FREE NOTES · NCERT + JEE/NEET LEVEL

Mechanical Properties of Fluids

Pressure, Pascal's law, buoyancy, continuity, Bernoulli, viscosity, Stokes' law, terminal velocity, surface tension aur capillarity. Har topic ke saath roz ki zindagi ke examples.

01 Pressure
02 Depth ke saath pressure
03 Pascal's law & hydraulic lift
04 Buoyancy (Archimedes' principle)
05 Streamline flow & continuity
06 Bernoulli's principle
07 Bernoulli ke applications
08 Viscosity
09 Stokes' law & terminal velocity
10 Surface tension
11 Drops, bubbles & capillarity
12 JEE Extra + Tricks
13 Solved numericals (g = 10 m/s²)
14 Common mistakes
15 Formula sheet
16 Practice questions
17 Quick revision: exam se pehle 5 minute

01 Pressure

Fluid = jo beh sake (liquid aur gas). Inki koi fixed shape nahi hoti.

$$P = F / A$$

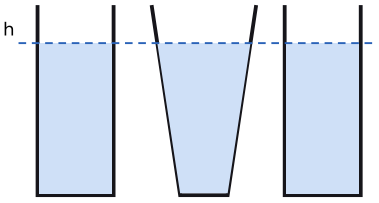
Normal force per unit area. Unit pascal (Pa) = N/m². Scalar. 1 atm = 1.013 × 10^5 Pa = 76 cm Hg. 1 bar = 10^5 Pa, 1 torr = 1 mm Hg.

Kam area pe zyada pressure: nukeeli keel aasaani se ghusti hai, camel ke chaude pair ret me nahi dhanste, ladki ki heel zameen pe nishaan chhodti hai.

02 Depth ke saath pressure

$$P = P_0 + \rho g h$$

P_0 = atmospheric pressure, h = depth. **Gauge pressure** = P − P_0 = ρgh (tyre gauge yahi padhta hai).



Teeno ke neeche pressure barabar

HYDROSTATIC PARADOX

Same depth pe pressure same, bartan ki shape ya kitna paani hai is pe depend nahi. Patla aur chauda bartan, same height tak bhara, neeche same pressure.

BAROMETER

Mercury ki column ka height = atmospheric pressure: $P_0 = \rho_{Hg} g h$, h ≈ 76 cm. Paani se karein toh ≈ 10.3 m chahiye.

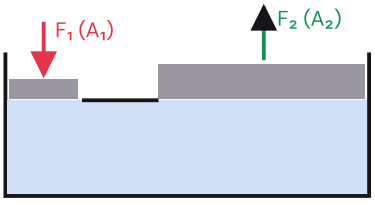
OPEN-TUBE MANOMETER

U-tube me levels ka fark h ⇒ gauge pressure = ρgh. Mercury/paani isme bharte hain.

03 Pascal's law & hydraulic lift

PASCAL'S LAW

Band (enclosed) fluid pe lagaya gaya pressure **har taraf aur har point pe barabar** pahunchta hai.



Chhota force, chhota piston ⇒ bada force, bada piston

HYDRAULIC LIFT / BRAKE

$$F_1/A_1 = F_2/A_2 \Rightarrow F_2 = F_1\,(A_2/A_1)$$

Force badhta hai par energy nahi: chhota piston zyada door chalta hai, $A_1d_1 = A_2d_2$. Car ke hydraulic brakes, dentist ki kursi, hydraulic press.

04 Buoyancy (Archimedes' principle)

$$\text{Upthrust (buoyant force)} = \rho_{\text{fluid}} \times V_{\text{doobi}} \times g$$

Body ke doobe hisse jitne fluid ka weight. Apparent weight = asli weight - upthrust.

Condition	Kya hoga
$\rho_{body} > \rho_{fluid}$	Doob jaayegi
$\rho_{body} = \rho_{fluid}$	Kahin bhi tair ke ruki rahegi
$\rho_{body} < \rho_{fluid}$	Tairegi; doobi fraction = ρ_{body}/ρ_{fluid}

Example: barf (0.9) paani (1.0) me 90% doobi rehti hai, isliye iceberg ka sirf 10% dikhta hai.

