

**SCHOOL OF SCIENCE AND TECHNOLOGY**

**APPLIED SCIENCE- I**

**BSN 1302**

**BIOPHYSICS**

**BIOCHEMISTRY**

**MICROBIOLOGY**



**BANGLADESH OPEN UNIVERSITY**

# SCHOOL OF SCIENCE AND TECHNOLOGY

## APPLIED SCIENCE– I

### BSN 1302

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# BANGLADESH OPEN UNIVERSITY

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BIOCHEMISTRY  
MICROBIOLOGY**

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**SCHOOL OF SCIENCE AND TECHNOLOGY  
BANGLADESH OPEN UNIVERSITY**

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# **Biophysics**



## Introduction

Until the eighteenth century what is now a whole series of specialties was treated as a single subject and called natural philosophy. A trend towards specialization began near the end of that century when a differentiation between chemistry and physics first became recognizable. Today the sciences can be broadly divided into two categories, the *physical sciences* and the *biological sciences*.

The physical science, which are concerned with two main sections—physics and chemistry. Physics is the science concerned with the properties of matter. Laws of physics are applicable to the world and everything in it, including human beings. The practical application of physics have allowed the development of technology without which today's world could not exist. In today's technological world, physics plays the vital role for nursing practice. Relationship of physics in nursing practice is very close. Occupational health nurse requires knowledge of the clinical effects of disease and a scientific understanding of the work environment.

Today many specialties and sub-specialties exist and those branches of science, which are of particular interest to nurses fall into three broad categories: physics, chemistry and biochemistry. The intricate interrelationships of composition and activity make study difficult and some knowledge of these basic sciences is essential if nurses are to understand the structure and function of the body and how it reacts and interacts with the diverse environmental conditions in which people live, work and play.

Concept, theory and laws of physics are now applied in the various fields of medicine and nursing practice. Medical equipment and apparatuses are made with basic concepts of physics. X-ray, laser ray etc. are widely used for treatment of eye, chest and for also in surgery. Knowledge about temperature, pressure etc. are applied in daily nursing practices. Optical fibers are used to identify and determination



of the object before operation. “Electrolyte” is not relevant only to industrial process. It is a word with which nurse will be familiar. For human being electrolytes are essential for the control of body fluids to maintain the body’s electrolyte balance. Electrophoresis, a means whereby substance can be separated because of their relative electro-negativity or electro-positivity. It has another important use of electrolysis. For example, it is used in the laboratory for the separation of the different proteins contained in blood plasma. Plasma proteins, having a negative charge move towards the anode. Because different proteins move at different speeds, it is possible to identify each type.

The properties of ionizing radiation can be used to beneficial effect in the treatment of disease. In particular the treatment of cancer, radiotherapy includes selective irradiation with X-rays. A high frequency sound ultrasound can be reflected off any object and a complete picture of that object can be built up from the pattern of reflections. In the 1950s this technique was introduced into medicine to study the unborn fetus. Today ultrasound is commonly used in obstetrics to determine the size and position of the fetus. It is also used for the diagnosis of diseases of the heart, and liver. These are few applications of physics in medical science and nursing practice. You can understand the necessity of studying physical science specially physics. This book is a guide for this purpose and it can help you to obtain solid knowledge about relationship between physical science and medical science including nursing practice.

# Unit 1: Motion and Energy

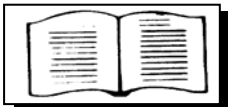
## Lesson 1: Speed, Velocity and Acceleration

### 1.1. Learning Objectives



On completion of this lesson you will be able to learn-

- ◆ about is motion
- ◆ different terms related to motion
- ◆ about mass and momentum.

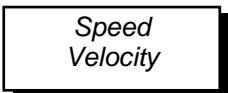


First of all, let us learn about motion. By motion we generally mean some movement. For example, a car moving from one place to another, blood goes from heart to the vein and return back, the earth moves around the sun etc.

The movement of an object is described by its change of position. Different laws of nature govern the motion. Below we shall learn the laws of motion. For this purpose we should know about various terms related to motion **speed, velocity, acceleration, mass and momentum.**

**Speed** is defined as the rate of change of distance moved with time e.g.

$$Speed = \frac{Distance\ travelled}{Time\ taken}$$



Speed is a scalar quantity. By scalar, we mean a quantity, which has only magnitude but no proper direction. For example, movement of body, movement of substances, movement of medicine or radioisotopes through a body, all refers to some speed. In metric system the unit of speed is metre per second (m/s).

**Velocity** is defined as the rate of change of distance moved with time in a particular direction e.g.

$$Velocity = \frac{Distance\ travelled\ in\ particular\ direction}{Time\ taken}$$

Velocity is a vector quantity. By vector we mean a quantity, which has both the magnitude and the direction.

In metric system, the unit of velocity is same as speed-metre per second (m/s).

**Acceleration** is defined as the rate of changes of velocity with time. It is the change in velocity per second e.g.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

Acceleration is regarded as positive, if the velocity is increasing and negative, if the velocity is decreasing. In metric system, the unit of acceleration is  $\text{m/s}^2$ .

<p>Acceleration Mass Momentum</p>
---

**Mass** is defined with the quantity of matter of a substance. In general, weight is used to measure an object. It is not correct, weight is the gravitational pull of the earth on the body. The mass of a body remains it everywhere, but the weight may vary. For example, the weights of a body become one-sixth of its value on the moon, since moon's gravitation is one-sixth of the earth. But mass of the body is same.

**Momentum** is this product of mass multiplied by its velocity.

Momentum = Mass x Velocity.

Momentum is also a vector quantity. If the velocity increases, momentum also increases. When two bodies, a heavy one and a light one, are acted upon by the same force for same time, the light body builds up a higher velocity than heavy one. But the momentum they gain is the same in both cases. The unit of momentum in the International System (SI) is, therefore, 1 kilogram multiplied by 1 metre per second (Kg. m/s).



## 1.2. Exercise

### 1.2.1. Multiple choice questions

1. Speed is a
  - i. scalar quantity
  - ii. vector quantity
  - iii. scalar and vector quantity
  - iv. all of the above.
  
2. Velocity is a
  - i. scalar quantity
  - ii. scalar and vector quantity
  - iii. vector quantity
  - iv. none of the above.
  
3. Which of the following depends on velocity?
  - i. speed
  - ii. vector
  - iii. momentum
  - iv. mass.
  
4. Momentum is a product of
  - i. mass and velocity
  - ii. mass and acceleration
  - iii. mass and speed
  - iv. none of the above.
  
5. Mass and weight of a substance are
  - i. same
  - ii. not same
  - iii. equal
  - iv. none of the above.

### 1.2.2. Short questions

1. What is motion?
2. What is the difference between speed and velocity?
3. What do you mean by mass and momentum?

### 1.2.3. Analytical question

1. Describe the units of speed, velocity, and acceleration.

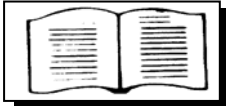
## Lesson 2: Newton's Laws of Motion

### 2.1. Learning Objectives



On completion of this lesson you will be able to learn-

- ◆ Newton's first law of motion
- ◆ Newton's second law of motion
- ◆ Newton's third law of motion.



Newton's three laws of motion give the fundamental properties of force and the relationship between force and acceleration. The first of these laws describes the natural state of motion of a body on which no external forces are acting, whereas the other two laws deal with the behaviour of bodies under the influence of external forces.

### 2.2. Newton's First Law

Newton's first Law summarizes experiments and observations on the motion of bodies on which no external forces are acting, thus the first law is -

*Newton's First Law*

**A body at rest remains at rest, and a body in motion continues to move at constant velocity unless acted upon by an external force.**

The tendency of a body to continue in its initial state of motion (a state of rest or a state of uniform velocity) is called its inertia. Accordingly, the **First Law is often called the law of inertia.**

### 2.3. Newton's Second Law

Newton's Second Law of motion establishes the relationship between the force acting on a body and the acceleration caused by this force. Newton's Second Law states:

*Newton's Second Law*

**External force acting on a body gives it an acceleration that acts in the direction of the force and has a magnitude directly proportional to the magnitude of the force and inversely proportional to the mass of the body.**

If we denote acceleration by a force  $F$  and mass by  $m$  then the second law of motion is given as -

$$a = F/m \quad (1)$$

or

$$ma = F \quad (2)$$

According to Eq. (1) the acceleration vector equals the force vector divided by the mass. Thus, this equation specifies both the magnitude and the direction of the acceleration.

The definition of force also relies on the Second Law. To measure a given force say, the force generated by a spring that has been stretched a certain amount; we apply this force to the standard kilogram. If the resulting acceleration of the standard kilogram is  $a$ , then the force has a magnitude

$$F = ma = 1 \text{ kg} \times a \quad (3)$$

In the metric system of units, the unit of force is the Newton (N). This is the force that will give a mass of 1 kg an acceleration of  $1 \text{ m/s}^2$ ,

$$1 \text{ Newton} = 1\text{N} = \text{kg.m/s}^2 \quad (4)$$

In metric system, the unit of acceleration is  $\text{m/s}^2$ , and the unit of mass is kilogram (Kg). In CGS system unit of force is Dyne (D).

$$1\text{N} = 10^5 \text{ D}. \quad (5)$$

#### 2.4. Newton's Third Law

*Newton's Third Law*

When you push with your hand against a table or wall, you can feel the wall pushing back at you. Thus, the mutual interaction of your hand and the wall involves two forces; the “action” force of the hand on the wall and the “reaction” force of the wall on the hand. The important point is that forces always occur in pairs; each of them cannot exist without the other.

Newton's Third Law gives the quantitative relationship between the action force and the reaction force.

**Whenever a body exerts a force on another body, the later exerts a force of equal magnitude and opposite direction on the former.**

This is sometimes stated, **to every action there is an equal and opposite reaction.**

For instance, if the push of your hand on the wall has a magnitude of 60N, then the push of the wall on your hand also has a magnitude of 60N.

This equality of the magnitudes of action and reaction holds even if the body you push against is not held in a fixed position (like a wall), but is free to move. Thus, if you push on a cart with a force of 60 N, the cart will push back on you with a force of 60 N. Note that although these action and reaction forces are of equal magnitudes, they act on different bodies and their effects are quite different: the first force gives an acceleration to the cart, whereas the second force merely slows your hand and prevents it from accelerating as much as it would if the cart were not there. Thus, **although action and reaction are forces of equal magnitudes and of opposite directions, their effects do not cancel because they are acting on different bodies.**



## 2.5. Exercises

### 2.5.1. Multiple choice questions

**Tick (✓) the correct answer**

1. Newton's laws of motion give
  - i. the relationship between force and acceleration
  - ii. current flow in a circuit
  - iii. electromagnetic radiation
  - iv. none of the above.
2. Newton's first law states
  - i. the law of inertia
  - ii. the law of electrostatic attraction
  - iii. law of vibration
  - iv. none of the above.
3. Newton's second law establishes
  - i. relationship between force and acceleration
  - ii. law of gravity
  - iii. the law of Inertia
  - iv. none of the above.
4. Newton's third law gives
  - i. relationship between action and reaction
  - ii. the cause of electromagnetic radiation
  - iii. law of inertia
  - iv. none of the above.

### 2.5.2. Fill up the gaps

- a. The tendency of a body to ..... in its initial state of ..... is called its .....
- b. The definition of force also relies on the .....
- c. Although ..... and .... are forces of equal ..... and of opposite ....., their effects do not .... because they are acting on different .....
- d. In the metric system of units, the unit of force is the .....

### 2.5.3. Short questions

1. What do you understand by inertia?
2. Explain a force of 1 Newton
3. Explain the physical meaning of 'action' and 'reaction' forces.

### 2.5.4. Analytical question

1. State and explain Newton's three laws of motion.

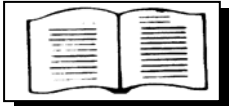
## Lesson 3: Work, Power and Energy

### 3.1. Learning Objectives



On completion of this lesson you will be able to learn

- ◆ the physical meaning of work
- ◆ the potential energy
- ◆ the kinetic energy
- ◆ other forms of energy.



### 3.2. What is Work?

To introduce the definition of work done by a force, we begin with the simple case of motion along a straight line, with the force along the line of motion, Consider a particle moving along a straight line, say, the x axis, and suppose that a constant force  $F$ , directed along the same straight line, acts on the particle. For example, the particle might be a stalled automobile that you are pushing along a road. **Then the work done by the force  $F$  on the particle as it moves some given distance  $S$  is defined as the product of the force and the displacement,**

*The work done by the force on the particle as it moves some given distance is defined as the product of the force and the displacement.*

$$W = F \cdot S = FS \cos \alpha \quad (1)$$

where  $\alpha$  is the angle between the force  $F$  and the displacement  $S$ . Work is a scalar quantity. The unit of work is

$$[W] = [F] [S]$$

In metric system, unit of work is Joule.

$$[W] = 1 \text{ Joule} = 1 \text{ N.m}$$

$$1 \text{ Joule} = 1 \frac{\text{Kg.m}}{\text{s}^2}$$

In CGS system, unit of work is erg.

Relation between the units of work is

$$1 \text{ Joule} = 1 \text{ N.m} = 10^5 \text{D. } 10^2 \text{ cm} = 10^7 \text{ ergs.}$$

*The amount of work done or energy expended per unit time is called power.*

### 3.3. Power

The amount of work done or energy expended per unit time is called **power**. The algebraic expression for power is

$$P = \frac{\Delta W}{\Delta T}$$



Where  $\Delta W$  is the energy expended in a time interval  $\Delta t$ .

The SI unit of power is called the watt (W) and it is defined as a rate of transfer of energy of 1 Joule per second. Thus 1 watt = 1 Joule /sec =  $10^7$  ergs/s. Larger units used are the kilowatt (KW) and the megawatt (MW).

$$1\text{KW} = 1000 \text{ W}$$

$$1 \text{ MW} = 1000000\text{W}.$$

### 3.4. Kinetic Energy

In everyday language, energy means a capacity for activities and hard work. Likewise, in physics, energy is a capacity for performing work. Energy is “stored” work, which can be converted into actual work under suitable conditions. For instance, a body in motion, such as a speeding arrow, has energy of motion, or kinetic energy. This energy will be converted into work when the arrow strikes a target. A high-speed arrow has a deeper penetration and delivers a larger amount of work to the target. Thus, we see that the kinetic energy of the arrow, or the kinetic energy of any kind of particle, must be large if the speed is large.

