# QuickStudy ACADEMIC

# 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.

| Base 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/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**.

## 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 occupies space.

1. Motion along a **straight line** is called **rectilinear**; the equation of motion describes the position of the particle and velocity for elapsed 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: $a = \frac{dv}{dt} = \frac{\Delta v}{\Delta t}$
   
   c. **a** & **v** are vectors, with magnitude and direction
   d. **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 (x) and velocity (v) 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 Two Dimensions (2-D)
1. For bodies moving along a **straight line**, derive x- and y-equations of motion
   $x = v_x t + \frac{1}{2} a_x t^2$
   $y = v_y t + \frac{1}{2} a_y t^2$
2. For a **rotating body**, use **polar coordinates**, an angle variable $\theta$, and r, a radial distance from the rotational center


**Polar**
Polar: (r, θ)
$x = r \cos\theta$,
$y = r \sin\theta$,
$r^2 = x^2 + y^2$

### 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 $\varphi$) and r, the radial distance from the origin


**Spherical**
$x = r \sin\theta \cos\phi$,
$y = r \sin\theta \sin\phi$,
$z = r \cos\theta$,

### D. 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;** 1N=1kg m/s²; the cgs unit is the **dyne;** 1 dyne = 1g cm/s²

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

### E. 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: $F_g = mg$
   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: $F_f = F_N = \mu F_N$
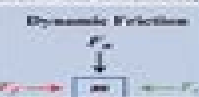      i. **Static friction** resists the movement of a body
      ii. **Dynamic friction** slows the motion of a body
      For an object on a **horizontal plane:**
      $F_f = \mu F_N = \mu m g$
      Net force = $F_a - F_f$


**Dynamic Friction**

### F. Circular Motion
1. Motion along a circular path uses polar coordinates: (r, θ)
2. Key Variables:


**Circular Motion**

| | | |
|---|---|---|
| $r$ | Meter | The distance from the rotation center (center of mass) |
| $\theta$ | Radian | The angle between r and the (x) axis |
| $\omega$ | Radian/second | The angular velocity |
| $\alpha$ | Radian/second² | The angular acceleration |
| $s$ | Meter | The circular motion arc s = rθ (θ in rad) |

3. **Tangential** acceleration & velocity:
   $v_t = r\omega$, $a_t = r\alpha$; v and a along the path of the motion are
4. **Centripetal** acceleration: $a_c = \frac{v^2}{r}$; a is directed toward the rotational center
   a. The centripetal force keeps the body in circular motion with a tangential acceleration and velocity

### G. Kinetic Energy & Work
1. **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):
   $1 J = 1 kg \cdot m^2/s^2$
2. **Momentum, p:** 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: $W = \int F \, ds$
   For a **constant force**, work is the scalar product of the two vectors: force, F, and path, r:
   $W = F \, d \cos(\theta) = F \cdot r$


Maximum work | No work

4. **Power (P)** is energy expended per unit time: $P = \frac{\Delta Work}{\Delta time} = \frac{\Delta Work}{\Delta t}$
   $Work = \int P(t) dt$
   The SI unit for power is the **Watt (W):**
   $1 W = 1 Joule/second = 1 J/s$
   Work for a **constant output of power:**
   $W = P \Delta t$

### 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:** $U(h) = mgh$
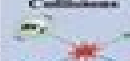   **Electrostatic:** $U(r_{12}) = \frac{q_1 q_2}{r_{12}}$
   If there are no other forces acting on the system, E is constant and the system is called **conservative**

### I. Collisions & Linear Momentum
1. **Types of Collisions**
   a. **Elastic:** conserve energy
   b. **Inelastic:** energy is lost as heat or deformation


**Collisions**

2. **Relative Motion & Frames of Reference:** A body moves with velocity v in frame S; into the velocity is v'; if $V_s'$ is the velocity of frame S' relative to S, therefore: $v = V_s' + v'$
3. **Elastic Collision**
   **Conserve Kinetic Energy:** $\sum \frac{1}{2} m_i v_i^2 = \sum \frac{1}{2} m_i v_i'^2$
   **Conserve Momentum:** $\sum m_i v_i = \sum m_i v_i'$
4. **Impulse** is a force acting over time
   $Impulse = F \Delta t$ or $\int F(t) dt$
   Impulse is also the **momentum change:** $p_{fin} - p_{init}$

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**Mike Jess**

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