APPLIED PHYSICS

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Scalar Quantity

A scalar quantity is a physical quantity that is completely described by its magnitude (size or numerical value) alone. It does not have any direction.

* ***Magnitude only***: All you need to know to fully describe a scalar quantity is "how much" or "how many."

* ***Follows ordinary arithmetic rules***: Scalar quantities can be added, subtracted, multiplied, and divided using the standard rules of algebra.

* **Examples:**

  * ***Mass***: A box has a mass of 10 kg. The direction isn't relevant to its mass.

  * ***Time***: A journey takes 2 hours. Time flows, but it doesn't have a specific spatial direction like "2 hours north."

  * ***Speed***: A car is traveling at 60 km/h. This tells you how fast it's going, but not where it's headed.

  * ***Distance***: You walked 5 meters. This is the total length of your path, irrespective of turns.

  * ***Temperature***: The room temperature is 25°C.

  * ***Volume***: A bottle contains 1 liter of water

Vector Quantity

A vector quantity is a physical quantity that is completely described by both its magnitude (size) and its direction.

* ***Magnitude and Direction***: To fully understand a vector quantity, you need to know "how much" and "in which direction."

* ***Requires special rules for operations***: Adding, subtracting, and

multiplying vectors require specific rules (like the triangle rule or parallelogram rule for addition) because their directions must be considered.

* ***Representation***: Vectors are often represented graphically by an arrow where:
  * The length of the arrow represents the magnitude of the vector.
  * The direction of the arrow represents the direction of the vector.
* ***Examples***:
  * ***Displacement***: You moved 5 meters east. This tells you both the distance and the direction from your starting point.
  * ***Velocity***: A car is traveling at 60 km/h north. This includes both its speed and direction.
  * ***Acceleration***: A falling apple accelerates at 9.8 m/s^2 downwards.
  * ***Force***: You push a box with 50 Newtons of force to the right

1. Distance

Definition: Distance is the total length of the path covered by a moving object.

Type: It is a **scalar quantity**, which means it only has **magnitude** (size), not direction.

Properties:

Always positive

Increases with motion

Depends on the path taken

Example:
If a person walks from point A to B (3 km), then from B to C (4 km), the total **distance** is:

Distance = AB + BC = 3 km + 4 km = 7 km

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2. Displacement

Definition: Displacement is the **shortest straight-line distance** from the initial to the final position of the object, including direction.

Type: It is a **vector quantity**, which means it has both **magnitude and direction**.

Properties:

Can be **positive, negative, or zero**

May be **less than or equal** to the distance

Independent of the path taken

Example:
Using the same case:

If the person goes 3 km east (A to B) and then 4 km west (B to C), the final position is 1 km west of the starting point.

So, **displacement = 1 km towards west**

Velocity

Velocity is a vector quantity that describes how fast an object is moving and in what direction. It's the rate of change of an object's position with respect to time.

- **Vector Quantity:** This means it has both magnitude (speed) and direction. For example, "50 km/h North" is a velocity, while "50 km/h" is just speed.
- **Formula:** $V = \Delta x / \Delta t$
  - v is velocity
  - Δx is the change in position (displacement)
  - Δt is the change in time
- **SI Unit:** meters per second (m/s)

Average and Instantaneous Velocity

Average Velocity is the total displacement of an object divided by the total time taken for that displacement. It gives you an overall idea of the motion over a period.

- **Formula:** V_{avg} = ***total displacement / total time*** = $\Delta x / \Delta t$

- It doesn't tell you anything about the specific speed or direction at any given moment within that time interval.

Instantaneous Velocity is the velocity of an object at a specific instant in time. It's the velocity at a single point on its path.

- **Calculus Definition:** Mathematically, instantaneous velocity is the derivative of position with respect to time: **$v = dx/dt$**
- Think of it as what a speedometer in a car reads at a precise moment, along with the direction the car is heading.