**The quantity  $\frac{1}{2} mv^2$  is the amount of work stored in the body or the kinetic energy of the body.** We represent the kinetic energy by the symbol K:

$$K = \frac{1}{2} mv^2 \quad (2)$$

*The kinetic energy represents the capacity of a body to do work by virtue of its speed.*

When a force does positive work on a body initially at rest, the kinetic energy of the body increases. The body then has a capacity to do work if the moving body subsequently is allowed to push against some obstacle, then this obstacle does negative work on the body and simultaneously the body does positive work on the obstacle. When the body does work, its kinetic energy decreases. The total amount of work the body can deliver to the obstacle is equal to its kinetic energy. Thus, **the kinetic energy represents the capacity of a body to do work by virtue of its speed.**

*The gravitational potential energy represents the capacity of the particle to do work by virtue of its height above the surface of the Earth.*

### 3.5. Potential Energy

**The gravitational potential energy represents the capacity of a body to do work by virtue of its height above the surface of the Earth.** When we lift a body to some height above the surface, we have to do work against gravity, and we thereby store work in the body. Thus, a body high above the surface is endowed with a large amount of latent work, which can be exploited and converted into actual work by allowing the body to push against some obstacle as it descends.

If a body with mass  $m$  is raised to a height of  $h$  against gravity, it will possess the potential energy

$$W = mgh \quad (3)$$

Energy is scalar quantity and it is measured in the unit Joule in the SI system and in CGS system the unit is erg.

### 3.6. Other Forms of Energy

**Heat** is a form of energy. If we take a macroscopic point of view, we ignore the atomic motions; then heat is to be regarded as distinct from mechanical energy. If we take a microscopic point of view, we recognize heat as kinetic and potential energy of the atoms; then heat is to be regarded as mechanical energy.

*Chemical energy  
and nuclear*

**Chemical energy and nuclear energy** are two other forms of energy. The former is kinetic and potential energy of the electrons within the atoms; the latter is kinetic and potential energy of the protons and neutrons within the nuclei. As in the case of heat, whether these are to be regarded as new forms of energy depends on the point of view.

**Electric and magnetic energy** are forms of energy associated with electric charges and with light and radio waves.

The energy of atomic and subatomic particles is usually measured in electron-volts (eV), where

$$1 \text{ electron-volt} = 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J} \quad (4)$$

J stands for energy in Joule.

The energy supplied by electric power plants is usually expressed in kilowatt-hours (KW.h),

$$1 \text{ kilowatt-hour} = 1 \text{ KW.h} = 3.60 \times 10^6 \text{ J} \quad (5)$$

And the thermal energy supplied by the combustion of fuels or by other chemical reactions is expressed in kilocalories (kcal),

$$1 \text{ kilocalorie} = 1 \text{ Kcal} = 4.178 \times 10^3 \text{ J} \quad (6)$$

*General law of  
conservation of  
energy*

All these forms of energy can be transformed into one another. For example, in an internal-combustion engine, chemical energy of the fuel is transformed into heat and kinetic energy; in a hydroelectric power station, gravitational potential energy of the water is transformed into electric energy; in a nuclear reactor, nuclear energy is transformed into heat, light, kinetic energy, etc. However, in any such transformation process, the sum of all the energies of all the pieces of matter involved on the process remains constant: the form of the energy changes, but

the total amount of energy does not change. This is the **general law of conservation of energy**.



### 3.7. Exercises

#### 3.7.1. Multiple choice questions

1. The physical meaning of energy is
  - a) capacity for motion
  - b) capacity for doing work
  - c) energy is expended per unit time
  - d) none of the above.
  
2. The kinetic energy represents
  - a) capacity of work by virtue of speed
  - b) capacity of work due to potential
  - c) energy is expended per unit time
  - d) none of the above.
  
3. The potential energy of a particle is the capacity for doing work
  - a) by virtue of its height above the surface
  - b) by virtue of its speed
  - c) by virtue of its acceleration
  - d) none of the above.

#### 3.7.2. Fill up the gaps

- a. Heat is a form of .....
- b. .... and ..... are form of energy associated with electric changes and with light and radio waves.
- c. In CGS system unit of energy is .....
- d. The amount of work done or energy expended per unit time is called .....
- e. In SI, unit of power is called .....

#### 3.7.3. Short questions

- a. What do you mean by work and power?
- b. Define the Joule, Watt and kilowatt.
- c. What is energy?

#### 3.6.4. Analytical questions

- a. Describe kinetic and potential energy.
- b. Describe briefly the others form of energy.

## Unit 2: Sound

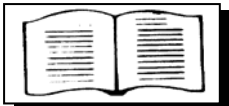
### Lesson 1: Sound Waves in Air

#### 1.1. Learning Objectives



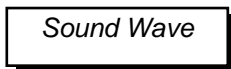
On completion of this lesson you will be able to learn

- ◆ sound waves in air
- ◆ how ear converts sounds into electric nerve pulses
- ◆ intensity of sound.



#### 1.2. Sound Wave

A sound wave in air consists of alternating zones of low and high density. The vibrating diaphragm of a loudspeaker generates such zones of alternating density. The alternating zones of low density and high-density travel to the right away from the source. However, although these density disturbances travel, the air as a whole does not travel, the air molecules merely oscillate back and forth.



The pushes of the loudspeaker or of the tuning fork on the air are longitudinal, and the sound wave itself is also longitudinal. The air molecules oscillate back and forth along the direction of propagation of the sound wave. The restoring force that drives these oscillations is the pressure of air. Wherever the density of molecules is higher than normal, the pressure also is higher than normal and pushes the molecules apart; wherever the density of molecules is lower than normal, the pressure also is lower than normal, and therefore the higher pressure of the adjacent regions pushes these molecules together. Thus, the pressure in air plays the same role as the tension in a string.

Velocity of sound in air is 330 m/s.

The frequency of the sound wave determines the pitch we hear; that is, it determines whether our ear perceives the tone as high or low.

#### 1.3. How Ear Converts Sounds Into Electric Nerve Pulses

The ear performs the task of converting the mechanical oscillations of a sound wave into electric nerve impulses. Thus, it is similar to a microphone, which also converts the mechanical oscillations of sound into electric signals. However, the ear is unmatched in its ability to accommodate a wide range of intensities of sound.

The human ear has three main parts: the outer ear, the middle ear, and the inner ear. The outer ear consists of the auricle and the ear canal. The auricle serves to funnel sound waves into the ear, especially waves arriving from the front of the listener. The ear canal is a tube, about 2.7

cm long, closed off at the inner end by the eardrum, or tympanum. The ear canal guides sound waves toward the eardrum, and also enhances sound waves of a frequency of a few thousand hertz, which are in resonance with the standing-wave modes of the air column in the canal.

#### 1.4. Middle Ear

##### *Middle Ear*

The middle ear is an air-filled cavity in the temporal bone of the skull. The cavity is connected to the nasopharynx by the Eustachian tube; this tube permits equalization of the air pressure in the middle ear with the external atmospheric pressure. The middle ear contains three small bones or ossicles: the hammer, the anvil, and the stirrup (malleus, incus, and stapes). These ossicles are arranged in a chain from the eardrum to the oval window of the inner ear. The chain of ossicles to the oval window transmits the vibrations generated by a sound wave striking the eardrum. Since the oval window has a much smaller area than the eardrum (about  $1/25$ ), the transmission of sound energy from the eardrum to the oval window results in a significant concentration of the energy, with a consequent increase of the amplitude of vibration. Besides transmitting the vibrations from the eardrum to the oval window, the middle ear plays a crucial role in accommodating the ear to very loud sounds. In response to such loud sounds, muscles in the middle ear retract the eardrum and pull the stirrup away from the oval window. This protects the eardrum and the oval window from overloads.

#### 1.5. Inner Ear

##### *Inner Ear*

The inner ear is a complex system of fluid-filled cavities in the temporal bone. Among these cavities are the three semicircular canals, whose function is not hearing, but rather the detection of movements of the head. The organ of the inner ear concerned with hearing is the cochlea, a tube of about 3.5cm coiled in a tight spiral. The tube is divided lengthwise into three adjoining ducts, separated by two membranes, Reissner's membrane and the basilar membrane. The sensory receptor of the inner ear is the organ of Corti, consisting of thousands of hair cells, which sit on the basilar membrane. The vibrations of the oval window excite a wave motion in the fluid of the cochlea, which shakes the basilar membrane. The hair cells detect this motion of the basilar membrane and convert the mechanical energy into electric nerve impulses. The basilar membrane is stiff at the end near the oval window, and soft at the distant end. Because of this, the near part of the membrane responds most readily to high-frequency disturbances. Thus, there is a correlation between the frequency of the incident sound and the regional pattern of motion of the basilar membrane. The hair cells, and the brain, recognize these regional patterns and thereby discriminate among frequencies.

The range of frequency audible to the human ear extends from 20Hz to 20,000 Hz. These limits are somewhat variable; for instance, the ears of older people are less sensitive to high frequencies. Sound waves above 20,000 Hz are called ultrasound; some animal's dogs, cats, bats, and dolphins can hear these frequencies.

Ultrasonic waves

**Ultrasonic waves** of very high frequency do not propagate well in air. They are rapidly dissipated and absorbed by air molecules. However, these waves propagate readily through liquids and solids. In recent years, this property has been exploited in the development of some interesting practical applications of ultrasound. For instance, such waves are now used in place of X-rays to take pictures of the interior to the human body. This technique, called **sonography**, permits examination of the fetus in the body of a pregnant woman, and avoids the damage that X-rays might do to the very sensitive tissues of the fetus. The ultrasonic “cameras” that take such pictures employ sound waves of a frequency of about  $10^6$  Hz. Further development of this technique has led to the construction of acoustic microscopes. The most powerful of these devices employ ultrasound waves of a frequency in excess of  $10^9$  Hz to make highly magnified pictures of small samples of materials. The wavelength of sound waves of such extremely high frequency is about  $10^{-6}$  m, roughly the same as the wavelengths of ordinary light waves. The micrographs made by experimental acoustic microscopes compare favorably with micrographs made by ordinary optical microscopes.

Ultrasound waves are being increasingly used in medical and surgical diagnosis by a technique based on the fact that different types of tissue, e.g. bone, fat, and muscle have different properties for very high frequency waves.

### 1.6. Intensity of Sound

A sound wave is intense and loud if it has a large amplitude. However, the amplitude of a sound wave is hard to measure directly, and it is more convenient to reckon the intensity of a sound wave by the energy it carries. **The intensity of a sound wave is defined as the energy per second transported by this wave per square meter of wave front, that is, the power transported by this wave per square meter.** Thus, to measure the intensity, we have to erect an area facing the wave, and we have to check how much energy the wave delivers in this area per second. It can be shown that the intensity of a sound wave is proportional to the square of the pressure disturbance it produces in the air; equivalently, the intensity is proportional to the square of the density disturbance.

The unit of intensity is the watt per meter squared ( $\text{W/m}^2$ ). At a frequency of 1000 Hz, the minimum intensity audible to the human ear is about  $2.5 \times 10^{-12} \text{ W/m}^2$ . This intensity is called **the threshold of hearing**. There is no upper limit for the audible intensity of sound;

however, intensity above  $1 \text{ W/m}^2$  produces a painful sensation in the ear.

Note that since the eardrum has an area of about  $4 \times 10^{-5} \text{ m}^2$ , the energy delivered per second by a sound wave of minimum intensity is only about  $2.5 \times 10^{-12} \text{ J/m}^2 \times 4 \times 10^{-5} \text{ m}^2 \cong 10^{-16} \text{ J}$ ; this is a very small amount of energy, and it testifies to the extreme sensitivity of the ear.

### 1.7. Decibel (dB)

**The intensity of sound is often expressed on a logarithmic scale called the intensity level. The unit of intensity level is the decibel (dB);** like the radian, this unit is a pure number, without any dimensions of m, s, or kg. The definition of intensity level is as follows: we take an intensity of  $1 \times 10^{-12} \text{ W/m}^2$  as our standard of intensity, which corresponds to 0 dB. An intensity 10 times as large corresponds to 10 dB; an intensity 100 times as large corresponds to 20 dB; man intensity 1000 times as large corresponds to 30 dB, and so on. This scale of intensity level is intended to agree with our subjective perception of the loudness of sounds. We tend to underestimate increments in the intensity of sound our ears perceive a sound of  $100 \times 10^{-12} \text{ W/m}^2$  (20 dB) as only twice as loud as a sound of  $10 \times 10^{-12} \text{ W/m}^2$  (10 dB). Mathematically, the relationship between the intensity and the intensity level in dB is given by a formula involving a logarithm:  $\text{intensity level} = 10 \log (I/I_0) \text{ dB}$ .

*The intensity of sound is often expressed on a logarithmic scale called the intensity level. The unit of intensity level is the decibel (dB)*

Where  $I$  is the intensity of the musical tone investigated and  $I_0$  is the standard intensity (threshold of availability). The human ear is most responsive to tones at frequencies from 700 to 6000 Hz. Within this range, the ear will readily pick up musical tones with an intensity of about  $10^{-11}$  to  $10^{-12} \text{ W/m}^2$ .



## 1.8. Exercises

### 1.8.1. Multiple choice questions

1. Velocity of sound in air is
  - i. 330 m/s
  - ii. 430 m/s
  - iii. 100 m/s
  - iv. 200 m/s.
  
2. Sound cannot travel through
  - i. a solid media
  - ii. a vaccum
  - iii. water
  - iv. an air media.
  
3. The unit of intensity of sound is
  - i.  $W/m^2$
  - ii.  $W/cm^2$
  - iii.  $KW/cm^2$
  - iv.  $V/m^2$ .

### 1.8.2. Fill up the gaps

- a. The human ear with its three main parts: ....., ....., .....
- b. A sound wave in air consists of alternating zones of low and .....
- c. The unit of intensity level is the .....

### 1.8.3. Short questions

1. What do you mean by sound?
2. Is there needed any medium to propagate sound?
3. Human ear cannot hear infra-sound or ultrasound. Why?

### 1.8.4. Analytical questions

1. How ear converts sounds into electric nerve pulses?
2. What is the intensity of sound? Describe briefly?



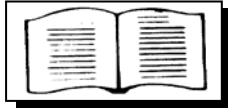
## Lesson 2: Ultrasound Images

### 2.1. Learning Objectives



On completion of this lesson you will be able to learn

- ◆ about various ultrasound images for diagnostics.



### 2.2. X-rays

Modern medicine relies heavily on a variety of imaging techniques. They generate pictures of the interior of the human body for diagnostic purposes. The oldest of these imaging techniques, is radiography. It generates pictures by irradiating the body with X-rays and recording the shadows of the internal anatomical structures. X-rays give us sharp and clear shadows of the bones, but they are not very well suited for imaging the soft tissues of the body. X-rays cannot discriminate between tissues of approximately equal densities. For instance, when they pass through the heart, X-rays do not discriminate between heart muscle and the blood filling the heart cavities - an X-ray picture of the heart is merely a blob, which does not reveal the details of the heart's anatomy.

