Al-Mustaqbal University / College of Engineering & Technology
Building and Construction Techniques Engineering Department
First Class
Subject: -ENGINEERING PHYSICS / Code: - UOMU023014
Lecturer Fatima Muslim
1ˢᵗ term – Lecture No.2 & Lecture Name UNITS AND DIMENSIONS

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DEFINITION OF DIMENSIONS

Dimensions: The powers, to which the fundamental units of mass, length and time written as M, L and T are raised, which include their nature and not their magnitude.

الأبعاد: القوى التي ترفع إليها الوحدات الأساسية للكتلة والطول والزمن والتي تكتب على هيئة M و L و T، والتي تشمل طبيعتها وليس مقدارها.

For example,

Area = Length x Breadth

على سبيل المثال،

المساحة = الطول × العرض

$$= [L^1] \times [L^1] = [L^2] = [M^0 L^2 T^0]$$

Power (0,2,0) of fundamental units are called dimensions of area in mass, length and time respectively.

e.g. Density = mass/volume

على سبيل المثال

الكثافة = الكتلة / الحجم

$$= [M^1]/[L^3]$$
$$= [M^1 L^3 T^0]$$

DIMENSIONAL FORMULAE AND SI UNITS OF PHYSICAL QUANTITIES

صيغ الأبعاد ووحدات النظام الدولي للكميات الفيزيائية

Dimensional Formula: An expression along with power of mass, length & time which indicates how physical quantity depends upon fundamental physical quantity.

صيغة الأبعاد: تعبير مع قوة الكتلة والطول والزمن يشير إلى كيفية اعتماد الكمية الفيزيائية على الكمية الفيزيائية الأساسية.

e.g. Speed = Distance/Time

على سبيل المثال، السرعة = المسافة/الزمن

$$= [L^1]/[T^1] = [M^0 L^1 T^{-3}]$$

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It tells us that speed depends upon L & T. It does not depend upon M.

يخبرنا أن السرعة تعتمد على L & T، ولا تعتمد على M.

Dimensional Equation: An equation obtained by equating the physical quantity with its dimensional formula is called dimensional equation.

معادلة الأبعاد: المعادلة التي يتم الحصول عليها عن طريق مساواة الكمية الفيزيائية مع صيغتها البعدية تسمى معادلة الأبعاد.

The dimensional equation of area, density & velocity are given as under: -

$Area\ =\ [M^0 L^2 T^0]$

$Density\ =\ [M^1 L^3 T^0]$

$$Velocity\ =\ [M^0 L^1 T^{-1}]$$

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Dimensional formula SI & CGS unit of Physical Quantities

صيغة الأبعاد لوحدة الكميات الفيزيائية في النظام الدولي للوحدات ونظام CGS

Sr.No.	Physical Quantity	Formula	Dimensions	Name of S.I unit
1	Force	Mass × acceleration	$[M^1L^1T^{-2}]$	Newton (N)
2	Work	Force × distance	$[M^1L^2\,T^{-2}]$	Joule (J)
3	Power	Work / time	$[M^1L^2\,T^{-3}]$	Watt (W)
4	Energy (all form)	Stored work	$[M^1L^2T^{-2}]$	Joule (J)
5	Pressure, Stress	Force/area	$[M^1L^{-1}T^{-2}]$	Nm⁻²
6	Momentum	Mass × velocity	$[M^1L^1T^{-1}]$	Kgms⁻¹
7	Moment of force	Force × distance	$[M^1L^2T^{-2}]$	Nm
8	Impulse	Force × time	$[M^1L^1T^{-1}]$	Ns
9	Strain	Change in dimension / Original dimension	$[M^0L^0T^0]$	No unit
10	Modulus of elasticity	Stress / Strain	$[M^1L^{-1}T^{-2}]$	Nm⁻²
11	Surface energy	Energy / Area	$[M^1L^0T^{-2}]$	Joule/m²
12	Surface Tension	Force / Length	$[M^1L^0T^{-2}]$	N/m
13	Co-efficient of viscosity	Force × Distance/ Area × Velocity	$[M^1L^{-1}T^{-1}]$	N/m²
14	Moment of inertia	Mass × (radius of gyration)²	$[M^1L^2T^0]$	Kgm²
15	Angular Velocity	Angle / time	$[M^0L^0T^{-1}]$	Rad. per sec
16	Frequency	1/Time period	$[M^0L^0T^{-1}]$	Hertz
17	Area	Length × Breadth	$[M^0L^2T^0]$	Metre²
18	Volume	Length × breadth × height	$[M^0L^3T^0]$	Metre³

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Example1: Derive the dimensional formula of following Quantity & write down their dimensions.

