. Biofeedback techniques have been greatly refined and computerized biofeedback training and psychological computer-assisted guidance programs in the privacy of one's home are now a reality.

13. Draw the functional block diagram of a diagnostic/therapeutic stimulating unit and explain the functioning.(September2020)

- A versatile electro-diagnostic therapeutic stimulator. It makes use of a variable rate multi-vibrator (M1) to set the basic stimulus frequency. The output from the free running multi-vibrator triggers a monostable multi-vibrator (M2) circuit which sets the pulse width.
- The output pulse from the monostable provides an interrupted galvanic output whose rate as well as duration can be independently controlled. Another astable multi-vibrator produces short duration pulses called faradic currents.

- Faradic currents are usually modulated at the frequency set by the multi-vibrator Ml, in a mixer circuit (M4). Since the modulation of Faradic pulses takes place with a slow rate of increase and decrease, the output of M4 is surged Faradic currents. By integrating the output of M2, the interrupted galvanic pulses can be modified to have an exponential rise and fall.
- The shape of these pulses is similar to a triangular waveform. Galvanic current is also made available by suitably tapping the DC supply.
- Finally, any one of the waveforms can be selected through a selector switch and fed either to an emitter-follower stage in order to provide a low output impedance constant voltage output or to a high output impedance constant current stage.
- Usually the output impedance of a constant voltage stimulator is of the order of 100 W and that of a constant current type is greater than 100 kW.



- The two methods have been widely used for providing isolation of the stimulator output, but they have some drawbacks.
- The simple transformer cannot transmit square waves without distorting the waveform and the method of radio-frequency is rather complex.
- Isolation can also be provided through the opto-isolation technique.

BM T61 – DIAGNOSTIC AND THERAPEUTIC EQUIPMENTS

UNIT-1V

2 MARKS

1. What is nebulizer? (May 2017, May 2018)

- Nebulizers are used to supply moisture in the form of droplets. A jet of air or gases may be used to entrain water drawn from a reservoir. Nebulizers based on this principle are also used in some ventilators.
- In ultrasonic nebulizers, water is broken into droplets by continuous bombardment of ultrasound energy which vigorously vibrates the water.

2. What is meant by inhalator? (May 2018)

- An apparatus used to help inhale air, anesthetics, medicinal vapors, etc is called as inhalator.
- An apparatus designed to mix carbon dioxide and oxygen, especially for use in artificial respiration.

3. Define tidal and residual volume. (May 2017)

Tidal Volume (TV): The volume of gas inspired or expired (exchanged with each breath) during normal quiet breathing, is known as tidal volume.

Residual Volume (RV): The volume of gas remaining in the lungs after a forced expiration.

3. Define tidal and inspiratory reserve volume. (Nov 2017)

Tidal Volume (TV): The volume of gas inspired or expired (exchanged with each breath) during normal quiet breathing, is known as tidal volume.

Inspiratory Reserve Volume (IRV): The volume of gas, which can be inspired from a normal end- tidal volume. IRV = VC – (TV + FRC)

4. What is the function of Nebulizers? (Nov 2017)

- Nebulizers are used to supply moisture in the form of droplets.

- A jet of air or gases may be used to entrain water drawn from a reservoir.

5. What is a spirometer? (May 2016)

- The instrument used to measure lung capacity and volume is called a spirometer.
- Spirometers are calibrated containers that collect gas and make measurements of lung volume or capacity that can be expired.

6. Write a note on tidal volume. (May 2016, Nov 2018)

Tidal Volume (TV):

- The volume of gas inspired or expired (exchanged with each breath) during normal quiet breathing, is known as tidal volume.
- Tidal volume is the depth of breathing or the volume of gas inspired or expired during each respiratory cycle. It can be calculated by multiplying the flow rate setting by the set inspiratory time(seconds).

7. Define Plethysmography. (Nov 2016)

- Plethysmography measures changes in volume in different areas of your body. It measures these changes with blood pressure cuffs or other sensors.
- These are attached to a machine called a plethysmograph.It can help your doctor determine if you have a blood clot in your arm or leg.

8. Write the working principe of ventilators? (Nov 2016)

- A ventilator is a machine that provides mechanical ventilation by moving breathable air into and out of the lungs, to deliver breaths to a patient who is physically unable to breathe, or breathing insufficiently.
- Ventilators are computerized microprocessor-controlled machines, but patients can also be ventilated with a simple, hand-operated bag valve mask. Ventilators are sometimes called "respirators".

9. What is so called cessation of breathing? (May 2019)

- Apnea is called the cessation of breathing.

- During apnea, there is no movement of the muscles of inhalation, and the volume of the lungs initially remains unchanged.

10. Differentiate nebulizer and ventilator. (May 2019)

Nebulizer	Ventilator
Nebulizers are used to supply moisture in the form of droplets.	A ventilator is a machine that provides mechanical ventilation by moving breathable air into and out of the lungs, to deliver breaths to a patient who is physically unable to breathe, or breathing insufficiently.
A nebulizer is a device used to administer nebulized medications to a patient.	It is used to breathe for a patient who cannot breathe. It is sometimes referred to as life support.

11. What is lung compliance? (Nov 2018)

- Lung compliance is the ability of the alveoli and lung tissue to expand on inspiration. The lungs are passive, but they should stretch easily to ensure the sufficient intake of the air.
- In clinical practice it is separated into two different measurements, static compliance and dynamic compliance.
- Static lung compliance is the change in volume for any given applied pressure. Dynamic lung compliance is the compliance of the lung at any given time during actual movement of air.

12. What is the role of aspirator in respiration therapy? (Sept 2020)

Aspirators are often included as part of a ventilator to remove mucus and other fluids from the airways. Alternatively, a separate suction device may be utilized to achieve the same purpose.

13. Write down the working principle of Fleisch Pneumotachometer. (Sept 2020)

- Flow transducers generally used in respiratory studies are the Fleisch-type pneumotachometer. Airflow can be measured directly with a pneumotachometer and a transducer.

- A pneumotachometer converts the flow of gases through it into a proportional signal of pressure difference on either side of a central mesh whose design ensures a signal linearity over a range of flow rates with a minimum dead space.

11 MARKS

1.Explain the need of whole body plethysmograph with neat block diagram. (Nov 2017, May 2018)

- Plethysmography can measure volumes not available through spirometry, although it is not appropriate in all circumstances.Spirometry is the standard method for measuring many lung volumes; however, it is not capable of providing information about absolute volumes of air in the lung.

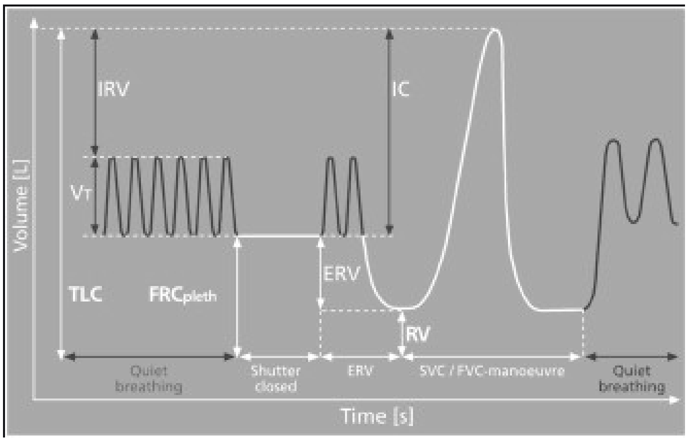
- A different approach is required to measure residual volume (RV), functional residual capacity (FRC), and total lung capacity (TLC). Two of the most common methods of obtaining information about these volumes are gas dilution tests and body plethysmography.

- Because they cannot be measured with simple spirometry, RV, FRC, and TLC, as well as airway resistance and airway conductance, are considered elusive lung volumes. TLC is the total volume of air in the chest after a maximal inspiration.

- FRC is the volume of air in the lungs at the end of a normal expiration, when the respiratory muscles are relaxed. Physiologically, it is an important lung volume because it approximates the normal tidal breathing range.

- Outward elastic-recoil forces of the chest wall tend to increase lung volume, but they are balanced by the inward elastic recoil of the lungs, which tends to reduce lung volume. These forces are normally equal and opposite at about 40% of TLC.

- Loss of lung elastic recoil in chronic obstructive pulmonary disease (COPD), for example, increases FRC. Conversely, the increased lung stiffness seen in pulmonary edema, interstitial fibrosis, and other restrictive lung disorders decreases FRC. The difference between total TLC and FRC is called inspiratory capacity.



- FRC has two components: residual volume (the volume of air remaining in the lungs at the end of a maximal expiration) and expiratory reserve volume. The RV normally accounts for about 25% of TLC. Normally, changes in the RV parallel those in the FRC.

- In restrictive lung disease and chest-wall disorders, however, RV decreases less than the FRC and TLC. In disease of the small airways, premature closure during expiration leads to air trapping, so the RV is elevated while the FRC and forced expiratory volume in 1 second remain close to normal.

- **The Plethysmography Procedure**
  During whole-body plethysmography, the subject is enclosed in a chamber equipped to measure pressure, flow, and volume changes.

- Secondary tests that can be performed during whole-body plethysmography include spirometry, bronchial challenge, diffusing capacity for carbon monoxide, single-breath nitrogen, multiple-breath nitrogen washout, pulmonary compliance, and occlusion pressure. Whole-body plethysmographs are usually found in pulmonary function laboratories, but they may also be used in cardiopulmonary laboratories, clinics, and pulmonology offices.

- During whole-body plethysmography, the patient sits or stands inside an airtight chamber and inhales or exhales to a particular volume (usually FRC); a shutter then drops across the breathing tube. The patient makes respiratory efforts against the closed shutter, causing chest volume to expand and decompressing the air in the lungs. The increase in chest volume slightly reduces the box's volume, thus slightly increasing the pressure in the box.

- **Selection Criteria**

  Indications for whole-body plethysmography include the diagnosis of restrictive lung disease, evaluation of obstructive lung disease, and measurement of lung volumes to distinguish between restrictive and obstructive processes.

- Patients should not be subjected to whole-body plethysmography if they are mentally confused, experience muscular incoordination, have conditions that prevent them from entering the plethysmograph cabinet or adequately performing the required maneuvers, are claustrophobic, or require continuous oxygen therapy that should not be discontinued, even temporarily.

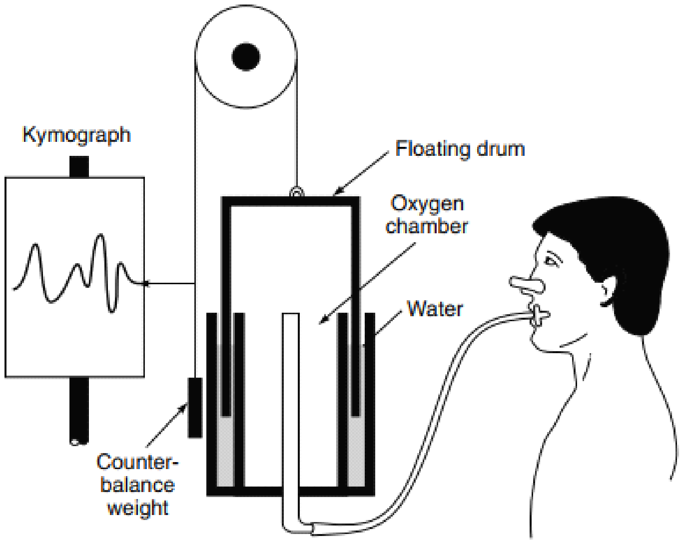
  In most cases, whole-body plethysmography is performed by the respiratory care technician. Providing attention to detail during the testing process and following the recommendations of the American Association for Respiratory Care (sidebar) will help to ensure the quality and validity of results.

2.Describe in detail about spirometer and describe the lung volume, tidal volume and residual volume of lung. (May 2017, May 2018, May 2019, Sept 2020)

- The instrument used to measure lung capacity and volume is called a spirometer. Basically, the record obtained from this device is called a spirogram. Spirometers are calibrated containers that collect gas and make measurements of lung volume or capacity that can be expired. By adding a time base, flow–dependent quantities can be measured. The addition of gas analyzers makes the spirometer a complete pulmonary function testing laboratory.

- Most of the respiratory measurements can be adequately carried out by the classic water-sealed spirometer. This consists of an upright, water filled cylinder containing an inverted counter weighted bell. Breathing into the bell changes the volume of gases trapped inside, and the change in volume is translated into vertical motion, which is recorded on the moving drum of a Kymograph. The excursion of the bell will be proportional to the tidal volume. For most purposes, the bell has a capacity of the order of 6–8.

- Also, the frequency response of a spirometer must be adequate for the measurement of the forced expiratory volume. The instrument should have no hysteresis, i.e. the same volume should be reached whether the spirometer is being filled or being emptied to that volume.

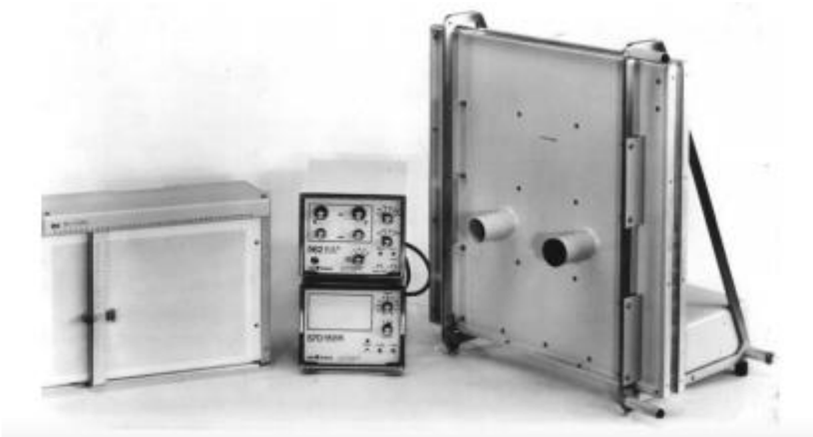


Basic water sealed spirometer

- As the water-sealed spirometer includes moving masses in the form of the bell and counter- weights, this leads to the usual problems of inertia and possible oscillation of the bell. This can lead to an over-estimation of the expiratory volume. This requirement applies not only to the spirometer, but also to the recorder used in conjunction with the recording device.

- The spirometer is a mechanical integrator, since the input is air flow and the output is volume displacement. An electrical signal proportional to volume displacement can be obtained by using a linear potentiometer connected to the pulley portion of the spirometer.

- The spirometer is a heavily damped device so that small changes in inspired and expired air volumes are not recorded. The spirometers can be fitted with a linear motion potentiometer, which directly converts spirometer volume changes into an electrical signal. A wedge spirometer consists of two square pans, parallel to each other and hinged along one edge. The first pan is permanently attached to the wedge casting stand and contains a pair of 5 cm inlet tubes.



Wedge spirometer

- As gas enters or leaves the wedge, the moving pan will change position in compensation for this change in volume. The construction of the wedge is such that the moving pan will respond to very slight changes in volume. Under normal conditions, the pressure gradient that exists between the wedge and the atmosphere amounts to only a fraction of a millimetre of water.

- Volume and flow signals for the wedge are obtained independently from two linear transducers. The transducers are attached to the fixed frame and are coupled to the edge of the moving pan. One transducer produces a dc signal proportional to displacement (volume), while the other has a dc output proportional to velocity (flow).

- The transducer outputs are connected to an electronics unit, which contains the power supply, an amplifier, and the built-in calibration networks.

- A pointer attached to the moving pan and a scale affixed to the frame, combine to provide a mechanical read out for determining the approximate volume position of the spirometer. When open to the atmosphere and standing upright, the wedge will empty itself due to the force of gravity acting on the moving member.

- Ultrasonic spirometers depend, for their action on transmitting ultrasound between a pair of transducers and measuring changes in transit time caused by the velocity of the intervening fluid medium. They employ piezo-electric transducers and are operated at their characteristic resonant frequency for their highest efficiency.