*X-rays*

### 2.3. Ultrasound Imaging

Several of the newer imaging techniques generate better pictures of soft tissues. Among these newer techniques is ultrasound imaging. Ultrasound imaging produces pictures of the anatomical structures by “illuminating” the body with sound waves of high frequency, far above the threshold of hearing. The sound waves used by medical ultrasound equipment have frequencies between  $10^6$  Hz and  $10^7$  Hz and wavelengths (in soft issue) between 1.5 mm and 0.15 mm. In contrast to X-rays, which produce a picture by penetrating through the body and shadowing the organs, the ultrasonic waves produce a picture by reflecting at the walls of organs.

*Ultrasound Imaging*

### 2.4. Sonar and Radar

Ultrasound imaging exploits an echo-detection scheme similar to that of sonar and radar. The sonar equipment in a ship detects an underwater target by sending a short pulse of sound waves into the water and listening for the echo returned by the target. The time delay for the return of the echo indicates the distance to the target. Likewise, medical ultrasound equipment detects the anatomical structures within the body by sending a short pulse of sound waves into the body and listening for the echo. The speed of sound in soft body tissues is about the same as that in water,  $v = 1500\text{m/s}$ . If the time delay for the return of the echo is  $\Delta t$ , then the round-trip distance traveled by the pulse is  $v\Delta t$ , and the actual distance to the point of reflection at the wall of the

*Sonar and Radar*

heart or some other organ is  $v\Delta t/2$ . For instance, if  $\Delta t = 10^{-4}$  s, then the distance is  $v \Delta t/2 = 1500\text{m/s} \times 10^{-4} \text{ s}/2 = 0.075\text{m}$ . Since the travel times for ultrasound echoes are quite short, the imaging equipment must be able to measure time with high precision.

## 2.5. Ultrasound are Generated by a Transducer

*Ultrasound are  
Generated by a  
Transducer*

The pulses of ultrasound are generated by a transducer, which converts a high-frequency electric signal into a sound signal. In principle, such a transducer is similar to the loudspeaker in radio, which also converts an electric signal into a sound wave. For this purpose, the loudspeaker uses a small electromagnet to push a diaphragm back and forth, thereby communicating periodic pushes to the air in front of the diaphragm. The ultrasound transducer uses a piezoelectric material, such as PZT, which contracts when an electric signal is applied to it. A layer of such material can easily vibrate at frequencies of  $10^7$  Hz. The ultrasound transducer is mounted at the tip of a probe which is placed in contact with the surface of the body. For good contact between probe and skin, the end of the probe is smeared with a schematic diagram of a piezoelectric transducer. The layer of piezoelectric material in the transducer has a curved shape to concentrate and focus the ultrasound in a narrow beam.

## 2.6. Scanning

*Scanning*

To build up a picture of the interior of the body, the beam of ultrasound must be swept through the body, either by moving the probe back and forth over the body or by swinging it from side to side, through some angle. For each position or direction of the probe, the time delays of the echoes must be recorded. Such a sweeping search for echoes is called a scan. The time-delay information for a complete scan is accumulated in the memory of a computer, which later processes this information and displays a picture on a video monitor. Ultrasound is now routinely used to examine pregnant women, to detect fetal abnormalities at an early stage. X-rays are unsuitable for this purpose, because they tend to produce genetic damage, to which the fetus is especially susceptible.

In the ultrasound probe is used for producing such a picture of the heart, several transducers are placed side by side, so the individual waves form a single wave front by superposition. The advantage of this arrangement, called a phased array, is that the wave front can be settled to the left or the right; such a delay tilts the wave front, and alters its direction of advance. A probe with a phased array can automatically sweep the direction of the ultrasound beam across the heart, and we do not need to move the probe itself. To perform a scan, the operator merely holds the probe steady against the body, and the electronic circuitry quickly sweeps the beam of ultrasound.

Fast scanning is especially valuable in echocardiography, because it is desirable to sweep the beam across the entire heart in a time so short that the heart hardly moves at all. Such a fast scan produces a snapshot of the heart and by repeating these snapshots in quick succession, we can make a movie that shows the motion of the heart in real time.



## **2.7. Exercise**

### **2.7.1. Short questions**

1. What do you mean by ultrasound images?
2. What is the main application of ultrasound?

### **2.7.2. Analytical question**

1. Describe briefly about various ultrasound images for diagnostics.

## Unit 3: Pressure

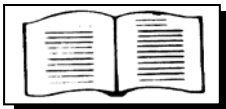
### Lesson 1: Motion of Fluids

#### 1.1. Learning Objectives



On completion of this lesson you will be able to learn

- ◆ fluid
- ◆ density of fluid
- ◆ pressure of fluids.



#### 1.2. Fluids

Both liquids and gases are fluids. These substances flow from one place to another. That's why they are known as fluids. Liquids have a volume but it takes the shape of the container. Gas occupies all the volume of the container. The molecules of the liquid are loosely bound. The gas molecules are very energetic.

*Both liquids and gases are fluids. These substances flow from one place to another. That's why they are known as fluids*

When a fluid completely fills a vessel and a pressure is applied to it at any part of its surface, as for example, by means of a cylinder and piston connected to the vessel then the pressure is transmitted equally throughout the whole of the enclosed fluid. This fact is called the principle of transmission of pressure in fluid.

#### 1.3. Density and Flow Velocity

Although a fluid is a system of particles, the number of particles in, say, a cubic centimeter of water is so large that it is not feasible to describe the state of the fluid in terms of the masses, positions, and velocities of all the individual particles in the system. Instead, we will **describe the fluid in terms of its velocity of flow, density, and pressure**. These quantities give us a macroscopic description of the fluid they tell us the average behaviour of the particles in regions within the fluid.

#### 1.4. Density

**The density is the amount of mass per unit volume.** The unit of density is the kilogram per cubic meter ( $\text{kg/m}^3$ ). Table-1 lists the densities of a few liquids and gases. In the table, the density is designated by the customary symbol  $\rho$  the Greek letter "rho". The densities of gases depend on the temperature and the pressure. The densities of liquids depend only slightly on pressure, but they do depend appreciably on temperature. For instance, water has a maximum density at about  $4^{\circ}\text{C}$ .

*The density is the amount of mass per unit volume*

Table: 1

Densities of Some Fluids and Gases	
	Density
<b>Water</b>	
0°C	999.8
4°C	1000.0
20°C	998.2
100°C	958.4
Sea water, 15°C	1025
Mercury	13,600
Sodium. liquid at 98°C	929
Texas crude oil, 15°C	875
Gasoline, 15°C	739
Olive oil, 15°C	920
Human blood, 37°C	1060
<b>Air</b>	
0°C	1.29
20°C	1.20
Water vapor, 100°C	0.598
Hydrogen	0.0899
Helium	0.178
Nitrogen	1.25
Oxygen	1.43
Carbon dioxide	1.98
Propane	2.01

### 1.5. Pressure

*The pressure within a fluid is defined in terms of the force that a small volume of fluid exerts on an adjacent volume or on the adjacent wall of a container*

The **pressure** within a fluid is defined in terms of the force that a small volume of fluid exerts on an adjacent volume or on the adjacent wall of a container. Suppose that the magnitude of the perpendicular force between the two cubes is  $F$  and that the area of one face of the cubes is  $A$ ; then the pressure  $p$  is defined as the magnitude  $F$  of the force divided by the area  $A$ :

$$P = F/A$$

According to this definition, pressure is simply the magnitude of the force per unit area. Note that, in contrast to the force, the pressure is a quantity without direction. We cannot associate a direction with the pressure, because a small volume of fluid, or any small body immersed in the fluid, experiences pressures from all directions, and the pressures from all directions are equal.

In the metric system, the unit of pressure is the Newton per square meter ( $\text{N/m}^2$ ), which has been given the name Pascal (Pa).

$$1 \text{ Pa} = 1\text{N/m}^2$$

Another unit in common use is the atmosphere (atm).

$$1 \text{ atm} = 1.01 \times 10^5 \text{ N/m}^2$$

This is the average value of pressure of air at sea level. Note that this is quite a large pressure. For instance, the force that the atmospheric pressure of 1 atm exerts on the palm of our hand, of approximate area  $0.006\text{m}^2$ , is

$$F = A.P = 0.006\text{m}^2 \times 1.01 \times 10^5 \text{ N/m}^2 = 600\text{N}$$

This is roughly the weight of 60kg, but we do not notice this pressure force because an equal pressure force of opposite direction acts on the back of your hand, leaving the hand in equilibrium.



## 1.6. Exercises

### 1.6.1. Multiple choice questions

1. Water has a maximum density at about
  - i.  $10^{\circ}\text{C}$
  - ii.  $4^{\circ}\text{C}$
  - iii.  $50^{\circ}\text{C}$
  - iv.  $1^{\circ}\text{C}$ .
  
2. Pressure is a quantity
  - i. without direction
  - ii. with direction
  - iii. with area
  - iv. without area.
  
3. 1 atm is equal to
  - i.  $1.01 \times 10^5 \text{ N/m}^2$
  - ii.  $1.01 \times 10^{.5} \text{ N/m}^2$
  - iii.  $1.01 \times 10^5 \text{ N/m}^2$
  - iv.  $200 \times 10^5 \text{ N/m}^2$ .

### 1.6.2. Fill up the gaps

- a. Both liquids and gases are .....
- b. The gas molecules are very .....
- c. The density of gases depends on the temperature and .....
- d. Another unit of pressure is the .....

### 1.6.3. Short questions

1. What is fluid?
2. What is the unit of pressure?

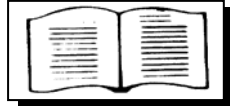
## Lesson 2: Measurement of Pressure

### 2.1. Learning Objectives



On completion of this lesson you will be able to learn

- ♦ how the pressure of liquids is measured.



### 2.2. Mercury Barometer

Several simple instruments for the measurement of pressure make use of a column of liquid. A mercury barometer consisting of a tube of glass, about 1m long, closed at the upper end and open at the lower end. The tube is filled with mercury, except for a small empty space at the top. The bottom of the tube is immersed in an open bowl filled with mercury. The atmospheric pressure action on the exposed surface of mercury in the bowl prevents the mercury from flowing out of the tube. At the level of the exposed surface, the pressure exerted by the column of mercury is  $\rho gh$  where  $\rho = 1.36 \times 10^4 \text{ kg/m}^3$  is the density of mercury and  $h$  the height of the mercury column. For equilibrium, this pressure must match the atmospheric pressure -

$$P_0 = \rho gh$$

*The average value of the atmospheric pressure at sea level is 760 mm-Hg, which by definition is one atmosphere (atm)*

This equation permits a simple determination of the atmospheric pressure from a measurement of the height of the mercury column.

In view of the direct correspondence of the atmospheric pressure and the height of the mercury column, the pressure is often quoted in terms of this height, usually expressed in millimeters of mercury (mm-Hg). The average value of the atmospheric pressure at sea level is 760 mm-Hg, which by definition is one atmosphere (atm). Hence,

$$\begin{aligned} 1 \text{ atm} &= 760 \text{ mm-Hg} = P \times g \times 0.760\text{m} \\ &= 1.36 \times 10^4 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 0.760\text{m} \\ &= 1.01 \times 10^5 \text{ N/m}^2 \end{aligned}$$

### 2.3. Manometer

*Manometer*

An open-tube manometer is a device for the measurement of the pressure of a fluid, such as that contained in the tank shown on the left. The tube contains mercury, or water, or oil. One side of the tube is in contact with the fluid in the tank; the other is in contact with the air. The fluid in the tank therefore presses down on one end of the mercury column and the air presses down on the other end. The difference  $h$  in the heights of the levels of mercury at the two ends gives the difference in the pressure at the two ends,

$$P - P_0 = Pgh$$



Hence, this kind of manometer indicates the amount of pressure in the tank in excess of the atmospheric pressure. This excess is called the **over pressure, or gauge pressure**. It is well to keep in mind that many of the pressure is the over pressure. For instance, the pressure gauges used for automobile tires read over pressure.



## 2.4. Exercise

### 2.4.1. Multiple choice questions

1. Mercury barometer is used for the measurement of
  - i. volume
  - ii. pressure
  - iii. density
  - iv. temperature.
2. Atmospheric pressure at sea level is
  - i. 760 mm. Hg
  - ii. 76 mm. Hg
  - iii. 560 mm. Hg
  - iv. 0.760 mm. Hg.

### 2.4.2. Short questions

1. What is a manometer?
2. Which equation permits a simple determination of the atmospheric pressure?

### 2.4.3. Analytical question

1. Describe briefly how pressure of liquids is measured.

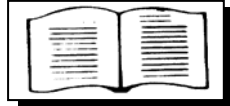
## Lesson 3: Flow of Blood

### 3.1. Learning Objectives



On completion of this lesson you will be able to learn

- ◆ the mechanism of flow of blood in human body.



### 3.2. Blood Flow

We are accustomed to thinking of the heart as a pump, but the heart is actually two pumps working in tandem. The first pump, on the right side of the heart, receives oxygen-depleted, dark-red blood from all parts of the body via the vena cava, and pumps this blood to the lungs. The second pump, on the left side of the heart, receives oxygen-rich, bright red blood from the lungs, and pumps this blood to all parts of the body via the aorta.

### 3.3. The Chambers and Valves of the Heart

Each of the pumps in the heart has two chambers. The upper chamber is called the **atrium**, and the lower chambers the ventricle (“belly”). The atria accumulate the blood arriving at the heart and then inject it into the ventricles. The ventricles eject the blood from the heart into the arteries; they perform most of the work required for the pumping. Each pump has two flap valves. The right pump has the tricuspid valve (between the atrium and the ventricle) and the pulmonary valve (at the beginning of the pulmonary artery). The left pump has the mitral valve (between the atrium and the ventricle) and the aortic valve (at the beginning of the aorta). These flap valves operate passively; their leaflets bend open to permit the flow of blood in the forward direction; but they flip shut when there is an incipient flow in the backward direction.

*The chambers and valves of the heart*

We can best understand the operation of the chambers and the valves of the heart by tracing the flow of a parcel of blood through the heart and around the entire circulatory system. The blood arrives at the heart via the inferior and the superior vena cava and enters the right atrium, where it accumulates until the atrium begins to contract and the tricuspid valve opens. The blood then flows into the relaxed right ventricle, filling and expanding it. When the ventricle begins to contract a moment later, the leaflets of the tricuspid valve flip into their shut position, while the leaflets of the pulmonary valve open. The contraction of the ventricle then propels the blood into the pulmonary artery. When the ventricle completes its contraction and begins to relax, the pulmonary valve shuts behind the parcel of blood, preventing any back flow. Within the lungs, the pulmonary artery branches into many small arterioles and even smaller capillaries. While passing through these pulmonary capillaries, the blood sheds its load of carbon dioxide and absorbs oxygen. The capillaries connect to veins, which

merge into the main pulmonary veins. These veins carry the blood to the left atrium of the heart, where it accumulates until the mitral valve opens. The blood then flows into the relaxed left ventricle, filling and expanding it. The ventricle begins to contract and the mitral valve shuts, while the aortic valve opens. The ventricle completes its contraction, pushing the blood into the aorta. When the ventricle begins to relax, the aortic valve shuts, preventing back flow of the parcel of blood. The aorta branches out into arteries, arterioles, and ultimately into capillaries, which distribute the blood throughout the body. While passing through these capillaries, the blood delivers oxygen to the cells and absorbs carbon dioxide dumped by the cells during their metabolic activity. The systemic capillaries merge into veins, and finally the blood returns to the heart via the inferior and the superior vena cava, completing the circuit.

