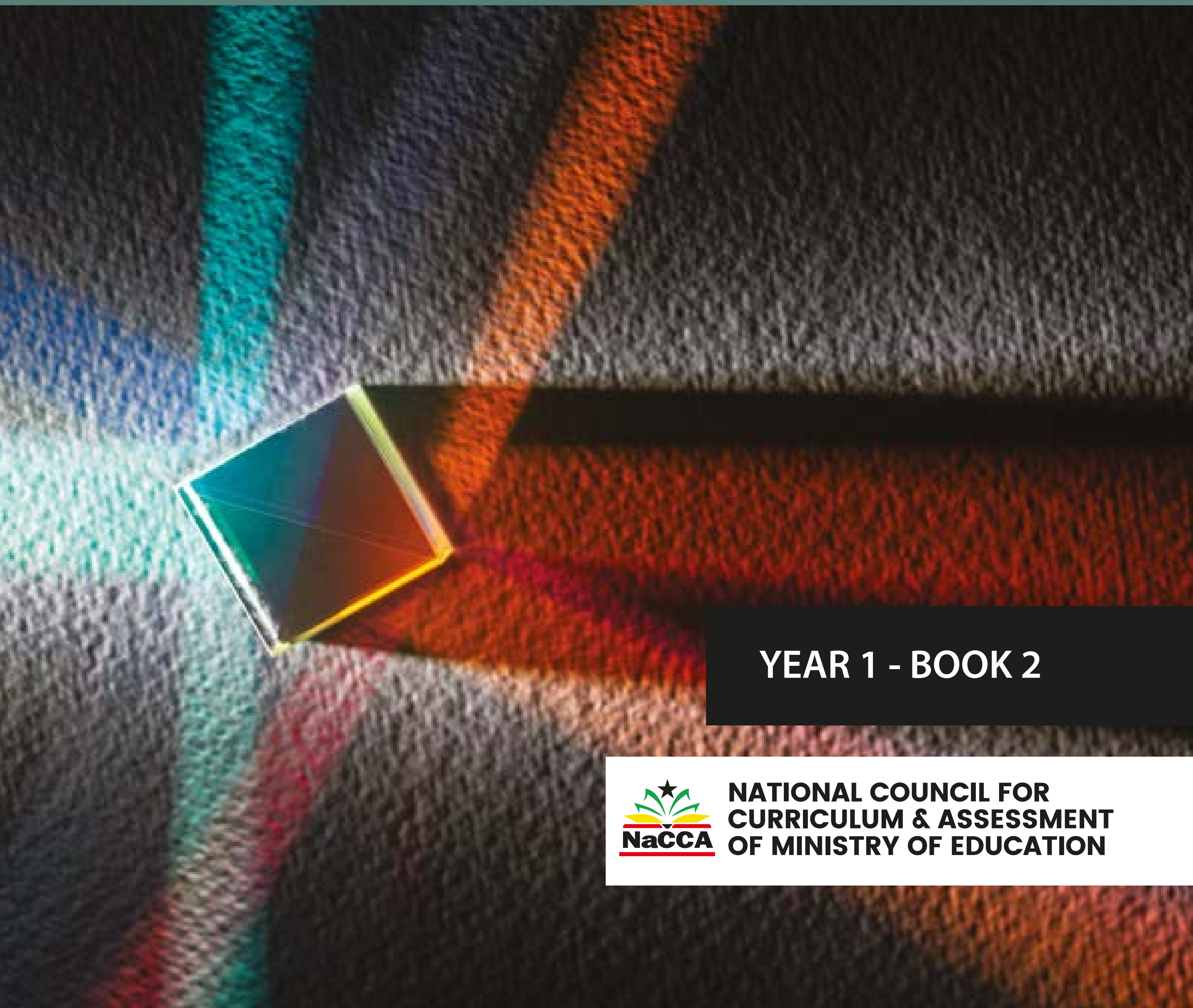
MINISTRY OF EDUCATION

PHYSICS

For Senior High Schools

TEACHER MANUAL



YEAR 1 - BOOK 2

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION

REPUBLIC OF GHANA

Physics

For Senior High Schools

Teacher Manual

Year One - Book Two

NATIONAL COUNCIL FOR
CURRICULUM & ASSESSMENT
OF MINISTRY OF EDUCATION

PHYSICS TEACHER MANUAL

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INTRODUCTION

The National Council for Curriculum and Assessment (NaCCA) has developed a new Senior High School (SHS), Senior High Technical School (SHTS) and Science, Technology, Engineering and Mathematics (STEM) Curriculum. It aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, competencies, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, further their education and enter the world of work.

This is the first time that Ghana has developed an SHS Curriculum which focuses on national values, attempting to educate a generation of Ghanaian youth who are proud of our country and can contribute effectively to its development.

This Book Two of the Teacher Manual for Physics covers all aspects of the content, pedagogy, teaching and learning resources and assessment required to effectively teach Year One of the new curriculum. It contains information for the second 12 weeks of Year One. Teachers are therefore to use this Teacher Manual to develop their weekly Learning Plans as required by Ghana Education Service.

Some of the key features of the new curriculum are set out below.

Learner-Centred Curriculum

The SHS, SHTS, and STEM curriculum places the learner at the center of teaching and learning by building on their existing life experiences, knowledge and understanding. Learners are actively involved in the knowledge-creation process, with the teacher acting as a facilitator. This involves using interactive and practical teaching and learning methods, as well as the learner's environment to make learning exciting and relatable. As an example, the new curriculum focuses on Ghanaian culture, Ghanaian history, and Ghanaian geography so that learners first understand their home and surroundings before extending their knowledge globally.

Promoting Ghanaian Values

Shared Ghanaian values have been integrated into the curriculum to ensure that all young people understand what it means to be a responsible Ghanaian citizen. These values include truth, integrity, diversity, equity, self-directed learning, self-confidence, adaptability and resourcefulness, leadership and responsible citizenship.

Integrating 21st Century Skills and Competencies

The SHS, SHTS, and STEM curriculum integrates 21st Century skills and competencies. These are:

- **Foundational Knowledge:** Literacy, Numeracy, Scientific Literacy, Information Communication and Digital Literacy, Financial Literacy and Entrepreneurship, Cultural Identity, Civic Literacy and Global Citizenship
- **Competencies:** Critical Thinking and Problem Solving, Innovation and Creativity, Collaboration and Communication
- **Character Qualities:** Discipline and Integrity, Self-Directed Learning, Self-Confidence, Adaptability and Resourcefulness, Leadership and Responsible Citizenship

Balanced Approach to Assessment - not just Final External Examinations

The SHS, SHTS, and STEM curriculum promotes a balanced approach to assessment. It encourages varied and differentiated assessments such as project work, practical demonstration, performance assessment, skills-based assessment, class exercises, portfolios as well as end-of-term examinations and final external assessment examinations. Two levels of assessment are used. These are:

- o Internal Assessment (30%) – Comprises formative (portfolios, performance and project work) and summative (end-of-term examinations) which will be recorded in a school-based transcript.
- o External Assessment (70%) – Comprehensive summative assessment will be conducted by the West African Examinations Council (WAEC) through the WASSCE. The questions posed by WAEC will test critical thinking, communication and problem solving as well as knowledge, understanding and factual recall.