3.Write notes on a) Humidifiers b)Apnea Monitors.(May 2017)

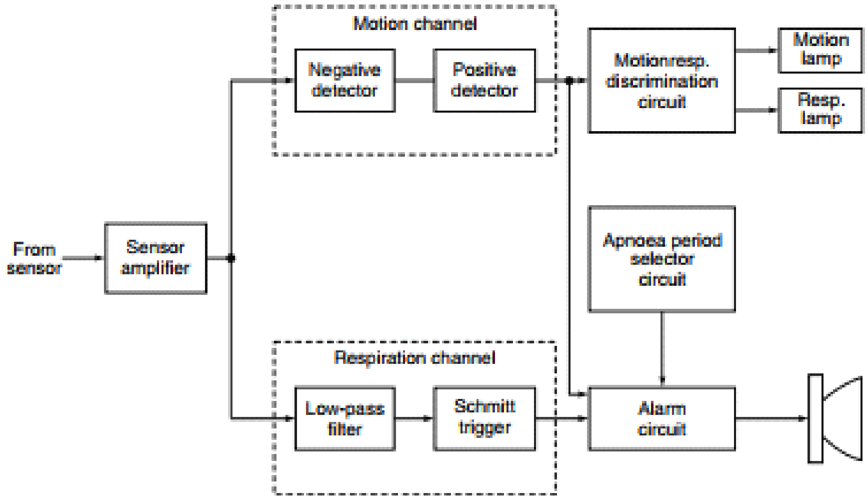
HUMIDIFIERS:

- The main task of a humidifier is to replace humidity in the upper air passages which has been lost by intubation. The humidity should be as close to 100% as possible, or speaking in terms of water, the absolute content per litre breathing gas should be more than 30 mg, regardless of environmental conditions. Therefore, in order to prevent damage to the patient's lungs, the air or oxygen applied during respiratory therapy must be humidified.
- Thus, all ventilators include arrangements to humidify the air, either by heat vapourization (stream) or by bubbling an air stream through a jar of water.Dry gases supplied by the anaesthesia machine may cause clinically significant desiccation of mucus. This may contribute to retention of secretion and the mucus flow may cease. Lung compliance will consequently fall.
- Therefore, air or anaesthetic gases need to be humidified. Absolute Humidity: This is the maximum mass of water vapour which can be carried by a given volume of air (mg/L). This quantity is pre-dominantly determined by temperature. Warm air can carry much more moisture.
- Relative Humidity (RH): This is the percentage of the amount of humidity present in a sample, as compared to the absolute humidity possible at the sample temperature.

- It is ideal to provide gases at body temperature and 100% RH to the patient's airway. The humidification measures that are commonly employed include heated airway humidifiers, nebulizers and heat and moisture exchangers.
- In the heated humidifiers, the air passes over the surface of the heated water and vapourization takes place. The temperature of the water is thermostatically controlled.Handbook of Biomedical Instrumentation.

APNEA MONITOR :

- Apnea monitors detect the cessation of breathing (apnea) in infants and adults who are at risk of respiratory failure and alert the parent or attendant to the condition.



- The Greek word "apnea" literally means "without breath." There are three types of sleep apnea: obstructive, central, and mixed. Of the three, obstructive sleep apnea, often called OSA for short, is the most common.
- Apnea is the cessation of breathing which may precede the arrest of the heart and circulation in several clinical situations such as head injury, drug overdose, anaesthetic complications and obstructive respiratory diseases. Apnea may also occur in premature babies during the first weeks of life because of their immature nervous system. Apnea monitors are particularly useful for monitoring the respiratory activity of premature infants.

- Apnea monitors detect the cessation of breathing (apnea) in infants and adults who are at risk of respiratory failure and alert the parent or attendant to the condition.This information is passed to a micro computer system.A home apnea monitor is a machine used to monitor a baby's heart rate and breathing after coming home from the hospital. Apnea is breathing that slows down or stops from any cause.

4.What is pneumotachometer? Explain how it is used for measuring the lung volumes.(Nov 2017)

- Pneumotachometers are devices that measure the instantaneous rate of volume flow of respired gases. Basically, there are two types of pneumotachometers, which are:

(i) Differential manometer—It has a small resistance, which allows flow but causes a pressure drop. This change is measured by a differential pressure transducer, which outputs a signal proportional to the flow according to the Poiseuille law, assuming that the flow is laminar. The unit is heated to maintain it at 37°C to prevent condensation of water vapour from the expired breath.

(ii) Hot–wire anemometer—It uses a small heated element in the pathway of the gas flow. The current needed to maintain the element at a constant temperature is measured and it increases proportionally to the gas flow that cools the element.

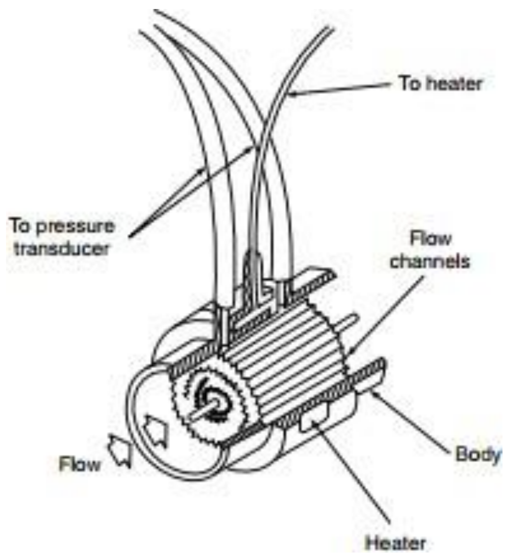
- Pneumotachometer is commonly used to measure parameters pertaining to pulmonary function such as forced expiratory volume (FEV), maximum mid-expiratory volume, peak flow and to generate flow-volume loops. Although these devices directly measure only volume flow, they can be employed to derive absolute volume changes of the lung (spirometry) by electronically integrating the flow signal.

Fleisch pneumotachometer:

- Flow transducers generally used in respiratory studies are the Fleisch-type pneumotachometers. These transducers are made by rolling a sheet of thin, corrugated metal with a plain strip of metal and inserting this core within a metal cover. Thus, these transducers are resistance elements consisting of small, parallel metal channels.

- This construction helps to maintain a laminar flow at much higher flow rates than would be possible for a gauze of similar area. In case of laminar flow, the pressure drop across the element is directly proportional to the flow rate of a gas passing through it.

- The output of the flow transducer appears as a differential pressure. To convert this pressure into an electrical signal, a second transducer is required. A capacitance type pressure transducer is used in such applications. They are more stable and less vibration-sensitive than resistive or inductive type transducers.



Venturi-type pneumatochometer:

- This type works similarly to the Fleisch pneumotachometer, but have a venturi-throat for the linear resistance element. The resulting pressure drop is proportional to the square of volume flow. They have open geometry and therefore are less prone to problems of liquid collection. Their main disadvantages are the non-linearity of calibration and the requirement for laminar flow.

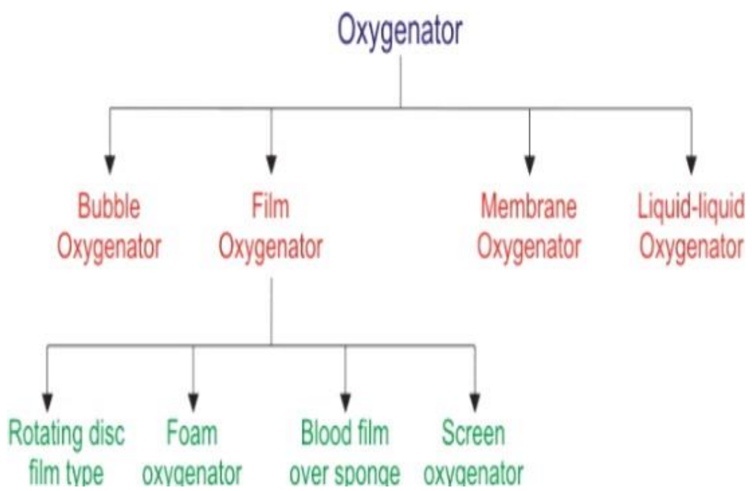
Turbine-type pneumatochometer:

- In this design, air flowing through the transducer rotates a very low mass (0.02 g) turbine blade mounted on jewel bearings. Rotation of the turbine blade interrupts the light beam of a light- emitting diode (LED). The interrupted light beam falls on a phototransistor, which produces a train of pulses, which are processed and accumulated to correspond to an accumulated volume in litres.

- A special feature of this transducer is a bias air flow, applied to the turbine blades from a pump. This flow keeps the blades in constant motion even without the sample flow through it.

5.Describe in detail about working principles of various types of oxygenators.(May 2016)

- An oxygenator is a medical device that is capable of exchanging oxygen and carbon dioxide in the blood of human patient during surgical procedures that may necessitate the interruption or cessation of blood flow in the body, a critical organ or great blood vessel.
- A heart-lung machine is connected to the heart by drainage tubes that divert blood from the venous system, directing it to an oxygenator. The oxygenator removes carbon dioxide and adds oxygen to the blood, which is then returned to the arterial system of the body.
- Oxygenators not only supply vital oxygen for the blood, but also transport carbon dioxide,anaesthetics and other gases into and out of the circulation.There are four types of oxygenators as shown below.

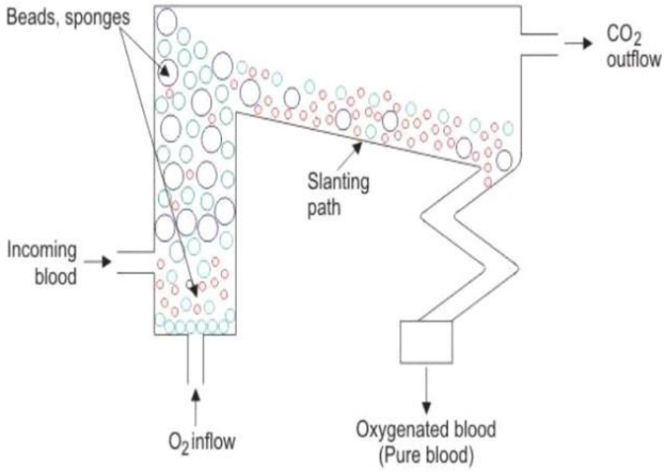


Types of oxygenators

BUBBLE OXYGENATORS: The venous blood is passed up a vertical column through which bubbles of oxygen are rising.Oxygen enters the blood and carbon dioxide is released.The gas exchange by directly infusing the gas into a column of systemic venous blood.

Oxygenating chambers: Bubbles produced by ventilating gas through diffusion plate into venous blood column.

Larger the number of bubbles; greater the efficiency of the oxygenators.Larger bubbles improve removal of CO_2,diffuses 25 times more rapidly in plasma than O_2.

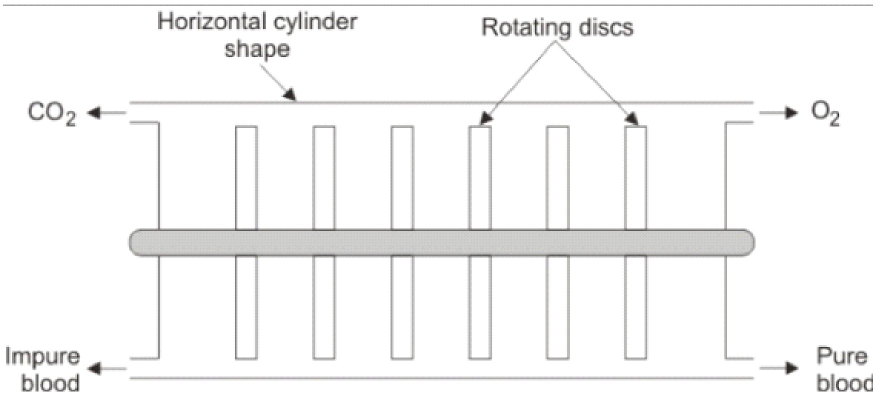


Bubble oxygenator

FILM OXYGENATOR:

Here the film of blood is spread on a rotating disc or metal screen and an oxygen mixture flows over this thin layer of blood.There are several types in this oxygenator.They are

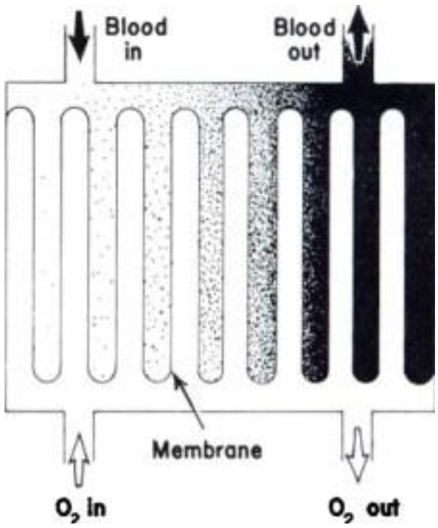
- Foam oxygenator
- Screen oxygenator
- Blood film over sponge
- Rotating disc film oxygenator



Film oxygenator

MEMBRANE OXYGENATOR:

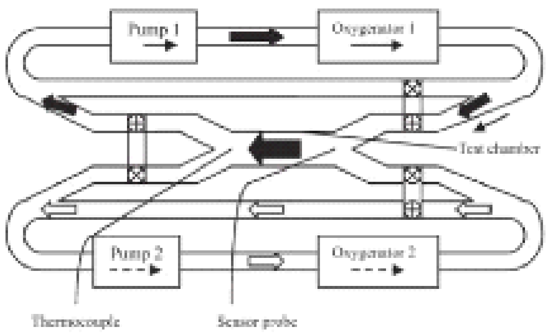
- A membrane oxygenator is a device used to add oxygen to, and remove carbon dioxide from the blood. It can be used in two principal modes: to imitate the function of the lungs in cardiopulmonary bypass (CPB), and to oxygenate blood in longer term life support, termed extracorporeal membrane oxygenation (ECMO).
- A membrane oxygenator consists of a thin gas-permeable membrane separating the blood and gas flows in the CPB circuit; oxygen diffuses from the gas side into the blood, and carbon dioxide diffuses from the blood into the gas for disposal.
- Effective oxygenation is obtained when oxygen and blood are running in opposite directions through a thin porous membrane.The blood flows on one side of a membrane permeable to gas and oxygen flows on other side.The membrane is made of microporous polyethylene which has highest permeability for oxygen.



Membrane oxygenator

LIQUID-LIQUID OXYGENATOR:

The oxygen dissolved fluoridised organic fluid and blood flow are flowing in the opposite directions and oxygenation of blood takes place.



Liquid - Liquid Oxygenator

Fluoridised organic liquid is the working liquid which readily dissolves oxygen and carbon dioxide which then diffuse.Even though the blood is in direct contact with the working liquid, it is entirely different chemical compound.

6.Explain in detail about the pulse oximetry and any one method to measure respiratory volume. (May 2016)

- **Pulse oximetry** is a non invasive method for monitoring a person's oxygen saturation. Peripheral oxygen saturation (SpO_2) readings are typically within 2% accuracy (within 4% accuracy in the worst 5% of cases) of the more desirable (and invasive) reading of arterial oxygen saturation (SaO_2) from arterial blood gas analysis.[1] But the two are correlated well enough that the safe, convenient, noninvasive, inexpensive pulse oximetry method is valuable for measuring oxygen saturation in clinical use.
- In its most common (transmissive) application mode, a sensor device is placed on a thin part of the patient's body, usually a fingertip or earlobe, or in the case of an infant, across a foot. Fingertips and earlobes have higher blood flow rates than other tissues, which facilitates heat transfer.
- A pulse oximeter is a medical device that indirectly monitors the oxygen saturation of a patient's blood (as opposed to measuring oxygen saturation directly through a blood sample) and changes in blood volume in the skin, producing a photoplethysmogram that may be further processed into other measurements

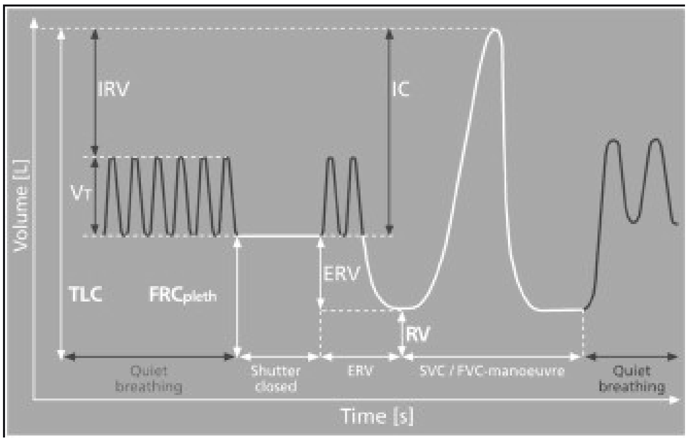
- . The pulse oximeter may be incorporated into a multiparameter patient monitor. Most monitors also display the pulse rate. Portable, battery-operated pulse oximeters are also available for transport or home blood-oxygen monitoring.

Method to measure respiratory volume:

- Plethysmography can measure volumes not available through spirometry, although it is not appropriate in all circumstances.Spirometry is the standard method for measuring many lung volumes; however, it is not capable of providing information about absolute volumes of air in the lung.

- A different approach is required to measure residual volume (RV), functional residual capacity (FRC), and total lung capacity (TLC). Two of the most common methods of obtaining information about these volumes are gas dilution tests and body plethysmography.

- Because they cannot be measured with simple spirometry, RV, FRC, and TLC, as well as airway resistance and airway conductance, are considered elusive lung volumes. TLC is the total volume of air in the chest after a maximal inspiration. FRC is the volume of air in the lungs at the end of a normal expiration, when the respiratory muscles are relaxed. Physiologically, it is an important lung volume because it approximates the normal tidal breathing range.



- Airway resistance can be measured directly using whole-body plethysmography, but is more commonly inferred from dynamic lung volumes and expiratory flow rates, which can be obtained more easily.

