

## KINEMATICS

**Vectors:** physical quantities with both magnitude and direction

- Examples: force, velocity

**Scalars:** physical quantities that have magnitude, but no direction

- Examples: mass, speed

### Vector Addition and Subtraction

**Tip-to-Tail Method of Finding Resultant of Two Vectors**



### Finding Resultant Using Component Method

- Resolve vectors into x & y components.
- Sum all the vectors in the x direction to get the resultant for the x direction, and do the same for the y-components.
- The magnitude of the resultant  $R = \sqrt{R_x^2 + R_y^2}$

**Displacement ( $\Delta x$ ):** the change in position that gives in a straight-line path from the initial position to the final. It is independent of the path taken (SI units: m)

**Average velocity:**  $v = \frac{\Delta x}{\Delta t}$  (SI units: m/s)

**Acceleration:** the rate of change of an object's velocity; it is a vector quantity:  $a = \frac{\Delta v}{\Delta t}$  (SI units: m/s<sup>2</sup>)

### Linear Motion

$$v = v_0 + at$$

$$\Delta x = v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a\Delta x$$

$$v_{avg} = \frac{v_0 + v}{2}$$

$$\Delta x = vt = \left[ \frac{v_0 + v}{2} \right] t$$

### Projectile Motion



- vertical component of velocity =  $v \sin \theta$
- horizontal component of velocity =  $v \cos \theta$

### Rotational Forces

**Static Friction ( $f_s$ ):** is the force that must be overcome to set an object in motion. It has the formula:  $0 < f_s \leq \mu_s N$

**Kinetic Friction ( $f_k$ ):** opposes the motion of objects moving relative to each other. It has the formula:  $f_k = \mu_k N$



## NEWTON'S LAWS

**Newton's First Law (Law of Inertia):** a body in a state of motion or at rest will remain in that state unless acted upon by a net force

**Newton's Second Law:** when a net force is applied to a body of mass  $m$ , the body will be accelerated in the same direction as the force applied to the mass. This is expressed by the formula:  $F = ma$  (SI unit: Newton (N) = kg·m/s<sup>2</sup>)



$F_{gravity} = F_{normal}$  when acceleration is zero  
 $F_g = F_{normal}$  terminal velocity is reached (person falls at constant velocity)

**Newton's Third Law:** if body A exerts a force on body B, then B will exert a force back onto A that is equal in magnitude, but opposite in direction. This can be expressed as:  $F_A = -F_B$

**Newton's Law of Gravitation:** All forms of matter experience an attractive force to other forms of matter in the universe. The magnitude of the force is represented by:  $F = G \frac{m_1 m_2}{r^2}$

- **Mass ( $m$ ):** a scalar quantity that measures a body's inertia
- **Weight ( $W$ ):** a vector quantity that measures a body's gravitational attraction to the earth ( $W = mg$ )

### Uniform Circular Motion:

$$a_c = \frac{v^2}{r}$$

$$F_c = \frac{mv^2}{r}$$



### Equilibrium

**First condition of equilibrium:** An object is in translational equilibrium when the sum of forces pushing it one direction is counterbalanced by the sum of forces acting in the opposite direction. It can be expressed as:  $\sum F = 0$



## Problem Solving Guide

- Resolve the forces into x and y components.
- $\sum F = 0$  must be true for equilibrium; therefore,  $\sum F_x = 0$  and  $\sum F_y = 0$ .
- Only forces in the x direction affect motion of the object.

$$\sum F_x = ma$$

## WORK, ENERGY & MOMENTUM

**Work:** For a constant force  $F$  acting on an object that moves through a distance  $d$ , the work is  $W = Fd \cos \theta$ . For a force perpendicular to the displacement,  $W = 0$  (SI unit: Joule = Nm)

**Power:** the rate at which work is performed, and is given by:  $P = \frac{W}{t}$  (SI unit: Watt = J/s)

### Mechanical Energy

**Energy** is a scalar quantity (SI unit: Joule)

**Kinetic energy:** the energy associated with moving objects. It is given by:

$$KE = \frac{1}{2}mv^2$$

**Potential energy:** the energy associated with a body's position. Gravitational potential energy of an object is due to the force of gravity acting on it, and it is expressed as:  $U = mgh$

### Total Mechanical Energy

$$E = U + K$$

Mechanical energy is conserved when the sum of kinetic and potential energies remains constant

### Work-Energy Theorem

Relates the work performed by all forces acting on a body in a particular time interval to the change in kinetic energy at that time. The expression is:  $W = \Delta KE$

### Conservation of Energy

When there are no nonconservative forces (e.g., friction) acting on a system, the total mechanical energy remains constant:  $\Delta E = \Delta K + \Delta U = 0$

**Momentum:** a vector quantity. It is given by:  $p = mv$



**Elastic Collision – Target at Rest**  
 Conservation of momentum:

$$m_1 v_{1i} = m_1 v_{1f} + m_2 v_{2f}$$

Conservation of kinetic energy:

$$\frac{1}{2}m_1 v_{1i}^2 = \frac{1}{2}m_1 v_{1f}^2 + \frac{1}{2}m_2 v_{2f}^2$$



**Completely Inelastic Collision – Target at Rest**

	Before	After
Momentum:	$m_1 v_i$	$(m_1 + m_2) v_f$
Kinetic energy:	$\frac{1}{2}m_1 v_i^2$	$\frac{1}{2}(m_1 + m_2) v_f^2$
Conservation of momentum:		$m_1 v_i = (m_1 + m_2) v_f$

$$\text{Impulse } (J) = F \Delta t = \Delta p$$

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## **Table of Contents Mcat Quicksheet Physics**

1. Understanding the eBook Mcat Quicksheet Physics
  - The Rise of Digital Reading Mcat Quicksheet Physics
  - Advantages of eBooks Over Traditional Books
2. Identifying Mcat Quicksheet Physics
  - 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 Mcat Quicksheet Physics
  - User-Friendly Interface
4. Exploring eBook Recommendations from Mcat Quicksheet Physics
  - Personalized Recommendations
  - Mcat Quicksheet Physics User Reviews and Ratings
  - Mcat Quicksheet Physics and Bestseller Lists
5. Accessing Mcat Quicksheet Physics Free and Paid eBooks
  - Mcat Quicksheet Physics Public Domain eBooks
  - Mcat Quicksheet Physics eBook Subscription Services
  - Mcat Quicksheet Physics Budget-Friendly Options
6. Navigating Mcat Quicksheet Physics eBook Formats

- ePub, PDF, MOBI, and More
  - Mcat Quicksheet Physics Compatibility with Devices
  - Mcat Quicksheet Physics Enhanced eBook Features
7. Enhancing Your Reading Experience
    - Adjustable Fonts and Text Sizes of Mcat Quicksheet Physics
    - Highlighting and Note-Taking Mcat Quicksheet Physics
    - Interactive Elements Mcat Quicksheet Physics
  8. Staying Engaged with Mcat Quicksheet Physics
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Mcat Quicksheet Physics
  9. Balancing eBooks and Physical Books Mcat Quicksheet Physics
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Mcat Quicksheet Physics
  10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
  11. Cultivating a Reading Routine Mcat Quicksheet Physics
    - Setting Reading Goals Mcat Quicksheet Physics
    - Carving Out Dedicated Reading Time
  12. Sourcing Reliable Information of Mcat Quicksheet Physics
    - Fact-Checking eBook Content of Mcat Quicksheet Physics
    - 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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