CLASS 9 • PHYSICS

UNIT 6
Mechanical Properties of Matter

Elasticity, Density, Pressure & Pascal's Law — Complete Notes

Definitions | Explanations | Solved Examples
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UNIT 6: Mechanical Properties of Matter

Long Questions & Answers

1 Define deforming force, elasticity and elastic limit.

Deforming Force: An external force that changes an object's size or shape.
Elasticity: The property of a material to regain its original size and shape after removal of the deforming force. Examples: a stretched spring, a rubber band, a tennis ball hit by a racket.
Elastic Limit: The limit up to which a material is elastic. Beyond it, deformation becomes permanent.

2 What is Hooke's Law? Give three applications.

Statement: Within the elastic limit, the extension/compression x of a spring is directly proportional to the applied force F.
$F = kx$ where k is the spring constant (N/m), a measure of stiffness.
Applications:

- Spring scales / weighing balances
- Balance wheel of mechanical clocks
- Galvanometer's hair spring

3 Define and explain the concept of density.

Density: Mass per unit volume: $\rho = m/V$. SI unit: kg/m^3 (also g/cm^3).
Important for architects/engineers in estimating strength needed for foundations and supporting structures.

4 Define and explain the term pressure.

Pressure: Force exerted normally per unit area: $P = F/A$. SI unit: pascal (Pa) = N/m^2.
Examples: Chopper blades and thumb pins are sharp (small area, high pressure); walking on pebbles hurts (reduced contact area); elephants have large flat feet (large area, lower pressure).

5 Derive an expression for pressure of a liquid in a container. What factors does it depend on?

Consider area A at depth h; liquid column volume $V = Ah$, mass $m = \rho Ah$, force $F = mg = \rho Ahg$.

$P = F/A = \rho gh$

Pressure depends on the **depth** and **density** of the liquid, and acts perpendicular to the surface.

6 Define and explain atmospheric pressure.

The pressure exerted by the layer of air (atmosphere) on the Earth's surface and everything on it, due to constant molecular collisions. It acts equally in all directions.

Standard value at sea level: 1.013×10^5 Pa. It extends to about 100 km and decreases with altitude.

7 Explain how atmospheric pressure changes with height, and how it indicates weather.

Like liquid pressure, atmospheric pressure is maximum at sea level and decreases with altitude (≈55 kPa at 5 km, ≈1 kPa at 30 km), since air density decreases with height.

Weather link: Lower density (less water vapour, cloudy regions) means lower pressure — meteorologists use falling pressure to predict approaching rain.

8 Describe the working of a simple mercury barometer.

A glass tube (~1 m), closed at one end, filled with mercury and inverted in a mercury dish (vacuum above the column).

Pressure at the mercury surface in the dish equals atmospheric pressure, which equals ρgh of the column. At sea level this height is 760 mm (using $P=1.013\times10^5$ Pa, $\rho=13.6\times10^3$ kg/m³).

9 How can pressure be measured using a manometer?

A U-shaped tube containing mercury, open at both ends, with equal mercury level initially. Connecting one arm to a gas source: if the mercury is lower in the short (connected) arm, the gas pressure is greater than atmospheric; if higher, it is less than atmospheric.

10 State Pascal's Law and give daily-life evidence.

Pascal's Law: Pressure applied at one point in an enclosed fluid is transmitted equally to all parts of the fluid without loss.

Evidence: A flask with side tubes shows equal water rise everywhere; an inflating balloon expands uniformly; a motorbike tyre inflates evenly from a single valve.

11 Describe the hydraulic press and hydraulic brakes as applications of Pascal's Law.

Hydraulic Press: Two connected cylinders (areas A1, A2) filled with incompressible liquid. Pressure from a small force F1 on the smaller piston ($P1=F1/A1$) is transmitted equally, producing a larger force $F2 = F1\times(A2/A1)$ on the larger piston — a force multiplier. Used to compress cotton bales and lift cars.

Hydraulic Brakes: Pressing the brake pedal pushes fluid from a small master cylinder, transmitting equal pressure to larger cylinders at each wheel, pressing brake pads against discs/drums to slow the vehicle.

Solved Examples

Example 6.1 — Density of an iron block

L=3cm,B=2cm,T=2cm, m=94 g

$V = 12\ cm^3$, $\rho = 94/12 = 7.8\ g/cm^3$

$\rho = 7800\ kg/m^3$

Example 6.2 — Pressure of a mercury column

$\rho=13.6\times10^3$, h=0.76 m, g=10

$P = \rho gh = 1.034\times10^5$ Pa

Example 6.3 — Water pressure at ground floor

h = 2+20 = 22 m, $\rho=1000$, g=10

$P = \rho gh = 2.2\times10^5$ Pa

Example 6.4 — Hydraulic press lifting force

r1=0.025m, r2=0.125m, F1=160N

A1=1.96e-3, A2=0.0491 m^2

P=8.16e4 Pa, $F2 = P\times A2 = 4000$ N

Numerical Problems

1. Spring stretched 20 mm by 40 N load. Find k, and load for 16 mm extension.

$K = F/x = 40/0.02 = 2000$ N/m

$F = K\Delta x = 2000\times0.016 = 32$ N

2. 5 L of milk has mass 4.5 kg. Find density.

