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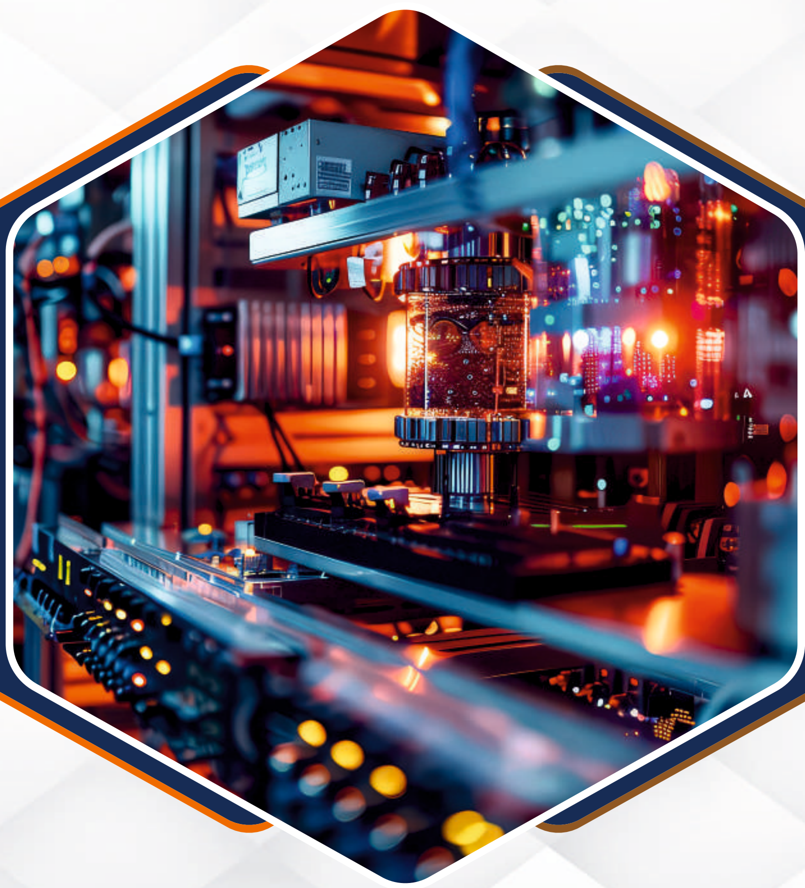


QUICK AND COMPREHENSIVE REVISION SERIES

CONTENTS

1 General Physics and Everyday Chemistry

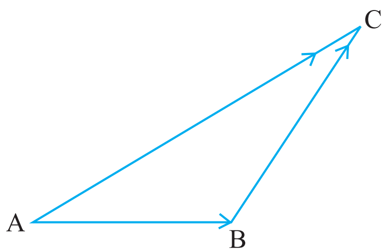
GENERAL PHYSICS

MECHANICS

Scalar and Vector Quantities

- **Scalar:** Has only magnitude (size).
  - **Examples:** Distance (5 m), Speed (60 km/h), Mass (10 kg).
- **Vector:** Has both magnitude and direction.
  - Vectors follow **Triangle law of addition.**
    A vector simply means the displacement from a point A to the point B. Now consider a situation that a girl moves from A to B and then from B to C. The net displacement made by the girl from point A to the point C, is given by the vector and expressed as

    $$\overline{AC} = \overline{AB} + \overline{BC}$$



    This is known as the triangle law of vector addition.
  - **Examples:** Displacement (5 m east), Velocity (60 km/h north), Force (10 N downward).

Some Key Terms

Velocity

- Velocity is a vector quantity that represents the rate of change of an object's position with respect to time in a specific direction. It tells both how fast an object is moving (speed) and in which direction.
- $v = \Delta s/\Delta t$, Where: v = velocity, Δs = displacement (change in position), Δt = time interval
- Velocity differs from speed because it includes direction, making it a vector quantity.

