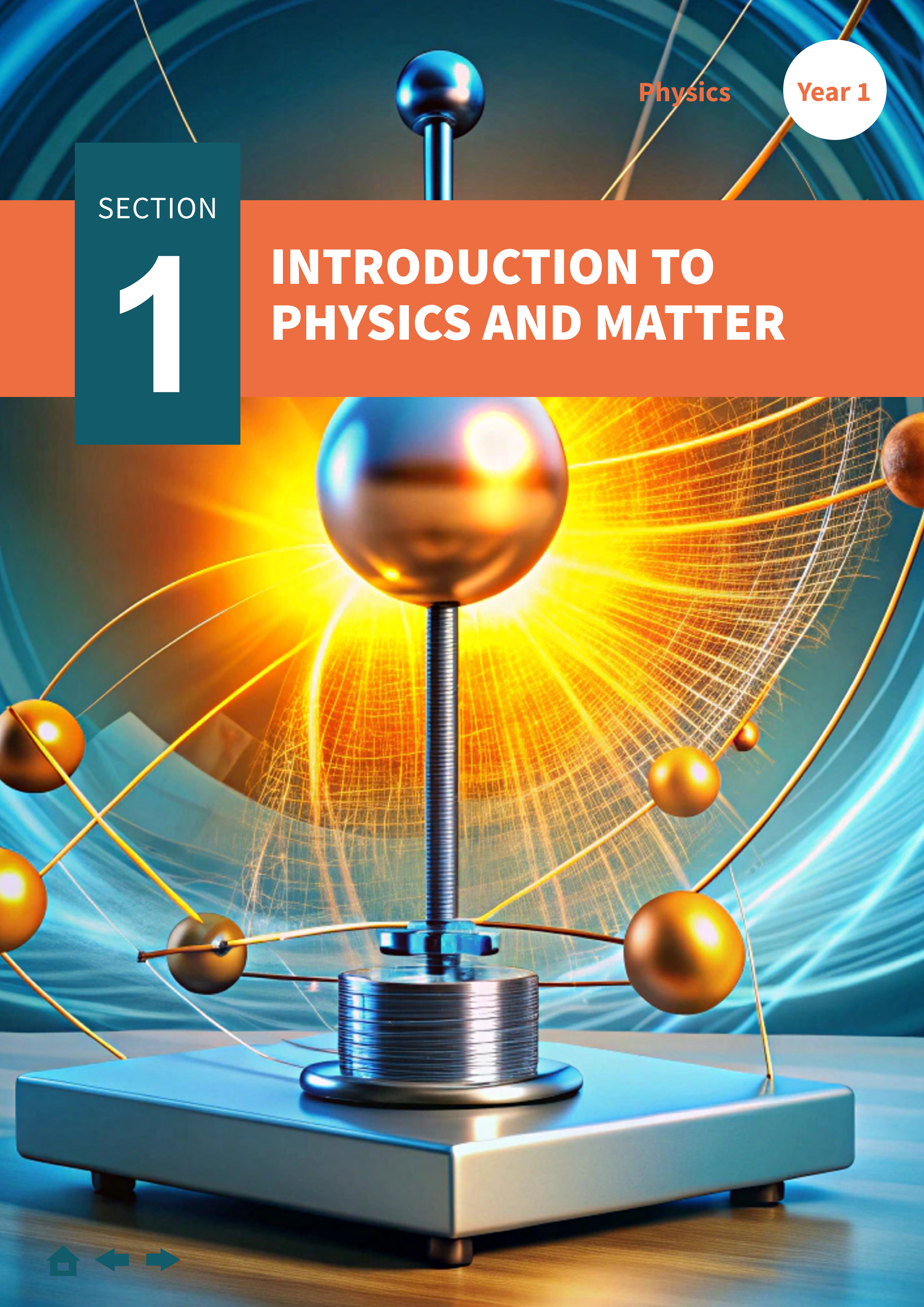


SECTION

1

INTRODUCTION TO PHYSICS AND MATTER

MECHANICS AND MATTER

1. Introduction To Physics

2. Matter

INTRODUCTION

In this section you will understand that Physics plays a crucial role in various economic sectors, leading to diverse career opportunities in fields such as healthcare, engineering, energy, and technology. Mastering basic mathematical concepts like trigonometric ratios, the Pythagorean theorem, and the sine and cosine rules is essential for solving complex problems. Additionally, a solid understanding of the basic units in physics, including meters, kilograms, and seconds, forms the foundation for precise measurement and scientific analysis. This section further highlights that in the study of physics, mastering the dimensions of key quantities like velocity, acceleration, mass, length, time, weight, energy, and force through dimensional analysis is crucial. Dimensions mostly express these quantities in terms of (mass [M], length [L], time [T]), clarifying their relationships and enabling accurate scientific calculations.

The part on scientific notation delves into the fundamentals of the concept to help you understand its structure and how it can be applied to real-world scenarios. You will be equipped with the knowledge and skills to write and interpret numbers confidently in scientific notation. You will understand its significance in scientific research, engineering, and other fields where precision and accuracy are paramount. Moreover, you will discover how scientific notation simplifies complex calculations and comparisons involving numbers with multiple decimal places or significant figures. Additionally, understanding and identifying errors in instruments such as the meter rule, protractor, electronic balance, vernier calliper, micrometer screw gauge, voltmeter, and ammeter are essential. Recognising systematic errors (consistent biases), random errors (unpredictable variations), and parallax errors (due to viewing angle issues) helps ensure precise measurements, fostering reliable data collection and interpretation in scientific experiments. Understanding the various states of matter, such as solids, liquids, gases, and plasmas, is essential for comprehending how substances behave. These states, determined by particle arrangement, movement, and energy, are deeply intertwined with the properties of materials, governed by intermolecular forces. Additionally, density, a fundamental concept in physics, describes the relationship between a substance's mass and the space it occupies. Learning about these states and calculating density not only helps us explain phenomena like why ice floats but also equips us with practical tools for scientific inquiry and everyday decision-making.

At the end of this section, you should be able to:

- Identify careers that are related to Physics in various sectors of the economy.
- Use basic mathematical concepts to solve problems i.e. trig ratios, Pythagoras theorem, sine and cosine rules, and indices.
- Identify the basic units in Physics.
- Determine the dimensions of common quantities e.*g*. velocity, acceleration, mass, length, time, weight, energy, and force.
- Identify the errors in the use of a meter rule, protractor, electronic balance, Vernier calliper, micrometre screw gauge, voltmeter and ammeter.
- Explain the type of errors; systematic, random, and parallax.
- Explain scientific notations and their unit multipliers.
- Distinguish scalars from vectors (qualitative treatment).
- Identify the various states of matter.
- Distinguish between the molecular arrangements of the various states of matter.

Key Ideas

- Physics-related careers span various sectors of the economy, such as healthcare, engineering, energy, technology, and research.
- Basic mathematical concepts like trigonometric ratios, the Pythagorean Theorem, sine and cosine rules, and indices are essential for problem-solving.
- It is fundamental to understand and use the basic units in physics, including meters, kilograms, and seconds, and adhere to the International System of Units (SI).

- Dimension expresses quantities using mass, length, and time. We can also determine the dimension of other physical quantities such as velocity and work among others.
- Measurement errors include parallax errors, systematic errors, and random errors. All these errors occur in measurements using instruments such as metre rule, protractor, electronic balance, vernier calliper, micrometer screw gauge, voltmeter, and ammeter.
- Systematic errors skew results, random errors cause variations, and parallax errors arise from incorrect eye alignment. All these can be minimised through calibration and proper reading techniques.
- Scientific notation provides a concise way to represent extremely large or small numbers by expressing them as a coefficient multiplied by a power of 10.
- The coefficient is a number between 1 and 10, while the power of 10 indicates how many places the decimal point should be moved.
- **Matter** refers to anything that has mass and occupies space.
- **Energy** is the capacity to do work or produce change, existing in various forms such as kinetic, potential, thermal, and electromagnetic.
- **Forces** involve interactions that cause changes in the motion of objects, including gravity, electromagnetism, and nuclear forces.
- Matter encompasses everything that occupies space and possesses mass. It exists in various states: **solid, liquid, gas,** and **plasma**.
- Solids maintain a fixed shape and volume, while liquids conform to the shape of their container while retaining a definite volume. Gases lack both definite shape and volume, filling the space available. **Plasma,** an ionised gas, represents the less familiar fourth state.
- Understanding states of matter involves grasping concepts like **intermolecular forces,** which bind molecules in different states, and **intermolecular motion**, which denotes molecular movement within substances.

APPLICATION OF PHYSICS IN VARIOUS SECTORS OF THE ECONOMY AND CAREER EXPLORATION

Definition and Meaning of Physics

Physics is the scientific study of matter, energy, and the fundamental forces of nature. It originates from the Latin word "**physica**," meaning "*natural thing*. It seeks to understand the behaviour and properties of the physical universe, from the smallest particles to the largest structures, through observation, experimentation, and mathematical modelling.

Careers Related to Physics

Physics opens doors to exciting careers in Ghana, driving economic and technological advancements. Careers such as carpentry, masonry, welding, vulcanising, and engineering all rely on various sub-fields of physics, such as mechanics, thermodynamics, electromagnetism, and material science. Carpenters and masons use mechanics to understand forces and structures, while welders and vulcanisers apply thermodynamics and material science to manage heat and material behaviour. Engineers across disciplines, including civil, electrical, and mechanical, utilise physics principles in designing machines, structures, and systems. In each of these careers, physics provides essential insights into the behaviour of materials, forces, and energy, ensuring safety and efficiency in practical applications..

To understand how physics principles are applied in everyday careers and advanced fields through practical exploration and research, let us do an activity.

You will find more information and possible solutions to some activities in **Annex 1.1** at the end of the section

Activity 1.1 Physics in everyday careers

Materials needed:

- Internet access or library resources for research
- Presentation software or materials for creating visual aids
- Writing materials for note-taking and brainstorming

What to do:

Choose a career: Select one of the everyday careers listed below:

- Carpentry
- Masonry
- Welding
- Vulcanizing
- Trading in the Market

Research and Presentation:

- Research Phase.
- Explore the specific physics principles involved in your chosen career.
- Investigate how these principles are applied in real-life situations.
- Use diagrams, graphs, animations, and real-life examples to illustrate your findings.

Presentation Phase: Create a presentation (either written or verbal) that highlights:

- The key physics principles in your chosen career.
- Examples of how these principles are applied practically.
- Potential impacts of this career on society and technology.

Presentation Guidelines: Address questions such as:

- What are the key physics principles involved?
- How do these principles apply to tasks and challenges within this career?
- Can you provide real-life examples where these principles are used?
- What are the potential impacts of this career on society and technology?

Activity 1.2 Exploring advanced careers in physics

Objective:

To understand how physics principles are applied in advanced fields through practical exploration and research.

Materials needed:

- Internet access or library resources for research

- Presentation software or materials for creating visual aids
- Writing materials for note-taking and brainstorming

What to do:

1. **Choose an advanced career:** Select one of the advanced careers in physics listed below:
    - Engineering (mechanical, civil, electrical)
    - Meteorology
    - Medicine (medical imaging, diagnostics, treatments)
    - Teaching
2. **Research and Presentation:**

    Research Phase:

    - Explore specific branches or applications of physics within your chosen advanced career.
    - Identify subfields of physics relevant to the career.
    - Investigate how these subfields contribute to innovations and advancements.
    - Provide real-life examples where physics has driven significant progress in this career.

    Presentation Phase: Create a presentation that covers:

    - The subfields of physics are involved in your chosen career.
    - How these subfields contribute to innovations and advancements.
    - Real-life examples demonstrating physics' impact on the career.
    - Potential impacts of this career on society and technology.
3. **Presentation Guidelines:** Address questions such as:
    - What are the subfields of physics involved in this career?
    - How do these subfields contribute to innovations and advancements?
    - Can you provide real-life examples where physics has driven significant progress?
    - What are the potential impacts of this career on society and technology?

Activity 1.3 Discovering subfields in physics

Objective:

To independently research and understand different areas of physics and their real-world applications.

What to do:

1. **Choose a Subfield:** Select one area of physics to explore:
    - Classical Mechanics
    - Thermodynamics
    - Electromagnetism
    - Quantum Mechanics
    - Relativity
    - Optics
    - Nuclear Physics
    - Particle Physics
2. **Research:** Use online resources or textbooks to learn about your chosen subfield. Focus on:
    - Key concepts and how they apply in everyday life.
    - Examples of how this subfield is used in technology.
    - Future impacts on science and technology.
3. Write a summary or create a short presentation using the following guidelines:
    - Explain what the subfield studies.
    - Give examples of how it is applied.
    - Discuss why it is important for future advancements.

Activity 1.4

Choose one of the careers above and think about how physics is used in that field.

Write down one example of how physics principles are applied in that career.

Share your thoughts with a classmate or teacher.

How do these principles help professionals solve real-world problems?

An example of this is presented below to guide you:

Worked Example: Engineering

1. How physics is used in engineering:
    - Engineers use physics to ensure that buildings and bridges are stable and safe. They apply principles like force distribution and material strength.
    - Engineers calculate the forces acting on the bridge, such as weight and tension, to determine the best materials and design. By understanding these forces, they can design a bridge that can withstand heavy loads and harsh weather conditions.

Think about a bridge in your community. What materials do you think were used? How might engineers have applied physics principles to ensure it is strong and safe?

Activity 1.5 Documentary Exploration

Objective: To understand how physics shapes various careers.

What to do:

1. Watch documentaries showcasing physics in different industries.
2. Discuss with your peers the impact on innovation and problem-solving.

Activity 1.6 Exploring Advanced Physics Careers

Objective:

Discover diverse physics-oriented careers.

What to do:

1. Research and present on careers in engineering, medicine, meteorology, and teaching.
2. Discuss their impact on Ghana's development.

   Do you want to know more about these careers?

   You will enjoy watching the video documentary on careers related to physics through the link provided below:

   https://www.youtube.com/watch?v=G60ujS-w3Ek
3. Share your experience with a friend.

BASIC MATHEMATICS IN PHYSICS TO SOLVE REAL-WORLD PROBLEMS

Welcome learner, in this lesson, you will practice applying some important mathematics concepts that help us solve different kinds of problems. You will be learning more about trigonometric ratios, Pythagoras' theorem, sine and cosine rules, and the laws of indices. These are basic ideas that are useful for solving most physics problems related to mathematics.

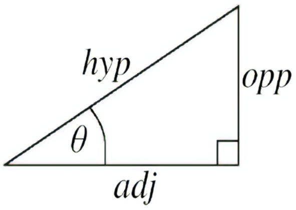
Let us take a closer look at each one and see how they work together to help us solve mathematics-related problems.

Trigonometric Ratios

Trigonometric ratios (sine, cosine, and tangent) relate the angles of a right triangle to the lengths of its sides.

