Toppersnotes®
Unleash the topper in you

SSC

CHSL

STAFF SELECTION COMMISSION (SSC)

Volume - 4

Science & Computer

SIERRA INNOVATIONS

INDEX

INDEX

1 CHAPTER

Measurement and Units

Physical Quantities

- Physical quantities are those that can be defined and measured.
- **Examples:** Length, Force, Temperature, etc.
- A physical quantity consists of a **numerical value** and a **unit**.

Types of Physical Quantities:

- **Fundamental Quantities:** Independent basic quantities; there are 7 types:
  - ✓ Mass, Temperature, Length, Time, Electric Current, Amount of Substance, Luminous Intensity
- **Derived Quantities:** Quantities derived from fundamental quantities.
  - ✓ **Examples:** Momentum, Volume, Force, etc.
- **Supplementary Quantities:** Neither fundamental nor derived.
  - ✓ **Examples:** Plane Angle, Solid Angle

Classification based on Direction:

- **Scalar Quantities:** Quantities having only magnitude, no direction.
  - ✓ **Examples:** Distance, Energy, Speed, Power, Mass
- **Vector Quantities:** Quantities having both magnitude and direction.
  - ✓ **Examples:** Displacement, Velocity, Force, Weight, Momentum

Measurement:

- Measurement is the process of determining the value of a physical quantity by comparing it with a known standard.
- It involves:
  - ✓ A numerical value
  - ✓ A measurement unit

Units:

- Units are standardized measures used to express physical quantities.

Types of Units:

- **Fundamental Units:** Used for fundamental quantities.
  Examples: Meter (m), Kilogram (kg), Second (s), Ampere (A)
- **Derived Units:** Expressed as combinations of fundamental units.
- **Supplementary Units:** Used for specific purposes; not part of fundamental or derived units.
  - ✓ **Plane Angle:** Ratio of arc length (ds) to radius (r), measured in **radians (rad)**
    Formula: Plane Angle = Arc / Radius
  - ✓ **Solid Angle:** Ratio of surface area (dA) to square of radius (r^2), measured in **steradians (sr)**

System of Units:

- The complete set of fundamental and derived units is called a **system of units**.

Physical Quantity	MKS System	CGS System	FPS System
Length	Metre (m)	Centimetre (cm)	Foot (ft)
Mass	Kilogram (kg)	Gram (g)	Pound (lb)
Time	Second (s)	Second (s)	Second (s)

SI System:

- The currently accepted international system of measurement is the **"Système International d'Unités" (International System of Units)**, abbreviated as **SI**.
- This system was developed by the **International Bureau of Weights and Measures (BIPM)** in 1971.

Fundamental Units of the SI System

S. No.	Physical Quantity	Symbol	Dimension	SI Unit	Important Practical Units
1	Length	L	[L]	Metre (m)	1 fermi = 10^{-15} m 1 Å (angstrom) = 10^{-10} m 1 nm = 10^{-9} m 1 μm = 10^{-6} m 1 mm = 10^{-3} m 1 cm = 10^{-2} m 1 inch = 2.54 cm 1 foot = 0.3048 m 1 km = 10^{3} m 1 mile = 1.6 km 1 nautical mile = 1852 m 1 AU = 1.5×10^{11} m 1 light year ≈ 9.46×10^{15} m 1 parsec ≈ 3.083×10^{16} m
2	Mass	M	[M]	Kilogram (kg)	1 μg = 10^{-9} kg 1 mg = 10^{-6} kg 1 g = 10^{-3} kg 1 quintal = 10^{2} kg 1 metric ton = 10^{3} kg 1 amu = 1.66×10^{-27} kg 1 pound = 0.4537 kg 1 slug = 14.59 kg Chandrasekhar limit ≈ 2.8×10^{30} kg
3	Time	T	[T]	Second (s)	1 ps = 10^{-12} s 1 ns = 10^{-9} s 1 μs = 10^{-6} s 1 ms = 10^{-3} s 1 min = 60 s 1 hour = 3600 s 1 day = 86400 s 1 week = 7 days 1 month = 28–31 days 1 year = 365.25 days 1 shake = 10^{-8} s
4	Electric Current	I	[I]	Ampere (A)	—
5	Temperature	Θ	[Θ]	Kelvin (K)	—
6	Amount of Substance	N	[N]	Mole (mol)	—
7	Luminous Intensity	J	[J]	Candela (cd)	1 nit = 1 cd/m^2

Derived Units

S. No.	Physical Quantity	Formula / Derivation	SI Unit	Dimensions	Notes
1	Area	Length × Breadth	m^2	$[M^0L^2T^0]$	1 barn = 10^{-28} m^2 1 hectare = 10^{4} m^2

