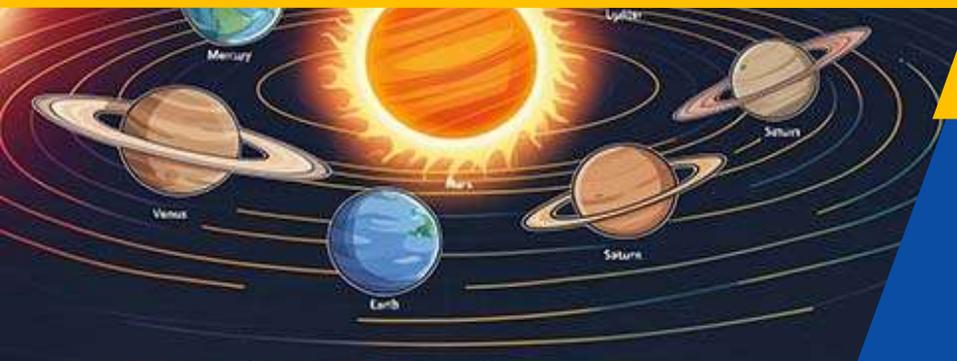




RQF LEVEL 5



GENDW502
CSA, MUP, ETE, SWD, NIT
and MPA

Applied Physics

TRAINEE'S MANUAL

October, 2024



APPLY DYNAMICS AND WAVES



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LIST OF ABBREVIATIONS AND ACRONYMS

CBET: Competence Base Education and Training

PPE: Personal Protective Equipment

RQF: Rwanda Qualification Framework

RS: Rwandan Standard

RSB: Rwanda Standards Board

RTB: Rwanda TVET Board

TVET: Technical and Vocational Education and Training

CSA: Computer Systems and Architecture

MUP: Multimedia Production

ETE: Electronic and Telecommunication

SWD: Software Development

NIT: Networking and Internet

MPA: Music and performing arts

LEO: Low Earth Orbit

GEO: Geostationary Orbit

MEO: Medium Earth Orbit

HEO: Highly Elliptical Orbit

CRT: Cathode Ray Tube

EM: Electromagnetic wave

TV: Television

DTV: Digital Television

AM: Amplitude Modulation

PM: Phase Modulation

FM: Frequency Modulation

PTT: Post, Telegraph, and Telephone

EMI: Electromagnetic Induction

EMF: Electromotive Force

MSC: Mobile Switching Centre

BW: Bandwidth

MW: Medium Wave

CB: Citizen Band

DSBFC: Double Sideband Full Carrier

DSBSC: Double Sideband Suppressed Carrier

SSB: Single Sideband

VSB: Vestigial Sideband

WFM: Wideband Frequency Moderation

NFM: Narrowband Frequency Moderation

LED: Light Emitting Diode

AC: Alternating Current

DC: Direct Current

BJT: Bipolar Junction Transistor

FET: Field Effect Transistor

UJT: Unijunction Transistor

CEIC: Integrated Circuit

RFIC: Radio Frequency Integrated Circuit

INTRODUCTION

This trainer's manual includes all the methodologies required to effectively deliver the module titled "**Applied Physics**". Trainees enrolled in this module will engage in practical activities designed to develop and enhance their competencies.

The development of this training manual followed the Competency-Based Training and Assessment (CBT/A) approach, offering ample practical opportunities that mirror real-life situations.

The trainer's manual is organized into Learning Outcomes, which is broken down into indicative content that includes both theoretical and practical activities. It provides detailed information on the key competencies required for each learning outcome, along with the objectives to be achieved.

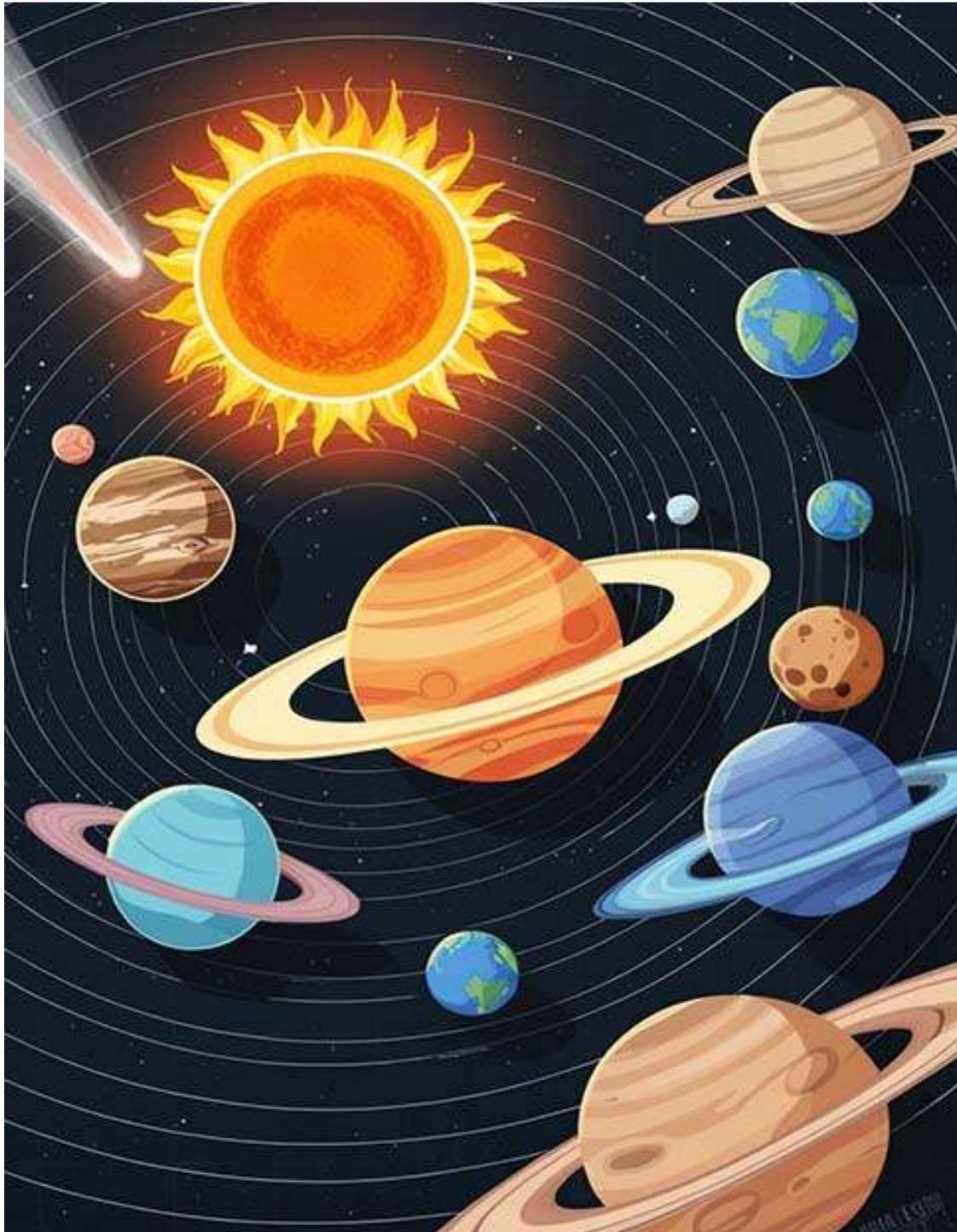
As a trainer, you will begin by asking questions related to the activities to encourage critical thinking and guide trainees toward real-world applications in the labor market. The manual also outlines essential information such as learning hours, didactic materials, and suggested methodologies.

This manual outlines the procedures and methodologies for guiding trainees through various activities as detailed in their respective trainee manuals. The activities included in this training manual are designed to offer students opportunities for both individual and group work. Upon completing all activities, you will assist trainees in conducting a formative assessment known as the end learning outcome assessment. Ensure that students review the key reading and the points to remember section.

Module Title: Dynamics and Waves

Learning Outcomes	Learning Hours	Topics
Learning Outcome 1: Motion in orbits	6	1.1 Universal Gravitation motion in orbits
		1.2 Kepler's laws
		1.3 Rockets and satellites motion
Learning Outcome 2: Effects of magnetism	10	2.1 Concepts of magnetism
		2.2 Magnetic field created by electric current
		2.3 Magnetic force
Learning Outcome 3: Vibrations and Waves	8	3.1 Concept of waves
		3.2 The Nature of Sound
		3.3 The Nature of Light
Learning Outcome 4: Concepts of electromagnetics	10	4.1 Induced electromotive force in a circuit
		4.2 Equation of propagation of electromagnetic waves
		4.3 Category of mobile phone and radio communication
Learning Outcome 5: Semiconductor material	6	5.1 Fundamental properties of semiconductor materials
		5.2 Principles of semiconductor devices
		5.3 Principles of operational amplifiers

LEARNING OUTCOME 1: DESCRIBE MOTION IN ORBITS



Learning outcome 1: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
 - a. What does the illustration show?
 - b. What do you think will be topics to be covered under this unit based on the illustration?
2. After the discussion, inform students that this unit is intended to provide them with the knowledge, skills and attitudes to describe motion in orbits. They will cover universal gravitation motion in orbits, Kepler's laws, rockets and satellites motion.
3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:
 - a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.
 - b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?
 - d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.
 - e. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.



Key Competencies:

Knowledge	Skills	Attitudes
1. Define the key concepts of universal gravitation, orbital motion, and cosmic velocities.	1. Solving problems related to gravitational force and Analyze diagrams and data related to orbital motion.	1. Precision and patience when solving detailed mathematical problems related to gravitation
2. Identify the forces acting on rockets and satellites in motion.	2. Interpret relationships between velocity, force, and distance in orbital motion.	2. Developing logical reasoning and attention to detail when interpreting planetary motion
3. Knowing the concepts of escape velocity and orbital velocity and their calculations	3. Calculating the escape velocity and orbital velocity	3. Understanding space missions require many people with different skills working together
4. Recognizing the types of satellites and their roles in communication navigation and research	4. Differentiate the types of satellites	4. Understanding how satellites make our lives better



Steps:



Discovery Activity



Task 1

1. Using question and answer methodology, guide trainees to share their prior experience from their understanding regarding to motion in orbits under task 1 in their Trainee's Manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are given.

Scenario:

Paul understands that the moon, planets, and revolve around the sun or star in definite orbit. He wants to study the motion of orbits and the motion of satellites, and he performs a simple experiment using a small ball (A tennis ball considered as the moon), a string of one meter, and a table. Paul holds a small ball (Tennis ball) above the ground and drops it down then he ties the rope to the small ball holds the other end of the rope and lets the ball swing in a circular motion around his hand.

- a. What happens to the tennis ball when dropped down?
 - b. Why does the ball keep moving in a circle and not fly away?
 - c. What do you think keeps the Moon moving around the Earth?
 - d. What would happen if the rope were cut?
 - e. Why don't satellites fall back to Earth?
 - f. Can planets move in a straight line in space? Why or why not?
2. Encourage all students to give their views.
 3. After sharing session, inform students that this activity was not intended for them to give the right answers but to give them a picture of what they will cover in the unit.
 4. Introduce Topic 1.1: Universal Gravitation motion in orbits

Topic 1.1: Description of universal Gravitation motion in orbits

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Describe clearly the key concepts of universal gravitation based on celestial objects.Calculate perfectly gravitational force between objects based on Newton’s universal gravitational lawDescribe effectively the variation of acceleration due to gravity based on celestial objects.
	<p>Time Required: 2 hours</p>
	<p>Learning Methodology: Small group work, trainer guided, brainstorming, and video.</p>
	<p>Materials, Tools and Equipment Needed: Marker pen, flipchart, Photo from internet and video from the internet, PPE, whiteboard, chalkboard, computer, projector, textbooks, Scientific calculator.</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Prepare geometric materials for drawing and download videos and images from the internet<input type="checkbox"/> Design problem-solving exercises and step-by-step demonstrations for calculations.<input type="checkbox"/> Arrange the training space with the necessary tools
	<p>Cross-Cutting Issues:</p> <ul style="list-style-type: none">✓ Encourage equal participation and leadership roles during group activities.✓ Ensure inclusivity by showcasing contributions of both men and women in physics and space science (e.g., Isaac Newton, Katherine Johnson).
	<p>Prerequisites:</p> <ul style="list-style-type: none">✓ Familiarity with fundamental concepts like force, acceleration, and mass.✓ Ability to perform algebraic manipulations and work with equations.



Activity 1: Problem-Solving

Task 2

1. Using discussion in pairs, guide trainees to analyze the scenario under task 2. Make sure instructions are understood, all the students are actively participating and necessary materials/tools are provided and being used basing on the group presentations, ask students to share their answers to the class.

Scenario:

You are a space scientist planning a satellite's orbit around Earth. Your goal is to determine what keeps the satellite in orbit and how its speed affects its motion. Work in small groups to answer the following scenario-based questions. Satellite is launched into universe and placed in orbit around Earth. You observe the following: The satellite does not fall to the ground; the satellite does not fly away into space; it moves in a circular path around Earth. Using this scenario, answer the following:

- a. What force keeps the satellite from flying into space?
- b. Why doesn't the satellite fall back to Earth?
- c. Describe in your own words why satellites orbit instead of moving in a straight line or falling straight down.

Answers to the Scenario's Questions

- a. The gravitational force exerted by the Earth keeps the satellite from flying into space. This force acts as the centripetal force, pulling the satellite toward the center of the Earth and preventing it from escaping into space.
- b. The satellite doesn't fall back to Earth because it is moving at a very high speed tangentially to the surface of the Earth. This speed creates a balance between the gravitational pull (pulling it toward Earth) and the satellite's inertia (its tendency to move in a straight line). This balance keeps it in a stable orbit.
- c. Satellites orbit the Earth due to the precise balance between two factors:

- i. Gravitational Force: Earth's gravity pulls the satellite toward its center, preventing it from moving in a straight line and flying away.
 - ii. Tangential Velocity: The satellite moves sideways at a high speed. This velocity is sufficient to ensure that as the satellite is pulled toward Earth, the Earth's surface curves away beneath it.
2. Encourage all trainees to give their views by share their answers to the class and write their responses for reference.
 3. After the sharing session, refer to Key facts 1.1a and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 2: Guided Practice



Task 3

1. Using the appropriate methodology such as individual work, pair-share, small group discussions, guide trainees to answer the questions as provided under task 3 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
2. Ask trainees to read questions in their trainee's manual and ask them to solve them step-by-step. Ask trainees to suggest the next step at each stage of the calculation.
 - a. Two masses, 8 kg and 12 kg, are placed 3 m apart. Calculate the gravitational force between them.

Answer:

Data given: $m_1 = 8\text{kg}$, $m_2 = 12\text{Kg}$, $r = 3\text{m}$

Formulae: $F = \frac{Gm_1m_2}{r^2} = 7.12 \times 10^{-10}\text{N}$

- b. Suppose that two objects attract each other with a gravitational force of 16 N. If the mass of both objects was doubled, and if the distance between the objects remained the same, then what would be the new force of attraction between the two objects?

Answer: The Formula: $F = \frac{Gm_1m_2}{r^2}$, Analyze the scenario:

- i. Initial force $F_1 = \frac{Gm_1m_2}{r^2} = 16\text{N}$

ii. New masses $m'_1 = 2m_1$, $m'_2 = 2m_2$

iii. Distance remains the same

$$\text{Derive new force: } F_2 = \frac{G(2m_1)(2m_2)}{r^2} = 4F_1 = 64N$$

- c. Determine the acceleration due to gravity at an altitude of 2000 km above Earth's surface. Assume Earth's radius $R = 6400$ km.

Answer: Formula $g' = g \frac{R^2}{(R+h)^2}$ where $g = \frac{9.8m}{s^2}$, $R = 6400km$, $h = 2000km$,

Substitute the Values in the formulae to find the value of g'

3. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in solving. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
4. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
5. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
6. After the sharing session, refer trainees to key fact 1.1 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 4

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:
 - A. A 1,200 kg car is parked on the surface of the Earth. The Earth's mass is 6×10^{24} kg, and the radius of the Earth is 6000 km. Using Newton's law of gravitation:
 - i. Calculate the gravitational force acting on the car due to the Earth (i.e., the car's weight).

Answer: Gravitational Force at the Earth's Surface

The Formula: $F = \frac{Gm_1m_2}{r^2}$, where $m_1 = 1200Kg$, $m_2 = 6 \times 10^{24}Kg$, $r = 6000 \times 10^3m$ according to the given data in the question. So by making subsisting in the formulae we get $F = 11800N$

- ii. If the car were moved to a location 500 km above the Earth's surface, what would its weight be?

Answer: Gravitational Force 500 km Above the Surface

Adjust r to be $F = \frac{Gm_1m_2}{(R+h)^2}$, where $h = 500km = 500000m$, by substitution into the formulae we get $F = 9840N$

B. Referring to the question 1 discussion to the following questions

- i. Why does the car's weight decrease as it moves further from the Earth's surface?

Answer: The car's weight decreases because gravitational force (F) depends on the distance (r) from the center of the Earth. According to Newton's law of universal gravitation: $F = \frac{Gm_1m_2}{r^2}$, As the car moves further from the Earth's surface, the distance r increases. Since F is inversely proportional to r^2 , even a small increase in r causes a significant decrease in F . Therefore, the gravitational pull (and the car's weight) weakens with altitude.

- ii. How would the gravitational force change if the car's mass were doubled?

Answer: If the car's mass (m_1) were doubled, the gravitational force would also double because F is directly proportional to the product of the masses: $F \propto m_1m_2$. For example, if the car's mass increased from 1,200 kg to 2,400 kg, the force would double from 11,800 N to 23,600 N at the Earth's surface.

- iii. What implications does this have for objects in orbit, such as satellites or the International Space Station?

Answer:

- ✓ **Weaker Gravity in Orbit:** Objects in orbit, like satellites, are positioned far above the Earth's surface, where r is much larger. This weaker gravity reduces the gravitational pull, allowing them to stay in orbit with less force acting on them.

- ✓ **Free-Fall Motion:** Satellites are in a state of continuous free fall towards the Earth. However, their high orbital velocity ensures they keep "missing" the Earth, maintaining a stable orbit. This is why astronauts inside the ISS experience microgravity or "weightlessness."
 - ✓ **Energy Requirements for Launch:** To place objects in orbit, significant energy is required to overcome the strong gravitational pull near the Earth's surface. Once in orbit, the reduced gravitational force requires less energy to maintain their position.
 - ✓ **Orbital Decay:** Over time, even small changes in altitude can affect the gravitational force acting on satellites. If a satellite's altitude decreases, the stronger gravity pulls it closer, eventually causing it to re-enter the Earth's atmosphere unless adjustments are made.
2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Description of universal gravitation motion in orbits.
 3. Each trainee will perform the task individually
 4. Inform them that they should demonstrate positive attitude when performing task.
 5. After trainees has performed, you'll give them feedback
 6. At the end summarize the topic

Topic 1.2: Explanation of Kepler's laws of planetary motion

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Explain properly Kepler's laws based on celestial objects.Demonstrate clearly how the movement of planets and stars is influenced by gravity.Explain properly the motion of celestial objects in elliptical orbits.
	<p>Time Required: 2 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion, Search engine.</p>
	<p>Materials, Tools and Equipment Needed: PPE, whiteboard, chalkboard computer, projector, textbooks, Chalks, Markers, Scientific calculator</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Study Kepler's laws, Brahe's data, and their historical context.<input type="checkbox"/> Organize the classroom for group work and interactive discussions.<input type="checkbox"/> Prepare the videos and photos from internet describing Kepler's laws
	<p>Cross Cutting Issues:</p> <ul style="list-style-type: none">✓ Show how Brahe and Kepler's collaboration reflects respect and learning across cultures.✓ Encourage everyone to participate and ensure no one is left out.
	<p>Prerequisites:</p> <ul style="list-style-type: none">✓ Familiarity with gravitational force and Newton's laws.✓ Interest in astronomy and the motion of celestial bodies.✓ Ability to calculate using simple formulas



Activity 1: Problem-Solving



Task 5

1. Using the appropriate methodology such as individual work, small group discussions, guided discussions or large group discussion, guide trainees to read the following scenario and answer the questions as provided under task 5 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used

Scenario:

The newly discovered planet, Planet X, orbits its star in an elliptical path. The star is located at one of the foci of the ellipse. The planet takes 10 Earth years to complete one orbit, and the closest distance to the star is $7.48 \times 10^{11}m$. Questions:

- a. Why does the planet move in an elliptical orbit and not a perfect circle?
- b. Predict how the speed of Planet X changes when it is closer to the star compared to when it is farther away.

Answers to the Scenario's Questions

- a. The planet moves in an elliptical orbit due to the gravitational interaction between the planet and its star, as described by Kepler's First Law of Planetary Motion, which states: "The orbit of a planet around a star is an ellipse, with the star located at one of the foci of the ellipse."

The elliptical shape arises because:

- ✓ The planet's initial velocity and the gravitational pull of the star create a balance that does not always result in a perfectly circular orbit.
 - ✓ Variations in the gravitational force (due to changes in distance between the planet and the star) influence the shape of the orbit, leading to an ellipse.
- b. The speed of Planet X increases when it is closer to the star and decreases when it is farther away. This behavior is explained by Kepler's Second Law of Planetary Motion, which states: "A line drawn from the planet to the star sweeps out equal areas in equal times."

- ✓ Closer to the star (perihelion): The gravitational pull is stronger, so the planet moves faster to conserve angular momentum.
 - ✓ Farther from the star (aphelion): The gravitational pull is weaker, so the planet moves slower.
2. Encourage all trainees to give their views by share their answers to the class and write their responses for reference.
 3. After the sharing session, refer trainees to Key facts 1.2 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions, they have.



Activity 2: Guided Practice



Task 6

1. Using the appropriate methodology such as individual work, pair-share, small group discussions, guide trainees to read and the scenario and answer the related questions as provided under task 6 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Scenario:

Aaron and Jacques are designing a mission to place a satellite in orbit around Mars. They use Kepler's Third Law to calculate the satellite's orbital period if its semi-major axis is 10,000 km and the mass of Mars is 6.39×10^{23} Kg. Discuss how understanding Kepler's Laws helps engineers and scientists design efficient satellite orbits.