In a right-angled triangle with angle θ:

- $\sin\theta = \dfrac{Opposite}{Hypotenuse}$
- $\cos\theta = \dfrac{Adjacent}{Hypotenuse}$
- $\text{Tan}\,\theta = \dfrac{Opposite}{Adjacent}$



Pythagoras Theorem

Pythagoras' theorem states that in a right triangle, the square of the length of the hypotenuse (c) is equal to the sum of the squares of the lengths of the other two sides (**a** and **b**):

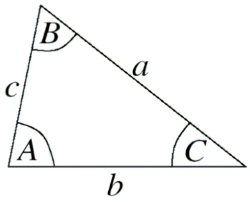
- $a^2 + b^2 = c^2$

This theorem is used to find the length of a side in a right triangle when the lengths of the other two sides are known.

Sine Rule

The sine rule relates the lengths of the sides of any triangle to the sines of its angles.

For a triangle with sides a, b, and c opposite angles **A**, **B**, and **C** respectively:



$$\frac{a}{sin(A)} = \frac{b}{sin(B)} = \frac{c}{Sin(C)}$$

The sine rule is useful for solving triangles when you know two angles and one side, or two sides and one angle.

Cosine Rule

The cosine rule relates the lengths of the sides of a triangle to the cosine of one of its angles.

For a triangle with sides a, b, and c opposite angles A, B, and C respectively:

$a^2 = b^2 + c^2 - 2bc \cos(A)$

The cosine rule is useful for solving triangles when you know all three sides or two sides and the included angle.

Indices

Indices (or exponents) represent repeated multiplication of the same number by itself.

Rules of indices:

$$a^m \times a^n = a^{m+n}$$
$$\frac{a^m}{a^n} = a^{m-n}$$
$$(a^m)^n = a^{mn}$$
$$a^0 = 1 \ (for\ a \neq 0)$$

Indices are used to simplify expressions and solve equations involving powers.

As you study these concepts, consider how your understanding of these tools can contribute to solving a variety of physics-related challenges.

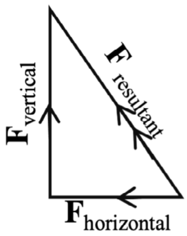
Let us find out together with some simple activities

Worked Examples

1. How can a right-angled triangle represent the resultant of two perpendicular forces acting on an object?

Solution

In a right-angled triangle, one side can represent the horizontal force ($F_{horizontal}$), another side the vertical force ($F_{vertical}$) and the hypotenuse the resultant force ($F_{resultant}$).



Using Pythagoras' theorem, $F^2_{resultant} = F^2_{horizontal} + F^2_{vertical}$

$$F_{resultant} = \sqrt{F^2_{horizontal} + F^2_{vertical}}$$

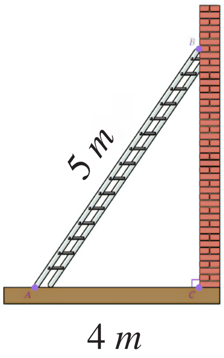
Applications of the Mathematics Tools to Solve Problems

Using Pythagoras theorem

Worked Example 1.1

A ladder leans against a wall with its foot 4 m away from the wall. If the ladder is 5 m long, how high does it reach on the wall?

Solution:



$$Height^2 = Ladder^2 - Base^2$$

$$\text{Height} = \sqrt{5^2 - 4^2}$$

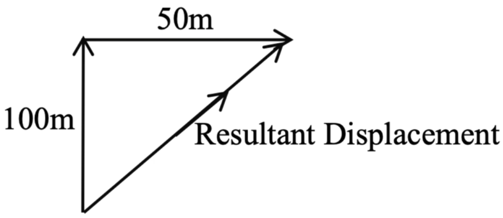
$$\text{Height} = \sqrt{25 - 16}$$

$$\text{Height} = \sqrt{9}$$

$$\text{Height} = 3\ m$$

Worked Example 1.2

A car travels 100 meters north and then turns and travels 50 meters east. What is the resultant displacement of the car?



Solution:

Using trigonometric ratios (Pythagoras' theorem for vectors):

$(\text{Resultant Displacement})^2 = (100)^2 + (50)^2$

$\text{Resultant Displacement} = \sqrt{10000 + 2500}$

$\text{Resultant Displacement} = \sqrt{12500}$

$\text{Resultant Displacement} = \mathbf{111.8}\ m$

Using Trigonometric Ratios

Worked Example 1.3

In a right-angled triangle, the opposite side of an angle is 3 N and the resultant 5N, what is the sine of the angle?

Solution

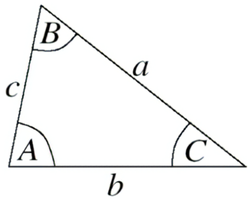
$$\sin\boldsymbol{\theta} = \frac{Opposite}{Hypotenuse}$$

$$\sin\theta = \frac{3}{5}$$

Using Sine and Cosine Rules

Worked Example 1.4

Given a triangle with sides a = 6 *cm*, b = 8 *cm*, and an angle C = 60°, find the length of side c using the Sine Rule.



Solution:

$$\frac{a}{sin(A)} = \frac{b}{sin(B)} = \frac{c}{Sin(c)}$$

$$\frac{6}{sin(60)} = \frac{8}{sin(B)}$$

Solving for sin(B), we get $\boldsymbol{B = 45°}$

Then, using the Sine Rule again,

$$\frac{8}{sin(45)} = \frac{\text{c}}{sin(60)}$$

Solving for c, we get c $\approx 7.75\ cm$

Activity 1.7: Self-Assessment Questions

1. A plane takes off from an airport and flies 500 kilometres due north. It then changes direction and flies 300 kilometres due east. What is the straight-line distance from the starting point to the final position of the plane?
2. You walk 4 kilometres west to visit a friend, and then walk 5 kilometres north to the library. What is the shortest distance you need to walk to go directly from your friend’s house to the library?
3. In a Ghanaian market, if a seller wants to calculate the total quantity of goods after several rounds of doubling the initial stock, what law of indices would be applicable?

Discuss your solutions with your friend, teacher or family member.

Practical Applications of the Mathematical Tools in Daily Life Situations Related to Physics

1. **Pythagoras' Theorem:**

   Building Construction: In a staircase design or construction.

2. **Trigonometric Ratios:**

   Navigation: Pilots and sailors use trigonometric ratios to determine their direction and position. For instance, a sailor can estimate their distance from that point using trigonometry.

3. **Sine Rule:**

   Architectural Design: Architects use the Sine Rule to determine the lengths of the sides of irregularly shaped buildings or structures, ensuring that all parts fit together harmoniously.

4. **Cosine Rule:**

   Mechanical Engineering: In mechanical designs, like designing gears or pulleys, the Cosine Rule can help calculate the forces and angles involved, ensuring smooth and efficient operation of machinery.

5. **Rules of Indices:**

   Scientific Notation: In physics, particularly when dealing with very large or very small numbers of scientists use indices or exponential notation to represent these values in a more manageable form. For example, the speed of light in a vacuum, $\mathbf{3 \times 10^8}$ ***m*/s,** is often represented this way.

BASIC AND DERIVED QUANTITIES, AND UNITS

Units in Physics are standards used to measure specific physical properties or dimensions.

Physical Quantities

A Quantity refers to a characteristic or property that can be measured or quantified. There are two types of quantities: Fundamental quantity and Derived quantity.

Fundamental quantities

A fundamental quantity is an independent physical quantity that cannot be defined in terms of other physical quantities. In other words, fundamental quantities are the basic building blocks from which all other quantities can be derived. Examples are Length, Mass, Time, Temperature, Electric Current, Amount of substance, and luminous intensity.

These fundamental quantities serve as the foundation for measuring various aspects of the physical world, and all other quantities can be expressed in terms of combinations of these fundamental quantities

Derived quantities

A derived quantity is a physical quantity that is derived from one or more fundamental quantities through mathematical combinations or relationships. In other words, derived quantities are built upon fundamental quantities. Examples are force, volume, pressure, work, energy, momentum, power, density, velocity, acceleration, *etc.*

Table 1.1: Derived quantities, symbols and relationship to basic units

Derived Quantity	Unit Name	Unit Symbol	Relationship to Basic Units
Area	Square meter	m^2	Length × Length
Volume	Cubic meter	m^3	Length × Length × Length
Speed	Meter per second	m/s	Length / Time
Acceleration	Meter per second squared	m/s^2	Speed / Time
Force	Newton	N	Mass × Acceleration ($kg \cdot m/s^2$)
Pressure	Pascal	Pa	Force / Area (N/m^2)
Energy	Joule	J	Force × Distance ($N \cdot m$)
Power	Watt	W	Energy / Time (J/s)
Electric Charge	Coulomb	C	Electric Current × Time ($A \cdot s$)
Electric Potential Difference	Volt	V	Power / Electric Current (W/A)

Units

Units typically refer to standardised measurements used to quantify various physical quantities, such as length, mass, time, temperature, and many others.

There are two types of units: Fundamental/ Basic units Derived units.

Basic units

Basic units, also known as fundamental units, are the standard units of measurement for the fundamental quantities in science and engineering. These units are defined independently and cannot be derived from other units. The International System of Units (SI) recognises seven basic units for seven fundamental quantities as shown in the table below.

The table below shows the seven fundamental quantities, their symbols, SI units and definitions.

Table 1.2: Fundamental quantities, their symbols, SI units and definitions

Fundamental Quantity	Unit Name	Unit Symbol	Definition
Length	Meter	*m*	The distance travelled by light in a vacuum is 1/299,792,458 of a second.
Mass	Kilogram	*kg*	The mass of the international prototype of the kilogram, a platinum-iridium cylinder stored at the International Bureau of Weights and Measures.
Time	Second	s	The duration of 9,192,631,770 periods of radiation corresponds to the transition between two hyperfine levels of the ground state of the cesium-133 atom.
Electric Current	Ampere	A	The amount of charge passing through a conductor in one second when there is a current of one coulomb.

Fundamental Quantity	Unit Name	Unit Symbol	Definition
Thermodynamic Temperature	Kelvin	K	The fraction 1/273.16 of the thermodynamic temperature of the triple point of water.
Amount of Substance	Mole	mol	The amount of substance containing as many entities (atoms, molecules, etc.) as there are in 0.012 kilograms of carbon-12.
Luminous Intensity	Candela	cd	The luminous intensity of a source emitting monochromatic radiation of frequency 540×10^{12} hertz with a radiant intensity of 1/683 watt per steradian.

Derived units

Derived units are units of measurement that are created by combining fundamental units according to specific mathematical relationships. They measure quantities derived from the basic or fundamental quantities. While fundamental units are the building blocks of measurement (like meters for length and kilograms for mass), derived units express more complex physical quantities.

Some derived quantities are presented in Table 1.3 below.

Table 1.3: Some common derived units, the quantities they measure, and their relationships to fundamental units.

Derived Quantity	Derived Unit	Unit Symbol	Relationship to Fundamental Units	Example
Area	Square meter	m^2	Length × Length ($m \times m$)	Area of a rectangle
Volume	Cubic meter	m^3	Length × Length × Length ($m \times m \times m$)	Volume of a box
Speed/ Velocity	Meter per second	m/s	Length / Time (m / s)	Speed of a car

Derived Quantity	Derived Unit	Unit Symbol	Relationship to Fundamental Units	Example
Acceleration	Meter per second squared	m/s^2	Change in Speed / Time (m/s / s)	Acceleration of a falling object
Force	Newton	N	Mass × Acceleration ($kg \times m/\text{s}^2$)	Force exerted by a push
Pressure	Pascal	Pa	Force / Area (N / m^2)	Air pressure in a tyre
Energy	Joule	J	Force × Distance ($\text{N} \times m$)	Energy used to lift an object
Power	Watt	W	Energy / Time (J / s)	Power consumption of a light bulb
Electric Charge	Coulomb	C	Electric Current × Time (A × s)	Electric charge stored in a battery
Electric Potential Difference	Volt	V	Power / Electric Current (W / A)	Voltage of a battery
Frequency	Hertz	Hz	1 / Time (1 / s)	Frequency of a radio wave
Density	Kilogram per cubic meter	kg/m^3	$\frac{\text{Mass}}{\text{Volume}}$	Density of a stone

Importance of units

1. **Consistency:** Units provide a consistent way to measure and report quantities, ensuring that everyone understands the magnitude of the measurement in the same way.
2. **Comparison:** Units allow for the comparison of different measurements. For example, knowing the length of two objects in meters allows you to compare their sizes directly.

3. **Communication:** Units enable clear and precise communication of scientific and engineering data. This is crucial for collaboration and progress in these fields.
4. **Standards:** Units provide standards that help maintain the accuracy and reliability of measurements in various industries and applications.

DIMENSIONS

The dimension of a physical quantity is an accepted symbol assigned to the dimensional quantities.

The dimension of a physical quantity refers to the expressive symbols that describe how a quantity relates to its dimension.

The dimension of a physical quantity is an expression that relates the physical quantity and the fundamental quantities. The symbol for dimension is represented by [ ]. For example, the dimension of length is represented by [Length] or [L].

Table 1.4 summarises the respective dimensions of the fundamental quantities.

Table 1.4: Dimensional symbols

No.	Physical Quantity	Dimensional unit or symbol
1	Length	L
2	Mass	M
3	Time	T
4	Temperature	Θ
5	Current	I
6	Luminous intensity	J
7	Amount of substance	N

Uses of Dimensions

Dimensions can be used in the following areas:

1. **Verification of Equations:** it ensures that equations are dimensionally consistent, which is crucial for their correctness and validity.
2. **Unit Conversion:** It helps convert units from one system to another, ensuring consistency across different measurement systems.
3. **Deriving equations between quantities:** By understanding the dimensions of physical quantities, one can derive relationships between different quantities in physics and engineering.
4. **Dimensional Homogeneity:** it ensures that only quantities with the same dimensions are added or subtracted, maintaining the integrity of equations.
5. **Error Checking helps identify** errors in mathematical and physical equations by checking for dimensional consistency.
6. **Scaling Laws:** they are used to develop scaling laws that relate different physical phenomena, essential in fields like fluid dynamics and astrophysics.
7. **Understanding Physical Nature:** Dimensions provide insights into the fundamental nature of physical quantities, helping to classify and understand them better.
8. **Design and Modeling:** In engineering, dimensions are crucial for designing and modelling systems, ensuring that all parts and processes are compatible.
9. **Dimensional Constants:** Dimensions help identify and understand fundamental constants in physics, such as the gravitational constant (G) and the speed of light (c).

These uses demonstrate the crucial role dimension plays in various aspects of science.

Dimensional Analysis

Dimensional analysis is a method used in physics to check the consistency of equations, convert units, and derive relationships between physical quantities.

Dimensional analysis verifies equations, determines units, and derives relationships between quantities. It aids in unit conversion and ensures consistency in mathematical operations. While not accounting for numerical constants, it offers deeper insights into physical quantities, enhancing measurement accuracy and consistency. Essential in physics and engineering, it helps learners understand physical relationships and units.