2	Volume	Length × Breadth × Height	m^3	$[M^0L^3T^0]$	1 litre = 10^{-3} m^3 1 gallon = 4.546 L
3	Velocity	Displacement / Time	m/s	$[M^0LT^{-1}]$	—
4	Acceleration	Change in velocity / Time	m/s^2	$[M^0LT^{-2}]$	—
5	Momentum	Mass × Velocity	kg·m/s	$[MLT^{-1}]$	—
6	Force	Mass × Acceleration	Newton (N)	$[MLT^{-2}]$	1 N = $kg·m/s^2$ 1 dyne = 10^{-5} N
7	Impulse	Force × Time	N·s	$[MLT^{-1}]$	—
8	Work / Energy	Force × Distance	Joule (J)	$[ML^2T^{-2}]$	1 J = $kg·m^2/s^2$ 1 cal = 4.184 J 1 erg = 10^{-7} J 1 kWh = 3.6×10^6 J 1 eV = 1.6×10^{-19} J
9	Power	Work / Time	Watt (W)	$[ML^2T^{-3}]$	1 HP = 746 W
10	Pressure	Force / Area	Pascal (Pa)	$[ML^{-1}T^{-2}]$	1 Pa = N/m^2 1 bar = 10^5 Pa 1 torr = 133.32 Pa 1 atm = 1.01×10^5 Pa
11	Density	Mass / Volume	kg/m^3	$[ML^{-3}T^0]$	—
12	Frequency	Repetitions per second	Hertz (Hz)	$[T^{-1}]$	1 Hz = 1/s
13	Electric Charge	Current × Time	Coulomb (C)	[IT]	1 C = A·s
14	Potential Difference	V = kQ/r	Volt (V)	$[ML^2T^{-3}I^{-1}]$	1 V = $kg·m^2/(A·s^3)$
15	Resistance	Potential Difference / Current	Ohm (Ω)	$[ML^2T^{-3}I^{-2}]$	1 Ω = $kg·m^2/(A^2·s^3)$
16	Capacitance	Charge / Potential Difference	Farad (F)	$[M^{-1}L^{-2}T^4I^2]$	1 F = $s^4·A^2/(kg·m^2)$
17	Magnetic Flux	Magnetic Field × Area	Weber (Wb)	$[ML^2T^{-2}I^{-1}]$	1 Wb = $kg·m^2/(s^2·A)$
18	Inductance	—	Henry (H)	$[ML^2T^{-2}I^{-2}]$	1 H = $kg·m^2/(s^2·A^2)$
19	Focal Length	—	Metre (m)	$[M^0L^1T^0]$	—

Did You Know?

- **Intensity of light**: Lux
- **Intensity of sound**: Decibel
- **Magnetic field intensity**: Oersted
- **Amount of radiation**: Curie

Powers of 10

Prefix	**Symbol**	**10 की घात**	**Prefix**	**Symbol**	**Powers of 10**
Yotta	Y	10^{24}	Yocto	y	10^{-24}
Zetta	Z	10^{21}	Zepto	z	10^{-21}

Exa	E	10^{18}	Atto	a	10^{-18}
Peta	P	10^{15}	Femto	f	10^{-15}
Tera	T	10^{12}	Pico	p	10^{-12}
Giga	G	10^{9}	Nano	n	10^{-9}
Mega	M	10^{6}	Micro	µ	10^{-6}
Kilo	k	10^{3}	Mili	m	10^{-3}
Hecto	h	10^{2}	Centi	c	10^{-2}
Deca	da	10^{1}	Deci	d	10^{-1}

2 CHAPTER Motion

Rest:

- If an object **does not change its position** with respect to its surroundings over time, it is said to be at **rest**.
- **Example:** A book kept on a table is considered at rest relative to the table.

Motion:

- When an object **continually changes its position** with respect to time, it is said to be in **motion**.
- **Example:** A bird flying in the sky.

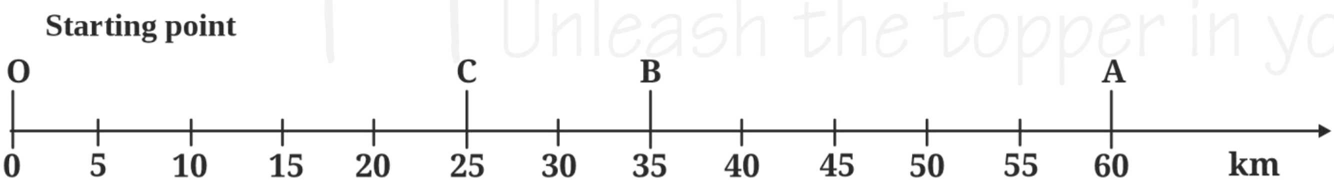
Types of Motion of a Body:

- **Rectilinear Motion:** Motion along a straight line.
  Example: A car moving straight on a road; an airplane flying straight in the sky.
- **Curvilinear Motion:** Motion along a curved path.
  Example: A roller coaster moving on a track.
- **Rotational Motion:** Motion of a body around a fixed axis or point.
  Example: A spinning top; a wheel rotating on an axle.
- **Circular Motion:** Motion along a circular path.
  Example: Earth revolving around the Sun.
- **Oscillatory Motion:** Motion of a body **back and forth around a fixed point**.
  Example: A swinging pendulum; vibration of a guitar string.
- **Periodic Motion:** Oscillatory motion that **repeats at regular intervals**.
  Example: Hands of a clock moving in circular motion.

Classification Based on Number of Directions (Dimensions) in Motion:

1. **One-Dimensional Motion:** Position changes along **only one direction**.
2. **Two-Dimensional Motion:** Position changes along **two directions**.
3. **Three-Dimensional Motion:** Position changes along **three directions**.