Acceleration

Acceleration is a vector quantity that describes the rate of change of velocity
Velocity, in physics, refers to both speed and direction. This means an object accelerates if:
 * It speeds up: (e.g., a car pressing the gas pedal)
 * It slows down: (e.g., a car applying the brakes; often called "deceleration" in everyday language, but it's still a form of acceleration in physics)
 * It changes direction: (e.g., a car turning a corner, even if its speed remains constant)

- **Formula: $A = \Delta V/\Delta T$**
    - a is acceleration
    - Δv is the change in velocity
    - Δt is the change in time
- **SI Unit:** meters per second squared ($m/s^{\wedge 2}$)

Units: The standard unit for acceleration is meters per second squared (m/s^2). This means for every second that passes, the velocity changes by a certain number of meters per second.

Momentum

Momentum is a measure of the "quantity of motion" an object possesses. It depends on both the object's mass and its velocity. The more massive an object is, or the faster it's moving, the more momentum it has. It is a measure of how much force is required to stop an object.Momentum is a vector quantity, meaning it has both magnitude and direction.

In simple word: A heavy truck moving slowly can have the same momentum as a small car moving very fast. This is why a slowly moving train is still dangerous – it has a huge amount of momentum due to its mass.

- **Definition:** It is the product of an object's mass and its velocity.
- **Formula:** $p = mv$
    - p is momentum is mass
    - v is velocity
- **SI Unit:** kilogram-meter per second (kg·m/s)
- **Conservation of Momentum:** In a closed system (where no external forces act), the total momentum remains constant. This principle is crucial in analyzing collisions and explosions.

Impulse

Impulse is a vector quantity that measures the effect of a force acting over a period of time. It's the change in an object's momentum.

- **Definition:** Impulse is equal to the average net force acting on an object multiplied by the time interval over which the force acts.

- **Formula: $J = F_{avg} \Delta T$**
  - J is impulse
  - F_{avg} is the average net force
  - Δt is the time interval
- **Impulse-Momentum Theorem:** This theorem states that the impulse applied to an object is equal to the change in its momentum: $J = \Delta p = p_{final} - p_{initial} = mv_{final} - mv_{initial}$.
- **SI Unit:** Newton-second (N·s), which is dimensionally equivalent to kg·m/s (the unit of momentum).

In essence, these concepts are interconnected: velocity describes motion, acceleration describes how velocity changes, momentum relates mass and velocity, and impulse quantifies the force-time interaction that causes a change in momentum.

W O R K

In physics, work is a scalar quantity that represents the transfer of energy to or from an object by means of a force acting on it as it undergoes a displacement. For work to be done, two conditions must be met:
 * A force must be applied to the object.
 * The object must undergo a displacement in the direction of (or at least have a component in the direction of) the applied force.
 * Formula (for a constant force in the direction of displacement): **W= F.D cos¢**
   * W is work
   * **F** is the magnitude of the force
   * **D** is the magnitude of the displacement
   * **¢** is the angle between the force vector and the displacement vector.
    * If **¢= 0** (force and displacement in the same direction), \cos(0) = 1, so W = F. d (positive work).
    * If **¢= 90** (force perpendicular to displacement), \cos(90)= 0, so W = 0 (no work done). For example, carrying a heavy bag horizontally across a room, no work is done by the person on the bag.
    * If **¢ = 180** (force opposite to displacement), \cos(180)= -1, so W = -F.d (negative work, meaning energy is removed from the object). For example, friction does negative work as it opposes motion.
 * SI Unit: Joule (J), which is equivalent to Newton-meter (N·m).

E N E R G Y

Energy is the ability to do work. It exists in various forms, and kinetic and potential energy are two fundamental types of mechanical energy.

TYPES

. **KINETIC ENERGY**

Kinetic energy is the energy an object possesses due to its motion. Any object that is moving has kinetic energy. The faster an object moves and the more massive it is, the more kinetic energy it has.

