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Volume - 6

Science and Technology

SIERRA INNOVATIONS

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SCIENCE & TECH

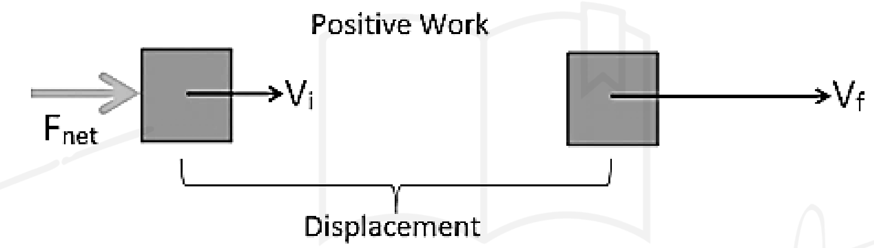
1 CHAPTER

Work, Power and Energy

Work

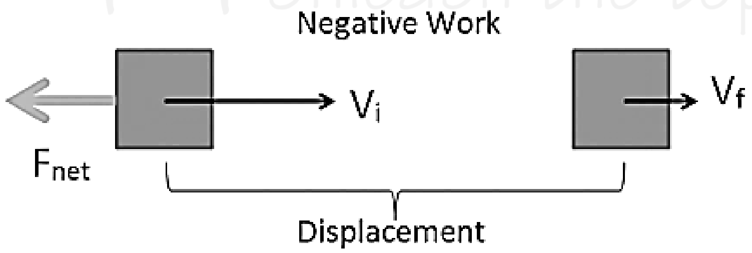
- When a **force acts on an object → displacement**, **force has done work** on the object.
- **2 conditions** need to be satisfied for work to be done:
  - A **force should act** on object
  - The **object** must be **displaced**
- **Work** = **Force** x **Displacement**
- **Unit**- Joule
- **1 Joule work** is said to be done **when 1 Newton force** is applied on an object and it shows the **displacement by 1 meter**.

Positive work



- When **force and displacement are in same direction**
- **Eg:** :a baby pulling a toy car parallel to the ground.
- **Work done** = product of the force and displacement.

Negative work



- When **force** and **displacement** are in **opposite direction**.
- **Eg**. work done by the frictional force, when we walk.

Power

What is Power ?

- We can **define power** as the **rate of doing work**, it is the **work done in unit time.**
- The **SI unit** of power is **Watt (W)** which is **joules per second** (J/s).
- Sometimes the **power** of **motor vehicles** and **other machines** is given in terms of Horsepower (hp), which is **approximately equal to 745.7 watts.**

What is Average Power ?

- We can define average power as the **total energy consumed divided** by the **total time taken**.
- In simple language, we can say that **average power** is the **average amount of work done** or **energy converted per unit of time.**

Power Formula

- **Power** is defined as the **rate at which work is done** upon an object.
- **Power** is a **time-based quantity.**
- Which is **related** to **how fast a job is done**.
- The **formula** for power is mentioned below.
    - **Power = Work / time (P = W / t)**

Unit of Power

- The **unit** for **standard metric work** is the **Joule** and the **standard metric unit** for **time** is the **second**, **so** the **standard metric** unit for power is a **Joule / second,** defined as a **Watt** and **abbreviated W.**

Energy

- **Capacity** of a body **to do work.**
- **SI unit:** Joule (J).
- Forms
    1. **Kinetic Energy**
        - Energy possessed by a body due to its motion.
        - Increases with speed.
        - Kinetic energy of body moving with a certain velocity = work done on it to make it acquire that velocity
    2. **Potential Energy**
        - Energy possessed by a body due to its position or shape.

Gravitational Potential Energy: (GP)

- **When an object is raised against gravity**.
- **Energy possessed** by **such object** is gravitational potential energy.

Conservation of Energy or the first law of thermodynamics:

- **Energy** can **neither** be **created nor destroyed** but only **changed** from **one form** to **another**.
- **Total energy before** and **after transformation** always **remains constant**.

Force

- An **external agent** capable of **changing state** of **rest** or **motion** of a particular body.
- Has both **magnitude** and **direction**.
- **Measured** using a **spring balance**.
- **SI unit:** Newton(N) or Kgm/s2.
- **Effects:**
    - Can **make a body move from rest**
    - Can **stop a moving body** or slow it down.
    - Can **accelerate speed** of a moving body.
- **Formula**: **F = ma**

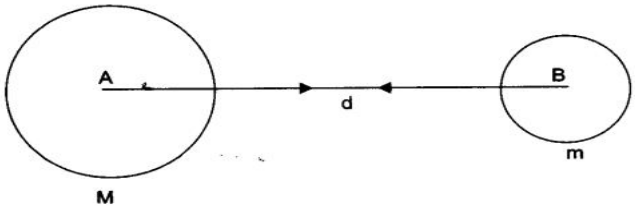
  Where, m = mass, a = acceleration

Gravitational Force

- **Force** that **attracts** a **body towards centre** of earth, or **towards any other physical body** having mass.
- **Every object** that has **mass exerts** a **gravitational pull** or force on every other mass.
- **Strength** of this pull **depends on** the **masses** of **objects**
- **Gets weaker** with **distance**.
- **Keeps planets in orbit** around sun and moon around the Earth
- **First discovered** in 1687 by Sir Isaac **Newton**.

