



NCERT

National Council of Educational Research and Training

Volume – 6

Science



INDEX

S. No.	Chapter Title	Page No.
	Physics	
1.	Motion, Measurement, and Time	1
2.	Measurement, Historical Evolution, and Advanced Motion Analysis	3
3.	Force, Motion, and Gravitation	5
4.	Work, Energy, Heat, and Atmospheric Dynamics	9
5.	The Science of Sound	13
6.	Principles of Light and Optical Phenomena	17
7.	Refraction of Light and Spherical Lenses	19
8.	The Human Eye and Vision	21
9.	Dispersion and Special Optical Systems	21
10.	Electricity and Electric Circuits	22
11.	Magnetism and Electromagnetic Effects	27
12.	Some Natural Phenomena	30
13.	Stars and the Solar System	31
	Chemistry	
14.	The Foundations of Matter (Atomic Theory)	35
15.	Atomic Nucleus and Isotopes	38
16.	Fundamental Science: Matter, Properties, and Changes	38
17.	Changes Around Us	42
18.	Classification of Elements and Periodicity in Properties	43
19.	Chemical Reactions and Equations	47
20.	Acids, Bases, and Salts	50
21.	Metals and Non-metals	53
22.	Carbon and its Compounds	56
23.	From Fibres to Synthetic Materials	60
24.	Coal and Petroleum	63
25.	Combustion	65

	Biology	
26.	The Cell	67
27.	Cell Organelles	69
28.	Diversity in Living Organisms	74
29.	Getting to Know Plants	78
30.	Nutrition in Plants	80
31.	Body Movements and Locomotion	82
32.	Life Processes	85
33.	Control and Coordination in Living Organisms	91
34.	Reproduction in Organisms	95
35.	Reaching the Age of Adolescence	99
36.	Heredity and Evolution	102
37.	Food Resources and Agricultural Management	105
38.	Integrated Study Guide: Why Do We Fall Ill?	108
39.	Foundations of Microbiology	111
40.	The Role of Microorganisms in Human Life	111
41.	Our Environment, Ecology, and Resource Management	113
42.	Soil Science	142

Motion, Measurement, and Time

This chapter consolidates fundamental concepts of physics necessary for understanding mechanics. It integrates the study of motion types, the measurement of physical quantities, and the graphical representation of time-dependent events.

1. The Concept of Motion

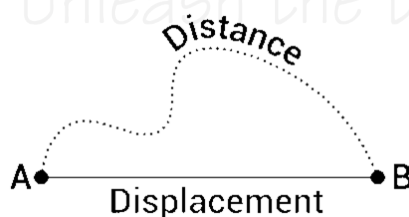
Motion is defined as the change in the position of an object with time. Whether an object is in motion or at rest is often relative to the observer.

- **Relative Nature of Motion:** An object may appear to be moving to one observer but stationary to another. For example, passengers inside a moving bus see their fellow passengers as stationary, while a person standing on the roadside perceives the entire bus and its occupants as moving.
- **Inferring Motion:** We often perceive motion through indirect evidence. For example, the movement of leaves and branches of trees helps us infer the motion of air (wind). Similarly, we infer the motion of the Earth to explain phenomena like sunrise, sunset, and the changing of seasons.

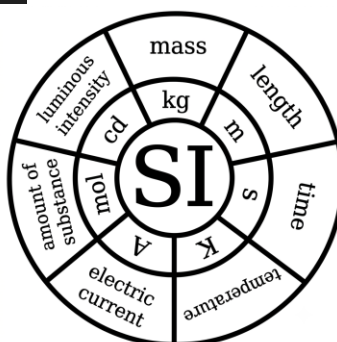
2. Describing Motion

To describe the position of an object, we must specify a **reference point** (or origin).

- **Distance:** The total path length covered by an object from its initial to final position. It is a scalar quantity (only magnitude matters).
- **Displacement:** The shortest distance measured from the initial to the final position of an object. Displacement can be zero if an object returns to its starting point, even if the distance covered is not zero.

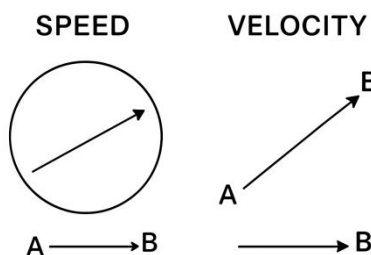


- **Uniform vs. Non-Uniform Motion:**
 - **Uniform Motion:** An object covers equal distances in equal intervals of time.
 - **Non-Uniform Motion:** An object covers unequal distances in equal intervals of time (e.g., a car in heavy traffic).

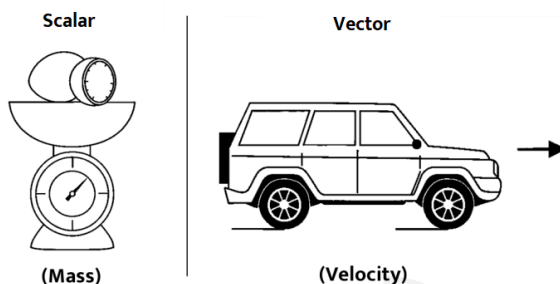
3. Measuring the Rate of Motion

The rate of motion is determined by how fast or slow an object moves.

- **Speed:** The distance covered by an object in unit time.
- Speed = Total Distance / Total Time
 - The SI unit of speed is **metre per second (m/s)**. Other common units include km/h.



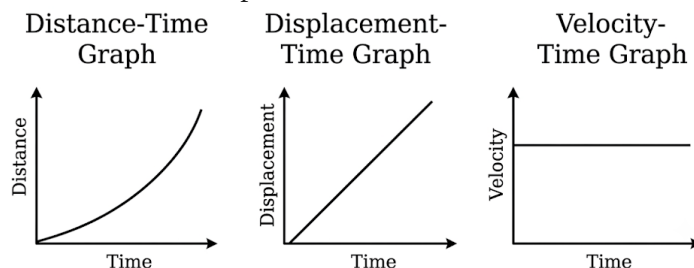
- **Velocity:** Speed with a specified direction. Velocity is the rate of displacement. It is vector quantity.



