

Essential Tool for Physics Laws, Concepts, Variables and Equations including ∞ Sample Problems, Δ 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. | 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 ($kg \cdot m/s^2 = \text{J/m}$) |
| Frequency | f, ν | Hertz - Hz (cycle/s) |
| Heat | Q | Joule - J |
| Magnetic Field | B | Tesla (Wb/ m^2) |
| Magnetic Flux | Φ_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 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 | $3 \times 10^8 \text{ m/s}$ |
| 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 | 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:** i along x, j along y, k along z
 b. **Vector:** $A = A_x i + A_y j + A_z k$
 c. **Length of A:** $|A| = \sqrt{A_x^2 + A_y^2 + A_z^2}$
 2. **Addition of vectors A & B:** add components:
 $A + B = (A_x + B_x)i + (A_y + B_y)j + (A_z + B_z)k$
 Δ **Sample Addition and Length Calculations:**
 $A = 3i + 4j - 3k$ $|A| = \sqrt{9 + 16 + 9} = \sqrt{34} = 5.83$
 $B = -2i + 6j + 5k$ $|B| = \sqrt{4 + 36 + 25} = \sqrt{65} = 8.06$
 $A + B = i + 10j + 2k$ $|A + B| = \sqrt{1 + 100 + 4} = \sqrt{105} = 10.25$
 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**
 Δ **Sample: Scalar product:**
 $A = 3i + 4j$ $B = 3i + 5j$
 $A \cdot B = 3 \times 3 + 4 \times 5 = 9 + 20 = 29$
 $|A| = \sqrt{25} = 5$ $|B| = \sqrt{29} = 5.385$
 $\cos\theta = \frac{A \cdot B}{|A||B|} = \frac{29}{5 \times 5.385} = 0.796$
 $\theta = \cos^{-1}(0.796) = 37^\circ = 0.2 \text{ rad}$ **Fig. 3**

b. Cross or Vector Product:

$C = A \times B = |A||B|\sin\theta e$
 θ = Angle between A and B, vector e is perpendicular to A and B
 $A \times B = \begin{vmatrix} i & j & k \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$
 Δ **Sample: Vector Product:**
 $A = 2i + j$ $B = i + 3j$
 $A \times B = \begin{vmatrix} i & j & k \\ 2 & 1 & 0 \\ 1 & 3 & 0 \end{vmatrix} = (6 - 1)k = 5k$
 - 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: $|A| = \sqrt{5}$ $|B| = \sqrt{10}$ $|C| = 5$
 $\sin\theta = \frac{5}{\sqrt{5} \times \sqrt{10}} = \frac{5}{5\sqrt{2}} = \frac{1}{\sqrt{2}}$
 $\therefore A \cdot B = 45^\circ = \pi/2 \text{ radians}$

c. The Right-Hand rule gives the orientation of vector 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. **Standard Cos waves **Fig. 6****

| θ 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 | ∞ |
| π (180) | 0.000 | -1.000 | 0.000 |



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