- **The Plethysmography Procedure**
  During whole-body plethysmography, the subject is enclosed in a chamber equipped to measure pressure, flow, and volume changes. Secondary tests that can be performed during whole-body plethysmography include spirometry, bronchial challenge, diffusing capacity for carbon monoxide, single-breath nitrogen, multiple-breath nitrogen washout, pulmonary compliance, and occlusion pressure. Whole-body plethysmographs are usually found in pulmonary function laboratories, but they may also be used in cardiopulmonary laboratories, clinics, and pulmonology offices.

- During whole-body plethysmography, the patient sits or stands inside an airtight chamber and inhales or exhales to a particular volume (usually FRC); a shutter then drops across the breathing tube. The patient makes respiratory efforts against the closed shutter, causing chest volume to expand and decompressing the air in the lungs. The increase in chest volume slightly reduces the box's volume, thus slightly increasing the pressure in the box.

- **Selection Criteria**
  Indications for whole-body plethysmography include the diagnosis of restrictive lung disease, evaluation of obstructive lung disease, and measurement of lung volumes to distinguish between restrictive and obstructive processes.

- Patients should not be subjected to whole-body plethysmography if they are mentally confused, experience muscular incoordination, have conditions that prevent them from entering the plethysmograph cabinet or adequately performing the required maneuvers, are claustrophobic, or require continuous oxygen therapy that should not be discontinued, even temporarily.
  In most cases, whole-body plethysmography is performed by the respiratory care technician. Providing attention to detail during the testing process and following the recommendations of the American Association for Respiratory Care (sidebar) will help to ensure the quality and validity of results.

7.Explain detail about intra-alveolar and thoracic pressure measurements.(May 2019)

Respiration is the process of gas exchange and occurs on two levels:

Internal Respiration: The use of oxygen by the mitochondria to produce ATP by oxidative phosphorylation with production of carbon dioxide as a waste product.

External Respiration : Exchange of oxygen and carbon dioxide between the atmosphere and body tissues.

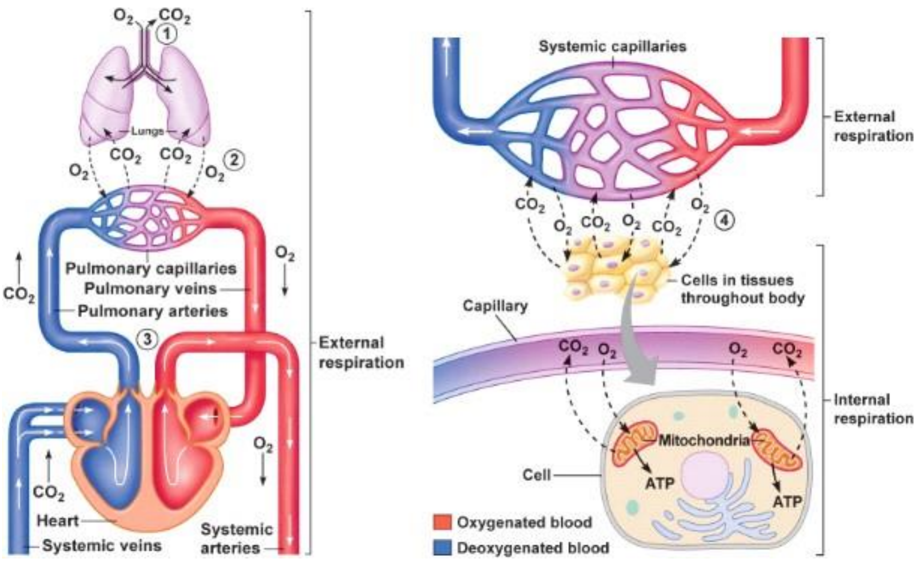
External Respiration Involves:

1. Pulmonary ventilation - movement of air in and out of the lungs.

2. Exchange of gases by diffusion between air and blood.

3. Transportation of gases by blood.

4. Exchange of gases by diffusion between blood and tissues.



Forces for Pulmonary Ventilation

Ventilation results from bulk flow of air as the result of pressure gradients created between alveoli and atmospheric pressure.

Pulmonary Pressures

There are four primary pressures associated with ventilation:

Atmospheric Pressure

The pressure of the outside air at sea level is 760 mm Hg. The remaining lung pressures are expressed relative to this pressure.

Intra-Alveolar Pressure

Varies with ventilation. During inspiration it is less than atmospheric pressure. During expiration it is greater than atmospheric pressure. At rest it is equal to atmospheric pressure. When it is equal to atmospheric pressure it is considered to be at 0 mm Hg.

Intrapleural Pressure

At rest it is - 4 mm Hg. It varies during ventilation but it is always less than intra-alveolar pressure and is always negative (that is, less than atmospheric pressure) during normal breathing. This negative pressure results from the elastic forces exerted on the intrapleural space by the chest wall and the lungs. Both the chest wall and lungs are elastic. The chest wall is compressed and the elastic forces are pulling it outward. The lung walls are stretched and the elastic forces are pulling them inward. Hence, the elastic forces are trying to open the intrapleural space. The tension resisting these elastic forces is the surface tension of the pleural fluid.

Transpulmonary Pressure

Transpulmonary pressure is the difference between the intrapleural pressure and the intra-alveolar pressure. This force operates across the walls of the lungs and causes the lungs to expand.

Mechanics of Breathing

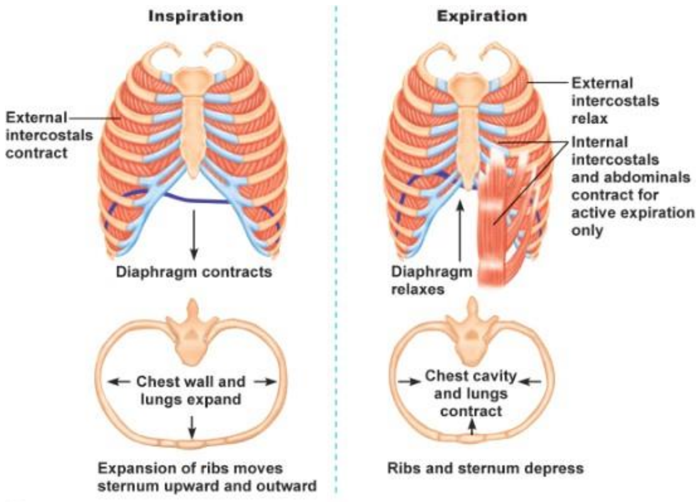
- Between breaths, when the lungs are at rest, the volume of air in the lungs is called the functional residual capacity (FRC). No air is moving into or out of the lungs during this time. Air flow results from the muscles of respiration creating pressure gradients by changing the volume of the lungs.
- The relationship between pressure and volume is expressed by Boyle's law. This law states that the pressure of gas in any container is inversely related to the volume of the container. In other words, when volume increases, pressure decreases and when volume decreases, pressure increases.
- Air flows into the lungs by bulk flow.

Determinants of Intra-alveolar Pressure

The changes in intra-alveolar pressure creates the pressure gradient that causes air to flow into and out of the lungs. Two factors determine intra-alveolar pressure:

1. the quantity (moles) of air molecules in the alveoli;

2. the volume of the alveoli



Inspiration

- The expansion of the thoracic cavity during respiration causes intrapleural pressure to decrease. This increases the transpulmonary pressure that is due to the difference between the intra-alveolar pressure and the intrapleural pressure.
- This increase in transpulmonary pressure causes the lungs to expand. The increase in the volume of the alveoli that accompanies this expansion decreases intra-alveolar pressure.

Expiration

- During normal breathing expiration is a passive process in which the muscles of inspiration relax and the elastic properties of the chest wall and lungs cause lung volume to decrease. This decrease in lung volume causes an increase in intra-alveolar pressure and creates the pressure gradient that causes an outflow of air.
- A more forceful expiration results from contraction of the muscles of expiration in a process called active expiration.

8.How is respiration rate measured? Explain. (Nov 2016)

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

- Under normal circumstances, this is rhythmic action with the result that the respiration rate provides a fairly good idea about the relative respiratory activity. Several techniques have been developed for the measurement of the respiration rate. The choice of a particular method depends mostly upon the ease of application of the transducer and their acceptance by the subject under test. Some of the commonly used methods for the measurement of respiration rate are explained below.

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

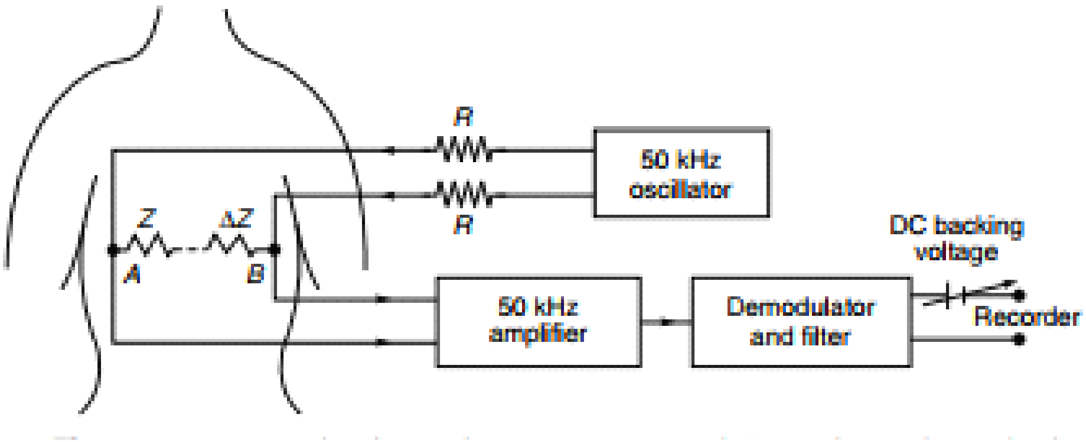
- The transducer is held by an elastic band, which goes around the chest. The respiratory movements result in resistance changes of the strain gauge element connected as one arm of a Wheatstone bridge circuit. Bridge output varies with chest expansion and yields signals corresponding to respiratory activity.

- Since air is warmed during its passage through the lungs and the respiratory tract, there is a detectable difference of temperature between inspired and expired air. This difference of temperature can be best sensed by using a thermistor placed in front of the nostrils by means of a suitable holding device.

- In case the difference in temperature of the outside air and that of the expired air is small, the thermistor can even be initially heated to an appropriate temperature and the variation of its resistance in synchronism with the respiration rate, as a result of the cooling effect of the air stream, can be detected. This can be achieved with thermistor dissipations of about 5 to 25 mW.

- Excessive thermistor heating may cause discomfort to the subject. The thermistor is placed as part of a voltage dividing circuit or in a bridge circuit whose unbalance signal can be amplified to obtain the respiratory activity. The method is simple and works well except in the case of some patients who object to having anything attached to their nose or face. This method is found to satisfy the majority of clinical needs including for operative and post-operative subjects.

- This is an indirect technique for the measurement of respiration rate. Using externally applied electrodes on the thorax, the impedance pneumograph measures rate through the relationship between respiratory depth and thoracic impedance change.



- To avoid the stimulation of sensory receptors, nerves and muscle, currents higher in frequency than 5 kHz must be used for the measurement of physiological events by impedance. Frequencies lower than 5 kHz are particularly hazardous since ventricular fibrillation may be produced with substantial current flow.

- The use of higher frequencies not only provides the protection sought in the avoidance of tissue stimulation, but also provides the safe use of currents of magnitude, which could be lethal if the frequencies were lower.

- Electrical impedance changes associated with physiological activity have been studied exten- sively. Some of the physiological quantities which have been measured and recorded by the impedance method include respiration, blood flow, stroke volume, autonomic nervous system activity, muscle contraction, eye movement, endocrine activity and activity of the brain cells.

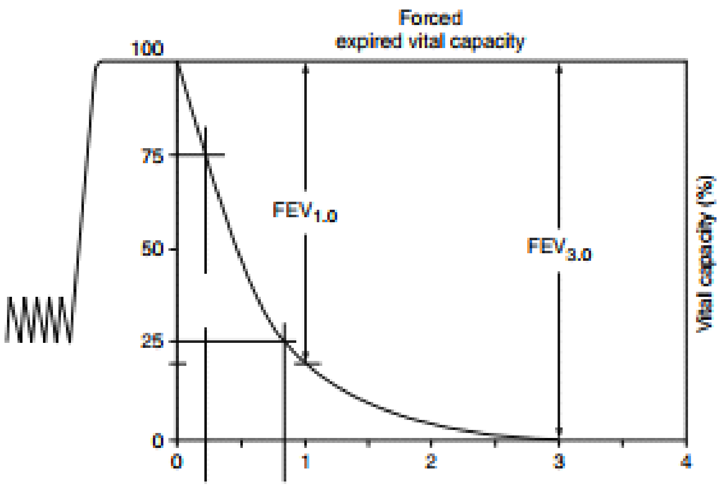
- Respiration rate can also be derived by continuously monitoring the CO_2 contained in the subject's alveolar air. Measurement of CO_2 in expired air is otherwise useful in several ways; for example, for originally setting up the respirator and in making adjustments to it afterwards, supervising patients suffering from respiratory paralysis, and other cases where there is respiratory involve- ment.

- 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 CO2, CO, and NO2) constituting the expired air. Rare gases and diatomic gases do not absorb infrared rays.

9.Explain the dynamic mechanics during small volume changes and flow in lungs.

(Nov 2016)

- A number of forced breathing tests are carried out to assess the muscle power associated with breathing and the resistance of the airway. Among these are:
- Forced Vital Capacity (FVC): This is the total amount of air that can be forcibly expired as quickly as possible after taking the deepest possible breath.
- Forced Expiratory Volume (FEV): The percentage of the VC that can be forced out of the lungs in a given period with 'maximal exertion'. This is written as FEVT where T is usually in seconds. Maximum Mid-Expiratory Flow (MMEF or MMF) or Maximum Mid-Flow Rate (MMFR): The maximum rate of flow of air during the middle half of the FEV spirogram. One half VC is obtained from the volume indicated by the curve between 25 and 75% VC. Mid-Expiratory Time (MET): It is the time in seconds over which this volume is forcibly exhaled. The MMEF is calculated from MMEF.



- Normal values for each of these volumes and capacities have been calculated. They have been found to vary with sex, height and age. All pulmonary volumes and capacities are about 20 to 25 % less in females than in males.

- A particular pattern of abnormal lung volume may occur in a particular form of lung disease and such a pattern is useful confirmatory evidence of a diagnosis made on clinical grounds. Further, serial lung function testing is of use in demonstrating progressive deterioration in function or in confirming a satisfactory response to therapy. If the FEV1/FVC is greater than 85%, a so called 'restrictive' defect may be present. This is seen in cases of diffuse pulmonary fibrosis.

- Pulmonary function tests are performed for the assessment of the lung's ability to act as a mechanical pump for air and the ability of the air to flow with minimum impedance through the conducting airways. These tests are classified into two groups: single-breath tests and multiple- breath tests.

There are three types of tests under the single-breathcategory. These are

- Tests that measure expired volume only.
- Tests that measure expired volume in a unit time.
- Tests that measure expired volume/time.

A resting person inspires about 0.5 litre of air with each breath, with the normal breathing rate of 12 to 20 breaths per minute. With exercise, the volume may increase 8 to 10 times and the breathing rate may reach 40 to 45 breaths per minute. A respiratory disease may be suspected if these volumes, capacities or rates are not in the normal range.

10. What are the various lung volumes and capacities that aids in the analysis of pulmonary function of an individual. Discuss about it.(Nov 2018)

Tidal Volume (TV): The volume of gas inspired or expired (exchanged with each breath) during normal quiet breathing, is known as tidal volume.

Minute Volume (MV): The volume of gas exchanged per minute during quiet breathing. It is equal to the tidal volume multiplied by the breathing rate.

Alveolar Ventilation (AV): The volume of fresh air entering the alveoli with each breath.

Alveolar Ventilation = (Breathing rate) * (Tidal volume – Dead space).

Inspiratory Reserve Volume (IRV): The volume of gas, which can be inspired from a normal end- tidal volume.

$$IRV = VC – (TV + FRC)$$

Expiratory Reserve Volume (ERV): The volume of gas remaining after a normal expiration less the volume remaining after a forced expiration.

$$ERV = FRC – RV$$

Residual Volume (RV): The volume of gas remaining in the lungs after a forced expiration.

Functional Residual Capacity (FRC): The volume of gas remaining in the lungs after normal expiration.

Total Lung Capacity (TLC): The volume of gas in the lungs at the point of maximal inspiration.

$$TLC = VC + RV$$

Vital Capacity (VC): The greatest volume of gas that can be inspired by voluntary effort after maximum expiration, irrespective of time.

Inspiratory Capacity (IC): The maximum volume that can be inspired from the resting end expiratory position.