- It can change if the object's speed, direction, or both change.
 - **Average Velocity:** For an object changing velocity at a uniform rate, it is the arithmetic mean of the initial (u) and final (v) velocity:
$$\text{Average Velocity} = \frac{u + v}{2}$$
- **Acceleration:** The measure of the change in velocity per unit time.
- Acceleration (a) =
$$\frac{\text{Final Velocity } (v) - \text{Initial Velocity } (u)}{\text{Time taken } (t)}$$
 - **Uniform Acceleration:** When velocity increases/decreases by equal amounts in equal time intervals.
 - **Negative Acceleration (Retardation):** Occurs when acceleration is in the direction opposite to the motion (e.g., applying brakes).

4. Graphical Representation of Motion

Graphs provide a visual method to interpret the nature of motion.



- **Distance-Time Graphs:**
 - **Straight Line:** Indicates the object is moving with **uniform speed**. The slope of this line represents the speed.
 - **Non-linear/Curved Line:** Indicates **non-uniform speed** (accelerated motion).
 - **Parallel to Time Axis:** The object is at **rest** (no change in distance).
- **Velocity-Time Graphs:**
 - **Straight Line Parallel to Time Axis:** Indicates **uniform velocity** (zero acceleration). The area under this graph represents the **displacement** of the object.
 - **Straight Sloping Line:** Indicates **uniformly accelerated motion**. The area under the graph here also represents the total distance (displacement) covered.

5. Equations of Motion (for Uniform Acceleration)

For an object moving in a straight line with uniform acceleration (a), the relationships between velocity (v), initial velocity (u), time (t), and distance (s) are:

1. $v = u + at$ (Velocity-Time Relation)
2. $s = ut + \frac{1}{2}at^2$ (Position-Time Relation)
3. $2as = v^2 - u^2$ (Position-Velocity Relation)

6. Uniform Circular Motion

When an object moves along a circular path with constant speed, its direction changes at every point. Since velocity involves direction, a change in direction means the velocity is changing, making it an **accelerated motion**.

- The speed (v) of an object moving in a circle of radius (r) in time (t) is given by:

$$v = \frac{2\pi r}{t}$$

Part 2: Measurement, Historical Evolution, and Advanced Motion Analysis

Building upon the physics of motion, we must understand the quantitative foundations of measurement and the diverse classifications of movement observed in the physical world.

1. The Story of Transport and Measurement

Humanity's quest for mobility has evolved from walking on foot to the development of complex spacecraft. This evolution necessitated the birth of **Measurement**—the comparison of an unknown quantity with a known fixed quantity called a **unit**.

- **Ancient Measurement Systems:** Before standard scales, humans used body parts:
 - **Cubit:** Length from the elbow to the fingertips (Ancient Egypt).
 - **Foot:** The length of a human foot.
 - **Angul/Mutthi:** Finger widths or fist lengths (Ancient India).
 - **Yard:** Distance between the end of an outstretched arm and the chin.
- **The Necessity of Standardization:** Because body dimensions vary from person to person, these methods created confusion. To ensure uniformity globally, scientists accepted the **International System of Units (SI Units)** in 1790 (Metric System).
 - **SI Unit of Length:** The **metre (m)**.
 - **Conversions:** 1 m = 100 cm
 - 1 cm = 10 mm
 - 1 km = 1000 m

2. Correct Techniques of Measurement

To minimize error, specific protocols must be followed when using standard scales:

- **Placement:** The scale must be placed in contact with the object along its length.
- **Broken Edges:** If the zero mark is unclear or broken, start from another full mark (e.g., 1.0 cm) and subtract that reading from the final measurement to find the true length.
- **Parallax Error:** To ensure accuracy, the eye must be positioned **exactly in front** of the point being measured. Viewing from the side leads to incorrect readings.
- **Curved Lines:** Lengths of curved lines (e.g., a map route) cannot be measured directly with a rigid scale. Use a **thread** to trace the curve, mark the endpoints on the thread, and then measure that segment against a straight scale.

3. Classifying Types of Motion

Objects around us exhibit distinct patterns of movement. These are classified as follows:

- **Rectilinear Motion:** Motion along a straight line (e.g., a car on a straight road, sprinters in a 100m race, or a falling stone).
- **Circular Motion:** Motion where an object moves such that its distance from a fixed point (center) remains constant (e.g., a stone whirled by a thread, the tip of an electric fan blade, or hands of a clock).
- **Periodic Motion:** Motion that repeats itself after a fixed interval of time (e.g., a simple pendulum, a child on a swing, strings of a guitar, or the needle of a sewing machine).
- **Rotational Motion:** Motion where an object turns around a fixed axis (e.g., a spinning top or a rolling ball).
- **Combination of Motions:** Many objects exhibit more than one type of motion simultaneously. For example, a **rolling ball** rotates (rotational) while also moving forward (rectilinear).

4. Measurement of Time

Time measurement relies on **periodic motion**. Historically, humans used natural events:

- **Day:** Time between one sunrise and the next.
- **Month:** Time from one new moon to the next.
- **Year:** Time taken by the Earth to complete one revolution around the Sun.
- **Mechanical Measurement:** Ancient devices included **sundials, water clocks, and sand clocks**.

The Simple Pendulum:

- A pendulum consists of a bob suspended by a thread.
- **Oscillation:** One complete to-and-fro motion (from mean position to extreme A, then extreme B, and back to mean position).
- **Time Period:** The time taken to complete one oscillation. Galileo Galilei discovered that the time period of a given pendulum is constant regardless of small initial displacements, which led to the creation of **pendulum clocks**.
- **Modern Precision:** Today, we use **quartz clocks** (using electric circuits) for accuracy. For scientific research, we measure intervals as small as **microseconds** (one-millionth of a second) or **nanoseconds** (one-billionth of a second).

5. Graphical Representation of Data

Graphs are essential tools for analyzing motion patterns, allowing us to determine speed or distance at any given instant.

- **The Distance-Time Graph:**
 - **X-axis:** Represents time.
 - **Y-axis:** Represents distance.
 - **Origin (O):** The point where both axes intersect, representing (0,0).
 - **Interpretation:** A straight-line graph signifies **constant speed**. The slope of the line allows us to calculate the distance covered at any intermediate time not explicitly listed in a table.
- **The Speedometer and Odometer:**
 - **Speedometer:** A device on a vehicle's dashboard that records **instantaneous speed** in km/h.
 - **Odometer:** A device that measures the total **distance** moved by the vehicle.

Summary of Key Units and Concepts

Concept	Basic Unit
Length	Metre (m)
Time	Second (s)
Speed	Metre per second (m/s)

Note: Always write symbols in singular form (e.g., 50 km, not 50 kms).

