

## CONTACT AND NON-CONTACT FORCES

Forces are interactions that can change the motion of an object, and cause it to accelerate, decelerate, or change its direction. In physics, these forces are classified into two main categories: **contact forces** and **non-contact forces**. Understanding these distinctions is crucial for grasping the basic principles of mechanics.

### Contact Forces

**Contact forces** arise when two interacting objects are physically touching each other. These forces result from the direct physical contact between objects, and they play a significant role in our everyday experiences. Some key examples of contact forces include:

- 1. Frictional Force:**
  - **Description:** Friction is the resistance that one surface or object encounters when moving over another. It always acts in the opposite direction of the motion, thereby slowing down or stopping moving objects.
  - **Example:** When you push a book across a table, the book eventually comes to a stop due to the frictional force between the book and the table surface.
- 2. Tension Force:**
  - **Description:** Tension is the force exerted by a string, rope, cable, or any similar object when it is pulled tight by forces acting from opposite ends.
  - **Example:** Consider a hanging light fixture supported by a cable. The tension force in the cable supports the weight of the light fixture, preventing it from falling.
- 3. Normal Force:**
  - **Description:** The normal force is the support force exerted upon an object that is in contact with another stable object. It acts perpendicular to the surface.
  - **Example:** If you place a book on a table, the table exerts an upward normal force on the book to balance the weight of the book. This is why the book stays at rest rather than falling through the table.
- 4. Air Resistance (Drag):**
  - **Description:** Air resistance, also known as drag, is a type of frictional force that acts against an object as it moves through the air. It depends on the object's speed, surface area, and the density of the air.
  - **Example:** A parachute slows down a skydiver as they descend because air resistance increases, balancing the force of gravity and allowing for a slower, controlled descent.
- 5. Applied Force:**
  - **Description:** An applied force is any force that is applied to an object by a person or another object.
  - **Example:** Pushing a shopping cart involves applying a force that causes the cart to move.

## Non-Contact Forces

**Non-contact forces** occur even when the interacting objects are not physically touching each other. These forces act over a distance and do not require direct contact between the objects. Some of the most common non-contact forces are:

### 1. **Gravitational Force:**

- **Description:** Gravity is the force of attraction between two objects due to their mass. It acts over large distances and is always attractive, meaning it pulls objects toward one another.
- **Example:** The Earth's gravitational force pulls objects toward its centre, which is why objects fall when dropped.

### 2. **Magnetic Force:**

- **Description:** Magnetic force is the attraction or repulsion between magnetic poles. It acts at a distance and can either attract or repel depending on the poles' orientation.
- **Example:** When you bring a magnet close to a refrigerator, the magnetic force pulls the magnet toward the fridge, causing it to stick. Similarly, like poles of two magnets will repel each other if brought close.

### 3. **Electrostatic Force:**

- **Description:** Electrostatic force is the force of attraction or repulsion between two charged objects. It acts over a distance and depends on the magnitude and sign of the charges.
- **Example:** Rubbing a balloon on your hair can cause the balloon to become negatively charged, and it will then attract small bits of paper or stick to a wall due to the electrostatic force.

### 4. **Nuclear Force:**

- **Description:** The nuclear force is the force that holds protons and neutrons together in the nucleus of an atom. This force acts over very short distances within the nucleus.
- **Example:** The stability of an atomic nucleus is due to the strong nuclear force, which is powerful enough to overcome the repulsive electrostatic force between the positively charged protons.

## **Conclusion**

In summary, forces are essential in determining how objects interact and move. **Contact forces** require physical contact between objects and include friction, tension, normal force, air resistance, and applied force. **Non-contact forces**, on the other hand, do not require physical contact and include gravitational, magnetic, electrostatic, and nuclear forces. Understanding these forces helps explain a wide range of physical phenomena, from everyday occurrences like walking and driving to complex interactions at the atomic level.

## **DIFFERENCE BETWEEN MASS AND WEIGHT**

Understanding the concepts of **weight** and **mass** is fundamental in physics and is often a source of confusion. Though they are related, weight and mass are distinct properties with different meanings and implications. Here, we'll explore the differences between these two concepts with clear definitions and examples.

## Mass

**Mass** is a measure of the amount of matter in an object. It is a scalar quantity, meaning it only has magnitude and no direction. Mass is a fundamental property of an object and does not change regardless of its location in the universe. The standard unit of mass in the International System of Units (SI) is the **kilogram (kg)**.