Acceleration

- It is defined as the rate of change of velocity with respect to time.
- $a = \Delta v/\Delta t$, where: a = acceleration, Δv = change in velocity, Δt = time interval

Momentum [UPSC 1997, 2000]

- Momentum is a vector quantity that represents the product of an object's mass and its velocity.
- It indicates how much motion an object possesses and is given by the equation:
  - **P = mv,** where P = momentum, v = velocity and m = mass
- **Law of Conservation of Momentum:** According to the law of conservation of momentum, the total momentum of an isolated system remains constant if no external forces act on it.
  - **Application:** Suppose a person is stuck in the middle of a frozen lake which offers almost no friction with his shoes. He cannot simply walk and come out as friction is required for walking. How can he come out if he has got just his bag and no other tool?
  - **Solution:** He can apply conservation of momentum here, if he throws the bag in one direction, the bag will get a velocity and thus a momentum in that direction. The man will attain velocity and momentum in the opposite direction so that net momentum of Man + Bag remains zero as no external force is applied on the Man + Bag system (friction is zero).

Force and Newton's Laws of Motion

Force

- Force is a push or pull exerted on an object that causes it to change its velocity (accelerate) or shape.
- It is a vector quantity and is measured in Newtons (N).

Newton's First Law (Law of Inertia)

- A body remains in a state of rest or uniform motion in a straight line unless acted upon by an external force.
- **Example:** A book on a table stays still until you push it.

Newton's Second Law (Law of Acceleration)

- The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. This means to give equal acceleration to two objects, one needs to apply greater force on the heavier object.
- **Equation: F = ma**, where: m is mass, and a is acceleration.
  - This equation can be expressed in terms of momentum also. **F = ΔP/Δt meaning Force is rate of change of momentum.**
- **Example:** A car accelerates faster when pushed with greater force.

Newton's Third Law (Action-Reaction)

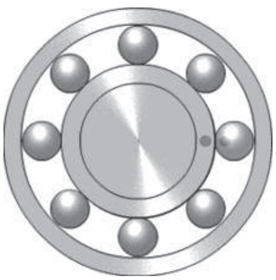
- For every action, there is an equal and opposite reaction.
- **Example:** A rocket moves upward by expelling gases downward. The gases being forced downward push the rocket upwards as explained by Third Law.

Friction

Friction is a force that opposes the relative motion between two surfaces in contact. It arises due to the interactions at the microscopic level of the surfaces involved. Greater the surface area in contact greater will be the friction.

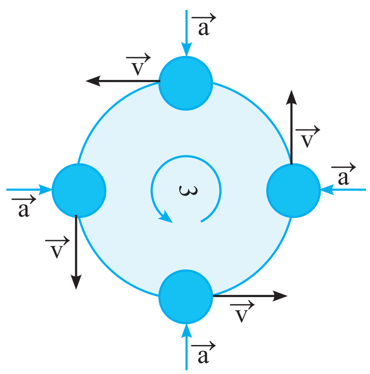
Types of Friction

1. **Static Friction:**
   - The force that must be overcome to start moving an object at rest.
2. **Kinetic (Sliding) Friction**
   - The force that opposes the motion of two surfaces sliding against each other.
3. **Rolling Friction**
   - The resistance encountered when an object rolls over a surface. Here the surface area of contact is reduced and thus movement becomes easy.



   - **Example: Ball bearing.** The balls roll between the inner and outer ring. Contact surface is limited to a single point at both surfaces thus greatly reducing the friction and making the motion smooth.**[UPSC 2013]**

Circular Motion and Centrifugal Force



Circular motion is the movement of an object along a circular path. It can be **uniform** (constant speed) or **non-uniform** (changing speed). A circular motion is always accelerated as direction of speed changes at every instant.

Imagine rotating a stone tied to a string in a horizontal circle. You will have to apply a force on the string towards the centre of the circle at every instant so that it remains in the circle.

v shows direction of velocity, **a** shows centripetal acceleration and also the direction of force applied by string on the stone.

