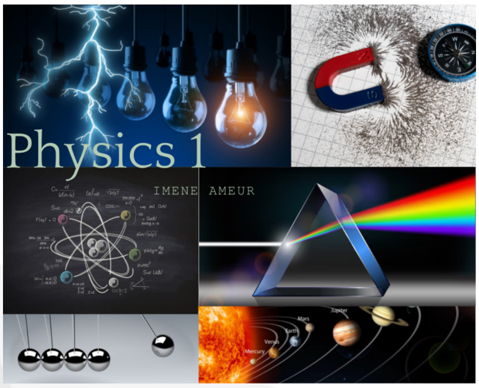
Course Physics1



Course Physics 1
CUMILA

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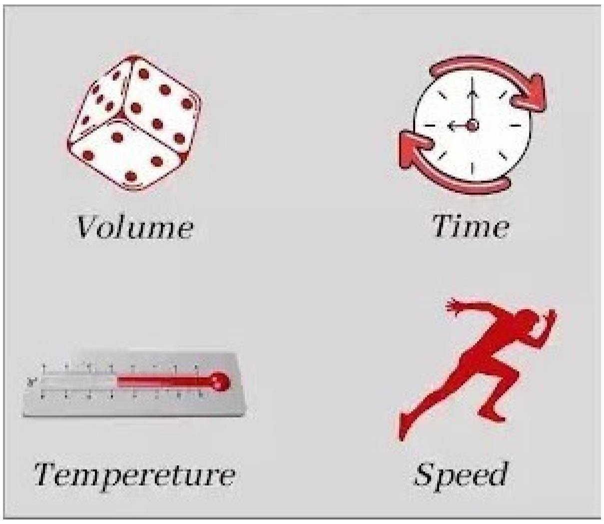
1. Introduction

Physics is an exact science that uses mathematical formulas to express physical phenomena; these mathematical formulas constitute a physical law. To describe these laws, physics uses the notions of physical quantities. This is possible in certain cases, but for others, it is necessary to use a modeling method such as Dimensional Analysis. Each of them must be well defined and we must know how to measure them, while measuring these quantities, many errors are committed that must be taken into consideration before giving the value of a specific quantity or proving a physical law.

2. Dimensional Analysis, Physical Quantities and their Units of Measurement

2.1. Physical Quantities

Those entities which can be measured or derived from mathematical formulas are termed Physical quantities. These physical quantities are subdivided into two subcategories, fundamental and derived quantities.



Physical quantities

Definition

- ***Fundamental quantities:*** are those quantities that can be expressed by a single type of entity and need no other entity to derive them. For example: mass, length, time...
- ***Derived quantities:*** are those quantities that can be expressed in terms of fundamental quantities. For example, speed is a derived quantity that depends on length and time.

2.2. Units of Measurement

The value of a physical quantity is given according to a standard called "Unit", the units of physical quantities are written according to that of fundamental quantities.

2.2.1. The International System of Units (SI system)

The international system of units SIor MKSA system consists of 7 base units adapted to 7 physical quantities, as shown in the following table

Physical quantities	Unit of measurement (SI)	Dimensional symbol
Length	Meter (m)	L
Mass	Kilogram (Kg)	M
Time	Second (s)	T
Temperature	Kelvin (K)	θ
Electric current	Ampere (A)	I
Light intensity	Candela (cd)	J
Quantity of matter	Mole (mol)	N

The international system of units (SI system)

To watch the video click *here*

Note

Dimensions aren't the same as units; dimension of physical quantities is its physical nature. For example, the physical quantity, speed, may be measured in units of meters per second, miles per hour etc.; but regardless of the units used, speed is always a length divided a time, so we say that the dimensions of speed are length divided by time.

2.3. Dimensional Analysis

[cf. Dimensional analysis]

The dimensional analysis is a theoretical tool for interpreting problems based on the dimensions of the physical quantities involved: length, time, mass, etc. Dimensional analysis makes it possible to

- Determine the unit of a physical quantity based on the essential units (meter, second, kilogram, etc.)
- Research into the nature of physical quantities
- Search for the homogeneity and the validity of physical laws

Any derived quantity X can be expressed as a function of the fundamental quantities (Length, Mass, Time, Current intensity, etc.) according to the expression

$$X = L^a . M^b . T^c . A^d . \theta^e . N^f . C^j$$

This expression is the “Equation of dimensions” of the quantity X

With:

a, b, c, d, e, f and j are real numbers

L, M, T, A, θ, N and C are the dimensions of length, mass, time, electric current, temperature, amount of substance and luminous intensity, respectively.

Example

We have the equation of speed

$$v = \frac{dl}{dt}$$

The equation of dimensions is $[v] = L T^{-1}$ and The unit is: m/s

Method

Dimensional analysis helps to confirm the validity of physical laws by matching the dimensions between the two sides of the law. It also helps formulate the final picture of the mathematical relationship based on the principle of dimensional matching as a condition for the validity of the relationship, as the unit of the right side of the equation must equal the unit of the left side of the equation, otherwise the equation is incorrect. For more information and comprehension, watch the video below.

3. Error and Uncertainty Calculation

One of the essential characteristics of physics is that it always works with approximations. When measurements are made on any quantity, errors are made because of the instruments used as well as the experimenter himself. This is why the measurements taken do not represent strict reality and it is therefore useful to know the precision with which these measurements were made.

Measurements tools

3.1. Error Calculation

Error: is when the true value is known in advance X (true), then after measurement X(measured) the error committed can be known, so error is the difference between the measured value and the true value of this quantity X

$$Absolute\ Error = |X_m - X_t|$$

Also the relative error is defined as

$$Relative\ Error = \frac{|X_m - X_t|}{X_m}$$

3.2. Uncertainty Calculation

Uncertainty: this is when we measure and we do not know the true value. The error committed cannot be determined. Uncertainty is scientific attempts to estimate error during measurement, where we estimate the error field within which we estimate the true value of this quantity.

