# Chapter: 05
## *Pressure and Deformation in Solids*

### Short Response 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?**
When you jump on a trampoline, the pressure you feel changes as you move. Pressure is defined as force per unit area. When you jump, your weight (force) is concentrated on the trampoline's surface for a short period of time, increasing the pressure beneath you. While standing still, the pressure is more evenly distributed. The trampoline compresses more when you jump due to the increase in force, thus causing a change in pressure.

**2. How does the shape of a thumb pin help it penetrate surfaces easily?**
A thumb pin has a sharp, pointed end, which decreases the surface area of the pin's tip. This small surface area allows the force applied to the pin to be concentrated in a smaller area, increasing the pressure at the tip. According to the principle that pressure increases with smaller areas, this helps the pin penetrate surfaces more easily.

**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?**
When you blow up a balloon, the air inside the balloon exerts pressure on the inner walls, and this pressure is counteracted by the external atmospheric pressure. Once you tie the balloon, the air inside maintains a higher pressure than the air outside, which causes the balloon to stay inflated. The internal pressure is balanced by the external pressure, allowing the balloon to retain its shape.

**4. Why an inner airtight layer of a space suit is designed to maintain a constant pressure around the astronaut?**
The airtight layer in a space suit ensures that the pressure inside the suit is maintained at a constant level. In the vacuum of space, there is no atmospheric pressure to exert force on the astronaut's body. The suit provides a controlled internal pressure, preventing bodily fluids from boiling and ensuring the astronaut's body functions properly in the absence of external pressure.

**5. If a liquid has density twice the density of mercury, what will be the height of the liquid column in a barometer?**
The height of a liquid column in a barometer is inversely proportional to the density of the liquid. If a liquid has twice the density of mercury, the height of the column would be halved. Since mercury in a barometer typically has a height of 760 mm, the height of the column of this denser liquid would be 380 mm.

**6. Why we wouldn't be able to sip water with a straw on the moon?**
On the moon, there is no atmosphere, meaning there is no atmospheric pressure to push



 

the liquid up the straw. When you drink with a straw on Earth, the atmospheric pressure pushes the liquid into your mouth when you reduce the pressure inside the straw. In the moon's vacuum, no external pressure exists to force the liquid upward.

**7. How are we able to break a metal wire by bending it repeatedly?**
When a metal wire is bent repeatedly, it undergoes elastic deformation until the metal reaches its elastic limit. Repeated bending causes the material to undergo plastic deformation, where the internal structure of the metal becomes damaged. Over time, the metal's internal bonds weaken, and it breaks after reaching its breaking point due to the accumulation of stress at the points of bending.

**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?**
When a spring is cut into two equal parts, the spring constant of each part will double. This is because the spring constant is inversely proportional to the length of the spring. By halving the length, the spring constant doubles, and thus the new spring constant of the cut spring will be 2k.

**9. Why do static fluids always exert a force perpendicular to the surface?**
Static fluids exert pressure in all directions. However, because the force is exerted uniformly in all directions, the force applied by the fluid on any surface is always perpendicular to that surface. This is a result of Pascal's Principle, where the pressure applied to the fluid is transmitted equally in all directions, ensuring the force is normal to the surface.

**10. How can a small car lifter lift a load heavier than itself?**
A small car lifter can lift a heavier load by applying Pascal's Principle, which states that when pressure is applied to a confined fluid, it is transmitted equally throughout the fluid. In the car lifter, a small force applied to a small piston is transferred to a larger piston, amplifying the force. The large piston can then lift a heavier load than the small piston can apply, providing the necessary mechanical advantage.

---

## Long Response Questions

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

**Answer:**
**Elasticity:**
Elasticity is the ability of a material to return to its original shape and size after the deforming force is removed. For example, a stretched rubber band or a compressed spring will return to its initial shape once the force is no longer applied.



 

**Elastic Limit:**
The elastic limit is the maximum extent to which a material can be deformed elastically, beyond which it will not return to its original shape. Once the force applied exceeds the elastic limit, the material enters the plastic region and deforms permanently.

**Force and Deformation in Solids:**
When a force is applied to a solid, it deforms by stretching, compressing, or bending. Within the elastic limit, the material will return to its original shape once the force is removed. If the force is increased beyond the elastic limit, the material experiences permanent deformation. This change in size or shape is due to the internal forces that resist deformation.

---

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

**Answer:**
**Hooke's Law:**
Hooke's Law states that within the elastic limit, the force needed to extend or compress a spring is directly proportional to the displacement or extension of the spring. This can be mathematically expressed as:

$$F = k \times x$$

Where:

- $F$ is the force applied (in Newtons, N)
- $k$ is the spring constant (in N/m)
- $x$ is the extension or compression (in meters, m)

**Applications of Hooke's Law:**

1. **Mechanical Watches:** The balance wheel in a mechanical watch operates based on Hooke's law, where the spring constant governs the regular oscillation of the wheel, ensuring accurate timekeeping.
2. **Spring Scales:** Hooke’s law is used in spring scales to measure weight or force. The displacement of the spring indicates the amount of force applied.
3. **Seismic Equipment:** In seismology, Hooke’s law is applied to measure earth tremors using spring-based devices that detect minute changes in displacement.

