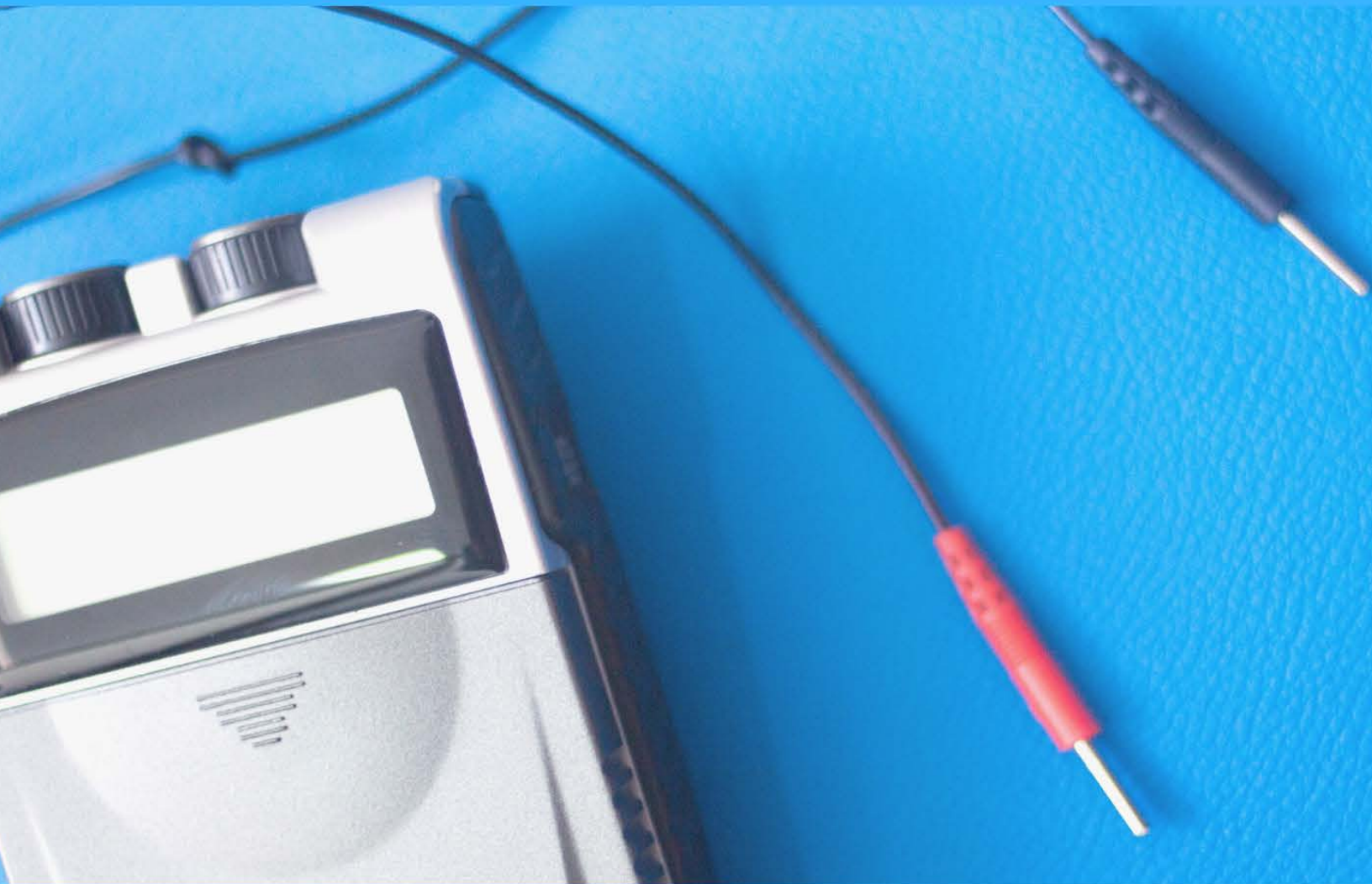


# PHYSICS

*For*

Senior Secondary School

# 1



**EDUBASE**

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**SS1**  
**PHYSICS**  
**FIRST TERM**

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# Week1

## **Topic: Analyzing the different aspects of Physics, Economic importance of Physics, Scholars and achievements in field of Physics.**

### **Introduction to Physics as a subject**

*Physics (from Greek φυσική (ἐπιστήμη), i.e. “knowledge of nature”, from φύσις, physics, i.e. “nature” is the natural science that involves the study of matter and its motion through space and time, along with related concepts such as energy and force. More broadly, it is the general analysis of nature, conducted in order to understand how the universe behaves.*

*Physics is one of the oldest science disciplines, perhaps the oldest through its inclusion of astronomy. Over the last two millennia, physics was a part of natural philosophy along with chemistry, certain branches of mathematics, and biology, but during the Scientific Revolution in the 17th century, the natural sciences emerged as unique research programs in their own right. Physics intersects with many interdisciplinary areas of research, such as biophysics and quantum chemistry, and the boundaries of physics are not rigidly defined. New ideas in physics often explain the fundamental mechanisms of other sciences, while opening new avenues of research in areas such as mathematics and philosophy.*

*Physics also makes significant contributions through advances that arise from theoretical breakthroughs. For example, advances in the understanding of electromagnetism or nuclear physics led directly to the development of new products which have dramatically transformed modern-day society, such as television, computers, domestic appliances, and nuclear weapons; advances in thermodynamics led to the development of industrialization; and advances in mechanics inspired the development of calculus.*

### ***Economic Importance of Physics; Using the UK as a case study.***

*More than 500 000 people are employed in high-value physics-based manufacturing in the UK, contributing more than £20 billion to the UK economy directly, and creating products and devices that enable growth in the aerospace and electricity generation sectors. Physics technologies such as photonics and precision optics drive progress in the information economy and the life sciences. Physics drives employment across the UK. Large employers such as Seagate in Northern Ireland use physics to develop advanced computer hard drives; Oxford Instruments is a world-leading manufacturer and exporter of scientific equipment*

*used in the development of novel materials. More people are employed in physics-based businesses in the UK than in both the finance and construction sectors. The recent economic downturn affected physics-based sectors as much as the broader economy, but the signs are there that physics can lead the recovery.*

*Exports from physics-based business amounted to more than £100B in 2009,*

*physics-based business in the UK account for more exports as a share of the total*

*than those in France. Physics-based sectors have increased their investment in research and development in the years following the crash.*

*For the UK economy to grow and be rebalanced in favor of high-tech, knowledge-intensive industries, there must be more and more-focused support for physics-based businesses through innovative public procurement and more ready access to the capital essential for growth. This, combined with sustained and stable funding of physics research and a ready supply of physics-trained workers, will allow physics – and the economy – to thrive*

### ***Scholars and achievements in the field of Physics.***

*Father of Physics: unarguably there is no way you would talk about the subject 'Physics' from the simple to the complex aspects without having to mention names of those who subjected themselves to thorough study of the subject and came out with all sorts of theories founded on commitment to achieve their set pursuits. Names go thus;*

*Sir Isaac Newton (1643-1727), Albert Einstein (1879-1955), Max Planck (1858-1947), Nicholas Copernicus, William Gilbert, Galileo Galilei (1564-1642), Nicholas Copernicus (1473-1543), Pierre-Simon Laplace, Michael Faraday (1791-1867), Rudolph Claudius, Ludwig Boltzmann, Marie and Pierre Curie, Louis De Broglie, Paul Dirac, James Prescott Joule. To mention but a very few of them, you can play around with and be conscious of this names to remind yourself of the progenitors of Physics, this makes you a more learned person than your contemporaries.*

### ***Highlights of some branches of Physics; involvements and contributions.***

*NB: Coverage here will be restricted to the limited scope of the knowledge of this class, so as not to overload and beat beyond the capacity of understanding at this level.*

*Classical physics became a separate science when early modern Europeans used these experimental and quantitative methods to discover what are now considered to be the laws of physics. Kepler, Galileo and more specifically Newton discovered and unified the different laws of motion. During the industrial revolution, as energy needs increased, so did research, which led to the discovery of new laws in thermodynamics, chemistry and electromagnetic.*

*Modern physics started with the works of Max Planck in quantum theory and Einstein in relativity, and continued in quantum mechanics pioneered by Heisenberg, Schrödinger and Paul Dirac. Classical physics is generally concerned with matter and energy on the normal scale of observation, while much of modern physics is*

concerned with the behavior of matter and energy under extreme conditions or on a very large or very small scale. For example, atomic and nuclear physics studies matter on the smallest scale at which chemical elements can be identified. The physics of elementary particles is on an even smaller scale, as it is concerned with the most basic units of matter; this branch of physics is also known as high-energy physics because of the extremely high energies necessary to produce many types of particles in large particle accelerators. On this scale, ordinary common sense notions of space, time, matter, and energy are no longer valid.

Uniform motion in a straight line and the general theory of relativity with accelerated motion, the two chief theories of modern physics present a different picture of the concepts of space, time, and matter from that presented by classical physics. Quantum theory is concerned with the discrete, rather than continuous, nature of many phenomena at the atomic and subatomic level, and with the complementary aspects of particles and waves in the description of such phenomena. The theory of relativity is concerned with the description of phenomena that take place in a frame of reference that is in motion with respect to an observer; the special theory of relativity is concerned with relative and its connection with gravitation. Both quantum theory and the theory of relativity find applications in all areas of modern physics.

Lets end it here so as not to go too much beyond the scope of this class, already we have gone a little beyond, however it is a way to go, in order to prepare you for the greater future, should you nurture ambition to be in the line of Physics related course(s).

**We can at this point test our knowledge on the history of Physics:**

1. Physics is the study of natural science that involves the study of matter and its motion through space and .....

A. Speed B. Distance C. Time D. Power

2. Name Scholars in Physics off-hand based on the note you have read?

3. Highlight achievements of some of the progenitors of Physics, according to the above note.

4. Modern physics started with the works of----- in quantum theory.

A. Albert Einstein B. Max Planck C. Paul Dirac D. Schrödinger

5. From what year to what year did Sir Isaac Newton live?

A. 1654-1727 B. 1701-1827 C. 1730-1800 D. 1643-1727

**ANSWERS:**

1. C, 3. B, 4. D, 5. D

## Week: 2

### Topic: Work, Energy and Power

Measurements and unit, Work done in a force field; definition of force field, Types of energy and energy conversion

In everyday life, the term *work* is applied to any form of activity that requires the exertion of physical or mental effort. Someone may say 'I go to work', another may say 'I work in the office of the director', so it is used variously with different meaning as it appeals to the user.

In physics however, the term is used in a specific sense. Work is said to be done whenever a force is applied to cause a body to move, when a car is pushed a certain distance, or a load is lifted from the floor on to the table, you are said to do work. When no movement takes place after you have applied a force to a body, no work is done. Read this and you will marvel, If at a point you lift a bowl full of oranges from the ground floor on to your head and you remain at that point for twenty years without moving an inch, you have done no work, except that you lifted the bowl of oranges from the ground to your head, which could only be regarded as though you have done work, in its scientific true sense no work has been done by you in carrying the load and failing to move away from that spot, again, since no distance was covered, you have only done nothing.

Work refers to an activity involving a force and movement in the direction of the force. A force of 20 newtons pushing an object 5 meters in the direction of the force does 100 joules of work.

Work is said to be done whenever a force moves its point of application a distance in the direction of the force.

**Work** is defined as the product of the force and the displacement in the direction of the force.

$$W = F \times S$$

The unit of work is the joule when the force is measured in newtons and the displacement in metres. Thus the work done when a force of 10 newtons displaces an object through 5 metres is given by  $W = 10 \times 5 = 50$  joules.

### Work Done in a Force Field

We must note that the earth's gravitational field was an example of a force field. In that gravitational field there is always a force pulling a body towards the earth's centre. We define the weight of a body as the force of attraction on the body due to the earth's gravity, this weight acts downward. To lift a load through a height  $h$ , a pulling force must be applied to overcome the weight of the body. Therefore, when an object is lifted vertically upwards, work is done against the force of gravity or against the weight of the body. The magnitude of the work done is given by;

Work = force x distance

$$= mg \times h$$

$$= mgh$$

Where  $m$  = mass of the body,  $g$  = acceleration due to gravity and  $h$  = height. ( $g = 10 \text{ ms}^{-2}$ ).

For instance if a boy of mass  $m$ , moves up a step of steps of total height  $h$ , the work done by the boy = his weight ( $mg$ ) x the height  $h$ .

Hence to lift a body against a force field (e.g. gravity) an opposing force is needed. Work done against gravity is equal to the product of the weight of the body ( $mg$ ) and the vertical upward displacement ( $h$ )

$$w = m g h.$$

If a body of mass 50 kg runs up a set of steps of total height 3.0 m, find the work done against gravity.

Solution: Work done =  $mgh = 50 \times 10 \times 3 = 1500$  joules

### Falling Bodies

When a body falls freely in a force field, the force of the field does work on the body. Hence for a body falling freely under gravity, the earth's gravitational force does work on the body. If a body of mass  $m$ , falls through a vertical height  $h$ , the work done by gravity on the body is given by  $w = mgh$

## Energy

Energy is defined as the capacity to do work. Anything that is capable of doing work has energy. A person pushing a car along a road is doing work on the car. The person is said to possess energy which he exercises by making the car move some distance. A student running down the school field has energy. He is capable of moving his weight some distance, a mango fruit falling from the top of the tree all possess energy.

Work and energy are measured in the same unit, the joule. There are many forms of energy. These include: mechanical energy, heat (thermal) energy, light energy, chemical energy, electrical energy, atomic energy and solar energy.

Under mechanical energy, there are two classifications i.e. *Potential and Kinetic energy*.

Potential Energy (P.E.) is simply 'stored energy' or the energy possessed by a body by virtue of its position or state.

Such stored is used to do work when the body is free to move. A heavy note on top of a table has potential energy. When allowed to fall on to a glass plate on the floor, it will shatter the plate. The potential energy of the plate due to its position above the floor is expended in shattering the plate.

A body may have a potential energy due to its position in a force field, if the force field is the gravitational field then the body is said to possess a gravitational potential energy. The stone resting on top of a table has gravitational potential energy due to its height above the ground level. If the body is of mass  $m$  and the height of the table is  $h$ , the gravitational potential energy is given by  $E_{gp} = mgh$ , where  $g$  is the acceleration due to gravity, if  $m$  is in  $kg$ ,  $g$  in  $ms^{-2}$  and  $h$  in metres, then  $E_{gp}$  the potential energy is in joules.

Other examples of potential energy are:

A magnet at rest in a magnetic field (magnetic potential energy), an electric charge at rest in an electric field (electrical potential energy), a coiled spring when stretched or compressed possesses elastic potential energy also chemical potential energy is released when petrol, wood and other fuel sources burn.

An object can store energy as the result of its position. For example, the heavy ball of a demolition machine is storing energy when it is held at an elevated position. This stored energy of position is referred to as potential energy. Similarly, a drawn bow is able to store energy as the result of its position. When assuming its *usual position* (i.e., when not drawn), there is no energy stored in the bow. Yet when its position is altered from its usual equilibrium position, the bow is able to store energy by virtue of its position. This stored energy of position is referred to as potential energy. Potential energy is the stored energy of position possessed by an object.

There is a direct relation between gravitational potential energy and the mass of an object. More massive objects have greater gravitational potential energy. There is also a direct relation between gravitational potential energy and the height of an object. The higher an object is elevated, the greater the gravitational potential energy.

### Kinetic Energy

Kinetic Energy is the energy of motion. An object that has motion – whether it is vertical or horizontal motion – has kinetic energy. There are many forms of kinetic energy – vibrational (the energy due to vibrational motion), rotational (the energy due to rotational motion), and translational (the energy due to motion from one location to another). To keep matters simple, we will focus upon translational kinetic energy. The amount of translational kinetic energy (from here on, the phrase kinetic energy will refer to translational kinetic energy) that an object has depends upon two variables: the mass ( $m$ ) of the object and the speed ( $v$ ) of the object. The following equation is used to represent the kinetic energy (KE) of an object.

$$K.E = \frac{1}{2} MV^2$$

where  $m$  = mass of object

$v$  = speed of object

This equation reveals that the kinetic energy of an object is directly proportional to the square of its speed. That means that for a twofold increase in speed, the kinetic energy will increase by a factor of four. For a threefold increase in speed, the kinetic energy will increase by a factor of nine. And for a fourfold increase in speed, the kinetic energy will increase by a factor of sixteen. The kinetic energy is dependent upon the square of the speed. As it is often said, an equation is not merely a recipe for algebraic problem solving, but also a guide to thinking about the relationship between quantities.

Kinetic energy is a scalar quantity; it does not have a direction. Unlike velocity, acceleration, force, and momentum, the kinetic energy of an object is completely described by magnitude alone. Like work and potential energy, the standard metric unit of measurement for kinetic

energy is the Joule. As might be implied by the above equation, 1 Joule is equivalent to  $1 \text{ kg} \times (\text{m/s})^2$ .

$$1 \text{ joule} = 1 \text{ kg} \times \text{m}^2/\text{S}^2$$

Find the potential energy of a boy of mass 10 kg standing on a building floor of 10 metres above the ground level.

Solution

$$\text{P.E.} = mgh$$

$$= 10 \times 10 \times 10 = 1000 \text{ joules.}$$

### Power

Power is defined as the time rate of doing work. If two boys of the same weight climb a flight of steps of the same height, the boy that gets to the top first is said to have the greater power. This is because he has done the work of moving that height at a shorter time. If the work  $W$  joules is done in time  $t$  seconds, then the power = work/time.

$$\text{Power} = \text{work done or energy expended}/\text{time}$$

Power is measured in watt, while 1 watt = 1 joule per second.

Other commonly used units of power are the kilowatt (kW), the megawatt (MW) and the horse power (h.p.).

$1 \text{ kW} = 1000 \text{ W} = 10^3 \text{ W}$ ,  $1 \text{ MW} = 1,000,000 \text{ W} = 10^6 \text{ W}$ ,  $1 \text{ h.p.} = 746 \text{ W}$  (Where h.p. means Horsepower).

### Transformation and Conservation of Mechanical Energy

In physics, the law of conservation of energy states that the total energy of an isolated system cannot change—it is said to be *conserved* over time. Energy can be neither created nor destroyed, but can change from one form to another, for instance chemical energy can be converted to kinetic energy in the explosion of a stick of dynamite.

By an *isolated or closed system*, we mean a group of object that neither receives energy from nor gives energy to objects outside the system.

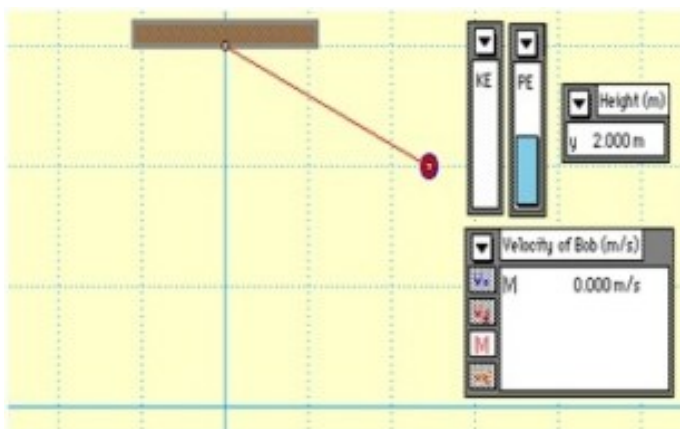
If we consider mechanical energy, the law shows that the sum of the potential energy and the kinetic energy is always constant for a given body, but the energy may change from potential energy to kinetic energy or from kinetic to potential.

A consequence of the law of conservation of energy is that a perpetual motion machine of the first kind cannot exist. That is to say, no system without an external energy supply can deliver an unlimited amount of energy to its surroundings.

### Potential and Kinetic Energy of a Simple Pendulum

The motion of a pendulum is a classic example of mechanical energy conservation. A pendulum consists of a mass (known as a *bob*) attached by a string to a pivot point. As the pendulum moves, it sweeps out a circular arc, moving back and forth in a periodic fashion. Neglecting air resistance, there are only two forces acting upon the pendulum bob. One force is gravity. The force of gravity acts in a downward direction and does work upon the pendulum bob. However, gravity is an internal force (or conservative force) and thus, does not serve to change the total amount of mechanical energy of the bob. The other force acting upon the bob is the force of tension. Tension is an external force and if it did do work upon the pendulum bob it would indeed serve to change the total mechanical energy of the bob. However, the force of tension does not do work since it always acts in a direction perpendicular to the motion of the bob. At all points in the trajectory of the pendulum bob, the angle between the force of tension and its direction of motion is 90 degrees. Thus, the force of tension does not do work upon the bob.

Since there are no external forces doing work, the total mechanical energy of the pendulum bob is conserved.



It is interesting to observe that the falling motion of the bob is accompanied by an increase in speed. As the bob loses height and PE, it gains speed and KE; yet the total of the two forms of mechanical energy is conserved.

## **ASSESSMENT**

1. Define Work?
2. What is Energy?
3. What is Kinetic Energy?
4. Define Power?

## **ANSWER**

1. Work is applied to any form of activity that requires the exertion of physical or mental effort.
2. Energy is defined as the capacity to do work.
3. Kinetic Energy is the energy of motion.
4. Power is defined as the time rate of doing work.

## **Week 3**

### **Topic: MEASUREMENT OF LENGTH, MASS, WEIGHT, TIME AND ELECTRIC CHARGE. FUNDAMENTAL AND DERIVED QUANTITIES, DIMENSIONAL ANALYSIS**

Measurement is a very important aspect of Physics and other sciences. No fact in science is accepted, no law is established unless it can be exactly measured and quantified. Every such measurement requires two things: first a number of quantity and secondly a unit, e.g. ten meters as the length of a room.

Measurements basically are a means of communication, used by engineers and scientists in order to understand unnatural phenomenon, also by the society for processing business functions and by the engineers for practical ends.

A unit or standard of measurement should be such that, it must be possible to define it unambiguously, easily reproducible, does not vary with time and place, should be possible to divide or multiply each of the standard.

Physicists use different instruments for measuring physical quantities and different units in which these quantities are expressed, also quantities and some uncertainties associated with the measuring devices are related.

**FUNDAMENTAL QUANTITIES:** Are the basic quantities that are independent of others and cannot be defined in terms of the other quantities or derived from them, while most quantities depend on them.

The three most important basic and fundamental quantities are length, time and mass.

Length may be defined as the extent of space or distance extended.

Mass is defined as the quantity of matter or material substance.

Time is defined as that in which events are distinct with respect to 'before or after'.

Fundamental Units are the basic units upon which other units depend. They are actually the units of the fundamental quantities.

**Table below shows fundamental quantities and units**

Quantities	Units	Unit Abbreviations
Length	Metre	M
Time	Second	S
Mass	Kilogram	Kg
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of substance	Mole	Mol

Note that units in the above table are S/(Systeme International) units, it is the most important system today and it is used in scientific work today.

Derived quantities and units are those gotten by some simple combination of the fundamental quantities and units, hence it is so, they are dependent on the fundamental quantities and units, the derivations of the quantities' units are tabulated below

Derived quantities	Derivation	Derived units
Area (A)	Length x breadth	$m^2$
Volume (V)	Length x breadth x height	$m^3$
Density	Mass/volume	$Kg.m^{-3}$
Velocity (v)	Displacement/time	$m.s^{-1}$
Acceleration (a)	Change in velocity/time	$m.s^{-2}$
Force (F)	Mass x acceleration	Newton, N
Energy or Work (W)	Force x distance	Joule (Nm)
Power (P)	Work/time	$J.s^{-1}$ (or watt, W)
Momentum	Mass x velocity	$Kg.m.s^{-1}$ ;Ns
Pressure (P)	Force/area	$N.m^{-2}$ , (Pascal, Pa) Per

Frequency (f)	Number of oscillations/time	second or s <sup>-1</sup> (hertz, Hz)
Electric charge		C (coulomb)
Electric Potential Difference		V (volt)
Electric resistance		Ohm
Electric capacitance		Farad (F)

Measurement play a crucial role in Physics, but never are they perfectly precise, we must note the reading accuracy of the measuring instruments and specify the measurement only in the correct number of significant figures. It is essential to state here that there are different measuring instruments used in physics and in other field of engineering endeavors, which are stated below;

Vernier Calipers, Main Scale and Vernier Scale, Micrometer Screw Guage, Graduated glass containers, there are also different types of balance as part of measuring instruments and vessels e.g. Beam balance, Chemical balance and Lever balance. While Stop watch, Stop clock are also parts of the measuring tools for time.



Below is the image of a vernier caliper

### Measurement of Volume:

Rectangular Block,  $V = l \times b \times h$

A Sphere,  $V = \frac{4}{3}\pi r^3$ , where  $r = d/2$ , for greater accuracy we obtain three different values of the diameter and find the mean value. NB:  $r$ =radius,  $d$ =diameter.

Cylindrical wire Volume=, where  $r = d/2$ .

### Confusion of Mass and Weight

A few further comments should be added about the single force that is a source of much confusion to many students of physics – the force of gravity. The force of gravity acting upon an object is sometimes referred to as the weight of the object. Many students of physics confuse weight with mass. **The mass of an object refers to the amount of matter that is contained by the object; the weight of an object is the force of gravity acting upon that object.**

**Mass is related to how much *stuff* is there and weight is related to the pull of the Earth (or any other planet) upon that *stuff*.** The mass of an object (measured in kg) will be the same no matter where in the universe that object is located. Mass is never altered by location, the pull of gravity, speed or even the existence of other forces. For example, a 2-kg object will have a mass of 2 kg whether it is located on Earth, the moon, or Jupiter; its mass will be 2 kg whether it is moving or not (at least for purposes of our study); and its mass will be 2 kg whether it is being pushed upon or not.

On the other hand, the weight of an object (measured in Newton) will vary according to where in the universe the object is. Weight depends upon which planet is exerting the force and the distance the object is from the planet. Weight, being equivalent to the force of gravity, is dependent upon the value of  $g$  – the gravitational field strength. On earth's surface  $g$  is 9.8 N/kg (often approximated as 10 N/kg). On the moon's surface,  $g$  is 1.7 N/kg. Go to another planet, and there will be another  $g$  value. Furthermore, the  $g$  value is inversely proportional to the distance from the center of the planet. So if we were to measure  $g$  at a distance of 400 km above the earth's surface, then we would find the  $g$  value to be less than 9.8 N/kg. Always be cautious of the distinction between the two, it is the source of much confusion for many students of physics. Very importantly we must distinguish clearly the difference between Mass and Weight, as so many people, even those who claim to be science students and lay men alike mix it up, but it is very essential for us to be able to get succinct understanding of the two.

Mass is defined as the quantity of matter contained in a body, as weight is the force, pull or impetus with which the earth attracts the body towards the centre of the earth. The various types of beam balance treated above are used to measure 'mass'.

The mass of a body is usually measured by comparing it with standard masses.

### **Dimensional analysis of physical quantities.**

Most physical quantities include a unit, but not all – some are dimensionless. Neither the name of a physical quantity, nor the symbol used to denote it, implies a particular choice of unit, though SI units are usually preferred and assumed today due to their ease of use and all-round applicability. For example, a quantity of mass might be represented by the symbol  $m$ , and could be expressed in the units kilograms (kg), pounds (lb), or Daltons (Da) in some texts, but it must be noted that both Pounds and Daltons are particularly archaic.

The notion of *physical dimension* of a physical quantity was introduced by Joseph Fourier in 1822. By convention, physical quantities are organized in a dimensional system built upon base quantities, each of which is regarded as having its own dimension.

If any quantity can be measured in units of lengths, then it has the dimension of length (L), the same applies to time, any quantity that can be measured in units of time is said to have a dimension of (T), any quantity which can be measured in unit of mass is said to have a dimension of (M).

The dimension of velocity (V) are written

$V = [\text{length}] / [\text{time}] [L]/[T]$ , or  $V = [L][T^{-1}]$

Dimension for area,  $A = \text{length} \times \text{breadth}$

$$= [L] \times [L] = [L^2]$$

For volume,  $V = [L] \times [L] \times [L] = [L^3]$

Force = mass x acceleration

Dimension of Force = Dimension of Mass x Dimension of Acceleration

$$= [M] \times [LT^{-2}] = [MLT^{-2}]$$

## Electric Charges

Electric charges are of two general types: positive and negative. Two objects that have an excess of one type of charge exert a force of repulsion on each other when relatively close together. Two objects that have excess opposite charges, one positively charged and the other negatively charged, attract each other when relatively near.

Many fundamental, or subatomic, particles of matter have the property of electric charge. For example, electrons have negative charge and protons have positive charge, but neutrons have zero charge. The negative charge of each electron is found by experiment to have the same magnitude, which is also equal to that of the positive charge of each proton. Charge thus exists in natural units equal to the charge of an electron or a proton, a fundamental physical constant. A direct and convincing measurement of an electron's charge, as a natural unit of electric charge, was first made (1909) in the Millikan oil-drop experiment. Atoms of matter are electrically neutral because their nuclei contain the same number of protons as there are electrons surrounding the nuclei. Electric current and charged objects involve the separation of some of the negative charge of neutral atoms. Current in metal wires consists of a drift of electrons of which one or two from each atom are more loosely bound than the rest. Some of the atoms in the surface layer of a glass rod positively charged by rubbing it with a silk cloth have lost electrons, leaving a net positive charge because of the un-neutralized protons of their nuclei. A negatively charged object has an excess of electrons on its surface.

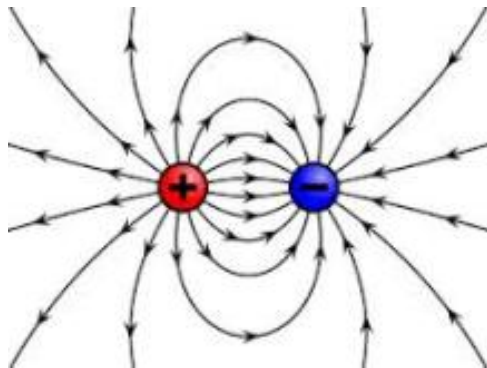


Image of Electric field of a positive and a negative point charge.

*Image of Electric field of a positive and a negative point charge.*

Conductors are materials that allow the easy flow of electrons through them, while insulators are materials that do not allow electrons to pass through them

Examples of conductors are almost all metals, damp air, graphite, acids, salt solution, the earth and the human body. For Insulators are plastic, polythene, Bakelite, ebonite, paper, dry hair, silk, oils, glass, sulphur and wood. It is very important to note that good conductors of heat are also good conductors of electricity

Electrostatic induction is the act of charging the human body by placing a charged body near it without placing any contact between them.

## **WAYS OF PRODUCING CHARGES**

By Friction, contact and electrostatic induction

Electric charge is conserved: in any isolated system, in any chemical or nuclear reaction, the net electric charge is constant. The algebraic sum of the fundamental charges remains the same.

The unit of electric charge in the metre–kilogram–second and SI systems is the coulomb, equivalent to the net amount of electric charge that flows through a cross section of a conductor in an electric circuit during each second when the current has a value of one ampere. One coulomb consists of  $6.24 \times 10^{18}$  natural units of electric charge, such as individual electrons or protons. One electron itself has a negative charge of  $1.602176565 \times 10^{-19}$  coulomb. In the centimetre–gram–second system there are two units of electric charge: the electrostatic unit of charge, esu, or statcoulomb; and the electromagnetic unit of charge, emu, or abcoulomb. One coulomb of electric charge equals about 3,000,000,000 esu, or one-tenth emu.

An electrochemical unit of charge, the faraday, is useful in describing electrolysis reactions, such as in metallic electroplating. One faraday equals  $9.64853365 \times 10^4$  coulombs, the charge of a mole of electrons (that is, an Avogadro's number,  $6.02214129 \times 10^{23}$ , of electrons).

**So you can test your understanding so far through attempting to derive the dimensions for both PRESSURE and WORK including ELECTRIC CHARGE.**

(1) Which of the followings is a fundamental unit?

A.  $m^2$  B.  $Kg.m^{-3}$  C. s D.  $m^3$  E.  $Nm^{-2}$

(2) Which of the units of the following physical quantities is not derived?

A. Area B. Frequency C. Pressure D. Mass

(3) Some of the internationally agreed system of unit (SI) for physical measurements are.

A. Lb, ft, sec B. g, m, sec C. kg, m, sec D. cm, g, sec E. kg, cm, sec

(4) Which of these materials is not a conductor?

A. Ebonite B. Aluminums C. Copper D. Acids

(5) When a body loses some of its electrons it becomes ....., when it gains electrons it becomes .....