Answer:

Kepler's First Law (Elliptical Orbits): Engineers use the elliptical nature of orbits to design satellite paths that minimize fuel usage for adjustments. For example, the satellite's position can be optimized for specific tasks like observations or communications.

Kepler's Second Law (Equal Areas in Equal Time): This law helps predict the satellite's velocity at different points in orbit. Understanding varying speeds ensures efficient energy use when adjusting the satellite's trajectory.

Kepler's Third Law (Orbital Period): The relationship between orbital period and semi-major axis allows scientists to design orbits with precise timing, critical for synchronization with other satellites or celestial events.

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in solving the questions. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to key fact 1.3 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 7

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

Activity:

- A. Materials: String, pins, and a pencil (for drawing ellipses) and Graph paper.
- B. Instructions:
 - ✓ Use the string-and-pin method to draw an ellipse on the graph paper.
 - ✓ Label the two foci of the ellipse.
 - ✓ Place a "Sun" at one focus and plot a planet's path along the ellipse.
 - ✓ Identify the points where the planet is closest (perihelion) and farthest (aphelion) from the Sun.

C. Questions to Answer:

- i. Where does the planet move fastest along its orbit? Why?
- ii. How does the shape of the orbit change as the distance between the foci increases?

Answer:

- i. A planet moves fastest at perihelion (closest to the Sun) because, per Kepler's second law, the line joining the planet and the Sun sweeps out equal areas in equal time. To cover the same area near perihelion in less time, the planet's speed increases.
 - ii. As the foci distance increases, the ellipse becomes more elongated, with higher eccentricity, deviating further from a circle.
2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Explanation of Kepler's laws of planetary motion
 3. Each trainee will perform the task individually
 4. Inform them that they should demonstrate positive attitude when performing task.
 5. After trainees has performed, you'll give them feedback
 6. At the end summarize the topic

Topic 1.3: Description of Rocket and Satellites Motion

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Define and explain correctly the three cosmic velocities with calculations.Identify satellites based on their classificationsDescribe clearly rockets and satellites based on a planetary motion.
	<p>Time Required: 2 hours</p>
	<p>Learning Methodology: Brainstorming, Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion</p>
	<p>Materials, Tools, and Equipment Needed: Projector, computer, flipchart, marker pen, PPE, whiteboard, chalkboard, chalk, textbooks, Scientific calculator.</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Ensure the sequence of lessons aligns with the curriculum and learning objectives.<input type="checkbox"/> Prepare diagrams, models, video projectors, and computers to demonstrate key concepts like planetary motion, satellite orbits, and rocket trajectories.<input type="checkbox"/> Be prepared to clarify any confusion about key concepts
	<p>Cross-Cutting Issues:</p> <ul style="list-style-type: none">✓ Ensure gender balance while forming groups, allocating tasks, and during presentations✓ Ensure inclusiveness while allocating tasks to students and provide facilities/environments that enable/allow participation of all✓ Ensure Peace and values education are in place while students are interacting in groups and during role play
	<p>Prerequisites:</p> <ul style="list-style-type: none">✓ Understanding of basic physics principles such as force, motion, and energy.

- ✓ Knowledge of concepts like speed, velocity, acceleration, and Newton's laws of motion.



Activity 1: Problem-Solving



Task 8

1. Using the appropriate methodology such as individual work, small group discussions, guide trainees to read the following scenario and answer the questions as provided under task 8 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used

Scenario:

Your team needs to decide which orbit is best for the satellite: Low Earth Orbit (LEO), Geostationary Orbit (GEO), or Polar Orbit. The satellite will monitor weather patterns globally. Which orbit should you choose for this mission and why?

Answer to the Scenario Question

For a satellite designed to monitor weather patterns globally, the best choice is a Polar Orbit. Here's why: Why Choose a Polar Orbit?

- i. **Global Coverage:** A satellite in a polar orbit travels over the Earth's poles, allowing it to pass over every part of the Earth's surface as the planet rotates underneath. This provides complete global coverage, which is essential for monitoring weather patterns worldwide.
- ii. **Frequent Revisit Times:** Polar orbiting satellites have shorter orbital periods (typically around 90-120 minutes), enabling them to revisit the same location multiple times a day. This is crucial for capturing dynamic weather changes.

- iii. **High-Resolution Imaging:** Because polar orbiting satellites operate at lower altitudes (typically 500-2,000 km), they can capture high-resolution images, which are vital for detailed weather observations.
- iv. **Monitoring Extreme Regions:** Polar orbits are ideal for observing weather patterns in polar regions (e.g., monitoring melting ice caps or Arctic storms), which geostationary satellites cannot observe effectively.

Why Not Low Earth Orbit (LEO) or Geostationary Orbit (GEO)?

- i. **Low Earth Orbit (LEO):** While LEO offers high-resolution imaging and close proximity to the Earth's surface, it lacks the global coverage needed for continuous monitoring of weather patterns.
- ii. **Geostationary Orbit (GEO):** GEO satellites remain fixed over one point on the Earth's equator, providing continuous coverage of a specific region. While excellent for regional weather monitoring, they cannot provide data for polar regions or global coverage. Additionally, their high altitude (about 36,000 km) reduces image resolution.

Conclusion: A Polar Orbit is the most suitable choice for a weather-monitoring satellite because it offers global coverage, frequent revisit times, and the ability to monitor polar regions and dynamic weather changes effectively.

- 2. Encourage all trainees to give their views by share their answers to the class and write their responses for reference.
- 3. After the sharing session, refer trainees to Key facts 1.3 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions, they have.



Activity 2: Guided Practice



Task 9

1. Using the appropriate methodology such as individual work, pair-share, small group discussions, guided discussions, guide trainees to solve the questions as provided under task 9 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
2. Engage students in collaborative problem-solving, enhance apply concepts of orbital mechanics to calculate satellite speeds.

Questions:

- a. Two satellites A and B orbit a planet P in circular orbits with radii $4R$ and R , respectively. If the speed of satellite A is $3V$, what is the speed of satellite B?

Answer:

Recall the orbital speed formula: $v = \sqrt{\frac{GM}{r}}$, where v is the orbital speed, G is the gravitational constant, M is the mass of the planet, and r is the orbital radius.

Step-by-Step Analysis: Compare speeds of satellites A and B:

$$\text{For satellite A: } v_A = \sqrt{\frac{GM}{4R}} = \frac{1}{2} \sqrt{\frac{GM}{R}}$$

$$\text{For satellite B: } v_B = \sqrt{\frac{GM}{R}} = 2v_A$$

$$\text{Relating the speeds: } v_A = 3V \quad v_B = 2 \times 3V = 6V$$

- b. A satellite of mass 500 kg is placed in a circular orbit around the Earth at an altitude of 500 km . The radius of the Earth is $6,371 \text{ km}$, and the mass of the Earth is $6 \times 10^{24} \text{ kg}$. Using the concepts of universal gravitation and orbital motion, calculate the orbital velocity of the satellite.

Answer: Orbital Velocity of the Satellite Formula: $v = \sqrt{\frac{GM}{r}}$, then after substituting the given data in the formulae we get $v = 7610 \text{ m/s}$

3. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in solving the problems. Your role is to guide them by using

probing questions such as Why? What? How? to enable them to come to informed responses.

4. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
5. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
6. After the sharing session, refer trainees to key fact 1.3 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 10

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

Scenario:

Suppose you are part of a space exploration team working on a mission to send a robotic probe to Mars. During a team meeting, the lead scientist explains the importance of escape velocity and its role in ensuring the probe leaves Earth successfully. However, one of your teammates asks: Why can't we just keep accelerating the rocket slowly until it reaches space? Then discuss the challenges of reaching and maintaining escape speeds in space.

Answer: While it may seem logical to accelerate a rocket slowly to save fuel, this approach would not work effectively due to gravity and atmospheric drag:

- i. **Overcoming Earth's Gravity:** Earth's gravitational pull constantly opposes the rocket's motion. If acceleration is too slow, gravity will continuously pull the rocket back down, requiring more energy over time. Escape velocity ensures the rocket has enough kinetic energy to overcome this pull in a single, efficient burst.

- ii. **Atmospheric Drag:** The Earth's atmosphere creates resistance. Moving slowly increases the time spent in the atmosphere, leading to greater energy loss due to drag. Rapid acceleration minimizes this time and energy loss.
- iii. **Fuel Efficiency:** Rockets carry limited fuel. Gradual acceleration would require more fuel to counteract gravity and drag over an extended period, making the mission impractical. Achieving escape velocity optimizes fuel use by reaching space faster.

Scenario 2: Your team must explain why achieving escape velocity is crucial for interplanetary missions like this one. How would you answer the teammate's question?

- a. How does escape velocity relate to Earth's gravitational pull and the energy required to overcome it?
 - b. What challenges might arise if the rocket doesn't reach escape velocity?
 - c. Could the concept of escape velocity differ on Mars or the Moon, and how would that affect future missions?
- a. Relation to Earth's Gravitational Pull and Energy:** Escape velocity is the speed needed to overcome Earth's gravitational force without additional propulsion. It is derived from the conservation of energy: Kinetic Energy ($\frac{1}{2}mv^2$) = Gravitational Potential Energy ($\frac{GMm}{r}$), Here, $v = \sqrt{\frac{2GM}{r}}$. By reaching this speed, the probe has enough energy to leave Earth's gravitational influence permanently.
- b. If the rocket fails to reach escape velocity:**
- It may fall back to Earth or enter an unstable orbit.
 - Additional propulsion would be required to compensate, which may not be feasible due to fuel constraints.
 - The mission could fail, wasting resources and risking damage to the spacecraft.
- c. Escape Velocity Differences on Mars or the Moon:**
- i. Escape velocity depends on the celestial body's mass (M) and radius (r): $v = \sqrt{\frac{2GM}{r}}$.
 - ii. Mars:
 - With a smaller mass and radius than Earth, Mars' escape velocity is approximately 5 km/s, much lower than Earth's 11.2 km/s.
 - Rockets require less fuel to leave Mars, simplifying mission logistics.

- iii. Moon:
 - The Moon's escape velocity is even lower, about 2.4 km/s, due to its smaller mass and radius.
 - This makes the Moon an ideal launch site for interplanetary missions, reducing energy costs.
 - iv. **Impact on Missions:** Lower escape velocities on Mars and the Moon could allow for lighter spacecraft or more payload capacity. However, designing spacecraft for different environments requires careful planning.
2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Description of Rocket and Satellites Motion
 3. Each trainee will perform the task individually
 4. Inform them that they should demonstrate positive attitude when performing task.
 5. After trainees has performed, you'll give them feedback
 6. At the end summarize the topic



Formative Assessment on Learning Outcome 1

Instructions:

- ✓ Answer all questions carefully, and
- ✓ Provide explanations for your answers where required.

1. Indicate whether the following statements are **TRUE** or **FALSE**

- a. The third cosmic velocity is the velocity needed to leave the Solar System. **Answer: True**
- b. Newton's law of universal gravitation states that the gravitational force between two bodies is inversely proportional to the square of the distance between them. **Answer: True**
- c. The gravitational force between two bodies moving in orbits is independent of their masses. **Answer: False**
- d. The free-fall acceleration, g , decreases with altitude because the gravitational force weakens as the distance from the Earth's center increases. **Answer: True**

2. Multiple questions

- I. Which of the following is not Kepler's law of planetary motion?
 - a. **The planet moves in a straight line with the sun as one of its foci.**
 - b. The line joining the sun and the planet sweeps out equal areas in equal periods
 - c. The square of the periods T of revolution of planets are proportional to the cubes of their mean distances R from the sun
- II. Spacecraft propulsion is
 - a. The method used in the fabrication of satellite
 - b. The device that can be sent in the space
 - c. **Any method used to accelerate an artificial satellite in space**

- III. The value of universal gravitational constant changes in which of the following medium?
- Air
 - Water
 - Plasma
 - The gravitational constant is independent of the medium**
- IV. From Kepler's law of orbit, we can infer that the Sun is located _____ of the planet's orbit.
- At the center
 - At one of the foci**
 - At both foci
 - Anywhere along the semi-minor axis

3. Complete the following sentences:

- a. According to Kepler's second law, a planet sweeps out _____ in equal _____ of time, meaning it moves _____ when closer to the Sun and _____ when farther away.

Answer: Equal areas; intervals; faster; slower.

- b. The escape velocity is defined as the minimum velocity required for an object to overcome the _____ of a celestial body and escape into _____. **Answer:**

Gravitational pull; space.

4. A planet orbits a star in an elliptical path. According to Kepler's laws, at which point in its orbit is the planet moving fastest, and why?

Answer: The planet moves fastest at perihelion because it is closest to the star, where the gravitational force is strongest, as per Kepler's second law.

5. Determine the acceleration due to gravity at an altitude of 2000 km above Earth's surface. Assume Earth's radius $R = 6400$ km and $g = 9.8$ m/s²

Answer: Use the following formulae and replace the known values: $g' = g \left(\frac{R}{R+h} \right)^2$

6. Suppose that two objects attract each other with a gravitational force of 16 N. If the mass of both objects was doubled, and if the distance between the objects remained the same, then what would be the new force of attraction between the two objects?

Answer: Formulae $F_1 = G \frac{m_1 m_2}{r^2} = 16N$ **by doubling the masses the New force is**
 $F_{New} = G \frac{(2m_1)(2m_2)}{r^2} = 4 \times 16 = 64N$

7. During a system test, the satellite's altitude is doubled. The team notices a change in gravitational pull. Do you think the gravitational pull on the satellite will remain the same, increase, or decrease? Why?

Answer: The gravitational pull will decrease. The gravitational force decreases with the square of the distance from the center of the Earth. Doubling the altitude increases the distance between the satellite and Earth, reducing the gravitational pull.

8. As the satellite moves farther away from Earth, the tracking system records a decrease in the force pulling it towards Earth. Why does the force of gravity change as the satellite moves farther from Earth?

Answer: The force of gravity decreases because it is inversely proportional to the square of the distance between the satellite and the center of the Earth. As the distance increases, the gravitational attraction weakens.

9. The satellite orbits at a height of 500 km above Earth's surface. A team member asks whether the gravity at that height is stronger, weaker, or the same as on Earth's surface. Do you think gravity at the satellite's height is more, less, or the same? Explain.

Answer: Gravity at 500 km is weaker than on Earth's surface. At higher altitudes, the distance from the Earth's center increases, reducing gravitational acceleration ($g' \propto \frac{1}{r^2}$).

10. A team of scientists measures gravitational acceleration g at different altitudes while ascending a mountain.

- a. How does the value of g change as altitude increases? Explain why this occurs. If g at sea level is 9.8 m/s^2

Answer: g decreases with increasing altitude because the distance from Earth's center increases, reducing the gravitational pull.

- b. Calculate the approximate g at an altitude of 5,000 m, assuming Earth's radius is 6,371 km.

Answer: Use the following formulae and replace the known values: $g' = g \left(\frac{R}{R+h} \right)^2$.

Where R is the radius of the earth and h is the distance above the earth's surface

- c. If Earth's density were lower, how would this affect gravitational acceleration at its surface?

Answer: If Earth's density were lower, the mass of Earth would decrease. Since $g = \frac{GM}{R^2}$, a lower mass would result in a smaller g , reducing gravitational acceleration at the surface.

Points to Remember

- Orbital motion is a motion that occurs when an object moving forward in space is at the same time pulled by gravity towards another object.
- An orbit is the trajectory followed by a body under the influence of the gravity of another body.
- Newton's universal gravitation law states that "The gravitational force of attraction between two masses m_1 and m_2 is directly proportional to the product of masses and inversely proportional to the square of their mean distance apart."
- The Force of Gravity between any two bodies moving in orbit depends only upon the following factors: masses of the two object and distance between those objects
- The acceleration due to gravity at a point above the surface of the earth is given by $g' = g \left(\frac{R}{R+h} \right)^2$ and at the point below the surface of the earth $g' = \frac{4}{3} \pi \rho G (R - d)$.

- Orbital motion is a motion that occurs when an object moving forward in space is at the same time pulled by gravity towards another object.
- An orbit is the trajectory followed by a body under the influence of the gravity of another body.
- The Planets are large natural bodies rotating around a star in definite orbits.
- A rocket is a device that produces thrust by ejecting stored matter. A rocket moves forward when hot gas expelled from its engine pushes it in the opposite direction.
- A satellite is an artificial or a natural body placed in orbit round the earth or another planet in order to collect information or for communication.
- A spacecraft is a vehicle or machine designed to fly in outer space.
- There are four classifications of satellite orbits that have been identified depending on the shape and diameter of each orbit (GEO, LEO, MEO and HEO)
- Orbital velocity of a satellite is the velocity required to put the satellite into its orbit around the earth. It is given by $v = \sqrt{\frac{GM}{r}} = R \sqrt{\frac{g}{R+h}}$.
- Time Period of Satellite: The period of a satellite is given by: $T = 2\pi \sqrt{\frac{R+h}{g}}$
- The height at which a satellite is launched is given by: $h = \frac{gT^2}{4\pi^2} - R$
- Escape velocity is the speed that an object needs to be traveling to break free of a planet or moon's gravity well and leave it without further propulsion.
- The cosmic velocity is the initial velocity which a body must have to be able to overcome the gravity of another object.
- The first cosmic velocity is $v_1 = \sqrt{\frac{GM_e}{R_e}}$, $v_1 = 7900m/s$.
- Second cosmic velocity is the speed needed to “break free” from the gravitational attraction of the Earth. $v_2 = \sqrt{\frac{2GM_e}{R_e}} = \sqrt{2}v_1 = 11265. \frac{38m}{s}$
- Third cosmic velocity is the initial velocity which a body has to have to escape the Solar System and its value is given by: $v_3 = 16.7Km/s$.



Self-Reflection

1. Ask learners to retake the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to Identify their areas of strength, areas for improvement, and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).



Further Information for the Trainer

1. Conduct additional research on magnetism to provide detailed explanations.¹
2. Use video tutorials to enhance learners' understanding and skills.²
3. Adapt or create assessments and adjust facilitation methods based on class size, trainees' backgrounds, resources, and time.

¹ Physics for TTC. Student's book. Year 2

² <https://www.youtube.com/shorts/8ajualAAHk>

LEARNING OUTCOME 2: EFFECTS OF MAGNETISM



Learning outcome 2: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
 - a. What does the illustration show?
 - b. What do you think will be topics to be covered under this unit based on the illustration?
2. After the discussion, inform students that this unit is intended to provide them with the knowledge, skills and attitudes to examine effects of magnetism. They will cover, Concepts of magnetism, Magnetic field created by electric current, Magnetic force.
3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:
 - a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.
 - b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?
 - d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.
 - e. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.



Key Competencies:

Knowledge	Skills	Attitudes
Define the magnetic field.	Use the right-hand rule.	Demonstrate curiosity in learning about forces.
State the relationship between current and magnetism.	Analyze magnetic interactions.	Maintain accuracy in practical tasks.
Recognize the applications of magnetism.	Solve problems involving magnetic fields.	Appreciate the role of magnetism in technology.



Steps:



Discovery Activity

Task 11:

- Using interactive discussion (question-answer) methodology guide trainees to share their prior experience from O'level regarding magnetism in their Trainee's Manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are given.

Scenario:

A local science fair is hosting a challenge: Design a model of an electric train that can move using magnetic forces. Your class is tasked with figuring out how magnets and electricity can work together to propel the train. To succeed, you need to understand three key concepts:

- What magnetism is and how it works.
 - How electric current generates a magnetic field.
 - How magnetic forces can be determined and applied.
- Encourage all students to give their views.

3. After the sharing session, inform students that this activity was not intended for them to give the right answers but to give them a picture of what they will cover in the unit.
4. Using their answers, lead them to the topic 2.1: Concepts of magnetism.

Topic 2.1: Description of concepts of magnetism

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Explain and identify clearly the concept of a magnet and its key characteristics, including its ability to attract certain materials.Classify properly magnets and magnetic materials based on their properties.Describe and perform effectively basic methods of magnetization, based on their applications in everyday life.
	<p>Time Required: 2 hours</p>
	<p>Learning Methodology: Group discussion, interactive discussion, Practical exercises, Demonstration and simulation, brainstorming, and trainer guided.</p>
	<p>Materials, Tools, and Equipment Needed: Whiteboard, chalkboard, flip chat, computer, projector, textbooks, chinks, markers, Scientific calculator, magnet, and compass.</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Availability of required materials, tools, and equipment<input type="checkbox"/> Readiness of learning place<input type="checkbox"/> Prepare simplified explanations for complex ideas<input type="checkbox"/> Test any equipment, such as projectors or interactive boards, to avoid technical issues.
	<p>Cross-Cutting Issues:</p> <ul style="list-style-type: none">✓ Consider gender mainstreaming while teaching.✓ Integration of inclusiveness in the learning and teaching process✓ Embedding inclusiveness throughout teaching and learning.
	<p>Prerequisites:</p> <ul style="list-style-type: none">✓ Difference between metals and non-metals,✓ Basic properties like conductivity and density,✓ Concept of forces (e.g., attraction and repulsion)



Activity 1: Problem-Solving



Task 12

1. Using discussion in small groups of two or three people, guide trainees to analyze the scenario and answer the questions provided under task 12 in their trainee's manuals.
2. Inform them that each group will present their findings. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Scenario:

A local workshop is facing a challenge. Many of their tools, such as screws, nails, and wrenches, seem to have lost their magnetic properties, making them less efficient for tasks. The workshop owner has asked your class to help figure out how to restore their magnetism and better understand why some materials respond to magnetism differently. Your mission is to investigate the following:

- a. What is a magnet, and how does it work?
 - b. What are the different types of magnets?
 - c. How can you magnetize objects?
 - d. Why do some materials like wrenches (ferromagnetic) become magnets, while others like wood or plastic do not?
3. Basing on the group presentations, ask students to share their answers to the class.
 4. After the sharing session, review Key Facts 2.1 together, discuss them, align the responses shared during the session, and address any questions participants may have.



