PHYSICS ASPECT OF GENERAL SCIENCE

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COURSE TITLE – GENERAL SCIENCE 1
COURSE CODE – SCI 101   SEMESTER HOUR: 3 HOURS
LEVEL OF COURSE: 100   SEMESTER: SECOND   SESSION: 2020- 2021

THIS MODULE CONTAINS FIVE (5) UNITS

UNIT 1

NATURE AND CHARACTER OF SCIENCE

Learning Objectives.

After studying this unit, you should be able to explain
1. what is Physics and what it studies.
2. why we need to study physics.
3. the types motion
4. the concepts of speed, velocity, acceleration and write the equations of motion with uniform acceleration

SCIENCE IN TODAY'S WORLD

What is physics? Physics is a branch of pure science together with Biology and Chemistry.
It is an incredibly rich discipline, which provides us not only with the basic understanding of the lanes of nature but it is the basics of most of modern high technology.

Like other sciences, physics starts with observation in the world around us or from laboratory experiments designed to obtain facts. The investigation of electricity for example, started when it was noticed that amber (a glass like fossil) attracts small light objects, when it is rubbed with a cloth.
Why do we need to study physics? Physics is one of the most fundamental of the sciences. Scientists from all disciplines make use of the ideas of physics. Physics is also the foundation of all engineering and technology. No engineer could design any kind of practical device without first understanding the basic principles involved. To design a car or even a mouse trap, one must understand the basic laws of physics. Studying physics is also an adventure. It is sometimes frustrating, occasionally painful, and often richly rewarding and satisfying. Presently, our study of physics is based on the foundations built by great scientists such as Galileo, Newton, Maxwell and Einstein. Do you know that Einstein was a refugee?

The study of physics can

1. Promote a knowledge and understanding of the world around us, making it a more interesting place.
Encourage an appreciation of the importance of physics and its applications in technology and perhaps enable us to use our discoveries and inventions more effectively.
2. Create an awareness of the social, economic and environmental implications of science and hopefully help us to make well informed judgements on such matters such as nuclear power, the impact of computers on employment and
3. Be a source of enjoyment, satisfaction and intellectual stimulation.

Concepts of physics

To help make sense of the facts of physics and explain the behaviour of the physical world, physicists invent terms called concepts. These concern quantities that can be measured. Some such as length are very basic and easily measured while others, like potential difference in electricity are less concrete and require more sophisticated measuring instruments.

UNIT 2
MEASUREMENTS

Learning Objectives: After this unit, students will know and should be able to

- Explain the need for measurements
- Recognize SI units and their importance for measurement
- Identify the instruments used for measuring length, mass and time
- Distinguish between accuracy, precision and error.
- Define the term “motion” and list the types of motion giving examples
- State Newton’s Laws of motion
- Define the terms: speed, velocity and acceleration
- List the equations of motion with uniform acceleration

MEASUREMENT AND CONCEPTS OF SCIENCE

Scientists use exact measurements that can be reproduced. Weights and measures were among the earliest tools invented. This was extremely important in order to bring fairness into buying and selling. The people of earlier times measured the lengths of objects by a “rule of thumb.” What was later called an inch was in those times the width of a man’s thumb! The old foot rule measure started out as the length of a man’s foot as was with the then King of England. King Henry I of England, in about A.D 1120, defined a yard as the distance from the tip of his nose to the end of his thumb when his arm was held level. In the fourteenth century, King Edward II defined the inch as the length of three dry barleycorns, laid end to end. Can you suggest a reason why such standards are not suitable?

Every field of science involves taking measurements, understanding them, and communicating them to others. In other words, we all have to speak the same basic language. Whether you are a chemist, a physicist, a biologist, an engineer, a medical doctor or even a social scientist, you need a consistent way of communicating size, mass, shape, temperature, time, amount, energy, power, and speed.

The International System of Units (abbreviated SI, from the French *Système international d’unités)* is the metric system used in science, industry, and medicine. Depending on your age and geographic location, you might be very familiar with the “imperial” system, which includes units such as gallons, feet, miles, and pounds. The imperial system is used for “everyday” measurements in a few places, such as the United States. But in most of the world (including Europe) and in all scientific circles, the SI system is in common use. In 1791, the metric system of measurement was developed in France. This was an entirely new set of standards, which Congress made legal in the United States in 1866. In 1960, a comprehensive system of measurements was adopted by a General Conference on Weights and Measurements. This system is now called the *Système international d’unités* Systeme (SI) or metric system is used by scientists all over the world. Every field of science involves taking measurements, understanding them, and communicating them to others.

In SI Units there are (7) fundamental physical quantities and units. They are represented in the table below.

S/N	NAME OF PHYSICAL QUANTITY	NAME OF UNIT	SYMBOL
1	Length	Metre	m
2	Mass	Kilogram	kg
3	Electric Current	Ampere	A
4	Time	Second	s
5	Temperature	Kelvin	K
6	Luminous Intensity	Candela	cd
7	Amount of substance	Mole	mol

All other units are described as derived units. Some examples are given in the table below.