## **ANSWER**

1. C 2. D 3. C 4. A 5. positively charged, negatively charged

## **WEEK 4**

### **Time: Concepts of Time, Ways of measuring Time i.e. both old and modern methods**

#### Introduction

Both Galileo and Newton and most people up until the 20th century thought that time was the same for everyone everywhere. This is the basis for timelines, where time is a parameter. Our modern conception of time is based on Einstein's theory of relativity, in which rates of time run differently depending on relative motion, and space and time are merged into space time, where we live on a world line rather than a timeline. Thus time is part of a coordinate, in this view, Physicists believe the entire Universe and therefore time itself began about 13.8 billion years ago in the big bang.

Time itself can be defined as that in which developments and happenings can be distinguishably analyzed with reference to before and after.

In the International System of Units (SI), the unit of time is the second (symbol is S). The most natural time unit is the solar day which is manifested by the passing of day and night. It takes the earth one solar day to complete one revolution about its axis. There is also a different time scale known as *siderea* used for astronomical purposes, this is the time interval between two successive passages of a star over the meridian. The essential mechanism of the devices used for marking the passage of time are masses so mounted or suspended that when set in motion under the influence of forces they repeat with great regularity fixed cycles of their motion. The pendulum of a clock and the balance wheel of a watch are two of such mechanisms.

## THE MODERN TIME

Today we measure and indicate time with clocks. In the laboratory time is measured with a stop-clock or a stop-watch and both can be started and stopped with the use of a knob which can be pressed and pushed, the stop-watch enables us to accurately measure small intervals of time to 0.1 seconds.

For instance 60 seconds = 1 minutes, 60 minutes = 1 hour, 24 hours = 1 days.

## THE OLD TIME

**Prehistoric man, by simple observation of the stars, changes in the seasons, day and night began to come up with very primitive methods of measuring time. This was necessary for planning nomadic activity, farming, sacred feasts, etc..**

**The earliest time measurement devices before clocks and watches were the sundial, hourglass and water clock.**

**The forerunners to the sundial were poles and sticks as well as larger objects such as pyramids and other tall structures. Later the more formal sundial was invented. It is generally a round disk marked with the hours like a clock. It has an upright structure that casts a shadow on the disk – this is how time is measured with the sundial.**

**The hourglass was also used in ancient times. It was made up of two rounded glass bulbs connected by a narrow neck of glass between them. When the hourglass is turned upside down, a measured amount of sand particles stream through from the top to bottom bulb of glass. Today's egg timers are modern versions of the hourglass.**

**Another ancient time measurer was the water clock or clepsydra. It was an evenly marked container with a spout in which water dripped out. As the water dripped out of the container one could note by the water level against the markings what time it was.**

**One of the earliest clocks was invented by Pope Sylvester II in the 990s. Later on chimes or bells were added as well as dials to the clocks.**

**Early clocks were powered by falling weights and springs. Later clocks with pendulums came into existence in 1657.**

Electric clocks came into being after 1850, but were not popular until the twentieth century. An electric motor with alternating current powers these clocks. Later digital clocks with LCD (liquid crystal displays) rivaled the electric clocks. Quartz clocks use the vibrations of a quartz crystal to power the clock.

Watches are different than clocks in that they are carried about or worn. The first watches appeared by the 1500s and were made by hand. They were very fancy and their faces were covered by fine metal strips to protect the markings. Watches were manufactured by machine in the mid 1800s.

At first watches had knobs on the outside that the wearer wound to keep the mainspring powered inside. Later on, self-winding watches derived power from the movement of the wearer. With the advent of quartz crystal watches with digital displays, the need for motors for watches has decreased.

Today's clocks and watches are increasingly digital devices, often set via satellite guidance, the reason we now have the Greenwich meridian time (GMT), central european time (CET) etc, such that around the world countries operate on different time zones, e.g. in USA there are different states with time differences of hours, same applies to continent to continent and country to country.



Try to ANSWER these questions as evidence of seriousness

1. An ancient method of measuring time that made use of shadows formed by the sun was a

A. water clock B. hourglass C. sundial

2. A device consisting of several glass bulbs connected by a narrow glass neck with grains of sand that flowed from one bulb to the other is a

A. water clock B. hourglass C. sundial

3. A container that had liquid pour into it slowly marked at regular intervals that denoted the time was a

A. water clock B. hourglass C. sundial

4. The earliest clocks were powered by

A. electricity B. quartz crystals C. Falling weights and springs

5. Watches that show numbers with the exact time rather than with hands and numbers are

A. digital B. standard C. timex

## **ANSWER**

1. C 2. B 3. A 4. C 5. A

## **Week 5**

# **Topic: DEFINITION, TYPES, CAUSES, PRACTICAL EXAMPLES AND EFFECTS OF CIRCULAR MOTION, CENTRIPETAL AND CENTRIFUGAL FORCES**

What is motion? It is the change of the position of a body from one point to the other with time, also concerns how things move and what makes them move, while Kinematics describes how objects move regardless of the forces causing their motion, Dynamics deals with why objects move the way they do.

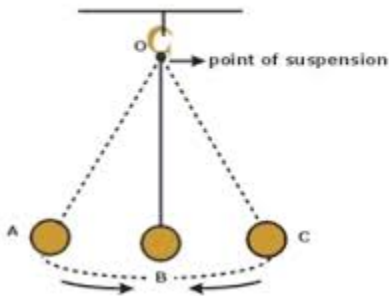
There are four types of motion, namely; Random, Translational, Rotational, Oscillatory (or Vibratory) motion.

### **Types of Motion**

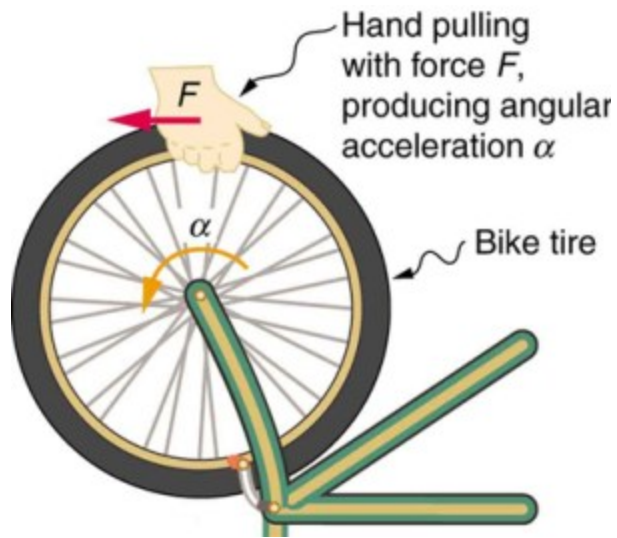
1. Translational motion results in a change of location. This category may seem ridiculous at first as motion implies a change in location, but an object can be moving and yet not go anywhere. I get up in the morning and go to work (an obvious change in location), but by evening I'm back at home (back in the very same bed where I started the day). Is this translational motion? Well, it depends. If the problem at hand is to determine how far I travel in a day, then there are two possible ANSWERS: either I've gone to work and back (thirteen miles each way for a total of 26 miles) or I've gone nowhere (thirteen miles each way for a total of zero miles). The first ANSWER invokes translational motion while the second invokes oscillatory motion.

2. Oscillatory motion is repetitive and fluctuates between two locations. In the previous example of going from home to work to home to work I am moving, but in the end I haven't gone anywhere. This second type of motion is seen in pendulums (like those found in grandfather clocks), vibrating strings (a guitar string moves but goes nowhere), and drawers (open, close, open, close — all that motion and nothing to show for it). Oscillatory motion is interesting in that it often takes a fixed amount of time for an oscillation to occur. This kind of motion is said to be periodic and the time for one complete oscillation (or one cycle) is called a period. Periodic motion is important in the study of sound, light, and other waves. Large chunks of physics are devoted to this kind repetitive motion. Doing the same thing over and over and going nowhere is pretty important; which brings us to our next type of motion.

## Oscillatory motion



3. Rotational motion occurs when an object spins. The earth is in a constant state of motion, but where does that motion take it? Every twenty-four hours it makes one complete rotation about its axis. (Actually, it's a bit less than that, but let's not get bogged down in details.) The sun does the same thing, but in about twenty-four days. So do all the planets, asteroids, and comets; each with its own period. (Note that rotational motion too is often periodic.) CDs, and wheels also rotate. That should be enough examples to keep us busy for a while."



5. Random motion is said to occur when objects move irregularly or at random or haphazardly or disorderly with no preferred direction or orientation. As a result of such random movement, the particles collide with one another. An example of such motion is the Brownian motion – an irregular motion of particles of various kinds suspended in water or of smoke particles suspended in air, or the motion of gas particles.

## What causes motion?

**Force**, it is that, which changes or tends to change the state of rest or of uniform motion in a straight line of a body. A block of resting on a table will remain at rest until it is pushed or pulled by an agent. A force can effect the movement of a body, changes its direction of motion, makes it either slow down or stop moving altogether.



## Types of forces;

there are two major types of forces, **contact forces** and **force fields**.

Contact forces are forces which are in contact or in touch with the body to which they are applied. Examples are forces push pull, tension, reaction and frictional forces.

Force fields, these are forces whose sources do not require contact with the body to which they are applied, examples are gravitational force, electrical force also known as electrostatic and magnetic force.

Electrostatic force is the force that exists round charged bodies.

Gravitational force is the type with which the earth attracts objects towards its centre.

Magnetic force exists around a bar magnet.

Where Force = mass x acceleration.  $f=ma$ .

## Circular motion

In physics, **circular motion** is a movement of an object along the circumference of a circle or rotation along a circular path. It can be uniform, with constant angular rate of rotation (and constant speed), or non-uniform with a changing rate of rotation. The rotation around a fixed axis of a three-dimensional body involves circular motion of its parts. The equations of motion describe the movement of the center of mass of a body.

**Examples of circular motion include:** an artificial satellite orbiting the Earth at constant height, a stone which is tied to a rope and is being swung in circles, a car turning through a curve in a race track, and a gear turning inside a mechanism.

Since the object's velocity vector is constantly changing direction, the moving object is undergoing acceleration by a centripetal force in the direction of the center of rotation. Without this acceleration, the object would move in a straight line, according to Newton's laws of motion.

Centripetal force is a force that makes a body follow a curved path, generally it is the cause of circular motion.

Centripetal force is the apparent force that draws away a rotating body from the centre of rotation. These different forces are equal in magnitude, but centrifugal and reactive centrifugal forces are opposite in direction to the centripetal force. The effect of centripetal force is felt by a person riding in a car as it turns a corner.

Centripetal acceleration is given by

$$a = v^2/r$$

Centripetal force is  $F_T = \text{mass} \times \text{acceleration}$ ,  $F_T = m \times a$ , where the immediate line above applies, then we have  $F_T = mv^2/r$ .

## Angular Speed and Velocity

Consider the speed of a stone that is whirled on the end of a string. The stone moves in a circular path

The angular velocity of motion is expressed as thus,  $\omega = \theta/t$  **1.0**

Angular velocity is defined as the angle turned through, divided by the elapsed time.

Linear velocity is,  $v = s/t$  **2.0**

The magnitude of angular velocity is defined analogously with ordinary linear velocity, instead of linear displacement, we use the angular displacement  $\theta$ . If the angle  $\theta$  is measured in radians, then it can be shown that  $\theta = s/r$ . **3.0**

The radian is a unit of angular measure just as the centimeter is a unit of linear measure. The radian is defined as the angle subtended by the arc of a circle whose length is equal to the radius of the same circle.

From equation 3, we could  $s = r\theta$ , putting this in equation 2, we have  $v = s/t = r\theta/t = r \cdot \theta/t = r\omega$ , this arrival means linear velocity is related to angular velocity  $\omega$  by  $v = r\omega$  **4.0**

Let us x-ray relevant parameters' units here; s is in metres, r is in metres, v is in metres per second ( $\text{ms}^{-1}$ ),  $\omega$  is in radians per second ( $\text{rad.s}^{-1}$ ).

NB radian as a unit has no dimension, it is a ratio between two lengths, so that  $\text{cm} \times \text{rad.s}^{-1}$ .

At this point let us test our knowledge as regards what we supposedly have learnt, endeavour to be faithful in attempting these questions for better knowledge acquisition.

(1) A mass of 1-kg is moving in a circular path of radius 2 m with a uniform speed of  $50 \text{ ms}^{-1}$ .

(a) Find the centripetal acceleration.

(A)  $1250 \text{ ms}^{-2}$  (B)  $1275 \text{ ms}^{-2}$  (C)  $2150 \text{ ms}^{-2}$  (D)  $1365 \text{ ms}^{-2}$

(1b) Also find the corresponding centripetal force.

(A) 25000 newtons (B) 14500 newtons (C) 12500 newtons (D) 10200 newtons

(2) A stone whirled at the end of a rope 30 cm long, makes 10 complete revolutions in 2 seconds. Find

(2a) the angular velocity in radians per second.

(2b) the linear speed

(2c) the distance covered in 5 seconds

(3) Which of the following correctly gives the relationship between linear speed  $v$  and angular speed  $\omega$  of a body moving uniformly in a circular radius  $r$ ?

A  $v = \omega r$  B  $v = \omega^2 r$  C  $v = \omega r$  D  $v^2 = \omega r$  E  $v = \omega/r$ .

(4) A man is rotating a sling with a stone in a 2 m long at the rate of 18 revolutions every 9 seconds. Find the rectilinear speed of the stone.

A.  $415 \pi \text{ m}$  B.  $288 \pi \text{ m}$  C.  $312 \pi \text{ m}$  D.  $298 \pi \text{ m}$

(5) A Clown riding a uni-cycle has the wheel base diameter as 60 cm. if the wheel rotates at the rate of 120 revolutions per minute, then find the Rectilinear speed at which the clown is traveling.

A.  $7000 \text{ cm/min}$  B.  $7200 \text{ cm/min}$  C.  $7100 \text{ cm/min}$  D.  $8200 \text{ cm/min}$

## ANSWERS:

1. A

2. a.  $31.4 \text{ rad}\cdot\text{s}^{-1}$ , b.  $0.942 \text{ ms}^{-1}$ , c.  $4.71 \text{ m}$

3. C

4.  $288 \text{ }\mu\text{m}$

5. B

## Week 6

### **Topic: Definition, Types of law of friction, Reduction, Advantages and Disadvantages**

When a solid is in contact with another, the rough state of the surfaces would inhibit them from sliding freely over one another. Such development is occasioned by the effect of friction.

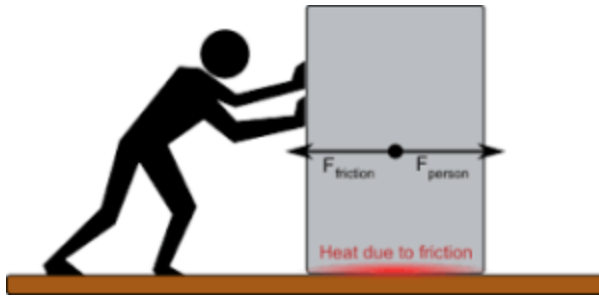
Friction is defined as the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other. Frictional forces act tangential to the surface of separation between two bodies in contact. Friction is a force of opposition. It does not appear unless there is relative motion, or a force tending to produce motion. Some frictional force has to be overcome before an object can move over one another, frictional force also continues to act as long as one body moves over another there are several types of friction: **Static and Dynamic friction.**

Starting or limiting friction is the maximum force that must be subdued before a body can just start to move over another.

Kinetic or Dynamic friction is the force that must be overcome so that a body can move with uniform speed over another body.

When a block is pulled along so that it moves on the surface of the board with uniform speed, the frictional force opposing motion is known as sliding, kinetic or dynamic friction. Sliding friction is less than static friction.

Friction varies with the type and properties of both surfaces, of these properties the main one is the surface roughness, these properties determine the coefficient of friction as surface roughness increases friction increases, it is important to note that  $F_{\text{solid}} > F_{\text{liquid}} > F_{\text{gas}}$ , friction in fluid is the resistance to flow or the friction of the particles rubbing = Viscosity, note here that fluids are both liquids and gases.



## Laws of friction:

Friction opposes the relative surfaces between two surfaces in contact, it acts in a direction opposite to that of the motion.

The friction between two surfaces is proportional to the force pressing on one another, being normal force or the perpendicular force.

When an object is moving, the friction is proportional and perpendicular to the normal force ( $N$ ), friction is independent of the area of contact so long as there is an area of contact the coefficient of static friction is slightly greater than the coefficient of kinetic friction. Within rather large limits, kinetic friction is independent of velocity, friction depends upon the nature of the surfaces in contact.

The force of friction increases to the same extent as the force which tends to start the motion.

It varies directly with normal force pressing the surfaces together i.e. it is proportional to the normal reaction  $R$  between the two surface in contact.

i.e.  $F \propto R$  i.e.  $F = \mu R$ , where the constant  $\mu$  is the coefficient of friction,  $\mu = F/R$ , which mean coefficient of friction is defined as the frictional force/normal reaction between the two surfaces in contact  $R$ .

For static friction the frictional force  $F$  required to determine  $\mu$  is the maximum force required to start the body moving  $\mu$  is then called the coefficient of static or limiting friction. For kinetic friction, the frictional force used is the force required to keep the body in uniform motion and  $\mu$  is referred to as the coefficient of dynamic or kinetic friction, while the coefficient of static friction is greater than the coefficient of dynamic friction, apparently there is need for more force to actuate a body into motion than keeping the body on motion having started it.

## Friction Reduction methods:

The use or the application of lubricants like oil, grease, air and graphite, the use of ball or roller bearings and the streaming of body shapes of moving objects.

## Advantages of friction and its uses:

Imagine if everything were completely slippery. That would be good for some machines that require parts to slide over one another. That would be bad for most things in real life. Like walking or driving or holding things.

Without friction, life as we know cannot continue! We cannot walk on a road or in the house. We can't use our normal modes of transport. Try living like in a space ship!

Resistance offered to the movement of one body past another body with which it is in contact. In certain situations friction is desired.

Without friction the wheels of a locomotive could not grip the rails nor could power be transmitted by belts.

Friction is the most common way we use to change the velocity of an object: you can use it to increase or decrease an objects speed or direction, like the way the tires of a car 'grip' the road during steering, acceleration and stopping, or the way we use the friction of our shoes against the ground when doing 'fancy footwork'

### **Disadvantages of friction:**

On the other hand, in the moving parts of machines a minimum of friction is desired; an excess of friction produces heat, which in turn causes expansion, the locking of the moving parts, and a consequent breakdown of the machinery. Lubrication is important in minimizing friction as are also such devices as ball and roller bearings.

Much useless work is done by machines in overcoming friction which opposes their motion. Thus friction causes loss of energy in machines, and therefore, reduces their efficiency.

Loss of energy/loss of efficiency

Friction needs extra force to be overcome and thus consumes energy. Friction leads to much wear and tear of surfaces on the moving parts of the machines.

Can we test our knowledge here on the topic Friction? Ok, let us play around with some few cheap questions:

1. A block of wood weighing 4 N is placed on a horizontal table. It is then pulled by means of a spring balance attached to one of its end. The block begins to move when the spring balance records a horizontal force of 2.5 N.

(a) What is the coefficient of static friction?

A. 0.743 B. 0.625 C. 0.945 B. 0.804

(b) What is the frictional force when a horizontal force of 2.0 N is recorded by the spring balance?

A. 4.0 N B. 2.7 N C. 2.0 N D. 5.0

2. What do you understand by the terms friction, frictional force, and coefficient of sliding friction?

3. A metal block of 5 kg lies on a rough horizontal platform. If a horizontal force of 8 N applied to the block through its centre of mass just slides the block to the platform, then the coefficient of limiting friction between the block and the platform is:

A. 0.16 B. 0.63 C. 0.80 D. 1.6 E. 2.00

4. Explain some of the advantages and disadvantages of friction as highlighted above.

5. What in word expression does  $\mu$  signify in friction?

A. Frictional force B. Coefficient of friction C. Force reduction D. Normal reaction

## **ANSWER**

1a. B. 1b. C 3. A 5. B

## Week 7

# Topic: Position: Distance, Displacement, Speed, Velocity and Distance-Time graph

The position of a point in space is determined by its distance and direction from other points. The statement of position is accomplished by means of a frame of reference or point of reference, which we shall call the origin.

**Distance** is the movement coverage of a body with no emphasis on direction, it is a change in the position of an object with no definite direction.

**Displacement** is defined as the distance travelled in a specified direction. It is a change in the position of an object which requires distance and direction to specify it.

To further distinguish between distance and displacement, a person strolling 500m to the east and then turning around and walking back (west), a distance of 300 m, the total distance travelled is 800 m but the displacement is only 200 m since he is now only 200 m from the starting position.

**Speed** is the rate at which a body covers a distance.

Speed = distance/ time, this is an average speed ( $v$ ) over the distance ( $s$ ),  $v = s/t$ , the SI unit (Standard International unit) of distance is meter, while for time is second, therefore, for speed is meter per second ( $\text{ms}^{-1}$ ), we could have units in centimeters per second and kilometer per hour.

### **Uniform Speed**

When a body covers equal distances in equal time intervals, no matter how small the time interval may be, the speed is said to be a uniform speed or constant speed.

### **Velocity**

Again, the word velocity and speed are often used interchangeably by most people, it will be fair to do justice to this lingering misconception, while studying motion it is necessary to draw a clear distinction between the two, in speed no direction is specified, while in velocity it is imperative to work on the direction, as treated above, displacement works with considered direction, so we define velocity in terms of displacement.

Velocity is the rate of change of displacement, Velocity = displacement/time,  $v = s/t$ .

### Uniform Velocity

When a body moves with equal displacement in equal time intervals, no matter how small the time intervals may be, the velocity is said to be a uniform velocity or a constant velocity, its SI unit is also in ( $\text{ms}^{-1}$ ), but in a case where a body moves round a circular path at constant speed, it is said to move with non-uniform velocity, because its direction of motion is constantly changing.

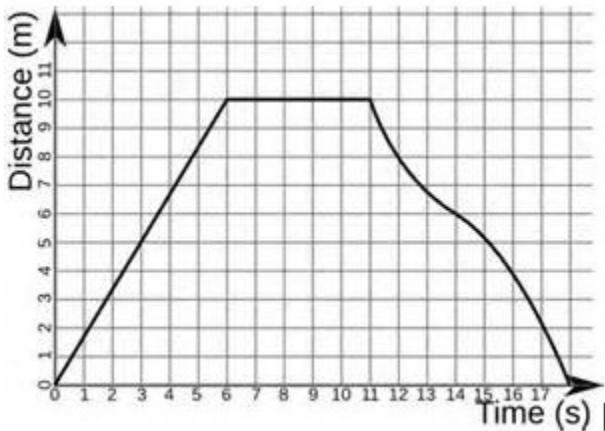
### Distance-Time Graph

Measuring the distance covered by a moving object at known time intervals (for instance 6 seconds), and we plot the values of distance on the Y-axis and time on the X-axis of a graph on joining the points, we obtain distance-time graph.

Such graphs do a lot in providing useful information about the motion of the object, at that point on the graph where the distance is a straight line from point O, the speed (or velocity) is uniform since the body covers equal distance in equal times. The gradient or slope of that straight line is  $0 - 10$  in meters as the unit of distance divide  $0 - 6$  in seconds as the unit of time.

Instantaneous Velocity is defined as the velocity at any instant of time. The speedometer of a moving vehicle indicates instantaneous velocity.

Shall we test our knowledge and understanding at this point? I think it is reasonable to do so and I advise you to be faithful to yourself in **ANSWER**ing the test questions in order to ascertain you're the level of your knowledge and understanding so far.



1. A car travels at an average speed of  $100\text{km}^{-1}$ , what distance does it cover in 5 minutes?

A. 7.5 km B. 9.7 km C. 8.3 km D. 7.9 km

2. A car travels for 3 hours to a distance city 200 km due East. What was its speed?

A.  $65.6 \text{ kmh}^{-1}$  B.  $66 \text{ kmh}^{-1}$  C.  $66.7 \text{ kmh}^{-1}$  D.  $70 \text{ kmh}^{-1}$

3. A bus travels with an average velocity of  $60 \text{ kmh}^{-1}$ . How long does it take to cover a distance of 500km?

A. 8.3 h B. 7.1 h C. 15 h D. 9.8 h

4. How much longer would it take to travel a distance of 600km at a speed of  $50 \text{ kmh}^{-1}$ , than it would at a speed of  $60 \text{ kmh}^{-1}$ ?

A. 5 h B. 6 h C. 2 h D. 9 h

5. Unit of distance is .....

A. ms B. m/s C.  $\text{m/s}^2$  D.  $\text{m/s}^{-1}$

**ANSWERS:**

1. C 2. C 3. A 4. C 5. B

## Week 8

# Topic: Rectilinear Acceleration: Concepts of acceleration, uniform, non-uniform acceleration and Velocity – Time graph

Acceleration is defined as the rate of change of velocity with time. Its unit is metre per second, ( $\text{ms}^{-2}$ ). Whenever the velocity of a moving body is changing, the body is said to be accelerating.

Acceleration ( $a$ ) = velocity change/time taken for change

When the velocity increases with time, the rate of change of velocity with time is termed acceleration but when the velocity decreases with time, it is called retardation. Retardation is negative acceleration.

Acceleration ( $a$ ) = final velocity – initial velocity/time

$$a = \frac{v - u}{t} \text{ or } v = u + at$$

1

Assume a car moves from a velocity of  $20\text{ms}^{-2}$  to a velocity of  $30\text{ms}^{-2}$  in 5 seconds, its average acceleration is given by

$$\begin{aligned} a &= \frac{30 - 20}{5} = 2 \text{ metre per sec per sec} \\ &= 2 \text{ ms}^{-2} \end{aligned}$$

The concept of acceleration is an important one when it comes to study of moving bodies. Acceleration refers to the rate in change of velocity of a moving body. If a body is moving at a constant velocity, there is no change and hence it has no acceleration. You can understand the concept with a moving car. If you are driving a car and moving at a constant speed of 50mph, you are not accelerating, but the moment you start pressing the accelerator and press it further at a constant rate, the car accelerates as its velocity increases at a constant rate. This is known as acceleration. There is another concept linked with acceleration, and known as retardation that people remain confused with. This article will clearly explain the differences between acceleration and retardation to dispel any doubts in the minds of the readers.

If you watch a cycling race, you often see a cyclist zipping past another cyclist. This happens because the faster cyclist is moving at a faster speed than the slower one. But there is more to it than catches your eyes. If the slower cyclist is moving at a constant speed, he has no acceleration. But it is apparent that the one coming from behind is speeding up, he has got a change of velocity that helps him go past the slower one. This rate of change of velocity or

change of velocity per unit of time is called acceleration and is explained through Newton's laws of motion.

If  $u$  is the initial velocity and  $v$  is the final velocity of the cyclist, acceleration is given by the following equation

$$v = u + at$$

$$\text{Or, } a = (v - u)/t$$

However, there are instances when a fast moving body may be slowing down as when a motorist applies brake at a traffic light or when a fast moving train halts slowly at a station. Here too there is a change in rate of velocity but in contrast to acceleration, the velocity is decreasing. These conditions are called cases of retardation (or deceleration). Let us see it with an example. When a boy throws up a ball in air, the ball has some initial velocity that gradually reduces until the ball reaches its highest point in the air. This means that this is a case of retardation. On the other hand, when the ball starts its downward journey, it has an initial velocity of zero but it increases gradually under gravity and is maximum just before it strikes the ground. This is a case of acceleration.

## Uniform acceleration

It is when the velocity of a moving body increases by equal amounts in equal intervals of time, no matter how small the time intervals may be, it is said to move with uniform acceleration.

Experiments have shown that if a body freely falling under gravity has a uniform or constant acceleration of about  $10\text{ms}^{-2}$ . If a body is thrown up in the air, it experiences a uniform but negative acceleration or retardation of about  $10\text{ms}^{-2}$  due to the influence of the earth's gravitational attraction.

## What is Rectilinear Motion?

Let us consider a body moving in a straight line, if we can see every particle (which the body is made of) is traveling the same path, we can call it Rectilinear Motion.

or

A body is said to experience rectilinear motion, if the two particles in that body travel the same distance along two parallel straight lines.

or

The Motion attained by a body so that every particle of a body follows a straight line path is defined as the motion which occurs in a straight line.

The parameters involved in a rectilinear motion are displacement, velocity, acceleration and time.

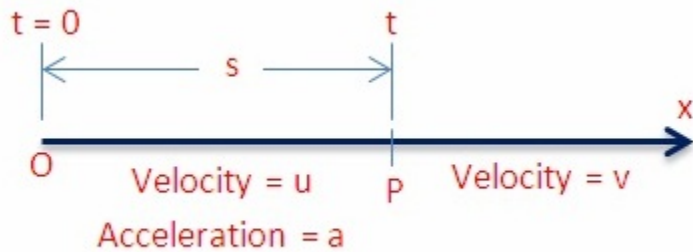
## Rectilinear Motion Equation

The equations for rectilinear motion can be derived from the first principle.

Let us assume that an object starts with an initial velocity  $\mathbf{U}$  and with a constant acceleration  $\mathbf{a}$ . A simple calculation tells us that after a time  $\mathbf{t}$ , the increase in velocity during that time  $\mathbf{t}$  is **acceleration  $\times$  time**, that is just  $\mathbf{at}$ . Since the object already had an initial velocity  $\mathbf{u}$  at the start, the quantity is also added to the increase in the velocity to determine the actual final velocity  $\mathbf{v}$ .

In other words, the first equation for final velocity is framed as,

A particle starts motion in a straight line from point  $\mathbf{O}$  having initial velocity  $\mathbf{u}$  with a constant acceleration  $\mathbf{a}$ . Let  $\mathbf{s}$  be the distance traveled by particle to reach point  $\mathbf{P}$  in time  $\mathbf{t}$ . At the point where it covers distance  $\mathbf{s}$  the final velocity is  $\mathbf{v}$ .



The Rectilinear motion equations are below, referred to as 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> respectively:

$$\mathbf{v = u + at}$$

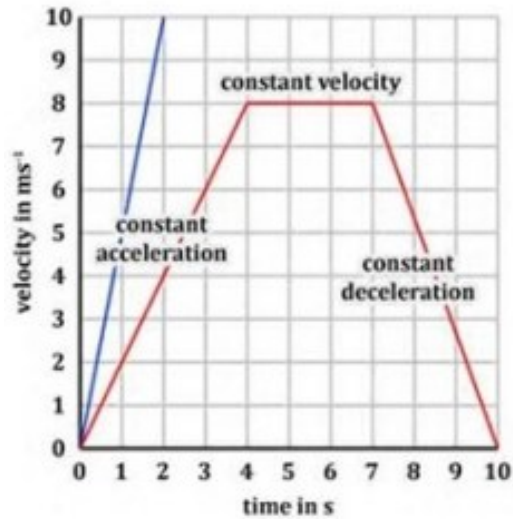
$$\mathbf{s = ut + \frac{1}{2} at^2}$$

$$\mathbf{v^2 = u^2 + 2as}$$

### Velocity-Time graph

What does the slope velocity – time graph show?

The rate of acceleration is a measure of the change of the velocity of an object with time. On a graph of velocity versus time, it is represented by the slope of the line so graphed. If velocity is changing in time, the object described is being accelerated. The greater the slope of the graph, the greater the change of velocity per unit of time and the greater the acceleration of that object.



Yet again, as much as it is important for us that you understand the topic treated above, we encourage you to work on the questions below, they are there for you to brush up your knowledge on the topic you just went through:

1. Acceleration is the measure of the change in what?

- A. density B. motion C. velocity D. mass

2. Deceleration has to do with decreasing .....

- A. Velocity B. Acceleration C. Force D. Height

3.  $v^2 = u^2 + 2as$  is the ..... equation of motion

- A. First B. Second C. Third D. Fourth

4. If a car accelerates from 3  $\text{m/s}$  to 12  $\text{m/s}$  in 3 seconds, what is the car's average acceleration?

- A. 1  $\text{m/s}^2$  B. 2  $\text{m/s}^2$  C. 3  $\text{m/s}^2$  D. 4  $\text{m/s}^2$

5. 18. Q: Acceleration due to gravity is represented by what symbol?

- A. v B. g C. t D. s

**ANSWERS:**

1. C 2. A 3. C 4. C 5. B

## Week 9

### Topic: Upthrust and Archimedes principle

If you try to lift up a weight in a swimming pool and then try to lift the same weight on the edge of the pool, it feels much lighter in the water.

This was supposed to have been first explained by the Greek scientist Archimedes. He said that the water gives an upward force or upthrust on any object in it.

