Properties of Matter

📖 Chapter PN02 · NDA Class 11–12 Level

🎯 NDA Level : High Priority

Properties of Matter examines *how materials respond to forces* (elasticity), *how fluids exert pressure and create buoyancy*, and the subtle surface behaviours of liquids — *surface tension* and *viscosity*. These topics appear regularly in NDA and are highly conceptual, often testing real-world applications over heavy calculation. Average students who understand the *why* behind each principle score well here.

📌 **What to expect in NDA (based on 2022–2025 pattern):**
(1) Stress, strain, and Young's modulus — definitions and formula-based questions;
(2) Hooke's law — spring constant, elastic limit, proportionality;
(3) Pressure in fluids, Pascal's law — hydraulic machines, dams;
(4) Archimedes' principle — buoyancy, floating/sinking conditions;
(5) Barometer — atmospheric pressure, height calculations;
(6) Surface tension — cohesion/adhesion, capillary rise formula;
(7) Viscosity — Stokes' law, terminal velocity of a falling sphere.

Topics at a Glance

① Elasticity
Stress, strain, Hooke's law, Young's modulus, elastic limit

② Pressure & Buoyancy
Fluid pressure, Pascal's law, Archimedes' principle, barometer

③ Surface Tension
Cohesion, adhesion, angle of contact, capillary action

④ Viscosity
Fluid friction, Stokes' law, terminal velocity, Poiseuille's law

1. Elasticity

1.1

Stress & Strain

How materials deform under applied forces — the language of elasticity

Elasticity is the property of a body by which it regains its original shape and size after the removal of a deforming force. A material is said to be *elastic* if it fully recovers, and *plastic* if it does not. Steel is more elastic than rubber — it deforms less for the same stress.

STRESS, STRAIN & ELASTIC MODULI

Stress = Force / Area (unit: N/m^2 = Pascal, Pa)

$\sigma = F / A$ Dimension: $ML^{-1}T^{-2}$

Strain = Change in dimension / Original dimension (dimensionless)

$\varepsilon = \Delta L / L$ (longitudinal strain)

Young's Modulus (Y):

Y = Longitudinal Stress / Longitudinal Strain

$Y = (F/A) / (\Delta L/L) = FL / (A \cdot \Delta L)$ unit: N/m^2 (Pa)

Bulk Modulus (K):

$K = -\Delta P / (\Delta V/V)$ (for volume change under pressure)

Compressibility = 1/K

Modulus of Rigidity (G):

G = Shear stress / Shear strain = τ / φ

Y is highest for steel ($\approx 2\times10^{11}$ Pa), moderate for copper, low for rubber ($\approx 10^5$ Pa). **Steel is more elastic than rubber** — counter-intuitive but correct! "Elastic" means it returns to original shape, not that it stretches more.

Types of Stress

- **Tensile/Compressive:** force along axis (pulls/pushes)
- **Shear stress:** force tangential to surface

Types of Strain

- **Longitudinal:** ΔL/L (change in length)
- **Volumetric:** ΔV/V (change in volume)
- **Shear strain:** angular deformation ϕ

- **Hydraulic stress:** equal pressure from all sides (volume change)
- Stress = internal restoring force / area

- Strain is always dimensionless (ratio)

1.2

Hooke's Law & Stress–Strain Curve

The linear elastic region — the foundation of material science

Hooke's Law: Within the elastic limit, stress is directly proportional to strain. This is the regime where materials behave like springs and return fully to their original shape.

HOOKE'S LAW & SPRING RELATIONS

Hooke's Law: Stress ∝ Strain → Stress = E × Strain

Spring form: $F = k \times x$ (k = spring constant, N/m)

(F = restoring force, x = extension)

Spring constant combinations:

Series: $1/k_{eff} = 1/k_1 + 1/k_2$ → k_{eff} < smallest k

Parallel: $k_{eff} = k_1 + k_2$ → k_{eff} > largest k

If a spring of constant k is cut into n equal parts:

Each part has spring constant = n × k (shorter spring → stiffer)

The elastic limit is the maximum stress within which Hooke's law holds. Beyond this, the material shows plastic deformation (permanent change). The yield point is where plastic deformation begins.