The split of external and internal assessment will remain at 70/30 as is currently the case. However, there will be far greater transparency and quality assurance of the 30% of marks which are school based. This will be achieved through the introduction of a school-based transcript, setting out all marks which learners achieve from SHS 1 to SHS 3. This transcript will be presented to universities alongside the WASSCE certificate for tertiary admissions.

An Inclusive and Responsive Curriculum

The SHS, SHTS, and STEM curriculum ensures no learner is left behind, and this is achieved through the following:

- Addressing the needs of all learners, including those requiring additional support or with special needs. The SHS, SHTS, and STEM curriculum includes learners with disabilities by adapting teaching and learning materials into accessible formats through technology and other measures to meet the needs of learners with disabilities.
- Incorporating strategies and measures, such as differentiation and adaptative pedagogies ensuring equitable access to resources and opportunities for all learners.
- Challenging traditional gender, cultural, or social stereotypes and encouraging all learners to achieve their true potential.
- Making provision for the needs of gifted and talented learners in schools.

Social and Emotional Learning

Social and emotional learning skills have also been integrated into the curriculum to help learners to develop and acquire skills, attitudes, and knowledge essential for understanding and managing their emotions, building healthy relationships and making responsible decisions.

Philosophy and vision for each subject

Each subject now has its own philosophy and vision, which sets out why the subject is being taught and how it will contribute to national development. The Philosophy and Vision for Physics is:

Philosophy: The next generation of scientists is empowered through critical and creative thinking by understanding the theoretical and practical application of related concepts in physics that leverage hands-on activities within a global environment.

Vision: To equip physics learners with 21st-century skills and competencies through hands-on experimentation, analysis and discovery of basic concepts in physics and science for sustainable development.

S/N	STRAND	SUB-STRAND	YEAR 1			YEAR 2			YEAR 3		
			CS	LO	LI	CS	LO	LI	CS	LO	LI
1.	Mechanics and Matter	Introduction to Physics	2	2	8	3	3	7	3	3	13
		Matter	1	1	2	1	1	4	-	-	-
		Kinematics	1	1	3	2	2	7	1	1	4
		Dynamics	2	2	6	1	1	2	1	1	3
2.	Energy	Heat	1	1	4	1	1	4	1	1	3
		Waves	3	3	10	2	2	8	2	2	6
3.	Electromagnetism	Electrostatics, Direct Current	2	2	7	2	2	9	3	3	7
		Magnetostatics, Alternating Current	1	1	3	3	3	10	2	2	6
		Analogue Electronics, Electromagnetic Induction & Applications	3	3	9	3	3	9	3	3	9
		Applications of Electronics	-	-	-	-	-	-	3	3	7
4.	Atomic and Nuclear Physics	Atomic Physics	1	1	2	1	1	3	1	1	4
		Nuclear Physics	1	1	3	1	1	3	1	1	3
Total			**18**	**18**	**57**	**20**	**20**	**66**	**21**	**21**	**65**

Overall Totals (SHS 1 – 3)

Content Standards	**59**
Learning Outcomes	**59**
Learning Indicators	**188**

SECTION 5: BEHAVIOUR OF LIGHT THROUGH DIFFERENT MEDIA

Strand: **Energy**

Sub-Strand: Waves

Content Standard: Demonstrate knowledge and understanding of refraction.

Learning Outcome: *Explain refraction and recognise its relevance in different media.*

INTRODUCTION AND SECTION SUMMARY

The week covered by this section is *Week 13: Refractive index, total internal reflection*

This section explores key concepts in optics related to the behaviour of light as it travels through different media.

The section begins by explaining how to determine the refractive index of a medium, which measures the extent to which light changes speed when transitioning from one medium to another. The refractive index is crucial for understanding the change in direction of light (refraction) as it enters or exits a medium and is a key factor in designing optical systems.

Next, the section describes total internal reflection, which occurs when light travels from a medium with a higher refractive index to a medium with a lower refractive index at an angle greater than the critical angle.

The section also explores the relationship between real depth, apparent depth, and refractive index. When light passes from one medium to another, objects submerged in the medium appear shallower (apparent depth) than their true position (real depth) due to the change in light speed and subsequent refraction. This relationship can be described mathematically and is essential for understanding how images are perceived in different media, impacting the design of optical instruments.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Pedagogical exemplars for teaching Section 5 should involve engaging instructional strategies to enhance understanding:

- Conduct experiments and demonstrations:
  - o Using Snell's law to calculate the refractive index of different media.
  - o Perform demonstrations with prisms or transparent media to illustrate total internal reflection and the critical angle.
  - o Offer hands-on activities where learners measure real and apparent depths in water or other media.
- Use real-world applications to emphasise the importance of these phenomena:
  - o Optics in glasses and fibre optics
  - o Discuss technological applications such as fibre optics, periscopes, and binoculars that rely on total internal reflection.
  - o Provide illustrative examples, such as the apparent depth of a pool.
- Incorporate interactive simulations for learners to manipulate variables and observe the effects on refractive index.

- Use visual aids like ray diagrams to show how light behaves when it reaches the boundary at angles greater than the critical angle.
- Teach the formula and guide learners in applying it.

ASSESSMENT SUMMARY

Assign problems that require learners to calculate the refractive index of different media, explain conditions for total internal reflection, and establish relationships between real and apparent depth.

Have learners conduct experiments to determine different media's refractive index, observe total internal reflection, and write detailed reports on their findings and conclusions. Assess learners' ability to perform optical experiments and accurately measure refractive index and depth.

Assign projects where learners create videos or animations explaining refraction and total internal reflection. Have learners draw and label diagrams illustrating refraction, total internal reflection, and real versus apparent depth.

Develop rubrics to provide clear criteria for assessing student work across different assessment tasks. Use rubrics to evaluate not only content knowledge but also skills such as critical thinking, communication and problem-solving.

Keep track of learners' scores and any feedback on their understanding of key concepts. Note areas where learners are struggling or excelling for targeted instructional support.

Week 13

Learning Indicators:

1. *Determine the refractive index of a medium.*
2. *Explain total internal reflection.*
3. *Establish the relationship between the real depth, apparent depth and the refractive index.*

Theme or Focal Area : Refractive Index of a Medium

The refractive index of a medium refers to how much light slows down as it passes through that medium compared to its speed in a vacuum.

The history of understanding refraction and the development of Snell's law, which is central to calculating the refractive index, has evolved through significant contributions from various scholars. Ptolemy of Alexandria was among the first to experiment systematically with refraction. He observed that the ratio of the angle of incidence to the angle of refraction remained constant for a given pair of media, indicating that this ratio depended on the inherent properties of the materials involved. However, it was the Arabian mathematician and physicist Ibn Sahl who, in 984, first articulated what we now refer to as the law of refraction or Snell's law. Later, in 1621, the Dutch mathematician Willebrord Snell refined the concept based on precise mathematical calculations and accurate experimental observations. Snell demonstrated that the ratio of the sines of the angles of incidence and refraction is constant when light transitions between two different media. This discovery significantly enhanced the scientific understanding of how light behaves.