Fundamental Quantities and their Dimensions

- **Length (L)**: Dimension symbol [L], SI unit meter (*m*).
- **Mass (M)**: Dimension symbol [M], SI unit kilogram (*kg*).
- **Time (T)**: Dimension symbol [T], SI unit second (s).

The common fundamental dimensional symbols are summarised in Table 1.5.

Table 1.5: Derived quantities and their dimensions

Derived quantity	Symbol	Dimension	Units
Velocity: The rate of change of displacement.	(v)	$[LT^{-1}]$	meters per second (*m*/s)
Acceleration: The rate of change of velocity.	(a)	$[LT^{-2}]$	meters per second squared (*m*/s²)
Force: An interaction that changes the motion of an object.	(F)	$[MLT^{-2}]$	newton (N)
Energy: The capacity to do work.	(E)	$[ML^2T^{-2}]$	joule (J)
Weight: The force exerted by gravity on an object.	(W)	Same as force $[MLT^{-2}]$	newton (N)

Activity 1.8 Dimensional analysis of everyday quantities

What to do:

1. Write the seven fundamental units earlier learned and put their dimension symbols beside them.
2. Underline dimensional symbols for time, mass and length.
3. Complete the equations below, starting with their fundamental units, and express the final answer regarding their dimension symbols. (Consult the indices learned in earlier lessons).
    - Volume = length × breadth × height
    - $\text{Velocity} = \frac{displacement}{time}$
    - $\text{Acceleration} = \frac{Velocity}{time}$
    - Force = mass × acceleration

  - Weight = mass × acceleration due to gravity
  - Work = force × distance
  - Power = $\frac{Work}{time}$

4. Summarise the dimensions for all the quantities.

Activity 1.9 Matching quantities with their dimensions

Objective: Reinforce understanding of dimensions by matching physical quantities to their dimensional formulae.

Materials needed:

- Flashcards with physical quantities (velocity, acceleration, force, energy, weight).
- Flashcards with dimensional formulae (LT^{-1}, LT^{-2}, MLT^{-2}, $ML^{2}T^{-2}$).

What to do:

1. Find a friend or friends.
2. Pick a set of flashcards containing an equal number of physical quantities and dimensional formulae.
3. Match the physical quantity cards with the correct dimensional formula cards.
4. After matching, present your matches to other friends and explain the reasoning behind your choices.

Connect formulae and definitions with their corresponding physical quantities, and you will find that it is helpful to reinforce your understanding and prepare for more complex dimensional analysis tasks.

Activity 1.10 Interactive Quiz: Dimensional Analysis

1. Pick a question or some questions from the interactive quiz questions provided below.
2. Think and write down your answers.
3. Review the correct answer and briefly explain why it is correct.
4. Discuss your reasoning with a friend.

Interactive Quiz Questions:

1. Formula: $v = \frac{d}{t}$. What is the quantity?

(A). Force (B). Energy

(C). Velocity (D). Acceleration

2. Definition: The time rate of change of velocity. What is the quantity?

(A). Time (B). Acceleration

(C). Force (D). Distance

3. **Formula**: $F = ma$. **What is the quantity?**

(A). Mass (B). Acceleration

(C). Force (D). Energy

4. Definition: The capacity to do work. What is the quantity?

(A). Energy (B). Power

(C). Force (D). Velocity

5. **Formula**: $W = mg$. **What is the quantity?**

(A) Weight (B) Work

(C) Mass (D) Velocity

6. **Definition**: The distance travelled per unit of time. **What is the quantity?**

(A). Force (B). Energy

(C). Velocity (D). Acceleration

7. **Formula**: $E = F{\cdot}d$. **What is the quantity?**

(A). Work/Energy (B). Power

(C). Velocity (D). Mass

Activity 1.11 Collaborative learning on formulae and units

Objective:

- To reinforce your understanding of physical quantities, their formulae, and corresponding units through collaborative learning.

Materials needed:

- A list of physical quantities
- Blank paper or worksheets
- Pens or pencils
- Fundamental unit table (provided for reference)

What to do:

1. Below is a list of physical quantities for you to work with:

   Velocity, Acceleration, Force, Energy, Power, Distance, Time, Mass, Weight
2. Carry out this activity with two of your friends or mates.
3. Write down the formula for each quantity, and include the corresponding units.
4. Take turns with your friends to lead discussions within the group, explaining the formulae and units to each other.
5. Take turns participating by asking questions, writing down your answers, and checking the accuracy of your work from relevant sources.
6. Share your findings with the class.

Activity 1.12 Finding the units of given quantities from their fundamental units

Objective: To find the units of physical quantities in terms of fundamental units

Materials needed:

- whiteboard and markers
- worksheets for learners
- fundamental unit table handout

What to do:

1. Go through the following worked examples on finding the unit of the given quantities.

a. Finding the SI unit of Force using its fundamental quantities**:**

Step-by-Step Solution:

i. Write the formula: Force (F) = $m \times$ a

ii. Identify the units for each of the quantities that constitute Force

- Mass (m): kilograms (kg)
- Acceleration (a): meters per second squared (m/s^2 or ms^{-2})

iii. Combine/ multiply the units: F = $kg \cdot \times ms^{-2}$

iv. Simplify the units: F = $kgms^{-2}$

v. Result: The unit of force is $kg\,ms^{-2}$, also known as a newton (N).

2. Given the formula of Velocity (v) = $\frac{d}{t}$, where (d) = displacement, and (t) = time, determine the SI unit of velocity.

Solution:

Distance (d): meters (m); Time (t): seconds (s)

Therefore, SI unit of Velocity (v): = $\frac{d}{t}$ = $\frac{m}{s}$ = ms^{-1}

3. Now, use the worksheet provided by your teacher to try your hand at solving the following questions:

a) Acceleration (a): a = $\frac{\Delta v}{t}$

b) Work (W): W = Fd

4. Obtain a worksheet with questions and recall the relevant formulae of:

a) Power (P): P=W/t

b) Momentum (p): p =mv

c) Kinetic Energy (KE): KE = $\frac{1}{2}mv^2$

5. Identify the units of more challenging questions without provided formulae.

Show that Gravitational Potential Energy (GPE), Kinetic Energy (KE), and Work (W) have the same units. [Hint: GPE = mgh ; KE = $\frac{1}{2}mv^2$; W=Fd]

Activity 1.13 Determining the dimensions and units of fundamental constants

Objective:

- To find out about fundamental constants such as the speed of light (c) and the gravitational constant (G);
- To determine their dimensions and units using provided formulae or definitions.

Materials needed:

- whiteboard and markers
- worksheets for learners
- fundamental unit table handout
- calculator (optional)

What to do:

1. **Fundamental Constants Overview**
    - **a.** Refer to this learner resource and other online or library sources to read about fundamental constants and their significance in physics.
    - **b.** “Give brief explanation of the following constants:
        - **i.** Speed of light (c)
        - **ii.** Gravitational constant (G)
2. Go through the following worked examples to derive the dimensions, units and formulae of the Speed of Light and Gravitational constant.
    - **a. Speed of light:**

      Definition: The speed at which light travels in a vacuum.

      Formula: $c = \frac{d}{t}$

Step-by-Step Solution:

i. Identify the formula: $c = \frac{d}{t}$

ii. Determine the units for distance (d) and time (t):

Distance (d): meters (m)

Time (t): seconds (s)

iii. Combine the units: $c = m/\mathrm{s} = \mathrm{ms}^{-1}$

iv. Determine the dimensions:

Distance: L

Time: T

v. Combine the dimensions: $[c] = LT^{-1}$

vi. Result: The unit of the speed of light is meters per second (m/s; also ms^{-1}), and the dimension is $[LT^{-1}]$.

b. Gravitational Constant (G):

i. Definition: The proportionality constant in Newton's law of universal gravitation.

ii. Formula: $F = G\frac{m_1 m_2}{r^2}$

Step-by-Step Solution:

- Identify the formula: $F = G\frac{m_1 m_2}{r^2}$
- Rearrange to solve for G: $G = \frac{Fr^2}{m_1 m_2}$
- Determine the units for each quantity:
  - Force (F): newtons (N)
  - Distance (r): meters (m)
  - Mass (m): kilograms (kg)

iii. Combine the units: $G = \frac{Nm^2}{kg^2} = \frac{kgm\,s^{-2}m^2}{kg^2}$

$G = N{\cdot}m^2\,kg^{-2} = m^3{\cdot}kg^{-1}{\cdot}s^{-2}$

iv. Determine the dimensions:

- Force: $[MLT^{-2}]$
- Distance: $[L]$
- Mass: $[M]$

v. Combine the dimensions: $[G] = [MLT^{-2}]{\cdot}[L]^2[M]^2 = [L^3M^{-1}T^{-2}]$

vi. Result: The unit of the gravitational constant is $m^3{\cdot}kg^{-1}{\cdot}s^{-2}$, and the dimension is $[L^3M^{-1}T^{-2}]$.

Activity 1.14. Learners' Practice

1. Determine the units and dimensions of Planck's constant (h) in $E = hf$, where f stands for frequency.

2. Determine the value for the unit and dimension of Boltzmann constant (k) in $E = kT$.

3. Recall formulae, determine the units, and find the dimensions in the following formulae:
    - a. The constant c in $E = mc^2$
    - b. The Universal gas constant (R) in $PV = nRT$

Activity 1.15 Benefits of dimensional analysis in physics

Objective: To understand the practical benefits and applications of dimensional analysis in physics through discussions.

Materials needed:

- whiteboard and markers
- discussion prompts handout
- paper and pens for notes

What to do:

1. Identify a friend or friends to form a small learner group.
2. Engage in group discussions with the following discussion prompts:
    - a. How can dimensional analysis help verify that a physics formula is correct?
    - b. How can dimensional analysis be used to convert units?
    - c. How can dimensional analysis help in solving physics problems?

Group Discussions

1. Allow 5-10 minutes for group discussions. Each group should appoint one member to record the answers from the discussions.
2. Think of simple examples or use those provided below.

Group Sharing

1. After the discussions, each group should share one key point from their discussion with the class or peers.

Discussion Points for Activity 1.15:

1. a. **Verifying Formulae**
    - i. **Example**: Checking the formula for speed $v = \frac{d}{t}$
        - Time (t): seconds (s)
        - Speed (v): *m*/s
        - The formula is correct because the units match.

b. **Converting Units**
   i. **Example**: Converting 1 hour to seconds
      - 1 hour = 60 minutes = 60 × 60 seconds = 3600 seconds
      - Dimensional analysis ensures the correct conversion.

c. **Solving Problems**
   i. **Example**: Finding the units for force F = ma
      - Mass (m): kilograms (kg)
      - Acceleration (a): meters per second squared (m/s^2)
      - Force (F): kg·m/s^2=N (newton)
      - Helps confirm that force is measured in newtons.

ERRORS IN THE USE OF MEASURING INSTRUMENTS

Accurate measurements are essential for scientific research, Engineering and many other fields. Analogue instruments such as rulers, Vernier callipers, micrometer screw gauges, thermometers, balances, and protractors, as well as digital instruments such as voltmeters and ammeters, enable us to quantify and compare physical quantities precisely. You must learn the proper usage of the instruments and also learn to overcome challenges when handling them.

The least count of a measuring instrument is the smallest value it can accurately measure, representing the smallest detectable subdivision or difference between values. It is crucial to determine **precision** and **accuracy** by ensuring fine distinctions between measurements. The least count also makes it possible to minimise uncertainties and errors by aiding in selecting appropriate instruments, and maintaining data consistency.

Furthermore, knowing the least count assists in proper calibration, reporting correct significant figures, and upholding quality control standards. This knowledge is fundamental for achieving high accuracy, precision, and reliability in scientific and engineering measurements.

Identifying Errors in Measurement Tools

By identifying common errors and understanding how to correct them, we can improve on the accuracy of our measurements in physics experiments. Below are some common error descriptions.

1. Metre rule

a. **Error Example**: Misalignment of the eye with the measurement mark.

   i. **Description**: If the learner's eye is not directly above the mark, a parallax error occurs, leading to incorrect readings.

   ii. **Solution**: Ensure the eye is level with the measurement mark for accurate readings.

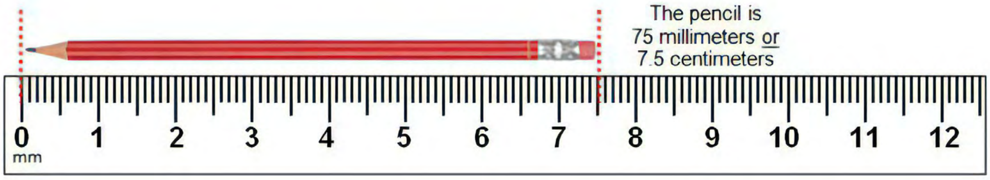
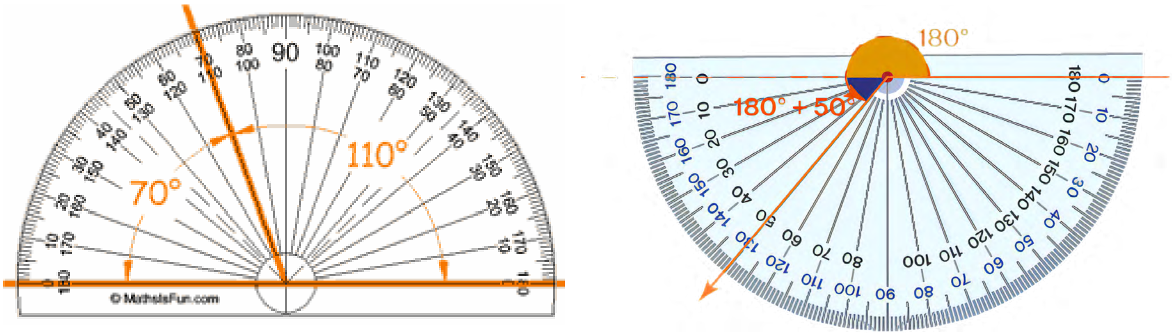


Fig. 1.1a: A rule in correct measurement

Fig. 1.1b: The zero of the rule coincides with the edge.

2. Protractor



(a) (b)

Fig. 1.2 (a) and (b): Protractor in different positions during measurement reading.

a. **Error Example**: Incorrect placement of the protractor's baseline.

   i. **Description**: Placing the baseline of the protractor off the angle's vertex results in inaccurate angle measurements.

   ii. **Solution**: Align the protractor's baseline precisely with the vertex of the angle.

3. Electronic balance

a. **Error Example**: Not zeroing the balance before use.

   i. **Description**: Forgetting to reset the balance to zero before measuring a sample, results in inaccurate mass readings.

   ii. **Solution**: Always press the "tare" or "zero" button before placing the object on the balance.

4. Vernier calliper

a. **Error Example**: Reading the vernier scale incorrectly.

   i. **Description**: Misinterpreting the vernier scale by not aligning the zero mark properly or reading the wrong line.

   ii. **Solution**: Carefully align the zero of the vernier scale (see fig. below) with the main scale and read the measurement at the point where the lines match best.

