PHYSICAL SCIENCE

Chapter: Motion & Force

Complete Study Notes for Government Job Examinations
West Bengal and Other Competitive Exams

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In calculations, g = 9.8 m/s² (taken as 10 m/s² where mentioned) for easy numerical work.

1. Distance and Displacement

Motion means a change in the position of an object with time, measured with respect to a reference point (origin). An object is at **rest** if its position does not change with time. Rest and motion are **relative**: a passenger sitting in a moving train is at rest with respect to the train but in motion with respect to the platform.

Distance

Distance is the **total length of the actual path** travelled by an object, irrespective of direction. It is a **scalar** quantity (magnitude only). It is always positive and never decreases. Its SI unit is the **metre (m)**. An odometer in a vehicle measures distance.

Displacement

Displacement is the **shortest straight-line distance** from the initial position to the final position, in the direction from initial to final. It is a **vector** quantity (magnitude and direction). Its SI unit is also the metre (m). Displacement can be positive, negative or zero.

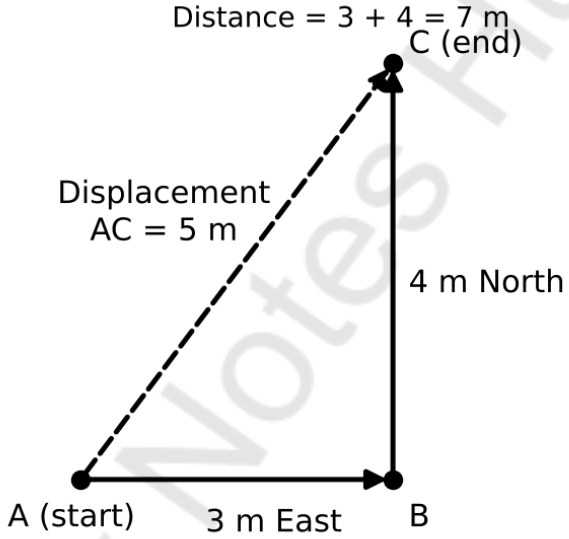


Figure 1: A person walks 3 m East and then 4 m North. Distance = 7 m, Displacement = 5 m (by Pythagoras theorem).

Difference between Distance and Displacement

Basis	Distance	Displacement
Meaning	Total length of path travelled	Shortest distance between initial and final points
Nature	Scalar	Vector
Value	Always positive (or zero at start)	Positive, negative or zero
Path dependence	Depends on the path followed	Depends only on the end points
Comparison	Distance ≥ |Displacement|	Magnitude ≤ distance
Measured by	Odometer	Shortest line (vector) between two points

Key Points

- Distance and displacement are **equal in magnitude** only when the object moves along a **straight line without changing direction**.

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- If an object returns to its starting point, its **displacement is zero** but the distance is not zero (e.g. one full lap of a circular track: distance = 2πr, displacement = 0).
- In half a circular lap: distance = πr and displacement = 2r (the diameter).
- The displacement is never greater than the distance travelled.
- For a person walking x m east and y m north: displacement = $\sqrt{(x^2 + y^2)}$.

Scalar and Vector Quantities

Type	Meaning	Examples
Scalar	Has magnitude only	Distance, speed, mass, time, work, energy, power, temperature, density, pressure, volume
Vector	Has magnitude and direction	Displacement, velocity, acceleration, force, momentum, weight, impulse, torque

Exam Tip: Questions often ask "Which of the following is a vector quantity?". Remember: Displacement, Velocity, Acceleration, Force, Momentum and Weight are vectors; Distance, Speed, Work, Energy and Power are scalars. Pressure is a scalar although it is defined using force.

2. Speed and Velocity

Speed

Speed is the **distance travelled per unit time**. Speed = Distance / Time. It is a scalar quantity. SI unit: **m/s**; common unit: km/h. If an object covers equal distances in equal intervals of time, it has **uniform speed**; otherwise it has **variable (non-uniform) speed**.

- **Average speed** = Total distance travelled / Total time taken.
- **Instantaneous speed** = speed at a particular instant (shown by the speedometer of a vehicle).
- Speed can never be negative or zero for a moving body in the sense of path-length rate; it is always ≥ 0.

Velocity

Velocity is the **displacement per unit time**. Velocity = Displacement / Time. It is a vector quantity. SI unit: **m/s**. Velocity changes if either the speed or the direction (or both) changes.

- **Average velocity** = Total displacement / Total time. For a body moving with uniform acceleration in a straight line: average velocity = (u + v)/2.
- **Uniform velocity**: equal displacements in equal intervals of time in the same direction.
- If a body returns to its starting point, its average velocity is **zero** but average speed is not zero.

Difference between Speed and Velocity

Basis	Speed	Velocity
Definition	Distance / time	Displacement / time
Nature	Scalar	Vector
Direction	Not required	Required
Value	Always positive	Positive, negative or zero
Instrument	Speedometer	Speedometer with direction (e.g. radar)

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Units and Conversion

Conversion	Rule
km/h to m/s	Multiply by 5/18
m/s to km/h	Multiply by 18/5 (i.e. 3.6)
Example	72 km/h = 72 × 5/18 = 20 m/s
Example	10 m/s = 10 × 18/5 = 36 km/h