You can weigh an object in air and then in water and actually work out the upthrust (upward force), it is the difference between the two readings. For this reason the upthrust is often called the loss in weight of the object.

Archimedes principle states that when a body is partly or totally immersed in a fluid it experiences an upthrust that is equal to the weight of fluid displaced by the through the object.

Upthrust = apparent loss of weight of object = weight in air – weight in liquid.

#### Example problem

A lump of iron of mass 8 kg is hung in brine of density  $1100 \text{ kg/m}^3$ . If the iron has a volume of  $0.001 \text{ m}^3$ , find:

- (a) the density of iron;
- (b) the loss of weight in brine;
- (c) the apparent weight in brine.

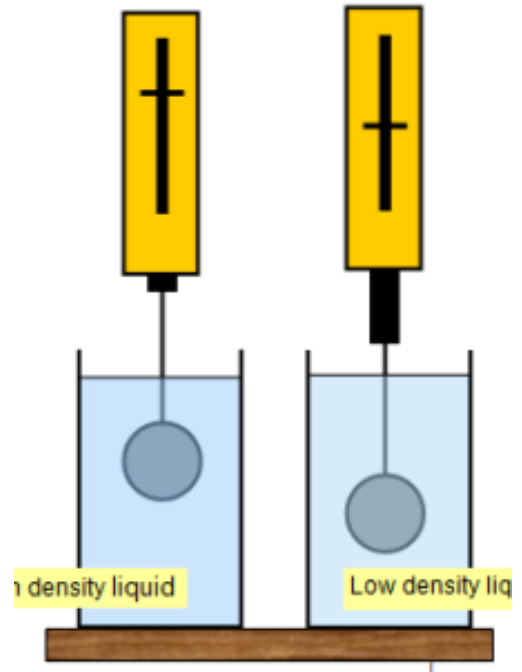
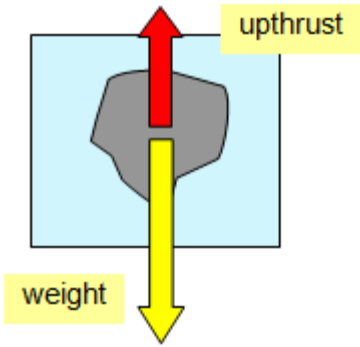
(a) density =  $8/0.001 = 8000 \text{ g/cm}^3$

(b) loss of weight =  $0.001 \times 1100 = 1.1 \times 10 = 11 \text{ N}$

(c) apparent weight =  $80 - 11 = 69 \text{ N}$

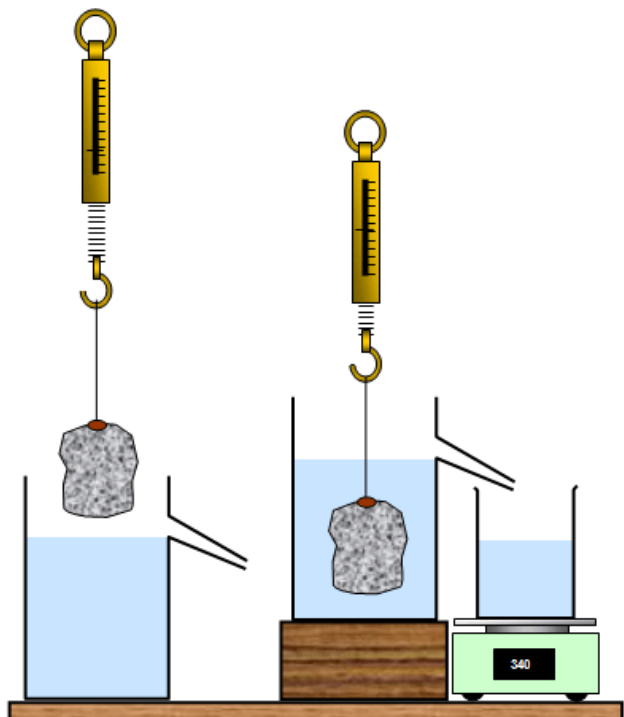
(Force of Earth's gravity (g) =  $10 \text{ N/kg}$ )

The weight of liquid displaced is the weight of the liquid that has been replaced by the object. The volume of this amount of liquid is equal to the volume of the object itself. The weight of fluid displaced and therefore the upthrust will be bigger if the density of the liquid is large. The upthrust in salty water (relative density = 1.1) is larger than that in water (relative density = 1.0) for the same object. This is why it is easier to swim in the sea than in a freshwater lake.



## Archimedes principle and upthrust

Archimedes principle states that when an object is immersed in a liquid the apparent loss of weight of an object is equal to the upthrust and this is also equal to the weight of the liquid displaced. You can prove this by the following experiments.



Volume of displaced water = volume of stone

Weigh an object in air and then lower it into a beaker of water that is resting on a top pan balance. The reading on the spring balance will get less while the reading on the top pan balance will increase by the same amount. If you already know the density of the liquid then you can simply measure the volume of displaced water and use  $\text{mass} = \text{volume} \times \text{density}$  to find its mass. This can easily be done using a measuring cylinder as shown in the diagram below.

You can see how the apparent weight of the stone gets less when it is immersed in water. If it was only partly immersed it would appear to weigh less than in air but not as little as when it is totally immersed in the water.

## **Floatation**

### **The story behind principle of floatation by Archimede**

Archimede was a Greek mathematician and physicsist, born in Sicily in 287 BC and died in 212 BC. Most of the inventions of Archimedes were made to help his country during the time of war. However, the story behind the formulation of the principle of floatation is an interesting one. Briefly put, it goes this way. The king of the land had got a golden crown made, to be offered to the deity of a temple. However, he doubted the honesty of the goldsmith, due to which he wanted to make sure that it was only pure gold that was used to make the crown. The great scientist that Archimedes was, he was called by the king and was asked to check the purity of the crown, without causing any damage to it. Now, this was certainly not an easy job and it put him in a fix. However, one day as he stepped into the bathtub, he noticed the water spilling over, at that very moment, an idea occurred to him, he realized that by measuring the volume of water displaced by the crown, he could easily calculate its density. All he needed to do was divide the mass of the crown by the volume of displaced water. So much was he excited by this discovery that he took to the streets shouting, "*Eureka, eureka!*" (I found it!)

When a piece of cork is pushed into water, the cork is seen to bob up when released due to the upthrust of the on the cork.

A reference to Archimede's principle; when a object is partially immersed in a liquid an upthrust equal to the weight of the liquid displaced acts upwards on the object. But when the upward is completely immersed in the liquid, the upthrust of the liquid on the object is much greater since more liquid would have now been displaced. If the upthrust equals the weight of the object before the object is completely immersed, then the object will not sink but it will float in the liquid. When an object floats in a fluid, the weight of fluid displaced by the floating object is equal to the weight of the object, this now leads us to the principle of floatation, again if you have ever wondered how come ships sail on the sea and inflated balloons rise up in the air, here your thirst is over.

The image below shows a large ship float on a sea



## Principle of Floatation

States that an object will float in a fluid (liquid or gas) when the upthrust exerted upon it by the fluid in which it floats equals the weight of the object.

Note that, any floating object is in equilibrium under two forces: (i) Its weight acting downwards (ii). The upthrust of the liquid on the object acting upwards, so when two forces balance each other then the object will float.

## Pressure

What is Pressure? It is the amount of force acting perpendicularly per unit area.

Pressure = Force/ Area,  $P = F/A$ , unit is  $N/m^2$  or Pascal (Pa) or  $kgm^{-1}s^{-2}$ .

## Examples of Pressure:

As part examples of varying pressures we bring you these: a finger can be pressed against a wall without making any lasting impression; however, the same finger pushing a thumbtack can easily damage the wall. Although the force applied to the surface is the same, the thumbtack applies more pressure because the point concentrates that force into a smaller area. Pressure is transmitted to solid boundaries or across arbitrary sections of fluid *normal* to these boundaries or sections at every point. Unlike stress, pressure is defined as a scalar quantity. The negative gradient of pressure is called the force density.

Another example is of a common knife. If we try to cut a fruit with the flat side it obviously will not cut. But if we take the thin side, it will cut smoothly. The reason is that the flat side has a greater surface area (less pressure) and so it does not cut the fruit. When we take the thin side, the surface area is reduced and so it cuts the fruit easily and quickly. This is one example of a practical application of pressure.

## Pressure of Fluids

A fluid exerts a pressure on all bodies immersed in it. For a fluid at rest the difference in pressure between two points in it depends only upon the density of the fluid and the difference in depth between the two points. For example, a swimmer diving down in a lake can easily observe an increase in pressure with depth. For each meter (foot) increase in depth, the swimmer is subjected to an increase in pressure of 9,810 N per sq m, because water weighs 9,810 N per cu m. Since a liquid is nearly incompressible, its density does not change significantly with increasing depth. Therefore, 'the increase in pressure is caused solely by the increase in depth'.

### Example

A piece of cork density  $0.25 \times 10^3 \text{ kgm}^{-3}$  floats in a liquid of density  $1.25 \times 10^3 \text{ kgm}^{-3}$ , what fraction of the volume of the cork will be immersed?

Solution: When the cork floats, its weight equals the weight of fluid displaced.

$$\text{i.e. } 0.25 \times 10^3 V_1 \text{ kg} = 1.25 \times 10^3 V_2 \text{ kg}$$

Then fraction of cork submerged will be,  $V_2/V_1 = 0.25 \times 10^3 / 1.25 \times 10^3 = 250/1250 = 1/5$  or 0.2.

The variations in pressure of a gas are more complicated. For example, since air has such a low density compared to a liquid, a change in its pressure is only measurable between points that have a great height difference. The air pressure in a typical room is the same everywhere, but it is noticeably lower at the top of a mountain than at sea level. Because air is a gas, it is compressible. Its density decreases with increasing altitude (height). Thus, changes in air pressure depend upon both the variations in the density of air and changes in the altitude at which it is measured.

## Influences on Pressure and Effects of Pressure

Different gas laws relate the pressure of a gas to its volume, its temperature, or both. A rise in pressure affects both the melting point and the boiling point of a substance, increasing the melting and boiling points of most substances. In the case of water, however, an increase in pressure lowers its melting point.

### Tools for measuring Pressure

The instrument for measuring atmospheric pressure, **the barometer**, is calibrated to read zero when there is a complete vacuum; the pressure indicated by the instrument is therefore called **absolute pressure**. The term “pressure gauge” is commonly applied to the other instruments used for measuring pressure. Pressure is also measured with **manometers** and **vacuometers**, as well as with various pressure sensors.

## ASSESSMENT

At this point, we should be concerned about how much we have gained in this topic by **ANSWER**ing few questions below:

1. Which is an instrument for measuring Pressure?

A. Cylinder B. Speedometer C. Barometer D. Burette

2. State the principle of floatation.

3. Which of these cannot be used as the unit of pressure?

A.  $\text{N/m}^2$  B.  $\text{kgm}^{-1}\text{s}^{-2}$  C.  $\text{kgms}^{-2}$  D. Pascal (P)

4. The volume of 50 g of a substance is  $20 \text{ cm}^3$ . If the density of water is  $1 \text{ gcm}^3$  will the substance float or not?

A.  $4.5 \text{ gcm}^{-3}$  B.  $2.5 \text{ gcm}^{-3}$  C.  $7.6 \text{ gcm}^{-3}$  D.  $9.2 \text{ gcm}^{-3}$

5. The volume of a 500 g sealed packet is  $350 \text{ cm}^3$ . Will the packet float or sink in water if the density of the water is  $1 \text{ gcm}^{-3}$ , what will be the mass of the water displaced by the packet?

A. 450 g B. 378 g C. 350 g D. 305 g

## ANSWER

1. C 3. C 4. B 5. C

Workings for:

4. **ANSWER:** Mass of substance (m) = 50 g, volume of substance (v) =  $20 \text{ cm}^3$

Density of the substance = mass/ volume

$$= 50/20 = 2.5 \text{ gcm}^{-3}$$

Since the density of the substance is more than the density of water, the substance will sink.

5. Mass of the pack (m) = 500 g, volume of the packet (v) = 350 cm<sup>3</sup>

$$\text{Density of the pack} = 500/350 = 1.428 \text{ gcm}^{-3}$$

Where the density of water is 1 gcm<sup>-3</sup>.

Since the density of the packet is higher than that of the water it will sink.

Mass of water displaced by the packet = volume of the packet x density of water

$$= 350 \text{ cm}^3 \times 1 \text{ gcm}^{-3} = 350\text{g}.$$

## Week 10

### **Topic: Density, Relative Density: Definition and Experiment. Determination of solid and liquid**

Equal volumes of different substances have different masses or weights. For example 1 m<sup>3</sup> of lead weighs differently from 1 m<sup>3</sup> of wood. Also 1 m<sup>3</sup> of water has a weight different from that of sulphuric acid or palm oil of the same volume. This is due to differences of in the quality of the substances known as density.

The principle of density was discovered by the Greek Scientist named Archimedes over 2000 years ago.

Density ( $\rho$ ) is defined as the mass per unit volume of the material.

To calculate the density (usually represented by the Greek letter “ $\rho$ ”) of an object, take the mass ( $m$ ) and divide by the volume ( $v$ ):

$$\rho = m / v$$

The SI unit of density is kilogram per cubic meter (kg/m<sup>3</sup>) Using Density .It is also frequently represented in the cgs unit of grams per cubic centimeter (g/cm<sup>3</sup>). For example the density of water at 4°C is approximately 1gcm<sup>-3</sup>.

$$1\text{g/cm}^3 = 1 \times 10^{-3}\text{kg}/10^{-6}\text{m}^3 = 10^3 \text{kgm}^{-3}$$

To convert density from cgs to S .I. unit we merely multiply the cgs density by 10<sup>3</sup>. Thus water has a density of 1 gcm<sup>-3</sup> or 10<sup>3</sup> kgm<sup>-3</sup>.

Table below shows the density values of some solids and liquids:

<b>Material</b>	<b>Density</b>
Aluminum	2.7 x 10 <sup>3</sup>
Copper	8.9 x 10 <sup>3</sup>
Bamboo wood	0.4 x 10 <sup>3</sup>
Gold	19.3 x 10 <sup>3</sup>
Glass	2.6 x 10 <sup>3</sup>

Lead	$11.3 \times 10^3$
Platinum	$21.5 \times 10^3$
Iron	$7.9 \times 10^3$
Steel (variable)	$7.8 \times 10^3$
Ice (at $0^\circ$ )	$0.92 \times 10^3$
Water (at $4^\circ$ )	$1 \times 10^3$
Mercury	$13.6 \times 10^3$
Sand (variable)	$2.6 \times 10^3$
Methylated spirit	$0.8 \times 10^3$
Paraffin wax	$0.9 \times 10^3$
Zinc	$7.1 \times 10^3$

One of the most common uses of density is in how different materials interact when mixed together. Wood floats in water because it has a lower density, while an anchor sinks because the metal has a higher density. Helium balloons float because the density of the helium is lower than the density of the air.



**To measure the density of a liquid**

*To find the mass;*

Weigh an empty graduated cylinder, and then weigh the graduated cylinder after pouring water into it.

Then subtract the two readings.

*To find the volume* simply note the level of water in the graduated cylinder.

**Relative Density or Specific Gravity**

A concept related to density is the specific gravity (or, even more appropriate, *relative density*) of a material, which is the ratio of the material's density to the density of water. An

object with a specific gravity less than 1 will float in water, while a specific gravity greater than 1 means it will sink.

Relative density is defined as: R.d. = mass (or weight) of a substance/mass (or weight) of equal volume of water, it is also defined as R.d. = density of substance/density of water, note that relative density has no unit, the relative density of mercury is 13.6 but its density  $13.6 \times 10^3 \text{ kgm}^{-3}$ . In the cgs unit where the density of water is  $1 \text{ gcm}^{-3}$ , the density of a substance is numerically equal to its relative density.

Material	Specific Gravity
Balsa Wood	0.2
Oak Wood	0.75
Ethanol	0.75
Water	1
Table Salt	2.17
Aluminium	2.7
Iron	7.87
Copper	8.96
Lead	11.35
Mercury	13.56
Depleted Uranium	19.1
Gold	19.3
Osmium	22.59

### **Measurement of Density and Relative Density**

1 A body that can sink in water e.g. lead

a. Regular solid

The density of a regular solid is obtained by measuring its mass (for example with a balance) and its volume by measuring its dimension.

**b. Irregular solid (e.g. A piece of stone)**

The mass is obtained as for regular solids but its volume is measured by immersing the object completely in a measuring cylinder containing water. The difference in the level of water before and after the immersion of the solid gives the volume of the solid. Then Density = Mass/Volume.

## **2 Relative density of a body which floats in water (e.g. cork) (using Archimedes principle)**

Because the cork cannot sink in water of its own accord, we make use of a 'sinker', i.e. a solid that can make the cork to sink or to be completely immersed in water. The sinker is first hung by a thread from the hook of spring balance and its weight when completely immersed in water is read from the balance. The cork is then tied to the thread carrying the sinker such that it does not touch the water surface. The new weight of sinker in water and the cork in air is obtained. Finally the cork is tied near the sinker and the weight of sinker and cork, both immersed in water is obtained. The relative density of cork is then calculated as follows:

Weight of sinker in water =  $W_1$

Weight of sinker in water and cork in air =  $W_2$

Weight sinker and cork in water =  $W_3$

Weight of cork in air =  $(W_2 - W_1)$

Upthrust on cork = apparent loss in weight of cork =  $(W_2 - W_3)$

Relative Density of cork = Weight of cork in air/Weight of equal volume of water

= Weight of cork in air/Upthrust on cork

=  $(W_2 - W_1) / (W_2 - W_3)$

## **3 Relative Density of solid in form of particles of powder (e.g. sand)**

We make use of a relative density bottle and a chemical balance: The relative density bottle is first cleaned, dried and weighed empty. It is then reweighed when about one third full of sand. The relative density bottle containing sand is now filled up filled with water and reweighed. Finally the bottle is emptied, cleaned of any sand particle and filled with water alone. The weight of bottle and water is cleaned. The relative density of sand is calculated as follows: Mass of empty bottle =  $M_1$

Mass of bottle + sand =  $M_2$

Mass of bottle + sand + water =  $M_3$

Mass of bottle + water only =  $M_4$

Mass of water filling the bottle =  $(M_4 - M_1)$

Mass of water having the same value as the sand =  $(M_4 - M_1) - (M_3 - M_2)$

Therefore, relative density of sand = Mass of sand/mass of equal volume of water

$$(M_2 - M_1) / (M_4 - M_1) - (M_3 - M_2)$$

4 Relative density of particle that is soluble in water (e.g. salt)

The experiment for the relative density of sand is repeated but now turpentine instead of water is used. If the density of turpentine is  $\rho \text{ gcm}^{-3}$  then the relative density is calculated as sand and become: R.D. =  $(M_2 - M_1)\rho / (M_4 - M_1) - (M_3 - M_2)$

5 Relative density of a liquid

a. Using a relative density bottle

A chemical balance is used in all the weighting involved In this experiment. The relative density bottle is cleaned, dried and weighed when empty. It is then reweighed when filled with the liquid. The emptied of the liquid, cleaned dried and reweighed when filled with the water , the R.D of the liquid calculated as follows:]

Mass of empty bottle =  $M_1$

Mass of bottle + liquid =  $M_2$

Mass of bottle + water =  $M_3$

Mass of liquid =  $(M_2 - M_1)$

Mass of equal volume of water =  $(M_3 - M_1)$

Relative density of liquid =  $M_2 - M_1 / M_3 - M_1$

Using Archimedes Principle

When an object is wholly immersed in a fluid, it experiences an upthrust (apparent loss of weight) which is equal to the weight of the fluid displaced by the object.

We make use of a solid e.g. a glass stopper. The solid is suspended from the hook of a spring balance and weighed in air, it is then weighed when completely immersed in the liquid. Finally it is cleaned, dried and reweighed when completely immersed in water. The relative density of the liquid is calculated as follows:

Mass of object in air =  $M_1$

Apparent mass of object in liquid =  $M_2$

Apparent mass of object in water =  $M_3$

Upthrust in liquid = weight of liquid displaced by the object =  $M_1 - M_2$

Upthrust in water = weight of water displaced by the object =  $M_1 - M_3$

Relative density = Upthrust in fluid/Upthrust in water

$$= \frac{M_1 - M_2}{M_1 - M_3}$$

**Quiz:** *time to test our knowledge on what has been read so far, please take each one seriously and attempt to better knowledge.*

1. Density is defined as the mass per unit .....

A. width B. height C. volume D. area.

2. A body weighs 0.30 N in air, 0.25 N when fully immersed in water and 0.27 when fully immersed in a liquid calculate: (a) its water weight loss (b) its relative density (c) the relative density of the liquid.

A. 0.07, 1, 1.6 B. 0.05, 6, 0.6 C. 0.9, 6, 1.10 D. 0.04, 9, 0.1

3. A metal block of density  $9000 \text{ kgm}^{-3}$  weighs 60 N in air. Find its weight when it is immersed in paraffin wax of density  $800 \text{ kgm}^{-3}$ . (Take  $g = 10 \text{ ms}^{-2}$ )

A. 54.67 N B. 60.67 C. 64.76 D. 96.45N

4. A relative density bottle weighs 20 g when empty, 80 g when filled with water and 100 g when filled with a liquid. Find the relative density of the liquid.

A. 1.45 B. 2.33 C. 2.08 D. 1.33

5. A stone has a mass of 120 g and a volume of  $20 \text{ cm}^3$ , what is the density of the stone?

**ANSWERS:**

1. C

2. B

3. A

4. 1.33

5.  $60 \times 10^3 \text{ kgm}^{-3}$



## Week 11

# Topic: Upthrust and Archimedes's Principle, Laws of Floatation. Pressure: definition, formulae and practical application

### Upthrust and Archimedes principle

If you try to lift up a weight in a swimming pool and then try to lift the same weight on the edge of the pool, it feels much lighter in the water.

This was supposed to have been first explained by the Greek scientist Archimedes. He said that the water gives an upward force or upthrust on any object in it.

You can weigh an object in air and then in water and actually work out the upthrust (upward force), it is the difference between the two readings. For this reason the upthrust is often called the loss in weight of the object.

Archimedes principle states that **when** a body is partly or totally immersed in a fluid it experiences an upthrust that is equal to the weight of fluid displaced by the through the object.

Upthrust = apparent loss of weight of object = weight in air – weight in liquid.

### Example problem

A lump of iron of mass 8 kg is hung in brine of density  $1100 \text{ kg/m}^3$ . If the iron has a volume of  $0.001 \text{ m}^3$ , find:

- (a) the density of iron;
- (b) the loss of weight in brine;
- (c) the apparent weight in brine.

(a) density =  $8/0.001 = 8000 \text{ g/cm}^3$

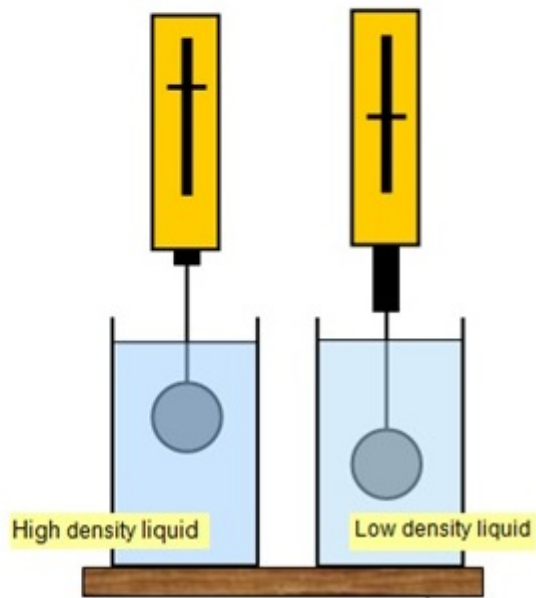
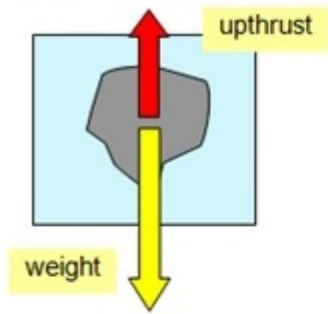
(b) loss of weight =  $0.001 \times 1100 = 1.1 \times 10 = 11 \text{ N}$

(c) apparent weight =  $80 - 11 = 69 \text{ N}$

(Force of Earth's gravity (g) =  $10 \text{ N/kg}$ )

The weight of liquid displaced is the weight of the liquid that has been replaced by the object. The volume of this amount of liquid is equal to the volume of the object itself. The weight of fluid displaced and therefore the upthrust will be bigger if the density of the liquid is large. The upthrust in salty water (relative density = 1.1) is larger than that in water (relative

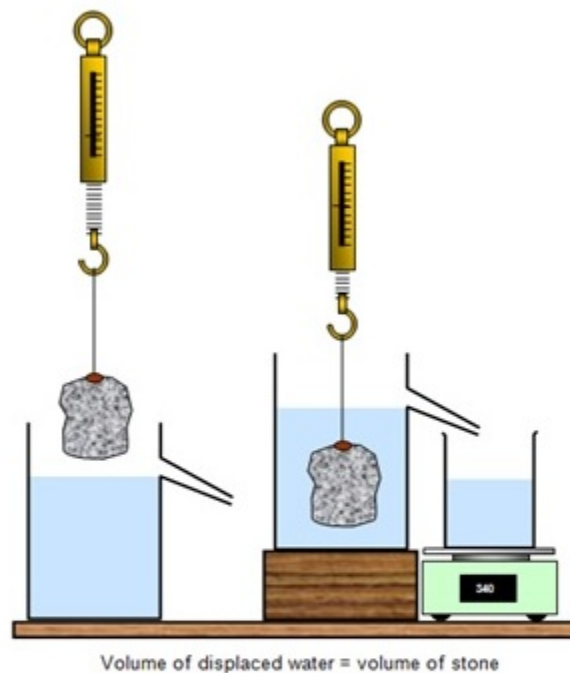
density = 1.0) for the same object. This is why it is easier to swim in the sea than in a freshwater lake.



## Archimedes principle and upthrust

Archimedes principle states that when an object is immersed in a liquid the apparent loss of weight of an object is equal to the upthrust and this is also equal to the weight of the liquid displaced. You can prove this by the following experiments.

Weigh an object in air and then lower it into a beaker of water that is resting on a top pan balance. The reading on the spring balance will get less while the reading on the top pan balance will increase by the same amount. If you already know the density of the liquid then you can simply measure the volume of displaced water and use  $\text{mass} = \text{volume} \times \text{density}$  to find its mass. This can easily be done using a measuring cylinder as shown in the diagram below.



You can see how the apparent weight of the stone gets less when it is immersed in water. If it was only partly immersed it would appear to weigh less than in air but not as little as when it is totally immersed in the water.

## Floatation

### *The story behind principle of floatation by Archimede*

Archimede was a Greek mathematician and physicist, born in Sicily in 287 BC and died in 212 BC. Most of the inventions of Archimedes were made to help his country during the time of war. However, the story behind the formulation of the principle of floatation is an interesting one. Briefly put, it goes this way. The king of the land had got a golden crown made, to be offered to the deity of a temple. However, he doubted the honesty of the goldsmith, due to which he wanted to make sure that it was only pure gold that was used to make the crown. The great scientist that Archimedes was, he was called by the king and was asked to check the purity of the crown, without causing any damage to it. Now, this was certainly not an easy job and it put him in a fix. However, one day as he stepped into the bathtub, he noticed the water spilling over, at that very moment, an idea occurred to him, he realized that by measuring the volume of water displaced by the crown, he could easily calculate its density. All he needed to do was divide the mass of the crown by the volume of displaced water. So much was he excited by this discovery that he took to the streets shouting, "*Eureka, eureka!*" (I found it!)

When a piece of cork is pushed into water, the cork is seen to bob up when released due to the upthrust of the on the cork.

A reference to Archimede's principle; when a object is partially immersed in a liquid an upthrust equal to the weight of the liquid displaced acts upwards on the object. But when the upward is completely immersed in the liquid, the upthrust of the liquid on the object is much greater since more liquid would have now been displaced. If the upthrust equals the weight of the object before the object is completely immersed, then the object will not sink but it will float in the liquid. When an object floats in a fluid, the weight of fluid displaced by the floating object is equal to the weight of the object, this now leads us to the principle of floatation, again if you have ever wondered how come ships sail on the sea and inflated balloons rise up in the air, here your thirst is over.

The image below shows a large ship float on a sea



### **Principle of Floatation**

States that an object will float in a fluid (liquid or gas) when the upthrust exerted upon it by the fluid in which it floats equals the weight of the object.

Note that, any floating object is in equilibrium under two forces: (i) Its weight acting downwards (ii). The upthrust of the liquid on the object acting upwards, so when two forces balance each other then the object will float.

### **Pressure**

What is Pressure? It is the amount of force acting perpendicularly per unit area.

Pressure = Force/ Area,  $P = F/A$ , unit is  $N/m^2$  or Pascal (Pa) or  $kgm^{-1}s^{-2}$ .

Examples of Pressure:

As part examples of varying pressures we bring you these: a finger can be pressed against a wall without making any lasting impression; however, the same finger pushing a thumbtack can easily damage the wall. Although the force applied to the surface is the same, the

thumbtack applies more pressure because the point concentrates that force into a smaller area. Pressure is transmitted to solid boundaries or across arbitrary sections of fluid *normal* to these boundaries or sections at every point. Unlike stress, pressure is defined as a scalar quantity. The negative gradient of pressure is called the force density.

Another example is of a common knife. If we try to cut a fruit with the flat side it obviously will not cut. But if we take the thin side, it will cut smoothly. The reason is that the flat side has a greater surface area (less pressure) and so it does not cut the fruit. When we take the thin side, the surface area is reduced and so it cuts the fruit easily and quickly. This is one example of a practical application of pressure.

### **Pressure of Fluids**

A fluid exerts a pressure on all bodies immersed in it. For a fluid at rest the difference in pressure between two points in it depends only upon the density of the fluid and the difference in depth between the two points. For example, a swimmer diving down in a lake can easily observe an increase in pressure with depth. For each meter (foot) increase in depth, the swimmer is subjected to an increase in pressure of 9,810 N per sq m, because water weighs 9,810 N per cu m. Since a liquid is nearly incompressible, its density does not change significantly with increasing depth. Therefore, 'the increase in pressure is caused solely by the increase in depth'.

### **Example**

A piece of cork density  $0.25 \times 10^3 \text{ kgm}^{-3}$  floats in a liquid of density  $1.25 \times 10^3 \text{ kgm}^{-3}$ , what fraction of the volume of the cork will be immersed?

Solution: When the cork floats, its weight equals the weight of fluid displaced.

$$\text{i.e. } 0.25 \times 10^3 V_1 \text{ kg} = 1.25 \times 10^3 V_2 \text{ kg}$$

Then fraction of cork submerged will be,  $V_2/V_1 = 0.25 \times 10^3 / 1.25 \times 10^3 = 250/1250 = 1/5$  or 0.2.

The variations in pressure of a gas are more complicated. For example, since air has such a low density compared to a liquid, a change in its pressure is only measurable between points that have a great height difference. The air pressure in a typical room is the same everywhere, but it is noticeably lower at the top of a mountain than at sea level. Because air is a gas, it is compressible. Its density decreases with increasing altitude (height). Thus, changes in air pressure depend upon both the variations in the density of air and changes in the altitude at which it is measured.

### **Influences on Pressure and Effects of Pressure**

Different gas laws relate the pressure of a gas to its volume, its temperature, or both. A rise in pressure affects both the melting point and the boiling point of a substance, increasing the melting and boiling points of most substances. In the case of water, however, an increase in pressure lowers its melting point.

## Tools for measuring Pressure

The instrument for measuring atmospheric pressure, **the barometer**, is calibrated to read zero when there is a complete vacuum; the pressure indicated by the instrument is therefore called **absolute pressure**. The term “pressure gauge” is commonly applied to the other instruments used for measuring pressure. Pressure is also measured with **manometers** and **vacuometers**, as well as with various pressure sensors.

At this point, we should be concerned about how much we have we have gained in this topic by answering few questions below:

1. Which is an instrument for measuring Pressure?

A. Cylinder B. Speedometer C. Barometer D. Burette

2. State the principle of floatation.

3. Which of these cannot be used as the unit of pressure?

A.  $\text{N/m}^2$  B.  $\text{kgm}^{-1}\text{s}^{-2}$  C.  $\text{kgms}^{-2}$  D. Pascal (P)

4. The volume of 50 g of a substance is 20  $\text{cm}^2$ . If the density of water is 1  $\text{gcm}^3$  will the substance float or not?

