Unit # 05

Pressure and Deformation in Solids

Q# 1 Define the term Elasticity?

Ans: The ability of a deformed body to return to its orlginal shape and size when the deforming forces are removed is called elasticity.

Explanation:

When a stretched spring is released, it comes back to its original form. When a tennis racket hits a tennis ball, the shape of the ball is distorted or deformed, but it regains its original shape when it bounces off the tennis ball.

Q# 2 Differentiate between elastic and inelastic materials?

- ⇨ **Elastic material:**

1) Material that returns to its original shape after being deformed.
2) Example: rubber, spring etc
3) Atoms do not slip pass on each other.

- ⇨ **Inelastic material**:

1) Material that does not return to its original shape after being deformed.
2) Example: clay, dough etc
3) Atoms slip pass on each other.

Q# 3 Define the term Elastic limit?

Ans: Elastic limit is the maximum stress a material can withstand before the permanent deformation. It is the material's highest limit before the material's plastic deformation can occur. Once the stress or force is removed from the material, the material comes back to its original shape.

Q# 04 What is hook's law?

Ans: Hooke's law states that within elastic limits the extension (or compression) 'x' is directly proportional to the restoring force 'F':

$$F=-kx$$

$$K=-\frac{F}{x}$$

Explanation:

Where 'k' is the ratio of restoring force to the extension and is known as the force constant or spring constant having units N/m . The negative sign shows that force is directed against displacement. This relationship is also true for a wire under tension. Provided that the limit of proportionality is not exceeded.

Q# 5 Writ applications of hook's law?

Ans: Hooke's law has many important practical applications, with one being the creation of a balance wheel, which made possible the creation of the mechanical clock, the portable timepiece.

- ⇨ **Balance wheel of the mechanical watches:**

A balance wheel is the timekeeping device used in mechanical watches. It is a weighted wheel that rotates back and forth, being returned toward its center position by a spiral torsion spring or hairspring. It is driven by the escapement, which transforms the rotating motion of the watch gear train into impulses delivered to the balance wheel. Each swing of the wheel (called a tick or 'beat) allows the gear train to advance a set amount, moving the hands of watch forward, The combination of the mass of the balance wheel and the elasticity of the spring keep the time between each oscillation or 'tick' very constant.

- ⇨ **Spring Scale**

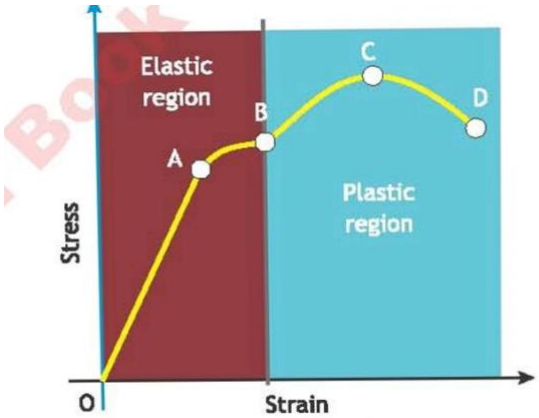
A spring scale (spring balance) is a type of mechanical force measuring instrument that make use of spring. This device is mainly used to weigh items or objects by connecting them to a hook at it bottom. Since by Hooke's law the force or weight that extends a spring is directly related to the distance that the spring is extended from its initial position. The spring scale converts this extension to measuring weight using an analog or digital gauge attached to the device.

- ⇨ **Galvanometer**:

Galvanometer is a device used for detecting current or voltage. It make use of the hair spring which not only electrical connection to coil and restoring the pointer back, but also make the deflection proportional to the force according to Hooke's law, and since the force is proportional to the current, it permits us to draw an analogue scale under the pointer and measure the current.

Q# 6 Explain the stress-strain curve?

Ans: s: Stress and strain curves are measured by stress tester, one such machine Rockwell hardness tester.. The applied stress is increased and the change in length is noted. The values are then printed on graph. A typical graph for metal is shown.



(b) typical stress - strain curve

Point (A) is the limit of proportionality, the limit up to which Hooke' law is obeyed called proportional limit.

Point (B) is the elastic limit, the limit up to which material shows elastic behaviour also called yield strength.

Point (C) is the maximum stress a material can bear before fracture (breaking) called ultimate stress

Point (D) is the breaking point, where material breaks.