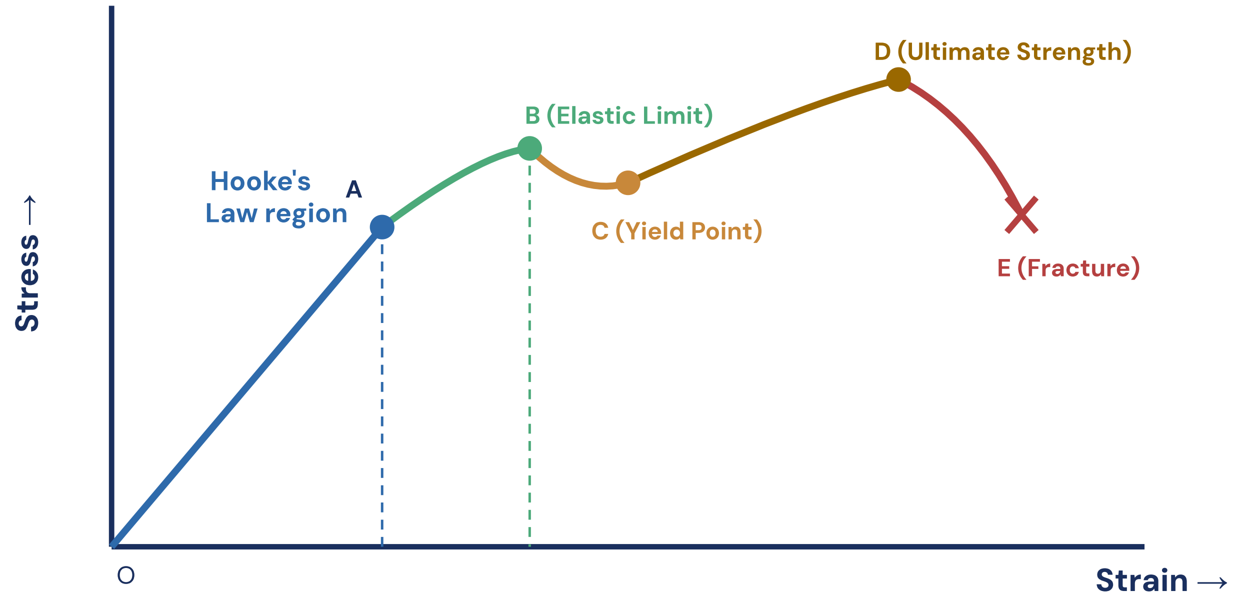

Fig. 1 — Stress–Strain curve for a ductile material (e.g., mild steel). OA = Hooke's law region; B = elastic limit; C = yield point; D = ultimate tensile strength; E = fracture point.

> ⚠ **NDA Exam Trap — Steel vs Rubber Elasticity:** Rubber stretches more for the same load — but rubber is *less elastic*. Elasticity is measured by how well a material *returns to original shape*, not how much it deforms. Steel has a higher Young's modulus (resists deformation more) and returns perfectly — hence **steel is more elastic than rubber**.

📝 TOPIC-WISE PYQ **Elasticity — NDA Pattern Questions**

Q1. The Young's modulus of a wire is Y. If the length and radius are both doubled, the Young's modulus becomes:

(a) Y/2 (b) 2Y (c) 4Y (d) Y

> **Answer: (d) Y**
> Young's modulus is an *intrinsic material property* — it does not depend on dimensions (length, radius, area). Changing dimensions changes the wire's behaviour but not Y of the material. Y remains **unchanged**.

Q2. Which of the following is most elastic?

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

Answer: (c) Steel
Elasticity is the ability to *return to original shape*. Steel has the highest Young's modulus (≈ 2×10^{11} Pa) and deforms least for given stress — it is the most elastic. Rubber deforms easily but is *least elastic* among these.

Q3. A spring of spring constant k is cut into 3 equal parts. The spring constant of each part is:

(a) k/3 (b) 3k (c) k (d) 9k

Answer: (b) 3k
Spring constant k ∝ 1/length. Cutting into 3 equal parts makes each part 1/3rd the length → spring constant = **3k** for each part. (Shorter spring = stiffer spring.)

🤔 TRICKY QUESTIONS **Elasticity — Conceptual Traps**

T1. Two wires A and B of the same material, same length, but wire B has double the radius. If the same force is applied, which wire stretches more?

Wire A stretches more.
$\Delta L = FL/(AY)$. Area $A \propto r^2$. Wire B has radius 2r → area = 4 times that of A. So $\Delta L_B = FL/(4A\cdot Y) = \Delta L_A/4$. Wire A (smaller cross-section) stretches **4 times more** than Wire B.