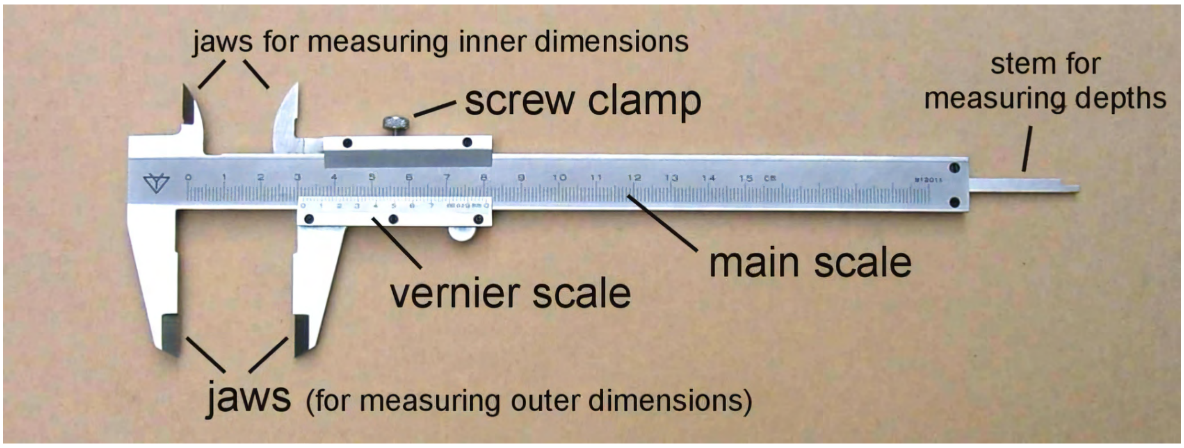


Fig. 1.3: Vernier calliper

5. Micrometer screw gauge

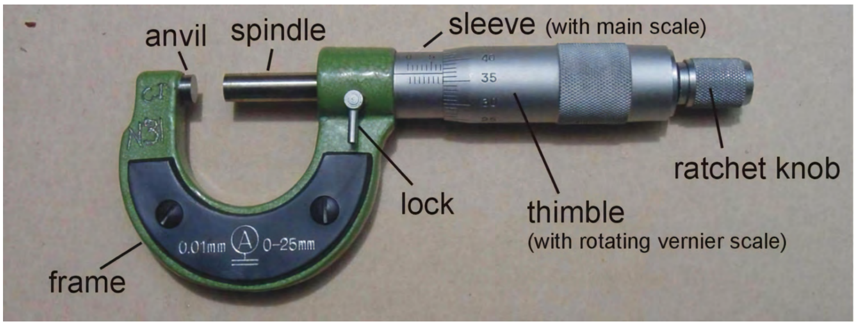


Fig. 1.4: A micrometer screw gauge.

Follow the site below to understand how to read the micrometer screw gauge later:

How to Read A Micrometer Screw Gauge | Mini Physics - Free Physics Notes

a. **Error Example**: Applying excessive force when measuring.
   i. **Description**: Turning the ratchet too hard can compress the object being measured, leading to smaller measurements.
   ii. **Solution**: Use the ratchet stop gently to ensure consistent and accurate measurements.

6. Voltmeter

a. **Error Example**: Connecting the voltmeter in series instead of parallel.
   i. **Description**: Connecting a voltmeter in series can alter the circuit and provide incorrect voltage readings.
   ii. **Solution**: Always connect the voltmeter in parallel with the component you are measuring.

Fig. 1.5: An analogue voltmeter having negative zero error

7. Ammeter

a. **Error Example**: Connecting the ammeter in parallel instead of series.

   i. **Description**: Connecting an ammeter in parallel can damage the meter or the circuit and result in incorrect current readings.

   ii. **Solution**: Always connect the ammeter in series with the circuit to measure current accurately.

Activity 1.16 Identifying measuring equipment and understanding least count

Objective: To identify various pieces of measuring equipment, understand their uses, and determine their least count through hands-on experience and group discussions.

Materials needed:

- metre rules
- vernier callipers
- protractors
- analogue and digital voltmeters
- analogue and digital ammeters
- post-it notes
- worksheets

What to do:

1. **Introduction**

   a. Refer to the concept of measuring equipment and the importance of least count (the smallest measurement that can be accurately read).

2. **Hands-On Activity:**

   a. Obtain various measuring instruments: metre rule, vernier callipers, protractors, voltmeters, and ammeters.

   b. Identify each piece of equipment and discuss its specific use.

   c. Look closely at each instrument and identify the least count.

3. **Group Discussions and Post-it Notes:**
   - **a.** **A:** Handle all the equipment, consider their use and precision, and write suggestions on post-it notes.
   - **b.** Get post-it notes to understand the least count and answer the following simple questions:
     - **i.** Why is it more appropriate to use a metre rule to measure the length of a textbook rather than vernier callipers?
     - **ii.** Do you know of any equipment that could measure longer distances, such as the length of a football pitch?
     - **iii.** Why should you repeat measurements when doing practical work?
   - **c.** **B:** Handle all the equipment with minimal support, use the internet for research if needed, and write suggestions on post-it notes.

     Now work out answers to the following challenging **questions**:
     - **i.** What is the advantage of vernier callipers over a screw gauge for measuring the internal diameter of a bottle neck?
     - **ii.** When measuring an angle using a protractor, how many different positions are you 'judging' the measurement? (Two —one at either side of the angle being measured).
     - **iii.** Three results for voltage are measured. They are: 1.02 V, 1.04 V, and 0.98 V. What is the range of the repeats? What is the percentage difference between the greatest measurement of V and the average V?
   - **d.** **C**: Complete the tasks as above but perform additional analysis or more complex tasks.

4. **Extension Questions**:
   - **a.** Calculate the mean (α) and standard deviation (β) for repeated measurements of a given length using a metre ruler.
   - **b.** Compare the precision of different instruments for the same measurement task and justify which is best and why.

5. **Conclusion**
   - **a.** **Review**: Summarise the key points from the discussions and the importance of knowing the least count for accurate measurements.
   - **b.** **Reflection**: Reflect on how errors can be avoided using the appropriate instruments and understanding their precision.

c. **Feedback**: Collect Post-it notes and discuss the suggestions and examples provided by your friends.

Examples of uses and least counts of some measuring tools

1. **Metre Rule:**
   a. **Use**: Measuring lengths up to 1 metre.
   b. **Least Count**: 1 *mm*.
   c. **Example Use**: Measuring the length of a textbook.
2. **Vernier Calliper:**
   a. **Use**: Measuring internal and external dimensions and depths.
   b. **Least Count**: 0.02 *mm*.
   c. **Example Use**: Measuring the internal diameter of a bottle neck.
3. **Protractor:**
   a. **Use**: Measuring angles.
   b. **Least Count**: 1 degree.
   c. **Example Use**: Measuring the angle of a triangle.
4. **Analogue Voltmeter:**
   a. **Use**: Measuring voltage in circuits.
   b. **Least Count**: Typically, 0.1V (varies by model).
   c. **Example Use**: Measuring the voltage of a battery.
5. **Digital Voltmeter:**
   a. **Use**: Measuring voltage in circuits.
   b. **Least Count**: Typically, 0.01V (varies by model).
   c. **Example Use**: Measuring the voltage of a power supply.
6. **Analogue Ammeter:**
   a. **Use**: Measuring current in circuits.
   b. **Least Count**: Typically, 0.1A (varies by model).
   c. **Example Use**: Measuring current through a resistor.

7. **Digital Ammeter:**
   a. **Use**: Measuring current in circuits.
   b. **Least Count**: Typically, 0.01A (varies by model).
   c. **Example Use**: Measuring small currents in electronic components.

Activity 1.17: Measuring lengths and identifying potential errors

Objective: To practice measuring lengths using a metre rule and identify potential errors in the measurements.

Materials needed:

- metre rulers (with *cm* markings)
- a set of objects or drawings of lines with varying lengths
- worksheets for recording measurements
- pens or pencils

What to do:

1. Identify some importance of accurate measurements and how to use a metre rule with *cm* markings.
2. Identify a friend or friends.
3. Obtain a metre rule and a set of objects or drawings of lines with varying lengths.
4. Measure the lengths of the objects or lines using the metre rule and record their measurements on the provided worksheet.
5. Take turns to measure and record the lengths to engage all learners.
6. After measuring, discuss and identify potential errors that might have occurred during your measurements. Guide yourself against the following points:
   a. **Parallax Error**: When the eye is not directly above the measurement mark, it causes incorrect readings.
   b. **Starting Point Error**: Not aligning the zero mark of the metre rule accurately with the start of the object or line.
   c. **Reading Error**: Misreading the scale due to unclear markings or poor lighting conditions.
7. Discuss the potential errors you have identified with a friend.

8. Record the identified errors on your worksheets.

9. Share one or two potential errors identified with your friends.

10. Discuss how these errors can be minimised or avoided in future measurements.

Examples of Potential Errors of Measuring Tools

1. Measuring the length of a book:
    a. Potential Errors:
        i. *Parallax Error:* The eye was not directly above the measurement mark.
        ii. *Starting Point Error:* The zero mark was not aligned with the edge of the textbook.
2. Measuring a line on paper:
    a. Potential Errors:
        i. *Reading Error:* Misreading the *cm* markings due to poor lighting.
        ii. *Movement Error:* The ruler moved during the measurement.
3. Measuring a Table Width
    a. Potential Errors:
        i. *Parallax Error:* Viewing the scale from an angle.
        ii. *Incorrect End Point:* Not marking the exact end of the table.

Self-Assessment Questions 1.1

1. What instruments can best be used to measure the following quantities?

a. thickness of a blade **b.** mass of a stone

c. volume of a stone

2. Determine the least count of the following instruments used in the laboratory.

a. Micrometer screw gauge **b.** Metre rule

c. Vernier calliper d. Protractor **e.** Voltmeter

ERRORS IN MEASUREMENTS

Errors in measurement are the discrepancies or uncertainties that can occur when making measurements. These errors can arise from various sources and can affect the accuracy and precision of the measured values. The types of errors are systematic, random and parallax.

Systematic Error

A systematic error is an error that consistently deviates from the true value in the same direction. It often arises due to zero errors in the equipment or errors in the scales on the equipment (e.*g*., a ruler with 1mm markings which are, in reality, 1.1mm apart).

The rule below has zero error because the mark does not start on zero exactly but rather it starts from 0.1 *cm*. The voltmeter has zero error because it does not start from zero but on 0.1 V. It has a positive zero error which has to be subtracted from final reading of 3.6 V to have an effective reading of 3.5 V (3.6 V – 0.1 V).

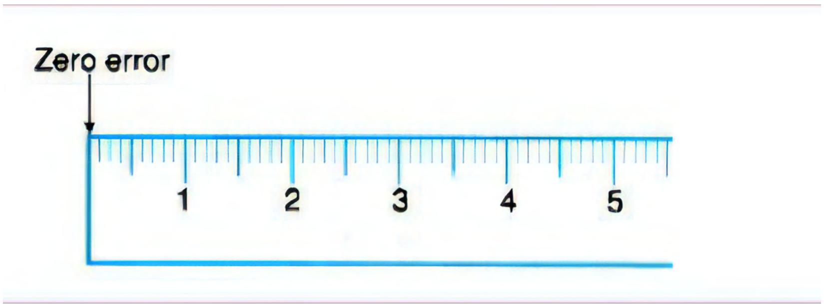


Fig. 1.6: Zero error on meter rule

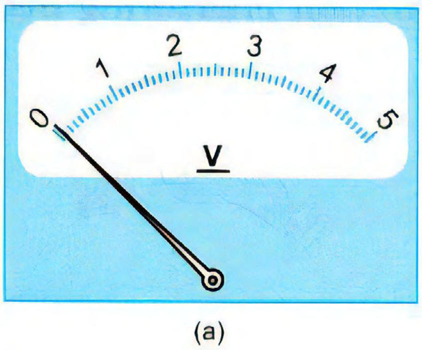


Fig. 1.7(a): Zero error on voltmeter

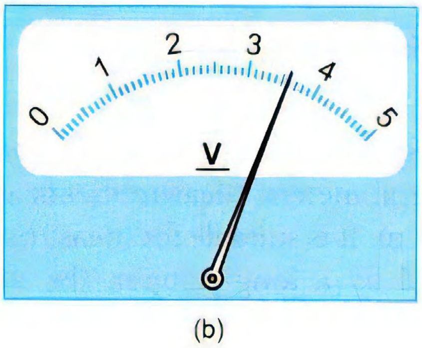


Fig. 1.7(b): Final measurement on zero-errored voltmeter

Random Errors

Random errors are errors made by the person carrying out the measuring or as a result of experimental conditions. Sources of random errors include incorrect timing, or inaccurate reading of instrument. Factors such as unpredictable fluctuations in temperature, voltage supply, and mechanical vibrations of experimental set-ups can also result in random errors.

This error can be reduced in many ways. One way is conducting a particular reading several times and finding the average.

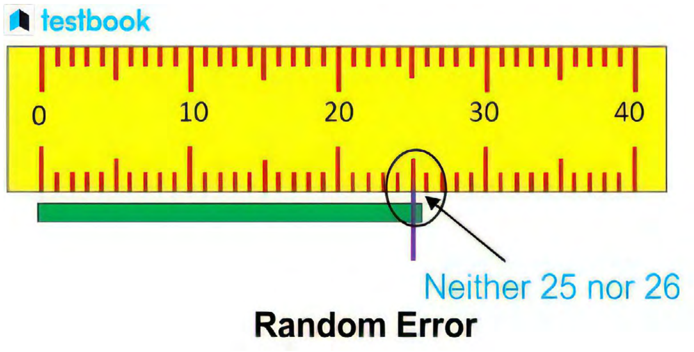


Fig. 1.8: A ruler showing random error

Parallax Error

A parallax error occurs when the eyes are incorrectly positioned while taking a reading on a measuring scale.

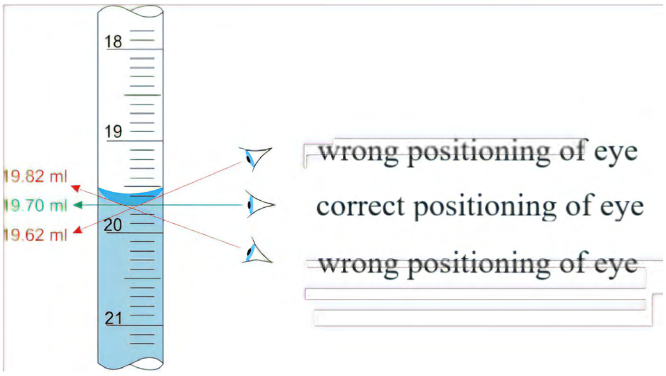


Fig. 1.9: The meniscus of a measuring cylinder showing parallax error of eye at two different positions

Avoiding measurement errors is essential to maintain the integrity of scientific research, ensure reliable and reproducible results, make informed decisions, uphold quality standards, promote scientific progress and safeguard safety in various domains.

