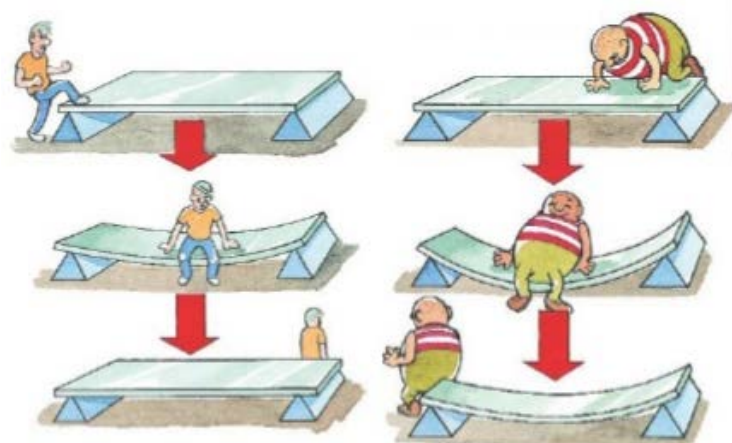
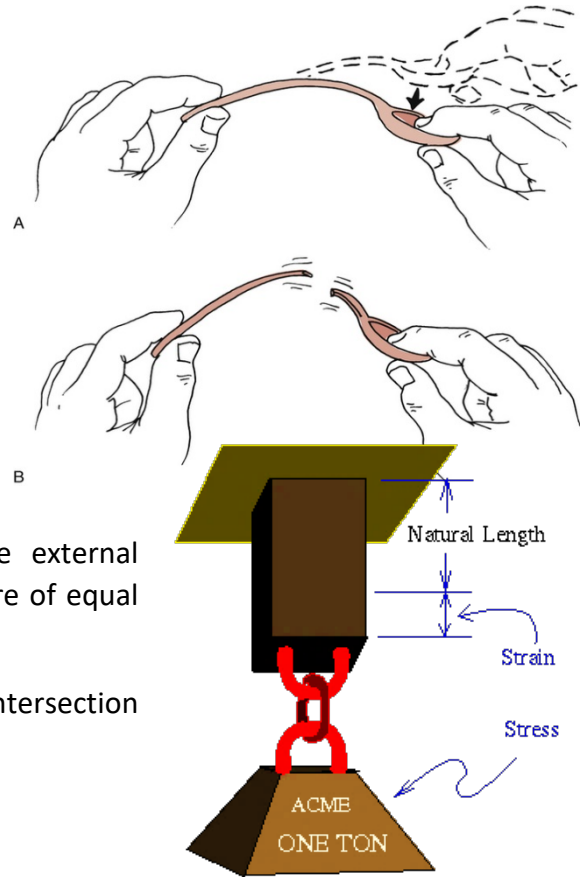


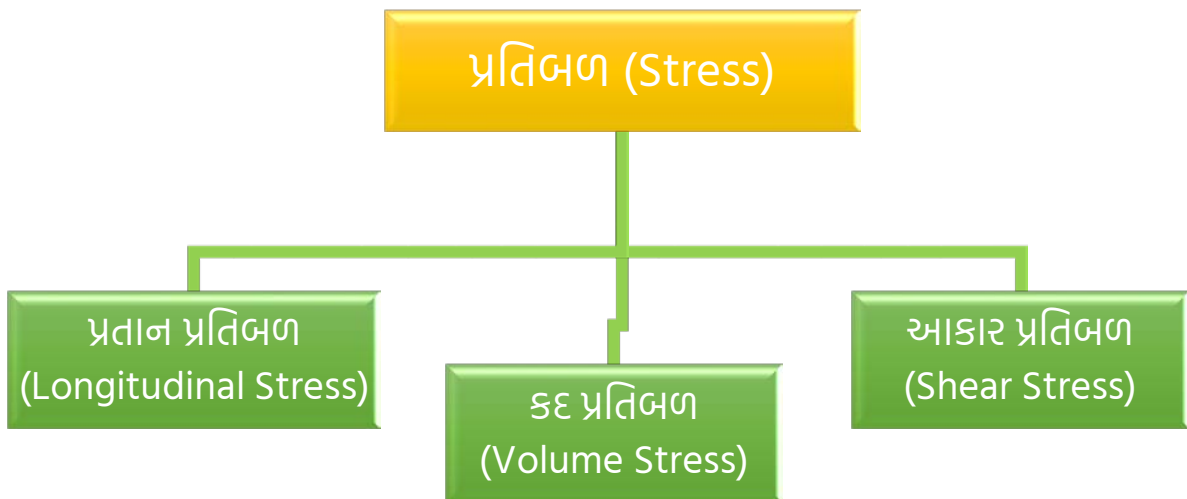
- Elasticity: According to Newton's law of motion, when an external force is applied to an object, a substance moves in a rapid motion. But in this section we will study the substances on which the objects do not move when an external force is applied.
- Exerting force on certain objects changes the length, shape, or shape of these substances, rather than moving them, such as rubber, for example, their length, shape, or size, as they are forced on certain substances.
- Exerting force on the object produces distortions in it. Whether or not a substance will attain its original state if this force is removed depends on that material substance. The property due to which an object resists the disruptive force exerted on it and tries to attain its original state is called elasticity. And a substance having such a property is called an elastic substance.



- Deforming Force: The force which can produce a deforming force in a substance in length, size or shape (increase or decrease) is called the deforming force.
- Plastic material: A substance which cannot partially achieve its original state after removing the destructive force is called a plastic material.
- Stress: The reinforcing force arising per unit area of the intersection of matter is called the force of resistance.
- When the material is in equilibrium, the external deflective force and the restorative force are of equal value.
- If the restoring force is F and the area of the intersection is A, the resistance,
- $\text{ପ୍ରତିଭଳ } \sigma = \frac{\text{ଭଳ}}{\text{କ୍ଷେତ୍ରଫଳ}} = \frac{F}{A}$
- The unit or pascal N/m^2 of resistance is.



Types of Stress :

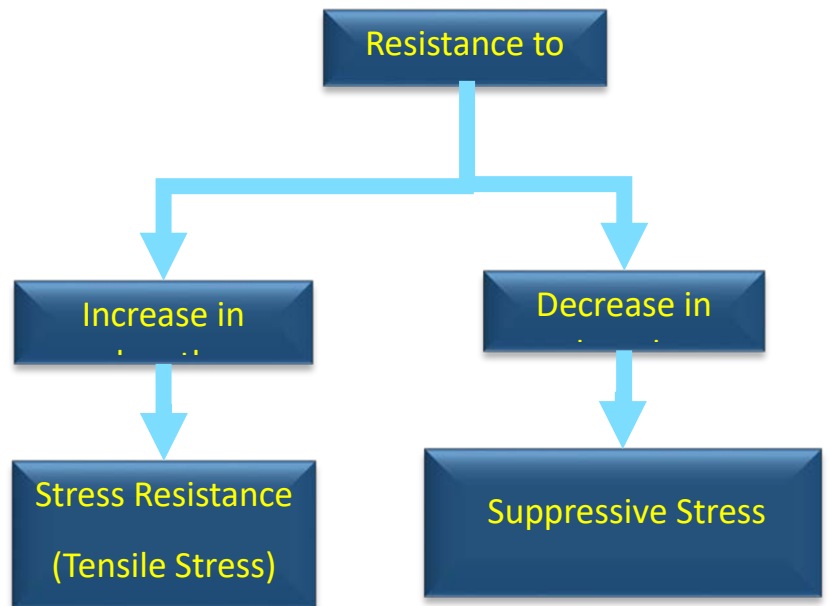


- **Types of resistance (Types of Longitudinal Stress): Resistance to temptation (Longitudinal Stress):** The force which increases or decreases the length of the substance is called the resistance to the substance.

પ્રદાન પ્રતિબળ $\sigma_l = \frac{F_{\perp}}{A}$

- If the resistance increases the length of the object, then such a force is called tensile stress.
- If the resistance decreases the length of the substance, it is called compressive stress.

Pratan is the unit or pascal of resistance N/m^2 .

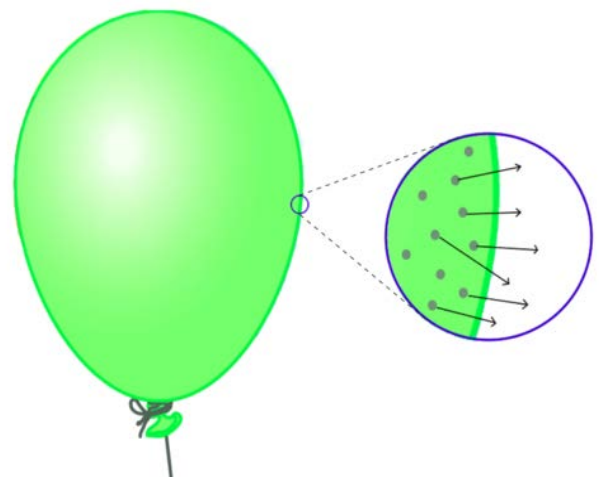
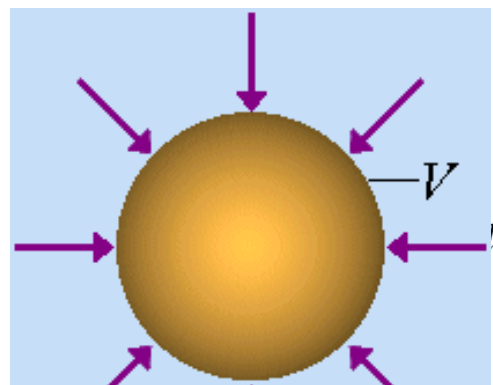


Size Resistance (Volume/Bulk Stress):

- Volume/Bulk Stress: The force that increases or decreases the size of an object is called size resistance.

કદ પ્રતિબળ $\sigma_v = \frac{F_{\perp}}{A}$

- Size is the unit or N/m^2 pascal of resistance.
- When the mermaids take a dip in the sea, they feel the force of the sea water from all sides. Here, the resistance exerted by water tries to shrink the size (body) of the body.
- The air inside exerts force on the inner surface of the air-filled balloon. In this case the resistance exerted by the air on the surface of the fuga increases the size of the fuga.



Factors	Resistance	pressure
definition	Resistance is the intensity of an internal resistance force arising from	Pressure refers to the intensity of an external force exerted at a point on an

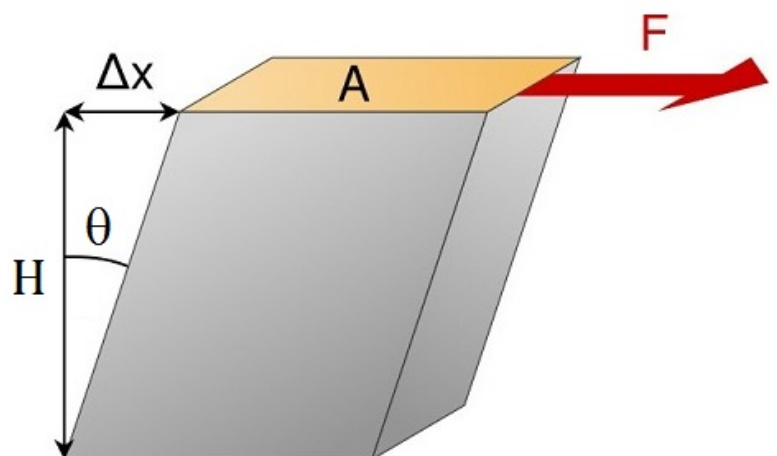
	an external force or pressure exerted on an object. It is the value of the internal force exerted per unit area. It originates inside a physical object.	object. It is the value of the external force exerted per unit area. It arises on the outer side of the object. .
Property	Resistance is a physical property.	Pressure is a unique property of thermodynamics or physics.
Symbol	The strength can be money or debt.	Pressure is always wealth.
Measurement	It cannot be measured with the help of any physical machine. For this, it can only be calculated with the help of distortion arising in the material.	It can be physically measured with the help of pressure gauges, monometers, or other physical pressure measuring machines.
kind	According to the weight force exerted on the substance, it is stressed, suppressed or shaped.	The surface of the physical object where the pressure is exerted tries to suppress the surface so the pressure is always of a suppressed type.
Value	At one point the value of the resistance felt in different directions can be different.	The pressure exerted at any one point is of equal value in all directions.
Depending on area	The value of the resistance varies with the type of surface area.	The pressure is independent of the contact-surface area. It does not depend on the type of surface.
Origin	The resistance arises internally.	The pressure arises externally.
Directional Basis	The resistance is the positive variable and it depends on the direction of the force exerted.	Pressure does not depend on the direction in which it is a scalar variable. Its direction is always perpendicular to the surface.
Causer/Cause	Resistance is the result of pressure.	Pressure is the cause of the emergence of resistance.

