

BASICS

A. Units for Physical Quantities

Base Units	Symbol	Unit
Length	L, x	Meter - m
Mass	m, M	Kilogram - kg
Temperature	T	Kelvin - K
Time	t	Second - s
Electric Current	I	Ampere - A (C/s)
Derived Units	Symbol	Unit
Acceleration	a	m/s^2
Ang. Accel.	α	$radian/s^2$
Ang. Momentum	L	$kg \cdot m^2/s$
Ang. Velocity	ω	$radian/sec$
Angle	θ, φ	radian
Capacitance	C	Farad F (C/V)
Charge	Q, q, e	Coulomb C (A·s)
Density	ρ	kg/m^3
Displacement	x, d, h	meter - m
Electric Field	E	V/m
Electric Flux	Φ_e	V·m
Electromotive Force (EMF)	\mathcal{E}	Volt - V
Energy	E, U, K	Joule J ($kg \cdot m^2 \cdot s^{-2}$)
Entropy	S	J/K
Force	F	Newton - N ($kg \cdot m/s^2 = J/m$)
Frequency	f, ν	Hertz - Hz (cycle/s)
Heat	Q	Joule - J
Magnetic Field	B	Tesla (Wb/ m^2)
Magnetic Flux	Φ_m	Weber Wb ($kg \cdot m^2/A \cdot s^2$)
Momentum	p	$kg \cdot m/s$
Potential	V	Voltage V (J/C)
Power	P, p	Watt - W (J/s)
Pressure	P	Pascal - Pa (N/ m^2)
Resistance	R	Ohm Ω (V/A)
Torque	τ	N·m
Velocity	v	m/s
Volume	V	m^3
Wavelength	λ	meter - m

B. Fundamental Physical Constants

Base Units	Symbol	Unit
Mass of electron	m_e	$9.11 \times 10^{-31} \text{ kg}$
Mass of proton	m_p	$1.67 \times 10^{-27} \text{ kg}$
Avogadro Constant	N_A	$6.022 \times 10^{23} \text{ mol}^{-1}$
Elementary charge	e	$1.602 \times 10^{-19} \text{ C}$
Faraday Constant	F	$96,485 \text{ C/mol}$
Speed of light	c	$3 \times 10^8 \text{ m/s}$
Molar Gas Constant	R	$8.314 \text{ J/mol} \cdot \text{K}$
Boltzmann Constant	k	$1.38 \times 10^{-23} \text{ J/K}$
Gravitation Constant	G	$6.67 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$
Permeability of Space	μ_0	$4\pi \times 10^{-7} \text{ N/A}^2$
Permittivity of Space	ϵ_0	$8.85 \times 10^{-12} \text{ F/m}$

C. Conversion factors and alternative units

	Unit	Description
Angle	$^\circ$ (degree)	$180^\circ = \pi \text{ rad}$
Energy	Erg	CGS unit ($kg \cdot cm^2/s^2$) $1 \text{ erg} = 10^{-7} \text{ J}$
Energy	Electron Volt	$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$
Force	Dyne	CGS unit ($g \cdot cm/s^2 = \text{erg/cm}$) $1 \text{ dyne} = 10^{-5} \text{ N}$
Volume	Liter	$1 \text{ L} = 1 \text{ dm}^3$
Pressure	Bar	$1 \text{ Bar} = 10^5 \text{ Pa}$
Length	Angstrom	$1 \text{ \AA} = 1 \times 10^{-10} \text{ m}$

MATHEMATICAL CONCEPTS

A. Vector Algebra
 1. Vectors are represented by a character with $\vec{A}, \vec{B}, \vec{C}$ and $\vec{a}, \vec{b}, \vec{c}$.
 Unit vectors: \hat{i} along x , \hat{j} along y , & \hat{k} along z .
 Vector $\vec{A} = A_x \hat{i} + A_y \hat{j} + A_z \hat{k}$
 c. Length of $\vec{A} = |\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$