Quantity	SI Unit	Symbol	Expressed in terms of SI units
Force	Newton	N	1N = 1 $kgms^{-2}$
Work, heat and energy	Joule	J	1 J= 1 Nm
Power	Watt	W	1 W = 1 Js^{-1}
Quantity of electricity	Coulomb	C	1 C = 1 As
Electric potential (voltage)	Volt	V	1 V = 1 WA^{-1}
Electric resistance	Ohm	Ω	1 Ω = 1 VA^{-1}
Frequency	Hertz	Hz	1 Hz = $1s^{-1}$
Density	kilogram/ $metre^3$	kg/m^3	
Electric charge	Coulomb	C	1 C = 1s·A

Numbers in SI units can be written in multiples and sub- multiples in base ten or the decimal system. There are 20 accepted prefixes. Some examples of the preferred SI prefixes are given below. Note that they are in multiples of 1000 or 10^3

Name of prefix	Symbol	Meaning
Peta	P	$\times 10^{15}$
Tera	T	$\times 10^{12}$
Giga	G	$\times 10^{9}$
Mega	M	$\times 10^{6}$
Kilo	k	$\times 10^{3}$
Milli	m	$\times 10^{-3}$
Micro	µ	$\times 10^{-6}$
Nano	n	$\times 10^{-9}$
Pico	p	$\times 10^{-12}$
Femto	f	$\times 10^{-15}$

It can be seen that the prefix "centi" is not a preferred SI prefix but it is sometimes used because of convenience.

Measurement of Time, Length, and Mass

1) **Time:** - All events which happen in Nature involve the idea of time. It is measured by a chronometer eg. clock, watch, stopwatch or stop clock. Quartz and electronic digital clocks and watches give a high degree of accuracy. Time is measured in seconds. There is an exact definition for a second, but this is beyond the scope of our study.

2) **Length**:-

Length is measured in metres. The basic unit of length in the metric system is the metre.

A metre is about the length of an ordinary broom handle. Scientists have defined the metre exactly, and this definition has been agreed upon by the countries of the world. Large distances are measured by means of **tapes**, graduated in metres. Shorter distances by a **metre rule or callipers**. These measure to the nearest 0.1cm. Smaller lengths (diameter of a rod, thickness of a plate) are measured using **Vernier Calipers** with an accuracy of 0.01cm. The diameter of a small ball or wire or thickness of paper is better measured using a **micrometer screw guage**. This measures to an accuracy of 0.001cm. Curved lines are measured with **opisometers** and the radius of a spherical surface such as a curved mirror or egg shell is measured with a **spherometer. Rulers**- Rulers are the most often used length measurement tool that we find in offices, schools, and home. It can measure objects up to 30 centimeters with sufficient precision of 1 millimetre.
The **laser measure** – This is a linear measurement tool that is by means of not touching the object physically; not like a tape measure that needs to stick out the blade onto the surface of something being measured. Its high precision, speed, and simplicity are exceptional features that laser measure has. It is used extensively in sports to measure field events and is even more more important during the present COVID-19 pandemic to measure lengths without touching the object.

Wheel measure or hodometer - Surveyors use it to measure the distance of two separated points on open land.

3) **Mass**: - The mass of a body is a measure of the quantity of matter it contains. It is measured usually by using a balance. There are different types of balances such as the chemical balance, lever balance, direct reading balance, dial spring balance and the beam balance. These are delicate instruments and should be handled with care. They give an accuracy of between 0.001grams and 1 gram depending on their sensitivity.

OTHER MEASURING INSTRUMENTS

i. Electrical current – Ammeter
ii. Electric potential (Potential difference) – Voltmeter
iii. Temperature – Thermometer

Weight: - Weight is a measure of force. It is a measure of the pull between the earth and an object. It is measured in Newtons. **W=mg.** The weight of an object depends on two things.

1) The distance of the object above the surface of the earth. The higher the object is above the earth, the less the force of gravitational attraction and
2) The amount of matter in the object.

It is measured using a spring balance and a spring scale.

Physical quantities are classified into two main types: Scalar and Vector.

Scalar:-A scalar quantity has only magnitude (size) e.g. time, temperature, speed, pressure, density, volume, distance, energy, work, power. The unit of measurement must also be given.

Vector:-A vector quantity has both magnitude and direction. **e.g.** velocity, acceleration, force, momentum, impulse, weight and displacement. The unit of measurement must also be included.

Accuracy and precision: Accuracy and precision are used in context of measurement.

Accuracy is how close a measurement is to the true, correct or absolute value for that measurement, while the **precision** of a measurement system is refers to how close the agreement is between repeated measurements (which are repeated under the same conditions

Measurements can be both accurate and precise, accurate but not precise, precise but not accurate, or neither. In other words, the **precision** of an experiment, object, or value is a measure of the reliability and consistency. The **accuracy** of an experiment, object, or value is a measurement of how closely results agree with the true or accepted value. Both accuracy and precision are terms used in the fields of science, engineering, and statistics. A good measuring instrument must have both accuracy and precision. Both of them are about the quality of the measurement. We have to understand the difference between them. Accuracy is about close to the real value, while precision is about close to the first value no matter it's near or far from the real value.

Error: All measurements are subject to error, which contributes to the uncertainty of the result. Errors can be classified as human error or blunder or technical error. A blunder, is an outright mistake. A person may record a wrong value, misread a scale, forget a digit when reading a scale or recording a measurement, or make a similar blunder. These blunder should stick out like sore thumbs if we make multiple measurements or if one person checks the work of another. Blunders should not be included in the analysis of data. Perhaps you are transferring a small volume from one tube to another and you don't quite get the full amount into the second tube because you spilled it: this is human error. Technical error can be broken down into two categories: random error and systematic error. Random error, as the name implies, occur periodically, with no recognizable pattern. Random errors are positive and negative fluctuations that cause about one-half of the measurements to be too high and one-half to be too low. Sources of random errors cannot always be identified. **Systematic Errors** are due to identified causes and can, in principle, be eliminated. Errors of this type result in measured values that are consistently too high or consistently too low. Systematic errors may be of four kinds:

1. Instrumental.
2. Observational.
3. Environmental.
4. Theoretical.

MOTION

Motion involves a change of position of a body.