Shape resistance (Shear Stress):

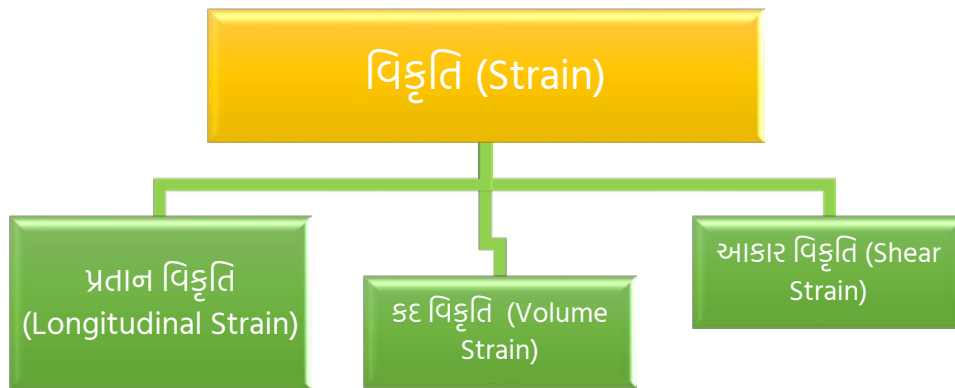
- Shear Stress: The force that changes the shape of an object is called shape resistance.

આકાર પ્રતિબળ $\sigma_s = \frac{F_{\perp}}{A}$

- Size is the unit or N/m^2 pascal of resistance.



Type of distortion (Types of Strain):



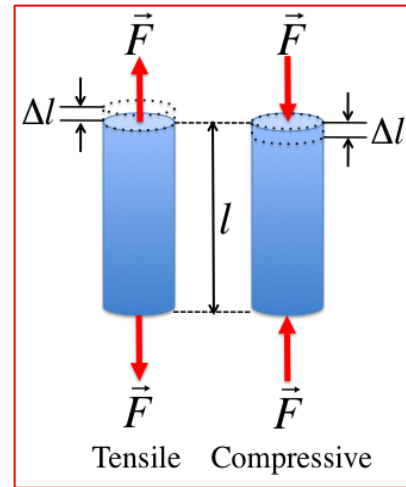
Longitudinal Strain:

- Longitudinal strain: The increase or decrease per unit length of an object due to the force of resistance is called the Pratan deformation.

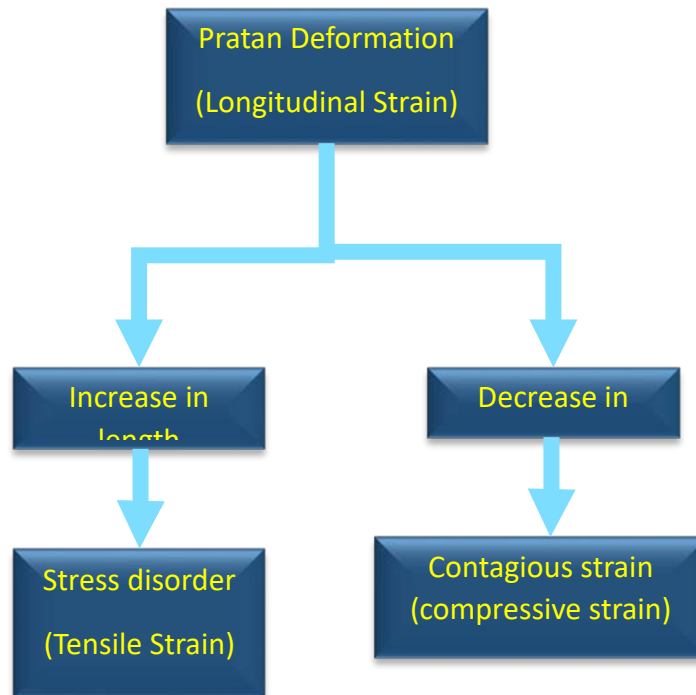
$$\text{પ્રદાન વિકૃતિ} = \epsilon_l = \frac{\Delta l}{l}$$

Where l is the original length and the change in that length. Δl

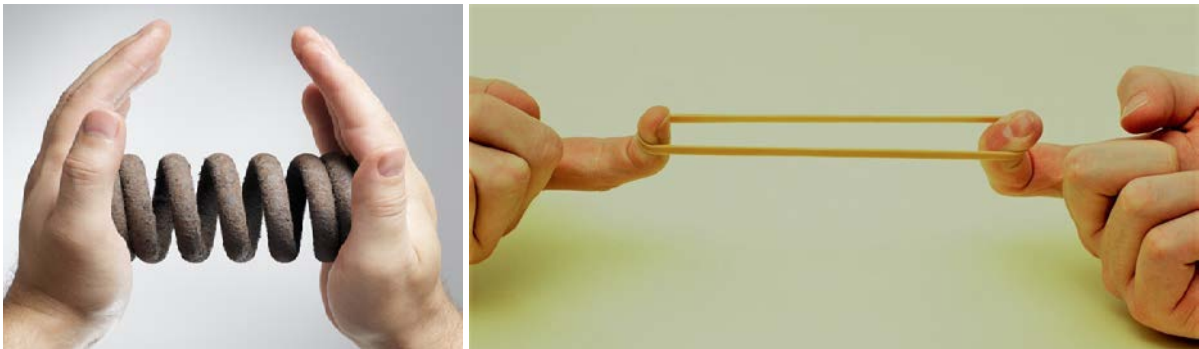
- If there is an increase in length due to an external force, then the particle distortion is called the tensile strain.
- If there is a decrease in length, it is called a compressive strain .
- Pratan is a physical rashi devoid of deformation units.



Types of deformation (Types of Longitudinal Strain):



Longitudinal strain: The increase or decrease per unit length of a substance due to the force of resistance is called the Pratan deformation.



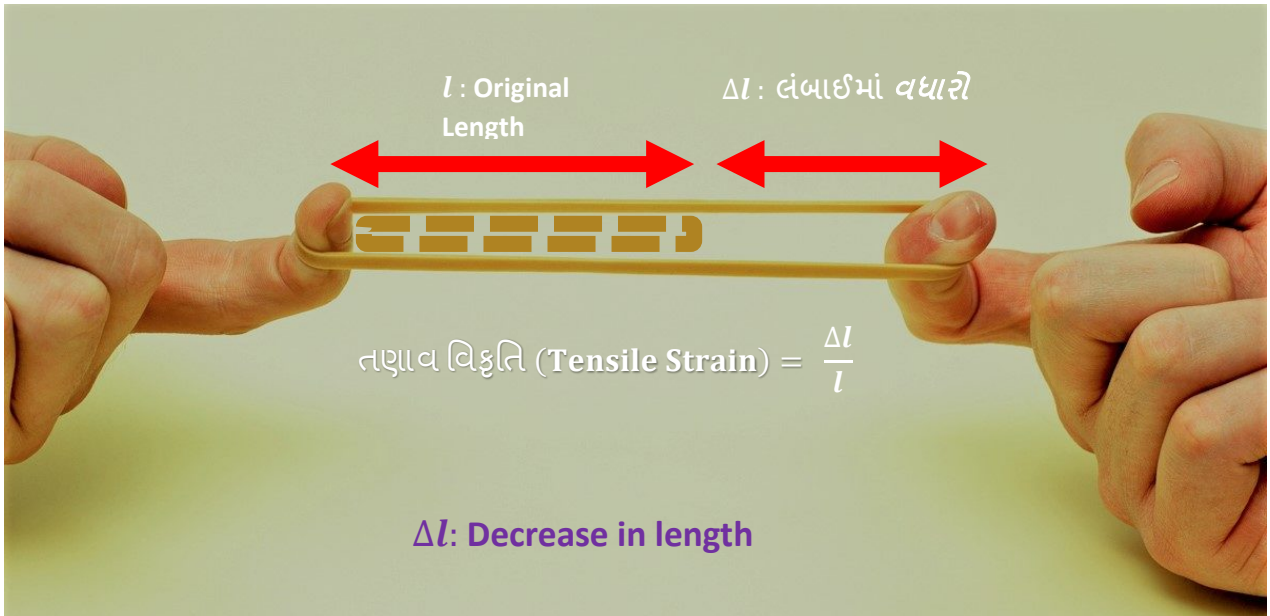
- प्रदान विकृति = $\epsilon_l = \frac{\Delta l}{l}$
- Where l is the original length and the change in that length. Δl
- Pratan is a physical rashi devoid of deformation units.

Tensile strain: Stress distortion is the distortion that occurs when the length of the object increases due to the resistance.

- तणाव विकृति = $\epsilon_l = \frac{\Delta l}{l}$

Compressive strain: The deformation that occurs when the length of the substance decreases due to the resistance is called the contagious deformation.

- दबाव विकृति = $\epsilon_l = \frac{\Delta l}{l}$



Size Distortion (Volume/Bulk Strain): Size Distortion (Volume Strain): The increase or decrease

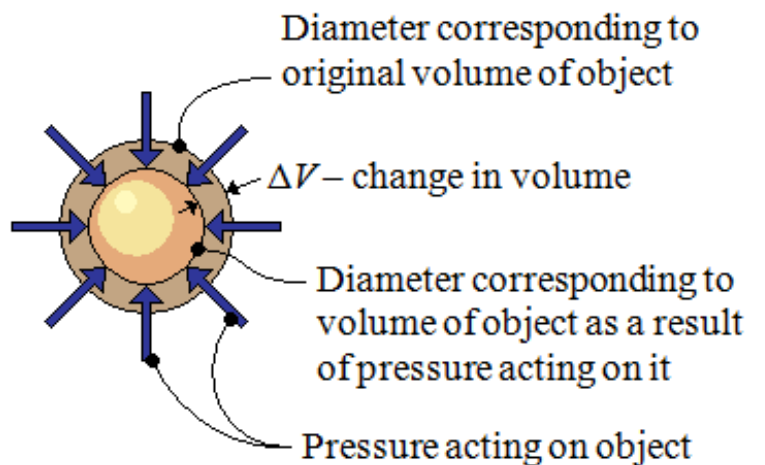


per unit size of an object due to the resistance is called size distortion.

$$\text{સદ વિકૃતિ} = \epsilon_v = -\frac{\Delta V}{V}$$

Where it is the change in the original size and that size. $V\Delta V$

- Here the debt sign indicates a decrease in size.
- Size deformation is a physical rashi devoid of unit.