Activity 1.18: Using various measuring equipment

Objective:

To identify and understand different types of errors in measurements using various instruments.

Materials needed:

- metre rulers
- vernier callipers
- protractors
- voltmeters
- ammeters
- objects of known dimensions
- worksheets or notebooks
- pens or pencils

What to do:

1. Identify one or two friends to form small groups.
2. Obtain different measuring instruments and objects.
3. Measure dimensions or quantities using each instrument and record their results in the table below:
4. You can let someone higher in knowledge or your teacher guide you in identifying any systematic, random, or parallax errors in your measurements.
5. Facilitate a discussion with others who have done this, compare their results, and discuss the types of errors encountered.
6. Create a written summary of the results obtained from the measurements as in Table 1.6 below.

Table 1.6: Summary table for reasons of occurrences of errors on measuring instruments

Summary of Results from Errors in Measurement Activity					
Materials/ measuring instruments	**What is to be measured**	**Type of Error**			**Reason(s) why certain error(s) occur(s)**
		Systematic	**Random**	**Parallax**	
Metre rule					
Vernier callipers					
Micrometer Screw gauge					
Thermometer					
Spring					
Protractors					
Voltmeters					
Ammeters					

7. Reflect on why certain errors occurred and how you could minimise them in future measurements and add them under *Reasons why certain errors occur*.
8. Share your summaries with others by discussing your findings and insights gained.

Precision and Accuracy in Measurements

When making measurements, the objective is to determine the true value of the measured quantity. However, all measurements inherently possess some degree of uncertainty, primarily stemming from potential errors associated with the measurement instrument, the instrument's least count, and various other factors.

Precision

Precision in measurement is about how consistent or reproducible a set of measurements is. It shows how closely measurements cluster around a central value when multiple measurements of the same quantity are taken using the same instrument. If the measurements are very close to each other and show little variation, then they are considered precise.

When repeated measurements using the same tool yield extremely similar or identical results, it means that the measurement tool or process is highly precise. This high degree of precision ensures accurate and reliable measurement outcomes. It is crucial in science, engineering, and manufacturing, where accurate and reliable measurements are essential for quality control, research, and problem-solving.

The precision of a measurement is reflected in the values recorded. Measurements to a greater number of decimal places are said to be more precise than those to a whole number.

Accuracy

Accuracy is the closeness of measured values to the true value. It is influenced by factors such as the precision of the measuring tool, environmental conditions, human error, and calibration procedures. Accurate measurements are crucial in science, engineering, and manufacturing, impacting data reliability and decisions based on those measurements.

Activity 1.19 Understanding accuracy and precision

Objective: To differentiate between accuracy and precision in measurements.

Materials needed: Pens, pencils, jotter, notebook for taking down notes

What to do:

Reflect silently and think about whether accuracy and precision are the same concepts.

Pair up with a partner and discuss your thoughts on accuracy and precision using the following questions as a guide:

a. What do you think accuracy in measurement is?

b. Think of some examples of accuracy involving measurement in real-life situations.

c. What do you understand by precision in measurement?

d. Think of some examples involving precision in measurement in real-life situations.

e. How is precision different from accuracy? Can you think of an example where something can be precise but not accurate, or accurate but not precise?

f. Why are accuracy and precision important in scientific experiments or measurements?

Write down your discussion points and share with the class.

Precision versus Accuracy

Measurements can lack accuracy even if they are precise when they consistently have the same error. Precision refers to the ability to obtain close readings with an instrument, while accuracy refers to how close those readings are to the true value.

The precision of a measuring tool is crucial for the accuracy and reliability of measurements. A precise measuring tool can measure values in very small increments. For example, while a standard ruler can measure length to the nearest millimetre, a calliper can measure length to the nearest 0.01 millimetre. The calliper is more precise because it can measure extremely small differences in length. The more precise the measuring tool, the more accurate and precise the measurements can be.

Here is an activity to reinforce your measurement skills and help you understand measurement concepts that will prepare you for more advanced scientific investigations.

Activity 1.20 Understanding measurement errors

Objective: To explore the concepts of accuracy and precision in measurements using various instruments and objects.

Materials needed:

- ruler
- protractor
- weighing scale (with intentional errors)
- objects of different lengths, angles, and masses
- worksheets or notebooks
- pens or pencils

What to do:

1. **Introduction (5 minutes)**

   Explain the difference between accuracy (closeness to the true value) and precision (repeatability of measurements) using simple examples.

2. **Preparation (5 minutes)**

   Set up the stations with different instruments and objects. Ensure some instruments have intentional errors (e.*g*., a non-zeroed weighing scale, a homemade ruler with incorrect markings).

3. **Measurement Activity (15-20 minutes)**

   a. Divide learners into pairs or small groups.

   b. Instruct each group to measure the lengths of various objects using the provided instruments.

   c. Encourage learners to note down their measurements and any observations about the instruments (e.*g*., difficulties in reading due to unclear markings).

4. **Discussion (10 minutes)**

   a. Gather the learners back together and facilitate a discussion:

      i. Ask learners to identify and describe any patterns or inconsistencies they noticed in their measurements.

      ii. Discuss how errors in instruments (systematic errors) can affect the accuracy of measurements.

      iii. Clarify the difference between systematic errors (consistent errors) and random errors (unpredictable errors).

5. **Questioning Levels (Differentiated)**

   a.

      i. Guide them through understanding the proper usage of instruments to avoid errors.

      ii. Ask simple questions about examples of systematic and random errors.

   b. Encourage them to research and think critically about eliminating errors in experiments.

   Pose questions on minimising parallax errors and the importance of calibration.

c. Challenging Question

Present an extension question about the impact of errors on calculations:

Example: “When a set of scales reads 2g with nothing on it and measures a rock as 154g, what type of error occurred? How would this affect the learner’s measurement of the rock’s density after measuring its volume?”

6. Conclusion (5 minutes)

a. Summarise key learnings about accuracy, precision, and the impact of errors in measurements.

b. Emphasize the importance of careful observation and proper use of instruments in scientific experiments.

The next activity will enhance your measurement skills and promote critical thinking and analysis of measurement data, essential for scientific investigations

Activity 1.21 Measuring Angles and Analysing Variations

Objective: To practice measuring angles accurately and analyse variations in measurements.

Materials needed:

- Protractors
- Internet, textbooks or library resources on how to use a protractor correctly
- worksheet with shapes or drawn angles
- pens or pencils

What to do:

1. Research how to use a protractor to measure angles accurately from a textbook, internet (via google) or visit your library to find out more.
2. Find out why it is important to take multiple measurements to ensure accuracy.
3. Take the protractors and worksheets your teacher will give you. The drawings on the worksheets will look like the ones below:

4. Observe the drawings carefully and read the resulting angles being measured. What is the angle in the triangle ACB below?

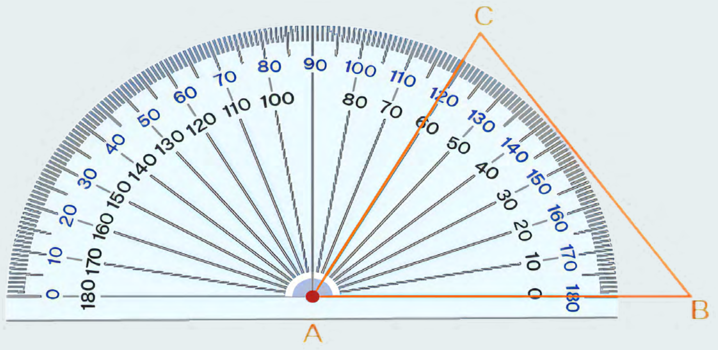


Fig. 1.10: A protractor measuring angle of a triangle

5. Now use the protractor accurately to measure the following angles on your worksheet. Remember to take multiple readings (at least 3) of each one and record.

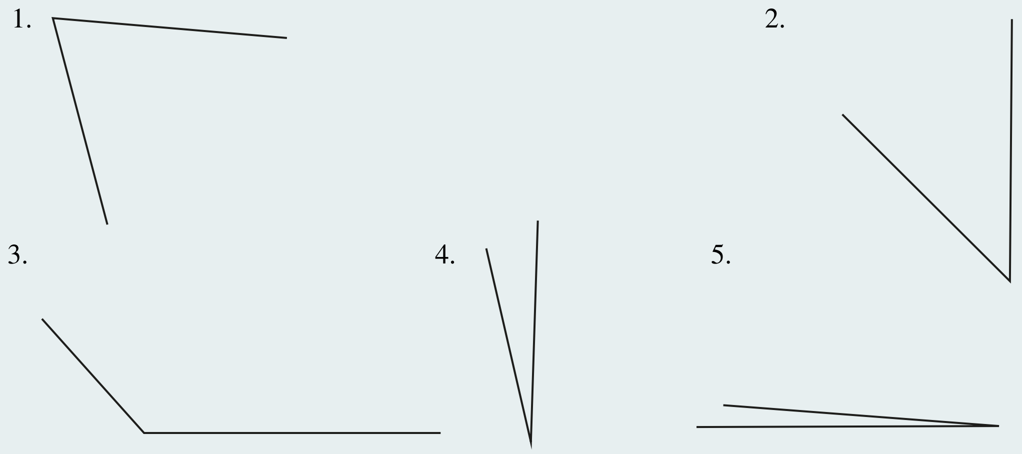


Fig. 1.11: Several angles for test measurements

6. Measure the angles of different shapes or drawn angles on the worksheet. Take multiple measurements for each angle to ensure consistency.

7. After measurements:

- **a.** Record your measurements neatly in a table or chart format.
- **b.** Analyse the variations in their measurements for each angle.
- **c.** Discuss possible reasons for variations (e.g., parallax error, technique, alignment) with your friends.
- **d.** Discuss strategies to minimise errors in angle measurement (e.g., proper alignment of protractor, minimising parallax)

8. Compare your answers to the expected values given below:

Expected values for angles measured:

1. 60 °
2. 70 °
3. 119 °
4. 45 °
5. 132 °
6. 14 ° 7. 4 °

a. How precise are your recorded values?
b. How accurate are your recorded values?

9. Share your findings and observations regarding the variations in angle measurements with your friends.

10. What do you think are the importance of precision and consistency in scientific measurements?

Activity 1.22 Errors in measurement readings

Objective: To collaboratively identify and discuss errors in measurement readings using the terms systematic, random, and parallax.

Materials needed:

- measurement instruments (e.*g*., ruler, protractor)
- worksheets with measurement data
- keywords cards (systematic, random, parallax) with definitions

What to do:

1. Review the content on systematic, random, and parallax errors from this learner resource and other relevant sources online or in your library.

2. Identify one, two or very few friends to form a small group. This can be best done in school.

3. Obtain measuring instruments, worksheets with measurement data, and keyword cards for your group.

Discussion:

a. Review your measurement data on the worksheets.

b. Discuss with your group members to identify any errors observed in the measurements.

c. Use the keywords (systematic, random, parallax) to categorise and describe the errors identified.

d. Consider why these errors might have occurred (e.g., instrument calibration, technique).

Each group should take turns to share your group's findings with the other groups, by presenting the identified errors, explaining how you categorised them. Listen attentively and respectfully to other groups' perspectives.

Summarise the key points about systematic, random, and parallax errors.

Why is important to ensure integrity in reporting and addressing measurement errors.

Reflect on how they can improve measurement techniques and minimise errors in future experiments.

Self-Assessment Questions 1.2

1. What are the sources of random and systematic errors? Give ways to reduce or eliminate them.
2. With examples of random and systematic errors each from real-life experimental situations, explain the difference between random error and systematic error.
3. A reading can be precise but inaccurate. Discuss.
4. **Challenge:** When a set of scales reads 2g with nothing on it and measures a rock as 154g, what type of error occurs?

How would this affect the learner's measurement of the rock's density after measuring its volume?"

Project Work

Identify ten measuring instruments. Write about how they can be used to measure and identify potential errors in each of them. The more potential errors, the more the marks. Show it to your teacher to mark.

SCIENTIFIC NOTATIONS AND THEIR UNIT MULTIPLIERS

Welcome to today's lesson on scientific notation. In this lesson, we will explore a powerful tool used in mathematics and the sciences to represent and work with numbers that are either very large or very small. Scientific notation provides a standardised and concise format for expressing such numbers, making them easier to understand and manipulate.

Let us start this lesson with an activity to enhance your understanding of scientific notations and improve your ability to express and interpret numbers in this format.

Activity: 1.23 Converting numbers to scientific notation

Objective: To practice converting numbers from standard notation to scientific notation.

Materials needed:

- pen or pencil
- paper or notebook

What to do:

1. Start by choosing a set of numbers that you would like to convert to scientific notation. You can either create your own list or use the following examples:
   - **a.** 2,500,000
   - **b.** 0.000,035
   - **c.** 420,000,000,000
2. Take the first number on your list and write it down in standard notation.
3. Examine the number and determine the coefficient, which should be a decimal between 1 and 10. Write down the coefficient.
4. Next, count the number of places you need to move the decimal point to the right (if the original number is greater than 1) or to the left (if the original number is less than 1) to obtain a value between 1 and 10. Write down the number of places as the exponent.

5. Combine the coefficient and the exponent to write the number in scientific notation. For example, if the coefficient is 2.5 and the exponent is 6, the scientific notation representation would be 2.5×10^6.
6. Repeat steps 2 to 5 for the remaining numbers in your list.
7. Check your answers once you have converted all the numbers to scientific notation. You can use a calculator or refer to the answer key provided.
8. Reflect on the patterns you observe during the conversion process. Are there any similarities or differences between the numbers? What do you notice about the coefficient and the exponent?
9. To further practice, try converting some numbers from scientific notation back to standard notation. Follow the reverse process by moving the decimal point according to the exponent and combining it with the coefficient.
10. Share your results and observations with a partner or discuss them in a group. Compare different approaches and strategies used during the activity. Scientific Notation

Scientific notation, also known as exponential notation, is a concise and standardised way to express very large or very small numbers. It is commonly used in scientific and mathematical calculations and to represent values in various scientific disciplines.

A scientific or exponential notation consists of two parts: a coefficient and a power of 10.

The coefficient is a number between 1 and 10 and a power of 10 indicates how many places the decimal point should be moved.

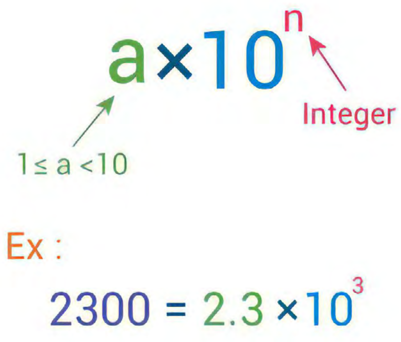


Fig. 1.12: Parts of a scientific notation.

