Unit 3

Unit 3: Motion, Force, and Work

This unit explores the fundamental concepts of motion, force, and work—cornerstones of physics. It delves into various types of motion, Newton's laws of motion, and key equations that relate motion and force.

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1. Motion

Definition of Motion:

Motion is the change in an object's position relative to its surroundings over time. For motion to occur, an object must have a reference point and undergo displacement.

Types of Motion:

1. **Uniform Motion**:
   - An object is in uniform motion when it covers **equal distances in equal intervals of time**.
   - Example: A car traveling at a constant speed of 60 km/h.
2. **Non-Uniform Motion**:
   - An object is in non-uniform motion when it covers **unequal distances in equal intervals of time**.
   - Example: A car accelerating or decelerating.

Speed, Velocity, and Acceleration:

1. **Speed**:
   - Speed is the distance an object travels per unit of time.
   - Formula:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

   - **SI Unit**: meters per second (m/s).
   - Example: A car travels 100 km in 2 hours. Speed = 50 km/h.
2. **Velocity**:
   - Velocity is the speed of an object in a **specific direction**.
   - Formula:

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

   - **SI Unit**: meters per second (m/s).
   - Velocity is a **vector quantity**, having both magnitude and direction.
   - Example: A car moving 60 km/h northward has a velocity of 60 km/h north.
3. **Acceleration**:
   - Acceleration is the rate of change in velocity.
   - Formula:

$$\text{Acceleration}(a) = \frac{\text{Change in Velocity}}{\text{Time Taken}}$$

- **SI Unit**: meters per second squared (m/s²).
- Example: If a car's velocity increases from 20 m/s to 30 m/s in 5 seconds, the acceleration is:

$$a = \frac{30 - 20}{5} = 2\,\text{m/s}^2$$

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2. Newton's Laws of Motion

First Law of Motion (Law of Inertia):

An object will remain at rest or in uniform motion unless acted upon by an **external force**.

- **Inertia**: An object's tendency to resist changes in its state of motion.
- Example: A book on a table remains stationary unless a force moves it.

Second Law of Motion:

The force acting on an object equals the object's **mass** multiplied by its **acceleration**.

- Formula:

$$F = ma$$

  Where:

  - F = Force (in Newtons)
  - m = Mass (in kilograms)
  - a = Acceleration (in m/s²)
- Example: If a 1000 kg car accelerates at 2 m/s², the force applied is:

$$F = 1000 \times 2 = 2000\,\text{N}$$

Third Law of Motion:

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

- Example: When you push a wall, it pushes back with equal force. The wall doesn't move because it's larger and fixed.

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3. Work, Energy, and Power

Work:

Work is done when a **force** causes an object to move.

- Formula:

$$W = F \times d$$

Where:

- W = Work (in joules)
- F = Force (in Newtons)
- d = Displacement (in meters)
- Example: Pushing a box with 50 N of force for 2 meters:

$$W = 50 \times 2 = 100\,\text{J}$$

Energy:

Energy is the capacity to do work. There are various forms of energy, but the two primary types are **kinetic energy** and **potential energy**.

1. **Kinetic Energy (KE)**:
   - Energy possessed by a moving object.
   - Formula:

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

     Where:
     - m = Mass (in kilograms)
     - v = Velocity (in meters per second)
   - Example: If a ball with a mass of 2 kg is moving with a velocity of 5 m/s, the kinetic energy is:

$$KE = \frac{1}{2} \times 2 \times 5^2 = 25\,\text{J}$$

2. **Potential Energy (PE)**:
   - Energy stored in an object due to its position or height.
   - Formula:

$$PE = mgh$$

     Where:
     - m = Mass (in kilograms)
     - g = Gravitational acceleration (9.8 m/s²)
     - h = Height (in meters)
     - Example: If a 5 kg object is raised to a height of 10 meters, the potential energy is:

$$PE = 5 \times 9.8 \times 10 = 490\,\text{J}$$

Power:

Power is the rate at which work is done or energy is transferred.

- Formula:

$$P = \frac{W}{t}$$

Where :

- P = Power (in watts)
- W = Work done (in joules)
- t = Time taken (in seconds)
- Example: If you do 100 J of work in 10 seconds, the power is:

$$P = \frac{100}{10} = 10\,\text{W}$$

Equations of Motion

These equations relate displacement, velocity, acceleration, and time for uniformly accelerated motion:

1. **First Equation**:

$$v = u + at$$

   Where:

   - v = Final velocity
   - u = Initial velocity
   - a = Acceleration
   - t = Time

2. **Second Equation**:

$$s = ut + \frac{1}{2}at^2$$

   Where:

   - s = Displacement
   - u = Initial velocity
   - a = Acceleration
   - t = Time

3. **Third Equation**:

$$v^2 = u^2 + 2as$$

   Where:

   - v = Final velocity
   - u = Initial velocity
   - a = Acceleration
   - s = Displacement

Important Definitions:

1. **Displacement**: The shortest distance between an object's initial and final positions.
2. **Force**: A push or pull that causes an object to move, stop, or change direction.
3. **Gravitational Force**: The force of attraction between any two objects with mass.
4. **Work**: The application of force resulting in object displacement.