### 3.4. Walls of the Heart

The walls of the heart consist of layers of muscle, wound several times around the atria and the ventricles in a complicated arrangement. The layers of muscle around the ventricles are thicker than those around the atria. The heart muscle pumps blood by its cyclic contractions and relaxation. The contracted phase of the heart is called systole, and the relaxed phase is called **diastole**. Each contraction begins in the walls of the atria, and this squeezes the blood from the atria into the ventricles; a moment later, the walls of the ventricle contract. Squeezing the blood out of the heart into the ventricles; a moment later, the walls of the ventricle contract, squeezing the blood out of the heart into the arteries. Since the walls of both atria contract jointly, and the walls of both ventricles also contract jointly, the right and the left pumps in the heart always operate in unison. The layers of muscle around the left ventricle are much thicker than those around the right ventricle. The left ventricle generates the highest pressures and does most of the mechanical work.

*The contracted phase of the heart is called systole, and the relaxed phase is called diastole*

Under conditions of rest, the heart typically goes through 70 cycles of contraction and relaxation per-minute, that is, 70 heartbeats per minute. Each contraction lasts about 0.3s, and each relaxation about 0.5s. However, under conditions of heavy exercise or stress, the heart rate may be as high as 180 heart beats per minute. The rate of flow of blood through each side of the heart is 5.5 liters per minute at rest. Trained athletes attain a rate of flow of up to 35 liters per minute, during heavy exercise. The total volume of blood -

Table- 2

<b>Some Data For The Human Circulatory System</b>	
<b>Pressure in aorta while resting</b>	
mean	100 mm-Hg
systole	120 mm-Hg
diastole	80 mm-Hg
Pressure in vena cava	$\cong 0$ mm-Hg
Pressure in pulmonary artery, mean	15 mm-Hg
Pressure in pulmonary vein	8 mm-Hg
Volume pumped with each heart beat	$78\text{cm}^3$
Heartbeat rate	70/min
Radius of aorta	1.2cm
<b>Speed of blood in aorta,</b>	
Mean	0.2m/s
Maximum	0.7m/s
Radius of capillary	$3\mu\text{m}$
Speed of blood in capillary, mean	0.3mm/s

*Blood in the human body is 5 to 6 liters, and therefore a rate of flow of 5.5 liters per minute implies that, on the average, a parcel of blood takes just about a minute to travel around the complete cardiovascular circuit*

in the human body is 5 to 6 liters, and therefore a rate of flow of 5.5 liters per minute implies that, on the average, a parcel of blood takes just about a minute to travel around the complete cardiovascular circuit. Since the blood flows on a closed circuit, without any loss of blood, the rate of flow must be the same everywhere along the circuit. Thus, if 5.5 liters per minute flow through the caval vein, then the same amount must flow through the systemic capillaries. However, the speed of flow is different at different points of the circuit, as required by the equation of continuity. The mean speed is about 0.2 m/s in the aorta, but it is much lower in the capillaries, only about 0.3 mm/s.

The pressure of the blood in the arteries fluctuates during each stroke of the pump. At the base of the aorta, the pressure during systole reaches 120 mm-Hg. and during diastole it falls to about 80 mm-Hg. The mean pressure is about 100 mm-Hg Table- 2. The pressure in the veins fluctuates much less; in the vena cava, near the heart, the pressure is nearly steady and nearly zeros. Thus, the mean pressure difference across the systemic segment of the circulatory system is about 100mm-Hg. A pressure difference is required to balance the viscous resistance of blood and to maintain a more or less steady rate of flow. Blood has a viscosity of  $2.1 \times 10^{-3}$ s. N/m<sup>2</sup>, about three times that of water. According to Poiseuille's equation, the pressure drop along a tube, such as an artery or a vein, is directly proportional to the viscosity, the length, and the rate of flow, and inversely proportional to the fourth power of the radius of the tube.

Most of the pressure drop actually occurs in the small arteries, or arterioles, that connect to the capillaries. In the capillaries themselves, the pressure drop is not so large, even though these are the smallest vessels in the circulatory system, with a radius of only  $3 \times 10^{-6}$ m. The arterioles have a larger radius than the capillaries, but they also have a

larger length and a higher rate of flow, and because of this they contribute a larger pressure drop than the capillaries.



### 3.5. Exercise

#### 3.5.1. Multiple choice questions

1. The contracted phase of the heart is called
  - i. systole
  - ii. diastole
  - iii. blood fluid
  - iv. electrolyte.
  
2. The relaxed phase is called
  - i. systole
  - ii. diastole
  - iii. blood pressure
  - iv. none of the above.
  
3. The pressure during systole reaches
  - i. 120 mm. Hg
  - ii. 150 mm. Hg
  - iii. 200 mm. Hg
  - iv. 80 mm. Hg.
  
4. Each of the pumps in the heart has
  - i. two chambers
  - ii. one chamber
  - iii. three chambers
  - iv. five chambers.

#### 3.5.2. Fill up the gaps

- a. Blood has a viscosity of .....
- b. The pressure drop along a tube is directly proportional to the .....

#### 3.5.3. Short questions

1. What do you mean by systole and diastole?
2. What is normal blood pressure of a man?

#### 3.5.4. Analytical question

1. Describe briefly about the chambers and valves of the heart.

## Unit 4: Electricity

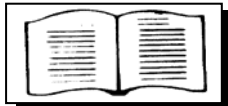
### Lesson 1: Electric Force and Electric Charge

#### 1.1. Learning Objectives



On completion of this lesson you will be able to learn

- ◆ about electric force
- ◆ about electric charge.



#### 1.2. Electric Force

Our society is dependent on electricity. An electric power failure demonstrates our dependence on electricity. Electricity is an essential ingredient in all the atoms in our bodies and in our environment. The forces that hold the parts of an atom together are electric forces. Furthermore, so are the forces that bind atoms in a molecule and hold these building blocks together in large-scale macroscopic structures, such as a rock, a tree, a human body, a skyscraper. Our immediate environment is dominated by **electric forces**.

*Electric Force*

In the following chapters, we will study electric forces and their effects. For a start, we will assume that the particles exerting these forces are at rest or moving only very slowly. The electric forces exerted under these conditions are called electrostatic forces. We will consider the electric forces when the particles are moving with uniform velocity or nearly uniform velocity. Besides the electrostatic force there arises a magnetic force, which depends on the velocities of the particles. **The combined electrostatic and magnetic forces are called electromagnetic forces.** Finally we will consider the forces exerted when the particles are moving with accelerated motion. The electromagnetic forces are then further modified with a drastic consequence, which is **the emission of electromagnetic waves, such as light and radio waves.**

*The combined electrostatic and magnetic forces are called electromagnetic forces*

Ordinary matter - solids, liquids, and gases - consists of atoms, each with a nucleus surrounded by a swarm of electrons. At the center of atom there is a nucleus made of protons and neutrons packed very tightly together - the diameter of the nucleus is only about  $6 \times 10^{-15}$  m. Moving around this nucleus are ten electrons; these electrons are confined to a roughly spherical region about  $1 \times 10^{-10}$  m across.

The atom somewhat resembles the Solar System, with the nucleus as Sun and the electrons as planets. In the Solar System, the force that holds a planet near the Sun is the gravitational force. In the atom, the force that holds an electron near the nucleus is the electric force of attraction between the electron and the protons in the nucleus. This electric force resembles gravitation that it decreases in proportion to

the inverse square of the distance. But the electric force is much stronger than the gravitational force. The electric attraction between an electron and a proton (at any given distance) is about  $2 \times 10^{39}$  times as strong as the gravitational attraction.

Table 1: Electric Forces (Qualitative)

Particles	Force
Electron and proton	Attractive
Electron and electron	Repulsive
Proton and proton	Repulsive
Neutron and anything	Zero

The other great difference between the gravitational force and the electric force is that the gravitational force between two particles is always attractive, whereas electric forces can be attractive, repulsive, or zero, depending on what two particles we consider. The electron-proton electric force is attractive; but the electron-electron-neutron and the proton-neutron electric forces are zero. Table 1 gives a qualitative summary of the electric forces between the fundamental particles.

### 1.3. Electric Charge

Particles that exert electric forces are said to have an electric charge particles that do not exert electric forces are said to have no electric charge. Thus, electric charge is thought of as the source of electric force, just as mass is the source of gravitational force. Electrons and protons have electric charge, but neutrons have no electric charge. Since the electron-proton force, the electron-electron force, and the proton-proton force all have the same magnitudes (for a given distance), the strengths of the sources on electrons and protons are of equal magnitudes; that is, their electric charges are of equal magnitudes. For the mathematical formulation of the law of electric force, we assign a positive charge to the proton and a negative charge (of equal magnitude) to the electron. We designate these charges of the proton and the electron by  $+e$  and  $-e$ , respectively Table-2 summarizes these values of the charges.

*Electric Charge*

#### **Like charges repel and unlike charges attract.**

In terms of these electric charges, we can then state that the electric force between charges of like sign is repulsive and the electric force between charges of unlike sign is attractive.

*Like charges repel and unlike charges attract*

Table 2: Electric Charges of protons, Electron, and Neutrons.

Particle	Charge
Proton, p	$+e$
Electron, e	$-e$
Neutron, n	0

The numerical value of the proton and electron charge depends on the system of units. In the metric, or SI, system of units, the electric charge is measured in Coulombs (C), and the corresponding numerical values of the charges of the proton and of the electron are

$$e = 1.60 \times 10^{-19} \text{ C for proton}$$
$$-e = - 1.60 \times 10^{-19} \text{ C for electron.}$$

*Atoms with missing electrons or with extra electrons are called ions*

The net electric charge of a body containing some number of electrons and protons is the (algebraic) sum of the electron and proton charges. For instance, the net electric charge of an atom containing equal numbers of electrons and protons is zero; that is, the atom is electrically neutral. Sometimes atoms lose an electron, and sometimes they gain an extra electron. **Such atoms with missing electrons or with extra electrons are called ions.** They have a net positive charge if they have lost electrons, and a net negative charge if they have gained electrons. The positive or negative charge on a macroscopic body—such as on a plastic comb electrified by rubbing—arises in the same way, from a deficiency or an excess of electrons.

The electric forces between two neutral atoms tend to cancel; each electron in one atom is attracted by the protons in the nucleus of the other atom and simultaneously, it is repelled by the equal number of electrons of that atom. However, the cancellation of these electric attractive and repulsive forces among the electrons and the protons in the two atoms is sometimes not complete. For instance, the “contact” force between two atoms close together arises from an incomplete cancellation of the attractive and repulsive forces. The force between the atoms depends on the relative locations of the electrons and the nuclei. If the distributions of the electrons are somewhat distorted so, on the average, the electrons in one atom are closer to the nucleus of the neighboring atom than to its electrons, then the electrons in the first atom will be more strongly attracted by the nucleus of the neighboring atom than they are repelled by its electrons; the net force between these atoms will be attractive.

Likewise, the electric forces between two neutral macroscopic bodies separated by some appreciable distance tend to cancel. For example, if the macroscopic bodies are a baseball and a tennis ball separated by a distance of 2 m, then the protons of the tennis ball attract each electron of the baseball, but simultaneously the electrons of the tennis ball repel it; and these forces cancel each other. Only when the surfaces of the two balls are very near each other (“touching”) will the atoms in the surface exert a net electric force on those in the other surface.

This cancellation of the electric forces between neutral macroscopic bodies explains why we do not see large electric attractions or repulsion between the macroscopic bodies in our environment, even though the electric forces between individual electrons and protons are much stronger than the gravitational forces. Most such macroscopic



bodies are electrically neutral, and they therefore exert no net electric forces on each other, except for contact forces.

#### 1.4. Conductor, Insulator and Semiconductor

*Conductor,  
insulator and  
semiconductor*

Let us have two metallic balls. One of them is strongly charged and the other one is electrically neutral. If we now join them with iron wire or by metallic substance, then the neutral metallic ball will gain charge. Now if we touch them all with a wooden stick or rubber, then neutral ball still remains neutral or chargeless. So, substance like iron or metallic balls are called **electrical conductors** and wooden stick or rubbers is called **nonconductor or insulator**. All metals are well electrical conductors.

Silicons and Carbons are called semiconductors. Semiconductors are in the middle category in sense of conductors and insulators.

All conductors are used to make electrical instrument, medical equipments. In the medical and nursing practice, their applications are wide and common.



### 1.5. Exercise

#### 1.5.1. Multiple choice questions

1. The combine electrostatic and magnetic forces are called
  - i. gravitation force
  - ii. electromagnetic force
  - iii. nuclear force
  - iv. weak force.
  
2. Electricity was first discovered through
  - i. friction
  - ii. oil
  - iii. atom
  - iv. none of the above.
  
3. Like charges
  - i. repel
  - ii. attract
  - iii. repel and attract
  - iv. none of the above.

#### 1.5.2. Fill up the gaps

- a. The electric forces between two neutral atoms tend to .....
- b. Like charges repel and unlike charges .....
- c. Such atoms with missing electrons or with extra electrons are called .....
- d. Most such macroscopic bodies are electrically .....

#### 1.5.3. Short questions

1. What is a charge? What kinds they are?
2. What is electromagnetic force?
3. What do you mean by ions?

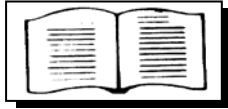
## Lesson 2: Coulomb's Law

### 2.1. Learning Objectives



On completion of this lesson you will be able to learn-

- ◆ Coulomb's law for electrostatic charges.



### 2.2. Coulomb's Law

As already mentioned above, the electric force between two particles decreases with the inverse square of the distance, just as does the gravitational force. Coulomb, who investigated the repulsion between small balls charged by rubbing, discovered the dependence of the electric force on distance through experiments. His experimental results are summarized in **coulomb's Law** -

*Coulomb's Law*

**The magnitude of the electric force that a particle exerts on another particle is directly proportional to the product of their charges and is inversely proportional to the square of the distance between them. The direction of the force is along the line from one particle to the other.**

To express this law mathematically, we denote the charges on the particles by  $q$  and  $q'$  and distance by  $r$ . Coulomb's Law is then represented by the formula

$$F = [\text{constant}] \times q \times q' / r^2 \quad (1)$$

This formula gives not only the magnitude of the force, but also direction, if we interpret a positive value of the force  $F$  as repulsive and a negative value as attractive. For instance, for the case of the force exerted by a proton on an electron, the charges are  $q' = e$  and  $q = -e$ , and the formula (1) yields

$$F = [\text{constant}] \times e \times (-e) / r^2 \quad (2)$$

which is negative, indicating attraction.