The purpose of scientific notation is to represent numbers in a concise and standardised format, making it easier to work with extremely large or small values.

Quantities that are usually very large or very small values are written in scientific notation (or standard form) when it is written in the form $a \times 10^{th}$, where $1 \leq 10$ and n is an integer.

The number of zeros corresponding to the power to which 10 is raised is called **the exponent** or **power** or **index of ten**.

In large numbers, n is a positive integer, whereas in small numbers less than 1 (decimals), n is negative.

Note that:

$10^0 = 1$

$10^1 = 10$

$10^2 = 10 \times 10 = 100$

$10^3 = 10 \times 10 \times 10 = 1,000$

$10^4 = 10 \times 10 \times 10 \times 10 = 10,000$

$10^5 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 100,000$

The velocity of light in a vacuum is 300,000,000 ms^{-1}.

The speed of light in vacuum is 3×10^8 ms^{-1}.

Exponents less than 1 can be expressed as follows:

$10^{-1} = \frac{1}{10} = 0.1$

$10^{-2} = \frac{1}{10 \times 10} = 0.01$

$10^{-3} = \frac{1}{10 \times 10 \times 10} = 0.001$

$10^{-4} = \frac{1}{10 \times 10 \times 10 \times 10} = 0.0001$

$10^{-5} = \frac{1}{10 \times 10 \times 10 \times 10 \times 10} = 0.00001$

Newton's gravitational constant G, is 0.0000000000667 Nm^2kg^{-2}, which is written in scientific notation to 3 significant figures as 6.67×10^{-11} Nm^2kg^{-2}

Conversion of Units

Worked Examples

1. Convert a length of 30 *cm* to metres

Solution

The conversion factor is 100 $cm = 1$ m

$\therefore 30\ cm = \frac{30\ cm \times 1\ m}{100\ cm} = 0.3\ m$

2. Convert 20 *g* to kilograms

Solution

The conversion factor is 1000g = 1 *kg*

Thus $20\ g = \frac{20\ g}{1000\ g} \times 1\ kg = 0.02\ kg$

3. Convert 1 g/cm^3 to kg/m^3

Solution

$1\ g = \frac{1}{1000}\ kg = 10^{-3}\ kg$

And $1\ cm = \frac{1}{100}\ m = 10^{-2}\ m$

$\therefore (1\mathrm{cm})^3 = (10^{-2}\ m)^3 = 10^{-6}\ \mathrm{m}^3$

Hence, $\frac{1\ g}{cm^3} = \frac{10^{-3}\ kg}{10^{-6}\ m^3} = \frac{10^{-3+6}\ kg}{10^{-}\ m^3}$

$= 1.0 \text{ x } 10^3\ kg/m^3$ or $1000\ kgm^{-3}$

4. Convert 0.5 mm^2 to m^2

Solution

$1\ mm = \frac{1}{1000}\ m = 10^{-3}\ m$

$\therefore 1\ \mathrm{mm}^2 = (10^{-3}\ m)^2 = 10^{-6}\ \mathrm{m}^2$

$\therefore 0.5\ \mathrm{mm}^2 = 0.5 \times 10^{-6}\ \mathrm{m}^2$

5. Convert 108 *km*/*h* to *m*/s

Solution

1000 *m* = 1 km,

60 s = 1 minute, and 60 min = 1 h

$\therefore 1\ \mathrm{h} = 60 \times 60 = 3600\ \mathrm{s}$

$\therefore \frac{108\ km}{h} = \frac{108 \times 1000}{3600} = 30\ m/\mathrm{s}$

6. Convert 900 nanometers (*nm*) into meters (*m*). You need to divide the value by 1,000,000,000 since there are 1,000,000,000 nanometers in a meter.

Solution

So, to convert 900 *nm* to meters:

$900\ nm = 900\ /\ 1{,}000{,}000{,}000\ m$

Simplifying the expression:

$900\ nm = 0.0000009\ m$

Therefore, 900 nanometers is equal to 0.0000009 meters.

Conversions from kilometer per hour (kmh^{-1}) to metres per seconds (ms^{-1})

A car moves with a speed of 7.2 kmh^{-1} and was brought uniformly to rest by the application of brakes. Convert the velocity of the car from kmh^{-1} to ms^{-1}

Solution

$u = 7.2\ kmh^{-1},\ t = 10\ \text{s},\ v = 0\ ,$

$1000\ m = 1\ km$

$7.2\ km = 7200\ m$

h^{-1} = per hour = divided by one hour

$$\frac{7200\ m}{1\ h} = \frac{7200\ m}{3600\ s} = 2\ ms^{-},\ \rightarrow \text{u} = 2\ ms^{-1}$$

Alternative

$36\ kmh^{-1} = 10\ \text{ms}^{-1}$

$7.2\ kmh^{-1} = x$

$7.2 \times 10 = 36\ x$

$$x = \frac{7.2\ kmh^{-1} \times 10\ ms^{-1}}{36\ kmh^{-1}} = 2\ ms^{-1}$$

Conversions from ms^{-1} to kmh^{-1}

A car moves with a speed of 2 ms^{-1} and was brought uniformly to rest by the application of brakes. Convert the velocity of the car from ms^{-1} to kmh^{-1}

Solution

$10\ ms^{-1} = 36\ kmh^{-1}$

$2\ ms^{-1} = x$

$2 \times 36\ kmh^{-1} = 10x$

$$x = \frac{2 \times 36\ kmh^{-1}}{10} = 7.2\ kmh^{-1}$$

SCALAR AND VECTOR QUANTITIES

In physics, quantities are categorised as either scalars or vectors based on their characteristics.

Scalars are quantities that are described solely by their magnitude, or size, and do not have a direction associated with them. Examples include distance, speed, time, and temperature.

Vectors, on the other hand, are quantities that have both magnitude and direction. Examples of vector quantities include velocity, displacement, force, and acceleration. Vectors are represented graphically by arrows, where the length of the arrow represents the magnitude of the vector, and the direction of the arrow indicates the direction of the vector quantity.

Table 1.7: Examples of vector and scalar quantities

VECTOR QUANTITIES	SCALAR QUANTITIES
Lift	Time
Displacement	Distance
Weight	Mass
Drag	Area
Torque	Volume
Force	Density
Momentum	Work
Acceleration	Temperature
Velocity	Speed
Electric field	Energy
Magnetic field	Power
Gravitational field	Pressure
Impulse	Height
	Resistance
	Efficiency
	Current

Activity 1.24 Measuring distance and displacement

Objective: To understand the concepts of scalar and vector quantities by measuring distance and displacement during a walk.

Materials:

- measuring tape or ruler
- stopwatch or timer
- paper and pen

What to do:

1. Find an open space, such as a park or a hallway, where you can walk freely.
2. Start by marking a starting point and measure the distance from the starting point to a designated endpoint using a measuring tape or ruler. Record this distance as the "total distance."
3. Begin walking from the starting point towards the endpoint, keeping track of the time with a stopwatch or timer.
4. After walking for a specific time interval (e.*g*. 2 minutes), stop and record the distance covered as the "distance travelled."
5. Resume walking towards the endpoint for the same time interval as before.
6. Stop at the end of the time interval and measure the straight-line distance from your current position to the starting point using a measuring tape or ruler. Record this distance as the "displacement."
7. Repeat steps 4 to 6 for a few more time intervals, covering a different distance during each interval.
8. Calculate the average speed by dividing the total distance covered by the total time taken.
9. Discuss the results and observations:
    - **a.** The total distance travelled represents a scalar quantity, as it only considers the magnitude or numerical value of the distance covered.
    - **b.** The displacement represents a vector quantity, as it includes both magnitude (straight-line distance) and direction (from the starting point to the current position).

c. Compare the total distance and displacement values. Are they the same or different? If different, explain why.

d. Is the average speed a scalar or vector quantity? Why?

e. Discuss real-life examples where knowing displacement (vector) is more important than total distance (scalar), such as navigation or tracking.

f. Conclude the activity by emphasising the differences between scalar and vector quantities, highlighting the importance of direction in vector quantities and how they provide more comprehensive information about motion.

Worked Examples

Find the equivalent units of

1. Nm^{-2}
2. Js^{-1}
3. w/s
4. Nm

Solution

1.

$\frac{N}{m^2}$ =, Newton is the unit of force, N = force = $kgms^{-2,}$

m^2 is the unit of area

$$\frac{N}{m^2} = \frac{kg \times ms^{-2}}{m^2} = \frac{kg \times m \times s^{-2}}{m \times m} = \frac{kg \times s^{-2}}{m} = kgm^{-1}s^{-2}$$

or $\frac{N}{m^2}$ = unit of pressure,

$$P = \frac{F}{A} = \frac{ma}{L \times B} = \frac{kg \times m \times s^{-2}}{m \times m} = \frac{Kg \times m \times s^{-2}}{m \times m} = kgm^{-1}s^{-2}$$

2.

$$\frac{\text{Work}}{\text{Time}} = \frac{J}{S} = Js^{-1,}$$

$$\frac{\text{Work}}{\text{Time}} = \frac{f \times d}{T} = \frac{mad}{T} = \frac{kg \times m \times s^{-2} \times m}{s^1}$$

$$\frac{\text{Work}}{\text{Time}} = kg \times m \times m \times s^{-2} \times s^{-1} = kg\ m^2s^{-3}$$

3.

$$w/s = \frac{\text{Work}}{T} = \frac{f \times d}{T} = \frac{m \times a \times d}{T}$$

$$w/s = \frac{kg \text{ x ms}^{-2} x\, m}{S} = \text{kgm}^2 \text{s}^{-3}$$

4.

$\text{Nm} \cdot \text{N}$ = Newton, which is the unit of force, m is the unit of metre

$\text{N} = \text{force} = \text{kgms}^{-2}$, $m = \text{metre} = m$

$\text{Nm} = \text{N} \times m = kg\ \text{ms}^{-2} \times m = kg\ \text{m}^2 \text{s}^{-2}$

Alternative

Nm = is the unit of Work

Work (w) = force (f) × distance (d)

$\text{F} = \text{ma}$, $\text{W} = \text{mad}$, $m = kg$, $\text{d} = m$, $\text{a} = \text{ms}^{-2}$

$\text{W} = kg \times \text{ms}^{-2} \times m$

$\text{W} = kg \times \text{m}^1 \times \text{s}^{-2} \times \text{m}^1 = kg\ \text{m}^2 \text{s}^{-2}$

STATES OF MATTER

Solid State

Solids are a state of matter characterised by closely packed molecules arranged in a regular pattern. This close packing results in solids maintaining a fixed shape, mass, and volume. The strong intermolecular forces between particles prevent them from easily moving past one another, leading to the solid's rigidity.

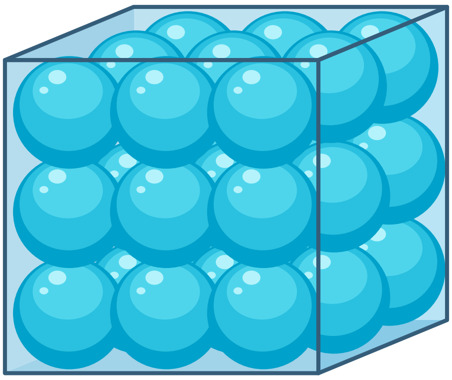


Fig 1.13: Closely packed molecules in solids

Liquid State

Liquids are a state of matter where molecules are relatively close together but not as tightly packed as in solids. This moderate spacing allows liquids to take the shape of their containing vessel, conforming to its contours. While liquids have a fixed volume, they lack a fixed shape, meaning they can flow and change shape depending on their container. Compared to gases, liquids are less compressible due to the intermolecular forces that resist compression.

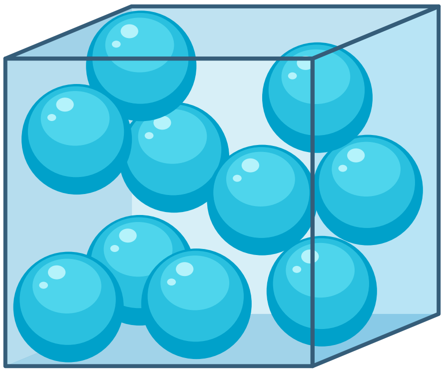


Fig 1.14: Molecules in a liquid

Gaseous State

Gases are a state of matter where molecules are spaced far apart and move freely in all directions. These molecules have high kinetic energy, resulting in constant and random motion. Gases have neither a fixed shape nor a fixed volume, as they expand to fill the entirety of their container. The weak intermolecular forces between gas particles allow for easy compression, meaning gases can be compressed into smaller volumes under pressure.

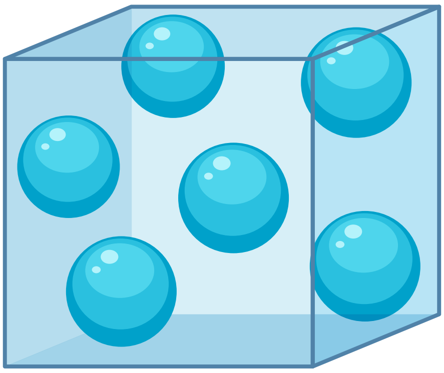


Fig. 1.15: Molecules in a gas

Plasma

Plasma is a unique form of matter, often forgotten, but it's actually the fourth state of matter, after solids, liquids, and gases. Just like how water turns into steam when heated, gases can turn into plasma when they get really hot. Plasma is like a mixture made of positively charged particles called ions and negatively charged particles called electrons. It's full of energy because the electrons are stripped away from their atoms. This makes plasma able to conduct electricity and react to magnetic fields.

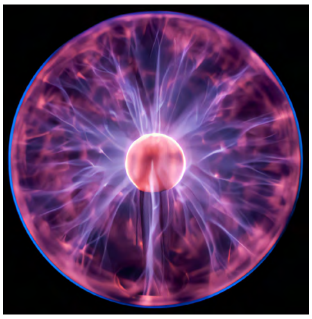


Fig 1.16: Plasma state

You can find plasma in places like stars, lightning, and fluorescent lights, where there is a lot of heat or energy.

Table 1.8: Various states of matter

Solid	Liquid	Gas	Plasma
• Cylinder • Chalk • Conical flask • Cutlass • Bar magnet • Wood • Tree • Gold • Stone • Block • Book	• Water • Kerosene • Petrol • Diesel • Turpentine • Alcohol • Ethanol • Beer • Pito	• Water vapour • Hydrogen gas • Natural gas • Ethane • Oxygen • Ozone • Hydrogen sulphide • Air • Helium • Nitrogen • Freon • Carbon dioxide	• Stars, • Neon signs, • Lightning

Activity 1.25 Exploration states of matter

Materials needed: A list of common objects. Stone, water, gas, lightening, kerosene, helium gas, book, ice cube, water, helium balloon, wooden block, stars, pencil lead, etc

What to do:

1. Pair up with a friend and list the three primary states of matter.
2. In pair or individually classify each object into one of the three states of matter.