Activity 2: Guided Practice



Task 13

1. Using the appropriate methodology such as individual work, small group discussions, guided discussions, guide trainees to analyze the scenario and answer the questions provided under task 13 in their trainee's manuals. Make sure instructions are understood, all the students are actively participating and necessary materials/tools are provided and being used.

Scenario:

Your class is on a field trip to a nature reserve, and you are using a compass to navigate through the forest. Suddenly, the compass needle starts behaving strangely, pointing in unusual directions instead of north. A student notices their phone and a portable speaker are nearby. Another student observes an overhead power line running through the forest. Curious about what might be happening, your group decides to investigate:

- ✓ Does the phone or speaker have anything to do with the compass needle's unusual movement?
- ✓ What happens when you bring two magnets (from a compass or other tool) close to each other?

Your task is to figure out how these effects are related to magnetism.

Activity Instructions:

Materials Needed: A compass, a smartphone, and a small speaker with a magnet, battery, a wire, two bar magnets

Procedure:

- a. Place the compass near the phone or speaker and observe the needle's behavior.
- b. Bring the two magnets close together and observe the interaction (attraction or repulsion).
- c. Predict and test what will happen if you flip one of the magnets.
- d. Place the compass near the wire when no current is flowing. Observe.
- e. Turn on the circuit and observe how the compass needle moves.

Discussion Questions:

- a. What similarities do you notice between the effects of the phone, speaker, magnets, and electric current on the compass?
- b. How do the observations help explain the strange behavior of the compass in the forest scenario?
- c. Can you think of other devices that use magnetism in their operation?

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in performing the activity given. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to Key Facts 2.1 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 14

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

Scenarios:

- A. Visit a nearby workshop, garage, or hardware store (if feasible) or research online/offline. Observe and identify tools or machines that use magnets.
- B. Identify household or community items that use magnets. Discuss with your classmates:
 - i. Why are magnets used in these items?
 - ii. How do these magnets simplify daily life?
- C. Imagine a problem in your community or workplace that could be solved using magnets

Answer 1: Tools or Machines That Use Magnets: From a visit to a workshop, garage, hardware store, or through research, tools and machines that use magnets include:

- i. **Magnetic drills:** Used for precision drilling in metalworking.
- ii. **Magnetic lifters:** For lifting heavy metal sheets or objects.
- iii. **Magnetic sweepers:** Collect metal debris like nails or screws from floors.
- iv. **Electric motors:** Found in power tools like drills and grinders.

- v. **Magnetic clamps:** Hold metal pieces together during welding.

Answer 2: Household or Community Items That Use Magnets

Examples:

- **Refrigerator magnets:** For holding notes or decorations.
- **Speakers and headphones:** Use magnets to produce sound by vibrating a diaphragm.
- **Door locks:** Magnetic locks for security.
- **Induction stoves:** Use electromagnetic fields to heat cookware.
- **Magnetic phone mounts:** Hold phones securely in vehicles.

a. Why Are Magnets Used in These Items?

- **Efficiency:** Magnets provide a non-mechanical way of holding, lifting, or transferring energy.
- **Reliability:** They don't wear out easily, reducing maintenance needs.
- **Precision:** Magnets enable accurate positioning and control in items like motors or locks.

b. How Do These Magnets Simplify Daily Life?

- They reduce manual effort, like picking up metal debris or holding objects securely.
- Magnets enable the functioning of essential devices like speakers, improving communication and entertainment.
- Magnetic locks enhance security with minimal complexity.

Answer 3: Imagining a Problem Solved Using Magnets

Community Problem: Metal waste like nails, screws, and sharp objects litter public spaces, posing a safety hazard.

Solution Using Magnets: A magnetic sweeper could be used to clean these areas efficiently. It would attract and collect metal debris, ensuring safety for pedestrians and vehicles while reducing cleanup time and effort.

2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Description of concepts of magnetism.
3. Each trainee will perform the task individually or in group if applicable
4. Inform them that they should demonstrate positive attitude when performing task.

5. After trainees has performed, you'll give them feedback
6. At the end summarize the topic

Topic 2.2: Explanation of magnetic field created by electric current

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Explained clearly the magnetic field created by electric current is according to the Ampere’s lawExplain effectively the principle of electromagnets and their applications in real world.Describe perfectly the working principles of magnetic field based on measuring instruments, including a Gauss meter.
	<p>Time Required: 3 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion and Research.</p>
	<p>Materials, Tools and Equipment Needed: Whiteboard, Chalkboard, computer, projector, textbooks, chalks, markers, scientific calculator, magnets, and compass</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Prepare all required materials and equipment and ensure all equipment is functional and safe for use.<input type="checkbox"/> Develop visual aids such as diagrams, slides, and charts<input type="checkbox"/> Arrange the classroom to facilitate group activities and experiments, ensuring each group has access to the necessary tools and materials.
	<p>Cross-Cutting Issues:</p> <ul style="list-style-type: none">✓ Ensure all students, including those with disabilities, can fully participate in activities.✓ Foster collaboration and mutual respect during group activities.
	<p>Prerequisites:</p> <ul style="list-style-type: none">✓ Understand magnetic fields, poles, and interactions.✓ Learn components like wires, batteries, and connections.✓ Explore and apply concepts of electromagnets and magnetic field instruments.



Activity 1: Problem-Solving



Task 15

1. Using interactive discussion, guide trainees to analyze the two scenarios and answer the questions provided for each scenario in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used

Scenarios:

- a. You wake up in the morning and start your day. You reach for your refrigerator to grab some milk for your breakfast. Then, later in the day, you pick up your phone to check your messages. Did you know that magnets or magnetic forces play a role in both of these activities? Can you think of two other things in your daily life where magnets or magnetic force might be used?
- b. You are a scientist exploring a mysterious area where magnetic fields are unusually strong. To study these fields, you need the right tools. You want to measure the strength of the magnetic field in different parts of the area, determine the direction of the magnetic field, and monitor any variations over time.
 - i. Which instrument would you use to measure the strength of the magnetic field?
 - ii. Which instrument would you use to find the direction of the magnetic field?
 - iii. Which instrument would help you monitor magnetic field variations accurately?

Answer:

- a. In addition to the refrigerator and the phone:
 - Credit/Debit Cards:** Magnets are used in the magnetic strip of credit/debit cards for storing data. This enables electronic transactions.
 - Speakers/Headphones:** Magnets are a key component in speakers and headphones. They interact with the coil to produce sound by vibrating the diaphragm.
- b. Daily uses of magnets include speakers/headphones and credit cards.
 - ✓ For studying magnetic fields: Use a magnetometer for strength,
 - ✓ Use a compass for direction,
 - ✓ Use a fluxgate magnetometer or SQUID for variations.

2. Encourage all trainees to give their views by share their answers to the class and write their responses for reference.
3. Encourage learners to thoroughly read and review Key Fact 2.2 to gain a deeper understanding and further clarification on the topic, ensuring they can connect it to the discussion and enhance their comprehension of the concepts being addressed.



Activity 2: Guided Practice



Task 16

1. Using individual work method, guide trainees to solve problems and identify applications related to Lorentz force, Fleming’s left-hand rule, and Ampere’s force law as provided under task 16 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Activity: A wire carries a current of 10 A. Calculate the magnetic field at a distance of 0.05 m from the wire.

Given	Value
Current	10 A
Distance	0.05m
Magnetic field	$B = \mu_0 \frac{I}{2\pi r} = \frac{(4\pi \times 10^{-7}) \times 10}{2\pi \times 0.5}$

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in solving problems and identify applications related to Lorentz force, Fleming’s left-hand rule, and Ampere’s force law. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.

3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to Key Fact 2.2 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 17

1. Ask trainees to perform the tasks provided in their trainee’s manuals as described below:
 - A. Using Electromagnets in Everyday Life. A factory uses electromagnets to sort metals in a recycling plant. You have knowledge on magnet and its applications, so you are tasked to separate magnetic and non-magnetic materials in the mixture of iron nails, paper clips, aluminum foil, plastic buttons. As an expert in the application of electromagnet sort the above material in magnetic and nonmagnetic materials.

Materials Required:

A battery (6V or 12V), Insulated copper wire, an iron nail (to serve as the core of the electromagnet), A switch, a collection of mixed materials (iron nails, paper clips, aluminum foil, plastic buttons) and a container to hold the materials

Procedure:

- ✓ Assemble the Electromagnet:
- ✓ Wrap the insulated copper wire tightly around the iron nail, leaving about 10 cm of wire on each end.
- ✓ Connect the ends of the wire to a battery through a switch to create a circuit.

Prepare the Materials: Place the mixed materials (magnetic and non-magnetic) in a shallow container.

Activate the Electromagnet: Close the circuit by turning on the switch to allow current to flow through the wire, making the nail magnetic.

Test the Electromagnet: Lower the electromagnet into the container of mixed materials. The magnetic materials (iron nails, paper clips) should stick to the electromagnet while non-magnetic materials remain in the container.

Observe and Record: Separate the magnetic materials by turning off the switch (deactivating the electromagnet). Observe how the magnetic and non-magnetic materials are sorted.

Conclusion: Electromagnets can effectively separate magnetic materials from non-magnetic ones due to their ability to temporarily magnetize objects when an electric current flows through the wire.

B. Measuring Magnetic Fields in Devices, Smartphones use sensors to detect magnetic fields (e.g., for navigation apps). Identify two other devices that use magnetic field measurements and explain how they work.

Devices That Use Magnetic Field Measurements:

Compass Sensors in Cars:

How It Works: Many vehicles have digital compasses that use magnetometers to detect the Earth's magnetic field. These sensors determine the vehicle's orientation relative to magnetic north, providing directional information to the driver.

MRI Machines in Medical Imaging:

How It Works: Magnetic Resonance Imaging (MRI) uses powerful magnetic fields and radio waves to create detailed images of the internal structures of the body. The magnetic field aligns hydrogen nuclei in the body, and when the field is altered, the nuclei emit signals that are captured to form images.

- d. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Explanation of magnetic field created by electric current
- e. Each trainee will perform the task individually
- f. Inform them that they should demonstrate positive attitude when performing task.
- g. After trainees has performed, you'll give them feedback
- h. At the end summarize the topic

Topic 2.3: Determination of magnetic force

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Determine clearly the magnetic force based on the Lorentz lawDetermine correctly the direction of force on a current-carrying conductor based on Fleming’s left-hand rule in various magnetic field orientations.Analyze and predict effectively the interaction (attraction or repulsion) between two parallel current-carrying conductors based on Ampere’s force law.
	<p>Time Required: 5hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion and Research.</p>
	<p>Materials, Tools and Equipment Needed: Whiteboard, Chalkboard, computer, projector, textbooks, chalks, markers, scientific calculator, magnets, compass, switches, power supply, iron fillings and wires</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Ensure all required materials are available, functional, and safely stored.<input type="checkbox"/> Set up and test all demonstrations, including current-carrying conductor interactions and field visualizations, to ensure they work as intended
	<p>Cross Cutting Issues:</p> <ul style="list-style-type: none">✓ Relate magnetic forces to preserving historical records with storage devices.✓ Highlight electromagnets in metal separation at recycling plants.✓ Design activities for all, including trainees with disabilities.✓ Explain magnetic forces in energy-efficient technologies.



Prerequisites:

- ✓ Familiarity with basic concepts of electric current, magnetic fields, and forces.
- ✓ Ability to solve algebraic equations and perform vector analysis.
- ✓ Understanding the importance of safety protocols when working with electrical currents and magnetic materials.



Activity 1: Problem-Solving



Task 18

1. Using the appropriate methodology such as interactive discussion, pair-share, group discussions, guide trainees to read the following scenario and answer the questions as provided under task 18 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used

Scenario:

A straight conductor is placed in a uniform magnetic field directed downward. The conductor carries a current from left to right. Determine the direction of the force acting on the conductor. If the current in the conductor is increased, what happens to the magnitude of the force?

Answer:

- a. To determine the direction of the force on the conductor, use the right-hand rule for the magnetic force on a current-carrying conductor:
 - ✓ Align your fingers in the direction of the current (from left to right).
 - ✓ Point your palm in the direction of the magnetic field (downward).
 - ✓ Your thumb will point in the direction of the force acting on the conductor.

In this case:

- Current: Left to right.
- Magnetic field: Downward.

- Force direction: Out of the plane of the conductor (toward you).
 - b. Since the current I is directly proportional to the force F , increasing the current will increase the magnitude of the force acting on the conductor.
2. Encourage all trainees to give their views by share their answers to the class and write their responses for reference.
 3. After the sharing session, refer trainees to Key facts 2.3 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions, they have.



Activity 2: Guided Practice



Task 19

1. Using the appropriate methodology such as individual work, small group discussions, trainer guided method, guide trainees to solve problems as provided under task 19 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Problems:

- a. A proton ($q = 1.6 \times 10^{-19}$ C) moves at a speed of 2×10^6 m/s through a magnetic field of 0.5 T. The angle between the motion and the field is 90° . Calculate the magnetic force.
- b. Two parallel wires carry currents of 5 A in the same direction and are 0.02 m apart. Calculate the force per unit length between them

Answer:

- a. The magnetic force F acting on a charged particle moving through a magnetic field is given by the formula: $F = qvB \sin \theta$, and by substitution : $F = 8 \times 10^{-14}$ N
- b. The force per unit length between two parallel wires carrying currents is given by

the formula: $\frac{F}{L} = \frac{(\mu_0 I_1 I_2)}{2\pi d}$. Then by substituting the given data we get;

$$\frac{F}{L} = \frac{4\pi \times 10^{-7} \times 5 \times 5}{2\pi \times 0.02} = 2.5 \times 10^{-4} \text{ N/m.}$$

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in solving problems. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the discussion, ensure to provide an in-depth expert perspective that thoroughly addresses any remaining questions or uncertainties. This should be done with careful reference to Key Facts 2.3, offering detailed explanations and clarifications as necessary to enhance understanding and reinforce the key concepts discussed.



Activity 3: Application



Task 20

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

Scenario:

You visit a local workshop where an electric motor is actively being used. Your task is to observe and analyze the components and operation of the motor. You need to understand how Fleming's left-hand rule applies to the motor's function, the role of magnetic forces in creating rotational motion, and identify all key components of the motor.

Problem: You are in the workshop and observe the following:

- i. Components of the Electric Motor: Identify and describe the key components of the electric motor, such as the rotor, stator, brushes, and commutator.
- ii. Application of Fleming's Left-Hand Rule: Explain how Fleming's left-hand rule helps in understanding the motion of the motor. Demonstrate the relationship between the magnetic field, current, and force that creates rotational motion.

- iii. Magnetic Forces and Rotational Motion: Discuss the role of magnetic forces in the production of rotational motion within the motor. How do these forces interact with the coil in the rotor to generate movement?

Hints to Solve the Problem:

Help trainees to recall the following:

- ✓ For question 1, focus on the physical structure of the motor, pointing out the stationary parts (stator) and moving parts (rotor).
- ✓ For question 2, recall the left-hand rule: when the left hand is held with the thumb, index finger, and middle finger mutually perpendicular, the thumb represents the direction of motion (force), the index finger represents the direction of the magnetic field, and the middle finger represents the direction of the current.
- ✓ For question 3, consider how the interaction between the magnetic field of the stator and the current in the rotor coil generates a force that causes the rotor to spin.

Answer Outline:

- ❖ Components of the Electric Motor: The stator is the stationary part of the motor, which generates a magnetic field. The rotor is the rotating part of the motor, which contains coils of wire through which current flows. The commutator is a switch that reverses the direction of current in the rotor coils to maintain continuous rotation. Brushes provide contact between the stationary and rotating parts, allowing current to flow into the rotor.
- ❖ Application of Fleming's Left-Hand Rule: According to Fleming's Left-Hand Rule, the magnetic field (from the stator) acts in one direction. The current (through the rotor coils) flows in a perpendicular direction. The force generated by this interaction causes the rotor to rotate. The left thumb shows the direction of the force (motion), the index finger shows the direction of the magnetic field, and the middle finger shows the direction of the current.
- ❖ Magnetic Forces and Rotational Motion: As current flows through the coils of the rotor, it creates a magnetic field around the coils. The interaction between this magnetic field and the magnetic field of the stator produces a force (Lorentz force). This force acts on the rotor, causing it to rotate. The continuous interaction between the magnetic fields ensures the motor keeps turning.

2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Explanation of magnetic field created by electric current
3. Each trainee will perform the task individually
4. Inform them that they should demonstrate positive attitude when performing task.
5. After trainees has performed, you'll give them feedback
6. At the end summarize the topic



Formative Assessment on learning outcome 2

Instruction:

- The assessment comprises of compulsory questions:
- Read the instructions for each question before you answer.

1. Which of the following is correct?

- a. When a current-carrying wire is in your right hand, thumb in the direction of the magnetic field lines, your fingers point in the direction of the current.
- b. When a current-carrying wire is in your left hand, thumb in the direction of the magnetic field lines, your fingers point in the direction of the current.
- c. **When a current-carrying wire is in your right hand, thumb in the direction of the current, your fingers point in the direction of the magnetic field lines.**
- d. When a current-carrying wire is in your left hand, thumb in the direction of the current, and your fingers point in the direction of the magnetic field lines.

2. Match the following types of magnetic materials with their properties:

1. Ferromagnetic materials	A. Weakly repelled by magnets.
2. Paramagnetic materials	B. Have moments that cancel out in pairs.
3. Diamagnetic materials	C. Exhibit magnetic ordering but with unequal moments.
4. Ferrimagnetic materials	D. Weakly attracted to magnets and lose magnetism quickly
5. Anti-ferromagnetic	E. Strongly attracted to magnets and retain magnetism.

3. Complete the sentence with the following statements:

- a. A magnet is defined as a material that produces a _____ and attracts materials like _____ and _____. **Answer: Magnetic field; iron; steel.**
- b. The process of making a material magnetic is called _____, and it occurs by aligning _____ in the material. **Answer: Magnetization; magnetic domains.**
- c. The magnetic field created by an electric current is explained by _____ law, which relates the magnetic field to the _____ around a current-carrying conductor. **Answer: Ampere's; loop.**

9. If the north poles of two bar magnets are brought close to each other, what will happen?

Repel each other

10. It is not good to put a magnet in the fire. why? **Heat demagnetizes, disrupts magnetic domains.**

11. A piece of iron is rubbed against a permanent magnet. Over time, the iron starts attracting small nails.

a. Define magnetization. **Process of aligning magnetic domains in a material.**

b. Explain the magnetization process observed in this scenario. **Iron domains align with the magnetic field during rubbing.**

c. Discuss other methods of magnetizing an object. **Induction, electrical current through a solenoid.**

d. What is a magnetizing field, and how does it influence the magnetization process? **External field aligning domains, strength determines magnetization.**

12. A teacher brings different materials (iron nail, aluminum foil, and graphite) and places them near a strong magnet. Only the iron nail is strongly attracted.

a. Classify the materials as ferromagnetic, paramagnetic, or diamagnetic.

Iron nail: Ferromagnetic

Aluminum: Paramagnetic and Graphite: Diamagnetic

b. What are the properties of ferromagnetic materials that make them strongly attracted to magnets?

High permeability, strong attraction to magnets, retain magnetism.

c. Discuss other types of magnetic materials, such as Ferrimagnetic and anti-ferromagnetic materials.

Ferrimagnetic: Mixed alignment of moments.

Antiferromagnetic: Opposing moments cancel out.

13. A wire-carrying current creates a circular magnetic field around it. The teacher uses iron filings to visualize the magnetic field lines.

a. Explain how a magnetic field is created by an electric current.

Moving charges create circular magnetic fields.

b. Use Ampere's law to derive the expression for the magnetic field around a straight

conductor. **Ampere's law: $B = \mu_0 \frac{I}{2\pi r}$**

- c. How does the direction of the current affect the direction of the magnetic field?

Current Direction: Determines field direction using the right-hand rule

14. A charged particle with a charge of 2 C moves at 3 m/s perpendicular to a magnetic field of 0.01 T. Calculate the magnetic force on the particle. **Answer: $F = qvB = 0.06N$**

15. A proton moves through a magnetic field at a right angle, experiencing a force. Meanwhile, two parallel wires carrying currents attract each other.

- a. State the Lorentz force law and explain the force on a moving charged particle in a magnetic field. **Lorentz Force Law: $\vec{F} = q\vec{v} \times \vec{B}$ Force acts perpendicular to velocity and field.**
- b. Use Fleming's left-hand rule to determine the direction of force on the proton.

Thumb: Force

Index: Field

Middle: Current

- c. Derive the expression for the force per unit length between two current-carrying conductors and discuss the conditions for attraction and repulsion.

$$\text{Answer: } \frac{F}{L} = \frac{(\mu_0 I_1 I_2)}{2\pi d}$$

Attraction: Currents in the same direction.

Repulsion: Opposite directions.



Points to Remember

- Magnetism is the study of physical phenomenon that includes forces exerted by magnets. It is the study of magnet and its properties on another object.
- Magnet is a piece of material that attracts some metals by magnetism.
- Types of magnet are permanent magnet and temporarily magnet
- Methods of magnetization are magnetization by stroking, magnetization by induction, by electricity
- Methods of demagnetization: by hammering, by heating, by electricity, by induction.