General Definitions Related to Motion:



Positions of a Moving Object on a Straight Linear Path

Distance:

- The **actual length** traveled by an object in a given time interval is called **distance**.
- **Unit:** meter (m)
- **Nature:** scalar quantity
- **Instrument:** Odometer is used to measure distance

Displacement:

- The **shortest distance** between the initial and final position of an object is called **displacement**.
- **Unit:** meter (m)
- **Nature:** vector quantity
- Displacement can be **positive, negative, or zero**

Speed:

- The distance covered by an object per unit time is called **speed**.
- Speed $= \frac{\text{Total distance}}{\text{Total time}}$
- **Unit:** meter per second (m/s)
- **Nature:** scalar quantity
- Speed can **never be zero**

Question: If a man covers a certain distance at a speed of 5 km/h in 36 minutes, what is the distance he covers?
Solution:
Speed: 5 km/h
Time: 36 minutes = 36/60 = 0.6 hours
Distance: Speed × Time = 5 × 0.6 = **3 km**

Velocity:

- Velocity of an object is the displacement done in a unit time in a specific direction.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

- **Unit:** meter per second (m/s)
- **Nature:** Vector quantity
- Velocity can be positive, negative, or zero

Types of velocity:

- **Uniform velocity:** Equal displacement in equal time intervals
- **Non-uniform velocity:** Unequal displacement in equal time intervals
- **Average velocity:**

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time}}$$

- **Instantaneous velocity:** Displacement at a particular instant of time

Acceleration:

- Rate of change of velocity with time is called acceleration.

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

- **Unit:** meter per second squared (m/s²)
- **Nature:** Vector quantity
- Value can be zero, positive, or negative
- **Negative acceleration** is called **retardation**, and its direction is opposite to velocity

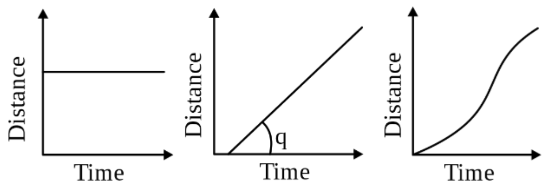
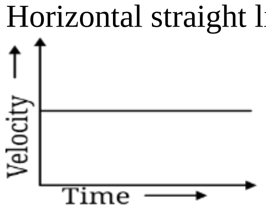
Types of acceleration:

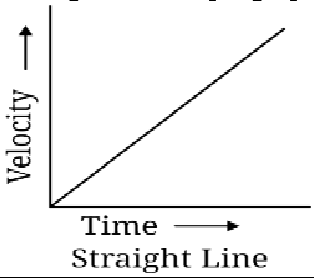
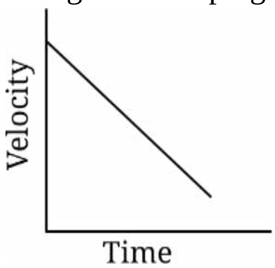
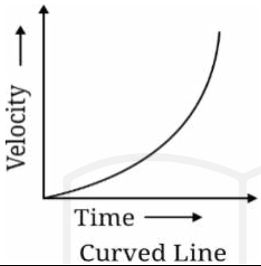
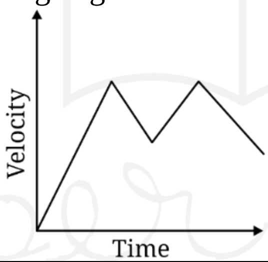
- **Uniform acceleration:** Velocity changes by equal amounts in equal intervals of time; acceleration is constant
- **Non-uniform acceleration:** Velocity changes irregularly (e.g., car in traffic)
- **Average acceleration:**

$$\text{Average acceleration} = \frac{\text{Total change in velocity}}{\text{Total time}}$$

- **Instantaneous acceleration:** Acceleration at a specific instant of time.

Graphical Representation of Motion:

S. No	State of Motion	Type of Graph	Graphical Representation	Main Feature
1	Object at rest	Displacement–Time graph	Straight line parallel to the time axis	Displacement constant; velocity = 0
2	Uniform motion	Displacement–Time graph	Straight line making an angle with the time axis	Constant slope ⇒ uniform velocity
3	Non-uniform motion / Acceleration	Displacement–Time graph	Curved line  When the object is at rest; When the object is in uniform motion; When the object is in non-uniform motion	Slope changes continuously
4	Uniform velocity	Velocity–Time graph	Horizontal straight line  Straight line parallel to x-axis	Velocity constant

5	Positive uniform acceleration	Velocity–Time graph	Straight line sloping upward 	Velocity increases uniformly
6	Negative uniform acceleration	Velocity–Time graph	Straight line sloping downward 	Velocity decreases uniformly
7	Non-uniform velocity	Velocity–Time graph	Curved line 	Velocity varies irregularly
8	Non-uniform acceleration	Velocity–Time graph	Zig-zag line 	Acceleration varies irregularly

Equations of Motion:

- Equations of motion describe the relationship between **displacement, initial velocity, final velocity, acceleration**, and time for an object moving with **uniform acceleration**.

For uniform acceleration:

1. $v = u + at$
2. $s = ut + \frac{1}{2}at^2$
3. $2as = v^2 - u^2$

Where: u =initial velocity v =final velocity
s =displacement t =time
a =acceleration

Under gravity (g) as acceleration:

1. $v = u + gt$
2. $s = ut + \frac{1}{2}gt^2$
3. $2gs = v^2 - u^2$

Question: A bus is moving on a straight road at **10 km/h** and increases its speed to **70 km/h** in **2 minutes**. What is the **average acceleration** of the bus?

