

Chapter 5

Pressure and Deformation in Solids

CHAPTER 5	1
SHORT QUESTIONS	1
LONG QUESTION	5
SHORT QUESTIONS (TOPIC WISE)	10
EXTRA LONG QUESTIONS (TOPIC WISE)	15
MCQS BASED ON ELASTICITY, PRESSURE, AND RELATED TOPICS	18

Short Questions

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

Answer:

You feel more pressure when you stand still because your entire weight is concentrated on a smaller area, increasing pressure.

Pressure changes with movement because jumping creates dynamic forces, and when landing, the force exerted on the trampoline is higher due to momentum.

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

Answer:

The sharp pointed end of a thumb pin has a very small surface area, which concentrates the applied force, increasing the pressure. This high pressure allows the pin to easily penetrate surfaces.

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?

Answer:

The balloon stays inflated because the air inside creates pressure against the inner walls of the balloon. This internal pressure balances the atmospheric pressure outside, preventing the balloon from deflating as long as it is sealed.

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

Answer:

The airtight layer maintains constant pressure to protect astronauts from the vacuum of

space. Without this, the lack of atmospheric pressure in space would cause bodily fluids to vaporize, leading to serious harm.

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

Answer:

The height of the liquid column will be half the height of a mercury column because pressure is given by $P = h \cdot \rho \cdot g$. For the same pressure, if the density (ρ) doubles, the height (h) must halve.

Example: If mercury's column height is 760 mm, the new liquid's column height will be 380 mm.

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

Answer:

We wouldn't be able to sip water on the moon because there is no atmospheric pressure. On Earth, atmospheric pressure pushes the liquid up the straw when we create a vacuum by sucking. In the absence of atmospheric pressure, this mechanism doesn't work.

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

Answer:

When a metal wire is bent repeatedly, the internal structure of the metal undergoes strain. This repeated bending causes:

1. **Fatigue in the Material:** The constant deformation weakens the bonds between metal particles.
2. **Work Hardening:** The metal becomes brittle due to continuous stress, making it easier to break.
3. **Localized Weakening:** The bending concentrates stress at specific points, eventually causing the wire to fracture.

Example: Breaking a thin metal wire, like a paper clip, after bending it multiple times.

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?

Answer:

When a spring is cut into two equal parts, the spring constant of each part doubles.

1. **Original Spring Constant:** k
2. **Spring Constant of Each Part:** $k' = 2k$

Explanation:

The spring constant depends on the length of the spring. When the length is halved, the stiffness increases because the shorter spring resists deformation more effectively.

Calculation:

For a spring with $k = 100 \text{ N/m}$, cutting it into two parts results in $k' = 2 \times 100 = 200 \text{ N/m}$.

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

Answer:

Static fluids exert force perpendicular to surfaces because of the **isotropic nature** of pressure in fluids. This means:

1. **Equal Pressure in All Directions:** The pressure in a static fluid is transmitted equally in all directions, ensuring no net force in any specific direction except perpendicular to the surface.
2. **Normal Force:** The molecules of the fluid exert normal force due to collisions with the surface.

Example:

- In a water tank, the walls experience pressure from water acting perpendicularly at every point.

10. How can a small car lifter lift a load heavier than itself?

Answer:

A small car lifter can lift a heavier load due to **Pascal's Law**, which states that pressure applied to a confined fluid is transmitted equally in all directions.

Working Principle:

1. **Small Force, Larger Area:**
 - The lifter uses a small piston to apply force over a smaller area.
 - This creates a uniform pressure in the fluid.
 - The larger piston (with a larger area) generates a greater lifting force.

Formula:

$$F_2 = F_1 \cdot \frac{A_2}{A_1}$$

Where:

- F_1 = Force applied,
- A_1 = Area of smaller piston,
- F_2 = Force generated,

Long Question

1. Define elasticity and elastic limit. Show that a force may produce change in size and shape of solids.

Answer:

Elasticity:

Elasticity is the property of a material by which it can return to its original shape and size after the removal of deforming forces. For example, a rubber band stretches when pulled but regains its shape once released.

Elastic Limit:

The elastic limit is the maximum amount of deformation a material can withstand while still returning to its original shape once the force is removed. If the force exceeds this limit, the material undergoes permanent deformation.

How force produces changes in solids:

When a force is applied to a solid, it can compress, stretch, or bend the material. The extent of deformation depends on the force's magnitude and the material's elasticity. For example, applying a force to a spring causes it to elongate or compress, and when the force is removed, it returns to its original shape (within its elastic limit).