Important Formulae

Situation	Formula
Average speed (equal distances at speeds v_1 and v_2)	$2v_1v_2 / (v_1 + v_2)$ (harmonic mean)
Average speed (equal times at speeds v_1 and v_2)	$(v_1 + v_2) / 2$ (arithmetic mean)
Relative velocity (same direction)	$v_1 - v_2$
Relative velocity (opposite direction)	$v_1 + v_2$
Train crossing a pole / man	Time = Length of train / Speed of train
Train crossing a platform	Time = (Length of train + Length of platform) / Speed

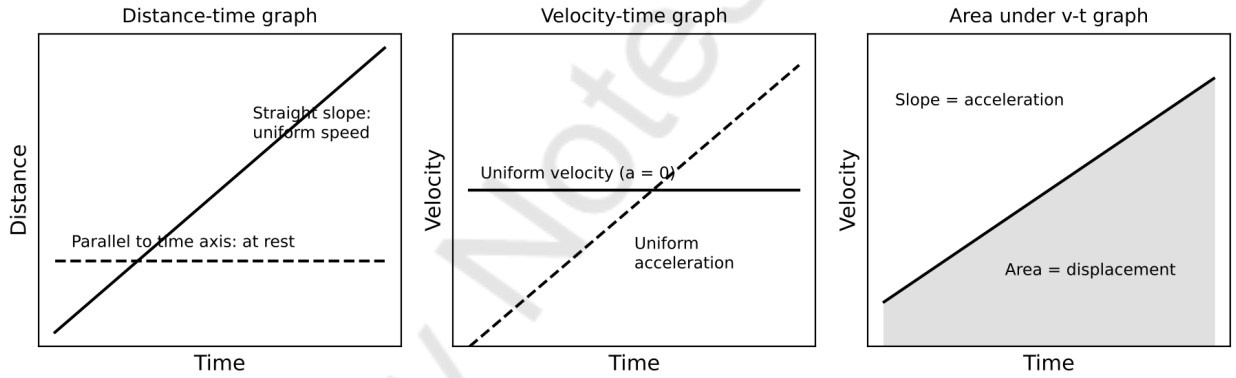


Figure 2: Motion graphs. Slope of the distance-time graph = speed; slope of the velocity-time graph = acceleration; area under the velocity-time graph = displacement.

Some Important Speeds

Quantity	Approximate value
Speed of light in vacuum	3×10^8 m/s
Speed of sound in air (about 20°C)	343 m/s (about 332 m/s at 0°C)
Speed of sound in solids	Greater than in liquids, and in liquids greater than in gases

Exam Tip: Speed of sound is highest in solids and lowest in gases; sound cannot travel in vacuum. Light travels the fastest of all. Average-speed problems with “equal distances” need the harmonic-mean formula, not the simple average. Example: 40 km/h and 60 km/h over equal distances gives 2 × 40 × 60 / 100 = 48 km/h.

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3. Acceleration

Acceleration is the **rate of change of velocity** with time. If the velocity of a body changes from **u** (initial) to **v** (final) in time **t**, then **a = (v − u) / t**. It is a **vector** quantity. SI unit: **m/s²**.

- **Positive acceleration**: velocity increases with time.
- **Negative acceleration (retardation or deceleration)**: velocity decreases with time.
- **Uniform acceleration**: equal change in velocity in equal intervals of time. **Non-uniform acceleration**: unequal change in velocity in equal intervals.
- A body moving in a circle with **constant speed** is still accelerated, because its direction (and hence velocity) keeps changing. Centripetal acceleration = v^2/r, directed towards the centre.

Equations of Motion (Uniform Acceleration in a Straight Line)

Equation	Name / use	Contains
$v = u + at$	First equation (velocity-time relation)	v, u, a, t (no s)
$s = ut + \frac{1}{2}at^2$	Second equation (position-time relation)	s, u, a, t (no v)
$v^2 = u^2 + 2as$	Third equation (position-velocity relation)	v, u, a, s (no t)
$s_n = u + a(2n - 1)/2$	Distance travelled in the nth second	s, u, a, n

Here **u** = initial velocity, **v** = final velocity, **a** = acceleration, **t** = time, **s** = displacement.

Motion Under Gravity (Free Fall)

When a body moves only under the influence of gravity, its acceleration is **g = 9.8 m/s²** directed towards the centre of the Earth, whatever its mass. Use the same equations of motion with a = g (for a downward throw/fall) or a = −g (for an upward throw).

Case	Initial velocity	Key results
Body dropped from rest	u = 0	$v = gt$; $h = \frac{1}{2}gt^2$; $v^2 = 2gh$
Body thrown upwards with speed u	Final velocity at top = 0	Maximum height $H = u^2/2g$; time to top = u/g; total time of flight = 2u/g
Body thrown downwards	$u \neq 0$	$v = u + gt$; $h = ut + \frac{1}{2}gt^2$

Worked Examples

1 A car starts from rest and attains 20 m/s in 5 s. Acceleration $a = (20 - 0)/5 =$ **4 m/s²**. Distance = $\frac{1}{2} \times 4 \times 5^2 =$ **50 m**.

2 A ball is thrown upwards at 19.6 m/s (g = 9.8). Maximum height = $19.6^2 / (2 \times 9.8) =$ **19.6 m**; time of flight = $2 \times 19.6 / 9.8 =$ **4 s**.

3 A stone dropped from a cliff reaches the ground in 3 s (g = 10). Height = $\frac{1}{2} \times 10 \times 9 =$ **45 m**; final speed = $10 \times 3 =$ **30 m/s**.

Exam Tip: In a velocity-time graph, a horizontal line means zero acceleration, an upward sloping line means positive acceleration and a downward sloping line means retardation. In free fall, a heavy and a light body reach the ground together in a vacuum (Galileo).