Solution:

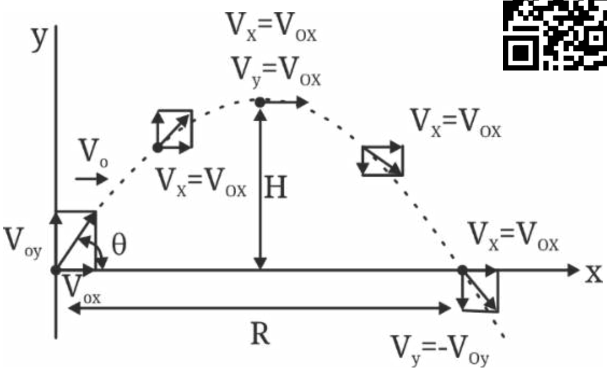
$$\text{Average acceleration} = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}} = \frac{70 - 10}{2\text{ min}} = \frac{60}{2} = 30\text{ km/h per minute}$$

Converting units:

$$30\text{ km/h per min} = 0.5\text{ km/min}^2$$

Answer: 0.5 km/min²

Projectile Motion:



- When an object is thrown at an angle under the influence of **gravity** and follows a **curved path** in the atmosphere, it is called **projectile motion**.
- **Example:** A stone thrown at an angle follows a curved path before landing.

Projectile Motion Terminology:

- **Trajectory:** The path followed by the projectile, which is **parabolic**.
- **Angle of projection (θ):** The initial angle formed with the horizontal at which the object is thrown.
- **Time of flight (T):** The time taken by the projectile to return to its initial height.

$$T = \frac{2u\sin\,\theta}{g}$$

where u =initial velocity, g =acceleration due to gravity (9.8 m/s²)

- **Horizontal range (R):** Maximum horizontal distance covered by the projectile.

$$R = \frac{u^2\sin\,2\theta}{g}$$

- **Maximum height (H):** The highest vertical position reached by the projectile.

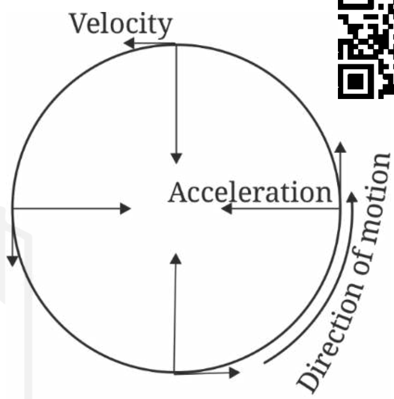
$$H = \frac{u^2\sin^2\theta}{2g}$$

Question: Which of the following equations of motion is correct?
I. $v = \frac{u}{2} + at$
II. $s = 2ut + at^2$
(A) Only I
(B) Neither I nor II
(C) Only II
(D) Both I and II
Answer: (B) Neither I nor II

Explanation: The correct first equation of motion is $v = u + at$, not $v = \frac{u}{2} + at$, so statement I is incorrect.
The correct displacement equation is $s = ut + \frac{1}{2}at^2$, not $s = 2ut + at^2$, so statement II is also incorrect.

Circular Motion:

- When an object moves along the circumference of a circle or a circular path, it is called **circular motion**. The velocity of an object moving along a circular path is called **instantaneous velocity**, as its direction continuously changes.

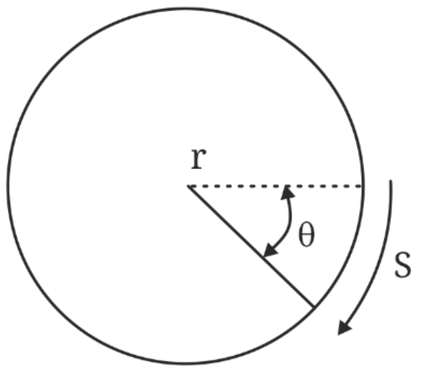


Types of Circular Motion:

- **Uniform Circular Motion:** The object moves along a circular path with **constant speed**. Although the speed is constant, the direction continuously changes, so the **velocity changes**.
- **Non-Uniform Circular Motion:** The object moves along a circular path with **changing speed**. Both **speed and direction change**, so velocity and acceleration vary.

Example: A car turning along a curved road exhibits circular motion with changing direction.

Key Terms Related to Circular Motion:



S. No.	Physical Quantity	Definition	Formula	SI Unit
1	Time Period (T)	Time taken by a particle to complete one full revolution on a circular path.	—	Second (s)
2	Frequency (n)	Number of revolutions completed per second on a circular path.	$n = 1/T$	Hertz (Hz)
3	Angular Displacement (θ)	Angle subtended at the center of a circle by the radius vector.	θ = Arc / Radius	Radian (rad)
4	Angular Velocity (ω)	Rate of change of angular displacement with time.	$\omega = \theta / t$	rad/s
5	Angular Acceleration (α)	Rate of change of angular velocity with time.	$\alpha = \omega / t$	rad/s^2
6	Centripetal Acceleration	Acceleration of a body moving in a circular path directed toward the center.	$a = v^2 / r$	m/s^2

3 CHAPTER

Force and Motion

Force:

- When an object is **pulled** or **pushed**, causing a change in its **position, shape, or motion**, the action is called a **force**.
- It is the result of an **external influence**, which can move a stationary object or stop a moving object.
- **Conservative force**: The work done by a conservative force does **not depend on the path**, only on the initial and final positions.
- Force has both **magnitude and direction**, so it is a **vector quantity**.
- **SI unit:** Newton (N), **CGS unit:** dyne.
- The force on an object is calculated using **Newton's second law of motion**:

  Force = Mass × Acceleration = ma

  ✓ **1 Newton (N) = 1 kg·m/s^2**

  ✓ **1 Newton (N) = 10^5 dyne**

Types of Force:

Type of Force	What It Is	Simple Example
Contact Force	Force produced due to direct physical contact between two objects.	Pushing or pulling an object
Muscular Force	Force generated by the action of muscles.	Lifting a box, pushing a door
Frictional Force	Force that opposes motion when two surfaces are in contact.	A sliding book coming to rest
Non-Contact Force	Force acting between objects without direct physical contact.	Earth pulling an object
Gravitational Force	Force by which the Earth attracts objects toward itself; a type of attractive force.	Falling of an apple
Electrostatic Force	Force between two charged particles or objects.	A balloon sticking to a wall
Magnetic Force	Force between two magnets or moving electric charges.	Attraction between magnets
Nuclear Force	Force that binds protons and neutrons inside the atomic nucleus.	Binding of proton and neutron in the nucleus
Balanced Force	When equal forces act on an object in opposite directions, resulting in zero net force and no change in motion.	Equal push from both sides
Unbalanced Force	When forces acting on an object are unequal, causing a change in motion.	Kicking a ball

Inertia:

- The property of an object due to which it **resists changes** in its **state of rest** or **uniform motion** is called **inertia**.

Types of Inertia:

1. **Inertia of Rest:** The property of an object to **resist changes** in its **state of rest**.
2. **Inertia of Motion:** The property of an object to **resist changes** in its **uniform motion**.
3. **Inertia of Direction:** The property of an object to **resist changes** in the **direction of its motion**.

Did you know?
Relationship between Inertia and Mass:

- The **inertia** of an object **depends on its mass**.
- Inertia is **directly proportional to mass**, i.e., if the mass increases, the inertia also increases, and vice versa.

Newton's Laws of Motion:

Newton's First Law of Motion:

- If an object is at rest, it will remain at rest, and if it is moving with uniform velocity, it will continue to move in the same velocity and direction **unless acted upon by an external force**.
- This is also called the **Law of Inertia** or **Galileo's Law**.
- This law helps in **defining force**. **Example:** When a tree is shaken, the branches move, but the fruits remain at rest due to inertia and fall down.

Momentum:

- The effect of an object's motion depends on its **mass** and **velocity**. This is called **momentum**.

$$p = m \times v$$

Where: m= mass, v= velocity

- Momentum is a **vector quantity**, SI unit: **kg·m/s**

Types of Momentum:

- **Linear Momentum:** For an object moving in a straight line, the product of mass and linear velocity is called linear momentum. The greater the mass and velocity, the higher the momentum.
- **Angular Momentum:** Momentum of an object in rotational or circular motion; depends on mass, velocity, and distance from the axis. **Example:** Rotating wheel, motion of planets.

Law of Conservation of Linear Momentum:

- According to this law, if no **external force** acts on a system of two or more objects, the **total linear momentum of the system remains constant**. The change in momentum of one object is **equal and opposite** to the change in another.
- Devices based on this principle: **rocket propulsion, Bunsen burner, fire extinguisher, recoil of a cannon**.

Collision of Two Bodies:

- When **two bodies collide**, the total momentum before and after the collision is conserved.
- Example: If **two balls with equal momentum** collide head-on, they may come to rest momentarily because the **total momentum before collision equals the total momentum after collision**, which can be zero.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Where:
m_1, m_2= masses of the two bodies
u_1, u_2= initial velocities
v_1, v_2= final velocities

Question: A ball has a momentum of 3000 units. If the velocity of the ball is doubled, what will be its new momentum?
Solution: With constant mass, doubling the velocity **doubles the momentum**.
New momentum $= 2 \times 3000 = 6000$ units

Newton's Second Law of Motion:

- According to this law, "The rate of change of momentum of an object is directly proportional to the applied force, and the force acts in the direction of the momentum change."
  Mathematical form:

$$F \propto \frac{\Delta p}{\Delta t} \implies F = ma$$

Where: F= force, m= mass, a= acceleration

- Force is calculated using Newton's second law: $F = m \times a$
  Example: Table tennis – When a player hits the ball, it does not hurt the hand because both mass and velocity of the ball are small, resulting in small acceleration and force.

Impulse:

- If a force acts on an object for a short time, the product of force and time interval is called *impulse* or the change in momentum.

$$I = F\Delta t$$

Where: I= impulse, F= applied force, Δt= duration of force

Relation between impulse and momentum:

$$\text{Impulse} = \text{Change in momentum} \implies I = \Delta p = m(v - u)$$

Characteristics of impulse:

- Vector quantity
  - ✓ SI unit: Newton-second (N·s)
  - ✓ For the same force:
    - Shorter time ⇒ smaller impulse
    - Longer time ⇒ larger impulse

Examples:

- Stopping a ball slowly increases time → smaller force → no injury to hand.
- Train buffers absorb shocks during shunting → increase collision time → reduce force → prevent damage.