ω is angular velocity and is given by angle covered per unit time in the circular motion.

1. **Centripetal Acceleration:**
   - Acceleration directed toward the centre of the circle, calculated as: v = velocity, r = radius

$$a_c = \frac{v^2}{r}$$

2. **Centripetal Force = mass × Centripetal acceleration**
   - The net force required to keep an object in circular motion:

$$F_c = \frac{mv^2}{r}$$

Centrifugal Force

Definition: Centrifugal force is an apparent outward force felt by an object moving in a circle, caused by inertia.It is directed away from the centre of the circle

Applications [UPSC 2003]

1. **Skimming of Milk:** In milk processing, when a container is spun, cream (less dense) moves outward due to centrifugal force, allowing separation from the milk.
2. **Vehicles on Curved Roads:** Centripetal force keeps cars on the road; insufficient friction can lead to skidding.
3. **Satellites:** Remain in orbit due to centripetal force from gravity.
4. **Shape of Earth:** Oblate spheroid shape is due to greater centrifugal force near the equator.
5. **Centrifuges:** Separate substances by spinning them rapidly, utilising centrifugal force.
6. **Tides:** Combined effect of gravitational pull of Sun, Moon and centrifugal force due to rotation of earth on its axis. **[UPSC 2015]**

PRESSURE

Definition: Pressure is the force exerted per unit area:

$$P = F/A$$

where P is pressure, F is force, and A is the area. It is measured in Pascals (Pa), Atmospheric pressure(atm) etc.

1 Pa = 1 Newton/metre square, 1 atm = 1.013 × 10^5 Pa.

Flow of Fluids

- **Pressure Difference:** Fluids flow from areas of higher pressure to areas of lower pressure. This principle governs many systems, such as water supply in pipes and blood circulation in the body.

Pressure and Altitude

- **Pressure Variation:** Atmospheric pressure decreases with altitude because the density of air decreases as altitude increases. This phenomenon explains why higher altitudes have lower oxygen availability, impacting human physiology and performance.
- **Cooking of Rice at Higher Altitude**
  - **Cooking Challenges:** At higher altitudes, the atmospheric pressure is lower, resulting in a lower boiling point for water (below 100°C). This means rice and other foods **take longer to cook,** as water does not reach as high a temperature.

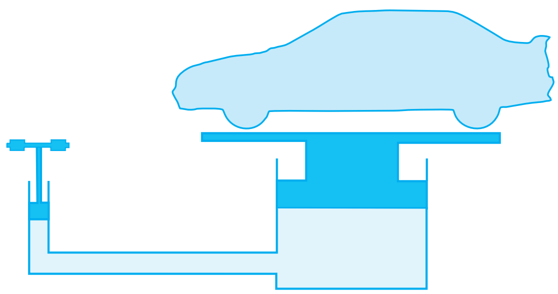
Boiling Point of Water and Increased Pressure

- The boiling point of water **increases with an increase in pressure**. At higher pressures, water molecules require more energy (higher temperature) to escape into the vapour phase, meaning **water boils at a temperature higher than 100°C.**

Cooking of Rice in Pressure Cookers [UPSC 2021]

- **Pressure Cookers:** Pressure cookers **raise the boiling point of water** due to increased pressure inside the cooker. This allows rice and other foods to cook faster, as the **temperature inside the cooker can exceed 100°C.**

Application of Pressure in Hydraulic Lifts



- **Hydraulic Lifts:** These devices use the principles of fluid pressure to lift heavy objects. By applying a small force on a piston, a large force is generated through a fluid, allowing for lifting capabilities in hydraulic systems, such as car lifts and elevators.

Practical Applications of Pressure

- **Straw Use:** When you suck on a straw, you create a **low-pressure area inside the straw.** The higher atmospheric pressure outside pushes the liquid up into the straw, allowing you to drink. **[UPSC 2012]**

Land and Sea Breezes

- **Breezes Formation:**
  - **Land Breeze:** At night, land cools faster than water, creating higher pressure over land and lower pressure over the sea. The wind blows from the land to the sea.
  - **Sea Breeze:** During the day, the land heats up faster than the sea, causing lower pressure over land and higher pressure over the sea. The wind blows from the sea to the land.