The electric force that the particle of charge  $q$  exerts on the particle of charge  $q'$  has the same magnitude as the force exerted by  $q'$  on  $q$ , but the opposite direction. These mutual forces are an action-reaction pair.

In SI units, the constant of proportionality in Coulomb's Law the value

$$[\text{constant}] = 8.99 \times 10^9 \text{ N.m}^2/\text{C}^2 \quad (3)$$

This constant is traditionally written in the form

$$[\text{constant}] = 1 / 4 \pi \epsilon_0 \quad (4)$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{C}^2/(\text{N.m}^2) \quad (5)$$

The quantity  $\epsilon_0$  (epsilon nought ) is called the permittivity constant. In terms of the permittivity constant, Coulomb's Law for the force that a particle of charge  $q'$  exerts on a particle of charge  $q$  becomes

$$F = \frac{1}{4\pi\epsilon_0} \times qq' \quad (6)$$

*One coulomb is the amount of electric charge that a current of one ampere delivers in one second.*

Although the second expression on the right side of Eq. (6) is most convenient for numerical calculations of the Coulomb force, the first expression with  $1/4\pi \epsilon_0$  is generally used in manipulations involving formulas. Of course, the two expressions are mathematically equivalent, and they give the same results.

Coulomb's Law applies to particles - electrons and protons - and also to any small charged bodies, provided that the sizes of these bodies are much smaller than the distance between them; such bodies are called **point charges**, Equation (6) clearly resembles Newton's law for the gravitational force,  $F = GMm/r^2$ . The constant  $1/4\pi \epsilon_0$  is analogous to the gravitational constant  $G$ , and the electric charges are analogous to the gravitating masses.

In SI the Coulomb is defined in terms of a standard electric current: **one Coulomb is the amount of electric charge that a current of one ampere delivers in one second.**



## 2.3. Exercise

### 2.3.1. Short questions

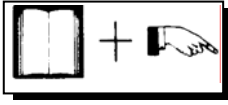
- a. What is the point charge?
- b. What do you mean by one coulomb?

### 2.3.2. Analytical question

- a. State coulomb's law.

## Lesson 3: The Electrocardiograph

### 3.1. Learning Objectives



On completion of this lesson you will be able to learn

- ♦ about is an electrocardiograph.



### 3.2. What is Electrocardiograph?

*What is  
electrocardiograph*

The human heart beats about 70 times per minute. Each beat begins with a contraction of the atria which is followed a moment later by the contraction of the muscle. The contractions of the heart muscle, like the contractions of other muscles, are triggered by electric signals. But in contrast to other muscles, where the electric signals travel along nerve fibers, the electric signals in heart muscle travel along the muscle fibers. These electric signals involve changes of the electric potential in and around the muscle fibers. The changes of the electric potential associated with the heartbeats are strongest in the immediate vicinity of the muscle fibers; but, with a sensitive detector, the changes in the potential can be measured at some distance from the heart, on the surface of the skin. The detector used to measure such changes of potential is called **electrocardiograph**; it is widely used by physicians to monitor the operation of the heart and to discover defects in the heart muscle.

The mechanism for the propagation of electric signals along muscle fibers is almost exactly the same as for the propagation along nerve fibers. Each muscle fiber is a single, long cell, sheathed in a membrane. When the muscle fiber is at rest (inactive), the membrane carries a layer of positive charge on its outside surface and a layer of negative charge on its inside surface. A membrane with such layers of opposite charges is said to be polarized. The positive charges are mainly  $K^+$  ions, and the negative charges are mainly  $Cl^-$  ions. Between these layers of charge there is a uniform electric field between oppositely charged parallel plates consequently there is a potential difference between the outside and the inside of the cell. The potential induced of the cell is negative. This resting potential is about 90 millivolts.

When a muscle fiber is stimulated by an electric signal from an adjacent muscle fiber, positive charges (mostly  $Na^+$  ions) from the interstitial fluid surrounding the fiber flows through the membrane into the fiber. The accumulation of these positive charges reverse the potential difference, from - 90 millivolts to about + 30 millivolts. The membrane is then said to be depolarized (actually, polarized in the reverse direction). The depolarization propagates along the length of the muscle fiber and constitutes the electric signal. This depolarization triggers the contraction process of the fiber. Within a short time, chemical processes within the fiber pump the positive charges out of

the fiber and restore the charge distribution to the initial resting state. The depolarized fiber is then ready for the next depolarization and the next contraction.

*Dipole moment*

The depolarization of muscle fibers can be detected at some distance from the fibers by the changes in the electric potential. Consider a muscle fiber that is initially polarized, and progressively becomes depolarized from left to right. Initially the positive charge distribution is centered on the negative charge distribution. The potential at a point M beyond one end of the fiber is nearly zero, since the average positions of the positive and the negative charge distributions are slightly different - the average position of the positive charge distribution is slightly to the right of the average position of the negative charge distribution. The separation between the average positions of the charge distributions implies that the muscle fiber has a **dipole moment**. The electric fields then do not cancel, and the potential at the exterior point is not zero.

In the heart, the depolarization and contraction of the muscle fibers of the atria and the ventricles are initiated respectively by the sinus node and the atrioventricular node (A-V node). These nodes are small clumps of muscle fibers. The sinus node is the primary pacemaker of the heart. Its muscle cells depolarize and contract spontaneously at regular intervals. The electric signals produced during this activity are transmitted to the muscles of the atria and initiate their contraction. When the electric signals reach the A-V node, it relays these signals to the ventricles and thereby initiates their contraction.

To observe the potential changes generated during the depolarization of the muscle fibers in the heart, electrodes (contacts) are placed on the skin and connected by wire leads to a sensitive voltmeter. The potential changes on the skin are of the order of a few millivolts, and to detect such small potentials, the voltmeters used in the electrocardiograph are equipped with amplifier circuits. The standard procedure for electrocardiography is to attach electrodes to the left wrist, the right wrist and the left ankle (other electrodes are attached).

The sinus node is the primary pacemaker of the heart to the chest wall, but we will ignore these. The electrodes are covered with a salt paste, for good electric contact. The choice of location of the electrodes on the arms and legs is a matter of convenience. The arms and the legs act as conducting segments, and attaching electrodes to the ends of the arms or legs. Measurements with the wrist and ankle electrodes are roughly equivalent to measurements at the vertices of a triangle centered on the heart called the Einthoven triangle.

With these three electrodes at the vertices of the triangle, six measurements are routinely made and plotted by the electrocardiograph: three “unipolar” measurements and three “bipolar” measurements. The unipolar measurements simply give the values of

the potential at the three vertices of the triangle. These potentials are designated  $V_R$  (for right wrist),  $V_L$  (for left wrist), and  $V_F$  (for left ankle or foot). The plus signs included next to these symbols indicate that the +e terminal of the voltmeter is connected to this electrode during the measurement. The -e terminal of the voltmeter is connected to a reference terminal, or “indifferent terminal,” whose potential is zero.

The bipolar measurements give the potential differences between adjacent vertices. These potential differences are designated I, II, and III. The plus and minus signs indicate where the + and - terminals of the voltmeter are connected during the measurement. Note that I, II, and III can be expressed as differences between  $V_R$ ,  $V_L$ , and  $V_F$ .

$$\begin{aligned} I &= V_L - V_R \\ II &= V_F - V_R \\ III &= V_F - V_L \end{aligned}$$

Figure 2 : is an example of an electrocardiogram (ECG) measures on a healthy individual. This ECG displays the potentials I, II, III,  $V_R$ ,  $V_L$ , and  $V_F$  as a function of time. Figure 2 is an enlarged sketch of the potential II. The main features of this plot are the maximum and minimum, called the P, Q, R, S, and T “waves”. These waves indicate the potentials generated by depolarizations and repolarizations of muscle fibers in different parts of the heart. The P wave indicates the depolarization of the atria; the Q wave that of the septum, the R wave that of the main mass of the ventricles, and the S wave that of a smaller, lateral portion of the right ventricle. The T wave indicates the depolarization of the ventricles.

These waves are of different magnitudes because the muscle mass is different (largest for ventricle, smallest for septum), and because the directions of the progressive depolarization of the muscle fibers are different. The direction of depolarization in the ventricle is on the average, aligned with the direction to which the potential II belongs and therefore this depolarization gives a large contribution to this potential.



### 3.3. Exercise

#### 3.3.1. Short question

1. What is electrocardiograph?

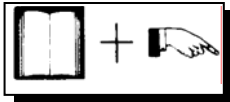
#### 3.3.2. Analytical question

1. Discuss about electrocardiograph.

## Unit 5: Light

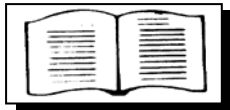
### Lesson 1: Nature of Light and Vision

#### 1.1. Learning Objectives



On completion of this lesson you will be able to learn-

- ◆ nature and properties of light
- ◆ threshold of vision
- ◆ defects of vision
- ◆ colour vision
- ◆ about applications of light
- ◆ the effects of ultraviolet and infrared ray.



#### 1.2. Nature of Light

Light is an electromagnetic radiation. Although light is only a tiny part of the electromagnetic spectrum, it has been the subject of much research both in physics and in biology. The importance of light is due to its fundamental role in living systems. The sun is still the major source of light in the world. The sun is both beneficial and hazardous to our health.

#### Nature of Light

The three general categories of light ultra-violet (UV), visible and infrared (IR). They are defined in terms of their wavelengths. Ultraviolet light has wave lengths from about 1000 to 4000  $\text{A}^0$ ; visible light extends from about 4000 to 7000  $\text{A}^0$  and IR light extends form about 7000 to 100000  $\text{A}^0$ .

#### 1.3. Properties of Light

Light has some interesting properties, many of which are used in medicine.

#### Properties of Light

1. The speed of light changes when it goes from one material to another. The ratio of the speed of light in vacuum to its speed in a given material is called the index of refraction. If a light beam meets a new material at an angle other than perpendicular, it bends, or is refracted. This property permits light to be focused and its the reason we can read and see objects clearly.
2. Light behaves both as a wave and as a particle. As a wave it produces interference and diffraction. As a particle a single molecule can absorb it. When a light photon is absorbed its energy is used in various ways. It can cause a chemical change in the molecule that in turn can cause an electrical change. This is basically what happens when a light photon is absorbed in one of the sensitive cells of the retina. The chemical change in a particular



point of retina triggers an electrical signal to the brain to inform it that a light photon has been absorbed at that point.

3. When light is absorbed its energy generally appears as heat. This property is the basis for the use in medicine of IR light to heat tissues.
4. Sometimes when a light photon is absorbed, a lower energy light photon is emitted. This property is known as fluorescence.
5. Light is reflected to some extent from all surfaces.

#### 1.4. Vision

Vision is our most important source of information about the external world. It has been estimated that about 70% of a person's sensory input are obtained through the eye. The three components of vision are the stimulus, which is light; the optical components of the eye, which image the light; and the nervous system, which processes and interprets the visual images. Let us to discuss about different type of vision.

#### 1.5. Threshold of Vision

The sensation of vision occurs when the photosensitive rods and cones absorb light. At low levels of light the main photoreceptors are the rods. Under optimum conditions the eye is a very sensitive detector of light. The human eye, for example, responds to light from a candle as far away as 20km. At the threshold of vision the light intensity is so small that we must describe it in terms of photons.

*Threshold of Vision*

#### 1.6. Defects in Vision

There are three common defects in vision associated with the focusing system of the eye. These are as follows -

*Defects in Vision*

- ◆ myopia (near sightedness)
- ◆ hyperopia (farsightedness) and
- ◆ astigmatism.

The relaxed normal eye focuses parallel light onto the retina. In the myopic eye the lens system focuses the parallel light in front of the retina. An elongated eyeball or an excessive curvature of the cornea usually causes this misfocusing. In hyperopia the problem is reversed. Parallel light is focused behind the retina. The problem here is caused by an eyeball that is shorter than normal or by the inadequate focusing power of the eye. Astigmatism is a defect caused by a nonspherical cornea.

All three of these defects can be corrected by lenses placed in front of the eye. Myopia requires a diverging lens to compensate for the excess refraction in the eye. Hyperopia is corrected by a converging lens, which adds to the focusing power of the eye. The uneven corneal curvature in astigmatism is compensated for by a cylindrical lens, which focuses light along one axis but not along the other.

### 1.7. Colour Vision

#### *Color Vision*

One of the remarkable abilities of the eye is its ability to see colour. The exact mechanism of colour vision is not well understood. It is fairly well accepted that there are three types of cones that respond to light from three different parts of the spectrum. If you examine a colour TV screen with a magnifying glass, you will see myriad of small red, green and blue dots. The dots can produce, in different combinations, all of the colours of the spectrum. Similarly, signals are sent to the brain from three “coloured” cones in different combinations and permit it to determine colour. If one of the colour sets is gone, a person is colour blind. He confuses certain colours. Approximately 8% of all men and 5% of all women are colour blind. It is rare that someone is completely colour blind. That person sees only shades of gray.

### 1.8. The Extension of Vision

#### *The extension of vision*

The range of vision of the eye is limited. The retina image of a 20m high tree at a distance of 500m is only 0.6mm high. The unaided eye cannot resolve the leaves on this tree. Over the past three hundred years, two types of optical instruments have been developed to extend the ranges of vision; the telescope and the microscope. The telescope is designed for the observation of distant objects. The microscope is used to observe small objects that cannot be seen clearly by the naked eye. Both of these instruments are based on the magnifying properties of lenses.

### 1.9. Applications of Visible Light

#### *Applications of visible light*

- ◆ An obvious use of visible light in medicine is to permit the physician to obtain visual information about the patient regarding, for example, the colour of his skin and the presence of abnormal structures in or on his body.
- ◆ A number of instruments, called endoscopes are used for viewing internal body.
- ◆ Transillumination is the transmission of light through the tissues of the body. Transillumination is used clinically in the detection of hydrocephalus in infants. It is also used to detect pneumothorax (collapsed lung) in infants.
- ◆ The sinuses, the gums, the breasts and testes have also been studied with transillumination.

- ◆ Visible light has an important therapeutic use. Since light is a form of energy and is selectively absorbed in certain molecules, it should not be surprising that it can cause important physiological effects.

### 1.10. Applications of UV and IR Light

*Applications of  
UV and IR light*

Ultraviolet light produces reactions in the skin then visible light. Some of these reactions are beneficial and some are harmful. One of the major beneficial effects of UV light from the sun is the conversion of molecular products in the skin into vitamin D. Ultraviolet light from the sun affects the melanin in the skin to cause tanning. However, UV light can produce sunburn as well as tan skin. Solar UV light is also the major cause of skin cancer in humans. The eye cannot see ultraviolet light because it is absorbed before it reaches the retina.