Liquid	Solid	Gas

3. Share your classifications with your group of friends and explain your classifications.
4. Compare your classifications with your friends and identify any differences.

Activity 1.26 Exploring the fourth state of matter - Plasma

Materials needed: Tablets for research, Poster paper, markers, and other art supplies (optional)

What to do:

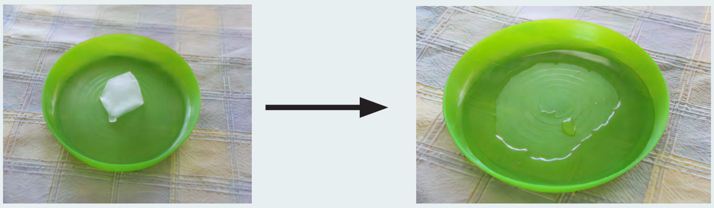
1. Check on the internet.
2. Search plasma states.
3. Draw your observation on your poster paper.
4. Share your results (10 minutes)

Activity 1.27 Melting ice cubes to demonstrate change of state from solid to liquid

Material needed: Ice cubes

What to do:

1. Take an ice cube.
2. Notice its coldness and solid state.
3. Place the ice cube in a bowl or cup.
4. Watch closely as the ice cube starts to melt.
5. Observe any changes in its appearance and texture as it turns into water.
6. Optionally, you can use a timer to see how long it takes for the ice cube to melt completely.
7. Reflect on what you observed during the melting process.
8. Think about other examples of solids turning into liquids in everyday life.
9. Share your observations with your friends.



Ice (solid) Water (liquid)

Fig. 1.17

10. Observe and record your observations on the following questions:
    - a. How does the rate of melting ice cubes vary when placed in different environments (e.*g*. at room temperature versus in direct sunlight)
    - b. What factors do you think contribute to these differences?
    - c. How does the size or shape of ice cubes affect the rate at which they melt, comparing large and small ice cubes or cubes with different shapes under similar conditions?

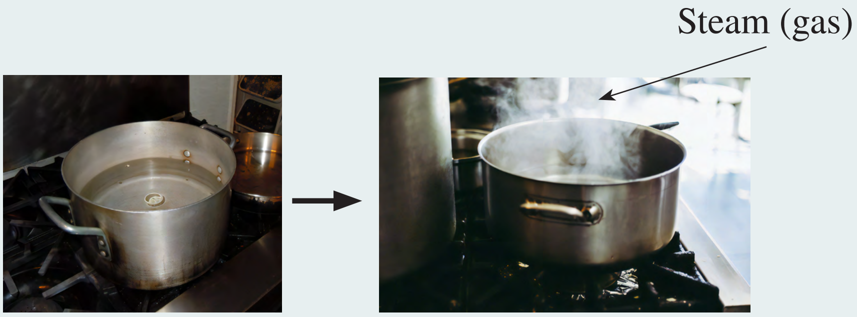
Activity 1.28 Evaporating Water - Liquid to gas

Materials needed:

- water
- pot or kettle
- stove or heat source

What to do:

1. Pour some water into the pot or kettle.
2. Place the pot or kettle on the stove or heat source.
3. Turn on the stove and wait for the water to heat up.
4. As the water heats up, observe closely what happens to it.
5. You will start to see steam rising from the surface of the water.
6. This steam is actually water vapour, which is the gaseous form of water.
7. Keep watching as more steam is produced, indicating that the water is evaporating into the air.
8. Share your observations and answers with your friends.



Water

Water heated to evaporate

Fig. 1.18

9. Investigate and share your observations and answers with your friend or teacher:

  a. How does the rate of water evaporation vary with different temperatures, and what factors influence this rate?

  b. How does the surface area affect the rate of water evaporation, comparing the evaporation rates of shallow versus deep containers of water under similar conditions?

Activity 1.29 A simple model to demonstrate how gas changes to plasma.

Materials needed: Balloons, an inflation pump, gas (air, helium), a microwave safe plate or tray, a microwave oven, a timer or stopwatch, pen/pencil and notebook for recording

What to do:

1. Inflate a balloon with gas (helium or air).

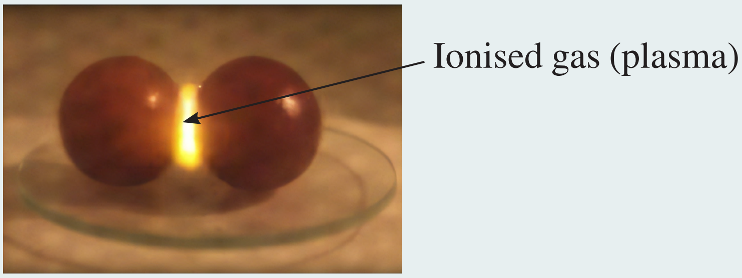
2. Tie the balloon securely to prevent the gas from escaping.

2. Place the balloon on the microwave-safe plate or tray.

3. Carefully place the plate with the balloon inside the microwave oven.

4. Close the microwave oven door and set the timer for a short duration (e.*g*., 10-15 seconds).

5. Turn on the microwave oven and observe.



Inside the microwave oven

Fig. 1.19

6. Share your observations with your friend, teacher or family member.

7. **Observation :**

The microwave oven generates electromagnetic waves at a specific frequency which interact with the gas molecules inside the balloon to gain energy and move more rapidly as collisions between them become more frequent and intense. This leads to some gas molecules losing their electrons and become ionized. As more and more gas molecules become ionized, the gas transitions into a plasma state.

Characteristics of the State of Matter

a. **Solid:** Has a definite shape and volume, particles are closely packed and vibrate in fixed positions.

b. **Liquid**: Has a definite volume but takes the shape of its container, particles are close together but can move and flow.

c. **Gas:** Has neither a definite shape nor volume, particles are far apart and move freely.

d. **Plasma**: Similar to a gas but consists of ionized particles, conducts electricity, and is influenced by magnetic fields.

Particle Behaviour in the State of Matter

a. **Solid:** Particles are tightly packed and vibrate in fixed positions.

b. **Liquid:** Particles are close together but can move and flow past each other.

c. **Gas**: Particles are far apart and move randomly at high speeds.

d. **Plasma:** Particles are highly ionized and move freely, influenced by electric and magnetic fields.

Real-life examples and Applications of the States of Matter

a. **Cooking**: Understanding the states of matter helps in determining cooking times and techniques for various ingredients.

b. **Weather forecasting**: Knowledge of states of matter helps in predicting changes in weather patterns, such as precipitation and cloud formation.

c. **Pharmaceutical industry:** Understanding states of matter is crucial for drug formulation, as it affects drug solubility and stability

Activity 1.30 Molecular arrangement in different states of matter

Molecular model kits (or digital simulations)

What to do:

1. Organise yourselves into small groups of 3-4 learners.

2. Using a molecular model kit (or access to digital simulations) and a worksheet observe and record the following:
   - **a.** How are the molecules arranged in a solid substance?
   - **b.** How do the molecule-molecule interactions differ between the solid, liquid, and gas phases?
   - **c.** What are the key differences in the energy of the molecules in each state of matter?
   - **d.** How does the spacing between molecules change from solid to liquid to gas?
   - **e.** How do the shapes and movements of the molecules differ in each state of matter?

Activity 1.31 Modelling the states of matter

What to do:

1. Put yourselves into smaller groups of 4-5 students.
2. You will be modelling the behaviour of particles in the three states of matter: solid, liquid, and gas.
3. Stand up and physically represent the particles in a solid state. Stand close together, vibrating slightly in place, with limited movement.

Fig. 1.20: Human model to represent the solid state

4. Repeat the process with the next group, this time modelling the particles in a liquid state. The students should move more freely but still remain somewhat close together, with the ability to flow and change shape.

Fig. 1.21

5. Repeat the process with the next group, this time modelling the particles in a gaseous state. The students should move more freely apart.
6. How has this activity helped deepen your understanding of the behaviour of particles in solids, liquids, and gases?
7. Reflect on the benefits of using the modelling and physical representations in the learning process.
8. Comparison of the molecular force, molecular motion, and molecular attraction in the four states of matter: solids, liquids, gases and plasmas.

SOLIDS

Molecular Force: In solids, the intermolecular forces are strong. These forces can include ionic bonds, covalent bonds, metallic bonds, or intermolecular forces such as hydrogen bonding, van der Waals forces, and dipole-dipole interactions. The strong forces keep the molecules tightly packed and maintain the solid's rigid structure.

Molecular Motion: In solids, the molecules have limited freedom of movement. They vibrate around fixed positions, but their overall motion is restricted. The molecules oscillate with small amplitudes around their equilibrium positions.

Molecular Attraction: The strong intermolecular forces result in significant molecular attractions. The molecules are held together in a fixed arrangement, maintaining the solid's shape and volume. The attractions between molecules give rise to properties such as high density, defined shape, and resistance to compression.

LIQUIDS

Molecular Force: In liquids, the intermolecular forces are weaker compared to solids. The forces can still include hydrogen bonding, van der Waals forces, and dipole-dipole interactions, but they are not as strong as in solids. The forces are sufficient to keep the molecules in close proximity to each other.

Molecular Motion: In liquids, the molecules have greater freedom of movement compared to solids. They can slide past each other and move more randomly. The molecules have more kinetic energy, leading to increased molecular motion compared to solids.

Molecular Attraction: The weaker intermolecular forces in liquids result in less rigid molecular attractions. The molecules are attracted to each other but are still able to move and flow past one another. Liquids exhibit properties such as moderate density, ability to flow, and moderate compressibility.

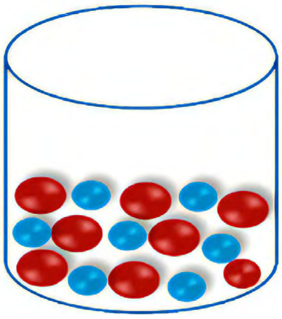


Fig 1.22: The arrangement of molecules in liquid

GASES

Molecular Force: In gases, the intermolecular forces are very weak compared to solids and liquids. The forces are primarily van der Waals forces and weak dispersion forces. The forces are not strong enough to hold the molecules together closely.

Molecular Motion: In gases, the molecules have high kinetic energy. They move freely and independently, colliding with each other and the container walls. The molecules have a high degree of random motion and travel in straight lines until they collide with other molecules or container boundaries.

Molecular Attraction: The weak intermolecular forces in gases result in negligible molecular attractions. The molecules are not tightly bound to each other, and they can move and expand to fill the entire container. Gases exhibit properties such as high compressibility, low density, and the ability to diffuse and mix rapidly.

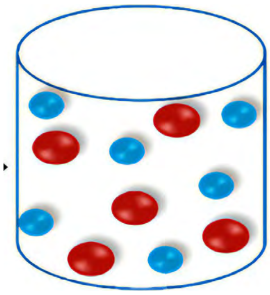


Fig 1.23: The arrangement of molecules in gas

PLASMAS:

Molecular Force: In plasmas, the molecular forces are significantly weakened or overcome due to high energy and ionization. The typical intermolecular forces found in condensed matter, such as van der Waals forces and hydrogen bonding, are generally negligible. Plasmas are primarily governed by electromagnetic forces. In plasma, molecules are not present but rather a mixture of ions and free electrons. It does not have a fixed molecular arrangement. The charged particles in plasma move independently and do not maintain fixed positions

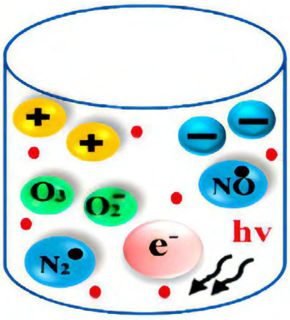


Fig 1.24: The arrangement of molecules in plasma

Molecular Motion: In plasmas, the charged particles, such as ions and free electrons, have high kinetic energy and move rapidly. They can travel long distances before colliding with other particles. The motion of particles in a plasma is highly influenced by electric and magnetic fields.

Molecular Attraction: Plasmas are characterized by the interactions between charged particles. These attractions and interactions are dominated by the Coulombic forces between charged particles. Electric fields and magnetic fields play significant roles in shaping the behaviour of plasmas. The interactions in plasmas are primarily electromagnetic rather than molecular.

Heating and cooling can have various effects on different states of matter, including solid, liquid, gas, and plasma. Let us explore the effects individually:

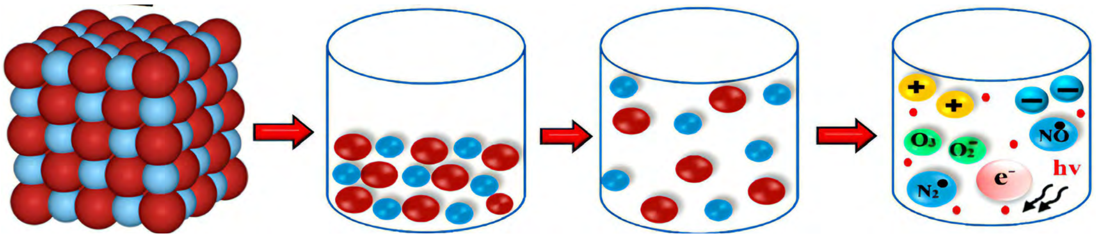


Fig 1.25: Summary of the molecular arrangement of various states of matter

1. **Solid:**
   - a. **Heating**: When you heat a solid, it gets warmer, and its molecules start vibrating faster. This extra energy makes the solid expand, getting a bit bigger. Eventually, if you heat it enough, it reaches its melting point. At this point, the forces holding the solid together weaken, and it turns into a liquid.
   - b. **Cooling**: Cooling a solid reduces its temperature, causing the atoms or molecules to vibrate less. As the thermal energy decreases, the solid contracts and its size decreases. Cooling can lead to the solid reaching its freezing point, where it transitions from a liquid to a solid state.
2. **Liquid**:
   - a. **Heating:** When a liquid is heated, its temperature increases, causing the average kinetic energy of its molecules to rise. The increased kinetic energy leads to faster molecular motion, resulting in the liquid expanding. As the temperature continues to rise, the liquid may eventually reach its boiling point, the liquid changes into a gas
   - b. **Cooling:** Cooling a liquid decreases its temperature and reduces the average molecular motion. As the thermal energy decreases, the liquid contracts and its volume decreases. Cooling can cause the liquid to reach its freezing point, leading to the formation of a solid.
3. **Gas**:
   - a. **Heating**: When a gas is heated, its temperature increases, which leads to an increase in the average kinetic energy of its molecules. The increased

kinetic energy causes the gas molecules to move more rapidly and with greater force, resulting in an expansion of the gas volume. Further heating can eventually lead to the gas reaching its critical temperature, where it transitions into a supercritical fluid or undergoes a phase change into a plasma.

   b. **Cooling**: Cooling a gas decreases its temperature, causing the average kinetic energy of its molecules to decrease. The reduced kinetic energy leads to slower molecular motion and a decrease in volume. Cooling can cause the gas to reach its condensation point, where it transitions into a liquid state.