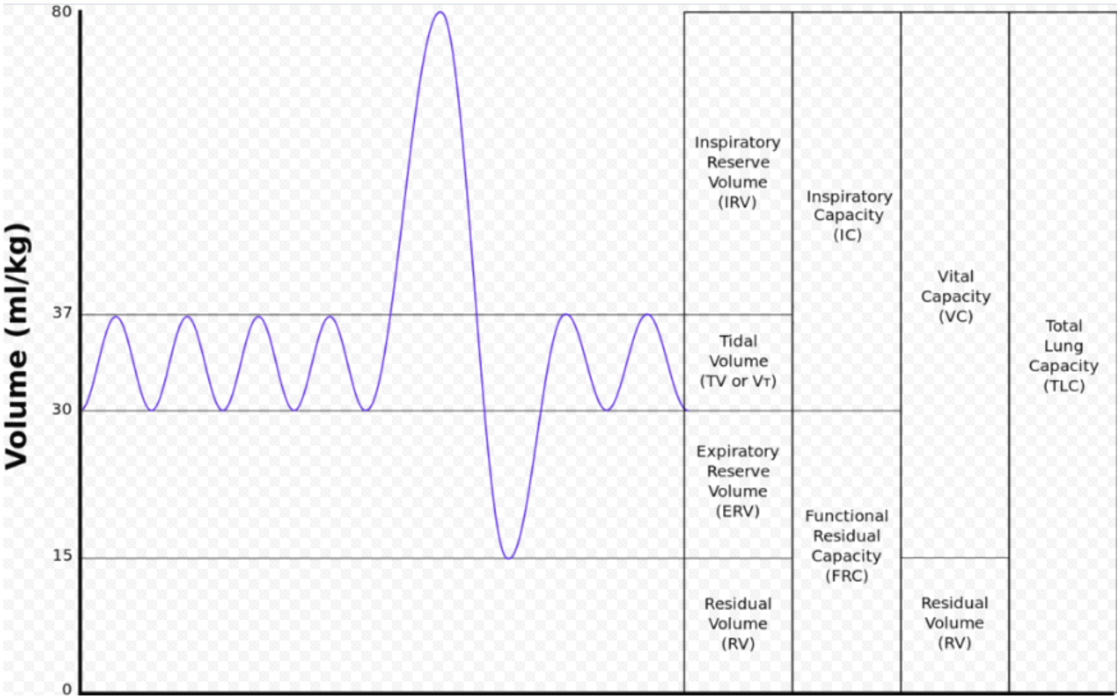
Dead Space: Dead Space is the functional volume of the lung that does not participate in gas exchange.**Compliance (C):** Change in volume resulting from unit change in pressure.

Lung Compliance : Change in lung volume resulting from unit change in transpulmonary pressure (PL)

Chest-Wall Compliance : Change in volume across the chest wall resulting from unit change in transchest-wall pressure.

Static Compliance : Compliance measured at point-of-zero airflow by interruption or breach- hold technique.

Elastance (E): Reciprocal of compliance. Units are cmH2O/litre.



Transpulonary Pressure: Pressure gradient developed across mouth (Pao) and pleural surface at lung (PPL).

Transalveolar Pressure: Pressure gradient developed between alveolar wall (PALV – PAL).
Transairway Pressure : Pressure gradient developed between alveoli and mouth.

Static Elastic Recoil Pressure : Pressure developed in elastic fibers of the lung by expansion.

A number of forced breathing tests are carried out to assess the muscle power associated with breathing and the resistance of the airway. Among these are:

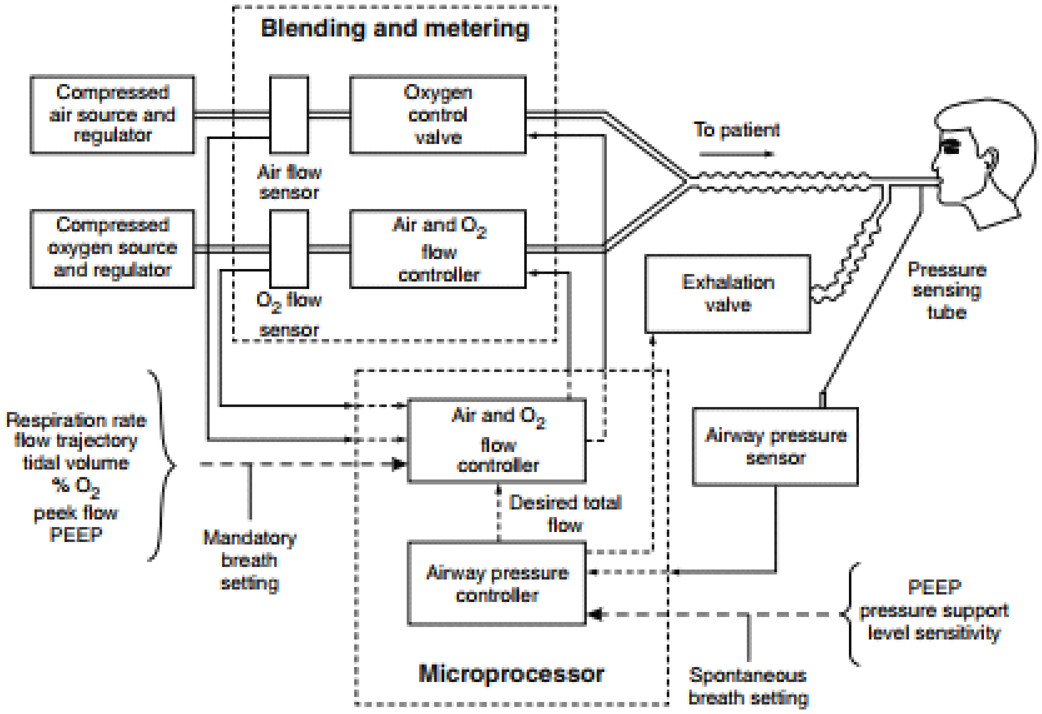
Forced Vital Capacity (FVC): This is the total amount of air that can be forcibly expired as quickly as possible after taking the deepest possible breath.

Forced Expiratory Volume (FEV): The percentage of the VC that can be forced out of the lungs in a given period with 'maximal exertion'. This is written as FEVT where T is usually in seconds. Maximum Mid-Expiratory Flow (MMEF or MMF) or Maximum Mid-Flow Rate (MMFR): The maximum rate of flow of air during the middle half of the FEV spirogram. One half VC is obtained from the volume indicated by the curve between 25 and 75% VC.

Mid-Expiratory Time (MET): It is the time in seconds over which this volume is forcibly exhaled. The MMEF is calculated from MMEF.

11. Explain the working of microprocessor controlled ventilator with block diagram. (Nov 2018, Sept 2020)

- The current and future trends in critical care ventilatory management demand precise flow, pressure and oxygen control for application to both adult and paediatric patients. In addition, patient monitoring and rapid, understandable alarms are extremely important for timely care of the patient. This has become possible by making use of computer technology in the ventilators to achieve a wide range of functions and controls.
- Modern ventilator machines consist of two separate but inter-connected systems: the pneumatic flow system and an electronic control system.
- These gases enter the air/oxygen mixer where they combine at the required percentage and reduced in pressure to 350 cm H2O. An electronically controlled flow valve proportions the gas flow from the reservoir tank to the patient breathing circuit. In some ventilators, an air compressor is used in place of a compressed air tank. The primary objective of the device is to ensure proper level of oxygen in the inspiratory air and deliver a tidal volume according to the clinical requirements.
- As the gasses leave the ventilator, they pass by an oxygen analyser, a safety ambient air inlet valve and a back-up mechanical over pressure valve. In the patient breathing circuit is a bi-directional flow sensor to measure the gas flows. The exhaled gasses exit through an electronically controlled exhalation valve located at pressure valve is used to provide safety in case the pressure in the patient circuit exceeds 110 cm of H2O.
- The electronic control system may use one or more microprocessors and software to perform monitoring and control functions in a ventilator. These parameters include setting of the respiration rate, flow waveform, tidal volume, oxygen concentration of the delivered breath, peak flow and PEEP.



Block diagram of microprocessor controlled ventilator

- The system consists of monitors for pressure flow and oxygen fraction. The sensors are connected to electronic processing circuits which makes them available for digital readouts. The signals are also compared with pre-set alarm levels so that if they fall outside a pre-determined normal range, alarms are sounded.

- The pressure sensors are normally of semiconductor strain gauge type placed in a bridge configuration. For measurement of fraction of oxygen in the inspired air, a fuel cell type oxygen sensor is used. This sensor generates a current proportional to pO2.As this sensor is temperature- sensitive, compensation for its operating temperature is included in the circuit. Usually, a thermistor is used to carry out this function.

- The flow sensor usually consists of a variable orifice and by measuring the pressure drop across the variable orifice, the patient flows can be calculated.Ventilators are life saving equipment and therefore need regular maintenance and calibration which should be carried out as per the instructions of the manufacturers.

BM T61 – DIAGNOSTIC AND THERAPEUTIC EQUIPMENTS

UNIT-5

2 MARKS

1) What is lithotripsy? (April/ May 2016)

- Lithotripsy is a medical procedure involving the physical destruction of hardened masses like kidney stones, bezoars or gallstones. The term is derived from the Greek words meaning "breaking stones".
- The two types of lithotripsy are extracorporeal shock wave lithotripsy (ESWL) and Laser Lithotripsy.

2) List out the applications of Laproscopy. (April/ May 2016)

- The diagnosis and treatment of endometriosis, chronic pelvic pain, pelvic inflammatory diseases, and causes of infertility
- The removal of fibroids, uterus, ovarian systs, lymph nodes, or an ectopic pregnancy
- The treatment of a range of disorders, including urinary incontinence, pelvic organ prolapse, and certain forms of cancer.
- Evaluating certain cancers, including those of the ovary, uterus and cervix.

3) State the principle of bubble oxygenator. (Nov 2016)

- By bubbling the oxygen through a large column of blood and then making the flow of blood through a slanting path, the carbon di oxide is removed from the blood.

4) (a) List few ICU/ CCU equipments. (May 2017)

(b) List out the equipments inside the ICU and CCU. (April/ May 2018)

(c) What are the various equipments used in ICU? (May 2019)

(d) Name the equipment mainly used in post-operative ICU. (Nov 2016)

- Ventilator
- CPAP System
- BPAP System
- Patient System
- Infusion Pump
- Syringe Pump
- Blood Warmer
- Defibrillator
- Multi para monitor

5) What is thermography? (May 2017, Nov/ Dec 2018)

- Thermography is the process of recording true thermal images of the surfaces of objects under study. In medicine, thermography displays images representing the thermal radiation of skin areas.
- Taking into account possible local changes in skin emissivity, these images may generally be considered as maps of temperature.
- Such thermograms contain both qualitative and quantitative information relevant to the images itself and to temperatures.
- Thermography is an important diagnostic aid in many diseases especially in Breast Cancers and in rhematic diseases (or) joint diseases.

6) What is the need for heart-lung machine? (Nov/ Dec 2017)

- During open heart surgery for installation of a valve prosthesis or correction of a congenital mal formation, the heart cannot maintain the circulation.
- It is necessary to provide extra-corporeal circulation with a special machine called **heart lung machine.** Further this is also used to provide circulatory assistance to support a faulty heart.
- While doing open heart surgery, it is necessary to bypass the heart to enable the surgeon to work in a bloodless field under direct vision.
- The heart-lung machine replaces the functions of heart and lung thereby providing the rest of the body with a continuous supply of oxygenated blood while the heart is stopped.

7) Give the principle of cryogenic techniques. (Nov/ Dec 2017)

- **Cryogenics –** also known as low temperature technology – is becoming increasingly important in industrial applications.
- Fields of application include storing liquid hydrogen as fuel for fuel cell vehicles.
- High-field superconducting magnets are another application area. In this case, liquid helium cools magnetic coils.

8) List out the different types of oxygenators used in heart-lung machines. (Sep 2020)

- Bubble Oxygenators
- Film Oxygenators

  Divided into following 4 types

  - Rotating disc film type
  - Foam oxygenator
  - Blood film over sponge

  - Screen oxygenator
- Liquid-Liquid Oxygenators
- Membrane Oxygenator

9) Difference between finger pump and roller pump. (April/ May 2018)

FINGER PUMP	ROLLER PUMP
Finger Pump push a series of rods against a flexible tubing in sequence, forcing fluid along the tube.	A Peristaltic pump, also commonly known as a **roller pump,** is a type of positive displacement pump used for pumping a variety of fluids.
Finger pump is often found in medical applications, pumping blood or other fluids.	The degree of trauma is considerably increased when high flow are needed – hence the **roller pump** is most often used in applications where flow rates are low, such as dialysis and apheresis.

10) Write the function of infusion pump. (Nov/ Dec 2018)

- In many medical applications, intra-venous (IV) fluids and drugs need to be infused over a period of time, which could be several minutes, hours and days.
- The most common method of doing this is by manual injection of bolus doses using syringes by manually setting the drip rate of gravity feed intra-venous infusion sets.
- The application of infusion delivery devices continues to grow, extending to patient–controlled analgesia, home therapy, chemotherapy, implantable drug pumps (such as insulin delivery pumps) etc.
- For meeting the exacting requirements of these applications in terms of flow rate of the fluids in a safe and effective manner, the pumps are becoming smaller and smarter.

11) Mention the types of detectors used in thermography. (Sep 2020)

- Infrared detectors are used to convert infrared energy into electrical signals.
- Basically, there are two types of detectors: thermal detectors and photo-detectors.
- Thermal detectors include thermocouples and thermistor bolometers.
- They feature constant sensitivity over a long wavelength region.

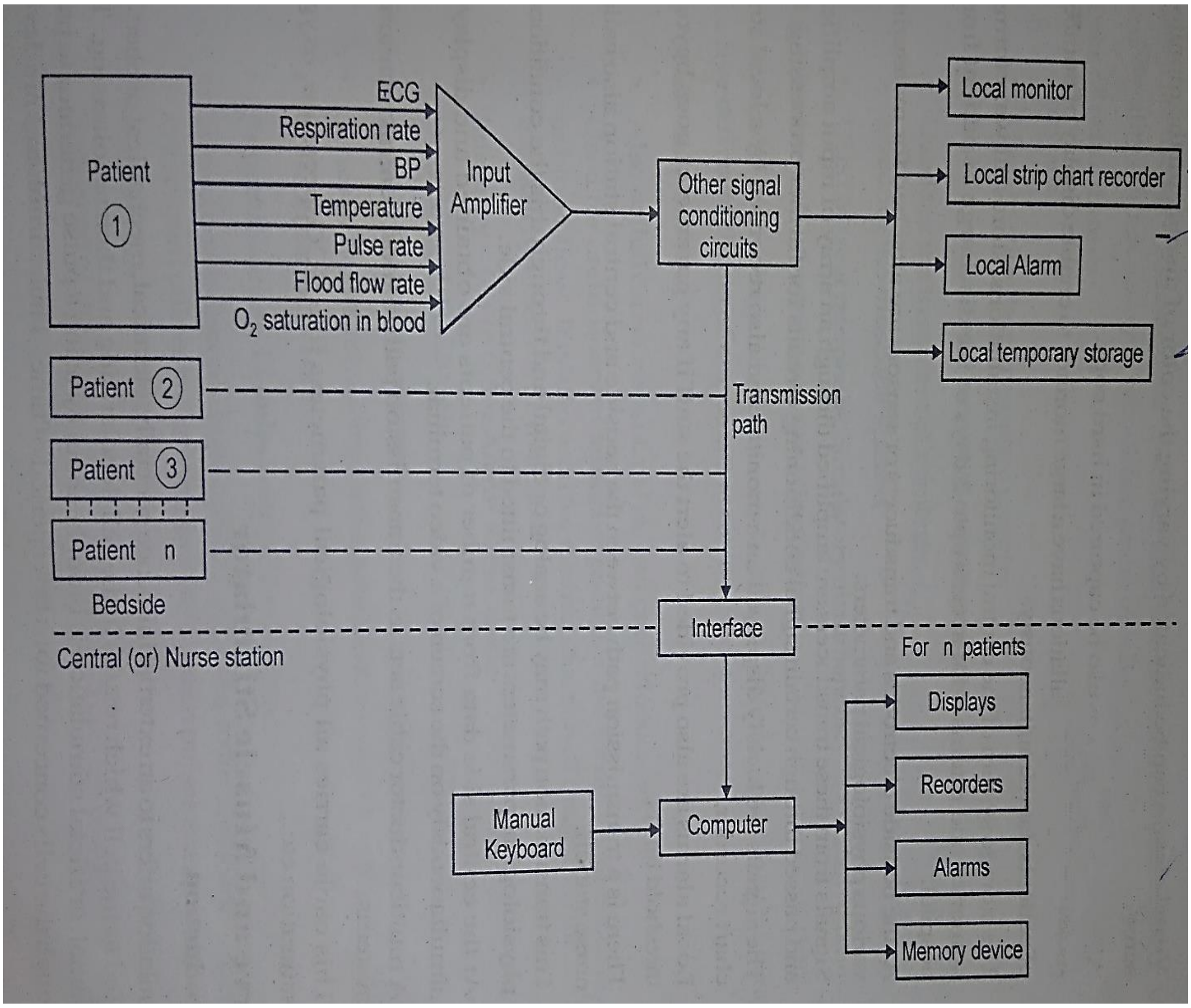
12) Why we go for lithotripsy and also mention the frequency of the wave used? (May 2019)

- Lithotripsy is a medical procedure involving the physical destruction of hardened masses like kidney stones, bezoars or gallstones.
- For optimal Shockwave Lithotripsy frequency range for treating urinary stones i.e., high frequency (100-120 waves/ minute), intermediate-frequency (80-90 waves/ minute), and low-frequency (60-70 waves/ minute) lithotripsy.
- In Laser Lithotripsy, in order to dust a stone it is indicated to use low energy (~5 Hz), high frequency (15-20 Hz), and long pulse (800 microseconds), with a total power of 7.5-10 W. Conversely, high energy (1.5-2 Hz), Low frequency (5 Hz), and short pulse (200 microseconds) are required for fragmentation.

