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# Physics (Quick Study Academic)

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**WHAT IS PHYSICS ALL ABOUT?**

Physics seeks to understand the natural phenomena that occur in our universe; a description of a natural phenomenon uses many specific terms, definitions and mathematical equations.

**Solving Problems in Physics**  
In physics, we use the SI units (International System) for data and calculations.

Base Quantity	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 (A/C)

Other physical quantities are derived from these basic units. **Prefixes** denote fractions or multiples of units; many variable symbols are Greek letters.

**Math Skills:** Many physical concepts are only understood with the use of algebra, statistics, trigonometry and calculus.

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**CLASSICAL MECHANICS**

**A. Kinematics of Newtonian Mechanics**  
The position of a body is given by an equation of motion with position, velocity and acceleration as variables; **mass** is the measure of the amount of matter; the standard unit for mass is kg, 1 kg = 1000 g; **inertia** is a property of matter, and so is such, it resists change.

- Motion along a straight line is called **rectilinear**; the equation of motion describes the position of the particle and velocity for elapsed time,  $s$ .
- Velocity (V)**: The rate of change of the displacement ( $s$ ) with time ( $t$ ),  $v = \frac{ds}{dt}$ .
- Acceleration (a)**: The rate of change of the velocity with time,  $a = \frac{dv}{dt}$ .
- $a$  &  $v$  are vectors, with magnitude and direction.
- Speed** is the absolute value of the velocity, scalar with the same units as velocity.

**Equations of Motion for One Dimension (1-D)**  
Equation of motion describes the future position ( $s$ ) and velocity ( $v$ ) of a body in terms of the initial velocity ( $u$ ), position ( $s_0$ ) and acceleration ( $a$ ).

- For constant acceleration, the position is related to the time and acceleration by the following equation of motion:  $s - s_0 = ut + \frac{1}{2}at^2$
- For constant acceleration, the velocity vs. time is given by the following:  $v - u = at$
- If the acceleration is a function of time, the equation must be solved using  $\int v = at$

**B. Motion in Two Dimensions (2-D)**

- Free bodies moving along a straight line, derive  $s$ - and  $v$ -equations of motion:  $s = v_0t + \frac{1}{2}at^2$ ,  $v = v_0 + at$
- For a rotating body, use **polar coordinates**, as angle variables,  $\theta$ , and  $r$ , a radial distance from the rotational center.

**C. Motion in Three Dimensions (3-D)**

- Cartesian System:** Equations of motion with  $x$ ,  $y$  and  $z$  components.
- Spherical Coordinate:** Equations of motion based on true angles ( $\theta$  and  $\phi$ ) and  $r$ , the radial distance from the origin.

**D. Newton's Laws of Motion**  
Newton's Laws are the basic principles for describing the motion of classical objects in response to forces; the SI unit of force is the Newton, N, (N=kg m/s<sup>2</sup>); the cgs unit is the dyne: 1 dyne = 1g cm/s<sup>2</sup>

- Newton's 1st Law:** A body remains at rest or in motion unless influenced by a force.
- Newton's 2nd Law:** Force and acceleration determine the motion of a body and predict future position and velocity:  $F = ma$  OR  $\Sigma F = ma$
- Newton's 3rd Law:** Every action is countered by an opposing action.

**E. Types of Forces**

- A **body force** acts on the entire body, with the force acting at the center of mass.
  - A gravitational force,  $F_g$ , pulls an object toward the center of the Earth,  $F_g = mg$ .
  - Weight** =  $F_g$ , gravitational force.
  - Mass** is a measure of the quantity of material, independent of  $g$  and other forces.
- Surface forces** act on the body's surface.
  - Friction,  $F_f$ ,** is proportional to the force normal to the part of the body in contact with a surface,  $F_f = \mu F_N$ .
  - Static friction** resists the movement of a body.
  - Dynamic friction** shows the motion of a body. For an object on a horizontal plane:  $F_f = \mu F_N = \mu mg$ . Net force =  $F - F_f$ .