- Materials can be classified as belonging to one of three categories, depending on their magnetic properties. Ferromagnetic, Paramagnetic and diamagnetic materials.
- A basic law of magnetism states that unlike poles attract each other and like poles repel.
- Ampere's law states that: "The magnetic field created by an electric current is proportional to the size of that electric current with a constant of proportionality equal to the permeability of free space.
- An electromagnet is a type of magnet in which the magnetic field is produced by an electric current. Electromagnets usually consist of wire wound into a coil.
- Electromagnetic is applied in the manufacture of electric bells, Headphones and loudspeakers, tape recorders, hard discs, etc...
- Instrument used to measure magnetic field are magnetic needle, tesla meter and magnetometer
- The Lorentz force law states that a magnetic field exerts a force on a moving ionic current. The hall effect further states that when a magnetic field is placed perpendicular to the direction of flow of an electric current, it will tend to deflect and separate the charged ions.
- The force exerted on a charged particle q moving with velocity v through an electric field E and magnetic field B . The entire electromagnetic force F on the charged particle is called Lorentz force (after the Dutch physicist Hendrick A. Lorentz) and is given by $F=qE+qV*B$, (E is electric field, q is charge, V is potential difference and B is magnetic field).
- Fleming's left-hand rule states that if we stretch the thumb, middle finger and the index finger of the left hand in such a way that they make an angle of 90° and the conductor placed in the magnetic field experiences magnetic force.
- Force between two parallel current-carrying conductors- definition of ampere. By Fleming's left-hand rule, this force acts towards right. Hence, two parallel wires carrying currents in the same direction attract each other and if they carry currents in the opposite direction, repel each other.

- Application of magnetic forces are applicable in electric motor, loudspeaker, charge deflection systems and so on.



Self-Reflection

1. Ask learners to retake the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to Identify their areas of strength, areas for improvement, and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).



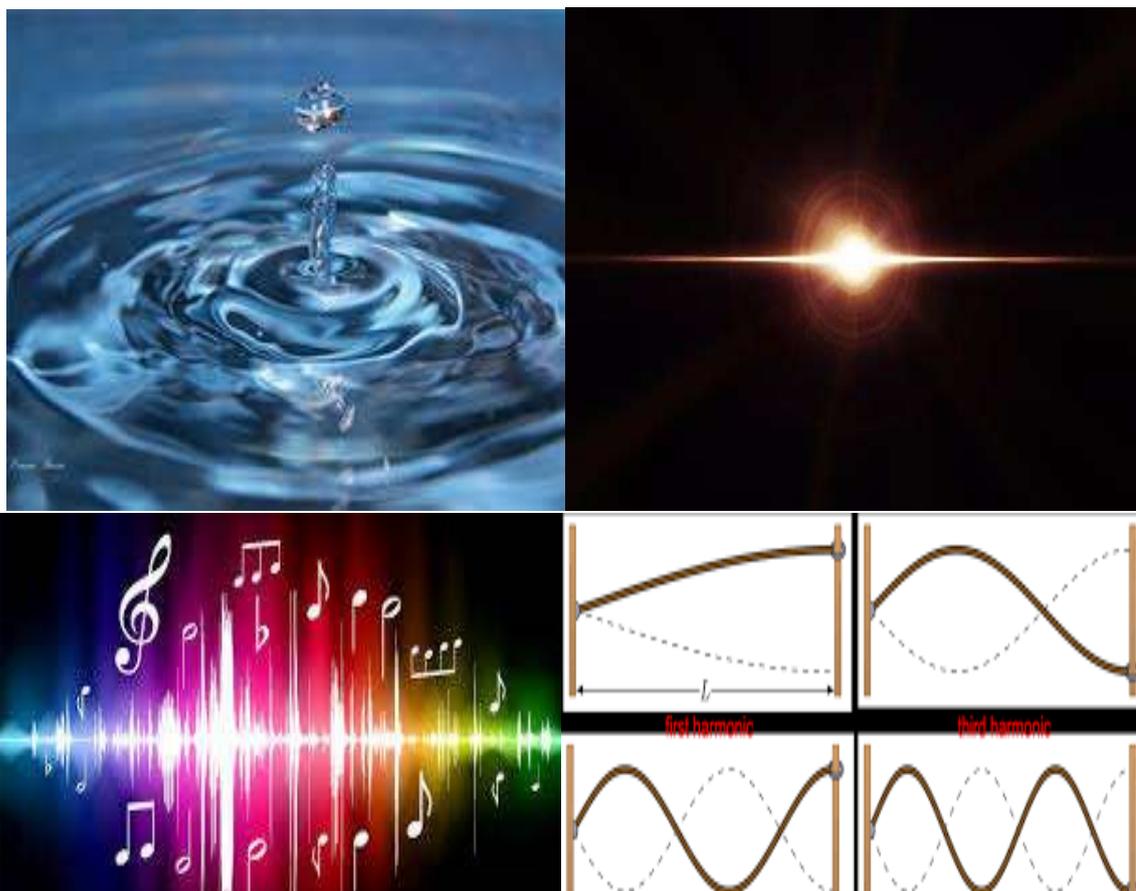
Further Information for the Trainer

1. As a trainer, do further research about the effects of magnetism.³
2. Where possible, use video tutorials to help learners increase knowledge, skills, and attitudes about the effects of magnetism.⁴
3. Conduct field trips where possible to get more experience in the application of magnetism.
4. The provided formative assessment is a sample; trainers may modify it within the same scope. Facilitation techniques can vary based on class size, trainee background, available resources, and time.

³ Physics for Rwandan Schools Learners book senior two

⁴ <https://www.youtube.com/shorts/NqvQluAMq8I>

LEARNING OUTCOME 3: DESCRIBE VIBRATIONS AND WAVES



Learning outcome 3: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
 - a. What does the illustration show?
 - b. What do you think will be topics to be covered under this unit based on the illustration?
2. After the discussion, inform students that this unit is intended to provide them with the knowledge, skills, and attitudes to describe vibrations and waves. They will cover the concept of waves, the Nature of Sound, and the nature of light.
3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:
 - a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.
 - b. There are no right or wrong ways to answer this assessment. It is for their reference and self-reflection on the knowledge, skills, and attitudes acquired during the learning process.
 - c. They should think about themselves: do they think they have the knowledge, skills, or attitudes to do this? How well?
 - d. They read the statements across the top and put a check in the column that best represents their level of knowledge, skills, or attitudes.
 - e. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement, and actions to be taken.



Key Competencies:

Knowledge	Skills	Attitudes
1. Define some Wave terminologies	1. Use wave terminologies to differentiate waves	1. Respect wave terminologies for categorizing different waves
2. Classify the wave types	2. Use wave types to classify waves from different sources	2. Avoid confusing the wave types
3. Describe Properties of waves	3. Apply wave properties formula to get wavelength, frequency, amplitude and period of a given wave	3. Be careful to use different formula by avoiding mistakes
4. Describe the Sound characteristics	4. Use sound characteristics to differentiate loudness and intensity of sound wave	4. Follow the sound characteristics to differentiate loudness and intensity of sound wave



Steps:



Discovery Activity

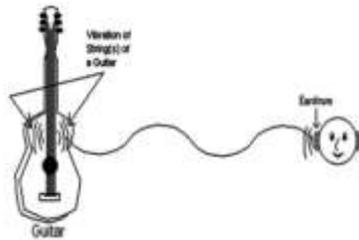


Task 21

1. Using the interactive discussion, guide trainees to brainstorm and share views about the picture under Task 21 in their Trainee's manual and ask them to answer related questions.

Make sure instructions are understood, all the students are actively participating, and the necessary materials/tools are given.

Look at the illustrations below and answer the related questions:



- a. What do you think these pictures illustrate?
 - b. Describe the situation that happened to the human ear's eardrum on the picture.
 - c. Explain the medium used between guitar and eardrum.
2. Encourage all trainees to give their views.
 3. After the sharing session, inform students that this activity was not intended for them to give the right answers but to give them a picture of what they will cover in the unit.
 4. Using their answers, lead them to the topic 3.1: Concepts of waves.

Topic 3.1: Explanation of concepts of waves

	Objectives: By the end of the topic, trainees will be able to: <ol style="list-style-type: none">Classify properly waves based on the medium of propagation.Explain correctly the concept of waves according to the vibrationsIdentify the main components of the electromagnetic spectrum
	Time Required: 4 hours
	Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion and Research.
	Materials, Tools, and Equipment Needed: PPE, whiteboard, chalkboard, computer, projector, textbooks, chinks, markers, scientific calculator.
	Preparation: <ul style="list-style-type: none"><input type="checkbox"/> Prepare the materials for producing the sound waves<input type="checkbox"/> Prepare the smart phones, computers for video and image playing<input type="checkbox"/> Prepare the flip charts, chalk, and marker pens.
	Cross-Cutting Issues: <ul style="list-style-type: none">✓ Promote equal participation with mixed-gender teams for wave experiments.✓ Discuss wave propagation in spreading peace and understanding.✓ Design activities that accommodate all learners, including those with disabilities.
	Prerequisites: <ul style="list-style-type: none">✓ Knowledge of algebraic manipulation.✓ Familiarity with graphs of sine and cosine functions.✓ Familiarity with velocity and acceleration.



Activity 1: Problem-Solving



Task 22

1. Using small group discussions, ask learners to answer the questions provided under task 22 in their trainee's manuals. Make sure instructions are understood, all the students are actively participating, and necessary materials/tools are provided and being used.

Question: You are a scientist working at a science fair. You are tasked with explaining and solving problems related to waves to both students and visitors. At your station, you demonstrate water waves in a tank, sound waves using a tuning fork, and light waves with a prism. Each wave has unique properties that visitors are curious about. A mechanical wave in the water tank travels at a speed of 2 m/s. The distance between successive crests (wavelength) is 0.5 m, and the amplitude of the wave is 0.3 m. Sketch a sine wave representing this water wave, labeling the crests, troughs, wavelength, and amplitude, and then Calculate the frequency of the wave.

2. After the sharing session, to gain a more thorough understanding and address any uncertainties, take time to carefully read and review Key Fact 3.1, as it provides additional explanations and clarifications that will help deepen your comprehension of the topic being discussed.



Activity 2: Guided Practice



Task 23

1. Using the appropriate methodology such as individual work, small group discussions, trainer guided method, guide trainees to solve wave-related problems as provided under task 23 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Problem 1: A wave traveling along a rope is represented as a sine wave on a graph. The distance between two consecutive crests is 2 meters, and the wave completes 5 oscillations per second. If the amplitude of the wave is 0.5 meters, calculate:

- The wavelength,
- The frequency,
- The period, and
- The wave speed.
- Additionally, explain the difference between transverse and longitudinal waves, using this rope wave as an example.

Answer:

- Wavelength:** The wavelength is the distance between two consecutive crests, which is 2 meters.
- Frequency:** The frequency is the number of oscillations per second, which is 5 Hz.
- Period:** The period is the reciprocal of the frequency: $T = \frac{1}{f} = 0.2 \text{ seconds}$
- Wave speed:** The wave speed is given by the formula: $v = f \times \lambda = \frac{10m}{s}$
- Difference between transverse and longitudinal waves:** A wave on a rope is a transverse wave because the particles of the rope move perpendicular to the direction of wave travel. In contrast, a longitudinal wave (e.g., sound waves in air) has particles moving parallel to the wave's direction.

Problem 2: Electromagnetic waves are classified based on their wavelengths in the electromagnetic spectrum. Explain the relationship between wavelength, frequency, and wave speed for electromagnetic waves. If an electromagnetic wave has a frequency of $3 \times 10^9 \text{ Hz}$, calculate its wavelength. What makes electromagnetic waves different from mechanical waves?

Answer: Relationship between wavelength, frequency, and wave speed: For all electromagnetic waves, the speed (c) in a vacuum is approximately $3 \times 10^8 \text{ m/s}$. The relationship is given by: $v = f \times \lambda$, where f is the frequency and λ is the wavelength. By substitution in the formulae we get $\lambda = 0.1m$

Difference between electromagnetic and mechanical waves: Electromagnetic waves (e.g., light, radio waves) do not require a medium and can travel through a vacuum. Mechanical waves (e.g., sound, water waves) require a medium (solid, liquid, or gas) to propagate.

Electromagnetic waves' properties: They are transverse waves with oscillating electric and magnetic fields perpendicular to each other and the direction of wave propagation. Their speed in a vacuum is constant and does not depend on frequency or wavelength.

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in solving waves related problems. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to key fact 3.1 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 24

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

Scenario:

- A. As you walk along the shore, you notice the gentle waves lapping at your feet. These are surface waves, a type of mechanical wave that travels through the water. You can see the crests and troughs of the waves as they move towards the shore.

Response: You observe the rhythmic motion of the waves and notice how they change in size and speed as they approach the shore. You might even try to surf or swim, experiencing the energy of the waves firsthand

- B. You appreciate the vibrant colors of the beach, from the blue sky to the golden sand. You might take photos to capture the beautiful scenery, using the light waves to create images. How will you differ the colors around you?

Response: The bright sunlight shining down on the beach is made up of electromagnetic waves. These waves have different wavelengths, which correspond to the different colors of light. The visible light allows you to see the beautiful scenery around you.

- C. As the day comes to an end, the trainees gather to watch the sunset. They learn that the beautiful colors they see in the sky are due to the scattering of light waves.
- i. Discuss about how the earth's atmosphere scatters wavelength.
 - ii. In which colors the sky appeared during sunrise and sunset.

Solution:

- i. Scattering at Sunrise and Sunset: During sunrise and sunset, the sun is low on the horizon, and its light must pass through a larger thickness of the Earth's atmosphere. This increased distance causes more scattering of the shorter wavelengths (blue and violet), leaving the longer wavelengths (red, orange, and yellow) to dominate the sky's color.
 - ii. During sunrise and sunset, the sky appears in beautiful shades of red, orange, and yellow. This is because the longer path through the atmosphere scatters the shorter blue and violet wavelengths out of our line of sight, allowing the longer red and orange wavelengths to reach our eyes. The result is the stunning array of warm colors that we associate with these times of day.
2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Explanation of the concepts of waves
 3. Each trainee will perform the task individually
 4. Inform them that they should demonstrate positive attitude when performing task.
 5. After trainees has performed, you'll give them feedback
 6. At the end summarize the topic

Topic 3.2: Description of the nature of sound

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Describe clearly sound based on the wave natureAssess effectively the effects of sound wave interference, identifying constructive and destructive interference with examples.Define correctly the characteristics of sound waves based on wave nature
	<p>Time Required: 2 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion</p>
	<p>Materials, Tools, and Equipment Needed: PPE, whiteboard, chalkboard computer, projector, textbooks, chalk, markers, Scientific calculator, Tuning forks, Strings, Plastic or metal pipes, and Speakers.</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Ensure tuning forks, pipes, and strings are ready.<input type="checkbox"/> Arrange a room for group experiments.<input type="checkbox"/> Prepare guiding questions and challenges.
	<p>Cross-Cutting Issues:</p> <ul style="list-style-type: none">✓ Encourage male and female trainees to lead group activities.✓ Discuss its impact and ways to mitigate it.✓ Use diverse musical instruments and sounds.
	<p>Prerequisites:</p> <ul style="list-style-type: none">✓ Ability to define basic wave properties (frequency, amplitude, wavelength).✓ Basic measurement skills (length, time, and sound intensity).



Activity 1: Problem-Solving



Task 25

1. Using the trainer guided method, guide trainees to read the following scenario and answer the questions as provided under task 25 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used
2. Engage students in exploring sound properties and wave interference through a hands-on challenge that encourages creativity and collaboration in designing a unique musical performance.

Preparation Steps

- A. Materials Collection:
 - a. Gather everyday objects such as glass bottles, rubber bands, pots, pans, wooden spoons, and plastic containers.
 - b. Provide water, rulers, and string for adjusting pitch and resonance.
- B. Set Up Workstations:
 - a. Arrange materials in groups with enough space for experimentation.
 - b. Provide additional items like mallets or sticks for striking objects.
- C. Prepare Demonstrations:
 - a. Demonstrate how to change pitch by filling bottles with varying levels of water.
 - b. Show how to create tension in rubber bands to adjust pitch.
- D. Develop Guiding Questions:
 - a. What happens when you strike a pot versus a pan?
 - b. How can you make two sounds cancel each other out?
 - c. What combinations of objects create the most pleasing or interesting sounds?
- E. Review sound properties (pitch, volume, resonance, interference) to guide discussions.

Activity Plan

A. Challenge Prompt (10 minutes)

a. Introduce the scenario:

Your task is to create a unique musical performance using everyday objects. Think about how to produce sounds that are loud, soft, high-pitched, or low-pitched. Experiment to see how sounds interact. Can you make them louder together or cancel each other out?

b. Provide initial demonstrations to spark ideas, such as:

- i. Filling bottles with water to change pitch.
- ii. Using rubber bands of different lengths and tensions.
- iii. Striking pots and pans to produce varying tones.

B. Group Experimentation (20–25 minutes)

a. Divide the class into small groups, each with a variety of objects.

b. Encourage students to explore and document:

- i. How to adjust pitch (e.g., water levels, rubber band tension).
- ii. How to increase or decrease loudness (e.g., striking harder or softer).
- iii. Examples of constructive and destructive interference by combining sounds.

C. Sharing and Discussion (15 minutes)

a. Groups present their findings, demonstrating:

- i. How they created a range of sounds.
- ii. Examples of interference (sounds combining or canceling out).

b. Trainer facilitates discussion:

- i. What worked well in creating high-pitched or low-pitched sounds?
- ii. How did you control the loudness of your sounds?
- iii. What surprised you about sound interactions?

D. Musical Composition (20 minutes)

a. Groups use their discoveries to arrange a short musical piece.

b. Encourage creativity in combining sounds to create rhythm and melody.

c. Performances can include:

- i. Demonstrating interference patterns for dramatic effect.

- ii. Alternating between loud and soft dynamics.

E. Summarize key points:

- a. Pitch depends on frequency and can be adjusted by tension, length, or material.
 - b. Loudness depends on amplitude and striking force.
 - c. Sounds interact through constructive (louder) and destructive (cancel out) interference.
3. Encourage students to think outside the box when creating sounds. Ensure all students actively participate and contribute to their group's performance. Use recyclable or reusable materials to highlight sustainable practices.
4. After the sharing session, refer trainees to Key facts 3.2 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions, they have.



Activity 2: Guided Practice



Task 26

1. Individually, ask learners to perform the following task as provided under task 26 in their trainee's manuals. Make sure instructions are understood all the students are actively participating, and necessary materials/tools are provided and being used.
2. Provide to the trainees, simple materials like rubber bands, bottles, and straws to create their instruments.
3. Ask trainees to perform the following in their respective groups:
 - a. Use straws to make flutes, rubber bands to make string instruments, and bottles to create percussion instruments.
 - b. Change the length of the straw or the tension of the rubber band to see how it affects the pitch of the sound.
 - c. Strike the bottles with different levels of force to observe how it changes the loudness.
 - d. Play two homemade instruments together and listen for interference or harmony. Discuss how musicians can use these effects to create beautiful music.

Answers to the Activity Observations:

Step 1: Building the Instruments

- a. **Flutes (Straws):** Shorter straws produce higher-pitched sounds because the air column is smaller, resulting in higher-frequency vibrations.
- b. **String Instruments (Rubber Bands):** Rubber bands with higher tension or thinner bands produce higher-pitched sounds because they vibrate faster. Looser or thicker rubber bands produce lower-pitched sounds due to slower vibrations.
- c. **Percussion Instruments (Bottles):** Bottles with more water produce lower-pitched sounds because the air column above the water is shorter. Bottles with less water produce higher-pitched sounds due to a longer air column. Striking the bottles with greater force creates louder sounds, as more energy is transferred into the vibration.

Step 2: Experimenting with Sound

- a. **Effect of Length and Tension on Pitch:** Shorter straws and tighter rubber bands increase pitch, while longer straws and looser bands lower pitch. This demonstrates how the frequency of vibration affects the sound's pitch.
- b. **Effect of Force on Loudness:** Greater striking force increases loudness because more energy is imparted to the vibrating object. Softer strikes produce quieter sounds as less energy is transferred.

Step 3: Creating Musical Interactions

- a. **Playing Together:** When two instruments are played together, interference patterns may be heard:
 - ✓ **Constructive interference:** When sound waves align, resulting in a louder, harmonious sound.
 - ✓ **Destructive interference:** When sound waves are out of phase, leading to quieter or clashing sounds.
- b. Harmony is achieved when the frequencies complement each other, while dissonance occurs when they do not.

Discussion Outcome:

- ✓ Musicians use these principles to create different musical effects, such as chords (harmony) and dynamic variations (loudness and pitch changes).
 - ✓ The activity reinforces the relationship between the physical properties of materials and the sound they produce.
4. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in Description of the nature of sound. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
 5. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
 6. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
 7. After the sharing session, refer trainees to key fact 3.2 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 27

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

Scenario:

You are at a concert, and the music sounds amazing. But sometimes, when two instruments play together, the sound becomes louder, softer, or even strange. Can you guess why this happens? What makes the sound from different instruments unique? Let's explore what causes these effects in sound waves and how musical instruments produce such beautiful sounds.

Answer:

- a. Why does the sound become louder, softer, or strange when two instruments play together?

Answer: This happens because of interference between sound waves. Sound waves are vibrations traveling through the air, and when two waves meet, they combine in different ways:

- i. **Constructive Interference:** When the peaks (compressions) of one wave align with the peaks of another, they amplify each other, making the sound louder.
- ii. **Destructive Interference:** When the peaks of one wave align with the troughs (rarefactions) of another, they cancel each other out partially or completely, making the sound softer or creating a strange effect.

This combination of sound waves creates patterns called beats when the frequencies are close but not identical, giving rise to a "wobbling" or pulsating sound.

What makes the sound from different instruments unique?

- b. The uniqueness of sound from each instrument is due to its timbre or tone quality. Timbre is influenced by:

- i. **Overtones/Harmonics:** Each instrument produces a fundamental frequency (the main pitch) and additional frequencies called overtones or harmonics. The specific mix of these harmonics creates the instrument's characteristic sound. For example, a violin and a flute playing the same note will sound different because their harmonic structures differ.
- ii. **Material and Shape:** The material (wood, metal, etc.) and shape of the instrument affect how sound waves resonate, further shaping the timbre.
- iii. **Attack and Decay:** How quickly a note starts (attack) and fades away (decay) also contributes to the instrument's distinct sound.

- c. How do musical instruments produce beautiful sounds?