Universal law of gravitation:

- **Every object** in the universe **attracts** every **other object with a force** which is **proportional to** the **product** of their **masses** and **inversely proportional** to the **square** of the **distance** between them.
- The **force** is **along** the **line joining** the **centres** of **two objects**.



Gravitational force between two uniform objects is directed along the line joining their centres.

Formula:

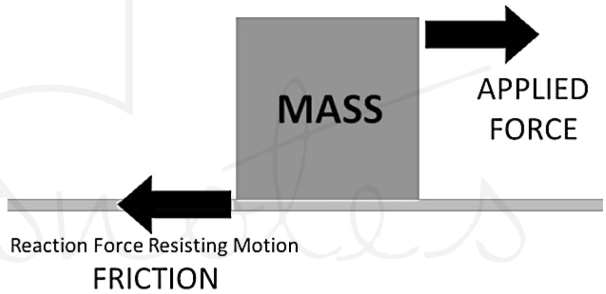
$$F = \frac{G \times M \times m}{d^2}$$

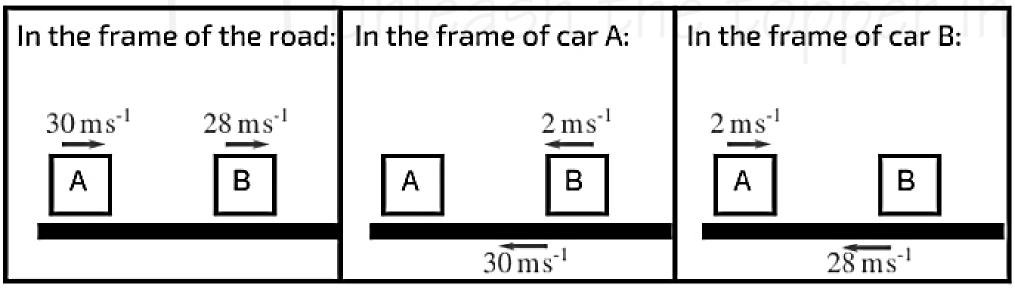
- Here M and m = masses of the objects interacting
- d- distance between the center of the masses
- G -gravitational constant (6.674×10^{-11} $m^3 \cdot kg^{-1} \cdot s^{-2}$)

Friction

- **Friction force:** The **external force** that **opposes relative motion** between 2 surfaces in contact.
- **Friction acts on** the **surface of contact** of both the bodies.

Relative motion: When one **object moves relative to another** it is called a relative motion.

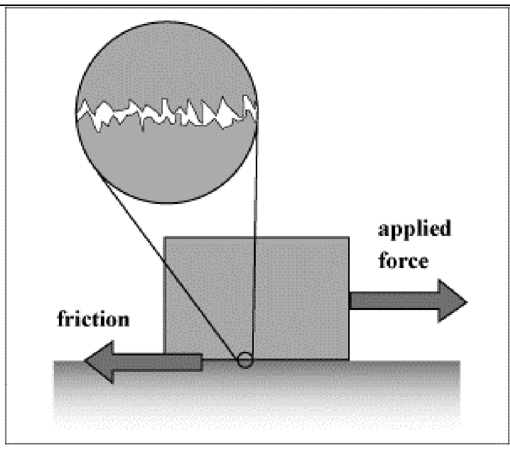




Causes of Friction

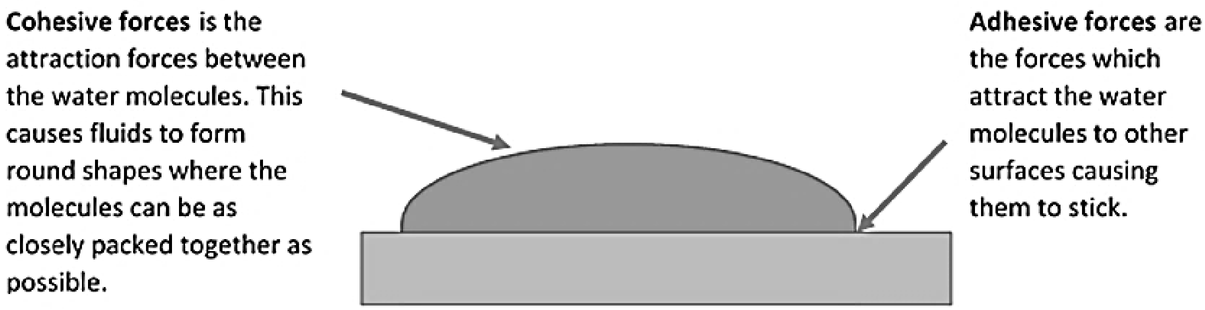
Surface irregularities

- All **surfaces** when **zoomed** into a **microscopic level** contain **hills and valleys** that **interlock** when they **move or rub on** top of **each other**.
- This **unevenness** of the **surface** is **called** as **surface irregularities** or **roughness**.
- **Rough surfaces** have **larger irregularities** while **smoother surfaces** have **lesser irregularities.**



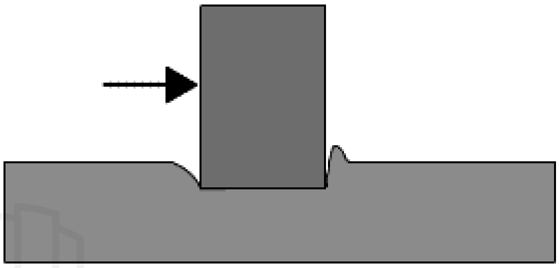
Adhesive forces

- When **two surfaces** are **in contact** they start to **form bonds** and begin to **stick to each other.** This **phenomenon** is called as **Adhesion.**
- When we try to **move objects** that are on **top of another**, we are **basically breaking** the **bonds or overcoming** the **adhesive forces**.