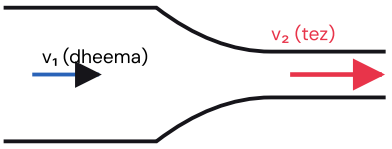
05 Streamline flow & continuity

Streamline (steady) flow: har point pe velocity time ke saath nahi badalti, particles ek hi raaste (streamline) pe chalte hain. Do streamlines kabhi nahi katati. Speed zyada ho toh **turbulent** flow (bhanwar).

EQUATION OF CONTINUITY

$$A_1 v_1 = A_2 v_2$$

Incompressible fluid ke liye. Volume flow rate (Av) har jagah same. Patli jagah pe tez, chaudi jagah pe dheema. Ye **mass conservation** hai.



Pipe patla ⇒ paani tez

Garden pipe ka munh ungli se dabao toh paani door jaata hai: area kam ⇒ speed zyada.

REYNOLDS NUMBER

$R_e = \rho v d/\eta$ (unitless). R_e < 1000: streamline. R_e > 2000: turbulent. Beech me unsteady.

06 Bernoulli's principle

STATEMENT

Streamline flow me, ek streamline ke har point pe:

$P + \frac{1}{2} \rho v^2 + \rho g h = \text{constant}$

Pressure energy + kinetic energy + potential energy (per unit volume) = constant. Ye **energy conservation** hai. Shart: non-viscous, incompressible, steady flow.

EK LINE ME

Same height pe: **jahan speed zyada, wahan pressure kam**.

07 Bernoulli ke applications

Application	Samjho
Torricelli's law (tanki ke chhed se paani)	$v = \sqrt{(2gh)}$, h = paani ki satah se chhed tak ki gehraai
Venturimeter	Pipe ke patle hisse me pressure kam; pressure ka fark naap ke flow speed nikaalte hain
Hawai jahaz ka lift	Pankh ke upar hawa tez ⇒ pressure kam ⇒ neeche se upar dhakka (dynamic lift)
Aandhi me chhat udna	Chhat ke upar tez hawa ⇒ upar pressure kam ⇒ andar ka zyada pressure chhat ko upar dhakelta
Spinning ball (Magnus effect)	Ghoomti ball ke ek taraf hawa tez ⇒ ball mud jaati (swing)
Sprayer / atomizer, Bunsen burner	Tez hawa se kam pressure ⇒ liquid ya gas kheench li jaati
Do trains / naav paas se guzrein	Beech me tez hawa/paani ⇒ kam pressure ⇒ ek doosre ki taraf kheenchti

TORRICELLI: PAANI KITNI DOOR GIREGA

Tanki ki height H, chhed upar se h neeche: $\text{range} = 2\sqrt{(h(H - h))}$, max jab h = H/2.

08 Viscosity

Fluid ki layers ke beech **friction jaisa** force jo relative motion ka virodh karta hai. Shahad zyada viscous, paani kam.

$$F = -\eta\, A\, (dv/dx)$$

η = coefficient of viscosity. Unit Pa·s (= poiseuille), CGS me poise (1 Pa·s = 10 poise). dv/dx = velocity gradient.

TEMPERATURE KA ASAR

Garam karne pe **liquid** ki viscosity **ghatti** (garam tel aasaani se behta), par **gas** ki viscosity **badhti**.

09 Stokes' law & terminal velocity

STOKES' LAW

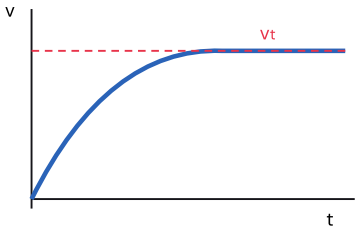
$$F = 6\pi \eta r v$$

Viscous fluid me chhoti gol body (radius r, speed v) pe drag force.

TERMINAL VELOCITY

$$v_t = 2 r^2 (\rho - \sigma) g / (9 \eta)$$

ρ = body ki density, σ = fluid ki. Jab weight = upthrust + drag, toh acceleration 0 aur speed constant. $v_t \propto r^2$.



Speed badhti hai phir v_t pe ruk jaati

Baarish ki boondein isi wajah se dheere girti hain (warna km upar se aati boond goli jaisi lagti). Badal ke chhote droplets ka v_t itna kam ki wo tairte dikhte hain. Parachute bhi isi idea pe.