Snell's law allows a medium's refractive index to be mathematically determined. This law has proven fundamental in optics and physics, providing a critical tool for analysing how light bends or refracts as it passes from one medium to another. The refractive index of a medium can be determined using mathematically as, $n_1 sin\theta_1 = n_2 sin\theta_2$

Where and are the refractive indices for media 1 and 2; θ_1 and $\theta_2$are the angles of incidence and refraction.

Understanding refractive indices is crucial in various fields, from optics and engineering to everyday applications, and it plays a vital role in shaping modern technology and enhancing our daily experiences. For example, Opticians use the knowledge of refractive indices to design and prescribe corrective lenses that properly focus light onto the retina, improving vision. By understanding how light bends as it passes through different materials (e.g., glass or plastic), they can correct vision problems like near-sightedness or far-sightedness.

Learning Tasks

1. Define the refractive index of a medium and demonstrate an understanding of its significance in optics.
2. Perform experiments to measure the refractive index of a transparent medium such as glass or water.
3. Solve problems involving light passing from one medium to another with different refractive indices, such as air to glass or water to air.

Pedagogical Exemplars

1. Discuss the importance of refractive indices in real-world applications, such as designing lenses for glasses, cameras and other optical devices.
2. Provide learners with a dataset that includes measurements of the angle of incidence and the angle of refraction for light passing through various transparent materials. Instruct learners to analyse the data to identify the consistent pattern Snell's Law describes. They should plot the sine of the angle of incidence against the sine of the angle of refraction to ascertain the linear relationship visually.
3. Guide learners to manipulate and solve problems with the formula for calculating the refractive index: $n_1 \sin\theta_1 = n_2 \sin\theta_2$
   - Less confident learners will need more support and at least one worked example to follow while they attempt a set of problems independently.
   - More confident learners should be able to perform calculations to find n_1, n_2, θ_1 or θ_2. They should be given more challenging questions asking them to find the change in the angle of refraction for a given change in the angle of incidence, etc.

The most able students may be able to derive Snell's law for themselves, by considering the distance travelled in a given time period by one wavefront before and after it passes a boundary at a non-zero angle (Fermat's principle). They could be given a scaffolded worksheet to guide them through this.

4. A simple optical apparatus consisting of a glass block, a light source, and a protractor is used to directly measure the angles of incidence and refraction. A diagram of the experimental set-up and of the angles that need to be measured should be provided, allowing each learner or group to perform measurements independently. Learners should be reminded that they need to draw a dotted normal in order to measure their angles. Provide a step-by-step guide on how to use these measurements to calculate the refractive index of the glass. Learners compare their experimental values to known refractive indices of the materials used.
5. Use interactive virtual simulations or online tools that allow learners to adjust the angle of incidence and observe how light bends as it enters different materials. This will help them visualise the laws of refraction in action.

Key Assessment

Assessment level 1: What is the refractive index of a medium?

Assessment level 2: Explain how you can determine the refractive index of a transparent solid using a glass block and a ray of light.

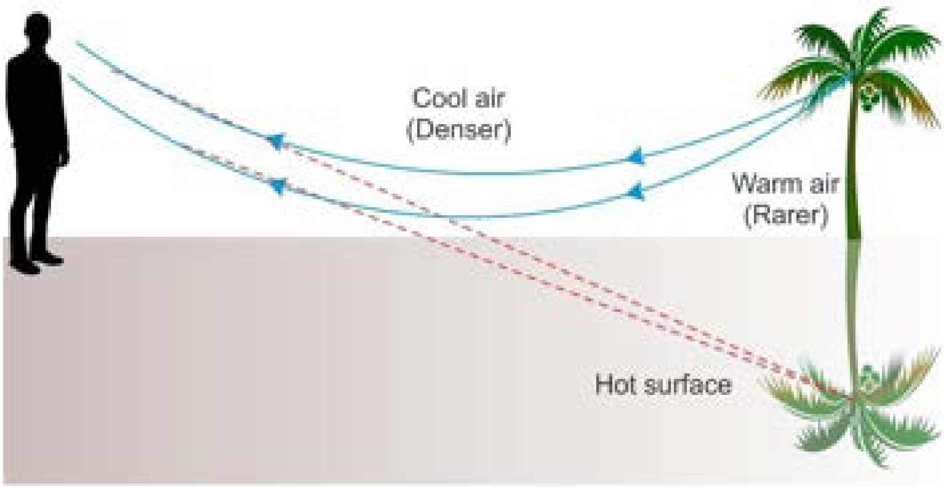
Assessment level 2: Refractive indices have a variety of applications in Physics-related careers. In optometry, the cornea has a refractive index of 1.38 in the human eye. It forms a single thin lens together with the lens to project light onto the retina. The index of refraction in the eye are crucial to its ability to form images. Calculate the angle of refraction when the angle of incident light travelling from air into the cornea is at 30^0

Theme or Focal Area: Total Internal Reflection

Like in many other parts of the world, internet connectivity in Ghana is primarily facilitated through undersea fibre optic cables. These cables are crucial for international data transmission, offering high-speed and large-capacity channels that connect Ghana to the global internet infrastructure. South Atlantic 3/West Africa Submarine Cable (SAT-3/WASC), Main One Cable and West Africa Cable System (WACS) are part of the extensive network of undersea cables that provide us with the opportunity to connect with others on Snapchat, WhatsApp, X, TikTok and other internet applications. The Physics principle behind this technology is total internal reflection.

Total internal reflection is a phenomenon that occurs when light travelling through a denser medium encounters a boundary with a less dense medium at an angle greater than the critical angle. Instead of passing through the boundary, the light is completely reflected into the denser medium.

In medicine, endoscopes are instruments used to look inside the body and utilise total internal reflection. These devices are equipped with a system of optical fibres that transmit light into the body and carry back images from inside, allowing for non-invasive visual inspections of the gastrointestinal tract, blood vessels, and other internal structures. In photonics, optical switches and reflectors use total internal reflection to direct light paths in integrated circuits. These devices are crucial for developing optical computing and advanced photonic technologies. A natural phenomenon observable in certain atmospheric conditions known as a mirage typically occurs due to total internal reflection. These applications demonstrate the versatility of total internal reflection in enhancing modern technology and daily life, making it a fundamental principle in both practical gadgets and high-tech innovations.



Mirage

Learning Tasks

1. Define total internal reflection and explain how TIR differs from regular reflection and refraction.
2. Identify and explain the essential conditions required for total internal reflection.
3. Calculate the critical angle for different combinations of refractive indices.
4. Describe some applications of total internal reflection.

Pedagogical Exemplars

1. Learners in mixed-ability groups use a refraction simulation, specifically focusing on situations where light moves from a medium of higher density to a lower-density medium. Learners should vary the angle of incidence and observe the effect of this on the path of the light.
2. Conduct a demonstration (or, if possible, perform a whole-class practical) using a laser pointer and a glass block. If this is not possible, use an online simulation. Show learners how light passes through the block and exits at an angle. Gradually increase the angle of incidence until they observe total internal reflection, where the light is ultimately reflected back into the block. Ask

the learners to use their observation to identify and explain in detail the two essential conditions required for total internal reflection to occur (this could involve discussions in mixed-ability groups or a think-pair-share activity).

a. The light must travel from a denser medium to a less dense medium.
b. The angle of incidence in the denser medium must exceed the critical angle specific to the pair of media involved. Include interactive visual aids or simulations to demonstrate these conditions dynamically.