Musical instruments produce sound through vibrations:

- i. **Strings (e.g., guitar, violin):** Vibrating strings transfer energy to the instrument's body, amplifying the sound.
- ii. **Wind (e.g., flute, trumpet):** Air columns vibrate inside the instrument, creating sound. The pitch depends on the length of the air column.

- iii. **Percussion (e.g., drums, xylophone):** Striking a surface causes it to vibrate, producing sound.
- iv. **Electronic (e.g., synthesizers):** Sounds are generated using electrical signals and manipulated digitally.

In a concert, the combination of these diverse timbres and the interaction of sound waves can create a rich, immersive experience—or occasional peculiar effects!

2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Description of the Nature of sound
3. Each trainee will perform the task individually
4. Inform them that they should demonstrate positive attitude when performing task.
5. After trainees has performed, you'll give them feedback
6. At the end summarize the topic

Topic 3.3: Description of the nature of light

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Describe clearly light based on the wave natureExplain correctly selective reflection and transmission with examples of colored objects.Define the nature of color and its dependence on light and perception.
	<p>Time Required: 2 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion</p>
	<p>Materials, Tools, and Equipment Needed: PPE, whiteboard, chalkboard computer, projector, textbooks, chalk, markers, Scientific calculator, Glass prism, Flashlight, Colored filters, White paper, Mirrors, and black surfaces.</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Gather and test all materials to ensure they work (e.g., light source, prism).<input type="checkbox"/> Prepare a simple diagram or visual aid to explain light dispersion and selective reflection.<input type="checkbox"/> Familiarize yourself with common misconceptions about light and color to address them effectively.
	<p>Cross-Cutting Issues:</p> <ul style="list-style-type: none">✓ Ensure all trainees have equal opportunities to participate in hands-on activities.✓ Highlight the role of light and color in understanding natural phenomena, such as rainbows and plant growth.
	<p>Prerequisites:</p> <ul style="list-style-type: none">✓ Basic knowledge of light as a wave and its interaction with objects.✓ Observation skills to analyze light and color phenomena.✓ Collaboration skills for group experiments.



Activity 1: Problem-Solving



Task 28

1. Using the appropriate methodology such as pair-share, group discussions (manageable groups), guide trainees to read the following scenario and answer the questions as provided under task 28 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being use

Scenario:

The school is preparing for a science fair, and the students are working on a colorful art installation using glass prisms, colored lights, and painted materials. One day, the teacher notices a problem and asks the students: “Something strange is happening with our display. When we shine white light through the prisms, we see beautiful rainbows. But when we use colored lights, some colors disappear, and others change completely! On top of that, certain painted surfaces look different under different lights. Can you figure out what’s going on? Let’s solve this mystery together”

2. Engage students in a collaborative exploration of the observed phenomena and guide them toward understanding the science behind light, prisms, and color perception.
 - A. Stimulate Curiosity by asking open-ended questions to prompt initial thoughts:
 - a. What do you already know about how light behaves?
 - b. What might cause colors to disappear or change?
 - B. Distribute a worksheet or share questions to guide their discussion:
 - a. What happens to white light when it passes through a prism?
 - b. What happens when colored light passes through a prism?
 - c. How do painted surfaces interact with different colors of light?
 - C. Allow groups to:
 - a. Shine white and colored lights through prisms and observe the outcomes.
 - b. Illuminate painted surfaces with different colored lights and note the changes.
 - D. Move between groups, listen to discussions, and provide hints if necessary. Encourage students to link their observations to their prior knowledge of light and color.

- E. Ask probing questions:
 - a. What patterns do you notice?
 - b. Can you explain why certain colors disappear or change?
 - F. Each group presents their findings and explanations to the class. As a class, discuss the results and clarify misconceptions:
 - a. White light contains all colors, which are separated by the prism due to dispersion.
 - b. Colored lights consist of specific wavelengths, so only those colors are refracted.
 - c. Painted materials reflect some colors and absorb others, appearing differently under various lights.
 - G. Summarize Key Concepts
 - a. Dispersion creates rainbows.
 - b. Colored light limits the spectrum observed.
 - c. Perception of painted surfaces depends on light sources.
 - H. Encourage Reflection
 - a. How does understanding light and color help us design better displays?
 - b. What new questions do you have about light and color?
3. Instruct the trainees to carefully review Key Fact 3.3, as it provides additional explanations and clarifications on the subject matter.



Activity 2: Guided Practice



Task 29

1. Using the appropriate methodology such as individual work, pair-share, small group discussions, trainer guided discussions, guide trainees to identifying the nature of light as provided under task 29 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Question 1: A beam of white light passes through a triangular glass prism. The light emerges as a spectrum, showing different colors. This phenomenon is known as dispersion. Why does each color in the spectrum bend by a different amount as it passes through the prism?

Answer: Each color in the spectrum bends by a different amount because the refractive index of the prism material varies with the wavelength of the light. Shorter wavelengths (like violet) refract more than longer wavelengths (like red) due to their interaction with the material's atomic structure, leading to dispersion. This causes the white light to spread out into its component colors.

Question 2: In a colored filter, certain colors of light are transmitted while others are absorbed. This selective transmission is responsible for the color of the filter. How does selective reflection relate to the color of an object?

Answer: Selective reflection occurs when a surface reflects certain wavelengths (colors) of light while absorbing others. The color of the object is determined by the wavelengths that are reflected. For example, a red apple reflects red light and absorbs other colors, giving it the appearance of being red. Selective transmission and reflection both rely on the interaction of light with the material's properties to determine the observed color.

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in identifying the nature of light. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to key fact 3.3 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 30

1. Ask trainees to perform the activities provided in their trainee's manuals as described below:

Activity 1: Shine white light through a prism and observe the dispersion of light into a spectrum of colors. Why does white light split into a rainbow of colors? What does this tell us about the nature of color? Allow each group to conduct the activity and note their observations. Encourage groups to share ideas about why the prism splits the light into colors. Prompt them to consider how light bends (refracts) differently based on wavelength.

Answer: Help students conclude that white light splits into a rainbow of colors because it is composed of multiple wavelengths, each corresponding to a different color. When light passes through a prism, it refracts (bends) due to a change in speed as it moves from one medium (air) to another (glass). Each color bends by a different amount because shorter wavelengths (like violet) refract more than longer wavelengths (like red). This phenomenon demonstrates that color is a property of light determined by its wavelength.

Activity 2: Ask trainees to shine red and blue lights through the same prism. Why don't we see a full rainbow with colored light? Have groups test red and blue lights and discuss their observations. Ask, What's different about red and blue light compared to white light?

Answer: When only red or blue light passes through the prism, we do not see a full rainbow because these lights consist of a single wavelength or a narrow range of wavelengths. Unlike white light, which is a mixture of all visible wavelengths, a single-wavelength light cannot disperse into multiple colors. Instead, the prism bends this light by an angle determined by its wavelength, producing only the original color.

Activity 3: Shine white light on a red object and observe that it appears red. Then, shine blue light on the same object. Why does the red object look dark or black under blue light? What does this tell us about how objects reflect certain colors? Let groups perform the activity with both light sources. Ask why the object appears red under white light but dark under blue light. To encourage the trainees

Answer: A red object appears red under white light because it reflects the red wavelengths of light and absorbs all other colors. When blue light shines on the red object, there is no red wavelength present for the object to reflect. Instead, it absorbs the blue light, making it appear dark or black. This demonstrates that objects appear colored based on the wavelengths they reflect and absorb, and the perceived color depends on the light illuminating the object.

Activity 4: Use colored filters (e.g., red, green, and blue) and shine white light through them. Why does the filter let only certain colors pass through? How does this affect the light that reaches our eyes? Let groups experiment with each filter and observe. Ask trainees to note the light passing through the filters and ask them why we see only certain colors.

Answer: A colored filter works by absorbing certain wavelengths of light and allowing others to pass through. For example, a red filter absorbs most wavelengths except for red, which it transmits. This selective transmission alters the composition of light that reaches our eyes, causing us to perceive the color of the filter. The filter effectively removes all other colors from the white light, emphasizing the color it transmits.

2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Description of the nature of light
3. Each trainee will perform the task individually
4. Inform them that they should demonstrate positive attitude when performing task.
5. After trainees has performed, you'll give them feedback
6. At the end summarize the topic



Formative Assessment on Learning Outcome 3

Read carefully and answer the following questions

1. A common source of wave motion is
 - a. **Wave pattern**
 - b. Harmonic object
 - c. Vibrating object
 - d. Region of variable high- and low-pressure
2. Match each term to the correct definition.

Column A	Column B
1. Crest	a. The lowest point of the wave.
2. Through	b. The distance between two successive crests or troughs.
3. Wavelength	c. The highest point of the wave.
4. Amplitude	d. The number of waves that pass a given point per second.
5. Frequency	e. The height of the wave from the rest position to the crest.

Answers:

1. **Crest**..... d
2. **Through**..... a
3. **Wavelength**..... b
4. **Amplitude**..... e
5. **Frequency** c

3. Match the types of waves with their characteristics

Types of waves	Characteristics of wave
1. Transverse wave	A. Can travel through a vacuum; does not require a medium.
2. Longitudinal wave	B. Particles move parallel to the direction of the wave. Combination of transverse and longitudinal wave motions.
3. Electromagnetic wave	C. Particles move perpendicular to the direction of the wave.

Answers:

- 1. Transverse wave..... C
- 2. Longitudinal wave..... B
- 3. Electromagnetic wave.....A

4. Fill in the blanks with the appropriate terms.

- a. The _____ is the number of waves that pass a point in one second.
- b. The _____ of a wave is the distance between two successive crests or troughs.
- c. Waves travel faster in a _____ medium compared to a _____ medium.

Solution:

- a. **Frequency**
- b. **Amplitude**
- c. **Denser medium, less dense**

5. Why are sound waves called longitudinal waves? **Answer: The air particles vibrate parallel to the direction of propagation.**

6. What determines the "loudness" of a musical note? **Answer: Amplitude**

7. How do you call the time for one cycle of a periodic process and the number of cycles per unit time?

- ✓ **The time for one cycle is called the period (T).**
- ✓ **The number of cycles per unit of time is called the frequency (f).**

8. A mass is attached to a vertical spring and bobs up and down between points A and B. Where is the mass located when its kinetic energy is a minimum?

- ✓ **The kinetic energy is minimum at points A and B, where the mass momentarily stops before changing direction.**

9. What do all electromagnetic waves have in common?

- ✓ **All electromagnetic waves travel at the speed of light in a vacuum and do not require a medium to propagate.**

10. How are electromagnetic waves different from mechanical waves?

- ✓ **Electromagnetic waves can travel through a vacuum, while mechanical waves require a medium (e.g., air, water).**

11. What is the period of a wave that travels through a spring at 2.5 m/s and has a wavelength of 1.3 meters?

- ✓ **Use the formulae: $T = \frac{\lambda}{v}$**

12. A wave travels at 10 m/s. If the wavelength is 10m, what are the frequency and period of the wave?

- ✓ **Use formula for frequency $f = \frac{v}{\lambda}$**

13. A sound wave produced by a clock 515 m away is heard 1.5 sec later.

a. What is the speed of sound in the air?

- ✓ **Use formulae $v = \frac{d}{t} = \frac{515m}{1.5s} = 343.33m/s$**

b. The sound wave has a frequency of 426 Hz, what is the wavelength?

- ✓ **Use formulae $f = \frac{v}{\lambda}$**



Points to Remember

- A wave is a disturbance that occurs in a material medium and such process, energy is transferred from one place to another.
- Sound is a type of wave that moves through matter and then vibrates our eardrums and we hear.
- Light is a special kind of wave that is made up of photons that help us to see. You can drop a rock into a pond and see wave formation in the water. We even use waves (microwaves) to cook our food fast.
- The period (T) of the wave is the time it takes for one complete vibration of the wave. It is also defined as the time taken between two successive wave crests or troughs. It is measured in seconds (s).
- The frequency f is the number of wavelengths that pass a point in space in one second. It can be defined as the number of complete oscillations or vibrations per second. Its SI unit is hertz (Hz).
- The wavelength (λ) is the horizontal distance in space between the two nearest points that are oscillating in phase. Its SI unit is metre (m).
- The wave speed v is the speed at which the wave advances. Its SI unit is m/s.
- Amplitude is defined as the maximum distance measured from equilibrium position (mean position). The amplitude is always taken as positive and is measured in meters.
- A crest is a point on a surface wave where the displacement of the medium is at a maximum.
- Constructive interference occurs when the wave amplitudes reinforce each other, building a wave of even greater amplitude.
- Destructive interference occurs when the wave amplitudes oppose each other, resulting in waves of reduced amplitude.



Self-Reflection

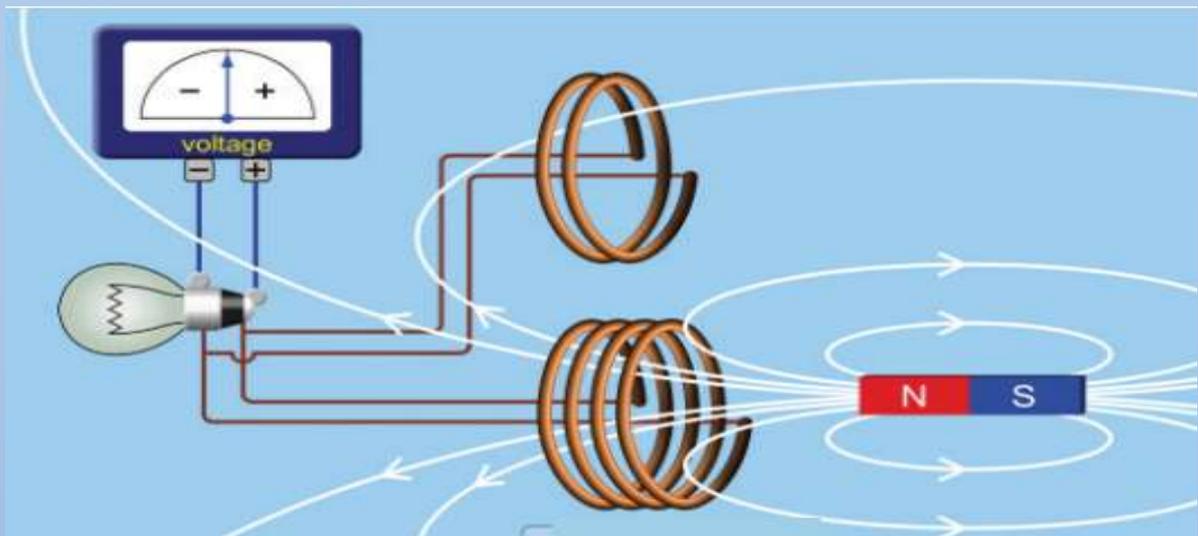
1. Ask learners to retake the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to Identify their areas of strength, areas for improvement, and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).



Further Information for the Trainer

1. During group discussions, the trainer monitors all groups and provides only clarifications/assistance when necessary. During problem-solving, it is better to use group discussion to facilitate group members thinking critically on facts linking them to real situations.
2. During discovery, it could be better if the teacher used brainstorming to consider the time allocation for the activity.
3. The trainer must vary the techniques depending on the class size, learners' prerequisites, and situation.
4. The assessment is given as a sample; the trainer can expand or change it but within the same scope.

LEARNING OUTCOME4: APPLY THE CONCEPTS OF ELECTROMAGNETIC FIELD



Learning outcome 4: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
 - a. What does the illustration show?
 - b. What do you think will be topics to be covered under this unit based on the illustration?
2. After the discussion, inform students that this unit is intended to provide them with the knowledge, skills, and attitudes to apply the concept of electromagnetic field. They will cover the induced emf in a circuit, the equation of propagation of electromagnetic waves, Categorization of mobile phone and radio communication.
3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:
 - a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.
 - b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?
 - d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.
 - e. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.



Key Competencies:

Knowledge	Skills	Attitudes
1. Understand the principle of electromagnetic induction.	1. Demonstrate how to induce current in a coil using a magnet.	1. Develop curiosity about how electromagnetic principles are applied.
2. Recognize the applications of EMI, such as transformers, generators, and induction cooking.	2. Apply the concept of EMI to solve real-life problems like determining the operation of generators or motors	2. Appreciate the role of EMI in modern life and its significance in technological advancement.
3. Identify the properties of electromagnetic waves, including their ability to propagate without a medium.	3. Analyze how electromagnetic waves are used in communication systems, such as cellular networks.	3. Cultivate a respectful attitude towards using communication technologies responsibly.
4. Explain the principle of cellular radio, the structure of cellular networks, and types of modulation (AM, FM, PM).	4. Design or interpret basic communication systems, focusing on signal modulation.	4. Value the importance of efficient communication in fostering global connectivity.
5. Describe the evolution of communication systems, including post, telegraph, and telephone (PTT).	5. Compare different modulation types (AM, FM, PM) and choose suitable applications for each.	5. Show an open-mindedness to exploring how traditional communication systems paved the way for modern technologies



Steps:



Discovery Activity



Task 31

1. Using the interactive discussion or question and answer techniques, guide trainees to explore the topic by asking the above questions and share views about the scenario in Task 31 in their Trainee's manual. Make sure instructions are understood, all the students are actively participating and necessary materials/tools are given.

Scenario

Suppose you are in the countryside, far from the city. You notice someone setting up a small wind turbine next to a cabin. Nearby, there's an old radio and a mobile phone placed on the table. Suddenly, the wind picks up, spinning the turbine's blades, and the radio begins to play music from a distant station. At the same time, your phone buzzes with a notification. Curious, you begin to think: What might be happening inside the turbine to power the radio? How does the radio pick up signals from a station far away? What makes the phone capable of sending and receiving messages instantly? To explore this, ask trainees to answer the following questions:

- a. What do you think happens when a magnet moves near a coil of wire?
 - b. Can you name any device that might use this concept?
 - c. What comes to mind when you hear "electromagnetic waves"?
 - d. How do you think waves can carry signals like light or sound?
 - e. How do you think mobile phones send and receive signals?
 - f. What do you think is the role of radio towers in communication?
2. Encourage all trainees to give their views.
 3. After the sharing session, inform students that this activity was not intended for them to give the right answers but to give them a picture of what they will cover in the unit.
 4. Using their answers, lead them to the topic 4.1. Induced electromotive force.

Topic 4.1: Determination of the induced electromotive force

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Determine correctly induced electromotive force in a circuit based on Faraday's lawDescribe properly practical applications of electromagnetic induction as applied in generators and transformers.Calculate accurately the magnitude of induced emf in a conductor moving through a magnetic field.
	<p>Time Required: 4 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided and Group discussion</p>
	<p>Materials, Tools and Equipment Needed: Whiteboard, chalkboard, computer, projector, textbooks, Chalks, markers, Scientific calculator, magnets, Copper wire, bar magnets, nails, small light bulbs, batteries, and small motors.</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Perform all planned demonstrations beforehand to troubleshoot any issues.<input type="checkbox"/> Identify which experiments can be demonstrated using available materials and prepare step-by-step guides.<input type="checkbox"/> Create examples: Include real-life examples relevant to Rwanda, such as bicycle dynamos or mini-hydro generators.

Cross-Cutting Issues:



- ✓ Highlight renewable energy like hydropower and wind turbines in discussions on electromagnetic induction.
- ✓ Ensure equal participation of boys and girls in experiments and group leadership roles.
- ✓ Foster teamwork and respect during group activities and discussions.
- ✓ Adapt activities for all students, ensuring accessibility for those with disabilities.



Prerequisites:

- ✓ Understanding of magnetism, electric circuits, and current flow.
- ✓ Perform basic algebraic calculations related to emf.
- ✓ Manipulate simple tools and materials safely



Activity 1: Problem-Solving



Task 32

1. Using the trainer trainer-guided method, guide trainees to follow the steps below to answer questions under task 32 in their trainee's manual and refer to the given scenario. At the end of the discussion instruct the trainees to carefully review Key Fact 4.1, as it provides additional explanations and clarifications on the subject matter.

Scenario

You are an engineer tasked with designing a device that converts mechanical energy into electrical energy. To do this, you need to understand how changing a magnetic field can produce an electric current. Experiment with a simple setup to observe this phenomenon.

Steps

- ✓ Use a coil of wire, a magnet, and a sensitive ammeter or galvanometer.
- ✓ Connect the coil of wire to the ammeter or galvanometer and Move the magnet into and out of the coil.

- ✓ Hold the magnet stationary inside the coil and Move the magnet faster and then slower through the coil.
- ✓ Record Your Observations and Note any deflection on the ammeter.
- ✓ Describe what happens when the magnet moves at different speeds or remains stationary.

Answer the Questions Below:

- a. What happens to the ammeter reading when the magnet is moved into or out of the coil?
- b. Why does the ammeter not deflect when the magnet is stationary?
- c. How does the speed of the magnet's movement affect the ammeter reading?
- d. Predict what will happen if you increase the number of turns in the coil.

Tools Needed: A coil of wire (10–20 turns), A bar magnet, A sensitive ammeter or galvanometer, A notebook and pen for recording observations.

Answer: Step to follow to perform the scenario given

Step 1: Introduction (10 Minutes)

- a. Briefly introduce electromagnetic induction and Faraday's Law. Emphasize that a changing magnetic field induces an emf (electromotive force) in a conductor.
- b. Ask trainees to think about what happens when a magnet moves inside a coil of wire.
- c. Ask them, why might the magnet's speed affect the ammeter reading.

Step 2: Guided Experimentation (30 Minutes)

Demonstration by Trainer:

- a. Show the setup and demonstrate moving the magnet in and out of the coil slowly and quickly.
- b. Hold the magnet stationary inside the coil and ask trainees to predict the ammeter reading.

Trainee's Activity (Small Groups):

- a. Connect the coil to the ammeter or galvanometer.
- b. Move the magnet into the coil, out of the coil, and hold it stationary.
- c. Move the magnet faster and slower, noting differences in ammeter deflection.
- d. Record all observations in notebooks.