11 MARKS

1) Write in detail about the working of digital central patient monitoring system. (April/ May 2016)

- The central monitoring system, the physiological values of patients are measured at bed side and these are displayed and recorded at a central station.
- The physiological parameters measured at the bedside include,
  - ECG
  - Respiration rate
  - Blood pressure
  - Temperature
  - Pulse rate
  - Oxygen saturation in blood, etc.,
- The electronics which aid for measurement and the signal condition are located at the bedside whereas the display, recorders, alarms, etc., are located at the central station.
- The central monitoring system is build up with many microprocessors which enable the smooth display of waveforms, alphanumerics and graphics on a single CRT.
- The central monitoring system provides all measured information at a glance. It generates audible and visual alarms if the value measured exceed their preset limit. It displays the patient's vital sign data.



Block diagram of typical central monitoring system

- Trend plots of patient's vital sign are also available which will guide for patients therapy. Trend plots may be long trend (9 hour to 24 hours) or short tuned 90 minutes.
- The information (physiological parameters) from patient's bed side like blood pressures ECG, heart rate, respiration, entidal Carbon dioxide, and temperatures are transmitted as analog signals through cables.
- Status signals like alarm signals are also carried by the same cable. The incoming physiological values are sampled and digitized by 10-bit analog to digital converter.
- ECG waveforms are sampled every two milliseconds to maintain the 0-100 Hz. Temperature is sampled every four seconds
- The display has 2 sections,
    - Raster type display – for wave forms

  - 300 x 260 picture element bit map – for alphanumerics

- The hard copy of the waveforms can also be obtained. Waveforms can also be temporarily stored for 24 hours. CMOS RAM is used.
- Alarms can be both audible and visual. Audible alarms can be distinguished by varying the pitch, volume, duration and sequencing of tones.
- Visual alarms can be indicated by varying the color of display on the monitor screen. Alarm condition can also be captured in hard copy.
- Central monitoring installations have a large monitor to enable display of number of patient's data simultaneously.
- The storage system of the central monitoring installations, stores all waveforms, numerics and retains it for access upto 3 days of the discharge of patient from hospital.
- All bedside electrodes and transducers or sensors are attached for measuring various physiological parameters.
- Signals from these transducers are amplified through an array of input amplifiers and passed through certain signal conducted circuits for further processing.
- Signals are locally displayed on the monitor and also recorded by a local strip chart recorder.
- Local alarms are also provided to alert the staff if any parameter goes beyond the threshold limits.
- There is a transmission path between the bedside and the central station also called nurse stations.
- This transmission path may be analog or digital and through this the conditioned physiological parameters are transmitted through the central side.
- At the central side the data from number of patients are obtained and displayed simultaneously on the screen of a video terminal.
- A multiconductor cable acts as a transmission path in most central monitoring systems. This cable carries all physiological parameters like ECG, pressure, oxygen saturation, etc.,

2) (a) Explain in detail about principles of cryogenic technique and add their applications. (April/ May 2016)

(b) Explain the principle of cryogenic and its application. (May 2019)

CRYOGENIC TECHNIQUES

Definition

- Cryogenics is the study of the production of very low temperature (below 123 K) and the behaviour of materials at those temperatures. Cryogenics uses the Kelvin scale of temperature.
- Liquefied gases such as liquid nitrogen and liquid helium are used in many cryogenic applications. Liquid nitrogen is the most commonly used element in cryogenic.
- Liquid helium is also commonly used and allows for the lowest attainable temperature to be reached.
- These liquids are held in special containers called Dewar flasks, which are generally about six feet in height and three feet in diameter.
- Scientists found that metals frozen to low temperature showed more resistance to wear and tear. This is known as cryogenic hardening.
- Cryogens like liquid nitrogen are further used especially for chilling and freezing applications.

Cryobiology

- The branch of biology involving the study of the effects of low temperatures on organisms (most often for the purpose of achieving cryopreservation).

Cryo-conservation of animal genetic resources

- The conservation of genetic material with the intention of conserving a breed.

Cryosurgery

- The branch of surgery applying cryogenic temperatures to destroy and kill tissue, e.g. cancer cells.

Production

- Cryogenic cooling of devices and material is usually achieved via the use of liquid nitrogen, liquid helium, or a mechanical cryocooler (which uses high-pressure helium lines).
- Gifford-McMahon cryocoolers, pulse tube cryocoolers and Stirling cryocoolers are in wide use with selection based on required base temperature and cooling capacity.
- The most recent development in cryogenics is the use of magnets as regenerators as well as refrigerators.
- These devices work on the principle known as the magnetocaloric effect.

Detectors

- There are various cryogenic detectors which are used to detect cryogenic particles.
- For cryogenic temperature measurement down to 30K, Pt100 sensors, a resistance temperature detector (RTD), are used. For temperatures lower than 30K it is necessary to use a silicon diode for accuracy.

Cryogenic fluids

Cryogenic fluids with their boiling point in kelvins

Fluid	Boiling point (K)
Helium-3	3.19
Helium-4	4.214
Hydrogen	20.27
Neon	27.09
Nitrogen	77.09
Air	78.8
Fluorine	85.24
Argon	87.24
Oxygen	90.18
Methane	111.7

MEDICAL APPLICATIONS

(i) Magnetic Resonance Imaging (MRI)

- MRI is used to scan the inner organs of human body by penetrating very intense magnetic field.
- The magnetic field is generated by super conducting coils with the help of liquid helium.
- It can reduce the temperature of the coil to around 4K. At this low temperature, very high resolution images can be obtained.
- Magnetic resonance imaging (MRI) is a complex application of NMR where the geometry of the resonances is deconvoluted and used to image objects by detecting the relaxation of protons that have been perturbed by a radio-frequency pulse in the strong magnetic field.
- This is mostly commonly used in health applications.

(ii) Nuclear magnetic resonance (NMR)

- It is one of the most common methods to determine the physical and chemical properties of atoms by detecting the radio frequency absorbed and subsequent relaxation of nuclei in a magnetic field.
- This is one of the most commonly used characterization techniques and has applications in numerous fields.
- Primarily, the strong magnetic fields are generated by supercooling electromagnets, although there are spectrometers that do not require cryogens.
- In traditional superconducting solenoids, liquid helium is used to cool the inner coils because it has a boiling point of around 4 K at ambient pressure.
- Cheap metallic superconductors can be used for the coil wiring.
- So-called high-temperature superconducting compounds can be made to super conduct with the use of liquid nitrogen, which boils at around 77 K.

(iii) Blood storage

- Certain rare blood groups are stored at low temperatures, such as −165 °C, at blood banks

3) (a) Reason out the need for a heart lung machine during open heart surgery and explain the principle of working? (Nov 2016)

(b) Explain the working of a heart lung machine. (May 2017)

(c) Describe in detail about need for heart lung machine. (April/ May 2018)

(d) What is the need for heart lung machine and also explain its function? (May 2019)

(e) Describe with the schematic diagram the working of heart lung machine used in cardiopulmonary bypass. (Nov/ Dec 2018)

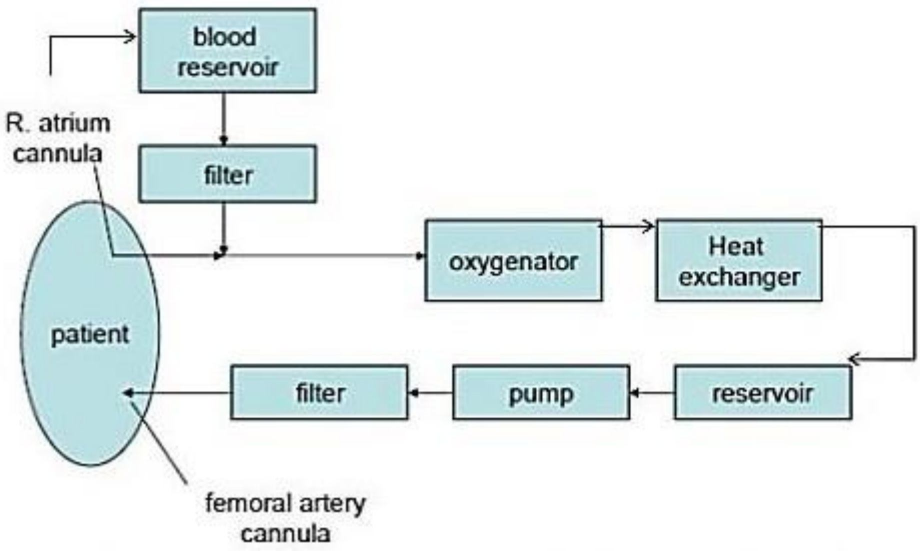
HEART-LUNG MACHINE

- During open heart surgery for installation of a valve prosthesis or correction of a congenital mal formation, the heart cannot maintain the circulation.
- It is necessary to provide extra-corporeal circulation with a special machine called **heart lung machine.** Further this is also used to provide circulatory assistance to support a faulty heart.
- While doing open heart surgery, it is necessary to bypass the heart to enable the surgeon to work in a bloodless field under direct vision.
- The heart-lung machine replaces the functions of heart and lung thereby providing the rest of the body with a continuous supply of oxygenated blood while the heart is stopped.
- In other words, the machine circulates the essential oxygen-rich blood to the brain and other vital organs during open-heart surgery, allowing the cardiac surgery team to operate on a heart that is blood-free and still.
- When the surgery is complete, the heart is restarted and the heart-lung machine is disconnected.

Function of heart-lung machine

- The heart-lung machine carries blood from the upper-right chamber of the heart (the right atrium) to a special reservoir called an oxygenator.
- Inside the oxygenator, oxygen bubbles up through the blood and enters the red blood cells.
- This causes the blood to turn from dark (oxygen-poor) to bright red (oxygen-rich)

Block Diagram of heart-lung machine



Block Diagram of Heart-Lung Machine

The main components of a heart-lung machine and their functions are briefly described below:

Roller-Pump

- The pump comfort frequently consists of numerous revolving motor pumps that peristaltically ‘massage’ tubing.
- Pumping action occurs because the rollers on the rotating arm comprises the tubings carrying the blood and forces the blood ahead of the compressed section.
- This action is called peristaltic action and this leads to a pulsatile flow of blood through the tubings. The heart-lung machine uses five pump heads normally.
- In some cases we use centrifugal pumps for the safeguarding and control of blood flow during the surgical procedure.
- By changing the RPM of pump head, blood flow is maintained. This kind of pumping action is measured to be better to the action of roller pumps because it produces less damage to the blood.

Oxygenator

- The oxygenator is planned to move oxygen to the infused blood and take away carbon dioxide from venous blood.

- So simply the oxygenator assembly allows to oxygenate the blood.
- Bubble oxygenators, membrane oxygenators and heparin coated blood oxygenators are the different types of oxygenators. Of them, heparin coated blood oxygenators are the commonly used one as they prevent blood coating.

Heat Exchanger

- Heat exchangers permit body and organ temperatures to be attuned. The uncomplicated heat exchange design is a container of water.
- As the blood transfers through the tubing positioned in the bath, the blood temperature will alter.
- A more complex system separated the blood and water interface with a metallic barrier. As the water temperature is changed, the blood temperature also changes, which in turn changes the tissue temperature.
- Once the tissue temperature reaches the desired level, the water temperature is maintained.
- Heat exchangers can be of two types namely plate type and coil type. In plate type of heat exchangers, two sheets of metals are used and they are coated with a non – thrombogenic substance.
- This configuration offers good efficient transfer of heat. Coil configuration consists of a hollow coil through which water circulates. The disadvantage of this type is it is a non-disposable unit and is very difficult to clean.

Temperature Controller

- During the time the patient uses a heart-lung machine, body temperature is to be maintained at a normal range.
- This unit allows the pump operator to keep the blood at a proper temperature.

Blood and Oxygen Dispersion Plates

- In a heart – lung machine, the gas bubbles are dispersed into the venous blood in the bubble column and acts as vehicles for both oxygen and carbon dioxide.
- Here oxygen diffuses from the bubble into the blood film surrounding the bubble. Various types of dispersion plates are used.

Reservoir

- A reservoir gather blood drained from the venous flow. Reservoir arranges include open or closed systems.
- The open system displays demarcations corresponding to blood volume in the container. The design is open to environment permitting blood to cross with environmental gases.
- The closed system contains a bag and it eliminates the air-blood interface. Volume is measured by weight or change in radius of the container.

Nylon Mesh Filters

- The nylon mesh filters used in heart-lung machines are attuned with a broad choice of solvents.
- They are particularly used for gathering of algae and cells, atom analysis, big particulate filtration, prefiltration of solvents and so on.

Cannulae

- Numerous cannulae are sewn into the suffering patient's body in a diversity of position depending on the kind of surgery.
- A venous cannula takes away the oxygen destitute blood from the patient's body and an arterial cannula is sewn into the suffering patient's body to impart oxygen rich blood.
- The cannula utilized to return oxygenated blood is frequently inserted in the rising aorta.

4) Why is Patient monitoring system necessary? (Nov 2016)

- The objective of patient monitoring is to have a quantitative assessment of the important physiological variables of the patients during critical periods of their biological functions.
- For diagnostic and research purposes, it is necessary to know their actual value or trend of change.
- Patient monitoring systems are used for measuring continuously or at regular intervals, automatically, the values of the patient's important physiological parameters.
- There are several categories of patients who may need continuous monitoring or intensive care.
- Critically ill patients recovering from surgery, heart attack or serious illness, are often placed in special units, generally known as intensive care units, where their vital signs can be watched constantly by the use of electronic instruments.

- The long-term objective of patient monitoring is generally to decrease mortality and morbidity by:
  a) Organizing and displaying information in a form meaningful for improved patient care,
  b) Correlating multiple parameters for clear demonstration of clinical problems,
  c) Processing the data to set alarms on the development of abnormal conditions,
  d) Providing information, based on automated data, regarding therapy
  e) Ensuring better care with fewer staff members.
- During a surgical operation, the patient is deprived of several natural reaction mechanisms, which normally restore abnormalities in his physical condition or alert other people.
- Indications or alarms that cannot be given by the patient himself can be presented by patient monitoring equipment.
- Besides this, in special cases, it is not uncommon for surgical procedures to last for several hours.
- During these lengthy operative procedures, it is difficult for the anaesthesiologist and the surgeon to maintain intimate contact with the patient’s vital signs and at the same time attend to anaesthesia, surgery, fluid therapy and many other details that are required under such circumstances.
- Also, when a patient is connected to a life-support apparatus, e.g. heart-lung machine or ventilator, correct functioning of these has to be monitored as well.
- A patient monitoring system thus better informs the surgeon and the anaesthesiologist of the patient’s condition.
- With patient monitoring systems, the risk that surgery involves has been considerably reduced since it is possible to detect the complications before they prove dangerous as suitable remedial measures can be taken well in time.
- The choice of proper parameters, which have a high information content, is an important issue in patient monitoring. It is, however, generally agreed that monitoring of the following biological functions is often needed.
- Electrocardiogram (ECG), heart rate (instantaneous or average), pulse rate, blood pressure (indirect arterial blood pressure, direct arterial blood pressure or venous blood pressure), body temperature and respiratory rate.

- In addition to these primary parameters, electroencephalogram (EEG), oxygen tension (pO2) and respiratory volume also become part of monitoring in special cases.
- In addition to these, equipment such as defibrillators and cardiac pacemakers are routinely needed in the intensive care wards.
- The general requirements for patient monitoring equipment have not changed much over the past few decades.
- However, today's equipment monitors more parameters and processes more information.
- Trends in monitoring include software control, arrhythmia monitoring, haemodynamics monitoring, monitoring during transportation of the patient and increased user friendliness.
- With more than 10 parameters to be monitored and scores of calculations to be made, the requirement for an easy-to-use user interface has assumed great significance.
- Monitoring is generally carried out at the bedside, central station and bedside with a central display.
- The choice amongst these is dependent upon medical requirements, available space and cost considerations.