A. 4.5  $\text{gcm}^{-3}$  B. 2.5  $\text{gcm}^{-3}$  C. 7.6  $\text{gcm}^{-3}$  D. 9.2 $\text{gcm}^{-3}$

5. The volume of a 500 g sealed packet is 350  $\text{cm}^3$ . Will the packet float or sink in water if the density of the water is 1  $\text{gcm}^{-3}$ , what will be the mass of the water displaced by the packet?

A. 450 g B. 378 g C. 350 g D. 305 g

## ANSWER:

1. C 3. C 4. B 5. C

Workings for:

4. **ANSWER:** Mass of substance (m) = 50 g, volume of substance (v) = 20  $\text{cm}^3$

Density of the substance = mass/ volume

=  $50/20 = 2.5 \text{ gcm}^{-3}$

Since the density of the substance is more than the density of water, the substance will sink.

5. Mass of the pack ( $m$ ) = 500 g, volume of the packet ( $v$ ) = 350 cm<sup>3</sup>

Density of the pack =  $500/350 = 1.428 \text{ gcm}^{-3}$

Where the density of water is  $1 \text{ gcm}^{-3}$ .

Since the density of the packet is higher than that of the water it will sink.

Mass of water displaced by the packet = volume of the packet x density of water

=  $350 \text{ cm}^3 \times 1 \text{ gcm}^{-3} = 350\text{g}$ .

## Week 12

### **Topic: Measurements and unit, Work done in a force field; definition of force field, Types of energy and energy conversion**

In everyday life, the term *work* is applied to any form of activity that requires the exertion physical or mental effort, someone may say 'I go to work', another may say 'I work in the office of the director', so it is used variously with different meaning as it appeals to the user.

In physics however, the term is used in a specific sense. Work is said to be done, whenever a force is applied to cause a body to move, when a car is pushed a certain distance, or a load is lifted from the floor on to the table, you are said to do work. When no movement takes place after you have applied a force to a body, no work is done. Read this and you will marvel, If at a point you lift a bowl full of oranges from the ground floor on to your head and you remain at that point for twenty years without moving an inch, you have done no work, except that you lifted the bowl of oranges from the ground to your head, which could only be regarded as though you have done work, in its scientific true sense no work has been done by you in carrying the load and failing to move away from that spot, again, since no distance was covered, you have only done nothing.

Work refers to an activity involving a force and movement in the direction of the force. A force of 20 newtons pushing an object 5 meters in the direction of the force does 100 joules of work.

Work is said to be done whenever a force moves its point of application a distance in the direction of the force.

**Work** is defined as the product of the force and the displacement in the direction of the force.

$$W = F \times S$$

The unit of work is the joule when the force is measured in newtons and the displacement in metres. Thus the work done when a force of 10 newtons displaces an object through 5 metres is given by  $W = 10 \times 5 = 50$  joules.

#### **Work done in a force field**

We must note that the earth's gravitational field was an example of a force field. In that gravitational field there is always a force pulling a body towards the earth's centre. We define the weight of a body as the as the force of attraction on the body due to the earth's gravity,

this weight acts downward. To lift a load through a height  $h$ , a pulling force must be applied to overcome the weight of the body. Therefore, when an object is lifted vertically upwards, work is done against the force of gravity or against the weight of the body. The magnitude of the work done is given by

Work = force x distance

$$= mg \times h$$

$$= mgh$$

Where  $m$  = mass of the body,  $g$  = acceleration due to gravity and  $h$  = height. ( $g = 10 \text{ ms}^{-2}$ ).

For instance if a boy of mass  $m$ , moves up a step of steps of total height  $h$ , the work done by the boy = his weight ( $mg$ ) x the height  $h$ .

Hence to lift a body against a force field (e.g. gravity) an opposing force is needed. Work done against gravity is equal to the product of the weight of the body ( $mg$ ) and the vertical upward displacement ( $h$ )

$$w = m g h.$$

If a body of mass 50 kg runs up a set of steps of total height 3.0 m, find the work done against gravity.

Solution: Work done =  $mgh = 50 \times 10 \times 3 = 1500$  joules

### ***Falling bodies***

When a body falls freely in a force field, the force of the field does work on the body. Hence for a body falling freely under gravity, the earth's gravitational force does work on the body. If a body of mass  $m$ , falls through a vertical height  $h$ , the work done by gravity on the body is given by  $w = mgh$

### **Energy**

Energy is defined as the capacity to do work. Anything that is capable of doing work has energy. A person pushing a car along a road is doing work on the car. The person is said to possess energy which he exercises by making the car move some distance. A student running down the school field has energy. He is capable of moving his weight some distance, a mango fruit falling from the top of the tree all possess energy.

Work and energy are measured in the same unit, the joule. There are many forms of energy. These include: mechanical energy, heat (thermal) energy, light energy, chemical energy, electrical energy, atomic energy and solar energy.

Under mechanical energy, there are two classifications i.e. *Potential and Kinetic energy*.

Potential Energy (P.E.) is simply 'stored energy' or the energy possessed by a body by virtue of its position or state.

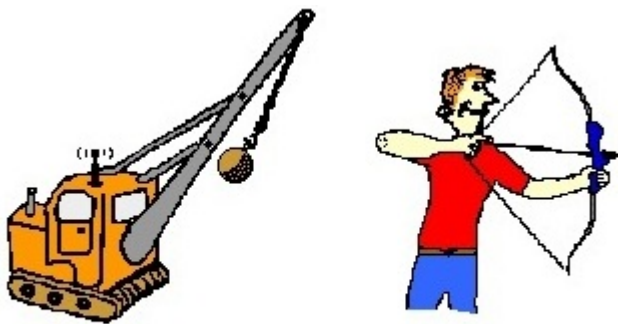
Such stored is used to do work when the body is free to move. A heavy note on top of a table has potential energy. When allowed to fall on to a glass plate on the floor, it will shatter the plate. The potential energy of the plate due to its position above the floor is expended in shattering the plate.

A body may have a potential energy due to its position in a force field, if the force field is the gravitational field then the body is said to possess a gravitational potential energy. The stone resting on top of a table has gravitational potential energy due to its height above the ground level .If the body is of mass  $m$  and the height of the table is  $h$ , the gravitational potential energy is given by  $E_{gp} = mgh$ , where  $g$  is the acceleration due to gravity, if  $m$  is in  $kg$ ,  $g$  in  $ms^{-2}$  and  $h$  in metres, then  $E_{gp}$  the potential energy is in joules.

**Other examples of potential energy are:**

A magnet at rest in a magnetic field (magnetic potential energy), an electric charge at rest in an electric field (electrical potential energy), a coiled spring when stretched or compressed possesses elastic potential energy also chemical potential energy is released when petrol, wood and other fuel sources burn.

An object can store energy as the result of its position. For example, the heavy ball of a demolition machine is storing energy when it is held at an elevated position. This stored energy of position is referred to as potential energy. Similarly, a drawn bow is able to store energy as the result of its position. When assuming its *usual position* (i.e., when not drawn), there is no energy stored in the bow. Yet when its position is altered from its usual equilibrium position, the bow is able to store energy by virtue of its position. This stored energy of position is referred to as potential energy. Potential energy is the stored energy of position possessed by an object.



**The massive ball of a demolition machine and the stretched bow possesses stored energy of position - potential energy.**

There is a direct relation between gravitational potential energy and the mass of an object. More massive objects have greater gravitational potential energy. There is also a direct relation between gravitational potential energy and the height of an object. The higher an object is elevated, the greater the gravitational potential energy.

## Kinetic Energy

Kinetic Energy is the energy of motion. An object that has motion – whether it is vertical or horizontal motion – has kinetic energy. There are many forms of kinetic energy – vibrational (the energy due to vibrational motion), rotational (the energy due to rotational motion), and translational (the energy due to motion from one location to another). To keep matters simple, we will focus upon translational kinetic energy. The amount of translational kinetic energy (from here on, the phrase kinetic energy will refer to translational kinetic energy) that an object has depends upon two variables: the mass ( $m$ ) of the object and the speed ( $v$ ) of the object. The following equation is used to represent the kinetic energy (KE) of an object.

$$K.E = \frac{1}{2} MV^2$$

where  $m$  = mass of object

$v$  = speed of object

This equation reveals that the kinetic energy of an object is directly proportional to the square of its speed. That means that for a twofold increase in speed, the kinetic energy will increase by a factor of four. For a threefold increase in speed, the kinetic energy will increase by a factor of nine. And for a fourfold increase in speed, the kinetic energy will increase by a factor of sixteen. The kinetic energy is dependent upon the square of the speed. As it is often said, an equation is not merely a recipe for algebraic problem solving, but also a guide to thinking about the relationship between quantities.

Kinetic energy is a scalar quantity; it does not have a direction. Unlike velocity, acceleration, force, and momentum, the kinetic energy of an object is completely described by magnitude alone. Like work and potential energy, the standard metric unit of measurement for kinetic energy is the Joule. As might be implied by the above equation, 1 Joule is equivalent to  $1 \text{ kg} \times (\text{m/s})^2$ .

$$1 \text{ joule} = 1 \text{ kg} \times \text{m}^2/\text{S}^2$$

Find the potential energy of a boy of mass 10 kg standing on a building floor of 10 metres above the ground level.

Solution

$$P.E. = mgh$$

$$= 10 \times 10 \times 10 = 1000 \text{ joules.}$$

## Power

**Power is defined as the time rate of doing work**

If two boys of the same weight climb a flight of steps of the same height, the boy that gets to the top first is said to have the greater power. This is because he has done the work of moving that height at a shorter time. If the work  $W$  joules is done in time  $t$  seconds, then the power = work/time.

### **Power = work done or energy expended/time**

Power is measured in watt, while 1 watt = 1 joule per second.

Other commonly used units of power are the kilowatt (kW), the megawatt (MW) and the horse power (h.p.).

1kW = 1000 W =  $10^3$  W, 1 MW = 1,000,000 W =  $10^6$  W, 1 h.p. = 746 W (Where h.p. means Horsepower).

### **Transformation and Conservation of Mechanical Energy**

In physics, the **law of conservation of energy** states that the total energy of an isolated system cannot change—it is said to be *conserved* over time. Energy can be neither created nor destroyed, but can change from one form to another, for instance chemical energy can be converted to kinetic energy in the explosion of a stick of dynamite.

By an *isolated or closed system*, we mean a group of object that neither receives energy from nor gives energy to objects outside the system.

If we consider mechanical energy, the law shows that the sum of the potential energy and the kinetic energy is always constant for a given body, but the energy may change from potential energy to kinetic energy or from kinetic to potential.

A consequence of the law of conservation of energy is that a perpetual motion machine of the first kind cannot exist. That is to say, no system without an external energy supply can deliver an unlimited amount of energy to its surroundings.

### **Potential and Kinetic Energy of a simple pendulum**

The motion of a pendulum is a classic example of mechanical energy conservation. A pendulum consists of a mass (known as a *bob*) attached by a string to a pivot point. As the pendulum moves, it sweeps out a circular arc, moving back and forth in a periodic fashion. Neglecting air resistance, there are only two forces acting upon the pendulum bob. One force is gravity. The force of gravity acts in a downward direction and does work upon the pendulum bob. However, gravity is an internal force (or conservative force) and thus, does not serve to change the total amount of mechanical energy of the bob. The other force acting upon the bob is the force of tension. Tension is an external force and if it did do work upon the pendulum bob it would indeed serve to change the total mechanical energy of the bob. However, the force of tension does not do work since it always acts in a direction perpendicular to the motion of the bob. At all points in the trajectory of the pendulum bob, the angle between the force of tension and its direction of motion is 90 degrees. Thus, the force of tension does not do work upon the bob.

Since there are no external forces doing work, the total mechanical energy of the pendulum bob is conserved.

It is interesting to observe that the falling motion of the bob is accompanied by an increase in speed. As the bob loses height and PE, it gains speed and KE; yet the total of the two forms of mechanical energy is conserved.

Use your understanding of Work, Energy and Power to **ANSWER** the following questions, in a bid to ascertain assimilation level>

1. Determine the kinetic energy of a 625-kg roller coaster car that is moving with a speed of 18.3 m/s.

A. 105600 J B. 104635 J C. 160000 J D. 124980 J

2. When a tightly pivoted pendulum is falling the speed ..... and it gains .....

A. decreases, PE B. Increases, KE C. Increases, PE D. Decreases, KE

3. A car is moving at a constant speed of  $20 \text{ ms}^{-1}$ . The force retarding its motion is 500 N. Calculate the engine power of the car required to maintain the motion.

A. 11.5 kW B. 12 kW C. 16kW D. 10 kW

4. A man of mass 50 kg ascends a flight of stairs 5 m high in 5 seconds. If acceleration due to gravity is  $10 \text{ ms}^{-1}$ , the power expended is

A. 100 W B. 200 W C. 250 W D. 500 W

5. What is the value of 1 h.p. in watts?

A. 467 W B. 580 W C. 746 W D. 980 W

## **ANSWER**

1. B 2. B 3. D 4. D 5. C

## Week 13

# Topic: DEFINITION AND EFFECTS, TERMINAL VELOCITY AND ITS EXPERIMENTAL VERIFICATION

**Viscosity simply means friction in fluids.**

It is observed that it is easier to pour water or kerosene from a container than to pour honey or engine oil. A little stone dropped into a cylinder of water gets to the bottom of the cylinder faster than when the same stone is dropped into a cylinder containing engine oil or glycerine, we can also draw inference from the time of movement of a teaspoonful of castor oil through your throat to that of a teaspoonful of water. These differences are due to the property of viscosity in these liquids.

Viscosity is the internal friction between layers of a liquid or gas in motion.

Liquids which pour slowly are said to be more viscous than those which pour faster. Hence very cold thick palm oil is more viscous than very cold water.

The movement of one layer of fluid over a neighboring layer is opposed by viscous forces.

Also when a stone or a ball bearing is thrown down a cylinder of a viscous fluid, the downward motion of the body is opposed by the viscosity of the liquid. The opposition to the movement of the stone is a function of the viscosity of the fluid and hence the slower its motion.

Viscosity is denoted by  $\eta$ , measured in  $\text{Nsm}^{-2}$  (SI Unit) and a vector quantity.

Thus,  $\eta = \text{Force} / \text{Area} \times \text{velocity gradient}$ .

Effects of Viscosity

It is responsible for the different rates of flow of fluids.

It affects motion of bodies in fluids.

## Terminal Velocity

When a stone falls through a viscous fluid, it is subject to three forces: its weight ( $W$ ) acting downwards, the upthrust ( $U$ ) of the liquid on the stone acting upwards and the viscous force ( $V$ ) opposing its motion. The viscous force acts opposite to the motion of the stone, i.e. upwards.

We can therefore write the equation of motion of the stone as  $W - V - U = ma$

Where  $a$  is the acceleration of the stone through the liquid, and  $m$  is the mass of the stone. The viscous force  $V$  increases with the speed of the stone. So as the stone falls faster and faster through the liquid, the viscous force opposing the motion increases until at a maximum speed, the viscous drag, balances the downward force of the weight of stone. At this point the stone moves with constant velocity because its acceleration  $a$  is now zero. Hence our equation becomes

$$W - V - U = ma = 0$$

$$\text{Or } V = W - U$$

This constant velocity is termed the *terminal velocity*.

The terminal velocity is the maximum velocity an object (e.g. a spherical ball in a liquid) when the frictional (viscous) force due to the motion of the object becomes or is equal to the apparent weight of the object in the fluid where there is no longer net force on the object. Thus, the force with which the object now moves is called the *Drag Force*.

## Experiment to determine the terminal velocity of an object falling through a viscous fluid

The experiment to determine the terminal velocity of an object e.g. steel falling through a viscous liquid, glycerine, is described below:

**AIM:** To determine the terminal velocity of a steel ball falling through a jar of glycerine.

**APPARATUS:** Glycerine, calibrated cylinder jar, spherical steel ball, spring or lever balance, stop-watch or clock and micro-meter screw-gauge.

### METHOD:

A small mass of a spherical steel ball is attached to a spring or level balance, which is then lowered into a cylindrical jar filled with glycerine nearly to the brim. The steel ball is then allowed to freely until it reaches its terminal or steady velocity.

The time taken to reach its terminal velocity is measured by the stopwatch or clock and the distance measured easily from the calibrated jar.

The diameter of the spherical steel ball is measured with the aid of the micro-meter screw-gauge, i.e. the radius of the spherical is obtained ( $2r = D$ ).

OBSERVATION: It was observed that the object accelerated initially but after attaining its terminal velocity (constant) velocity, the steel – ball moves slowly in this velocity until it reaches the bottom of the jar.

**PRECAUTION:**

1. Drop the ball gently.
2. The ball must fall centrally down on the viscous liquid (glycerine)
3. Avoid error of measurement, i.e. of mass, time, radius of the spherical ball.

Questions:

1. Which of these is not correct for the equation of motion of the sphere?

A.  $W - V - U = ma$  B.  $W - V - U = ma = 0$  C.  $V = W + U$  D.  $V = W - U$

2. Examples of low viscous fluids are, except?

A. Kerosene B. Engine oil C. Petrol D. Ethanol

3. Examples of high viscous fluid are, except?

A. Syrup B. Grease C. Glycerine D. Alcohol

4. Viscous force ( $V$ ) ..... the motion of the sphere.

A. Supports B. Parallels C. Opposes D. None of the options correct.

5. Viscosity is the internal between layers of a liquid or gas in motion.

A. Support B. force C. velocity D friction

**ANSWER:**

1. C 2. B 3. D 4. C 5. D

## Week 14

# Topic: FIELD CONCEPT AND TYPES OF FIELD

### Concept of Fields

We define a field as a region of space under the influence of some physical agency such as gravitation, magnetism and electricity.

Force fields are forces whose sources do not require contact with the body to which they are applied. We identify such force fields as gravitational force, electric force, magnetic force and electromagnetic force.

There are two classes of force fields – scalar fields and vector fields. A scalar field is the one that has only magnitude but no direction, e.g. temperature, energy and density. A vector field is a field that has both magnitude and direction, e.g. gravitational, magnetic and electric fields.

### Gravitational Field

If we throw up massive objects, it is our common observation that they move up to their highest points, stay stationary very briefly and eventually move downwards, falling faster and faster until they hit the ground level or the lowest level on their path. The up and down movements of objects on the earth's surface are subject to the influence of the Gravitational field of the earth.

Gravitational field is a convenient and informative method of describing the gravitational attraction of one body for another at a distance. Gravitational field is a force field and influences the motion of objects in the space where it operates, without coming in contact with the objects. Gravitational field acts over a distance, it surrounds every object that has mass and it permeates all of space.

The earth attracts every object existing in the earth's gravitational field. This attraction is called gravitational attraction and its effect is to change the velocity of objects under its influence, i.e. to accelerate such objects.

The acceleration of objects due to the earth's gravitational attraction is called the acceleration due to gravity. It is represented by the symbol  $g$  whose average value is about  $9.81 \text{ ms}^{-2}$ .

The acceleration due to gravity  $g$  is uniform at a given place and is the same for all bodies irrespective of their masses. It however varies from place to place. It is minimum at the equator ( $9.78 \text{ ms}^{-2}$ ) and increases with latitude reaching the maximum value of  $9.83 \text{ ms}^{-2}$  at the poles of the earth. Hence it is less in Lagos than in London.

It is because the acceleration due to gravity is the same for all bodies in the same locality that all objects whatever their masses, when released from rest at the same point above the ground fall to the ground simultaneously (at the same time).

The force of gravitational attraction is given by  $F = mg$ , where  $g$  is the acceleration due to gravity and  $m$  is the mass of the object. When  $m = 1$ ,  $F = g$ . This is known as the Acceleration of free fall ( $g$ ) due to gravity. This is the force of attraction on a unit mass.

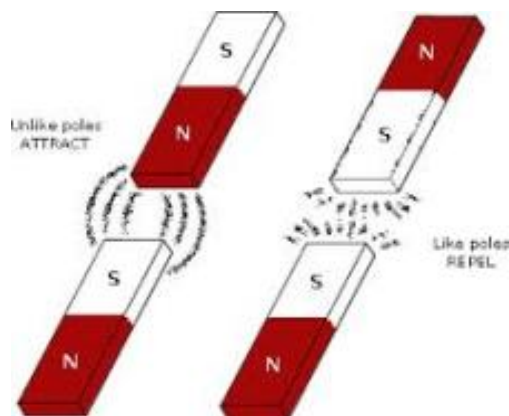
All bodies at the same place in its earth's gravitational field are accelerated at the same rate,  $g$ , due to earth's gravitational attraction. We should therefore expect a stone and a feather or a sheet of paper, when dropped from the same height to reach the ground at the same time. This is not however the observation, as the stone is seen to fall faster and thus takes a shorter time to reach the ground than the feather.

This is due to air friction or resistance which retards the movement of the feather more than that of the heavier stone. Due to its large surface area, the feather falls more slowly than the stone because of the large amount of air resistance (i.e. in a vacuum) both the heavier stone and the lighter feather will reach the ground at the same time.

In the absence of air resistance or friction all bodies fall with the same acceleration irrespective of their masses.

The strength of the gravitational field is smaller on the moon than on the Earth. So an astronaut has a lower weight on the Moon than on the Earth. The force pulling him down is smaller, so he can move easily on the Moon.

## Magnets



The pole of a magnet is the proportion of the magnet where its magnetic attraction appears to be strongest.

A magnet can attract pieces of iron, nickel and cobalt. Such substances that can be attracted by a magnet are known as magnetic substances and this ability of a magnet to attract magnetic substances is called magnetism.

A bar magnet suspended about its centre in such a way as to swing freely, quickly comes to rest with its axis aligned approximately in the North-South direction.

The end of the magnet that points in the northward direction is the North pole. The other end that points approximately in the southward direction is the South Pole. If we bring the north pole of another magnet near the north pole of the suspended magnet, we will notice that the suspended magnet moves away from the new magnet. Thus there appear to be a force of repulsion between the two north poles of these magnets. Similarly a south pole of a magnet brought near the south pole of the suspended magnet will repel it.

Now we can reverse this experiment and bring the north pole of a magnet near the south pole of the suspended magnet. We will notice that the two poles now attract each other. The same attraction is noticed when south pole is brought near the north pole of the suspended magnet. We therefore conclude that:

Like or similar poles of magnets repel one another but unlike or dissimilar poles attract one another.

### **Magnetic Field**

The region around a magnet in which the influence of the magnet can be felt or detected is called a magnetic field.

This space can be mapped out using a magnetic compass needle. The compass needle when placed in a magnetic field swings around and settled in a definite direction. The swinging of the needle when in the vicinity of the magnet shows that it has been subjected to a force. The force is known as the magnetic field. Thus, magnetic field is a force field. Magnetic force can be felt at a distance. It influences an object even when not in contact with it.

Magnetic field is also a vector field, i.e. it has both magnitude and direction.

We can demonstrate the pattern or nature of the magnetic field around a bar magnet by use of (a) iron fillings (b) magnetic compass needle.

### **ASSESSMENT**

1. Define Field?
2. What is Gravitational Field?
3. Define Magnetic Field?

### **ANSWER**

1. We define a field as a region of space under the influence of some physical agency such as gravitation, magnetism and electricity.
2. Gravitational field is a convenient and informative method of the describing the gravitational attraction of one body for another at a distance.

- 
- 
3. The region around a magnet in which the influence of the magnet can be felt or detected is called a magnetic field.

**SS1**  
**PHYSICS**  
**SECOND TERM**

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## week 1

# **Topic: HEAT ENERGY, CONCEPT OF HEAT AND TEMPERATURE. EFFECTS OF HEAT: CHANGE OF STATE/ PHASE RISE/FALL IN TEMPERATURE EXPANSION/CONTRACTION, CHANGE OF RESISTANCE, SOURCE, USES OF HEAT.**



knowing the difference between heat and temperature is important. It can lead to a clearer understanding of energy. Above is a picture of an ice cube melting in a small dish. The ice, water, dish, and air are experiencing heat exchanges and temperature changes. In this section we will define both heat and temperature and hopefully reach an understanding of how they are related, but not identical ideas. What follows are introductions.

Often the concepts of heat and temperature are thought to be the same, but they are not.

Perhaps the reason the two are usually and incorrectly thought to be the same is because as human beings on Earth our everyday experience leads us to notice that when you add heat to something, say like putting a pot of water on the stove, then the temperature of that something goes up. More heat, more temperature – they must be the same, right? Turns out, though, this is not true.



## Initial Definitions

Temperature is a number. That number is related to energy, but it is not energy itself.

Temperature is a number that is related to the average kinetic energy of the molecules of a substance.

Read that last sentence carefully. It does not say that temperature is kinetic energy, nor does it state exactly what is the relation between temperature and kinetic energy?

Here is the relation: If temperature is measured in Kelvin degrees, then its value is directly proportional to the average kinetic energy of the molecules of a substance. Note that temperature is not energy, it is a number proportional to a type of energy.

Heat, on the other hand, is actual energy measured in Joules or other energy units. Heat is a measurement of some of the energy in a substance. When you add heat to a substance, you are adding energy to the substance. This added heat (energy) is usually expressed as an increase in the kinetic energies of the molecules of the substance. If the heat (energy) is used to change the state of the substance, say by melting it, then the added energy is used to break the bonds between the molecules rather than changing their kinetic energy.

So, temperature is not energy. It is, though, a number that relates to a type of energy possessed by the molecules of a substance. Temperature directly relates to the kinetic energy of the molecules.

### **Temperature can be measured in a variety of units.**

If you measure it in degrees Kelvin, then the temperature value is directly proportional to the average kinetic energy of the molecules in the substance.

Notice we did not say that temperature is the kinetic energy. We said it is a number, if in degrees Kelvin, that is proportional to the average kinetic energy of the molecules of a substance. That means if you double the Kelvin temperature of a substance, you double the average kinetic energy of its molecules.

When the average kinetic energy of the molecules goes up (a rise in temperature), the average speed of the molecules increases. A change in average kinetic energy is not directly proportional to a change in average speed.

### **More about Heat**

Heat is energy. When you add heat to a substance, you are adding energy.

*When heat (energy) goes into a substance one of two things can happen:*

1. The substance can experience a rise in temperature. The heat (the added energy) can be realized as an increase in the average kinetic energy of the molecules. The molecules now, on average, have more kinetic energy. This increase in average kinetic energy is registered as a number called temperature that changes proportionally with it. Note that this increase in the average kinetic energy of the molecules means that they will now, on average, be traveling faster than before the heat arrived.

2. The substance can change state. For example, if the substance is ice, it can melt into water. Perhaps surprisingly, this change does not cause a rise in temperature. At the exact moment before melting, the average kinetic energy of the **ice** molecules is the same as the average kinetic energy of the **water** molecules at the exact moment after melting. That is, the melting ice and the just melted water are at the same temperature. Although heat (energy) is absorbed by this change of state, the absorbed energy is not used to change the average kinetic energy of the molecules, and thus proportionally change the temperature. The energy is used to change the bonding between the molecules. Changing the manner in which the molecules bond to one another can require absorption of energy (heat) as in the case of melting, or require a release of energy (heat) as in the case of freezing.

So, when heat comes into a substance, energy comes into a substance. That energy can be used to increase the kinetic energy of the molecules, which means an increase in their temperature which means an increase in their speed. Or at certain temperatures the added heat could be used to break the bonds between the molecules causing a change in state that is not accompanied by a change in temperature.

## CHANGES OF STATE/CHANGES OF PHASE

The term 'change of phase' means the same thing as the term 'change of state'.

There are four states, or phases, of matter. They are:

- Solid
- Liquid
- Gas
- Plasma

We will not be discussing the plasma state here.

When a substance changes from one state, or phase, of matter to another we say that it has undergone a change of state, or we say that it has undergone a change of phase.

These changes of phase always occur with a change of heat. Heat, which is energy, either comes into the material during a change of phase or heat comes out of the material during this change. However, although the heat content of the material changes, the temperature does not.

## Here are the five changes of phase, listed below:

Description of Phase Change	Term for Phase Change	Heat Movement During Phase Change	Temperature Change During Phase Change
Solid to liquid	Melting/Fusion	Heat goes into the solid as it melts.	None
Liquid to solid	Freezing	Heat leaves the liquid as it freezes.	None
Liquid to gas	Vaporization, which includes boiling and evaporation	Heat goes into the liquid as it vaporizes.	None
Gas to liquid	Condensation	Heat leaves the gas as it condenses.	None
Solid to gas	Sublimation	Heat goes into the solid as it sublimates.	None

So, how could there be a change in heat during a state change without a change in temperature? During a change in state the heat energy is used to change the bonding between the molecules. In the case of melting, added energy is used to break the bonds between the molecules. In the case of freezing, energy is subtracted as the molecules bond to one another. These energy exchanges are not changes in kinetic energy. They are changes in bonding energy between the molecules.

If heat is coming into a substance during a phase change, then this energy is used to break the bonds between the molecules of the substance. Whenever ice melts into water, immediately after the molecular bonds in the ice are broken the molecules are moving at the same average speed as before, so their average kinetic energy remains the same, and, thus, their Kelvin temperature remains the same.

The molecule of ice and the molecule of water move with the same rate of vibration. This is meant to show that they have the same average speed and thus the same average kinetic energy (since they have the same mass) and thus the same Kelvin temperature. The motions are, though, greatly exaggerated. Actually, the motions of the molecules should be considered tiny vibrations.

In the ice the molecules are strongly bonded to one another, thus forming a rigid solid. When heat is added to the ice it melts, and these bonds are broken, The molecules afterward bond to one another with less strength, and water is formed.

Now, before the melting, the molecules were actually moving when in the solid state. They were vibrating back and forth. They had an average kinetic energy. So they had a Kelvin temperature proportional to this average kinetic energy.

After the melting the water molecules are moving, also. And they have the same average kinetic energy as they had before the melting. So, the water is at the same temperature the moment after the melting that the ice was at the moment before the melting.

Heat came into the situation, but it was not used to change the kinetic energy of the molecules. It was used to change the bonding between the molecules. Breaking the bonds between the molecules of the ice requires energy, and this energy is the added heat.

In a similar way heat enters a liquid to change the molecular bonding when the liquid boils or evaporates into a gas, and heat enters a solid to change the molecular bonding when it sublimates into a gas.

In an inverse way heat leaves a gas to change the molecular bonding when the gas condenses into a liquid, and heat leaves a liquid to change the molecular bonding when it freezes into a solid.

In none of these changes of state is the heat (energy) that is input or output used to change the speed of the molecules. **The average speed of the molecules is the same before and after a phase change, and so is the average kinetic energy.** And so, again, note that the temperature does not change during a change in phase, since it is proportional, in Kelvin degrees, to the average kinetic energy, which does not change.

## Sources and Uses

We consume energy in dozens of forms. Yet virtually all of the energy we use originates in the power of the atom. Nuclear reactions energize stars, including our sun. The energy we capture for use on Earth comes largely from the sun or from nuclear forces local to our own planet.

Sunlight is by far the predominant source, and it contains a surprisingly large amount of energy. On average, even after passing through hundreds of kilometers of air on a clear day, solar radiation reaches Earth with more than enough energy in a single square meter to illuminate five 60-watt light bulbs if all the sunlight could be captured and converted to electricity.

The sun's energy warms the planet's surface, powering titanic transfers of heat and pressure in weather patterns and ocean currents. The resulting air currents drive wind turbines. Solar energy also evaporates water that falls as rain and builds up behind dams, where its motion is used to generate electricity via hydropower.

Most Americans, however, use solar energy in its secondhand form: fossil fuels. When sunlight strikes a plant, some of the energy is trapped through photosynthesis and is stored in chemical bonds as the plant grows. We can recover that energy months or years later by burning wood, which breaks the bonds and releases energy as heat and light. More often, though, we use the stored energy in the much more concentrated forms that result when organic matter, after millions of years of geological and chemical activity underground, turns into fossil fuels, such as coal, oil, or natural gas. Either way, we're reclaiming the power of sunlight.

The only other original source of energy on Earth's surface is found in more local nuclear reactions, where atoms of radioactive elements such as uranium split apart into smaller atoms and liberate energy in the process. Harnessed as heat, the released energy boils

water, producing steam that turns turbines, thereby being converted to mechanical energy that generates electricity. Nuclear energy currently provides 20% of total electricity generation in the United States.

Finally, the heat of Earth's molten interior, itself largely the result of the nuclear decay of radioactive elements, provides geothermal energy. At present, it is chiefly used in only a few places, such as California and Iceland, where proximity to high temperature geothermal fields makes it practical.