Step 3: Observation and Discussion (15 Minutes)

- a. Compare observations within groups.
- b. Discuss the following questions:
 - i. What happens to the ammeter reading when the magnet is moved into or out of the coil? **Answer: The ammeter deflects, indicating current is induced.**
 - ii. Why does the ammeter not deflect when the magnet is stationary? **Answer: There is no change in magnetic flux, so no emf is induced.**
 - iii. How does the speed of the magnet's movement affect the ammeter reading? **Answer: Faster movement induces a larger emf, causing a greater deflection.**
 - iv. Predict what will happen if you increase the number of turns in the coil. **Answer: Increasing the number of turns increases the induced emf and the ammeter deflection.**

Step 4: Application and Real-World Relevance (10 Minutes)

- a. Explain how this principle is used in electric generators to produce electricity.
- b. Discuss examples like wind turbines and hydroelectric generators.
- c. Ask trainees to brainstorm how they might improve the efficiency of the setup (e.g., more turns in the coil, stronger magnets).

Step 5: Assessment (10 Minutes)

Assessment:

- a. Ask trainees to summarize their observations and explain the relationship between magnetic flux changes and induced emf.
- b. Collect predictions and reasoning about increasing the coil turns.

Performance Evaluation:

- a. Observe group work during the experiment to assess teamwork and application of knowledge.
 - b. Evaluate the accuracy and depth of recorded observations.
2. Encourage all trainees to give their views by share their answers to the class and write their responses for reference.
 3. After the sharing session, refer trainees to Key facts 4.1 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions, they have.



Activity 2: Guided Practice



Task 33

1. Using the appropriate methodology such as individual work, pair-share, small group discussions, guided discussions or large group discussion, guide trainees to solve questions related to induced current as provided under task 33 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Question: A coil of 50 turns is placed in a magnetic field. The magnetic flux through the coil changes from 0.2 Wb to 0.05 Wb in 0.1 seconds.

- a. Calculate the induced emf in the coil.
- b. Determine whether the current induced in the circuit will oppose the change in flux (use Lenz's law to explain).

Response table

Steps	Details	Trainee response
Known values	Write the given data	
Formulae	Write the formulae of induced emf	
Substitution	Substitute the known values in the formulae	
Calculation	Perform the calculation step by step	
Interpretation	Explain the result and how it applies to the circuit's behavior	

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in solving problems related to the induced current. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to key fact 4.1 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 34

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

Scenario 1: You are riding a bicycle equipped with a small electric light powered by a dynamo. As you pedal, the light turns on. What is causing the light to turn on when you pedal? How does electromagnetic induction play a role in this process?

Answer:

- a. The light turns on because the dynamo converts the mechanical energy of pedaling into electrical energy. As the wheel spins, it drives the dynamo, generating electricity that powers the light.
- b. Electromagnetic induction occurs when a conductor moves through a magnetic field, causing a current to be induced in the conductor. In the dynamo, as the bicycle wheel spins, it rotates a coil of wire or a magnetic field inside the dynamo. This movement induces an electric current in the coil, providing power to the light.

Scenario 2: You place your phone on a wireless charging pad. After a few seconds, the phone begins charging without any physical connection to the pad. How does electromagnetic induction help charge the phone without wires?

Answer: The wireless charging pad contains a coil that generates a changing magnetic field when electricity flows through it. This magnetic field induces an electric current in a coil inside the phone, a process known as electromagnetic induction. The induced current is then converted into DC electricity, which charges the phone's battery.

2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Determination of the induced electromotive force
3. Each trainee will perform the task individually
4. Inform them that they should demonstrate positive attitude when performing task.
5. After trainees has performed, you'll give them feedback and at the end summarize the topic

Topic 4.2: Application of the equation of propagation of electromotive waves

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none"> Apply effectively the equation of propagation of electromagnetic waves based on mechanical waves Calculate correctly the wavelength, frequency, or speed of electromagnetic waves using the wave equation $v = f\lambda$ Identify properly the types of electromagnetic waves in the electromagnetic spectrum based on their applications.
	<p>Time Required: 3 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided and Group discussion</p>
	<p>Materials, Tools and Equipment Needed: Whiteboard, chalkboard, computer, projector, textbooks, Chalks, markers, Scientific calculator, bar magnets, a ruler.</p>
	<p>Preparation:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Create simple examples of calculations using the wave equation. <input type="checkbox"/> Develop step-by-step instructions for group or individual exercises. <input type="checkbox"/> Develop step-by-step instructions for group or individual exercises.
	<p>Cross Cutting Issues:</p> <ul style="list-style-type: none"> ✓ Highlight how electromagnetic waves enable solar panels and efficient communication systems for environmental conservation. ✓ Promote equal participation of boys and girls in calculations and experiments.
	<p>Prerequisites:</p> <ul style="list-style-type: none"> ✓ Understanding of multiplication, division, and simple algebra for calculations. ✓ Readiness to participate actively in discussions and activities.



Activity 1: Problem-Solving



Task 35

1. Using Demonstration and Simulation Method or Jigsaw Method, guide trainees to read the following scenario and answer the questions as provided under task 35 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used

Scenario

You're a member of a team designing a new communication device that can send signals over long distances. One day, while testing the device, you notice that the signal is weak, and you are not sure why. The signal is supposed to travel through the air without any problems, but something seems to be wrong. The project manager asks you: "Can you figure out what affects the strength and speed of our signal? What could be causing the weak signal, and how do we make it better?"

Approach 1: Demonstration and Simulation Method

Preparation:

A. Materials/Equipment:

- i. Diagrams or animations showing electromagnetic wave properties (speed, frequency, wavelength, amplitude).
- ii. Simulation software or online tools demonstrating signal propagation and attenuation (e.g., PhET simulations).
- iii. A physical or virtual spectrum analyzer to illustrate how signals behave across different frequencies.

B. Learning Goals:

- i. Understand how properties of electromagnetic waves influence signal strength and speed.
- ii. Identify factors causing weak signals in communication systems.
- iii. Propose solutions to improve signal transmission.

Steps:

A. Introduction (5 Minutes):

- i. Briefly explain the scenario and the importance of understanding wave properties in communication systems.
- ii. Pose the guiding question:
- iii. "What might cause weak signals, and how can we improve them using our knowledge of electromagnetic waves?"

B. Demonstration (15 Minutes):

- a. Wave Properties: Use a simulation or animation to demonstrate:
 - i. Speed: How electromagnetic waves travel at the speed of light in free space but slower in mediums like air or glass.
 - ii. Frequency and Wavelength: Show their inverse relationship and how they affect signal penetration and bandwidth.
 - iii. Amplitude: Demonstrate how higher amplitude correlates with stronger signals.
- b. Signal Behavior: Simulate how signals weaken due to:
 - i. Distance (attenuation).
 - ii. Interference from obstacles or overlapping frequencies.
 - iii. Atmospheric conditions (e.g., rain, fog).

C. Simulation Activity (20 Minutes):

- a. Trainee Task:
 - i. Use the simulation to experiment with different frequencies, amplitudes, and wavelengths.
 - ii. Observe how these changes impact signal strength and speed.
- b. Guiding Questions:
 - i. What happens to the signal when you increase the frequency?
 - ii. How does amplitude affect the clarity of the signal?

D. Discussion (10 Minutes):

- a. Debrief on observations and insights gained from the simulation.
- b. Relate findings to real-world examples (e.g., Wi-Fi signals, mobile networks).

Approach 1: Jigsaw Method

Preparation:**A. Divide the Topic into Subtopics:**

- i. Speed of electromagnetic waves and its dependence on the medium.
- ii. Frequency, wavelength, and their relationship to signal properties.
- iii. Amplitude and its impact on signal strength.
- iv. Types of electromagnetic waves and their roles in communication (radio waves, microwaves, etc.).
- v. External factors affecting signals (distance, interference, obstacles).

B. Learning Goals:

- ✓ Foster collaborative learning by having trainees teach each other.
- ✓ Develop a comprehensive understanding of wave properties and their influence on communication systems.

Steps:**A. Group Division (5 Minutes):**

- i. Divide trainees into expert groups (Ask trainees to count from 1 up to the number of subtopic) to form home groups
- ii. Ask those who counted the same number to join to form expert groups, with each expert group assigned a specific subtopic.

B. Expert Group Activity (15 Minutes):

- i. Each group researches and discusses their assigned subtopic using provided resources (diagrams, simulations, articles).
- ii. Prepare a summary or visual aid to explain their findings.

C. Teaching Phase (20 Minutes):

- i. Ask trainees to return to their home groups, with one member from each expert group in each home group.
- ii. Each trainee teaches their subtopic to the others in their home group starting for those who counted one.

- D. Whole-Class Discussion (10 Minutes): Discuss how the pieces fit together to address the scenario:
- Why might the signal be weak?
 - How do wave properties and external factors interact to affect communication?
 - Give more clarification on the topic.
- Encourage trainees to reflect on how these principles apply to real-world scenarios, such as designing better communication devices or troubleshooting existing systems.
 - Instruct the trainees to thoroughly read Key Fact 4.2, as it contains important details and further clarifications that will enhance their understanding of the topic.



Activity 2: Guided Practice



Task 36

- Using an appropriate methodology such as individual work, pair work or small group work, ask trainees to answer the given problems under task 36 in their trainee's manual. guide trainees to answer the questions as provided under task 36 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Problem 1: Calculate the wavelength of an electromagnetic wave with a frequency of $5 \times 10^{14} \text{ Hz}$.

Problem 2: Calculate the frequency of a wave with a wavelength of $2 \times 10^{-3} \text{ m}$.

Task	Given Information	Formula Used	Solution
Wavelength Calculation	$f = 5 \times 10^{14} \text{ Hz}$ $f = 3 \times 10^8 \text{ m/s}$	$c = \lambda f$	$\lambda = 600 \text{ nm}$
Frequency calculation	$\lambda = 0.002 \text{ m}$	$c = \lambda f$	$f = 1.5 \times 10^{11} \text{ Hz}$

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in solving problems. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to key fact 4.2 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 37

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

Scenario:

You are working at a mobile phone company. His team has just launched a new radio communication system that uses a specific frequency range for its operations. The system needs to be tested to ensure that the radio waves are operating within the designated frequency band.

- a. Identify the type of electromagnetic wave used for radio communication (based on the frequency range).
- b. Calculate the wavelength of a radio wave with a frequency of $9 \times 10^8 \text{ Hz}$.
- c. Discuss with your neighbor how the properties of the wave (wavelength, frequency) affect the signal transmission and communication quality.
- d. Link the wavelength and frequency to the potential range and effectiveness of mobile phone communication.

Answer:

a. Identify the Type of Electromagnetic Wave Used for Radio Communication

- i. The electromagnetic wave used for radio communication typically falls under the category of radio waves, which are part of the electromagnetic spectrum.
- ii. Radio waves operate in a frequency range of approximately 3 kHz to 300 GHz.
- iii. The frequency 9×10^8 Hz (900 MHz) lies in the UHF (Ultra High Frequency) range (300 MHz to 3 GHz), commonly used for mobile communication, TV broadcasting, and Wi-Fi.

b. Calculate the Wavelength of a Radio Wave with a Frequency of 9×10^8

The relationship between the speed of light c , wavelength λ , and frequency f is given by:

$c = f \cdot \lambda$, where: $c = 3 \times 10^8$ m/s (speed of light in a vacuum), $f = 9 \times 10^8$ Hz. Substitute the values:
Wavelength: 0.33 m (33 cm).

c. How Wavelength and Frequency Affect Signal Transmission and Communication Quality

i. Higher Frequency and Shorter Wavelength:

Advantages: Allows for higher data transmission rates and more bandwidth, crucial for mobile communication and modern systems like 4G and 5G. Improved resolution in applications like radar or GPS.

Disadvantages: Shorter wavelength signals are more susceptible to attenuation (loss of strength) due to obstacles like buildings, trees, or walls. Reduced range compared to lower-frequency signals.

ii. Lower Frequency and Longer Wavelength:

Advantages: Longer wavelengths can travel farther and penetrate obstacles more effectively. Suitable for long-range communication, such as AM/FM radio or maritime communication.

Disadvantages: Limited bandwidth and lower data rates, making it less ideal for modern, high-speed applications.

d. Linking Wavelength and Frequency to Range and Effectiveness of Mobile Phone Communication

Range: Longer wavelengths (lower frequencies) can travel greater distances and are less affected by terrain and obstacles, making them suitable for rural or wide-area coverage. Shorter wavelengths (higher frequencies) are better for urban and densely populated areas with higher traffic demand.

Effectiveness: Higher frequencies allow for better signal quality and higher data rates, essential for advanced services like video streaming and real-time communication. Lower frequencies are more effective for basic voice and text communication, especially in areas with poor signal penetration.

In mobile phone communication: Frequencies in the 900 MHz band (like 9×10^8 Hz) strike a balance, offering good range and reliable data transmission, making them ideal for widespread mobile network coverage.

2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Application of the equation of propagation of electromotive waves
3. Each trainee will perform the task individually
4. Inform them that they should demonstrate positive attitude when performing task.
5. After trainees has performed, you'll give them feedback
6. At the end summarize the topic

Topic 4.3: Categorization of mobile phone, radio communication

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Categorize efficiently mobile phone and radio communication in line with telecommunication systemsDefine effectively key terms in transmission systems as used in communicationExplain perfectly the differences between AM, FM, and PM modulations based on their practical applications.
	<p>Time Required: 3 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided and Group discussion</p>
	<p>Materials, Tools and Equipment Needed: Whiteboard, chalkboard, computer, projector, textbooks, Chalks, markers, Scientific calculator, magnets</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Research and Simplify Concepts<input type="checkbox"/> Prepare Visual Aids and Demonstrations<input type="checkbox"/> Adapt Content to Local Needs
	<p>Cross Cutting Issues:</p> <ul style="list-style-type: none">✓ Ensure that examples and case studies in the training are inclusive of both genders✓ Use examples of public health campaigns that utilize communication networks to spread awareness about HIV/AIDS, STIs, and family planning.✓ Include activities that show how communication systems can promote peace, resolve conflicts, and enhance mutual understanding.

**Prerequisites:**

- ✓ Familiarity with Communication Tools
- ✓ Teamwork and Curiosity
- ✓ Trainees should know the difference between sound, light, and electrical signals and how they can be transmitted over a distance.

**Activity 1: Problem-Solving****Task 38**

1. Using trainer guided method work, guide trainees to read the following scenario and answer the questions as provided under task 38 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used
2. Begin by reading the scenario aloud or asking a trainee to read it. Emphasize that the activity will help them understand and apply concepts of communication systems.

Scenario:

Florence is part of a team that is designing a new communication system for a company. Her task is to explain how the system works using the following terms: Transmitter, Channel, Receiver, Digital Communication, and Analog Communication. Imagine you are Florence, then perform the following tasks:

- a. Identify and define the role of each of the following components in the communication system.
- b. What is the function of the transmitter in the system?
- c. What is the channel, and what role does it play in transmitting the signal?
- d. How does the receiver work, and what is its function in receiving the signal?
- e. Determine whether the communication system in the scenario uses Digital Communication or Analog Communication. Explain the difference between the two and decide which one is more suitable for the system you're designing.

Answer:

- a. Identify and Define the Role of Each Component

Transmitter: Explain that it converts messages into signals suitable for transmission.

Channel: The medium (e.g., air, cables) through which the signal travels.

Receiver: Converts the transmitted signal back into a format understandable by the recipient.

Digital Communication: Encodes information as discrete signals (0s and 1s).

Analog Communication: Encodes information as continuous signals (e.g., radio waves).

- b. Transmitter's job is to take the input message (e.g., voice, text) and encode it into a signal that can travel through the channel.
- c. Channel acts as the pathway for the signal, addressing possible challenges such as interference or noise.
- d. The receiver decodes the transmitted signal into its original form and delivers it to the user.
- e. Explain the Difference:
- ✓ Digital Communication is more reliable, less prone to noise, and better for modern systems.
 - ✓ Analog Communication is continuous but more susceptible to interference.

Digital communication is likely more suitable for a modern company system due to its accuracy and adaptability.

3. Guide the trainees to carefully review Key Fact 4.3, as it offers essential details and explanations. This will help deepen their understanding of the topic.



Activity 2: Guided Practice



Task 39

1. Using an appropriate methodology such as pairs or small groups, guide trainees to read the given scenario and answer the related questions as they are provided under task 39 in their trainee's manual. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Scenario:

You are working in a mobile phone repair shop. A customer complains that their FM radio is not working properly. While checking the issue, you need to explain to the customer:

- a. The difference between AM and FM modulation.
- b. Why FM is better for music transmission.

Instructions:

- ✓ Write a short explanation of AM and FM modulation.
- ✓ Include why FM has better sound quality than AM.
- ✓ Create a simple diagram showing how a radio receiver processes a signal.

Explanation of AM and FM Modulation

a. Difference Between AM and FM Modulation

Amplitude Modulation (AM): In AM, the amplitude of the carrier wave varies according to the audio signal (message signal), while the frequency remains constant. AM is more susceptible to noise since noise primarily affects amplitude.

Frequency Modulation (FM): In FM, the frequency of the carrier wave varies according to the audio signal, while the amplitude remains constant. FM is less affected by noise since noise does not significantly impact frequency.

b. Why FM Is Better for Music Transmission

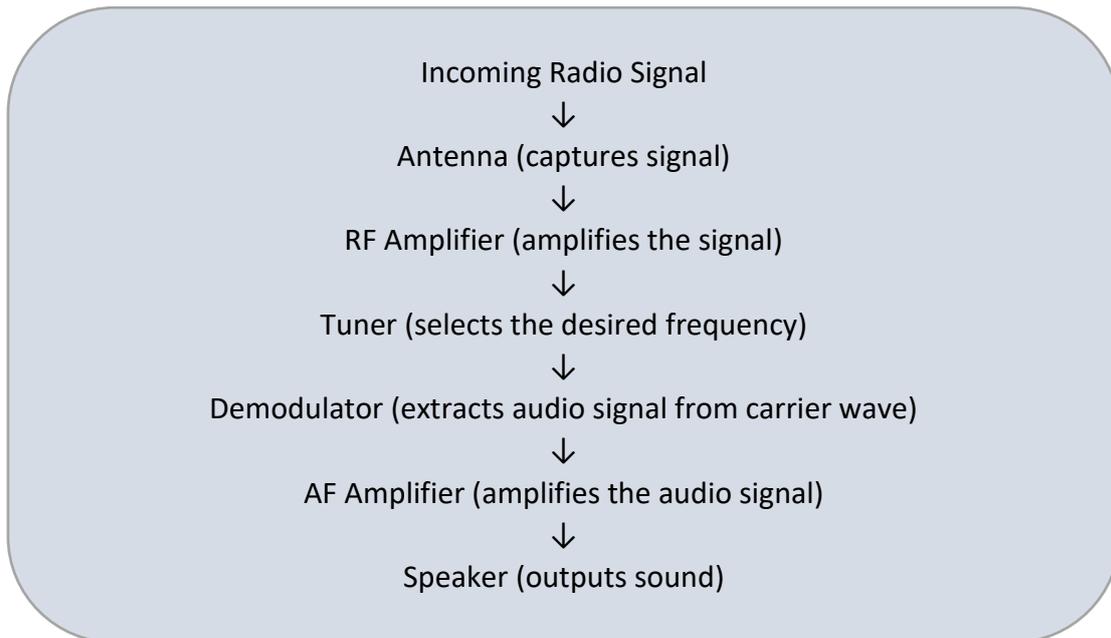
Sound Quality: FM provides higher fidelity and better sound quality due to its larger bandwidth (88–108 MHz). This allows for clearer transmission of music and complex audio signals.

Noise Resistance: FM is less prone to static and interference since it encodes information in frequency, which is not easily affected by environmental noise.

Stereo Sound: FM supports stereo transmission, enhancing the listening experience for music.

Diagram: How a Radio Receiver Processes a Signal

Here's a simple diagram to illustrate how a radio receiver works:



Explanation of Each Component:

- a. **Antenna:** Captures the electromagnetic waves transmitted by FM radio stations.
 - b. **RF Amplifier:** Boosts the weak radio signals to a level suitable for processing.
 - c. **Tuner:** Selects the specific frequency of the desired FM station.
 - d. **Demodulator:** Extracts the audio signal from the frequency-modulated carrier wave.
 - e. **AF Amplifier:** Amplifies the extracted audio signal to drive the speaker.
 - f. **Speaker:** Converts the electrical signal into sound.
2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in answering the questions. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.

3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to key fact 4.2 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 40

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

Scenario:

You are part of a team tasked with designing a simple communication system for a rural village. The system will include transmitting information (e.g., weather updates, community announcements), using cellular network principles, and considering traditional methods like post and telegraph for backup.

- a. Identify and explain the roles of the transmitter, channel, and receiver in the system.

Answer: Roles of Transmitter, Channel, and Receiver:

- ✓ Transmitter: Converts information (e.g., weather updates) into signals for transmission. In the system, this could be a local broadcasting tower or cellular base station.
- ✓ Channel: The medium through which signals travel, e.g., radio waves for cellular communication or physical lines for post/telegraph backups.
- ✓ Receiver: Converts received signals back into information for end-users, such as mobile devices or radios.

- b. Decide whether the system will use digital or analog communication and justify his/her choice.

Answer: Choice: Digital communication.

Justification:

- ✓ Higher efficiency and better signal quality over long distances.
 - ✓ Easier integration with modern cellular networks.
 - ✓ Greater resistance to noise and interference compared to analog systems.
- c. Design a simple cellular network for the village, including base stations and cells.

Answer: Simple Cellular Network Design:

- ✓ Divide the village into hexagonal cells.
 - ✓ Each cell has a base station (tower) that connects users in its area.
 - ✓ Base stations link to a central hub via microwave or fiber-optic connections.
 - ✓ Ensure overlapping coverage for seamless communication.
- d. Explain how dividing the area into cells improves communication efficiency.