T2. A wire suspended from the ceiling breaks when a weight of 200 N is hung. How many such wires would be needed to support a weight of 1000 N safely (in parallel)?

At least 5 wires.
In parallel, total load capacity = n × load per wire = n × 200 N. For 1000 N: n = 1000/200 = **5 wires**. (Each wire bears equal share of load in parallel arrangement.)

2. Pressure & Buoyancy

2.1 Fluid Pressure & Pascal's Law

Pressure acts equally in all directions in a fluid at rest

A fluid (*liquid or gas*) at rest exerts pressure on all surfaces in contact with it. Pressure at a point depends only on the **depth** below the free surface, the **density** of the fluid, and g — not on the shape or size of the container.

⚡ FLUID PRESSURE FORMULAE

Pressure: $P = F/A$ (unit: Pascal = N/m^2)

Pressure at depth: $P = P_0 + \rho g h$

P_0 = atmospheric pressure ($\approx 1.013 \times 10^5$ Pa = 1 atm)

ρ = density of fluid (kg/m^3)

h = depth below free surface (m)

Gauge pressure: $P_{gauge} = P - P_0 = \rho g h$

(Pressure above atmospheric = what gauges read)

Pascal's Law: Pressure applied to enclosed fluid is transmitted equally and undiminished in all directions.

Hydraulic Machine: $F_1/A_1 = F_2/A_2 \rightarrow F_2 = F_1(A_2/A_1)$

(Mechanical advantage = A_2/A_1 — larger piston gives larger force)

Pascal's law is the basis of hydraulic lifts, hydraulic brakes, and hydraulic presses. A small force on a small area creates same pressure transmitted to large area, giving large output force.

📌 Atmospheric Pressure & Barometer

- 1 atm = 101,325 Pa $\approx 1.013 \times 10^5$ Pa
- Equivalent to 76 cm (760 mm) of mercury column
- Barometer: measures atmospheric pressure using Hg column

🔸 Pressure Key Facts

- Pressure is a *scalar* quantity
- Acts perpendicular to any surface in fluid
- Independent of shape/area of container
- Pressure same at same depth

- $P_{atm} = \rho_{Hg} \times g \times h = 13,600 \times 10 \times 0.76 \approx 10^5$ Pa
- At higher altitude: P_{atm} decreases, Hg column falls

regardless of path

- Interconnected vessels: liquid levels equal if same density

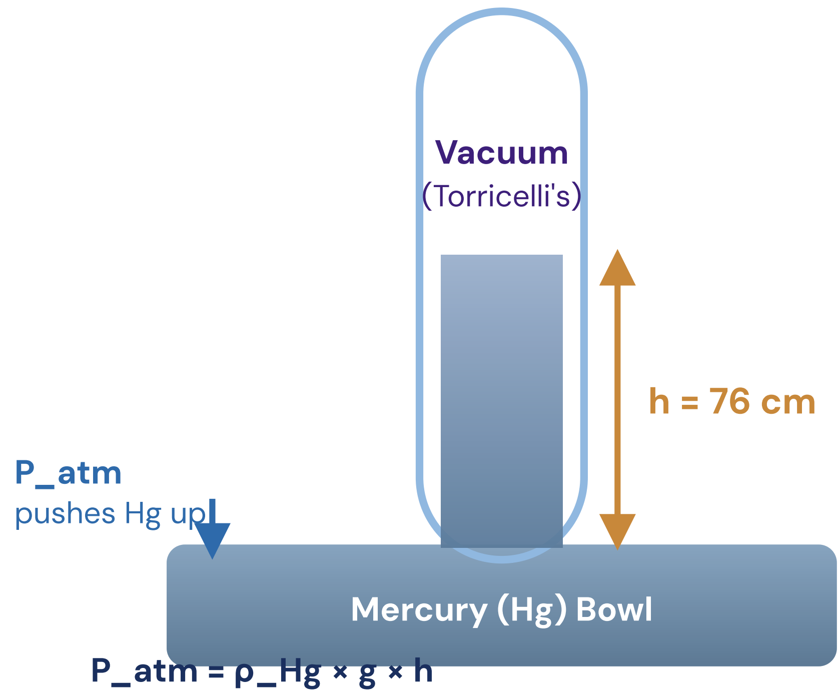

Fig. 2 — Fortin Barometer. Atmospheric pressure balances the weight of the mercury column. At sea level, h ≈ 76 cm Hg ≡ 1 atm.