- **Definition:** Mass is the quantity of matter contained in an object.
- **Measurement:** Mass is measured using a balance or scale, which compares an object's mass to a standard mass.
- **Units:** The SI unit of mass is the kilogram (kg), but other units like grams (g) and tonnes (t) are also used.
- **Independence from Location:** The mass of an object remains the same whether it is on Earth, the Moon, or in outer space.

### **Example of Mass:**

- A 1-litre bottle of water has a mass of approximately 1 kilogram. If you take that bottle to the Moon or Mars, its mass remains 1 kilogram, as the quantity of water (matter) in the bottle does not change.

## Weight

**Weight**, on the other hand, is the force exerted on an object due to gravity. Weight is a vector quantity, which means it has both magnitude and direction. An object's weight depends on its mass and the gravitational acceleration acting upon it. Since gravitational acceleration varies depending on where you are in the universe, an object's weight can change depending on its location. The SI unit of weight is the **newton (N)**.

## FORMULA:

$$W=mg$$

- **Definition:** Weight is the force exerted by gravity on an object.
- **Measurement:** Weight is measured using a scale or a spring balance, which measures the force of gravity acting on an object.
- **Units:** The SI unit of weight is the newton (N), derived from the formula.
- **Dependence on Location:** Weight changes with the strength of gravitational acceleration, which varies on different planets or celestial bodies.

### **Example of Weight:**

- On Earth, where the gravitational acceleration is approximately  $9.8 \text{ m/s}^2$ . On the Moon, where the gravitational acceleration is about  $1.6 \text{ m/s}^2$ . same 1-kilogram would weigh only about 1.6 newtons. The object's mass remains 1 kilogram, but its weight decreases due to the weaker gravity.

## **Key Differences Between Mass and Weight**

### 1. Nature:

- **Mass** measures the amount of matter in an object and is a scalar quantity (magnitude only).
- **Weight** is the force exerted by gravity on that mass and is a vector quantity (magnitude and direction).

### 2. Dependency:

- **Mass** does not depend on the location of the object; it remains constant regardless of where the object is.
- **Weight** depends on the gravitational pull at the location of the object. It varies based on the strength of gravity, which changes from place to place (e.g., Earth, Moon, Mars).

### 3. Units:

- The SI unit of **mass** is the **kilogram (kg)**.
- The SI unit of **weight** is the **newton (N)**.

### 4. Measurement Tools:

- **Mass** is measured using a balance, which compares it to known masses.
- **Weight** is measured using a scale or spring balance, which measures the gravitational force on the object.

## Conclusion

In summary, mass and weight are closely related but fundamentally different. **Mass** is a measure of the amount of matter in an object and remains constant everywhere in the universe. **Weight**, however, is the gravitational force acting on that mass and varies depending on the strength of gravity at a given location. Understanding this distinction is crucial, especially in fields such as physics and engineering, where precise measurements and calculations are essential.

## RESULTANT FORCES:

**Resultant force** is a concept in physics that describes the overall effect of multiple forces acting on an object. When two or more forces act on an object, these forces can be combined into a single force that has the same effect as all the individual forces put together. This combined force is known as the resultant force.

### Understanding Resultant Force

The resultant force is the vector sum of all the forces acting on an object. It takes into account both the magnitude and direction of the individual forces. The object will accelerate in the direction of the resultant force according to Newton's Second Law of Motion, which states:

$$F_{\text{resultant}} = m \times a$$

Where:

- $F_{\text{resultant}}$  is the resultant force,
- $m$  is the mass of the object,
- $a$  is the acceleration of the object.

## Free Body Diagram

A **free-body diagram (FBD)** is a visual representation used to illustrate all the forces acting on a single object. The object is typically represented as a simple shape (like a box or a dot), and the forces acting on it are shown as arrows pointing in the direction of the forces.

### Example of Resultant Force with a Free Body Diagram

**Scenario:** Imagine a box on a rough surface being pushed to the right by a person with a force of 10 N, while friction opposes this motion with a force of 4 N. There is also a normal force acting upwards and the weight of the box acting downwards.

Let's analyse this scenario step by step.

#### Step 1: Identify All Forces

1. **Applied Force (Applied):** 10 N to the right.
2. **Frictional Force (F friction):** 4 N to the left.
3. **Normal Force (F normal):** Acts upward, perpendicular to the surface.
4. **Weight (W):** The force due to gravity, acts downward.