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4. Newton's Laws of Motion

Sir Isaac Newton presented the three laws of motion in his book **Principia Mathematica (1687)**. These laws form the foundation of classical mechanics.

First Law: Law of Inertia

A body continues in its state of rest or of uniform motion in a straight line unless an external unbalanced force acts on it. The property of a body to resist any change in its state of rest or motion is called **inertia**. Inertia is measured by **mass**: greater mass means greater inertia.

- **Inertia of rest**: a body at rest stays at rest. Example: passengers fall backward when a bus suddenly starts; dust falls off a carpet when it is beaten.
- **Inertia of motion**: a moving body stays in motion. Example: passengers lurch forward when a moving bus suddenly stops; an athlete takes a run-up before a long jump.
- **Inertia of direction**: a body cannot change its direction by itself. Example: passengers are thrown outward when a car takes a sharp turn.

Second Law: F = ma

The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction of the force. For a body of constant mass, **F = ma**. The SI unit of force is the **newton (N)**: 1 N = 1 kg·m/s², i.e. the force that produces an acceleration of 1 m/s² in a body of mass 1 kg.

- Acceleration is directly proportional to force and inversely proportional to mass.
- The first law gives the definition of force; the second law gives its measure.
- Weight W = mg is a particular case of the second law.

Third Law: Action and Reaction

To every action there is an equal and opposite reaction. Action and reaction are equal in magnitude, opposite in direction, and always act on **two different bodies**, so they never cancel each other.

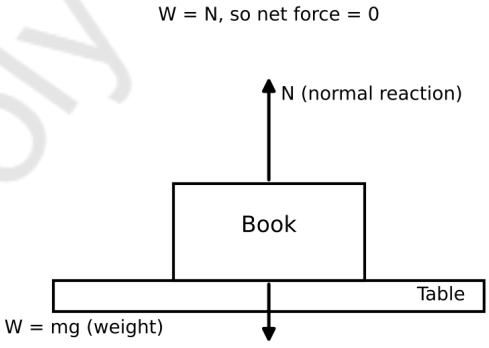


Figure 3: A book resting on a table. Weight W (down) and normal reaction N (up) balance each other, so the book stays at rest.

- **Rocket propulsion**: hot gases are pushed downward (action) and the rocket moves upward (reaction).
- **Recoil of a gun**: the bullet moves forward and the gun recoils backward.
- **Walking**: we push the ground backward and the ground pushes us forward.
- **Swimming**: the swimmer pushes the water backward and water pushes the swimmer forward.

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- **Flight of a bird or an aeroplane** and the **jumping of a person from a boat** (boat moves backward).

Summary of Newton's Laws

Law	Statement in brief	Formula / Idea	Example
First	Body keeps its state unless a force acts	Inertia; mass measures inertia	Passenger lurches forward in a braking bus
Second	Force = rate of change of momentum	$F = ma$	Heavier cart needs more force for the same acceleration
Third	Action and reaction are equal and opposite	$F_{12} = -F_{21}$	Rocket, gun recoil, swimming

Exam Tip: Newton's first law is called the Law of Inertia; the second law gives F = ma; the third law explains rockets, guns and swimming. A frequently asked point: action and reaction do not cancel because they act on different bodies. Mass is the measure of inertia.

5. Force and Momentum

Force

Force is a **push or pull** that can change the state of rest or motion, speed, direction or shape of a body. It is a **vector** quantity. SI unit: **newton (N)**; CGS unit: **dyne**. **1 N = 10^5 dyne**. Also, 1 kgf = 9.8 N.

- **Balanced forces**: net force is zero; the state of motion does not change.
- **Unbalanced forces**: net force is not zero; it produces acceleration.
- **Contact forces**: muscular force, friction, tension, normal reaction. **Non-contact forces**: gravitational, electrostatic and magnetic forces.
- Resultant of two forces acting in the same direction = $F_1 + F_2$; in opposite directions = $F_1 - F_2$.

Four Fundamental Forces of Nature

Force	Relative strength	Range / Remark
Strong nuclear force	Strongest	Very short range; binds protons and neutrons in the nucleus
Electromagnetic force	About 1/137 of the strong force	Long range; acts between charged particles
Weak nuclear force	Much weaker	Very short range; responsible for beta decay
Gravitational force	Weakest	Long range; always attractive

Linear Momentum

Momentum is the **quantity of motion** in a body, equal to the product of its mass and velocity: **$p = m \times v$**. It is a **vector** quantity. SI unit: **kg·m/s**. The direction of momentum is the direction of velocity. A heavy truck and a bullet may have the same momentum even though their masses and speeds are very different.

Impulse

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Impulse is the product of force and the (small) time for which it acts: **Impulse = F × Δt = change in momentum (mv − mu)**. SI unit: **N·s** (same as kg·m/s). A large force acting for a short time can produce the same impulse as a small force acting for a long time.

Law of Conservation of Momentum

If no external force acts on a system, the total momentum of the system remains constant. That is, the total momentum before collision equals the total momentum after collision: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$.