2.2

Buoyancy & Archimedes' Principle

Why objects float, sink, or hover — and how submarines work

When an object is partly or fully immersed in a fluid, the fluid exerts an upward force on the object called the **buoyant force** or **upthrust**. This is explained by Archimedes' principle.

ARCHIMEDES' PRINCIPLE & BUOYANCY

Archimedes' Principle:

"A body immersed in a fluid experiences an upward buoyant force equal to the weight of the fluid displaced."

Buoyant Force: $F_B = \rho_{fluid} \times g \times V_{submerged}$

Conditions:

Float: ρ_object < ρ_fluid → F_B = Weight (partial immersion)

Sink: ρ_object > ρ_fluid → F_B < Weight

Hover: ρ_object = ρ_fluid → neutral buoyancy (submarines)

Apparent weight = True weight − Buoyant force

= mg − ρ_fluid × g × V_submerged

Relative Density = Weight in air / Loss of weight in water

= ρ_substance / ρ_water

The buoyant force acts at the **centre of buoyancy** (= centroid of displaced fluid). The weight acts at the centre of gravity. For stable floating, the metacentre must be above the centre of gravity.

📈 Float / Sink Conditions

- Wood floats in water: $\rho_{wood} < \rho_{water}$
- Iron sinks: $\rho_{iron} > \rho_{water}$
- Iron ship floats: effective density (ship + air) < ρ_{water}
- Hot air balloon: air inside less dense than outside air
- Submarine: adjusts buoyancy by filling/emptying ballast tanks

🚨 Common Applications

- Hydrometer: measures density of liquids using floating depth
- Lactometer: checks purity of milk
- Ice floats in water: ice is less dense than liquid water
- Object lighter in water: buoyant force reduces apparent weight
- Lakes don't boil over in winter: water density max at 4°C

📝 TOPIC-WISE PYQ

Pressure, Buoyancy & Archimedes — NDA Pattern Questions

Q1. An object weighs 60 N in air and 50 N when fully submerged in water. What is the buoyant force and volume of object? ($g = 10\ m/s^2$, $\rho\_water = 1000\ kg/m^3$)

(a) 10 N, 10^{-3} m³ (b) 5 N, 5×10^{-4} m³ (c) 10 N, 10^{-2} m³ (d) 20 N, 2×10^{-3} m³

Answer: (a) 10 N, 10^{-3} m³

Buoyant force = 60 − 50 = **10 N**. $F_B = \rho g V \rightarrow V = F_B/(\rho g)$ = 10/(1000×10) = **10^{-3} m³ = 1 litre**.

Q2. A hydraulic press has pistons of cross-sectional areas 10 cm² and 1000 cm². If 200 N is applied on the smaller piston, what force is exerted on the larger piston?

(a) 2 N (b) 2000 N (c) 20,000 N (d) 200 N

Answer: (c) 20,000 N

By Pascal's law: $F_2 = F_1 \times (A_2/A_1)$ = 200 × (1000/10) = **20,000 N**. Mechanical advantage = 100.

Q3. The pressure at the bottom of a lake 20 m deep is (g = 10 m/s², ρ_{water} = 1000 kg/m³, $P_0 = 10^5$ Pa):

(a) 10^5 Pa (b) 2×10^5 Pa (c) 3×10^5 Pa (d) 5×10^5 Pa

Answer: (c) 3×10^5 Pa

$P = P_0 + \rho g h = 10^5 + 1000\times10\times20 = 10^5 + 2\times10^5 =$ **3×10^5 Pa**.

😳 TRICKY QUESTIONS Pressure & Buoyancy — Exam Surprises

T1. A wooden block is floating in water with half its volume submerged. If the block is taken to a planet where g is double that of Earth, what fraction will now be submerged?

Still half — no change.

Floating condition: $\rho_{wood} \times V_{total} \times g = \rho_{water} \times V_{submerged} \times g$. The g cancels from both sides. So the fraction submerged = ρ_{wood}/ρ_{water} — which depends only on densities, not on g. **Half submerged on any planet.**

T2. When ice floating in a glass of water melts completely, does the water level rise, fall, or remain the same?

Water level stays the same.

Ice floats by displacing water equal to its own weight. When ice melts, it becomes liquid water of exactly the same mass — which occupies the same volume as was displaced. So the water level remains **unchanged**. (This is because ice floats entirely due to weight, and melted water fills exactly that displaced volume.)

