VOLUME 1

EE1416: Biomedical Instrumentation & it's Application

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MESSAGE / MESSAGES

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ACKNOWLEDGMENTS

Unit-1

Q1: What factors should be considered to design a medical instrumentation system?

In the design or specification of medical instrumentation systems, each of the following factors should be considered.

1.Range

The range of an instrument is generally considered to include all the levels of input amplitude and frequency over which the device is expected to operate. The objective should be to provide an instrument that will give a usable reading from the smallest expected value of the variable or parameter being measured to the largest.

2. Sensitivity

The sensitivity of an instrument determines how small a variation of a variable or parameter can be reliably measured. This factor differs from the instrument's range in that sensitivity is not concerned with the absolute levels of the parameter but rather with the minute changes that can be detected. The sensitivity directly determines the resolution of the device, which is the minimum variation that can accurately be read. Too high a sensitivity often results in nonlinearities or instability. Thus, the optimum sensitivity must be determined for any given type of measurement. Indications of sensitivity are frequently expressed in terms of scale length per quantity to be measured—for example, inches per microampere in a galvanometer

coil or inches per millimeter of mercury. These units are sometimes expressed reciprocally. A sensitivity of 0.025 centimeter per millimeter of mercury (cm/mm Hg) could be expressed as 40 millimeters of mercury per centimeter.

3. Linearity

The degree to which variations in the output of an instrument follow input variations is referred to as the linearity of the device. In a linear system the sensitivity would be the same for all absolute levels of input, whether in the high, middle, or low portion of the range. In some instruments a certain form of nonlinearity is purposely introduced to create a desired effect, whereas in others it is desirable to have linear scales as much as possible over the entire range of measurements. Linearity should be obtained over the most important segments, even if it is impossible to achieve it over the entire range.

4. Hysteresis

Hysteresis (from the Greek, hysterein, meaning “to be behind" or “to lag") is a characteristic of some instruments whereby a given value of the measured variable results in a different reading when reached in an ascend-ing direction from that obtained when it is reached in a descending direction. Mechanical friction in a meter, for example, can cause the movement of the indicating needle to lag behind corresponding changes in the measured variable, thus resulting in a hysteresis error in the reading.

5. Frequency Response

The frequency response of an instrument is its variation in sensitivity over the frequency range of the measurement. It is important to display a wave shape that is a faithful reproduction of the original physiological signal. An instrument system should be able to respond rapidly enough to reproduce all frequency components of the waveform with equal sensitivity. This condition is referred to as a "flat response" over a given range of frequencies.

6. Accuracy

Accuracy is a measure of systemic error. Errors can occur in a multitude of ways. Although not always present simultaneously, the following errors should be considered:

1. Errors due to tolerances of electronic components.
2. Mechanical errors in meter movements.
3. Component errors due to drift or temperature variation.
4. Errors due to poor frequency response.
5. In certain types of instruments, errors due to change in atmospheric pressure or temperature.

6. Reading errors due to parallax, inadequate illumination, or excessively wide ink traces on a pen recording. Two additional sources of error should not be overlooked. The first concerns correct instrument zeroing. In most measurements, a zero, or a baseline, is necessary. It is often achieved by balancing the Wheatstone bridge or a similar device. It is very important that, where needed, balancing or zeroing is done prior to each set of measurements. Another source of error is the effect of the instrument on the parameter to be measured, and vice versa. This is especially true in measurements in living organisms and is further discussed later in this chapter.

7. Signal-to-Noise Ratio

It is important that the signal-to-noise ratio be as high as possible. In the hospital environment, power-line frequency noise or interference is common and is usually picked up in long leads. Also, interference due to electromagnetic, electrostatic, or diathermy equipment is possible. Poor grounding is often a cause of this kind of noise problem. Such "interference noise/' however, which is due to coupling from other energy sources, should be differentiated from thermal and shot noise, which originate within the elements of the circuit itself because of the discontinuous nature of matter and electrical current. Although thermal noise is often the limiting factor in the detection of signals in other fields of electronics, interference noise is usually more of a problem in biomedical systems. It is also important to know and control the signal-to-noise ratio in the actual environment in which the measurements are to be made.

8. Stability

In control engineering, stability is the ability of a system to resume a steady state condition following a disturbance at the input rather than be driven into uncontrollable oscillation. This is a factor that varies with the amount of amplification, feedback, and other features of the system. The overall system must be sufficiently stable over the useful range. Baseline stability is the maintenance of a constant baseline value without drift.

9. Isolation

Often measurements must be made on patients or experimental animals in such a way that the instrument does not produce a direct electrical connection between the subject and ground. This requirement is often necessary for reasons of electrical safety or to avoid interference between different instruments used simultaneously. Electrical isolation can be achieved by using magnetic or optical coupling techniques, or radio telemetry. Telemetry is also used where movement of the person or animal to be measured is essential, and thus the encumbrance of connecting leads should be avoided.

10. Simplicity

All systems and instruments should be as simple as possible to eliminate the chance of component or human error. Most instrumentation systems require calibration before they are actually used. Each component of a measurement system is usually calibrated individually at the factory against a standard. When a medical system is assembled, it should be calibrated as a whole. This step can be done external to the living organism or in situ (connected to or within the body). This point is discussed in later chapters. Calibration should always be done by using error-free devices of the simplest kind for references. An example would be that of a complicated, remote blood-pressure monitoring system, which is calibrated against a simple mercury manometer.

Q2: What are the major categories and objectives of instrumentation system?

The basic objectives of any instrumentation system generally fall into one of the following major categories:

1. Information gathering: In an information-gathering system, instrumentation is used to measure natural phenomena and other variables to aid man in his quest for knowledge about mself and the universe in which he lives. In this setting, the characteristics of the measurements may not be known in advance.

2. Diagnosis: Measurements are made to help in the detection and, hopefully, the correction of some malfunction of the system being measured. In some applications, this type of instrumentation may be classed as * 'troubleshooting equipment."
3. Evaluation: Measurements are used to determine the ability of a system to meet its functional requirements. These could be classified as "proof-of-performance" or quality control" tests.
4. Monitoring: Instrumentation is used to monitor some process or operation in order to obtain continuous or periodic information about the state of the system being measured.
5. Control: Instrumentation is sometimes used to automatically control the operation of a system based on changes in one or more of the internal parameters or in the output of the system.

Q3: Draw and explain man-instrumentation system.

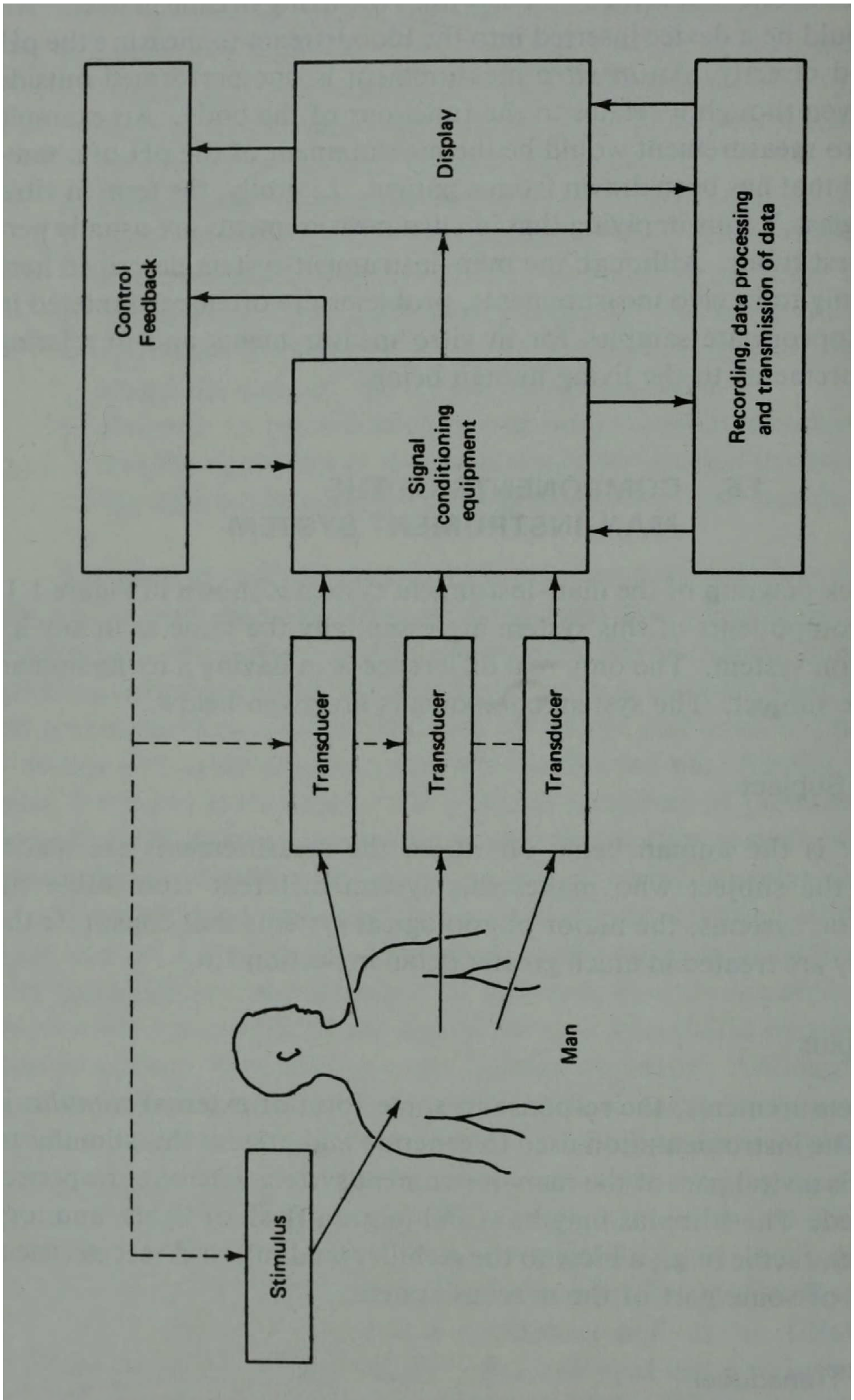
Control
Feedback
Display
Signal
conditioning
equipment
Recording, data processing
and transmission of data
Transducer
Transducer
Transducer
Man
Stimulus

Diagram 1.1

A block diagram of the man-instrument system is shown in Figure. The basic components of this system are essentially the same as in any instrumentation system. The only real difference is in having a living human being as the subject. The system components are given below.

1. The Subject

The subject is the human being on whom the measurements are made. Since it is the subject who makes this system different from other instrumentation systems, the major physiological systems that constitute the human body.

2 Stimulus

In many measurements, the response to some form of external stimulus is required. The instrumentation used to generate and present this stimulus to the subject is a vital part of the man-instrument system whenever responses are measured. The stimulus may be visual (e.g., a flash of light), auditory (e.g., a tone), tactile (e.g., a blow to the Achilles tendon), or direct electrical stimulation of some part of the nervous system.

3. The Transducer

In general, a transducer is defined as a device capable of converting one form of energy or signal to another. In the man-instrument system, each transducer is used to produce an electric signal that is an analog of the phenomenon being measured. The transducer may measure temperature, pressure, flow, or any of the other variables that can be found in the body, but its output is always an electric signal. As indicated in Figure 1.1, two or more transducers may be used simultaneously to obtain relative variations between phenomena.

4. Signal-Conditioning Equipment

The part of the instrumentation system that amplifies, modifies, or in any other way changes the electric output of the transducer is called signal conditioning (or sometimes signal-processing) equipment. Signal-conditioning equipment is also used to combine or relate the outputs of two or more transducers. Thus, for each item of signal-conditioning equipment, both the input and the output are electric signals, although the output signal is often greatly modified with respect to the input. In essence, then, the purpose of the signal-conditioning equipment is to process the signals from the transducers in order to satisfy the functions of the system and to prepare signals suitable for operating the display or recording equipment that follows.

5. Display Equipment

To be meaningful, the electrical output of the signal-conditioning equipment must be converted into a form that can be perceived by one of man's senses and that can convey the information obtained by the measurement in a meaningful way. The input to the display device is the modified electric signal from the signal-conditioning equipment. Its output is some form of visual, audible, or possibly tactile information. In the man-instrumentation system, the display equipment may include a graphic pen recorder that produces a permanent record of the data.

6. Recording, Data-Processing, and Transmission Equipment

It is often necessary, or at least desirable, to record the measured information for possible later use or to transmit it from one location to another, whether across the hall of the hospital or halfway around the world. Equipment for these functions is often a vital part of the man-instrument system. Also, where automatic storage or processing of data is required, or where computer control is employed, an on-line analog or digital computer may be part of the instrumentation system. It should be noted that the term recorder is used in two different contexts in biomedical instrumentation. A graphic pen recorder is actually a display device used to produce a paper record of analog waveforms, whereas the recording equipment referred to in this paragraph includes devices by which data can be recorded for future playback, as in a magnetic tape recorder.

7. Control Devices

Where it is necessary or desirable to have automatic control of the stimulus, transducers, or any other part of the man-instrument system, a control system is incorporated. This system usually consists of a feedback loop in which part of the output from the signal-conditioning or display equipment is used to control the operation of the system in some way.

Q4: With the help of diagram, explain how man communicates with his environment?

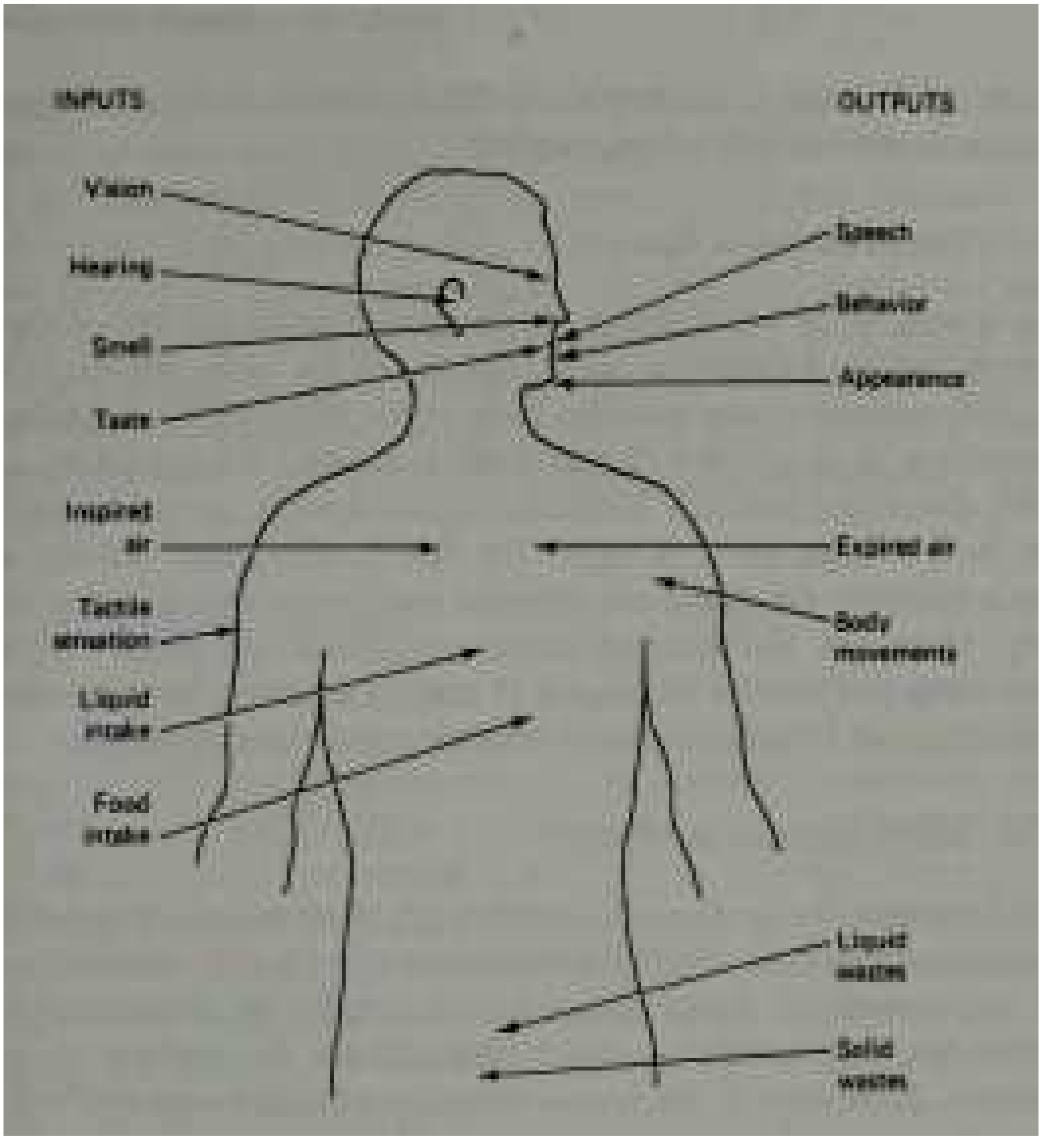

Diagram 1.2

1. The Biochemical System
2. The Cardiovascular System
3. The Respiratory System
4. Nervous System

These functional systems can be broken down into subsystems and organs, which can be further subdivided into smaller and smaller units. The process can continue down to the cellular level and perhaps even to the molecular level. The major goal of biomedical instrumentation is to make possible the measurement of information communicated by these various elements. If all the variables at all levels of the organization hierarchy could be measured, and all their interrelationships determined, the functions of the mind and body of man would be much more clearly understood and could probably be completely defined by presently known laws of physics, chemistry, and other sciences. The problem is, of course, that many of the inputs at the various organizational levels are not accessible for measurement. The interrelationships among elements are sometimes so complex and involve so many systems that the "laws" and relationships thus far derived are inadequate to define them completely. Thus, the models in use today contain so many assumptions and constraints that their application is often severely limited.

Q5: What are the problems encountered in measuring a living system?

The previous discussions of the man-instrument system and the physiological systems of the body imply measurements on a human subject. In some cases, however, animal subjects are substituted for humans in order to permit measurements or manipulations that cannot be performed without some risk. Although ethical restrictions sometimes are not as severe with animal subjects, the same basic problems can be expected in attempting measurements from any living system.
They can be summarized as follows.
1. Inaccessibility of Variables to Measurement
One of the greatest problems in attempting measurements from a living system is the difficulty in gaining access to the variable being measured. In some cases, such as in the measurement of dynamic neurochemical activity in the brain, it is impossible to place a suitable transducer in a position to make the measurement. Sometimes the problem stems from the required physical size of the transducer as compared to the space available for the measurement. In other situations the medical operation required to place a transducer in a position from which the variable can be measured makes the measurement impractical on human subjects, and sometimes even on animals. Where a variable is inaccessible for measurement, an attempt is often made to perform an indirect measurement. This process involves the measurement of some other related variable that makes possible a usable estimate of the inaccessible variable under certain conditions. In using indirect measurements, however, one must be constantly aware of the limitations of the substitute variable and must be able to determine when the relationship is not valid.
2. Variability of the Data
Few of the variables that can be measured in the human body are truly deterministic variables. In fact, such variables should be considered as stochastic processes. A stochastic process is a time variable related to other variables in a nondeterministic way. Physiological variables can never be viewed as strictly deterministic values but must be represented by some kind of statistical or probabilistic distribution. In other words, measurements taken under a fixed set of conditions at one time will not necessarily be the same as similar measurements made under the same conditions at another time. The variability from one subject to another is even greater. Here, again, statistical methods must be employed in order to estimate relationships among variables.
3. Lack of Knowledge about Interrelationships
The foregoing variability in measured values could be better explained if more were known and understood about the interrelationships within the body. Physiological measurements with large tolerances are often accepted by the physician because of a lack of this knowledge and the resultant inability to control variations. Better understanding of physiological relationships would also permit more effective use of indirect measurements as substitutes for inaccessible measures and would aid engineers or technicians in their job of coupling the instrumentation to the physiological system.
4. Interaction among Physiological Systems
Because of the large number of feedback loops involved in the major physiological systems, a severe degree of interaction exists both within a given system and among the major systems. The result is that stimulation of one part of a given system generally affects all other parts of that system in some way (sometimes in an unpredictable fashion) and often affects other systems as well. For this reason, “cause-and-effect" relationships become extremely unclear and difficult to define. Even when attempts are made to open feedback loops, collateral loops appear and some aspects of the original

feedback loop are still present. Also, when one organ or element is rendered inactive, another organ or element sometimes takes over the function. This situation is especially true in the brain and other parts of the nervous system.

5. Effect of the Transducer on the Measurement

Almost any kind of measurement is affected in some way by the presence of the measuring transducer. The problem is greatly compounded in the measurement of living systems. In many situations the physical presence of the transducer changes the reading significantly. For example, a large flow transducer placed in a bloodstream partially blocks the vessel and changes the pressure-flow characteristics of the system. Similarly, an attempt to measure the electrochemical potentials generated within an individual cell requires penetration of the cell by a transducer. This penetration can easily kill the cell or damage it so that it can no longer function normally. Another problem arises from the interaction discussed earlier. Often the presence of a transducer in one system can affect responses in other systems. For example, local cooling of the skin, to estimate the circulation in the area, causes feedback that changes the circulation pattern as a reaction to the cooling. The psychological effect of the measurement can also affect the results. Long-term recording techniques for measuring blood pressure have shown that some individuals who would otherwise have normal pressures show an elevated pressure reading whenever they are in the physician's office.

This is a fear response on the part of the patient, involving the autonomic nervous system. In designing a measurement system, the biomedical instrumentation engineer or technician must exert extreme care to ensure that the effect of the presence of the measuring device is minimal.

Because of the limited amount of energy available in the body for many physiological variables, care must also be taken to prevent the measuring system from “loading’’ the source of the measured variable.

6. Artifacts

In medicine and biology, the term artifact refers to any component of a signal that is extraneous to the variable represented by the signal. Thus, random noise generated within the measuring instrument, electrical interference (including 60-Hz pickup), cross-talk, and all other unwanted variations in the signal are considered artifacts. A major source of artifactsin the measuring of a living system is the movement of the subject, which in turn results in movement of the measuring device. Since many transducers are sensitive to movement, the movement of the subject often produces variations in the output signal. Sometimes these variations are indistinguishable from the measured variable; at other times they may be sufficient to obscure the desired information completely. Application of anesthesia to reduce movement may itself cause unwanted changes in the system.

7. Energy Limitations

Many physiological measurement techniques require that certain amount of energy be applied to the living system in order to obtain a measurement.

For example, resistance measurements require the flow of electric current through the tissues or blood being measured. Some transducers generate a small amount of heat due to the current flow. In most cases, this energy level is so low that its effect is insignificant. However, in dealing with living cells, care must continually be taken to avoid the possibility of energy concentrations that might damage cells or affect the measurements.

8. Safety Considerations

As previously mentioned, the methods employed in measuring variables in a living human subject must in no way endanger the life or normal functioning of the subject. Recent emphasis on hospital safety requires that extra caution must be taken in the design of any measurement system to protect the patient. Similarly, the measurement should not cause undue pain, trauma, or discomfort; unless it becomes necessary to endure these conditions in order to save the patient's life.

Q6: What do you understand by artifact in biomedical instrumentation?

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Q7: What do you understand by Biometrics?

The branch of science that includes the measurement of physiological variables and parameters is known as biometrics. Biomedical instrumentation provides the tools by which these measurements can be achieved. In later chapters each of the major forms of biomedical instrumentation is covered in detail, along with the physiological basis for the measurements involved.

Q8: Explain in vivo and in vitro measurements in biomedical instrumentation measurements.