Plowing effect

- When **surfaces** are **soft or** can **change their shape easily**, they **get deformed when** they come **in contact** with **another object**.
- **Ex:** carpets, when a heavy object is placed on them, it looks like a valley that is caused by the deformation of the shape.
- This **effect** of the **surfaces sinking** into each other is **known as Plowing effect.**



Factors Affecting Friction

Depends on the **nature of surfaces** in **contact**. (Friction exists between two surfaces) E.g.: glass and rubber

Nature of surface in contact

- **Friction depends** on **how hard** the **two surfaces pressed together**, as **more surface** in **contact** and **more bonds** are **formed**→ more bonds to break → means **more friction.**
- **Only** the **normal reaction force** (exactly perpendicular) to the two surfaces **increases friction.**

Atmospheric pressure

- The **weight** of a **column** of **air contained** in a **unit area from** the **mean sea level** to the **top** of the **atmosphere** is **called** the **atmospheric pressure.**
- It is **measured** in force per unit area.
- It is **expressed** in **'milibar'** or **mb unit.**
- In the **application level**, the **atmospheric pressure** is **stated** in **kilo-pascals.**
- It is **measured** by the **aneroid barometer** or **mercury barometer.**
- In the **lower atmosphere**, the **pressure declines rapidly** with height.
- The vertical pressure gradient force is much **larger than** that of the **horizontal pressure gradient** and is **commonly balanced** by an **almost equal but opposite** gravitational force.
- The **low-pressure system** is **encircled** by **one or more isobars** with the **lowest pressure** at the centre.
- The **high-pressure system** is also **encircled** by **one** or **more isobars** with the **highest pressure** in the **centre**.
- **Isobars** are **lines connecting** places **having equal pressure.**

2 CHAPTER Units and Measurements

Mass

- **Quantity of matter contained** in a **body**.
- A **scalar** quantity.
- **Unit** - **kilogram**.
- A body **contains** the **same quantity** of **matter whether** it be on the **earth**, **moon** or even in **outer space**. Thus, **mass** is **constant** and **does not change** from place to place.
- **Denoted** by the small letter **'m'**.
- **Cannot be zero**.

Weight

- Measure of **force of gravity** acting on a body.
- **Formula** : w = mg
- **Unit**- Newton (as it is a force).
- **Vector quantity**

Difference between Mass and Weight

Mass	Weight
• **Quantity of matter** possessed by a body	• **Force** with which a **body** is **attracted towards** the **centre** of the earth.
• **Scalar** quantity.	• **Vector** quantity.
• S.I. unit - **kilogram** (kg.)	• S.I. unit - **Newton** (N).
• **Remains constant** at all places	• **Changes** from place to place.
• **Never zero**.	• **Becomes zero** at the centre of the earth.
• **Measured** by a **beam balance**.	• **Measured** by a **spring balance**.

Every measurement has two parts.

- The **first** is a **number** (n) and the **next** is **a unit** (u).
- **Q = nu**.
- **For Example**, the **length** of an **object** = **40 cm**.
- The **number expressing** the **magnitude** of a **physical quantity** is **inversely proportional** to the **unit selected.**
- **If n1** and **n2** are the **numerical values** of a **physical quantity** corresponding to the **units u1** and **u2,** then **n1u1 = n2u2.**
- **For Example**,
  - 2.8 m = 280 cm
  - 6.2 kg = 6200 g.

Fundamental Quantities

The **quantities** that are **independent of other quantities** are **called fundamental quantities**.

- The **units** that are **used** to **measure** these **fundamental quantities** are **called fundamental units**.
- There are **four systems** of **units namely**
  - C.G.S,
  - M.K.S,
  - F.P.S,
  - SI.
- The **quantities** that are **derived using** the **fundamental quantities** are **called derived quantities**.
- The **units** that are **used** to **measure** these **derived quantities** are **called derived units.**

Fundamental and Supplementary Physical Quantities in SI system

Fundamental Quantity	System of units		
	C.G.S.	**M.K.S.**	**F.P.S.**
Length	centimeter	Meter	foot
Mass	gram	Kilogram	pound
Time	second	Second	second

Physical quantity	Unit	Symbol
Length	Meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Intensity of light	candela	cd
Quantity of substance	mole	mol

SI Units

- **Most SI units** are **used** in **scientific research**.
- **SI** is a **coherent system of units.**