We usually say that a force is a push or a pull. If it is so, then a force can:

1. Cause an object to start moving or to move faster
2. Cause a moving object to change direction
3. Cause an object to slow down or to stop moving
4. Change the shape of an object

While these actions occur, time marches on. Rate describes these events by how fast or how slowly they happen.

Rate is a general term. It is defined by using time as one of the factors. Rates usually measure how fast or how slowly often something happen.

We will only consider the following rates: speed, velocity, acceleration and power.

There are four types of motion

1. **Random Motion:** This motion does not follow any definite pattern. It is completely erratic and it is impossible to predict the position at one instant from the position at a previous instant. A butterfly might exhibit this type of motion if several of them are sucking nectar from a limited number of flowers. Random motion is more commonly observed at molecular level. Some physical properties of matter can be explained by assuming that certain particles undergo random motion. This assumption is used in the Kinetic Theory of gases.
2. **Rotational motion:** It is the motion of a body in circular path about some point fixed in the body or fixed in a space, e.g. a bicycle wheel turning about its axis or the second hand of a clock rotating about its pivot. Another example is the motion of the blades of a ceiling fan. Also called circular motion.

3. **Oscillatory motion:** This is when a body moves to and fro about a given point just like a simple pendulum motion or a vertical loaded spring when displaced. Other examples include plucked guitar string and a drum, which has been struck. This can also be called simple harmonic motion (SHM) or vibration motion.

4. **Translational motion**: This is a movement along a continuous path away from the starting position such that all parts of it undergo the same type of motion, e.g. motor car moving along the road and an athlete running a 100-metre race or moving from our homes to the class.

Motion in a straight line. This is a form of translational motion

When describing motion in a straight line four parameters are required –

time (t), speed or velocity (v), acceleration(a) and distance or displacement(s)

Speed is defined as the rate of change of distance with time.

$$\text{Speed} = \frac{\text{distance travelled}}{\text{Time taken}}, \text{ m/s}$$

The SI units are metres/second (ms^{-1}). But at times km/h is also used for convenience. Not all speeds are the same. A snail moves at 0.001 m/s, a paving machine spreading asphalt (tar) as our roads are being resurfaced moves at about 0.025 m/s. Human beings normally walk at about 1 m/s to 2m/s but a car moving down our roads is limited to 60 km/h (17 m/s) . Imagine, an orbiting communication satellite moves at 3000m/s and light travels in a vacuum at 300000000 m/s. Speed does not tell us in which direction motion takes place, therefore it is a scalar quantity. But if the direction is specified, then we now talk about velocity.

Therefore: Velocity (v) is defined as the rate of change of displacement or distance moved in a specified direction with time.

$$\text{Velocity} = \frac{\text{distance travelled in a specified direction}}{\text{Time taken}} = \frac{\text{displacement}}{\text{Time taken}}, \text{ m/s}$$

The SI unit of measurement is m/s but units such as km/h is sometimes used if the distance travelled is very large. The direction must be specified e.g. East, West, North, South or a combination of them. Directions such as upward, downward, leftward or rightward can also be used. Velocity is therefore a vector quantity.

ACCELERATION: This is defined as the change in velocity with time.

$$\text{Acceleration } a = \frac{\text{change in velocity}}{\text{Time taken}}, \text{ m/s}^2$$

If acceleration is the change in velocity with time, then the following situations are possible:
1) If the final velocity is greater than the initial velocity i.e. (Positive change), acceleration is said to take place.
2) If the final velocity is less than the initial velocity i.e. (Negative change), deceleration or retardation takes place. It must be noted that deceleration leads to the stopping of the moving object.
3) If the final and initial velocities are the same i.e. (no change). This type of motion is known as constant velocity or no acceleration.

EQUATIONS OF LINEAR MOTION WITH UNIFORM ACCELERATION

If a body starts with an initial velocity u, accelerates uniformly along a straight line with an acceleration a, covers a distance s, in a time t, when the velocity reaches a final velocity v, then the following equations are used.

1) $v = u + a\,t$
2) $s = ut + \frac{1}{2}\,a\,t^2$
3) $v^2 = u^2 + 2as$

In a distance – time graph. The gradient of the graph is the speed (velocity).

Sir Isaac Newton working on Galilei Gailileo's work on motion formulated three laws, which became known as Newton's Laws of Motion. These laws can be formulated as:-

1. A body will continue in its state of rest or if moving, will continue in its straight line unless acted upon by an external force.
2. This establishes a relationship between force and acceleration.

The rate of change of momentum is proportional to the applied force and takes place in the direction of the force. This leads us to the famous expression: **F = ma**

where F = force, N
m = mass, kg
a = acceleration, m/s^2

3. To every action, there is an equal and opposite reaction. In other words, action and reaction are equal and opposite.

UNIT 3

WORK, ENERGY, POWER, EFFICIENCY AND MACHINES

OBJECTIVES

After reading through this unit, learners shouls be able to

- **Define work, energy, power and efficiency and give their SI units**
- **Establish a relationship between work and energy**
- **Distinguish between potential and kinetic energy.**
- **State the forms of energy and identify areas where energy is converted from one form to another.**
- **Know what machines are and how to classify them.**

Work: - Work is done when a force moves its point of application along its line of action. It is equal to the product of the force and the distance moved.

For example, work is done if a body is lifted vertically upward against the downward pull of the Earth; or if a spring is stretched, compressed or bent against the elastic resistance to deformation; or if a body is accelerated against the reluctance or inertia which all matter shows to change of its motion (even horizontally)

The SI unit of work is the Joule (J)

When work is done, energy is converted to or from some form of mechanical energy including kinetic energy and potential energy, either gravitational or elastic strain energy or it may be converted into heat energy or electrical energy.