**Question:**

1. Temperature is not energy; it is ..... proportional to a type of energy.  
A. Gas B. A Form C. A Number D. geologically
2. Freezing is the conversion from  
A. Liquid to solid B. Solid to gas C. Gas to liquid D. Liquid to gas
3. Heat enters a liquid to change the ..... when the liquid boils or evaporates into a gas.  
A. Atomic bonding B. Molecular bonding C. Nuclear Bonding D. Chemical bonding
4. The predominant source of energy in this 21<sup>st</sup> century is from the.  
A. Nuclear reactor B. Sunlight C. Sea D. Ground
5. Heat leaves a gas to change the molecular bonding when the gas condenses into a liquid.  
A. Liquid B. Solid C. Steam D.

**ANSWER:**

1. C    2. A    3. B    4. B    5. A

## week 2

### **Topic: Evolution of the Thermometer**

A thermometer is a device that gauges temperature by measuring a temperature-dependent property, such as the expansion of a liquid in a sealed tube. The Greco-Roman physician Galen (c. 129-c. 199) was among the first thinkers to envision a scale for measuring temperature, but development of a practical temperature-measuring device—the thermoscope—did not occur until the sixteenth century.

The great physicist Galileo Galilei (1564-1642) may have invented the thermoscope; certainly he constructed one. Galileo's thermoscope consisted of a long glass tube planted in a container of liquid. Prior to inserting the tube into the liquid—which was usually colored water, though Galileo's thermoscope used wine—as much air as possible was removed from the tube. This created a vacuum (an area devoid of matter, including air), and as a result of pressure differences between the liquid and the interior of the thermoscope tube, some of the liquid went into the tube.

But the liquid was not the thermometric medium—that is, the substance whose temperature-dependent property changes were measured by the thermoscope. (Mercury, for instance, is the thermometric medium in many thermometers today; however, due to the toxic quality of mercury, an effort is underway to remove mercury thermometers from U.S. schools.) Instead, the air was the medium whose changes the thermoscope measured: when it was warm, the air expanded, pushing down on the liquid; and when the air cooled, it contracted, allowing the liquid to rise.

#### **Early Thermometers: The Search for a Temperature Scale**

The first true thermometer, built by Ferdinand II, Grand Duke of Tuscany (1610-1670) in 1641, used alcohol sealed in glass. The latter was marked with a temperature scale containing 50 units, but did not designate a value for zero. In 1664, English physicist Robert Hooke (1635-1703) created a thermometer with a scale divided into units equal to about 1/500 of the volume of the thermometric medium. For the zero point, Hooke chose the temperature at which water freezes, thus establishing a standard still used today in the Fahrenheit and Celsius scales.

Olaus Roemer (1644-1710), a Danish astronomer, introduced another important standard. Roemer's thermometer, built in 1702, was based not on one but two fixed points, which he designated as the temperature of snow or crushed ice on the one hand, and the boiling point of water on the other. As with Hooke's use of the freezing point, Roemer's idea of designating the freezing and boiling points of water as the two parameters for temperature measurements has remained in use ever since.

#### **How a Thermometer Works**

Today, there are a variety of types of thermometers. The type that most of us are familiar with

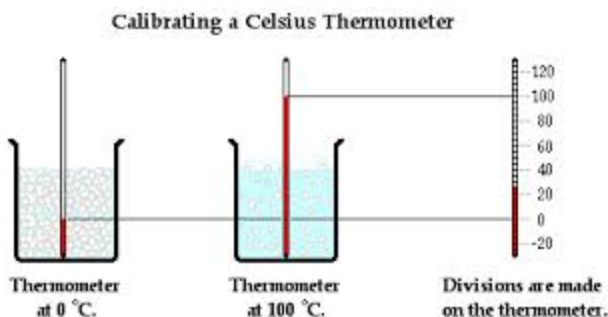
from science class is the type that consists of a liquid encased in a narrow glass column. Older thermometers of this type used liquid mercury. In response to our understanding of the health concerns associated with mercury exposure, these types of thermometers usually use some type of liquid alcohol. These liquid thermometers are based on the principle of thermal expansion. ***When a substance gets hotter, it expands to a greater volume. Nearly all substances exhibit this behavior of thermal expansion. It is the basis of the design and operation of thermometers.***

***As the temperature of the liquid in a thermometer increases, its volume***

***increases.*** The liquid is enclosed in a tall, narrow glass (or plastic) column with a constant cross-sectional area. The increase in volume is thus due to a change in height of the liquid within the column. The increase in volume, and thus in the height of the liquid column, is proportional to the increase in temperature. Suppose that a 10-degree increase in temperature causes a 1-cm increase in the column's height. Then a 20-degree increase in temperature will cause a 2-cm increase in the column's height. And a 30-degree increase in temperature will cause a 3-cm increase in the column's height. The relationship between the temperature and the column's height is linear over the small temperature range for which the thermometer is used. This linear relationship makes the calibration of a thermometer a relatively easy task.

The calibration of any measuring tool involves the placement of divisions or marks upon the tool to measure a quantity accurately in comparison to known standards. Any measuring tool – even a meter stick – must be calibrated. The tool needs divisions or markings; for instance, a meter stick typically has markings every 1-cm apart or every 1-mm apart. These markings must be accurately placed and the accuracy of their placement can only be judged when comparing it to another object known to have an accurate length.

A thermometer is calibrated by using two objects of known temperatures. The typical process involves using the freezing point and the boiling point of water. ***Water is known to freeze at 0°C and to boil at 100°C at an atmospheric pressure of 1 atm.*** By placing a thermometer in mixture of ice water and allowing the thermometer liquid to reach a stable height, the 0-degree mark can be placed upon the thermometer. Similarly, by placing the thermometer in boiling water (at 1 atm of pressure) and allowing the liquid level to reach a stable height, the 100-degree mark can be placed upon the thermometer. With these two markings placed upon the thermometer, 100 equally spaced divisions can be placed between them to represent the 1-degree marks. Since there is a linear relationship between the temperature and the height of the liquid, the divisions between 0 degree and 100 degree can be equally spaced. With a calibrated thermometer, accurate measurements can be made of the temperature of any object within the temperature range for which it has been calibrated.



### Temperature Scales

The thermometer calibration process described above results in what is known as a centigrade thermometer. A centigrade thermometer has 100 divisions or intervals between the normal freezing point and the normal boiling point of water. *Today, the centigrade scale is known as the Celsius scale, named after the Swedish astronomer Anders Celsius who is credited with its development. The Celsius scale is the most widely accepted temperature scale used throughout the world. It is the standard unit of temperature measurement in nearly all countries, the most notable exception being the United States. Using this scale, a temperature of 28 degrees Celsius is abbreviated as 28°C.*

Traditionally slow to adopt the metric system and other accepted units of measurements, the United States more commonly uses the Fahrenheit temperature scale. A thermometer can be calibrated using the Fahrenheit scale in a similar manner as was described above. The difference is that the normal freezing point of water is designated as 32 degrees and the normal boiling point of water is designated as 212 degrees in the Fahrenheit scale. As such, there are 180 divisions or intervals between these two temperatures when using the Fahrenheit scale. *The Fahrenheit scale is named in honor of German physicist Daniel Fahrenheit.* A temperature of 76 degree Fahrenheit is abbreviated as 76°F. In most countries throughout the world, the Fahrenheit scale has been replaced by the use of the Celsius scale.

Temperatures expressed by the Fahrenheit scale can be converted to the Celsius scale equivalent using the equation below:

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32^{\circ})/1.8$$

Similarly, temperatures expressed by the Celsius scale can be converted to the Fahrenheit scale equivalent using the equation below:

$$^{\circ}\text{F} = 1.8 \cdot ^{\circ}\text{C} + 32^{\circ}$$

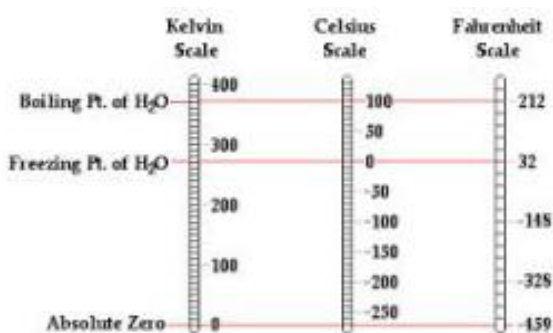
### The Kelvin Temperature Scale

While the Celsius and Fahrenheit scales are the most widely used temperature scales, there are several other scales that have been used throughout history. For example, there is the *Rankine scale, the Newton scale and the Romer scale*, all of which are rarely used. Finally, there is the Kelvin temperature scale, which is the standard metric system of temperature measurement and perhaps the most widely used temperature scale used among scientists.

The Kelvin temperature scale is similar to the Celsius temperature scale in the sense that there are 100 equal degree increments between the normal freezing point and the normal boiling point of water. However, the zero-degree mark on the Kelvin temperature scale is 273.15 units cooler than it is on the Celsius scale. ***So a temperature of 0 Kelvin is equivalent to a temperature of -273.15 °C.*** Observe that the degree symbol is not used with this system. So a temperature of 300 units above 0 Kelvin is referred to as 300 Kelvin and not 300 degree Kelvin; such a temperature is abbreviated as 300 K. Conversions between Celsius temperatures and Kelvin temperatures (and vice versa) can be performed using one of the two equations below.

$$^{\circ}\text{C} = \text{K} - 273.15^{\circ}$$

$$\text{K} = ^{\circ}\text{C} + 273.15$$



The zero point on the Kelvin scale is known as absolute zero. It is the lowest temperature that can be achieved. The concept of an absolute temperature minimum was promoted by Scottish physicist William Thomson (a.k.a. Lord Kelvin) in 1848. Thomson theorized based on thermodynamic principles that the lowest temperature which could be achieved was  $-273^{\circ}\text{C}$ . Prior to Thomson, experimentalists such as Robert Boyle (late 17th century) were well aware of the observation that the volume (and even the pressure) of a sample of gas was dependent upon its temperature. Measurements of the variations of pressure and volume with changes in the temperature could be made and plotted. Plots of volume vs. temperature (at constant pressure) and pressure vs. temperature (at constant volume) reflected the same conclusion – the volume and the pressure of a gas reduces to zero at a temperature of  $-273^{\circ}\text{C}$ . Since these are the lowest values of volume and pressure that are possible, it is reasonable to conclude that  $-273^{\circ}\text{C}$  was the lowest temperature that was possible.

Thomson referred to this minimum lowest temperature as *absolute zero* and argued that a temperature scale be adopted that had absolute zero as the lowest value on the scale. Today, that temperature scale bears his name. Scientists and engineers have been able to cool matter down to temperatures close to  $-273.15^{\circ}\text{C}$ , but never below it. In the process of cooling matter to temperatures close to absolute zero, a variety of unusual properties have been observed. These properties include superconductivity, super fluidity and a state of matter known as a Bose-Einstein condensate.

## Questions:

1. Principle of thermal expansion; when a substance gets hotter

A. It expands to a greater volume B. It expands to a greater mass C. It expands to a greater pressure D. It contracts to a lesser mass.

2. Which is correct, conversion between Celsius temperatures and Kelvin temperatures?

1.  $^{\circ}\text{C} = \text{K} + 273.15^{\circ}$  B.  $^{\circ}\text{C} = \text{K} - 273.15^{\circ}$  C.  $^{\circ}\text{C} = \text{K} - 273.15^{\circ}$  D.  $^{\circ}\text{C} = \text{K} + 273.15^{\circ}$

3. Temperatures expressed by the Fahrenheit scale can be converted to the Celsius scale equivalent using the equation below:

1.  $^{\circ}\text{C} = (\text{F} - 32^{\circ})/1.6$  B.  $^{\circ}\text{C} = (\text{F} - 32^{\circ})/1.8$  C.  $^{\circ}\text{C} = (\text{F} + 32^{\circ})/1.7$  D.  $^{\circ}\text{C} = (\text{F} + 32^{\circ})/1.8$

4. A thermometer is a device that ..... temperature by measuring a temperature-dependent property.

A. distributes B. reduces C. gauges D. manipulates

5. The first true thermometer, built by Ferdinand II, Grand Duke of Tuscany (1610-1670) in 1641, used ..... sealed in glass.

A. alcohol B. nitric acid C. ammonium D. water

**ANSWER:**

1. A 2. C 3. B 4. B 5. A

## week 3

### **Topic: Expansivity**

When heated, most solids and liquids expand. They almost contract when cooled. Expansion means an increase in the size of an object.

According to the kinetic molecular theory, when an object is heated the molecules acquire more kinetic energies which enables them to overcome their intermolecular forces. Therefore the vibrations of the molecules increase and their displacements about their mean positions increase.

As a result of this, the average distance between the molecules of the substance becomes larger leading to an increase in the size of the substance. This increase in the dimension of the heated object depends on the strength of the intermolecular forces. If these forces are stronger, the expansion will be small and vice versa.

The intermolecular forces are stronger in solids than in liquids and weakest in gases. Hence when heat is applied, gases expand more than liquids and liquids expand more than solids.

Each particular substance has an intermolecular force peculiar to it. Therefore the addition of heat causes different expansions in different substances.

#### **Advantages of expansion**

- i. Red-hot rivets in ship
- ii. Removal of tight glass stopper
- iii. Fire-alarms e.g. electric bell
- iv. Fitting of wheels in rims
- v. Expansion of metals used in bimetallic thermometer
- vi. Bimetallic strip used in thermostat

#### **Disadvantages of expansion**

- i. Expansion of metal or concrete bridges
- ii. Cracking of glass cup when hot water is poured into it

- iii. Expansion of balance wheel or wrist-watch
- iv. Sagging of overhead – wire
- v. Expansion of railway lines
- vi. Bursting of water pipes.

## Expansion in Solid

Solids expand when heated and contract when cooled. We can demonstrate this by the 'ball and ring experiment'.

### Ball and Ring Experiment



In experiments, the **ball and ring experiment** is a volume expansion demonstration experiment in which: (a) a cold (room temperature) brass ball is shown to be able to pass through tightly-fitted brass ring, (b) the ball is then heated with a flame, and (c) the experimenter then shows that the hot steel ball is unable to fit through the ring, as it previous was able to before, in the cold state, thus providing experimental proof that bodies do measurably expand when heated.

A *circa* 1900 version of the ring and ball experiment, is shown adjacent, wherein, a brass ball with a diameter of 29 mm, at height 260 mm, when heated will not pass through the brass ring, but when cold or ambient temperature will.

### Steel rod Experiment

This experiment shows how a solid expands when subjected to a particular temperature and contracts when cooled. Consider a rod clamped on a retort stand so that its order end is just on an insulator and allowed to roll on. When it is heated, the rod expands away from its initial point on the rule, which can be seen as the pointer moves and when the flame is removed, the rod contracts and the pointer returns to its original position. This shows expansion when heated and contraction when cooled.

## Application of Expansion

1. Railway tracks: Railway tracks have gaps to make allowance for expansion due to a rise in temperature, otherwise the rails would buckle. In past years, many miles of railway tracks have been replaced with long sections of continuously welded track. The old track had fish-plate junctions at fairly short intervals. A “clickety-click” effect was then felt as the train passed over the jointed parts. The newer and safer track has long rail lengths joined by rigid welds. These are flat with the rail surfaces to give a much smoother train ride.

Bimetal Strips: A bimetal strip is heated, it curves with the brass outside of the curve. This shows that brass expands more than iron for the same temperature rise. The bimetal strip straightens when it cools to room temperature. If it cooled below room temperature, the brass would contract more than the iron. So, the strip would curve with the iron on the outside of the curve.

Rivets: Steel plate such as those used in ship building or in large boilers are usually riveted together using red-hot rivets. Plates are made in the overlapping plates, A and C, a red-hot rivet is pushed through and its head, H, held tightly against plate A. The other end B of the rivet is hammered tight against the other plate C. On cooling, the rivet contracts and holds the plates even more tightly together. This provides a good seal against the sea for ship plates and against steam in large boilers.

## ASSESSMENT

1. When water is heated from  $0^{\circ}\text{C}$  to  $20^{\circ}\text{C}$  its volume
  - (a) goes on increasing
  - (b) goes on decreasing
  - (c) remains constant up to  $15^{\circ}\text{C}$  and then increases
  - (d) first decreases and then increases
  - (e) remains constant up to  $4^{\circ}\text{C}$  and then increases
2. 5 g of ice at  $0^{\circ}\text{C}$  is mixed with 10 g of water at  $10^{\circ}\text{C}$ . The temperature of the mixture is
  - (a)  $0^{\circ}\text{C}$
  - (b)  $2^{\circ}\text{C}$
  - (c)  $2.5^{\circ}\text{C}$
  - (d)  $5^{\circ}\text{C}$
  - (e)  $7.5^{\circ}\text{C}$
3. Equal masses of three liquids of specific heats  $C_1$ ,  $C_2$  and  $C_3$  at temperatures  $t_1$ ,  $t_2$  and  $t_3$  respectively are mixed. If there is no change of state, the temperature of the mixture is

- (a)  $(t_1 + t_2 + t_3)/3$
- (b)  $(C_1 t_1 + C_2 t_2 + C_3 t_3)/[3(C_1 + C_2 + C_3)]$
- (c)  $(C_1 t_1 + C_2 t_2 + C_3 t_3)/(C_1 + C_2 + C_3)$
- (d)  $3(C_1 t_1 + C_2 t_2 + C_3 t_3)/(C_1 + C_2 + C_3)$
- (e)  $3(t_1 + t_2 + t_3)$

4. The amount of heat required to raise the temperature of one mole of an ideal mono atomic gas through  $2^\circ\text{C}$  at constant pressure is (universal gas constant =  $R$ )
- (a)  $2R$
  - (b)  $3R$
  - (c)  $5R$
  - (d)  $5R/2$
  - (e)  $7R/2$
5. (5) Two identical rectangular strips, one of copper and the other of steel, are riveted as shown to form a bi-metal strip. On heating, the bi-metal strip will
- (a) get twisted
  - (b) remain straight
  - (c) bend with steel on the convex side
  - (d) bend with steel on the concave side
  - (e) contract

## **ANSWER**

- 1. d
- 2. a
- 3. d
- 4. c
- 5. d

## Week 4

### Topic: EXPANSIVITY

When a solid is heated to a particular temperature, the molecules it contains absorb some kinetic energy, since kinetic energy is the measure of velocity (i.e. the higher the kinetic energy, the higher the velocity of the molecules). These molecules move faster and collide with one another and with the wall of the system to the extent that the strong molecular force of attraction is broken after several collisions and by so doing the system expands. Linear expansivity of solid (metal) is defined as the increase in length per unit rise in temperature. It is denoted by  $\alpha$  and measured in  $K^{-1}$  or  $^{\circ}C^{-1}$  (SI unit).

Original length at  $t^{\circ}C = L_0$

Final length when heated at  $t_1^{\circ}C = L_1$

Final length when heated at  $t_2^{\circ}C = L_2$

Linear expansivity/coefficient of expansion =  $\alpha$

Change in temperature from  $t_2 - t_1 = \Delta\theta$ .

$$\alpha = \frac{L_2 - L_1}{L_1 \Delta\theta}$$

$$L_2 - L_1 = L_1 \alpha \Delta\theta$$

$$L_2 = L_1 (1 + \alpha \Delta\theta)$$

Example: If a metal rod of length 50m expands when heated at a temperature change of 10k, find the change in length (linear expansivity of metal), [ $\alpha = 1.5 \times 10^{-8} k^{-1}$ ]

Solution:

Using  $\alpha = \frac{L_2 - L_1}{L_1 \Delta t}$  given that  $L_1 = 50m$ ,  $t = 10k$

$$\Delta L = L_2 - L_1 = L_1 \Delta t \quad \alpha = 1.5 \times 10^{-8} k^{-1}$$

$$\Delta L = L_2 - L_1 = 1.5 \times 10^{-8} \times 10 \times 50$$

$$\Delta L = L_2 - L_1 = 750 \times 10^{-8}$$

$$\Delta L = L_2 - L_1 = 7.5 \times 10^{-6} \text{m}$$

Change in length is  $7.5 \times 10^{-6} \text{m}$

Area and Volume expansivity

When a solid is heated, it expands in all directions – in length, in breadth and in height. Hence there is an increase in the area as well as in the volume of the solid. The increase in area when a body is heated is known as area or superficial expansion.

The area or superficial expansivity,  $\beta$ , of a solid is the increase in area per unit area degree Kelvin increase in temperature or the fractional increase in area per Kelvin rise in temperature.

Similarly, an increase in volume when a body is heated is known as cubic or volume expansion and we define expansivity as follows:

The volume or cubic expansivity,  $\gamma$ , is the increase in volume of a substance per unit volume per Kelvin rise in temperature or the fractional increase in volume per Kelvin rise in temperature.

Area expansivity  $\beta$

= change in area/original area x temperature rise

$$\beta = \frac{A_2 - A_1}{A_1} \times \theta$$

where  $A_2$  = area at temperature  $\theta_2$

$A_1$  = area at temperature  $\theta_1$

$$\theta = \theta_2 - \theta_1$$

$$A_2 = A_1(1 + \beta\theta)$$

$$\text{Increase in area} = A_2 - A_1 = A_1 \beta\theta$$

**Volume Thermal Expansion:** When the temperature of a volume changed  $\Delta T$ , the change of its volume  $\Delta V$  is very nearly proportional to its initial volume multiplied by  $\Delta T$ . The Volume Expansion equation is:

$$\Delta V = \beta V_0 \Delta T$$

Where:

$\beta$ : the Coefficient of volume expansion

$V_0$ : Initial volume of the object

$\Delta V$ : Volume change of the object

$\Delta T$ : Temperature change of the object

We have seen that change in length (or volume) with changing temperature can be used to create a thermometer. The old-fashioned mercury in glass thermometer relies on this phenomenon.

But exactly how much does an object change its length (or volume) as the temperature changes? Experimentally we find that for a solid or liquid, the length change is given by,

$$\Delta l = \alpha l_0 \Delta T$$

Where  $l_0$  is the “original” length,  $\Delta T$  is the change in temperature and  $\alpha$  is the coefficient of linear expansion. The coefficient of linear expansion is approximately independent of temperature and is very small, e.g. for steel  $\alpha = 12 \times 10^{-6} \text{ K}^{-1}$ .

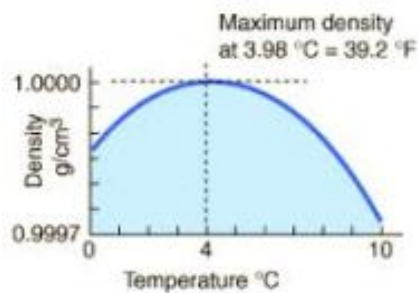
*Linear* expansion is important only when one dimension of an object is much larger than the other two. For *volume* expansion it can be shown that,

$$\Delta V = \beta V_0 \Delta T$$

where  $V_0$  is the “original” volume and  $\beta = 3\alpha$  is the volume coefficient of expansion.

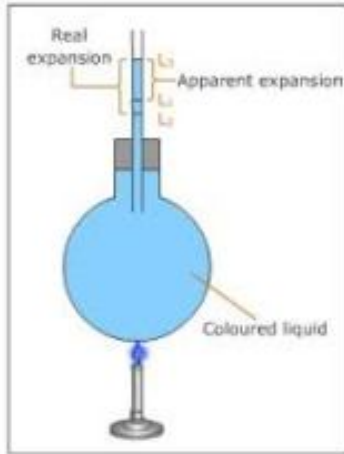
### Anomalous Expansion of Water

Water is a unique material in many ways. Without it and its unusual properties life as we know it could not exist. One of these critical properties is the so-called anomalous expansion. When heated, most substances expand according to the simple description above, but when heated through the temperature range 0 – 4°C water contracts (its density increases).



Furthermore, as you are probably aware, when water is cooled and freezes (at 0°C) the frozen water (ice) expands becoming less dense, causing problems with roads, buildings etc. This property is very unusual, most substances, on freezing contract rather than expand. This property of water explains why ice floats. If this were not the case, the ice created in the winter would sink to the bottom of lakes and oceans and would be insulated from melting in the summer. After a short time our oceans and lakes would consist of a solid mass of ice with only a thin layer at the surface alternately freezing and melting as the seasons came and went – hardly conducive to the development of life.

### Expansion of Liquid



## Liquid Expansion

### Real expansivity of liquid

Real expansivity of liquid is sometimes called cubic expansivity of liquid and it is defined as the increase in volume per unit degree rise in temperature. Since liquid does not have a particular length or area, then we talk of its volume about its container.

The cubic expansivity is sometimes called the real expansivity  $\gamma_r$

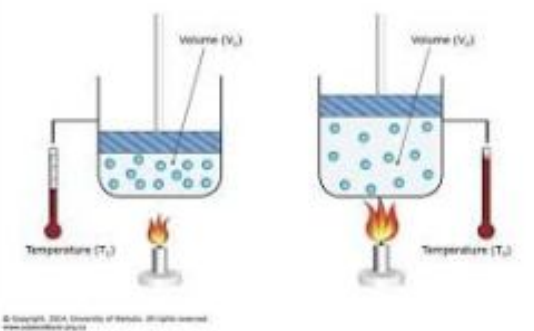
When a liquid is heated in a vessel, expansion occurs both in the liquid and in the vessel. Then from the vessel we have apparent expansivity of the liquid.

### Apparent cubic expansivity

Apparent cubic expansivity of a liquid is define as the mass of the liquid expelled per unit divided by mass left or remaining when the temperature increases by  $1^\circ\text{C}$ . It is measured in  $\text{K}^{-1}$ .

Thus,

Apparent cubic expansivity = mass of liquid expelled/mass of liquid left x temperature rise.



## Expansion of various liquids

### **ASSESSMENT**

1. On heating, amplitude of vibration of atoms or molecules of an object
  - (a) increases
  - (b) decreases
  - (c) remains constant
  - (d) none of above
2. Melting point of water is
  - (a) 323 °C
  - (b) 100 °C
  - (c) 273 °C
  - (d) 0 °C
3. Melting point is also known as
  - (a) fusion point
  - (b) constant point
  - (c) boiling point
  - (d) freezing point
4. Coefficient of volume expansion of solids is
  - (a) greater than liquids
  - (b) equal to gases
  - (c) less than liquids
  - (d) equal to liquids
5. Temperature of land rises more quickly than that of sea because
  - (a) specific heat of soil is more than water
  - (b) specific heat of soil is less than water
  - (c) soil is solid
  - (d) none of above

### **ANSWER**

1. a
2. d
3. a
4. b

5. c

## WEEK 5

### Topic: HEAT TRANSFER

Heat flows from a body at higher temperature to another at a lower temperature to another at a lower temperature. This transfer of heat can happen in three ways: conduction, convection and radiation.

#### Conduction

It is our everyday experience but when we pour hot water into an aluminum cup, the handle of the cup soon feels hot to the touch. If you deep a silver spoon into a hot tea, the handle of the spoon very quickly feels hotter than it was before. The heat from the hot water has been transferred along the metal handle to the other end of the cup or spoon by the process of conduction.

Conduction of heat is the process by which heat energy is transferred through a metal, the average position of the particles of the material remaining the same.



Heat energy is always transferred when different parts of a solid body are at different temperatures. The direction of heat transfer is always from the hotter to the cooler parts of the solid. For example, for the spoon dipped into a hot tea, the heat is transferred for the bowl of the spoon inside the hot tea to the handle of the spoon outside the tea.

Most metals (e.g copper, aluminium, silver, iron) allow heat energy to pass through them very easily. Such materials are known as good conductors of heat. Most non-metals (e.g. water, air, wood, plastic, cloth, cotton, wool, cork) are poor conductors of heat or insulators. Such materials do not allow heat to pass easily through them. The handle of a cooking utensil is made of wood or plastic which are insulators, but the cooking utensil itself is made of a good conductor (e.g. aluminum), so that heat can be conducted quickly through utensil but not through the handle. The ability of a metal to conduct heat is known as its thermal conductivity.

## **Practical application of good and bad conductors**

### **1. Cooking Utensils**

Good conductors are used whenever it is necessary to conduct heat quickly. Thus cooking pots and frying pans are usually made of metals such as aluminium which is a good conductor. Thus ensure quick transfer of heat from the fire to the food being cooked, and a quick cooking of the food.

On the other hand, the handles of cooking utensils are made of insulators like wood or plastic materials, so that the utensils when hot can be held comfortably by the handle.

### **2. Use of rugs on floors**

A tile floor is much colder to the feet than a rug covered floor at the same temperature. This is because tile is a better conductor of heat than rug. Heat transferred from one foot to the rug is not conducted away rapidly, so the rug quickly heats up on its surface to the temperature of the foot; but the tile conducts the heat away rapidly from one's foot, and thus can take more heat from the foot, so its surface temperature drops and the foot feels cold.

### **3. Home Cooling in the Tropics**

It is our common experience that thatched-roofed houses are cooler inside than galvanized iron roofed ones, especially in the absence of asbestos ceilings. The iron conducts the heat from the sun and heats up inside the house. To reduce this heat asbestos ceilings are used. Asbestos is an insulator and prevents the heating up of the house. Thatched-roofed houses need no ceilings to maintain cool temperatures because their materials are insulators and do not conduct the heat from the sun into the room.

### **4. The use of cloth to keep warm**

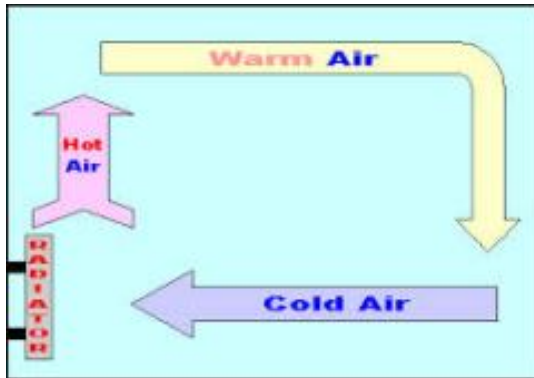
Clothes keep us warm through holding air between the cloth and the body. It is not the clothes that warm the body but the air (a poor conductor) that the cloth traps around the body. Hence clothing made from woolen and fur materials are worn in the cold climates to retain heat and keep the body warm.

## **Convection**

Heat can be transferred by convection in liquids and gases. Particles in the liquid or gas collide with a substance that has a high temperature and the particles gain kinetic energy. The particles move to a region which has substance at a lower temperature and the particles transfer heat by colliding with the colder substance. In this way the high temperature substance has heat taken away from it and gets colder. The low temperature substance has heat given to it and gets warmer. The liquid or gas that transfers the heat can circulate round and round between the hot and cold regions. The flow of liquid or gas is called convection current. Convection currents are caused by changes in density.

You may be asked to draw the direction of convection currents and explain why they move in this way.

The picture below shows a radiator heating a room in a house.



The hot radiator transfers heat to the nearby air when air molecules collide with the radiator surface.

The air is also heated by infra-red radiation. The hot air near to the radiator expands and increases in volume. Hot air expands because the particles move further apart as they get hotter (see the structure of a gas). This makes the density of the hot air decrease and it starts to rise upwards. The colder air above it gets pushed along to the right and then circulates as shown by the arrows. The arrows show how the convection currents move. As the hot air moves around the room, it loses its heat by collision with the walls, ceiling and the objects in the room. Finally the colder air circulates near to the radiator where it is heated and the whole process repeats itself. The efficiency of convection can be improved by placing shiny metal foil behind the radiator.

### **Convection current in Nature: Land and Sea Breezes**

Land and sea breezes are the result of convection current in nature. In a hot day the sun warms the land more quickly than the sea, because the land is a better absorber of heat and also has a lower specific heat capacity. As a result, the air near the land warms up and rises. Cooler air from the sea moves in to replace the risen air. The convection current is completely by the air in the upper atmosphere moving down in the opposite direction.

The cool breeze that blows inland from the sea is known as a sea breeze.

At night, the reverse process takes place. The sea retains much of its heat in the night, while the land temperature drops considerably. As a result the sea is warmer than the land. Convection current is set up in the opposite direction to the daytime. The breeze from the land to the sea is known as land breeze.

## **Practical application of convection currents in cooling devices**

### **1. Ventilation**

Good ventilation in houses relies on the continuous circulation of convection air currents. Air heated by respiration and fires, rises towards the ceiling and escapes through the ventilators placed near the ceiling. This is replaced by fresh, cool air from outdoor which enters the room through the windows and other openings. In this way the room is ventilated.

## **2. Cooling of motor car engine**

The motor car engine requires to be cooled to prevent overheating. Continuous convection current are utilized in the cooling process of the car engine. Water circulates round the engine by convection currents. The heat generated by the engine is conducted by the metal to the water in the jacket. The water itself is cooled by the draught of air created round the radiator by the motion of the car and the movement of the fan.