4. **Plasma**:

   a. **Heating**: Plasma is an ionised gas consisting of positively charged ions and negatively charged electrons. Heating a gas to extremely high temperatures causes the atoms to lose electrons, resulting in the formation of a plasma. The added thermal energy provides enough energy for the electrons to break free from their atomic orbits, creating a mixture of free electrons and ions. This process, called ionisation, is what distinguishes plasma from ordinary gases. Plasma conducts electricity and responds to magnetic fields due to its charged particles.

   b. **Cooling**: When plasma cools down, the free electrons begin to recombine with the positively charged ions to form neutral atoms or molecules. As the temperature decreases, the energy available for ionisation reduces, leading to the plasma reverting to a neutral gas state. The recombination of electrons with ions releases energy in the form of light or heat, which can be observed as the plasma transitions back to its non-ionised state

Annex 1.1

A: Additional Reading: Density

Density is how much substance is packed into an object. It depends on both its mass (how heavy it is) and its volume (how much space it takes up). Density doesn't change, no matter how big or small something is. Different materials have different densities. When things get hotter, they usually become less dense, and when they're squished, they become denser. If something is denser than water, it sinks, but if it's less dense, it floats. In the density column experiment, we layer liquids with different densities, and they separate based on their weight. Ice floats on water because it's less dense than liquid water, which happens because ice's molecules spread out more when they freeze."

Density is defined as the mass per unit volume of a substance at a particular temperature

Mathematically:

Density, $\rho = \frac{Mass,\ m}{Volume,\ V}$

Example

1. A piece of an iron has a volume 15 cm^3 and a mass of 27 g. calculate the density of the iron in

   (a) g/cm^3 (b)kg/m^3

Solution

v = 15 $cm^{3,}$ $m = 27\ g$

$$\rho = \frac{mass}{volume} = \frac{27\ g}{15\ cm^3} = 1.8\ gcm$$

(a) $$15\ \text{cm}^3 = \frac{15 \times 1\ m^3}{1000000\ cm^3} = 0.00015\ \text{m}^3$$

$$\rho = \frac{mass}{volume} = \frac{0.0\ 27\ kg}{0.00015\ m^3} = 1800\ kgm^{-3}$$

Alternatively

$M = 27\ g,\ v = 15\ cm^3 \text{,} 10^6 = 1000000$

$$\rho = \frac{mass}{volume} = \frac{\frac{27}{1000}}{\frac{15}{1000000}} = \frac{27\ x\ 10^3}{15\ x\ 10^6} = 1800\ kgm^{-3}$$

B: Additional Learning on Prefixes for Scientific Notations

Prefixes

A unit **prefix** is a specifier or reminder that is attached to units of measurement to indicate multiples or fractions of the units. The use of such prefixes commonly forms units of various sizes. Eg $5\mu F = 5 \times 10^{-6}F$, $5mH = 5 \times 10^{-3}H$. These convections are used in other topics such as alternate current, electrostatics, etc. You need to use it (apply it) without nobody telling you.

The table below shows the multiples and submultiples and their corresponding symbols and magnitudes.

Table 1.9: Prefixes and their multipliers

Multiple	Prefix	Symbol	Example
10^3	Kilo	k	kilogram, $kg(=10^3g)$
10^6	mega	M	megavolt, $MV(=10^6V)$
10^9	giga	G	Gigavolt, $GV(=10^9V)$
10^{-2}	centi	c	Centimetre, $cm(=10^{-2}m)$
10^{-3}	cilli	m	Millimetre, $mm(=10^{-3}m)$
10^{-6}	micro	μ	Micrometre, $\mu m(=10^{-6}m)$
10^{-9}	nano	n	Nanometre, $nm(=10^{-9}m)$
10^{-12}	pico	p	Picofarad, $pF(=10^{-12}F)$
10^{-15}	femto	f	femtometre, $fm\ (=10^{-15}m)$
10^{-18}	atto	a	Attometre, $am(=10^{-18}m)$

Submultiples	Prefix	Symbol
10^{-1}	Deci	D
10^{-2}	Centi	C
10^{-3}	Milli	M

Factor	Prefix name	Symbol
$10^{24} = (10^3)^8$	Yotta	Y
$10^{21} = (10^3)^7$	zetta	Z
$10^{18} = (10^3)^6$	exa	E
$10^{15} = (10^3)^5$	peta	P
$10^{12} = (10^3)^4$	Tera	T
$10^9 = (10^3)^3$	giga	G
$10^6 = (10^3)^2$	mega	M
$10^3 = (10^3)^1$	kilo	k
10^2	hector	h
10^1	deka	da

Activity: Exploring Metric Prefixes

Objective: This activity aims to familiarise you with metric prefixes and their corresponding powers of 10. It will also help you understand the relationship between different metric units and their relative size.

Materials needed:

- Pen or pencil
- Paper or notebook

What to do:

1. Start by creating a table with three columns. Label the columns: ***Prefix***, ***Symbol***, and ***Power of 10***.
2. Begin with the base unit, which is the meter (*m*). Write "meter" in the Prefix column, "*m*" in the Symbol column, and "1" in the Power of 10 column.

3. Research and list the most commonly used metric prefixes. Include prefixes such as kilo-, centi-, milli-, micro-, and nano-. You can also include less commonly used prefixes if you like.

4. In the Symbol column, write down the symbol or abbreviation for each prefix. For example, "k" for kilo-, "c" for centi-, "*m*" for milli-, "µ" (mu) for micro-, and "n" for nano-.

5. Determine the power of 10 associated with each prefix. For example, kilo- represents 10^3, centi- represents 10^{-2}, milli- represents 10^{-3}, micro- represents 10^{-6}, and nano- represents 10^{-9}. Write down the corresponding powers of 10 in the Power of 10 column.

6. Complete the table by filling in the remaining rows with the prefixes, symbols, and powers of 10 you have researched.

7. Once you have completed the table, examine the prefixes and their associated powers of 8. Notice how each prefix represents a specific multiplication or division by powers of 10. For example, kilo- represents multiplication by 10^3, while milli- represents division by 10^3.

9. Use the table to convert between different metric units. For instance, if you have a distance of 500 millimetres, you can use the table to determine that it is equivalent to 0.5 meters.

10. Create conversion problems for yourself or others using the metric prefixes and their corresponding powers of 10. For example, convert 2.5 kilometres to meters or convert 75 milligrams to grams.

11. Share your findings and experiences with a partner or discuss them in a group. Compare different approaches and strategies used during the activity.

Review Questions

Review Questions 1.1

1. In this exercise, you will match different careers with the physics principles they utilise, demonstrating your understanding of how physics concepts apply to various professions.

   Instructions:

   i. Read the list of careers and the physics principles they employ, provided in **Table A** below.

   ii. Match each career with the physics principle or principles that you believe are most relevant to that profession in **Table B**

   iii. Think critically and select from **Table C** to match each career from **Table A** with the physics principle or principles you identified in **Table B**, showing how each career applies physics principles to solve real-world problems.

   iv. Once you have completed the matching activity, review your choices and be prepared to discuss your reasoning with your friend, teacher or family member.

TABLE A Career
Mechanical Engineers
Electrical Engineers
Renewable Energy Engineers
Medical Physicists
Radiologists
Environmental Scientists
Meteorologists
Biophysicists

TABLE B Physics Principles Employed
Atmospheric physics
Electricity and magnetism
Energy conversion and
Electromagnetism
Radiation and modern physics
Motion and force
Earth's physical properties and processes
Medical physics

2.

TABLE C
They use medical physics to make sure X-rays and MRIs give clear pictures, helping doctors diagnose and treat illnesses correctly.
They use atmospheric physics to understand weather patterns and predict changes, helping us plan for rain, storms, and other weather events.
They study how forces affect living things, from cells to animals, using this knowledge to develop new medicines and protect the environment.
They use radiation and modern physics to create medical machines like X-rays and MRIs for accurate diagnosis and treatment.
They study Earth's properties and processes to protect the environment, making sure we use natural resources wisely and keep the planet healthy
They use principles of motion and force to design machines and systems that move well and can handle different forces.
They apply principles of electricity and magnetism to design and improve electrical systems and devices for better energy use.
They look at how energy changes and how magnets work to create renewable energy solutions like solar panels and wind turbines

3. A ramp has a length of 10 *m* and a height of 4 *m*. Calculate the angle of inclination of the ramp using Pythagoras' theorem.

4. Match each derived quantity with its correct definition and unit based on what you have explored in the table provided. Rewrite your answers in your notebook and share them with your teacher or peers.

Derived Quantities	Definitions	Derived Units
Acceleration	A. Force applied perpendicular to the surface of an object per unit area.	a. meter per second squared (m/s^2)
Force	B. The rate at which an object covers distance.	b. ms^{-1}
Pressure	C. The rate of change of velocity.	c. Pascal (Pa) [N/m^2]
Energy	D. Mass per unit volume.	d. Joule (J) [$N\cdot m$]

Derived Quantities	**Definitions**	**Derived Units**
Power	E. The rate at which work is done or energy is transferred.	e. Watt (W) [J/s]
Density	F. A push or pull that can change the state of motion of an object.	f. kilogram per cubic meter (kg/m^3)
Frequency	G. Number of occurrences of a repeating event per unit of time.	*g.* Hertz (Hz) [1/s]
Electric Charge	H. The quantity of motion of a moving body.	h. Coulomb (C)
Momentum	I. Physical property of matter that causes it to experience a force when placed in an electromagnetic field.	i. kilogram meter per second ($kg \cdot m/s$)
Speed	J. capacity to do work or produce change in a system	j. Newton(N)

5. Compare and contrast the fundamental quantities of temperature and time, including their SI units and scales of measurement.

6. Your mother has shared the route she plans to take to the market. She intends to walk 2 kilometres south to reach a river and then travel 3 kilometres east to reach the market. How would you advise your mother to take a shorter route? What is the shortest distance she needs to walk directly from home to the market?

7. During a traditional festival in Ghana, the distance between two villages is measured to be 500 meters, and the angle of elevation from one village to the top of a hill is measured to be 30^o. How can the sine rule be used to estimate the height of the hill?

Review Questions 1.2

1. Give three uses of dimensional analysis.

2. Use dimensions to determine the fundamental units of the following quantities:

a. Acceleration **b.** Forcec. Energy d. Power

3. Evaluate the usefulness of dimensional analysis.

Review Questions 1.3a

1. A rocket is fired, and it is to escape the gravitational attraction of the earth by the value $\sqrt{2gR}$, where g is the acceleration due to the gravity of the earth and R is the radius of the earth Use dimension analysis to find the possible quantity of the expression.

2. Assuming a (i) positive zero error of 0.03 *cm* and (ii) a negative zero error of 0.06 *cm* in the vernier calliper in Fig. below, calculate the corrected reading.

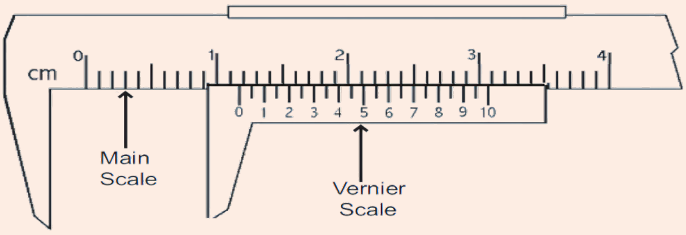


Fig. 2.12: Vernier calliper having a much smaller least count

3. In a special reconnaissance aerial intelligence and information-gathering mission, the pilot of a jet fighter came under fire. But, through special manoeuvring and manoeuvring skills, he was able to escape. He sighted the target through a radar screen and returned fire, which was on target. What error do you think he avoided here? Give the reason.

4. A photographer tries to snap a 100 *m* finishing race with an adjustable camera. He centres the finishing line through the viewfinder to ensure the athlete is centred and aligned with the focus point. What type of error do you think he is trying to avoid?

5. A learner, in his final examination, measures time for one oscillation of a simple pendulum three times. Why did you think he was doing that? How can he get his final reading to be a reliable one?

6. Shamo, Aku, Kwei, and Atswei measure the time of a simple pendulum with a stopwatch to make twenty oscillations and calculate the period of a simple pendulum. Their results were as follows: 34.99 s, 34.92 s, 31.25 s and 34.91 s. What do you observe when taking the measurements? Suggest two probable errors of a measuring instrument in the experiment and state two ways each of eliminating these errors in the measurement.

7. (a) Which of the spring balance in the figure below can measure to good accuracy? Why?

Fig. 2.13: A spring balance (Snapshot from PRESEC, Osu Lab)

Review Questions 1.3b

1. What is the fundamental difference between a vector quantity and a scalar quantity?
2. Give examples of vector quantities and scalar quantities.
3. How are vector quantities represented in physics? Describe the notation used.
4. What are the essential characteristics of a vector quantity? Explain.

Review Questions 1.4

1. How does the force of attraction between particles in a plasma compared to that of a gas?
2. How does the force of attraction between particles in a plasma compared to that of a solid?
3. Explain molecular motion?
4. How does molecular motion differ in solids, liquids, gases, and plasmas?

EXTENDED READING

1. Recognise aspects and branches of physics as exhibited in everyday life:
   a. Books:
      - Physics of Everyday Phenomena" by W. Thomas Griffith and Juliet W. Brosing
      - The Flying Circus of Physics" by Jearl Walker

   b. Websites:
      - Khan Academy Physics
      - HyperPhysics

   c. Videos: YouTube channels like **Veritasium**, **Minute Physics**, and **Physics Girl**
2. Classify Quantities into Fundamental, Derived, Scalars, and Vectors:
   a. Books:
      - Physics for Scientists and Engineers" by Raymond A. Serway and John W. Jewett
      - Fundamentals of Physics" by David Halliday, Robert Resnick, and Jearl Walker

   b. Websites:
      - Physics Classroom
      - OpenStax Physics
3. American Physical Society (APS) Careers in Physics: https://www.aps.org/careers/index.cfm
   - Physics World Careers: https://www.physicsworld.com/careers/
   - The International System of Units (SI): https://www.bipm.org/en/measurement-units/
   - Khan Academy: https://www.khanacademy.org/science/physics
4. Measurements & Uncertainties:

   https://www.deanza.edu/faculty/lunaeduardo/documents/MeasurementsUncertainties2A.pdf
5. Random versus systematic error definitions and examples:

   https://www.thoughtco.com/random-vs-systematic-error-4175358
6. Types of measuring instruments: https://www.pinterest.com/pin/641270434451943987/
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11. Vectors and Scalars: https://www.khanacademy.org/science/physics/two-dimensional-motion/introduction-to-vectors-and-scalars/a/introduction-to-vectors-and-scalars
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    - https://climatekids.nasa.gov/states-of-matter/
    - CK-12 Foundation: “States of Matter”: https://www.ck12.org/chemistry/states-of-matter/

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ACKNOWLEDGEMENTS

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