About half of the energy from the sun is in the IR region. The warmth we feel from the sun is mainly due to the IR component. The IR rays are not usually hazardous-even though the cornea and lens of the eye onto the retina focus them. Our eyes also cannot see IR light.



### 1.11. Exercise

#### 1.11.1. Multiple choice questions

1. The wavelength range of visible light is from about
  - i.  $4000\text{Å}^0$  to  $7000\text{Å}^0$
  - ii.  $1000\text{Å}^0$  to  $4000\text{Å}^0$
  - iii.  $7000\text{Å}^0$  to  $100000\text{Å}^0$
  - iv.  $3000\text{Å}^0$  to  $7000\text{Å}^0$ .
  
2. Our eyes cannot see
  - i. visible light
  - ii. ultraviolet light only
  - iii. infrared light only
  - iv. both ultraviolet and infrared light.
  
3. About half of the energy comes from the sun is in the
  - i. visible light region
  - ii. ultraviolet light region
  - iii. infrared light region
  - iv. both ii) and iii).

#### 1.11.2. Fill up the gaps with the appropriate words

- a. Light is an ..... wave.
- b. Still the major source of light is ..... in the world.
- c. Light is composed of small packets of energy called .....
- d. Light behaves both as a wave and as a .....

#### 1.11.3. Short questions

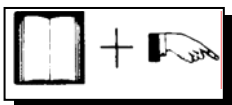
1. Give the wavelengths of visible, IR and UV light?
2. What is fluorescence?
3. List three biological effects of UV light.
4. Why does the eye not see UV light and IR light?
5. What do you mean by colour blind?
6. List two instruments that extend our vision.

#### 1.11.4. Analytical questions

1. Give the properties of light, which are used in medicine.
2. What is a vision? Discuss the different kinds of defects in vision.
3. What are the main applications of light?

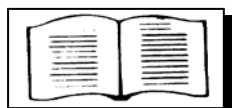
## Lesson 2: Reflection and Refraction of Light

### 2.1. Learning Objectives



On completion of this lesson you will be able to learn -

- ◆ reflection of light
- ◆ laws of reflection
- ◆ total internal reflection
- ◆ optical fiber and its application in medicine.



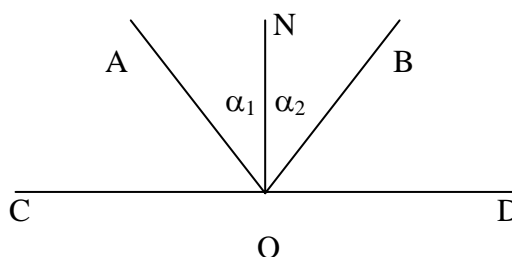
### 2.2. Concept of Reflection

The idea that light travels in straight lines is uppermost, while its wave character and other physical aspects are disregarded. Since the laws of reflection and refraction corollaries of the wave nature. Sources of light, such as the sun, stars, and electric lamps can be seen when the light they produce reaches the eyes. However, most objects can only be seen when light is reflected off the surface of an object. An object that reflects no light appears to be black. On the other hand an object that reflects all of the light appears the same colour as the light source, for instance something which reflects all of the white light reaching it from the sun appears white light mirrors and highly polished surfaces, reflect light strongly and we shall now deal with the laws governing the reflection.

*Concept of Reflection*

### 2.3. Laws of Reflection

In the Fig. 1.1 Illustrates the terms that we use in the study of reflected light.



*Laws of Reflection*

Laws of reflection

Represents the surface of a plane. AO, called the incident ray, is the direction in which light falls onto the reflecting surface. O is the point of incidence and OR the, reflected ray. The angles, which the incident and reflected rays make with ON, the normal or perpendicular to the reflected surface at the point of incidence, are, called the angles of incidence and reflection respectively. Laws of reflection are -

- ◆ The incidence ray, the reflected ray and the normal at the point of incidence all lie in the same plane.
- ◆ The angle of incidence is equal to the angle of reflection.

#### 2.4. Total Internal Reflection

At the interface of two media, the incident light beam is separated into two: reflected and refracted. If light falls with the angle on the surface of the interface, which differs from straight then at the interface light changes its direction. It is called **refraction** of light.

##### Total Internal Reflection

Of the two media in which light propagated at different velocity that in which the light velocity is lower and refraction index, denoted by  $n$  is greater will be called optically denser media. For examples glass ( $n = 1.5$  to  $1.7$ ) is optically denser than water ( $n = 1.33$ ).

When light propagates from a denser media to light media, then the angle of incidence  $\alpha_1$  approaches a certain value  $\alpha_{crit}$ , the angle of refraction tends to the right angle  $\alpha_0 \rightarrow \pi/2$ , and the intensity of the refraction beam tends to zero at a very fast rate. At all angles of incidence exceeding  $\alpha_{cr}$  which is called the **critical angle** and there will be no refracted beam. In this case light will be totally reflected from the interface as if it were an ideal mirror. This phenomenon is called **total internal reflection** or simply **total reflection**.

#### 2.5. Application of Optical Fiber

##### Application of Optical Fiber

Optical fibers are not only used for light communication but it is used in medicine for lighting difficult place of the human body, as for example, internal organ of a man. As a result of application of optical fiber gives clear image of disturbing point. For example doctor gets possibility to check up wall of the stomach by placing wave-guide into stomach. Light is sent through the one of the part of optical fiber for brightness of the stomach and through the other part reflection of light is got at another part of fiber.

The instrument based on optical fiber is used for this purpose is called Endoscopes. It is very useful for checking up difficult place of human body, when it needs for operation or fined wound place of patients without any surgical disturbance.



## **2.6. Exercise**

### **2.6.1. Short questions**

1. What do you mean by reflection of light?
2. What is refraction of light?
3. What is optical fiber and where do we use it?

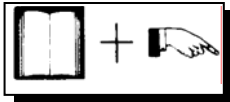
### **2.6.2. Analytical questions**

1. Describe the laws of reflection.
2. Describe total internal reflection.
3. Describe briefly main application of optical fiber in medicine.

## Unit 6: Heat Transmission

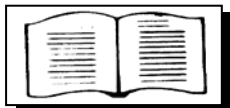
### Lesson 1: Heat

#### 1.1. Learning Objectives

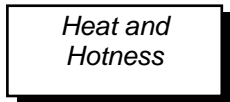


On completion of this lesson you will be able to learn

- ◆ heat and transmission of heat
- ◆ temperature scale.



#### 1.2. Heat and Hotness



The sensation of hotness is certainly familiar to all of us. When two bodies, one hot and the other cold, are placed in an enclosure, the hotter body will cool and the colder body will heat until the degree of hotness of the two bodies is the same. Clearly something has been transferred from one body to the other in order to equalize this hotness. That which has been transferred from the hot body to the cold body is called **heat**. Heat may be transferred into work. Therefore it is a form of energy. Heated water, for example, can turn into steams, which can push a piston.

#### 1.3. Specific Heat



**Specific heat** is the quantity of heat required to raise the temperature of 1gm of a substance by 1 degree. The human body is composed of water, protein fat, and minerals. Its specific heat reflects this composition. With 75% water and 25% protein, the specific heat of the body would be

$$\text{Specific heat} = 0.75 \times 1 + 0.25 \times 0.4 = 0.85.$$

The specific heat of the average human body is closer to 0.83 due to its fat and mineral content, which we have not included in the calculation. The specific heats of some substances are shown in the following table-1.

Table 1

Substance	Specific heat (cal/gm)
Water	1
ICE	0.84
Average for human body	0.83
Soil	0.20 to 0.80 (depending on water content)
Aluminum	0.214
Protein	0.40



### 1.4. Latent Heat

In order to convert a solid to a liquid at the same temperature or to convert a liquid to a gas, heat energy must be added to the substance. This energy is called **latent heat**.

### 1.5. Transmission of Heat

Heats are transferred from one region to another in three ways. They are conduction, convection and radiation.

#### ◆ Conduction

*Transmission of Heat*

When one end of a metal rod is heated, the unheated end soon becomes warm. This is because heat travels through the metal by the process of conduction.

All electrons are constantly vibrating and in metals the electrons are mobile. When a metal is heated the kinetic energy of its electrons is increased and they begin to move more rapidly and to move towards the cooler parts of the metal. Hence their energy is transferred to the cooler molecule.

#### ◆ Convection

In the process of convection heat is carried by and transferred by the movement of a liquid or gas. When liquid is heated at the bottom of a container a current of hot liquid moves upwards to be replaced by a current of cold liquid moving down.

#### ◆ Radiation

Radiation is the way in which heat travels from the sun across space to the earth's atmosphere. This "radiant energy" consists of invisible electromagnetic waves, which are partly reflected and partly absorbed. It comes from the sun directly or indirectly and when coming directly travels through 150 million km of space.

Conduction and convection are methods of heat transfer which both require a medium but radiation is a method of heat transfer, which requires no medium.

### 1.6. Temperature Scales

*Temperature Scales*

Temperature is difficult to measure directly. We usually measure it indirectly by measuring one of many physical properties that change.

The most common temperature scale is the Fahrenheit ( $^{\circ}\text{F}$ ) scale. Its freezing point is at  $32^{\circ}\text{F}$  and boiling point is at  $212^{\circ}\text{F}$  and the normal body temperature is about  $98.6^{\circ}\text{F}$ .

## Applied Science- I

Celsius ( $^{\circ}\text{C}$ ) scale uses throughout most of the world. Water freezes at  $0^{\circ}\text{C}$  and boils at  $100^{\circ}\text{C}$ , and the normal body temperature is about  $37^{\circ}\text{C}$ .

Another important scale used for scientific work is the Kelvin ( $^{\circ}\text{K}$ ) or absolute scale. Water freezes at  $273^{\circ}\text{K}$  and boils at  $373^{\circ}\text{K}$ .

$0^{\circ}\text{K}$  (absolute zero) =  $- 273^{\circ}\text{C}$ .



## 1.7. Exercise

### 1.7.1. Multiple choice questions

1. The specific heat of the average human body is closer to
  - i. 0.48
  - ii. 0.83
  - iii. 0.214
  - iv. 0.40.
  
2. The method of heat transfer which requires no medium is
  - i. conduction
  - ii. convection
  - iii. radiation
  - iv. none of them.
  
3. The absolute zero temperature is
  - i.  $-273^{\circ}\text{C}$
  - ii.  $0^{\circ}\text{C}$
  - iii.  $-273^{\circ}\text{K}$
  - iv.  $-373^{\circ}\text{K}$ .

### 1.7.2. Fill up the gaps with the appropriate words

- a. Heat is a form of .....
- b. The human body is composed of ..... protein, fat and .....
- c. The most important route of heat lost is via .....
- d. The normal human body temperature in Fahrenheit scale is about .....

### 1.7.3. Short questions

1. What is specific heat? Given the list of SP heat of some substances.
2. What do you mean by latent heat?
3. What is calorie?
4. List the temperature ranges of different temperature scales.

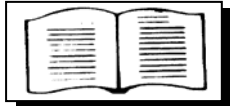
## Lesson 2: Physiological Changes of Heat

### 2.1. Learning Objectives



On completion of this lesson you will be able to learn-

- ◆ heat gain and heat loss
- ◆ heat therapy.



### 2.2. Heat Gain

Heat is gained by metabolism. Without loss of heat normal metabolism would increase the body temperature by  $1^{\circ}\text{C}$  every hour. To a lesser extent, heat is gained from a hot environment and from eating hot food and drinks.

*Heat Gain*

### 2.3. Heat Lost

Heat is lost from the body via the skin, lungs and excretions. The most important route of heat loss is via the skin. Depending on external and internal circumstances, about 85 percent of heat loss occurs in this way. The average heat loss of the average male adult is equivalent to that of a 60-watt electric bulb. Heat is lost via the skin in the three ways: namely, conduction, convection and radiation.

*Heat Lost*

### 2.4. Heat Therapy

Several thousand years ago it was recognized that hot baths were therapeutic. Hot baths, hot packs, electric heating pads, and occasionally hot paraffin applied to the skin heat the body by conduction. Conductive heating is used in treating conditions such as arthritis, neuritis, sprains and strains, contusions, sinusitis and back pain. Radiant heat is also used for surface heating of the body.

*Heat Therapy*

When alternating electric current passes through the body, various effects such as heating and electric shock take place. The amount of heat that can be transferred to the body by electrical diathermy increases as the frequency of the current increases. Short wave diathermy uses electromagnetic waves in the radar range.

Heat from diathermy penetrates deeper into the body than radiant and conductive heat. Short wave diathermy heats the deep tissues of the body. It has been used in relieving muscle spasms, degenerative joint disease and nursing and as a deep heating agent hot joint.

Ultrasonic waves are also used for deep heating of body tissue. Ultrasonic heating has been found useful in relieving the tightness and scarring that often occur in joint disease. It greatly aids joints that have limited motion. Heat therapy may be beneficial in the treatment of cancer when it is combined with radiation therapy. The tumor is heated

by diathermy to about  $42^{\circ}\text{C}$  for 20 for 30 minute and the radiation treatment is given after the heat treatment.



## 2.5. Exercise

### 2.5.1. Fill up the gaps with the appropriate words

- a. Heat is gained by .....
- b. The average heat loss of the average male is equivalent .....
- c. Heat therapy may be beneficial ..... cancer ..... combined with .....

### 2.5.2. Short questions

1. How heat is gained by a body?
2. How it is lost form the body?

### 2.5.3. Analytical question

1. Describe briefly the mechanism of heat therapy.

## Unit 7: X-rays and Radiation

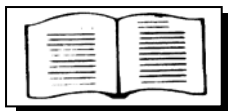
### Lesson 1: Physics of Diagnostic X-rays

#### 1.1. Learning Objectives



On completion of this lesson you will be able to learn-

- ◆ x-rays
- ◆ properties of X-rays
- ◆ uses of X-rays
- ◆ bad effects of X-rays.



#### 1.2. Historical Background of X-rays

In 1895, W.K. Rontgen a physicist at the University of Wurzburg in Germany was studying cathode rays in his laboratory. He was using a fairly high voltage across a tube covered with black paper that had been evacuated to a low pressure. When he excited the tube with high voltage, he noticed that some crystals on a nearby bench glowed and that the ray/radiation's causing this fluorescence could pass through solid matter. He called this radiation X-rays. Rontgen showed that X-rays could expose film and produce image of objects opaque containers. Such pictures are possible if the container transmits X-rays more rapidly than the objects inside. A film exposed by the X-rays shows the shadow cast by the objects. Within three weeks of Rontgen's announcement two French physicians Oudin and Barthelemy obtained X-rays of bones in a hand. Since then, X-rays become one of the most important tools in medicine.