4) How does a hemodialyser unit help in purification of blood? Explain with a block diagram. (May 2017)

Hemodialysis

- Hemodialysis, also spelled haemodialysis, or simply dialysis, is a process of purifying the blood of a person whose kidneys are not working normally.
- This type of dialysis achieves the extracorporeal removal of waste products such as creatinine and urea and free water from the blood when the kidneys are in a state of kidney failure.
- Hemodialysis is one of three renal replacement therapies (the other two being kidney transplant and peritoneal dialysis).
- An alternative method for extracorporeal separation of blood components such as plasma or cells is apheresis.

Medical uses

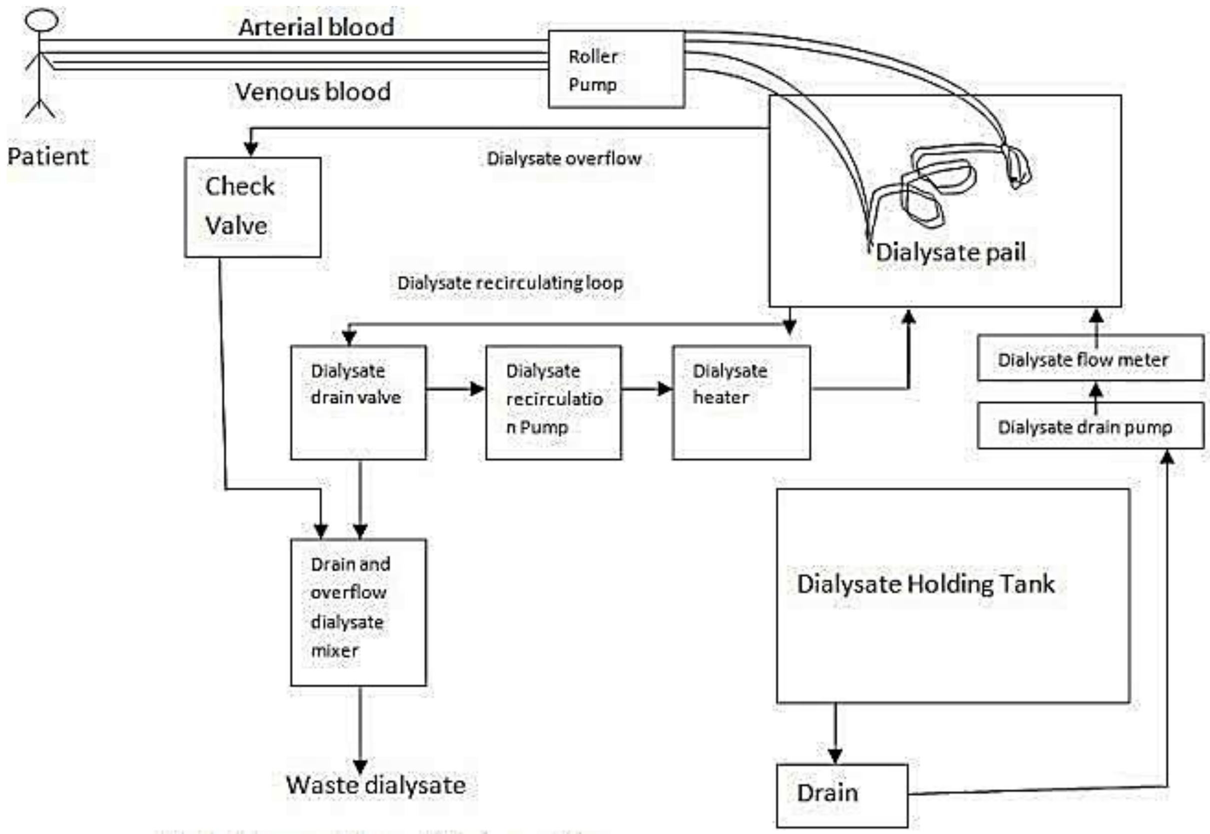
- Hemodialysis is the choice of renal replacement therapy for patients who need dialysis acutely, and for many patients as maintenance therapy. It provides excellent, rapid clearance of solutes.

Hemodialysis Machine Working

- The aim of hemodialysis machine is to replace the vital kidney functions. But in most cases this ‘artificial kidney’ cannot replace the vital kidney functions. But in most cases this ‘artificial kidney’ cannot replace the total kidney operation.
- The hemodialysis machine propels the patient’s blood and dialysate through a dialyzer.
- The newest dialysis machines on the marketplace are extremely automated and constantly check different parameters including blood flow rate, dialysate flow rate, dialysis solution conductivity, blood pH, temperature etc.
- Any evaluation that is out of usual range, triggers an easy to hear alarm to aware the patient care technician. An extensive water filtration system is totally fundamental for hemodialysis machine.
- If the water utilized amid dialysis method not carefully filtered, mineral contaminations or bacterial endotoxins can go into the patient's body to cause numerous health problems.
- Hence water utilized as a part of hemodialysis machine is precisely purified before utilize. At first it is filtered and temperature balanced and its pH is rectified by including an acid or base.
- Primary purification is finished by forcing water through a penetrable with very little pores. This membrane is called reverse osmosis membrane. This gives the water pass through and holds back even very small solutes. Once filtered water is blended with dialysate concentrate, its conductivity would increases.
- Amid dialysis the conductivity of dialysate solution is consistently checked to clear that the water and the dialysate concentrate are blended in proper proportions. The block diagram representation of a hemodialysis machine is shown in figure.

Hemodialysis Machine Block Diagram

- The blood is occupied from the artery of the patient and mixed with an anticoagulant such as heparin and forced into the equipment called artificial kidney or hemodialysis machine.



Block Diagram of Hemodialysis machine

Dialysate Pail

- Dialysate pail is the storage place of the dialysate.
- It is through the dialysate that the blood from the patient is directed to flow through channels or tubes bounded by cellophane membrane.
- This membrane is permeable to small solutes and impermeable to macromolecules.

Dialyzer

- Dialyzer is the major part of equipment that actually filters the blood. Dialyzer membranes have dissimilar pore sizes.
- Those with lesser pore size are called low flux membrane and those with bigger pore size are called high flux membranes.
- Dialyzer membranes used in made of cellulose. Another group of membrane is made from synthetic objects using polymers.

- Nanotechnology is used in some high flux membranes to produce uniform pore size. Dialyzers come in numerous dissimilar sizes.
- A bigger dialyzer with a bigger membrane can remove more solutes.

Dialysate Heater

- The dialysate should be kept at a proper temperature.
- The temperature is controlled by the dialysate heater.

Check Valve

- The function of dialysate check valve is to control the flow of dialysate to the dialysate pail.
- If the overflow condition of dialysate occurs, it will be directed by the check valve to the dialysate overflow and drain mixer where the dialysate will be mixed with the drained dialysate.
- The mixed component is thrown out as exhaust.

Dialysate Recirculating Loop

- This loop acts in such a way that the drained dialysate is reconverted into fresh dialysate and properly heated and redirected to the dialysate pail itself.
- The dialysate may moreover be discarded after each action or be used again. Reused dialyzers are not shared between patients.
- If the reuse of dialyzers is finished cautiously and properly it will produce similar outcomes to a single use of dialyzers.

Dialysate Holding Tank

- The dialysate holding tank holds the fresh dialysate and whenever the dialysate of the pail has to be changed, the fresh dialysate from the holding tank is taken to the pail.

Flow Meter

- In order to regulate the flow of fresh dialysate from the dialysate holding tank to the dialysate pail, we normally use a flow meter in the machine set up.

Disadvantages

- Restricts independence, as people undergoing this procedure cannot travel around because of supplies' availability
- Requires more supplies such as high water quality and electricity
- Requires reliable technology like dialysis machines
- The procedure is complicated and requires that care givers have more knowledge
- Requires time to set up and clean dialysis machines, and expense with machines and associated staff.

Complications

- First-use syndrome
- Fluid shift
- Access related
- Venous needle dislodgement
- Anticoagulation related
- Cardiovascular
- Vitamin deficiency
- Electrolyte imbalances

5) (a) Explain the working of any two types of oxygenators. (Nov/ Dec 2017)
(b) Describe the types of oxygenators. (April/ May 2018)

OXYGENATORS

- An oxygenator is a medical device that is capable of exchanging oxygen and carbon dioxide in the blood of human patient during surgical procedures that may necessitate the interruption or cessation of blood flow in the body, a critical organ or great blood vessel.
- A heart-lung machine is connected to the heart by drainage tubes that divert blood from the venous system, directing it to an oxygenator. The oxygenator removes carbon dioxide and adds oxygen to the blood, which is then returned to the arterial system of the body.
- Oxygenators not only supply vital oxygen for the blood, but also transport carbon dioxide, anaesthetics and other gases into and out of the circulation. In ideal oxygenators the following conditions are required:
    a. Lower priming volume
    b. Minimum trauma to blood
    c. Simple, safe and reliable operation
    d. Ensured sterilization
    e. No microembolus formation and

f. Short preparation time

- There are four types of oxygenators. They are:
  - Bubble Oxygenators
  - Film Oxygenators

    Divided into following 4 types
    - Rotating disc film type
    - Foam oxygenator
    - Blood film over sponge
    - Screen oxygenator
  - Liquid-Liquid Oxygenators
  - Membrane Oxygenator

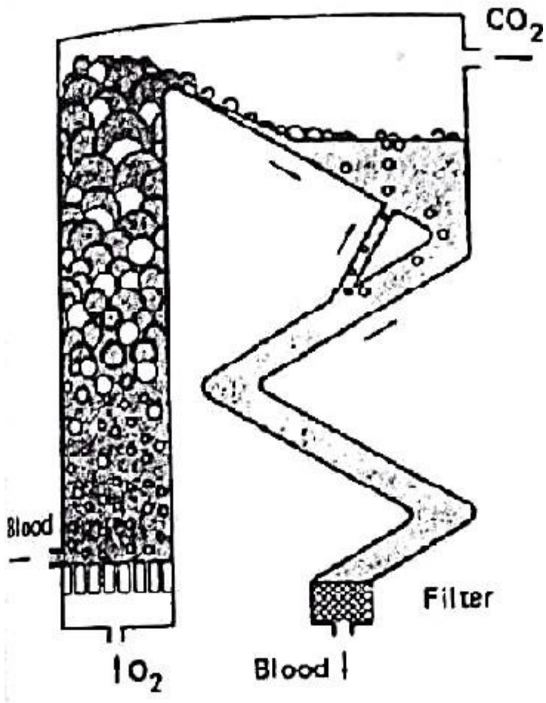
(A) <u>BUBBLE OXYGENATOR</u>

Principle

- By bubbling the oxygen through a large column of blood and the making the flow of blood through a slanting path, the carbon di oxide is removed from the blood.

Working

- There are two major components. In one component, oxygen is bubbled through the blood in a finely dispersed form.
- In the other component called gas separating component, gaseous exchange is taking place. Meanwhile the bubbles and foam are removed.
- The existence of bubbles in blood causes air emboli. To remove bubbles, beads, sponges, meshes and fabrics coated with defoaming agent like silicon is used.
- The surface tension of bubbles is reduced by the silicon and hence it causes the bubbles to break. There are also permanent and disposable oxygenators.



Bubble Oxygenator

Features

1. The oxygenators is effective because of the large surface area. But large surface area leads to pronounced foaming and damage to the red cells. Therefore these are suitable only for short operations.
2. It is the simplest among the different oxygenators.
3. Due to the mechanical strees introduced by the bubbles, trauma produced in it is the highest.
4. In the case of disposable unit, except the long preparation time and expensive material cost, we can get cleaniness, sterility, simplicity and inexpensive manpower cost. But in the case of permanent unit, except the difficulty in cleaning and expensive manpower cost, we can get shorter preparation time and inexpensive material cost.

(B) FILM OXYGENATOR

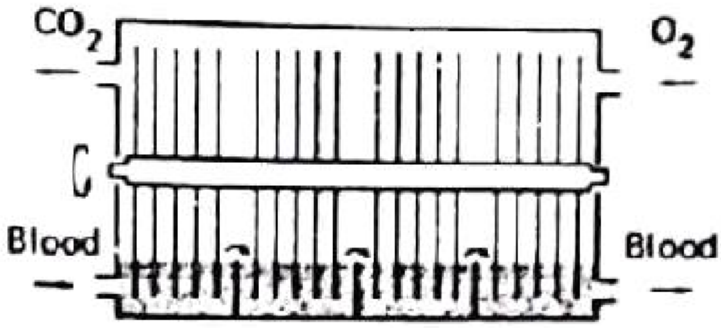
Principle

- Here the thin film of blood is spread on a rotating disc or metal screen and an oxygen mixture flows over this thin layer of blood.

Working

There are several types in this oxygenator.

(i) <u>Rotating disc film type oxygenator</u>



<u>Film Oxygenator (Disc Type Oxygenator)</u>

- A horizontal cylinder in which a number of discs are mounted on a central axis. In the above figure rotating discs are shown as vertical line.
- A blood level is maintained at the hollow of the cylinder so that only the outer edge of the disc is immersed in the blood.
- Rotation of the central axis of the cylinder causes a thin blood film to form on the periphery of the discs.
- After a short exposure to oxygen which is filled in the oxygenator housing, the blood is washed off from the discs.
- At the same time a new blood film is formed on the same disc. This new film is also washed off at the next revolution.
- Since the cylinder is rotated at 120 RPM the exposure time of the blood film with the oxygen atmosphere is only 0.5 seconds.

Features

1. These are difficult to clean
2. Trauma produced in these are very small.
3. Effective oxygenation can be done.

(ii) <u>Foam oxygenator</u>

- Blood is poured over the top of the blood foam.

- The oxygen mixture is bubbled through the blood in the opposite direction.
- The blood is spreading over the surface of the bubble in a thin film form and effectively it is exposed to oxygen.
- The filmed blood is oxygenated while falling down. Defoaming is done afterwards.

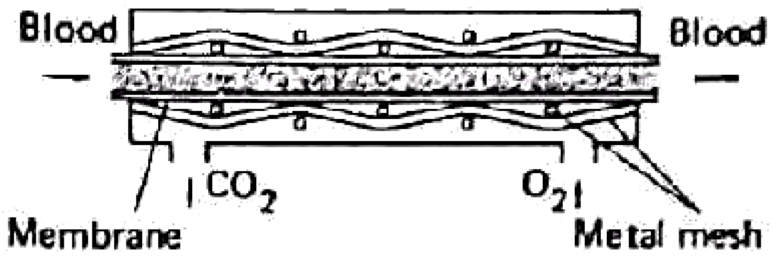
(iii) Blood film over sponge

- A small volume of sponges saturated with blood provides a large surface area for blood oxygenators if oxygen is simultaneously distributed in the sponge.
- It is called artificial alveoli.

(iv) Screen oxygenator

- A thin film of blood is over a screen (stationary or rotating) is exposed to oxygen for oxygenation.
- This causes less trauma to blood.
- Disposable units are also available in this type.

(C) MEMBRANE OXYGENATOR



Membrane oxygenator

Principle

- Effective oxygenation is obtained when oxygen and blood are running in opposite direction through a thin porous membrane.

Working

- The blood flows on one side of a membrane permeable to gas and oxygen flows on the other side of it.

- The membrane is made of microporous polyethylene which has higher permeability for oxygen. Silicone rubber is also rarely used.
- Here the carbon di oxide transport is limited by the permeability of the membrane. Further the oxygen transport is also limited by the thickness of the blood layer.

Features

1. These are so expensive and hence these are not commonly used.
2. Trauma produced in these oxygenators is very small which we compare it with others. This is due to the advantage that the blood does not come into direct contact with the oxygen mixture. Therefore bubbles and form do not form.
3. These are very difficult to clean.

(D) LIQUID-LIQUID OXYGENATOR

Liquid-Liquid Oxygenator

Principle

- The oxygen dissolved fluoridised organic fluid and blood are flowing in the opposite directions and oxygenation of the blood takes place.

Working

- Fluoridizes organic liquid is the working liquid which readily dissolves oxygen and carbondioxide which then diffuse to and from the blood respectively.
- Eventhough the blood is in direct contact with the working liquid, it is entirely a different chemical compound with respect to the blood constituents and so there is no chemical reaction between them.
- During their opposite flow through a small tube, gaseous exchange takes place.