Q# 7 Define the term pressure ?

Ans: Pressure is defined as force per unit area.

Mathematically:

Pressure is represented by letter 'P' , if force 'F is applied on area *A , the pressure is given by:

$$P=F/A$$

Unit:

The SI unit of pressure is pascal (Pa) which equals newton per square meter (N/m^2).

Q# 8 Why does a balloon burst easily when pricked with a pin, but not when squeezed by our hand? T

Ans: As we know pressure and area are inversely to each other if area is small pressure is large so in this case.

Reason:

The reason is that the force applied to the small area of the needle tip creates enough pressure to burst the balloon.

Q# 9 Have, you ever wondered why a blunt knife cannot cut meat easily?

Ans: This is due to large pressure.

Reason:

When, you apply the same force on sharp and blunt knife, the sharp knife offers little surface area thereby increasing pressure, which help to cut meat easily.

Q# 10 Define the term Atmospheric pressure?

Ans: 'The pressure that atmospheric particles exert on the surface of earth and all over the surface of objects on the earth is called atmospheric pressure'.

Explanation:

The pressure of the air at a given place varies slightly according to the weather and height from sea level. At sea level, the pressure of the atmosphere on average is 1.013 x 10 N/m^2 (or 1.013 x 105 Pa).

Note: 1 atm = 1.013 x 105 Pa

1 bar = 1.000 x 10^5 Pa.

Q# 11 How a suction cup gets its sticking force? Ans: It s because of the atmospheric pressure.

Reason:

When we push the cup against a smooth wall, we actually force the air out of the cup, allowing atmospheric pressure to hold it to the wall.

Q# 12 Give an example of atmospheric pressure?

Ans: There are many examples such as:

1) Atmospheric pressure can be seen when we pump the air out of sealed can, atmospheric pressure produces an inward force that is unopposed, this results in the collapse of the can.

2) In 17th century Otto Von Guericke (German physicist) fitted two hollow bronze hemispheres together and removed the air from the resulting sphere with a pump. Two eight horse teams were unable to pull the halves apart, even though the hemispheres fell apart when the air was readmitted.

Q# 13 How we measure atmospheric pressure? Ans: A liquid barometer is a device that measures atmospheric pressure. The most common type of liquid barometer is the mercury barometer.

Principle:

The liquid barometer works on the principle of hydrostatic equilibrium, which states that the pressure at any point in a fluid at rest is the same at all depths.

Explanation:

In a mercury barometer, a tube filled with mercury is inverted into a container of mercury .The mercury in the tube seeks a level where the Normal Higher atmospheric weight of the mercury column is balanced by atmospheric pressure on the surface of the atmospheric pressure mercury in the container. At sea level, the atmosphere will push down mercury in the tub and make it rise up in a tube to a height of approximately 760 millimeters (mmHg).

Changes in pressure cause the mercury level to rise or fall, indicating pressure variations associated with altitude and local weather conditions**.**

Q# 14 Write applications of liquid barometer.

Ans: Liquid barometers have various applications:

1) Altitude Measurement:

Liquid barometers (including mercury barometers), can estimate altitude. As atmospheric pressure decreases with increasing altitude, the height of the mercury column decreases, allowing for altitude calculations. They are essential instruments in aviation for altitude measurements and setting aircraft altimeters.

2)Weather Forecasting: They are used in

meteorology to measure atmospheric pressure, which is associated with weather changes. A falling barometer may indicate an approaching storm, while a rising barometer suggests improvement in weather conditions.

3) Industrial Applications: Liquid barometers are used in industrial settings where precise pressure measurements are needed for specific processes or equipment.

Q# 15 Why does the atmospheric pressure vary with height?

Ans: The atmospheric pressure depends upon number of air particles (Density) .

As we go high in the atmosphere, the density of the air becomes low. Due to this reason, atmospheric pressure decreases as we go high.

Q# 16 What does it mean when the atmospheric pressure at place fall suddenly?

Ans: A sudden fall in atmospheric pressure often followed by a storm, rain and typhoon to occur in few hours time,

Q# 17 What changes are expected in weather if the barometer reading shows a sudden increase?

Ans: A sudden increase in atmospheric pressure means that it will soon followed by decrease in the atmospheric pressure indicating Poor weather ahead.

Q# 18 How we indicate weather using atmospheric pressure?

