

# 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.

Basic Quantity	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/Vs)

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

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

## 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 kg = 1000 g.; inertia is a property of matter, and as such, it resists space.

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

a. Velocity ( $v$ ): The rate of change of the displacement ( $s$ ) with time ( $t$ ):  $v = \frac{ds}{dt} = \frac{d^1 s}{dt}$ .

b. Acceleration ( $a$ ): The rate of change of the velocity with time:  $a = \frac{dv}{dt} = \frac{d^2 s}{dt^2}$ .

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 future position ( $s$ ) and velocity ( $v(t)$ ) of a body in terms of the initial velocity ( $v_0$ ), position ( $s_0$ ) and acceleration ( $a$ )

a. For constant acceleration, the position is related to the time and acceleration by the following equation of motion:  $s(t) = s_0 + v_0 t + \frac{1}{2} a t^2$

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  $a = \dot{a}(t)$

### 3. Motion in Two Dimensions (2-D)

1. For bodies moving along a straight line, derive x- and y-equations of motion:  $x = x_0 + [v_0 t]$ ,  $y = y_0 + [a_0 t]$

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

### 4. 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.

### 5. 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, N:  $1\text{N} = 1\text{kg m/s}^2$ ; the cgs unit is the dyne: 1 dyne = 1g cm/s<sup>2</sup>

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  $\sum F = m a$

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

### 6. Types of Forces

1. A 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 allows the motion of a body

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

Net Force =  $F_x - F_f$



### 7. Circular Motion

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

2. Key Variables:

$r$	Meter	The distance from the center (center of mass)
$\theta$	Radian	The angle between $r$ and the $(x, y)$ axis
$\omega$	Radian/second	The angular velocity
$\alpha$	Radian/second <sup>2</sup>	The angular acceleration
$\nu$	Meter	The circular motion arc: $\nu = r\omega$ ( $\theta$ in rad)

3. Tangential acceleration & velocity:

$\nu_t = r\omega$ ,  $a_t = r\omega^2$ ,  $v$  and  $a$  along the path of the motion arc

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

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

### C. Kinetic Energy & Work

1. Kinetic energy,  $K$ : 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; for a general force,  $F$ , and a body moving a path,  $s$ :  $W = \int F \cdot ds$ .

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



4. Power ( $P$ ): is energy expended per unit time:  $P = \frac{d\text{Work}}{d\text{Time}} = \frac{dW}{dt}$

Work =  $\int F \cdot ds$

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:  $W = P t$

### D. Potential Energy & Energy Conservation

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

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: Gravitational:  $U(r) = -mgh$

Electrostatic:  $U(r) = \frac{q_1 q_2}{r}$

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

### E. Collisions & Linear Momentum

1. Types of Collisions

a. Elastic: conserve energy

b. Inelastic: energy is lost as heat or deformation

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

3. Elastic 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:  $\Delta p = F \cdot \Delta t$

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**Jerry D. Wilson, Anthony J. Buffa, Bo  
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