استنتج صيغة الأبعاد للكمية التالية واكتب أبعادها. الكثافة، القدرة، معامل اللزوجة، الزاوية

1. Density
2. Power
3. Co-efficient of viscosity
4. Angle

Solution:

1. **Density** = mass/volume
   $= [M]/[L^3] = [M^1 L^{-3} T^0]$

2. **Power** = Work/Time
   =Force x Distance/Time
   $= [M^1 L^1 T^{-2}] \, x \, [L^1]/[T^1]$
   $= [M^1 L^2 T^{-3}]$

3. **Co-efficient of viscosity** = [Force x Distance] / [Area x Velocity]
   = [Mass x Acceleration x Distance x time] / [length x length x Displacement]
   $= [M^1] \, x \, [L^1 T^{-2}] \, x \, [L^1] \, [T^1]/[L^2] \, x \, [L^1]$
   $= [M^1 L^{-1} T^{-1}]$

4. **Angle** = arc (length)/radius (length)
   $= [L^1]/[L^1]$
   $= [M^0 L^0 T^0] = no\ dimension$

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Example2: Explain which of the following pair of physical quantities have the same dimension:

اشرح أي من أزواج الكميات الفيزيائية التالية لها نفس البعد:

(أ) العمل والقوة (ب) الإجهاد والضغط (ج) الزخم والدفع

1. Work & Power
2. Stress & Pressure
3. Momentum & Impulse

Solution:

1. Dimension of work = force x distance
   $= [M^1L^2T^{-2}]$

   Dimension of power = work / time
   $= [M^1L^2T^{-3}]$

Work and Power have not the same dimensions.

العمل والقوة ليس لهما نفس الأبعاد.

2. Dimension of stress = force / area
   $= [M^1L^1T^{-2}]/[L^2] = [M^1L^{-1}T^{-2}]$

   Dimension of pressure = force / area
   $= [M^1L^1T^{-2}]/[L^2] = [M^1L^{-1}T^{-2}]$

Stress and pressure have the same dimension.

الضغط والاجهاد لهما نفس البعد.

3. Dimension of momentum = mass x velocity
   $= [M^1L^1T^{-1}]$

   Dimension of impulse = force x time
   $= [M^1L^1T^{-1}]$

Momentum and impulse have the same dimension.

الزخم والاندفاع لهما نفس البعد.

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PRINCIPLE OF HOMOGENEITY OF DIMENSIONS

مبدأ تجانس الأبعاد

It states that the dimensions of all the terms on both sides of an equation must be the same. According to the principle of homogeneity, the comparison, addition & subtraction of all physical quantities is possible only if they are of the same nature i.e., they have the same dimensions.

If the power of M, L and T on two sides of the given equation are same, then the physical equation is correct otherwise not. Therefore, this principle is very helpful to check the correctness of a physical equation.

تنص على أن أبعاد جميع الحدود على جانبي المعادلة يجب أن تكون متماثلة. وفقًا لمبدأ التجانس، فإن المقارنة والجمع والطرح لجميع الكميات الفيزيائية ممكنة فقط إذا كانت من نفس الطبيعة أي أن لها نفس الأبعاد.

إذا كانت قوة M و L و T على جانبي المعادلة المعطاة متماثلة، فإن المعادلة الفيزيائية صحيحة وإلا فلن تكون كذلك. لذلك، فإن هذا المبدأ مفيد جدًا للتحقق من صحة المعادلة الفيزيائية.

Example3: A physical relation must be dimensionally homogeneous, i.e., all the terms on both sides of the equation must have the same dimensions.

$$S \ = \ ut \ + \ ½ \, at^2$$

يجب أن تكون العلاقة الفيزيائية متجانسة الأبعاد، أي أن جميع الحدود على جانبي المعادلة يجب أن يكون لها نفس الأبعاد.

$$S \ = \ Distance \ , u \ = \ Velocity \ , t \ = \ Time \ , a \ = \ Acceleration$$

Solution:

$S \ = \ [L^1]$

$u \ = \ [L^1 T^{-1}]$

$t \ = \ [T^1]$

$a \ = \ [L^1 T^{-2}]$

½ is a constant and has no dimensions.