Measurements in which biomedical instrumentation is employed can also be divided into two categories: in vivo and in vitro. An in vivo measurement is one that is made on or within the living organism itself. An example would be a device inserted into the bloodstream to measure the pH of the blood directly. An in vitro measurement is one performed outside the body, even though it relates to the functions of the body. An example of an in vitro measurement would be the measurement of the pH of a sample of blood that has been drawn from a patient. Literally, the term in vitro means “in glass," thus implying that in vitro measurements are usually performed in test tubes. Although the man-instrument system described here applies mainly to in vivo measurements, problems are often encountered in obtaining appropriate samples for in vitro measurements and in relating these measurements to the living human being.

Q9: Define or explain Sensitivity of a measuring instrument.

The sensitivity of an instrument determines how small a variation of a variable or parameter can be reliably measured. This factor differs from the instrument's range in that sensitivity is not concerned with the absolute levels of the parameter but rather with the minute changes that can be detected. The sensitivity directly determines the resolution of the device, which is the minimum variation that can accurately be read. Too high a sensitivity often results in nonlinearities or instability. Thus, the optimum sensitivity must be determined for any given type of measurement. Indications of sensitivity are frequently expressed in terms of scale length per quantity to be measured—for example, inches per microampere in a galvanometer
coil or inches per millimeter of mercury. These units are sometimes expressed reciprocally. A sensitivity of 0.025 centimeter per millimeter of mercury (cm/mm Hg) could be expressed as 40 millimeters of mercury per centimeter.

Q10: Define or explain Linearity of a measuring instrument.

The degree to which variations in the output of an instrument follow input variations is referred to as the linearity of the device. In a linear system the sensitivity would be the same for all absolute levels of input, whether in the high, middle, or low portion of the range. In some instruments a certain form of nonlinearity is purposely introduced to create a desired effect, whereas in others it is desirable to have linear scales as much as possible over the entire range of measurements. Linearity should be obtained over the most important segments, even if it is impossible to achieve it over the entire range.

Q11: Define or explain Accuracy of a measuring instrument.

Accuracy is a measure of systemic error. Errors can occur in a multitude of ways. Although not always present simultaneously, the following errors should be considered:

1. Errors due to tolerances of electronic components.
2. Mechanical errors in meter movements.
3. Component errors due to drift or temperature variation.
4. Errors due to poor frequency response.
5. In certain types of instruments, errors due to change in atmospheric pressure or temperature.

Unit-2

Q1: Define active and passive transducers?

Active transducers/ Sensors generate electric current or voltage directly in response to environmental stimulation.

Passive transducers/ Sensors produce a change in some **passive** electrical quantity, such as capacitance, resistance, or inductance, as a result of stimulation.

1). Active Transducer

The active transducer is one kind of device which can be used to change the specified energy which is non-electrical into electrical. The best examples of this transducer mainly include PV cell, thermocouple, etc.

2). Passive Transducer

The passive transducer is one kind of device which can be used to change the specified energy which is non-electrical into electrical with external power. The best examples of this transducer mainly include a differential transformer, resistance strain, etc.

Q2: Write the difference between active and passive transducers? Give their examples.

Parameter	Active Transducer	Passive Transducer
Operating Principle	Operational energy is derived from quantity being measured.	Operational energy is taken from external power source.
Alternatively known as	Self-generating transducer	Externally powered transducer
Output generated	Electrical current or voltage.	Variation in quantity associated with passive elements is observed
Conversion	Simple	Complex
External energy	Not required	Required
Further amplification	Needed	Not needed
Example	Piezoelectric crystal, Thermocouple etc.	Potentiometer, Thermistor etc.

Table No 2.1

Q3: Draw and explain inductive transducer for measurement of linear and rotary motion.

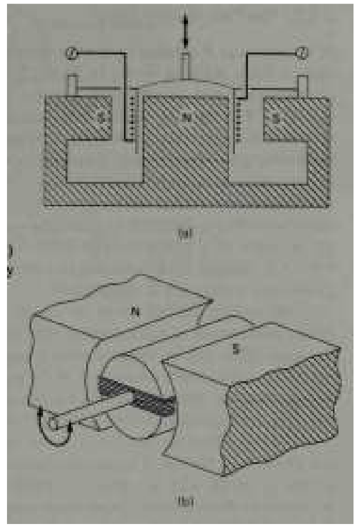

Diagram 2.1

If an electrical conductor is moved in a magnetic field in such a way that the magnetic flux through the conductor is changed, a voltage is induced which is proportional to the rate of change of the magnetic flux. Conversely, if a current is sent through the same conductor, a mechanical force is exerted upon it proportional to the current and the magnetic field. The result, which depends on the polarities of voltage and current on the electrical side or the directions of force and motion on the mechanical side, is a conversion from electrical to mechanical energy, or vice versa. All electrical motors and generators and a host of other devices, such as solenoids and loudspeakers, utilize this principle.
Two basic configurations for transducers that use the principle of magnetic induction for the measurement of linear or rotary motion are shown in Figure. The output voltage in each case is proportional to the linear or angular velocity. The most important biomedical applications
are heart sound microphones, pulse transducers, and electromagnetic blood-flow meters.
Magnetic induction also plays an important role at the output of many biomedical instrumentation systems. Analog meters using d'Arsonval movements, light-beam galvanometers in photographic recorders, and pen motors in ink or thermal recorders are all based on the principle of magnetic induction and closely resemble the basic transducer configuration shown in Figure.

Q4: Explain the working principle of piezoelectric transducers. With the help of electrical equivalent circuit explain how piezoelectric transducer is used to measure force. Draw and explain the output voltage waveforms with various values of R and C.

By cutting the slab from the crystal at a different angle (or by a different application of the electrical field in the case of the barium titanate) the same effect can be obtained when a bending force is applied. Frequently, two slices, with proper orientation of the polarity of the piezoelectric voltages, are sandwiched between layers of conductive metal foil, thus forming the bimorph configuration shown in Figure. The electrically equivalent circuit of a piezoelectric transducer, shown in Figure, is that of a voltage source having a voltage, Vp, proportional to the applied mechanical force connected in series with a capacitor, which represents the conductive plates separated by the insulating piezoelectric material. The capacitive properties of the piezoelectric transducer interacting with the input impedance of the amplifier to which they are connected affect the response of the transducer.
This effect is shown in Figure. The top trace shows the force applied to the transducer, which, after time T, is removed again. While the electrical field generated by the piezoelectric effect and the internal transducer voltage, Kp, of Figure follow the applied force, the voltage, F4, measured at the

input of the amplifier depends on the values of the transducer capacitance, C, and the amplifier input impedance, R, with respect to the duration of the force (time T). If the product of R and C is much larger than T, the effect of the voltage division between these two components can be neglected and the measured voltage is proportional to the applied mechanical force as shown in trace
To meet this condition, even for large values of T, it may be necessary to make the amplifier input impedance very large. In some applications, electrometer amplifiers or charge amplifiers with extremely high input impedances have to be used. As an alternative, an external capacitor can be connected in parallel with the amplifier input. This effectively increases the capacity of the transducer but also reduces its sensitivity. Because the output voltages of piezoelectric transducers can be very high (they have occasionally even been used as high-voltage generators for ignition purposes),

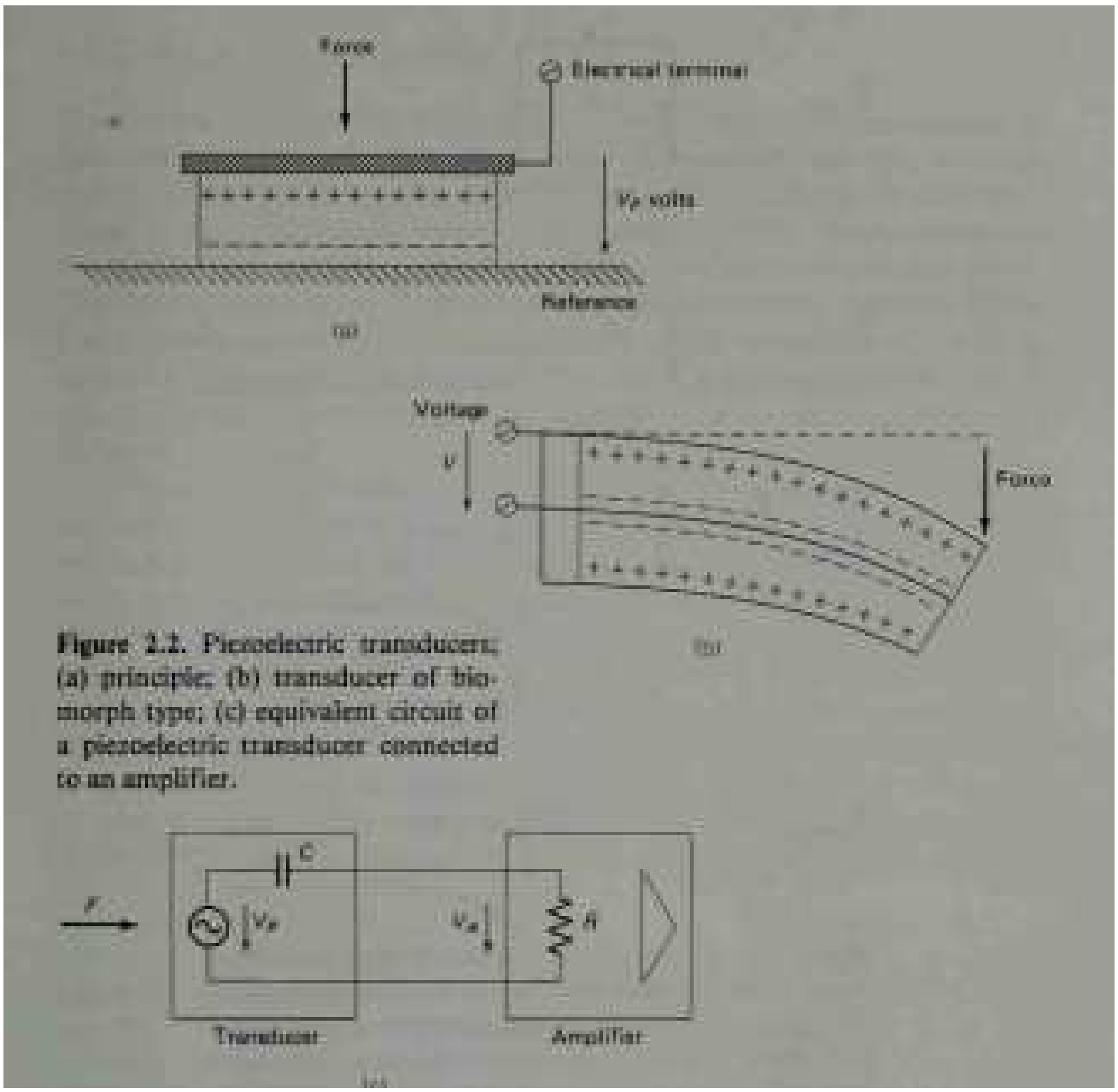

Figure 2.2. Piezoelectric transducers; (a) principle; (b) transducer of bimorph type; (c) equivalent circuit of a piezoelectric transducer connected to an amplifier.

Diagram 2.2

this approach may be permissible in certain applications. Changes of the input capacity, and thus the sensitivity, can also be caused by the mechanical movement of attached shielded or coaxial cables which can introduce motion artifacts. Special types of shielded cable that reduce this effect are available for piezoelectric transducers. If the product of resistance and capacitance is made much smaller than r, the voltage at the amplifier input is proportional to the time derivative of the force at the transducer (or proportional to the rate at which the applied force changes) as shown in trace 3 of Figure. If the product of R and C is of the same order of magnitude as T, the resulting voltage is a compromise between the extremes in the two previous traces, as shown in trace 4. Because any mechanical input signal will contain various frequencies (corresponding to different times, T, in the time domain).

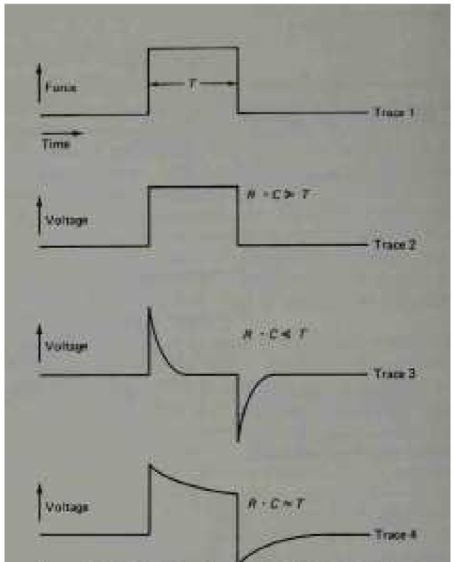

Figure 2.3. Output signal of a piezoelectric transducer under different conditions. Trace 1: Force at the input of the transducer. Trace 2: Output signal when the product of R and C is much larger than T; the output voltage is proportional to the force. Trace 3: Output signal if the product of R and C is much smaller than T; the output voltage is proportional to the rate of change of the force. Trace 4: Output signal if the product of R and C is approximately equal to T; the output signal is a combination of the two other cases.

Diagram 2.3

Q5: Explain the working principle of thermocouple with double reference junction measurement circuit.

If two wires of dissimilar metals (e.g., iron and copper) are connected so that they form a closed conductive loop as shown in Figure, a voltage can be observed at any point of interruption of the loop which is proportional to the difference in temperature between the two junctions between the metals. The polarity depends on which of the two junctions is warmer.
The device formed in this fashion is called a thermocouple, shown in Figure, The sensitivity of a thermocouple is small and amounts to only 40 microvolts per degree Celsius (mV/°C) for a copper-constantan and 53 mV/°C for an iron-constantan pair (constantan is an alloy of nickel and copper).
The principle of active transducers requires that any electrical energy delivered at the output of the transducer be obtained from the nonelectrical variable at the input of the transducer. In the case of the thermocouple it might not be quite obvious how the thermal energy is converted. Actually, the delivery of electrical energy causes the transfer of heat from the hotter to the colder junction; the hotter junction gets cooler while the colder junction gets warmer. In most practical applications of thermocouples this effect can be neglected. Because the thermocouple measures a temperature difference rather than an absolute temperature, one of the junctions must be kept at a known reference temperature, usually at the freezing point of water (0°C or 32 °F). Frequently, instead of an ice bath for the reference

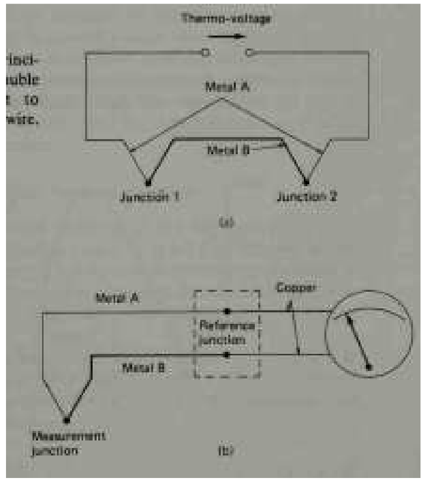

Diagram 2.4

Q6: Draw and explain passive transducer using resistive element for measurement of linear and rotary displacement.

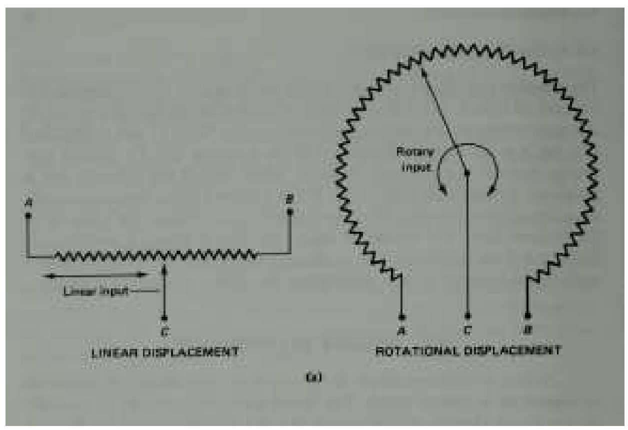

Diagram 2.5

Any resistive element that changes its resistance as a function of a physical variable can, in principle, be used as a transducer for that variable. An ordinary potentiometer, for example, can be used to convert rotary motion or displacement into a change of resistance. Similarly, the special linear potentiometers shown in Figure can be used to convert linear displacement into a resistance change.
The resistivity of conductive materials is a function of temperature. In resistors this characteristic is a disadvantage; however, in resistive temperature transducers it serves a useful purpose. In certain semiconductor materials the conductivity is increased by light striking the material. This effect which occurs as a surface effect in certain polycrystalline materials such as cadmium sulfide, is used in photo resistive ceils, a form of photoelectric transducer. This type of transducer is very sensitive, but has a somewhat limited frequency response. A different type of photoelectric transducer is the photo diode, which utilizes charge carriers generated by incident radiation in a reverse-biased diode junction. Although less sensitive than the photo resistive cell, the photodiode has improved frequency response. A photo diode can also be used as a photo electric transducer without a bias voltage. In this case it operates as an active transducer. The photoemissive cell (either vacuum or gas-filled) is only of historical interest because it has generally been replaced by photoelectric transducers of the semiconductor type.

Most transducers used for mechanical variables utilize a resistive element called the strain gage. The principle of a strain gauge can easily be understood with the help of Figure shows a cylindrical resistor element which has length, L, and cross-sectional area, A. If it is made of a material having a resistivity of r ohm-cm, its resistance is R = r*L/A ohms(n).

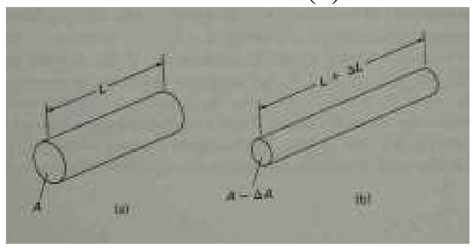

Diagram 2.6

GUAGE FACTOR: - In the above diagram a cylindrical resistor element which has length 'L' and cross sectional area 'A' the resistance 'R' is given by-

$$R= (\rho*L)/A,$$

Where, ρ is resistivity of material.

An axial force is applied to the element to cause it to strength, its length increases by an amount 'ΔL' and cross sectional area decreases by 'ΔA' the ratio of resulting the resistance change (ΔR/R) to the change in length (ΔL/L) is called as GUAGE FACTOR G. Thus,

$$G= (\Delta R/R)/ (\Delta L/L)$$

The gage factor for metals is about 2, whereas the gage factor for silicon (a crystalline semiconductor material) is about 120.

Q7: Define gauge factor in strain gauge. Explain the working principle of strain gauge using un-bonded strain gauge.

GUAGE FACTOR: - In the above diagram a cylindrical resistor element which has length 'L' and cross sectional area 'A' the resistance 'R' is given by-

$$R= (\rho*L)/A,$$

Where, ρ is resistivity of material.

An axial force is applied to the element to cause it to strength, its length increases by an amount 'ΔL' and cross sectional area decreases by 'ΔA' the ratio of resulting the resistance change (ΔR/R) to the change in length (ΔL/L) is called as GUAGE FACTOR G. Thus,

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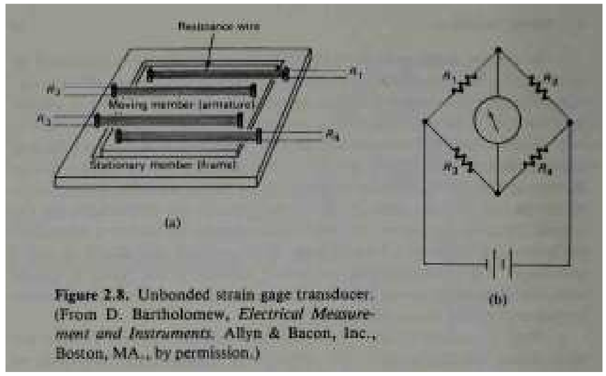


Figure 2.8. Unbonded strain gage transducer. (From D. Bartholomew, *Electrical Measurement and Instruments.* Allyn & Bacon, Inc., Boston, MA., by permission.)

Diagram 2.7

The basic principle of the strain gage can be utilized for transducers in a number of different ways. In the mercury strain gauge the resistive material consists of a column of mercury enclosed in a piece of silicone rubber tubing.
The use of this type of strain gage for the measurement of physiological variables (the diameter of blood vessels) was first described by Whitney. Mercury strain gages are, therefore, sometimes called Whitney gages. An application of this type of transducer, the mercury strain gauge plethysmography. Because the silicone rubber yields easily to stretching forces, mercury strain gages are frequently used to measure changes in the diameter of body sections or organs. A disadvantage is that for practical dimensions the resistance of the mercury columns is inconveniently low (usually only a few ohms). This problem can be overcome by substituting an electrolyte solution for the mercury. However, silicone rubber is permeable to water vapor, so elastomers other than silicone rubber have to be used as the enclosures for gages containing electrolytes.
When metallic strain gages are used rather than mercury, the possible amount of stretching and the corresponding resistance changes are much more limited. Metal strain gages can be of two different types: unbondedand bonded. In the unbonded strain gage, thin wire is stretched between insulating posts as shown in Figure. In order to obtain a convenient resistance (120 n is a common value), several turns of wire must be used.
Here the moving part of the transducer is connected to the stationary frame by four unbonded strain gages, /?, through R^. If the moving member is forced to the right, R2 and R^ are stretched and their resistance increases while the stress in /?, and R^ is reduced, thus decreasing the resistance of these strain gage wires. By connecting the four strain gages into a bridge circuit as shown in Figure, all resistance changes influence the output voltage in the same direction, increasing the sensitivity of the transducer by a factor of 4. At the same time, resistance changes of the strain gage due to changing temperatures tend to compensate each other. In the form shown, the unbonded strain gage is basically a force transducer. The same principle is also utilized in transducers for other variables. For example, the blood pressure transducers
Q8: Define gauge factor in strain gauge. Explain the working principle of strain gauge using bonded strain gauge.

GUAGE FACTOR: - In the above diagram a cylindrical resistor element which has length 'L' and cross sectional area 'A' the resistance 'R' is given by-

$$R= (\rho*L)/A,$$

Where, ρ is resistivity of material.

An axial force is applied to the element to cause it to strength, its length increases by an amount 'ΔL' and cross sectional area decreases by 'ΔA' the ratio of resulting the resistance change ($\Delta R/R$) to the change in length ($\Delta L/L$) is called as GUAGE FACTOR G. Thus,

$$G= (\Delta R/R)/ (\Delta L/L)$$

The gage factor for metals is about 2, whereas the gage factor for silicon (a crystalline semiconductor material) is about 120.

The principle of the bonded strain gage is shown in Figure. A thin wire shaped in a zigzag pattern is cemented between two paper covers or is cemented to the surface of a paper carrier. This strain gage is then cemented to the surface of a structure. Any changes in surface dimensions of the structure due to mechanical strain are transmitted to the resistance wire, causing an increase or decrease of its length and a corresponding resistance change. The bonded strain gage, therefore, is basically a transducer for surface strain.

Related to the bonded wire strain gauge is ihQ foil gauge. In this gage the conductor consists of a foil pattern on a substrate of plastic which is manufactured by the same photo etching techniques as those used in printed circuit boards. This process permits the manufacture of smaller gages with more complicated gauge patterns (rosettes), which allow the measurement of different strain components.

