

Essential Tool for Physics Laws, Concepts, Variables and Equations including \sim Sample Problems, Δ Common Pitfalls and \mathcal{H} 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	$8.314 \text{ J mol}^{-1} \text{ K}^{-1}$
Boltzmann Constant	k	$1.38 \times 10^{-23} \text{ J K}^{-1}$
Gravitation Constant	G	$6.67 \times 10^{-11} \text{ m}^2 \text{ kg}^{-1} \text{ s}^{-2}$
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: \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:
 $A + B = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j} + (A_z + B_z)\hat{k}$

\sim **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)

\sim **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

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

\sim **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 : $\sin\theta = \frac{|C|}{|A||B|}$

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

$$\sin\theta = 5 / (\sqrt{5} \times \sqrt{10}) = 5 / \sqrt{50} = 1 / \sqrt{2}$$

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

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)

Values Of sin, cos and tan

θ rad [$^\circ$]	$\sin\theta$	$\cos\theta$	$\tan\theta$
0 [0 $^\circ$]	0.000	1.000	0.000
$\pi/6$ [30 $^\circ$]	0.500	0.866	0.577
$\pi/4$ [45 $^\circ$]	0.707	0.707	1.000
$\pi/3$ [60 $^\circ$]	0.866	0.500	1.732
$\pi/2$ [90 $^\circ$]	1.000	0.000	—
π [180 $^\circ$]	0.000	-1.000	0.000

sin and cos waves



Mastering Physics Chapter 9

Maya Anglaw



Mastering Physics Chapter 9:

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What You Will Learn Fundamentals and components of scientific computing Scientific computing data management Performing numerical computing using NumPy and SciPy Concepts and programming for symbolic computing using SymPy Using the plotting library matplotlib for data visualization Data analysis and visualization using Pandas matplotlib and IPython Performing parallel and high performance computing Real life case studies and best practices of scientific computing

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