TRICK

8 barabar boondein milke ek badi bane: radius 2 guna (volume 8 guna) ⇒ v_t 4 guna.

10 Surface tension

Liquid ki surface **khinchi hui jhilli** jaisi behave karti hai. Surface ke molecules ko andar ki taraf net kheench milti hai, isliye liquid apna surface area kam se kam rakhna chahta hai (isliye boondein gol hoti hain).

$$S = F / L = \text{Surface energy} / \text{Area}$$

Unit N/m = J/m². Area ΔA badhane me work = S × ΔA. Soap bubble ki **do surfaces** hoti hain, toh work = 2SΔA. Temperature badhe ⇒ S ghatta. Sabun/detergent milao ⇒ S ghatta.

Angle of contact θ	Liquid-solid	Example
θ < 90° (acute)	Liquid surface ko geela karta, meniscus concave	Paani-kaanch
θ > 90° (obtuse)	Geela nahi karta, meniscus convex	Mercury-kaanch, paani-wax/patta

11 Drops, bubbles & capillarity

Cheez	Andar ka extra pressure
Liquid drop	$2S/r$
Air bubble (liquid ke andar)	$2S/r$
Soap bubble (hawa me, 2 surfaces)	$4S/r$

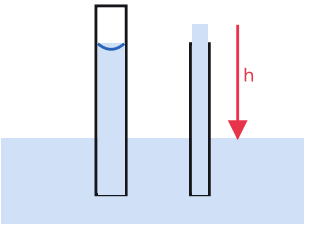
DHYAN DO

Chhoti bubble me pressure zyada. Do bubbles jod do toh hawa **chhoti se badi** me jaati hai.

CAPILLARY RISE

$$h = 2\,S\cos\theta\,/\,(\rho\,g\,r)$$

Patli nali me liquid chadhta ($\theta < 90°$) ya utarta (mercury, $\theta > 90°$). $h \propto 1/r$, isliye $hr = \text{constant}$.



Patli nali me paani zyada upar

Examples: lantern ki batti me tel chadhna, blotting paper syahi sokhna, paudhon me paani upar jaana (partially), towel paani sokhna.

Chhoti boondein milke badi: n boondein (radius r) milein toh badi ka radius $R = n^{(1/3)}\,r$, surface area ghatta ⇒ energy **nikalti** hai (garmi). Badi boond ko todo toh energy deni padti hai.

12 JEE Extra + Tricks

JEE LEVEL

- Torricelli: nikalne ki speed $v = \sqrt{(2gh)}$; chhed liquid column ki aadhi oonchaai pe ho to horizontal range max.
- Terminal velocity $v_t = 2r^2(\rho - \sigma)g/(9\eta) \propto r^2$.
- Capillary rise $h = 2T\cos\theta/(r\rho g)$; $h \cdot r$ = constant (Jurin); chhoti tube me liquid bahar nahi bahta (meniscus ka radius badal jaata).
- Excess pressure: liquid drop $2T/r$, soap bubble $4T/r$ (do surface), liquid me hawa ka bulbula $2T/r$.
- Soap bubble banane ka kaam = $T \times 8\pi r^2$ (do surface).
- Reynolds number $Re = \rho vD/\eta$: <1000 streamline, >2000 turbulent (lagbhag).

13 Solved numericals ($g = 10\ m/s^2$)

Q1. Hydraulic lift: chhota piston 10 cm², bada 1000 cm². 1000 kg ki car uthane ke liye force?
$F_1 = F_2 \times A_1/A_2 = 10^4 \times 10/1000 = 100$ N. **Ans: 100 N**

Q2. Swimming pool me 3 m gehraai pe total pressure? ($P_0 = 10^5$ Pa)
$P = 10^5 + 1000 \times 10 \times 3 = 1.3 \times 10^5$ Pa. **Ans: 1.3×10^5 Pa**

Q3. 2 cm radius wali pipe me paani 3 m/s se, aage 1 cm radius. Wahan speed?
$A \propto r^2 \Rightarrow v_2 = 3 \times 4 = 12$ m/s. **Ans: 12 m/s**

Q4. Tanki me paani ki satah se 5 m neeche chhed. Paani ki speed?
$v = \sqrt{(2gh)} = \sqrt{100} = 10$ m/s. **Ans: 10 m/s**