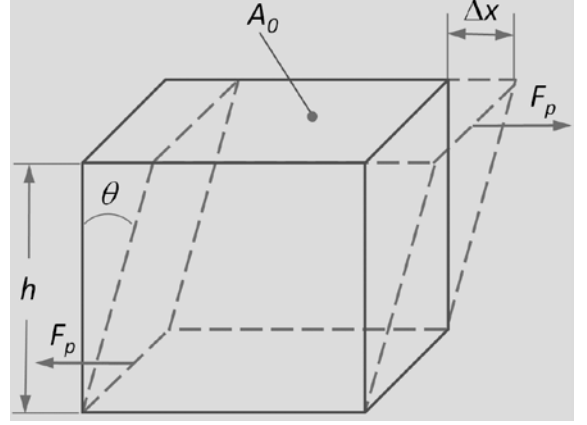
Shear strain: The change in the shape of a substance due to resistance is called shape distortion.

$$\text{આકાર વિકૃતિ} = \tan \theta = \frac{\Delta x}{h}$$

Where h is the original height and the change in it. $h\Delta x$

Hook's Law: Hooke's Law: Hook's Law:

Statement: For a small deformation, the force exerted on the object and the distortion produced in it are proportional to each other.



$$\sigma(\text{પ્રતિબળ}) \propto \varepsilon(\text{વિકૃતિ})$$

$$\sigma = k \varepsilon$$

Where k is the constant of symmetry.

$$\therefore k = \frac{\sigma}{\varepsilon}$$

- In other words, presenting,

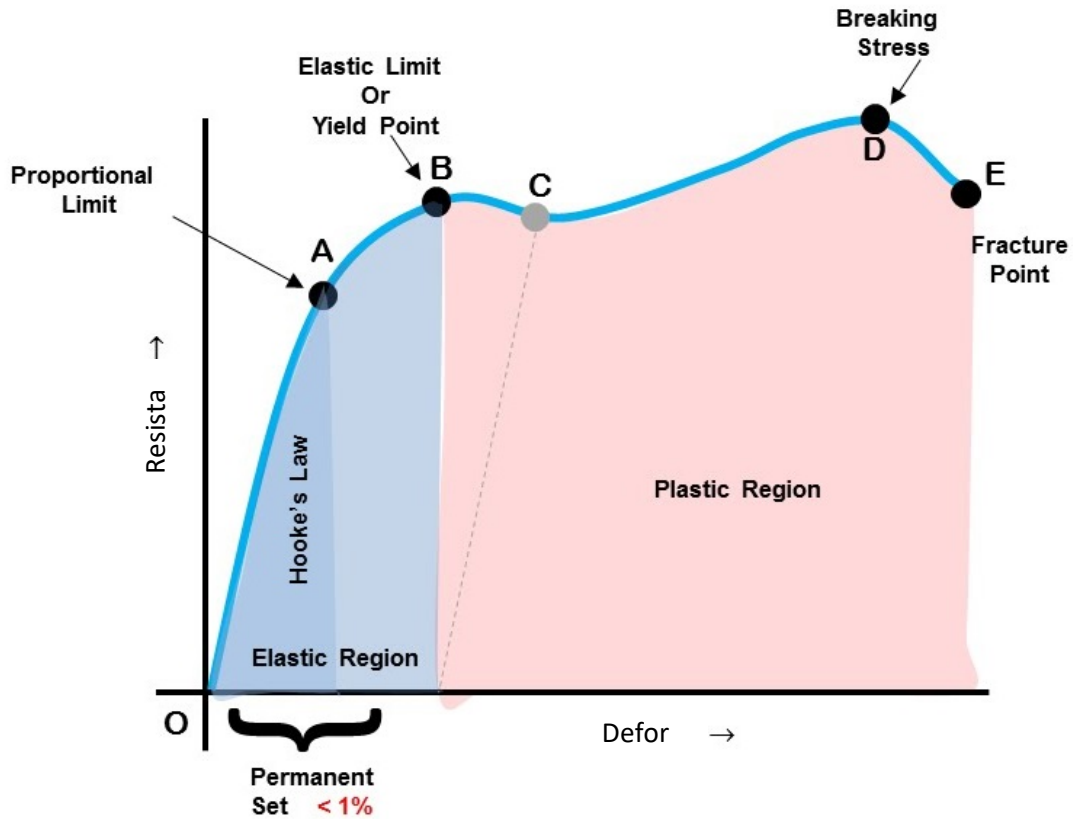
$$k = \frac{\sigma}{\varepsilon} = \frac{\text{પ્રતિબળ}}{\text{વિકૃતિ}} = \frac{\text{પદાર્થમાં વિરૂપણ ઉત્પન્ન કરવા માટે જરૂરી બળનું મૂલ્ય}}{\text{પદાર્થમાં ઉત્પન્ન થતી વિકૃતિનું મૂલ્ય}}$$

- Hooke's law for every object holds true only to a certain value of the force.

Elastic limit: Here is a graph of the resistance of the proton and the deformation of the pratan for copper or soft iron wire.

- This graph appears to be aligned up to point A, i.e., only up to the first 1%, which shows that matter follows Hooke's law only up to point A, i.e. if the resistance imposed on the object is removed, the deformation of the substance will be zero, i.e. the object will achieve its original length.
- Going from point A to B, the resistance and deformation are no longer symmetrical. However, matter is said to be elastic, because if the resistance exerted on the object is gradually removed, the material returns to point O in its original path. This is an elastic anomaly reversal.
- The elastic area ends in front of point b. Hence it is called yield point.

- Beyond this point, if the resistance is increased, there is a steady increase in deformation. If a point outside the limits of resilience C If the resistance to the object



is removed further, then the object does not achieve its original length, But it attains such a state in the way shown in the intermittent way so that there is a permanent increase in its length. Permanent installation of this state (Permanent set) Says.

- Beyond this point, the deformation of a substance increases much faster than the increase in its repulsion, which is called plastic behavior, at the end of which the object breaks down before point E, which is called the fracture point.

Young Modulus (Young Modulus):

According to Hooke's law, for small deformations,

$$\sigma = Y\epsilon$$

Here it is called the young modulus of resilience. Y

Suppose that when hanging as much as the weight at the end of a wire with radius and length, it seems to be torture $rl_0 mg$

$$\text{प्रतिबल } \sigma = \frac{\text{दबाव बल}}{\text{क्षेत्रफल}} = \frac{mg}{\pi r^2}$$

$$\text{प्रदान विस्तृति } \epsilon = \frac{\text{लंबाईमां थतो वधारो}}{\text{मूल लंबाई}} = \frac{l - l_0}{l} = \frac{\Delta l}{l}$$

$$\therefore Y = \frac{\sigma}{\epsilon} = \frac{\frac{mg}{\pi r^2}}{\frac{\Delta l}{l}}$$

$$\therefore Y = \frac{mgl}{\pi r^2 l}$$

- Young is the SI unit or (pascal) of the modulus. N/m²Pa
- Young modulus depends on the type of substance.

Bulk Modulus: The ratio of size resistance to size distortion is called size elasticity number.

When increased by the force exerted on the object, its size becomes distorted. Thus $p + \Delta p \Delta V/V_0$, size elasticity digit

$$B = \frac{\text{Bulk Stress}}{\text{Bulk Strain}} = \frac{\Delta p}{-\frac{\Delta V}{V_0}} = -\frac{V_0 \cdot \Delta p}{\Delta V}$$

Here a negative sign is shown to indicate that an increase in pressure decreases the size of the substance.

- Size elasticity is the unit or (pascal) of the digit. N/m²Pa
- Size elasticity is called compressibility .

$$k = \frac{1}{B} = -\frac{1}{V_0} \frac{\Delta V}{\Delta p}$$

- It has a unit. Pa⁻¹ अथवा atm⁻¹
- For water, there is a value of durability, which means that if the pressure $46.4 \times 10^{-6} Pa$ on water is increased by 1 atm, its size decreases by only 46.4 parts in 10,00,000 parts.

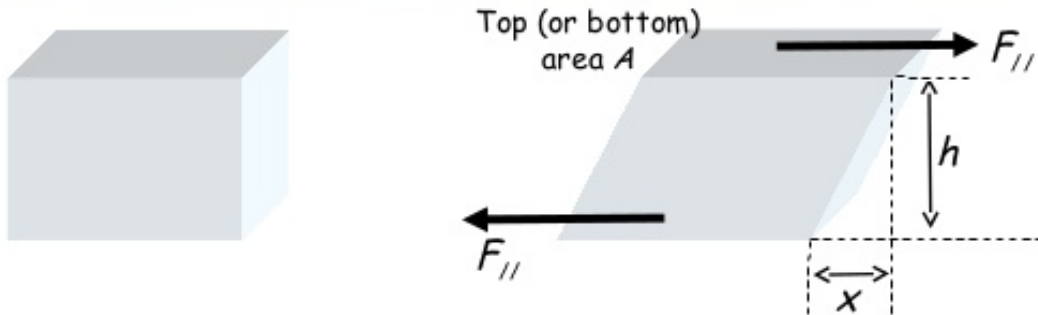
Material	Young's Modulus (Gpa)
Stainless Steel	190-210
Ti	116
Al 7075	72
Invar 36	147
Si	179
Au	79
W	400
Super Invar	148
Pyrex	61
Zerodur	91
SiO ₂ (crystalline quartz)	72
Sapphire (Al ₂ O ₃)	345
HOPG	36 (⊥ to basal plane)
SiO ₂ (oxide film)	66
Muscovite Mica	48 (parallel to c-axis)

Material	Bulk Modulus B (N/m ²)
Aluminum	7.1×10^{10}
Brass	6.7×10^{10}
Copper	1.3×10^{11}
Lead	4.2×10^{10}
Nylon	6.1×10^9
Pyrex glass	2.6×10^{10}
Steel	1.4×10^{11}
Liquids	
Ethanol	8.9×10^8
Oil	1.7×10^9
Water	2.2×10^9

Shear Modulus or (Modulus of Rigidity): The ratio of shear stress to shear strain is called the Shear Modulus (Modulus of Rigidity).

$$\eta = \frac{\text{Shear Stress}}{\text{Shear Strain}}$$

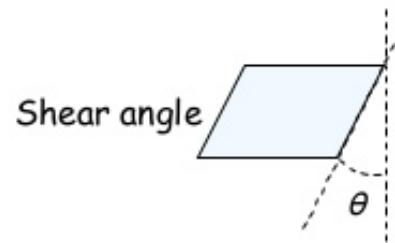
- Unit of Shear modulus: $\frac{N}{m^2}$ or Pa



Shear modulus

$$S = \frac{\frac{F_P}{A}}{\frac{x}{h}}$$

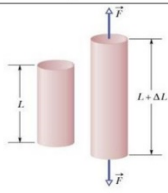
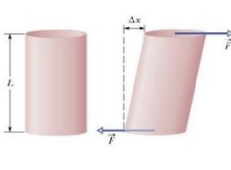
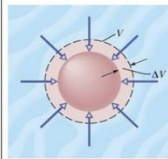
stress
strain



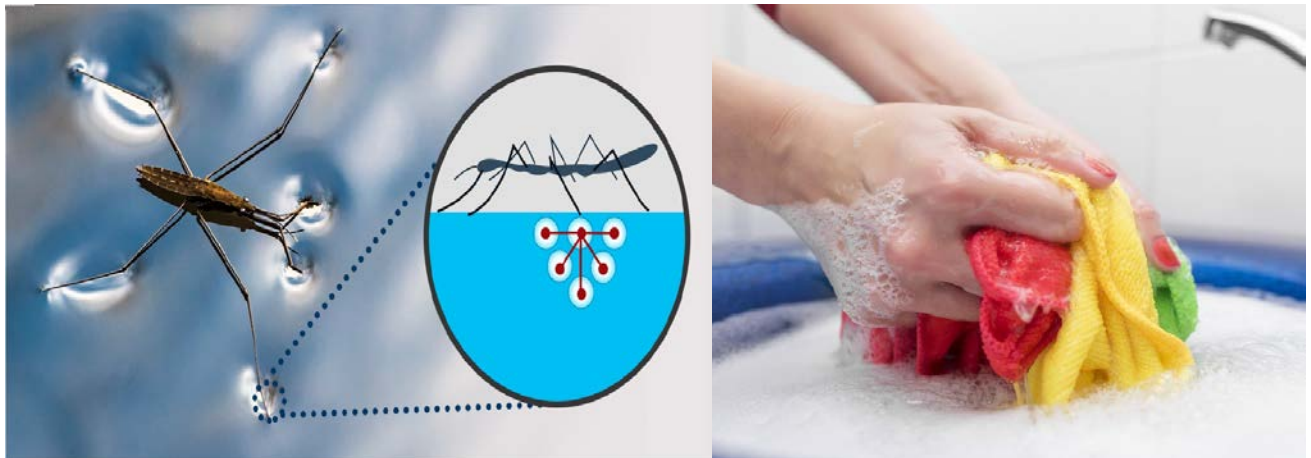
$$\text{strain} = \tan \theta = \frac{x}{h}$$

- As the value of the shear modulus is higher, so is the value of the force to be given in the opposite direction, so such a material is considered to be harder. For this reason, the shear modulus is also often called the modulus of rigidity.