Problem: A 10 kg object is acted upon by a constant force for 2 seconds. Its velocity increases from 5 m/s to 10 m/s. Find the magnitude of the force. If the same force is applied for 5 seconds, what will be the final velocity?

Solution:

Acceleration:

$$a = \frac{v-u}{t} = \frac{10-5}{2} = 2.5 \text{ m/s}^2$$

Force using Newton's second law:

$$F = ma = 10 \times 2.5 = 25 \text{ N}$$

Final velocity if applied for 5 s:

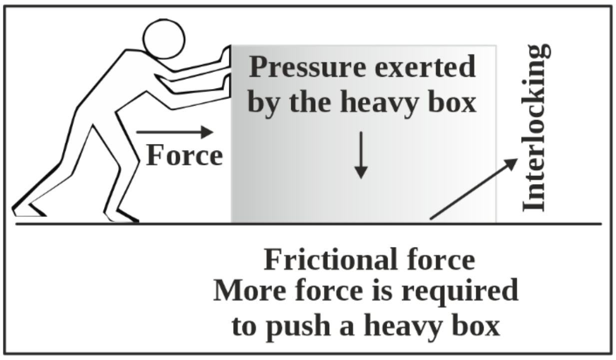
$$v = u + at = 5 + (2.5 \times 5) = 17.5 \text{ m/s}$$

Newton's Third Law of Motion:

- *"For every action, there is an equal and opposite reaction."*
- Also called *action-reaction law*.
- Example: A rocket moves forward due to the reaction of fast exhaust gases.

Friction:

- Friction is the force that resists relative motion when an object slides, rolls, or attempts to move over another surface. The direction of friction is always opposite to the relative motion.

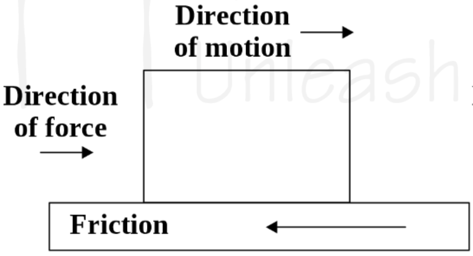


Examples:

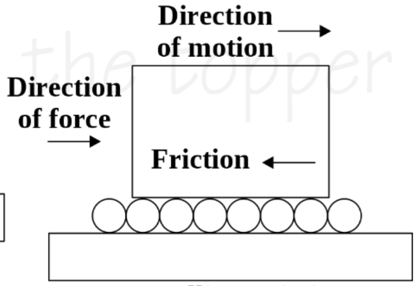
- Walking – friction between shoes and ground helps movement.

Types of Friction:

1. **Static friction:** Acts when two surfaces are in contact but not moving relative to each other. Increases until motion starts. Also called self-adjusting force.
2. **Limiting friction:** Maximum value of static friction, just before motion starts; depends on surface nature, not contact area.
3. **Kinetic friction:** When an object slides over a surface.
   a. **Sliding friction:** Object slides.
   b. **Rolling friction:** Object rolls.



Sliding Friction



Rolling Friction

4. **Fluid friction:** Occurs when an object moves through a fluid like water or air. Depends on fluid density.

- **Ways to reduce friction:** Polishing surfaces, Using lubricants, Employing ball bearings, Using friction-reducing materials

Fluid Friction:

- Fluid friction occurs when an object moves through a fluid like water or air, and it depends on the fluid's density.
- **Ways to reduce friction:** Polishing, using lubricants, employing ball bearings, and using friction-reducing materials.

Centripetal and Centrifugal Force

Centripetal Force:

- When a particle moves along the circumference of a circle, its speed remains constant but its direction changes continuously. This requires a force directed toward the center of the circle, called **centripetal force**.

- **Note:** This force always acts toward the center of the circle.
- **Examples:**
  - ✓ Swinging a stone tied to a rope – the rope provides the centripetal force.
  - ✓ Planets orbiting the Sun – gravitational force pulls planets toward the Sun.

Centrifugal Force:

- Sometimes it appears as if an object in circular motion experiences an outward force. In reality, no actual force acts outward. This apparent force is called **centrifugal force**. It is a fictitious force acting radially outward from the center.
- **Applications:** Centrifuge, centrifugal clutch, pump, dryer/washing machine, cream separator, fan, and gold separator – all use centrifugal force to separate substances or push them outward.

Torque:

- "Torque about an axis is the product of the force magnitude and the perpendicular distance from the axis to the line of action of the force."

$$\tau = F \times r \times \sin\ \theta$$

Where:

τ= torque, F= applied force, r= lever arm distance, θ= angle between force and lever arm

- **SI unit:** Newton-meter (N·m)
- Maximum torque occurs at $\theta = 90°$.
- **Examples:**
  - ✓ Pushing a door – torque rotates the door.
  - ✓ Using a wrench to loosen a bolt – torque is applied.

Couple:

- Two equal and opposite parallel forces whose lines of action do not coincide form a **couple**. The perpendicular distance between the forces is the **arm of the couple**.

$$\tau = F \times d$$

Where: τ= torque, F= magnitude of each force, d= perpendicular distance between the forces

- **Characteristics:** Produces rotation only, does not translate the center, Torque depends only on force and distance, giving pure rotational effect.
- **Examples:** Steering wheel of a car, turning a key in a lock, operating a hand pump or tubewell, tightening a nut with a screwdriver.

