A Handbook on

Mechanical Engineering

Revised & Updated

Contains well illustrated formulae & key theory concepts

For

IES, GATE, PSUs

& OTHER COMPETITIVE EXAMS

MADE EASY Publications

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Director's Message

B. Singh (Ex. IES)

In the Current Era of globalization and international competition in the field of Science and Technology, its challenging task to ensure Indian participation and contribution through skilled technical professionals. Constant efforts and desire are required to excel and achieve top positions.

I firmly believe that every candidate has the ability to succeed but competitive and quality guidance are required to attain sky high goals. At MADE EASY, we help you to discover your hidden talent and success quotient to make you reach your dreams. In my opinion IAS, IES, GATE and PSU's exams are the tools to bring out true potential of serving the Nation. The actual application of knowledge and talent lies in the successful accomplishment of assigned roles and responsibilities in the working arena. We at MADE EASY ensure that you are trained to become a winner in your life and achieve job satisfaction in your chosen field.

Right since its inception, MADE EASY alumnae have been sharing their winning stories of success and expressed their gratitude towards the quality guidance provided by MADE EASY. Our students have not only secured All India First Ranks in IES, GATE and PSUs but also secured top positions in their career. I invite you to become a part of MADE EASY to explore and achieve ultimate aims of your life. I promise to provide you quality guidance with competitive environment which is far advanced and beyond the reach of other institutes. I ensure you to give a comprehensive guidance, support and inspiration that you need to reach the pinnacle of your career.

I have true desire to serve the Society and Nation by contributing to the field of education. Needless to say, the endeavor to nurture and even further enhance the quality of education will be our constant feature.

After a very long experience of teaching in Mechanical Engineering, MADE EASY team has realized that there is a need of good Handbook which can provide the crux of Mechanical Engineering in a concise form for the students to brush up the formulae and important concepts required for IES, GATE, PSUs and other competitive examinations. This handbook contains all the formulae and important aspects of Mechanical Engineering. It provides much needed revision aid and study guidance before the examinations.

B. Singh (Ex. IES)
CMD, MADE EASY Group

A Handbook on

Mechanical Engineering

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Fluid Mechanics & Fluid Machines

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Introduction

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1. Ideal Fluid and Real Fluid

- Ideal fluid

  A fluid is said to be ideal if it is assumed to be both incompressible and non-viscous. Its bulk modulus is infinite.

- Real fluid

  Real fluid have viscosity, finite compressibility and surface tension.

Remember: ....

- Ideal fluid has no surface tension.
- Ideal fluid are imaginary and do not exist in nature.

2. Specific Weight, Specific Volume, Specific Gravity

- Specific weight (ω) or weight density

$$= \frac{\text{Weight}}{\text{Volume}}$$

$$= \frac{mg}{V} = \rho g$$

Here, ρ = Density

g = Acceleration due to gravity

Specific weight of water = 9810 N/m^3

- Specific Volume

$$= \frac{1}{\text{Density}}$$

- Specific gravity (S) or Relative density

$$\text{Specific gravity} = \frac{\text{Density of fluid}}{\text{Density of standard fluid}}$$

$$= \frac{\text{Specific weight of fluid}}{\text{Specific weight of standard fluid}}$$

Remember

- Specific gravity for water is 1.0 at 4°C and for mercury it is 13.6
- Specific gravity varies with temperature therefore it should be determined at specified temperature (4°C or 27°C).

3. Newton's Law of Viscosity

$$\tau = \mu \cdot \frac{du}{dy} = \mu \frac{d\theta}{dt}$$

τ = shear stress
μ = coefficient of viscosity or
absolute viscosity or
dynamic viscosity

Here, $\frac{du}{dy}$ = Velocity gradient

$\frac{d\theta}{dt}$ = Rate of angular deformation or

Rate of shear strain

- For newtonian fluid, coefficient of viscosity remain constant.