2. Addition of vectors \vec{A} & \vec{B} : add components.
 Sample Addition and Length Calculations:
 $\vec{A} = 3\hat{i} + 4\hat{j} - 1\hat{k}$ $|\vec{A}| = \sqrt{9 + 16 + 1} = 5$
 $\vec{B} = -2\hat{i} + 6\hat{j} + 5\hat{k}$ $|\vec{B}| = \sqrt{4 + 36 + 25} = \sqrt{65} = 8.06$
 $\vec{A} + \vec{B} = \hat{i} + 10\hat{j} + 2\hat{k}$ $|\vec{A} + \vec{B}| = \sqrt{1 + 100 + 4} = \sqrt{105} = 10.25$

Note: $|\vec{A}| + |\vec{B}| \geq |\vec{A} + \vec{B}|$

3. Multiply \vec{A} & \vec{B} :
 a. Dot or scalar product: $\vec{A} \cdot \vec{B} = |\vec{A}| |\vec{B}| \cos \theta = (A_x B_x) + (A_y B_y) + (A_z B_z)$
 Note: θ is the angle between \vec{A} and \vec{B} .
 $\vec{A} \cdot \vec{B} = 0$, if $\theta = \pi/2$. **Fig 3**
 Sample: Scalar product:
 $\vec{A} = 3\hat{i} + 4\hat{j}$ $\vec{B} = 1\hat{i} + 5\hat{j}$
 $\vec{A} \cdot \vec{B} = 3 \times 1 + 4 \times 5 = 3 + 20 = 23$
 $|\vec{A}| = \sqrt{25} = 5$ $|\vec{B}| = \sqrt{26} = 5.1$
 $\cos \theta = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}| |\vec{B}|} = \frac{23}{5 \times 5.1} = 0.90$
 $\theta = \cos^{-1}(0.90) = 26^\circ = 0.45 \text{ rad}$ **Fig 3**

b. Cross or Vector Product:
 $\vec{C} = \vec{A} \times \vec{B} = |\vec{A}| |\vec{B}| \sin \theta \hat{e}$
 θ = Angle between \vec{A} and \vec{B} , vector \hat{e} is perpendicular to \vec{A} and \vec{B} .
 $\vec{A} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$
 Sample: Vector Product:
 $\vec{A} = 2\hat{i} + \hat{j}$ $\vec{B} = 1\hat{i} + 3\hat{j}$
 $\vec{A} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 1 & 0 \\ 1 & 3 & 0 \end{vmatrix} = (6 - 1)\hat{k} = 5\hat{k}$
 - If \vec{A} and \vec{B} are in $x-y$ plane, $\vec{A} \times \vec{B}$ is along the $+z$ direction.
 - θ is the angle formed by \vec{A} & \vec{B} : $\sin \theta = \frac{|\vec{C}|}{|\vec{A}| |\vec{B}|}$
 Given: $|\vec{A}| = \sqrt{5}$ $|\vec{B}| = \sqrt{10}$ $|\vec{C}| = 5$
 $\sin \theta = \frac{5}{\sqrt{5} \times \sqrt{10}} = \frac{5}{5\sqrt{2}} = \frac{1}{\sqrt{2}} = 0.707$
 $\theta = \sin^{-1}(0.707) = 45^\circ = \pi/4 \text{ radians}$

c. The Right-Hand Rule gives the orientation of vector \hat{e} . **Fig 4**

D. Trigonometry
 1. Basic relations for a triangle **Fig 5**
 $\sin \theta = \frac{y}{r}$
 $\cos \theta = \frac{x}{r}$
 $\tan \theta = \frac{y}{x} = \frac{\sin \theta}{\cos \theta}$
 $\sin^2 \theta + \cos^2 \theta = 1$
 2. Sine and Cos waves **Fig 6**

Values Of sin, cos and tan

θ rad ($^\circ$)	$\sin \theta$	$\cos \theta$	$\tan \theta$
0 (0°)	0.00	1.00	0.00
$\pi/6$ (30°)	0.50	0.866	0.577
$\pi/4$ (45°)	0.707	0.707	1.00
$\pi/3$ (60°)	0.866	0.50	1.732
$\pi/2$ (90°)	1.00	0.00	∞
π (180°)	0.00	-1.00	0.00

sin and cos waves **Fig 6**

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