Cloud Formation and Rainfall

- **Cloud Formation:** Clouds form in areas of low pressure when warm, moist air rises and cools, reducing its capacity to hold moisture. As the air cools, water vapour condenses into tiny droplets, forming clouds.
- **Rainfall:** When cloud droplets coalesce and grow heavy enough, they fall as precipitation (rain). This process is influenced by atmospheric pressure variations.

Desert Formation

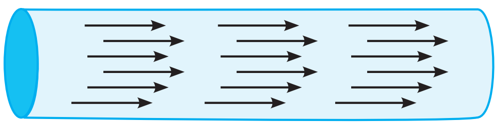
- **Desert Conditions:** Deserts often form in areas of high pressure, where dry air descends, inhibiting cloud formation and precipitation. This leads to arid conditions and limited rainfall.

FLUID DYNAMICS

Laminar Flow:

- In laminar flow, the fluid moves in parallel layers without mixing. Velocity at any point in the fluid remains constant over time, and the flow lines are smooth and orderly. This type of flow occurs when the Reynolds number (a dimensionless number that indicates flow type) is low.
- **Example: Blood flowing through narrow capillaries** follows laminar flow, where each layer of blood moves smoothly past the others.

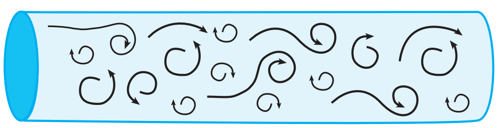
Laminar Flow



Turbulent Flow:

- Turbulent flow is chaotic, with irregular velocity at different points in the fluid. Eddies and vortices form, and the flow becomes highly mixed. Turbulent flow occurs when the Reynolds number is high, indicating that inertial forces dominate over viscous forces.
- **Example:** Water rushing through a large pipe or river exhibits turbulence, with swirling currents and unpredictable flow paths.

Turbulent Flow



Diffusion

- Diffusion is the random movement of particles (like atoms or molecules) due to thermal energy. Over time, particles spread out from regions of high concentration to low concentration until equilibrium is reached. It is governed by **Fick's Law,** which states that the rate of diffusion is proportional to the concentration gradient.

- **Example:** The **diffusion of oxygen into red blood cells** across the alveolar membrane in the lungs, where the concentration of oxygen is higher in the alveoli than in the blood.

Osmosis

- Osmosis is a special case of diffusion involving the movement of water across a semipermeable membrane. Water moves from a region of low solute concentration to one of high solute concentration to balance the concentration on both sides of the membrane. It is driven by osmotic pressure.
- **Example:** Plant roots absorb water from the soil through osmosis, as the concentration of water is higher in the soil than in the root cells.

Dialysis

- Dialysis involves the selective movement of solute particles through a semipermeable membrane based on size or concentration. It uses diffusion to remove unwanted particles (such as toxins or waste products) from a solution, allowing only small molecules to pass through the membrane.
- In **kidney dialysis**, a machine uses a semipermeable membrane to remove waste products from the blood of patients with kidney failure.

Surface Tension

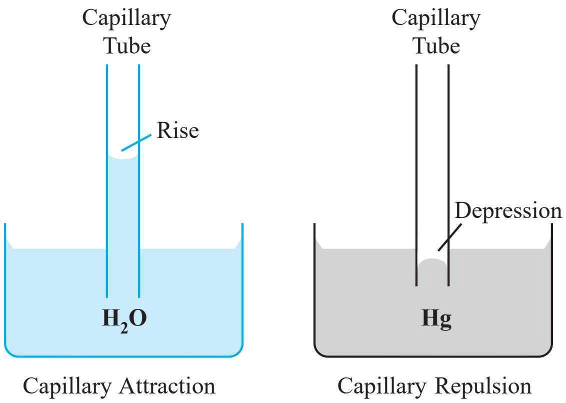
- Surface tension arises because molecules at the surface of a liquid experience a **net inward force due to cohesion** (attractive forces between similar molecules). This creates a "skin" on the liquid's surface, minimising its surface area.
- **Example:** Water droplets on a leaf **bead up** due to surface tension, and small insects like water striders can walk on water without sinking.