Types of Collision

Type	Momentum	Kinetic energy	Example
Elastic collision	Conserved	Conserved	Collision between gas molecules, billiard balls (nearly)
Inelastic collision	Conserved	Not conserved (partly lost as heat/sound)	Car crash, ball hitting wet clay
Perfectly inelastic	Conserved	Maximum loss; bodies stick together	Bullet embedded in a wooden block

Applications of Impulse and Momentum

- A cricketer pulls his hands back while catching a fast ball: the time of impact increases and so the force on the hands decreases.
- Seat belts and air bags in cars increase the stopping time and reduce the force during a collision.
- A high jumper lands on a sand bed or foam mattress to increase the stopping time.
- **Recoil of a gun**: by conservation of momentum, recoil velocity of gun = −(mass of bullet × velocity of bullet) / mass of gun.

Worked Examples

1 Momentum of a 2 kg body moving at 10 m/s = 2 × 10 = **20 kg·m/s**.

2 A bullet of mass 0.02 kg is fired at 300 m/s from a gun of mass 4 kg. Recoil velocity = (0.02 × 300)/4 = **1.5 m/s** (backward).

3 A force of 50 N acts on a body for 0.2 s. Impulse = 50 × 0.2 = **10 N·s**.

Exam Tip: Newton's second law in its original form is F = Δp/Δt. Rocket propulsion, gun recoil and the motion of a jet aeroplane follow the law of conservation of momentum. Momentum is conserved in all types of collision, but kinetic energy is conserved only in elastic collisions.

6. Friction

Friction is the **force that opposes the relative motion (or tendency of motion) between two surfaces in contact**. It acts along the surfaces of contact and in a direction **opposite** to the relative motion. It arises because of the roughness (irregularities) of the surfaces and the molecular adhesion between them. Friction is a contact force and is a self-adjusting force up to a limit.

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$$f = \mu N$$

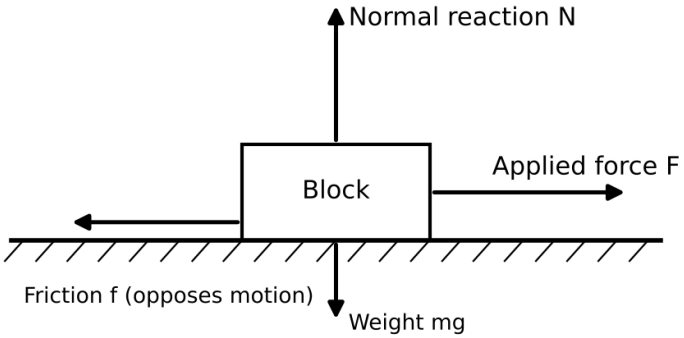


Figure 4: Forces on a block pulled along a rough surface. Friction f acts opposite to the direction of motion.

Types of Friction

Type	Meaning	Remarks
Static friction	Friction acting when there is no relative motion	Self-adjusting; equals the applied force up to a maximum value
Limiting friction	Maximum value of static friction (when the body is just about to move)	Greater than sliding friction
Kinetic (sliding) friction	Friction when one surface slides over another	Less than limiting friction; nearly constant
Rolling friction	Friction when a body rolls over a surface	Least of all; so wheels are used

Order of magnitude: Limiting (static) friction > Sliding friction > Rolling friction.

Laws of Friction

- Friction depends on the **nature of the surfaces** in contact (roughness) and on the **normal reaction (N)**.
- The limiting friction is directly proportional to the normal reaction: **f = μN**, where μ is the **coefficient of friction** (no unit, dimensionless).
- Friction is (nearly) **independent of the area of contact** and of the speed of sliding.
- On an inclined plane, the angle of repose θ satisfies **tan θ = μ**.

Advantages and Disadvantages of Friction

Friction is useful (advantage)	Friction is harmful (disadvantage)
Walking on the ground, holding objects, writing with a pencil	Wear and tear of machine parts, shoes and tyres
Vehicles start, stop and turn because of friction (brakes, tyres)	Loss of useful energy as heat in machines, reducing efficiency
Nails, screws and knots stay fixed	Makes it harder to move objects such as furniture
Matchstick lights by rubbing	Heating and noise in moving parts

Methods of Changing Friction

To reduce friction	To increase friction
Use lubricants (oil, grease), graphite powder	Make surfaces rough (grooves in tyres, treads on shoes)

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To reduce friction	To increase friction
Use ball bearings or rollers (sliding becomes rolling)	Sprinkle sand on slippery roads
Polish the surfaces; streamline the shape	Use rubber soles; apply rosin on hands of players
Use air cushion (hovercraft), magnetic levitation	Increase the pressing force (normal reaction)

Fluid Friction

A fluid (liquid or gas) also opposes the motion of a body moving through it. This is called **drag** or **viscous force**. Boats and aeroplanes have streamlined shapes to reduce fluid friction.

Worked Example

A block of mass 10 kg rests on a surface with $\mu = 0.3$. Taking $g = 10\ m/s^2$: $N = mg = 100$ N; limiting friction $f = \mu N = 0.3 \times 100 =$ **30 N**. A force less than 30 N will not move the block.

Exam Tip: Rolling friction is the least; limiting friction is the greatest. Friction is called a "necessary evil". Friction produces heat (rubbing hands, meteors burning in the atmosphere). The coefficient of friction has no unit.

7. Work, Power and Energy

Work

Work is said to be done when a force acts on a body and the body is displaced in the direction (or partly in the direction) of the force. **Work = Force × Displacement in the direction of force**, i.e. **$W = F\ s \cos\theta$**, where θ is the angle between force and displacement. It is a **scalar** quantity. SI unit: **joule (J)**; 1 J = 1 N × 1 m. CGS unit: erg; **$1\ J = 10^7$ erg**.