Force, Motion, and Gravitation

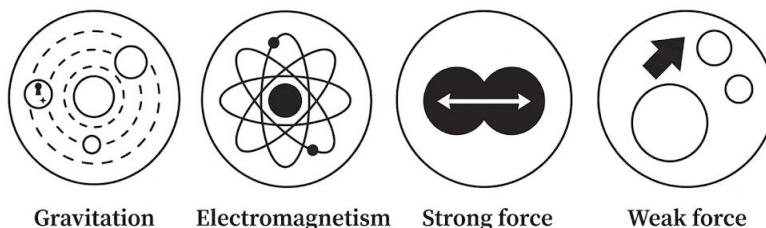
1. The Nature of Force and Motion

- For centuries, philosophers and scientists struggled to understand the cause of motion. The common observation that an object stops after being hit led many to believe that **rest** is the "natural state" of an object. Galileo Galilei and Isaac Newton later revolutionized this understanding.

1.1 What is Force?

- Force is not something that can be seen, tasted, or felt; it is understood through its **effects**. Force is defined as a **push, a pull, or a hit** applied to an object.

Four fundamental forces:



- Effects of Force:**
 - Change in Motion:** It can put a stationary object in motion or stop a moving object.
 - Change in Velocity:** It can change the magnitude (speed) of velocity or its direction.
 - Change in Shape/Size:** It can deform objects (e.g., stretching a spring, squeezing a ball).

1.2 Balanced and Unbalanced Forces

Forces do not always result in motion.

- Balanced Forces:** When multiple forces act on an object and their **net force is zero**, the state of rest or motion does not change.
- Unbalanced Force:** If opposite forces have different magnitudes, the net force is non-zero, and the object moves in the direction of the greater force. An unbalanced force is **essential** to change the state of motion or to accelerate an object.
- The Role of Friction:** Friction is an ever-present force that acts opposite to the direction of motion. To keep an object moving at a uniform velocity, the applied force must be balanced by the frictional force.

2. Laws of Motion

Newton formulated three fundamental laws that govern how objects behave under the influence of force.

Newton's Laws of Motion

1st Law	2nd Law	3rd Law
$\vec{E} \rightarrow (V) \rightarrow (V)$ Then (V) forever or (at rest) forever	$F \rightarrow (m) \rightarrow a$ $F = ma$	$F_1 \rightarrow$ $\leftarrow F_2$ $F_1 = F_2$

2.1 First Law of Motion: The Law of Inertia

Definition: An object remains in a state of rest or uniform motion in a straight line unless compelled to change that state by an applied unbalanced force.

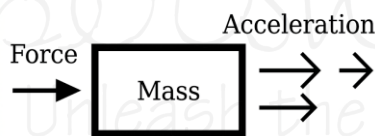
- **Inertia:** This is the natural tendency of an object to resist a change in its state of motion or rest.
- **Mass and Inertia:** **Mass is a measure of inertia.** A heavier (more massive) object offers more resistance to a change in motion than a lighter one. For example, a train has more inertia than a bicycle.
- **Real-world Examples:**
 - **Passengers in a car:** When brakes are applied, the body continues moving forward due to inertia. Conversely, when a bus accelerates suddenly, the body falls backward.
 - **Turning:** When a car takes a sharp turn, passengers slip to one side because their body tends to continue in its original straight-line path.

2.2 Second Law of Motion: Momentum and Force

To understand how force is measured, we must first define **Momentum (p)**.

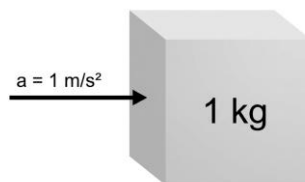
- **Momentum ($p = mv$):** It is the product of mass (m) and velocity (v). It has both magnitude and direction. The SI unit is **kg m/s**.
- **The Law:** The rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of the force.
- **Mathematical Formulation:**
 - Change in momentum = $mv - mu$
 - Rate of change = $\frac{m(v - u)}{t} = ma$
 - **$F = ma$** (where F is Force, m is mass, a is acceleration).

$$f = m \cdot a$$



- **Unit of Force:** The SI unit is the **Newton (N)**. 1 Newton is the force that produces an acceleration of 1 m/s^2 in a **1 kg** mass.

1 N



- **Everyday Application:** Fielder pulling hands back while catching a cricket ball, or athletes jumping on sand/cushions. These actions **increase the time** taken to stop the object, thereby **decreasing the rate of change of momentum** and reducing the impact force.

2.3 Third Law of Motion: Action and Reaction

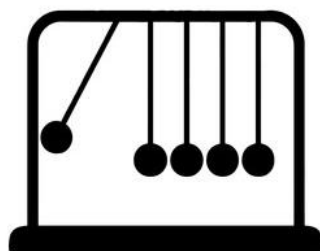
Definition: To every action, there is an equal and opposite reaction, and they act on two different bodies.

- **Nature of Forces:** Action and reaction forces never cancel each other because they act on different objects.

- **Examples:**

- **Recoil of a Gun:** The forward force on the bullet is matched by an equal backward force on the gun.
- **Walking:** We push the road backward, and the road pushes our feet forward.
- **Sailor jumping:** The force on the boat moves it in the opposite direction of the jump.

3. Law of Conservation of Momentum



In an **isolated system** (where no external unbalanced force acts), the total momentum of two objects before collision is equal to the total momentum after collision.

- **Formula:** $m_A u_A + m_B u_B = m_A v_A + m_B v_B$
- This is a fundamental law in physics. It is verified by experiments and used to explain various everyday phenomena, from rocket propulsion (balloon release experiment) to collisions in sports.

4. Gravitation: The Universal Force

- After establishing the laws of motion, we must address the force that governs the universe: **Gravitation**. Isaac Newton concluded that the same force responsible for an apple falling to the earth also keeps the moon in its orbit and planets around the Sun.

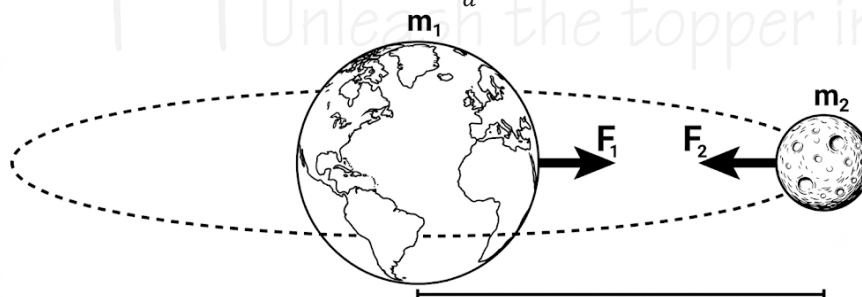
4.1 The Universal Law of Gravitation

Every object in the universe attracts every other object with a force that is:

1. **Directly proportional** to the product of their masses ($M \times m$).
2. **Inversely proportional** to the square of the distance (d^2) between their centres.