- Water droplets take a spherical shape because surface tension pulls the water molecules inward, reducing the surface area as much as possible. **A sphere has the smallest surface area for a given volume, so it's the most efficient shape.**

Capillarity (Capillary Action)

- **Physics Explanation:** Capillarity occurs when a liquid spontaneously rises or falls in a narrow tube due to adhesive forces between the liquid and the tube's walls and cohesive forces within the liquid itself. **[UPSC 2012]**

Capillary Action



- **Shape of Meniscus:** concave up, convex up or flat depends upon whether cohesive forces among molecules of liquid dominate over adhesive force between capillary tube and molecules of the liquid.
  - Cohesive > Adhesive = convex up, Mercury, liquid level falls as shown.
  - Adhesive > Cohesive = concave up, Water, liquid level rises in the capillary tube as shown.
- **Example:** Capillary action helps water travel up the xylem in plants, allowing water to reach the top leaves.

HEAT AND THERMODYNAMICS

Temperature and Heat

- **Temperature:**
  - **Definition:** Temperature measures the average kinetic energy of particles in a substance, determining how hot or cold something is.
  - **Units:** Measured in Celsius (°C), Fahrenheit (°F), or Kelvin (K). Kelvin is the SI unit, directly related to absolute temperature.
- **Heat vs. Temperature:**
  - **Heat:** The energy transferred due to temperature difference, measured in joules (J).
  - **Temperature:** A measure of the average motion of particles in a substance.
  - **Difference:** Heat depends on mass and temperature difference, whereas temperature is an intensive property (does not depend on the amount of substance).

Heat Transfer and Conductivity

- **Good and Bad Conductors of Heat:**
  - **Good Conductors:** Materials like metals that quickly transfer heat, due to free electrons.
  - **Bad Conductors (insulators):** Materials like wood or rubber, which restrict heat flow, making them useful for insulation.

- **Modes of Heat Transfer:**
  - **Conduction:** Transfer of heat through direct contact (e.g., metal rod in a flame).
  - **Convection:** Heat transfer through fluid motion (e.g., boiling water).
  - **Radiation:** Heat transfer without a medium, through electromagnetic waves (e.g., heat from the sun).

Specific Heat Capacity and Its Applications

- **Specific Heat Capacity:**
  - **Definition:** The amount of heat needed to raise the temperature of 1 kg of a substance by 1°C.
  - **High Specific Heat of Water:** Water requires more energy to change its temperature, which stabilises Earth's climate.
- **Applications:**
  - **Oceans and Climate:** Oceans store large amounts of heat due to water's high specific heat. During winters, oceans release this heat slowly, keeping coastal regions warmer.
- **Relation Between Surface Area and Rate of Cooling:**
  - **Newton's Law of Cooling:** The rate of heat loss is proportional to surface area and the temperature difference between the object and its surroundings. Larger surface areas result in faster cooling. Larger temperature difference between object and surrounding leads to larger rate of cooling.
  - **Example:** A 60 degree celsius iron rod cools faster in a room at 5 degree celsius than in a room at 15 degree celsius.

Water: Phases and Special Properties

- **Phases of Water:**
  - Water exists in three phases: Solid (ice), liquid, and gas (vapour). Phase changes involve latent heat, energy absorbed or released without changing temperature.
- **Latent Heat:**
  - **Definition:** Energy required for a substance to change its phase (e.g., from ice to water) without temperature change.
  - **Significance:** Latent heat explains why ice absorbs large amounts of energy when melting, stabilising temperatures.
- **Water's Maximum Density and Frozen Lakes:**
  - **Density Anomaly:** Water is **densest at 4°C**. This causes lakes to freeze on the surface first while the denser, warmer water stays below, allowing aquatic life to survive.