Cohenrent System Of Units

- A coherent system of units is **one in which** the **units of derived quantities** are **obtained** as **multiples or submultiples** of certain basic units.
- **SI system** is a **comprehensive**, **coherent** and **rationalized** M.K.S. Ampere system (RMKSA system) and was devised **by Prof. Giorgi.**
- **Meter:** A meter is **equal** to **1650763.73 times** the **wavelength** of the **light emitted** in **vacuum due to electronic transition** from 2p10 state to 5d5 **state in Krypton-86**.
  - But **in 1983**, **17th General Assembly** of **weights and measures adopted** a **new definition** for the **meter** in **terms of velocity of light**.
  - According to this definition, a **meter** is **defined as** the **distance traveled** by **light in vacuum during** a **time interval** of 1/299, 792, 458 of a second.
- **Kilogram:** The **mass** of a cylinder of **platinum-iridium alloy** kept **in** the **International Bureau** of **weights** and **measures preserved** at Serves **near Paris** is **called one kilogram.**
- **Second:** The **duration** of **9192631770 periods** of the **radiation corresponding** to the **transition between** the **two hyperfine levels** of the **ground state** of **cesium-133 atoms** is **called one second.**
- **Ampere:** The **current** which **when flowing** in **each** of **two parallel conductors** of **infinite length** and **negligible cross-section** and placed **one meter apart** in vacuum, **causes** each **conductor** to **experience** a **force** of **2 × 10-7 newtons per meter** of length **is known** as **one ampere.**
- **Kelvin:** The **fraction** of **1/273.16** of the **thermodynamic temperature** of the **triple point** of **water** is **called Kelvin.**
- **Candela:** The **luminous intensity** in the **perpendicular direction** of a **surface** of a **black body** of area **1/600000 m2** at the **temperature** of **solidifying platinum** under a **pressure of 101325 Nm-2** is known as **one candela.**
- **Mole:** The **amount** of a **substance** of a **system** which **contains** as **many elementary entities** as there are **atoms** in **12 × 10-3 kg** of **carbon-12** is known as **one mole.**
- **Radian:** The **angle made** by an **arc** of the **circle equivalent** to its **radius** at the **center** is known as **radian**.
  - **1 radian = $57^{0}17^{I}45^{II}$.**

- **Derived SI units with Special Names:**

Physical quantity	SI unit	Symbol
Frequency	hertz	Hz
Energy	joule	J
Force	newton	N
Power	watt	W
Pressure	pascal	Pa
Electric charge or quantity of electricity	coulomb	C
Electric potential difference and emf	volt	V
Electric resistance	ohm	Ω
Electric conductance	siemen	S
Electric capacitance	farad	F
Magnetic flux	weber	Wb
Inductance	henry	H
Magnetic flux density	tesla	T
Illumination	lux	Lx
Luminous flux	lumen	Lm

Dimensional Formulas for Physical Quantities

Physical quantity	Unit	Dimensional formula
Acceleration or acceleration due to gravity	ms^{-2}	LT^{-2}
Angle (arc/radius)	rad	$M^oL^oT^o$
Angular displacement	rad	$M^ol^oT^o$
Angular frequency (angular displacement/time)	$rads^{-1}$	T^{-1}
Angular impulse (torque x time)	Nms	ML^2T^{-1}
Angular momentum (Iω)	kgm^2s^{-1}	ML^2T^{-1}
Angular velocity (angle/time)	$rads^{-1}$	T^{-1}
Area (length x breadth)	m^2	L^2
Boltzmann's constant	JK^{-1}	$ML^2T^{-2}\theta^{-1}$
Bulk modulus	Nm^{-2}, Pa	$M^1L^{-1}T^{-2}$
Calorific value	Jkg^{-1}	L^2T^{-2}
Coefficient of linear or areal or volume expansion	$^oC^{-1}$ or K^{-1}	θ^{-1}
Coefficient of surface tension (force/length)	Nm^{-1} or Jm^{-2}	MT^{-2}
Coefficient of thermal conductivity	$Wm^{-1}K^{-1}$	$MLT^{-3}\theta^{-1}$
Coefficient of viscosity	poise	$ML^{-1}T^{-1}$
Compressibility (1/bulk modulus)	Pa^{-1}, m^2N^{-2}	$M^{-1}LT^2$
Density (mass / volume)	kgm^{-3}	ML^{-3}
Displacement, wavelength, focal length	m	L
Electric capacitance (charge/potential)	CV^{-1}, farad	$M^{-1}L^{-2}T^4I^2$
Electric conductance (1/resistance)	Ohm^{-1} or mho or siemen	$M^{-1}L^{-2}T^3I^2$
Electric conductivity (1/resistivity)	siemen/metre or Sm^{-1}	$M^{-1}L^{-3}T^3I^2$
Electric charge or quantity of electric charge	coulomb	IT
Electric current	ampere	I
Electric dipole moment (charge x distance)	Cm	LTI
Electric field strength or Intensity of electric field (force/charge)	NC^{-1}, Vm^{-1}	$MLT^{-3}I^{-1}$
Electric resistance	ohm	$ML^2T^{-3}I^{-2}$
Emf (or) electric potential (work/charge)	volt	$ML^2T^{-3}I^{-1}$
Energy (capacity to do work)	joule	ML^2T^{-2}
Energy density	Jm^{-3}	$ML^{-1}T^{-2}$
Entropy	$J\theta^{-1}$	$ML^2T^{-2}\theta^{-1}$
Force (mass x acceleration)	newton (N)	MLT^{-2}
Force constant or spring constant (force/extension)	Nm^{-1}	MT^{-2}
Frequency (1/period)	Hz	T^{-1}

