Government of Tamil Nadu

Department of Employment and Training

Course : TNPSC Combined Civil Services Examination - IV(Group IV / VAO)

Subject : Physics

Topic : Mechanics and Properties of Matter

Commissioner,

Department of Employment and Training.

MECHANICS AND PROPERTIES OF MATTER

Mechanics is one the most important subject in physics.

You will learn many concepts and key points under mechanics title those will also be used in other subjects of physics.

Mechanics can be defined as the behavior of the particle under any effects.

It can be studied under main two topics which are kinematics concerning the motion of the particle and dynamics concerning the causes of motion.

KINEMATICS

Kinematics deals with the motion of particles *not* the causes of the motion.

- Distance
- Displacement
- Speed
- Velocity
- Acceleration

Distance and Displacement

Distance is a scalar quantity representing the interval between two points. It is just the magnitude of the interval.

However, ***Displacement*** is a vector quantity and can be defined by using distance concept. It can be defined as distance between the initial point and final point of an object. It must be the shortest interval connecting the initial and final point that is a straight line.

SPEED

Speed can be defined as "how fast something moves" or it can be explained more scientifically as "the distance covered in a unit of time". It is a scalar quantity.

$$\textbf{Speed} = \frac{\textbf{Distance}}{\textbf{Time}}$$

VELOCITY

Velocity can be defined as "speed having direction". It is a vector quantity having both magnitude and direction.

Velocity may also be defined as the “rate of change of displacement” whereas “the speed is rate of change of distance”.

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

ACCELERATION

Acceleration can be defined as “change in velocity”.

This change can be in the magnitude (speed) of the velocity or the direction of the velocity.

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

DYNAMICS

It deals with the causes of motion.

FORCE

Force is a vector quantity having both magnitude and direction.

The change in position of the object due to the work done or the cause of motion is “force”. The unit of force is Newton or $kg.m/s^2$.

Dynamics Equilibrium

Equilibrium in physics means, forces are in balance. The net force should be zero. In other words, forces acting downward and acting upward, and forces acting right and acting left should be equal in magnitude.

Relative Motion

Velocity of the moving objects with respect to other moving or stationary object is called “**relative velocity**” and this motion is called “**relative motion**”.

Projectile Motion

The motion in two dimensions or motion under the effect of gravitational force is called projectile motion.

MATTER AND ITS PROPERTIES

Matter

Everything around us has mass and volume and they occupy space, and we called them as **matter**. It can be in four sate, like solid, liquid, gas and plasma.

The main properties of matter that are discussed in this unit are mass, volume, density, elasticity, inertia, etc.,

Mass

Mass is the quantity of the matter in a substance.

Units of mass can be gram (g) or kilogram (kg)**.**

It is not the distinguishing property but common property of matters, because different matters can have same mass.

Volume

Volume is the space occupied by the matter. It is also common property of matter and does not help us in distinguishing them. Its unit used in SI system is m^3.

Density of Matter

Density is the quantity of mass in a unit of volume. It is the distinguishing property of matter. Each matter has its own density.

Representation of density is **d**; unit of it is **g/cm³**.

Formula of density;

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Inertia

Inertia is one of the properties of matter. It is the resistance of the matter to change its state of motion. An unbalanced force can only change the state of motion of the matter.

Elasticity

The property of a material to regain its original state when the deforming force is removed is called elasticity

Elastic limit

If an elastic material is stretched or compressed beyond a certain limit, it will not regain its original state and will remain deformed. The limit beyond which permanent deformation occurs is called the elastic limit.

Stress and Strain

The restoring force per unit area of a deformed body is known as stress.

$$\text{Stress} = \frac{\text{estoring Force}}{\textit{Area}} = \frac{\text{Nm}^{-2}}{\textit{Area}}$$

Its dimensional formula is $ML^{-1}T^{-2}$.

Strain produced in a body is defined as the ratio of change in dimension of a body to the original dimension.

$$\text{Strain} = \frac{\text{hange in Dimension}}{\textit{Original Dimension}}$$

Strain is the ratio of two similar quantities. Therefore it has no unit.

Hooke's law

Within the elastic limit, strain produced in a body is directly proportional to the stress that produces it. (i.e) stress α strain

$$\frac{\text{Stress}}{\textit{Strain}} = \text{Constant}$$

Pascal's law

Pascal's law states that if the effect of gravity can be neglected then the pressure in a fluid in equilibrium is the same everywhere.

Applications of Pascal's law

(i) Hydraulic lift

(ii) Hydraulic brake

Viscosity

Viscosity is the property of the fluid by virtue of which it opposes relative motion between its different layers. Both liquids and gases exhibit viscosity but liquids are much more viscous than gases.

Co-efficient of viscosity

The coefficient of viscosity of a liquid is numerically equal to the viscous force acting tangentially between two layers of liquid having unit area of contact and unit velocity gradient normal to the direction of flow of liquid.

The unit of η is Ns m^{-2}. Its dimensional formula is $ML^{-1}T^{-1}$.

Streamline flow

The flow of a liquid is said to be steady, streamline or laminar if every particle of the liquid follows exactly the path of its preceding particle and has the same velocity of its preceding particle at every point

Turbulent flow

When the velocity of a liquid exceeds the critical velocity, the path and velocities of the liquid become disorderly. At this stage, the flow loses all its orderliness and is called turbulent flow.

Stoke's law (for highly viscous liquids)

1. Coefficient of viscosity η of the liquid depends on
2. Radius a of the sphere and
3. Velocity v of the spherical body.