#### Step 2: Draw the Free Body Diagram

In the Free Body Diagram:

- The box is represented by a square.
- An arrow to the right represents the applied force (10 N).
- An arrow to the left represents the frictional force (4 N).
- An arrow pointing up represents the normal force.
- An arrow pointing down represents the weight.

Since the normal force and the weight are equal in magnitude and opposite in direction, they cancel each other out. Thus, they do not affect the horizontal motion of the box.

#### Step 3: Calculate the Resultant Force

The resultant force in the horizontal direction is the difference between the applied force and the frictional force because they are in opposite directions.

$$F_{\text{resultant}} = F_{\text{applied}} - F_{\text{friction}}$$

$$F_{\text{resultant}} = 10\text{N} - 4\text{N} = 6\text{N to the right}$$

This 6 N force to the right is the resultant force, meaning the box will accelerate to the right.

#### Free Body Diagram Representation:

- **Box:** Represented as a square.
- **Forces:**
  - An arrow pointing right labelled **10 N** (Applied Force).
  - An arrow pointing left labelled **4 N** (Friction).
  - An arrow pointing up labelled **F<sub>normal</sub>**(Normal Force).
  - An arrow pointing down labelled **W** (Weight).

### Key Points to Remember:

- The resultant force determines the motion of the object.
- If the resultant force is zero, the object will remain at rest or move at a constant velocity (Newton's First Law).
- If there is a non-zero resultant force, the object will accelerate in the direction of that force (Newton's Second Law).

## THE RELATIONSHIP BETWEEN FORCE AND ELASTICITY:

The relationship between force and elasticity is a fundamental concept in physics that explains how objects deform when subjected to external forces and how they return to their original shape when the forces are removed. This relationship is governed by **Hooke's Law**, which describes the behaviour of elastic materials.

### Elasticity

**Elasticity** refers to the ability of a material to return to its original shape and size after being deformed by an external force. When an elastic material, such as a spring or a rubber band, is stretched or compressed, it experiences a change in shape. If the material is elastic, it will return to its original shape once the force is removed.

### Hooke's Law

**Hooke's Law** is the principle that quantifies the relationship between the force applied to an elastic material and the resulting deformation (extension or compression) of that material. It states that:

$$\mathbf{F} = \mathbf{K} \times \mathbf{\Delta X}$$

Where:

- F is the force applied to the material (in newtons, N),
- k is the spring constant (or stiffness) of the material (in newtons per meter, N/m),
- Δx is the extension or compression of the material from its original length (in meters, m).

### Understanding the Components of Hooke's Law:

1. **Force (F):** The external force applied to an elastic material that causes it to stretch or compress.
2. **Spring Constant (K):** This is a measure of the stiffness of the material. A larger K value indicates a stiffer material that requires more force to produce the same amount of deformation. The spring constant is unique to each material and depends on its physical properties.
3. **Extension/Compression ( $\Delta x$ ):** This represents the change in the length of the material when the force is applied. It is the difference between the material's original length and its length after the force is applied.

## Direct Proportionality

According to Hooke's Law, the extension or compression of an elastic material is directly proportional to the applied force, as long as the material remains within its **elastic limit**. The elastic limit is the maximum amount of force that can be applied to a material before it is permanently deformed and no longer returns to its original shape.

- **Linear Relationship:** The relationship between force and extension/compression is linear, meaning if you double the force, the extension or compression will also double, provided the material is within its elastic limit.

## Graphical Representation

If you plot a graph of force (F) against extension ( $\Delta x$ ) for an elastic material:

- **The Slope:** The slope of the line in the graph represents the spring constant K. A steeper slope indicates a stiffer material.
- **Linear Region:** The straight-line portion of the graph indicates that the material is behaving elastically, following Hooke's Law.
- **Beyond the Elastic Limit:** If the force applied exceeds the elastic limit, the graph will curve, indicating the material is no longer obeying Hooke's Law, and permanent deformation occurs.

## Examples of Force and Elasticity:

1. **Spring:** When you apply a force to stretch or compress a spring, it changes length. Once the force is removed, the spring returns to its original length if it has not been stretched beyond its elastic limit.
  - **Example:** A spring with a spring constant k of 100 N/m will extend by 0.1 meters if a force of 10 N is applied to it.
2. **Rubber Band:** Similar to a spring, a rubber band stretches when a force is applied. The amount it stretches depends on the force and the material's elasticity. Once the force is released, the rubber band returns to its original size.
3. **Metal Rod:** A metal rod can be compressed or stretched slightly by applying force. As long as the force is within the elastic limit of the material, the rod will return to its original shape.