Gravitational potential (work/mass)	Jkg^{-1}	L^2T^{-2}
Heat (energy)	J or calorie	ML^2T^{-2}
Illumination (Illuminance)	lux (lumen/metre^2)	MT^{-3}
Impulse (force x time)	Ns or $kgms^{-1}$	MLT^{-1}
Inductance (L) or coefficient of self-induction	henry (H)	$ML^2T^{-2}I^{-2}$
Intensity of gravitational field (F/m)	Nkg^{-1}	L^1T^{-2}
Intensity of magnetization (I)	Am^{-1}	$L^{-1}I$
Joule's constant or mechanical equivalent of heat	$Jcal^{-1}$	$M^oL^oT^o$
Latent heat (Q = mL)	Jkg^{-1}	$M^oL^2T^{-2}$
Linear density (mass per unit length)	kgm^{-1}	ML^{-1}
Luminous flux	lumen or (Js^{-1})	ML^2T^{-3}
Magnetic dipole moment	Am^2	L^2I
Magnetic flux (magnetic induction x area)	weber (Wb)	$ML^2T^{-2}I^{-1}$
Magnetic induction (F = Bil)	$NI^{-1}m^{-1}$ or T	$MT^{-2}I^{-1}$
Magnetic pole strength (unit: ampere–meter)	Am	LI
Modulus of elasticity (stress/strain)	Nm^{-2}, Pa	$ML^{-1}T^{-2}$
Moment of inertia (mass x radius^2)	kgm^2	ML^2
Momentum (mass x velocity)	$kgms^{-1}$	MLT^{-1}
Permeability of free space	Hm^{-1} or NA^{-2}	$MLT^{-2}I^{-2}$
Permittivity of free space	Fm^{-1} or $C^2N^{-1}m^{-2}$	$M^{-1}L^{-3}T^4I^2$
Planck's constant (energy/frequency)	Js	ML^2T^{-1}
Poisson's ratio (lateral strain/longitudinal strain)	—	$M^oL^oT^o$
Power (work/time)	Js^{-1} or watt (W)	ML^2T^{-3}
Pressure (force/area)	Nm^{-2} or Pa	$ML^{-1}T^{-2}$
Pressure coefficient or volume coefficient	$^oC^{-1}$ or θ^{-1}	θ^{-1}
Pressure head	m	M^oLT^o
Radioactivity	Disintegrations per second	$M^oL^oT^{-1}$
Ratio of specific heats	—	$M^oL^oT^o$
Refractive index	—	$M^oL^oT^o$
Resistivity or specific resistance	–m	$ML^3T^{-3}I^{-2}$
Specific conductance or conductivity (1/specific resistance)	siemen/metre or Sm^{-1}	$M^{-1}L^{-3}T^3I^2$
Specific entropy (1/entropy)	KJ^{-1}	$M^{-1}L^{-2}T^2\theta$
Specific gravity	—	$M^oL^oT^o$
Specific heat (Q = mst)	$Jkg^{-1}\theta^{-1}$	$M^oL^2T^{-2}\theta^{-1}$
Specific volume (1/density)	m^3kg^{-1}	$M^{-1}L^3$
Speed (distance/time)	ms^{-1}	LT^{-1}
Stefan's constant	$Wm^{-2}\theta^{-4}$	$ML^oT^{-3}\theta^{-4}$
Strain (change in dimension/original dimension)	—	$M^oL^oT^o$
Stress (restoring force/area)	Nm^{-2} or Pa	$ML^{-1}T^{-2}$
Surface energy density (energy/area)	Jm^{-2}	MT^{-2}
Temperature	^oC or θ	$M^oL^oT^o\theta$
Temperature gradient	$^oCm^{-1}$ or θm^{-1}	$M^oL^{-1}T^o\theta$
Thermal capacity (mass x specific heat)	$J\theta^{-1}$	$ML^2T^{-2}\theta^{-1}$
Time period	second	T
Torque or moment of force (force x distance)	Nm	ML^2T^{-2}
Universal gas constant (work/temperature)	$Jmol^{-1}\theta^{-1}$	$ML^2T^{-2}\theta^{-1}$
Universal gravitational constant	Nm^2kg^{-2}	$M^{-1}L^3T^{-2}$
Velocity (displacement/time)	ms^{-1}	LT^{-1}
Velocity gradient (dv/dx)	s^{-1}	T^{-1}
Volume (length x breadth x height)	m^3	L^3
Water equivalent	kg	ML^oT^o
Work (force x displacement)	J	ML^2T^{-2}

3 CHAPTER Motion

Motion

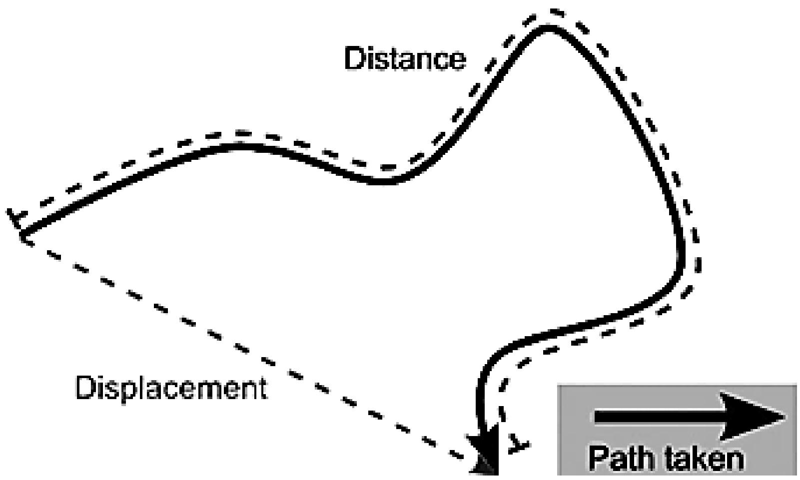
- **An object** is said to be **in motion if** it **changes** its **position with time**.
- A **body which does not move** is said to be at **rest**, **motionless**, or **stationary**.
- An **object's state of motion** or rest **cannot change unless** it is **acted upon** by a **force**.
- **Described in** terms of **displacement**, **velocity**, and **displacement**.

