CHAPTER - 1: FORCE & PRESSURE

1) Definitions and Facts Of Force:

- Force acts as an external agent which has the power to move a body from the position of rest or motion or tends to move an object or a body from its state of rest or position. (Extra definition)
- Force is a **Vector Quantity**. (Vector quantities are physical quantities which have both direction and magnitude, they can be simplified through **Vector Algebra**)
- The **SI unit of Force** is **Newton**, which is represented as **N** or **Kgm/s^2**.
- This name is derived as the scientist (physicist) who researched in the field of force and provided details about it was **Isaac Newton**, and hence the **SI unit of force** was named after him for his revolutionizing research in the field of physics, especially force.
- He devised the **Laws of Motion** and Force.
- For Example: **i)** A push or a pull.
  ii) Trying to move a wall.
  iii) Pulling a rope in a game of tug-of-war.

2) Mathematical Representation Of Force:

- The mathematical representation of motion helps us to define and understand how the forces of motion could be calculated and their working, they are represented as:

$$F = ma$$

Where;
F = Force
m = Mass of a body
a = Acceleration of the body

- By this mathematical representation we understand that to calculate the force that is applied to any object, we need to multiply the mass of the object with the acceleration of the object in which it changed its position of rest or motion.

- Now to find the force of a car whose mass is 1500 kg and it is accelerating at a speed of 5 meter per second square ($5m/s^2$):
  Given:
  m = 1500 kg
  a = 5 m/s
  We know that,
  F = ma,
  F = 1500 kg x 5 m/s^2
  F = 1500 x 5
  F = 7500 N
- Hence, the force exerted by that car of 1500 kg and acceleration of 5 m/s^2 will be **7500 N**.

3) Characteristics of Force:

- Force can change the **state of rest or motion of a body** or an object. **For Example** - Pushing a car when it is punctured etc.
- Force can change the **position of a body** or an object. **For Example -** Picking up a glass of water and placing it at any other position etc.
- Force can **accelerate or decelerate an object** or a body. **For Example -** Pedaling a bicycle etc.
- Force can change the **shape of an object** or a body. **For Example -** Change in the shape of dough while preparing food etc.
- Force can change the **dimensions of an object** or a body. **For Example -** Volume, Length, Breadth/Width etc.
- Force can change the **direction of motion** of an object or a body. **For Example -** Pushing an object towards any other direction while it is moving in a straight line etc.
- Force can change the **state of matter**. **For Example -** While rubbing an ice cube, it turns into water etc.

4) Types of Forces:

- There are several types of forces, which are as follows:
  i) *Contact Force*
  ii) *Unbalanced Force*

iii) *Balanced Force*
iv) *Unbalanced Force*

- ***Contact Force:-*** Forces that **physically impact** an object or a body is known as a **contact force**. **For Example** - Muscular Force, Frictional Force etc.
  i) Muscular Force - A force **exerted by a living organism on any object** or a body is known as a **Muscular Force**. **For Example -** Push or pull, walking, running, jumping, etc.

  ii) Frictional Force - The force responsible for changing the state of motion of an object or a body. Friction **opposes motion** as it is a **reaction force** (that would be elaborated in higher classes). This type of force is known as a **Frictional Force**. **For Example** - Brakes applied in a car etc.

- ***Non-Contact Force:-*** Forces that **do not physically impact** an object or a body is known as a **non-contact force**. **For Example** - Gravitational Force, Electrostatic Force, Magnetic Force etc.

  i) Gravitational Force - All the objects present in our world come under the influence of gravity. **Gravity** is a force that **pulls down all the objects** in the simplest words, it **does not come into contact** with the object or body upon which it is acting, and hence, it is a **non-contact force**.

  ii) Electrostatic Force - The force **exerted by a charged body** on another charged or uncharged body is called **Electrostatic Force**. For Example **-** When you rub a scale on your hair, it generates an **electrostatic force** which attracts other uncharged or charged material like small bits of paper, etc.

  iii) Magnetic Force - The **magnetic force** is the **force of attraction** or repulsion that arises between **electrically charged particles** due to their motion. Also the force applied by a magnet towards another magnet can be referred to as **Magnetic force**. **For Example -** *When a magnet attracts an iron nail, it applies magnetic force* etc.

  Net Force:

- The vector sum of all forces acting on an object. It determines the object's acceleration according to Newton's Second Law.
- **Balanced and Unbalanced Forces**:

i) Balanced Forces: Forces that are equal in magnitude but opposite in direction, resulting in no change in motion.

ii) Unbalanced Forces: Forces that cause a change in the object's motion or state of rest.

1. **Centripetal Force**: The force required to keep an object moving in a circular path. It is directed towards the center of the circle.
   F centripetal = m v^2 / r
   where:

m = mass of the object

v = velocity

r = radius of the circular path

- **Friction Force**: The force that resists relative motion between two surfaces in contact. It can be calculated using the coefficient of friction and normal force.