Comparison of three Modulus

Young's modulus	Shear modulus	Bulk modulus
Under tension and compression	Under shearing	Under hydraulic stress
		
Strain is $\Delta L / L$	Strain is $\Delta x / L$	Strain is $\Delta V / V$
$E = \frac{\text{Stress}}{\text{Strain}} = \frac{F}{A} \frac{L}{\Delta L}$	$G = \frac{\text{Stress}}{\text{Strain}} = \frac{F}{A} \frac{L}{\Delta x}$	$B = \frac{\text{Stress}}{\text{Strain}} = p \frac{V}{\Delta V}$

Surface Tension: Each liquid medium has a specific type of elastic behavior, which make the liquid behave in such a way that the area of its outer surface minimizes.



- Soap water removes and cleanses the oily substances from the cloth.
- Some insects, such as mosquitoes, bees can walk on the surface of water.
- Surface tension is responsible for many other examples like the above two examples.
- At the molecular level of all these phenomena, the forces of attraction between the molecules of the liquid as well as between the molecules of the liquid and its surrounding atmosphere play a large part.

Cohesion	Adhesion
Cohesion involves molecules of the same type interacting with each other, like water with water.	Adhesion involves interactions between different types of molecules, such as water and glass.
The force in cohesion arises from the attraction among like molecules.	The force in adhesion arises from the attraction between different molecules.
Cohesion can cause a liquid to form a convex meniscus, like mercury does in a tube.	Adhesion can cause a liquid to form a concave meniscus, like water in a tube.
Due to cohesion, liquids tend to form droplets when placed on a solid surface.	Due to adhesion, liquids tend to spread out when in contact with certain solid surfaces.
Cohesion is responsible for phenomena like surface tension in cell membranes.	Adhesion plays roles such as helping cells attach to surfaces, aiding processes like inflammation
An example of cohesion is beads of water forming on a surface.	An example of adhesion is when water spreads out on a leaf.
In plants, cohesion helps in forming continuous water columns which are crucial for transport.	Adhesion in plants causes water to climb up plant stems, assisting in capillary action.
Fundamental Forces Behind Cohesion The primary force responsible for cohesion in many liquids, including water, is the hydrogen bond. In molecules without hydrogen bonding, other intermolecular forces like van der Waals forces or dipole-dipole interactions can lead to cohesive behavior.	The strength of cohesive or adhesive forces comes down to the molecular interactions involved: <ol style="list-style-type: none"> 1. Hydrogen Bonding: Water, for instance, exhibits strong hydrogen bonding, leading to significant cohesive forces. However, when water is in contact with surfaces like glass that can also participate in hydrogen bonding, the adhesive forces can surpass the cohesive ones.

	<ol style="list-style-type: none"> 2. Van der Waals Forces: These forces can contribute to both cohesion and adhesion, depending on the molecules involved. 3. Electrostatic Interactions: Some adhesion can be attributed to electrostatic forces, especially in cases involving charged surfaces. 4. Chemical Bonding: In some instances, actual chemical bonds can form at interfaces, leading to exceptionally strong adhesion.
<p>Examples of Cohesion</p> <ul style="list-style-type: none"> • Water Drops: When you see water drops on a leaf or on your car window, it's cohesion in action. The water molecules prefer to stick together, forming droplets. • Mercury in a Glass Thermometer: Mercury, unlike water, does not wet the glass. It remains cohesive and forms a distinct convex meniscus in a glass tube. • Surface Tension: It's the reason small insects like water striders can walk on the surface of water. The cohesive forces create a "film" on the water surface, preventing the insect from sinking. • Water's High Boiling Point: Water has a higher boiling point than many other molecules of its size due to the strong cohesive forces from hydrogen bonding. • Formation of Liquid Beads: When a liquid is spilled, it tends to form beads or droplets. This is especially pronounced for liquids with high cohesive forces. 	<p>Examples of Adhesion</p> <ul style="list-style-type: none"> • Wetted Surfaces: When water spreads on materials like paper or cloth, it's due to adhesive forces between water molecules and the material's molecules. • Capillary Rise: In thin tubes or porous materials, liquids often rise against gravity. Water, for example, climbs up plant roots and stems because of adhesion to the cell walls. • Paint on a Wall: The reason paint sticks to walls is because of adhesive forces between the paint molecules and the wall molecules. • Stickers or Glue: The adhesive material can stick to surfaces because of the attractive forces between the adhesive and the surface. • Liquid Meniscus in Tubes: When you place water in a glass tube, it forms a concave meniscus. This is because the adhesive forces (water-glass) are stronger than the cohesive forces (water-water).
<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> •

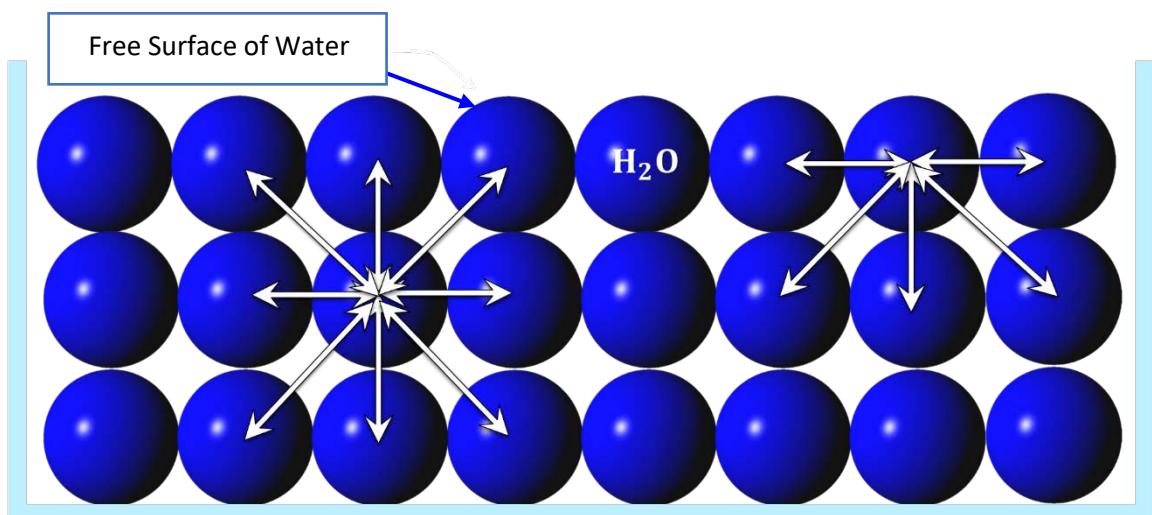
According to Vander-Wal theory, there exists an attractive force among molecules.

Molecular range: The maximum distance up to which a molecule can exert the force of attraction on another molecule is known as Molecular range.

- It is of the order of $10^{-9} m$ for solids and liquids. So, the utmost detachment up to which the intermolecular force is effectual is called the range of molecular range.
- These molecules attract each other by consistent force. But these forces have only a small range. The Molecular range is the radius around a molecule in a material to which the molecule can exert attraction force on another molecule. This is distance. The molecular range is the utmost distance up to which a molecule can make use of force of magnetism on another molecule.
- **Sphere of influence** is a sphere drawn around a particular molecule as a center and molecular range as a radius. The central molecule exerts a force of attraction on all the molecules lying within the sphere of influence. It is a pretend sphere drawn with a molecule as a center and the range of molecular magnetism as a radius.
- A sphere is drawn with a particle as a center and the range of molecular magnetism as the radius is called the sphere of influence of that molecule. It is the area over which a group or association has power, which is divide from whoever is conventionally in control. Sphere of influence is the spherical space/volume around a molecule in a material, inside which the molecule at the middle can exert an attractive force on another molecule.

Laplace Molecular Theory

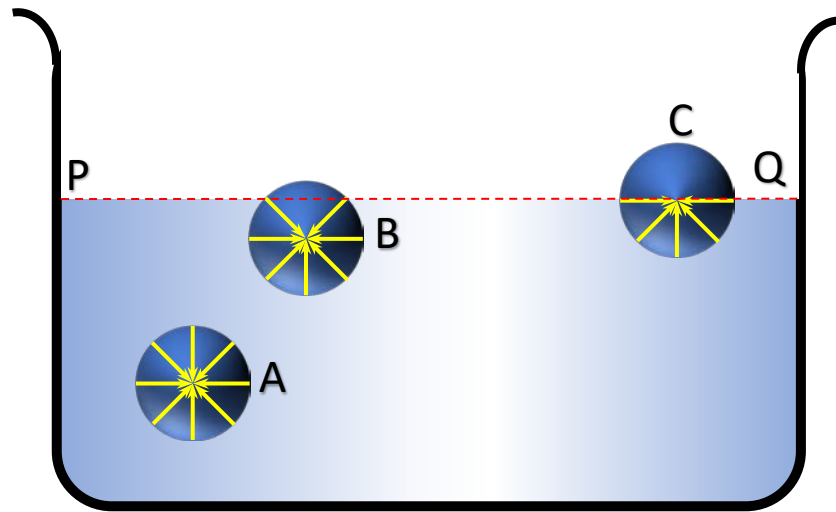
- Let us consider four molecules A, B, C and D of a liquid. Sphere A is well inside this



liquid; B near the surface of the liquid; C, just on the surface and D, above the liquid surface.

- Draw a sphere of influence around them.

- The sphere of influence of molecule A is fully inside the liquid, it is attracted equally in all directions by other molecules. So, the resultant cohesive force on it is zero. So, it will remain in a state as it was.