Work = force × displacement

Though force and displacement are both vector quantities, work is a scalar quantity.

Work done can be positive, negative or zero.

Work done is positive if the applied force moves in the direction of motion, e.g. moving an object lying on the floor.

Negative work is done by frictional and other resistive forces.

No work is done by the force of gravity if the object is moving horizontally.

Energy: - Energy is usually defined is the ability or capacity to do work.

If an electric motor is supplied with energy, it can do work. The energy in an electric motor can be used to turn a fan.

If you have energy stored in your body, you can also do work. You can move things from one position to another or do some other forms of work. This explains why you are able to lift or move items from one position to another. The energy you use to do work is stored in your muscles. Sometimes when you use energy to do work, the work you do results in a different form of energy. An example is when a pump lifts water from a lake to a water tower; work is done by the pump. The work is stored in the water that has been moved to a higher position. This stored energy can be used later to do work, **e.g.** to produce electrical energy.

Energy is an important part of our daily lives. We use energy to power our cars, to pump water into our homes, to operate many electrical devices we use every day, e.g. this module could not have been prepared without using a computer which uses electrical energy. We also use energy to cook our food. We must also not forget that the cost of energy is significant these days and also supply is short at times. Therefore if we rely on the use of energy, we must try to use it efficiently and also to pay our bills at the recommended time so as to prevent energy interruptions.

In today's world, most of the energy used to do work comes from burning fossil fuels such as coal or oil. In this process of burning, stored chemical energy, originally provided by the sun, is changed into heat energy. Other sources of energy that are used to do work include water power, solar energy and nuclear energy.

There are two (2) kinds of energy:

a**) Potential energy and b) Kinetic energy**

If a force is applied and work is done to change an object's vertical position, the object has gained potential energy. It is called Potential because the energy is stored and can be used at a later time. This type of stored energy is better known as Gravitational Potential Energy.

Other types of potential energy include

a) Energy stored in stretched springs or compressed springs. This is also known as elastic strain energy.

b) Energy stored when a clock or watch is wound. **Note!** This does not include quartz watches and clocks.

If something is moving, it has kinetic energy. However, work must be done to get the object to move. The work shows up as energy – in the form of motion.

The word **kinetic comes** from the Greek language. It means **motion** or **movement.** Kinetic energy can be found in moving fluids, such as in water or steam. This energy can be used to produce electricity in hydro-electric power stations.

The units of work and energy are the same. In SI units, work and energy are measured in Newton.metre (N.m) or Joules (J).

<u>FORMS OF ENERGY</u>

There are various forms of energy but all of them can be classified either as kinetic or potential energy by nature or from its source. These forms of energy include the following:

1. Heat or Thermal energy
2. Electrical energy
3. Chemical energy
4. Sound energy
5. Mechanical energy i.e. (Potential energy + Kinetic energy)
6. Light and radiation energy
7. Nuclear or Atomic energy.

THE LAW OF CONSERVATION OF ENERGY

This is one of the most fundamental laws in nature. It tells us that a system's total energy remains constant. While energy can be transferred or transformed, the **total amount of energy does not change** – this is called **energy conservation**.

The Law states that energy can neither be created nor destroyed but can be converted or transformed from one form to another.

If this Law is not properly looked at, then we will think that if a ball is dropped from a height then it must bounce back to the same height and this process should continue forever. We must take into account that there will be some energy 'losses'. In fact what is termed here as energy losses are merely energy converted into some other forms that we do not usually consider. Every time the ball touches the ground some energy will be converted into heat and also sound and in some cases even light. These are also forms of energy. Some energy will also be used to overcome the effects of air resistance. Therefore it will be noticed that the ball will bounce back to a height lower than the previous height in each case and sooner or later it will not rise at all. The ball will eventually stop.

In real life situations, energy is converted from one form to another depending on a lot of factors e.g. We know that electrical energy is the most practical and transportable of all energies. It is widely used in life not in the electrical form but in some other form.

Examples of energy conversions in real life situations include:

- Electrical energy to mechanical energy. This takes place in electric motors found in electric fans, electric sewing machines, drilling machines etc.
- Mechanical energy to electrical energy. This occurs in generators and dynamos and especially in hydro-electric power stations.
- Heat energy to mechanical energy. Occurs in steam engines
- Mechanical energy to heat energy. Occurs when friction is being overcome, eg. when stopping a moving vehicle.
- Heat energy to electrical energy. Occurs in solar cells and in some electric generating power plants.
- Electrical energy to heat energy. Occurs in electric kettles, electric irons, electric soldering irons, electric hair dryers etc.
- Sound energy to electrical energy. Occurs in microphones.
- Electrical energy to sound energy. Occurs in telephone earpiece and speakers.
- Chemical energy to electrical energy. Occurs in batteries.
- Electrical energy to chemical energy. Occurs when charging a battery.
- Chemical energy to heat energy. This occurs when fossil fuels and products from crude oil and gas, coal, wood are burnt. The heat released is used to drive cars etc, cook our foods, heat our homes when it is cold or even to produce electricity in our petrol or diesel generators etc.
- Electrical energy to light and heat energy. This occurs in filament lamps.
- Nuclear to heat and electrical energy. This takes place in the reactors of a nuclear power plant during fusion or fission process. This process is very important as a lot of heat and subsequently produced. The process must be carefully controlled because of the high risk of radiation and consequently tremendous environmental catastrophe.
- The Sun transforms nuclear energy into heat and light energy.
- Our bodies convert chemical energy in our food into mechanical energy for us to move
- Lightning converts electrical energy into light, heat and sound energy

3) Power (P)

This is defined as the rate of doing work or the rate of conversion or transfer of energy.