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

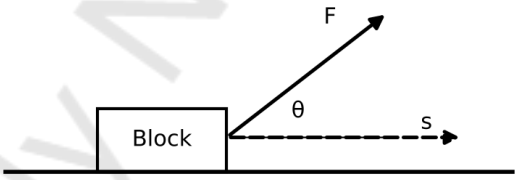


Figure 5: Work done by a force F at an angle θ to the displacement s.

Case	Angle θ	Work done	Example
Positive work	0° (force along displacement)	W = Fs (maximum)	Pushing a trolley; a stone falling down
Zero work	90° (force perpendicular)	W = 0	Centripetal force in circular motion; carrying a load on a horizontal path; pushing a wall that does not move
Negative work	180° (force opposite)	W = −Fs	Friction on a moving body; brakes applied to a vehicle

Energy

Energy is the **capacity to do work**. It is a scalar quantity with the same unit as work (joule). Common units: calorie (1 cal = 4.18 J) and kilowatt-hour (**$1\ kWh = 3.6 \times 10^6$ J**, the commercial

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unit of electrical energy; one “unit” on the electricity bill).

Mechanical Energy: Kinetic and Potential

Energy	Meaning	Formula	Remark
Kinetic energy (KE)	Energy due to motion	KE = ½mv²	Proportional to v²; doubling speed makes KE four times
Gravitational potential energy (PE)	Energy due to position (height)	PE = mgh	Depends on height above the reference level
Elastic potential energy	Energy stored in a stretched or compressed spring	½kx²	k = spring constant, x = extension

- **Work-Energy theorem**: net work done on a body = change in its kinetic energy.
- **Law of Conservation of Energy**: energy can neither be created nor destroyed; it can only change from one form to another. The total energy of an isolated system remains constant.
- For a freely falling body, the sum KE + PE (total mechanical energy) remains constant at every point; PE converts into KE.
- Einstein's mass-energy relation: **$E = mc^2$** (c = speed of light).

Power

Power is the **rate of doing work**: **P = W/t** (also P = F × v). It is a scalar. SI unit: **watt (W)**; 1 W = 1 J/s. Larger units: 1 kW = 1000 W; 1 MW = 10^6 W; **1 horsepower (hp) = 746 W**. **Efficiency** = (useful output energy / total input energy) × 100%.

Common Energy Conversions

Device / Process	Energy conversion
Electric bulb	Electrical → Light + Heat
Electric motor / fan	Electrical → Mechanical
Generator / dynamo	Mechanical → Electrical
Solar cell	Light (solar) → Electrical
Battery / cell	Chemical → Electrical
Microphone	Sound → Electrical
Loudspeaker	Electrical → Sound
Photosynthesis	Light → Chemical
Hydroelectric plant	Potential (water) → Kinetic → Electrical
Nuclear reactor	Nuclear → Heat → Electrical

Worked Examples

1. KE of a 2 kg body moving at 3 m/s = ½ × 2 × 3^2 = **9 J**.
2. PE of a 5 kg body at a height of 10 m (g = 10) = 5 × 10 × 10 = **500 J**.
3. A boy lifts a 50 kg load through 10 m in 10 s (g = 10). Work = 50 × 10 × 10 = 5000 J; Power = 5000/10 = **500 W**.
4. A 1000 W heater used for 5 hours consumes 1 kW × 5 h = **5 kWh (5 units)**.

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Exam Tip: Work done by the centripetal force is always zero. Work done by a coolie carrying a load on his head along a level road is zero (physically). Kilowatt-hour is a unit of energy, not of power. Watt is the SI unit of power; 1 hp = 746 W.

8. Gravitation

Universal Law of Gravitation

Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. The force acts along the line joining the two bodies. **$F = G m_1 m_2 / r^2$**, where G is the **universal gravitational constant**.

- **$G = 6.67 \times 10^{-11}$ N·m²/kg²** (a universal constant; same everywhere). It was first measured by **Henry Cavendish** (1798).
- Gravitational force is always **attractive**, acts on all bodies, is a long-range force and is the weakest of the four fundamental forces. It forms an action-reaction pair (Newton's third law).
- It is responsible for the motion of the Moon around the Earth, the planets around the Sun, tides in the sea, and the weight of objects.

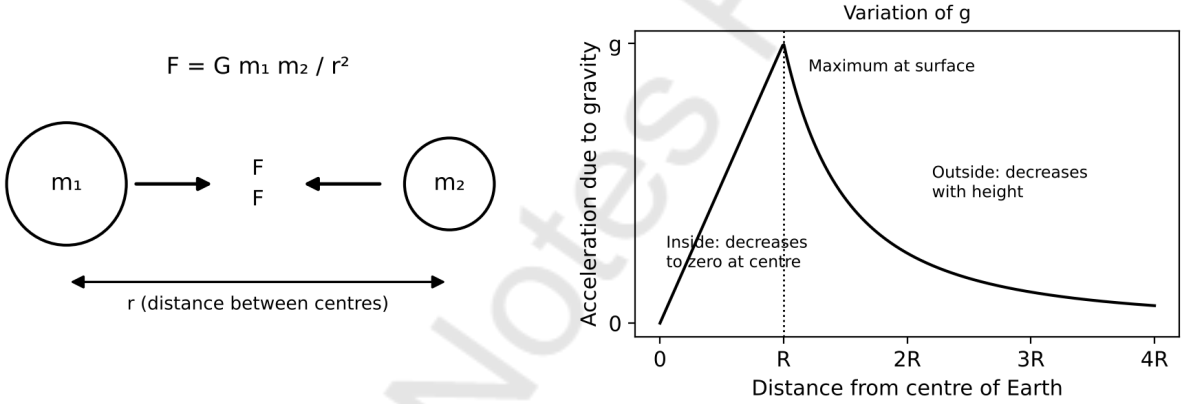


Figure 6: (Left) Mutual gravitational attraction of two masses. (Right) Variation of g with distance from the centre of the Earth.