Formula:

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

Where:

* KE is kinetic energy
* m is mass
* v is velocity (specifically, the magnitude of the velocity, or speed)

Units: The standard unit for energy (including kinetic energy) is the joule (J). One joule is defined as the energy expended when a force of one newton acts over a distance of one meter (1 J = 1 N \cdot m).

Key points

* Kinetic energy is always positive because mass (m) and speed squared (v^2) are always non-negative.
* It depends on the square of the speed, meaning if you double the speed, the kinetic energy quadruples.
* SI Unit: Joule (J)

POTENTIAL ENERGY

Potential energy is the energy an object possesses due to its position or configuration. It's "stored" energy that has the potential to do work. There are various **types** of potential energy, with the most common being:

* **gravitational potential energy** Energy an object has due to its position in a gravitational field (i.e., its height above a reference point).
  * Formula: **P.E = mgh**
    * m is the mass of the object
    * g is the acceleration due to gravity (approximately 9.8{ m/s^2 on Earth's surface)
    * h is the height above a chosen reference level

Elestic potential energy

Energy stored in elastic materials (like springs or rubber bands) when they are stretched or compressed.

* Formula: **P.E = ½ KX^2**
  * k is the spring constant (a measure of the spring's stiffness)
  * x is the displacement from the spring's equilibrium position
* SI Unit: Joule (J)

P O W E R

Power is the rate at which work is done or energy is transferred. It tells us how quickly work is performed or how quickly energy is converted from one form to another.

* Formula **$P = W/ \Delta t$ or $\Delta E / \Delta T$**
  * **P** is power
  * **W** is the work done
  * Δ**E**is the change in energy
  * Δ**T** is the time interval over which the work is done or energy is transferred
* Alternative Formula (for constant force and velocity): **p= f.v cos ¢** (where **¢** is the angle between force and velocity)
  * If force and velocity are in the same direction, **p = F.v**
* **SI Unit**: Watt (W), which is equivalent to Joule per second (J/s).
* **Key points**: A powerful machine can do a lot of work in a short amount of time, or transfer a lot of energy very quickly. A less powerful machine might do the same amount of work, but it will take longer.

C O N D U C T O R

A conductor is a material that allows electric charge (usually in the form of electrons) to flow

through it easily.
* **How it**'s **work :** Conductors have "free" electrons in their outermost atomic shells. These electrons are not tightly bound to individual atoms and can move relatively freely throughout the material. When an electric field is applied (e.g., by connecting a voltage source), these free electrons drift in a directed manner, creating an electric current.

Properties

* Low electrical resistance: This means they offer very little opposition to the flow of electric current.
* Presence of free charge carriers: Typically free electrons in metals, or ions in solutions/molten salts.
* Good thermal conductors: Often also good at conducting heat.

Example Most metals are excellent conductors, such as:

* Copper (commonly used in electrical wiring)
* Aluminum (used in power transmission lines)
* Gold and Silver (excellent conductors but expensive)
* Graphite (a form of carbon)
* Electrolyte solutions (like saltwater)

I N S U L A T O R

An insulator is a material that resists the flow of electric charge. It does not allow electric current to pass through it easily.

*__Ho__w **it's work:** In insulators, the electrons are tightly bound to their atoms and are not free to move around. Even when an electric field is applied, these electrons do not readily break free to form a current.

* **Properties**
  * High electrical resistance: They offer significant opposition to the flow of electric current.
  * Absence of free charge carriers: Their electrons are generally fixed in their atomic orbits.
  * Often poor thermal conductors.
  * High dielectric strength: The ability to withstand a high electric field without breaking down and becoming conductive.
* **Examples**
  * Rubber (used to coat wires)
  * Plastic
  * Glass
  * Wood (especially dry wood)
  * Ceramics
  * Air (under normal conditions)

Electric Current And Its Unit

Electric current is the rate of flow of electric charge through a conductor. It's essentially how many charge carriers (like electrons) pass a given point in a circuit per unit of time.