2. What is Hooke's law? Illustrate its applications. Also, define and calculate spring constant.

Answer:

Hooke's Law:

Hooke's law states that the extension or compression of an elastic object (e.g., a spring) is directly proportional to the applied force, provided the elastic limit is not exceeded.

Mathematically:

$$F = kx$$

Where:

- F is the applied force,
- k is the spring constant,
- x is the extension or compression.

Applications of Hooke's Law:

1. Designing springs for mechanical systems like car suspensions.
2. Measuring forces using spring balances.
3. Engineering structures such as bridges and towers to withstand loads.

Spring Constant:

The spring constant (k) is a measure of a spring's stiffness. It is calculated as:

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

For example, if a spring extends by 0.02 m under a force of 10 N, the spring constant is:

$$k = \frac{10}{0.02} = 500 \text{ N/m}$$

3. Draw and explain force-extension graph for elastic solids.

Answer:

The force-extension graph for an elastic solid consists of three regions:

1. **Proportionality Region:**

In this region, the extension is proportional to the applied force. The graph is a straight line, obeying Hooke's law.

2. **Elastic Limit:**

Beyond this point, the material stops obeying Hooke's law, but it can still return to its original shape after removing the force.

3. **Plastic Region:**

After the elastic limit, the material undergoes permanent deformation and does not return to its original shape.

4. **Fracture Point:**

If the force is increased further, the material breaks or fractures.

4. Define and explain pressure. What is the effect of area on pressure acting on a surface?

Answer:

Pressure:

Pressure is defined as the force acting per unit area. Mathematically:

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

Where:

- P is pressure,
- F is the force,
- A is the area.

Effect of Area on Pressure:

Pressure is inversely proportional to the area. If the force is applied over a smaller area, the pressure increases. Conversely, if the area is larger, the pressure decreases. For example:

- A knife with a sharp edge applies more pressure and cuts better because its area is small.

- Snowshoes prevent sinking into snow by spreading the force over a larger area.

5. Explain the term atmospheric pressure along with its units. How is atmospheric pressure measured with a liquid barometer? Explain its construction and applications.

Answer:

Atmospheric Pressure:

Atmospheric pressure is the pressure exerted by the weight of the Earth's atmosphere on a surface. At sea level, it is approximately $101,325 \text{ Pa}$ ($101,325 \text{ Pa}$ (Pascal)).

Units of Atmospheric Pressure:

1. Pascal (Pa)
2. Bar ($1 \text{ bar} = 10^5 \text{ Pa}$)
3. mmHg ($1 \text{ atm} = 760 \text{ mmHg}$)

Measuring with a Liquid Barometer:

A barometer consists of a long glass tube filled with mercury, inverted into a mercury reservoir. Atmospheric pressure pushes on the mercury in the reservoir, causing it to rise in the tube. The height of mercury in the tube indicates the atmospheric pressure.

Applications:

1. Weather forecasting.
2. Measuring altitude in aviation.
3. Scientific experiments.

6. Explain with examples how atmospheric pressure varies with altitude. What kind of weather change is indicated by variation in atmospheric pressure? What are different applications of atmospheric pressure?

Answer:

Variation with Altitude:

Atmospheric pressure decreases as altitude increases because the density of air reduces with height. For example:

- At sea level: Atmospheric pressure is $101,325 \text{ Pa}$.
- On a mountain: Atmospheric pressure is much lower.

Weather Changes:

1. **Low Pressure:** Indicates storms, rainfall, or windy weather.
2. **High Pressure:** Indicates clear and calm weather.

Applications:

1. Designing aircraft cabins to withstand low pressure at high altitudes.
2. Using pressure cookers for faster cooking by increasing pressure.
3. Blood pressure monitors for healthcare.

7. Show that liquid in a container exerts pressure equal to $P = \rho g h$. What is the effect of depth on pressure of liquid?

Answer:

Liquid Pressure Formula:

The pressure exerted by a liquid column is given by:

$$P = \rho g h$$

Where:

- ρ is the density of the liquid,
- g is the gravitational acceleration,
- h is the depth of the liquid.

Derivation:

Pressure is the force per unit area, and the force is due to the weight of the liquid:

$$F = \text{Weight} = m \cdot g = (\rho V)g = (\rho A h)g$$

$$P = \frac{F}{A} = \frac{(\rho A h)g}{A} = \rho g h$$

Effect of Depth:

As depth increases, pressure increases because the weight of the liquid above increases. For example:

- Divers experience higher pressure as they go deeper underwater.