#### 1.3. What is X-ray?

*What is X-rays*

X-ray consists of high-energy photons. Electromagnetic radiation with wavelengths from about 0.01 to about 10nm falls into the category of X-rays. X-rays are nothing but electromagnetic waves of very short wavelengths. X-rays are produced when fast moving electron or a beam of cathode rays impinge on matter.

#### 1.4. Properties of X-rays

The following are the important properties of X-rays

*Properties of X-rays*

1. X-rays are transverse electromagnetic radiation like visible light but of much shorter wavelengths.
2. X-rays are uncharged particles since electric or magnetic field does not deflect them.

3. They produce a photo - chemical action and affect a photographic plate.
4. They cause fluorescence in many substance e.g. Barium, Cadmium etc.
5. They can ionize a gas, through which they pass and also eject electrons from certain metals on which they fall.
6. They have a destructive effect on living tissue.

There are two types of X-rays -

- ◆ Lower energy or soft X-rays
- ◆ Higher energy or hard X-rays.

### 1.5. Uses of X-rays

The uses of X-rays in the diagnostic of various medical problems are so common.

#### *Uses of X-rays*

- ◆ In surgery, X-rays are used for discovering broken bones and detecting the presence of foreign bodies, fractures diseased organs etc. inside the human body.
- ◆ In therapy, X-rays are used for the detection of cancer, ulcer and other diseases.
- ◆ In industry, X-rays are used in finding out internal cracks or holes in metal sheets.
- ◆ X-rays have been employed to investigate the structure of crystal structure and properties of atoms and arrangement of atoms and molecules in matter.
- ◆ X-rays are used for ionizing gas.
- ◆ X-rays always damage living tissues. Cancer cells are more readily damaged and killed than are normal cells, so that X-rays can be used to cure cancer.

### 1.6. Bad Effects of X-rays

#### *Bad effects of X-rays*

X-rays can produce biological effects. The most observed effects are the reddening of the skin after prolonged exposure. A continuation of exposure produces ulceration or even complete destruction of the tissues. Another sequel of excessive irradiation is the induction of cancers of the skin or of the blood (Leukemia), both of which caused the deaths of many pioneers in the radiological field.

### 1.7. Diagnostic user of X-rays

Perhaps the most widely used of X-rays effects is that on photographic material. Photographic film exposed to X-rays and then developed, will be found to be blackened. Bone can absorb X-rays better than tissues. To make use of photographic effect into different parts of the body, radiologists often inject contrast media.

*Diagnostic user  
of X-rays*

Compounds containing iodine are often injected into the blood stream to show the arteries and an oily mist containing iodine is sometimes sprayed into the lungs to make the airways visible radiologists give barium compounds orally to see parts of the upper gastrointestinal tract and barium enemas to view the other end of the digestive system.

With current techniques it is even possible to view internal body organs that are quite transparent to X-rays. Injecting into the organ a fluid opaque to X-rays does this. The wall of the organ then shows up clearly by contrast.

Since gases are poorer absorbers of X-rays than liquid and solids, its is possible to use air as a contrast medium. When a phemoencephalogram Photograph is taken air is used to replace some of the fluid in the ventricles of the brain. In a double contrast study barium and air are used separately to show the same organ.



**1.8. Exercise****1.8.1. Multiple choice questions**

1. The wave lengths of X-rays are
  - i. the same as visible light
  - ii. much shorter than V.L
  - iii. longer than visible light
  - iv. none of them.
2. Hard X-rays is the
  - i. lower energy X-rays
  - ii. higher energy X-rays
  - iii. zero energy X-rays
  - iv. none of the above.

**1.8.2. Fill in the gaps with the appropriate words**

- a. X-rays are nothing ..... waves of very short.....
- b. X-rays have a ..... effect on living tissue.

**1.8.3. Short questions**

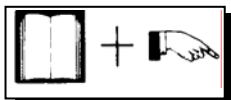
1. Who did discover X-rays? When?
2. What is X-rays? How it is produced?
3. Define soft X-rays and hard X-rays.
4. Describe the properties of X-rays.
5. List 3 contrast materials commonly used in diagnostic radiology.

**1.8.4. Analytic questions**

1. Describe briefly the historical background of discovery of X-rays.
2. Discuss the diagnostic uses of X-rays. What are the bad effects of X-rays?

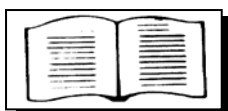
## Lesson 2: Radiation Hazards

### 2.1. Learning Objectives



On completion of this lesson you will be able to learn-

- ◆ sources of radiation
- ◆ effects of ionizing radiation on human body
- ◆ biological effects of ionizing radiation
- ◆ immediate and delayed effects of radiation
- ◆ radiation protection.



### 2.2. What is Radioactivity?

**Radioactivity** is the process of spontaneous disintegration of certain (unstable) atomic nuclei accompanied by the emission. Radiation is emitted by the unstable and excited nuclei can normally cause ionization in a matter through which they pass. This radiation's can cause extensive damage to the molecular structure of a substance either as a result of the direct transfer of energy to its atoms or molecules or as a result of the secondary electrons released by ionization. In biological tissue, the effect of ionizing radiation can be very serious. The ionizing radiation can cause harmful somatic and genetic effects on human body.

### 2.3. Sources of Radiation

We live in an environment of low level ionizing radiation. Ionizing radiation has been present in the earth since its creation and the human beings are continuously being exposed to such radiation. The natural background radiation comes mainly from three sources viz -

- ◆ Cosmic radiation - here in the reaction  $^{14}\text{N}(n,p)$ ,  $^{14}\text{C}$ ,  $^{14}\text{C}$  is a  $\beta$  emitter having a half life of  $\sim 5568$  years.
- ◆ Radiation from naturally occurring radio nuclides in the ground and building materials - Uranium, Thorium, Actinium and Neptunium with their decay products etc.
- ◆ Radioactivity in the body -  $^{40}\text{K}$ ,  $^{14}\text{C}$  and gaseous decay products of uranium and thorium i.e. radon and thoron.

*Sources of  
Radiation*

After the discovery and use of artificial radiation, men are being exposed to both natural and artificial radiation. The amount of annual absorbed dose per capita is increasing day by day. It is for the contamination of atmosphere, water (sea and river) and soil due to the nuclear fallout, weapon test and reactor accident of developed countries. The use of nuclear energy and application of its by products i.e., ionizing radiation

and radioactive substances, continue to increase around the world. A significant amount of radiation dose is received by population from the use of radioisotopes in industry, agriculture, and medicine, use of irradiator for food preservation, radiotherapy machines and handling of radioisotopes in laboratories. The use of X- ray is another cause of small amount of radiation.

#### 2.4. Advantage

##### *Advantage*

The uncontrolled application and misuse of ionizing radiation and radioactive materials are detrimental to health and safety of the medical scientist's technician's assistants, patient and public as well. Though radiation poses threats to our lives, it is on the other hand has been used to bring enormous benefits to our lives as well. Radioactivity and ionizing radiation find extensive use in industry to trace the flow of materials, in agriculture for genetic mutation and processing seeds. In food processing for killing rotting bacteria's in sterilizing medical equipment and in medicine for both diagnostic and therapeutic purpose. A more subtle advantage of radioisotopes is that they can be used on localized areas of organs by appropriate radiopharmaceuticals.

#### 2.5. The Related Quantities

##### ◆ Exposure

Exposure is quantity expresses in amount of ionizing caused in an X-radiation. Exposures are commonly expressed in two ways.

##### ◆ Acute Exposure

##### *The Related Quantities*

It is the exposure to a large dose of radiation within a relative's short time. The radiation damages are much more severe in cases of acute exposure.

##### ◆ Chronic Exposure

The chronic exposure is the long term, low-level overexposure. The total amount of radiation received may be the same as received in the acute exposure but the radiation damages are of much two severity.

#### 2.6. Effects of Ionizing Radiation on Human Body

##### *Effects of Ionizing radiation on human body*

The effect of ionizing radiation on human body is the result of damage to the individual cells. These effects may be conveniently divided into two classes namely somatic and genetic. These effects may arise by acute or chronic exposure. However, the effects of radiation on biological matter depends on -

- ◆ the energy and the type of radiation
- ◆ the dose rate
- ◆ the volume irradiated, and
- ◆ the sensitivity of the tissue.

### **Somatic Effects**

#### *Somatic Effects*

The somatic effects are from damage to the ordinary cells of the body and affect only the radio - exposed individual. The somatic effects depend on whether the irradiation is acute or chronic. These effects also depend on -

- ◆ the degree of oxidation and hence temperature of the exposed part of the body
- ◆ the metabolic state and hence the diet
- ◆ the irradiated person's sex; and
- ◆ the body colour.

The somatic effects are-

- ◆ inhibition of mitosis
- ◆ chromosome aberration and breakage and
- ◆ death of cell.

### **Genetic Effects**

#### *Genetic effects*

The genetic effects are due to the damage or mutation or alteration in the chromosome structure of sperm or ovum i.e. germ cells of may be passed through generation to generation. Ionizing radiation acts directly on genetic materials. The effect is proportional to the dose and the dose rate. Thus there is no threshold and a radio - expose individual has a definite probability of producing a mutagenetic effect. However the natural background radiation is responsible for from 4 to 10% of all naturally occurring genetic mutations.

## **2.7. Biological Effects of Ionizing Radiation**

#### *Biological effects of ionizing radiation*

In 1904, Madam Curie reported in her Ph. D thesis that a radium source she had placed on her husband's arm for a few hours had produced a painful some that extended well below the skin and was slow to heal. The biological effects of ionizing radiation are of two general types somatic. Somatic effects affect an individual directly (loss of hair, reddening for the

skin etc.). Genetic effects consist of mutations in the reproductive cells that affect later generations.

In order to evaluate the genetic effects of X-rays on the population, the concept to genetically significant dose (GSD) is useful. The GSD due to an exposure depends on the dose to the individual's ovaries or tests and the individual's age. Somatic effects depend on the amount of radiation the part of the body irradiated and the age of the patient.

In general, the younger person, the more hazardous the radiation. In fact, the most dangerous period to receive radiation is before birth. At certain periods in the development of the fetus radiation can produce deformities.

### 2.8. Immediate, Early or Short Term Effects

*Immediate, early  
or short term  
effects*

These effects are due to an acute radio - exposure and manifest within a few weeks of exposure. These are somatic effects and inevitable. The immediate effects manifest as Chromosome aberration, blood changes nausea, vomiting, and diarrhea loss of appetite, fatigue appellation, skin epilation, sterility etc., and death.

### 2.9. Delayed Effects

These effects are due to acute or chronic radio exposure and generally manifest after a few years of exposure. These effects are various types of cancer, leukemia, contract, hereditary effects etc.

*Delayed Effects*

Depending on the threshold dose and the probability of effects upon dose, the effects of radiation on human body are classified into two types: stochastic effects and non- stochastic effects.

Stochastic effects: For the manifestation of certain biological affects no threshold dose can be defined.

These effects may occur at any dose, the probability for manifestation increases with absorbed dose.

Non-stochastic effects. The effects of ionizing radiation on human body for which a threshold dose of occurrence can be defined are called non-stochastic effects.

*Health effects of  
low level  
radiation*

### 2.10. Health Effects of Low Level Radiation Exposure

Since there is no threshold dose for the induction of various types of cancer, leukemia, life shortening and hereditary effects, there exists a

certain probability for the occurrence of the mentioned effects by low-level radiation exposure.

The science of protecting workers and the public from unnecessary radiation is known as radiation protection. It involves the accurate measurement of radiation workers and the public and the design and use of method to reduce this radiation.

The radiation exposure to every individual should be kept as low as reasonably achievable; this can be achieved by -

- ◆ Keeping a maximum distance possible from the source
- ◆ Working with a source for the minimum time required
- ◆ Employing adequate shielding
- ◆ Shifting duties.

Patient's movement should be restricted in one place. Using syringe shields during dispensing and administration of radioactive injections can minimize exposures very efficiently.

The basic solution to the radiation protection problem in the medical field can be stated in one word - education. The medical user are often unconcerned by the hazards. X-ray are so common to them that they have a tendency not to worry about them just as we do not worry about having an automobile accident every time we get into a car.

There is probably no absolutely safe amount of radiation. The problem is to balance the benefits against the risks. When we go for a ride in a car or a plane we realize in exchange for the benefits of the trip. Similarly, we should balance the ability of an X-ray to detect a medical **problem against the slight risk from the radiation** in research laboratories and nuclear power station, so that the workers there receive no, in more than the permitted maximum level of radiation. Radioisotopes are handled by mechanical tongs operated by remote control equipment from behind thick walls made by lead, concrete or other suitable material, which absorbs the dangerous reactions.

### 2.11. The Dose Units Used in Radiotherapy

The amount of radiation dissipated in absorbed by a specific mass of volume of material is referred to as a dose of radiation. In the very early days of radiation therapy the unit used to measure the amount of radiation to the patient was the erytéma dose the quantity of X-rays that caused a reddening of the skin. From 1950 to 1975 "rad" was the official unit of absorbed dose. The "rad" is defined as 100 ergs/gm. That is a radiation

*The dose units  
used in  
radiotherapy*

beam that gives 100 ergs of energy to 1gm of tissue. It gives the tissue an absorbed dose of 1 rad. In 1975 the International Commission of Radiological units (ICRU) adopted the “gray” (GY) as the international (SI) unit of dose.  $1\text{GY} = 1\text{J/kg} = 100\text{ rads}$ . This unit was named after Harold Gray, the British medical physicist who discovered the oxygen effect.

### 2.12. Dose rate

The amount of radiation absorbed by a body per unit time is called the **dose rate**. The common unit of dose rate is GY/hour.



### 2.13. Exercise

#### 2.13.1. Fill in the gapes with appropriate words

- a. Radiations are emitted by the ..... nuclei.
- b. The younger person, the more ..... the radiation.
- c. Ionizing radiation can cause harmful ..... and ..... effects on human body.

#### 2.13.2. Short questions

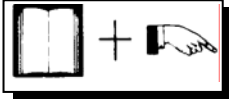
1. What is Radioactivity?
2. Define exposure, acute exposure and chronic expose.
3. Explain immediate and delayed effects of exposure.
4. List some advantages of radiation.
5. List three natural radioactive nuclides.

#### 2.13.3. Analytic questions

1. What are the main sources of background radiation?
2. How can we protect these hazardous effects of radiation?

## Unit 8: Physiotherapy

### Lesson 1: Electrotherapy - Physiological Changes Produced by Application of Energy



#### 1.1. Learning Objectives

On completion of this lesson you will be able to learn -

- ◆ about electrotherapy
- ◆ about physiological changes produced by application of energy.



#### 1.2. What is Electrotherapy?

**Electrotherapy** is one kind of physiotherapy and it is a method of treatment in which a series of brief electrical shocks is administered, via electrodes, placed on the wound part of the human body.