Mathematical Formula:

$$F = \frac{G (M \times m)}{d^2}$$



- **G (Universal Gravitational Constant):** Its value is $G = 6.673 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$. It is the same for all bodies in the universe.
- **Significance:** It binds us to the earth, governs the motion of celestial bodies, and causes tides.

4.2 Free Fall and Acceleration due to Gravity (g)

When objects fall towards the earth under the influence of gravitational force alone, they are in **free fall**.

- **Acceleration (g):** During free fall, the earth exerts acceleration on the object. This is denoted by **g**.
- **Value of g:** The value of g on the surface of the earth is approximately **9.8 m/s²**.
- **Characteristics:**
 - g is independent of the mass of the falling object (a feather and a stone fall at the same rate in a vacuum).
 - g varies slightly; it is greater at the poles and smaller at the equator because the earth is not a perfect sphere.

4.3 Mass vs. Weight

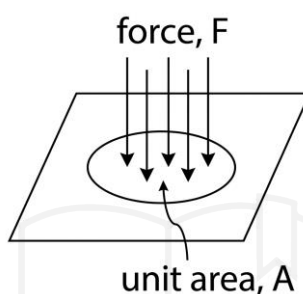
Students often confuse these two, but they are fundamentally different:

- **Mass (m):** The measure of an object's **inertia**. It is constant everywhere (on earth, moon, or space).
- **Weight (W):** The force with which the earth attracts an object. Formula: $W = m \times g$.
- **Variation:** Because g varies with location, weight changes depending on where the object is.
- **Weight on the Moon:** The mass of the moon is less than the earth; therefore, the weight of an object on the moon is **1/6th** of its weight on earth.

5. Thrust and Pressure

When force is applied, its effect depends on the area over which it is distributed.

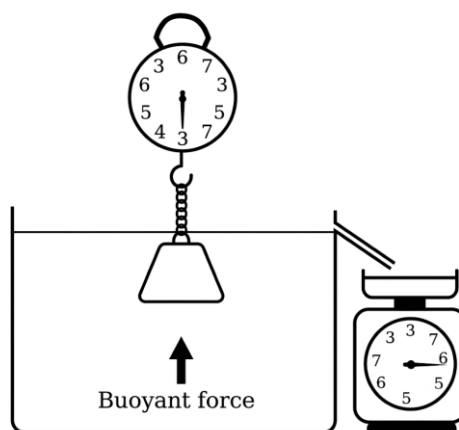
- **Thrust:** The force acting on an object **perpendicular** to the surface.
- **Pressure:** The thrust acting on a **unit area**.
 - **Formula:** $\text{Pressure} = \text{Thrust} / \text{Area}$



- **Unit:** Pascal (Pa), where $1 \text{ Pa} = 1 \text{ N/m}^2$.
- **Practical Application:**
 - Small area = Larger pressure (e.g., pointed tip of a nail, sharp knife).
 - Large area = Smaller pressure (e.g., wide tyres on trucks, wide straps on school bags).

5.1 Pressure in Fluids

- **Fluids:** Both liquids and gases are fluids. They exert pressure on the base and walls of the container.
- **Atmospheric Pressure:** The earth is surrounded by an envelope of air called the atmosphere. The pressure exerted by this air column is atmospheric pressure. We are not crushed by it because the pressure inside our bodies balances it.
- **Buoyancy:** When an object is immersed in a fluid, it experiences an **upward force** called upthrust or **buoyant force**.
 - **Floating/Sinking:** If an object's density is **less** than the fluid, it floats. If it is **greater**, it sinks.



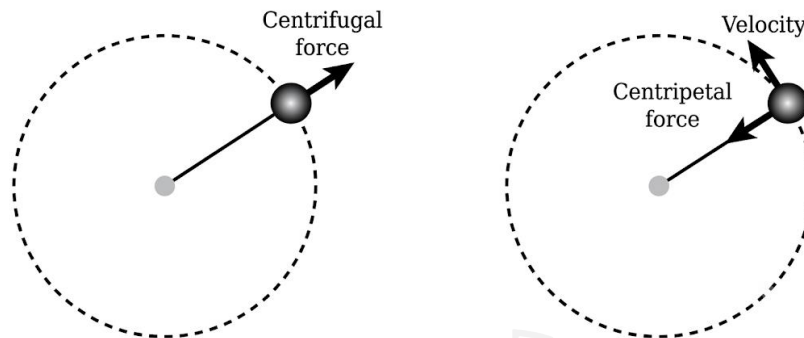
5.2 Archimedes' Principle

This principle is critical for designing ships and submarines.

- **Definition:** When a body is immersed fully or partially in a fluid, it experiences an upward force equal to the **weight of the fluid displaced** by it.
- **Relative Density:** This is the ratio of the density of a substance to the density of water. It is a ratio of similar quantities and therefore has no unit. It helps determine the purity of substances.

Summary of Key Terminology

- **Inertia:** Resistance to change.
- **Momentum:** Product of mass and velocity.
- **Centripetal Force:** Force acting towards the center of a circular path.



- **Drag:** Frictional force exerted by fluids.
- **Lubricants:** Substances (oil, grease) used to reduce friction.
- **Static Friction:** Friction when trying to move an object from rest.
- **Sliding Friction:** Friction when an object slides (smaller than static friction).
- **Rolling Friction:** Resistance when one body rolls over another (smallest friction).

Work, Energy, Heat, and Atmospheric Dynamics

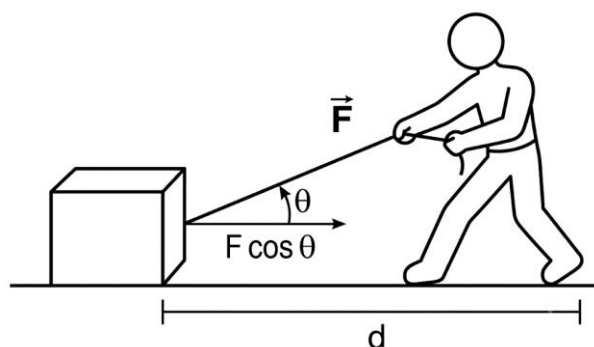
1. The Concept of Work and Energy

In scientific terms, **work** and **energy** are precisely defined, often differing from their common-parlance usage.