## Elastic Potential Energy

When a force is applied to an elastic material, the work done to deform the material is stored as **elastic potential energy**. This energy is released when the material returns to its original shape.

## **FORMULA:**

$$E_{\text{elastic}} = \frac{1}{2}k \times \Delta X^2$$

### **Conclusion**

The relationship between force and elasticity is essential in understanding how materials deform and return to their original shape. Hooke's Law provides a clear mathematical description of this relationship, stating that the deformation of an elastic material is directly proportional to the applied force, within the elastic limit. This principle is foundational in various fields, including engineering, materials science, and mechanics, where understanding the elastic properties of materials is crucial for designing structures and systems that can withstand external forces without permanent damage.

## **Relationship between distance and displacement:**

**Distance** and **displacement** are both measures of how far an object has moved, but they differ significantly in meaning and application.

### **Distance**

- **Definition:** Distance is a scalar quantity that refers to the total path length travelled by an object, regardless of direction. It only has magnitude and does not consider the direction of travel.
- **Characteristics:**
  - Always positive.
  - It's the actual ground covered by an object.
  - Does not provide any information about the direction of motion.
- **Example:**
  - Imagine you walk 3 km north, then 4 km east. The total distance you have walked is 7 km (3 km + 4 km), which is simply the sum of the path lengths you travelled.

### **Displacement**

- **Definition:** Displacement is a vector quantity that refers to the straight-line distance from the starting point to the final position of an object, considering the direction. It has both magnitude and direction.
- **Characteristics:**
  - Can be positive, negative, or zero depending on the direction.
  - It represents the shortest path between the starting and ending points.

- Gives information about the direction of motion.
- **Example:**
  - Using the same scenario: You Walk 3 km north and then 4 km east. The displacement would be the straight-line distance from your starting point to your final position, which forms the hypotenuse of a right-angled triangle. Using the Pythagorean theorem:
  - **DISPLACEMENT** =  $\sqrt{(3\text{km})^2 + (4\text{km})^2} = 5\text{km}.$
  - The displacement is 5km in the northeast direction.
  - **RELATION BETWEEN SPEED AND VELOCITY**

**Speed** and **velocity** are both measures of how fast an object is moving, but they have different meanings and implications.

### Speed

- **Definition:** Speed is a scalar quantity that refers to how fast an object is moving. It is the rate at which an object covers distance and does not take direction into account.
- **Formula:** Speed is calculated as the total distance travelled divided by the time it took to travel that distance:
- **SPEED = DISTANCE / TIME**
- **Characteristics:**
  - Always positive.
  - Has no direction, only magnitude.
  - Describes how quickly an object is moving, regardless of the direction.
- **Example:**
  - If you drive 100 km in 2 hours, your average speed is:

- $\text{Speed} = 100\text{km} / 2\text{hours} = 50\text{km/hours}.$

### Velocity

- **Definition:** Velocity is a vector quantity that refers to the rate at which an object changes its position. It considers both speed and direction of motion.
- **Formula:** Velocity is calculated as displacement divided by the time taken:

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- **VELOCITY=DISPLACEMENT / TIME**
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- **Characteristics:**
  - Can be positive, negative, or zero depending on the direction.
  - Describes how fast an object is moving in a specific direction.
  - If the direction changes, even if the speed remains constant, the velocity changes.
- **Example:**
  - If you walk 50 meters east in 25 seconds, your velocity is:
  - **Velocity=50m/25sec=2m/sec east**

This gives both the magnitude of your motion (2 m/s) and the direction (east).

- **Changing Velocity:**
  - If you walk 50 meters east in 25 seconds and then immediately walk 50 meters west in another 25 seconds, your speed remains constant at 2 m/s, but your velocity changes direction from east to west. Moreover, if we calculate your overall velocity for the entire trip:
  - **Average velocity=0m/50sec=0m/sec.**

The average velocity is zero because you end up at the same place you started, despite having moved.

### Summary

- **Distance vs. Displacement:** Distance is the total path length travelled without regard to direction, while displacement is the shortest straight-line distance between the starting and ending points, considering direction.
- **Speed vs. Velocity:** Speed is how fast an object is moving without regard to direction, while velocity is how fast an object is moving in a specific direction.

