
📚 Classical Mechanics: A Deep Dive into Newtonian Physics

1️⃣ Newton’s Laws of Motion

Newton’s three laws form the foundation of classical mechanics, explaining how objects move and interact.

🔹 First Law (Law of Inertia)

"An object at rest remains at rest, and an object in motion continues in uniform motion unless acted upon by an external force."

- This means that objects resist changes in their state of motion.
- The property of resisting change in motion is called **inertia**.
- 🚗 Example: If you're in a moving car and the driver suddenly hits the brakes, your body keeps moving forward because of inertia!

🔹 Second Law (F = ma)

"The acceleration of an object depends on the net force acting on it and its mass."

- The equation: **F = ma**
  - **F** = Force (Newton, N)
  - **m** = Mass (kg)
  - **a** = Acceleration (m/s²)
- 🚀 Example: A heavier object requires more force to move than a lighter object.

🔹 Third Law (Action-Reaction)

"For every action, there is an equal and opposite reaction."

- 🏀 Example: When you throw a basketball downward, the ground pushes it back up!
- 🚀 Rocket propulsion works on this principle: gases are expelled downward, and the rocket moves upward.

2️⃣ Work, Energy, and Power

🔹 Work (W)

- Work is done when a force causes displacement.
- Formula: **W = F × d × cos(θ)**
    - **F** = Force applied (N)
    - **d** = Displacement (m)
    - **θ** = Angle between force and displacement
- 🚧 Example: Lifting a box up requires work, but carrying it horizontally without changing its height does **not** do work against gravity!

🔹 Energy (E)

Energy is the ability to do work. It exists in many forms:

1. **Kinetic Energy (KE)** – Energy of motion.
    - Formula: **KE = (1/2)mv²**
2. **Potential Energy (PE)** – Stored energy due to position.
    - Formula: **PE = mgh**
    - Example: A ball held at a height has gravitational potential energy.

🔹 Power (P)

Power is the **rate** at which work is done.

- Formula: **P = W/t**
- Unit: Watt (W)
- Example: A 100W light bulb consumes energy at a rate of 100 joules per second.

3️⃣ Momentum and Collisions

🔹 Linear Momentum (p)

Momentum measures an object's motion.

- Formula: **p = mv**
- **Conservation of Momentum**: The total momentum of a system remains constant unless an external force acts on it.
- Example: In billiards, when a cue ball hits another ball, the total momentum before and after the collision is the same.

🔹 Types of Collisions

1. **Elastic Collision** – Kinetic energy is conserved.
    - Example: Two billiard balls colliding.
2. **Inelastic Collision** – Some kinetic energy is lost as heat/sound.
    - Example: A car crash.
3. **Perfectly Inelastic Collision** – Objects stick together after the collision.

4️⃣ Circular Motion and Gravitation

🔹 Centripetal Force (Fc)

Objects moving in a circle require a force directed toward the center of the circle.

- Formula: $\mathbf{Fc = (mv^2)/r}$
- Example: The Moon orbits the Earth due to gravitational centripetal force.

🔹 Newton's Law of Universal Gravitation

"Every mass attracts every other mass with a force proportional to the product of their masses and inversely proportional to the square of their distance."

- Formula: $\mathbf{F = G(m_1m_2)/r^2}$
    - **G** = Gravitational constant (6.674×10^{-11} N·m²/kg²)
- Example: The Earth's gravity pulls objects downward with an acceleration of **9.8 m/s²**.

5️⃣ Special Relativity (Einstein's Magic)

For speeds close to the speed of light ($\mathbf{c = 3 \times 10^8}$ **m/s**), Newtonian mechanics breaks down, and Einstein's **Theory of Relativity** takes over.

🔹 Time Dilation (Slower Time at High Speeds)

- Time moves slower for objects moving near the speed of light.
- Formula: $\mathbf{t' = t / \sqrt{(1 - v^2/c^2)}}$
- 🚀 Example: If an astronaut travels close to the speed of light and returns, they will have aged less than people on Earth!

🔹 Mass-Energy Equivalence

Einstein's famous equation: $\mathbf{E = mc^2}$

- **Energy (E)** and **mass (m)** are interchangeable.
- Example: Nuclear reactions release huge amounts of energy from tiny masses!

🔥 Fun Fact: The Fastest Thing in the Universe?

The **speed of light (c = 299,792,458 m/s)** is the fastest possible speed. Nothing with mass can travel at light speed because it would require **infinite energy**. 🚀