1.1 Defining Work

In science, two conditions must be met for work to be done:

1. **A force must act** on an object.
2. **The object must be displaced** in the direction of the force.
 - **Mathematical Expression:** If a constant force F acts on an object causing a displacement s in the direction of the force, the work done W is:
 - $W = F \times s$



- **Unit of Work:** The **Joule (J)**. One Joule is the work done when a force of 1 Newton displaces an object by 1 meter.

- **Sign of Work:**
 - **Positive Work:** When force and displacement are in the same direction.
 - **Negative Work:** When force acts opposite to the direction of displacement (e.g., friction or gravity acting against motion).
 - **Zero Work:** If force is applied but there is no displacement, or if the force is perpendicular to the direction of displacement.

1.2 The Concept of Energy

An object possessing the **capacity to do work** is said to possess **energy**. Energy is transferred from an object doing work to the object on which work is done. Like work, the unit of energy is the **Joule (J)**.

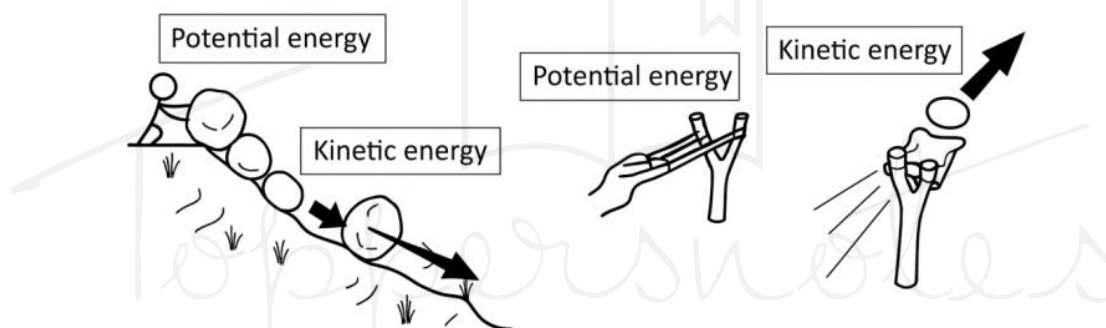
Forms of Mechanical Energy

1. **Kinetic Energy (K.E.):** Energy possessed by an object due to its **motion**. It increases with speed.

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

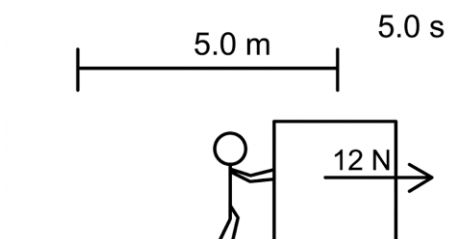
2. **Potential Energy (P.E.):** Energy stored in an object due to its **position or configuration** (shape).

- **Gravitational Potential Energy:** Energy gained by raising an object to a height h against gravity.
- $P.E. = mgh$ (where g is acceleration due to gravity).



1.3 Conservation and Power

- **Law of Conservation of Energy:** Energy can neither be created nor destroyed; it can only be transformed from one form to another. The total energy in an isolated system remains constant.
- **Power:** Defined as the **rate of doing work** or the rate of energy transfer.
 - Power (P) = Work / Time
 - Unit: Watt (W)
 - The standard unit of power in physics is the Watt (W), which is equivalent to one joule per second (J/s). Because a joule is defined as a Newton-meter, power can also be expressed in terms of Newton-meters per second (Nm/s).



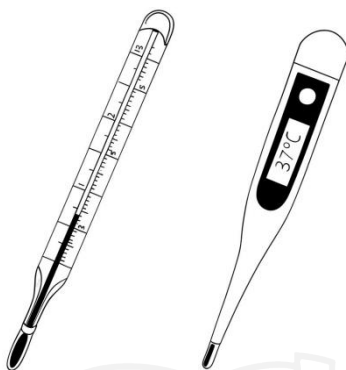
- **Commercial Unit:** Electrical energy is measured in **kilowatt-hour (kWh)**.
 - $1 \text{ kWh} = 3.6 \times 10^6 \text{ Joules}$

2. Heat: The Thermal Dimension

Heat is a form of energy that flows from a body at a higher temperature to a body at a lower temperature.

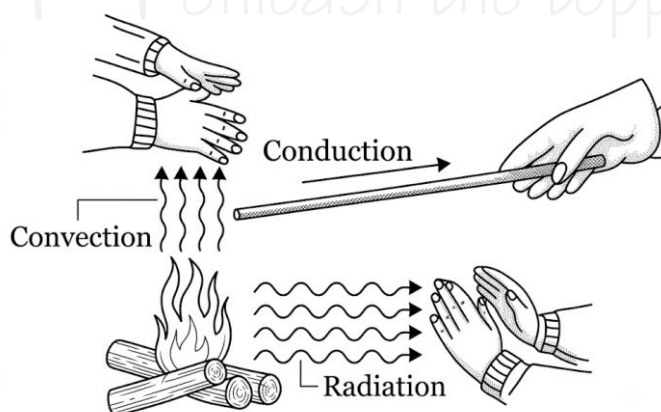
2.1 Temperature Measurement

- **Temperature** is a reliable measure of the degree of hotness or coldness.
- **Clinical Thermometer:** Designed for human body temperature (35°C to 42°C). It contains a **kink** to prevent mercury from falling back, allowing an accurate reading after removal from the body.
- **Laboratory Thermometer:** Used for objects other than the human body; range is usually -10°C to 110°C .



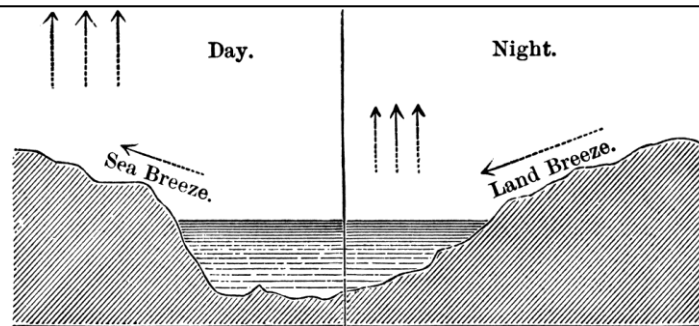
2.2 Modes of Heat Transfer

1. **Conduction:** Transfer of heat from the hotter end to the colder end in **solids** through direct contact.
 - **Conductors:** Materials that allow heat to pass easily (e.g., metals like iron, copper).
 - **Insulators:** Materials that do not allow heat to pass easily (e.g., plastic, wood).
2. **Convection:** Transfer of heat in **liquids and gases** where warmer, lighter molecules rise and are replaced by cooler, denser molecules.
3. **Radiation:** Heat transfer that does not require any medium (e.g., heat from the Sun reaching Earth). All hot bodies radiate heat.