Thus, the dimensions of the term on L.H.S. is $S = [L^1]$

and Dimensions of terms on R.H.S.

$ut \ + \ ½ \, at^2 \ = \ [L^1 T^{-1}] \, [T^1] \ + \ [L^1 T^{-2}] \, [T^2] \ = \ [L^1] \ + \ [L^1]$

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Here, the dimensions of all the terms on both sides of the equation are the same.

Therefore, the equation is dimensionally homogeneous.

هنا، أبعاد جميع الحدود على جانبي المعادلة هي نفسها. وبالتالي، فإن المعادلة متجانسة الأبعاد.

DIMENSIONAL EQUATIONS, APPLICATIONS OF DIMENSIONAL EQUATIONS

المعادلات البعدية، تطبيقات المعادلات البعدية

Dimensional Analysis: A careful examination of the dimensions of various quantities involved in a physical relation is called dimensional analysis. The analysis of the dimensions of a physical quantity is of great help to us in a number of ways as discussed under the uses of dimensional equations.

التحليل البعدي: الفحص الدقيق لأبعاد الكميات المختلفة المشاركة في علاقة فيزيائية يسمى التحليل البعدي. إن تحليل أبعاد الكمية الفيزيائية يساعدنا كثيرًا بعدة طرق كما هو موضح في استخدامات المعادلات البعدية.

Uses of dimensional equation: The principle of homogeneity & dimensional analysis has put to the following uses:

استخدامات المعادلات البعدية: لقد استخدم مبدأ التجانس والتحليل البعدي في الاستخدامات التالية:

1. Checking the correctness of physical equation.
2. To convert a physical quantity from one system of units into another.
3. To derive relation among various physical quantities.

- التحقق من صحة المعادلة الفيزيائية.
- تحويل كمية فيزيائية من نظام وحدات إلى آخر.
- استنتاج علاقة بين كميات فيزيائية مختلفة.

Example4: Check the correctness of the following formulae by dimensional analysis.

تحقق من صحة الصيغ التالية عن طريق التحليل البعدي.

a. $F = mv^2/r$
b. $t = 2\pi\sqrt{l/g}$
Solution:

- $F = mv^2/r$
L.H.S Force

$F = [M^1 L^1 T^{-2}]$

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R.H.S

$mv2/r =$ $[M^1]\,[L^1T^{-1}]^2 / [L]$

$\qquad = [M^1L^2T^{-2}]/\,[L]$

$\qquad = [M^1L^1T^{-2}]$

The dimensions of the term on the **L.H.S** are equal to the dimensions of the term on **R.H.S.** Therefore, the relation is correct.

<div dir="rtl">أبعاد المصطلح على الجانب الأيسر تساوي أبعاد المصطلح على الجانب الأيمن، وبالتالي فإن العلاقة صحيحة.</div>

- $t= 2\pi\sqrt{l/g}$

L.H.S, t $= [T^1] = [M^0L^0T^1]$

R.H.S (length) $= [L^1]$

g (acc due to gravity) $= [L^1T^{-2}]$

2π being constant have no dimensions.

$2\pi\sqrt{l/g}$ on R.H.S

$= (L^1/\,L^1T^{-2}])\,\frac{1}{2} = [T^1] = [M^0L^0T^1]$

Thus, the dimensions of the terms on both sides of the relation are the same i.e., [MᵒLᵒT¹]. Therefore, the relation is correct.

<div dir="rtl">وبالتالي، فإن أبعاد الحدود على جانبي العلاقة متساوية، أي (MᵒLᵒT¹) وبالتالي، فإن العلاقة صحيحة.</div>

H.W: Using Principle of Homogeneity of dimensions, check the correctness of equation,

    a. $h = 2Td\,/rgCos\theta$
Height (h)، (T)surface tension، (D)density، (r)radius، (g)acc. due to gravity

    b. $V = \sqrt{Ed}$
(V) velocity of sound, (E)elasticity and (d)density of the medium