

Essential Tool for Physics Laws, Concepts, Variables and Equations including  $\infty$  Sample Problems,  $\Delta$  Common Pitfalls and  $\mathcal{D}$  Helpful Hints

## BASICS

### A. Units for Physical Quantities

Base Units	Symbol	Unit
Length	$L, s$	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.	$\alpha$	radian/ $s^2$
Ang. Momentum	$L$	$kg \cdot m^2/s$
Ang. Velocity	$\omega$	radian/sec
Angle	$\theta, \phi$	radian
Capacitance	$C$	Farad F (C/V)
Charge	$Q, q, e$	Coulomb C (A s)
Density	$\rho$	$kg/m^3$
Displacement	$s, d, h$	meter - m
Electric Field	$E$	V/m
Electric Flux	$\Phi_e$	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 ( $kg \cdot m/s^2 = \text{J/m}$ )
Frequency	$f, \nu$	Hertz - Hz (cycle/s)
Heat	$Q$	Joule - J
Magnetic Field	$B$	Tesla (Wb/ $m^2$ )
Magnetic Flux	$\Phi_m$	Wbber 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 $\Omega$ (V/A)
Torque	$\tau$	N m
Velocity	$v$	m/s
Volume	$V$	$m^3$
Wavelength	$\lambda$	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	$c$	$3 \times 10^8 \text{ m/s}$
Molar Gas Constant	$R$	$8.314 \text{ J mol}^{-1} \text{ K}^{-1}$
Boltzmann Constant	$k$	$1.38 \times 10^{-23} \text{ J K}^{-1}$
Gravitational Constant	$G$	$6.67 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$
Permeability of Space	$\mu_0$	$4\pi \times 10^{-7} \text{ N/A}^2$
Permittivity of Space	$\epsilon_0$	$8.85 \times 10^{-12} \text{ F/m}$

### 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:  
 $A + B = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j} + (A_z + B_z)\hat{k}$   
 $\Delta$  **Sample Addition and Length Calculations:**  
 $A = 3\hat{i} + 4\hat{j} - 3\hat{k}$       $|A| = \sqrt{9 + 16 + 9} = \sqrt{34} = 5.83$   
 $B = -2\hat{i} + 6\hat{j} + 5\hat{k}$       $|B| = \sqrt{4 + 36 + 25} = \sqrt{65} = 8.06$   
 $A + B = \hat{i} + 10\hat{j} + 2\hat{k}$       $|A + B| = \sqrt{1 + 100 + 4} = \sqrt{105} = 10.25$

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:  $\theta$  is the angle between A and B:  
 $A \cdot B = 0$ , if  $\theta = \pi/2$  **Fig. 2**  
 $\Delta$  **Sample: Scalar product:**  
 $A = 3\hat{i} + 2\hat{j}$       $B = 3\hat{i} + 5\hat{j}$   
 $A \cdot B = 3 \times 3 + 2 \times 5 = 15 + 10 = 25$   
 $|A| = \sqrt{25} = 5$       $|B| = \sqrt{29} = 5.385$   
 $\cos\theta = \frac{A \cdot B}{|A||B|} = \frac{25}{5 \times 5.385} = 0.796$   
 $\theta = \cos^{-1}(0.796) = 37^\circ = 0.2\pi \text{ rad}$  **Fig. 3**

### b. Cross or Vector Product:

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

### c. The Right-Hand rule gives the orientation of vector $\hat{n}$ **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. **Standard Cos waves **Fig. 6****

$\theta$ rad ( $^\circ$ )	$\sin \theta$	$\cos \theta$	$\tan \theta$
0 (0)	0.000	1.000	0.000
$\pi/6$ (30)	0.500	0.866	0.577
$\pi/4$ (45)	0.707	0.707	1.000
$\pi/3$ (60)	0.866	0.500	1.732
$\pi/2$ (90)	1.000	0.000	$\infty$
$\pi$ (180)	0.000	-1.000	0.000



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**Chao Zhang**



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