2.3 Thermal Applications

- **Sea Breeze (Day):** Land heats faster than water; air over land rises, and cool air from the sea rushes in.
- **Land Breeze (Night):** Water cools slower than land; cool air from land moves toward the sea.
- **Clothing:** **Dark-coloured** surfaces absorb more heat (preferred in winter), while **light-coloured** surfaces reflect heat (preferred in summer). **Wool** keeps us warm because it is a poor conductor of heat and traps air between its fibres.



3. Atmospheric Dynamics: Winds, Storms, and Cyclones

Atmospheric pressure and temperature variations drive global weather phenomena. **Wind** is defined simply as moving air.

3.1 Principles of Air Pressure

- **Air Exerts Pressure:** Air exerts pressure in all directions. A decrease in air pressure is caused by a reduction in the density or quantity of air in a specific space.
- **Wind Speed and Pressure:** Increased wind speed is always accompanied by **reduced air pressure**. This principle explains why high-speed winds can lift roofs or cause objects to be pulled toward the path of the wind.

3.2 Dynamics of Uneven Heating

Uneven heating of the Earth is the primary driver of wind currents.

- **Air Expansion:** Air expands on heating and becomes lighter (less dense), causing it to rise. Conversely, it contracts on cooling and sinks.
- **Global Patterns:**
 - **Equator vs. Poles:** Regions near the equator receive maximum solar heat, causing air to rise and creating low-pressure areas. Cooler air from the poles and the 0°–30° latitude belts rushes in to fill these voids, setting up global wind circulation. The Earth's rotation causes these winds to deflect from a straight North-South path.
 - **Land vs. Water (Monsoons):** In summer, land warms faster than water, creating low pressure over the land, which draws moisture-laden winds from the Indian Ocean (Monsoon winds). In winter, the process reverses.

3.3 Severe Weather Phenomena

Thunderstorms

- **Formation:** Develop in hot, humid tropical areas (like India). Strong upward winds carry water droplets to high altitudes where they freeze and fall. The vigorous movement of this falling water and rising air creates **lightning and sound**.
- **Safety Precautions:** Avoid isolated trees, metallic objects, and open sheds. A car or bus is generally a safe place to take shelter.

Cyclones

- **Structure:** A cyclone is a violently rotating mass of air (10–15 km high). The center is a calm area called the "**eye**." Around the eye is a 150 km-wide region of high-speed winds (150–250 km/h) and heavy rain.
- **Formation:** As water vapor condenses into raindrops, it releases heat into the atmosphere, warming the air. This warmed air rises, creating a low-pressure system that draws more air into the center, repeating the cycle and intensifying the wind speed.
- **Destruction:** Cyclones push seawater toward the shore, creating a "water-wall" that can be 3–12 meters high, causing severe flooding and loss of life.
- **Global Names:** Known as **Hurricanes** in the American continent and **Typhoons** in the Philippines and Japan.

Tornadoes

- **Nature:** A dark, funnel-shaped cloud reaching from the sky to the ground. Most are weak, but violent ones can travel at speeds of 300 km/h. They can form *within* cyclones.
- **Safety:** Seek shelter in a room deep underground or inside the building with no windows, bowing down on knees to protect the head and neck.

3.4 Safety and Mitigation

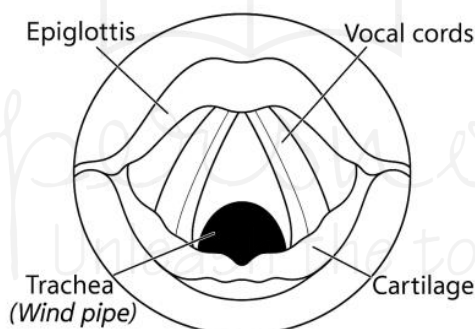
- **Advanced Technology:** The use of satellites and radars allows for a **Cyclone Alert** (48 hours in advance) and a **Cyclone Warning** (24 hours in advance).
- **Measuring Instruments:** An **anemometer** is the instrument used to measure wind speed.
- **Effective Measures:**
 - **Government/Administrative:** Rapid communication of warnings, construction of cyclone shelters, and evacuation arrangements.
 - **Individual Responsibility:** Do not ignore official warnings; store emergency drinking water; move essential goods to safer places; do not touch wet switches or fallen power lines; avoid driving through flooded roads.

The Science of Sound

1. The Nature of Sound

Sound is a form of **energy** that produces a sensation of hearing in our ears. It is produced by the **vibrations** of objects—a rapid to-and-fro or back-and-forth motion.

- **Energy Conversion:** Sound production utilizes energy (mechanical, muscular, etc.). In humans, the **vocal cords** within the **larynx** (voice box) vibrate to produce sound.



- **Vibration Principle:** Whether it is a plucked string (sitar), a struck membrane (tabla/drum), or a vibrating air column (flute), all sound sources rely on physical vibration. When vibration stops, the sound ceases.
- **Energy Conservation:** As per the law of conservation of energy, sound energy cannot be created or destroyed; it is transformed from other forms of energy (e.g., kinetic energy from a moving finger or breath).

2. Propagation of Sound

Sound requires a material **medium** (solid, liquid, or gas) to travel. It cannot propagate through a **vacuum**.

- **Mechanism of Propagation:** When an object vibrates, it displaces adjacent particles in the medium. These particles exert force on their neighbors, creating a chain reaction. Crucially, the **particles themselves do not travel** from the source to the ear; only the **disturbance (wave)** moves forward.
- **Wave Characteristics:**
 - **Compressions (C):** Regions of high pressure/density where particles are crowded together.
 - **Rarefactions (R):** Regions of low pressure/density where particles are spread apart.