* **Analogy:** Think of water flowing through a pipe. The current is like the volume of water flowing past a point per second.
* **Direction:** By convention, electric current is defined as the direction in which positive charges would flow. However, in most metallic conductors, it is actually the negatively charged electrons that move, so they flow in the opposite direction to the conventional current.
* Formula: $\mathbf{I=\Delta Q/ \Delta t}$

* **I** is the electric current
* Δ**Q** is the amount of electric charge that passes a point
* Δ**T**is the time interval over which the charge passes
* **SI Unit:** The SI unit of electric current is the Ampere (A), often shortened to "amp."
* ***One Ampere*** is defined as one Coulomb of charge passing a point per second.
* **1A= 1 C/s** (where C is Coulomb, the unit of charge).
* **Types of Current:**
* ***Direct Current (DC):*** The charge flows in only one direction (e.g., from a battery).
* ***Alternating Current (AC):*** The direction of charge flow periodically reverses (e.g., household electricity).

Resistance and Resistors.

Resistance

Resistance is a measure of a material's opposition to the flow of electric current. When electrons move through a conductor, they collide with atoms and other electrons, impeding their flow. This opposition is what we call resistance.

* **Factors Affecting Resistance:**
* ***Material***: Different materials have different inherent resistivities. Conductors (like copper) have low resistance, while insulators (like rubber) have very high resistance.
* ***Length***: The longer the conductor, the more resistance it offers (more opportunities for collisions).
* ***Cross-sectional Area:*** The wider the conductor, the less resistance it offers (more pathways for electrons to flow).
* ***Temperature:*** For most conductors, resistance increases with temperature, as increased thermal vibrations make it harder for electrons to move.
* ***Ohm's Law:*** This fundamental law relates voltage (V), current (I), and resistance (R):

V = I.**R**

This means that for a given voltage, a higher resistance will result in a lower current, and vice versa.

* ***SI Unit:*** The SI unit of electrical resistance is the Ohm (\Omega), named after Georg Simon Ohm. One Ohm is defined as the resistance between two points of a conductor when a constant potential difference of 1 volt, applied to these points, produces a current of 1 ampere. So, 1 \Omega = 1 \text{ V/A}.

Resistors

A resistor is a passive two-terminal electrical component specifically designed to introduce a known amount of resistance into an electrical circuit.

* **Purpose in Circuits:**
* ***Limit current:*** They prevent too much current from flowing to sensitive components (e.g., protecting an LED from burning out).
* ***Divide voltage***: Used in voltage divider circuits to provide specific voltage levels.
* ***Generate heat:*** In heating elements (like those in toasters or electric heaters), resistance is used to convert electrical energy into heat.
* ***Adjust signal levels***: In audio or communication circuits.
* **Types:**

Resistors come in various types (e.g., carbon film, metal film, wirewound) and fixed or variable

resistances (potentiometers).
 * ***How they work:*** Resistors are typically made from materials with a controlled resistivity and designed with specific lengths and cross-sectional areas to achieve the desired resistance value.

Magnetic field due to current 🧲
This phenomenon describes how an electric current creates a magnetic field around it, linking the seemingly separate phenomena of electricity and magnetism. This fundamental discovery was made by Hans Christian Ørsted in 1820.
 * ***The Principle***: Any moving electric charge (which constitutes an electric current) generates a magnetic field in the space around it. The strength and direction of this magnetic field depend on the magnitude and direction of the current.
 * **Characteristics of the Magnetic Field:**
   * ***Shape around a straight wire:*** For a straight current-carrying wire, the magnetic field lines form concentric circles around the wire, with the wire at the center.
   * ***Direction (Right-Hand Rule for Straight Wire***): If you point the thumb of your right hand in the direction of the conventional current (positive charge flow), your curled fingers will indicate the direction of the magnetic field lines around the wire.
   * ***Strength:*** The strength of the magnetic field:
     * Is directly proportional to the magnitude of the current.
     * Is inversely proportional to the distance from the wire.