Q5. 2 mm radius ki steel ball ($\rho = 8000$) glycerine ($\sigma = 1300$, $\eta = 0.83$ Pa·s) me. Terminal velocity?
$v = 2 \times (2 \times 10^{-3})^2 \times 6700 \times 10/(9 \times 0.83) = 2 \times 4 \times 10^{-6} \times 67000/7.47 = 0.536/7.47 \approx 0.072$ m/s. **Ans: ≈ 7 cm/s**

Q6. 0.5 mm radius ki capillary, paani S = 0.07 N/m, θ = 0. Kitna chadhega?
$h = 2 \times 0.07/(1000 \times 10 \times 5 \times 10^{-4}) = 0.14/5 = 0.028$ m. **Ans: 2.8 cm**

Q7. 1 cm radius ki soap bubble (S = 0.03 N/m) me extra pressure? Aur ise bananae me work?
$\Delta P = 4S/r = 0.12/0.01 = 12$ Pa. $W = S \times 2 \times 4\pi r^2 = 0.03 \times 8\pi \times 10^{-4} \approx 7.5 \times 10^{-5}$ J. **Ans: 12 Pa, ≈ 7.5×10^{-5} J**

14 Common mistakes

- Soap bubble me 2S/r likhna. Do surfaces hain, 4S/r aur work me bhi 2 lagao.
- Pressure ko bartan ki shape pe depend maan lena.
- Garam karne pe gas ki viscosity bhi ghatti maan lena. Gas ki badhti hai.
- Hydraulic lift ko energy badhane wali machine samajhna.
- Terminal velocity ko r pe depend maan lena (r^2 pe hai).
- cm, mm ko m me badalna bhool jaana.

15 Formula sheet

Pressure at depth	$P = P_0 + \rho g h$
Pascal / hydraulic	$F_1/A_1 = F_2/A_2$
Buoyant force	$\rho_f V g$
Continuity	$A_1 v_1 = A_2 v_2$
Bernoulli	$P + \frac{1}{2}\rho v^2 + \rho g h = \text{const}$
Torricelli	$v = \sqrt{(2gh)}$
Viscous force	$F = \eta A\, dv/dx$
Stokes / terminal	$6\pi\eta r v$ / $2r^2(\rho - \sigma)g/9\eta$
Reynolds number	$R_e = \rho v d/\eta$
Surface tension	$S = F/L$, $W = S\Delta A$
Excess pressure	drop $2S/r$, soap bubble $4S/r$
Capillary rise	$h = 2S\cos\theta/(\rho g r)$

16 Practice questions

1. Wood (ρ = 600) paani me tair raha hai. Kitna fraction doobega?
2. Capillary ka radius aadha karo. Paani kitna chadhega?
3. Do soap bubbles ke radius 1 : 2. Andar ke extra pressure ka ratio?
4. Tanki 20 m oonchi, chhed beech me (10 m). Paani kitni door girega?
5. Rain drop ka radius 3 guna. Terminal velocity?

ANSWERS
1) 0.6 (60%) · 2) 2 guna · 3) 2 : 1 · 4) $2\sqrt{(10 \times 10)} = 20$ m · 5) 9 guna

17 Quick revision: exam se pehle 5 minute

STATICS

- $P = P_o + \rho gh$; shape pe depend nahi.
- Pascal: $F_1/A_1 = F_2/A_2$.
- Doobi fraction = ρ_{body}/ρ_{fluid}.
- 1 atm = 76 cm Hg = 1.013×10^5 Pa.

FLOW

- $A_1v_1 = A_2v_2$ (mass conservation).
- $P + \frac{1}{2}\rho v^2 + \rho gh$ = const (energy).
- Tez speed ⇒ kam pressure.
- Torricelli $v = \sqrt{(2gh)}$.

VISCOSITY

- $F = 6\pi\eta rv$; $v_t \propto r^2$.
- Garmi: liquid η ghatta, gas η badhta.
- R_e < 1000 streamline, > 2000 turbulent.

SURFACE TENSION

- Drop 2S/r, soap bubble 4S/r.
- $h = 2S\cos\theta/\rho gr$, hr = const.
- Boondein milein ⇒ energy nikalti.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.