Acceleration due to Gravity (g)

The acceleration produced in a freely falling body due to the Earth's gravity is **$g = GM/R^2$**, where M is the mass of the Earth (6×10^{24} kg) and R is its radius (6.4×10^6 m). The value of g is **9.8 m/s²** near the surface of the Earth. It is independent of the mass of the falling body.

Variation of g

Factor	Effect on g
Altitude (height above surface)	g decreases as we go up
Depth (below surface)	g decreases as we go down; it is **zero at the centre of the Earth**
Latitude (shape of Earth)	g is **maximum at the poles** and **minimum at the equator** (the Earth is flattened at the poles)
Rotation of the Earth	Reduces g at the equator; no effect at the poles
On the Moon	g_{moon} = 1.63 m/s² ≈ 1/6 of g on Earth

Mass and Weight

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Basis	Mass	Weight
Meaning	Quantity of matter in a body	Force with which the Earth attracts the body
Formula	—	W = mg
Nature	Scalar	Vector (acts towards the centre of the Earth)
SI unit	kilogram (kg)	newton (N)
Variation	Constant everywhere	Changes with the value of g
Measured by	Physical (beam) balance	Spring balance
At the centre of the Earth	Same	Zero

A body of mass 60 kg has weight = 60 × 9.8 = 588 N on the Earth, but only about 98 N on the Moon. Mass remains 60 kg. In a freely falling lift or in an orbiting satellite, a person feels **weightlessness** (apparent weight is zero) although gravity still acts.

Escape Velocity and Orbital Velocity

Term	Meaning	Value for Earth
Escape velocity (v_e)	Minimum velocity needed to escape from the gravitational pull of a planet; $v_e = \sqrt{(2gR)}$; independent of the mass of the body	About **11.2 km/s** (Moon: about 2.4 km/s)
Orbital velocity (v_o)	Velocity needed to revolve in a circular orbit near the surface; $v_o = \sqrt{(gR)}$	About **7.9 km/s** ($v_e = \sqrt{2} \times v_o$)

Kepler's Laws of Planetary Motion

1. **Law of Orbits:** Every planet moves around the Sun in an **elliptical orbit**, with the Sun at one focus.
2. **Law of Areas:** The line joining the planet and the Sun sweeps **equal areas in equal times**. So a planet moves faster when it is nearer the Sun.
3. **Law of Periods:** The square of the time period of revolution is proportional to the cube of the semi-major axis of the orbit (**$T^2 \propto r^3$**).

Satellites

- A satellite is a body that revolves around a planet. The Moon is the natural satellite of the Earth; **Aryabhata** (1975) was India's first artificial satellite.
- **Geostationary satellite**: time period 24 hours; orbits in the equatorial plane from west to east at a height of about **36,000 km** (35,786 km); appears fixed in the sky. Used for communication and broadcasting (e.g. INSAT series).
- **Polar satellites** orbit at about 500-800 km and pass over the poles; used for remote sensing, weather and mapping.

Exam Tip: G is a universal constant, while g changes from place to place. g is highest at the poles, zero at the centre of the Earth. Mass never changes but weight does. Escape velocity of the Earth = 11.2 km/s. A geostationary satellite has a period of 24 h.

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9. Pressure

Thrust is the force acting **perpendicular** to a surface. **Pressure** is the thrust acting per unit area: **P = F / A**. It is a **scalar** quantity. SI unit: **pascal (Pa)**; 1 Pa = 1 N/m². Pressure increases when the area decreases for the same force.

- A sharp knife cuts easily and a nail pierces the wall because their small area gives a large pressure.
- Skis, broad straps of school bags, the broad foundation of buildings and wide tyres of tractors spread the force over a larger area and reduce pressure.
- A camel can walk easily on sand because of its broad feet.

Units of Pressure

Unit	Value
1 pascal (Pa)	1 N/m²
1 bar	10^5 Pa
1 standard atmosphere (atm)	101325 Pa ≈ 1.013 × 10^5 Pa = 760 mm of Hg = 76 cm of Hg
1 mm of Hg (1 torr)	133.3 Pa

Pressure in Liquids

A liquid exerts pressure on the bottom and walls of its container. Pressure at a depth h in a liquid of density ρ is **P = hρg**. (Total pressure = atmospheric pressure + hρg.)

- Pressure increases with **depth** and with the **density** of the liquid.
- At a given depth the pressure is the **same in all directions** and does not depend on the shape or size of the container or the amount of liquid. This is why the wall of a dam is made thicker at the bottom.
- The pressure at the same level in a liquid at rest is the same.

Pascal's Law

Pressure applied to an enclosed liquid is transmitted equally and undiminished in all directions throughout the liquid. Applications: **hydraulic lift, hydraulic press, hydraulic brakes** and car jacks. In a hydraulic machine, **$F_1/A_1 = F_2/A_2$**, so a small force on a small piston gives a large force on a large piston.