Dimensionally it can be proved that

$$F = k \eta a v$$

Experimentally Stoke found that

$$k = 6\pi$$

$$\therefore F = 6\pi \eta a v$$

This is Stoke's law.

Application of Stoke's law

Falling of rain drops: When the water drops are small in size, their terminal velocities are small. Therefore they remain suspended in air in the form of clouds. But as the drops combine and grow in size, their terminal velocities increase. Hence they start falling as rain.

SURFACE TENSION

Surface tension is a contractive tendency of the surface of a liquid that allows it to resist an external force.

It is revealed, for example, in the floating of some objects on the surface of water, even though they are denser than water, and in the ability of some insects (e.g. water striders) to run on the water surface.

Surface tension has the dimension of force per unit length, or of energy per unit area.

Intermolecular forces

The force between two molecules of a substance is called intermolecular force. The intermolecular forces are of two types. They are (i) cohesive force and (ii) adhesive force.

The strong intermolecular forces results in surface tension.

(i) Cohesive force

Cohesive force is the force of attraction between the molecules of the same substance. This cohesive force is very strong in solids, weak in liquids and extremely weak in gases.

(ii) Adhesive force

Adhesive force is the force of attraction between the molecules of two different substances.

For example due to the adhesive force, ink sticks to paper while writing. Fevicol, gum, etc., exhibit strong adhesive property.

Capillarity

The property of surface tension gives rise to an interesting phenomenon called capillarity. The rise of a liquid in a capillary tube is known as capillarity

Illustrations of capillarity:

(i) A blotting paper absorbs ink by capillary action. The pores in the blotting paper act as capillaries.

(ii) The oil in a lamp rises up the wick through the narrow spaces between the threads of the wick.

(iii) A sponge retains water due to capillary action.

(iv) Walls get damped in rainy season due to absorption of water by bricks.

Applications of Surface Tension

1. Surface tension is visible in other common phenomena, especially when surfactants are used to decrease it. Soap bubbles have very large surface areas with very little mass. Bubbles in pure water are unstable. The addition of surfactants, however, can have a stabilizing effect on the bubbles.

2. Emulsion

Emulsions are a type of solution in which surface tension plays a role. Tiny fragments of oil suspended in pure water will spontaneously assemble themselves into much larger masses. But the presence of a surfactant provides a decrease in surface tension, which permits stability of minute droplets of oil in the bulk of water (or vice versa).

3. Several effects of surface tension can be seen with ordinary water: Beading of rain water on a waxy surface, such as a leaf. Water adheres weakly to wax and strongly to itself, so water clusters into drops. Surface tension gives them their near- spherical shape, because a sphere has the smallest possible surface area to volume ratio.

4. Formation of drops occurs when a mass of liquid is stretched.

5. Flotation of objects denser than water occurs when the object is non-wettable and its weight is small enough to be borne by the forces arising from surface tension.

6. Separation of oil and water (in this case, water and liquid wax) is caused by a tension in the surface between dissimilar liquids. This type of surface tension is called "interface tension", but its physics are the same.

7. Tears of wine is the formation of drops and rivulets on the side of a glass containing an alcoholic beverage. Its cause is a complex interaction between the differing surface tensions of water and ethanol; it is induced by a combination of surface tension modification of water by ethanol together with ethanol evaporating faster than water.

Bernoulli's theorem

Streamline flow of a non-viscous and incompressible liquid, the sum of the pressure energy, kinetic energy and potential energy per unit mass is a constant.

$$\frac{P}{\rho} + \frac{v^2}{2} + gh = \text{constant}$$

This equation is known as Bernoulli's equation

Application of Bernoulli's theorem

(i) Lift of an aircraft wing

(ii) Blowing of roofs

(iii) Bunsen burner

(iv) Motion of two parallel boats

Liquids

Liquids flow from one place to another. They have a definite volume. They take the shape of the container. Liquids show very little change in volume even when large compressive forces are applied. So we assume that liquids are incompressible.

Pressure at any point inside a liquid is

$$P = hpg$$

This shows that pressure increases with depth.

Buoyant Force

When a body floats or immerses in a liquid, the pressure on the bottom surface is more than that the pressure on the top surface. Due to the difference in pressure, an upward force acts on the body. **This upward force is called upthrust or buoyant force.** The buoyant force is equal to the weight of the liquid displaced.

Archimedes Principle

When a body is immersed in fluid (liquid or gas) it experiences an apparent loss of weight which is equal to the weight of the fluid displaced.

Laws of floatation

1. The weight of the floating body is equal to the weight of the liquid displaced by it.
2. The center of gravity of the floating body and the center of gravity of the liquid displaced (center of buoyancy) are in the same vertical line. A ship made up of

iron floats in water. This is because the ship is hollow and contains air. The large space inside the ship enables it to displace a volume of water much greater than the actual volume of iron that was used in the construction. So the weight of water displaced is greater than the weight of the ship.

Hydrometers

The laws of floatation are made use of in the construction of hydrometers used for the determination of the relative densities of solids and liquids.

There are two types of hydrometers.

The constant immersion hydrometer, in which the weight of the hydrometer is adjusted to make it sink to the same fixed mark in all liquids.

The variable immersion hydrometer in which the weight of the hydrometer remains the same, but the depth to which it sinks in different liquids vary.

A common hydrometer used to test the purity of milk by noting its specific gravity is called a LACTOMETER.