Moment of Inertia:

- When an object rotates about a fixed axis, it resists rotational motion due to **moment of inertia**.

$$I = \sum mr^2$$

- Depends on the object's shape, size, and mass distribution.
- **Applications:** Rolling a nut on a rope, rotating machines, Earth's rotation.

Galileo and Inertia:

- Galileo used an inclined plane to reduce friction and observed that the object's speed changes slowly on a gentle slope. In an ideal frictionless scenario, the object moves at constant speed.
- **Key conclusion:** Motion changes only when an external force is applied. Without force, a stationary object remains stationary, and a moving object continues at uniform speed.
- **Relation to Newton's First Law:** Galileo's observations laid the foundation for the concept of inertia, later formalized as Newton's first law.

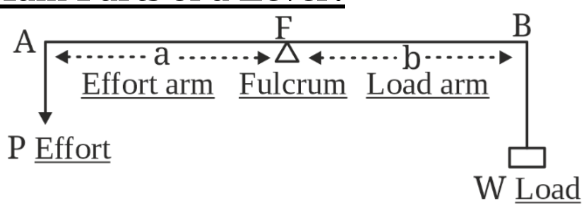
Simple Machines:

- A **simple machine** is a device that allows a smaller force to move or lift a heavier load efficiently. It includes levers, gears, screw wheels, axles, and pulleys.

Lever:

- A **lever** is a rigid rod that rotates around a fixed point (fulcrum) to lift a load with less effort.

Main Parts of a Lever:



1. **Fulcrum:** The fixed point around which the lever rotates.

2. **Effort:** The applied force.
3. **Load:** The object to be lifted.

Principle of Lever:

- In equilibrium, **moment of effort = moment of load**.

Types of Lever:

- **First-Class Lever:** Fulcrum is in the middle. Examples: Seesaw, scissors.
- **Second-Class Lever:** Load is in the middle. Example: Lemon squeezer.
- **Third-Class Lever:** Effort is in the middle. Examples: Tweezers, human arm.

Archimedes' Principle:

- Archimedes was a great Greek mathematician, physicist, engineer, inventor, and astronomer, considered one of the founders of classical mechanics.

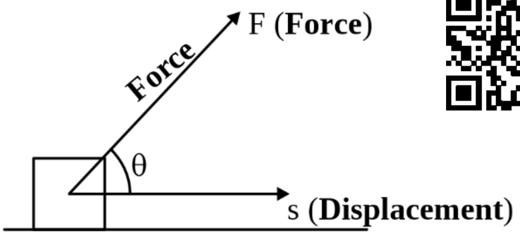
Major Contributions of Archimedes:

S. No.	Contribution	Description / Importance
1	**Law of Lever**	The force required to lift an object is inversely proportional to its distance from the **fulcrum**. A heavy object can be lifted with a smaller force if the force is applied at a greater distance from the fulcrum.
2	**Pulley and Mechanical Advantage**	Pulley systems make it possible to lift heavy loads with less effort. Explained the concept of **mechanical advantage**.
3	**Foundation of Statics**	Study of forces acting on bodies in **static equilibrium**. Led to the development of **statics** in mechanics.
4	**Overall Contribution to Mechanics**	Archimedes' principles influenced the development of both **theoretical and practical mechanics**.

4 CHAPTER Work, Energy and Power

Work:

- In physics, **work** is the process in which a force is applied on an object causing it to be displaced in the direction of the force. When a force acts on an object and the object moves some distance in the direction of the force, work is said to be done.



Displacement

Mathematical Expression:

- If a **force F** is applied on an object causing it to move a displacement **s**, then work done: $W = F \times s$
- If the angle between force and displacement is **θ**, then:

$$W = F \times s \times \cos\,\theta$$

- Work is a **scalar quantity**.
- SI unit of work: **Joule (J)**
  - ✓ 1 Joule = work done when 1 Newton force displaces an object by 1 meter in the direction of the force.
  - ✓ 1 J = 1 N × 1 m
- CGS unit: **erg**
  - ✓ 1 erg = 10^{-7} J
- Larger unit: **Kilowatt (kW)**
  - ✓ 1 kW = 1000 W

Special Cases:

- θ = 0° → cosθ = 1 → Work maximum
- θ = 90° → cosθ = 0 → Work = 0
- If displacement s = 0 or force F = 0 → Work = 0

Example: A brick is pushed with a force of 7 N and it moves 5 m.
Sol-

$$W = F \times d = 7 \times 5 = 35 \text{ J}$$

Work done = **35 Joules**

Energy:

- The **capacity of an object to do work** is called **energy**.
- Energy is a **scalar quantity**.
- SI unit of energy: **Joule (J)**

Unit	Definition	Conversion
Erg	CGS unit of energy.	1 erg = 10^{-7} joule
Calorie	Amount of energy required to raise the temperature of 1 gram of water by 1°C.	1 calorie ≈ 4.2 joule
Kilowatt-hour (kWh)	Common unit of electrical energy used in households.	1 kWh = 3.6 × 10^{6} joule
Electron Volt (eV)	Energy gained by an electron when it passes through a potential difference of 1 volt.	1 eV = 1.6 × 10^{-19} joule
Kilojoule (kJ)	Larger unit of energy.	1 kJ = 1000 joule

Kinetic Energy (KE):

- The **kinetic energy** of an object moving with a certain velocity is equal to the work done to bring it to that velocity.

$$E_k = \frac{1}{2}mv^2$$

where **m** is mass and **v** is velocity. KE is always positive.