3. Surface Tension

3.1 Cohesion, Adhesion & Surface Tension

The skin on water — why insects walk on water and droplets are round

Cohesion is the force of attraction between molecules of the *same substance*. **Adhesion** is the force between molecules of *different substances*. The interplay between cohesion and adhesion gives rise to surface tension and capillary action.

SURFACE TENSION & RELATED FORMULAE

Surface Tension (T): T = Force / Length (N/m)

T = Surface Energy / Area = E/A (J/m^2)

Excess pressure inside a curved surface:

Liquid drop (1 surface): P = 2T/r

Soap bubble (2 surfaces): P = 4T/r ← double the drop!

Air bubble in liquid: P = 2T/r

Capillary Rise:

h = 2T cosθ / (ρgr)

where θ = angle of contact, r = radius of tube

If θ < 90° (water-glass): liquid rises → cohesion < adhesion

If θ > 90° (mercury-glass): liquid falls → cohesion > adhesion

Effect of temperature on T:

T decreases as temperature increases

T = 0 at critical temperature

Surface tension is why water forms spherical drops (minimum surface area for given volume = sphere), why needle floats on water, and why soap bubbles are spherical.

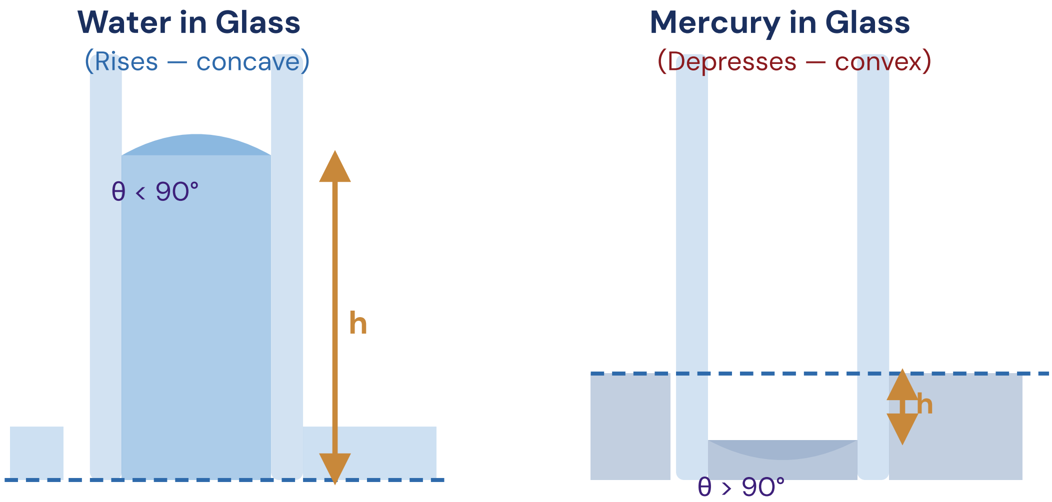

Fig. 3 — Capillary action. Left: Water (adhesion > cohesion) — concave meniscus, liquid rises. Right: Mercury (cohesion > adhesion) — convex meniscus, liquid depresses.

Angle of Contact

- $\theta < 90°$: liquid wets the solid (water-glass)
- $\theta > 90°$: liquid does not wet solid (mercury-glass)
- $\theta = 0°$: complete wetting (water on clean glass)
- $\theta = 90°$: liquid surface is flat at the tube wall
- Detergents reduce $\theta \rightarrow$ better wetting/cleaning

Real-Life Applications

- Water rises in plant roots: capillary action
- Blotting paper absorbs ink: capillary action
- Soap reduces surface tension: cleans better
- Insects walk on water: surface acts like elastic film
- Raindrops spherical: minimum surface area for volume

TOPIC-WISE PYQ **Surface Tension — NDA Pattern Questions**

Q1. Excess pressure inside a soap bubble of radius r and surface tension T is:

(a) T/r (b) 2T/r (c) 4T/r (d) T/(2r)

Answer: (c) 4T/r
A soap bubble has *two surfaces* (inner and outer film). Excess pressure = 2 × (2T/r) = **4T/r**. For a single surface (liquid drop or air bubble in liquid): P = 2T/r. The factor of 2 for soap bubble is a very common NDA exam point.

Q2. Water rises to height h in a capillary tube of radius r. If another capillary of radius 2r is used, the height of water rise will be:

(a) 2h (b) 4h (c) h/2 (d) h/4

Answer: (c) h/2
$h = 2T\cos\theta / (\rho g r)$. So $h \propto 1/r$. Doubling radius halves the height: h' = **h/2**. Narrower tube → higher rise.