3. Provide a step-by-step tutorial on how to calculate the critical angle for different combinations of refractive indices using the formula:

$$\theta_c = sin^{-1}\left(\frac{n_2}{n_1}\right)$$

Where *n* is the refractive index of the denser medium and is the refractive index of the less dense medium. Guide learners to solve problems that calculate the critical angle for common materials like water-air, glass-air, and diamond-air combinations.

- Problems should be differentiated in order to challenge learners of varying abilities in this area. Less able students should be given worked examples to follow, and some more straightforward problems requiring little formula manipulation. More able students should be required to manipulate the formula and should be able to suggest the effect of a) using a medium with a higher optical density or b) changing the angle of incidence.

4. Provide learners with practical applications of total internal reflection, such as periscopes or fibre-optic endoscopes, and ask them to describe how this phenomenon enables these devices to work effectively.

5. Assign learners to research and present examples of total internal reflection in nature, such as the internal reflection of light within certain gemstones or the behaviour of light in underwater environments.
   - Students could be assigned topics based on their confidence and ability, i.e. more able students should be given more complicated scenarios to present and explain.
   - Presentations could be written or oral.

Key Assessment

Assessment level 1: What is total internal reflection?

Assessment level 1: What conditions are necessary for total internal reflection?

Assessment level 2: Calculate the critical angle for light moving from water (n=1.33) into air.

Assessment level 3: You are a jewellery designer aiming to maximise a diamond's sparkle for a client's wedding ring. With your understanding of how light interacts with the gemstone and given that the refractive index of the diamond is approximately 2.42 and that of air is 1.00, calculate the critical angle for light within the diamond. How does this knowledge help design jewellery that enhances the diamond's brilliance?

Assessment level 4: On your way home, you saw a puddle of water a distance away. On reaching the place where the puddle was, you noticed there was no sign of one. How do you explain to your friends how this is caused with your knowledge of total internal reflection?

Theme or Focal Area: Relationship Between The Real Depth, Apparent Depth And The Refractive Index

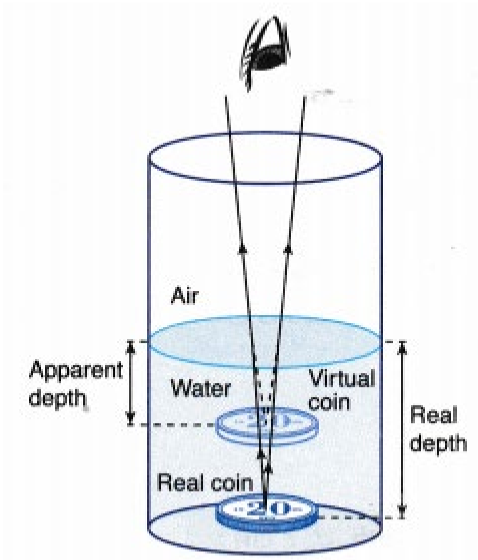
From Snell's law, the refractive index (n) is related to the apparent depth and the real depth as follows:

$$n = \frac{(real\ depth)}{(apparent\ depth)}$$

apparent displacement = real depth — apparent depth

When you place a coin at the bottom of a bowl of water, you'll notice that the coin appears shifted or displaced from its actual position. This phenomenon is due to the refraction of light as it passes from the water to the air.

The real depth in this scenario is the physical distance between the bottom of the bowl and the coin. The apparent depth, on the other hand, is the perceived position of the coin as observed from above the water's surface.



Coin placed in a glass of water

Learning Tasks

1. Define and distinguish between real depth and apparent depth.
2. Conduct a demonstrative experiment.
3. Engage in problem-solving exercises that calculate the real depth, apparent depth, and refractive index.
4. Present case studies where understanding of these optical concepts is essential.

Pedagogical Exemplars

1. Following the introduction through the definition of real and apparent depth, learners place a coin at the bottom of a transparent container filled with water in small groups of mixed-abilities. They observe the coin from various angles - directly above and on the side. Learners observe first-hand how the apparent position of the coin changes due to refraction and discuss their observations with their peers.

2. Learners then tackle mathematical problems involving the calculation of real depth, apparent depth, and refractive index. They solve various scenarios that challenge them to apply what they've learned in a quantitative context.

3. Engage in case study discussions and group presentations that explore the importance of these optical principles in real-world contexts such as gemology (the science of studying, cutting and valuing gems), optometry and marine biology. Each group investigates how the refractive index is utilised in a specific industry and then presents their findings to the class.
   - Students could be assigned topics based on their confidence and ability, i.e. more able students should be given more complicated scenarios to present and explain.
   - Presentations could be written or oral.

Key Assessment

Assessment level 2: In 2019, an estimated 236,000 people died from drowning, making drowning a major public health problem worldwide. Following instructions while swimming at the poolside is imperative to avoid injury or death. The pool floor appears to be at a depth of 1.5 m when viewed vertically from above. If the refractive index of the water in the pool is 1.3, determine:

(i) the depth of the pool

(ii) the apparent displacement of the swimming pool floor

Assessment level 3: Derive an equation that relates the apparent displacement to a medium's refractive index and a pond's apparent depth but does *not* include the real depth.

Section 5 Review

Learners should understand the concept of refractive index as a measure of light's speed in different media. Learners should be able to draw ray diagrams to visualise the phenomenon of total internal reflection. Learners should understand how and why total internal reflection occurs, particularly at the interface of optically dense and optically less dense mediums. Learners should recognise the practical applications of apparent depth, such as in the design of swimming pools and the phenomenon of bent sticks in water.

References

1. Grover, J. (2023, December 18). Total Internal Reflection: conditions, formula and applications. Collegedunia. https://collegedunia.com/exams/total-internal-reflection-physics-articleid-76

2. Veerendra. (2022, November 17). How are apparent depth and real depth related to the refractive index? A Plus Topper. https://www.aplustopper.com/apparent-depth-real-depth-related-refractive-index/

SECTION 6: ELECTRICAL CHARGE AND MAGNETISM

Strand: **Electromagnetism**

Sub-Strands:

1. Electrostatics
2. Magnetostatics

Content Standards:

1. Demonstrate knowledge and understanding of the differences between conductors, semiconductors and insulators.
2. Demonstrate knowledge and understanding of the differences between the two types of particles (positive and negative) involved in electric interactions.
3. Demonstrate knowledge and understanding of the basics of magnets, magnetisation, demagnetisation and magnetic fields.