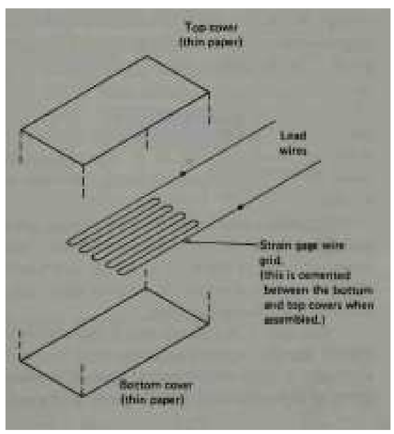


Diagram 2.8

In semiconductor strain gages a small slice of silicon replaces the wire or foil pattern as a conductor. Because of the crystalline nature of the silicon, these strain gages have a much larger gage factor than metal strain gauges. Typical values are as high as 120. By varying the amount of im-purities in the silicon its conductivity can be controlled. With modern manufacturing techniques developed for semiconductor components, silicon strain gages can be made even smaller than the smallest foil gages. If the structure whose surface strain is to be measured is also made of silicon (e.g, in the shape of a beam or diaphragm), the size of the strain gage can be reduced even further by manufacturing it as a resistive pattern on the silicon surface. Such patterns can be obtained using the photolithographic and diffusion techniques developed for the manufacture of integrated circuits. The gauges are isolated from the silicon substrate by reverse-biased diode junctions.

Q9: Draw and explain passive transducer using inductive element for measurement of linear displacement.

Passive Transducers Using Inductive Elements

In principle, the inductance of a coil can be changed either by varying its physical dimensions or by changing the effective permeability of its magnetic core. The latter can be achieved by moving a core having permeability higher than air through the coil as shown in Figure. This arrangement appears to be very similar to that of an inductive transducer. However, in the inductive transducer the core is a permanent magnet which when moved induces a voltage in the coil. In this passive transducer the core is made of a soft magnetic material which changes the inductance of the coil when it is moved inside. The inductance can then be measured using an ac signal.

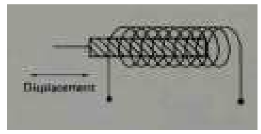


Diagram 2.9

Q10: Draw and explain working principle of linear variable differential transformer for the measurement of linear displacement.

Another passive transducer involving inductance is the variable reluctance transducer, in which the core remains stationary but the air gap in the magnetic path of the core is varied to change the effective permeability.

This principle is also used in active transducers in which the magnetic path includes a permanent magnet.

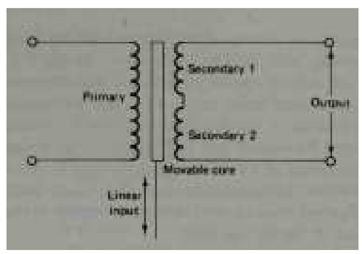


Diagram 2.10

The inductance of the coil in these types of transducers is usually not related linearly to the displacement of the core or the size of the air gap, especially if large displacements are encountered. The linear variable differential transformer (LVDT), shown in Figure, overcomes this limitation. It consists of a transformer with one primary and two secondary windings. The secondary windings are connected so that their induced voltages oppose each other. If the core is in the center position, as shown in the figure, the voltages in the two secondary windings are equal in magnitude and the resulting output voltage is zero. If the core is moved upward as indicated by the arrow, the voltage in secondary 1 increases while that in secondary 2 decreases. The magnitude of the output voltage changes with the amount of displacement of the core from its central or neutral position. Its phase with respect to the voltage at the primary winding depends on the direction of the displacement. Because nonlinearities in the magnitudes of the voltages induced in the two output coils tend to compensate each other, the output voltage of the differential transducer is proportional to core movement even with fairly large displacements.

Q11: With block diagram and construction details, explain the working of photoelectric displacement transducer.

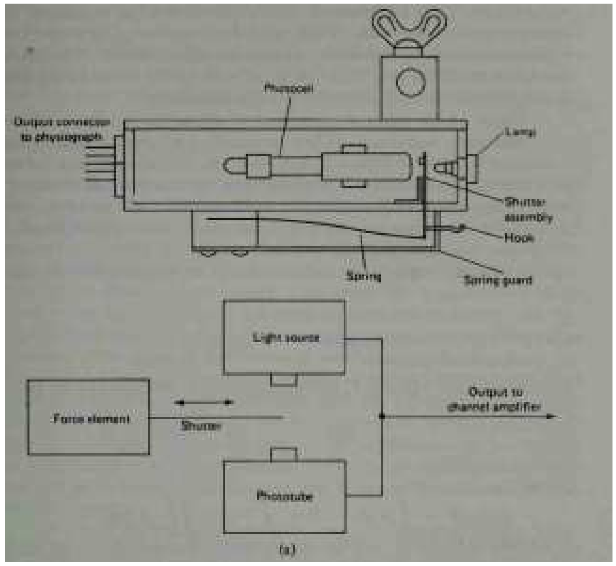


Diagram 2.11

Here the displacement of a spring is used to modulate the intensity of a light beam via a mechanical shutter. The resulting light intensity is measured by a photo resistive cell. In this example, a multiple conversion of variables takes place: force to displacement, displacement to light intensity, and light intensity to resistance. This principle is actually employed in the commercial transducer shown in above Figure.

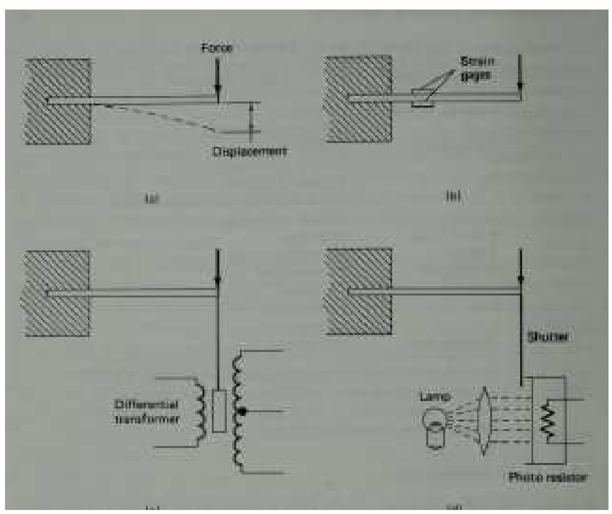


Diagram 2.12

Q12: Draw and explain resting potential, depolarization, action potential and after potential of a cell. Draw the waveform to explain it.

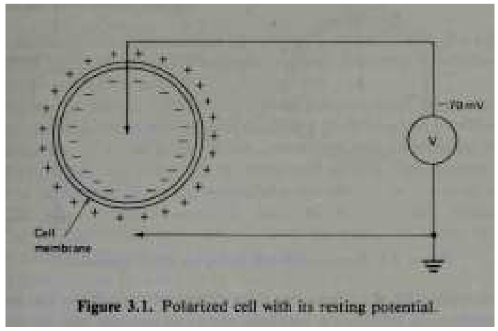
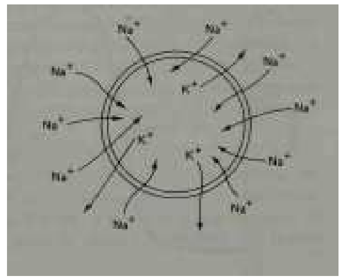


Figure 3.1. Polarized cell with its resting potential.



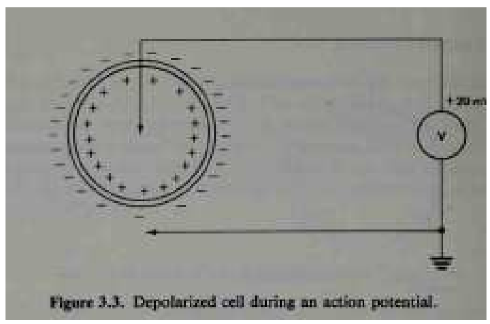


Figure 3.3. Depolarized cell during an action potential.

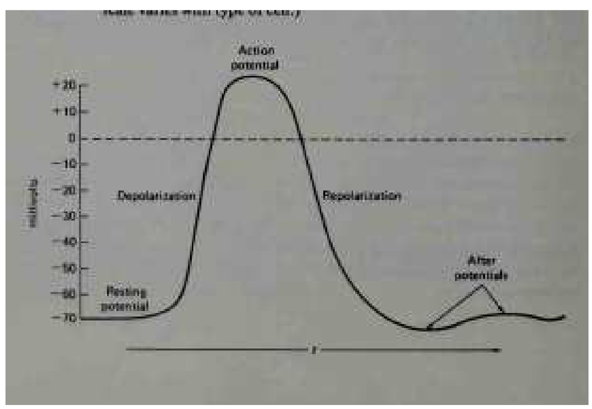


Diagram 2.13

Surrounding the cells of the body are the body fluids. These fluids are conductive solutions containing charged atoms known as ions. The principal ions are sodium (Na+), potassium (K+), and chloride (C-). The membrane of excitable cells readily permits entry of potassium and chloride ions but effectively blocks the entry of sodium ions. Since the various ions seek a balance between the inside of the cell and the outside, both according to concentration and electric charge, the inability of the sodium to penetrate the membrane results in two conditions. First, the concentration of sodium ions inside the cell becomes much lower than in the intercellular fluid outside. Since the sodium ions are positive, this would tend to make the outside of the cell more positive than the inside. Second, in an attempt to balance the electric charge, additional potassium ions, which are also positive, enter the cell, causing a higher concentration of potassium on the inside than on the outside. This charge balance cannot be achieved, however, because of the concentration imbalance of potassium ions.

Equilibrium is reached with a potential difference across the membrane, negative on the inside and positive on the outside. This membrane potential is called the resting potential of the cell and is maintained until some kind of disturbance upsets the equilibrium. Since measurement of the membrane potential is generally made from inside the cell with respect to the body fluids, the resting potential of a cell is given as negative. Research investigators have reported measuring membrane potentials in various cells ranging from - 60 to - 100 mV. Figure illustrates in simplified form the cross section of a cell with its resting potential. A cell in the resting state is said to be polarized.

When a section of the cell membrane is excited by the flow of ionic current or by some form of externally applied energy, the membrane changes its characteristics and begins to allow some of the sodium ions to enter. This movement of sodium ions into the cell constitutes an ionic current flow that further reduces the barrier of the membrane to sodium ions. The net result is an avalanche effect in which sodium ions literally rush into the cell to try to reach a balance with the ions outside. At the same time potassium ions, which were in higher concentration inside the cell during the resting state, try to leave the cell but are unable to move as rapidly as the sodium ions. As a result, the cell has a slightly positive potential on the inside due to the imbalance of potassium ions. This potential is known as the action potential and is approximately + 20 mV. A cell that has been excited and that displays an action potential is said to be depolarized; the process of changing from the resting state to the action potential is called depolarization.

Figure shows the ionic movements associated with depolarization, and Figure illustrates the cross section of a depolarized cell. Once the rush of sodium ions through the cell membrane has stopped(a new state of equilibrium is reached), the ionic currents that lowered the barrier to sodium ions are no longer present and the membrane reverts back to its original, selectively permeable condition, wherein the passage of sodium ions from the outside to the inside of the cell is again blocked. Wereth is the only effect, however, it would take a long time for a resting potential to develop again. But such is not the case. By an active process, called a sodium pump, the sodium ions are quickly transported to the outside of the cell, and the cell again becomes polarized and assumes its resting potential. This process is called repolarization. Although little is known of the exact chemical steps involved in the sodium pump, it is quite generally believed that sodium is withdrawn against both charge and concentration gradients supported by some form of high-energy phosphate compound. The rate of pumping is directly proportional to the sodium concentration in the cell. It is also believed that the operation of this pump is linked with the influx of potassium into the cell, as if a cyclic process involving an exchange of sodium for potassium existed. Figure shows a typical action-potential waveform, beginning at the resting potential, depolarizing, and returning to the resting potential after repolarization. The time scale for the action potential depends on the type of cell producing the potential. In nerve and muscle cells, repolarization occurs so rapidly following depolarization that the action potential appears as a spike of as little as 1 msec total duration. Heart muscle, on the other hand, repolarizes much more slowly, with the action potential for heart muscle usually lasting from 150 to 300 msec.

Regardless of the method by which a cell is excited or the intensity of the stimulus (provided it is sufficient to activate the cell), the action potential is always the same for any given cell. This is known as the all-or-nothing law. The net height of the action potential is defined as the difference between the potential of the depolarized membrane at the peak of the action potential and the resting potential.

Following the generation of an action potential, there is a brief period of time during which the cell cannot respond to any new stimulus. This period, called the absolute refractory period, lasts about 1 mSec in nerve cells. Following the absolute refractory period, there occurs a relative refractory period, during which another action potential can be triggered, but a much stronger stimulation is required. In nerve cells, the relative refractory period lasts several milliseconds. These refractory periods are believed to be the result of after-potentials that follow an action potential.

Q13: Explain Electroretinogram (ERG), Electro-oculogram (EOG) and Electrogastrogram (EGG).

1. Electroretinogram (ERG): A record of the complex pattern of bioelectric potentials obtained from the retina of the eye. This is usually a response to a visual stimulus.
2. Electro-oculogram (EOG): A measure of the variations in the corneal-retinal potential as affected by the position and movement of the eye.
3. Electrogastrogram (EGG): The EMG patterns associated with

Q14: With the help of equivalent circuit, explain biopotential. Explain how biopotential is measured with TWO electrodes.

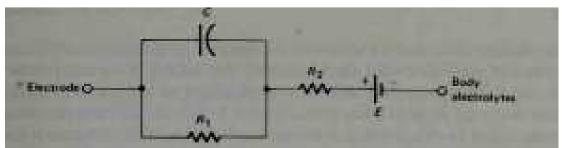


Figure 4.1. Equivalent circuit of biopotential electrode interface.

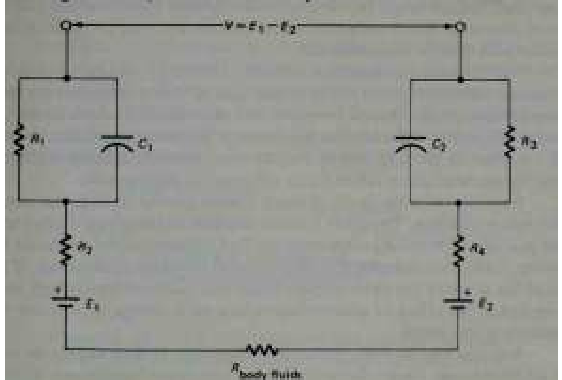


Figure 4.2. Measurement of biopotentials with two electrodes—equivalent circuit.

Diagram 2.14

All three types of biopotential electrodes have the metal-electrolyte interface described in the previous section. In each case, an electrode potential is developed across the interface, proportional to the exchange of ions between the metal and the electrolytes of the body. The double layer of charge at the interface acts as a capacitor. Thus, the equivalent circuit of biopotential electrode in contact with the body consists of a voltage in series with a resistance-capacitance network of the type shown in Figure.
Since measurement of bioelectric potentials requires two electrodes, the voltage measured is really the difference between the instantaneous potentials of the two electrodes, as shown in Figure. If the two electrodes are of the same type, the difference is usually small and depends essentially on the actual difference of ionic potential between the two points of the body from which measurements are being taken. If the two electrodes are different, however, they may produce a significant dc voltage that can cause current to flow through both electrodes as well as through the input circuit of the amplifier to which they are connected. The dc voltage due to the difference in electrode potentials is called the electrode offset voltage. The resulting current is often mistaken for a true physiological event. Even two electrodes of the same material may produce a small electrode offset voltage.

The resistance-capacitance networks shown in Figures represent the impedance of the electrodes (one of their most important characteristics)as fixed values of resistance and capacitance. Unfortunately, the impedance is not constant. The impedance is frequency-dependent because of the effect of the capacitance. Furthermore, both the electrode potential and the impedance are varied by an effect called polarization.

Polarization is the result of direct current passing through the metal electrolyte interface. The effect is much like that of charging a battery with the polarity of the charge opposing the flow of current that generates the charge. Some electrodes are designed to avoid or reduce polarization. If the amplifier to which the electrodes are connected has an extremely high input impedance, the effect of polarization or any other change in electrode impedance is minimized.

Q15: Draw and explain partial pressure oxygen tension transducer (P_{02}) used to measure amount of oxygen diffused in blood.

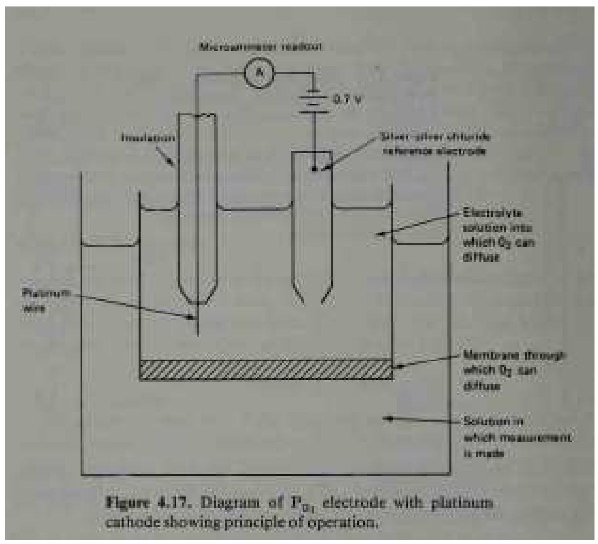


Figure 4.17. Diagram of P_{O_2} electrode with platinum cathode showing principle of operation.

Diagram 2.15

Among the more important physiological chemical measurements are the partial pressures of oxygen and carbon dioxide in the blood. The partial pressure of a dissolved gas is the contribution of that gas to the total pressure of all dissolved gases in the blood. The partial pressure of a gas is proportional to the quantity of that gas in the blood. The effectiveness of both the respiratory and cardiovascular systems is reflected in these important parameters.

The partial pressure of oxygen, Po_2, often called oxygen tension, can be measured both in vitro and in vivo. The basic principle is shown in Figure.

A fine piece of platinum or some other noble metal wire, embedded in glass for insulation purposes, with only the tip exposed, is placed in an electrolyte into which oxygen is allowed to diffuse. If a voltage of about 0.7 V is applied between the platinum wire and a reference electrode (also placed into the electrolyte), with the platinum wire negative, reduction of the oxygen takes place at the platinum cathode. As a result, an oxidation-reduction current proportional to the partial pressure of the diffused oxygen can be measured. The electrolyte is generally sealed into the chamber that holds the platinum wire and the reference electrode by means of a membrane across which the dissolved oxygen can diffuse from the blood.

The platinum cathode and the reference electrode can be integrated into a single unit (the Clark electrode). This electrode can be placed in a cuvette of blood for in vitro measurements, or a micro version can be placed at the tip of a catheter for insertion into various parts of the heart or vascular system for direct in vivo measurements. One of the problems inherent in this method of measuring

Po_2 is the fact that the reduction process actually removes a finite amount of the oxygen from the immediate vicinity of the cathode. By careful design and use of proper procedures, modern Po_2 electrodes have been able to reduce this potential source of error to a minimum. Another apparent error in Po_2 measurement is a gradual reduction of current with time, almost like the polarization effect described for skin surface electrodes. This effect, generally called aging, has also been minimized in modern Po_2 electrodes.

Unit-3

Q1: Draw and explain the cardiovascular circulation system.

OR

Q2: With the help of diagram explain the physiological system of heart and cardiovascular circulation system.

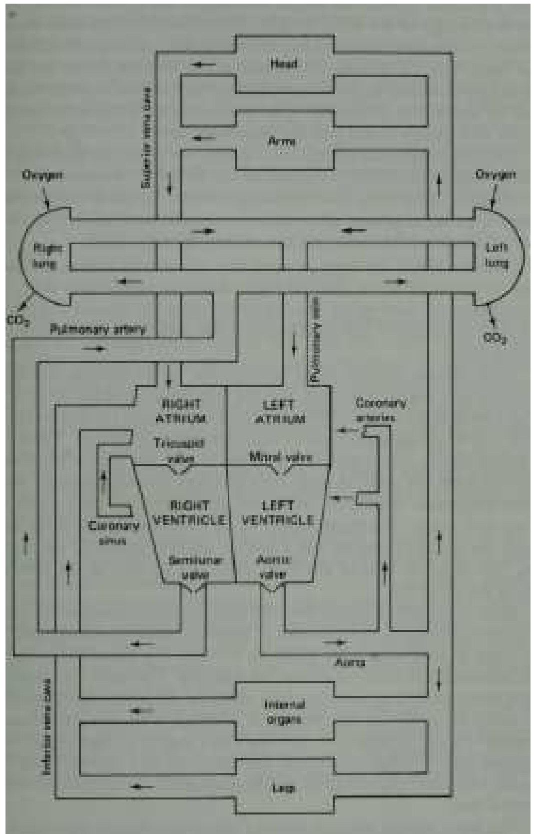


Figure 5.2. Cardiovascular circulation.

Diagram 3.1

The heart functions as a pump and acts as a double pump in the cardiovascular system to provide a continuous circulation of blood throughout the body. This circulation includes the systemic circulation and the pulmonary circulation. Both circuits transport blood but they can also be seen in terms of the gases they carry. The pulmonary circulation collects oxygen from the lungs and delivers carbon dioxide for exhalation. The systemic circuit transports oxygen to the body and returns relatively de-oxygenated blood and carbon dioxide to the pulmonary circuit.

Blood flows through the heart in one direction, from the atria to the ventricles, and out through the pulmonary artery into the pulmonary circulation, and the aorta into the systemic circulation. The pulmonary artery (also trunk) branches into the left and right pulmonary arteries to supply each lung. Blood is prevented from flowing backwards (regurgitation) by the tricuspid, bicuspid, aortic, and pulmonary valves.

The function of the *right heart*, is to collect de-oxygenated blood, in the right atrium, from the body via the superior vena cava, inferior vena cava and from the coronary sinus and pump it, through the tricuspid valve, via the right ventricle, through the semilunar pulmonary valve and into the pulmonary artery in the pulmonary circulation where carbon dioxide can be exchanged for oxygen in the lungs. This happens through the passive process of diffusion. In the *left heart* oxygenated blood is returned to the left atrium via the pulmonary vein. It is then pumped into the left ventricle through the bicuspid valve and into the aorta for systemic circulation. Eventually in the systemic capillaries exchange with the tissue fluid and cells of the body occurs; oxygen and nutrients are supplied to the cells for their metabolism and exchanged for carbon dioxide and waste products. In this case, oxygen and nutrients exit the systemic capillaries to be used by the cells in their metabolic processes, and carbon dioxide and waste products will enter the blood.

The ventricles are stronger and thicker than the atria, and the muscle wall surrounding the left ventricle is thicker than the wall surrounding the right ventricle due to the higher force needed to pump the blood through the systemic circulation. Atria facilitate circulation primarily by allowing uninterrupted venous flow to the heart, preventing the inertia of interrupted venous flow that would otherwise occur at each ventricular systole. Our heart beats 100,000 times a day, pushing 5,000 gallons of blood through our body every 24 hours. It delivers oxygen- and nutrient-rich blood to our tissues and carries away waste.

The wall of the heart consists of three layers of tissue:

- **Epicardium** — protective layer mostly made of connective tissue.
- **Myocardium** — the muscles of the heart.
- **Endocardium** — lines the inside of the heart and protects the valves and chambers.

These layers are covered in a thin protective coating called the pericardium.

Each heartbeat can be split into two parts:
Diastole: the atria and ventricles relax and fill with blood.
Systole: the atria contract (atrial systole) and push blood into the ventricles; then, as the atria start to relax, the ventricles contract (ventricular systole) and pump blood out of the heart. When blood is sent through the pulmonary artery to the lungs, it travels through tiny capillaries on the surface of the lung's alveoli (air sacs). Oxygen travels into the capillaries, and carbon dioxide travels from the capillaries into the air sacs, where it is breathed out into the atmosphere.
The muscles of the heart need to receive oxygenated blood, too. They are fed by the coronary arteries on the surface of the heart. Where blood passes near to the surface of the body, such as at the wrist or neck, it is possible to feel your pulse; this is the rush of blood as it is pumped through the body by the heart.