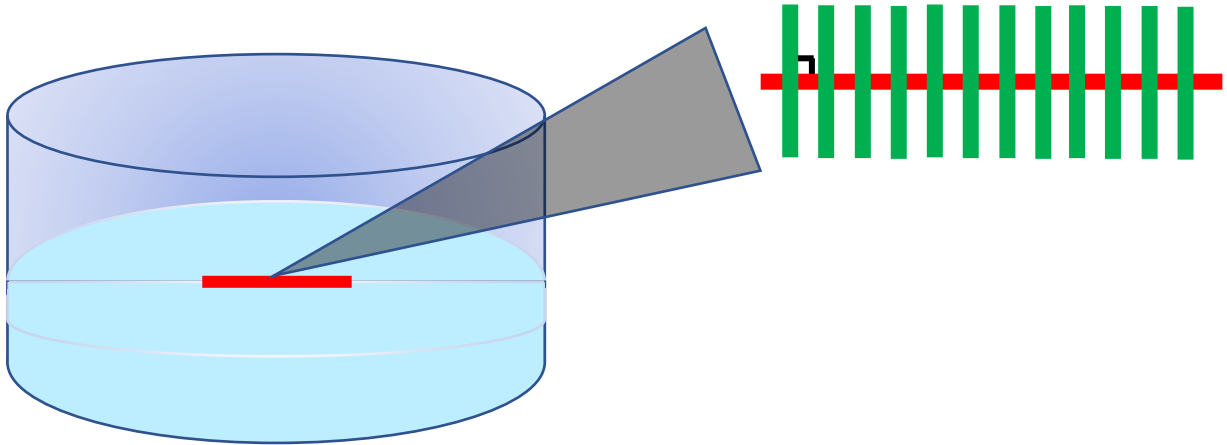


- The sphere of influence of molecule B lies partly outside the liquid, this part contains only a few molecules of air(vapor) compared to the liquid molecules in the lower part. So, the downward attractive force due to liquid molecules exceeds that of upward force of attraction by vapor molecules. So, there is a resultant downward force acting on B.
- Since the molecule C lies on the surface of the liquid the one-half of its sphere of influence lies inside and the other half lies above the surface of the liquid. This part contains only few molecules of air (vapor). But the entire lower half contains liquid molecules and thus the downward force, in this case is maximum.
- This phenomenon will be observed for all the molecules lying on the surface. This downward or inward force per unit area of a liquid surface is called cohesive pressure, which is the cause of cohesion.
- It is thus clear that all over the surface of the liquid PQ there is a downward pull due to attraction between molecules. This surface tends to contract, i.e., it tends to decrease the area of surface PQ. Surface tension originates from this tendency of surface contraction. This tension acts tangentially to the surface of the liquid.

Definition: Surface Tension: The force exerted by molecules in the direction of the tangent that perpendicular to the unit length of imaginary line drawn tangent to the free surface of a stationary fluid is called surface tension.

$$\text{Surface Tension (T)} = \frac{\text{Force}}{\text{Length}} = \frac{F}{l}$$

- According to this definition, Surface Tension, the MKS unit is $\frac{N}{m}$ and the CGS unit is $\frac{\text{dyne}}{\text{cm}}$
- At 20°C, the surface tension of water is $72 \frac{\text{dyne}}{\text{cm}} = 0.072 \frac{N}{m}$



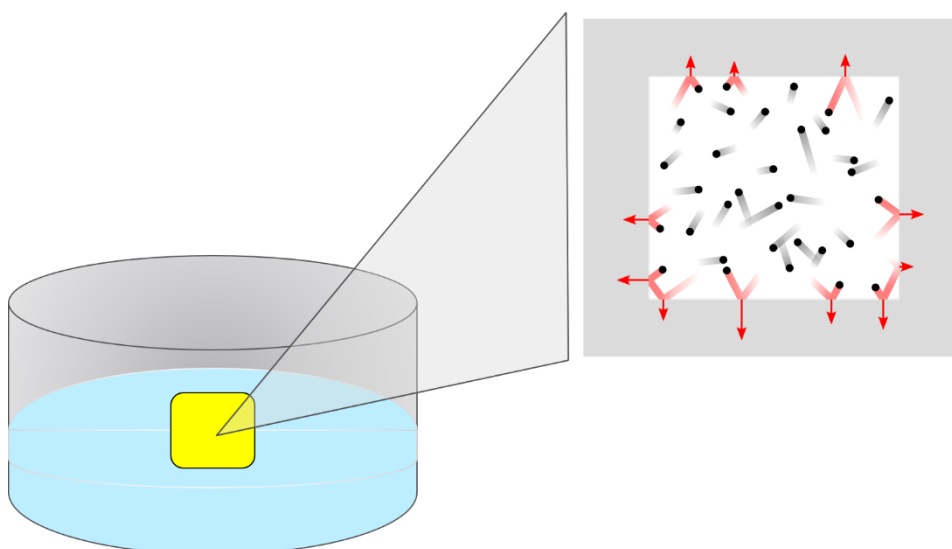
- At 20°C, The surface tension of mercury is $465 \frac{\text{dyne}}{\text{cm}} = 0.465 \frac{N}{m}$

Definition: Surface tension: The total surface energy of atoms per unit area of the free surface of a liquid is called surface tension.

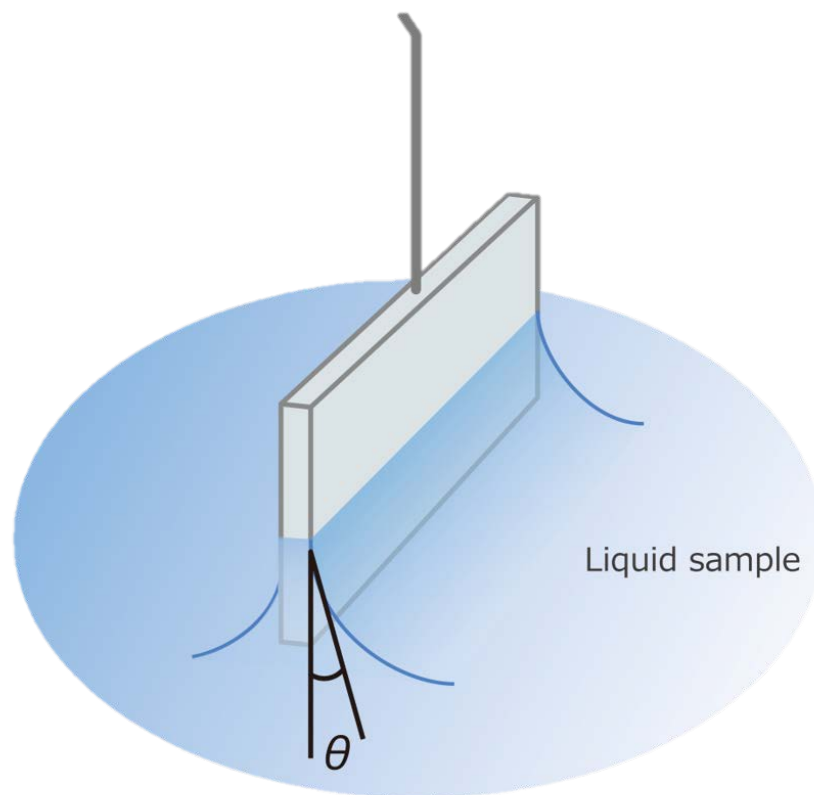
$$\text{Surface Tension (T)} = \frac{\text{Total Potential Energy (Surface Energy)}}{\text{Area}} = \frac{E}{A}$$

- According to this definition, MKS unit is $\frac{J}{m^2}$ and the CGS unit is $\frac{\text{erg}}{\text{cm}^2}$

Angle of contact: Here is a representation of the adhesion force of fluids such as water and mercury to the glass surface.



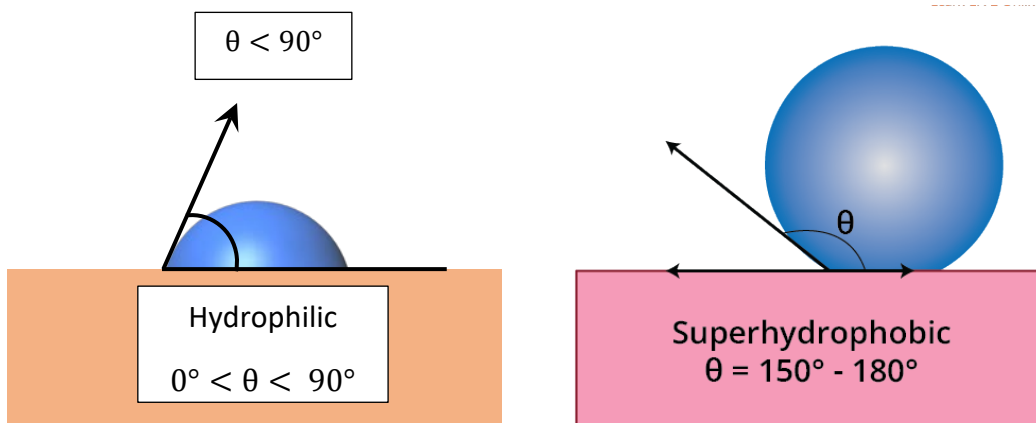
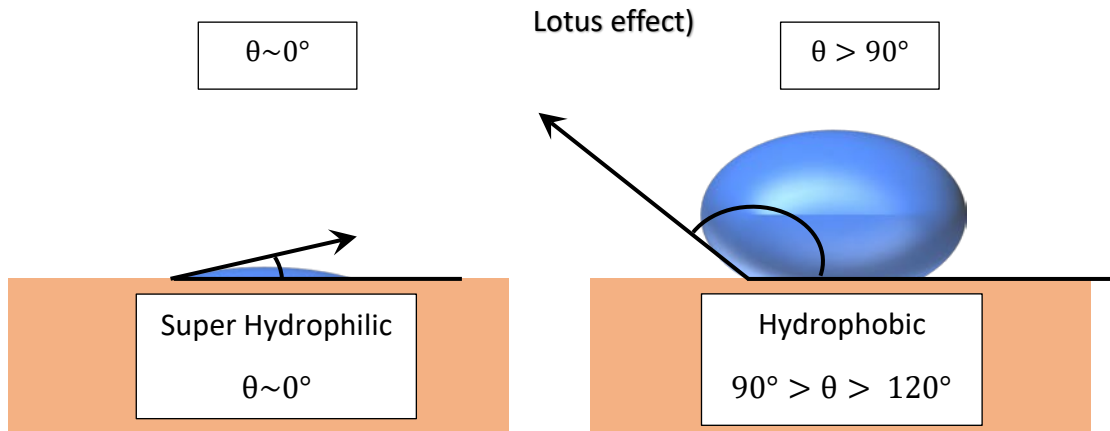
Definition: *The angle measured in the fluid between the surface of the tangent and the surface plane of the solid that draws the surface of the liquid before the intersection point of the free*



surface of the liquid and the contact surface of the solid is called the angle of touch.

- The shape of the free surface of the static fluid in the vessel and it will soak up the surface and not depend on the angle of touch.
- The angle of touch of a liquid depends on the relative intensity of the contraction force and the adhesion force prevailing in the liquids.
- If the contraction force of a liquid is greater than its adhesion force, then it is larger than the angle of touch and the liquid $90^\circ (\theta > 90^\circ)$ becomes more pointy and the liquid takes on a spherical shape.
- If the adhesion force of the fluid is greater than its convection force, then it is smaller than the angle of touch, and as such, the liquid abandons the pointless shape and begins to take a more and more flat shape $90^\circ (\theta < 90^\circ)$ and spread more to the surface.
- Angle of touch: 0° : The surface is completely wet. (Super-hydrophilic surface)
- Angle of touch: Between 0° and 90° : The surface is wet. (Hydrophilic surface)

- Angle of touch: Between 90° and 180° : The surface is not nearly wet. (Hydrophobic surface)
- Touch angle: 180° : The fully attractive surface is not wet. (Ultrahydrophobic surface – Lotus effect)

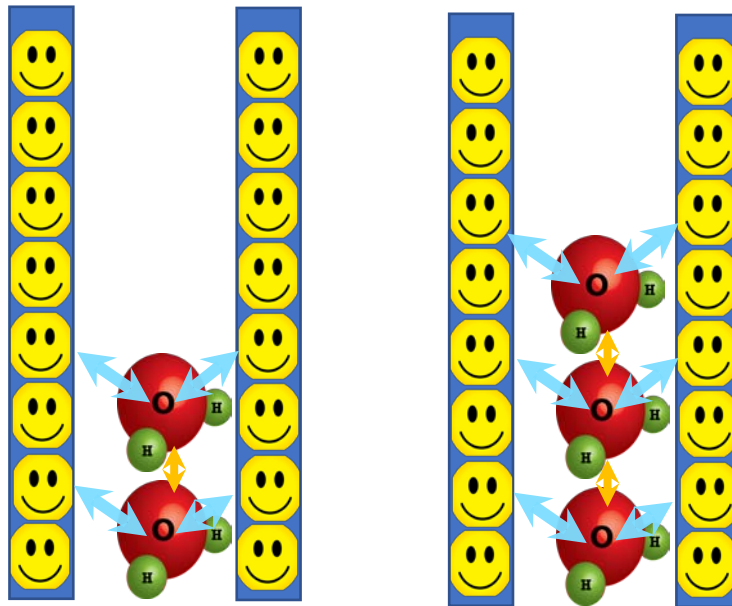


Surface (Interface)	Contact angle θ
Water–glass	0°
Organic liquids (most)–glass	0°
Ethyl alcohol–glass	0°
Kerosene–glass	26°
Water–silver	90°
Water–paraffin	107°
Mercury–glass	140°

Kerosene (Capillary Action - Capillary Action):

- Repulsion: *The ability of a liquid to flow against the force of gravity without any assistance in a narrow-flowing tube is called capillaration.*

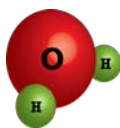
- the adhesion force with the glass molecules and water molecules inside the capillary when the capillary is immersed upward in the liquid; Water is greater than the convection force between water molecules.
- Therefore, the water molecule is attracted to the glass molecules, so that the area of its free surface increases. So according to the property of surface tension, the liquid rises further to shrink the area of its free surface.
- On the contrary, mercury descends into the capillaries as it has a high convulsive force.