Types of Motion

Rotary Motion	• Anything **that moves in a circle.** • **Example:** spinning wheel on which people spun wool, working of car's engine • **Applications: rotary actuators** are used across a wide range of industries and can be electric, pneumatic and hydraulic options.
Oscillating Motion	• **Back** and **forth oscillation** causes this motion • If a **thing repeats** the **motion cycle** after a certain period is considered to be oscillating. • **Example:** sprinkler system, the pendulum of a clock ,sound waves.
Linear Motion	• If **something moves in** a **straight line** like linear actuators then it is linear motion • **Time moves** in a **linear fashion**. • **Eg:** linear cylinders in electric, pneumatic or hydraulic options • **Application:** automation, manufacturing, robotics.
Uniform motion	• When an **object covers equal distances** in **equal** intervals of **time**.
Non-uniform motion	• When an **object covers unequal distances** in **equal intervals** of **time**.

Displacement

- **Shortest distance from** the **initial to** the **final position** of the object.
- **Represents** the **length** and **direction of** the **straight path**.
- **Vector quantity** as it has **both magnitude** and **direction**



Distance

- **Scalar quantity** measuring only the length of path.

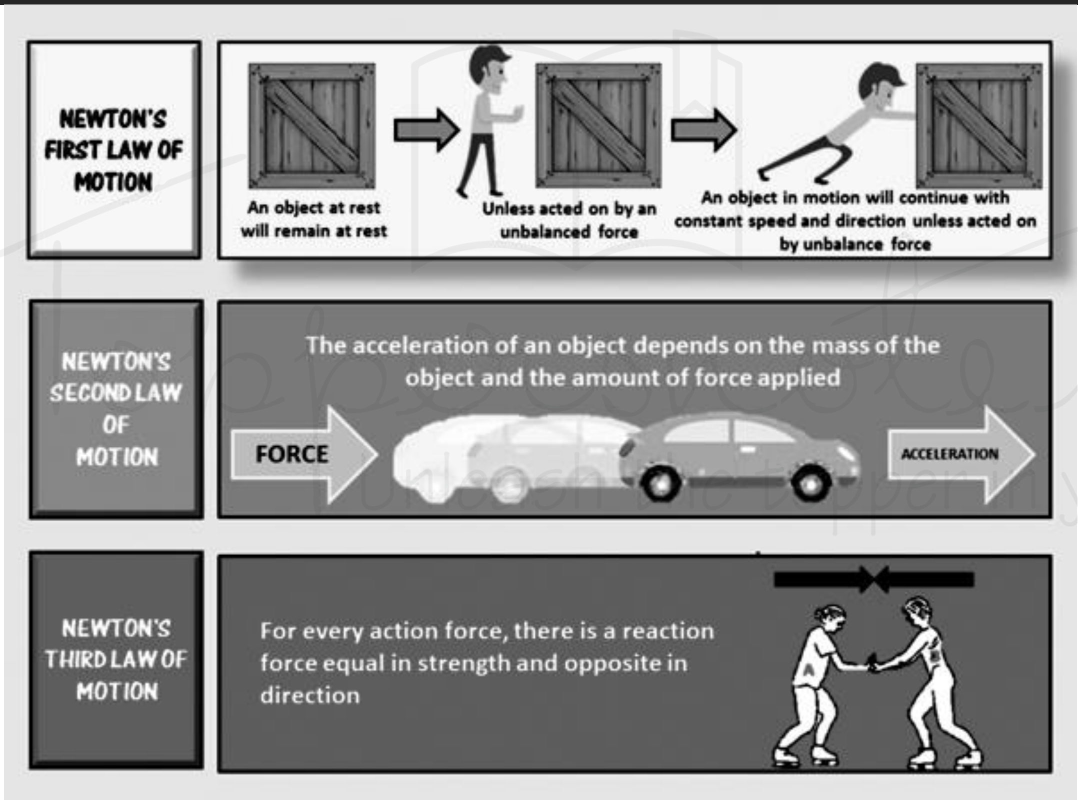
Velocity

- **Speed in a given direction.**
- **Describes** only **how fast** an **object** is **moving** and **direction** of object's **motion**
- A **vector quantity**.
- **Unit** - meter per second (m/s).

Acceleration

- **Rate of change of velocity with time.**
- **Rate** at which an **object speeds up** or **slows down**.
- **Positive Acceleration:** If the object speeds up.
- **Negative Acceleration:** If the object slows down.
- A **vector quantity**.
- **SI unit:** meter per second squares (m/s2).

Laws of Motion



Inertia:

- **Resistance** of any physical object **to any change in its velocity.**
- **Includes changes** to the **object's speed**, or **direction** of **motion**.
- **Tendency of objects** to **keep moving** in a **straight line** at a **constant speed** or to **remain** in state of **rest** when **no forces act** upon them, according to the first law of motion.

