

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, $1 \text{ kg} = 1000 \text{ g}$; 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

$$(x) \text{ with time } (t): v = \frac{dx}{dt} = \frac{dx}{dt}$$

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

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 (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

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

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



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

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

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 (θ and ϕ) and r , the radial distance from the origin.



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; $1 \text{ N} = 1 \text{ kg m/s}^2$, the cgs unit is the dyne; $1 \text{ dyne} = 1 \text{ g cm/s}^2$

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. 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.

$$F_f = F_N = \mu F_N$$

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:

$$F_f = \mu F_N = \mu m g$$

$$\text{Net force} = F_f + F_g$$



F. Circular Motion

1. Motion along a circular path uses polar coordinates: (r, θ)

2. Key Variables:

r	Meter	The distance from the rotation center (center of mass)
θ	Radian	The angle between r and the (x) axis
ω	Radian/second	The angular velocity
α	Radian/second ²	The angular acceleration
s	Meter	The circular motion arc $s = r\theta$ (θ in rad)

3. **Tangential acceleration & velocity:**

$$v_t = r \omega; a_t = r \alpha; v \text{ and } a \text{ along the path of the motion are}$$

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 ; $K = \frac{1}{2} m v^2$

The SI energy unit is the Joule (J); $1 \text{ J} = 1 \text{ kg m}^2/\text{s}^2$

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 :

$$W = F d \cos(\theta) = F \cdot r$$



4. **Power (P):** energy expended per unit time:

$$P = \frac{dW}{dt} = \frac{dW}{dt}$$

$$W = \int P(t) dt$$

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:

$$W = P \Delta t$$

H. Potential Energy & Energy Conservation

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

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

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. **Relative 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: $v = V_s + v'$

3. **Elastic Collision:**

$$\text{Conserve Kinetic Energy: } \Sigma \frac{1}{2} m v^2 = \Sigma \frac{1}{2} m v'^2$$

$$\text{Conserve Momentum: } \Sigma m v_i = \Sigma m v_f$$

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

$$\text{Impulse} = F \Delta t \text{ or } \int F(t) dt$$

Impulse is also the momentum change: $p_{\text{fin}} - p_{\text{ini}}$



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Table of Contents Physics Regents Quick Study Guide

1. Understanding the eBook Physics Regents Quick Study Guide
 - The Rise of Digital Reading Physics Regents Quick Study Guide
 - Advantages of eBooks Over Traditional Books
2. Identifying Physics Regents Quick Study Guide
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Physics Regents Quick Study Guide
 - User-Friendly Interface
4. Exploring eBook Recommendations from Physics Regents Quick Study Guide
 - Personalized Recommendations
 - Physics Regents Quick Study Guide User Reviews and Ratings
 - Physics Regents Quick Study Guide and Bestseller Lists
5. Accessing Physics Regents Quick Study Guide Free and Paid eBooks
 - Physics Regents Quick Study Guide Public Domain eBooks
 - Physics Regents Quick Study Guide eBook Subscription Services
 - Physics Regents Quick Study Guide Budget-Friendly Options
6. Navigating Physics Regents Quick Study Guide eBook Formats

- ePub, PDF, MOBI, and More
- Physics Regents Quick Study Guide Compatibility with Devices
- Physics Regents Quick Study Guide Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Physics Regents Quick Study Guide
 - Highlighting and Note-Taking Physics Regents Quick Study Guide
 - Interactive Elements Physics Regents Quick Study Guide
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 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Physics Regents Quick Study Guide
- 9. Balancing eBooks and Physical Books Physics Regents Quick Study Guide
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Physics Regents Quick Study Guide
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Physics Regents Quick Study Guide
 - Setting Reading Goals Physics Regents Quick Study Guide
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Physics Regents Quick Study Guide
 - Fact-Checking eBook Content of Physics Regents Quick Study Guide
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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