Glass



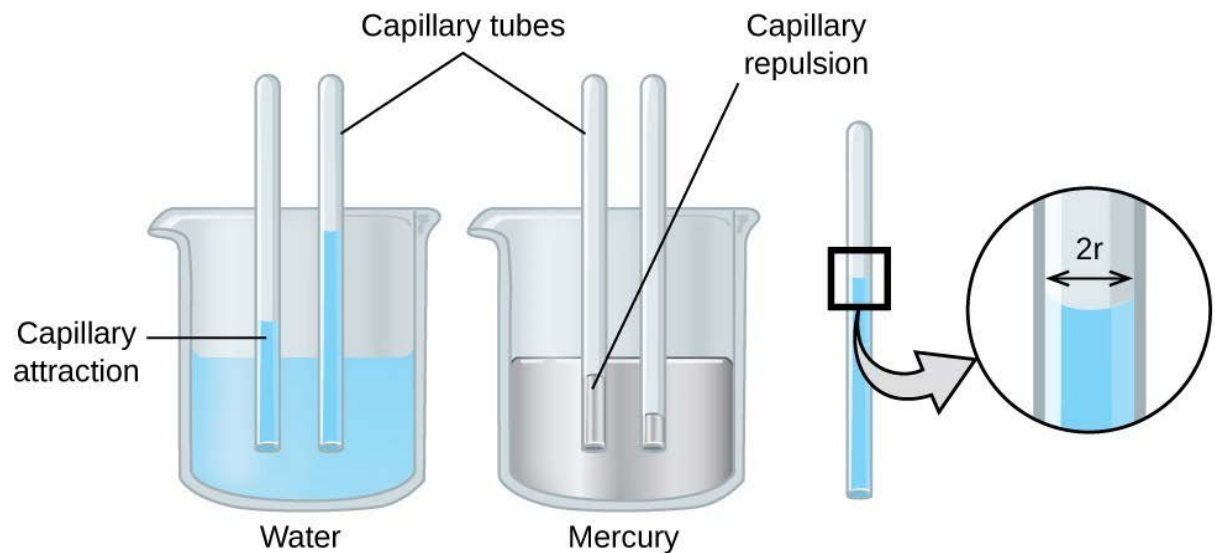
Attachm



Water



The



Surface tension Applications/examples:

1. Water droplets are spherical in shape because of the surface tension.
2. Oil-like liquids are attracted upwards by capillary attraction through the cotton kept in the lamp.
3. Small insects like mosquitoes or water striders can walk on water.
4. Paperclips or needles placed on the surface of stagnant water can float.
5. In early morning, water dews are found on the leaves of the plant.
6. The water droplets on the surface of the glass takes circular shape.
7. On the surface of a waxed or painted car, water flows easily without accumulating.
8. Liquids such as water and oil do not mix with each other due to having different surface tension.
9. Surface tension is used to blend different types of oils into one another.
10. The sanitizer used to clean the hands, due to its low surface tension, easily spreads all over the hand and disinfects it.
11. Since the surface tension of toothpaste is low, it easily cleans it by spreading it to each tooth.
12. By adding a detergent, it reduces the surface tension of the water so that the bubbles forms easily and cleans the clothes by attracting dirt and oily substances from the clothes.

13. Rainwater does not pass through the cloth of umbrellas and certain types of tents because of the surface tension, it fills in pores of tent fiber and blocks them.
14. The ink used in the fountain pen also descends to the paper according to the principle of capillary actions.
15. "Tears of wine" appear on the inner surface of the glass in the wine-filled glass, which helps to determine the percentage (%) of the alcohol in the wine.
16. Mercury does not wet the surface of the glass at all due to this property mercury is used in thermometers.
17. The plants have thin xylems for the transport of water, which transmit the water absorbed by the root to its leaves according to the principle of capillary repulsion.
18. For the diagnosis of a disease such as jaundice, the properties of surface tension are used by the Hay's Test to examine bile salts present in the urine.
19. Antiseptics, used to treat wounds on human skin, can easily spread around the wound because of its low surface tension.
20. In order to make a bead or bullet, molten glass or metal is poured from high in a tube filled with cold water. Due to the surface tension of the water, they take a circular shape.
21. The right substance is applied to the specific fabric to make a waterproof fabric. Adding such a substance increases the value of angle of contact which makes the fabric waterproof.
22. Reptiles such as rattle-snakes have fangs that can penetrate to hypodermic tissue of its prey and releases venom at high intensity. Reptiles have a difference in the surface tension on the inside and outside of their tooth groove which is actual method of transmitting venom.

Viscosity:

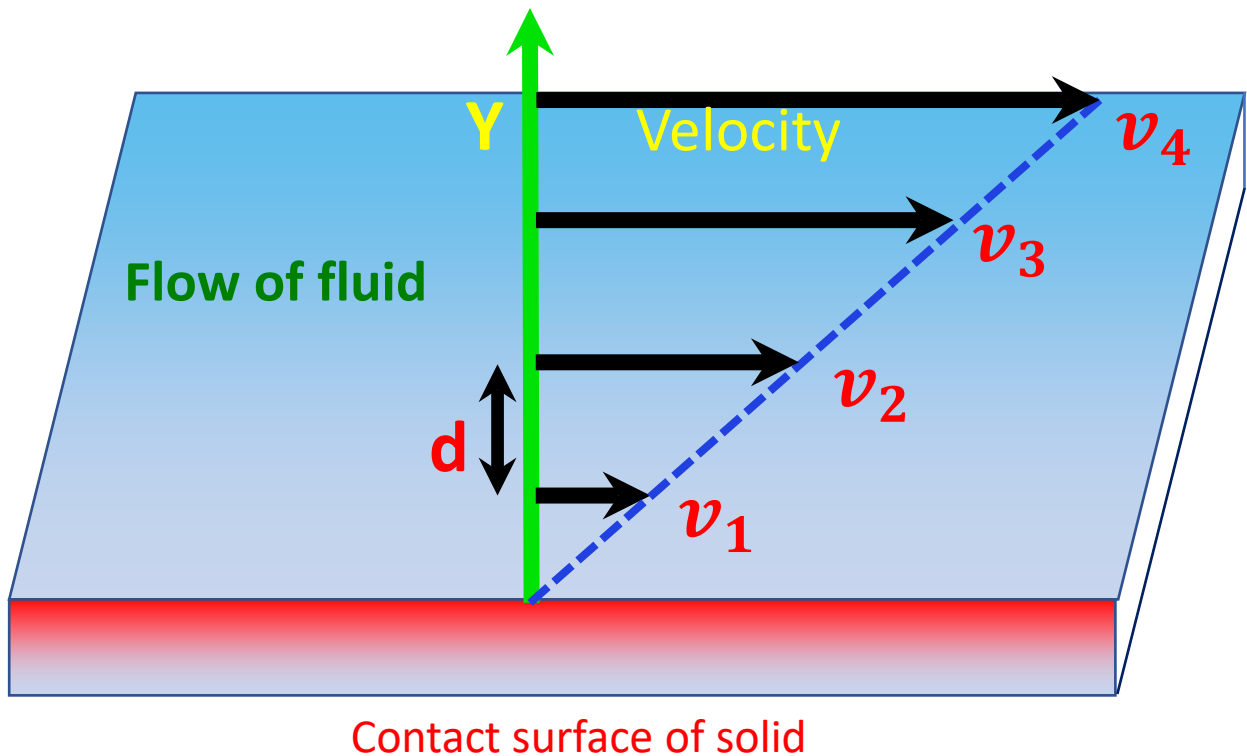
Basic Idea: Liquids such as water and alcohol can flow very quickly on the surface of a solid, while liquids such as honey or oil are transported very slowly.

How fast a liquid can be transported depends on the viscosity of that liquid.



Viscosity:

- A fluid flow on a stationary surface is shown in the figure.
- The velocity of the liquid layer in contact with the stationary surface is zero, and the velocity of each successive layers moving progressively to the upper surface increases to the maximum.
- The difference in velocity between each layer causes friction and a force emerges. This force opposes the speed of the fluid.



Definition: The property of a liquid due to which the relative motion between its two layers is hindered is called the viscosity of a liquid.

- Viscosity is an intrinsic property of a fluid, which opposes its own flow.
- Honey does not flow as easily as water as it has more viscosity than water.

Velocity gradient: In a layered flow, the difference in velocity of two successive layers, which are unit apart from each other in the direction of the direction of the flow of a fluid.

$$\text{Velocity gradient} = \frac{v_2 - v_1}{d}$$

- the unit of Velocity gradient is s^{-1}

Newton's Law of Viscosity: Newton proved through experiments at constant temperature that the force produced in the layered conduction of a liquid is proportional to the surface area of the liquid and the velocity of that fluid.

$$F \propto A$$

$$F \propto \frac{v_2 - v_1}{d}$$

$$\therefore F \propto A \left(\frac{v_2 - v_1}{d} \right)$$

$$\therefore F = \eta A \left(\frac{v_2 - v_1}{d} \right)$$

Here it is the viscosity coefficient that depends on the type of liquid and the temperature of the liquid η .

$$\eta = \frac{F/A}{\left(\frac{v_2 - v_1}{d} \right)}$$

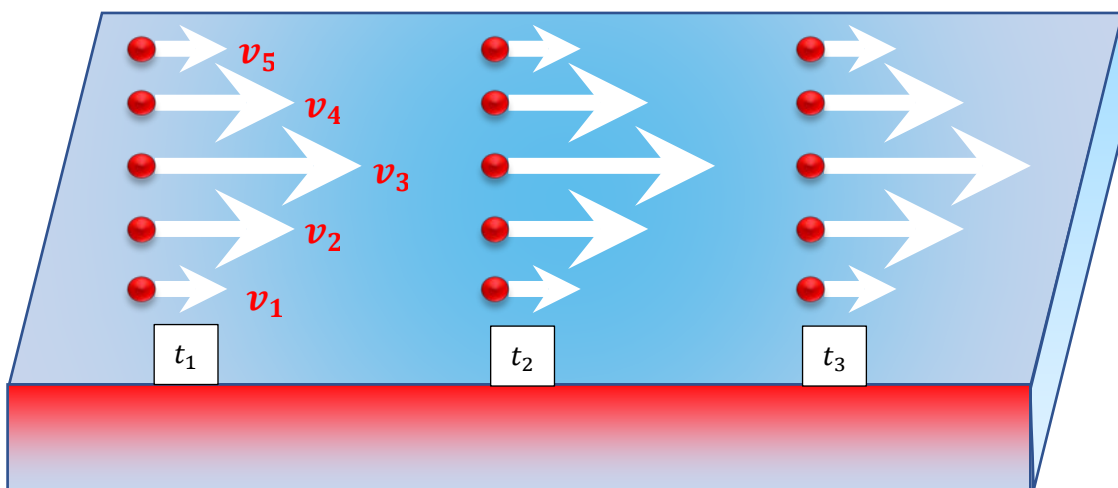
η CGS unit of $\text{poise} = \text{N} \cdot \text{s}/\text{m}^2$

η MKS unit $\text{dyne} \cdot \text{s}/\text{cm}^2$

Its other unit $1 \frac{\text{dyne} \cdot \text{s}}{\text{cm}^2} = 1 \text{ poise}$

Laminar/Streamline Flow: If the velocity of the fluid near each point in the level in the liquid conduction remains constant over time, then such type of conduction is called fluid conduction.

e.g., Water coming from a less opened tap, a slow flowing spring.