Q3. Which of the following has the same dimensions as surface tension?

(a) Force (b) Energy per unit area (c) Pressure × volume (d) Power

Answer: (b) Energy per unit area
Surface tension T = F/L (MT^{-2}) = Energy/Area ($J/m^2 = MT^{-2}$). Both have the same dimension. This is why surface tension can also be defined as surface energy per unit area.

🤔 TRICKY QUESTIONS

Surface Tension — Think Carefully!

T1. Two soap bubbles of radii r_1 = 3 cm and r_2 = 6 cm coalesce. What is the radius of the resulting bubble, assuming no loss of gas and isothermal conditions?

Answer: $r = 3\sqrt{5} \approx 6.7$ cm
In isothermal coalescence, total surface energy is conserved: use $r^3 = r_1^3 + r_2^3$. $r^3 = 27 + 216 = 243$. $r = \sqrt[3]{243} \approx$ **6.24 cm**. (If pressure conservation is used: $P_1V_1 + P_2V_2 = PV \rightarrow (4T/r_1)(4\pi r_1^3/3) + \ldots \rightarrow r^2 = r_1^2 + r_2^2 \rightarrow r = \sqrt{(9+36)} = \sqrt{45} = 3\sqrt{5} \approx 6.7$ cm.) NDA typically uses $r^2 = r_1^2 + r_2^2$ form.

T2. Why does hot soup have a larger oil patch (spreading) on its surface compared to cold soup?

Surface tension decreases with temperature.
Hot soup → higher temperature → lower surface tension of water → oil spreads more on the weakened water surface. Cold soup → higher surface tension → oil stays in compact drops. This is why detergents (hot water) clean better — lower surface tension promotes spreading.

4. Viscosity

4.1 Viscosity, Stokes' Law & Terminal Velocity

Internal friction in fluids — why honey pours slowly and rain doesn't kill us

Viscosity is the property of a fluid by which it offers resistance to the relative motion of its layers. It is essentially *internal friction in fluids*. Liquids become less viscous on heating; gases become more viscous on heating — a key NDA distinction.

VISCOSITY & TERMINAL VELOCITY FORMULAE

Newton's Law of Viscosity:

$F = \eta \times A \times (dv/dx)$

η = Coefficient of viscosity   unit: Pa·s (poise in CGS; 1 Pa·s = 10 poise)

dv/dx = velocity gradient (rate of change of velocity with distance)

Stokes' Law:

$F_{drag} = 6\pi\eta rv$

(viscous drag on a sphere of radius r moving at velocity v in fluid of viscosity η)

Terminal Velocity:

Weight = Buoyancy + Stokes' drag

$v_T = 2r^2(\rho_{sphere} - \rho_{fluid}) \times g / (9\eta)$

$v_T \propto r^2$ (larger sphere → much higher terminal velocity)

$v_T \propto 1/\eta$ (less viscous fluid → higher terminal velocity)

Poiseuille's Law (flow in pipe):

$Q = \pi P r^4 / (8\eta L)$ (volume flow rate; r = pipe radius, L = length)

Terminal velocity is reached when net downward force (weight – buoyancy) equals viscous drag upward. At this point, **acceleration = 0 and velocity is constant** (terminal).