## **Radiation**

Radiation is the process by which heat is transferred from a hotter to a cooler place without heating of the intervening medium.

Thus no material medium is required in radiation, but in conduction and convection, material medium is necessary. Heat from the sun reaches the earth by radiation. Also when you warm yourself by the fire side, the heat from the fire reaches by radiation.

Infra-red radiation (also called thermal radiation) transfers heat between all objects. The frequency at which an object emits electromagnetic radiation is called its principle frequency. The principle frequency increases as the temperature increases. The Sun is hotter than the Earth and so has a higher principle frequency. Infra-red radiation is an electromagnetic wave and can travel through a vacuum. Heat from the Sun reaches us through the vacuum of space by travelling as infra-red radiation.

An object can absorb radiation (take it in), emit radiation (give it out) and reflect radiation. The hotter an object, the faster it will emit infra-red radiation. Hotter objects will emit infra-red radiation faster than they absorb it from colder objects around them. Colder objects will absorb infra-red radiation faster than they emit it to hotter objects around them. In this way heat is transferred from hotter to colder objects.

An object whose temperature does not change emits infra-red radiation at the same rate as it is absorbed.

Objects that are at the same temperature as each other absorb, emit and reflect infra-red radiation at different rates depending on the type of surface that the object has.

## **Applications of radiation**

### **Medical applications**

The uses of radiation in diagnosis and treatment have multiplied so rapidly in recent years that one or another form of radiation is now indispensable in virtually every branch of medicine. The many forms of radiation that are used include electromagnetic waves of widely

differing wavelengths (*e.g.*, radio waves, visible light, ultraviolet radiation, X rays, and gamma rays), as well as particulate radiations of various types (*e.g.*, electrons, fast neutrons, protons, alpha particles, and pi-mesons).

## **Imaging techniques**

Advances in techniques for obtaining images of the body's interior have greatly improved medical diagnosis. New imaging methods include various X-ray systems, positron emission tomography, and nuclear magnetic resonance imaging.

### **X-ray systems**

In all such systems, a beam of X radiation is shot through the patient's body, and the rays that pass through are recorded by a detection device. An image is produced by the differential absorption of the X-ray photons by the various structures of the body. For example, the bones absorb more photons than soft tissues; they thus cast the sharpest shadows, with the other body components (organs, muscles, etc.) producing shadows of varying intensity.

The conventional X-ray system produces an image of all structures in the path of the X-ray beam, so that a radiograph of, say, the lungs shows the ribs located in front and as well as in back. Such extraneous details often make it difficult for the physician examining the X-ray image to identify tumours or other abnormalities on the lungs. This problem has been largely eliminated by **computerized tomographic** (CT) scanning, which provides a cross-sectional image of the body part being scrutinized. Since its introduction in the 1970s, CT scanning, also called **computerized axial tomography** (CAT), has come to play a key role in the diagnosis and monitoring of many kinds of diseases and abnormalities.

In CT scanning a narrow beam of X rays is rotated around the patient, who is surrounded by several hundred X-ray photon detectors that measure the strength of the penetrating photons from many different angles. The X-ray data are analyzed, integrated, and reconstructed by a computer to produce images of plane sections through the body onto the screen of a television-like monitor. Computerized tomography enables more precise and rapid visualization and location of anatomic structures than has been possible with ordinary X-ray techniques. In many cases, lesions can be detected without resorting to exploratory surgery.

### **Positron emission tomography (PET)**

This imaging technique permits physicians to determine patterns of blood flow, blood volume, oxygen perfusion, and various other physiological, metabolic, and immunologic parameters. It is used increasingly in diagnosis and research, especially of brain and heart functions.

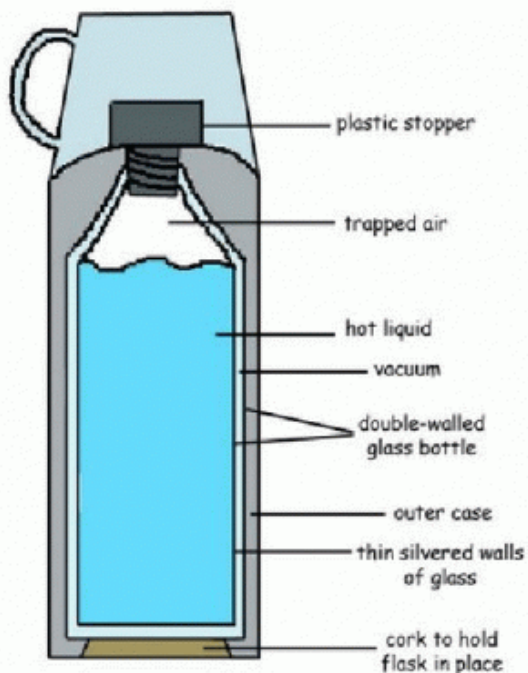
PET involves the use of chemical compounds "labeled" with short-lived positron-emitting isotopes such as carbon-11 and nitrogen-13, positron cameras consisting of photomultiplier-scintillator detectors, and computerized tomographic reconstruction techniques. After an appropriately labeled compound has been injected into the body, quantitative

measurements of its activity are made throughout the sections of the body being scanned by the detectors. As the radioisotope disintegrates, positrons are annihilated by electrons, giving rise to gamma rays that are detected simultaneously by the photomultiplier-scintillator combinations positioned on opposite sides of the patient.

### **Nuclear magnetic resonance (NMR) imaging**

This method, also referred to as magnetic resonance imaging (MRI), involves the beaming of high-frequency radio waves into the patient's body while it is subjected to a strong magnetic field. The nuclei of different atoms in the body absorb radio waves at different frequencies under the influence of the magnetic field. The NMR technique makes use of the fact that hydrogen nuclei (protons) respond to an applied radio frequency by reemitting radio waves of the same frequency. A computer analyzes the emissions from the hydrogen nuclei of water molecules in body tissues and constructs images of anatomic structures based on the concentrations of such nuclei. This use of proton density makes it possible to produce images of tissues that are comparable, and in some cases superior, in resolution and contrast to those obtained with CT scanning. Moreover, since macroscopic movement affects NMR signals, the method can be adapted to measure blood flow. The ability to image atoms of fluorine-19, phosphorus-31, and other elements besides hydrogen permit physicians and researchers to use the technique for various tracer studies as well.

### **Thermos flask – The Physics**



A thermos flask has double walls, which are evacuated and the vacuum bottle is silvered on the inside. The vacuum between the two walls prevents heat being transferred from the inside to the outside by conduction and convection. With very little air between the walls, there is almost no transfer of heat from the inner wall to the outer wall by convection.

Conduction can only occur at the points where the two walls meet, at the top of the bottle and through an insulated support at the bottom.

The silvered walls reflect radiated heat back to the inside, the same way a space blanket does. The diagram below shows across section through a thermos.

### **Action**

The students will examine the flask and explain how the three processes of heat transfer are affected by the flask. They should note that while the liquid inside is hot, and hence the inner wall is also hot, the outer wall is at approximately room temperature.

### **ASSESSMENT**

1. With respect to heat transfer through conduction, which of following inequalities place solids', 'liquids' and 'gases' in right order?
  - (a) Solids < liquids < gases
  - (b) Solids < gases < liquids
  - (c) Solids > gases > liquids
  - (d) Solids > liquids > gases
2. Which of following does not belong to list of factors that affect rate of transfer of energy by radiation?
  - (a) Color and texture of surface
  - (b) Temperature of surface
  - (c) Movement of air above surface
  - (d) Surface area
3. Rate of transfer of energy by radiation can be increased by
  - (a) increasing surface temperature
  - (b) decreasing surface area
  - (c) using shiny white surfaces instead of dull and black surfaces
  - (d) decreasing atmospheric pressure
4. Process of heat transfer that involves continual emission of infrared waves from surface of bodies and transmission of these waves without aid of medium is known as
  - (a) Conduction
  - (b) Convection
  - (c) Radiation
  - (d) None of above

5. Vacuum in a vacuum flask prevents heat transfer through process of
- (a) Conduction only
  - (b) Convection only
  - (c) Conduction and Convection
  - (d) Radiation only

## **ANSWER**

1. d
2. c
3. a
4. c
5. c

## WEEK 6

### **Topic: Production of Charges**

1. Ensure your hair is dry, then rub the barrel of a plastic biro or ball pen vigorously on it. Hold the rubbed pen near some small pieces of paper and observe the effect of the pen on the paper.
2. Rub a plastic ruler vigorously against the sleeve of your shirt or blouse. Then hold the rubbed ruler over small pieces of paper and observe the effect on the paper.
3. Comb on a hair on a dry day with a plastic comb. Observe that tufts of hair will be attracted to various parts of the comb.

Repeat this activity in front of a mirror in a dark room and report your observations.

The rubbed plastic biro or ruler attracts small pieces of paper. The comb in the above experiment attracts some hair tufts and in dark room we can observe tiny sparks between the comb and hair especially during the dry harmattan season. Also during a dry day you can feel some crackling sensation as you comb your dry hair with a plastic comb.

The plastic passing through the dry hair as well as the hair itself acquire some electric charges by friction between the two and is said to be electrified or charged or to have a charge. Similarly the plastic biro or ruler rubbed vigorously on a shirt acquires electric charge by friction between the rulers and the shirt. These electrostatically charged materials attract the small pieces of, before attracting it. The piece of paper is also charged before being attracted.

There are other observations of static electricity in our daily experience. For example we often hear some crackling noise near the ear when taking off a dry sweater or a nylon garment especially during the dry harmattan weather. Also when the attempt to take off nylon or terylene clothes in a dry weather, the clothes tend to stick to the body because they are strongly electrified. The hair on our body has a strong pull on this types of clothes.

### **Types of Charges**

There are two types of charges – positive and negative charges.

One type of electric charge could be produced by rubbing a glass rod with silk. This is the positive charge. A different type of charge could be obtained on an ebonite rod by rubbing it with fur. This type is known as the negative charge.

Rub a glass rod vigorously with silk and suspend it by a thread with a paper stirrup. Rub another glass rod by with silk and bring it near the first rod. Notice the repulsion between the two as the suspended glass rod moves away from the second glass rod.

In a similar fashion, rub an ebonite rod with fur and bring it near the suspended glass rod. Observe the attraction between the two rods.

Now, replace the suspended glass rod with an ebonite rod which has been charged by rubbing with fur. Repeat the previous experiment by bringing a charged ebonite rod and a charged glass rod in turn towards the suspended ebonite; observe that attraction and repulsion occur when the charged glass and ebonite rods are brought near the suspended charged ebonite rod.

## **ASSESSMENT**

1. Property of material due to which it attracts or repels other objects is
  - (a) friction
  - (b) velocity
  - (c) current
  - (d) charge
2. Plastic rod rubbed with fur and glass rod rubbed with silk
  - (a) repel each other
  - (b) mix up with each other
  - (c) attract each other
  - (d) none of the above
3. A negative charge
  - (a) repels neutral charge
  - (b) attracts neutral charge
  - (c) repels negative charge
  - (d) repel positive charge
4. Electric charge between two bodies can be produced by
  - (a) sticking
  - (b) rubbing
  - (c) oiling
  - (d) passing AC current
5. If mica and woolen cloth are rubbed together, then mica gets
  - (a) positively charged
  - (b) negatively charged

(c) remains neutral

(d) dual charged

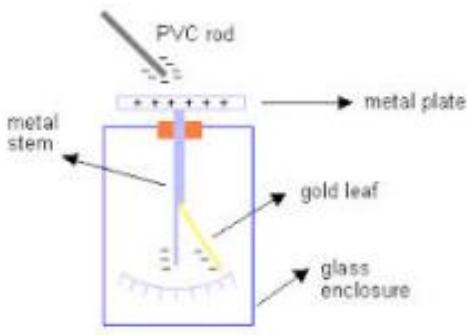
## **ANSWER**

1. d
2. c
3. c
4. b
5. a

## WEEK 7

# Topic: GOLD LEAF ELECTROSCOPE AND ITS USES, LIGHTNING CONDUCTOR

A gold leaf electroscope measures potential difference between the leaf and the base (or earth). The leaf rises because it is repelled by the stem (support). The leaf and its support have the same type of charge. A typical school electroscope will show a deflection for a charge as small as 0.01 pC (the unit pC is a pico coulomb,  $1 \times 10^{-12}$  coulombs, equivalent to the charge on over 6 million electrons).



### Charging an electroscope

There are a number of ways of charging an electroscope. They include:

**Charging by contact:** Rub an insulator to charge it up. Then stroke it across the top plate of the electroscope. This will transfer charge from the insulator to the electroscope. This method is direct and clear to students. However, the charge left on the electroscope will not always leave it fully deflected.

**Charging by induction:** This is a quick way to get a larger charge onto the electroscope. However, it can look a bit magical to students. So it should be used with some care.

Rub an insulator to charge it up. Bring it close to the top plate of the electroscope – but don't let it touch. This will induce the opposite charge on the plate of electroscope leaving a net charge on the gold leaf – which will rise. Now touch the plate with your finger momentarily to earth it (still holding the charged insulator near the top plate). The charge on the top plate will be neutralised but there will still be a charge on the gold leaf. Let go of the plate and then take the charged insulator away. The charge that had been pushed down to the gold

leaf will now redistribute itself over the plate and the leaf, leaving the whole thing charged. The leaf will show a good deflection.

## Detecting small currents

The electroscope can be used to demonstrate that a small current is flowing in a circuit – for example in experiments to show the ionisation of the air.

Using the hook rather than the plate makes the electroscope more sensitive to small amounts of charge. A charge of around 0.01 pC will cause a noticeable deflection of the gold leaf. So it is possible to watch it rise (or fall) slowly due to a current as small as 1 pA.

Put the electroscope in series (as though it were an ammeter). Any charge that flows in the circuit will move onto the electroscope making the gold leaf rise. You may need to discharge the electroscope when you first switch on the power supply because there will be an initial movement of charge due to the capacitance in the circuit.

Alternatively, you can use the electroscope as a source of charge and watch it discharge. It is like a capacitor with its own display. Charge it up and then connect it into a circuit. If the circuit conducts, the electroscope (capacitor) will discharge and, at the same time, the leaf will display how much charge is left.

## Using the electroscope as a voltmeter or electrometer

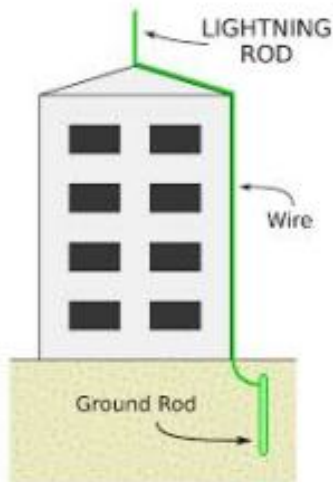
The electroscope has a very high (as good as infinite) resistance. *If you earth the electroscope case*, the electroscope measures potential so it is well suited to detecting potentials in electrostatic experiments. *Without earthing*, the quantity it is measuring is charge. This is *related to p.d.* (by its capacitance  $C$ , i.e.  $V = Q/C$ ). But it isn't the same as *p.d.* because the capacitance can vary a lot – even during an experiment. Capacitance depends on the position of the electroscope, people nearby and so on. So although the electroscope is useful as an indication of a voltage, it isn't a reliable means of measuring it.

## Cosmic radiation

School electroscopes are open to the air (more refined ones are in a vacuum). Cosmic radiation will ionise this air and cause a small leakage current. So the electroscope will discharge over time. Historically, the discharging of electroscopes led to the suggestion of the existence of cosmic radiation. Victor Hess and Carl Anderson shared the Nobel Prize for Physics in 1936, for discoveries related to cosmic radiation.

## Lightning Conductors

A lightning conductor is a metal rod or metallic object mounted on top of a building, electrically bonded using a wire or electrical conductor to interface with ground or “earth” through an electrode, engineered to protect the building in the event of lightning strike. If lightning hits the building it will preferentially strike the rod and be conducted to ground through the wire, instead of passing through the building, where it could start a fire or cause electrocution.



A lightning rod is a single component in a lightning protection system. Lightning rods are also called finials, air terminals or strike termination devices. The lightning rod requires a connection to earth to perform its protective function. Lightning rods come in many different forms, including hollow, solid, pointed, rounded, flat strips or even bristle brush-like. The main attribute of all lightning rods is they are conductive.

Copper and its alloys are the most common materials used in lightning protection.

## **Distribution of Charges on Conductors**

Experimental works have shown that charges are distributed where there is a sharp curve. The density of these charges are greater at the surface of sharp curve. The sharp per unit area of a charged surface is called surface density. Surface density is greater at the corner or pointed edge than at the plain surface.

## **ASSESSMENT**

1. If body is positively or negatively charged leaves of electroscope will
  - (a) diverge
  - (b) converge
  - (c) stay still
  - (d) shrink
2. A sensitive instrument for detecting charges is called
  - (a) gold leaf electroscope
  - (b) telescope
  - (c) compound microscope
  - (d) chemical electroscope

3. Electroscope can be charged by
  - (a) convection
  - (b) radiation
  - (c) conduction
  - (d) both A and B
4. By using electroscope, if body is negatively charged then due to electrostatic induction, then on leaves there will be appear
  - (a) both positive and negative charges
  - (b) negative charge
  - (c) positive charge
  - (d) no charge
5. Divergence of leaves depends upon the
  - (a) current
  - (b) the amount of charge
  - (c) nature of leaves
  - (d) nature of disc

## **ANSWERS**

1. a
2. a
3. c
4. b
5. b

## Week 8

# Topic: FIELD CONCEPT AND TYPES OF FIELD

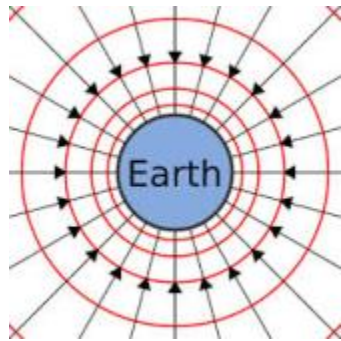
## Concept of Fields

We define a field as a region of space under the influence of some physical agency such as gravitation, magnetism and electricity.

Force fields are forces whose sources do not require contact with the body to which they are applied. We identify such force fields as gravitational force, electric force, magnetic force and electromagnetic force.

There are two classes of force fields – scalar fields and vector fields. A scalar field is the one that has only magnitude but no direction, e.g. temperature, energy and density. A vector field is a field that has both magnitude and direction, e.g. gravitational, magnetic and electric fields.

### Gravitational Field



If we throw up massive objects, it is our common observation that they move up to their highest points, stay stationary very briefly and eventually move downwards, falling faster and faster until they hit the ground level or the lowest level on their path. The up and down movements of objects on the earth's surface are subject to the influence of the Gravitational field of the earth.

Gravitational field is a convenient and informative method of the describing the gravitational attraction of one body for another at a distance. Gravitational field is a force field and influences the motion of objects in the space where it operates, without coming in contact with the objects. Gravitational field acts over a distance, it surrounds every object that has mass and its permeates all of space.

The earth attracts every object existing in the earth's gravitational field. This attraction is called gravitational attraction and its effect is to change the velocity of objects under its influence, i.e. to accelerate such objects.

The acceleration of objects due to the earth's gravitational attraction is called the acceleration due to gravity. It is represented by the symbol  $g$  whose average value is about  $9.81 \text{ ms}^{-2}$ .

The acceleration due to gravity  $g$  is uniform at a given place and is the same for all bodies irrespective of their masses. It however varies from place to place. It is minimum at the equator ( $9.78 \text{ ms}^{-2}$ ) and increase with latitude reaching the maximum value of  $9.83 \text{ ms}^{-2}$  at the poles of the earth. Hence it is less in Lagos than in London.

It is because the acceleration due to gravity is the same for all bodies in the same locality that all objects whatever their masses, when released from rest at the same point above the ground fall to the ground simultaneously (at the same time).

The force of gravitational attraction is given by  $F = mg$ , where  $g$  is the acceleration due to gravity and  $m$  is the mass of the object. When  $m = 1$ ,  $F = g$ . This is known as the Acceleration of free fall ( $g$ ) due to gravity. This is the force of attraction on a unit mass.

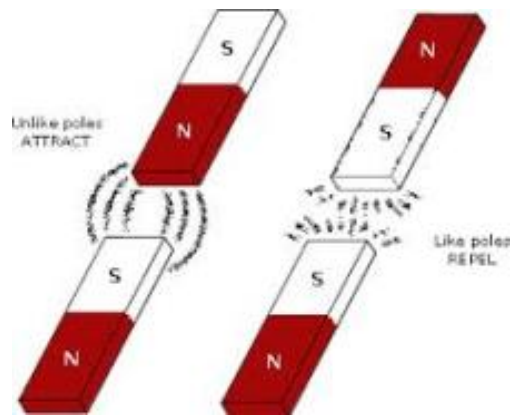
All bodies at the same place in its earth's gravitational field are accelerated at the same rate,  $g$ , due to earth's gravitational attraction. We should therefore expect a stone and a feather or a sheet of paper, when dropped from the same height to reach the ground at the same time. This is not however the observation, as the stone is seen to fall faster and thus takes a shorter time to reach the ground than the feather.

This is due to air friction or resistance which retards the movement of the feather more than that of the heavier stone. Due to its large surface area, the feather falls more slowly than the stone because of the large amount of air resistance (i.e. in a vacuum) both the heavier stone and the lighter feather will reach the ground at the same time.

In the absence of air resistance or friction all bodies fall with the same acceleration irrespective of their masses.

The strength of the gravitational field is smaller on the moon than on the Earth. So an astronaut has a lower weight on the Moon than on the Earth. The force pulling him down is smaller, so he can move easily on the Moon.

## **Magnets**



The pole of a magnet is the proportion of the magnet where its magnetic attraction appears to be strongest.

A magnet can attract pieces of iron, nickel and cobalt. Such substances that can be attracted by a magnet are known as magnetic substances and this ability of a magnet to attract magnetic substances is called magnetism.

A bar magnet suspended about its centre in such a way as to swing freely, quickly comes to rest with its axis aligned approximately in the North-South direction.

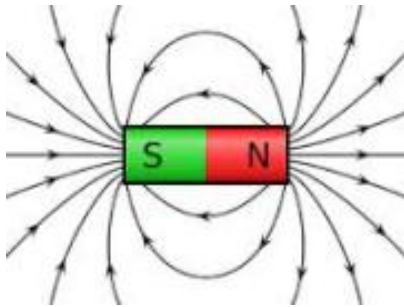
The end of the magnet that points in the northward direction is the North pole. The other end that points approximately in the southward direction is the South Pole. If we bring the north pole of another magnet near the north pole of the suspended magnet, we will notice that the suspended magnet moves away from the new magnet. Thus there appears to be a force of repulsion between the two north poles of these magnets. Similarly a south pole of a magnet brought near the south pole of the suspended magnet will repel it.

Now we can reverse this experiment and bring the north pole of a magnet near the south pole of the suspended magnet. We will notice that the two poles now attract each other. The same attraction is noticed when a south pole is brought near the north pole of the suspended magnet. We therefore conclude that:

Like or similar poles of magnets repel one another but unlike or dissimilar poles attract one another.

## Magnetic Field

The region around a magnet in which the influence of the magnet can be felt or detected is called a magnetic field.



This space can be mapped out using a magnetic compass needle. The compass needle when placed in a magnetic field swings around and settled in a definite direction. The swinging of the needle when in the vicinity of the magnet shows that it has been subjected to a force. The force is known as the magnetic field. Thus, magnetic field is a force field. Magnetic force can be felt at a distance. It influences an object even when not in contact with it.

Magnetic field is also a vector field, i.e. it has both magnitude and direction.

We can demonstrate the pattern or nature of the magnetic field around a bar magnet by use of (a) iron fillings (b) magnetic compass needle.

## **ASSESSMENT**

1. Electric field intensity is
  - (a) a base quantity
  - (b) a scalar quantity
  - (c) A and B both
  - (d) a vector quantity
2. Field lines always emerge from
  - (a) negative charge
  - (b) positive charge
  - (c) can be both charges
  - (d) the central point of both charges
3. Direction of free test charge will be
  - (a) direction of electric intensity
  - (b) direction of coulomb's force
  - (c) direction of magnetic intensity
  - (d) direction of protons
4. Spacing between field lines shows
  - (a) their direction

- (b) their position
  - (c) both A and B
  - (d) their strength
5. Region around a charge  $q$  in which it exerts force on a test charge is called
- (a) electric field intensity
  - (b) electric force
  - (c) electric field
  - (d) coulomb's force

## **ANSWERS**

- 1. d
- 2. b
- 3. a
- 4. d
- 5. c

## Week 9

### Topic: ELECTRIC FIELD

An electric field is a region of space where a charged body experiences an electric force.

The electric field is just a way of describing the action at a distance of one charge upon another. Such a field is another example of a force field and is represented by electric lines of force. Since force is a vector quantity, an electric force field has both magnitude and direction.

The direction of an electric field at any point is given by direction of the force acting on a small positive charge placed at that point.

There are two lines of fields –

- a. uniform field, in which the field lines are straight,
- b. variable field, in which the field lines are curved.

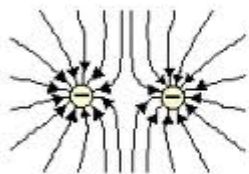
Electric line of force is an imaginary line drawn in an electric field in such a way that the direction at any point (or the direction of the tangent) gives the direction of the electric field at such a point. OR, the path which an isolated small positive charge would follow if placed in the field.

### Patterns of electric field

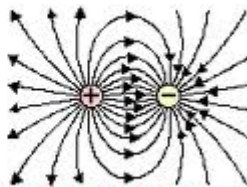
The field about an isolated positive charge is radially outward, because a positive charge placed at any point around it is repelled outward along a line through the two charges.

Similarly the field about a negative charge is radially inwards as shown. The fields for other charges or a combination of charges as shown below.

#### Other Charge Configurations

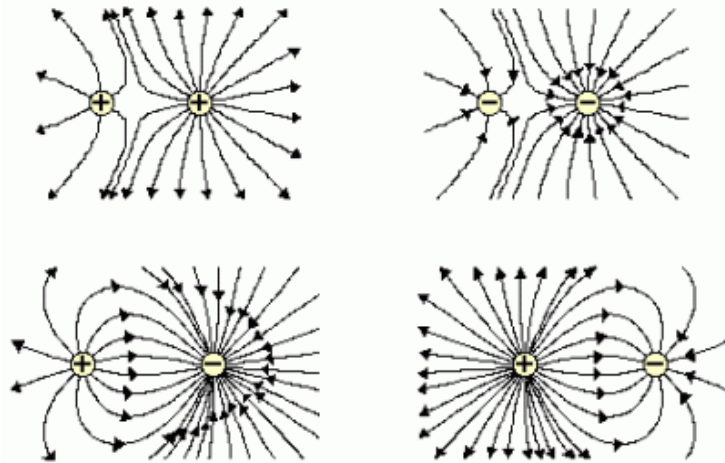


Two Negatively Charged Objects



A Positively and a Negatively Charged Object

### Electric Field Line Patterns for Objects with Unequal Amounts of Charge



## Properties of Electric Lines of Force or Field Lines

1. The electric lines of force are imaginary lines.
2. A unit positive charge placed in the electric field tends to follow a path along the field line if it is free to do so.
3. The electric lines of force emanate from a positive charge and terminate on a negative charge.
4. The tangent to an electric field line at any point gives the direction of the electric field at that point.
5. Two electric lines of force can never cross each other. If they do, then at the point of intersection, there will be two tangents. It means there are two values of the electric field at that point, which is not possible.

Further, electric field being a vector quantity, there can be only one resultant field at the given point, represented by one tangent at the given point for the given line of force.

6. Electric lines of force are closer (crowded) where the electric field is stronger and the lines spread out where the electric field is weaker.
7. Electric lines of force are perpendicular to the surface of a positively or negatively charged body.
8. Electric lines of force contract lengthwise to represent attraction between two unlike charges.
9. Electric lines of force exert lateral (sideways) pressure to represent repulsion between two like charges.

10. The number of lines per unit cross-sectional area perpendicular to the field lines (i.e. density of lines of force) is directly proportional to the magnitude of the intensity of electric field in that region.

11. Electric lines of force do not pass through a conductor. Hence, the interior of the conductor is free from the influence of the electric field.

12. Electric lines of force can pass through an insulator.

## **ASSESSMENT**

1. Particles involved in movement within material are
  - (a) protons
  - (b) electrons
  - (c) neutrons
  - (d) positrons
2. Phenomena in which a charged body attracts an uncharged body is called
  - (a) electrostatic induction
  - (b) electric current
  - (c) charge movement
  - (d) magnetic induction
3. An uncharged object has
  - (a) more protons
  - (b) more electrons
  - (c) equal electrons and protons
  - (d) no protons and electrons
4. Fields that act on objects with masses are
  - (a) electric fields
  - (b) magnetic fields
  - (c) force fields
  - (d) gravitational fields
5. Where an electric charge experiences a force, there is an
  - (a) electric field
  - (b) magnetic field
  - (c) electric current
  - (d) conventional current

## ANSWERS

1. b
2. a
3. c
4. d
5. a

## Week 10

# **Topic: PRODUCTION OF CONTINUOUS ELECTRIC CURRENT, CHEMICAL ENERGY, HEAT ENERGY, MECHANICAL ENERGY, SOLAR ENERGY**

### **Production of Electric Current**

Electric current or a continuous flow of charge can be generated from (a) chemical energy (b) heat energy (c) mechanical energy (d) solar energy.

Electricity is produced from chemical energy through the use of electric cells. A cell is a device for converting chemical energy into electrical energy.

### **Electricity from chemical energy**

Electricity is produced from chemical energy through the use of electric cells. A cell is a device for converting chemical energy into electrical energy.

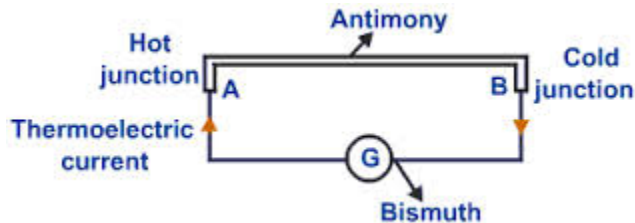
A cell consists of two dissimilar (or unlike) metals separated by solutions of various acids or salts. The metals are known as the anode, the negative electrode is the cathode. A simple cell consists of a copper rod and a zinc plate immersed in a container filled with dilute sulphuric acid (tetraoxosulphate (VI) acid).

A simple cell consists of a copper rod and a zinc plate immersed in a container filled with dilute sulphuric acid (tetraoxosulphate (VI) acid).

When the copper rod and zinc plate are joined by a conductor (e.g. a metallic wire), the zinc slowly dissolves in the acid and bubbles of hydrogen gas are formed on the copper rod. At the same time as a result of chemical reaction, electrons flow through the connecting wire from zinc to copper. Copper is the anode (+ve electrode). Zinc is the cathode (-ve electrode). By convention, current is taken to flow from copper to zinc even though the electrons move in opposite direction from zinc to copper. A bulb connected between the copper and zinc terminals will light up, showing that current is flowing through the external circuit.

### **Electricity from heat energy (The thermoelectric effect)**

We can show that heat energy can be converted into electric currents by joining two different metallic wires (e.g. copper and iron) at one end and connecting the free ends to the terminals of a sensitive current detecting device, e.g. a milli-galvanometer. When the junction of the metals is put in hot water, a current is observed to flow along the wires as indicated by the milli-galvanometer. The junction placed in hot water is known as the hot junction, while the ends connected to the instrument constitute the cold junction.



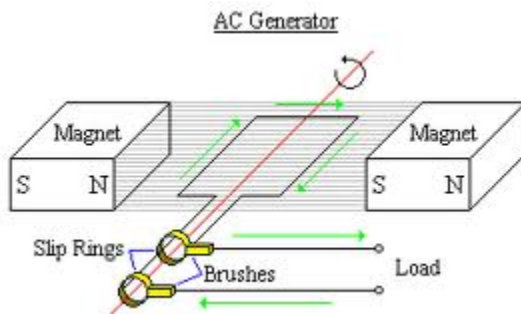
The greater the difference in temperature between the hot and cold junctions, the greater the current flow.

The two metal joined in this way constitute a device known as a thermocouple and the electricity (known as thermoelectricity) is produced by a process known as the thermoelectric effect. The current produced by the thermoelectric effect is small and can only be detected by very sensitive galvanometers.

## Electricity from mechanical energy

A great majority of the world's electricity is produced from the conversion of mechanical energy into electrical energy. When coils of insulated wire move across the magnetic field between two magnets, current is induced in the coils because the coils cut across the magnetic lines of force. The current is tapped using split-ring commutators and carbon brushes.