4. Viscosity/Kinematic Viscosity

Due to viscosity a fluid offer resistance to flow

(i) Dynamic Viscosity (μ):
- Its SI unit is pascal-second or **N-sec/m²**
- Its CGS unit is Poise = Dyne-sec/cm²
- 1 poise = **0.1** N-s/m²

(ii) Kinematic Viscosity

$$\nu = \frac{\text{Dynamic viscosity } (\mu)}{\text{Mass density } (\rho)}$$

- Its SI unit is m^2/s.
- Its CGS unit is cm^2/s or stoke.
- 1 stoke = 10^{-4} m^2/s

Remember

- Viscosity of ***liquids*** decreases with temperature whereas viscosity of ***gases*** increases with increase in temperature.
- Liquids with increasing order of viscosity are gasoline, water, crude oil, castor oil.
- Viscosity of ***water*** at 20°C is 1 centipoise.
- Viscosity of liquids is due to **cohesion** *and* ***molecular momentum transfer.***

5. Type of Fluid

- Type of Fluids
  - Newtonian
  - Non-newtonian
    - Time independent
      - (i) Dilatent
      - (ii) Bingham Plastic
      - (iii) Pseudoplastic
    - Time dependent
      - (i) Thixotropic
      - (ii) Rheopectic

- **Non-Newtonian Fluids**

  These do not follow Newton's law of viscosity. The relation between shear stress and velocity gradient is

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$

where A and B are constants depending upon type of fluid and condition of flow.

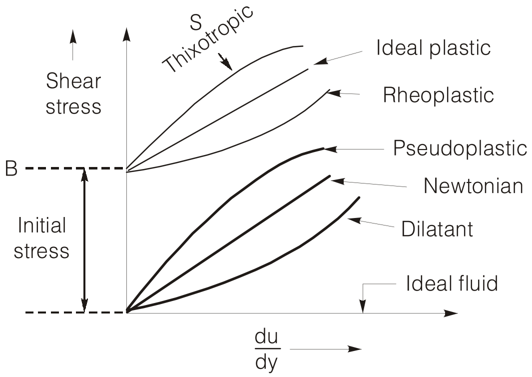
(i) For Dilatant Fluids: $n > 1$ & $B = 0$,
Ex. Butter, Quick sand.

(ii) For Bingham Plastic Fluids: $n = 1$ & $B \neq 0$
Ex. Sewage sludge, Drilling mud, tooth paste and gel.
These fluids always have certain minimum shear stress before they yield.

(iii) For Pseudoplastic Fluids: $n < 1$ & $B = 0$
Ex. Paper pulp, Rubber solution, Lipsticks, Paints, Blood, Polymetric solutions etc.

(iv) For Thixotropic Fluids: $n < 1$ & $B \neq 0$
Viscosity increases with time.
Ex. Printers ink and Enamels.

(v) For Rheopectic Fluids: $n > 1$ & $B \neq 0$
Viscosity decreases with time.
Ex. Gypsum solution in water & Bentonite solution.

- 

6. Compressibility (β), Isothermal Bulk Modulus (k_T) and Adiabatic Bulk Modulus

- Compressibility (β)

  It is inverse of bulk modulus of elasticity.

$$\beta = \frac{1}{k} = \frac{-dv}{vdp}$$

$$\beta = \frac{d\rho}{\rho \cdot dP}$$

Here, k = bulk modulus of elasticity

ρ = Density

v = Volume

- Isothermal bulk modulus (k_T)

$$k_T = P_{final} = \rho RT$$

- Adiabatic bulk modulus

$$k_a = \gamma \cdot P_{final}$$

Here, $\gamma = \frac{C_p}{C_v}$

C_p = Specific heat at constant pressure

C_v = Specific heat at constant volume

7. Surface Tension/Pressure Inside Drop, Bubble and Jet

Surface tension occur at the interface of liquid and a gas *or* at the interface of two liquid. Surface tension is inversely proportional to temperature and it also acts when fluid is at rest.

- Pressure inside drop (Solid like sphere)

$$P = \frac{4\sigma}{d}$$

- Pressure inside bubble

$$P = \frac{8\sigma}{d}$$

Remember

- The pressure inside the droplet of soap bubble will be higher than P_{atm}.
- The higher the pressure inside the soap bubble the smaller the size of soap bubble.