It is measured in Watts (W)

$$\text{Power} = \frac{\text{Energy}}{\text{Time}} = \frac{\text{Work}}{\text{Time}}, \text{ W}$$

4) Efficiency η – This is the ratio of energy output to energy input. It has no units but is usually expressed as a percentage.

$$\text{Efficiency } \eta = \frac{\text{Energy output}}{\text{Energy input}} \times 100\%$$

Efficiency can also be expressed in terms of mechanical advantage and velocity ratio.
Mechanical Advantage (M.A) = Force of the load over Force of the effort
Velocity Ratio (V.R) = distance moved by effort over distance moved by load
Efficiency η = M.A / V.R
The efficiency of a machine is never equal to unity or 100%. This is so because machines have moving parts and therefore some energy will be used to overcome friction. The efficiency of machines can be increased therefore by reducing friction. This can be done by lubricating the moving parts or by using ball or roller bearings. In general a lot of energy is wasted or simply converted into other forms that cannot be considered as useful e.g. the heat or sound produced by friction is not useful at all. They are forms of energy and are given out to the environment thereby reducing the output energy.

5. Machines

A machine is a device by means of which work can be done more conveniently.
The principle of conservation of energy (and specifically the Second law of thermodynamics) limits the maximum work, which the machine can do. Machines may receive energy in different forms. **A simple machine takes energy basically mechanical and gives out mechanical energy e.g. Levers. A machine which accepts one form of energy and gives out energy in a different form is a complex machine e.g. an Electrical generator receives mechanical energy, and gives out electrical energy.** Our study will be limited only to simple machines.
There are different classes of simple machines which include the following:

1. The lever.
2. The screw and screw jack
3. The inclined plane
4. Pulleys
5. The wheel and axle
6. Wedge

These six have very specific features and do unique jobs, even though some may work in similar ways. In fact, some simple machines may be a combination of simple machines.

Important:

Simple machines, unlike complex ones, do not work on their own. They only increase the pull or push, (force or effort) that a person uses, increase or decrease the distance, or change the direction of a movement so that more work can be done. They can:

- transfer a force from one place to another
- change the direction of a force
- increase the magnitude of a force
- increase the distance or speed of a force

Features of a simple machine

- They do not use electricity
- They have one or fewer moving parts
- They give us mechanical advantage
- Even though they make work easier for us, they still need input (force or effort) from a person.
- They make tough jobs easier by changing the force, direction or speed of a movement

Complex Machines

Simple machines are different from complex (or compound machines). Complex machines, like trucks or wagons, or bicycles use many moving parts. They combine many simple machines such as levers, pulleys, and gears to get work done.

A lever is a rigid body pivoted about a point called the fulcrum (F). An effort (E) is applied at one on the lever and this overcomes a load (L) at some other point.
There are three (3) classes or orders of levers.

1. First class levers-

This is perhaps the most common type of levers. The Fulcrum (F) is situated between the load (L) and the effort (E). Examples include claw hammer, crowbar, pliers, scissors, seesaw, handle of common water pump, bicycle hand brakes etc

2. Second class levers

The load (L) is located between the Effort (E) and the Fulcrum (F). Examples include the wheel barrow, nutcracker, door knob, bottle opener, hand flour grinder etc.

3. Third class levers

Here the Effort (E) is located between the load (L) and the Fulcrum. Examples include sugar tongs, laboratory tongs, the forearm of a human body, boat paddle, broom, fishing rod, stapler, forceps etc.
Tongs are used to pick up cubes of sugar especially in restaurants and drop them into our tea cups or coffee cups or can be used also to pick up pieces of meat or chicken. This prevents one's hand to contact the food and thereby making the process of serving food very hygienic and safe as there is no physical contact between the food and our hands or fingers. The same can also be said about specimens in the laboratory.

Pulley- A pulley consists of a wheel with a groove along its circumference, and a rope that is placed inside the groove of the wheel. It uses the principle of applying force over a longer distance, and also the tension in the rope or cable, to amplify the magnitude of the applied force.
The drive element of a pulley system can be a rope, cable, belt, or chain that runs over the pulley inside the groove.
Pulleys can be of many types- fixed pulley, movable pulley, compound pulley.
Pulleys are used on ships to raise and lower sails, in industry to raise and lower heavy cargo, or on cranes for use in moving heavy construction equipment. Elevators also use pulleys to move the car up and down from floor to floor.

Wheel and Axle- The wheel is considered the most important invention in the history of mankind. And the introduction of the axle to the wheel changed the course of world history. An axle is a rod or pole centred in the wheel in such a way that it allows the wheel to turn around it. The wheel and axle rotate together and transfer force from one to the other.
Sometimes, there may be two wheels attached to both ends of the axle.
Gears are a form of the wheel and axle. An electric motor, electric fan, car, bicycle, a Ferris wheel are all examples of uses of wheel and axle.

Inclined Plane- An inclined plane does not have any moving parts. It is simply a surface with an even slope. Sliding a heavy load over the slope makes it easier for us to move that load to a higher or lower surface, than if we tried to just lift the load directly upwards. According to historical evidence, ancient Egyptians used inclined planes to carry heavy stones to build pyramids.
The most common example of an inclined plane is a ramp used in houses and public spaces to move wheelchairs or trolleys loaded with shopping.

