

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 (Δx): 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/s²)

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: $0 < f_s < \mu_s N$

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/s²)



$F_{gravity} = F_{normal}$ 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: $\sum F = 0$



Elastic Collisions – Target at Rest

Conservation of momentum:

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

Conservation of kinetic energy:

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

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

$$E = K + U$$

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: $p = mv$



Completely Inelastic Collisions – Target at Rest

	Before	After
Momentum	$m_1 v_1$	$(m_1 + m_2) v_f$
Kinetic energy	$\frac{1}{2} m_1 v_1^2$	$\frac{1}{2} (m_1 + m_2) v_f^2$
Conservation of momentum:	$m_1 v_1 = (m_1 + m_2) v_f$	

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

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John D. Cutnell



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