Learning Outcomes:

1. *Distinguish between conductors, insulators and semiconductors based on the behaviour of electrons as charge carriers.*
2. *Describe forces between like and opposite charges.*
3. *Distinguish between magnetic and non-magnetic materials and explain magnetisation and demagnetisation.*

INTRODUCTION AND SECTION SUMMARY

The weeks covered by the section are:

Week 14: Gold leaf electroscope and Mobile charge carriers

The gold leaf electroscope, used to detect electrical charges, demonstrates the movement of gold leaves in response to charge. Electrons are mobile charge carriers in conductors and semiconductors, facilitating electrical currents, while insulators restrict charge flow.

Week 15: Charge, Charge distribution, Conservation of charge and types of charge

Charges distribute differently on surfaces depending on the shape, with spherical surfaces showing even distribution and pointed surfaces concentrating charges. Charge is a fundamental property of matter, similar to mass, and exists in positive and negative forms. The conservation of charge principle maintains that total charge in a closed system remains constant.

Week 16: Magnetic and non-magnetic materials, Magnetic field, magnetisation and demagnetisation

The section also differentiates between magnetic and non-magnetic materials. Magnetic materials like iron exhibit magnetic properties, while non-magnetic materials do not. Magnetic fields, represented by lines of force, affect magnetic materials and are vital to understanding magnetic interactions. Magnetisation aligns magnetic domains in a material, while demagnetisation disrupts this alignment.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Pedagogical exemplars for teaching Section 6 should involve using various strategies to engage learners, clarify complex concepts, and reinforce learning:

- Conduct demonstrations and inquiry-based activities:
  - Hands-on experiments to illustrate electron movement in materials like conductors, semiconductors and insulators.
  - Show how the electroscope detects and measures electrical charges.
  - To explore the processes and effects of magnetisation and demagnetisation.
  - Perform experiments to classify materials based on their magnetic properties.
  - Hands-on experiments with iron filings or compasses to observe magnetic fields.
- Conduct interactive demonstrations and role-playing activities to explore:
  - Attraction and repulsion between charges.
  - Attraction and repulsion between poles of a magnet.
- Use concept mapping and real-life examples to emphasise charge as a fundamental property of matter.
- Use visual representations like field lines.

ASSESSMENT SUMMARY

Provide diagrams of gold leaf electroscope setups, charged surfaces (spherical, pear-shaped, sharp point), and magnetic field lines, and ask learners to interpret and explain the observed phenomena.

Use short answer questions by assessing learners' ability to define charge as a fundamental property of matter, explain the conservation of charge, differentiate between positive and negative charges, and distinguish between magnetic and non-magnetic materials.

Assign tasks where learners design experiments to investigate specific aspects of charge behaviour, such as the distribution of charges on different surfaces or the behaviour of charges in various materials. Ask learners to conduct demonstrations of phenomena such as charging by induction, magnetisation and demagnetisation.

Provide scenarios or case studies that require learners to analyse and evaluate the implications of charge behaviour and magnetic properties in real-world situations. Assign essays or reports where learners explore specific areas in more depth, such as the role of charge in electrostatic phenomena or the applications of magnetism in technology.

Develop rubrics to provide clear criteria for assessing student work across different assessment tasks. Use rubrics to evaluate not only content knowledge but also skills such as critical thinking, communication and problem-solving.

Keep track of learners' scores and any feedback on their understanding of key concepts. Note areas where learners are struggling or excelling for targeted instructional support.

Week 14

Learning Indicators:

1. *Explain how the gold leaf electroscope can detect the charge carried by a body.*
2. *Identify electrons as mobile charge carriers.*
3. *Explain how charge carriers in conductors, semiconductors and insulators behave.*

Theme or Focal Area: Gold Leaf Electroscope

The gold leaf electroscope is a classic scientific instrument that detects electric charges. It consists of a glass jar with a metal rod passing through its lid, ending in two thin strips of gold leaf inside the jar. The jar is typically made of glass to allow for visual observation of the gold leaf strips. Its development traces back to the early 18th century and has played a crucial role in exploring electrostatic phenomena.

When an electric charge is applied to the metal rod, it separates charges in the gold leaf strips. Like charges repel each other, the gold leaf strips, which carry the same charge, spread apart. This spreading of the gold leaf strips is easily observable and provides a visual indication of the presence and magnitude of the electric charge. This method of charging is called charge sharing.

The sensitivity of the gold leaf electroscope allows it to detect minimal electric charges. It can be used to determine whether an object is positively or negatively charged by bringing it near the metal rod. If the gold leaf strips diverge further, it suggests that the object has the opposite charge to that induced on the metal rod.

Gold leaf electroscope

Learning Tasks

1. Draw a labelled diagram of the Gold leaf electroscope.
2. Demonstrate the principles of electrostatics using a Gold leaf electroscope.

Pedagogical Exemplars

1. Show the learners a physical gold leaf electroscope and explain its essential components, such as the metal rod, the metal leaves and the housing. Demonstrate how the electroscope responds when charged. A video or picture can be used where the equipment is not available.
2. Provide a charged object (e.g., a plastic rod rubbed with a cloth). Using the process of charge separation, instruct learners to touch the metal rod of the electroscope with the charged object and observe the response of the gold leaves.
3. Ask the learners to bring different objects (e.g., plastic, glass, metal) and experiment with charging the electroscope by induction. Have them predict and observe the behaviour of the gold leaves in each case. Safety precautions should be adhered to.
4. Provide learners with a positively charged object and a negatively charged object. Ask them to charge the electroscope using each object separately and compare the behaviour of the gold leaves in each case.
5. Demonstrate charging the electroscope by friction with different materials (e.g., rubbing a glass rod with silk, rubbing a plastic rod with fur). Have learners predict the behaviour of the electroscope before each demonstration.

Key Assessment

Assessment level 2: How does a gold leaf electroscope detect a charge?

Assessment level 2: Historically, Gold leaf electroscopes were used to study atmospheric electricity. This was done by observing changes in the electroscope's behaviour during weather events like thunderstorms. How would you use the gold leaf electroscope to detect the charge carried by a body?

Assessment level 3: Design an experiment to detect charge using the gold leaf electroscope.

Theme or Focal Area: Electrons as Mobile Charge Carriers

Electrons are fundamental carriers of electric charge and in many substances, such as metals, they are responsible for transporting electric charges. These subatomic particles carry a negative charge and orbit the atomic nucleus within distinct energy layers or shells. In conductive materials like metals, electrons in the outermost energy shell, valence electrons are delocalised from their atoms. These "free" or "delocalised" electrons are not tightly bound to any specific atom, allowing them to move freely throughout the material. This mobility of electrons is crucial for the functioning of electrical circuits. For example, in a household electrical system, the flow of electrons through wiring allows electricity to power devices such as lights, computers and refrigerators. When you switch on a light, you complete a circuit that allows electrons to flow through the wire and produce light. This fundamental understanding of electron behaviour is key to modern technology, from simple circuits to advanced computer systems.

Learning Tasks

1. Define mobile charge carriers.
2. Explain how electrons function as mobile charge carriers in a conductor.

Pedagogical Exemplars

1. Based on previous knowledge, explore the basic properties of atoms and electrons through discussion and multimedia resources such as videos, diagrams and interactive simulations.

Introduce the term "mobile charge carrier" and define it as any particle that can move and carry electric charge within a material.