The electric generator or dynamo produces electricity in this way. A common example of such device is the bicycle dynamo used to supply light to the headlamp of a bicycle.



## Electricity from solar energy

When sunlight falls on a photosensitive surface (e.g. the surface of potassium, an alkaline metal), electrons are produced whose movements constitute a current. A photoelectric cell or photocell consists of a photosensitive surface as a cathode and a wire ring as the anode. If visible light falls on this surface, electrons are emitted by the photoelectric effect and the flow of these electrons can be detected as current by a micrometer.

The electrons are usually accelerated from the cathode to the anode which is at a higher potential with respect to the cathode. Solar electricity can be used to light up a whole village.

## **ASSESSMENT**

1. A boulder sitting on top of a mountain has \_\_\_\_\_ energy.
  - (a) mechanical
  - (b) kinetic
  - (c) mechanical potential
  - (d) chemical electrical
2. The form of energy found in food, wood, and batteries is \_\_\_\_\_ energy.
  - (a) chemical
  - (b) mechanical kinetic
  - (c) electrical
  - (d) solar
3. When you move your arm from side to side, your body changes
  - (a) chemical energy into mechanical kinetic energy
  - (b) heat energy into electrical
  - (c) mechanical potential energy into heat energy
4. Burning wood in a fireplace transforms \_\_\_\_\_ energy into \_\_\_\_\_ energy.
  - (a) sound, light
  - (b) chemical, heat and light
  - (c) light, heat
  - (d) mechanical kinetic, mechanical potential
5. The sun causes a tomato plant to produce tomatoes through a process called photosynthesis. What energy transformation best explains this process?
  - (a) solar to heat
  - (b) solar to chemical
  - (c) solar to electrical
  - (d) solar to mechanical kinetic

## **ANSWERS**

1. c
2. a
3. a
4. b
5. b

**SS1**  
**PHYSICS**  
**THIRD TERM**

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# Week 1

## Topic: Electricity Concept

### Electric Current

An electric charge can be at rest or in motion. We speak of static electricity when the charge is at rest, but when the charge is in motion, it is referred to as current electricity.

Electric current,  $I$ , is defined as the rate of flow of electric charge along a conductor.

A stream of moving charges (or electrons) constitute an electric current. We can describe the flow of electric charge along a conductor, e.g. a metallic wire, by expressing it in terms of the section of the conductor in a given time  $t$ . The quantity of charge  $Q$  is measured in coulombs and the time  $t$  in seconds. Hence, current  $I$ , is given mathematically by the expression:



$$I = Q/t$$

Current = quantity of charge/time

If  $Q$  is in coulombs, and  $t$  is in seconds, the current  $I$  is in amperes (A). Hence 1 ampere = 1 coulomb per second and thus we can define the coulomb as the quantity of electricity passing a section of a conductor in one second when the current is in one ampere. The commonly used submultiples of the ampere are the milliampere (mA) and the microampere ( $\mu$ A)

$$1 \text{ mA} = 10^{-3} \text{ A}, 1 \text{ } \mu\text{A} = 10^{-6} \text{ A}$$

Such low currents are common in transistor radios and the electric calculators.

Such low currents are common in transistor radios and electric calculators.

The ammeter is an instrument for measuring current. Milliammeters measure smaller currents. Very small currents are detected by sensitive instruments called galvanometers.

An ammeter is said to be sensitive, if it can detect or measure very small currents. It is said to be accurate if the current it measures is close to the true value of the current flowing in the instrument.

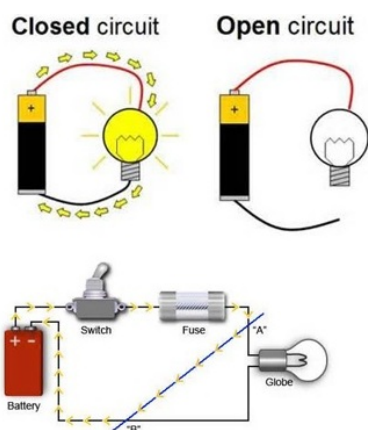
## Electric Circuit

An electric circuit is the path provided for the flow of electric current. The circuit consists of the source of electric energy (e.g.) a battery connected through a conductor (e.g. a wire) to a load (e.g. an electric bulb), and a key or a switch. The switch serves to complete (close) or break (open) the circuit.

A closed circuit is the circuit in which there is no gap (key close) along the conducting path. In such a circuit the current flows through an external resistor (or load) and the bulb lights up.

An open circuit is a circuit with a gap or opening (key open) in the conducting path. In such a circuit, the battery maintains no current in an external resistor (or load) and the bulb does not light up.

A short circuit is a closed circuit which has no load on it.



*Short circuit*

## Potential Difference

The voltage difference between any two points in a circuit is known as the **Potential Difference, p.d.** or **Voltage Drop** and it is the difference between these two points that makes the current flow. Unlike current which flows around a closed electrical circuit in the form of electrical charge, potential difference does not move or flow it is applied.

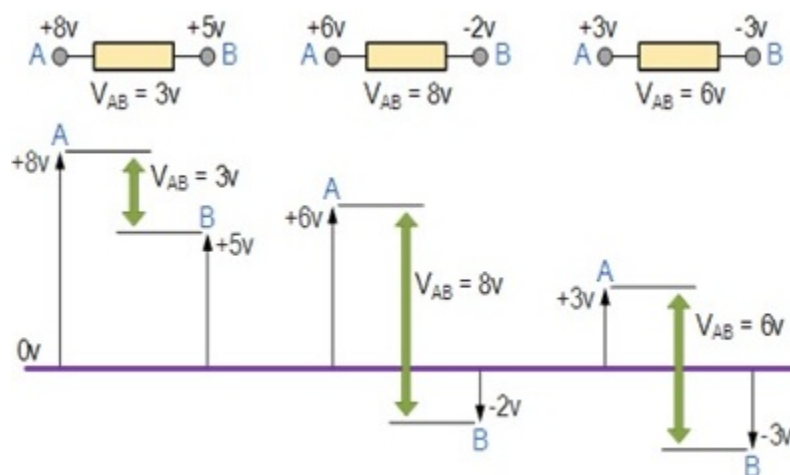
The unit of potential difference generated between two points is called the **Volt** and is defined as the potential difference across a resistance of one ohm carrying a current of one ampere. In other words, one volt = one amp x one ohm, or  $V = I \times R$

Ohm's Law states that for a Linear Circuit the current flowing through it is proportional to the potential difference across it so the greater the potential difference across any two points the bigger will be the current flowing through it.

For example, if the voltage at one side of a  $10\Omega$  resistor measures 8V and at the other side of the resistor it measures 5V, then the potential difference across the resistor would be 3V ( 8 - 5 ) causing a current of 0.3A to flow. If however, the voltage on one side was increased from 8V to say 40V, the potential difference across the resistor would now be  $40V - 5V = 35V$  causing a current of 3.5A to flow. The voltage at any point in a circuit is always measured with respect to a common point, generally 0V.

For electrical circuits, the earth or ground potential is usually taken to be at zero volts ( 0V ) and everything is referenced to that common point in a circuit. This is similar in theory to measuring height. We measure the height of hills in a similar way by saying that the sea level is at zero feet and then compare other points of the hill or mountain to that level.

In a very similar way we can call the common point in a circuit zero volts and give it the name of ground, zero volts or earth, then all other voltage points in the circuit are compared or referenced to that ground point. The use of a common ground or reference point in electrical schematic drawings allows the circuit to be drawn more simply as it is understood that all connections to this point have the same potential. For example:



As the units of measure for **Potential Difference** are volts, potential difference is mainly called **voltage**. Individual voltages connected in series can be added together to give us a “total voltage” sum of the circuit as seen in the resistors in series tutorial. Voltages across components that are connected in parallel will always be of the same value as seen in the resistors in parallel tutorial, for example.

For series connected voltages,

$$V_T = V_1 + V_2 + V_3 \dots \text{etc}$$

For parallel connected voltages,

$$V_T = V_1 = V_2 = V_3 \dots \text{etc}$$

## Electrical Resistance of a Conductor

The flow of electric charge is the cause of electric current. The electric current is due to the flow of electrons. The measurement of electrical system is done by using some properties related to it. These include resistance, electromotive force, and electric charge. The electromotive force is the flow of charges which cause of flow of electric current. It is measured in volts. It's similar to electrical pressure.

The concept of resistance is given by **Ohm in its law**. This makes redistrict in the electrical flow in the conductor. All materials have some resistance power natural which makes flow of electricity less. Materials which have low resistance increase electricity flow while materials with greater resistance need electromotive force for electricity flow. Let's discuss more about the resistance, with its units and problem based on it.

## Electrical Resistance Definition

Electrical Resistance is the property of an electrical element to oppose the flow of the current passing through it when a voltage is applied across the element. It is, mathematically, represented as the ratio of the voltage to current.

$$R = V/I$$

where,

R = resistance

V = voltage across the electrical element

I = current flowing through the electrical element

## Unit of Electrical Resistance

The Electrical Resistance is measured in ohm (O). The unit is named after German physicist *George Simon Ohm*, who discovered the famous Ohm's law. The Ohm's law states

that the current flowing through an electrical element between two points on the element is directly proportional to the voltage difference across those points.

**The unit ohm can be defined as the resistance offered by an element when a voltage of 1 volts applied to the element produces a current of 1 ampere in the element.**

The resistance of conductor is constant for large range of temperature and pressure, while there are materials other than conductors for which the resistance changes with the change in temperature or pressure or both.

The resistance is related to the resistivity of the material. The resistivity is the opposition strength of the electrical elements. The high resistivity indicates that the material have high opposition to the flow of current and low resistivity indicates that the material have low opposition to the flow of current.

The electrical element is also associated with the conductivity. It is the ability of the electrical element to allow current to pass through it. It is reciprocal of the resistivity of the element.

The resistance can be represented as, with respect to resistivity,

$$R = \rho l / A$$

where,

R = resistance of the element

$\rho$  = resistivity of the element

l = length of the element

A = cross-sectional area of the element

The Electric Resistance is also related to heat (or power) as:

$$P = V \times I$$

$$P = V \times VR$$

$$P = V^2 R$$

$$P = I \times R \times I$$

$$P = I^2 R$$

So, the power is directly proportional to the resistance of the electrical element, if the current flowing through it is constant. While the power is inversely proportional to the resistance of the electrical element, if the voltage applied to the electrical element is constant. Let's consider that the current is constant so the power (or heat) produced by the electrical element is equivalent to the resistance it offers to the flow of current. This shows

that the water heaters with high power rating are of high resistance. The heat is produced since the current is opposed by the heater and hence the generated energy is converted to the heat.

## Examples

1. Consider a copper wire with diameter 0.5mm and length 7m. Find its resistance? (Hint: resistivity of Copper is  $=1.7 \times 10^{-8} \Omega\text{-m}$ )

### Solution:

Putting all the values in the formula

$$A = \pi R^2 = \pi (0.25 \times 10^{-3})^2 = 0.19625 \times 10^{-6}$$

$$L = 7; \text{ and } \rho = 1.7 \times 10^{-8}$$

$$\text{So, } R = 1.7 \times 10^{-8} \times 70.19625 \times 10^{-6}$$

Solving, we get

$$R = 60.6369 \times 10^{-2} \Omega.$$

## ASSESSMENT.

1. Find the resistance of the metal conductor if the current passing through it is 2 amps when it is 6 V supply?

A. 4 ohms B. 6 ohms C. 3 ohms D. 12 ohms

A voltage of 1.5 volts is applied to the copper wire of diameter 20mm and length 2m?

2. Find its resistance

A.  $0.0108 \times 10^{-3}$  B.  $0.0108 \times 10^{-2}$  C.  $0.0180 \times 10^{-2}$  D.  $10.08 \times 10^{-4}$

3. The current flowing through it?

A. 13852.94 Amp B. 24852.94 Amp C. 245.45 Amp D. 2456.9 Amp

4. Three 3.0 ohms resistors are connected in parallel. What is the equivalent resistance?

A. 9.0 ohm B. 1.0 ohm C. 0.33 ohm D. 6.0 ohm

5. An electric lamp is marked 240 volts, 60 watts. What is its resistance when it is operated at the correct voltage?

A. 1/960 B.  $\frac{1}{4}$  C. 4 D. 960

## ANSWER

1. c 2. B 3. A 4. B 5. D

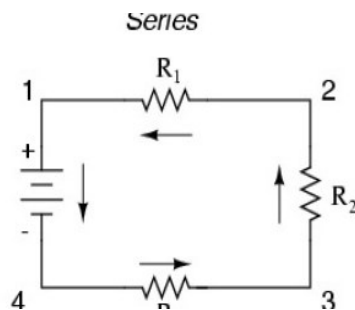
## Week 2

# Topic: Resistors in Series and Parallel

### Introduction

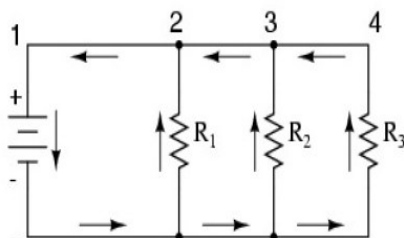
Circuits consisting of just one battery and one load resistance are very simple to analyze, but they are not often found in practical applications. Usually, we find circuits where more than two components are connected together.

There are two basic ways in which to connect more than two circuit components: *series* and *parallel*. First, an example of a series circuit:



Here, we have three resistors (labeled  $R_1$ ,  $R_2$ , and  $R_3$ ) connected in a long chain from one terminal of the battery to the other. (It should be noted that the subscript labeling — those little numbers to the lower-right of the letter “R” — are unrelated to the resistor values in ohms. They serve only to identify one resistor from another.) The defining characteristic of a series circuit is that there is only one path for electrons to flow. In this circuit the electrons flow in a counter-clockwise direction, from point 4 to point 3 to point 2 to point 1 and back around to 4.

Now, let’s look at the other type of circuit, a parallel configuration:

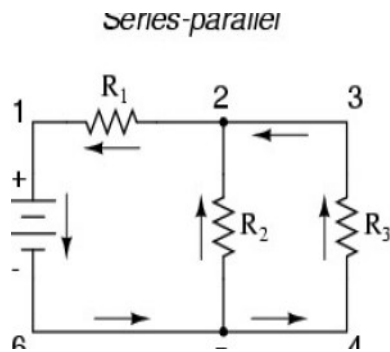


Again, we have three resistors but this time they form more than one continuous path for electrons to flow. There’s one path from 8 to 7 to 2 to 1 and back to 8 again. There’s another from 8 to 7 to 6 to 3 to 2 to 1 and back to 8 again. And then there’s a third path from 8 to 7 to 6 to 5 to 4 to 3 to 2 to 1 and back to 8 again. Each individual path (through  $R_1$ ,  $R_2$ , and  $R_3$ ) is

called a *branch*.

The defining characteristic of a parallel circuit is that all components are connected between the same set of electrically common points. Looking at the schematic diagram, we see that points 1, 2, 3, and 4 are all electrically common. So are points 8, 7, 6, and 5. Note that all resistors as well as the battery are connected between these two sets of points.

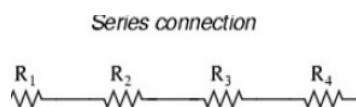
And, of course, the complexity doesn't stop at simple series and parallel either! We can have circuits that are a combination of series and parallel, too:



In this circuit, we have two loops for electrons to flow through: one from 6 to 5 to 2 to 1 and back to 6 again, and another from 6 to 5 to 4 to 3 to 2 to 1 and back to 6 again. Notice how both current paths go through  $R_1$  (from point 2 to point 1). In this configuration, we'd say that  $R_2$  and  $R_3$  are in parallel with each other, while  $R_1$  is in series with the parallel combination of  $R_2$  and  $R_3$ .

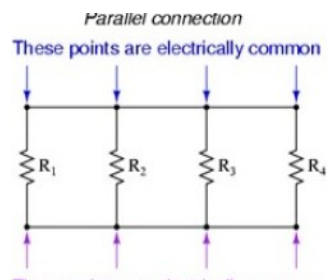
This is just a preview of things to come. Don't worry! We'll explore all these circuit configurations in detail, one at a time!

The basic idea of a "series" connection is that components are connected end-to-end in a line to form a single path for electrons to flow:



The basic idea of a "parallel" connection, on the other hand, is that all components are connected across each other's leads. In a purely parallel circuit, there are never more than two sets of electrically common points, no matter how many components are connected.

There are many paths for electrons to flow, but only one voltage across all components:



Series and parallel resistor configurations have very different electrical properties. We'll explore the properties of each configuration in the sections to come.

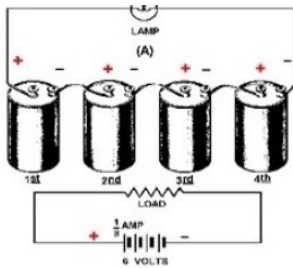
# Cells in Series and Parallel

Components of an electrical circuit or electronic circuit can be connected in many different ways. The two simplest of these are called **series** and **parallel** and occur very frequently. Components connected in series are connected along a single path, so the same current flows through all of the components. Components connected in parallel are connected so the same voltage is applied to each component.

A circuit composed solely of components connected in series is known as a **series circuit**; likewise, one connected completely in parallel is known as a **parallel circuit**.

In a series circuit, the current through each of the components is the same, and the voltage across the circuit is the sum of the voltages across each component. In a parallel circuit, the voltage across each of the components is the same, and the total current is the sum of the currents through each component.

Assume that a load requires a power supply of 6 volts and a current capacity of 1/8 ampere. Since a single cell normally supplies a voltage of only 1.5 volts, more than one cell is needed. To obtain the higher voltage, the cells are connected in series as shown



(A) Pictorial view of series-connected cells; (B) Schematic of series connection.

the load is shown by the resistance symbol and the battery is indicated by one long and one short line per cell.

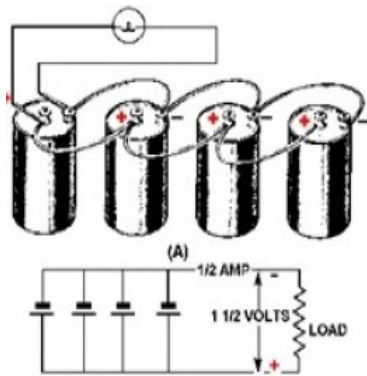
In a series hookup, the negative electrode (cathode) of the first cell is connected to the positive electrode (anode) of the second cell, the negative electrode of the second to the positive of the third, etc. The positive electrode of the first cell and negative electrode of the last cell then serve as the terminals of the battery. In this way, the voltage is 1.5 volts for each cell in the series line. There are four cells, so the output terminal voltage is  $1.5 \times 4$ , or 6 volts. When connected to the load, 1/8 ampere flows through the load and each cell of the battery. This is within the capacity of each cell. Therefore, only four series-connected cells are needed to supply this particular load.

**Note:**

When connecting cells in series, connect alternate terminals together (- to +, - to +, etc.) Always have two remaining terminals that are used for connection to the load only. Do not connect the two remaining terminals together as this is a short across the battery and would not only quickly discharge the cells but could cause some types of cells to explode.

## Parallel-Connected Cells

In this case, assume an electrical load requires only 1.5 volts, but will require 1/2 ampere of current. (Assume that a single cell will supply only 1/8 ampere.) To meet this requirement, the cells are connected in parallel, as shown in figure 2-7 view A and schematically represented in 2-7 view B. In a parallel connection, all positive cell electrodes are connected to one line, and all negative electrodes are connected to the other. No more than one cell is connected between the lines at any one point; so the voltage between the lines is the same as that of one cell, or 1.5 volts. However, each cell may contribute its maximum allowable current of 1/8 ampere to the line. There are four cells, so the total line current is  $1/8 \times 4$ , or 1/2 ampere. In this case four cells in parallel have enough capacity to supply a load requiring 1/2 ampere at 1.5 volts.



(A) Pictorial view of parallel-connected cells; (B) Schematic of parallel connection.

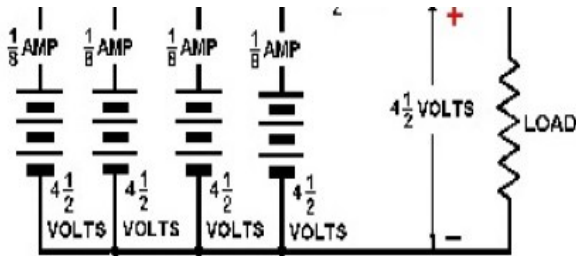
## Series-Parallel-Connected Cells

The figure depicts a battery network supplying power to a load requiring both a voltage and a current greater than one cell can provide. To provide the required 4.5 volts, groups of three 1.5-volt cells are connected in series. To provide the required 1/2 ampere of current, four series groups are connected in parallel, each supplying 1/8 ampere of current.

## Schematic of series-parallel connected cells

The connections shown have been used to illustrate the various methods of combining cells to form a battery. Series, parallel, and series-parallel circuits will be covered in detail in the next chapter, "Direct Current."

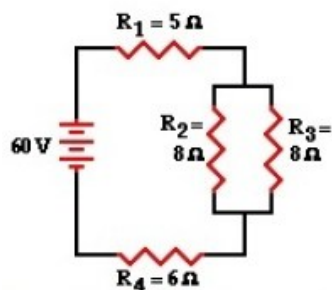
Some batteries are made from primary cells. When a primary-cell battery is completely discharged, the entire battery must be replaced. Because there is nothing else that can be done to primary cell batteries, the rest of the discussion on batteries will be concerned with batteries made of secondary cells.



## Example

The first example is the easiest case – the resistors placed in parallel have the same resistance. The goal of the analysis is to determine the current in and the voltage drop across each resistor.

The first example is the easiest case - the resistors placed in parallel have the same resistance. The goal of the analysis is to determine the current in and the voltage drop across each resistor.



$R_{tot} =$ _____	$I_{tot} =$ _____
$I_1 =$ _____	$\Delta V_1 =$ _____
$I_2 =$ _____	$\Delta V_2 =$ _____
$I_3 =$ _____	$\Delta V_3 =$ _____
$I_4 =$ _____	$\Delta V_4 =$ _____

The first step is to simplify the circuit by replacing the two parallel resistors with a single resistor

The first step is to simplify the circuit by replacing the two parallel resistors with a single resistor that has an equivalent resistance. Two  $8 \Omega$  resistors in series is equivalent to a single  $4 \Omega$  resistor. Thus, the two branch resistors ( $R_2$  and  $R_3$ ) can be replaced by a single resistor with a resistance of  $4 \Omega$ . This  $4 \Omega$  resistor is in series with  $R_1$  and  $R_4$ . Thus, the total resistance is

$$R_{tot} = R_1 + 4 \Omega + R_4 = 5 \Omega + 4 \Omega + 6 \Omega$$

$$R_{tot} = 15 \Omega$$

Now the Ohm's law equation ( $\Delta V = I \cdot R$ ) can be used to determine the total current in the circuit. In doing so, the total resistance and the total voltage (or battery voltage) will have to be used.

$$I_{\text{tot}} = \Delta V_{\text{tot}} / R_{\text{tot}} = (60 \text{ V}) / (15 \Omega)$$

$$I_{\text{tot}} = 4 \text{ Amp}$$

The 4 Amp current calculation represents the current at the battery location. Yet, resistors  $R_1$  and  $R_4$  are in series and the current in series-connected resistors is everywhere the same. Thus,

$$I_{\text{tot}} = I_1 = I_4 = 4 \text{ Amp}$$

For parallel branches, the sum of the current in each individual branch is equal to the current outside the branches. Thus,  $I_2 + I_3$  must equal 4 Amp. There are an infinite number of possible values of  $I_2$  and  $I_3$  that satisfy this equation. Since the resistance values are equal, the current values in these two resistors are also equal. Therefore, the current in resistors 2 and 3 are both equal to 2 Amp.

$$I_2 = I_3 = 2 \text{ Amp}$$

Now that the current at each individual resistor location is known, the Ohm's law equation ( $\Delta V = I \cdot R$ ) can be used to determine the voltage drop across each resistor. These calculations are shown below.

$$\Delta V_1 = I_1 \cdot R_1 = (4 \text{ Amp}) \cdot (5 \Omega)$$

$$\Delta V_1 = 20 \text{ V}$$

$$\Delta V_2 = I_2 \cdot R_2 = (2 \text{ Amp}) \cdot (8 \Omega)$$

$$\Delta V_2 = 16 \text{ V}$$

$$\Delta V_3 = I_3 \cdot R_3 = (2 \text{ Amp}) \cdot (8 \Omega)$$

$$\Delta V_3 = 16 \text{ V}$$

$$\Delta V_4 = I_4 \cdot R_4 = (4 \text{ Amp}) \cdot (6 \Omega)$$

$$\Delta V_4 = 24 \text{ V}$$

## **ASSESSMENT.**

1. Define electric currents and state its effects.
2. State ohm's law.

3. Name two advantages of potentiometer over ammeter.
4. Give three methods of measuring resistance.
5. Differentiate between shunt and multiplier.

## Week 3

### Topic: Electrical Energy and Power

#### Nuclear magnetic resonance (NMR) imaging

Electrical Energy

Electrical energy is the work done when a quantity of charge moves between two points of potential differences measured in joules.

Work done = Quantity of charge x p.d

$$V = w/Q$$

$$W = QV \dots \dots \dots (i)$$

W = Work done, Q = Quantity of charge, V = p.d. across the terminals and we already know that  $Q = It$

Meaning  $W = (It)v$

$$W = Itv \dots \dots \dots (ii)$$

Where I = Current, V = Voltage, T = Time

Since  $V = IR$

$$W = I (IR)t$$

$$= I^2Rt \dots\dots\dots (iii)$$

Since  $I = V/R$

$$W = V^2/R^2 \times Rt$$

$$W = V^2t/R \dots\dots\dots (iv)$$

### Example

Calculate the electrical energy produced by a heater with a voltage supply of 200v, when a current of 10amps passed through it for 5 minutes.

Solution

$$I = 10\text{amps}, V = 220\text{v}, t = 5 \times 60 = 300\text{s}$$

$$W = Ivt = 10 \times 220 \times 300$$

$$= 660000 \text{ joules (j)}$$

$$= 660\text{KJ}$$

### Heating Effect of Electric Energy

When current passes through a wire or a conductor, electrical energy is converted entirely into heat energy. Thus, Joules law of electrical heating states that: The heat developed in a wire is directly proportional to:

- (i) Time: for a given resistance and current, i.e,  $W \propto t$  (R, I are constant).
- (ii) The square of the current: for a given resistance and time, i.e,  $W \propto I^2$  (R, t are constant)
- (iii) The resistance of the wire: for a given constant current and time, i.e  $W \propto R$  (I and t are constant)

Energy conversion

- (i) Conversion of electrical energy into mechanical energy i.e, in lifting of a load using an electric motor.
- (ii) The conversion of solar energy to electrical and heat energy, as in solar cells, solar heaters, etc.

(iii) The conversion of electrical energy to heat energy, e.g. a solar plate, electrical heater, electric cable, etc.

### Electrical Power

Electrical power is the time rate at which the energy is used up. Power is measured in watts (w).

$$\text{Power} = \text{workdone}/\text{time} = lvt/t$$

$$\text{Then, Power} = Iv \dots \dots \dots (i)$$

$$\text{or Power} = I^2R \dots \dots \dots (ii)$$

$$\text{Power} = V^2/R \dots \dots \dots (iii)$$

### Example

Calculate the power dissipated by a heater of 220V and a resistance of 10 Ohms

Solution:

$$P = V^2/R = 220 \times 220/10 = 4840 \text{ watts} = 4.84 \text{ Kilowatt (Kw)}$$

### Types of Power

(i) real (ii) apparent (iii) active (iv) reactive power

1. Real Power: This is the power used in driving machines in the factories in which (cos  $\theta$ ) power factor is considered, e.g. induction motor fluorescent, etc.

It is represented as  $IV \cos\theta$

2. Apparent power: Apparent power is just the power available for any electrical appliance which is simply structured, e.g. a transistor radio, computer, etc.

$$\text{Power factor} = \text{Real power}/\text{Apparent power}$$

$$\text{Power factor} = \cos\theta$$

$$\text{Real power} = IV \cos\theta$$

$$\text{Apparent power} = \text{Real power}/\text{power factor}$$

$$\text{Apparent power} = IV \cos\theta/\cos\theta$$

Apparent power =  $IV$

3. Active and reactive power: This is too advanced for this level, but little of it has been dealt with under Simple AC Circuit.

Measurement of Electric Power

Electrical power consumed by an electrical appliance is measured in watt.

Watt is the product of electrical and the p.d between the two points.

1 watt = volts x Ampere

Kilowatts-hour = volt x Ampere/1000 x time (hours)

Horse power is equivalent 746 watts approximated to 750 watts

1 watt = volts x Amperes

Kilowatt hour = power (Kw) x time (hrs)/1000

Kilowatt-hour is the unit of electrical energy watt-hour = volt x Amperes x hours

Watt hour = watts x hours

Example

Calculate the work done when a current at 5 Amps flows through a conductor for 10 secs if the p.d applied is 5v.

Solution

$I = 5A, V = 5V$  and  $t = 10\text{sec}$

$W = IVt$

$W = 5 \times 5 \times 10 = 25 \times 10 = 250J$

Electrical Energy Consumed

Power is consumed in kilowatt-hours (KWh). Meters are calibrated in (KWh) so that 1 KWh is the energy supplied at working rate of 1000watts for 1 hour.

1 hour =  $(60 \times 60)$  secs = 3600sec

1 Kilowatt = 1000 watts

1KWh = 1 Kilowatt x 1 hour

= 1000 x 60 x 60

= 3600000 Joules (J)

= 3.6MJ

Larger value

Kilowatt = 1000 =  $10^3$ watts

Megawatt = 1000000 watts =  $10^6$ watts

Gigawatt =  $10^9$ watts

## **ASSESSMENT.**

1. Calculate the workdone when a current at 5Amps flows through a conductor for 10secs if the p.d applied is 5v.
2. A lamp is marked 12V,240w. How many joules does it consume in an hour and what is the current it passes?
3. An electric welding machine has a power factor of 0.5. When the apparent power is 100W, find the real power.
4. Calculate the power dissipated by a heater of 220V and a resistance of 10 ohms

## Week 4

# Topic: Safety Devices and Detecting Faults in Current

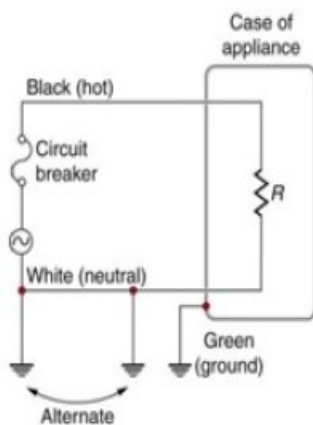
## Introduction

Electricity has two hazards. A thermal hazard occurs when there is electrical overheating. A shock hazard occurs when electric current passes through a person. Both hazards have already been discussed. Here we will concentrate on systems and devices that prevent electrical hazards.

This is not how power is distributed in practice. Modern household and industrial wiring requires the three-wire system, which has several safety features. First is the familiar *circuit breaker* (or *fuse*) to prevent thermal overload. Second, there is a protective *case* around the appliance, such as a toaster or refrigerator. The case's safety feature is that it prevents a person from touching exposed wires and coming into electrical contact with the circuit, helping prevent shocks.



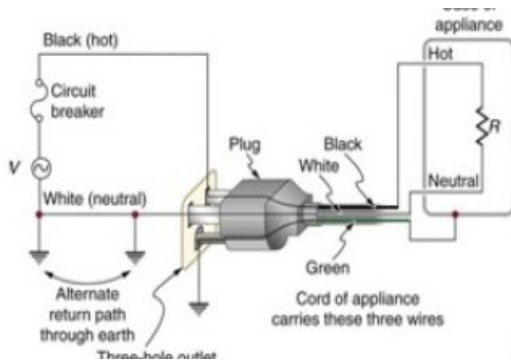
Schematic of a simple AC circuit with a voltage source and a single appliance represented by the resistance  $R$ . There are no safety features in this circuit.



Schematic of a simple AC circuit with a voltage source and a single appliance represented by the resistance  $R$ . There are no safety features in this circuit.

The three-wire system connects the neutral wire to the earth at the voltage source and user location, forcing it to be at zero volts and supplying an alternative return path for the current through the earth. Also grounded to zero volts is the case of the appliance. A circuit breaker or fuse protects against thermal overload and is in series on the active (live/hot) wire. Note that wire insulation colors vary with region and it is essential to check locally to determine which color codes are in use (and even if they were followed in the particular installation).