5) Principles and Laws Related to Force:

1. Newton's Laws of Motion:
   - First Law (Law of Inertia): An object will remain at rest or in uniform motion unless acted upon by an external force.
   - 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.
     F=maF = m aF=ma
   - Third Law (Action and Reaction): For every action, there is an equal and opposite reaction.
2. Hooke's Law:
   - Describes the behavior of springs and elastic materials. The force required to stretch or compress a spring is proportional to the displacement from its equilibrium position.
     F=kx

3. Law of Universal Gravitation:
    - Every particle of matter 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.
4. Work-Energy Theorem:
    - The work done by the net force on an object is equal to the change in its kinetic energy.
      W = ΔKW \ Delta KW=ΔK

6) Application Based Learning Of Force:

- Imagine you are in a park playing volleyball and, at that current moment, gravity is impacting you but you are not falling because there is a reaction force acting on behalf of your support. When you hit the volleyball, a muscular force is being applied on the volleyball. Then, on the other end, the other person throws a volleyball at you and you run to hit the volleyball. At the time you are running, frictional force is being applied when you are running.
- **Engineering and Construction**:
    - Force analysis is crucial for designing structures like bridges, buildings, and dams to ensure they can withstand various loads and stresses.
- **Mechanical Systems**:
    - Understanding force is essential for designing machines, engines, and other mechanical systems that rely on force interactions.
- **Sports and Biomechanics**:
    - Analyzing forces helps in improving performance and reducing injuries by understanding the forces involved in human movement and equipment.
- **Transportation**:
    - Force considerations are vital in vehicle design, including automobiles, airplanes, and trains, to ensure safety, efficiency, and performance.
- **Aerospace**:

    - Forces are crucial in the design of rockets, spacecraft, and satellites, particularly in terms of thrust, drag, and gravity.
- **Medicine**:
    - Understanding force helps in designing prosthetics, orthotics, and other medical devices to improve patient mobility and comfort.

7) Definitions and Facts Of Pressure:

- **Pressure** is the measure of the f**orce applied per unit area**, in the simplest words.
- The **SI unit of pressure is Pascal(Pa)/Nm^2.**
- It is also represented in units such as Atmosphere(atm), Bar and Torr, where 1 atm = 101325 Pa, 1 Bar = 100000 Pa and 1 Torr = 1 / 760 atm
- This name was again kept after a great **French mathematician, scientist and physicist Blaise Pascal**, who did a great amount of research and work in the field of physics, especially **Pressure**.
- Atmosphere (atm): 1 atm = 101,325 Pa
- Bar: 1 bar = 100,000 Pa
- Millimeters of mercury (mmHg): 1 mmHg ≈ 133.322 Pa
- Pounds per square inch (psi): 1 psi ≈ 6894.76 Pa
- Pressure is a Vector Quantity.
- It can be added, subtracted, multiplied or divided using **Vector Algebra**.
- For Example: Imagine being submerged to some depth in water. The water above you would be pushing down on you because of the force of gravity and would therefore be exerting pressure on you. If you go deeper, there will be more water above you, so the weight and pressure from the water would increase too.

8) Mathematical Representation Of Pressure:

- Pressure(P) can be mathematically represented as Force(F) divided by the surface area(A):
- **$P = F/A$**

- Here, **Pressure of an object or a body can be found when the Force of that particular object or body is divided by the surface area of that particular object or body**.

- **Example 1**: Calculate the pressure developed by a force of 50 N acting on an area of 10m square
- Solution: Given: area = 10 m^2 and force: 50N
  P = Force/surface area
  =50 N/10m^2
  =5 Pa

9) Types Of Pressure:

- **Absolute Pressure:** The total pressure exerted on a system, including atmospheric pressure, is referred to as Absolute Pressure.Measured relative to a perfect vacuum. For Example: If your tire gauge reads 34 psi (pounds per square inch), then the absolute pressure is 34 psi plus 14.7 psi (Patm in psi), or 48.7 psi (equivalent to 336 kPa). Absolute pressure is the sum of gauge pressure and atmospheric pressure.
- **Gauge Pressure:** Pressure relative to atmospheric pressure, is referred to as Gauge Pressure. It is often used in everyday applications, such as tire pressure. For Example: Tire pressure is measured relative to atmospheric pressure. When a car drives up a mountain the gauge pressure goes up as the atmospheric pressure decreases, but the absolute pressure of the tire remains unchanged assuming the tire does not leak at all.
- **Differential Pressure:** The difference in pressure between two points in a fluid or gas, is referred to as Differential Pressure. Differential pressure is calculated by subtracting one of these values from the other. For Example: If Pipe A flows at 100 psi and Pipe B flows at 30 psi, the differential pressure would be 70 psi.