8. State Pascal's law. Describe the working principle of hydraulic lift using Pascal's law. What do you mean by force multiplier?

Answer:

Pascal's Law:

Pascal's law states that when pressure is applied to a confined fluid, it is transmitted equally in all directions throughout the fluid.

Hydraulic Lift Working Principle:

1. A small force is applied to a smaller piston, increasing pressure in the fluid.
2. This pressure is transmitted to a larger piston, producing a larger force to lift heavy objects.

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3. Since pressure remains constant ($P = F/AP = F/AP = F/A$), a smaller area requires less force to generate the same pressure as a larger area.

Force Multiplier:

A hydraulic lift acts as a force multiplier by amplifying the input force. For example:

- Using a small force to lift a car by applying pressure through hydraulic fluid.

Short Questions (Topic Wise)

5.1 Elasticity

1. Define elasticity and give examples from daily life.

Answer:

Elasticity is the property of a material to regain its original shape and size after being deformed when the applied force is removed.

Examples:

1. Stretching a rubber band.
 2. Compression and release of a spring.
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2. What is the elastic limit? Why is it important?

Answer:

The elastic limit is the maximum extent to which a material can be deformed without permanently losing its shape.

Importance:

1. Beyond this limit, the material undergoes plastic deformation.
 2. It determines the safe range for material usage.
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3. Differentiate between elastic and plastic deformation.

Answer:

- **Elastic Deformation:** Temporary deformation; material returns to its original shape.
 - **Plastic Deformation:** Permanent deformation; material does not return to its original shape.
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4. Explain Hooke's Law with its mathematical expression.

Answer:

Hooke's Law states that the extension of an elastic object is directly proportional to the applied force within the elastic limit.

Formula: $F = kx$

Where:

- F = Force,
 - k = Spring constant,
 - x = Extension.
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5.2 Pressure

1. Define pressure and write its formula.

Answer:

Pressure is the force applied per unit area on a surface.

Formula: $P = \frac{F}{A}$ or $F = PA$

Where:

- P = Pressure,
- F = Force,
- A = Area.

2. How does pressure vary with area?

Answer:

Pressure is inversely proportional to area. A smaller area results in higher pressure.

Example: A sharp knife cuts better because its small surface area increases pressure.

3. Why do pointed heels exert more pressure than flat shoes?

Answer:

Pointed heels have a smaller contact area, which increases the pressure exerted on the ground compared to flat shoes.

4. Explain how pressure is applied in hydraulic systems.

Answer:

Hydraulic systems use fluid pressure to transmit force. According to Pascal's Principle, pressure applied to a confined fluid is transmitted equally throughout the fluid.

5.3 Atmospheric Pressure

1. What is atmospheric pressure, and how is it measured?

Answer:

Atmospheric pressure is the pressure exerted by the weight of the atmosphere on the Earth's surface. It is measured using a barometer.

2. Why is atmospheric pressure lower at higher altitudes?

Answer:

At higher altitudes, the density of air decreases, reducing the weight of the atmosphere and, hence, the pressure.

3. How does atmospheric pressure affect weather conditions?

Answer:

Low pressure often leads to storms and rain, while high pressure is associated with clear and stable weather.

4. Explain why we don't feel atmospheric pressure acting on our body.

Answer:

Our body exerts an equal internal pressure, balancing the atmospheric pressure, so we don't feel its effects.

5.4 Liquid Pressure

1. What is liquid pressure, and how is it calculated?

Answer:

Liquid pressure is the pressure exerted by a liquid due to its weight.

Formula: $P = \rho gh$

Where:

- ρ = Density of the liquid,
 - g = Gravitational acceleration,
 - h = Depth of the liquid.
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2. How does liquid pressure vary with depth?

Answer:

Liquid pressure increases with depth because the weight of the liquid above increases.

3. Why do dams have thick walls at the bottom?

Answer:

Dams are built thicker at the bottom to withstand the high pressure exerted by the water at greater depths.

4. Explain the importance of liquid pressure in hydraulic systems.

Answer:

Hydraulic systems rely on liquid pressure to transfer and amplify forces, enabling heavy lifting with minimal effort.

5.5 Manometer

1. What is a manometer, and what is its purpose?

Answer:

A manometer is a device used to measure the pressure of liquids or gases.