Black Body Radiation

Black Body: It is a perfect absorber and emitter of all wavelengths of radiation. A black body emits radiation based on its temperature. This principle is fundamental to understanding the heat emission of stars and planets.

Greenhouse Effect

- **Mechanism:**

  Definition: The greenhouse effect is the trapping of the sun's heat by Earth's atmosphere, through gases like CO_2, water vapour, and methane.

  Importance: It keeps Earth warm enough for life by preventing excessive heat from escaping into space.
- **Cloudy Nights and Greenhouse Effect: Warmer Nights:** Clouds act as a thermal blanket, trapping heat during the night, which prevents rapid cooling. This is an extension of the greenhouse effect.

Cryogenics and its Application

Cryogenics is the study of materials at very low temperatures such as below -150°C, revealing unique properties like superconductivity.

Key Applications **[UPSC 1999, 2008, 2002]**

- **Cryogenic Refrigeration:** Used for freezing biological samples (e.g., liquid nitrogen).
- **Superconducting Materials:** Critical in MRI machines and particle accelerators (e.g., Large Hadron Collider).
- **Space Exploration:** Utilizes cryogenic fuels (liquid hydrogen/oxygen) for rocket propulsion.
- **Medical Applications:** Cryosurgery employs liquid nitrogen to remove tumors.
- **Cryopreservation:** Cells and tissues stored at ultra-low temperatures for fertility treatments.
- **Scientific Research:** Studying materials in condensed matter physics and quantum mechanics.
- **Industrial Applications:** Natural gas liquefaction for efficient transport.

OPTICS AND SOUND

Optics

Light: Light is radiant energy that travels in waves. Scientists have long debated its nature, and now understand that it behaves both like waves and particles. In a vacuum, light moves at a constant speed of about 299,792 kilometers (186,281 miles) per second, with measurable wavelengths.

Reflection

- **Definition:** The bouncing back of light when it hits a smooth surface, governed by the laws of reflection.
- **Laws of Reflection:**
  - The angle of incidence equals the angle of reflection.
  - The incident ray, reflected ray, and normal to the surface lie in the same plane.

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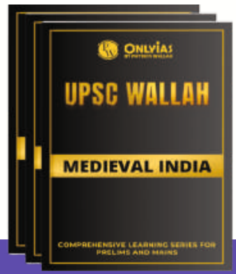

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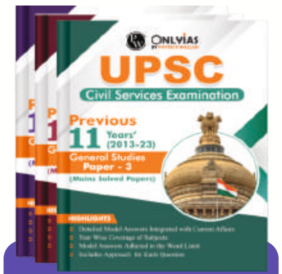

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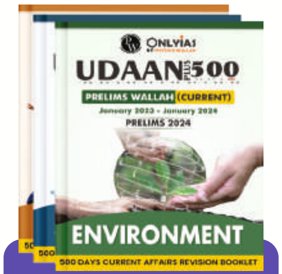

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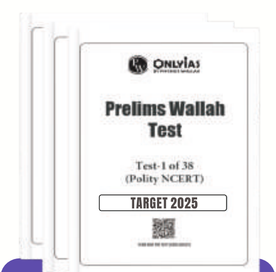

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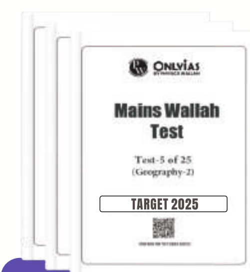

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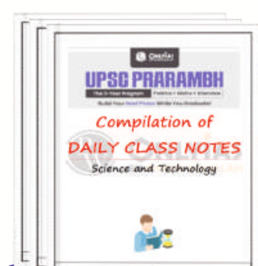

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