

# PHYSICS

## 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.

## CLASSICAL MECHANICS

**A. Classical or 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;  $1 \text{ kg} = 1000 \text{ g}$ ; inertia is a property of matter, and as such, it resists space.

**1. Motion along a straight line:** is called rectilinear; the equation of motion describes the position of the particle and velocity for elongated time; t.

**a. Velocity (v):** The rate of change of the displacement (x) with time (t):  $v = \frac{dx}{dt} = \frac{\Delta x}{\Delta t}$ .

**b. Acceleration (a):** The rate of change of the velocity with time:  $a = \frac{dv}{dt} = \frac{\Delta v}{\Delta t}$ .

a & v are vectors, with magnitude and direction.

c. Speed is the absolute value of the velocity, scalar with the same units as velocity.

**2. Equations of Motion for One Dimension (1-D):** Equations of motion describe the three position (x), velocity (v), and acceleration (a) of a body in terms of the initial velocity ( $v_0$ ), position ( $x_0$ ) and acceleration (a).

a. For constant acceleration, the position is related to the time and acceleration by the following equation of motion:  $x(t) = x_0 + v_0 t + \frac{1}{2} a t^2$ .

b. For constant acceleration, the velocity vs. time is given by the following:  $v(t) = v_0 + a t$ .

c. If the acceleration is a function of time, the equation must be solved using  $a = a(t)$ .

**B. Motion in Three Dimensions (3-D):**

1. For bodies moving along a straight line, derive x-, y- and z-equations of motion:

$$x = v_{0x} t + \frac{1}{2} a_x t^2$$

$$y = v_{0y} t + \frac{1}{2} a_y t^2$$

2. For a rotating body, use polar coordinates, an angle variable,  $\theta$ , and  $r$ , a radial distance from the rotational center.

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

1. **Cartesian System:** Equations of motion with x, y, and z components.

2. **Spherical Coordinates:** Equations of motion based on two angles ( $\theta$  and  $\phi$ ) and  $r$ , the radial distance from the origin.

### Newton's Laws of Motion

Newton's Laws are the core principles for describing the motion of classical objects in response to forces. The SI unit of force is the Newton,  $1 \text{ N} = 1 \text{ kg m/s}^2$ ; the erg unit is the dyne:  $1 \text{ dyne} = 1 \text{ g cm/s}^2$ .

Base Quantity	Symbol	Unit
Length	$x, y$	Meter - m
Mass	$m, M$	Kilogram - kg
Temperature	$T$	Kelvin - K
Time	$t$	Second - s
Electric Current	$I$	Ampere - A (C/s)

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.

**1. Newton's 1st Law:** A body remains at rest or in motion unless influenced by a force.

**2. Newton's 2nd Law:** Force and acceleration determine the motion of a body and predict future position and velocity:  $F = m a$  OR  $\Sigma F = m a$ .

**3. Newton's 3rd Law:** Every action is countered by an opposing action.

### E. Types of Forces

1. **Body Force:** acts on the entire body, with the force acting at the center of mass.

a. A gravitational force,  $F_g$ , pulls an object toward the center of the Earth:  $F_g = m g$ .

b. Weight =  $F_g$ ; gravitational force.

c. Mass is a measure of the quantity of material, independent of g and other forces.

2. **Surface Forces:** act on the body's surface.

a. **Friction:**  $F_f$ , is proportional to the force normal to the part of the body in contact with a surface:  $F_f = \mu F_n$ .

i. **Static friction:** resists the movement of a body.

ii. **Dynamic friction:** slows the motion of a body.

For an object on a horizontal plane:  $F_f = \mu F_n = \mu m g$ .

Net force =  $F_n - F_f$ .



### F. Circular Motion

1. Motion along a circular path uses polar coordinates:  $(r, \theta)$ .

2. Key Variables:

$r$	Meter	The distance from the rotation center (center of mass)
$\theta$	Radian	The angle between $r$ and the $0x$ axis.
$\omega$	Radian/second	The angular velocity
$\alpha$	Radian/second <sup>2</sup>	The angular acceleration

3. Tangential acceleration  $\alpha_t$  velocity:

$$\alpha_t = r \omega \alpha_t = r \omega \alpha_t = r \alpha_t$$

4. Centripetal acceleration:  $a_c = \frac{v^2}{r}$ ;  $a_c$  is directed toward the rotational center.

a. The centripetal force keeps the body in circular motion with a tangential acceleration and velocity.

### G. Kinetic Energy & Work

1. **Kinetic energy:** KE Kinetic energy is the energy of motion; mass, m and velocity, v:  $K = \frac{1}{2} m v^2$ . The SI energy unit is the Joule (J):  $1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$ .

2. **Momentum:**  $mv$  Momentum is a property of motion, defined as the product of mass and velocity:  $p = m v$ .

3. **Work (W):** Work is a force acting on a body moving a distance;  $w = \int F \cdot ds$ .

For a constant force, work is the scalar product of the two vectors: force,  $F$ , and path,  $s$ :  $W = F \cdot \text{dis} \cdot \cos(\theta) = F \cdot r \cdot v$ .



4. **Power (P):** is energy expended per unit time:  $P = \frac{dW}{dt} = \frac{dE}{dt}$ .

$W = \int P(t) dt$

The SI unit for power is the Watt (W):  $1 \text{ W} = 1 \text{ Joule/second} = 1 \text{ J/s}$ .

Work for a constant output of power:  $W = P \cdot t$ .

### H. Potential Energy & Energy Conservation

1. The total energy of a body, E, is the sum of kinetic,  $K$ , & potential energy,  $U$ :  $E = K + \sum U$ .

2. Potential energy arises from the interaction with a potential from an external force.

Potential energy is energy of position:  $U(r)$ ; the form of U depends on the force generating the potential.

Gravitation:  $U(r) = -\frac{G m}{r}$ .

Electricity:  $U(r) = \frac{q_1 q_2}{4 \pi \epsilon_0 r}$ .

If there are no other forces acting on the system, E is constant and the system is called conservative.

### I. Collisions & Linear Momentum

1. **Types of Collisions:**

a. Elastic: conserve energy

b. Inelastic: energy is lost as heat or deformation

2. **Relativistic Motion & Frames of Reference:** A body moves with velocity  $v$  in frame S; in frame S' the velocity is  $v'$ ; if  $V_s$  is the velocity of frame S' relative to S, therefore:  $v = v' + V_s$ .

3. **Classic Collision:**

**Conservative Kinetic Energy:**  $\sum \frac{1}{2} m v_i^2 = \sum \frac{1}{2} m v_f^2$ .

**Conservative Momentum:**  $\sum m v_i = \sum m v_f$ .

4. **Impulse:** is a force acting over time.

Impulse =  $F \cdot \Delta t$  or  $\int F(t) dt$ .

Impulse is also the momentum change:  $p_f - p_i$ .

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