2. How does a U-tube manometer work?

Answer:

A U-tube manometer measures pressure by comparing the liquid levels in its two arms, which change based on the applied pressure.

3. Why is mercury commonly used in manometers?

Answer:

Mercury is used because of its high density and low vapor pressure, making it ideal for precise pressure measurements.

4. Differentiate between absolute pressure and gauge pressure.

Answer:

- **Absolute Pressure:** Total pressure, including atmospheric pressure.
- **Gauge Pressure:** Pressure measured relative to atmospheric pressure.

5.6 Pascal's Principle

1. State Pascal's Principle and write its formula.

Answer:

Pascal's Principle states that pressure applied to a confined fluid is transmitted equally in all directions.

Formula: $P = \frac{F}{A}$ or $F_1/A_1 = F_2/A_2$

2. Explain the working principle of a hydraulic lift using Pascal's Principle.

Answer:

In a hydraulic lift, a small force applied on a small piston generates a larger force on a larger piston due to the equal transmission of pressure in the fluid.

3. What is meant by "force multiplier" in hydraulic systems?

Answer:

A force multiplier amplifies the input force using Pascal's Principle by applying the same pressure over a larger area.

4. List practical applications of Pascal's Principle.

Answer:

1. Hydraulic brakes.
2. Hydraulic jacks.
3. Car lifts in garages.
4. Presses used in manufacturing.

Extera Long Questions (Topic Wise)

1. Elasticity

Answer:

Elasticity:

Elasticity is the property of a material that allows it to regain its original shape and size after the removal of an external force causing deformation.

Elastic Limit:

The elastic limit is the maximum extent to which a material can be stretched or compressed without undergoing permanent deformation. If the force exceeds this limit, the material will not return to its original state.

Significance in Daily Life:

Elasticity is important in designing objects that need to endure stretching or compression while returning to their original shape, such as rubber bands, springs, and shock absorbers.

Examples:

- **High Elasticity:** Rubber, steel, and springs.
- **Low Elasticity:** Clay and dough.

2. Pressure

Answer:

Definition of Pressure:

Pressure is defined as the force exerted per unit area of a surface. Mathematically:

$$P = \frac{F}{A} \quad \text{or} \quad F = PA$$

Where:

- P is pressure,
- F is the force,
- A is the area.

Factors Affecting Pressure:

1. **Force:** Pressure increases with an increase in applied force.
2. **Area:** Pressure decreases if the area over which the force is applied increases.

Applications in Daily Life:

1. **Engineering:** Designing dams to withstand water pressure.
 2. **Healthcare:** Measuring blood pressure using a sphygmomanometer.
 3. **Tools:** Sharp knives create high pressure for cutting.
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3. Atmospheric Pressure

Answer:

Definition of Atmospheric Pressure:

Atmospheric pressure is the force exerted by the weight of the atmosphere per unit area on a surface. At sea level, it is approximately 101,325 Pa.

Variation with Altitude:

Atmospheric pressure decreases as altitude increases because the density of air is lower at higher altitudes. For example, mountain climbers experience lower atmospheric pressure, which can cause breathing difficulties.

Importance of Atmospheric Pressure:

1. It helps in weather forecasting by identifying high and low-pressure areas.
2. It is used in aviation to calculate altitudes.
3. It is crucial for the working of barometers and vacuum pumps.

4. Liquid Pressure

Answer:

Formula for Liquid Pressure:

The pressure exerted by a liquid column is given by:

$$P = \rho gh$$

Where:

- P is liquid pressure,
- ρ is the density of the liquid,
- g is the acceleration due to gravity,
- h is the depth of the liquid.

Factors Affecting Liquid Pressure:

1. **Depth (h):** Pressure increases with depth.
2. **Density (ρ):** Liquids with higher density exert more pressure.

Examples and Applications:

1. Dams are built thicker at the base to withstand high liquid pressure at greater depths.
2. Submarines are designed to endure the high pressure of deep water.
3. Liquid pressure is used in hydraulic systems for lifting heavy objects.

5. Pascal's Principle

Answer:

Pascal's Principle:

Pascal's principle states that when a force is applied to a confined fluid, the pressure is transmitted equally in all directions throughout the fluid.

Working Principle of a Hydraulic Lift:

1. A small force is applied on a smaller piston, creating pressure in the fluid.
2. This pressure is transmitted to a larger piston, which lifts a heavy load.
3. Since pressure remains constant ($P = F/AP = F/AP = F/A$), the larger piston produces a greater force due to its larger area.