Wedge- A wedge is technically an inclined plane or two inclined planes put together to form a pointed triangle that moves to exert a force along the lengths of the sides. Axes, knives, and chisels are all wedges.
The longer and thinner a wedge is, i.e. the sharper it is, the more work it does with little effort.
Wedges have been used by man for millions of years. The earliest tools used by man, such as sharp stones used as spears to hunt and cut trees, were forms of wedges. Modern cars, bullet trains, speed boats and jets also use the concept of wedges. All these have wedge-shaped pointed noses that help them to cut through air and water.

Screw- A screw is simply an inclined plane wrapped around a cylindrical shaft. The inclined plane is in the form of helical grooves or ridges called threads that wrap around the cylindrical shaft on the outside.
Screws are of utmost importance in construction as they can hold things together. Additionally, they can be used to lift very heavy objects and tighten things. Corkscrews, taps, light bulbs, bottle caps all make use of the concept of screws to work.
A drill bit becomes a powerful tool that can drill holes in hard materials like metal and stones when attached to an electric drill machine.

Evaluation

- Where do we use the inclined plane and why is it called a simple machine?
- How do pulleys work?
- Where do we use the wedge in our community?
- Give at least one example each of the three classes of levers different from the examples stated above.
- Why is the forearm of a human body, a third class lever? Give a sketch if possible.

UNIT 4
FRICTION

OBJECTIVES

After this lesson, students should know and be able to

- Define and explain the nature of friction
- State the laws of friction and
- Explain the advantages and disadvantages of friction and how friction can be reduced.

DEFINITION OF FRICTION

Friction is a resistive force acting between bodies that tend to oppose and damp out motion. It occurs in all moving parts of a machine. Friction is usually distinguished as being either static friction (the frictional force opposing placing a body at rest into motion) and kinetic friction (the frictional force tending to slow a body in motion). In general, static friction is greater than kinetic friction.

The force due to kinetic friction is generally proportional to the applied force, so "a coefficient of kinetic fiction" is defined as the ratio of frictional force to the normal force on the body.

There are two coefficients of friction, namely, Coefficient of Static or Limiting friction, F_S and Coefficient of Sliding or Dynamic or Kinetic friction F_d.

It has been shown that F_d is usually less than F_s.

The frictional force F is parallel to the surfaces and its magnitude is proportional to the normal reaction between the surfaces. This can be expressed mathematically as:

$F=\mu N$ where μ is the coefficient of friction. It depends on the nature of the two surfaces and it is not affected by the size of the areas in contact.

N is the normal reaction and it is the force exerted by the surface on the block and it is always normal to the surface.

Laws of friction: There are five laws of friction:

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

ADVANTAGES OF FRICTION

1. Friction plays a vital role in our daily life. Without friction we are handicap.
2. It is becomes difficult to walk on a slippery road due to low friction. When we move on ice, it becomes difficult to walk due to low friction of ice or walking on a slippery floor.
3. We cannot fix nail, screw in the wood or wall if there is no friction. It is friction which holds the nail.
4. A horse cannot pull a cart unless friction furnishes him a secure Foothold.
5. Friction belts or belt drive are used in machines. This can be found in the fan belts of car engines and also chains in bicycles.
6. The grindstone which is a very rough surface is used to wear away metal surfaces to sharpen knives and chisels.
7. Friction between a rubber belt and pulley wheels is used to enable a pulley wheel connected to the engine to drive a pulley wheel connected to the fan.

DISADVANTAGES OF FRICTION

Despite the fact that the friction is very important in our daily life, it also has some disadvantages like:

1. The main disadvantage of friction is that it produces heat in various parts of machines. In this way some useful energy is wasted as heat energy.

2. Due to friction we have to exert more power in machines.

3. It opposes the motion.

4. Due to friction, noise is also produced in machines.

5. Due to friction, engines of automobiles consume more fuel which is a money loss.

DISADVANTAGES OF FRICTION

Friction has the following disadvantages such as:

a) It causes wear especially on shoes, brake lining materials and bearings.

b) It uses up energy and reduces the efficiency of machines. Energy is wasted when motion occurs through air. (it is much easier to cycle or run with the wind rather than against it. It must be noted also that world records are not recognized if the sprinter is running with a wind and the wind speed exceeds a certain value).

c) Energy is wasted to overcome friction and heat is generated. This heat is usually not useful as it is given out to the atmosphere or environment.

METHODS OF REDUCING FRICTION

Friction can be reduced by

a) Lubricating the surfaces which are sliding over each other with a liquid or grease or graphite. Usually oils are used. It must be noted that oils lubricate better when hot.

b) In machines where possible, sliding friction can be replaced by rolling friction by using ball bearing.

c) Using graphite

d) Using talc (powder)

e) Streamlining. Friction can be reduced by changing the design of fast moving objects (streamling). The front of vehicles are made oblong to minimize friction.

f) Polishing the surface(s)

Evaluation

1. Justify the reason for the shape of aeroplanes
2. Why do fastening devices rely on friction? Explain giving an example
3. Explain the reason why oils can be used for lubricating in certain areas whereas greases are used in other areas.

UNIT 5 MAGNETS

OBJECTIVES

The students after completing this unit should be able to answer the following questions:

1. What are magnets and what types of materials are used to make magnets?
2. What are temporary magnets?
3. What are permanent magnets?
4. What are electromagnets?
5. What is the Rule of magnetism?
6. What are some uses of magnets?

What is a magnet and what type of materials are used to make magnets?

A **magnet** is a material or object that produces a magnetic field and attract metals like iron, nickel and cobalt. This magnetic field is invisible but is responsible for the most notable property of a magnet: a force that pulls on other ferromagnetic materials, such as iron, and attracts or repels other magnets.