Answer: Benefits of Dividing the Area into Cells:

- ✓ Improved Frequency Reuse: Same frequencies can be reused in non-adjacent cells, increasing network capacity.
 - ✓ Localized Coverage: Reduces power requirements and enhances signal strength.
 - ✓ Scalability: Allows for future expansion by adding more cells or base stations.
- e. Choose a modulation type (AM, FM, or PM) for transmitting community announcements.

Answer: Choice: Frequency Modulation (FM).

Reason: FM offers better sound quality and noise resistance, ensuring clear announcements. Suitable for rural areas where audio clarity is crucial for effective communication.

- f. Explain why this type of modulation is most suitable.

Answer: Suitability of FM for the System:

- ✓ Noise Immunity: FM is less affected by environmental interference.
- ✓ Range and Clarity: Provides excellent audio quality over moderate distances, ideal for village-wide coverage.

- g. Discuss how post, telegraph, or telephone might serve as backup communication methods in case of system failure.

Answer: Backup Communication Methods:

- ✓ Post: Reliable for delivering non-urgent messages (e.g., letters, official notices).
 - ✓ Telegraph: Useful for short, urgent text-based communications in emergencies.
 - ✓ Telephone: Landlines can serve as a fallback for voice communication, especially in power outages.
2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Categorization of mobile phone, radio communication
 3. Each trainee will perform the task individually
 4. Inform them that they should demonstrate positive attitude when performing task.
 5. After trainees has performed, you'll give them feedback
 6. At the end summarize the topic

Formative Assessment on Learning Outcome 4

PART 1: WRITTEN ASSESSMENT

SECTION A: MULTIPLE-CHOICE QUESTIONS (MCQS)

1. Which law explains the magnitude of induced emf in a circuit?
 - a. Ohm's Law
 - b. Faraday's Law**
 - c. Lenz's Law
 - d. Ampere's Law
2. According to Lenz's Law, the direction of induced current will:
 - a. Enhance the change in magnetic flux
 - b. Oppose the change in magnetic flux**
 - c. Be in the direction of magnetic flux
 - d. Always be clockwise
3. What is the primary function of a transformer?
 - a. Convert mechanical energy to electrical energy
 - b. Change the frequency of an AC signal
 - c. Change the voltage of an AC signal**
 - d. Store electrical energy
4. Which of these is NOT a property of electromagnetic waves?
 - a. They require a medium for propagation**
 - b. They travel at the speed of light in a vacuum
 - c. They have both electric and magnetic components
 - d. They can be polarized

SECTION B: TRUE/FALSE QUESTIONS

5. Electromagnetic waves consist of oscillating electric and magnetic fields that are perpendicular to each other. **Answer: True**
6. Induced emf in a transformer depends on the rate of change of magnetic flux. **Answer: True**
7. FM modulation changes the amplitude of the carrier wave to transmit information. **Answer: False (It changes the frequency.)**

8. Analog communication involves the transmission of discrete signals. **Answer: False (It involves continuous signals.)**

SECTION C: SHORT ANSWER QUESTIONS

9. Explain in your own words why the induced EMF in a circuit depends on the rate of change of the magnetic flux.

Answer: The induced EMF is directly proportional to the rate at which the magnetic flux changes through a circuit. This occurs because electromagnetic induction, as described by Faraday's Law, states that a change in magnetic flux creates an electric field, which drives the current. The faster the flux changes, the greater the electric field and the induced EMF.

10. Why are electromagnetic waves critical for communication systems? Give two examples of their application.

Answer: Electromagnetic waves are essential for communication systems because they can propagate through space and carry information in the form of varying amplitudes, frequencies, or phases. Their ability to travel vast distances and penetrate through various media makes them indispensable for transmitting signals.

Examples:

- ✓ **Mobile communication: EM waves carry voice and data signals between mobile phones and cellular towers.**
- ✓ **Satellite communication: EM waves enable data transmission between Earth and satellites for GPS, television broadcasts, and internet services.**

11. A microwave has a frequency of 2.4 GHz. Calculate its wavelength.

Answer: The wavelength (λ) of an electromagnetic wave is given by: $\lambda = \frac{c}{f}$ Where: $c =$

$3 \times 10^8 \text{ m/s}$ (speed of light), $f = 2.4 \text{ GHz} = 2.4 \times 10^9 \text{ Hz}$. Substituting in the formulae we get $\lambda = 0.125$

12. Explain the role of Fleming's right-hand rule in determining the direction of induced current.

Answer: Fleming's right-hand rule states that if the thumb, forefinger, and middle finger are held perpendicular to each other, the thumb indicates the direction of motion, the forefinger points in the direction of the magnetic field, and the middle finger indicates the direction of induced current.

13. List three applications of electromagnetic induction in daily life. **Answer: Electric generators, Induction stoves and Transformers**

PART 2: PERFORMANCE ASSESSMENT

1. Experiment: Demonstrating Electromagnetic Induction
2. Objective: Show the production of induced emf using a coil and a magnet.
3. Procedure:
 - a. Use a coil of wire connected to a galvanometer.
 - b. Move a bar magnet in and out of the coil.
 - c. Observe the deflection in the galvanometer.
4. Assessment Criteria:
 - a. Proper setup of the experiment
 - b. Accurate observation and explanation of results
 - c. Clear understanding of Faraday's and Lenz's laws

PART 3: ORAL ASSESSMENT

1. Explain the difference between AM, FM, and PM modulations.

Answer:

- ✓ **AM (Amplitude Modulation): Varies the amplitude of the carrier wave while keeping frequency constant.**
 - ✓ **FM (Frequency Modulation): Varies the frequency of the carrier wave while keeping amplitude constant.**
 - ✓ **PM (Phase Modulation): Varies the phase of the carrier wave to encode information.**
2. Describe the structure of a cellular network.

Answer: A cellular network consists of:

- ✓ **Base stations: Provide coverage for specific areas (cells).**
- ✓ **Mobile switching centers: Manage connections between base stations and the wider network.**
- ✓ **Channels: Facilitate communication between mobile devices and base stations.**



Points to Remember

- Electromagnetic Induction is a current produced because of voltage production (electromotive force) due to a changing magnetic field.
- Magnetic flux (Φ) is a measure of the quantity of magnetism, being the total number of magnetic lines of force passing through a specified area in a magnetic field. The SI unit is weber (symbol Wb).
- Magnetic flux density (B) is the amount of magnetic flux through a unit area taken perpendicular to the direction of the magnetic flux, it is a vector quantity. Its SI unit is tesla (symbol T).
- The Faraday's law states that the electromotive force induced in a conductor is directly proportional to the rate at of change of the magnetic flux linked to the conductor.
- Lenz's law states that the direction of the induced current is such that it opposes the change producing it.
- Fleming's Right Hand Rule states that if we arrange our thumb, forefinger and middle finger of the right-hand perpendicular to each other, then the thumb points towards the direction of the motion of conductor relative to the magnetic field, the forefinger points towards the direction of the magnetic field and the middle finger points towards the direction of the induced current.
- Induced electromotive force (EMF) is the voltage generated in a conductor when it is exposed to a changing magnetic field.
- The magnitude of the induced EMF is directly proportional to the rate of change of the magnetic flux through the loop.
- Factors Affecting Induced EMF are number of turns in the Coil, Rate of Change of magnetic Flux and strength of the magnetic field.
- A transformer is a device that transfers electrical energy between two or more circuits through electromagnetic induction.
- Formula for transformer $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

- Applications of transformer is increase or to decrease voltage for power transmission.
- Motional EMF occurs when a conductor moves through a magnetic field, causing a change in magnetic flux.
- AM is a type of modulation where the amplitude of the carrier wave varies in proportion to the information signal (e.g., voice or music).
- FM is a type of modulation where the frequency of the carrier waves changes according to the information signal.
- PM is a type of modulation where the phase of the carrier wave varies based on the information signal.
- The postal system is used to send and receive letters, parcels, and other documents.
- The telegraph is an old communication system that sends messages over long distances using electrical signals. Invented by Samuel Morse in 1837.
- The telephone is a communication device that transmits voice signals over a network. Invented by Alexander Graham Bell in 1876.
- How It Works:
- The microphone converts sound waves into electrical signals.
- Telephone Instant Voice Communication Widely used in modern forms (mobile, VoIP).



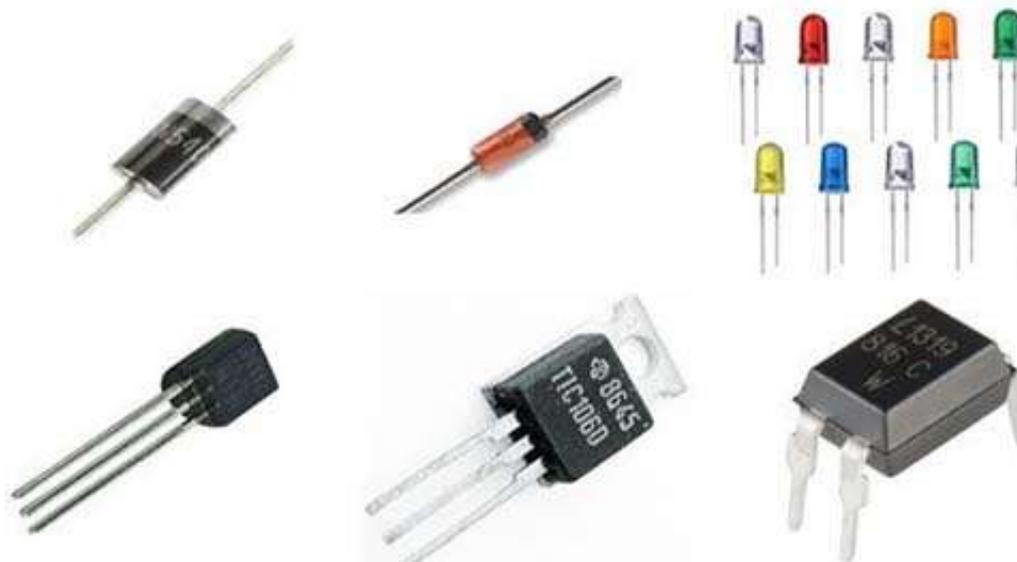
Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to Identify their areas of strength, areas for improvement and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

Further Information for the Trainer

1. While group discussions, the trainer monitors all groups and provide only clarifications/assistance when necessary.
2. During problem solving, it is better to use group discussion to facilitate group members think critically on facts linking them to real situation.
3. During discovery, it could be better if the teacher use brainstorming consider the time allocation for the activity.
4. The trainer must vary the techniques depending on the class size, learners' prerequisites and situation.
5. The assessment is given as sample; the trainer can expand or change it but within the same scope.

LEARNING OUTCOME 5: DESCRIBE SEMICONDUCTOR MATERIALS



Learning outcome 5: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
 - a. What does the illustration show?
 - b. What do you think will be topics to be covered under this unit based on the illustration?
2. After the discussion, inform students that this unit is intended to provide them with the knowledge, skills and attitudes describe semiconductor material. They will cover fundamental properties of semiconductor materials, principles of semiconductor devices, principles of operational amplifiers.
3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:
 - a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.
 - b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
 - c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?
 - d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.
 - e. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.



Key Competencies:

Knowledge	Skills	Attitudes
1. Identify the fundamental properties of semiconductor materials.	1. Analyze the conductivity of different materials (conductors, insulators, semiconductors).	1. Appreciate the importance of semiconductors in modern technology.
2. Explain the behavior of valence electrons, free electrons, and holes in semiconductors.	2. Demonstrate how to differentiate between intrinsic and extrinsic semiconductors.	2. Show curiosity in exploring the principles behind semiconductor devices.
3. Describe the working principles of PN junctions and transistors.	3. Illustrate the current flow in transistors and diodes.	3. Adopt a detail-oriented approach when working with semiconductor components.



Steps:



Discovery Activity



Task 41

1. Using interactive discussion, guide trainees to share their prior experience from their understanding regarding to the concept of electromagnetic field under task 41 in their Trainee's Manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are given.
2. Begin by asking trainees:
 - a. Can you name a material that is neither a good conductor (like copper) nor a good insulator (like rubber)?

- b. Why do you think it behaves this way?
 - c. Observe and describe the properties of each of the following materials in terms of conductivity. Copper wire, a rubber eraser, and a silicon wafer or LED component.
 - d. Which of these materials might fall between conductors and insulators? Why?
3. Encourage trainees to think individually and jot down their answers.
 4. After the sharing session, inform students that this activity was not intended for them to give the right answers but to give them a picture of what they will cover in the unit.
 5. Introduce Topic 5.1: Fundamental properties of semiconductor materials

Topic 5.1: Description of fundamental properties of semiconductor materials

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none"> Define correctly the concept of electrical conductivity based on the conductive properties Classify effectively materials based on their conductive properties. Describe clearly the fundamental properties of semiconductor materials based on electron mobility
	<p>Time Required: 2 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion and Research</p>
	<p>Materials, Tools and Equipment Needed: PPE, whiteboard, chalkboard, computer, projector, textbooks, Chalks, markers, Scientific calculator.</p>
	<p>Preparation:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Test the Multimeter and circuit components to ensure reliability during demonstrations. <input type="checkbox"/> Arrange the classroom to facilitate group discussions and hands-on activities
	<p>Cross Cutting Issues:</p> <ul style="list-style-type: none"> ✓ Discuss how semiconductors (e.g., communication devices) promote peace by sharing unity messages and preventing conflicts. ✓ Highlight the environmental impact of mining semiconductor materials.
	<p>Prerequisites:</p> <ul style="list-style-type: none"> ✓ Recognize basic electrical concepts such as voltage, current, and resistance. ✓ Identify common materials and their general properties (e.g., metals, rubber, silicon). ✓ Perform simple tasks such as connecting a circuit or using a Multimeter



Activity 1: Problem-Solving



Task 42

1. Using the appropriate methodology such as individual work, group discussions, guide trainees to read the following scenario and answer the questions as provided under task 42 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used

Scenario:

Peter is a detective investigating the mysterious technology behind modern devices. His mission is to uncover the secrets of semiconductors and their vital role in our daily lives. Suppose you are in his team then answer the following questions asked by Peter

- a. He gathers his team and ask, "What is a semiconductor?"
- b. Next, he holds up a list and ask, "Can anyone provide examples of materials that are semiconductors?"
- c. He examines a smartphone and ponder aloud, "Why are semiconductors so important in modern electronic devices?"
- d. He challenges the team, "Name some devices that use semiconductors."
- e. Finally, he gathers the group for a comparison. "What's the difference between a conductor, an insulator, and a semiconductor?"

Answer:

- a. A semiconductor is a material whose electrical conductivity lies between that of a conductor (like metals) and an insulator (like glass). Its conductivity can be controlled by adding impurities (doping) or by external factors like temperature, light, or electric fields, making it an essential component in modern electronics.
- b. Examples of materials that are semiconductors include:
 - ✓ Silicon (Si)
 - ✓ Germanium (Ge)
 - ✓ Gallium arsenide (GaAs)
 - ✓ Cadmium sulfide (CdS)

- c. Semiconductors are crucial in modern electronic devices because:
- i. Control of conductivity: Their conductivity can be precisely modified through doping or external factors.
 - ii. Miniaturization: Semiconductors enable the creation of small, complex, and efficient circuits.
 - iii. Versatility: They are used in key components like diodes, transistors, and integrated circuits.
 - iv. Energy efficiency: Devices made with semiconductors consume less energy compared to older technologies.
 - v. Foundation of innovation: Semiconductors power smartphones, computers, solar cells, and countless other technologies that form the backbone of modern life.
- d. Devices that use semiconductors include:
- ✓ Smartphones
 - ✓ Computers and laptops
 - ✓ Solar panels
 - ✓ Light-emitting diodes (LEDs)
 - ✓ Television screens
 - ✓ Transistors and integrated circuits (ICs)
 - ✓ Sensors and detectors
 - ✓ Microwave ovens
- e. Difference between a conductor, an insulator, and a semiconductor

Property	Conductor	Insulator	Semiconductor
Conductivity	High	Very low	Intermediate
Band gap	No significant band gap	Large band gap	Small band gap
Examples	Copper, aluminum, silver	Glass, rubber, plastic	Silicon, germanium, GaAs
Temperature effect	Conductivity decreases with temperature	Little to no effect on conductivity	Conductivity increases with temperature

Use	Electrical wiring, conductors	Prevent current flow	Electronics and circuits
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2. Encourage all trainees to give their views by share their answers to the class and write their responses for reference.
3. After the sharing session, refer trainees to Key facts 5.1 Concept of electromagnetic induction (EMI) and discuss them together while harmonizing their responses provided in the sharing session and answer any questions, they have.



Activity 2: Guided Practice



Task 43

1. Using the appropriate methodology such as individual work, pair-share, small group discussions, guide trainees to Describe fundamental properties of semiconductor materials as provided under task 43 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
2. Ask trainees to complete the table given under the task 43.2 in their trainee's manual by classifying each material as a conductor, insulator, or semiconductor. Then, write a short explanation for each material based on its ability to conduct electricity.

Material	Type	Explanation
Copper	Conductor	Allows electricity to flow easily due to free electrons.
Rubber	Insulator	Prevents electrical flow because it lacks free electrons.
Silicon	Semiconductor	Conducts moderately, with conductivity controlled by doping.
Aluminum	Conductor	High electrical conductivity, used in wiring.
Germanium	Semiconductor	Similar to silicon, its conductivity depends on temperature or doping.

3. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in Description of fundamental properties of semiconductor materials. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
4. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
5. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
6. After the sharing session, refer trainees to key fact 5.1 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 44

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:

You are working in a factory that manufactures smartphones. The phones use semiconductor materials (such as silicon) to control the flow of electricity. You are tasked with explaining the role of semiconductors in the phone's performance.

 - a. Explain why silicon is chosen as a semiconductor for the phone's components (transistors, diodes, etc.).
 - b. Describe the role of intrinsic and extrinsic semiconductors in the phone.
 - c. If the phone's battery is not charging, what could be the problem with the semiconductor material? How would you solve this issue?

Understanding the Role of Semiconductors in Smartphone Performance

Why Silicon is Chosen as a Semiconductor for the Phone's Components?

Silicon is a widely used semiconductor in smartphones due to the following reasons:

- ✓ **Abundance and Cost:** Silicon is the second most abundant element on Earth, making it relatively inexpensive.
- ✓ **Thermal Stability:** Silicon can operate efficiently across a wide range of temperatures, ensuring reliability in various environments.
- ✓ **Excellent Semiconductor Properties:** Silicon has an ideal bandgap of 1.1 eV, enabling efficient conduction and insulation properties when needed.
- ✓ **Ease of Doping:** Silicon can be easily doped with impurities to create n-type and p-type semiconductors, essential for building diodes, transistors, and integrated circuits.
- ✓ **Oxide Layer Formation:** Silicon forms a stable and protective oxide layer (silicon dioxide), crucial for creating insulated gates in transistors and other components.

Role of Intrinsic and Extrinsic Semiconductors in the Phone

Intrinsic Semiconductors:

- ✓ Pure semiconductors like undoped silicon with balanced electrons and holes.
- ✓ Serve as the base material for manufacturing phone components.
- ✓ Have limited conductivity, which is enhanced through doping to create extrinsic semiconductors.

Extrinsic Semiconductors:

- ✓ **Doped Semiconductors:** Silicon is doped with impurities to enhance its conductivity:
 - N-Type Semiconductors: Doped with donor atoms (e.g., phosphorus) to increase free electrons.
 - P-Type Semiconductors: Doped with acceptor atoms (e.g., boron) to increase holes (positive charge carriers).

✓ **These are used to create essential components:**

- Diodes: For rectification, voltage regulation, and signal processing.
- Transistors: Act as switches and amplifiers in the phone's processors and memory units.
- Integrated Circuits: Form the backbone of the phone's CPU, GPU, and other chips.

If the Phone's Battery is Not Charging

Possible Problems with the Semiconductor Material:

- a. **Faulty Diodes:** Diodes in the charging circuit might be malfunctioning, causing improper rectification of AC to DC. Damage could result from overheating or excessive current.
- b. **Damaged Transistors:** Transistors in the power management IC (integrated circuit) might fail to regulate power to the battery.
- c. **Short Circuit in Semiconductors:** Overheating or physical damage might have caused a short circuit in the semiconductor material.
- d. **Corrosion or Physical Damage:** Environmental factors could degrade the semiconductor pathways, interrupting current flow.
- e. **Doping Defects:** Poor-quality doping during manufacturing could lead to unstable performance or early failure of components.

Solutions:

- a. **Diagnose the Faulty Components:** Use a Multimeter or oscilloscope to test the diodes and transistors in the charging circuit. Replace any damaged components.
 - b. **Inspect and Replace Power Management IC:** If the IC managing the battery is malfunctioning, replace it with a new one.
 - c. **Check for Physical Damage:** Inspect for broken connections or corrosion and repair as necessary.
 - d. **Improve Cooling Systems:** Ensure proper heat dissipation to prevent overheating of semiconductor materials.
 - e. **Upgrade Quality Control:** Implement stricter testing during manufacturing to avoid issues like improper doping or assembly defects.
2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Description of fundamental properties of semiconductor materials

3. Each trainee will perform the task individually
4. Inform them that they should demonstrate positive attitude when performing task.
5. After trainees has performed, you'll give them feedback
6. At the end summarize the topic

Topic 5.2: Explanation of principles of semiconductor devices

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Explain correctly the working principle of a diode and its role as used in rectification.Explain clearly principles of semiconductor devices according to PN-junctionAssess effectively the practical applications of diodes and transistors as used in electronic circuits.
	<p>Time Required: 2 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion and Research</p>
	<p>Materials, Tools and Equipment Needed: Whiteboard, chalkboard, computer, projector, textbooks, Chalks, markers, Scientific calculator, diodes, transistor</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Set up demonstration circuits to show diode rectification and transistor switching/amplification.<input type="checkbox"/> Prepare clear and concise explanations for each concept (N-type, P-type, diode, transistor).<input type="checkbox"/> Arrange the classroom to facilitate hands-on activities and group discussions.
	<p>Cross Cutting Issues:</p> <ul style="list-style-type: none">✓ Ensure equal participation of male and female trainees in activities like building circuits.✓ Teach collaboration, respect, and shared values through activities.✓ Semiconductors: Highlight their role in bridging communication gaps.✓ Foster an environment where everyone feels included and valued.