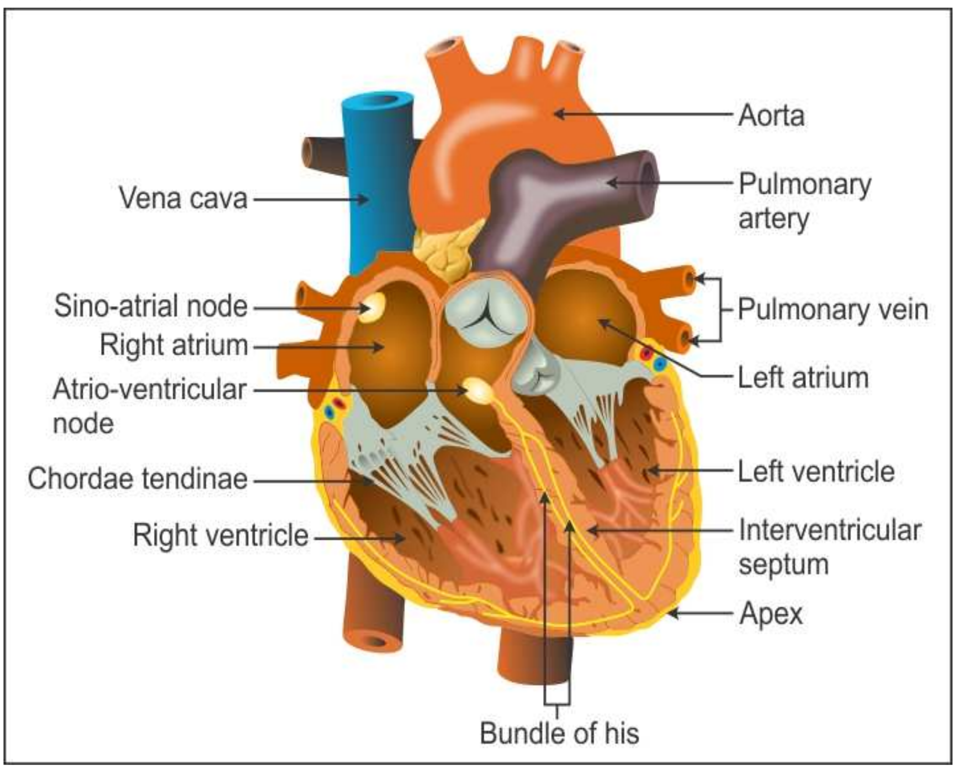


Diagram 3.2

The circulatory system, also called the **cardiovascular system** or the vascular system, is an organ system that permits blood to circulate and transport nutrients (such as amino acids and electrolytes), oxygen, carbon dioxide, hormones, and blood cells to and from the cells in the body to provide nourishment and help in fighting The essential components of the human cardiovascular system are the heart, blood and blood vessels. It includes the pulmonary circulation, a "loop" through the lungs where blood is oxygenated; and the systemic circulation, a "loop" through the rest of the body to provide oxygenated blood. The systemic circulation can also be seen to function in two parts – a macrocirculation and a microcirculation. An average adult contains five to six quarts (roughly 4.7 to 5.7 liters) of blood, accounting for approximately 7% of their total body weight. Blood consists of plasma, red blood cells, white blood cells, and platelets. Also, the digestive system works with the circulatory system to provide the nutrients the system needs to keep the heart pumping. The cardiovascular systems of humans are closed, meaning that the blood never leaves the network blood vessels. In contrast, oxygen and nutrients diffuse across the blood vessel layers and enter interstitial fluid, which carries oxygen and nutrients to the target cells, and carbon dioxide and wastes in the opposite direction. The other component of the circulatory system, the lymphatic system, is open.

The cardiac cycle is the sequence of events that occurs in one complete beat of the heart. The pumping phase of the cycle, also known as systole, occurs when heart muscle contracts. The filling phase, which is known as diastole, occurs when heart muscle relaxes. At the beginning of the cardiac cycle, both atria and ventricles are in diastole. During this time, all the chambers of the heart are relaxed and receive blood. The atrioventricular valves are open. Atrial systole follows this phase. During atrial systole, the left and right atria contract at the same time and push blood into the left and right ventricles, respectively. The next phase is ventricular systole. During ventricular systole, the left and right ventricles contract at the same time and pump blood into the aorta and pulmonary trunk, respectively. In ventricular systole, the atria are relaxed and receive blood. The atrioventricular valves close immediately after ventricular systole begins to stop blood going back into the atria. However, the semilunar valves are open during this phase to allow the blood to flow into the aorta and pulmonary trunk. Following this phase, the ventricles relax that is ventricular diastole occurs. The semilunar valves close to stop the blood from flowing back into the ventricles from the aorta and pulmonary trunk. The atria and ventricles once again are in diastole together and the cycle begins again.

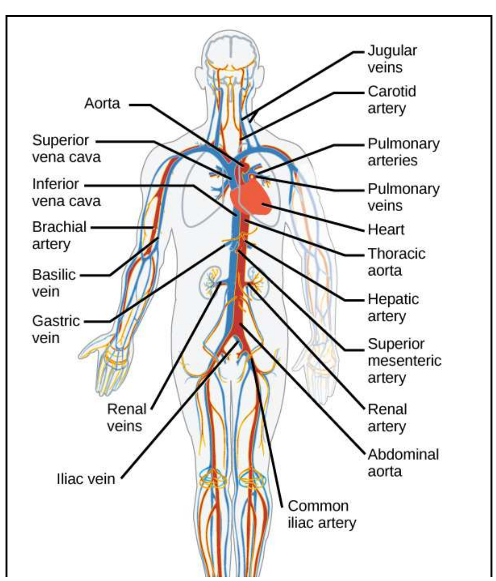


Diagram 3.3

Q3: Draw the engineering analogy of heart as pump to explain, how it control and maintained blood pressure of arteries.

OR

Q4: With the help of engineering equivalent piping diagram of cardiovascular circulation system, explain pulmonary circulation and systemic circulation.

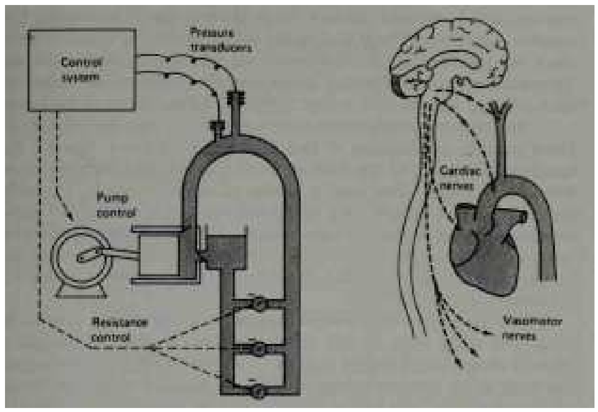


Diagram 3.4

A good engineering analog is illustrated in Figure, which shows the physiological system as a pump model. The pump is initially set to operate under predetermined conditions, as are the valves representing the resistance in the various organs. The pressure transducers sense the pressure continuously. With the pressure head set at some normal level, if one of the valves opens farther to obtain greater flow in that branch, the pressure head will decrease. This is picked up as a lower pressure by the sensors, which feed a signal to the controller, which, in turn, closes other valves, speeds up the pump, or does both in order to try to maintain a constant pressure head.

Q5: With waveform, explain blood pressure variation in aorta, left atrium and left ventricle with respect to ECG.

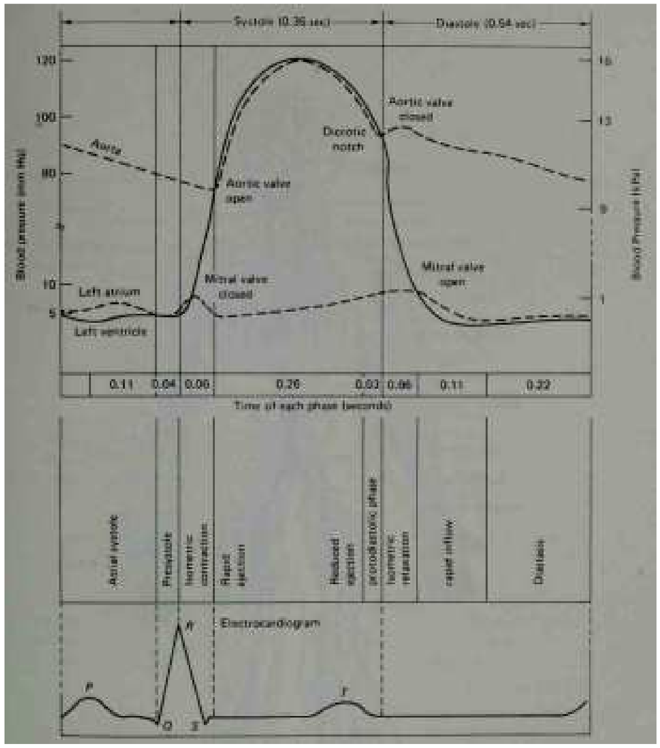


Diagram 3.4

With regard to measurements, the events in the heart that relate to the blood pressure as a function of time should be understood. Figure illustrates this point. The two basic stages of diastole and systole are shown with a more detailed time scale of phases of operation below. The blood pressure waves for the aorta, the left atrium, and the left ventricle are drawn to show time and magnitude relationships. Also, the correlated electrical events are shown at the bottom in the form of the electrocardiogram, and the basic relationship of the heart sounds.

Examining the aortic wave, it can be seen that during systole, the ejection of blood from the left ventricle is rapid at first. As the rate of pressure change decreases, the rounded maximum of the curve is obtained. The peak aortic pressure during systole is a function of left ventricular stroke volume, the peak rate of ejection, and the distensibility of the walls of the aorta. In a diseased heart, ventricular contractability and rigid atherosclerotic arteries produce unwanted rises in blood pressure. When the systolic period is completed, the aortic valve is closed by the back pressure of blood (against the valve). This effect can be seen on the pressure pulse waveform as the dicrotic notch. When the valve is closed completely, the arterial pressure gradually decreases as blood pours into the countless peripheral vascular networks. The rate at which the pressure falls is determined by the pressure achieved during the systolic interval, the rate of outflow through the peripheral resistances, and the diastolic interval. The form of the arterial pressure pulse changes as it passes through the arteries. The walls of the arteries cause damping and reflections; and as the arteries branch out into smaller arteries with smaller cross-sectional areas, the pressures and volumes change, hence the rate of flow also changes. The peak systolic pressure gets a little higher and the diastolic pressure flatter. The mean pressure in some arteries (e.g., the brachial artery) can be as much as 20 mm Hg higher than that in the aorta.

As the blood flows into the smaller arteries and arterioles, the pressure decreases and loses its oscillatory character. Pressure in the arterioles can vary from about 60 mm Hg down to 30 mm Hg. As the blood enters the venous system after flowing through the capillaries, the pressure is down to about 15 mm Hg. In the venous system, the pressure in the venules decreases to approximately 8 mm Hg, and in the veins to about 5 mm Hg. In the vena cava, the pressure is only about 2 mm Hg. Because of these differences in pressure, measurement of arterial blood pressure is quite different from that of venous pressure. For example, a 2-mm Hg error in systolic pressure is only of the order of 1.5 percent. In a vein, however, this would be a 100 percent error. Also because of these pressure differences, the arteries have thick walls, while the veins have thin walls. Moreover, the veins have larger internal diameters. Since about 75 to 80 percent of the blood volume is contained in the venous system, the veins tend to serve as a reservoir for the body's blood supply.

Q6: Draw and explain Electrocardiogram (ECG) mentioning amplitude and duration of each wave and intervals. Define bradycardia and tachycardia?

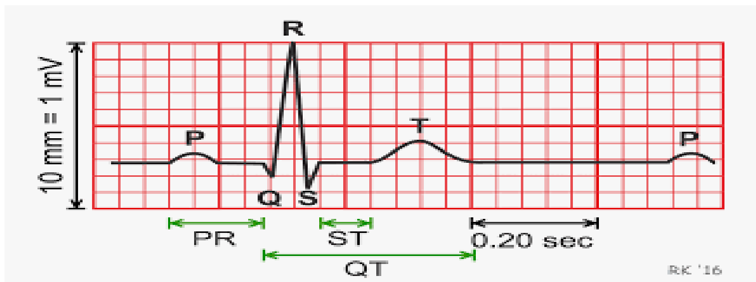


Diagram 3.5

The electrocardiogram (ECG or EKG) is a graphic recording or display of the time-variant voltages produced by the myocardium during the cardiac cycle. Figure shows the basic waveform of the normal electrocardiogram. The P, QRS, and T waves reflect the rhythmic electrical depolarization and repolarization of the myocardium associated with the contractions of the atria and ventricles. The electrocardiogram is used clinically in diagnosing various diseases and conditions associated with the heart. It also serves as a timing reference for other measurements.
To the clinician, the shape and duration of each feature of the ECG are significant. The waveform, however, depends greatly upon the lead configuration used, as discussed below. In general, the cardiologist looks critically at the various time intervals, polarities, and amplitudes to arrive at his diagnosis.

Some normal values for amplitudes and durations of important ECG parameters are as follows:
Amplitude: P wave 0.25 mV
R wave 1.60 mV
Q wave 25<Vo of R wave
T wave 0.1 to 0.5 mV
Duration: P-R interval 0.12 to 0.20 sec
Q-T interval 0.35 to 0.44 sec
S-T segment 0.05 to 0.15 sec
P wave interval 0.11 sec
QRS interval 0.09 sec

For his diagnosis, a cardiologist would typically look first at the heart rate. The normal value lies in the range of 60 to 100 beats per minute. A slower rate than this is called bradycardia (slow heart) and a higher rate, tachycardia (fast heart). He would then see if the cycles are evenly spaced. If not, an arrhythmia may be indicated. If the P-R interval is greater than 0.2 second, it can suggest blockage

of the AV node. If one or more of the basic features of the ECG should be missing, a heart block of some sort might be indicated.
In healthy individuals the electrocardiogram remains reasonably constant, even though the heart rate changes with the demands of the body. It should be noted that the position of the heart within the thoracic region of the body, as well as the position of the body itself (whether erect or recumbent), influences the “electrical axis" of the heart. The electrical axis (which parallels the anatomical axis) is defined as the one along which the greatest electromotive force is developed at a given instant during the cardiac cycle. The electrical axis shifts continually through a repeatable pattern during every cardiac cycle.
Under pathological conditions, several changes may occur in the ECG. These include (1) altered paths of excitation in the heart, (2) changed origin of waves (ectopic beats), (3) altered relationships (sequences) of features, (4) changed magnitudes of one or more features, and (5) differing durations of waves or intervals. As mentioned earlier, an instrument used to obtain and record the electrocardiogram is called an electrocardiograph.

Q7: Draw and explain ECG amplifier used for amplification of bioelectric signals.

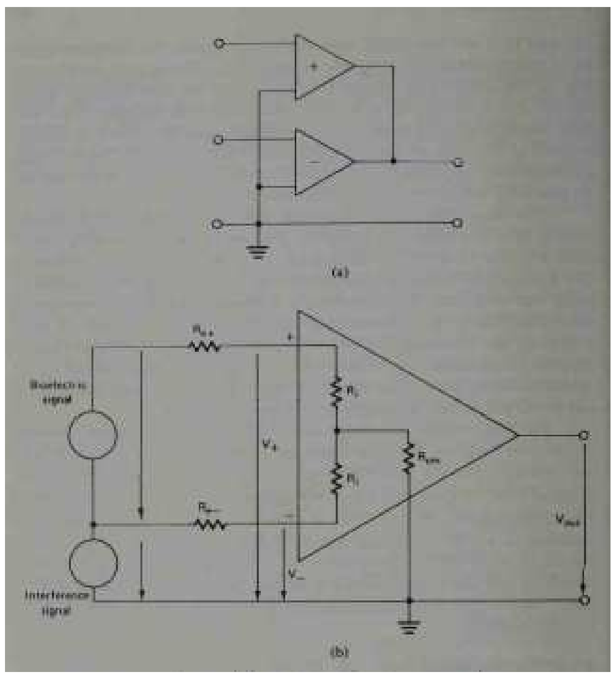


Diagram 3.6

The early string galvanometer had the advantage that it could easily be isolated from ground. Thus, the potential difference between two electrodes on the patient could be measured with less electrical interference than can be done with a grounded system. Electronic amplifiers, however, are normally referenced to ground through their power supplies. This creates an interference problem (unless special measures are taken) when such amplifiers are used to measure small bioelectric potentials. The technique usually employed, not only in electrocardiography but also in the measurement of other bioelectric signals, is the use of a differential amplifier. The principle of the differential amplifier can be explained with the help of Figure
A differential amplifier can be considered as two amplifiers with separate inputs, but with a common output terminal, which delivers the sum of the two amplifier output voltages. Both amplifiers have the same voltage gain, but one amplifier is inverting (output voltage is 180 out of phase with respect to the input) while the other is noninverting (input and output voltages are in phase). If the two amplifier inputs are connected to the same input source, the resulting common-mode gain should be

zero, because the signals from the inverting and the noninverting amplifiers cancel each other at the common output. However, because the gain of the two amplifiers is not exactly equal, this cancellation is not complete.
Rather, a small residual common-mode output remains.

Q8: Explain various ECG lead configurations. Draw and explain Einthonven triangle.

Various ECG lead configurations is shown below

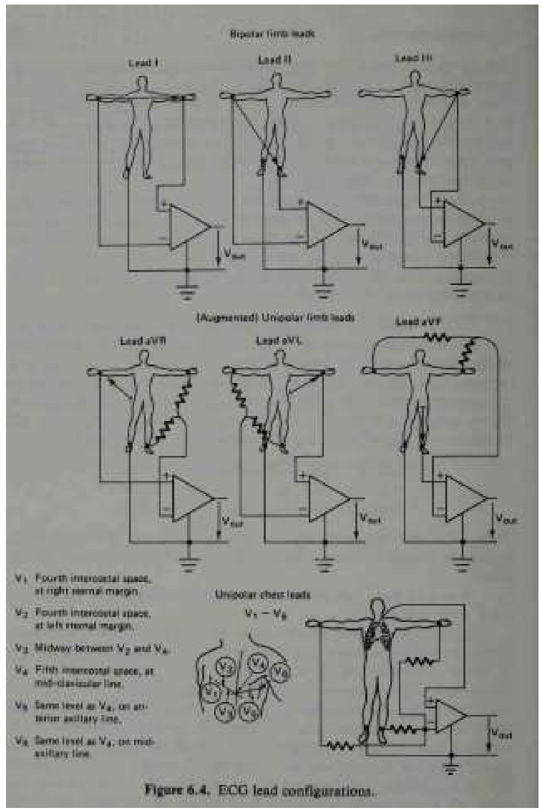
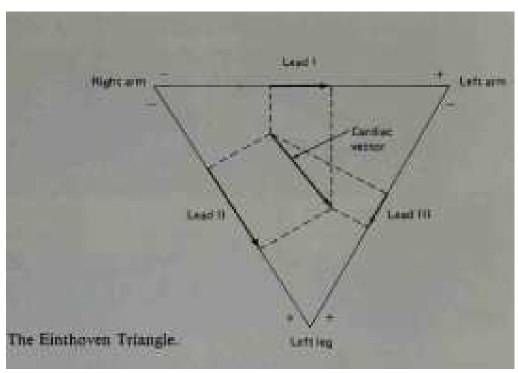


Figure 6.4. ECG lead configurations.



The Einthoven Triangle.

Diagram 3.7

The sides of the triangle represent the lines along which the three projections of the ECG vector are measured. Based on this, Einthoven showed that the instantaneous voltage measured from any one of the three lead positions is approximately equal to the algebraic sum of the other two.

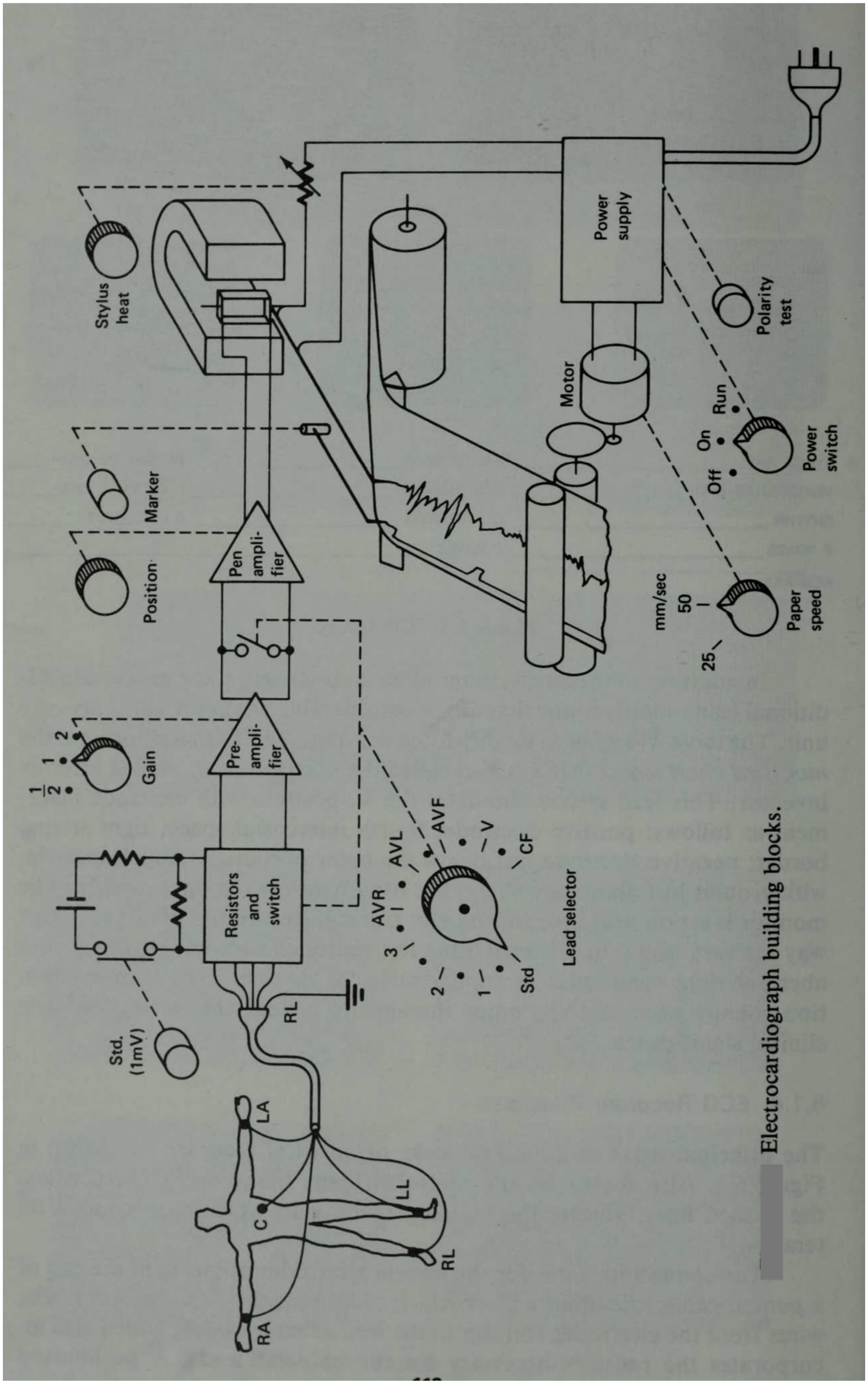
Q9: With building block of Electrocardiograph , explain the working of ECG recorder.

The principal parts or building blocks of an ECG recorder are shown in Figure. Also shown are the controls usually found on ECG recorders; the dashed lines indicate the building block with which each control interacts.