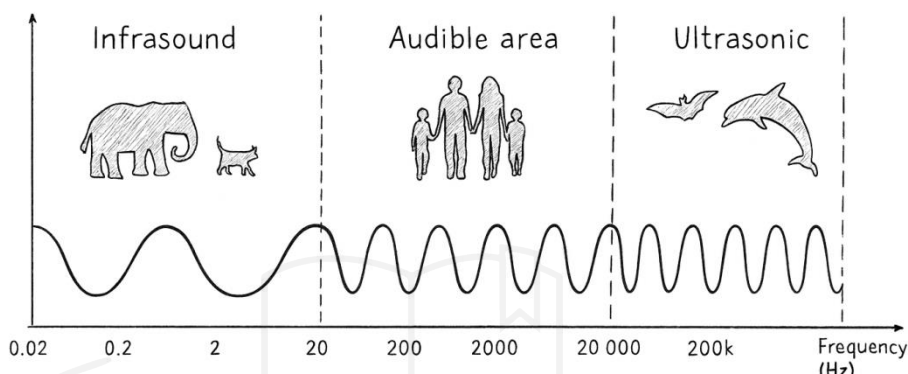
- **Longitudinal Waves:** Sound is a **mechanical, longitudinal wave**. In these waves, medium particles oscillate back and forth **parallel** to the direction of wave propagation.
- **Comparison (Transverse vs. Longitudinal):** Unlike sound, transverse waves (like water ripples or light) involve particles moving perpendicular to the wave direction. Light is not a mechanical wave and does not require a medium.

3. Characteristics of a Sound Wave

A sound wave is defined by its physical parameters, which dictate how we perceive it:

A. Frequency (ν)

- **Definition:** The number of oscillations or vibrations per unit time.
- **Unit: Hertz (Hz)**, named after Heinrich Rudolph Hertz.
- **Relation to Pitch:** Frequency determines the **pitch** (shrillness) of a sound. High frequency = high pitch (e.g., a whistle or a bird's chirp); low frequency = low pitch (e.g., a drum or a lion's roar).



B. Amplitude (A)

- **Definition:** The magnitude of the maximum disturbance on either side of the mean position.
- **Relation to Loudness:** Loudness is a physiological response proportional to the square of the amplitude. Large amplitude = loud sound; small amplitude = feeble sound.
- **Measurement:** Expressed in **decibels (dB)**. Exposure above 80 dB becomes physically painful.

C. Time Period (T)

- **Definition:** The time taken for one complete oscillation.
- **Relationship:** Frequency and time period are inversely related: $f = \frac{1}{T}$.

D. Wavelength (λ)

- **Definition:** The distance between two consecutive compressions or two consecutive rarefactions.
- **Speed Equation:** The speed of sound (v) is calculated as:

$$v = \lambda \times f$$
- (Speed = Wavelength $\times$ Frequency)

E. Quality (Timbre)

- **Definition:** The characteristic that allows us to distinguish between different sounds (e.g., a flute vs. a violin) even if they have the same pitch and loudness. A sound of a single frequency is a **tone**, while a mixture of frequencies is a **note**.

4. Speed of Sound in Different Media

The speed of sound is finite and depends on the **nature** and **temperature** of the medium.

- **Medium Dependency:** Sound generally travels fastest in **solids**, followed by liquids, and slowest in **gases**.
- **Temperature Effect:** In any medium, as temperature increases, the speed of sound increases.
- **Supersonic Speed:** When an object exceeds the speed of sound, it produces **shock waves** that generate a loud, destructive sound known as a **sonic boom**.

5. Reflection of Sound

Sound follows the **laws of reflection** identical to light: the angle of incidence equals the angle of reflection, and the incident sound, reflected sound, and normal all lie in the same plane.

- **Echo:** The repetition of sound caused by reflection from a distant obstacle (like a cliff or tall building).
 - *Condition:* The human brain retains sound for **0.1 seconds**. Therefore, for a distinct echo, the reflected sound must reach the ear after at least 0.1s. At a speed of 344 m/s, the obstacle must be at least **17.2 meters** away.
- **Reverberation:** The persistence of sound in a large hall due to repeated reflections. This is mitigated in auditoriums by using **sound-absorbent materials** (compressed fibreboard, draperies).
- **Practical Applications of Reflection:**
 - **Megaphones/Horns:** Conical openings guide sound in one direction.
 - **Stethoscope:** Multiple reflections carry heart/lung sounds to the doctor's ears.
 - **Curved Ceilings:** Reflect sound toward the audience in concert/cinema halls.
 - **Soundboards:** Placed behind stages to distribute sound evenly.

6. The Human Ear: Structure and Mechanism

The ear is a highly sensitive device that converts pressure variations in the air (sound waves) into electrical signals interpreted by the brain.

- **Outer Ear (Pinna):** Collects sound waves from the surroundings and directs them through the **auditory canal**.
- **Eardrum (Tympanic Membrane):** A thin, stretched membrane at the end of the auditory canal. When compressions strike it, it moves inward; when rarefactions strike it, it moves outward. These vibrations are the fundamental trigger for hearing.
 - **Safety Note:** Never insert sharp or hard objects into the ear, as this can damage the eardrum and cause permanent hearing impairment.
- **Middle Ear:** Contains three small bones (the **hammer, anvil, and stirrup**) that amplify the vibrations received from the eardrum before transmitting them to the inner ear.
- **Inner Ear:** The **cochlea** receives the pressure variations and converts them into electrical signals. These signals are sent to the brain via the **auditory nerve**, where they are perceived as sound.

7. Range of Hearing

Human hearing is limited to specific frequency bands.

- **Audible Range:** The average human ear detects frequencies between **20 Hz and 20,000 Hz (20 kHz)**.
- **Infrasonic Sound (Infrasound):** Frequencies **below 20 Hz**. Humans cannot hear these. However, animals like rhinoceroses, whales, and elephants communicate using infrasound. Some animals exhibit disturbed behavior before earthquakes because they detect the low-frequency infrasound produced by seismic waves.
- **Ultrasonic Sound (Ultrasound):** Frequencies **above 20,000 Hz**. Humans cannot hear these. Animals like dolphins, bats, porpoises, and certain moths use ultrasound for navigation, communication, and hunting.

8. Technological Applications of Ultrasound

Because ultrasonic waves have high frequencies, they can travel along well-defined paths even through obstacles, making them invaluable in medicine and industry.