Features

1. No trauma is produced.
2. Effective oxygenation can be required.

6) Explain the principle, recording and clinical application of thermography. (Nov/ Dec 2017)

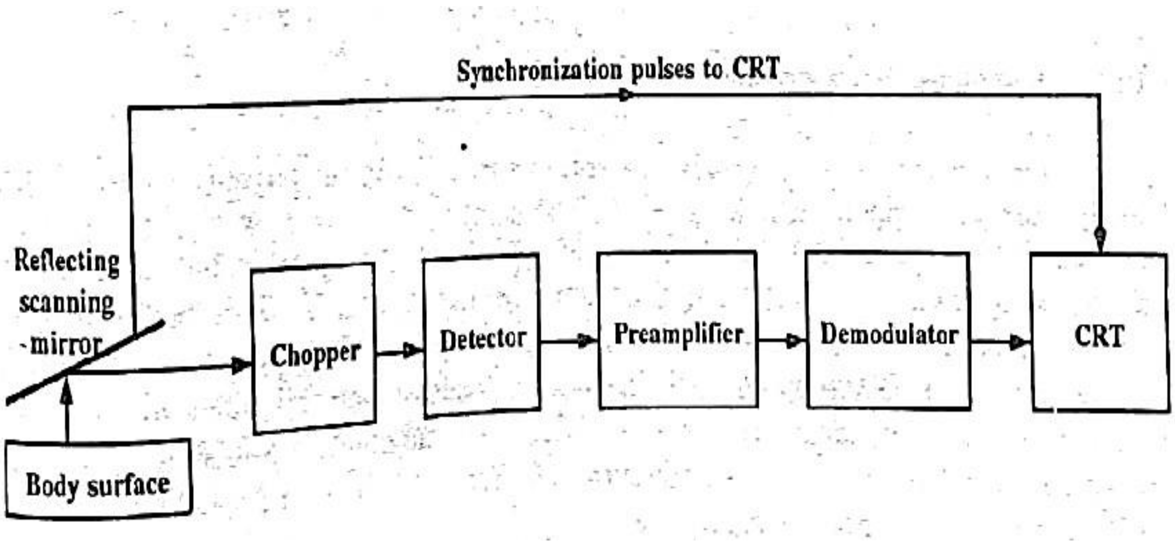
THERMOGRAPHY=PRINCIPLE

- Medical Thermography (digital infrared thermal imaging – DITI) is used as a method of research for early pre-clinical diagnosis and control during treatment of homeostatic imbalances.
- There are few devices, which operate in a passive method like infrared Thermography medicine; amongst these are the ECG and EEG.
- The intrinsic safety of this method makes infrared Thermography free from any limitations or contra- indications.
- Thermography is a non-invasive, non-contact tool that uses the heat from your body to aid in making diagnosis of a host of health care conditions. Thermography is completely safe and uses no radiation.
- Medical Thermography equipment usually has two parts, the IR camera and a standard PC or laptop computer. These systems have only a few controls and relatively easy to use.
- Monitors are high-resolution full colour, isotherm or grey scale, and usually include image manipulation, isothermal temperature mapping, and point-by-point temperature measurement with a cursor or statistical region of interest.
- The systems measure temperatures ranging from 10° C – 55° C to an accuracy of 0.1° C. Focus adjustment should cover small areas down to 75 x 75mm.
- These systems are PC based and therefore able to store tens of thousands of images (and these images may be retrieved for later analysis).
- The ability to statistically analyse the thermograms at a later date is very important in clinical work.
- Copies of images can easily be sent (via e-mail, floppy disk, etc.) to referring doctors or other healthcare professionals.
- The medical applications of DITI are extensive, particularly in the fields of Rheumatology, Neurology, Oncology, Physiotherapy and sports medicine.

- Thermal imaging systems are an economical easy-to-use tool for examining and monitoring patients quickly and accurately.
- Utilising high-speed computers and very accurate thermal imaging cameras, the heat from your body is processed and recorded in the computer into an image map which can then be analyzed on screen, printed or sent via email.
- A doctor can then use the image map to determine if abnormal hot or cold areas are present. These hot and cold areas, can relate to a number of conditions for which the Food and Drug Administration, Bureau of Medical Devices has approved the thermography procedure.
- These include, the screening for breast cancer, extra-cranial vessel disease (head and neck vessels), neuro-musculo-skeletal disorders and vascular disease of the lower extremities.
- There have been a number of advancements in the past decade, which has brought thermal imaging in medicine back to the forefront of diagnosis. As technology has advanced, so has our “medical” concept of thermal imaging.

RECORDING OF THERMOGRAPHY

- The following figure shows the simplified block diagram of thermographic equipment. Every thermographic equipment is provided with a special infrared camera that scans the object and a display unit for displaying the thermal picture on the screen.
- The camera contains an optical system in the form of an oscillating flat plane mirror which scan the field of view at a very high speed horizontally and vertically and focuses the collected infrared radiation onto the chopper.
- The chopper disc interrupts the infrared beam so that a.c signals are produced and amplified and demodulated further.



Block diagram description of thermography equipment

- The demodulated signals are given to the cathode ray tube in synchronization with scanning mechanism.
- The signals are displayed on the screen by intensity modulation which controls brightness and contrast with the strength of the signal.

CLINICAL APPLICATIONS OF THERMOGRAPHY

Breasts pathologies

- Probably the most applied area of Medical Thermography – breast cancer, benign tumours, mastitis, and fibrocystic breast disease.
- The utilization of thermography as a screening tool in the detection of breast cancer has been for the past decade a very controversial topic within the health care community.
- However, the technology has gained in scientific acceptance, has been approved for screening purposes and is clearly a powerful tool in the war on breast cancer.
- The concept is quite simple. Thermography measures the heat coming from your body. Metastatic cancers create heat which can be imaged by digital infrared imaging. This is due to two separate yet connected factors.
- The first is the metabolic activity of the tumour tissue as compared with the temperature of tissue adjacent to the tumour, and in the opposite breast.
- By comparing the breast in question with the normal breast which acts as the patient's own control, abnormal heat signatures associated with the metabolism of the tumour can be detected easily. These differences in temperature are referred to as a Delta T.

- The second method of detection is due to the angiogenesis of the tumour. I.e. Cancerous tumours produce a chemical which actually promotes the development of blood vessels supplying the area where the tumour resides.
- Also, normal blood vessels which are under the control of the sympathetic nervous system are essentially paralyzed, causing vaso-dilation, or an increase in size of the blood vessel.
- The increase in blood in the region due to angiogenesis and combined with the vaso-dilation simply means more heat, recordable with thermal imaging procedures.

Extra-Cranial Vessel Disease

- In a similar way, a variety of conditions which relate to flow of blood through the vessels of the neck and head are readily accessed with thermal imaging.
- As the blood vessels in the face and skull are coursing through very thin tissue between the bones of the skull and the skin covering the skull, they are readily and easily visualized with thermal imaging.
- As the vessels of the neck are very large calibre vessels, they too are very easily visualized with thermography and clues to the potential of developing vascular disease which might lead to stroke are a consideration when performing thermography.
- The use of thermography in differentiation of various types of headache (migraine, cluster, cervical spine related), facial nerve injury as in the case of a blow to the face or a car accident where the face contacts a windshield or the steering wheel, the visualization of TMJ disorders (tempero-mandibular joint) are commonly used aspects of thermographic diagnosis and analysis of the head and neck.
- The ability of thermal imaging to safely indicate the heat from sources in the jaw and teeth is providing a very exciting opportunity to screen individuals for dental decay and cavitations without routine screening x-rays.
- Also, a number of patients have been seen with heat signatures in the jaw related to amalgam fillings which might be toxic for that particular patient. This area of thermal imaging is very promising.

Neuro-Musculo-Skeletal

- This is one of the clearest examples of thermography's ability to accurately diagnose patients with a host of back, neck and extremity disorders.

- When muscle tissue is strained or torn, it releases chemicals which cause increased heat. This can be seen as intense patterns of hyperthermia in the region of the muscle, or trigger point, as in the case of fibromyalgia.
- Heat patterns can also be seen in the legs and soles of the feet which indicate altered gait or weight bearing mechanics, which might relate to a low back or foot condition.
- Further, back strain produces very consistent heat patterns which not only tell us about the source of probable spinal injuries, but can also tell us about areas of spinal compensation,
- In effect, a low back might be being treated by a chiropractor, when the mid back or neck is actually the source of the problem.
- Nerve damage, as occurs in disc herniation and spinal nerve root compression displays on the thermographic map in exactly the opposite direction as muscle injury by revealing cool areas of hypothermia in the nerve tracts coming from the spine. In this way, thermography can demonstrate and document permanency of spinal injuries which are causing a person disability.

Other areas where medical Thermography is successfully applied:

- Respiratory dysfunctions
- Digestive disorders
- Urinary diseases
- Nervous dysfunctions
- Endocrine Disorders
- Surgical Assistance
- Skin Problems
- Ear, Nose, and Throat dysfunction
- Dentistry

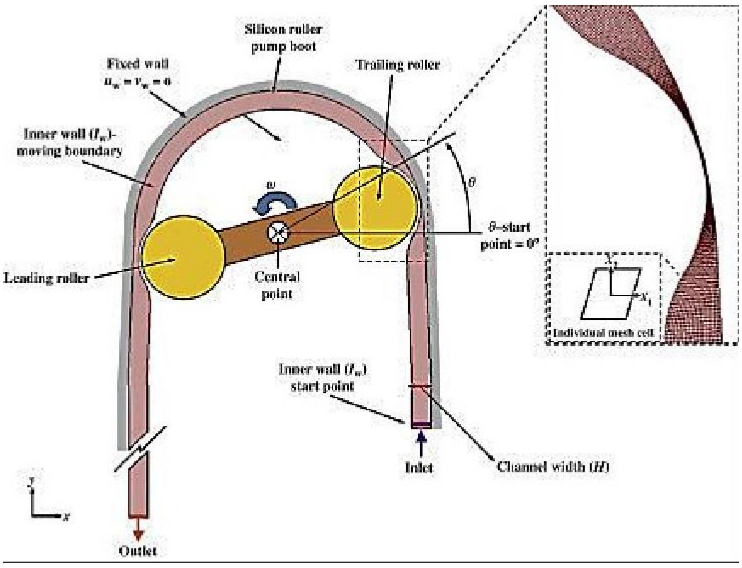
7) Write note on finger pump and roller pump. (May 2019)

<u>FINGER PUMP</u>

- Finger pumps push a series of rods against a flexible tubing in sequence, forcing fluid along the tube. In this pump the fluid moves from left to right.
- Since nothing but the tube actually touches the fluid, the fluid can be kept clean so this pump is often found in medical applications, pumping blood or other fluids.
- The individual fingers can be operated by a rotating camshaft above them, by individual solenoids electronically actuated in sequence, or by other methods.

ROLLER PUMP

- The roller pump comes under the category of positive displacement pumps and has been the most commonly used pump for CPB for the past 50 years.
- The golden era of this pump is passing due to developments in systems using radial (centrifugal) pumps. The roller pump contains a tubing placed inside a curved wall. This wall is located at the travel perimeter of rollers installed on the ends of rotating arms.
- One of these arms always compresses the tubing at all times. The blood is pushed ahead by this compression and the moving roller, which produces continuous blood flow.
- The output of the rotary pump is determined by the frequency of rotation or revolutions per minute (RPM) of the pump.
- The volume of pumped blood depends on the size of the tubing, the length of the track and the RPM of motor.
- The roller pumps are categorized as single, double and multiple roller pumps. The single roller pumps were used for CPB in the middle of the 20^{th} century.
- The flow in this type was more pulsatile. The most commonly used pump for CPB is the double-roller pump. This pump consists of a 210° semicircular support plate and two rollers with the rotating arms set 180° apart.
- When one roller ends its operational phase, the second roller has already begun its phase. Due to hemolysis issues, the third type (multiple roller pump) is not clinically available. The following figure shows a schematic of a roller pump (pumping chamber).
- As the figure shows, there are two rollers (leading and trailing). The central point of rotation is connected to an electric motor which controls the speed of rotation and the blood flow rate of the blood pump.
- Compressing of the tube by the rollers leads to an increasing hemolysis (blood cell damage) which is an important issue for patients (see Fig. below).



Schematic of a roller pump operation

- There are three materials currently used for tubing in the medical device industry: silicone; latex and polyvinyl chloride (PVC).
- Regarding microparticle releasing, the PVC is the best material for tubing because the latex generates more hemolysis and the silicon tube releases more microparticles than the PVC. One of the common problems in blood pumps is the tube occlusion.
- Occlusion can be controlled by either increasing or decreasing the compression of the tube by the rollers and the optimization between increasing and decreasing the compression is very vital in pumping the blood, because more compression increases hemolysis and less generates occlusion, although the priority is with forward output of the blood.
- Selection of these pumps depends on several factors such as flow rate, pressure, rate of hemolysis, operation time, etc. The blood flow rate and pressure (pump head) are the most important aspects among pump features.

Advantages

- No contamination. Because the only part of the pump in contact with the fluid being pumped is the interior of the tube, it is easy to sterilize and clean the inside surfaces of the pump.
- Low maintenance needs and easy to clean; their lack of valves, seals and glands makes them comparatively inexpensive to maintain.
- They are able to handle slurries, viscous, shear-sensitive and aggressive fluids.

- Pump design prevents backflow and siphoning without valves.
- A fixed amount of fluid is pumped per rotation, so it can be used to roughly measure the amount of pumped fluid.

Disadvantages

- The flexible tubing will tend to degrade with time and require periodic replacement.
- The flow is pulsed, particularly at low rotational speeds. Therefore, these pumps are less suitable where a smooth consistent flow is required. An alternative type of positive displacement pump should then be considered.
- Effectiveness is limited by liquid viscosity

Applications

- Peristaltic pumps are typically used to pump clean/sterile or highly reactive fluids without exposing those fluids to contamination from exposed pump components.
- Some common applications include pumping IV fluids through an infusion device, apheresis, highly reactive chemicals, high solids slurries, and other materials where isolation of the product from the environment are critical.
- They are also used in heart-lung machines to circulate blood during a bypass surgery, and in hemodialysis systems, since the pump does not cause significant hemolysis, or rupture of the blood cells

Typical application

- Peristaltic pump used in chemical treatment process of a water purification plant
- Medicine
- Dialysis machines
- Open-heart bypass pump machines
- Medical infusion pumps
- Testing and research
- AutoAnalyzer
- Analytical chemistry experiments
- Carbon monoxide monitors
- Media dispensers

8) Discuss the principle of oximetry. With suitable diagrams explain transmission and reflection type pulse-oximetry. (Nov/ Dec 2018)

OXIMETRY

- Oximetry refers to the determination of the percentage of oxygen saturation of the circulating arterial blood.
- By definition:

$$\text{Oxygen saturation} = \frac{[HbO_2]}{[HbO_2] + [Hb]}$$

- Where [HbO2] is the concentration of oxygenated haemoglobin [Hb] is the concentration of deoxygenated haemoglobin.
- In clinical practice, percentage of oxygen saturation in the blood is of great importance. This saturation being a bio-constant, is an indications of the performance of the most important cardio-respiratory functions.
- It is maintained at a fairly constant value to within a few percent in an healthy organism.
- The main application areas of oximetry are the diagnosis of cardiac and vascular anomalies; the treatment of post-operative anoxia and the treatment of anoxia resulting from pulmonary affections.
- Also, a major concern during anaesthesia is the prevention of tissue hypoxia, necessitating immediate and direct information about the level of tissue oxygenation.
- Oximetry is now considered a standard of care in anaesthesiology and has significantly reduced anaesthesia-related cardiac deaths.

PULSE OXIMETRY

- Pulse oximetry is based on the concept that arterial oxygen saturation determinations can be made using two wavelengths, provided the measurements are made on the pulsatile part of the waveform.
- The two wavelengths assume that only two absorbers are present; namely oxyhaemoglobin (HbO2) and reduced haemoglobin (Hb). These observations, proven by clinical experience, are based on the following:

(i) Light passing through the ear or finger will be absorbed by skin pigments, tissue, cartilage, bone, arterial blood, venous blood.

(ii) The absorbances are additive and obey the Beer-Lambert law:

$$A = -\log T = \log I_0 / I = \varepsilon D C$$

Where

Io and I are incident and transmitted light intensities,

e is the extinction coefficient,

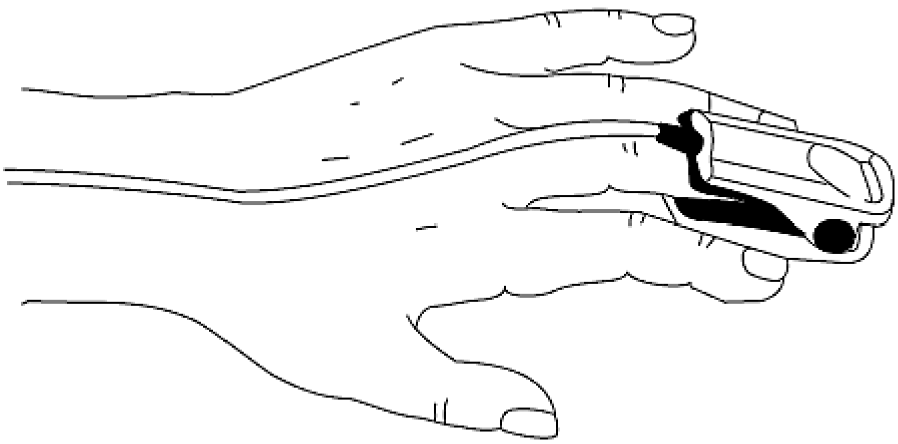
D is the depth of the absorbing layer

C is concentration.

(iii) Most of the absorbances are fixed and do not change with time. Even blood in the capillaries and veins under steady state metabolic circumstances is constant in composition and flow, at least over short periods of time.