The magnetic field's **lines of force** exit the magnet from its north pole and enter its south pole. **Permanent** or **hard** magnets create their own magnetic field all the time. **Temporary** or **soft** magnets produce magnetic fields while in the presence of a magnetic field and for a short while after exiting the field. **Electromagnets** produce magnetic fields only when electricity travels through their wire coils.

A **permanent magnet** is an object made from a material that is magnetized and creates its own persistent magnetic field. An everyday example is a refrigerator magnet used to hold notes on a refrigerator door. Materials that can be magnetized, which are also the ones that are strongly attracted to a magnet, are called ferromagnetic. These include iron, nickel, cobalt, some alloys of rare earth metals, neodymium gadolinium and dysprosium (when at a very low temperature) and some naturally occurring minerals such as iron ore. Although ferromagnetic materials are the only ones attracted to a magnet strongly enough to be commonly considered magnetic, all other substances respond weakly to a magnetic field, by one of several other types of magnetism.

Ferromagnetic materials can be divided into magnetically "soft" materials like annealed iron, which can be magnetized but do not tend to stay magnetized, and magnetically "hard" materials, which do. Permanent magnets are made from "hard" ferromagnetic materials such as alnico and ferrite that are subjected to special processing in a powerful magnetic field during manufacture, to align their internal microcrystalline structure, making them very hard to demagnetize.

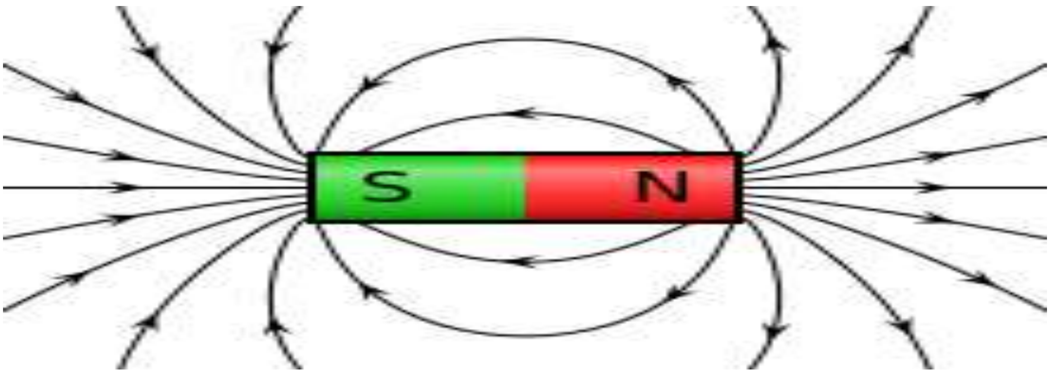
Magnets can be made by placing a magnetic material such as iron or steel, in a strong magnetic field. Permanent, temporary and electromagnets can be made in this manner.
Soft iron and certain iron alloys, such as permalloy (an alloy of iron and nickel) can be easily magnetized, even in a weak field. However as soon as the field is removed, the magnetism is lost. These materials make excellent temporary magnets that are used in telephones and electric motors etc.
Other kinds of alloys such as alnico (an alloy of aluminium, nickel, iron, cobalt) make excellent permanent magnets. Small amounts of other elements are added to enhance the properties of the magnet. Ferrites and other materials made from iron oxide, nickel and cobalt also make excellent permanent magnets. These magnets are very difficult to demagnetize even after the magnetic field has been removed.
Some magnets are straight and are called bar magnets. Others are shaped like a horse shoe and some are round. Some magnets are even shaped like a pencil.

List of Properties of Magnet:
Attractive **Property** – **Magnet** attracts ferromagnetic materials like iron, cobalt, and nickel.

Repulsive **Properties** – Like magnetic poles repel each other and unlike magnetic poles attract each other.

Directive **Property** – A freely suspended **magnet** always points in a north-south direction.

FERROMAGNETISM
Certain metallic materials possess a permanent magnetic moment in the absence of an external field, and manifest very large and permanent magnetizations. These are the characteristics of **ferromagnetism,** and they are displayed by the transition metals iron, cobalt, nickel, and some of the rare earth metals such as gadolinium (Gd).



Paramagnetism: Paramagnetism refers to the magnetic state of an atom with one or more unpaired electrons. The unpaired electrons are attracted by a magnetic field due to the electrons' magnetic dipole moments. This capability allows paramagnetic atoms to be attracted to magnetic fields. Diatomic oxygen, Cl_2 is a good example of paramagnetic material.

Diamagnetism: Diamagnetic substances are characterized by paired electrons: except in the previously-discussed case of transition metals, there are no unpaired electrons. This causes the magnetic fields of the electrons to cancel out; thus there is no net magnetic moment, and the atom cannot be attracted into a magnetic field. In fact, diamagnetic substances are weakly ***repelled*** by a magnetic field eg. Water, plastics

WHAT ARE ELECTROMAGNETS AND WHERE ARE THEY USED?

An electromagnet is made from a coil of wire that acts as a magnet when an electric current passes through it but stops being a magnet when the current stops. Often, the coil is wrapped around a core of "soft" ferromagnetic material such as steel, which greatly enhances the magnetic field produced by the coil.

Electromagnets are used when really strong magnets are required. Electromagnets are produced by placing a metal core (usually an iron alloy) inside a coil of wire carrying an electric current. The electricity in the coil produces a magnetic field. Its strength depends on the strength of the electric current and the number of coils of wire. Its polarity depends on the direction of the current flow. While the current flows, the core behaves like a magnet, but as soon as the current stops, the magnetic properties are lost. Electric motors, televisions, maglev trains, telephones, computers and many other modern devices use electromagnets.