2. Facilitate a learner-led discussion on why metals are good conductors, focusing on the presence of free electrons. Conduct a role-playing activity (where some pupils behave as circuit components while others behave as electrons transferring energy to/from the components) or a simple experiment using a circuit board, wires, a battery, and a light bulb to demonstrate how electrons move through a circuit and what happens when the circuit is broken.
3. Give pupils the formula relating charge, current and time (Q = It), as well as the charge on an electron (1.6 × 10^-19C), and provide them with a differentiated worksheet assessing their ability to calculate the number of electrons passing a point in a wire in a given period of time.
   - Less able (AP) students should not be expected to do complicated unit conversions, while P students should be expected to convert units and use standard form in more challenging ways.
   - More able students may be able to go on to calculate the density of mobile charge carriers within a conductor if given the conductor's dimensions and other relevant information.

Key Assessment

Assessment level 1: Define a mobile charge carrier and identify examples.

Assessment level 3: Briefly explain how electrons behave in metallic conductors and the importance of this behaviour in everyday electrical applications.

Assessment level 3: Assign learners to research and present how understanding mobile charge carriers has led to technological innovations (e.g., the development of semiconductors and solar cells).

Theme or Focal Area: Charge Carriers in Conductors, Semiconductors

The exploration of charge carriers in conductors, semiconductors, and insulators provides a comprehensive view of how materials interact with electricity, forming the foundation of modern technology. Each type of material plays a pivotal role in electronic applications, from powering devices to controlling the flow of electrical currents.

Attempting to solve a long-standing controversy regarding the nature of cathode rays, which occur when an electric current is driven through a vessel from which most of the air or other gas has been pumped out, J J Thomson (awarded the Nobel Prize in Physics in 1906) discovered the electrons, identifying them as the primary charge carrier. He initially called them corpuscles to explain these tiny particles in the same terms as biological cells (corpuscles are a minute body or cell in an organism). In conductors like metals, electrons are not tightly bound to any specific atom and can move freely, facilitating efficient electrical conductivity. This discovery opened the doors to the electronic revolution, enabling the development of myriad devices that rely on the unimpeded flow of electrical current.

The invention of the transistor in 1947 by John Bardeen, Walter Brattain, and William Shockley, who shared the Nobel Prize in Physics in 1956, changed the game by allowing precise control over electrical conductivity and marked the beginning of the digital age. Semiconductors use both electrons and "holes" (positive charge carriers) in a controlled manner through a process known as doping. This ability to fine-tune electrical properties makes semiconductors ideal for various applications, from microprocessors in our cell phones and kitchen appliances to solar panels.

Often overlooked, insulators are materials that do not readily conduct electricity under normal conditions. They have tightly bound electrons that do not freely move, preventing electrical current flow. This property makes insulators critical in every electrical circuit, serving as protectors and separators that prevent unwanted flow of current, ensuring safety and functionality in electrical systems. Common insulators include rubber, glass and most plastics, each playing a crucial role in everything from household wiring to complex electronic circuits.

Learning Tasks

1. Identify and explain the key electrical properties that differentiate conductors, semiconductors and insulators.
2. Classify materials into conductors, semiconductors and insulators.
3. Describe the behaviour of electrons in conductors, semiconductors and insulators.

Pedagogical Exemplars

1. Explain the fundamental properties that distinguish conductors, semiconductors and insulators and highlight the role of electron configuration and bonding in defining these properties.
2. Facilitate a brainstorming session where learners in groups classify various items, such as metals, plastics, rubber, paper, etc, as conductors, semiconductors, or insulators, using their prior knowledge of material properties.
3. If available, conduct a simple lab activity using circuits that include a light bulb, a battery, wires and switches made from different materials to show conductivity in real time. Learners could experiment with NTC thermistors or LDRs in order to establish the relationship between environmental conditions and the current flow in the circuit.
   - The activity could be done in mixed-ability groups, such that learners can discuss and suggest why, for example, an NTC thermistor behaves as it does. More able students should be able to identify the relationship between temperature, thermal energy and the liberation of electrons. Less able students could be provided with key words that will help them to build their explanations and suggestions.
4. Use computer simulations or role play to demonstrate how electrons flow in conductors, how they are manipulated in semiconductors, and why they are blocked in insulators. Discuss how these behaviours, such as wires, transistors and electrical insulators, affect device functionality.

Key Assessment

Assessment level 1: Give two examples each of:

(i) Conductors

(ii) Semi-conductors

(iii) Insulators

Assessment level 2: Describe how electrons flow in conductors, semiconductors and insulators.

Assessment level 3: Describe a series of tests that can be used to determine whether a material is a conductor, semiconductor or insulator.

Week 15

Learning Indicator(s):

1. *Explain the distribution of charges on surfaces: spherical, pear-shaped and sharp points.*
2. *Define charge as a fundamental property of matter (like mass).*
3. *Explain the conservation of charge and its behaviour.*
4. *Differentiate between the two charges (positive and negative).*

Theme or Focal Area: Charge

Electric charge is a fundamental physical property of matter that interacts with electromagnetic fields and is central to many modern technologies and industries. Charge is a physical property that causes matter to experience a force within an electromagnetic field. It is measured in Coulombs. Historically, the study of electric charge gained momentum with pioneers like Benjamin Franklin and Charles-Augustin de Coulomb in the 18th century. Franklin's experiments established the electrical nature of lightning, while Coulomb quantified the forces between charges, laying the groundwork for electrostatics.

Electric charge is crucial in electricity generation and distribution, powering homes, businesses and public infrastructure. It is also foundational in electronics and information technology, enabling the operation of everything from smartphones to global communication networks. In the medical field, electric charge is used in diagnostic and surgical procedures, such as electrocardiograms and electrosurgery. Furthermore, electrostatic precipitation supports industrial processes like electroplating, electrolysis and pollution control.

Understanding electric charge reveals its indispensable role in driving technological advancements and improving human well-being, highlighting its significance across diverse sectors of modern life.

Learning Tasks

1. Explore the historical development of the concept of electric charge.
2. Conduct a simple experiment to demonstrate electrostatic phenomena using everyday materials like balloons, wool and plastic wrap.
3. Discuss real-world applications of charge.

Pedagogical Exemplars

1. Ask learners to list fundamental properties of matter they are already familiar with (e.g., mass, volume, density). Prompt them to discuss what they know about electric charge and how it might be related to the other properties.
2. Learners in mixed-ability groups should mind-map the fundamental properties of matter and show links between these where appropriate (e.g. attraction to a magnet and electrical conductivity, thermal conductivity and electrical conductivity, physical state and density etc).
3. Learners research and create a timeline of key discoveries related to electric charge, focusing on contributions by Benjamin Franklin and Charles-Augustin de Coulomb.

4. Provide learners with a chart comparing the properties of mass and electric charge. Have them analyse the similarities and differences between these fundamental properties.

Key Assessment

Assessment level 1: What is electric charge?

Assessment level 2: Write a brief essay explaining how the experiments by Benjamin Franklin and Charles-Augustin de Coulomb contributed to our current understanding of electric charge.