4 CHAPTER Sound

SOUND

- A **form of energy which produces a sensation of hearing** in our ears.
- **Produced due to vibration** of different objects.
- **Propagate** as **compressions** & **rarefactions** in medium - **longitudinal waves**.
- **Mechanical waves-** need a material medium to travel.
- **Medium:** Matter or material through which sound propagates

Medium of Propagation

- **Sound** is a **sequence of waves** of pressure which **propagates through compressible media** such as air or water.
- **During** their **propagation**, waves can be **reflected**, **refracted**, or **attentuated** by the medium.
- The **purpose** of this experiment is **to examine** what **effect** the **characteristics of the medium** have on **sound.**

Ground Wave or Surface Wave Propagation

- A ground wave **travels along** the **surface of the earth**.
- These **waves** are **vertically polarized**.
- So, **vertical antennas** are **useful** for these **waves. If** a **horizontally polarized** wave is **propagated** as a **ground wave**, due to the **conductivity** of the **earth**, the **electric field** of the **wave gets short-circuited.** As the **ground wave travels away** from the transmitting **antenna** it gets **attenuated**. To **minimize** this **loss** the **transmission path** must be **over** the **ground** with **high conductivity**.
- **With** respect to this **condition**, **sea water** should be the **best conductor but** it was **observed** that large storage of **water** in **ponds**, **sandy** or **rocky soil** shows **maximum losses**.
- **Hence**, **high power low-frequency transmitters**, using **ground wave propagations**, are preferably **located** on **Ocean fronts**.
- As **ground losses increase rapidly** with **frequency**, this **propagation** is used **practically** for **signals** up to **frequency 2 MHz only.**

Sky Wave Propagation

- Every **long radio communication** of **medium** and **high frequencies** are **conducted** using **skywave propagation.**
- In this mode **reflection** of **EM waves** from the ionized region in the **upper part** of the **atmosphere** of the **earth** is **used** for **transmission** of waves to **longer distances.**
- **This part** of the atmosphere is **called ionosphere** which is at about **70-400 km height.**
- **Ionosphere reflects back** the **EM waves** if the frequency is **between 2 to 30 MHz's**. Hence, this **mode** of **propagation** is also **called** as **Short wave propagation**.
- **Using** sky wave propagation **point to point communication** over **long distances** is **possible**. With the **multiple reflections** of **sky waves**, **global communication** over **extremely long distances** is **possible.**

Space Wave Propagation

- When we are **dealing** with **EM waves** of frequency **between 30 MHz to 300 MHz**, then **space wave** propagation is **useful**.
- Here **properties** of **Troposphere** are **used** for **transmission**. When **operating** in space wave propagation mode, the **wave reaches** the **receiving antenna directly from** the **transmitter or after reflection** from **troposphere** which is present at **about 16km above** the earth surface. **Hence space wave** mode **consists** of **two components**.i.e. **direct wave and indirect wave.**
- **Short wave broadcasting** usually takes place **in** the frequency **range of 1.7 - 30 MHz**.
- As we have seen **above** the **frequencies** in this range are **propagated through Skywave propagation mode**.

- **Depending** on the **frequency** or **wavelength** the **electromagnetic waves produce** different **Effects** in **various materials** and **devices**.
- **Hence**, the **different parts** of the **electromagnetic spectrum** are **utilized** for **various applications**

Audible and Inaudible sound

Inaudible sound

- **Human ear cannot detect** sound **frequencies less than 20 vibrations per second** i.e. 20 Hz.
- **So** any **sound below** this **frequency** will be **inaudible** sound **for humans**.
- **In** the **high-frequency range**, the human **ear cannot detect** frequencies **above 20000 vibrations per second** (20 kHz) and the **amplitude** of the **wave** would **be dependent** on the **loudness** of the **sound**.
- So the **frequencies below 20 Hz** and **above 20 kHz** comes **under** the **category** of **inaudible frequencies.** The **low-frequency sound** which the **human ear cannot detect** is also **known** as **infrasonic sound. Whereas** the **higher range inaudible frequency** is also known as **ultrasonic sound.**
- Some **animals** like dogs have the **ability** to **hear sounds** having **frequencies higher** than **20 kHz.**
- The **police department** uses **whistles** with **frequencies higher** than **20 kHz** so that **only dogs can listen** to it.
- **Inaudible frequencies** are **helpful** for **many purposes**.
- **These** are **used** in **many fields** like **research** and **medicine**.
- The **ultrasound equipment** used **for tracking** and **studying** many **medical problems** works at **frequencies above 20 kHz.**

Audible Sound

- The human **ear** can **easily detect** frequencies **between 20 Hz and 20 kHz.**
- **Hence**, **sound waves** with **frequency ranging** from **20 Hz to 20 kHz** is **known** are **audible sound**.
- The **human ear** is **sensitive** to **every minute pressure** difference **in** the **air if they are** in the **audible frequency range.**
- It **can detect pressure difference** of **less** than **one billionth** of **atmospheric pressure.**
- As **we grow older** and are **exposed to sound** for a **longer period** of time, **our ears** get **damaged** and the **upper limit** of **audible frequencies decreases**.
- **For** a **normal middle-aged adult person**, the **highest frequency** which they **can hear** clearly **is 12-14 kilohertz.**