*What is electrotherapy?*

The electrical activity of the brain can be demonstrated on an electroencephalogram (EEG). A wide spectrum of frequencies is present and these have been divided into alpha, beta and delta. The pattern of waves depends on many factors such as age and the area over of the brain being studied.

Another type of electrotherapy is called **electrocardiogram (ECG)**. The electrocardiogram records the electrical activity of the heart. It can be used to study disturbances in the generation and transmission of the cardiac impulse. An electric shock is sometime administered to restore normal cardiac rhythm. Electrodes from the apparatus known as the defibrillator can be placed either on the heart wall or directly to the heart.

**Electro convulsive therapy (ECT)** is a method of treatment in which a series of brief electrical shocks is administered via electrodes placed on the skull. It has in the past been used in the treatment of many mental disorders but current evidence suggests that it is beneficial only to severely depressed patients.

A solution, which conducts electricity by the movement of its charged ions, is known as an electrolyte. In one important way the conduction of electricity by solutions differs from conduction by metals is that the former is attended by chemical change is called electrolysis. The process of electrolysis requires a supply of electric current. Electrolyte is a word with which reader will be familiar, for in human being electrolytes are essential for the control of body fluids. For example, it is by exerting



surplus inorganic ions that the kidney helps to maintain the body's electrolyte balance.

The electrolysis most essential to the maintenance of health is –

- ◆ Sodium chloride (NaCl)
- ◆ Potassium chloride (KCl)
- ◆ Sodium bicarbonate (NaHCO<sub>3</sub>)
- ◆ Potassium bicarbonate (KHCO<sub>3</sub>).

### 1.3. Energy for Life Process

The cells that make up the human body are **constantly changing**. Within a few days molecules have become 'old' and are broken down at the same time new cells are being formed.

*Energy for life  
process*

The work is done by the cell and the provision of production and utilization of the energy which makes this possible can be summed up in one word - **metabolism**. The process of metabolism includes all material and energy changes, which occur, and in its absence there will be no life. Protoplasm is constantly changing it, producing heat and electrical energy and undergoing chemical change.

From electrophysiological chambered organ, one formed by the atria and the other by ventricles. The two electrophysiological chambers are separated by an electrically inert conduction barrier formed by the fibrous a - v ring. At any moment in time the heart can be viewed as a dipole or doublet consisting of a positive and negative charge separated by a small distance. The human body by convention acts as a volume conductor in which heart is immersed. The electrical field so generated by heart action is supposed to be symmetrically distributed and the lines of electrical fields are symmetrical in relation to a time that is perpendicular to and transects dipole at mid- point.



### 1.4. Exercise

#### 1.4.1. Short questions

1. What is electrotherapy?
2. Describe physiological changes produced by application of energy.
3. What is electroconvulsive therapy?
4. What do you mean by electrolysis? Describe the common use of electrolysis in medical science.

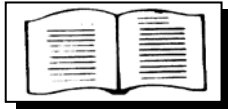
## Lesson 2: Physics for Radiotherapy

### 2.1. Learning objectives



On completion of this lesson you will be able to learn -

- ◆ radiotherapy
- ◆ principles of Radiotherapy
- ◆ short distance Radiotherapy
- ◆ a short course in Radiotherapy treatment planning
- ◆ closing thought on Radiotherapy.



### 2.2. What is Radiotherapy?

**Radiotherapy** is recognized as an important tool in the treatment of many types of cancer. The probability of having cancer during your lifetime is about 1 out of 4. Each year about 1 million people in the United States get cancer. Currently three major methods are used alone or in combination to treat cancer. About half of all cancer patients receive radiation as part or all of their treatment.

The success of radiotherapy depends on -

- ◆ the type and extent of the cancer
- ◆ the skill of the radiotherapist
- ◆ the physician who specializes in the treatment of cancer with radiation
- ◆ the kind of radiation used in the treatment
- ◆ the accuracy with which the radiation is administered to the tumor.

The last factor is the responsibility of the radiological physicist. Before 1950 radiological science was used for many disease besides cancer, and it is still used occasionally for a nonmalignant condition that does not respond to other treatment. However because of the possibility of radiation-induced cancer it is generally safer to use other types of treatment when possible.

*Principle of  
radiotherapy*

There is evidence that an error of 5% to 10% in the radiation dose to the tumor can have a significant effect on the result of the therapy. Too little radiation does not kill the entire tumor, too much can produce serious complications in normal tissue.

### 2.3. Principle of Radiotherapy

The basic principle of radiotherapy is to maximize damage to the tumor while minimizing damage to normal tissue. This is generally accomplished by directing a beam of radiation at the tumor from several directions so that the maximum dose occurs at the tumor.

Some normal tissues are more sensitive to radiation than others, and this is taken into account when the therapist and physicist plan the treatment.

### 2.4. A Short Course in Radiotherapy Treatment Planning

The physicist working in radiotherapy has three important functions -

*A short course in  
radiotherapy  
treatment  
planning*

1. To determine how much radiation is being produced by a given therapy machine under standard conditions, that is, to calibrate the machine.
2. To calculate the dose to be administered to the tumor and any normal tissues in the patient. This is not easy, and many radiotherapy department use computers to aid with this computation.
3. To confirm that the correct amount of radiation was really administered to the patient at the proper location.

The process to determine the best combination of radiation beams and their orientation is called treatment planning. It is usually done cooperatively by the radiotherapist and the radiological physicist. The dosimetist aids with this process.

Before radiotherapy treatments started, the patient is carefully examined to determine the location and extent of the tumor. In some cases the therapist will palpate (feel with his finger) the tumor and surrounding tissues. Since many tumors are deep inside the body it is often necessary to use diagnostic X-rays devices have been developed to assist in these determinations.

### 2.5. Closing Thought on Radiotherapy

*Closing thought  
on radiotherapy*

Until an effective cure for cancer is found we can expect scientists and politicians to be willing to spend time and money to carry on cancer research. Progress has been made but it has been slow. The combination of the talents of basic scientists and medical scientists has accounted for much of the progress to date. **Modern radiotherapy** is treating cancer. It will eventually be replaced by a “cancer cure”. We all hope that such a cure will be found, but in the meantime the proper use of radiation therapy offers many cancer victims their best chance of survival. In some types of cancer, radiation therapy is the treatment of choice. When used in the early

stage of the disease it has a cure rate (5 yr survival) of over 90%. The radiotherapist should have access to modern therapy equipment and should work in close cooperation with a radiological physicist to assure the accuracy of the administered dose. The result of a successful radiotherapy treatment can be dramatic.



## **2.6. Exercise**

### **2.6.1. Fill up the gaps with the appropriate words**

- a. .... is recognized as an important tool in the treatment of many types of .....
- b. The basic principle of radiotherapy is to ..... damage to the tumor while ..... damage to normal tissue.

### **2.6.2. Short questions**

1. What is radiotherapy?
2. Write the factors on which the success of radiotherapy depends.

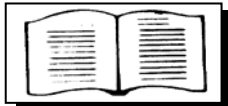
## Lesson 3: Hydrotherapy - Physiological Effects of Water

### 3.1. Learning Objectives



On completion of this lesson you will be able to learn -

- ◆ water and hydrotherapy
- ◆ electrolytes and body fluids
- ◆ therapeutic bath.



### 3.2. What is Hydrotherapy?

Water like air is a basic necessity without which life cannot be maintained. Water is the principal constituent of the human body. It is indispensable to the metabolic processes in the cells. Water is universal solvent. Almost all water is derived from rain, hail, snow and dew etc. All human beings need safe and pure water for drinking purpose. Safe water is one which when taken does not harm the consumer. Hydrotherapy is one kind of physiotherapy. A treatment by using water for metallic process in the cell swimming is called **hydrotherapy**.

### 3.3. Electrolytes and Body Fluids

The diagnosis and treatment of electrolyte disorders is a skill learned by experience and practice. Like all clinical skills it is dependent on a proper understanding of the basic science. We are still very dependent on ready access to water for our survival and man cannot survive for more than a couple of days without a source of fresh water. Dehydration is still a major cause of loss of human life. Millions of life is lost each year in developing countries from disorders of fluid and electrolyte therapy.

*Electrolytes and  
body fluids*

A proper understanding of the control of fluid and electrolyte balance is essential. This can only be achieved by considering the extra - cellular fluids as a watery environment whose composition is critical to the function of every organ, tissue and cell in the body.

### 3.4. Body Water and Fluid Compositions

*Body water and  
fluid compositions*

Water is the main constituent of the body and total body water varies with age and sex and it ranges from 45- 60% of body weight or 40-60 litres of water. Normal males have around 60% of body weight as water and females 52% of body weight. The lower percentage of water in the female is due to the higher fat content of the body.

Body water can be divided into two compartments intracellular fluid (ICF) as the major component comprising two third of body water and extra cellular fluid (ECF) making up the remaining one third of body water. Plasma influences the composition of the extra cellular fluid around all the cells of the body. Plasma is circulated around the body via cardiovascular system and changes in the composition of plasma affects all cells.

Total body water is divided into extra-cellular fluid (ECF) and intracellular fluid (ICF) compartments. The ECF can be further divided into an infra - vascular compartment (Plasma) and interstitial fluid (IntF)  $\text{Na}^+$  is the major action of ECF and  $\text{K}^+$  the major action of ICF.

### 3.5. Therapeutic Baths

#### Therapeutic baths

Water has been used as a valuable therapeutic agent since time immemorial. In all major ancient civilizations, bathing was considered an important measure for the maintenance of health and prevention of disease. Water exerts beneficial effects on the human system. It equalizes circulation, boosts muscular tone and aids digestion and nutrition. It also tones up the activity of preparatory gland and in the process eliminates the damaged cells and toxic matter from the system. The common water temperature chart is cold  $10^{\circ}\text{C}$  to  $18^{\circ}\text{C}$ , neutral  $32^{\circ}\text{C}$  to  $36^{\circ}\text{C}$ , and hot  $40^{\circ}\text{C}$  to  $45^{\circ}\text{C}$ . Above  $45^{\circ}\text{C}$ , water loses its therapeutic value and is destructive.

The main methods of water treatment, which can be employed in the healing of various diseases, are described below.

#### ◆ Cold Compress

This is a local application using a cloth, which has been wrung out in cold water. The cloth should be folded into a broad strip and dipped in cold water or ice water. The compress is generally applied to the head, neck, chest, abdomen and back. The cold compress is an effective means controlling inflammatory conditions of the liver, spleen, stomach, kidneys, intestines, lungs, brain, pelvic organ and so on. It is also advantageous in cases of fever and heart disease.

#### ◆ Heating Compress

This is a cold compress covered in such a manner as to bring warmth. A heating compress consists of three or four folds of linen cloth wrung out on cold water. Then it is covered completely with dry flannel or blanket to prevent the circulation of air and help accumulation of body heat. It is sometimes applied for several hours. A heating compress can be applied to the throat, hoarseness, tonsillitis, pharyngitis and laryngitis. An abdominal compress helps those suffering from gastritis hyperacidity, indigestion,

and jaundice diarrhoea, dysentery. The chest compress is helpful for inflamed joints, rheumatism, rheumatic fever and sprains.

### ◆ **Hip Baths**

The hipbath is one of the most useful forms of hydrotherapy. This mode of treatment involves only the hips bath and the abdominal region below the naval. A special type tub is used for the purpose. The tub is filled with water in such a way that it covers the hips and reaches upto the naval when the patient sit in it. Hipbath is given in cold, hot, and neutral of alternative temperatures. Let us discuss about them in below.

#### **i. Cold Hip Bath**

The water temperature should be 10°C to 18°C. The duration of the bath is usually 10 minutes. A cold hipbath is a routine treatment in most diseases. It relieves constipation, indigestion, and obesity and helps the eliminative organs to function properly. It is also helpful in uterine problems like irregular menstruation, chronic uterine infections, pelvic inflammation, piles, hepatic congestion, chronic congestion of the prostate gland, uterine and ovarian displacements, diarrhea, dysentery, hemorrhage of the bladder and so on.

#### **ii. Hot Hip Bath**

The bath is generally taken for 8 to 10 minutes at a water temperature of 40°C to 45°C. The bath should start at 40°C and gradually increased to 45°C. A hot hipbath helps to relieve painful menstruation, pain in the pelvic organs, painful urination and painful piles.

#### **iii. Neutral Hip Bath**

The temperature of the water should be 32°C to 36°C. This bath is generally taken for 20 minutes to an hour. The neutral hipbath helps to relieve all acute and sub-acute inflammatory conditions. It also relieves neuralgia of the fallopian tubes, painful spasms of vagina.

#### **iv. Alternate Hip Bath**

The temperature in the hot tub should be 40°C to 45°C and in the cold tub 10°C to 18°C. The patient should be alternately sit in the hot tub for 5 minutes and then in the cold tub for 3 minutes. The duration of the bath is generally 10 to 20 minutes. The bath relieves chronic inflammatory conditions of the pelvic viscera such a salpigitis, ovaritis, cellulitis.

**v. Hot Foot Bath**

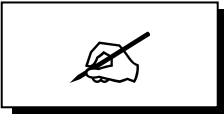
In this bath, the patient should keep his /her legs in a tub of bucket filled with hot water at as temperature of 40°C to 45°C. Before taking this bath, a glass of water should be taken and the body should be covered with a blanket so that no heat escapes from the footbath. The head should be protected with a cold compress. The duration of the bath is generally from 5 to 10 minutes. The hot footbath stimulates the involuntary muscles of the uterus, intestines, bladder and other pelvic and abdominal organs. It also relieves sprains and ankle joint pains, headaches. In woman, it helps restore menstruation if suspended.

**3.6. Precaution**

*Precaution*

Certain precautions are necessary while taking this therapeutic baths. Full baths should be avoided within 3 hours after a meal and one hour before it. Local baths like the hipbaths and footbaths may, however, be taken two hours after a meal. Clean and pure water must be used for baths and water once used should not be used again. While taking baths, temperature and duration should be strictly observed to obtain the desired effects. Women should not take any of the baths during menstruation. They can take only hipbaths during pregnancy till the completion of the third month.





### 3.7. Exercise

#### 3.7.1. Multiple choice questions

1. Water loses its therapeutic value and is destructive
  - i. above 45°C
  - ii. above 10°C
  - iii. below 45°C
  - iv. none of them.
2. Full baths should be avoided within 3 hours after meal
  - i. one hour before it
  - ii. two hours before it
  - iii. five hours before it
  - iv. none of them.

#### 3.7.2. Fill up the gaps with the appropriate words

- a) ----- is the principal constituent of the human body.
- b) Water is a ----- solvent.

#### 3.7.3. Short questions

1. What is hydrotherapy?
2. Give the common water temperature chart.

#### 3.7.4. Analytical questions

1. How can we use water therapeutically?
2. Describe briefly about precaution of hydrotherapy.
3. Describe the therapeutic baths.