Chapter 5:-

Dimensional Analysis and Similiraty

- **dimensional analysis** is a **method** for reducing the number and complexity of expiremental variables

- **Variables and constants:-**

→ **Dimensional variables** :- quantities that has dimensions and theire numerical values may chang; ex, speeed, velocity, acc- ---

→ **Dimensional constants**:- equantities that has dimensions but its numerical values are Constant ex: g, Plank's constant ---

→ Pure constants, Angles and revalutions are dimensionless

The Pi Theorem :-

The dimensionless groups founed from the theorem are power products denoted by π_1, π_2, π_3 ....

Steps of finding pi's :-

1- Find number of variables n

Ex: $P = f(F, A, \mu)$
① ② ③ ④

$n = 4$ (P is included : Do NOT forget the first variable)

2- Find number of repeating variables j (P,F ليس Repeating)
لازم يكون متحكم بالسيستم

3- Find number of Pi's : $k = n - j = 4 - 2 = 2$
A μ

5- Determine which System to use:

MLTΘ FLTΘ

mass ↙ length ↘ Time ↘ Temperture ↘ Force

4- List the dimensons of each variable:
لازم اكتبها قبل عشان تعرف
كتار الـ system

6- Take the First Group:-

$\pi_1 = (A)^1 P^a F^b = F^0 L^0 T^0$ or $M^0 L^0 T^0$

Dimensionless

$\pi_2 = (\mu)^1 P^a F^b = F^0 L^0 T^0$ or $M^0 L^0 T^0$

find a, b in each case

See Example 5.3

5.5 Modeling and Prototype

Model → Prototype

1. Geometrically similarity
2. Kinematic similarity
3. Dynamic similarity

1- The scale should be the same for all dimensions

Angles stay the same

2- Froude number must be equal

$Fr_m = Fr_p$

$\frac{V_m^2}{g L_m} = \frac{V_p^2}{g L_p}$

ممكن يعطيك طول ال prototype
وال scale ، وانت بتوجد
طول ال model

$L_m = \alpha \, L_p$ → α = scale

$$\sqrt{\alpha} = \frac{V_m}{V_p} = \left(\frac{L_m}{L_p}\right)^{1/2} = \frac{T_m}{T_p}$$

3- Dynamic Similarity :- Re and Mash equality

- Compressible flow
  - Reynolds number and Mach number and specific heat ratio
- Incompressible flow
  - No free surface
    - Reynolds are equal
  - with a free surface
    - Ray. equal
    - Froude num
    - Weber num
    - Cavitation num

Scanned with CamScanner

- Explanation of Ma, Re, Fr

① Mash number

$$Ma = \frac{V}{a}$$ (V → Velocity)

$$a = \sqrt{KRT}$$ (T → Temp; R → Gas. Constant)

$$K = \frac{c_p}{c_v}$$

② Raynold's number:-

$$Re = \frac{\rho V L}{\mu}$$

ρ → Density; V → Velocity; L → length / Diameter of inlet; μ → Viscosity

③ Froude number $= \frac{V}{\sqrt{2gL}}$

Combining Pi's Theorem and modeling

If the Question is asking for a specific value of a property for a model or a prototype (with similarity : Dynamically and Geometrically)

- you can use Pi Theorem to find a law for the property and Then use relation

$$(\Pi)_{model} = (\Pi)_{prototype} = \text{constant}$$