Ans: On a hot day, air above the Earth becomes hot and expands. This causes a fall of atmospheric pressure in that region.

On the other hand, during cold chilly nights, air above the Earth cools down. This causes an increase in atmospheric pressure.

Q# 19 Write applications of atmospheric pressure?

1) DRINKING BY STRAW:

The drinking through straw is possible by lowering the pressure in the mouth below atmospheric pressure. The action of sucking increases the volume of lungs, thereby reducing the air pressure in the lungs and the mouth. The atmospheric pressure acting on the surface of the liquid will then be greater than the pressure in the mouth, thus forcing the liquid to rise up the straw into the mouth.

2) **DRAWING LIQUID BY SYRINGE:**

We can draw liquid up the syringe, the piston of the syringe is drawn back upwards. This decreases the pressure within the cylinder. Atmospheric pressure acting on the surface of the liquid drives the liquid into the cylinder through the nozzle of the syringe.

Q# 20 Why it is difficult to cook food at high altitudes?

Ans: As altitude increases and atmospheric pressure decreases, the boiling point of water decreases. To compensate for the lower boiling point of water, the cooking time must be increased. Turning up the heat will not help cook food

Q. 1: Derive a relation for pressure in liquids?

Ans: Consider a surface of area A in a liquid at a depth h as shown by shaded region in figure. The length of the cylinder of liquid over this surface will be h. The force acting on this surface will be the weight w of the liquid above this surface. If p is the density of the liquid and m is mass of liquid above the surface, then

$$m = \rho \times V \quad \text{---------(i)}$$

$$A = l \times w$$

$$V = l \times w \times h$$

$$V = A \times h \quad \text{---------(ii)}$$

Put value of V in eq.(i)

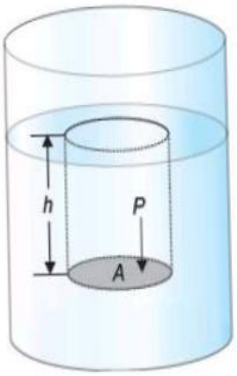
$$m = \rho \times A \times h$$

$$F = w = mg$$

$$= Ah\rho g$$

$$P = \frac{F}{A}$$

$$= \frac{Ah\rho g}{A}$$



∴ Liquid pressure at depth h = P = ρgh

Above expression shows that liquid pressure depends on three factors:

- Density of liquid (ρ)
- Depth of liquid (h)
- Gravitational acceleration (g)

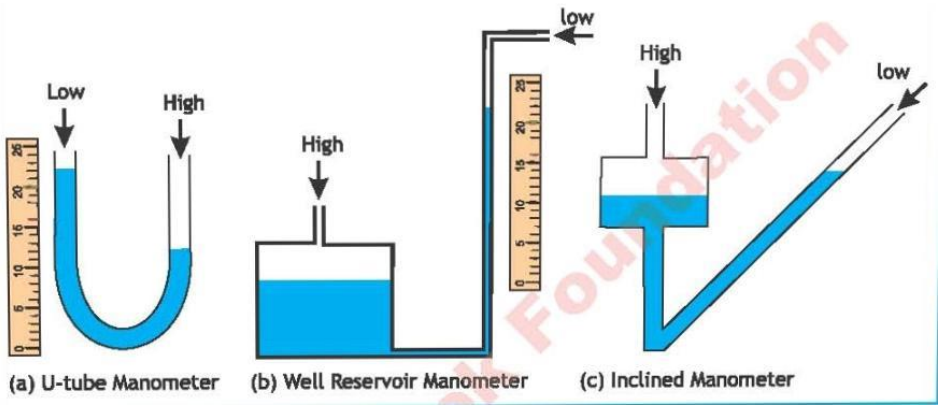
Q# what is manometer?

Ans: Manometer can be defined as a device that is used to measure the pressure in a fluid using fluid dynamics. The fluid can be a gas or a liquid**.**

Formula:

$$P=\rho gh$$

Diagram:



Working:

The working principle of a manometer is that one end is connected to a seal-tight gas to measure the source of pressure. Whereas, its other end is left open to the atmospheric pressure of the earth. If the pressure present in it is greater than 1 atm then the fluid present in the column will be forced down by that pressure. However, it will cause an increase in equal amounts in the present column.

Q# Write applications of Manometer?

Ans: It is used to measure the pressure of the fluids using mechanical properties of fluids.