The connecting wires for the patient electrodes originate at the end of a patient cable, the other end of which plugs into the ECG recorder. The wires from the electrodes connect to the lead selector switch, which also incorporates the resistors necessary for the unipolar leads. A pushbutton allows the insertion of a standardization voltage of 1 mV to standardize or calibrate the recorder. Although modern recorders are stable and their sensitivity does not change with time, the ritual of inserting the standardization pulse before or after each recording when recording a 12-lead ECG is still followed. Changing the setting of the lead selector switch introduces an artifact on the recorded trace. A special contact on the lead selector switch turns off the amplifier momentarily whenever this switch is moved and turns it on again after the artifact has passed. From the lead selector switch the ECG signal goes to a preamplifier, a differential amplifier with high common-mode rejection. It is ac-coupled to avoid problems with small dc voltages that may originate from polarization of the electrodes. The preamplifier also provides a switch to set the sensitivity or gain. Older ECG machines also have a continuously variable sensitivity adjustment, sometimes marked standardization adjustment. By means of this adjustment, the sensitivity of the ECG recorder can be set so that the standardization voltage of 1 mV causes a pen deflection of 10 mm. In modern amplifiers the gain usually remains stable once adjusted, so the continuously variable gain control is now frequently a screwdriver adjustment at the side or rear of the ECG recorder.

The preamplifier is followed by a dc amplifier called the pen amplifier, which provides the power to drive the pen motor that records the actual ECG trace. The input of the pen amplifier is usually accessible separately, with a special auxiliary input jack at the rear or side of the ECG recorder. Thus, the ECG recorder can be used to record the output of other devices, such as the electromotograph, which records the Achilles reflex. A position control on the pen amplifier makes it possible to center the pen on the recording paper. All modern ECG recorders use heat-sensitive paper, and the pen is actually an electrically heated stylus, the temperature of which can be adjusted with a stylus heat control for optimal recording trace. Beside the recording stylus, there is a marker stylus that can be actuated by a pushbutton and allows the operator to mark a coded indication of the lead being recorded at the margin of the electrocardiogram. Normally, electrocardiograms are recorded at a paper speed of 25 mm/s, but a faster speed of 50 mm/s is provided to allow better resolution of the QRS complex at very high heart rates or when a particular waveform detail is desired.

The power switch of an ECG recorder has three positions. In the ON position the power to the amplifier is turned on, but the paper drive is not running. In order to start the paper drive, the switch must be placed in the/?LW position. In some ECG machines the lead selector switch has auxiliary positions (between the lead positions) in which the paper drive is stopped. In older ECG machines a pushbutton or metal “finger contact" allows the operator to check whether the recorder is connected to the power line with the right polarity. Because the improper connection of older machines can create a shock hazard for the patient, this test must be performed prior to connecting the electrodes to the patient.



Electrocardiograph building blocks.

Diagram 3.8

Q10: Draw and explain wall-mounted sphygmomanometer to measure blood pressure. Define systolic and diastolic blood pressure.

OR.

Q11: Explain indirect method of blood pressure measurement using wall-mounted sphygmomanometer. Define systolic and diastolic blood pressure.

Diagram 3.9

Indirect Measurements

As stated earlier, the familiar indirect method of measuring blood pressure involves the use of a sphygmomanometer and a stethoscope. The sphygmomanometer consists of an inflatable pressure cuff and a mercury or aneroid manometer to measure the pressure in the cuff. The cuff consists of a rubber bladder inside an inelastic fabric covering that can be wrapped around the upper arm and fastened with either hooks or a Velcro fastener.

The cuff is normally inflated manually with a rubber bulb and deflated slowly through a needle valve.

A wallmounted sphygmomanometer is shown in Figure. These devices are also manufactured as portable units. The sphygmomanometer works on the principle that when the cuff is placed on the upper arm and inflated, arterial blood can flow past the cuff only when the arterial pressure exceeds the pressure in the cuff. Furthermore, when the cuff is inflated to a pressure that only partially occludes the brachial artery, turbulence is generated in the blood as it spurts through the tiny arterial opening during each systole. The sounds generated by this turbulence, Korotk off sound can be heard through a stethoscope placed over the artery downstream from the cuff. To obtain a blood pressure measurement with a sphygmomanometer and a stethoscope, the pressure cuff on the upper arm is first inflated to a pressure well above systolic pressure. At this point no sounds can be heard through the stethoscope, which is placed over the brachial artery, for that artery has been collapsed by the pressure of the cuff. The pressure in the cuff is then gradually reduced. As soon as cuff pressure falls below systolic pressure, small amounts of blood spurt past the cuff and Korotk off sounds begin to be heard through the stethoscope. The pressure of the cuff that is indicated on the manometer when the first Korotk off sound is heard is recorded as the systolic blood pressure. As the pressure in the cuff continues to drop, the Korotk off sounds continue until the cuff pressure is no longer sufficient to occlude the vessel during any part of the cycle. Below this pressure the Korotk off sounds disappear, marking the value of the diastolic pressure.

Q12: Draw and explain programmed electro-sphygmomanometer (PE-300).

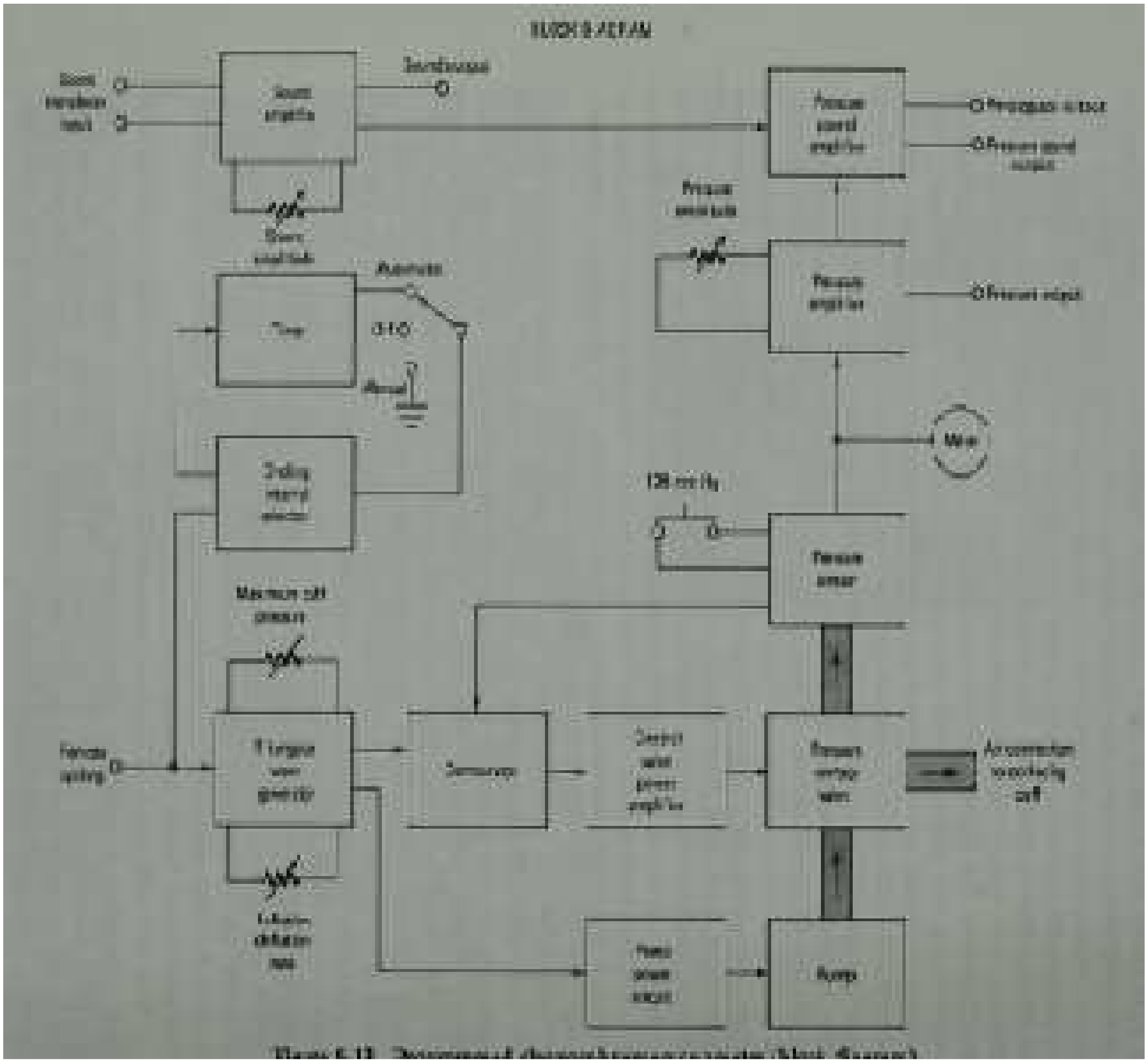


Diagram 3.10

Many of the commercially available automatic blood pressure meters work well when demonstrated on a quiet, healthy subject but fail when used to measure blood pressure during activity or when used on patients in circulatory shock. Methods other than those utilizing the Korotkoff sounds have been tried in detecting the blood pulse distal to the occlusion cuff.

Among them is impedance plethysmography, which indicated directly the pulsating blood flow in the artery, and ultrasonic Doppler methods, which measure the motions of the arterial walls. An early example of an automatic blood pressure meter is the programmed electrosphygmomanometer PE-300, illustrated in figures in block diagram and pictorial form. This instrument is designed for use in conjunction with an occluding cuff, microphone, or pulse transducer, and a recorder for the automatic measurement of indirect systolic and diastolic blood pressures from humans and many animal subjects. The PE-300 incorporates a transducer-preamplifier that provides two output signals, a voltage proportional to the cuff pressure, and the amplified Korotkoff sounds or pulses. These

signals can be monitored individually or with the sounds or pulses superimposed on the calibrated cuff recorder. The combined signal can be recorded on a graphic pen recorder.
The self-contained cuff inflation system can be programmed to inflate and deflate an occluding cuff at various rates and time intervals. Equal and linear rates of cuff inflation and deflation permit two blood pressure determinations per cycle. The PE-300 can be programmed for repeat cycles at adjustable time intervals for monitoring of blood pressure over long periods of time. Single cycles may be initiated by pressing a panel-mounted switch.
Provision is also made for remote control via external contact closure. The maximum cuff pressure is adjustable, and the front-panel meter gives a continuous visual display of the cuff pressure.

Q13: Draw interior construction of liquid-column pressure transducer (P23ID) used to measure blood pressure. Explain it in detail.

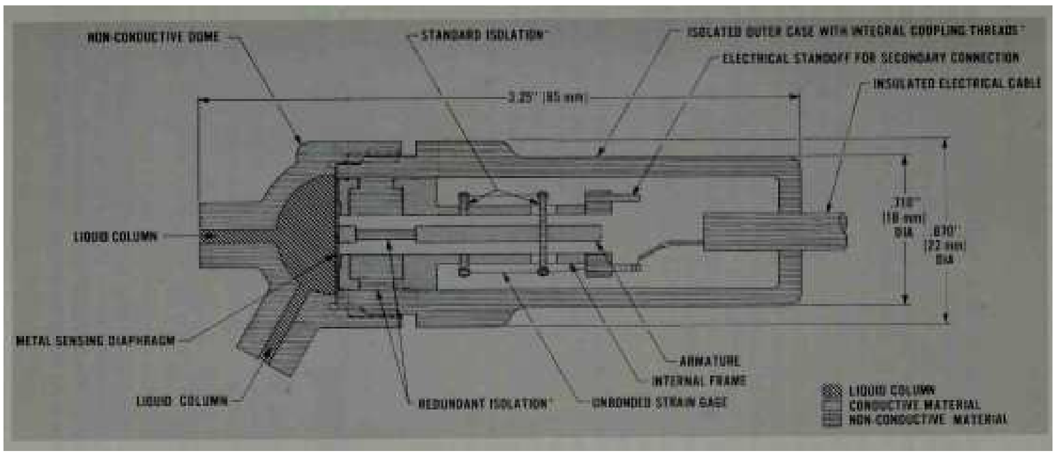


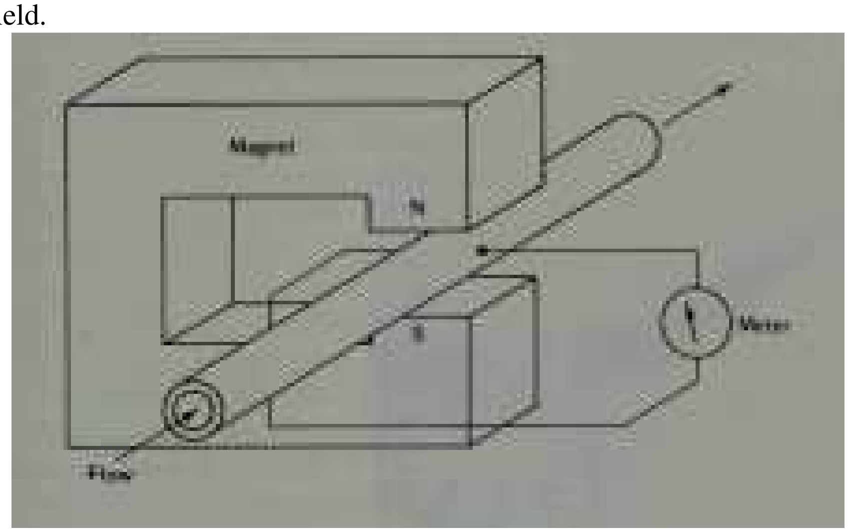
Diagram 3.11

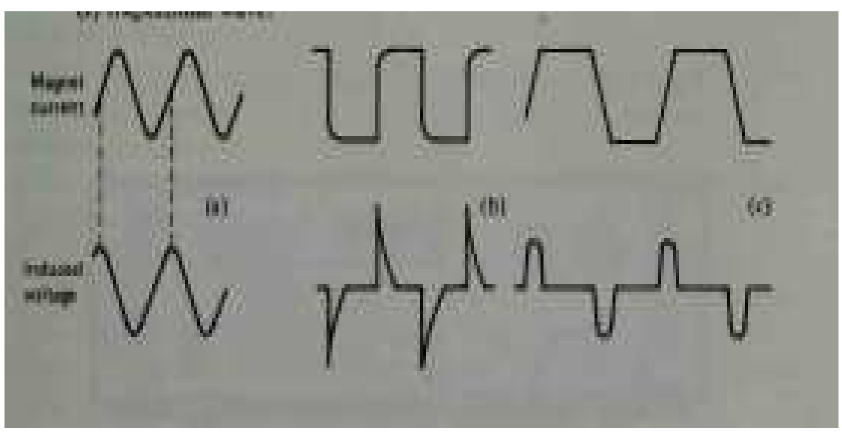
Liquid-column methods, A typical liquid-column blood pressure transducer, the Gould Statham P 23 ID, is illustrated in Figure is a cutaway drawing to show the interior construction and the isolation features of the same transducer, which is considered a standard size in hospital practice. The heart of the P 23 transducer is the unbounded strain gauge, which is connected in a standard Wheatstone bridge configuration. The metal sensing diaphragm can be seen on the left side. It is a precision-made part that must deflect predictably with a given fluid pressure. When the diaphragm is deflected downward by the pressure of the liquid being measured, the tension on two of the bridge wires is relaxed and the tension on the other two wires is tightened, changing the resistance of the gage. For negative pressures, the opposite wires are stretched and relaxed. The transducer is connected through the cable to an instrument which contains zero-balance and range controls, amplifier circuits, and readout.
The shielded cable is attached to the case through a liquid-tight seal that permits immersion of the transducer for cleaning. The transducer case is vented through the cable so that measurements are always referenced to atmospheric pressure. The dome is the reservoir for the liquid that transmits blood pressure to the diaphragm. It is made of transparent plastic to facilitate the detection and removal of bubbles, since even the most minute bubble can degrade the frequency response of the pressure-monitoring system. The dome is fitted with two ports. One port is coupled through tubing to the cannula; the other is used for venting air from the dome.
It should be noted in figure that there are three modes of isolation:
(1) external isolation of the case with a plastic sheath, which provides protection from extraneous voltages; (2) standard internal isolation of the sensing (bridge) elements from the inside of the transducer case and the frame; and (3) additional isolation (internal) of the frame from the case and the diaphragm in case of wire breakage. Thus, isolation of the patient/fluid column from electrical

excitation circuitry is assured, even in the event of failure of the standard internal isolation. This transducer is 56 mm (2.21 in.) long, with a maximum diameter at the base of 18 mm (0.71 in.). Its rated excitation voltage is 7.5 V which may
be dc or an ac carrier.

Q14: Draw and explain working principle of magnetic blood flow meter. Draw the magnetic current and corresponding voltage waveforms.

Magnetic blood flow meters are based on the principle of magnetic induction. When an electrical conductor is moved through a magnetic field, a voltage is induced in the conductor proportional to the velocity of its motion. The same principle applies when the moving conductor is not a wire, but rather a column of conductive fluid that flows through a tube located in the magnetic field. Figure shows how this principle is used in magnetic blood flow meters. A permanent magnet or electromagnet positioned around the blood vessel generates a magnetic field perpendicular to the direction of the blood flow. The voltage induced in the moving blood column is measured with stationary electrodes located on opposite sides of the blood vessel and perpendicular to the direction of the magnetic field.





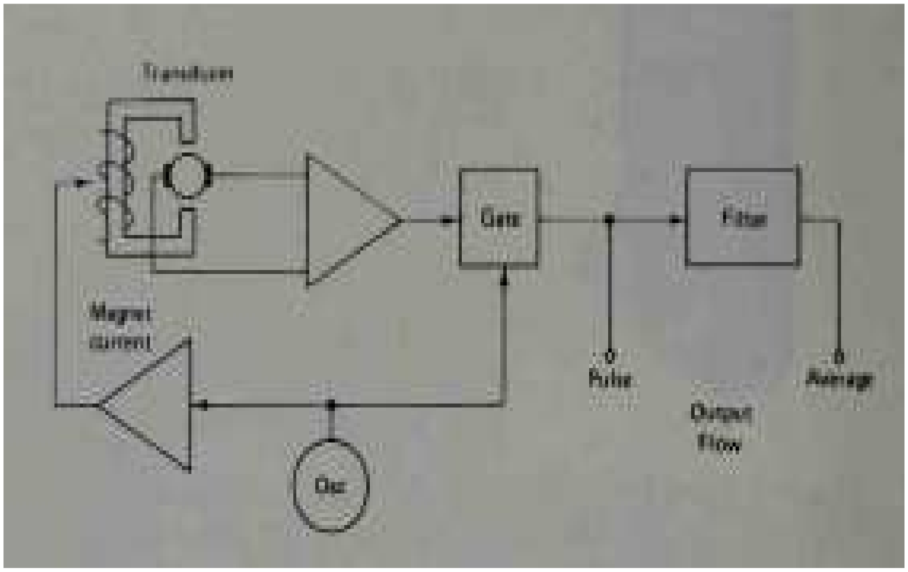


Diagram 3.12

Q15: Draw and explain working principle of Doppler type ultrasonic blood flow meter.

Ultrasonic Blood Flow Meters.

In an ultrasonic blood flow meter, a beam of ultrasonic energy is used to measure the velocity of flowing blood. This can be done in two different ways. In the transit time ultrasonic flow meter, a pulsed beam is directed through a blood vessel at a shallow angle and its transit time is then measured. When the blood flows in the direction of the energy transmission, the transit time is shortened. If it flows in the opposite direction, the transit time is lengthened.

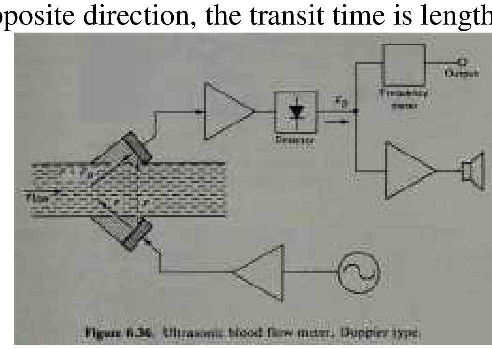


Figure 6.36. Ultrasonic blood flow meter, Doppler type.

Diagram 3.13

More common are ultrasonic flow meters based on the Doppler principle. An oscillator, operating at a frequency of several megahertz, excites a piezoelectric transducer (usually made of barium titanate). This transducer is coupled to the wall of an exposed blood vessel and sends an ultrasonic beam with a frequency F into the flowing blood. A small part of the transmitted energy is scattered back and is received by a second transducer arranged opposite the first one. Because the scattering occurs mainly as a result of the moving blood cells, the reflected signal has a different frequency due to the Doppler effect. Its frequency is either $F + F^{-}$) or $F - F_D$, depending on the direction of the flow. The Doppler component F_D is directly proportional to the velocity of the flowing blood. A fraction of the transmitted ultrasonic energy, however, reaches the second transducer directly, with the frequency being unchanged. After amplification of the composite signal, the Doppler frequency can be obtained at the output of a detector as the difference between the direct and the scattered signal components.

Q16: Draw and explain working of flow measurements by indicator dilution method. Explain it with open and closed circulation.

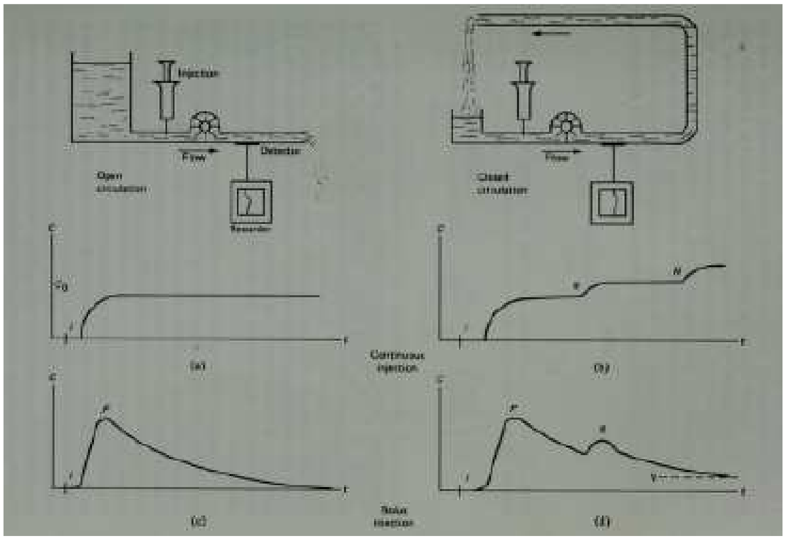


Diagram 3.14

Measurement by Indicator Dilution Methods

The indicator or dye dilution methods are the only methods of blood flow measurement that really measure the blood flow and not the blood velocity. In principle, any substance can be used as an indicator if it mixes readily with blood and its concentration in the blood can be easily determined after mixing. The substance must be stable but should not be retained by the body. It must have no toxic side effects. An indocyanine dye, Cardiogreen, used in an isotonic solution was long favored as a indicator. Its concentration was determined by measuring the light absorption with a densitometer (colorimeter). Radioactive isotopes (radioiodited serum albumen) have also been employed for this purpose.

The indicator most frequently used today, however, is isotonic saline, which is injected at a temperature lower than the body temperature. The concentration of the saline after mixing with the blood is determined with a sensitive thermistor thermometer.