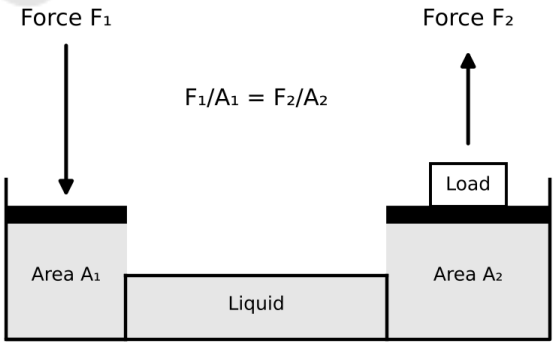


Figure 7: Hydraulic lift based on Pascal's law.

Atmospheric Pressure

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The air around the Earth exerts pressure on all objects, called **atmospheric pressure**. At sea level it is about 101325 Pa (1 atm). It is measured by a **barometer**; the mercury barometer was invented by **Evangelista Torricelli** (1643). Other instruments are listed below.

Instrument	Use
Mercury barometer	Measures atmospheric pressure
Aneroid barometer	Portable barometer; used in aircraft and mountaineering as an altimeter (to find height)
Manometer	Measures pressure of a gas or liquid in a closed vessel
Sphygmomanometer	Measures blood pressure (normal about 120/80 mm of Hg)
Pressure cooker	Water boils at a higher temperature (above 100°C) because of higher pressure

- Atmospheric pressure **decreases** with increasing height. At high altitudes, water boils below 100°C and cooking takes longer; people may feel nose bleeding because blood pressure inside exceeds the outside pressure.
- A sudden fall in the barometer reading predicts a storm; a slow rise indicates fair weather.
- Drinking through a straw, a syringe, a rubber suction cup and a dropper work due to atmospheric pressure.

Buoyancy and Archimedes' Principle (Related Concept)

A body immersed in a fluid experiences an upward force called **upthrust (buoyant force)**. **Archimedes' principle**: the upthrust equals the weight of the fluid displaced by the body. A body **floats** if its density is less than that of the liquid and **sinks** if its density is greater. Ships float because of their hollow shape, which displaces a large volume of water. Relative density = density of substance / density of water. Density of water = 1000 kg/m³.

Worked Examples

1 A force of 100 N acts on an area of 0.5 m². Pressure = 100/0.5 = **200 Pa**.

2 Pressure at a depth of 10 m in water (g = 10, ρ = 1000 kg/m³) = 10 × 1000 × 10 = **10^5 Pa** (about 1 atm), excluding atmospheric pressure.

Exam Tip: The SI unit of pressure is pascal; blood pressure is measured by the sphygmomanometer; the barometer was invented by Torricelli. 1 atm = 101325 Pa = 760 mm Hg. Pascal's law is the principle behind hydraulic brakes and lifts; Archimedes' principle explains floating and sinking.

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Practice Set: 50 Multiple Choice Questions

Choose the correct option. The answer key is given at the end.

Q1. Which of the following is a vector quantity?
(A) Distance (B) Speed (C) Displacement (D) Time

Q2. A runner completes one full lap of a circular track of radius r. His displacement is:
(A) 2πr (B) πr (C) r (D) Zero

Q3. A person walks 3 m east and then 4 m north. The magnitude of displacement is:
(A) 7 m (B) 5 m (C) 1 m (D) 12 m

Q4. A speed of 72 km/h is equal to:
(A) 10 m/s (B) 15 m/s (C) 20 m/s (D) 25 m/s

Q5. The slope of a distance-time graph gives:
(A) Acceleration (B) Speed (C) Displacement (D) Force

Q6. A car covers the first half of a distance at 40 km/h and the second half at 60 km/h. Its average speed is:
(A) 50 km/h (B) 48 km/h (C) 52 km/h (D) 45 km/h

Q7. The speedometer of a vehicle measures:
(A) Average speed (B) Distance (C) Instantaneous speed (D) Acceleration

Q8. The area under a velocity-time graph gives:
(A) Acceleration (B) Speed (C) Force (D) Displacement

Q9. The SI unit of acceleration is:
(A) m/s (B) m/s^2 (C) N (D) m^2/s

Q10. A car starting from rest accelerates at 5 m/s^2 for 4 s. Its final velocity is:
(A) 9 m/s (B) 20 m/s (C) 1.25 m/s (D) 25 m/s

Q11. Negative acceleration is also called:
(A) Retardation (B) Velocity (C) Inertia (D) Momentum

Q12. The value of acceleration due to gravity near the Earth's surface is approximately:
(A) 9.8 m/s^2 (B) 98 m/s^2 (C) 0.98 m/s^2 (D) 6.67 m/s^2

Q13. Which equation of motion does not involve time?
(A) $v = u + at$ (B) $s = ut + \frac{1}{2}at^2$ (C) $v^2 = u^2 + 2as$ (D) $s = vt$

Q14. Newton's first law of motion is also called the law of:
(A) Gravitation (B) Inertia (C) Momentum (D) Energy

Q15. A passenger standing in a moving bus falls forward when the bus stops suddenly. This is due to:
(A) Inertia of motion (B) Inertia of rest (C) Inertia of direction (D) Gravity

Q16. The force required to give a mass of 5 kg an acceleration of 4 m/s^2 is:
(A) 1.25 N (B) 9 N (C) 20 N (D) 0.8 N

Q17. Rocket propulsion is based on:
(A) Newton's third law (B) Newton's first law (C) Law of gravitation (D) Ohm's law

Q18. Action and reaction forces act on:
(A) The same body (B) Different bodies (C) Neither body (D) Only on solid bodies

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Q19. The SI unit of momentum is:

(A) kg·m/s (B) kg·m/s² (C) N·m (D) Joule

Q20. The momentum of a 2 kg body moving at 10 m/s is:

(A) 5 kg·m/s (B) 12 kg·m/s (C) 20 kg·m/s (D) 0.2 kg·m/s

Q21. Impulse is equal to:

(A) Change in kinetic energy (B) Change in momentum (C) Force × distance (D) Mass × velocity²

Q22. A cricketer pulls his hands back while catching a ball in order to:

(A) Increase the time of impact and reduce the force (B) Increase the force on hands (C) Reduce the mass of the ball (D) Increase the speed of the ball

Q23. Which is the strongest of the fundamental forces?