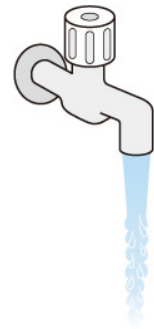
Turbulent Flow: If the velocity of the liquid near each point in the level in the liquid conduction varies with time, then such a type of conduction is called turbulent conduction.

- e.g., The speed of the sea waves, the water falling in the form of waterfalls.

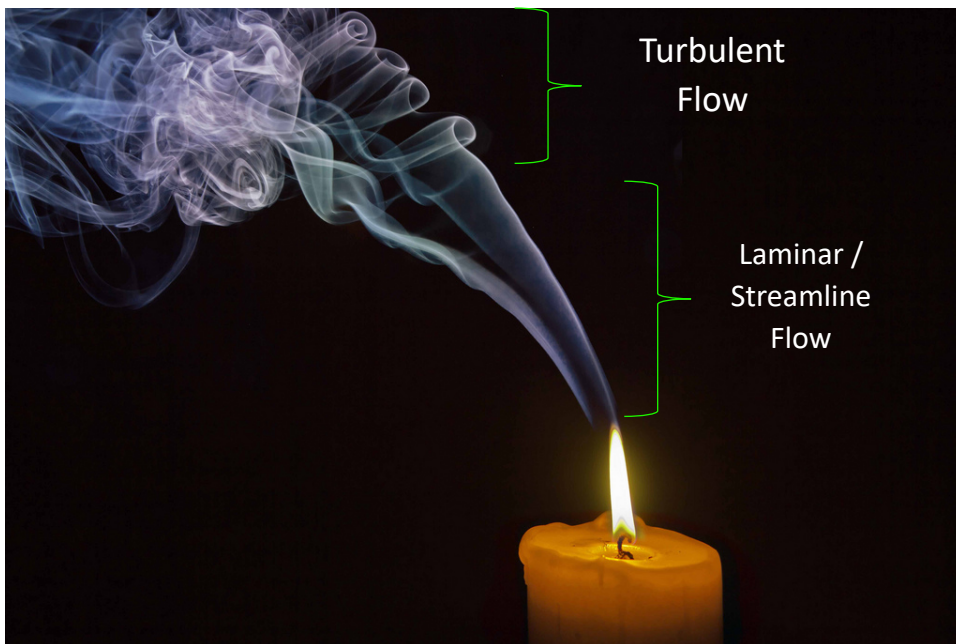
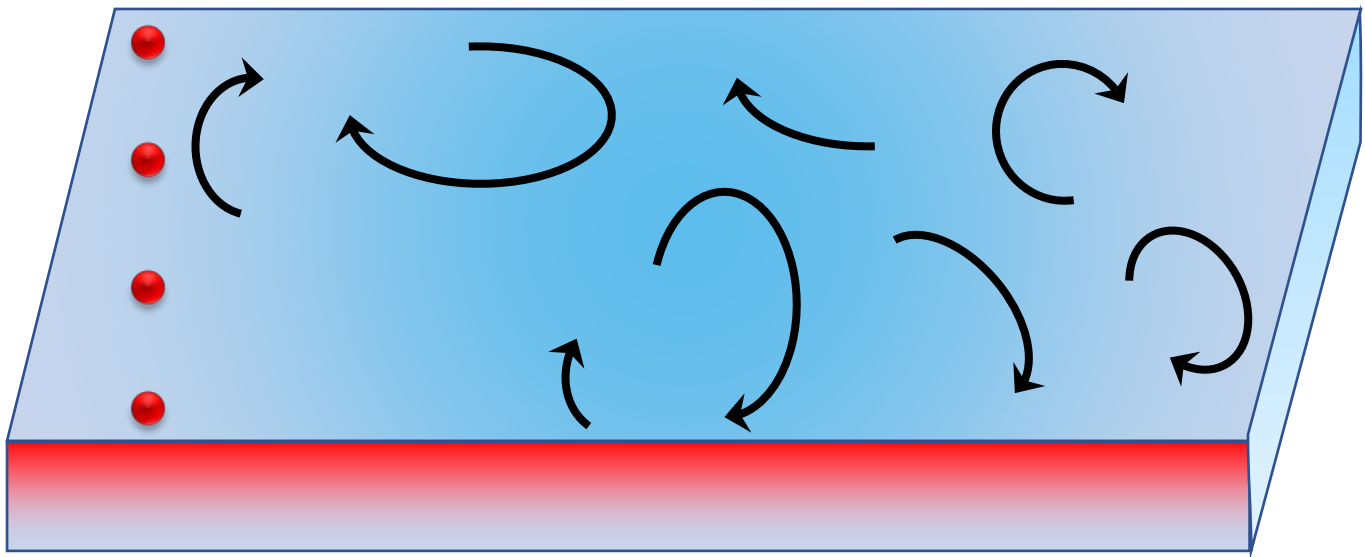
Critical Velocity: The value of the velocity in the conduction of a liquid for which the conduction of a liquid changes from the linear to the turbulent conduction is called the revolution velocity.



(a) Laminar flow



(b) Turbulent flow



Reynold Number: British scientist Reynold Number proved that the type of fluid flowing into the tube depends on the following factors.

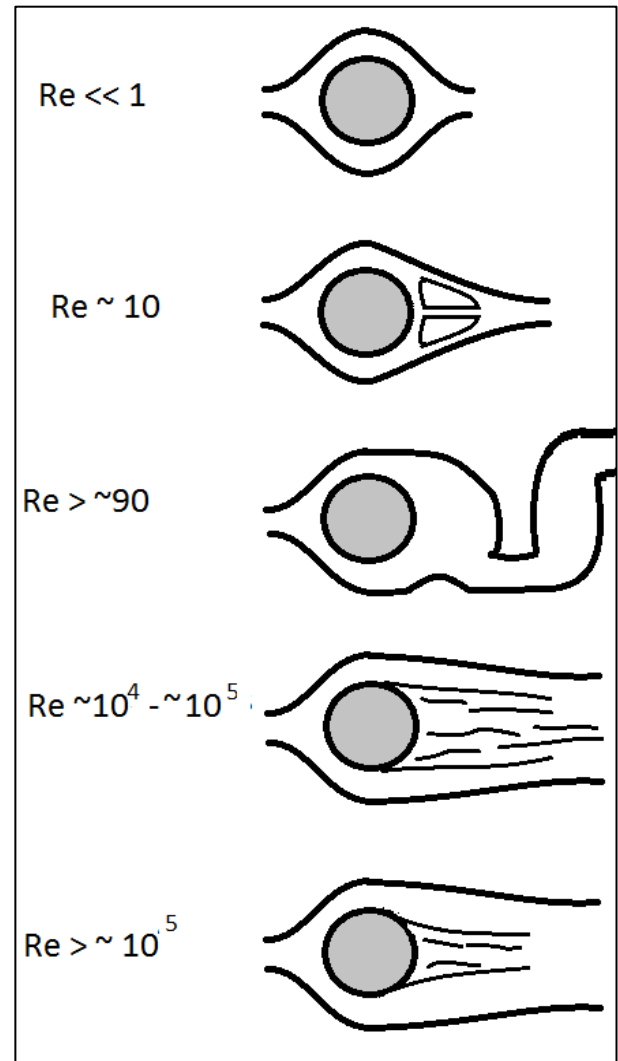
- (1) Viscosity coefficient of the liquid(η)
- (2) Density of liquid(ρ)
- (3) The average velocity of the liquid(v)
- (4) The diameter of the tube through which the liquid is flowing (D)

From these points, the scientist Reynold presented the following formula.

$$R_e = \frac{\rho \cdot v \cdot D}{\eta}$$

The values of the factors associated with liquid conduction are laid down in the above formula. This value is classified as follows,

- (1) If so, the conduction of the liquid is continuous. $R_e < 2300$
- (2) If there is, the conduction of the liquid is disturbed. $R_e > 4000$
- (3) If so, the conduction of the liquid is disturbed $2300 < R < 4000$.



Thus, the type of flow of fluid depends on the value of the Reynold number (R).

Critical Reynold number (R_c): If the velocity of the fluid is equal to the revolution velocity, then the Reynold number obtained is called the critical Reynold number.

Applications of Reynold Number:

- It is most commonly used to determine the type of flow of a fluid.
- It is used to calculate the viscosity in case of an loss caused by frictional force.
- The Reynold number is very useful for determining the design of the piping system used for the transportation of fluids in industrial sectors.
- The air in the atmosphere can also be considered fluid. So, the Reynold number can be calculated for it.
- It is used for the aerodynamic study of the surfaces of materials in wind tunnel testing.
- The Reynold number is calculated to determine the shape and type of wings of an air craft used for air travel.

- The Reynold number is useful for determining the similarity between the experimental model of the aircraft and its full-size model.
- In fluid mechanics, it is used to determine the range of flow of fluid.
- The Reynold number is used for two liquids to determine the dynamical equivalence of their flow.
- The Reynold number is also used to determine an experimental model of how microorganisms such as bacteria will swim in fluid such as water or cells.

Stokes' Law: When a solid substance collapses freely into a liquid, it feels pulled by the viscosity force of the liquid.