The principle of the dilution method is shown in Figure. The upper left drawing shows a model of a part of the blood circulation under the (very simplified) assumption that the blood is not recirculated. The indicator is injected into the flow continuously, beginning at time t, at a constant infusion rate / (grams per minute). A detector measures the concentration downstream from the injection point. Figure shows the output of a recorder that is connected to the detector. At a certain time after the injection, the indicator begins to appear, the concentration increases, and, finally, it reaches a constant value, Co (milligrams per liter). From the measured concentration and the known injection rate, I (in milligrams per minute), the flow can be calculated as

$$F \text{ (liters per minute)} = \frac{I \text{ (in milligrams per minute)}}{Co \text{ (milligrams per liter)}}$$

Unit-4

Q1: Draw and explain working principle of Plethysmograph. Draw the waveform showing blood volume verses time.

PLETHYSMOGRAPHY

Related to the measurement of blood flow is the measurement of volume changes in any part of the body that result from the pulsations of blood occurring with each heartbeat. Such measurements are useful in the diagnosis of arterial obstructions as well as for pulse-wave velocity measurements. Instruments measuring volume changes or providing outputs that can be related to them are called plethysmographs, and the measurement of these volume changes, or phenomena related thereto, is called plethysmography.

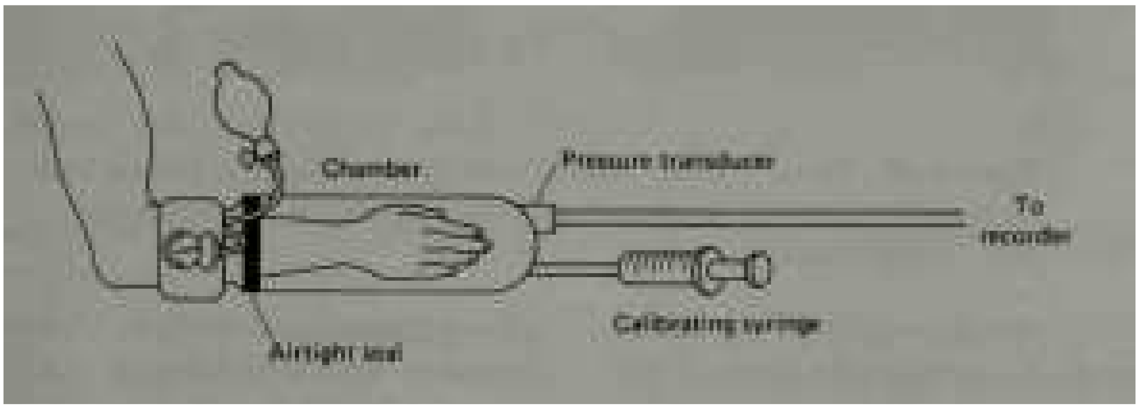


Diagram 4.1 Plethysmograph

A "true" plethysmograph is one that actually responds to changes in volume. 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, as shown in Figure. The cup is tightly sealed to the member to be measured so that any changes of volume in the limb or digit reflect as pressure changes inside the chamber. Either fluid or air can be used to fill the chamber.

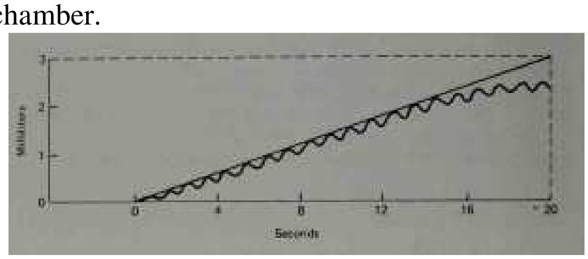


Diagram 4.2

Q2: Draw and explain Tidal volume (TV), Inspiratory reserve volume (IRV), Expiratory reserve volume (ERV), Residual volume (RV), Vital Capacity (VC), Total Lung Capacity (TLC), and Inspiratory Capacity (IC) related with lung volume and capacity.

OR

Q3: Define Tidal volume (TV), Inspiratory reserve volume (IRV), Expiratory reserve volume (ERV), Residual volume (RV), Vital Capacity (VC), Total Lung Capacity (TLC), and Inspiratory Capacity (IC) related with lung volume and capacity.

OR

Q4: With the help of waveform explain Tidal volume (TV), inspiratory reserve volume (IRV),

Tidal Volume (symbol VT or TV) :-

TV is the volume of gas inspirated and expirated level.

Inspiratory Reserve Volume (IRV) :-

IRV is the extra volume of gad that a person can inspire with maximal after reaching normal end inspiratory level. The end inspiratory level is the lev reached at the end of normal inspiration.

Expiratory Reserve Volume (ERV) :-

ERV is the extra volume of gas that can be expired with maximal exhaled beyond the end of expiratory level.

Residual Volume (RV) :-

RV is the volume of gas remaining in the lungs at the end of maximal expiration.

Vital Capacity (VC) :-

VC is the maximal volume of gas that can be expired form the lungs by forceful after a maximum inspiration. It is actual the ref between the level of maximum inspiration and the residual volume and it measured without respected time. The VC is also the sum of tidal volume, inspiratory reserved volume, expiratory reserve volume.

Total Lung Capacity (TLC) :-

expiratory reserve volume, residual volume(RV), vital capacity(VC), total lung capacity (TLC) .

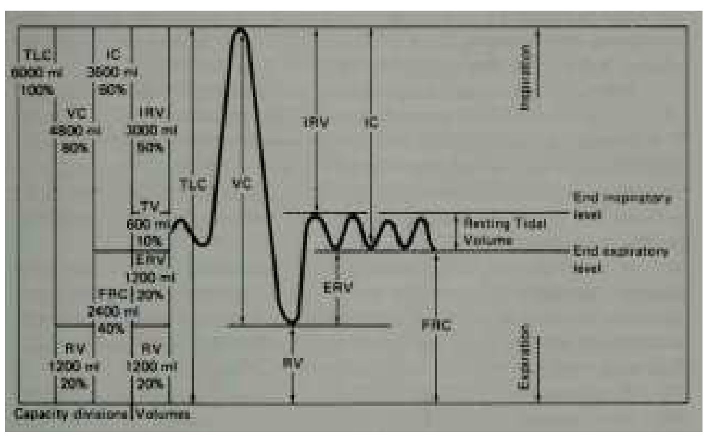


Diagram 4.3

TLC is the amount of gas contain in the lungs at the end of maximal inspiration. It is the sum of vital capacity and residual volume or total lungs capacity also the sum of tidal volume, inspiratiory and expiratory reserve volume and residual volume.

Q5: Draw and explain working principle of Spirometer.

Diagram 4.4

The most widely used laboratory instrument for respiratory volume measurements is the recording spirometer, an example of which is shown in Figure . All lung volumes and capacities that can be determined by measuring the amount of gas inspired or expired under a given set of conditions or during a specified time interval can be obtained by use of the spirometer. Included are the timed vital capacity and forced expiratory volume measurements. The only volume and capacity measurements that cannot be obtained with a spirometer are those requiring measurement of the gas that cannot be expelled from the lungs under any conditions. Such measurements include the residual volume, functional residual capacity, and total lung capacity.

The standard spirometer consists of a movable bell inverted over a chamber of water. Inside the bell, above the water line, is the gas that is to be breathed. The bell is counterbalanced by a weight to maintain the gas inside at atmospheric pressure so that its height above the water is proportional to the amount of gas in the bell. A breathing tube connects the mouth of the patient with the gas under the bell. Thus, as the patient breathes into the tube, the bell moves up and down with each inspiration and expiration in proportion to the amount of air breathed in or out. Attached to the bell or the counterbalancing mechanism is a pen that writes on an adjacent drum recorder, called a kymograph. As the kymograph rotates, the pen traces the breathing pattern of the patient.

Q6: Explain Inhalators, Humidifiers, Nebulizers and Aspirators.

Inhalators

The term inhalator generally indicates a device used to supply oxygen or some other therapeutic gas to a patient who is able to breathe spontaneously without assistance. As a rule, inhalators are used when a concentration of oxygen higher than that of air is required. The inhalator consists of a source of the therapeutic gas, equipment for reducing the pressure and controlling the flow of the gas, and a device for administering the gas. Devices for administering oxygen to patients include nasal cannulae and catheters, face masks that cover the nose and mouth, and, in certain settings, such as pediatrics, oxygen tents. The oxygen concentration presented to the patient is controlled by adjusting the flow of gas into the mask.

Humidifiers, Nebulizers, and Aspirators

In order to prevent damage to the patient's lungs, the air or oxygen applied during respiratory therapy must be humidified. Thus, virtually all inhalators, ventilators, and respirators include equipment to humidify the air, either by heat vaporization (steam) or by bubbling an air stream through a jar of water. When therapy requires that water or some type of medication be suspended in the inspired air as an aerosol, a device called a nebulizer is used. In a nebulizer the water or medication is picked up by a high-velocity jet of oxygen (or some other gas) and thrown against one or more baffles or other surfaces to break the substance into controllable-sized droplets or particles, which are then applied to the patient via a respirator.

A more effective (but also more expensive) type of nebulizer is the ultrasonic nebulizer, shown in Figure. This electronic device produces high-intensity sound energy well above the audible range. When applied to water or medication, the ultrasonic energy vibrates the substance with such intensity that a high volume of minute particles is produced. Such equipment usually consists of two parts, a generator that produces a radiofrequency current to drive the ultrasonic transducer, and the nebulizer itself, in which the transducer generates the ultrasound energy and applies it to the water or medication. Unlike the conventional nebulizer, the ultrasonic unit does not depend on the breathing gas for operation. Thus, the therapeutic agent can be administered during oxygen therapy or a mechanical ventilation procedure. Aspiration and other types of suction apparatus are often included as part of a ventilator or inhalator to remove mucus and other fluids from the airways. Where the aspirator is not provided as part of the respiratory therapy equipment, a separate suction device may be utilized.

Unit-5

Q1: Draw and explain working principle of X-ray tube.

The cathode and anode are contained in the envelope, which provides vacuum, support and electrical insulation. The envelope is most often made from glass, although some tubes contain envelopes formed from ceramic or even metal. For some demanding application such as dual energy CT (RET) are used. Unlike conventional x-ray tubes in RETs not only the anode, but the entire vacuum tube rotates, furthermore, the anode is in direct contact with the liquid coolant, resulting in improved heat conduction and increased performance [7].

The energy used for this process is provided from the generator, connected by an electrical circuit connected to the system. The generator also needs to convert the alternating current (AC), from the power supply, into direct current (DC), as needed by the x-ray tube.

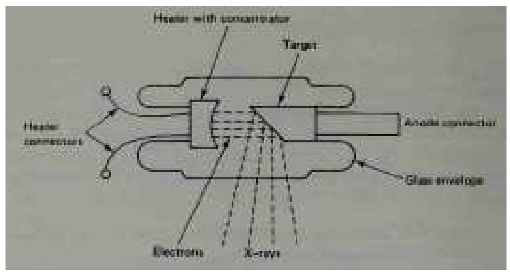


Diagram 5.1

To summarize, x-rays are produced in a standard way: by accelerating electrons with a high voltage and allowing them to collide with the focal spot. X-rays are produced when the electrons are suddenly decelerated upon collision with the metal target. These x-rays are called "braking radiation". If the electrons have high energy, they can expel an electron out of the atomic shell of the bombarded atom. Electrons from a higher energy level fill the place of the expelled electron, emitting x-ray photons with quantized (precise) energies, determined by the respective electron energy levels. The x-rays produced in this way are called "characterizing x ray" the tube) and exposure time, usually a fraction of a second

Q2: Draw and explain the use of X-rays to visualize the inner structure of the body.

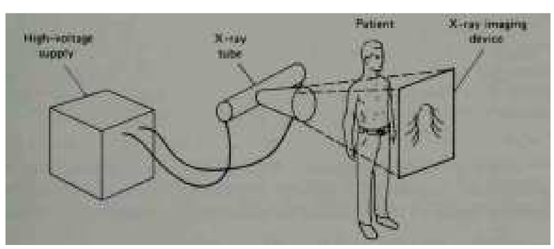


Diagram 5.2

The use of X rays as a diagnostic tool is based on the fact that various components of the body have different densities for the rays. When X rays from a point source penetrate a body section, the internal structure of the body absorbs varying amounts of the radiation. The radiation that leaves the body, therefore, has a spatial intensity variation that is an image of the internal structure of the body. When, as shown in Figure, this intensity distribution isvisualized by a suitable device, a shadow image is generated that corresponds to the X-ray density of the organs in the body section. Bones and foreign bodies, especially metallic ones, and air-filled cavities show up well on these images because they have a much higher or a much lower density than the surrounding tissue. Most body organs, however, differ very little in density and do not show up well on the X-ray image, unless one of the special techniques described later is used.

Q3: Draw and explain working principle of X-Ray image intensifier for visual observation and recording of X- ray picture.

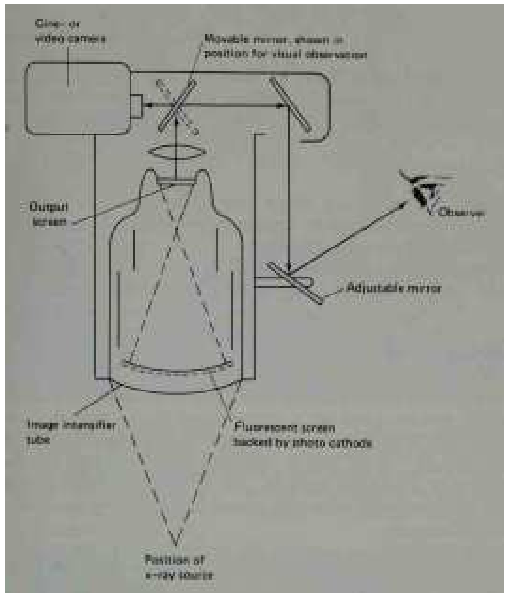


Diagram 5.3

Image intensifiers. The faint image of a fluoroscopic screen can be made brighter with the help of an electronic image intensifies as shown in Figure. The intensifier tube contains a fluorescent screen, the surface of which is coated with a suitable material to act as a photocathode. The electron image thus obtained is projected onto a phosphor screen at the other end of the tube by means of an electrostatic lens system. The resulting brightness gain is due to the acceleration of the electrons in the lens system and the fact that the output image is smaller than the primary fluorescent image. The gain can reach an overall value of several hundred, and not only allows the X-ray intensity to be decreased but makes it possible to observe the image in a normally illuminated room. The intensifying tube, however, is rather heavy and requires a special suspension. For chest or pelvic examinations with the patient in a supine position, the screen on which the intensified image appears is high above the patient and requires a system of lenses and mirrors to present the image to the radiologist, who normally stands right next to the patient. For this reason, a TV camera is now used frequently to pick up the intensified image, which can then be observed on conveniently placed TV monitors. This TV picture can also be recorded on a TV tape recorder. Similarly, a movie camera can be used to record directly the intensified X-ray image during an examination.

Q4: Explain Angiography method.

Angiography

In angiographic procedures, the outlines of blood vessels are made visible on the X-ray image by injecting a bolus of contrast medium directly into the bloodstream in the region to be investigated. Because the contrast medium is rapidly diluted in the blood circulation, an X-ray photo or a series of such photos must be taken immediately after the injection. This procedure is often performed automatically with the help of a power operated syringe and an electrical cassette changer.

Q5: Explain Cardiac Catheterization method.

Cardiac Catheterization

Cardiac catheterization is a technique used primarily to diagnose valve deficiencies, septal defects, and other conditions of the heart characterized by hemodynamic changes. For this purpose, a special catheter is inserted through an artery, vein, or occasionally, directly through the chest wall into the heart. Under fluoroscopic control (with an image intensifier), the catheter is manipulated until its tip is in the desired position within the heart. By means of the catheter, intracardiac pressures can be measured in various parts of the heart that show characteristic changes if the heart valves are either narrowed or do not close completely. Septal defects can be detected by withdrawing blood samples from various heart chambers and measuring the oxygen concentration of the samples. Similarly, pumping efficiency can be assessed by measuring pressures within the ventricles at various points of the cardiac cycle. By injection of an indicator through the catheter the cardiac output can be measured. By the injection of a contrast medium through a suitably placed cardiac catheter (selective angiography) the vascular structures of the heart, including the coronary arteries (coronary arteriography), can be visualized.

Q6: Draw and explain Scintillation detector method for detection of gamma radiation for vitro measurements.

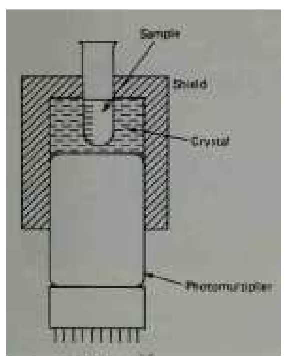


Diagram 5.4

Almost all nuclear radiation detectors used for medical applications utilize the light flashes caused by radiation in a suitable medium. Such scintillation detectors (also called scintillation counters) for gamma rays use a crystal made from thallium-activated sodium iodide, which is in close contact with the active surface of a photomultiplier tube. Each radiation quantum passing the crystal causes an output pulse at the photomultiplier, the amplitude of which is proportional to the energy of the radiation. This property of the scintillation detector is used to reduce the background, (counts due to natural radioactivity) by means of a pulse-height analyzer. This is an electronic circuit that passes only pulses within a certain amplitude range. The limits of this circuit are adjusted in such a way that only pulses from the radioisotope used can pass, whereas pulses with other energy levels are rejected. Figure shows types of scintillation detectors used for the determination of the concentration of gamma-emitting radioisotopes in medical applications. In the well counter, the scintillation crystal has a hole into which a test tube with the sample is inserted. In this configuration almost all radiation from the sample passes the crystal and is counted while a lead shield reduces the background count.

Q7: Draw and explain Scintillation detector method for detection of gamma radiation for vivo measurements.

OR

Q8: Draw and explain Lead Collimator method for detection of gamma radiation for vivo measurements.

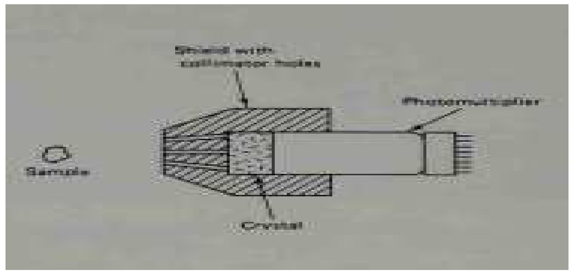


Diagram 5.5

For activity determinations inside the body, a collimated detector, also shown in Figure, is used. In this detector, a lead shield around the scintillation crystal has holes arranged in such a way that only radiation from a source located at one particular point in front of the detector can reach the crystal. Only a very small part of the radiation coming from this source, however, passes the crystal. This detector, therefore, is much less sensitive than the well counter type.

Q9: Draw and explain Well counter method for detection of gamma radiation for vitro measurements.

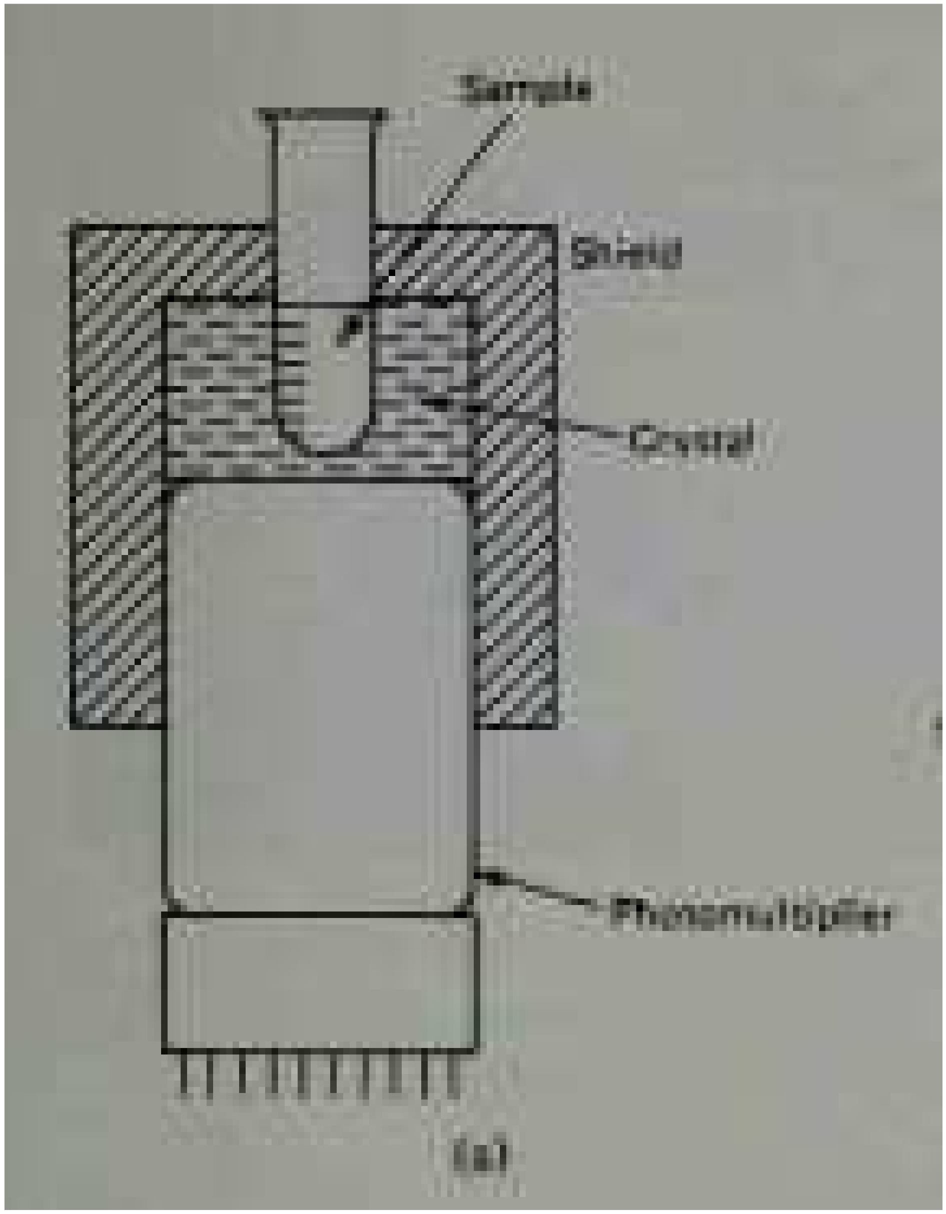


Diagram 5.6

Almost all nuclear radiation detectors used for medical applications utilize the light flashes caused by radiation in a suitable medium. Such scintillation detectors (also called scintillation counters) for gamma rays use a crystal made from thallium-activated sodium iodide, which is in close contact with the active surface of a photomultiplier tube. Each radiation quantum passing the crystal causes an output pulse at the photomultiplier, the amplitude of which is proportional to the energy of the radiation. This property of the scintillation detector is used to reduce the background, (counts due to natural radioactivity) by means of a pulse-height analyzer. This is an electronic circuit that passes only pulses within a certain amplitude range. The limits of this circuit are adjusted in such a way that only pulses from the radioisotope used can pass, whereas pulses with other energy levels are rejected. Figure shows types of scintillation detectors used for the determination of the concentration of gamma-emitting radioisotopes in medical applications. In the well counter, the scintillation crystal has a hole into which a test tube with the sample is inserted. In this configuration almost all radiation from the sample passes the crystal and is counted while a lead shield reduces the background count.

Q10: Draw and explain an instrumentation system for measurements of medical radioisotope procedure.

OR

Q11: Draw the block diagram of an Instrumentation System for radioisotope procedure and explain radioisotope measurements for vivo applications.