(A) Gravitational force (B) Electromagnetic force (C) Strong nuclear force (D) Weak nuclear force

Q24. The recoil of a gun on firing a bullet is explained by:

(A) Conservation of energy (B) Conservation of momentum (C) Friction (D) Gravitation

Q25. Which type of friction is the least?

(A) Static friction (B) Sliding friction (C) Rolling friction (D) Limiting friction

Q26. The coefficient of friction:

(A) Has unit newton (B) Has unit N/m (C) Has unit kg (D) Has no unit

Q27. A block of mass 10 kg rests on a surface with $\mu = 0.4$ ($g = 10$ m/s²). The limiting friction is:

(A) 4 N (B) 25 N (C) 40 N (D) 100 N

Q28. Which of the following helps to reduce friction?

(A) Making the surface rough (B) Using lubricants (C) Increasing the load (D) Using treads on tyres

Q29. The SI unit of work is:

(A) Watt (B) Joule (C) Newton (D) Pascal

Q30. The work done by the centripetal force in uniform circular motion is:

(A) Positive (B) Negative (C) Zero (D) Infinite

Q31. The kinetic energy of a 2 kg body moving at 3 m/s is:

(A) 6 J (B) 9 J (C) 18 J (D) 3 J

Q32. 1 kilowatt-hour (kWh) is equal to:

(A) 3.6×10^3 J (B) 3.6×10^6 J (C) 746 J (D) 1000 J

Q33. 1 horsepower is equal to:

(A) 746 W (B) 1000 W (C) 550 W (D) 100 W

Q34. A generator converts:

(A) Electrical energy into mechanical energy (B) Mechanical energy into electrical energy (C) Chemical energy into electrical energy (D) Heat into light

Q35. The potential energy of a 10 kg body at a height of 5 m ($g = 10$ m/s²) is:

(A) 50 J (B) 500 J (C) 5 J (D) 5000 J

Q36. The SI unit of power is:

(A) Joule (B) Newton (C) Watt (D) Pascal

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Q37. The value of the universal gravitational constant G is:

(A) 6.67×10^{-11} N·m²/kg² (B) 9.8 N·m²/kg² (C) 6.67×10^{11} N·m²/kg² (D) 3×10^{8} N·m²/kg²

Q38. The acceleration due to gravity (g) is maximum at:

(A) The equator (B) The centre of the Earth (C) The poles (D) The top of a mountain

Q39. The weight of a body on the Moon compared with its weight on the Earth is about:

(A) 1/6 (B) 6 times (C) 1/9 (D) The same

Q40. The escape velocity from the surface of the Earth is:

(A) 7.9 km/s (B) 9.8 km/s (C) 11.2 km/s (D) 3×10^{5} km/s

Q41. The time period of a geostationary satellite is:

(A) 12 hours (B) 24 hours (C) 365 days (D) 90 minutes

Q42. According to Kepler's third law:

(A) $T \propto r$ (B) $T^2 \propto r^3$ (C) $T \propto r^2$ (D) $T^3 \propto r^2$

Q43. The SI unit of pressure is:

(A) Pascal (B) Newton (C) Joule (D) Watt

Q44. A force of 100 N acts on an area of 0.5 m². The pressure is:

(A) 50 Pa (B) 200 Pa (C) 100 Pa (D) 0.005 Pa

Q45. A hydraulic lift works on the principle of:

(A) Archimedes' principle (B) Bernoulli's principle (C) Boyle's law (D) Pascal's law

Q46. The standard atmospheric pressure (1 atm) is equal to:

(A) 101325 Pa (B) 1000 Pa (C) 760 Pa (D) 10^{6} Pa

Q47. The mercury barometer was invented by:

(A) Newton (B) Torricelli (C) Pascal (D) Archimedes

Q48. The pressure at a point inside a liquid depends upon:

(A) Area of the surface (B) Shape of the container (C) Depth and density of the liquid (D) Volume of the liquid

Q49. A sharp knife cuts easily because:

(A) It has more area and less pressure (B) It has less area and more pressure (C) It has more mass (D) It has more friction

Q50. With increase in altitude, atmospheric pressure:

(A) Increases (B) Remains constant (C) Decreases (D) Becomes infinite

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Answer Key

Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans
1	C	11	A	21	B	31	B	41	B
2	D	12	A	22	A	32	B	42	B
3	B	13	C	23	C	33	A	43	A
4	C	14	B	24	B	34	B	44	B
5	B	15	A	25	C	35	B	45	D
6	B	16	C	26	D	36	C	46	A
7	C	17	A	27	C	37	A	47	B
8	D	18	B	28	B	38	C	48	C
9	B	19	A	29	B	39	A	49	B
10	B	20	C	30	C	40	C	50	C

Quick Revision: Use the exam tips given at the end of every topic for last-minute revision.

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