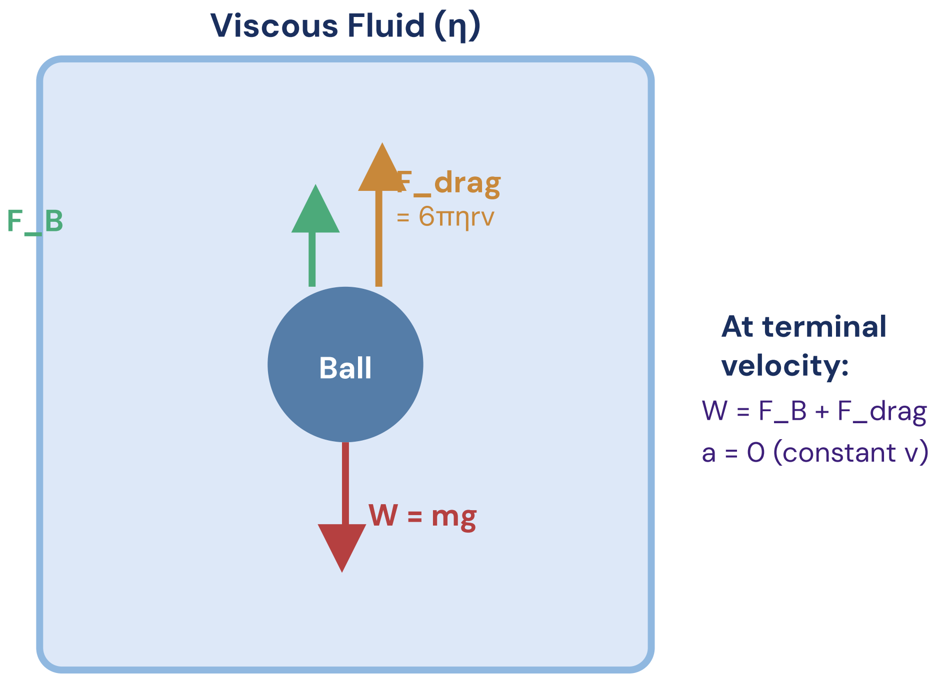

Fig. 4 — Forces on a sphere falling through a viscous fluid. At terminal velocity, Weight = Buoyant force + Stokes' drag. Net force = 0, acceleration = 0.

🕐 Viscosity vs Temperature

- **Liquids:** viscosity decreases with temperature (honey thins when heated)
- **Gases:** viscosity increases with temperature (gas molecules move faster, more collisions)
- This difference is a common NDA MCQ topic
- Oil in engines: too thick when cold, too thin when very hot

🚀 Terminal Velocity — Key Points

- $v_T \propto r^2$ — double radius → 4× terminal velocity
- $v_T \propto (\rho_{sphere} - \rho_{fluid})$ — less difference → lower v_T
- $v_T = 0$ when densities are equal (neutral buoyancy)
- Raindrops: terminal velocity ~ 9 m/s (otherwise fatal!)
- Parachute: large surface → high drag → low terminal v

💡 **Poiseuille's Law Insight:** Flow rate $Q \propto r^4$ — the fourth power of radius! Doubling the pipe radius increases flow 16 times. This is why a small blockage in a blood artery (reducing r) drastically reduces blood flow — critical in cardiovascular medicine. NDA occasionally tests this proportionality.

📝 TOPIC-WISE PYQ

Viscosity & Terminal Velocity — NDA Pattern Questions

Q1. A steel ball of radius r falls with terminal velocity v in a viscous liquid. If another ball of same material but radius 2r is dropped, its terminal velocity will be:

(a) v (b) 2v (c) 4v (d) v/4

Answer: (c) 4v
$v_T \propto r^2$. Doubling radius: $v_T \propto (2r)^2 = 4r^2$. So terminal velocity = **4v**. Same material means same density, same fluid means same η — only r changes.

Q2. The viscosity of a liquid on heating:

(a) Increases (b) Decreases (c) First increases then decreases (d) Does not change

Answer: (b) Decreases
On heating, intermolecular forces in liquids weaken → viscosity decreases. (For gases, viscosity increases with temperature — opposite behaviour.) A classic NDA distinction.

Q3. The unit of coefficient of viscosity in SI system is:

(a) N/m (b) N·s/m² (c) N·m (d) N·s/m

Answer: (b) N·s/m²
From $\eta = F / (A \times dv/dx) = N / (m^2 \times (m/s)/m) = N/(m^2 \cdot s^{-1})$ = **N·s/m² = Pa·s**. (Also called Poiseuille or decapoise in SI.)

🤔 TRICKY QUESTIONS **Viscosity & Fluids — Reasoning Traps**

T1. A body reaches terminal velocity in a viscous liquid. Is any force acting on it? Is it in equilibrium?

> **Forces act, but net force = 0. It is in dynamic equilibrium.**
> Three forces act: weight (down), buoyancy (up), Stokes' drag (up). At terminal velocity these balance exactly. Net force = 0 → acceleration = 0 → constant velocity. The body is in *dynamic* (not static) equilibrium — it is still moving, but at constant velocity.

T2. Why does blood flow more easily through wider arteries? By what power does flow rate depend on radius?

> **Flow rate $\propto r^4$ (Poiseuille's law).**
> $Q = \pi P r^4/(8\eta L)$. Even a small reduction in artery radius (due to plaque) drastically reduces blood flow — halving radius reduces flow to 1/16th. This is why arterial narrowing is medically dangerous. The r^4 dependence means radius has an enormous effect.