3.2.1. Absolute Uncertainty

The absolute uncertainty represents the upper limit of the error committed during the measurement. Thus, if we wish to measure a physical quantity x, we will write that

$$X = X_{mes} \pm \Delta X$$

Where

ΔX is the absolute uncertainty

This also means that the real value of the quantity x is in the interval [$X_{mes} - \Delta X$, $X_{mes} + \Delta X$], and it is not possible to know it with accuracy.

Example

Length = (6 ± 0.001)m ⇒ 5.999 < length < 6.001 m

Method

- If the measurement is direct, the absolute uncertainty is the sum of the systematic error ΔXs, the reading error ΔXr and the instrumental error ΔXi
  $\Delta X = \Delta X_s + \Delta X_r + \Delta X_i$
- If the measurement is indirect and the physical quantity is related to other quantities through a mathematical relationship. In that case, we can use the mathematical tool "the total differential or logarithm method " to determine the uncertainties.

3.2.2. Relative Uncertainty

To determine the accuracy of the measurement, we resort to calculating the relative uncertainty, which is equal to the absolute uncertainty (Δx) over the measured value (x)

$$\varepsilon = \frac{(\Delta X)}{X} \times 100$$

ε: is the relative uncertainty has no units and is generally expressed in %

4. Vectors Operations: Dot and Cross Product

4.1. Vectors Operations

[cf. Vectors operations]

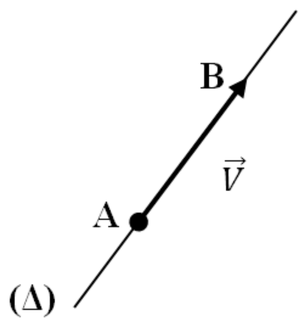
Operations on vectors are the vectors that are performed especially on vector quantities, such quantities have both magnitude and direction, and operating them with normal rules of mathematics is not possible. So we have to use various vector operations that include

- Addition of Two Vectors
- Subtraction of Two Vectors
- Multiplication of Vector with Scalar
- Product of Two Vectors (Dot and Cross-Product)

Definition

A vector is an oriented segment characterized by:

- ***The module:*** is equal to the length of the segment [AB]
- ***The holder:*** is defined by the line that carries the segment (Δ)
- ***The trend:*** designates the vector's orientation or the movement direction of a mobile.



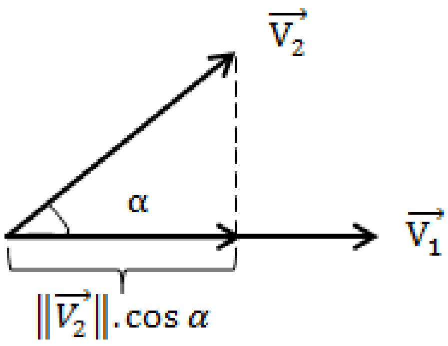
Vector AB

4.2. Dot Product

The scalar or dot product of the vectors $\vec{V}_1$ and $\vec{V}_2$ is given by

$$\vec{V}_1 . \vec{V}_2 = ||\vec{V}_1||.||\vec{V}_2||. \cos(\alpha)$$

Such that α is the angle between the two vectors



✎ *Note*

The scalar product of two vectors is equal to the product of the modulus of one of the vectors in the projection of the modulus of the other vector onto the carrier of this vector.

4.2.1. Analytical Expression of the Dot Product

We have the two vectors $\vec{V}_1$ and $\vec{V}_2$ in the basis $\vec{i},\vec{j},\vec{k}$ with $\vec{V}_1 = x_1\vec{i} + y_1\vec{j} + z_1\vec{k}$ and $\vec{V}_2 = x_2\vec{i} + y_2\vec{j} + z_2\vec{k}$

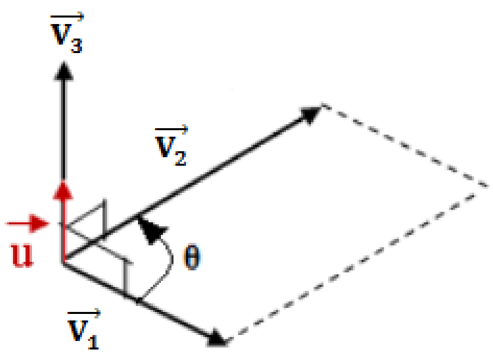
The dot product of these two vectors is expressed by: $\vec{V}_1 . \vec{V}_2 = x_1 x_2 + y_1 y_2 + z_1 z_2$

4.3. Cross Product

The cross product of vectors $\vec{V}_1$ and $\vec{V}_2$ is a vector $\vec{V}_3$ whose magnitude is given by

$$\vec{V}_1 \wedge \vec{V}_2 = ||\vec{V}_1||.||\vec{V}_2||.\sin(\theta)\vec{u}$$

θ is the angle between the two vectors $\vec{V}_1$, $\vec{V}_2$



4.3.1. Analytical Expression of the Cross Product

We have two vectors $\vec{V}_1$ and $\vec{V}_2$ in the basis $\vec{i},\vec{j},\vec{k}$, and $\vec{V}_3$ the cross product of these two vectors and is expressed by

$$\vec{V}_3 = \vec{V}_1 \wedge \vec{V}_2 = (y_1 z_2 - y_2 z_1)\vec{i} + (x_1 z_2 - x_2 z_1)\vec{j} + (x_1 y_2 - x_2 y_1)\vec{k}$$

Advice

We can find the expression of cross product easily using the determinant method (3 orders)