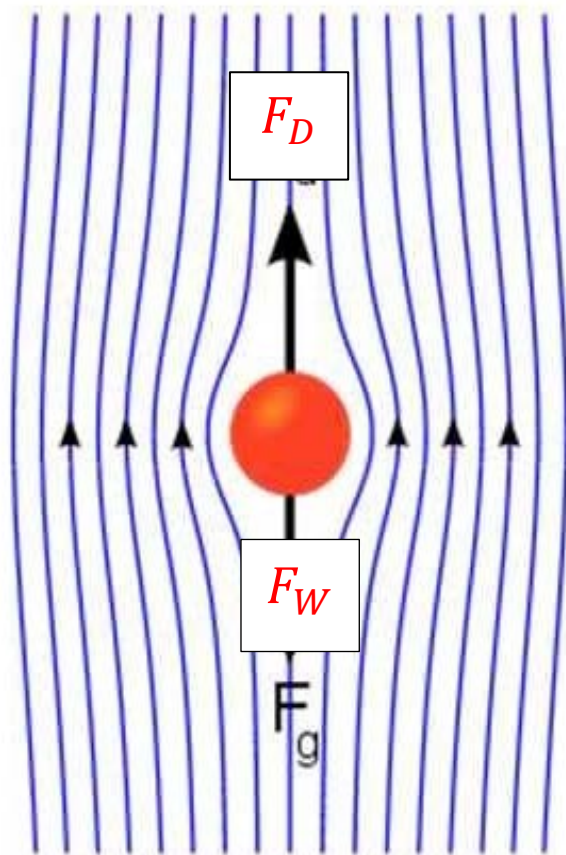
(1) When the parachute jumper falls free

(2) When the spacecraft enters the atmosphere from the vacuum

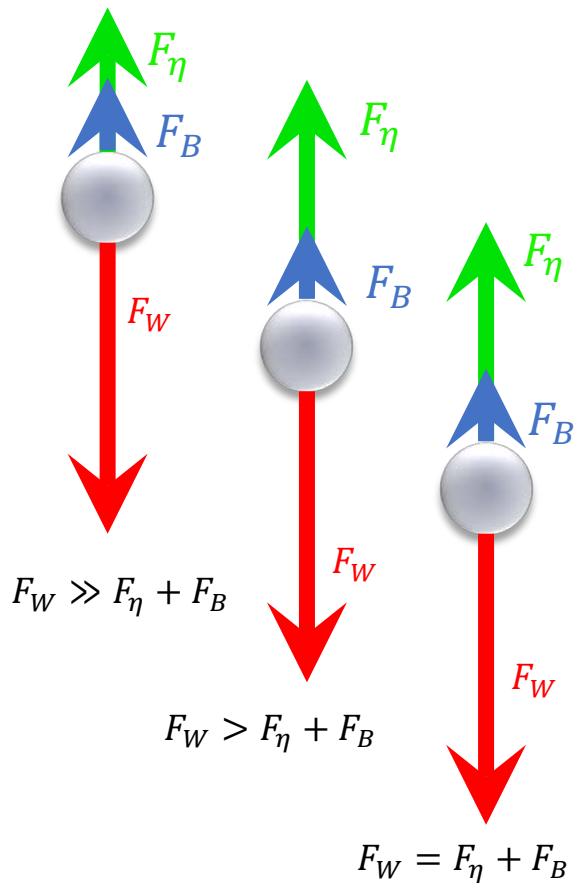
- The formula for the force on a spherical object falling free in a liquid was first given by a scientist named George Gabriel Stokes in 1851.
- When a spherical substance collapses free into the liquid, it pulls the fluid of the liquid. This pull causes relative motion between different layers of fluid resulting in the generation of viscosity force that drives the motion of the viscosity force object.
- Rule: *When a liquid with as much viscosity as it moves at the same speed and has radius on a spherical object $\eta v r$*

$$F = 6\pi \eta r v$$

- When a spherical object collapses free into a liquid, there are three types of forces on it.
 - (1) F_W - Gravity - in the downward direction
 - (2) F_η - Viscosity force of the liquid - in the upward direction
 - (3) - F_B The stimulating force of the liquid - in the upward direction
- It is at the beginning of the free fall of the sphere. $F_W > F_\eta + F_B$



- During the continuous collapse of the sphere in the liquid, the velocity of the sphere increases due to gravity in the primary stage.
- Since the viscosity force exerted on the object is proportional to the velocity of the sphere, the value of the viscosity force also increases. At one time, the forces in the upward direction of the sphere and the forces in the downward direction are of the same value. Thus, $F_W = F_\eta + F_B$
- Thus the total force exerted on the sphere becomes zero. According to Newton's law, when the force exerted on an object is zero, the object moves at a constant velocity.
- Thus, since the total force exerted on the sphere is zero, it moves at a constant velocity. This velocity is called the terminal velocity.



$$v_t = \frac{2 r^2 (\rho - \sigma) g}{9 \eta}$$

Terminal Velocity: According to Newton's law, when the force exerted on an object is zero, the object moves at a constant velocity.

- Here, since the force of gravity and drag force of the sky diver are of the same value and in the opposite direction, the total force exerted on the sphere is zero, so it moves at a constant velocity. This velocity is called the terminal velocity. v_t

$$v_t = \frac{2 r^2 (\rho - \sigma) g}{9 \eta}$$

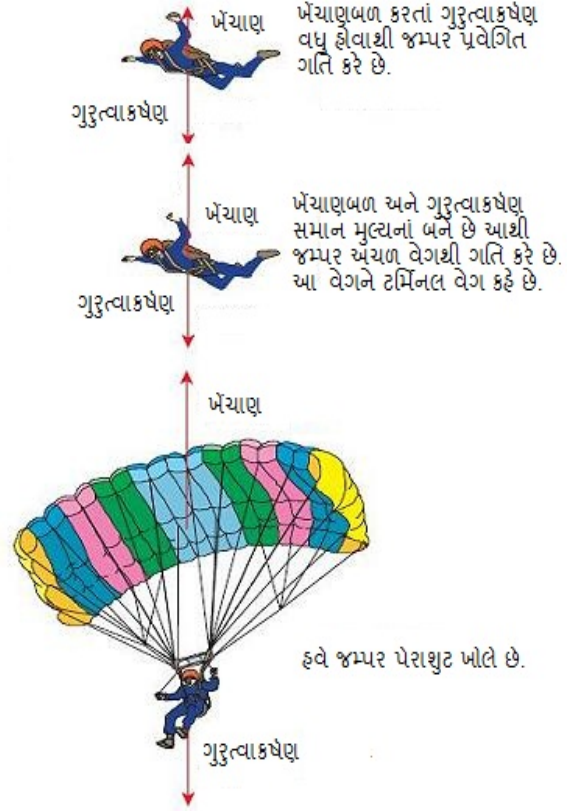
where r = ગોળાની ત્રિજ્યા

ρ = ગોળાની ઘનતા

σ = પ્રવાહીની ઘનતા

g = પૃથ્વીનો ગુરુત્વપ્રવેગ

η = પ્રવાહીની સ્નિગ્ધતા



Applications of Viscosity:

- Cosmetics: Manufacturers of cosmetics such as foundation, lip gloss, eye liner, mascara, nail polish, etc. take special care that it stays on the body parts for a long time after applying it. For this, they mix oil and wax in it in the final stage of production of the product until the product is desired.
- Body Shampoo: The softness of the body shampoo is kept in such a way that it remains on the body until the mail on the body is cleared.
- Ointments: Since the viscosity of the ointment is very high, it is not absorbed by the skin like a cream. It stays on the applied part of the body for a long time. Due to this



property, it is widely used in the medical field.

- Food Industry: Scented foods can easily be given the right shape and spread and can



also be combined with other types of food. E.g. Yogurt, Mayonnaise

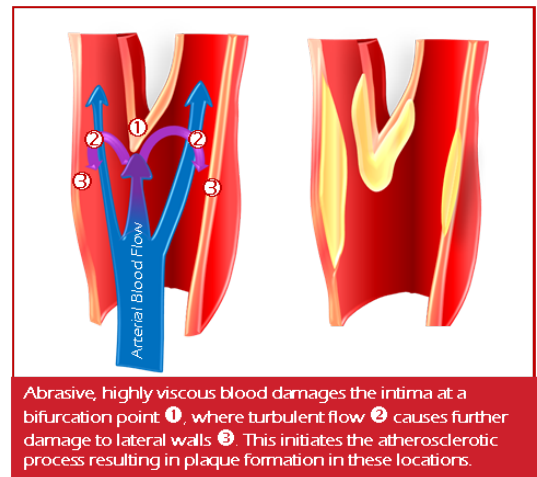
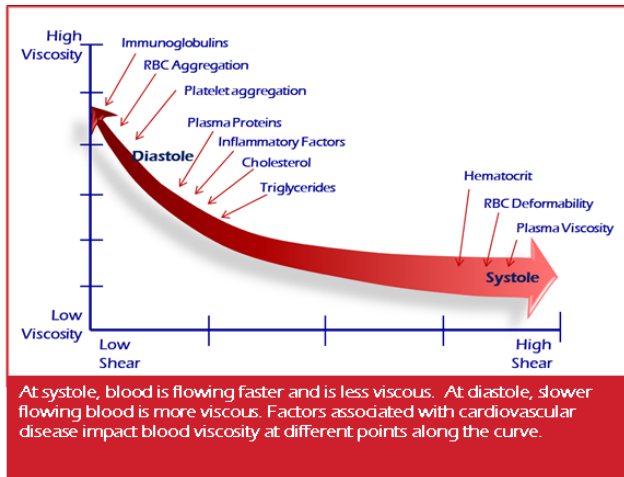
While making a sandwich, mayonnaise holds the salad between the two layers of bread well, which oil cannot do.

- The cream that is added while making pasta keeps the pasta and toppings together well. Cream and butter become more smooth when cooked, so it is used as the base of many recipes .
- Gravy is essential for making certain types of dishes (Punjabi), but this gravy is cooked till it becomes more viscous. Thus, it combines properly with the other ingredients present in it, which in the end makes the dish delicious.
- Milk is essential for making ice cream, but heating milk reduces its viscosity. Hence, starch or CNC powder is added to it, making it more viscous. Thus, it retains its shape and form for as long as it can be eaten.
- When creating a Tomato soup, the viscosity of the Soup increases after the water is finally evaporated. As the gas bubbles are in the soup, there are small explosions. These Mini Volcano eruptions.
- Health Science: Proper viscosity of blood is very important for the human body.



Blood with more viscosity cannot flow as quickly throughout the body as normal blood. Thus, the body cells, muscles, and brain do not get enough of the necessary nutrients and oxygen, so that sometimes the cells die.

- For example, the blood of a person lying in extremely cold water becomes more viscous due to cold. This condition (Hypothermia) can also lead to the death of a



person who lives for a long time.

- Volcanology: From the viscosity of volcanic magma, it can be known how dangerous a volcanic eruption can be.

- When the viscosity of the magma is low, the Crater is thrown out of the volcano's mouth at low pressure and it easily flows from the mountain. For example, the volcano of Hawaii Island



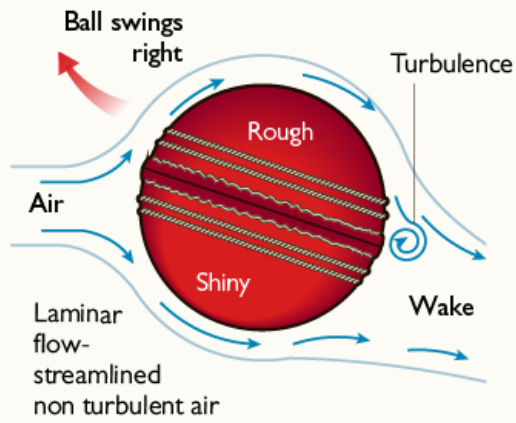
- Sports: In the game of cricket, the ball can swing in two ways. One surface of the ball is roughed while the surface on the other side is lush. Turbulence is produced on the rough surface while moving through the air, which swings the ball left or right.

-

The two types of swing

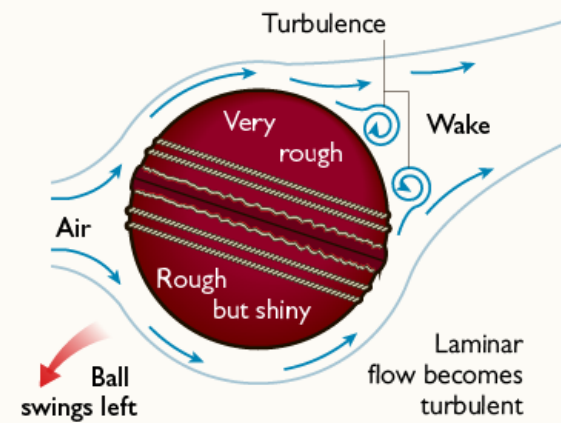
Conventional swing

The ball moves in the direction of the rougher side of the ball



Reverse Swing

Only when the ball is older. It moves away from the rougher side



← Direction of travel