Noise and Music

- The **unpleasant sounds** around us are **called noise.**
- **Noise** is **produced** by the **irregular vibrations** of the sound **producing source.**
- **For Ex**: **Running of mixer** and grinder in the kitchen, **blowing** of **horns** of motor vehicles, **bursting of crackers**, **barking** of **dogs**, **shattering of glass, landing** and **flying** of **aeroplane**, **sounds** coming **from construction** site, all **students talking** together **loudly** in a classroom etc.
- The **sounds** which are **pleasant** to hear **are called all musical sound**.
- They are **produced by** the **regular vibrations** of the sound producing source.
- All the **musical instruments** produce **musical sounds.**
- The **speakers** of **radio**, **stereo system** and **television** also **produce musical sound.**
- When a **person sing** a **song** he or she also **produces musical sound.**
- If **however** a **musical sound** becomes **too loud it becomes noise.**

Terminology of Sound

Wavelength	• **Distance between 2 successive crests or troughs**. • Represented by **λ** • **SI unit:** metre (m).
Time period	• **Time taken by 2 consecutive compressions or rarefactions** to **cross** a fixed **point** • **SI unit:** seconds (s).
Frequency	• **Number** of **compressions** or **rarefactions per unit time**. • Represented b ⍰ • **SI unit:** Hertz (s−1)
Amplitude	• **Magnitude of disturbance** in a medium **on either side** of the **mean value**
Pitch	• **Directly proportional** to **frequency**.
Intensity	• **Amount of sound** energy **flowing per unit time** through a **unit area**

Note and Tone	• **Sound** of a **single frequency** - **tone**. • **Sound** produced with a **mixture of several frequencies**- **note**.
Quality	• **Richness** or **timber** of **sound**. • **Sound** with the **same pitch** and **loudness** can be **distinguished** by **quality**. • **Eg.** difference b/w sound of a flute and violin.

- **Speed of sound:** Solids > Liquids > Gases

Reflection of Sound

- **Reflects off a surface** in the **same way** as **light reflects** and **follows same rules** of **reflection**.
- **Incident sound** and **reflected sound make equal angles with** the **normal** and **all three** are **in** the **same plane**.

Echo

- **Phenomenon where** a **sound produced** is **heard again due** to **reflection** .

> **Human range of hearing** - 20Hz- 20kHz.

Ultrasonic sounds/ Ultrasound

- **High**-**frequency** sound having a frequency **> 20kHz** (inaudible range).
- **Applications**:
  - Scanning images of human organs
  - Detecting cracks in metal blocks
  - Cleaning parts that are hard to reach
  - Navigating, communicating or detecting objects on or under the surface of the water (SONAR).

Infrasonic sounds

- **Low frequency** sound having frequency **< 20 Hz.**
- **Animals like elephants** use infrasounds for communication.

SONAR

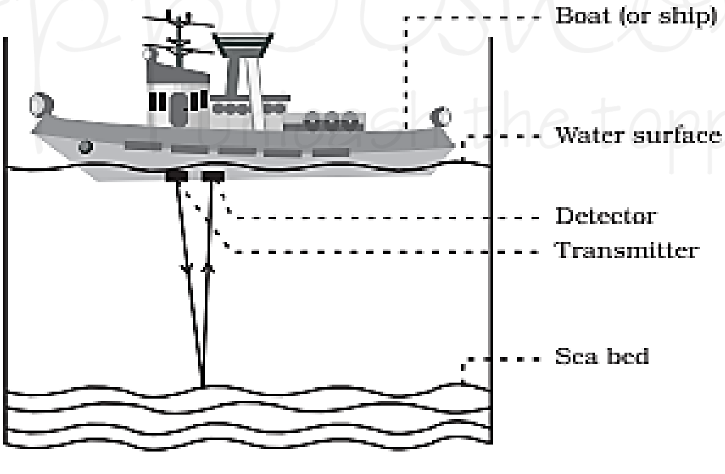


Fig : Ultrasound set by the transmitter and received by the detector

- Stands for **"Sound Navigation And Ranging".**
- A **technique** that **uses sound** or **ultrasonic waves** to **measure distance**.
- Consists of a **transmitter** and **detector mounted** on a **boat** or **ship**. **Transmitter sends ultrasonic** sound waves to **seabed** which **gets reflected back** and **picked** up by the **detector**.
- **Method** k/a **echo**-**location** or **echo ranging**.

Reverberation

- **Repeated reflection** that **results** in the **persistence** of **sound**
- To **reduce highly undesirable reverberation sounds**, the **roof** and **walls** of the **auditorium** or big halls are **generally covered** with **sound**-**absorbent materials** like **compressed fibreboard**, **rough plaster** or **draperies**.
- The **seat materials** are also **selected** on the basis of their **sound absorbing properties**.

Structure of Human Ear

- A sensitive organ of the body.
- **Function:** Detecting, transmitting and transducing sound and maintaining a sense of balance
- Parts:
  1. **Outer ear:**
     - **Pinna** - cartilaginous and directs sound wave towards external auditory canal.
     - **External auditory canal -** channels sound to tympanic membrane (eardrum).
     - **Eardrum**- Thin and semi-transparent.
       - **Vibrates when sound** waves **strike** its **surface**.
  2. **Middle Ear –**
     - **3 tiny bones -** hammer, anvil and stirrup
     - **Amplify vibrations** and **transmit** these to **inner ear**.
  3. **Inner Ear –**
     - aka **labyrinth**.
     - **Cochlea**- helps in hearing.
     - **Vestibular system**