$\rho = m/V = 4.5/(5\times10^{-3}) = 900\ kg/m^3$

3. Solid of mass 60 g raises water level from 40 to 44 cm³. Find density.

$V = 4\ cm^3 = 4\times10^{-6}\ m^3$

$\rho = 0.060/4\times10^{-6} = 15000\ kg/m^3$

4. Wood block density 8×10³ kg/m³, volume 60 cm³. Find mass.

$m = \rho V = 8000\times60\times10^{-6} = 0.48\ kg$

5. Brick 5×10×20 cm, mass 5 kg. Find max & min pressure on a surface.

$F = mg = 50\ N$

$P_{max} = F/A_{min}(0.005) = 10000\ Pa$

$P_{min} = F/A_{max}(0.02) = 2500\ Pa$

6. Hydraulic brake: A1=5cm², F1=500N. Find pressure and force on A2=20cm².

$P = F1/A1 = 1.0\times10^6\ Pa$

$F2 = P\times A2 = 2000\ N$

7. Deep-sea diver at 10 m; sea water density 1030 kg/m³. Find pressure.

$P = \rho gh = 1030\times10\times10 = 1.03\times10^5\ Pa$

8. Hydraulic press: A1=10cm², A2=200cm², lift a 4000 N car. Find F1.

$F1 = (A1/A2)\times F2 = (10/200)\times4000 = 200\ N$

Short Questions

1. Why do heavy animals like elephants have a large foot area?
P=F/A — a large foot area spreads their weight, reducing the pressure exerted on the ground.

2. Why is it painful to walk barefoot on pebbles?
The small contact area with pebbles causes a high pressure (P=F/A) at each point, causing pain.

3. State Pascal's law and give one application.
Pressure applied at one point in an enclosed fluid is transmitted equally throughout. Application: hydraulic brakes.

4. Why is the cutting edge of a knife made very thin?

P=F/A — a thin edge gives a very small area, producing very high pressure for the same force, allowing an easy cut.

5. Why are water tanks built at the highest point of a house?
P=ρgh — a higher tank increases pressure at the outlets below, ensuring good water flow throughout the house.

6. Why are dams made thicker at the bottom?
Liquid pressure P=ρgh increases with depth, so the dam wall must be thicker at the bottom to withstand the greater pressure there.

7. Why can't water be used instead of mercury in a barometer?
Water's much lower density would require an impractically tall column (~10.3 m) to balance atmospheric pressure, versus 0.76 m for mercury.

Multiple Choice Questions

1. Wire diameter halved; extension becomes:

(a) one half (b) double (c) one fourth (d) four times

Answer: (d)

2. Wires of same material, same load — which elongates most?

(a) L1m,d1mm (b) L2m,d2mm (c) L3m,d3mm (d) L4m,d0.5mm

Answer: (d)

3. Two plates (2 & 3 m^2) at same depth — ratio of pressures:

(a) 1:1 (b) √2:√3 (c) 2:3 (d) 4:9

Answer: (a)

4. Pressure at a point in liquid is proportional to:

(a) density (b) depth (c) g (d) all of the above

Answer: (d)

5. Pressure applied to an enclosed fluid is:

(a) increased & applied to every part (b) diminished & transmitted to walls
(c) increased proportionally then transmitted
(d) transmitted unchanged to every part & walls

Answer: (d)

6. Hydraulic press is based on:

(a) Hooke's law (b) Pascal's law (c) conservation of energy
(d) conservation of momentum

Answer: (b)

7. Compressed spring possesses which form of energy?

(a) kinetic (b) potential (c) internal (d) heat

Answer: (b)

8. Most elastic material:

(a) Rubber (b) Wood (c) Glass (d) Steel

Answer: (d)

9. Hooke's law holds good up to:

(a) Proportional limit (b) Yield limit (c) Elastic limit (d) Plastic limit

Answer: (c)

10. 2 kg mass displaces a spring 5 cm. Spring constant:

(a) 400 N/m (b) 40 N/m (c) 4 N/m (d) 4000 N/m

Answer: (a)

11. Materials not regaining shape after deformation are called:

(a) Elastic (b) Plastic (c) Rigid (d) Hooke's materials

Answer: (b)

12. SI unit of pressure:

(a) Pascal (b) Newton (c) Zero (d) Infinite

Answer: (a)

13. Divers wear special suits to protect from:

(a) Low pressure (b) High pressure (c) Low temp (d) High temp

Answer: (b)

14. Atmospheric pressure commonly measured using:

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

Answer: (b)

15. Pressure of liquid in a container increases with:

(a) Base (b) Volume (c) Depth (d) Mass

Answer: (c)