10) Principles Related to Pressure

i) Pascal's Principle

- It was proposed by **Blaise Pascal** in **1647**.
- Pascal's principle states that a change in pressure applied to an enclosed fluid is transmitted undiminished to all portions of the fluid and to the walls of its container. This principle is the basis for hydraulic systems, like brakes and lifts.

ii) Boyle’s Law

- It was proposed by **Robert Boyle** in **1662**.
- Boyle's Law states that the pressure of a gas is inversely proportional to its volume when temperature is held constant:
- $P1V1=P2V2$
- Where:
- $P1$ and $P2$ are the initial and final pressures,
- $V1$ and $V2$ are the initial and final volumes.

iii) Charles's Law

- It was proposed by **Jacques Charles** in **1787**.
- Charles's Law states that the volume of a gas is directly proportional to its absolute temperature when pressure is constant:
- $V1/T1=V2/T2$
- Where:
- $T1$ and $T2$ are the initial and final temperatures in Kelvin.

iv) Ideal Gas Law

- It was proposed by **Émile Clapeyron** in the year **1834**.
- The **Ideal Gas Law** is a combination of the earlier gas laws and was developed by combining the work of several scientists. It integrates **Boyle’s Law, Charles’s Law, and Gay-Lussac's Law into a single equatio**n.
- The Ideal Gas Law combines Boyle’s, Charles’s, and Gay-Lussac's laws into a single equation:
- $PV=nRT$
- Where:

- P is pressure,
- V is volume,
- n is the number of moles of gas,
- R is the ideal gas constant (8.314 J/(mol/k))
- T is temperature in Kelvin.

11) Applications of Pressure

1. Applications of Pressure in Solids

Structural Engineering

- **Stress Analysis**: In structural engineering, pressure (or stress) analysis is crucial for designing buildings, bridges, and other structures. Engineers calculate the stress on materials to ensure they can withstand forces such as wind, weight, and seismic activity without failing.
- **Material Testing**: Pressure tests, such as compressive strength tests, determine how materials like concrete and steel will behave under load. This helps in selecting appropriate materials and ensuring safety and durability.

Manufacturing and Material Processing

- **Metal Forming**: Processes like forging, stamping, and extrusion involve applying pressure to metals to shape them. For example, in forging, a metal is heated and then pressed between dies to achieve the desired shape and properties.
- **Powder Metallurgy**: Pressure is used to compact metal powders into shapes before sintering (heating to form a solid mass). This method is used to create complex shapes and control material properties.

Geotechnical Engineering

- **Soil Pressure**: Engineers use pressure measurements to assess soil stability and behavior under loads, which is essential for foundations and excavation projects.
- **Tunneling and Mining**: Understanding the pressure of surrounding rock and soil helps in designing tunnels and mining operations to prevent collapses and ensure safety.

2. Applications of Pressure in Liquids

Hydraulics

- **Hydraulic Systems**: Pressure is used in hydraulic systems to transmit force and perform work. Examples include hydraulic brakes, lifts, and machinery. Hydraulic systems use pressurized fluids to multiply force and enable precise control.
- **Hydraulic Engineering**: Pressure calculations are vital for designing dams, pipelines, and water distribution systems. Engineers must consider pressure changes due to elevation, flow rate, and pipe friction.

Fluid Mechanics

- **Pressure Measurement**: Instruments like manometers and pressure gauges measure fluid pressure, which is essential for controlling and optimizing various processes.
- **Pumps and Turbines**: Pressure differences drive pumps and turbines, which are used in water supply systems, power generation, and various industrial processes.

Chemical Engineering

- **Reactor Design**: In chemical reactors, pressure affects reaction rates and equilibrium. Engineers control pressure to optimize reaction conditions and product yield.
- **Distillation**: Pressure is used to control boiling points in distillation processes, which separate mixtures based on differences in vapor pressure.

3. Applications of Pressure in Gases

Aerodynamics

- **Aircraft Design**: Pressure differences around an aircraft’s wings generate lift. Aerodynamicists study these pressure variations to design efficient and safe aircraft.
- **Wind Tunnels**: Engineers use wind tunnels to test the aerodynamic properties of vehicles and structures by analyzing how air pressure changes with different designs.

Gas Dynamics

- **Compressors**: Pressure is used in compressors to increase the pressure of gasses for various applications, including refrigeration and air conditioning.
- **Propulsion**: In rocket engines, gasses are expelled at high pressure to produce thrust, following Newton's third law of motion.

Medicine

- **Hyperbaric Oxygen Therapy**: This therapy uses high-pressure oxygen to treat conditions like decompression sickness and chronic wounds. The increased pressure allows more oxygen to dissolve in blood and accelerate healing.
- **Respiratory Devices**: Devices like CPAP machines use pressure to assist with breathing in patients with sleep apnea, ensuring that the airways remain open.

4. Applications Across Multiple Phases

Environmental Science

- **Weather Prediction**: Atmospheric pressure is a key factor in weather forecasting. Changes in pressure can indicate weather patterns like high-pressure systems (clear skies) or low-pressure systems (storms).
- **Oceanography**: Pressure is used to study the ocean's depth and the impact of pressure changes on marine life. Deep-sea exploration involves managing high pressures to protect equipment and researchers.

Physics and Research

- **High-Pressure Physics**: Scientists use high-pressure experiments to study materials under extreme conditions, revealing new phases and properties of substances.
- **Pressure in Space Exploration**: Spacecraft must withstand the vacuum of space and pressure changes during launch and re-entry. Engineers design spacecraft and spacesuits to manage these pressures and protect astronauts.