**Spring Constant Calculation:**
The spring constant $k$ can be calculated using Hooke's law formula:



 

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

For example, if a force of 490 N stretches a spring by 0.1 m, the spring constant would be:

$$k = \frac{490}{0.1} = 4900 \text{ N/m}$$

---

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

**Answer:**
**Force-Extension Graph:**

The force-extension graph for elastic solids typically shows a straight line at the beginning, representing Hooke's law, and then a curve when the material reaches its elastic limit. The graph is divided into two regions:

1. **Elastic Region:**
   In this region, the graph is linear, and the force is directly proportional to the extension. The material behaves according to Hooke's law, meaning it will return to its original shape when the force is removed.

2. **Plastic Region:**
   Once the elastic limit is exceeded, the graph begins to curve, and the material enters the plastic region. In this region, the material will not return to its original shape, indicating permanent deformation.

**Diagram:**

- The x-axis represents the extension (in meters), and the y-axis represents the force (in Newtons).
- The initial straight-line portion corresponds to the elastic region, and the curved portion represents the plastic region.

---

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

**Answer:**
**Pressure Definition:**
Pressure is defined as the force applied per unit area. It is a scalar quantity and is represented by the formula:

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



 

Where:

- $P$ is pressure (in pascals, Pa)
- $F$ is the force applied (in Newtons, N)
- $A$ is the area over which the force is distributed (in square meters, $m^2$)

**Effect of Area on Pressure:**
The pressure acting on a surface is inversely proportional to the area over which the force is applied. If the force is constant, a smaller area will result in a higher pressure. Conversely, a larger area reduces the pressure. This principle explains why sharp objects (like needles) can easily penetrate surfaces (high pressure), while blunt objects (like a broad knife) require more force to achieve the same result (low pressure).

---

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

**Answer:**
**Atmospheric Pressure:**
Atmospheric pressure is the force exerted by the weight of the air on the surface of objects on Earth. It is caused by the continuous movement and collisions of air molecules. At sea level, the average atmospheric pressure is 1013.25 hPa (hectopascals), which is equivalent to 1 atmosphere (atm).

**Units of Atmospheric Pressure:**
The SI unit of pressure is the pascal (Pa), where:

$$1\ \text{Pa} = 1\ \text{N/m}^2$$

1 atmosphere (atm) is equal to 101325 Pa or 1013.25 hPa.

**Measurement with Liquid Barometer:**
A liquid barometer works on the principle of hydrostatic equilibrium. It consists of a tube filled with mercury, which is inverted into a dish filled with mercury. The atmospheric pressure on the surface of the mercury in the dish supports the mercury column in the tube. The height of the mercury column gives the value of the atmospheric pressure. At sea level, this height is approximately 760 mm.

**Construction and Applications:**

- **Construction:** A liquid barometer consists of a glass tube, an open end submerged in mercury, and the other end closed.

 

- **Applications:** Liquid barometers are used in weather forecasting, altitude measurement, and in scientific experiments to measure atmospheric pressure. They help in predicting weather patterns by detecting pressure changes.

---

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

**Answer:**
**Atmospheric Pressure and Altitude:**
Atmospheric pressure decreases with altitude. As we rise above sea level, the air becomes thinner, meaning fewer air molecules exert pressure on the surface. For example, at the top of Mount Everest, the atmospheric pressure is around 33 kPa, while at sea level, it is 101.325 kPa.

**Weather Changes Indicated by Atmospheric Pressure:**

- **Low Pressure:** Areas of low pressure are generally associated with stormy weather and precipitation. A falling barometer reading typically indicates the approach of a storm.
- **High Pressure:** Areas of high pressure generally indicate clear, calm weather with less chance of rain. A rising barometer indicates fair weather.

**Applications of Atmospheric Pressure:**

- **Weather Forecasting:** Variations in atmospheric pressure help meteorologists predict changes in weather.
- **Altitude Measurement:** Barometers can be used to measure altitude, as atmospheric pressure decreases with height.
- **Suction Devices:** Devices like suction cups use atmospheric pressure to stick to surfaces by reducing the air inside the cup, creating a pressure difference.

---

**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:**
**Derivation:**
To derive the formula for pressure exerted by a liquid, consider a column of liquid of density $\rho$, height $h$, and base area $A$. The weight of the liquid column is given by:

$$F = \text{Weight} = mg = \rho \times A \times h \times g$$



 

Where:

- $m$ is the mass of the liquid,
- $g$ is the acceleration due to gravity,
- $\rho$ is the density of the liquid,
- $A$ is the cross-sectional area of the column.

Pressure is defined as force per unit area, so:

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

**Effect of Depth on Pressure:**
From the equation $P = \rho g h$, we can see that pressure increases linearly with the depth of the liquid. The deeper the liquid, the greater the weight of the liquid above, which increases the pressure at that depth. This explains why the pressure at the bottom of the ocean is much greater than at the surface.

---

**8. State Pascal's law. Describe 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 any change in pressure applied to an enclosed fluid is transmitted undiminished to all parts of the fluid. This means that pressure applied at any point in a confined fluid is equally distributed throughout the fluid.

**Working Principle of Hydraulic Lift:**
A hydraulic lift uses Pascal's law to amplify force. Consider a system with two pistons of different areas connected by a pipe filled with hydraulic fluid. When a small force is applied to the small piston, the pressure in the fluid increases, and this pressure is transmitted equally to the larger piston. The larger piston then exerts a much larger force on the load.

**Force Multiplier:**
A hydraulic system acts as a force multiplier because the force applied to the smaller piston is magnified on the larger piston. The force multiplication factor depends on the ratio of the areas of the two pistons. If the area of the large piston is 100 times larger than the small piston, the force applied on the small piston is multiplied by 100 on the large piston.

---



 