- Pressure inside jet

$$P = \frac{2\sigma}{d}$$

Here d = Diameter of drop

P = Gauge pressure

Remember

- It is a ***surface*** phenomenon
- It is force per unit length (N/m)
- For ***water-air*** interface at 20°C its value is 0.0736 N/m and Air-mercury Interface σ = 0.480 N/m
- At critical point, liquid-vapuor state are same thus surface tension = 0
- It is due to ***cohesion*** only

8. Capillary Action

- Height of water in capillary tube

$$h = \frac{4\sigma\cos\theta}{\rho g d}$$

Where, h = rise in capillary

σ = surface tension of water & glass

d = dia of tube

θ = angle of contact between the liquid and the material.

θ = 0° for water and glass (clean)

θ = 128° for mercury and glass (clean)

- When a liquid surface supports another liquid of density "ρ_b", then rise in capillary is given as

$$h = \frac{4\sigma\cos\theta}{(\rho - \rho_b)gd}$$

- Capillary action is due to adhesion and cohesion, ***both***.
- For capillary action diameter of tube should be ***less*** than 3 cm.

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Manometry

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1. Pascal's Law

- The intensity of fluid at any point in a stationary fluid is same in all directions.

  $$p_x = p_y = p_z$$

- Pressure varies ***only with depth*** in stationary fluids, whereas if fluids is in motion pressure may vary in horizontal direction also.
- Fluid pressure is measured in Force/Area and it is expressed in Pascal (N/m^2) or Bar.

  $$1 \text{ Bar} = 10^5 \text{ N/m}^2$$

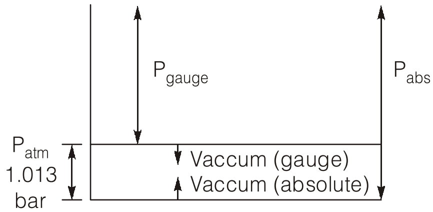
  $$1 \text{ MPa} = 10 \text{ Bar}$$

- Barometer shows ***atmospheric*** pressure.
- 1 kgf = 9.81 Newton.
- Pressure is a scaler quantity.

2. Absolute Pressure

Pressure measured with reference to absolute zero. Absolute pressure cannot be negative

Asbolute pressure = gauge pressure + local atmospheric pressure



- $$P_{gauge} = \rho g h$$

  Here, ρ = Density of fluid

  g = Acceleration due to gravity

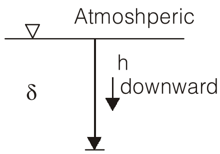
  h = Height

- ***Gauge*** pressure can be positive, negative or zero.
- Atmospheric pressure varies with ***altitude***, ***temperature*** and ***local*** conditions.
- At ***mean sea level*** atmospheric pressure is 1.01×10^5 Pascal or 1 Bar or 10.3 mts. of height of water or 76 cm height of ***mercury***.

3. Hydrostatic Law

- For downward 'h'

$$\frac{dP}{dh} = w$$



- For upward 'h'

$$\frac{dP}{dh} = -w$$

> Remember
> - Hydrostatic pressure distn. flows linear variation of depth below the free surface.

4. Conversion of one Fluid Column to Another Fluid Column

$$\rho_1 h_1 = \rho_2 h_2$$

$$s_1 h_1 = s_2 h_2$$

Here, ρ = Density of fluid

s = Relative density

> Remember
> - Piezometer is suitable for ***small*** and ***positive*** pressure measurement.
> - The manometric liquid should have ***high density*** and ***vapour pressure***.
> - Simple manometer/U-tube manometer can measure both ***positive*** and ***negative*** pressure.
> - Aneroid/Mecury barometer used to measure ***local*** atmospheric pressure on ***absolute*** scale.
> - Density of mercury = 13.6×10^3 kg/m^3
>   Density of air = 1.24 kg/m^3

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