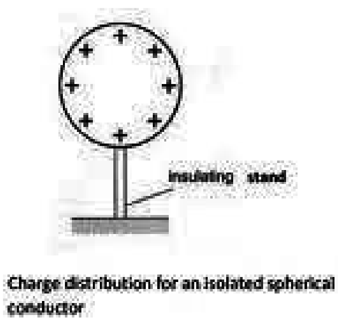
Assessment level 4: In groups, choose a specific application of electric charge (e.g., in environmental technologies or medical devices). Research current technologies, identify limitations and propose innovative improvements or new applications. This includes creating a project proposal outlining their innovation's scientific, technical and practical aspects.

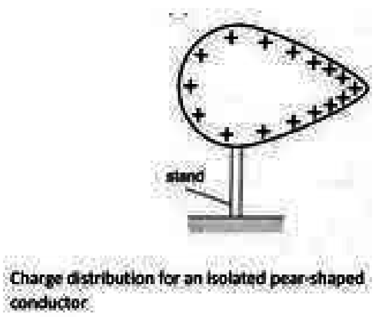
Theme or Focal Area: Distribution of Charges on Surfaces

The distribution of electrical charges on a surface, influenced by the geometry of that surface, has significant practical applications across various fields. Spherical surfaces exhibit a uniform charge distribution due to their symmetrical shape, allowing charges to spread evenly. This uniformity is crucial in applications such as Van de Graaff generators used in particle accelerators and educational demonstrations where consistent and stable charge distribution is necessary to ensure smooth operation and safety.

However, pear-shaped surfaces see more charges concentrated at the sharper, narrower end. This characteristic is beneficial in the design of lightning rods. The sharper end facilitates a higher charge concentration, enhancing the rod's ability to draw lightning away from the structure it protects by providing a preferred path for the lightning's electrical discharge.

Moreover, surfaces with sharp points, such as needles or the tips of cones, show a concentration of charges at these high-curvature points. This phenomenon is exploited in technologies such as corona discharge applications, where sharp points are used to ionise air and other gases. This principle is applied in devices like electrostatic precipitators and photocopiers. In electrostatic precipitators, for example, ionised particles are attracted to oppositely charged collector plates, removing pollutants from air or gases. In photocopiers, sharp-pointed corona wires deposit toner onto paper uniformly.





Charge distribution for an isolated spherical conductor and isolated pear-shaped conductor

Learning Tasks

1. Explain how charges distribute on different surfaces, particularly conductors and insulators.
2. Explain the concept of surface charge density.

Pedagogical Exemplars

1. Provide various objects with different shapes (spherical fruits, tapered sticks, sharp metallic objects) for students to handle and study. Use these objects to discuss and demonstrate static electricity by rubbing cloths against them. Students may be given a blank worksheet/table to fill in to provide scaffolding for them to analyse the effects that they see (e.g. "name of object", "shape of object", "conductor, insulator or other?", "effect of rubbing with a cloth and then placing close to small pieces of tissue" etc). Go through the answers with the class, allowing them to share their ideas. Draw students' attention to the idea that insulators build up a surface charge where conductors do not, and the subsequent behaviour that we can see when they are brought near to small pieces of tissue or an electroscope. Emphasise the effect of the shape of the objects in charge distribution for the insulators.
2. Conduct a simple experiment with balloons, wool and plastic wrap to show electrostatic effects – rubbing these materials to generate and observe static charges.
3. Guide learners in building a simple electroscope using a glass jar, aluminium foil, and plastic or wooden sticks. Demonstrate how to bring charged objects near the electroscope to observe the behaviour of the foil. Use sewing needles or nails to show how charge concentrates at points by bringing these near the built electroscope.
4. Engage learners in identifying a local problem where electrostatic principles could be applied, such as reducing static interference in community radio equipment or protecting homes from lightning strikes. Learners in groups of mixed abilities use their understanding of charge distribution to propose solutions, using locally sourced materials for mock-ups or models. Research may be presented as a poster, computer presentation or orally.

Key Assessment

Assessment level 1: How do charges distribute themselves on the surface of a conductor?

Assessment level 1: Describe the distribution of charges on a spherical conductor.

Assessment level 2: Compare the charge distribution on a pear-shaped conductor to that on a spherical conductor. How does the shape affect the charge density?

Theme or Focal Area: Positive And Negative Charges

This theme/focal area delves into the essential principles of electrostatics, emphasising the distinct behaviours of positively and negatively charged bodies within electric fields. Understanding that only mobile electrons move between objects in electrostatic phenomena is crucial. Positively charged bodies lack electrons, whereas negatively charged bodies have an excess of them. Protons in the nucleus do not participate in these electrostatic interactions due to their stability and strong binding forces.

This fundamental concept is exemplified by lightning, a natural occurrence resulting from the separation and sudden discharge of positive and negative charges in the atmosphere. Understanding these charge dynamics is vital for comprehending various electromagnetic phenomena and informs the development of related technologies.

Learning Tasks

1. Identify and distinguish between positively and negatively charged objects.
2. Explain a natural phenomenon based on knowledge of positive and negative charges.
3. Demonstrate the movement of electrons and explain electrostatic phenomena.

Pedagogical Exemplars

1. Distribute balloons, wool, plastic rods and pieces of cloth to small groups of learners and instruct them to rub the items with the cloth to generate static electricity. Then, test how these items interact (attract or repel each other). Facilitate a class discussion where learners hypothesise which objects are positively and negatively charged based on their observations.
2. Provide learners with basic information about charge separation in thunderstorms and ask them to research more details using classroom resources or the internet. Learners create a storyboard or comic strip that illustrates the process of charge building up in clouds and culminating in a lightning strike. Each group presents their storyboard to the class, explaining each step of the charge separation and discharge process.

Key Assessment

Assessment level 1: What type of charge does an object have if it has more electrons than protons?

Assessment level 4: "The claim in the letter by Esprit et al., that mobile phones are a risk when used in a storm is misleading. Although some people speculate that mobile phones pose a risk when used outdoors because lightning is attracted to metal, mobile phone handsets generally contain insignificant amounts of metal. Following worldwide media interest in the letter, the US National Oceanic and Atmospheric Administration (NOAA) responded, saying lightning was not attracted to people carrying mobile phones: 'People are struck because they are in the wrong place at the wrong time. The wrong place is anywhere outside. The wrong time is anytime a thunderstorm is nearby". Write an essay agreeing or disagreeing with this article.

Theme or Focal Area:Conservation Of Charge

Conservation of charge explores the fundamental principle in physics that the total electric charge in an isolated system remains constant regardless of changes within that system. This concept is crucial for understanding electrical phenomena and underpins many modern technological applications.

The law of conservation of charge states that the total charge in an isolated system can neither be created nor destroyed, only transferred from one part of the system to another. This principle was formalised in the early 20th century but had roots going back to the work of Benjamin Franklin in the 18th century. Franklin, who coined terms like "battery," "conductor," and "charge," was among the first to suggest that the total amount of electric charge in a system remained constant.