There are *three connections to earth or ground* (hereafter referred to as “earth/ground”). Recall that an earth/ground connection is a low-resistance path directly to the earth. The two earth/ground connections on the *neutral wire* force it to be at zero volts relative to the earth, giving the wire its name. This wire is therefore safe to touch even if its insulation, usually white, is missing. The neutral wire is the return path for the current to follow to complete the circuit. Furthermore, the two earth/ground connections supply an alternative path through the earth, a good conductor, to complete the circuit. The earth/ground connection closest to the power source could be at the generating plant, while the other is at the user’s location. The third earth/ground is to the case of the appliance, through the green *earth/ground wire*, forcing the case, too, to be at zero volts. The *live or hot wire* (hereafter referred to as “live/hot”) supplies voltage and current to operate the appliance.

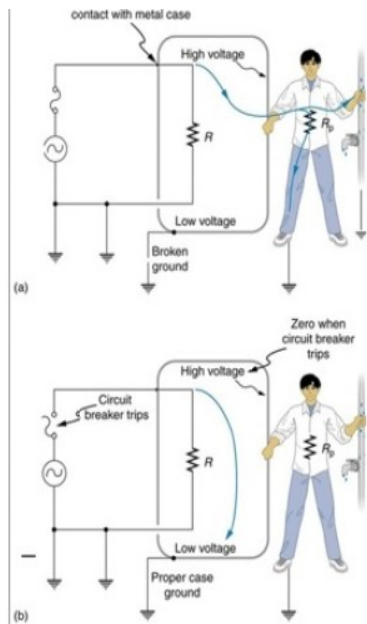


The standard three-prong plug can only be inserted in one way, to assure proper function of the three-wire system.

A note on insulation color-coding: Insulating plastic is color-coded to identify live/hot, neutral and ground wires but these codes vary around the world. Live/hot wires may be brown, red, black, blue or grey. Neutral wire may be blue, black or white. Since the same color may be used for live/hot or neutral in different parts of the world, it is essential to determine the color code in your region. The only exception is the earth/ground wire which is often green but may be yellow or just bare wire. Striped coatings are sometimes used for the benefit of those who are colorblind.

The three-wire system replaced the older two-wire system, which lacks an earth/ground wire. Under ordinary circumstances, insulation on the live/hot and neutral wires prevents the case from being directly in the circuit, so that the earth/ground wire may seem like double

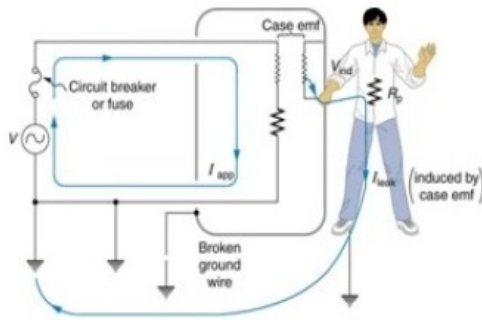
protection. Grounding the case solves more than one problem, however. The simplest problem is worn insulation on the live/hot wire that allows it to contact the case. Lacking an earth/ground connection (some people cut the third prong off the plug because they only have outdated two hole receptacles), a severe shock is possible. This is particularly dangerous in the kitchen, where a good connection to earth/ground is available through water on the floor or a water faucet. With the earth/ground connection intact, the circuit breaker will trip, forcing repair of the appliance. Why some appliances are still sold with two-prong plugs? These have non-conducting cases, such as power tools with impact resistant plastic cases, and are called *doubly insulated*. Modern two-prong plugs can be inserted into the asymmetric standard outlet in only one way, to ensure proper connection of live/hot and neutral wires.



Worn insulation allows the live/hot wire to come into direct contact with the metal case of this appliance. (a) The earth/ground connection being broken, the person is severely shocked. The appliance may operate normally in this situation. (b) With a proper earth/ground, the circuit breaker

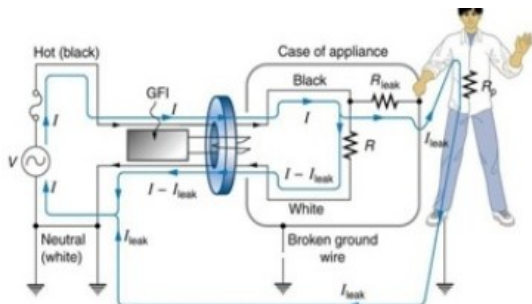
Worn insulation allows the live/hot wire to come into direct contact with the metal case of this appliance. (a) The earth/ground connection being broken, the person is severely shocked. The appliance may operate normally in this situation. (b) With a proper earth/ground, the circuit breaker trips, forcing repair of the appliance.

Electromagnetic induction causes a more subtle problem that is solved by grounding the case. The AC current in appliances can induce an emf on the case. If grounded, the case voltage is kept near zero, but if the case is not grounded. Current driven by the induced case emf is called a *leakage current*, although current does not necessarily pass from the resistor to the case.



AC currents can induce an emf on the case of an appliance. The voltage can be large enough to cause a shock. If the case is grounded, the induced emf is kept near zero.

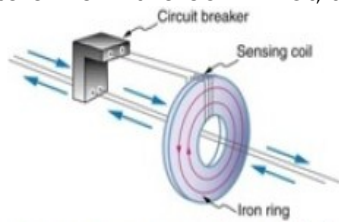
A *ground fault interrupter* (GFI) is a safety device found in updated kitchen and bathroom wiring that works based on electromagnetic induction. GFIs compare the currents in the live/hot and neutral wires. When live/hot and neutral currents are not equal, it is almost always because current in the neutral is less than in the live/hot wire. Then some of the current, again called a leakage current, is returning to the voltage source by a path other than through the neutral wire. It is assumed that this path presents a hazard. GFIs are usually set to interrupt the circuit if the leakage current is greater than 5 mA, the accepted maximum harmless shock. Even if the leakage current goes safely to earth/ground through an intact earth/ground wire, the GFI will trip, forcing repair of the leakage.



A ground fault interrupter (GFI) compares the currents in the live/hot and neutral wires and will trip if their difference exceeds a safe value. The leakage current here follows a hazardous path that could have been prevented by an intact earth/ground wire.

A ground fault interrupter (GFI) compares the currents in the live/hot and neutral wires and will trip if their difference exceeds a safe value. The leakage current here follows a hazardous path that could have been prevented by an intact earth/ground wire.

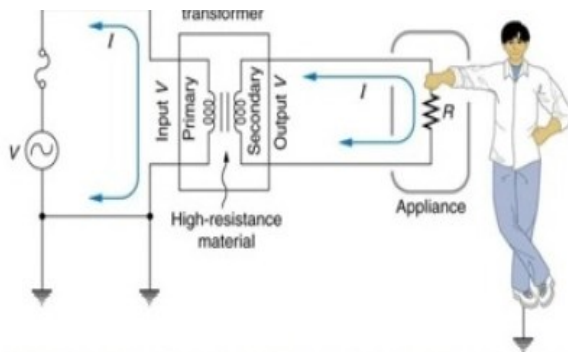
If the currents in the live/hot and neutral wires are equal, then they induce equal and opposite emfs in the coil. If not, then the circuit breaker will trip.



A GFI compares currents by using both to induce an emf in the same coil. If the currents are equal, they will induce equal but opposite emfs.

A GFI compares currents by using both to induce an emf in the same coil. If the currents are equal, they will induce equal but opposite emfs.

Another induction-based safety device is the *isolation transformer*. Most isolation transformers have equal input and output voltages. Their function is to put a large resistance between the original voltage source and the device being operated. This prevents a complete circuit between them, even in the circumstance shown. There is a complete circuit through the appliance. But there is not a complete circuit for current to flow through the person in the figure, who is touching only one of the transformer's output wires, and neither output wire is grounded. The appliance is isolated from the original voltage source by the high resistance of the material between the transformer coils, hence the name isolation transformer. For current to flow through the person, it must pass through the high-resistance material between the coils, through the wire, the person, and back through the earth—a path with such a large resistance that the current is negligible.



An isolation transformer puts a large resistance between the original voltage source and the device,

An isolation transformer puts a large resistance between the original voltage source and the device, preventing a complete circuit between them.

The basics of electrical safety presented here help prevent many electrical hazards. Electrical safety can be pursued to greater depths. There are, for example, problems related to different earth/ground connections for appliances in close proximity. Many other examples are found in hospitals. Microshock-sensitive patients, for instance, require special protection. For these people, currents as low as 0.1 mA may cause ventricular fibrillation. The interested reader can use the material presented here as a basis for further study.

## **ASSESSMENT**

1. What are the two types of Electricity hazard?
2. What is a GFI?
3. What is a GFI used for?

## Week 5

### Topic: Structure Of Matter

#### Structure of matter

##### a. Evidence of the particle nature of matter

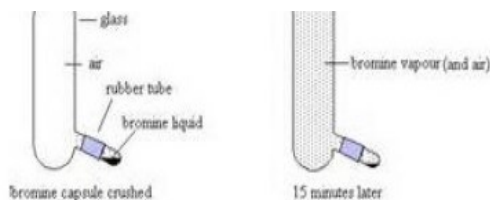
The idea that matter is made up of minute particles called atoms dates back to the ancient Greeks. According to the Greek philosopher Democritus, a given piece of substance, say a piece of yam, can be cut into smaller and smaller bits, until eventually a smallest piece of that substance would be obtained which not be further subdivided. This smallest, indivisible, piece was called an atom. The atomic theory of matter assumes that all matter is made up of tiny particles called atoms and that these are all at times in a rapid state of motion. The nature of this motion and its activity depend upon the temperature of matter and other factors.

The experimental evidence of this particle or atomic nature of matter is the Brownian movement, named after the Biologist Robert Brown who was credited with its discovery in 1827. While observing tiny pollen grains suspended in water under a microscope, he noticed that the tiny pollen grains moved about in zig-zag paths even though the water appeared to be perfectly still. The pollen grains were supposed to be jostled or knocked about here and there by the vigorously moving molecules of water.

Another evidence in favour of the particle nature of matter was obtained from analysis of chemical reactions. This crucial piece of evidence is known by chemists as the Law of Definite Proportions which states that when two or more elements combine to form a compound, they always do so in the same proportions by weight.

For example, the compound water ( $H_2O$ ) is always formed by two parts of hydrogen ( $H_2$ ) and sixteen parts of oxygen (O) and the common salt (NaCl) is always formed from 23 parts of sodium and 35 parts of chlorine by water.

A third evidence that matter is composed of extremely small is provided by the process of diffusion. If we place a few drops of liquid bromine at the bottom of a gas jar on top of which is placed a cover glass, after sometime the brown bromine vapour will be seen in the upper part of the gas jar in spite of the fact that bromine vapour is much denser than air and should remain at the bottom of the jar. We can explain this diffusion or spreading out of the bromine by assuming that liquid bromine is composed of particles and that the particles can move about easily.



All the evidence we have given that matter is composed of particles are indirect evidence. We have no direct evidence for the existence of these particles since we cannot observe them with even the

All the evidence we have given that matter is composed of particles are indirect evidence. We have no direct evidence for the existence of these particles since we cannot observe them with even the most powerful microscopes.

## b. Simple atomic structure

An atom is the smallest indivisible particle of an element which can take place in chemical change.

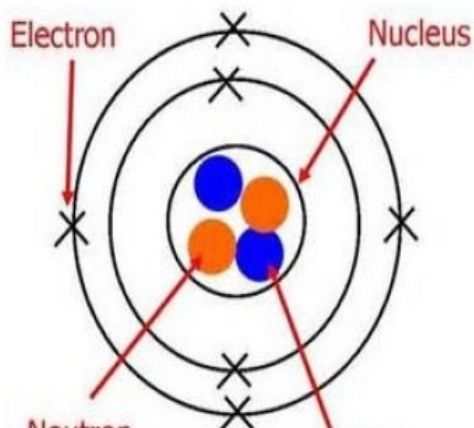
### Activity

1. Get a tuber of yam and cut out a piece of this tuber about the size of a cube of sugar.
2. Divide this tube into two halves.
3. Take one of these halves and cut it into another half. Continue this process of cutting each successive half into two until you can no longer cut the remaining portion into further bits.

If we suppose the piece of yam to represent an element (e.g. sodium) the smallest bit of the yam represents the atom of the element. The smallest particle of an element, in order to be an atom of that element must be capable of a separate existence.

There are many theories concerning the structure of the atom. It shall be discussed in higher classes, a little above this class. For now, we shall consider the atom as simply consisting of two parts held together by electric forces. The two parts of the atom are (1) the nucleus and (2) the electrons.

a little above this class. For now, we shall consider the atom as simply consisting of two parts held together by electric forces. The two parts of the atom are (1) the nucleus and (2) the electrons.



The nucleus is the heavy portion of the atom and is located at its centre. It consists of two parts – the protons and the neutrons. The protons carry a positive charge, the neutrons carry no charge.

The second part of the atom is the electron. The electrons are very light (about  $1/840$  of the mass of the proton.) They are negatively charged. The lightness of electrons makes it easy to transfer them when two materials are rubbed against each other. The electrons circle in orbits around the heavy nucleus and are held in place due to the electrostatic attraction between them and the protons of the nucleus.

In a neutral atom, the total charges due to the electrons must balance the total charges due to the protons.

## Molecules

Most substances cannot exist by themselves as individual atoms. They combine their atoms with themselves or with other atoms to form molecules.

A molecule is the smallest particle of a substance which can have a separate existence and still retains the properties of that substance.

The molecules of any substance are identical. They have the same structure, the same mass and the same mechanical and electrical properties.

A molecule may be made up of similar atoms of the same elements or different atoms or two or more elements. For example, a molecule of hydrogen is made up of two atoms of hydrogen but a molecule of water is a combination of two atoms of hydrogen and an atom of oxygen, and a molecule of sodium chloride is a combination of an atom of sodium and an atom of chlorine.

Atoms combine in simple proportion to form molecules. The simplest model of a molecule is that of a rigid sphere, like a small billiard ball, capable of moving and colliding with other

molecules or with a wall, and of exerting attractive or repulsive forces on neighbouring molecules.

## The size of a molecule

The size of a molecule is extremely small. It is of the order of  $10^{-9} - 10^{-10}$  m ( $10^{-7} - 10^{-8}$  cm). As a result of this small size, one gram of an element contains several millions of molecules. For example a gram of hydrogen contains about  $10^{23}$  molecules.

## Brownian motion

Brownian motion, also called Brownian movement, any of various physical phenomena in which some quantity is constantly undergoing small, random fluctuations. It was named for the Scottish botanist Robert Brown, the first to study such fluctuations (1827).

Brownian motion is the rapid, constant and irregular motion of tiny particles

If a number of particles subject to Brownian motion are present in a given medium and there is no preferred direction for the random oscillations, then over a period of time the particles will tend to be spread evenly throughout the medium. Thus, if  $A$  and  $B$  are two adjacent regions and, at time  $t$ ,  $A$  contains twice as many particles as  $B$ , at that instant the probability of a particle's leaving  $A$  to enter  $B$  is twice as great as the probability that a particle will leave  $B$  to enter  $A$ . The physical process in which a substance tends to spread steadily from regions of high concentration to regions of lower concentration is called diffusion. Diffusion can therefore be considered a macroscopic manifestation of Brownian motion on the microscopic level. Thus, it is possible to study diffusion by simulating the motion of a Brownian particle and computing its average behaviour. A few examples of the countless diffusion processes that are studied in terms of Brownian motion include the diffusion of pollutants through the atmosphere, the diffusion of "holes" (minute regions in which the electrical charge potential is positive) through a semiconductor, and the diffusion of calcium through bone tissue in living organisms.

## Diffusion

Diffusion, process resulting from random motion of molecules by which there is a net flow of matter from a region of high concentration to a region of low concentration. A familiar example is the perfume of a flower that quickly permeates the still air of a room.

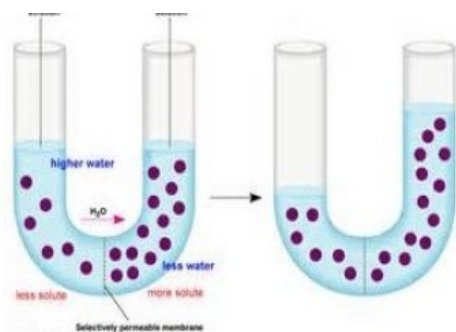
Heat conduction in fluids involves thermal energy transported, or diffused, from higher to lower temperature. Operation of a nuclear reactor involves the diffusion of neutrons through a medium that causes frequent scattering but only rare absorption of neutrons.

The rate of flow of the diffusing substance is found to be proportional to the concentration gradient. If  $j$  is the amount of substance passing through a reference surface of unit area per unit time, if the coordinate  $x$  is perpendicular to this reference area, if  $c$  is the concentration of the substance, and if the constant of proportionality is  $D$ , then  $j = -D(dc/dx)$ ;  $dc/dx$  is the

rate of change of concentration in the direction  $x$ , and the minus sign indicates the flow is from higher to lower concentration.  $D$  is called the diffusivity and governs the rate of diffusion.

## Osmosis

Osmosis is the spontaneous net movement of solvent molecules through a partially permeable membrane into a region of higher solute concentration, in the direction that tends to equalize the solute concentrations on the two sides. It may also be used to describe a physical process in which any solvent moves across a semi permeable membrane (permeable to the solvent, but not the solute) separating two solutions of different concentrations. Osmosis can be made to do work.



The osmotic pressure is defined to be the pressure required to maintain an equilibrium, with no net movement of solvent. Osmotic pressure is a colligative property (properties of solutions that depend upon the ratio of the number of solute particles to the number of solvent molecules in a solution, and not on the type of chemical species present), meaning that the osmotic pressure depends on the molar concentration of the solute but not on its identity.

Osmosis is a vital process in biological systems, as biological membranes are semipermeable. In general, these membranes are impermeable to large and polar molecules, such as ions, proteins, and polysaccharides, while being permeable to non-polar and/or hydrophobic molecules like lipids as well as to small molecules like oxygen, carbon dioxide, nitrogen, and nitric oxide. Permeability depends on solubility, charge, or chemistry, as well as solute size. Osmosis provides the primary means by which water is transported into and out of cells. The turgor pressure of a cell is largely maintained by osmosis across the cell membrane between the cell interior and its relatively hypotonic environment.

## ASSESSMENT.

1. Protons, neutrons and electrons are the main composition of an atom. Discuss.
2. State the similarities among the three states of matter.
3. What is diffusion?
4. Explain the rise of water in a glass capillary tube using the Kinetic theory.
5. Compare and contrast crystalline and amorphous substance.

## Week 6

# Topic: Surface Tension

### Introduction

We observe many things in our day-to-day life. **Surface Tension** Phenomenon is one among them. Often we confuse the Phenomena of Surface tension with Buoyancy. Both the phenomena are entirely different to each other in the sense, in Buoyancy a portion of the body gets dipped in the liquid whereas in Surface tension the body will be remaining on the layer of water without getting wet.

Let us observe these leaves on the surface of water. We could see them moving in the water without getting wet.

For these leaves to be on the layer, there should be some force acted by the upward layer of water which keeps the leaf on the surface. This is nothing but the Surface tension. Let us study more about the Surface tension in this section.

### What is Surface Tension?

The Surface tension is defined as: The dragging force observed in the given liquid per unit length. It is given by the formula:

$$T = FL$$

where,

F = Force per unit length

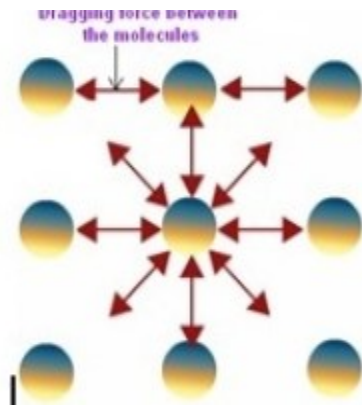
L = Length over which the force acts.

The Surface tension is expressed in Newton per meter.

### What causes Surface Tension?

Surface tension is a physical property of water. Here the cohesive force keeps the water intact. Each molecule in the beaker is pulled in every direction equally by adjacent molecules.

Let us observe the following diagram:



The dragging force acts between the each molecules by the other molecule. Therefore the resulting net force is zero.

At the surface of water in a beaker, the water molecule does not have another water molecule around the sides of them. Therefore creation of internal pressure. Water molecules at the surface are pulled inwards. Top layer of liquid surface of beaker are compressed to minimum area.

## Effects of Surface Tension

Several effects of surface tension can be seen with ordinary water:

**A.** Beading of rain water on a waxy surface, such as a leaf. Water adheres weakly to wax and strongly to itself, so water clusters into drops. Surface tension gives them their near-spherical shape, because a sphere has the smallest possible surface area to volume ratio.

**B.** Formation of drops occurs when a mass of liquid is stretched. The animation shows water adhering to the faucet gaining mass until it is stretched to a point where the surface tension can no longer bind it to the faucet. It then separates and surface tension forms the drop into a sphere. If a stream of water was running from the faucet, the stream would break up into drops during its fall. Gravity stretches the stream, then surface tension pinches it into spheres.

**C.** Flotation of objects denser than water occurs when the object is non-wettable and its weight is small enough to be borne by the forces arising from surface tension. For example, water striders use surface tension to walk on the surface of a pond. The surface of the water behaves like an elastic film: the insect's feet cause indentations in the water's surface, increasing its surface area.

**D.** Separation of oil and water (in this case, water and liquid wax) is caused by a tension in the surface between dissimilar liquids. This type of surface tension is called “interface tension”, but its chemistry is the same.

**E.** Tears of wine is the formation of drops and rivulets on the side of a glass containing an alcoholic beverage. Its cause is a complex interaction between the differing surface tensions of water and ethanol; it is induced by a combination of surface tension modification of water by ethanol together with ethanol evaporating faster than water.

## Surface tension Formula

The Surface tension is expressed by the formula:

$$T = FL$$

Where F = Force per unit length and  
L = Length over which the force acts.

To calculate the tension we use the formula:

$$T = 12 \rho g r h.$$

where  $h = h + r/3$ .

Here

r = radius of the capillary tube at the liquid meniscus

h = height of the liquid in the capillary tube above the free surface of liquid in beaker.

$\rho$  = Density of water ( $\rho = 1 \times 10^3 \text{ kg/m}^3$  for water).

## ASSESSMENT.

1. Define surface tension.
2. State two applications of surface tension.
3. Why does water wet a clean glass surface and water does not?
4. Describe an experiment to illustrate surface tension.
5. State two methods which the surface tension of a liquid will be reduced.

## Week 7

### Topic: Capillarity

When we dip three tubes with fine bores but with different diameters into a clean water, we observe that water rises in the tubes but the narrower the bore the higher the height to which the rises.

**Capillary action** (sometimes **capillarity**, **capillary motion**, or **wicking**) is the ability of a liquid to flow in narrow spaces without the assistance of, and in opposition to, external forces like gravity. The effect can be seen in the drawing up of liquids between the hairs of a paint-brush, in a thin tube, in porous materials such as paper, in some non-porous materials such as liquefied carbon fiber, or in a cell. It occurs because of inter molecular forces between the liquid and surrounding solid surfaces. If the diameter of the tube is sufficiently small, then the combination of surface tension (which is caused by cohesion within the liquid) and adhesive forces between the liquid and container act to lift the liquid. In short, the capillary action is due to the pressure of cohesion and adhesion which cause the liquid to work against gravity.

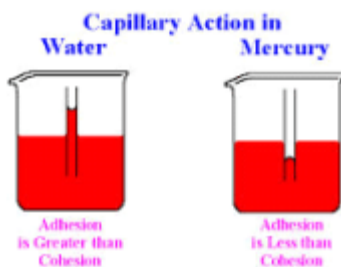
Capillarity or capillary action is the tendency of a liquid to rise or fall in a narrow tube.

In both the water and the soap solution, the surface of the liquid or its meniscus curves upwards. But in mercury the meniscus is curved downwards away from cohesion and adhesion will be required to explain this capillary action.

Cohesion is the force of attraction between molecules of the same kind, e.g. the molecules of water.

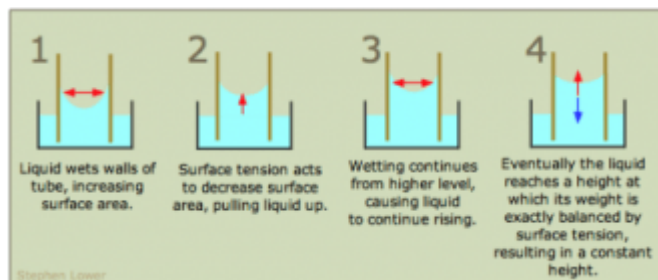
Adhesion is the force of attraction between molecules of different kinds, e.g. the molecules of water and glass.

Cohesion and adhesion explain the different action of water and mercury when spilled on a clean glass surface.



Because the adhesion of water molecules to glass is stronger than the cohesion between water molecules, water spreads out on a clean glass surface when sprinkled on it and wets the glass. This is not so in the case of mercury which does not spread on glass or wet it. The cohesion of mercury molecules is greater than the adhesion of the mercury molecules to those of glass. As a result the mercury forms into goblets or spherical beads on the glass surface.

## Capillary Action



**Key Difference:** In terms of chemistry and physics, adhesion is the tendency of dissimilar particles or surfaces to cling to one another. Cohesion is the tendency of similar or identical molecules to cling to each other.

Adhesive and cohesive are two words that sound very similar because of the 'sive' at the ends, however they are completely different from each other. They are derived from the words 'adhesion' and 'cohesion' respectively. Both these words are most commonly associated with chemistry and physics; however cohesion is also used in computer programming. Let's look at the difference between the two words.

Adhesive and Adhesion has been listed as an adjective and a noun. As an adjective, adhesive means to tend to remain in memory or to adhere to something. As a noun, adhesive is described as glue, which is known to have adhesive properties that help two substances stick together. Merriam Webster defines, 'adhesion' (adjective) as:

1. Steady or firm attachment
2. The action or state of adhering
3. Agreement to join
4. The molecular attraction exerted between the surfaces of bodies in contact.

In terms of chemistry and physics, adhesion is the tendency of dissimilar particles or surfaces to cling to one another. The most commonly known adhesive is glue, which is used to stick two different surfaces together. The intermolecular forces that cause adhesion can be divided into several types: mechanical adhesion, chemical adhesion, dispersive adhesion, electrostatic adhesion and diffusive adhesion.

In mechanical adhesion, adhesive materials fill the pores of the surfaces and hold surfaces together by interlocking. Chemical adhesion requires bonding at a molecular level, where two materials join and form ionic, covalent or hydrogen bonds upon contact and hold together. In dispersive adhesion, two materials are held together by van der Waals forces: the attraction between two molecules, each of which has a region of slight positive and negative charge. Dew is an example of dispersive adhesion. Electrostatic adhesion is when conducting materials pass electrons to form a difference in electrical charge at the join. This is similar to a capacitor, which creates electrostatic force in between the materials. Diffusive adhesion is when two materials merge and form a new material at diffusion. This occurs when the molecules of both materials are mobile and soluble in each other.

'Cohesive' is defined as, "exhibiting or producing cohesion or coherence." While, cohesion is defined as:

The act or state of sticking together tightly; especially: unity

Union between similar plant parts or organs

Molecular attraction by which the particles of a body are united throughout the mass

Though, cohesion is more popularly used in chemistry it is also used in computer programming. Yourdon and Constantine describe cohesion as the degree to which the elements of a module belong together. Cohesion is a measure of how strongly-related or focused the responsibilities of a single module are.

In terms of chemistry, cohesion is the tendency of similar or identical molecules to cling to each other. It is considered as the opposite of adhesion. Cohesive attraction, intramolecular force or cohesive force is the force that pushes similar molecules to join together and form a strong bond. This force is an intrinsic property of a substance because of the shape and structure of its molecules, which makes distribution of orbiting molecules difficult when the molecules get closer to one another, creating an electrical attraction. Cohesion allows for surface tension, creating a solid-like state upon which low-density materials can be placed. Water and mercury are strongly cohesive.

## **Applications of Capillarity**

1. Lubricating oil spread easily on all parts because of their low surface tension.
2. Cotton dresses are preferred in summer because cotton dresses have fine pores which act as capillaries for sweat.
3. Dirt gets removed when detergents are added while washing clothes because surface tension of water is reduced.
4. The absorption of ink by a blotting paper is due to capillary action, as the blotting paper is porous. When it is placed over the ink, the ink rises into the pores. Also rise of oil in the wick of a lamp is due to capillary action.

5. If one end of a towel is dipped into a bucket of water and the other end hangs over the bucket, the entire towel soon becomes wet due to capillary action.

6. The supply of water to the leaves at the top of even a tall tree is through capillary rise.

7. A fabric can be waterproof, by adding suitable waterproofing materials to the fabric. This addition increases the angle of contact, thereby making the fabric waterproof.

## **ASSESSMENT.**

1. What is capillary action?
2. Differentiate between cohesion and adhesion.
3. state the applications of capillarity.
4. Describe an experiment to illustrate capillarity.

## Week 8

### Topic: Elasticity

Elasticity is the ability of a material to regain its original shape or size after deformation or after removal of stress/force, or after it has been compressed. Deformation occurs when a wire is stretched or compressed. Deformation is elastic if the wire returns to its original position, while it is plastic if it does not return to its original position.

#### Terms used in Elasticity

1. Elastic limit: Elastic limit is the maximum load (force) which a body can experience and still retain its original size/shape once the load/force has been removed. It can also be defined as “the point on a stress/strain or load/extension graph beyond which Hooke’s law is no longer obeyed.
2. Yield point: Is reached when a stretched wire does not return to its original position
3. Maximum load: When a load is added to a wire that it cannot stand any further increase, it is called *maximum load*.
4. Breaking point: Is the point at which the wire breaks away from the original, having been stretched beyond the yield point where it cannot stand any further stretching.

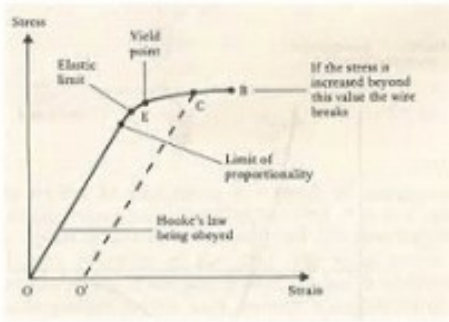
#### Hooke’s Law

Hooke’s law states that the force applied to spring is directly proportional to the extension (E) produced, provided the proportionality limit (of the spring) is not exceeded.

Mathematically,  $E \propto L$

$$E/L = K$$

$$E_1/L_1 = E_2/L_2$$



## ***Strength of Material***

1. Tensile/Compressive stress: Tensile stress is the ratio of load or force (F) to its cross-sectional area (A). It is measured in  $\text{Nm}^{-2}$  or  $\text{N/m}^2$ .

Thus, tensile / compressive stress = Force/Area =  $F/A$

2. Tensile / Compressive strain: Tensile strain is the ratio of extension to its original length of a wire. It has no limit. Thus, tensile/compressive strain

= extension/Length (original) =  $e/L$

3. Young modulus: Young modulus is the ratio of tensile / compressive stress to tensile / compressive strain. It is denoted by E and measured in  $\text{N/m}^2$  or  $\text{Nm}^{-2}$  (S.I units). Thus,

Young modulus = tensile/compressive stress/Tensile/compressive strain

$$E = F/A / e/L = FL/Ae$$

$$\text{Hence, } F = EAe / L$$

4. Force-constant: Force-constant is the amount of force that causes a unit expansion of an elastic material or the ratio of  $f/e$  of an elastic. It is denoted by K, measured in  $\text{Nm}^{-1}$

Thus,  $F = Ke$

$$\therefore K = F/e$$

### **Example**

The extension on a spring when 5g was hung from it was 0.56cm. If Hooke's law is obeyed, what is the extension caused by a load of 20g.

### **Solution**

$$F_1 = 5g, E_1 = 0.56\text{cm}, E_2 = x, F_2 = 20g$$

If Hooke's law is obeyed

$$F \propto e, \rightarrow F = Ke$$

$$\therefore F_1/e_1 = F_2/e_2$$

$$5/0.56 = 20/x$$

$$5x = 20 \times 0.56$$

$$X = 20 \times 0.56/5 = 2.24\text{cm}$$

## **ASSESSMENT**

1. What is elasticity?
2. State Hooke's law and explain terms used in the statement.
3. Describe and experiment to illustrate Hooke's law.
4. Find the work done, when a force is applied and a string resulting in extension of 20m, if the spring has a stiffness of 500N/m