Examples: Running person, falling ball, flowing water, swinging pendulum.

Example Problem:
Question- Two objects A (2 kg) and B (3 kg) are dropped from different heights. A takes 5 s and B takes 3 s to reach the ground. Find the ratio of their kinetic energies upon impact.

Solution: In free fall, final velocity $v = gt$ → $KE \propto \frac{1}{2}mv^2 \propto mt^2$

$$KE_A : KE_B = (2 \times 5^2) : (3 \times 3^2) = 50 : 27$$

Potential Energy (PE):

- Energy stored in an object due to its **position** or **configuration**.
- **Gravitational PE:** Depends on height.

$$PE = mgh$$

Examples: Book on a shelf.

- **Elastic PE:** Energy stored in stretched or compressed objects.
  Examples: Bow-arrow, spring toys.
- **Chemical Energy:** Stored in chemical bonds and released during reactions.
  Examples: Battery, food, petrol.
- **Nuclear Energy:** Energy stored in atomic nuclei released via fission or fusion.
  Examples: Nuclear reactor, Sun.

Fact:

- The sum of **kinetic energy** and **potential energy** is called **mechanical energy**.

Example Problem: A 2 kg object is dropped from 10 m. Find PE and KE at 5 m height. $g = 10\ \text{m/s}^2$

Solution:

$PE_{10m} = mgh = 2 \times 10 \times 10 = 200\,J$

$PE_{5m} = 2 \times 10 \times 5 = 100\,J \Rightarrow KE = 100\,J$

$PE : KE = 1 : 1$

Work-Energy Theorem:

- The work done by a force on a particle equals the **change in its kinetic energy**.

Law of Conservation of Energy:

- Energy can transform from one form to another but cannot be created or destroyed. Total energy remains constant. **Example:** Falling book: gravitational PE converts into kinetic energy.

Einstein's Mass-Energy Equivalence:

- According to Einstein, every substance possesses energy due to its mass. This is called **mass energy**, and mass can be converted into energy and energy can be converted into mass.
- If an object of mass is completely converted into energy, then the total energy produced is given by

$$E = mc^2$$

where **$c = 3 \times 10^8$ m/s** (speed of light in vacuum).

Forms of Energy and Their Conversion:

Form of Energy	Description	Energy Conversion
Thermal Energy	Energy due to temperature of a body.	Steam engine → Mechanical energy Thermal power plant → Electrical energy
Electrical Energy	Energy produced by the movement of electrons.	Bulb → Light energy Heater → Thermal energy
Light Energy	Energy transmitted through waves (e.g., sunlight).	Solar panel → Electrical energy
Sound Energy	Energy produced by vibrations.	Microphone → Electrical energy Speaker → Sound energy
Mechanical Energy	Sum of kinetic and potential energy.	Fan, windmill, generator, etc.
Chemical Energy	Energy stored in chemical reactions.	Battery, engine, candle, etc.

Non-Conventional Energy Sources

Energy Source	Description	Example / Conversion
Wind Energy	Energy from fast-moving air.	Wind turbine → Electrical energy
Hydro Energy	Energy obtained from flowing water.	Hydroelectric plant → Electrical energy
Biomass Energy	Energy obtained from organic waste or dead plants/animals.	Biogas plant → Thermal energy

Solar Energy	Energy obtained from the Sun.	Solar cooker → Thermal energy Solar panel → Electrical energy
Tidal Energy	Energy stored in ocean tides.	Tidal dam → Electrical energy
Wave Energy	Kinetic energy of ocean waves.	Turbine → Electrical energy
Ocean Thermal Energy	Energy from temperature difference between surface and deep sea water.	OTEC plant → Electrical energy
Geothermal Energy	Heat stored inside the Earth.	Hot water sources → Electricity generation
Nuclear Energy	Energy obtained from nuclear fission or fusion.	Nuclear plant → Thermal energy → Electrical energy

Power (P):

- **Power** is the rate of doing work or the rate of energy transfer. It measures how quickly or slowly work is done.

$$P = \frac{W}{t}$$

where **W** = work done, **t** = time taken.

- **SI unit:** Joule per second (J/s) = **Watt (W)**
  1 W = 1 J/s
- **High power levels:** expressed in kilowatt (kW)
  1 kW = 1000 W

Example Problem: A heater produces 60 kJ of heat in 1 minute 20 seconds. Find the power of the heater.
Solution:
$Q = 60\text{ kJ} = 60000\text{ J}, t = 1\text{ min }20\text{ s} = 80\ s$
$P = Q/t = 60000/80 = 750\text{ W}$

Horsepower (HP):

- One horsepower is the power with which a horse can do 33,000 foot-pounds of work in 1 minute. It is a non-SI unit of power for engines and machines.
- **Mechanical HP:** 1 HP ≈ 746 W
- **Metric HP:** 1 HP ≈ 736 W