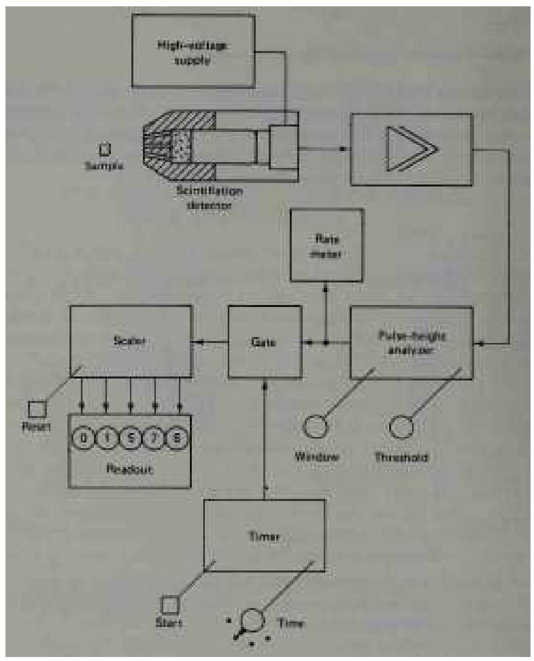


Diagram 5.7

Figure shows the other building blocks that constitute a typical instrumentation system for medical radioisotope measurements. The pulses from the photomultiplier tube are amplified and shortened before they pass through the pulse-height analyzer. A timer and gate allow the pulses that occur in a set time interval to be counted by means of a scaler (decimal counter with readout). A rate meter (frequency meter) shows the rate of the pulses. Its reading can be used in aiming the detector toward the location of maximal radioactivity and to set the pulse-height analyzer to where it passes all pulses from the particular isotope used. An automatic system for the measurement of radioactivity in *4n vitro" samples is shown in Figure . The automatic sample changer arm (right) obtains test tubes containing the samples from a carousel and drops them into a counting well. The number of radioactive disintegrations measured over a preselected time interval is printed out on the printer shown on the left side. A background correction can be made if desired.

Q12: Draw and explain planchet or gas flow counter method to detect beta radiation for vitro measurements.

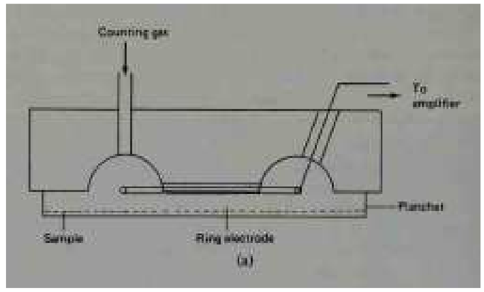


Diagram 5.8

The sample is placed in a planchet, a round, flat dish made of aluminum or stainless steel, in which the solvent is evaporated. In Siplanchet counter [shown in Figure .the planchet becomes part of a Geiger-Muller tube. The thin layer in which the sample is spread and its close contact with the collection electrodes result in a fairly high counting efficiency for beta radiation. The counting cell is continuously purged by a flow of gas that removes ionization products.

Q13: Draw and explain liquid scintillation counter method to detect beta radiation for vitro measurements.

For the soft beta radiation from tritium, a radioactive isotope of hydrogen, however, the sensitivity of the planchet counter is marginal and liquid scintillation counters are now normally used instead. In these devices the sample is placed in a small counting vial, where it is mixed with a solvent containing chemicals that scintillate when struck by beta rays. The vial is then placed in a detector Fig. in which it is positioned between two photomultiplier tubes. The light signal picked up is very weak.

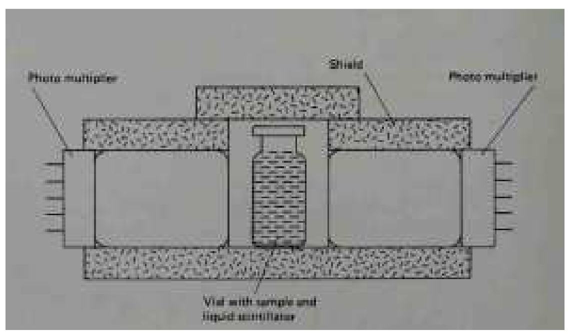


Diagram 5.9

and erroneous counts from tube noise must be reduced by a coincidence circuit, which passes only pulses that occur at the outputs of both tubes simultaneously. The remainder of the circuit is similar to the gamma measurement system shown in Figure. The low activities often encountered in measurements of this type sometimes require very long counting times.
This situation has lead to the development of systems that automatically change the samples and print out the results.

Q14: Write notes on Radiation therapy.

RADIATION THERAPY
The ionizing effect of X rays is utilized in the treatment of certain diseases, especially of certain tumors. In dermatology very soft X rays that do not have enough penetration power to enter more deeply into the body are used for treatment of the skin. They are called Grenz rays (from the German

word Grenze, meaning border) because in the spectrum they are actually at the border between the normally used X rays and the ultraviolet range (Figure). In the therapy of deep-seated tumors, on the other hand, very hard X rays that are generated with voltages much higher than those for diagnostic X rays are used. Sometimes linear accelerators or betatrons are used to obtain electrons with a very high voltage for this purpose. Changing the direction of entry of the beam in successive therapy sessions or rotating the patient during a session reduces the radiation damage to unafflicted body parts while concentrating the radiation at the site of the tumor.

Q15: What are the elements of intensive care unit (ICU)?

Intensive care unit (ICU) include patient monitoring, respiratory and cardiac Support, pain management, engaging resuscitation devices ,and other Life Support equipment designed to care for patient who are seriously injured, Have a critical or have gone major surgical procedure thereby requiring 24 Hours care and monitoring thus simply we can say it includes patient Monitoring life support and emergency rescapitation device.

Q16: What are the components of Cardiac care unit (CCU)?

A Cardiac Care Unit (CCU) is a specially staffed and equipped section of a healthcare facility for the support, monitoring and treatment of highly dependent patients with medical or surgical cardiac conditions which are life threatening or potentially life-threatening.

The Cardiac Care Unit component would:

- be a discrete unit usually associated with a designated Cardiac Ward with step-down and telemetry beds for monitoring of patients with acute coronary disease, heart failure or life-threatening arrhythmias
- provide the full range of invasive and non-invasive monitoring for cardiac patients, with access to the full range of cardiac investigations and 24 hours on call echocardiography, angiography, angioplasty, permanent pacemaker services
- have an inpatient and outpatient cardiac rehabilitation programme
- provide Hospital in the Home, outreach and remote monitoring services.

  The Cardiac Care Unit will consist of the following Functional Areas:
- Inpatient areas and dedicated clinical support areas
- Staff offices and amenities.

Q17: Explain internal and external pacemaker.

OR

Q18: Write difference between internal and external pacemaker.

Pacemaker Systems

A device capable of generating artificial pacing impulses and deHvering them to the heart is known as a pacemaker system (commonly called a pacemaker) and consists of a pulse generator and appropriate electrodes. Pacemakers are available in a variety of forms. Internal pacemakers may be permanently implanted in patients whose SA nodes have failed to function properly or who suffer from permanent heart block because of a heart attack. An internal pacemaker is defined as one in which the entire system is inside the body. In contrast, an external pacemaker usually consists of an externally worn pulse generator connected to electrodes located on or within the myocardium.

External pacemakers are used on patients with temporary heart irregularities, such as those encountered in the coronary patient, including heart blocks. They are also used for temporary management of certain arrhythmias that may occur in patients during critical postoperative periods and in patients during cardiac surgery, especially if the surgery involves the valves or septum. Internal pacemaker systems are implanted with the pulse generator placed in a surgically formed pocket below the right or left clavicle, in the left subcostal area, or, in women, beneath the left or right major pectoral muscle. Internal leads connect to electrodes that directly contact the inside of the right ventricle or the surface of the myocardium. The exact location of the pulse generator depends primarily on the type of electrode used, the nature of the cardiac dysfunction, and the method (mode) of pacing., that may be prescribed. Since there are no external connections for applying power, the pulse generator must be completely self-contained, with a power source capable of continuously operating the unit for a period of years.

External pacemakers, which include all types of pulse generators located outside the body, are normally connected through wires introduced into the right ventricle via a cardiac catheter. The pulse generator may be strapped to the lower arm of a patient who is confined
to bed, or worn at the midsection of an ambulatory patient.

Q19: Explain types of pacing modes in pacemaker.

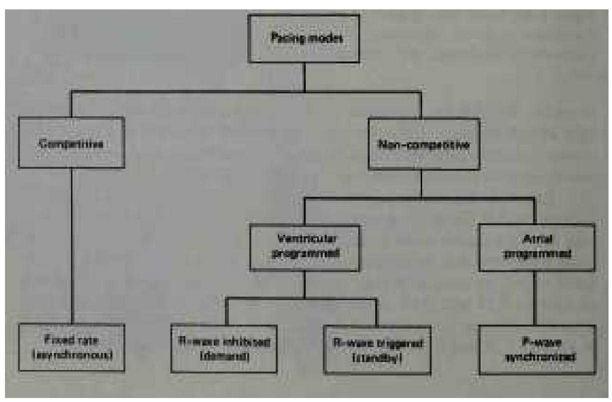


Diagram 5.10

Pacing Modes and Pulse Generators Several pacing techniques are possible with both internal and external pacemakers. They can be classed as either competitive and noncompetitive pacing modes as shown in Figure. The noncompetitive method, which uses pulse generators that are either ventricular programmed by the atria, is more popular. Ventricular-programmed pacemakers are designed to operate either in a demand (R-wave-inhibited) or standby (R-wave-triggered) mode, whereas atrial-programmed pacers are always synchronized with the P wave of the ECG.
The first (and simplest) pulse generators v/qtq fixed-rate or asynchronous (not synchronized) devices that produced pulses at a fixed rate (set by the physician or nurse) and were independent of any natural cardiac activity. Asynchronous pacing is called competitive pacing because the fixed-rate impulses may occur along with natural pacing impulses generated by the heart and would therefore be in competition with them in controlling the heartbeat. This competition is largely eliminated through use of ventricularor atrial-programmed pulse generators.

Fixed-rate pacers are sometimes installed in elderly patients whose SA nodes cannot provide proper stimuli. They are also used temporarily to determine the amplitude of impulses needed to pace or capture the heartbeat of a patient prior to or during the implantation of a more permanent unit. The amplitude at which capture occurs is referred to as the pacing threshold. While the implantable fixed-rate units tend to fail less frequently than the more sophisticated demand or standby pacers, their battery life (if the batteries are not rechargeable) is generally shorter because they are in constant operation.

The problems of shorter battery life and competition for control of the heart led, in part, to the development of ventricular-programmed (demand or standby) pulse generators. Either type of ventricular-programmed pulse generator, when connected to the ventricles via electrodes, is able to sense the presence (or absence) of a naturally occurring R wave. The output of an R-wave-inhibited (demand) unit is suppressed (no output pulses are produced) as long as natural (intrinsic) R waves are present. Thus, its output is held back or inhibited when the heart is able to pace itself. However, should standstill occur, or should the intrinsic rate fall below the preset rate of the pacer (around 70 BPM), the unit will automatically provide an output to pace the heart after an escape interval at the designated rate. In this way, ventricular-inhibited pacers are able to pace on demand. Other controls allow the setting of the pacer's rate anywhere between 30 and 180 BPM, as well as the amplitude of output pacing pulses between 0.1 and 20 mA. Some external demand pacers have a sense-pace indicator that deflects for each detected R wave or pacer-initiated impulse. The ON-OFF switch of some external pacers is provided with an interlock mechanism to prevent the unit from being accidentally turned off. A demand pacer, in the absence of R waves, automatically reverts to a fixed-rate mode of operation. For testing purposes at the time of implantation and for evaluation later, implanted demand pacers are purposely placed in a fixed-rate mode, usually by means of a magnet provided by the manufacturer. When placed over the skin layer covering the pacer, the magnet activates a magnetically operated switch that prevents the pacer from sensing R-wave activity. This process causes the pacer to operate in a fixed-rate mode at a slightly higher rate (about 10 BPM higher than the demand-mode pacing rate that had been preset). For a patient with a normal sinus rhythm, this procedure is used to ensure that an implanted demand pacer whose output is normally inhibited is capable of providing pacing pulses when needed. Evidence of the presence of pacing impulses is obtained from the electrocardiogram. Pacing impulses appear as pacing artifacts or spikes. Occasionally, they may seriously distort the recorded QRS complex.

Q20: With block diagram explain internal pacemaker.

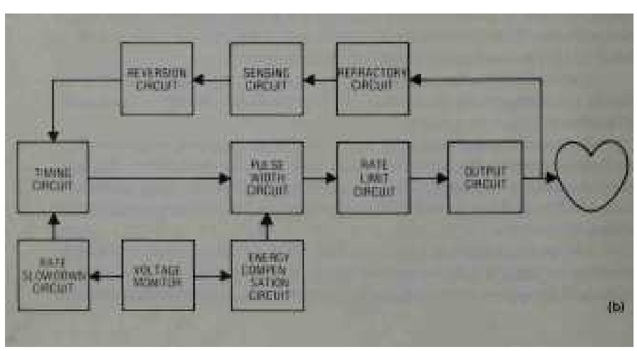


Diagram 5.11

Above Figure is a block diagram showing components of the circuitry. The timing circuit which consists of an RC network, a reference voltage source, and a comparator determines the basic pacing rate of the pulse generator. Its output signal feeds into a second /?C network, the pulse width circuit, which determines the stimulating pulse duration. A third RC network,
the rate-limiting circuit, disables the comparator for a preset interval and thus limits the pacing rate to a maximum of 120 pulses per minute for most single-component failures. The output circuit provides a voltage pulse to stimulate the heart. The voltage monitor circuit senses cell depletion and signals the rate slowdown circuit and energy compensation circuit of this event. The rate slowdown circuit shuts off some of the current to the basic timing network to cause the rate to slow down 8 ± 3 beats per minute when cell depletion has occurred. The energy-compensation circuit causes the pulse duration to increase as the battery voltage decreases, to maintain nearly constant stimulation energy to the heart.
There is also a feedback loop from the output circuit to the refractory circuit, which provides a period of time following an output pulse or a sensed R-wave during which the amplifier will not respond to outside signals. The sensing circuit detects a spontaneous R wave and resets the oscillator timing capacitor. The reversion circuit allows the amplifier to detect a spontaneous R wave in the presence of low-level continuous wave interference. In the absence of an R wave, this circuit allows the oscillator to pace at its preset rate ± 1 beat per minute.

Q21: Define fibrillation? Explain artrial fibrillation and ventricular fibrillation .

DEFIBRILLATORS
As discussed earlier in this chapter, the heart is able to perform its important pumping function only through precisely synchronized action of the heart muscle fibers. The rapid spread of action potentials over the surface of the atria causes these two chambers of the heart to contract together and pump blood through the two atrioventricular valves into the ventricles. After a critical time delay, the powerful ventricular muscles are synchronously activated to pump blood through the pulmonary and systemic circulatory systems. A condition in which this necessary synchronism is lost is known as fibrillation. During fibrillation the normal rhythmic contractions of either the atria or the ventricles are replaced by rapid irregular twitching of the muscular wall. Fibrillation of atrial muscles is called atrial fibrillation; fibrillation of the ventricles is known as ventricular fibrillation. Under conditions of atrial fibrillation, the ventricles can still function

Q22: Define defibrillation. Draw and explain the working principle of DC Defibrillator circuit, also explain its discharge waveform.

OR

Q23: Explain DC Defibrillator and also explain dual peak monophasic defibrillator.

If sufficient current to stimulate all musculature of the heart simultaneously is applied for a brief period and then released, all the heart muscle fibers enter their refractory periods together, after which normal heart action may resume. The discovery of this phenomenon led to the rather widespread use of defibrillation by applying a brief (0.25 to 1 sec) burst of 60-Hz ac at an intensity of around 6 A to the chest of the patient through appropriate electrodes. This application of an electrical shock to resynchronize the heart is sometimes called countershock. If the patient does not respond, the burst is repeated until defibrillation occurs. This method of countershock was known as ac defibrillation.

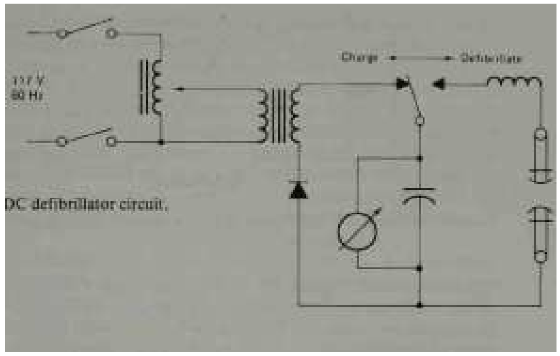


Diagram 5.12

About 1960, a number of experimenters began working with direct current defibrillation. Various schemes and waveforms were tried until, in late 1962, Bernard Lown of the Harvard School of Public Health and Peter Bent Brigham Hospital developed a new method of dc defibrillation that has found common use today. In this method, a capacitor is charged to a high dc voltage and then rapidly discharged through electrodes across the chest of the patient.

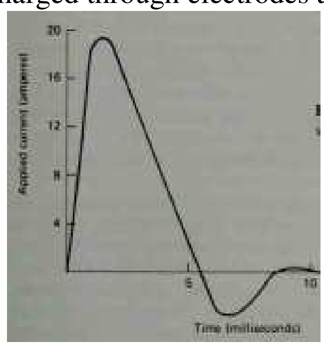


Diagram 5.13

It was found that dc defibrillation is not only more successful than the ac method in correcting ventricular fibrillation, but it can also be used successfully for correcting atrial fibrillation and other types of arrhythmias. The dc method requires fewer repetitions and is less likely to harm the patient.

Depending on the defibrillator energy setting, the amount of electrical energy discharged by the capacitor may range between 100 and 400 W-sec, or joules. The duration of the effective portion of the discharge is approximately 5 msec. The energy delivered is represented by the typical waveform shown in above Figure as a time plot of the current forced to flow through the thoracic cavity. The area under the curve is proportional to the energy delivered. It can be seen that the peak value of current is nearly 20 A and that the wave is essentially monophasic, since most of its excursion is above the baseline. An inductor in the defibrillator is used to shape the wave in order to eliminate a sharp, undesirable current spike that would otherwise occur at the beginning of the discharge.

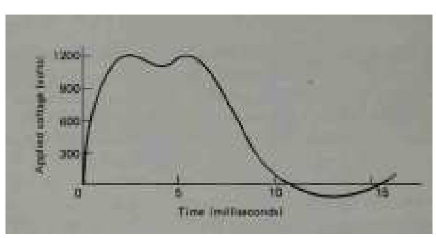


Diagram 5.14

Even with dc defibrillation, there is danger of damage to the myocardium and the chest walls because peak voltages as high as 6000 V may be used. To reduce this risk, some defibrillators produce dual-peak waveforms of longer duration (approximately 10 msec) at a much lower voltage. When this type of waveform is used, effective defibrillation can be achieved in adults with lower levels of delivered energy (between 50 and 200 W-sec).

A typical dual-peak waveform is shown in above Figure. Effective defibrillation at the desirable lower-voltage levels is also possible with the truncated waveform. The amplitude of this waveform is relatively constant, but its duration may be varied to obtain the amount of energy required. To properly deliver a large current discharge applied through the skin large electrodes are used. These electrodes, paddles, have metal disks that usually measure from 8 to 10 cm (3 to 4 in.) in diameter for external (transthoracic) use. For internal use (direct contact with the heart) or for use on infants, smaller paddles are applied. In external use, a pair of electrodes is firmly pressed against the patient's chest. Conductive jelly or a saline-soaked gauze pad (the latter is preferred) is applied between each paddle surface and the skin to prevent burning.

However, if conductive jelly is applied to the paddles prior to electrode placement, care must be taken that when the paddles are applied, the jelly does not accidentally form a conductive bridge between the paddles. If it does, the defibrillation attempt may not be successful. To protect the person applying the electrodes from accidental electric shock, special insulated handles are provided. A thumb switch, located in one (or both) of the handles, is generally used to discharge the defibrillator when the paddles are properly positioned. This device prevents the patient, or someone else, from receiving a shock prematurely.

Q24: What are the physiological effects of electrical current on human body?

Electrical accidents are caused by interaction of electric current with tissues of body. For an accident to occur current of sufficient magnitude must flow through body of victim. Three conditions have to be simultaneously satisfied. To contacts must be provided to body called as first and second contact together with voltage source to drive current through these contacts.

The physiological effects of current depend not only on their magnitude but also on current pathway through body which it turns depend on location of first and second contact full stop to particular situation have to be considered separately with both contacts are applied to the surface of body and when first contact is applied directly to the heart. Because current sensitivity of heart is much higher in second case, the effect of current applied directly to heart is often referred as Microshock. While effect of current of lateral surface contact is called Macroshock.

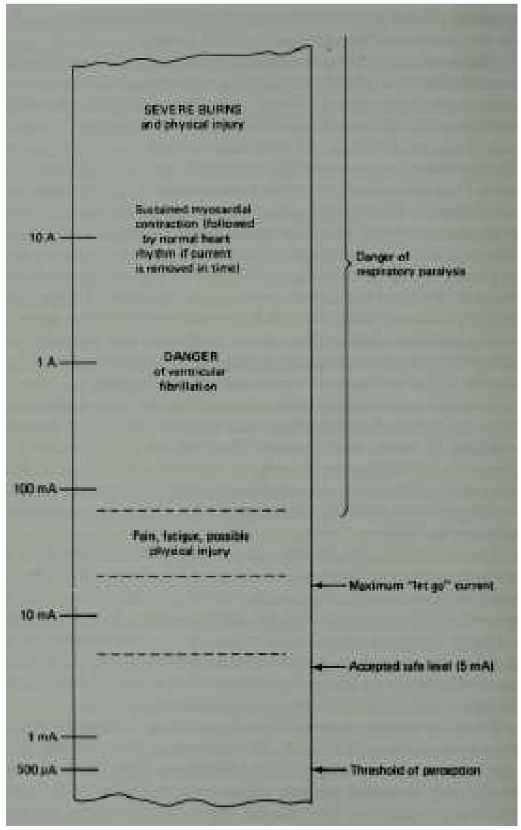


Diagram 5.15

Basically electric current can affect issue in two different ways

1) the electric energy dissipated in tissue resistance causes temperature increase. If high enough temperature is rich, tissue damage occurs. With threshold current, electrical burns are usually limited to localised damage at near contact point. Industrial accidents with high voltage as well as in lightning accidents, the dissipated electrical energy can be sufficient to cause burns involving larger part of the body.

2) transmission of impulse through sensory or motor nerve involved electro-chemical action potential. An electric current of sufficient magnitude can cause local voltages that can Trigger action potential and stimulate nerves. When sensory nerves are stimulated in this way, electric current causes a tingling sensation which which at sufficient intensity becomes unpleasant and painful. The stimulation of motor nerve causes contraction of muscle fibre in muscles or group of muscles affected.

For most people, perception threshold of skin for light finger contact is approximately 500 micro ampere, although much lower current intensity can be detected with tongue. With form of hand threshold is about 1 milliampere full stop a current with intensity not exceeding 5 milliampere is generally not considered harmful. When at least one of contact with source of electricity is made in contact with electrical conductor. Current in excess of about 10 or 20 milliampere can damage muscle. Maximum current level a person can tolerate and still voluntarily let go of conductor is his let go current level.

Ventricular fibrillation can occur at currents about 75 milliampere, why current in excess of about 1 or 2 ampere can cause contraction of heart, which variable to normal reason if current is discontinued in time, this condition may also be accompanied by respiratory paralysis.

Physiological effect of electric current from 1 second external contact with body.

Above 10A - Severe burns and physical injury

10A - Sustained micrcardial contraction followed by normal heart Rhythm if current is removed

1A - Danger of ventricular fibrillation

100mA -Pain, fatigue coma possible physical injury

1mA - Accepted safe level (5mA)

500μA - Threshold of perception

Q25: What are the methods of accident prevention?