**Prerequisites:**

- ✓ Basic understanding of electrical circuits and current flow.
- ✓ Ability to use basic tools like Multimeter and breadboards.
- ✓ Familiarity with terms like conductor, insulator, and semiconductor.

**Activity 1: Problem-Solving****Task 45**

4. Using the appropriate methodology such as pair-share, small group discussions, guided discussions, guide trainees to read the following question and answer the it as provided under task 45 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Question:

A silicon crystal is doped with the following impurities: Phosphorus (5 valence electrons) and Boron (3 valence electrons)

- a. Identify which doping results in an N-type semiconductor and which results in a P-type semiconductor.
- b. Explain why these materials are classified as N-type or P-type.

Answers:

- a. Identify which doping results in an N-type semiconductor and which results in a P-type semiconductor.
 - ✓ Phosphorus (5 valence electrons): Results in an N-type semiconductor.
 - ✓ Boron (3 valence electrons): Results in a P-type semiconductor.
- b. Explain why these materials are classified as N-type or P-type.

i. N-type Semiconductor:

When silicon (4 valence electrons) is doped with phosphorus (5 valence electrons), the phosphorus atom replaces a silicon atom in the crystal lattice. Phosphorus has one extra valence electron compared to silicon, which is not needed for bonding. This extra electron becomes a free electron, which increases. Because the majority carriers are electrons, this type of semiconductor is called N-type, where "N" stands for negative.

ii. P-type Semiconductor:

When silicon is doped with boron (3 valence electrons), the boron atom replaces a silicon atom in the lattice. Boron has one less valence electron than silicon, creating a hole (a missing electron in the lattice) in the silicon crystal structure. These holes' act as positive charge carriers. Since the majority carriers are holes, this type of semiconductor is called P-type, where "P" stands for positive.

5. Encourage all trainees to give their views by share their answers to the class and write their responses for reference.
6. After the sharing session, refer trainees to key fact 5.2 Properties of electromagnetic waves and discuss them together while harmonizing their responses provided in the sharing session and answer any questions, they have.



Activity 2: Guided Practice



Task 46

1. Using the appropriate methodology such as individual work, small group discussions, guided discussions or large group discussion, guide trainees to read and answer the problems as provided under task 46 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Question: Complete the table below by identifying whether the given material is N-type or P-type and state the type of charge carrier responsible for conduction.

Answer:

Doping Material	Semiconductor Type (N-type or P-type)	Charge Carrier
Arsenic	N-type	5 valence electrons, donates extra electron
Gallium	P-type, Holes	3 valence electrons, creates a hole

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in answering the questions. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to key fact 46 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 47

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:
You are working in an electronics repair shop. A customer brings in a faulty LED circuit. The circuit diagram shows the LED connected to a 6 V battery, but the LED does not light up.
 - a. Determine whether the LED is forward-biased or reverse-biased.
 - b. Suggest a possible reason for the malfunction.

Analyzing the Faulty LED Circuit:

a. Determine Whether the LED is Forward-Biased or Reverse-Biased

- ✓ **Forward-Biased:** An LED is forward-biased when the positive terminal of the battery is connected to the anode (longer leg) of the LED, and the negative terminal is connected to the cathode (shorter leg). This allows current to flow through the LED, causing it to emit light.
- ✓ **Reverse-Biased:** If the connections are reversed, current cannot flow through the LED, and it will not light up.

To determine the biasing: Inspect the physical connections in the circuit. If the anode is connected to the battery's positive terminal and the cathode to the negative terminal, the LED is forward-biased. If the connections are reversed, the LED is reverse-biased, and it will not light up.

b. Suggest a Possible Reason for the Malfunction

- ✓ **Incorrect Polarity:** The LED may be reverse-biased, preventing it from conducting current.
- ✓ **Burned-Out LED:** Excessive current through the LED (e.g., due to the absence of a current-limiting resistor) may have damaged it.
- ✓ **Faulty Connections:** Loose or broken wires, soldering issues, or poor contact points in the circuit could interrupt current flow.
- ✓ **Insufficient Voltage:** LEDs typically have a forward voltage drop (e.g., 2–3 V for standard LEDs). If the battery voltage is too low after accounting for this drop, the LED may not light.
- ✓ **Missing or Faulty Current-Limiting Resistor:** Without a resistor, the LED could receive too much current, leading to damage.

2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Explanation of principles of semiconductor devices

3. Each trainee will perform the task individually

4. Inform them that they should demonstrate positive attitude when performing task.

5. After trainees has performed, you'll give them feedback

6. At the end summarize the topic

Topic 5.3: Description of principles of operational amplifiers

	<p>Objectives:</p> <p>By the end of the topic, trainees will be able to:</p> <ol style="list-style-type: none">Describe properly the principles of operational amplifiers referring to semiconductor devicesDemonstrate perfectly the use of operational amplifiers in circuits such as inverting and non-inverting amplifiers.Design a simple circuit using operational amplifiers to solve a practical problem.
	<p>Time Required: 2 hours</p>
	<p>Learning Methodology: Demonstration and simulation, Individual and group work, Practical exercise, Trainer guided, Group discussion and Research</p>
	<p>Materials, Tools and Equipment Needed: Whiteboard, chalkboard, computer, projector, textbooks, Chalks, markers, Scientific calculator.</p>
	<p>Preparation:</p> <ul style="list-style-type: none"><input type="checkbox"/> Review and prepare examples of operational amplifier applications.<input type="checkbox"/> Organize materials and ensure sufficient quantities for all trainees<input type="checkbox"/> Test all equipment
	<p>Cross Cutting Issues:</p> <ul style="list-style-type: none">✓ Highlight women's contributions and ensure hands-on involvement.✓ Show op-amps' role in healthcare and reproductive health.✓ Provide accessible tools and value every trainee's input.
	<p>Prerequisites:</p> <ul style="list-style-type: none">✓ Basic understanding of electrical circuits and components (resistors, capacitors, power supplies).✓ Familiarity with the use of basic tools like Multimeter.



Activity 1: Problem-Solving



Task 48

1. Using the appropriate methodology such as group discussions, guide trainees to read the following scenario and answer the questions as provided under task 48 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

Scenario:

A high-tech security company is facing a critical issue: their alarm system has stopped working. The students are hired as engineers to diagnose and fix the problem. The Challenge Begins:

- a. The teacher, playing the role of the company's manager, explains, "Our flame sensor and heat sensor are malfunctioning. These devices rely on operational amplifiers in their circuits. Can you investigate and help us restore the system?"
- b. The teacher interrupts, "How do we ensure the amplifiers perform reliably?"

Answers to the Scenario's Questions

- a. To investigate and restore the malfunctioning sensors, follow these steps:

Diagnose the Problem:

- i. **Check Power Supply:** Ensure the operational amplifiers (op-amps) and sensors are receiving the proper voltage and current.
- ii. **Inspect Components:** Verify that the flame and heat sensors are not physically damaged. Inspect the connections to the op-amps.
- iii. **Test the Op-Amps:** Use a Multimeter or oscilloscope to check the input and output signals of the op-amps. Confirm they are amplifying correctly.
- iv. **Examine the Circuit Design:** Review the circuit diagram to identify possible design flaws or improperly connected components.

Restore the System:

- i. **Replace Faulty Components:** If any op-amps, resistors, or sensors are damaged, replace them with new ones.
 - ii. **Calibrate the Sensors:** Fine-tune the op-amp circuit by adjusting resistors or potentiometers to ensure the sensors respond accurately to heat and flame.
 - iii. **Recheck Connections:** Ensure all wires and soldered joints are secure and free of shorts or breaks.
 - iv. **Test the System:** After repairs, simulate flame and heat conditions to confirm the sensors and op-amps are functioning as expected.
- b. To ensure the reliable performance of the operational amplifiers, consider the following steps:
- i. Use High-Quality Components:
 - ✓ Select op-amps with low offset voltage, high input impedance, and low noise for better accuracy and stability.
 - ✓ Use precision resistors and capacitors for consistent performance.
 - ii. Design Robust Circuits:
 - ✓ Implement proper feedback loops to stabilize the gain and prevent oscillations.
 - ✓ Add bypass capacitors near the op-amps to filter out noise and stabilize the power supply.
 - iii. Thermal Management:
 - ✓ Ensure the op-amps operate within their specified temperature range.
 - ✓ Use heat sinks or place op-amps in well-ventilated areas to avoid overheating.
 - iv. Proper Grounding and Shielding:
 - ✓ Use a common ground to minimize noise.
 - ✓ Shield the circuit from electromagnetic interference (EMI) by using grounded enclosures or ferrite beads.
 - v. Regular Maintenance:
 - ✓ Periodically inspect the system for loose connections, corrosion, or component aging.
 - ✓ Test the op-amp circuits at regular intervals to detect early signs of failure.

- vi. Environmental Considerations: Protect the sensors and circuits from dust, moisture, or extreme environmental conditions that could degrade their performance.
2. Encourage all trainees to give their views by share their answers to the class and write their responses for reference.
 3. After the sharing session, refer trainees to Key facts 5.3 Interpretation of concepts in transmission and discuss them together while harmonizing their responses provided in the sharing session and answer any questions, they have.



Activity 2: Guided Practice



Task 49

1. Using the appropriate methodology such as individual work, pair-share, small group discussions, or trainer guided method, guide trainees to solving the questions as provided under task 49 in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
 - a. An operational amplifier is configured as an inverting amplifier. The input resistor R_{in} is 10 k Ω , and the feedback resistor R_f is 100 k Ω . The input voltage (V_{in}) is 0.2 V. Calculate the output voltage V_{out} .

Answer:

- vii. Highlight the formulas used for each configuration: Inverting: $V_{out} = -\frac{R_f}{R_{in}} \times V_{in}$

Data given $R_{in} = 10k\Omega$, $R_f = 100k\Omega$, $V_{in} = 0.2V$.

Unknown value to be found: V_{out}

Substitute the values step-by-step, ensuring they follow the calculations: $V_{out} =$

$$-\frac{100}{10} \times 0.2 = -2V$$

- b. An operational amplifier is configured as a non-inverting amplifier. The resistors are $R_1=10$ k Ω and $R_2=40$ k Ω . The input voltage (V_{in}) is 0.5 V. Calculate the output voltage V_{out} .

Answer:

Highlight the formulas used for each configuration: Non-Inverting: $V_{out} = \left(1 + \frac{R_2}{R_1}\right) \times V_{in}$

Data given $R_1 = 10k\Omega$, $R_2 = 40k\Omega$, $V_{in} = 0.5V$.

Identify what needs to be found: V_{out}

Substitute the values step-by-step, ensuring they follow the calculations: $V_{out} = \left(1 + \frac{40}{10}\right) \times 0.5 = 2.5V$

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in solving problems. Your role is to guide them by using probing questions such as Why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, financial education among others. Also attitudes and behavior changes should be handled during this activity.
4. Encourage all trainees to give their views by sharing their answers to the class and Write their responses for reference.
5. After the sharing session, refer trainees to key fact 5.3 and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.



Activity 3: Application



Task 50

1. Ask trainees to perform the tasks provided in their trainee's manuals as described below:
 - a. Amplifier is used as a flame sensor circuit. The input sensor detects the presence of a flame, generating a small voltage signal, which is then fed into the op-amp to amplify the signal. The output signal is used to trigger an alarm when the flame is detected.
 - i. Describe how an operational amplifier can be used in this application.
 - ii. What type of feedback would you use in this circuit (positive or negative) and why?

- b. In an industrial setting, a heat sensor circuit uses an operational amplifier to monitor temperatures. The temperature sensor produces a voltage that varies with temperature. The op-amp amplifies this signal and sends it to a microcontroller for further processing.
- i. Calculate the output voltage if the input voltage from the temperature sensor is 0.2 V and the gain of the amplifier is 50.
 - ii. Explain how this output could be used to control a cooling system.

Amplifier as a Flame Sensor Circuit

a. How an operational amplifier can be used in this application?

An operational amplifier (op-amp) amplifies weak signals from the input sensor (e.g., photodiode or thermocouple) that detects the flame. When a flame is present, the sensor generates a small voltage signal proportional to the intensity of the flame. The op-amp takes this small input signal and amplifies it to a larger voltage signal. The amplified signal can then drive an alarm or other output devices, indicating the presence of a flame.

Key features of an op-amp in this application:

- ✓ High Gain: Amplifies the weak flame detection signal.
- ✓ Signal Conditioning: Filters out noise and ensures a clean signal for further processing.
- ✓ Comparator Mode: In some designs, the op-amp can act as a comparator, triggering an alarm when the input signal exceeds a preset threshold.

b. Type of Feedback to Use and Why?

Negative feedback is used in this circuit for the following reasons:

- ✓ Stability: Negative feedback stabilizes the gain of the amplifier, ensuring predictable and accurate amplification.
- ✓ Linearity: It improves the linearity of the circuit, ensuring the output signal is a faithful representation of the input.
- ✓ Noise Reduction: Negative feedback reduces noise and distortion in the amplified signal, ensuring reliable flame detection.

Heat Sensor Circuit in an Industrial Setting

a. Calculation of Output Voltage

The output voltage (V_{out}) of an amplifier is calculated using the formula: $V_{out} = AV_{in}$ where: A is Gain of the amplifier and V_{in} is Input voltage from the sensor.

Given: $V_{in} = 0.2V$, $A=50$, so $V_{out} = 50 \cdot 0.2 = 10V$

b. How This Output Could Control a Cooling System

The output voltage from the amplifier, proportional to the temperature, is fed into a microcontroller. The microcontroller can use the voltage to perform the following functions:

- ✓ Temperature Monitoring: The microcontroller continuously monitors the amplified signal to determine the current temperature.
 - ✓ Threshold Detection: If the output voltage exceeds a preset threshold (indicating excessive temperature), the microcontroller activates the cooling system.
 - ✓ Actuation: The microcontroller sends a control signal to relays, fans, or cooling compressors to lower the temperature.
 - ✓ Feedback System: The microcontroller can create a feedback loop to adjust the cooling intensity based on real-time temperature data.
2. Explain to the trainees that the following task links them to the world of work. Inform trainees that each of them will assume that he/she has been assigned to Description of principles of operational amplifiers
 3. Each trainee will perform the task individually
 4. Inform them that they should demonstrate positive attitude when performing task.
 5. After trainees has performed, you'll give them feedback
 6. At the end summarize the topic



Formative Assessment on Learning outcome 5

Read carefully and answer the following questions:

1. Answer true for correct statement and false for incorrect one:
 - a. Electrical conductivity is the ability of a material to allow the flow of electric current through it. **Answer: True**
 - b. Rubber has better insulating properties than glass. **Answer: False**
 - c. In semiconductors, "holes" are considered as positively charged particles. **Answer: True**
2. Complete the following questions with appropriate statement:
 - a. Valence electrons are bound to an atom in the outermost shell, while free electrons are _____ and move freely within a material, contributing to _____. **Answer: Delocalized; electrical conductivity.**
 - b. A PN junction in forward bias reduces the _____ and allows the _____ of current. **Answer: Depletion region; flow.**
3. In an operational amplifier, feedback is used to control the _____ of the circuit and improve its _____. **Answer: Gain; stability.**
4. For the following questions chose the correct answer
 - a. Which of the following is a good conductor of electricity?
 - i. Glass
 - ii. Rubber
 - iii. Copper
 - iv. Wood**Answer: iii) Copper**
 - b. What is the primary difference between intrinsic and extrinsic semiconductors?
 - i. Intrinsic semiconductors have impurities, while extrinsic semiconductors are pure.
 - ii. Intrinsic semiconductors are pure, while extrinsic semiconductors have added impurities to enhance conductivity.
 - iii. Intrinsic semiconductors have higher conductivity than extrinsic semiconductors.
 - iv. Both are identical in composition.**Answer: ii) Intrinsic semiconductors are pure, while extrinsic semiconductors have added impurities to enhance conductivity.**

c. What is the main function of a diode?

- i. Amplify current
- ii. Convert AC to DC
- iii. Store charge
- iv. Measure resistance

Answer: ii) Convert AC to DC

d. Which type of transistor has the current flow from the emitter to the collector when the base is negatively biased?

- i. NPN transistor
- ii. PNP transistor
- iii. Field-effect transistor
- iv. Bipolar junction transistor

Answer: b) PNP transistor

5. Define electrical conductivity.

Answer: Electrical conductivity is the ability of a material to allow the flow of electric current. It is the reciprocal of resistivity.

6. Which material is a better insulator: rubber or glass?

Answer: Both are good insulators, but rubber is more flexible and commonly used in insulation.

7. What is the difference between valence electrons and free electrons?

Answer: Valence electrons are the outermost electrons in an atom, involved in bonding while Free electrons are electrons that are not bound to any atom and can move freely, contributing to conductivity.

8. What are "holes" in semiconductors?

Answer: Holes are the absence of an electron in the valence band of a semiconductor. They act as positive charge carriers.

9. Which has higher mobility in semiconductors: electrons or holes?

Answer: Electrons have higher mobility than holes.

10. What is the main difference between intrinsic and extrinsic semiconductors?

Answer: Intrinsic semiconductors are pure and have equal numbers of electrons and holes while extrinsic semiconductors are doped with impurities to increase either electrons (N-type) or holes (P-type).

11. What is the primary function of a diode?

Answer: A diode allows current to flow in one direction while blocking it in the reverse direction.

12. Name two types of diodes.

Answer: Light Emitting Diode (LED), Zener Diode, Photodiodes, ...

13. What is the role of feedback in an operational amplifier circuit?

Answer: Feedback controls the gain of the amplifier and improves stability. Negative feedback is most commonly used.

14. What is the gain of an operational amplifier configured as a summing amplifier with three inputs $V_1=0.5V$, $V_2=0.3V$, $V_3=0.2V$ and equal resistances? **Answer: The output voltage**

$$V_{out} = -(V_1 + V_2 + V_3) = -1.0V$$

15. In a flame sensor circuit using an operational amplifier, what triggers the alarm?

Answer: The operational amplifier amplifies the small voltage signal from the flame sensor. When the output signal exceeds a certain threshold, it triggers the alarm.

16. Calculate the output voltage of a heat sensor circuit with an input voltage of 0.1 V and an amplifier gain of 100.

$$V_{out} = Gain \times V_{in} = 10V$$

17. Name two common types of integrated circuits.

Answer: Operational Amplifiers (Op-Amps), Timer ICs (e.g., 555 Timer)

18. What is the primary application of a ramp generator circuit?

Answer: A ramp generator produces a linearly increasing or decreasing voltage signal, commonly used in timing and waveform generation.

19. Given a PN junction diode in reverse bias, what happens to the current?

Answer: In reverse bias, only a small leakage current flows through the diode until breakdown occurs.

20. A summing amplifier has two inputs, $V_1 = 1V$ and $V_2 = 2V$, with equal resistors. Calculate the output voltage if the gain is -1 .

$$V_{out} = Gain \times (V_1 + V_2) = -3V$$



Points to Remember

- An electrical conductor is defined as materials that allow electricity to flow through them easily.
- The flow of electrons in a conductor is known as the electric current.
- The materials that do not allow electricity to pass through are insulators.
- Some examples of conductors of electricity are Copper, Aluminium, Silver, Gold, Graphite, Platinum, Water.
- Examples of non – conductors are Sulphur, Phosphorus, and Wood.
- A semiconductor device conducts electricity poorly at room temperature but has increasing conductivity at higher temperatures.
- Examples of Semiconductors: Gallium arsenide, germanium, and silicon are some of the most commonly used semiconductors.
- Valence electrons are the electrons located in the outermost shell of an atom.
- In semiconductor materials like silicon and germanium, each atom has 4 valence electrons.
- These valence electrons form covalent bonds with neighboring atoms, creating a stable crystal lattice.
- At room temperature or under external energy like heat, some of these electrons can break free, affecting the material's conductivity.
- Free electrons are electrons that have gained enough energy to leave their parent atom and move freely through the lattice.
- Free electrons move under an electric field, creating an electric current.
- A hole is the absence of an electron in a covalent bond, which acts like a positively charged particle.
- Electron mobility is a measure of how easily free electrons can move through a semiconductor when an electric field is applied.
- Holes mobility measures how easily holes can "move" through a semiconductor under an electric field.

- Hole mobility is generally lower than electron mobility because the motion of holes depends on the movement of bound electrons, which is less efficient.
- Electron and hole mobility are critical for designing efficient semiconductor devices like transistors, diodes, and integrated circuits.
- If the semiconductor material in the phone is damaged (e.g., due to high temperature), it may not conduct electricity effectively, causing the battery to fail to charge.
- Temperature increases can excite electrons in the silicon, making it conduct more easily (increasing current flow).
- If the semiconductor is doped to create N-type or P-type material, the temperature can affect the movement of electrons and holes.
- N-Type Contains extra electrons as charge carriers. It is an impurity mixed semiconductor material used in electronics.
- P-Type Contains extra holes as charge carriers.
- A diode is a semiconductor device that allows current to flow in one direction.
- A transistor is a semiconductor device used to amplify or switch electronic signals. It is composed of semiconductor material, usually with at least three terminals for connection to an electronic circuit.
- Based on planned use, an IC integrated circuit can be classified as a digital integrated circuit, mixed integrated circuit and analogue integrated circuit.



Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to Identify their areas of strength, areas for improvement and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

Further Information for the Trainer

1. During group discussions, the trainer monitors all groups and provides clarifications or assistance only when necessary.
2. For problem-solving, group discussions are effective in encouraging critical thinking and connecting facts to real-life situations.
3. In discovery activities, brainstorming can be useful if time allocation is carefully considered.
4. The trainer should adapt techniques based on class size, learners' prerequisites, and the situation.
5. The assessment is a sample; the trainer may expand or modify it while staying within the same scope.

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