- It is also used to measure vacuum.
- It is also used to measure the flow of the fluid.
- It is used to measure the filter pressure drop of the fluids.

• It is also used for meter calibrations.

• It is used to measure leak testing.

• It is also used to measure the liquid level present in a tank.

Q# Write difference b/w Manometer and Barometer?

Ans: Manometer:

- It is a device that is used to measure the pressure of the fluid but that of a liquid concerning the earth's atmospheric pressure.
- It comes only in one basic design for all its types
- These are filled with mercury or any heavy liquid material but in some cases, they can be filled with a lighter liquid material

  Barometer
- It is a device that is used to measure fluid pressure but that of air as it can differ with distance when it's below or above sea level
- It comes in different forms
- In all its cases, these are only filled with mercury or any heavy liquid material

Q# State Pascal's principle?

Ans: An external pressure applied to an enclosed fluid is transmitted unchanged to every point within the fluid.

Example:

When you blow up a balloon, the pressure inside the balloon goes up. This pressure spreads out evenly in all directions. The force from the pressure pushes outward and goes straight across the surface of the balloon, making it get bigger.

Q# Why deep-sea divers need specialized Suits?

Ans: As you dive deeper underwater, the pressure increases due to the weight of the water above. The force exerted by this pressure is perpendicular to the surface of your body.

Q# Explain the Working of Hydraulic lift?

Ans: **Hydraulic press:** Hydraulic press is a machine which works on Pascal's law.

Construction: Hydraulic Press consists of two cylinders of different cross sectional area as shown in the given figure. These both cylinder are fitted with pistons of cross section area 'a' and 'A'

Working : The object to be compressed or lift up is placed over the piston of large cross-sectional area A.

Pressure on small piston

The force (F_1) applied on the piston of small cross-sectional area a. The pressure (P_1) produced by small piston is transmitted equally to the large piston and a force F_2 acts on A which is much larger than F_1

Pressure on piston of small area a is given by

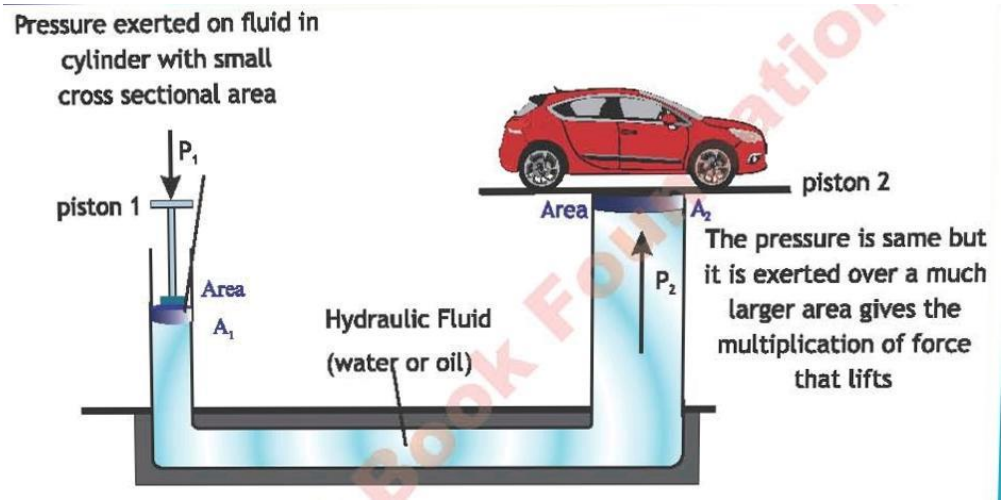
$$P_1 = \frac{f}{a} \text{---------- (1)}$$

Apply Pascal's law, the pressure on large piston of area A will be the same as on small piston. $P = \frac{F}{A}$ ---------- (2)

Comparing equations (1) and (2), we get

$$F = \frac{f}{a}A$$

that acts on the larger piston is greater than the force F_1 acting on the smaller piston.



Q: How braking system of cars works?

Ans: The operation of hydraulic car brake system as shown in figure 5.20 is based on Pascal's principle, in the brake system:

A. Brake Pedal (Force Input): When we press the brake pedal, it exerts force on the master cylinder's piston.

B. Master Cylinder (Pressure Increase): The force on the piston increases the pressure in the brake fluid.

C.Brake Lines (Pressure Transmission). The increased pressure is transmitted equally through the brake fluid in the brake to all wheels.