### Understanding Acceleration

**Acceleration** is a fundamental concept in physics that describes how the velocity of an object changes over time. It is a vector quantity, meaning it has both magnitude and direction. Acceleration occurs when there is a change in the speed of an object, the direction of its motion, or both.

### Definition of Acceleration

- **Acceleration** is defined as the rate of change of velocity concerning time.

**ACCELERATION= CHANGE IN  
VELOCITY / TIME TAKEN**

Mathematically, this is expressed as:

$$a = \Delta v / \Delta t$$

Where:

- $a$  is the acceleration (measured in meters per second squared,  $m/s^2$ ),
- $\Delta v$  is the change in velocity (in meters per second,  $m/s$ ),
- $\Delta t$  is the time taken for this change (in seconds,  $s$ ).

### Types of Acceleration

1. **Positive Acceleration:** Occurs when an object's velocity increases over time.
2. **Negative Acceleration (Deceleration):** This occurs when an object's velocity decreases over time.
3. **Zero Acceleration:** This occurs when an object moves at a constant velocity, meaning its speed and direction do not change.

### Uniform Acceleration

**Uniform acceleration** refers to a situation where an object's acceleration remains constant over time. This means the object's velocity changes at a constant rate. Uniform acceleration is a specific type of constant acceleration, often encountered in situations like free-fall (neglecting air resistance), where the acceleration due to gravity remains constant.

### Characteristics of Uniform Acceleration

- **Constant Rate of Change:** The velocity of the object changes by the same amount in each unit of time.
- **Linear Motion:** The motion of the object is typically in a straight line.
- **Examples:**
  - An object in free-fall near the Earth's surface (neglecting air resistance) experiences a uniform acceleration of approximately  $9.8 \text{ m/sec}^2$  due to gravity.
  - A car accelerating uniformly from rest, where it increases its speed by the same amount every second.

### Equations of Motion with Uniform Acceleration

When dealing with uniform acceleration, the following equations of motion are frequently used:

1. **Velocity-Time Relation:**
2.  **$V = u + at$**

Where:

- $V$  is the final velocity,

- u is the initial velocity,
- a is the uniform acceleration,
- t is the time.

3. **Position-Time Relation:**

4.  **$S = ut + \frac{1}{2} at^2$**

Where:

- s is the displacement,
- The other variables are as defined above.

5. **Velocity-Position Relation:**

6.  **$V^2 = u^2 + 2as$**

This equation relates the velocities, acceleration, and displacement without involving time.

**Constant Acceleration**

**Constant acceleration** is a broader term that encompasses any situation where acceleration does not change over time. Uniform acceleration is a specific case of constant acceleration in one-dimensional motion. However, constant acceleration can also occur in more complex scenarios, such as circular motion, where the direction of the velocity changes, but the magnitude of the acceleration remains constant.

**Characteristics of Constant Acceleration**

- **Same Magnitude:** The acceleration remains the same in magnitude throughout the motion.
- **Possibly Varying Direction:** In some cases, like circular motion, while the magnitude of acceleration remains constant, its direction changes continuously.
- **Examples:**
  - A car moving along a straight path with a steadily increasing speed is an example of constant acceleration in a straight line.
  - An object moving in a circular path with constant speed has constant centripetal acceleration directed towards the centre of the circle, even though the direction of motion is continuously changing.

**Key Differences Between Uniform and Constant Acceleration**

1. **Motion Type:**

- **Uniform Acceleration:** Typically refers to straight-line (linear) motion where the acceleration is both constant in magnitude and direction.
- **Constant Acceleration:** This can refer to motion where the acceleration is constant in magnitude, but the direction of motion might change (e.g., circular motion).

2. **Examples:**

- **Uniform Acceleration:** A car accelerating at a constant rate on a straight road.

- **Constant Acceleration:** A satellite in orbit around Earth has constant acceleration towards the planet due to gravity, even though its path is circular.

## **Conclusion**

In summary:

- **Acceleration** is the rate of change of velocity, and it can be positive, negative, or zero.
- **Uniform Acceleration** refers to a situation where the acceleration remains constant in both magnitude and direction, leading to a linear change in velocity.
- **Constant Acceleration** is a broader term that includes any scenario where acceleration does not change over time, regardless of the direction of motion.

These concepts are fundamental to understanding how objects move under various forces, forming the basis for more complex topics in mechanics.

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