ATTRACTING AND REPELLING PROPERTIES AND THE RULES OF MAGNETISM

Magnets will pull some things towards them. We say, the things have been attracted to the magnet. The things which are attracted to magnets are all made of metal. They are made of iron and steel. Magnets attract things made of the metals, nickel and cobalt.

The pull of a magnet is strongest at its ends or poles. One magnet sometimes attracts another magnet. If the north pole of the one magnet is pointed towards the south pole of another, they will attract each other. But if you point the south pole of one magnet towards the south pole of another, they will not attract each other. The two magnets push each other away. We say the two magnets repel each other.

In the same way, the north pole of one magnet will repel the north pole of another. Therefore two south poles repel each other and two north poles repel each other, but a north and South Pole attract each other. We say ***like poles repel, unlike poles attract.***

The rules can thus be stated as

1. Like poles repel and
2. Unlike poles attract

The Compass & the Earth as a magnet

Hundreds of years ago Chinese sailors use pieces of magnetite, made into needles, to help them find their way if they were lost. A piece of magnetite, or a bar magnet, when freely suspended, generally comes to rest pointing in a north – south direction (a compass needle is a magnet). The Earth is like a giant magnet and behaves as if there is a huge bar magnet in the centre. The north and south ends of the earth are called the north and south poles. Because of the Earth's iron-nickel core, the Earth behaves like a magnet. The Earth's magnetic poles are near the geographic poles.

A compass needle is also a magnet, with north and south poles one poles of needle is north-seeking and is marked "N", that is, it always points to the Earth's magnetic north pole. Similarly, the other pole of the compass needle, marked "S", is south seeking and always points to the Earth's south magnetic pole.

Making and destroying magnets

Making magnets: One way to make a magnet is to use a piece of steel e.g. sewing or knitting needle. Strike the needle with one end of a magnet. Repeat the process in the same direction several times. The more you strike the needle the powerful the magnet will be. A magnet will retain its magnetic properties as long as it is used carefully.

Secondly, electromagnets are produced by placing a metal core (usually an iron alloy) inside a coil of wire carrying an electric current. The electricity in the coil produces a magnetic field. Its strength depends on the strength of the electric current and the number of coils of wire.

Destroying magnets: If you drop a magnet several times on a hard surface or hammer it, it will cease to be become a magnet altogether. Magnets can also be destroyed by heating them red hot and leaving them to cool in the East – West direction.

USES OF MAGNETS

The discovery of magnets was very important as they are used to make electric motors and generators.

1. Magnetic recording media: VHS tapes contain a reel of magnetic tape. The information that makes up the video and sound is encoded on the magnetic coating on the tape. Common audio cassettes also rely on magnetic tape. Similarly, in computers, floppy disks and hard disks record data on a thin magnetic coating. It is difficult these days to come across video cassettes, floppy discs and audio tapes and recorders.
2. Credit, debit, and automatic teller machine cards: All of these cards have a magnetic strip on one side. This strip encodes the information to contact an individual's financial institution and connect with their account(s).
3. Common televisions and computer monitors: TV and computer screens containing a cathode ray tube employ an electromagnet to guide electrons to the screen. Plasma screens and LCDs use different technologies. Every time you use a computer, you're using magnets. A hard drive relies on magnets to store data, and some monitors use magnets to create images on the screen. If your home has a doorbell, it probably uses an electromagnet to drive a noisemaker.
4. Speakers and microphones: Most speakers employ a permanent magnet and a current-carrying coil to convert electric energy (the signal) into mechanical energy (movement that creates the sound).
5. Electric guitars use magnetic pickups to transduce the vibration of guitar strings into electric current that can then be amplified.
6. Electric motors and generators: Some electric motors rely upon a combination of an electromagnet and a permanent magnet, and, much like loudspeakers; they convert electric energy into mechanical energy. A generator is the reverse: it converts mechanical energy into electric energy by moving a conductor through a magnetic field.
7. Medicine: Hospitals use magnetic resonance imaging (MRI) to spot problems in a patient's organs without invasive surgery or to verify the age of young sportsmen and women to avoid cheating (under 19)
8. Compasses: A compass (or mariner's compass) is a magnetized pointer free to align itself with a magnetic field, most commonly Earth's magnetic field.
9. Art: Vinyl magnet sheets may be attached to paintings, photographs, and other ornamental articles, allowing them to be attached to refrigerators and other metal surfaces.
10. Magnets can be used to make jewelry. Necklaces and bracelets can have a magnetic clasp, or may be constructed entirely from a linked series of magnets and ferrous beads.
11. Magnets can pick up magnetic items (iron nails, staples, tacks, paper clips) that are either too small, too hard to reach, or too thin for fingers to hold. Some screwdrivers are magnetized for this purpose.
12. Magnets can be used in scrap and salvage operations to separate magnetic metals (iron, cobalt, and nickel) from non-magnetic metals (aluminum, non-ferrous alloys, etc.). The same idea can be used in the so-called "magnet test", in which an auto body is inspected with a magnet to detect areas repaired using fiberglass or plastic putty.
13. Magnetic levitation transport, or Maglev, is a form of transportation that suspends, guides and propels vehicles (especially trains) through electromagnetic force. The maximum recorded speed of a maglev train is 581 kilometers per hour.

Evaluation

1. Where does the word **'magnet'** come from?
2. List examples of ferromagnetic, paramagnetic, diamagnetic materials
3. Name five things in your homes or in your possession which contain magnets

sThank You for completing this Module.