Force Multiplier:

A hydraulic system acts as a force multiplier by amplifying the input force. For example, a hydraulic lift enables a small force to lift a heavy car in a garage.

Applications of Pascal's Principle:

1. Hydraulic brakes in vehicles.
2. Hydraulic jacks for lifting heavy loads.
3. Machinery in industries for pressing and molding.

MCQs Based on Elasticity, Pressure, and Related Topics

1. What is the elastic limit?

- a) The maximum stress a material can endure without permanent deformation. b) The point at which a material fractures. c) The limit where the material stops deforming. d) None of the above

Answer: a) The maximum stress a material can endure without permanent deformation.

2. Which of the following materials is highly elastic?

- a) Rubber b) Plastic c) Iron d) Glass

Answer: a) Rubber

3. Hooke's law is valid up to:

- a) Breaking point b) Elastic limit c) Yield point d) None of the above

Answer: b) Elastic limit

4. Elasticity is the property of a material to:

- a) Resist changes in shape b) Return to its original shape after deformation c) Break under stress d) Retain its new shape

Answer: b) Return to its original shape after deformation

5. Pressure is defined as:

- a) Force per unit area b) Area per unit force c) Mass per unit area d) Energy per unit volume

Answer: a) Force per unit area

6. Pressure increases when:

- a) Force decreases b) Area increases c) Force increases and area decreases d) None of the above

Answer: c) Force increases and area decreases

7. The SI unit of pressure is:

- a) Pascal b) Joule c) Newton d) Bar

Answer: a) Pascal

8. Which of the following applications is based on pressure?

- a) Hydraulic brakes b) Pulley systems c) Gears d) Levers

Answer: a) Hydraulic brakes

9. Atmospheric pressure is measured using:

- a) Thermometer b) Barometer c) Manometer d) Hygrometer

Answer: b) Barometer

10. Atmospheric pressure decreases with:

- a) Increasing altitude b) Decreasing altitude c) Increasing temperature d) Increasing volume

Answer: a) Increasing altitude

11. The unit commonly used to measure atmospheric pressure is:

a) mmHg b) kg/m^2 c) m/s^2 d) Kelvin

Answer: a) mmHg

12. What causes atmospheric pressure?

a) The weight of the air b) The rotation of the Earth c) The movement of wind d) Changes in temperature

Answer: a) The weight of the air

13. Liquid pressure depends on:

a) Depth of the liquid b) Density of the liquid c) Gravitational force d) All of the above

Answer: d) All of the above

14. The formula for liquid pressure is:

a) $P = gh$ b) $P = \rho gh$ c) $P = mg$ d) $P = v/h$

Answer: b) $P = \rho gh$

15. Pressure at greater depths in a liquid is:

a) Lower b) Higher c) Equal d) Independent of depth

Answer: b) Higher

16. Which of the following is a practical application of liquid pressure?

a) Water supply systems b) Steam engines c) Electric circuits d) Wind turbines

Answer: a) Water supply systems

17. A manometer is used to measure:

a) Pressure b) Temperature c) Humidity d) Density

Answer: a) Pressure

18. Which liquid is commonly used in a manometer?

a) Water b) Mercury c) Alcohol d) Oil

Answer: b) Mercury

19. The difference in liquid levels in a manometer indicates:

a) Temperature b) Pressure difference c) Density d) Volume

Answer: b) Pressure difference

20. Manometers work on the principle of:

a) Pascal's law b) Conservation of energy c) Gravitational potential d) Hooke's law

Answer: a) Pascal's law

21. Pascal's Principle states that:

- a) Pressure in a confined fluid is transmitted equally in all directions
- b) Pressure increases with force
- c) Pressure decreases with area
- d) Pressure depends on depth

Answer: a) Pressure in a confined fluid is transmitted equally in all directions

22. Which device operates on Pascal's Principle?

- a) Hydraulic lift
- b) Pulley system
- c) Inclined plane
- d) Spring scale

Answer: a) Hydraulic lift

23. Pascal's Principle is used in:

- a) Braking systems
- b) Electric motors
- c) Nuclear reactors
- d) Solar panels

Answer: a) Braking systems

24. Force multipliers in hydraulic systems work because of:

- a) Pascal's Principle
- b) Conservation of momentum
- c) Newton's Second Law
- d) Hooke's Law

Answer: a) Pascal's Principle