D.Brake Calipers: At each wheel, the pressure acts on brake calipers or wheel cylinders, applying force to brake pads.

Conceptual Questions

Q# 1 While walking on trampoline. Do you feel more pressure when you stand still or jump up and down? Why does pressure change with movement?

Ans: we feel more pressure on the trampoline when you jump up and down compared to when you stand still.

Reason:

This is because jumping introduces dynamic forces that are greater than your static weight due to rapid acceleration and deceleration, resulting in increased pressure on the trampoline during impact phases.

$$P=F/A$$

Q#2 How does the shape of a thumb pin help it penetrate surfaces easily?

Ans: The shape of a thumb pin, typically with a sharp, pointed tip, helps it penetrate surfaces easily because the small area of the tip concentrates the force applied, allowing it to exert a higher pressure on the surface.

$$P=F/A$$

This high pressure overcomes the resistance of the surface materials, such as paper or cork board, making it easier for the pin to pierce and secure into place.

Q# 3. If you blow up a balloon and then tie it closed, why does it stay inflated even though you stop blowing? How does pressure play a role here?

Ans: The inflated balloon stays inflated because the pressure of the air inside the balloon is higher than the atmospheric pressure outside This higher internal pressure pushes against the elastic walls of the balloon, keeping it expanded and sealed even after you stop blowing.

Q# 4Why an airtight layer of a space suit is designed to maintain a constant pressure around the astronaut?

Ans: An airtight layer of a space suit maintains a constant pressure around the astronaut to protect against the vacuum of space. This pressure ensures that the astronaut's body can function normally without the harmful effects of exposure to low pressure environments, such as decompression sickness or tissue damage.

Q# 5 If a liquid has density twice the density of mercury, what will be height of liquid column in barometer?

Ans $\rho_{liquid} = 2\rho_{Hg}$

Pressure in case of liquid

$$P = \rho_{liquid}\, g\, H_{liquid} \quad \text{.....(1)}$$

Pressure in case of Hg

$$P = \rho_{hg}\, g H_{hg} \quad \text{.....(2)}$$

Comparing equation 1 and 2 we get

$$\rho_{liquid}\, g\, H_{liquid} = \rho_{hg}\, g H_{hg}$$

$$H_{liquid} = \frac{height\ of\ mercury}{2}$$

Thus the height of the column of liquid is half of the height of the mercury

column.

Q#6 Why we wouldn't be able to sip water with a straw on the moon?

Ans: We wouldn't be able to sip water with a straw on the moon because there is no atmospheric pressure. On Earth, when you suck on the straw, you reduce the air pressure inside it, allowing atmospheric pressure to push the water up the straw. On the moon, the lack of atmospheric pressure means there is no force to push the water up the straw when you suck making it impossible to sip water this way.

Q#7 How are we able to break a metal wire by bending it repeatedly?

Ans: We are able to break a metal wire by bending (producing strain) it repeatedly because repeatedly bending a metal wire causes microcracks to form and grow. These microcracks weaken the wire over time through a process called fatigue. Eventually, the wire can no longer support the stress, and it breaks at the point of greatest weakness.

Q#8 A spring, having spring constant k when loaded with mass m', is cut into two equal parts One of the parts is loaded with the same mass m again. What will be its spring constant now?

$$F = kx$$

$$k = \frac{F}{x}$$

$$k = \frac{mg}{x}$$

$$k' = \frac{mg}{x'}$$

$$k' = \frac{mg}{\frac{x}{2}}$$

$$k' = \frac{2mg}{x}$$

k'= 2k

The new spring constant will be doubled.

Q# 9 Why do static fluids always exert a force perpendicular to the surface?

Ans: Static fluids always exert a force perpendicular to the surface because fluid molecules are in random motion and distribute pressure equally in all directions. When these molecules collide with surface, a they exert a force normal (perpendicular) to that surface. This perpendicular force distribution ensures stability and prevents any preferential direction of pressure, which would otherwise cause the fluid to move or flow.

Q#10 How can a small car lifter lifts load heavier than itself?

Ans: A small car lifter lift a load heavier than can itself by using hydraulic principles, where a small force applied to a smaller piston creates pressure in a fluid, which is then transferred to a larger piston with greater surface area, enabling it to lift heavier loads.