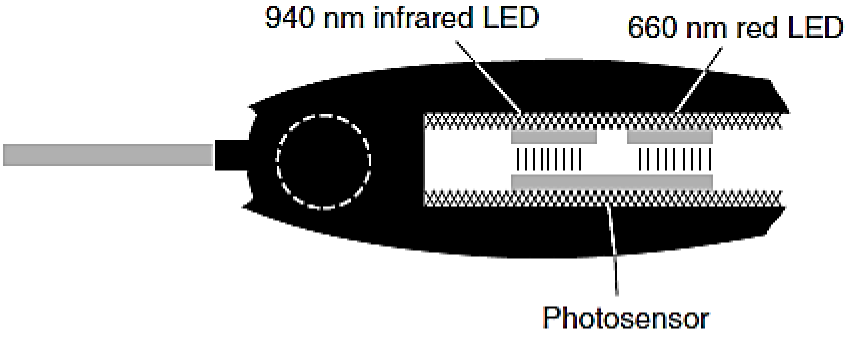
(iv) Only the blood flow in the arteries and arterioles is pulsatile.

- Therefore, only measuring the changing signal, measures only the absorbance due to arterial blood and makes possible the determination of arterial oxygen saturation (SaO2).
- This is uninfluenced by all the other absorbers which are simply part of the constant background signal.
- Figure below shows a typical finger-tip oximeter probe in use.



A typical finger-tip pulse oximeter probe in use

- Figure below shows the construction of a typical pulse oximeter probe.



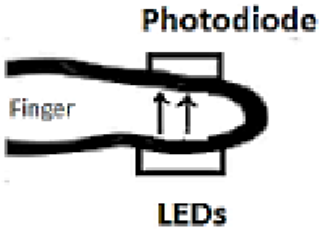
Components of a pulse oximeter probe

- This has two LEDs (light emitting diodes), one that transmits infrared light at a wavelength of approximately 940 nm and the other transmitting light at approximately 660 nm.
- The absorption of these select wavelengths of light through living tissues is significantly different for oxygenated haemoglobin (HbO2) and reduced haemoglobin (Hb).
- The absorption of these selected wavelengths of light passing through living tissue is measured with a photosensor.
- The red and infrared LEDs within the probe are driven in different ways, depending on the manufacturer. Most probes have a single photodetector (PIN-diode), so the light sources are generally sequenced on and off.

TYPES OF PULSE OXIMETER PROBES

- Currently, the 2 basic types of pulse oximeter probes are transmission probes and reflectance probes.

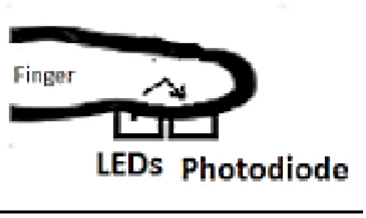
TRANSMISSION MODE



Transmission mode

- With transmission probes, the light emitter and sensor are placed opposite each other on pulsatile tissue such as a digit or ear.
- The lights used to measure tissue oxygenation are typically placed across from a detector surrounding approximately 5-10 mm of tissue that contains pulsatile blood flow, such as a fingertip or ear lobe.

REFLECTANCE MODE



Reflectance mode

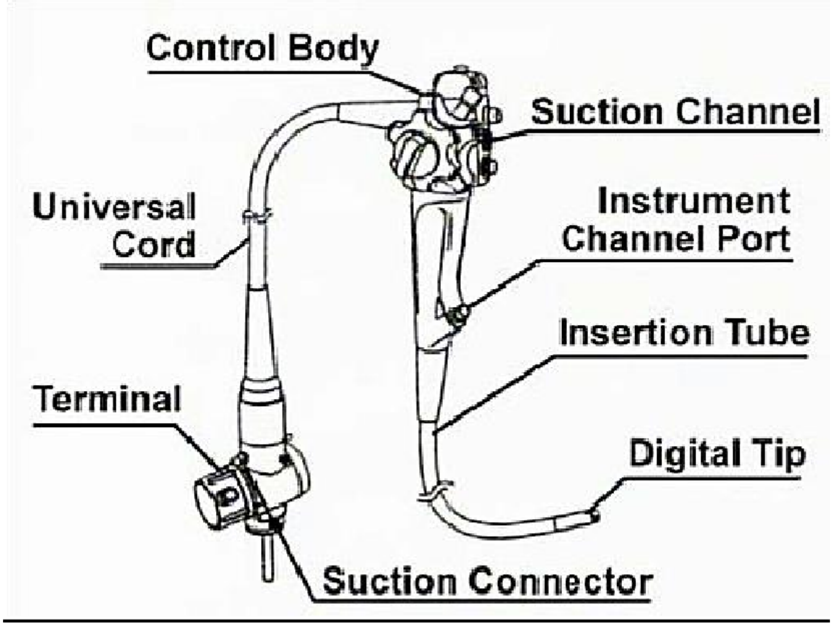
- With reflectance probes, the light emitter and sensor are placed side by side on a flat body surface.
- The detector lies adjacent to the light source on a flat surface such as the forehead. This information can be used noninvasively to help evaluate the hemodynamic status of a patient and to detect hypoxemia in various clinical settings.

9) With neat diagram explain the components of an endoscopy. (Sep 2020)

ENDOSCOPES

- Essentially, an endoscope may be described as a long, thin illuminated flexible tube that has a camera on one end.
- Today, the endoscope has become of the most important devices in medicine serving to view the inside of body cavities.
- Although endoscopes are usually inserted through such openings as the mouth and the rectum, they are also inserted into the body through small incisions on the skin particularly during keyhole surgery (minimal invasive surgery).

PARTS OF ENDOSCOPE



General Flexible Endoscopes

- A standard endoscope in composed of the following parts:
  - A thin, long flexible tube
  - A lens or lens system
  - A light transmitting system
  - The eyepiece
  - Control system

WORKING OF ENDOSCOPE

- Basically, a typical endoscope uses fiber optics, which allow for effective transmitting of light. In this technique (fiber optics) light is transmitted through a flexible fiber of glass (transparent) known as optical fiber(s).
- The optical fiber allows for light to travel through curved paths, which makes one of the best systems to view spaces that would normally be difficult to reach.
- Here, total internal reflection makes it possible for light to travel along the fibers with the light rays hitting the fiber walls at an angle (minimum angle of 82 degree).
- Given that individual fibers can be thinner than human hair, fiber optics is one of the best techniques to enter and view different areas of the body. There are typically two sets of the fibers.

- These include the outer fiber that functions to supply light and an inner coherent ring that serves to transmit the image.

The outer fiber

- This fiber contains a number of fibers that have been bundled together in no particular order. It is for this reason that the outer fiber is commonly referred to as the incoherent bundle.
- The fiber is entirely enclosed with a sleeve to protect it. Typically, it is coated with either plastic or steel which protects it from water or moisture (making it waterproof).

Inner fiber

- Like the outer fiber, the inner bundle is also composed of a bundle of fibers. However, unlike the outer bundle, the inner fiber is in perfect order, which is why it is referred to as the coherent bundle.
- The tiny lens connected to the end of this bundle allows for light to be effectively focused so that reflected light from the object of interest can be collected and transmitted for viewing.

OTHER IMPORTANT PARTS

- **Water pipes** - The pipes serve to carry water which is used to wash the lens thereby maintaining a clear view.
- **The operational channel** - This is an opening on the device that is used to move various accessories to the distil end (of the endoscope) for surgery purposes.
- **Control cables** - This is used to control the direction that the distil end will bend as it moves through body cavities.

NEW ENDOSCOPE TECHNOLOGIES

(a) Wireless Capsule Endoscopy

- Capsule endoscopy is one of the new procedures that involve the use of a very small wireless camera to take pictures in the digestive system.
- For this procedure, one swallows a capsule the size of vitamin-sided capsule or a large pill. The technology involves the use of a wireless miniature encapsulated camera that takes pictures as the capsule travels through the digestive system.

- As it travels down the digestive system, the capsule wirelessly transmit the images it captures which can then be used to detect any issues in the digestive tract.
- The images (it can take thousands of images) are then transmitted to a recorder from which they can be retrieved. Like ingested food, the capsule travels through the digestive system and ultimately leaves the body when the individual passes stool.

The main components of capsule endoscopy include:

- **Sensor array (electrodes)** - The patient wears this around the abdomen area like a sensor belt
- **Data recorder** worn by the patient and connected to the electrodes
- **The capsule** that is 26mm by 11mm in size - Some of the components of the capsule include; a lens, diodes (that emit light) a semi-conductor, an antenna as well as a transmitter.
- Since its approval by the FDA in 2001, capsule endoscopy has been shown to be an effective procedure with a number of advantages that include:
    - painless
    - disposable
    - non-invasive

(b) Confocal Laser Endomicroscopy and Endocytoscopy

- These are some of the new procedures aimed at enhanced high resolution in the assessment of gastrointestinal mucosal histology at both the cellular and sub- Basically, the technique is based on the principle of illuminating the tissue of interest with low power laser which in turn allows for the detection of fluorescent light that is reflected from the tissue.
- With this procedure, it becomes possible to carry out in vivo examinations with images being displayed in real-time.
- It has been shown to be particularly beneficial in the detection of abnormal growth of tissue in conditions like ulcerative colitis.

USES OF ENDOSCOPES

Although endoscopy is largely used for the purposes of examining a patient's digestive tract, endoscopes are also used for:

- Arthroscopy
- Bronchoscopy
- Endoscope Biopsy
- Laparoscopy

10) Explain the functioning of lithotripter system with neat diagram. (Sep 2020)

Lithotripsy

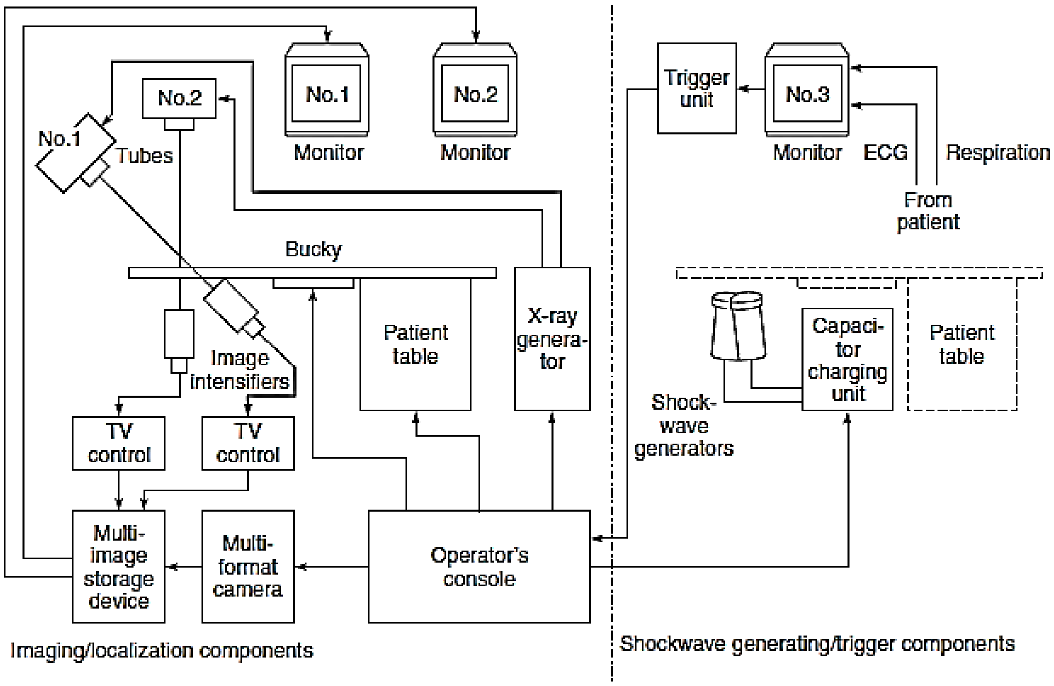
- Lithotripsy is a procedure that uses shock waves to break up stones in the kidney and parts of the ureter (tube that carries urine from your kidneys to your bladder). After the procedure, the tiny pieces of stones pass out of your body in your urine.

Modern Lithotriptor system

- First generation electro-hydraulic lithotriptors had several major disadvantages. The early machines were relatively expensive to install and operate, and required dedicated facilities and treatment.
- Besides, using the systems was painful and required general anaesthesia, which resulted inprolonged in-patient stays and higher overall costs. Modern machines incorporate clinical advantages over their predecessors.
- The integration of a variety of reflector sizes and control over voltage and power output allows for greater ease of use as well as customization of treatment parameters for increased treatment efficiency and decreased discomfort for the patient.
- Shock-wave lithotripsy machines currently in the market vary in terms of several operational factors such as the energy source, the focusing system and stone localization system.
- In general, the main components of a lithotriptor system are:
    - Focused shock-wave source;
    - Means for acoustic coupling of the shock-wave to the body;
    - Imaging modalities for stone localization and therapy control;
    - A patient table with either the table or the shock-wave source movable in three dimensions;
    - System for the measurement of physiological variables and their monitoring; and

- Trigger generation and control system.

➢ Figure below shows the schematic diagram of a lithotriptor system:



Schematic diagram of a lithotriptor system with biplane X-ray imaging

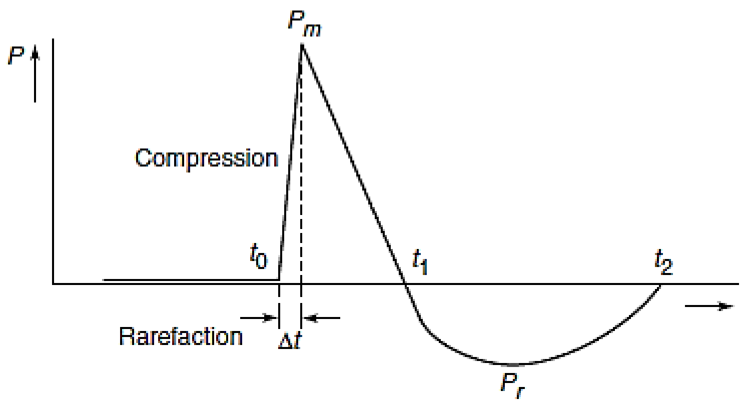
Focused shock-wave source

➢ Focused acoustic shock-waves are necessary for extra-corporeal lithotripsy for which focal pressures of 10 to 100 Megapascal (100-1000 bars) acting in a cigar-shaped focal volume with a across-sectional diameter of approximately 2 to 8 mm and a length of about 25 to 50 mm, are required depending on the design of the particular device.

➢ These shock-waves are generated by an emitter outside the body and transmitted as pulsed longitudinal waves through a fluid coupling medium and the body tissue to the target, the concrement to be destroyed.

➢ Shock-waves are unharmonic and non-linear acoustic phenomena, characterized by an extremely steep change in pressure amplitude, the shock front.

➢ It is generally accepted that an ideal shock-wave for extracorporeal lithotripsy shows a shock front only in the compressional part of the pulse up to a peak pressure, followed by decay (Fig. below).



Schematic of an acoustic shock-wave pulse

- Due to general physical principles, this compression is accompanied by a rarefaction. The characteristic parameters of the shock-wave are the peak value of the pressure and duration of compression and rarefaction, and the rise time of pressure Delta t.
- In order to achieve the best results, the shock-wave must be developed with a sufficiently high positive pressure amplitude and a low negative-pressure amplitude.
- Shock-waves in lithotripsy need to be strongly focused in order to keep the area of interaction with tissue or concrements restricted to the pre-determined region of interest. Any tissue in front of, behind or adjacent the target area should be left unaffected.
- The technical answer to this medical requirement is to use large aperture systems which spread the shock-wave energy over a wide skin entrance area.
- Simultaneously, the system concentrates the acoustic energy precisely to a small focal volume with a cross-sectional diameter of a few millimeters.
- Modern systems use aperture angles of 80 to 90 degrees to provide these favourable field parameters. Depending on the type of indication, focal distances up to 16.5 cm are available for the treatment of deeply lying structures like the kidney and ureteral stones.
- To-date there is no standard to define the ‘strength’ of shock-waves. However, for comparison and dosage purposes, the ‘energy flux density’ measured by milli joule per mm2 (mJ/mm2) turns out to match fairly well with clinical efficiency.
- Of clinical importance is the ability of shock-wave devices to precisely adjust the delivered shock-wave energy.
- Electro-hydraulic or spark gap technology cannot provide shock-wave pulses of precisely defined energy due to the statistical nature of spark gap formation.

- Peak focal pressures of spark gap systems may show a pulse to pulse variability exceeding 50% whereas a state-of-the-art electromagnetic system provides a repetition accuracy better than 3%.
- The three basic types of shock-wave sources for lithotripsy are:

  1. Plasma explosion method;
  2. Electromagnetic system;
  3. Piezo-ceramic system.

- These excitation sources are coupled with the following focusing methods:

  (a) Ellipsoidal reflector;

  (b) Focusing with an acoustic lens; and

  (c) Self-focusing source.