1) Grounding:

The term grounding is commonly used in the electrical industry to mean both “equipment grounding” and “system grounding”. Equipment grounding means the connection of earth ground to non-current carrying conductive materials such as conduit, cable trays, junction boxes, enclosures, and motor frames. System grounding means the connection of earth ground to the neutral points of current carrying conductors such as the neutral point of a circuit, a transformer, rotating machinery, or a system, either solidly or with a current-limiting device.It is effective only as long as good ground protection exist.

2) Double insulation:

Double or reinforced insulation is another method of protection against electric shock, consisting of an extra layer of supplementary insulation over the basic insulation, or a single layer of special reinforced insulation directly over the live parts. There are some appliances which do not have an earth wire. They have another way to protect the user: double insulation. Double insulation protects the user of the appliance from an electrical shock by preventing any possibility of the external casing becoming live , thus eliminating the need for an earth connection

3) Protection by Low Voltage:

It is a device or group of components that ensure that if the input voltage drops below a certain value, it will be cut-off completely. The reason for this is that most circuits have a range of input voltage within which they operate as designed. It is easy to see why a higher voltage could cause damage as voltage limits for components could be exceeded. But lower voltages can also be problematic for certain types of circuits. When the voltage is too low, half the things may work while other things don’t; the result could be oscillations, malfunctions and various other undesired outcomes. So in order to avoid this, a low-voltage cut-off circuit will cleanly cut the voltage once it

An isolation power system provides an ungrounded electrical service for various applications within a hospital or a medical office building. These isolation power systems remain in operation in the event of a single line-to-ground fault situation. These systems also eliminate the danger of an electric shock to patients who may be more susceptible to leakage current and unable to move in their beds.

drops below a limit.

4) Ground-Fault Circuit Interrupter

A ground fault circuit interrupter (GFCI) is a type of circuit breaker which shuts off electric power when it senses an imbalance between the outgoing and incoming current. The main purpose is to protect people from an electric shock caused when some of the current travels through a person's body due to an electrical fault such as a short circuit, insulation failure, or equipment malfunction. Standard circuit breakers shut off power when the current is too high, like 10, 15, or 20 amps, but a mere 0.030 amps through a body can cause paralysis of skeletal muscles and stop the human heart. This breaks the circuit when it detects an imbalance of only 0.005 amps .

5) Isolated Power Distribution System

An isolation power system provides an ungrounded electrical service for various applications within a hospital or a medical office building. These isolation power systems remain in operation in the event of a single line-to-ground fault situation. These systems also eliminate the danger of an electric shock to patients who may be more susceptible to leakage current and unable to move in their beds.

If there is a fault, the system alarm in the isolation panel activates. When the alarm is activated, the critical medical equipment remains operational, because no ground fault protection or overcurrent protective device trips. The triggering of an alarm from a single ground fault must be rectified as soon as possible at a “safe” time, as a second ground fault could trigger the short circuit protection and take an entire operating room offline. The definition of isolated power system in the NEC indicates “a system comprising an isolated transformer or its equivalent, a line isolation monitor, and its ungrounded circuit conductors.” The NEC also defines a line isolation monitor as a “test instrument designed to continually check the balanced and unbalanced impedance from each line of an isolated circuit to ground and equipped with a built in test circuit to exercise the alarm without adding to the leakage current hazard.”

Q25: Explain Microshock and Macroshock.

The current sensitivity of heart is much higher in second case, the effect of current applied directly to heart is often referred as Microshock. While effect of current of lateral surface contact is called Macroshock.

Unit-6

Q1: Explain what telemedicine is? What are the applications of telemedicine?

Definition:-

A tool that makes healthcare more accessible, cost-effective, and that increases patient engagement – is telemedicine. Since making its debut in the late 1950's, advances in telemedicine has contributed to seniors having the choice to age in place. In addition, the patients that reside in rural areas that previously had difficulties accessing a physician, can now reach them virtually.

Physicians and patients can share information in real time from one computer screen to another. And they can even see and capture readings from medical devices at a faraway location. Using telemedicine software, patients can see a doctor for diagnosis and treatment without having to wait for an appointment. Patients can consult a physician at the comfort of their home.

Applications:-

• Application of telemedicine is much more valuable in case of emergency, when time is a critical factor in the outcome of the diseases during disaster situation, a specialist can provide his services through telemedicine in disaster affected area post operation (Post Surgery) follow up since the patient is not required to travel unnecessarily and hence saving money and

Monitoring national health programs providing medical care in custodial settings such as prison, juvenile home, rehabilitation centers

• Providing training for primary health doctors

Q2: Draw and explain the concept of teleradiology.

Teleradiology is a branch of telemedicine in which telecommunication systems are used to transmit radiological images from one location to another. Interpretation of all noninvasive imaging studies, such as digitized x-rays, CT, MRI, ultrasound, and nuclear medicine studies, can be carried out in such a manner.

The earliest efforts in teleradiology probably date back to 1929, when dental x-rays were transmitted with the help of telegraph to a distant location. An early attempt at using the Web in an emergency medical situation describes the use of digital cameras to take clinical photographs and scanners to scan radiographs, conversion of the resulting digital images to a JPEG format using Adobe Photoshop, and then transmission via the Internet.

Today, digitized images are transmitted around the globe via high-speed telecommunication links on a regular basis.

Q3: With block diagram, explain telecardiology.

Telecardiology is a modern medical practice, which uses the power of telecommunications to achieve remote diagnosis and treatment of heart disease. This includes coronary heart disease, chronic and acute, as well as arrhythmias, congestive cardiac failure and sudden cardiac arrest.

In this situation, doctors and other healthcare providers use electrocardiographic data, which is transmitted remotely, in real time, for interpretation by a specialist. It enables specialist care to be accessed by people in remote locations. Advancing technology is making it easier and less expensive to set up wireless or satellite networks for this purpose, increasing their effectiveness and ease. .

Q4: Explain telepsychiatry.

Telepsychiatry, a subset of telemedicine, can involve providing a range of services including psychiatric evaluations, therapy (individual therapy, group therapy, family therapy), patient education and medication management.

Telepsychiatry can involve direct interaction between a psychiatrist and the patient. It also encompasses psychiatrists supporting primary care providers with mental health care consultation and expertise. Mental health care can be delivered in a live, interactive communication. It can also involve recording medical information (images, videos, etc.) and sending this to a distant site for later review.

Diagram 6.1

Types of Disorder: Alcohol Dependence, Drug Dependence, Mood Disorder, Depression, Stress related Disorders, Anxiety, Mental Retardation

Psychiatrists assess all mental and physical symptoms. They make a diagnosis and work with you to develop a management plan for your treatment and recovery. **Psychiatrists** provide psychological treatment, prescribe medications.
Disadvantage of telepsychiatry is not being in the physical presence of the patient. This means that the doctor cannot conduct a physical exam. Although not a requirement for diagnosing psychiatric conditions, having the option is beneficial when patients report physical symptoms.
Personal Touch: Decreases face-to-face interactions between the patient and their treating providers.
Technical: Hardware/Software Glitches, broadband connection disruptions, need for electronic devices and technological training.
Advantages
Video-based telepsychiatry helps meet patients' needs for convenient, affordable and readily-accessible mental health services. It can benefit patients in a number of ways, such as:
Improve access to mental health specialty care that might not otherwise be available (e.g., in rural areas)

- Bring care to the patient's location
- Help integrate behavioral health care and primary care, leading to better outcomes
- Reduce the need for trips to the emergency room
- Reduce delays in care
- Improve continuity of care and follow-up

- Reduce the need for time off work, childcare services, etc. to access appointments far away

Q5: Explain teledermatology.

Teledermatology means sending pictures of skin lesions or rashes to a specialist for advice on diagnosis or management. It is a way for primary investigation.Teledermatology is a subspecialty of dermatology and probably among the most popular applications of e-health and telemedicine. In this field, telecommuncation technologies are being used to transfer medical information over varying distances through audio, visual and data communication.

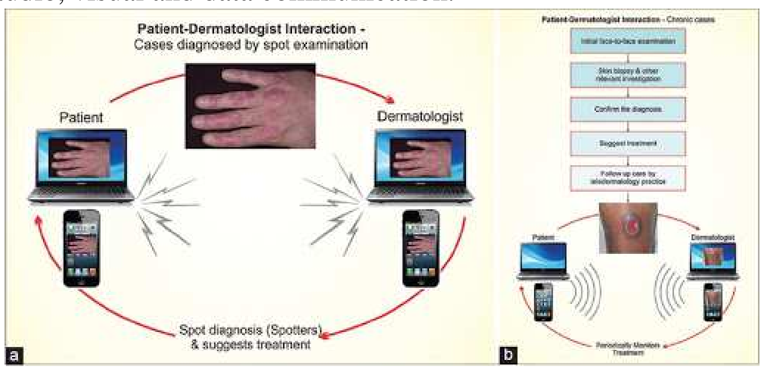


Diagram 6.2

Advantage: Teledermatology can reduce wait times by allowing dermatologists to treat minor conditions online while serious conditions requiring immediate care are given priority for appointments.n real-time/ live interactive teledermatology applications, provider and individuals usually interact via live videoconferencing. It may also involve remote surgery and the use of telerobotic microscopes in dermatopathology. This mode generally requires more sophisticated and costly technology than used in the SAF mode. Both participants must be available at the same time.

Q6: Draw and explain telesurgery system.

Telesurgery

•Telesurgery means performing surgeryViarobotic tools, as opposed to traditional laproscopy or even more traditional open surgery.

•This allows surgeons to perform minimally invasive” operations withmore control than ordinary laproscopy.

Telesurgery, which is also called remote surgery, is when a surgeon performs surgical tasks while being physcially away from the patient. This newer technology combines elements of telerobotics and laparoscopic surgery. When a surgery takes place, surgical tasks are performed using a robot surgical system that generally consists of one or more arms, a master control, and a sensory system to provide feedback to the user. Remote surgery combines components of robotics and communication technology. This technology is very promising at the moment and, with further research and development, could ensure the availability of surgical expertise in remote areas for difficult or rare operations, saving the lives of many.

- **Telesurgery**:In order to have a safe and effective procedure, telesurgery requires rapid and accurate transmission of information
- Telesurgery and other computer assisted surgeries have the ability to cut out a significant amount of human error in operating rooms.
- filtering out hand tremors of the surgeon

Q7: Draw and explain Telerobotic and Remote Telesurgery.

Telerobotic

Telerobotic is the area of robotics that is concerned with the control of robots from a distance. With a robotic surgery system, surgeons can perform minimally invasive surgeries.

The Intuitive Surgical, has become the most commonly used instrument for telesurgery. It has two parts: the control console and the patient side.

Diagram 6.2

Remote Telesurgery

•Remote telesurgery is the same as normal telesurgery, except that the surgeon and the patient are separated by significant distances.

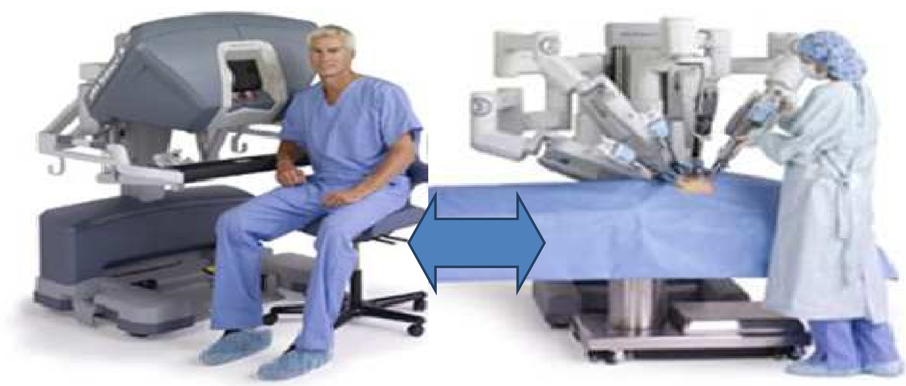


Diagram 6.3

Remote Telesurgery

•In 2001, Dr. Jacques Marescaux was able to perform a gall bladder surgery while he was in New York and the patient was in France.

Diagram 6.4

Advantages of Remote Telesurgery
•Allows inexperience surgeons to ask for help from more experienced surgeons
•Reduces patient travel time
•Multiplies the effectiveness of the most expert surgeons.

Q8: What is Laparoscopic Surgery?

Laparoscopic or “minimally invasive” surgery is a specialized technique for performing surgery. In the past, this technique was commonly used for gynecologic surgery and for gall bladder surgery. Over the last 10 years the use of this technique has expanded into intestinal surgery. In traditional “open” surgery the surgeon uses a single incision to enter into the abdomen. Laparoscopic surgery uses several 0.5-1cm incisions. Each incision is called a “port.” At each port a tubular instrument known as a trochar is inserted. Specialized instruments and a special camera known as a laparoscope are passed through the trochars during the procedure. At the beginning of the procedure, the abdomen is inflated with carbon dioxide gas to provide a working and viewing space for the surgeon. The laparoscope transmits images from the abdominal cavity to high-resolution video monitors in the operating room. During the operation the surgeon watches detailed images of the abdomen on the monitor. This system allows the surgeon to perform the same operations as traditional surgery but with smaller incisions.

Q9: What are the components of Hospital Information System (HIS)?

OR

Q10: What is meant by hospital information system?

A hospital information system (HIS) is an element of health informatics that focuses mainly on the administrational needs of hospitals. In other words, it is a computer system that can manage all the information to allow health care
providers to do their jobs effectively.
The role of information systems: Its role is to support the key aspects of running an organization, such as communication, record-keeping, decision making, data analysis and more. Companies use this information to improve their business operations, make strategic decisions and gain a competitive edge.

Why do we need information systems?
One of the main reasons why we need information systems is because they improve efficiency, which can boost productivity. They typically support data-intensive operations. ... Every organization runs on information and each business entity has a particular way of gathering, recording, storing and manipulating information.

Hospital information system (HIS)

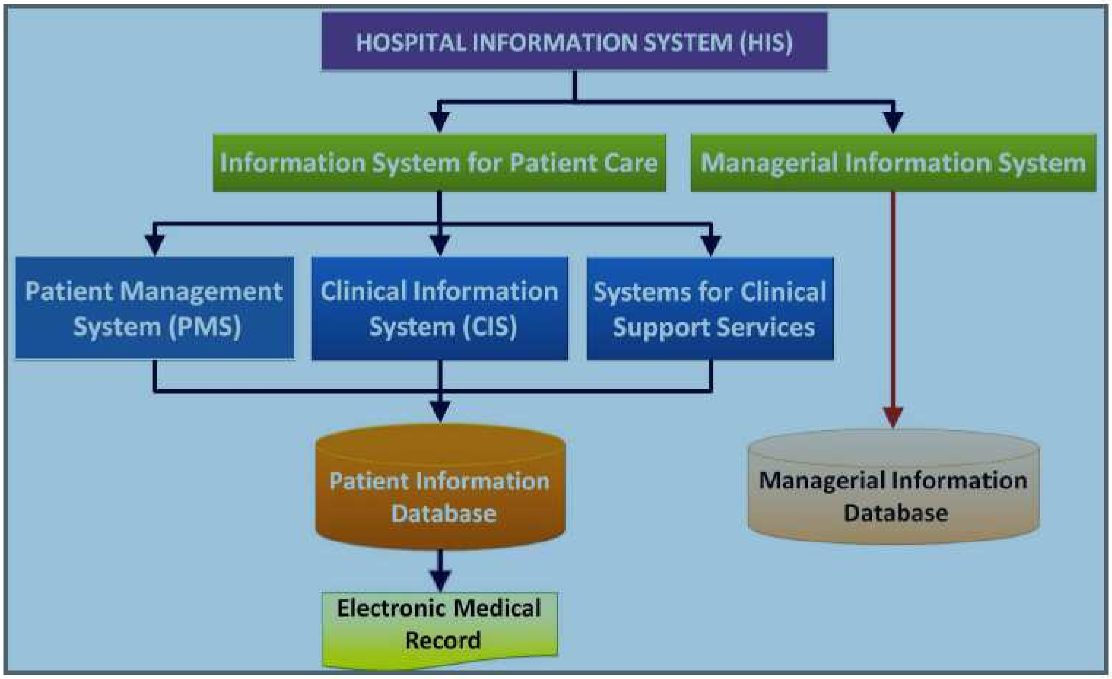


Diagram 6.5

Q11: What is a Hospital Management System?
The IT system has revolutionised the field of medicine. In this fast-paced world of medicine, it is a daunting task to manage a multi-speciality hospital. A hospital management system (HMS) is a computer or web-based system that facilitates managing the functioning of the hospital or any medical set up1. This system or software will help in making the whole functioning paperless. It integrates all the information regarding patients, doctors, staff, hospital administrative details etc. into one software4. It has sections for various professionals that make up a hospital.

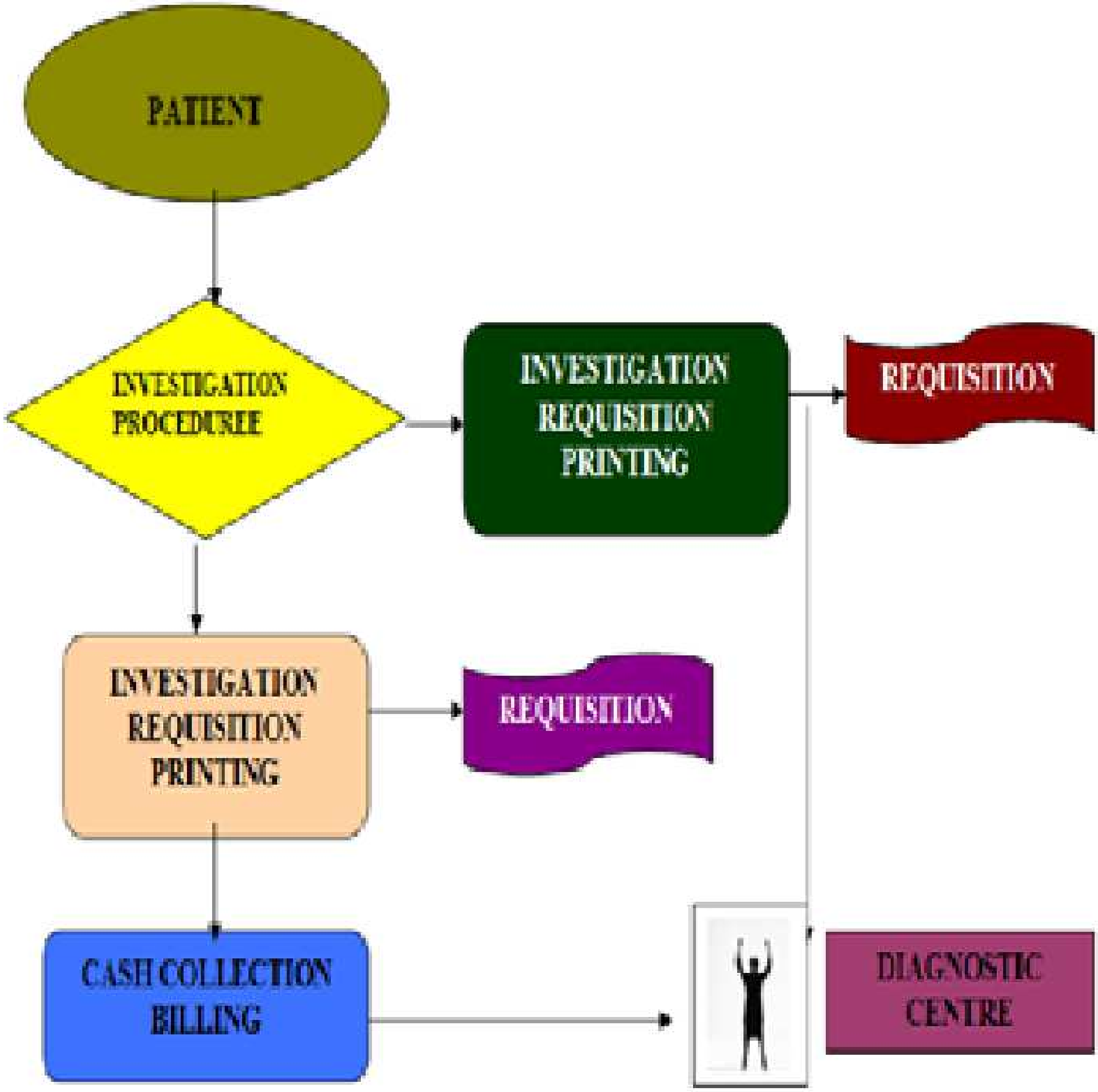


Diagram 6.6

Q12: What are different types of telemedicine?

There are three main types of telemedicine, which include store-and-forward, remote monitoring and real-time interactive services. Each of these has a beneficial role to play in overall health care and, when utilized properly, can offer tangible benefits for both healthcare workers and patients.

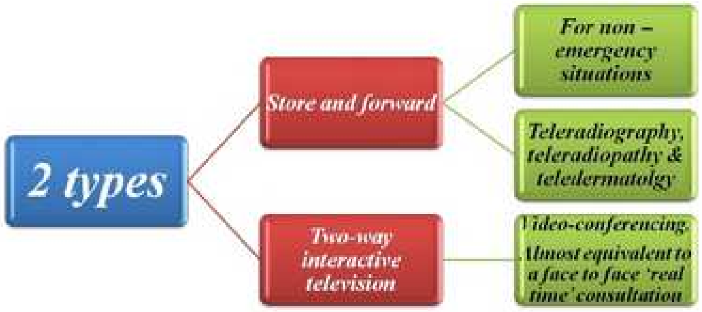


Diagram 6.7

Store-and-Forward

Store-and-forward telemedicine surpasses the need for the medical practitioner to meet in person with a patient. Instead, data such as medical images or biosignals can be sent to the specialist as needed when it has been acquired from the patient. This practice is common in the medical fields of dermatology, radiology and pathology.

With proper structure and care, this technique can save time and allow medical practitioners to serve the public with their services more fully. However, it relies on a history report and documented information or images, rather than a physical examination, which has the potential to cause complications such as misdiagnosis.

Remote Monitoring

Also known as self-monitoring or self-testing, remote monitoring uses a range of technological devices to monitor health and clinical signs of a patient remotely. This is extensively used in the management of chronic diseases such as cardiovascular disease, diabetes mellitus and asthma.

Benefits of remote monitoring include cost effectiveness, more frequent monitoring and greater patient satisfaction. There is some risk that tests conducted by the patients themselves may be inaccurate, but the outcomes are generally thought to be similar to professional-patient tests.

Real-Time Interactive Services

Interactive services can provide immediate advice to patients who require medical attention. There are several different mediums utilized for this purpose, including phone, online and home visits. A medical history and consultation about presenting symptoms can be undertaken, followed by assessment similar to those usually conducted in face-to-face appointments.

Teleneuropsychology is an example of this type of telemedicine that includes neuropsychological consultation and assessment over the phone with patients that have, or are suspected to have, a cognitive disorder. Standard evaluation techniques are implemented to assess the patient via video technology. A study from 2014 found that this method provides a feasible and reliable alternative to traditional in-person consultations, although it was noted that quality standards and administration must be upheld.

Advantage:

- the patient, GP and specialist do not have to be available at the same time – improving efficiency and convenience
- they do not need to travel – participants can be located anywhere
- waiting times are reduced – specialist reports are often received within a few hours of the request
- second opinions can be quickly obtained
- outpatient appointments are freed up for patients that need them most
- unnecessary prescriptions and surgical procedures are minimised.

Disadvantage

A disadvantage of store-and-forward consultations is that the specialist does not examine the patient directly. It may be necessary to arrange an in-person or video consultation at a later date.

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