A. Industrial Applications

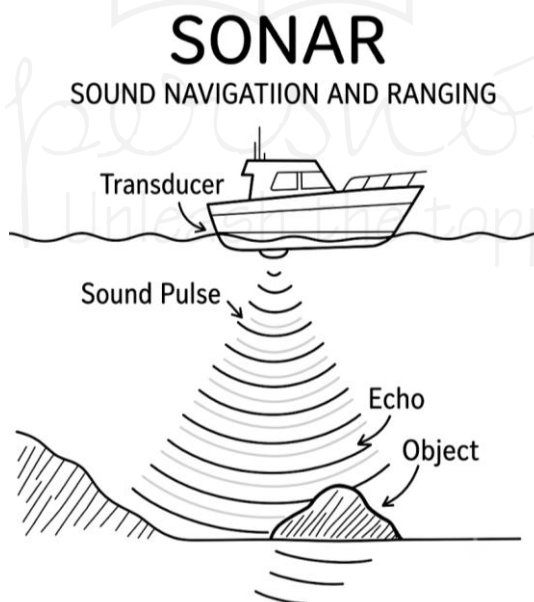
- **Cleaning:** Used to clean parts in hard-to-reach places (e.g., spiral tubes, electronic components). Ultrasonic waves in a cleaning solution detach dust, grease, and dirt from the objects.
- **Defect Detection:** Used to find invisible cracks or flaws in metal blocks (used in bridges, buildings, and machines). If a flaw exists, the ultrasound reflects back to a detector, indicating the defect.

B. Medical Applications

- **Echocardiography:** Uses ultrasound to image the heart.
- **Ultrasonography:** A scanner uses ultrasound to image internal organs (liver, gall bladder, kidney, uterus). It detects stones or tumors by identifying changes in tissue density that reflect the waves. It is also standard for monitoring **foetal development** during pregnancy.
- **Lithotripsy:** Ultrasound is used to break down kidney stones into fine grains that can be flushed out of the body.

C. SONAR (SOUND Navigation And Ranging)

- **Function:** SONAR uses ultrasonic waves to measure the distance, direction, and speed of underwater objects.
- **Mechanism:** A transmitter sends ultrasonic waves through water. These strike an object (seabed, submarine, iceberg) and reflect back to a detector.
- **Calculation:** The total distance ($2d$) traveled by the pulse is calculated using the formula:
 $2d = \text{speed of sound} \times \text{time interval (t)}$
- Where d is the depth or distance of the object.



9. Noise vs. Music and Noise Pollution

- **Music:** Sounds that are pleasant to the ear and typically possess rich quality (a mixture of several frequencies). A single frequency sound is called a **tone**.
- **Noise:** Unpleasant, harsh, or unwanted sounds.
- **Noise Pollution:** The presence of excessive or unwanted sound in the environment.
 - **Sources:** Vehicles, industrial machines, loudspeakers, construction sites, and household appliances (desert coolers, air conditioners).
 - **Health Impacts:** Noise pollution causes lack of sleep, hypertension (high blood pressure), anxiety, and permanent hearing impairment.

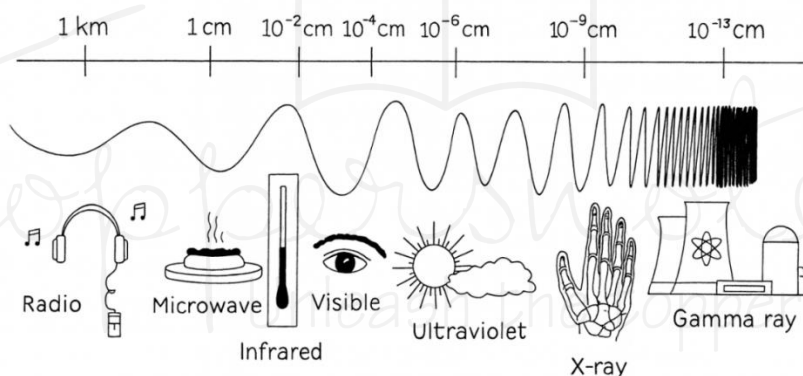
- **Control Measures:**
 - Installing **silencing devices** in engines and industrial machines.
 - Conducting noisy operations away from residential areas.
 - Minimizing automobile horn usage.
 - Running sound systems at low volumes.
 - **Planting trees** along roads and buildings, as they absorb and cut down on the sound reaching residents.

Key Terminology Summary

- **Oscillation:** To-and-fro or back-and-forth motion of an object.
- **Amplitude:** Maximum displacement of a particle from its mean position.
- **Frequency:** Number of oscillations per second.
- **Pitch:** Perception of the shrillness or depth of a sound based on frequency.
- **Loudness:** Physiological response to sound intensity (energy per unit area per second).
- **Hearing Aid:** An electronic, battery-operated device that uses a microphone to convert sound into electrical signals, amplifies them, and uses a speaker to deliver clearer sound to the ear.

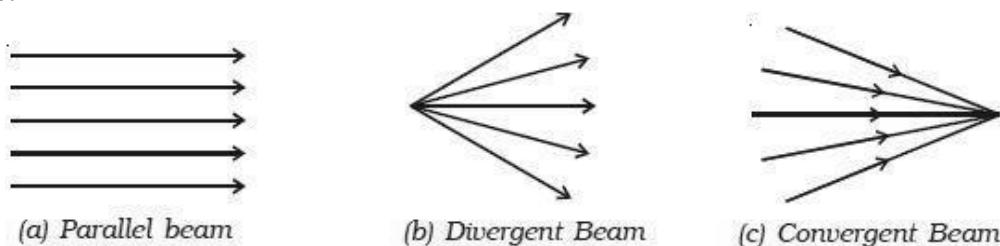
Principles of Light and Optical Phenomena

Light is a form of energy that enables the sensation of vision. Our ability to see objects depends on light entering our eyes, either by being emitted by the object itself (**Luminous objects** like the Sun, fire, candle flames) or by being reflected by an object (**Illuminated objects** like the Moon, chairs, or trees).



1. Rectilinear Propagation of Light

Light travels along **straight lines**. This is why opaque objects, when placed in the path of light, cast a **shadow**.



- **Shadows:** Formed only when an opaque object obstructs the path of light and the light is received on a **screen** (ground, wall, or cardboard).
- **Pinhole Camera:** A simple device based on the rectilinear propagation of light. It forms images of brightly lit objects. Images in a pinhole camera are **upside down (inverted)** and can show the colors of the object.
- **Natural Pinhole Camera:** When sunlight passes through gaps between leaves of a tree, the irregular gaps act as pinholes, creating circular images of the Sun on the ground.