⚡ High-Yield Formula Sheet — PN02 Properties of Matter

🔸 Elasticity

- Stress = F/A (Pa = N/m²)
- Strain = ΔL/L (dimensionless)
- Young's modulus Y = (F/A)/(ΔL/L)
- Hooke's Law: F = kx (Spring)
- Springs in series: $1/k = 1/k_1 + 1/k_2$
- Springs parallel: $k = k_1 + k_2$

🌊 Fluid Pressure

- P = F/A; P at depth = $P_0 + \rho g h$
- Pascal's law: $F_2 = F_1(A_2/A_1)$
- Gauge pressure = $\rho g h$
- 1 atm = 10^5 Pa = 76 cm Hg
- Barometer: $P_{atm} = \rho_{Hg} \times g \times h$

🚴 Buoyancy

- $F_B = \rho_{fluid} \times g \times V_{submerged}$
- Float: $\rho_{obj} < \rho_{fluid}$
- Apparent wt = True wt − F_B
- Relative density = wt in air / loss in water

💧 Surface Tension

- $T = F/L = E/A$ (N/m or J/m²)
- Liquid drop: $P = 2T/r$
- Soap bubble: P = **4T/r**
- Capillary: $h = 2T\cos\theta/(\rho g r)$
- T decreases with temperature rise

🔫 Viscosity

- η unit = Pa·s (N·s/m²)
- Stokes' drag: $F = 6\pi\eta r v$
- Terminal velocity: $v_T = 2r^2(\rho-\rho_f)g/9\eta$
- $v_T \propto r^2$ (double r → 4× v_T)
- Liquid η: decreases with T; Gas η: increases with T

📌 Key Distinctions

- Steel more elastic than rubber ($Y_{steel} \gg Y_{rubber}$)
- Soap bubble: 4T/r; Drop: 2T/r (2 surfaces vs 1)
- Water: concave meniscus (rises); Hg: convex (falls)
- $h \propto 1/r$ — narrower tube, higher rise
- $Q \propto r^4$ — Poiseuille (radius most critical)

📌 **Dimensions to Remember:** Stress = $ML^{-1}T^{-2}$, Surface Tension = MT^{-2}, Viscosity = $ML^{-1}T^{-1}$, Young's Modulus = $ML^{-1}T^{-2}$, Pressure = $ML^{-1}T^{-2}$.

⚡ Quick Revision Booster — PN02 Properties of Matter

📌 Elasticity Must-Know

- Y is a material property — doesn't change with size/shape

🌊 Pressure & Pascal

- 1 atm = 76 cm Hg = 10^5 Pa (remember all three)
- Pressure at depth $P = P_0 + \rho g h$ (not just $\rho g h$!)

🚴 Buoyancy Rules

- Ice melts in water → level unchanged
- Floating fraction = $\rho_{object} / \rho_{fluid}$
- Fraction in water doesn't change on

- Steel > Rubber in elasticity (higher Y = more elastic)
- Spring cut to n parts: each part has k × n
- Series springs: k_eff < smallest k (weaker combined)
- Parallel springs: k_eff = $k_1 + k_2$ (stronger combined)

- Gauge pressure = P − P_0 = ρgh only
- Hydraulic press: large area → large force
- Altitude up → P_atm down → barometer Hg falls

changing g

- Apparent weight in fluid = wt − buoyancy
- Iron ship floats: hollow → low effective density

💧 Surface Tension

- Bubble: **4T/r**; Drop/Air bubble in liquid: **2T/r**
- h ∝ 1/r — narrower → higher capillary rise
- T decreases with rising temperature
- Cohesion > adhesion → liquid depresses (Hg)
- Detergents lower T → better cleaning & wetting

🔫 Viscosity Facts

- Liquid: η ↓ on heating; Gas: η ↑ on heating
- v_T ∝ r^2 (size matters enormously)
- Terminal vel: net force = 0, acceleration = 0
- Stokes' law: F = 6πηrv
- Poiseuille: Q ∝ r^4 (key for artery/pipe problems)

🚨 Critical Exam Traps

- Steel more elastic than rubber — NOT the other way
- Soap bubble: 4T/r (two surfaces) — NOT 2T/r
- Mercury in glass: falls (convex meniscus), not rises
- Floating in liquid: g cancels — ratio independent of g
- Viscosity of liquid ↓ with temp (opposite to gas)

📝 Mock Tests | 🎯 Subject Quizzes | ✈️ Telegram