

Essential Tool for Physics Laws, Concepts, Variables and Equations including ~ Sample Problems, ~ Common Pitfalls and ~ Helpful Hints

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	s, 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_B	Weber Wb ($kg \cdot m^2/A \cdot s^2$)
Momentum	p	$kg \cdot m/s$
Potential	V	Voltage V (J/C)
Power	$P, \mathcal{P}$	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
Work	W	Joule - J (N·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	$3 \times 10^8 \text{ m/s}^{-1}$
Molar Gas Constant	R	$8.314 \text{ J/mol} \cdot \text{K}^{-1}$
Boltzmann Constant	k	$1.38 \times 10^{-23} \text{ J/K}^{-1}$
Gravitation Constant	G	$6.67 \times 10^{-11} \text{ m}^2 \cdot \text{kg}^{-1} \cdot \text{s}^{-2}$
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 ($g \cdot cm^2/s^2$) $1 \text{ erg} = 10^{-7} \text{ J}$
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. Vector: Denotes directional character using (x, y, z) components (Fig. 1)

 a. Unit vectors: $\hat{i}$ along x; $\hat{j}$ along y; $\hat{k}$ along z

 b. Vector $A = A_x \hat{i} + A_y \hat{j} + A_z \hat{k}$

 c. Length of $A = |A| = \sqrt{A_x^2 + A_y^2 + A_z^2}$

 2. Addition of vectors A & B , add components:

$$A + B = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j} + (A_z + B_z)\hat{k}$$

~ Sample Addition and Length Calculations:

$$A = 3\hat{i} + 4\hat{j} - 3\hat{k} \quad |A| = \sqrt{9 + 16 + 9}$$

$$= \sqrt{34} = 5.83$$

$$B = -2\hat{i} + 6\hat{j} + 5\hat{k} \quad |B| = \sqrt{4 + 36 + 25}$$

$$= \sqrt{65} = 8.06$$

$$A + B = \hat{i} + 10\hat{j} + 2\hat{k} \quad |A + B| = \sqrt{1 + 100 + 4}$$

$$= \sqrt{105} = 10.25$$

 Note: $|A| + |B| \geq |A + B|$

 3. Multiply A & B :

 a. Dot or scalar product: $A \cdot B = |A||B|\cos\theta = (A_x B_x + A_y B_y + A_z B_z)$

 Note: θ is the angle between A and B ;

 $A \cdot B = 0$, if $\theta = \pi/2$ (Fig. 2)

~ Sample: Scalar product:

$$A = 3\hat{i} + 4\hat{j} \quad B = 3\hat{i} + 5\hat{j}$$

$$A \cdot B = 3 \times 3 + 4 \times 5 = 9 + 20 = 29$$

$$|A| = \sqrt{25} = 5 \quad |B| = \sqrt{34} = 5.83$$

$$|B| = \sqrt{9 + 25} = \sqrt{34} = 5.83$$

$$\cos\theta = \frac{A \cdot B}{|A||B|} = \frac{29}{5 \times 5.83} = 0.99$$

$$\theta = \cos^{-1}(0.99) = 3^\circ = 0.2 \text{ rad} \quad \text{Fig. 3}$$

b. Cross or Vector Product:

$$C = A \times B = |A||B|\sin\theta \hat{n}$$

 θ = Angle between A and B , vector n is perpendicular to A and B

$$A \times B = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

~ Sample: Vector Product:

$$A = 2\hat{i} + \hat{j} \quad B = \hat{i} + 3\hat{j}$$

$$A \times B = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 1 & 0 \\ 1 & 3 & 0 \end{vmatrix} = (6 - 1)\hat{k} = 5\hat{k}$$

 ~ If A and B are in $x-y$ plane, $A \times B$ is along the $+z$ direction

 θ is the angle formed by A & B : $\sin\theta = \frac{|C|}{|A||B|}$

 Given: $|A| = \sqrt{5}$, $|B| = \sqrt{10}$, $|C| = 5$

$$\sin\theta = \frac{5}{\sqrt{5} \times \sqrt{10}} = \frac{5}{5\sqrt{2}} = \frac{1}{\sqrt{2}}$$

$$\therefore A, B: \theta = 45^\circ = \pi/2 \text{ radians}$$

 c. The Right-Hand rule gives the orientation of vector n (Fig. 4)

B. 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)

$$\sin\theta = \frac{y}{r}$$

$$\cos\theta = \frac{x}{r}$$

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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