**F. Circular Motion**

- Motion along a circular path uses **polar coordinates** ( $r, \theta$ ).
- Key Variables:**

$r$	Radius	The distance from the rotation center (center of mass)
$\theta$	Angle	The angle between $r$ and the (x) axis
$\omega$	Radian/second	The angular velocity
$\alpha$	Radian/second <sup>2</sup>	The angular acceleration
$v$	Meter	The circular motion arc, $s = R\theta$ ( $\theta$ in rad)
- Tangential acceleration & velocity:**  $v_t = r\omega$ ,  $a_t = r\alpha$ ;  $v$  and  $a$  along the path of the motion are.
- Centripetal acceleration:**  $a_c = \frac{v^2}{r}$ ,  $a_c$  is directed toward the rotational center.
  - The centripetal force keeps the body in circular motion with a tangential acceleration and velocity.

**G. Kinetic Energy & Work**

- Kinetic energy,  $K$ :** Kinetic energy is the energy of motion, mass,  $m$  and velocity,  $v$ ,  $K = \frac{1}{2}mv^2$ . The SI energy unit is the Joule (J): 1J = 1 kg m<sup>2</sup>/s<sup>2</sup>
- Momentum,  $p$ :** Momentum is a property of motion, defined as the product of mass and velocity:  $p = mv$ .
- Work (W):** Work is a force acting on a body moving a distance; for a constant force,  $F$ , and a body moving a path,  $s$ ,  $W = F \cdot s$ . For a constant force, work is the scalar product of the two vectors: force,  $F$ , and path,  $s$ :  $W = F \cdot s \cos(\theta) = F \cdot s$ .

**H. Potential Energy & Energy Conservation**

- The total energy of a body,  $E$ , is the sum of kinetic,  $K$ , & potential energy,  $U$ :  $E = K + U$ .
- Potential energy** arises from the interaction with a potential from an external force. Potential energy is energy of position. Unit, the form of  $U$  depends on the force producing the potential. Gravitational:  $U_g = mgh$ . Electrostatic:  $U_e = \frac{q_1q_2}{4\pi\epsilon_0 r^2}$ . If there are no other forces acting on the system,  $E$  is constant and the system is called **conservative**.

**I. Collisions & Linear Momentum**

- Types of Collisions:**
  - Elastic: conserve energy
  - Inelastic: energy is lost as heat or deformation.
- Reference Motion & Frames of Reference:** A body moves with velocity  $v$  in frame  $S$ ; in frame  $S'$  the velocity is  $v'$ ; if  $S'$  is the velocity of frame  $S'$  relative to  $S$ , then  $v = v' + v'$ .
- Elastic Collision:**
  - Conserve Kinetic Energy:  $\Sigma \frac{1}{2}mv^2 = \Sigma \frac{1}{2}mv'^2$
  - Conserve Momentum:  $\Sigma mv = \Sigma mv'$
- Impulse** is a force acting over time:  $Impulse = F \cdot \Delta t = \Delta p$ . Impulse is also the momentum change:  $P_{fin} - P_{in}$ .



## Synopsis

Reference and outline to concepts in physics.

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This chart has errors in some of the equations. Equations listed for magnetic force (such as  $F = qv \times B$ ) that should have a cross product have a dot product instead. I was disappointed to find this because it means this product is not properly refined and therefore useless to me as a student. I really like it otherwise, as it covers all the stuff seen in standard sophomore level physics classes.

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Mine may be a different edition because there is a cross product in the magnetic force formula, but I am missing a dot in the definition of magnetic flux and the magnetic field of a long conducting wire (for the Biot-Savart Law sample) is incorrect. It shows division by  $4\pi$  when it should be  $2\pi$ . I would recommend students using these guides double check the formulas with their textbooks the first time they use them.

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