The principle gained further scientific grounding through the work of Michael Faraday and James Clerk Maxwell. Faraday's experiments in the mid-19th century on static electricity and electric fields hinted at the conservation principles. Maxwell's equations formally incorporated the conservation of charge into the theoretical framework of electromagnetism. Charge conservation is a fundamental principle that plays a crucial role in understanding various phenomena in electromagnetism, such as the behaviour of electrical circuits, the interaction of charged particles in atoms, and the generation and flow of electric currents.

Today, the conservation of charge is a key concept in all fields involving electricity and magnetism. It is essential in designing electrical circuits, understanding electromagnetic fields, and developing technologies such as capacitors and batteries. Engineers and physicists apply this principle to ensure that systems are safe, efficient and functional. The principle also helps troubleshoot electrical malfunctions and guide energy storage and transfer innovations.

Learning Tasks

1. State and explain the principle of conservation of charge.
2. Demonstrate the conservation of charge through a simple experiment.
3. Discuss and apply the conservation of charge to solve a practical problem.

Pedagogical Exemplars

1. Facilitate a classroom discussion around the redistribution of electric charge. Use the example of rubbing a balloon with a cloth and asking learners to hypothesise what happens to the charge in the system. This discussion helps learners understand that while charge may be transferred between objects, the total charge in an isolated system remains constant.
2. Guide learners to create a simple electric circuit using lemons or potatoes, zinc nails, copper wires, and a small LED. This activity demonstrates how electric charge moves through a circuit. It visually underscores the principle of charge conservation as the LED lights up, indicating that the charge is not lost but merely transferred.
3. Task learners with diagnosing and fixing a non-operational torchlight. This problem-solving activity involves checking connections and verifying battery integrity, applying their knowledge of how charge flows in a circuit. Based on the knowledge gained, learners actively use their understanding of charge conservation to identify and correct issues in real-world applications.
4. More able learners should be encouraged to research the process of beta-minus and beta-plus decay, and should describe and explain how the process is a good example of charge conservation. They could also extend their research to explain what physical property of particles is also conserved in interactions and led to the postulation of the neutrino.

Key Assessment

Assessment level 1: Answer the following question: "Can the total charge in an isolated system be created or destroyed?"

Assessment level 3: Design a simple experiment to demonstrate charge conservation using materials easily found in your surroundings (e.g., creating a static electricity demonstration).

Week 16

Learning Indicators:

1. *Distinguish between magnetic and non-magnetic materials.*
2. *Describe the magnetic field.*
3. *Describe the processes involved in magnetisation and demagnetisation.*

Theme or Focal Area: Magnetic And Non-Magnetic Materials

Magnetic materials are substances that can be magnetised and inherently possess magnetic properties. These materials are naturally attracted to magnets and play a crucial role in generating and manipulating magnetic fields. Examples of magnetic materials include iron, nickel, cobalt and alloys such as steel. These materials are integral to various applications, from the simple compass used in navigation to complex electrical motors and generators that power our homes and industries.

Conversely, non-magnetic materials do not easily magnetise or exhibit significant magnetic properties. These materials do not interact strongly with magnetic fields, making them essential in applications where magnetic interference needs to be avoided. Examples of non-magnetic materials include wood, plastic, rubber, glass, copper and aluminium. Such materials are used extensively in everything from insulation and housing for electronic components to the construction of MRI (Magnetic Resonance Imaging) rooms where magnetic interference could be detrimental.

Understanding the distinction between magnetic and non-magnetic materials and their applications is fundamental in basic science education and advanced technological applications, enabling innovations in engineering and industry.

Learning Tasks

1. Identify and differentiate between magnetic and non-magnetic materials.
2. Explore how magnetic and non-magnetic materials are used in everyday objects.
3. Understand the role of magnetic materials in electromagnetic applications.

Pedagogical Exemplars

1. Facilitate an interactive session where learners test various materials with a magnet to observe which are attracted and which are not. Materials like nails, coins, plastic utensils, and pieces of fabric can be used for this purpose. Learners compile a list of materials tested and categorise them as magnetic or non-magnetic, enhancing their ability to distinguish between the two based on empirical evidence.
2. Learners in groups should identify items from the home and school that utilise magnetic or non-magnetic materials, such as speakers (magnets), cooking pots (steel, magnetic), window frames (aluminium, non-magnetic), and plastic toys (non-magnetic). Each group presents their findings, explaining how the properties of the materials are suited to their specific uses.
3. Demonstrate how to create a simple electromagnet using a battery, copper wire, and an iron nail. Students should investigate the effect of changing the supply voltage and changing the number of turns on the wire on the strength of the electromagnet (an interactive simulation could be used in the absence of experimental equipment).
   - Less able students could be provided with a method.

- More able students should be able to design their own experiment and be asked to discuss how to improve its accuracy and precision.

4. Discuss the role of the iron nail as a magnetic core and why materials like copper and rubber are used for insulation. Learners observe and describe how electricity can temporarily magnetise a magnetic material and discuss the implications of this in technology, such as in electric bells or lifting electromagnets.

Key Assessment

Assessment level 1: List examples of magnetic and non-magnetic materials.

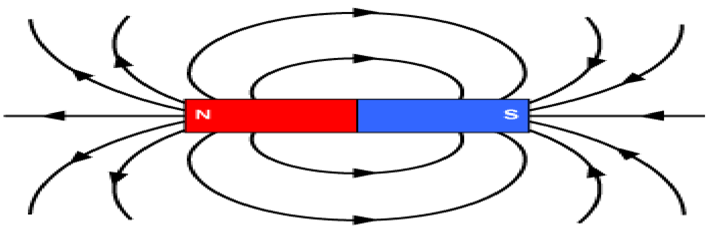
Assessment level 2: Explain why non-magnetic materials like plastic or glass are used in electronic device housings (casings).

Assessment level 3: Design a simple device that uses both magnetic and non-magnetic materials, such as a doorbell or a small motor.

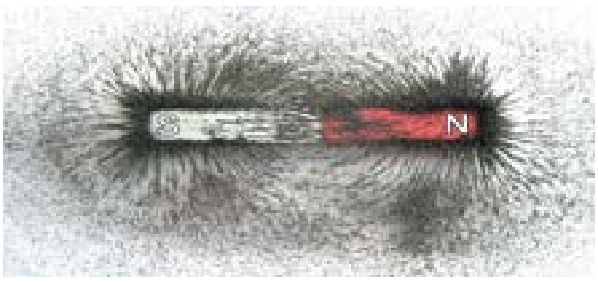
Theme or Focal Area: Magnetic Field

Magnetic fields are invisible forces exerted by magnets that influence other magnets and magnetic materials without direct contact. The concept, integral to understanding forces acting at a distance, has a rich history that dates back to ancient navigators using lodestones for compass navigation. This early application significantly aided global exploration. In the 19th century, scientists like Hans Christian Ørsted and Michael Faraday advanced our understanding by linking electricity and magnetism and introducing magnetic field lines to visualise how magnets interact with their environment.

Today, magnetic fields are essential in many modern technologies, from electric motors that convert electrical energy into mechanical motion to MRI machines that use magnetic fields to image the human body. They are also used to separate magnetic materials from non-magnetic ones. This technique is employed in recycling facilities, mineral processing plants, and waste management to separate and recover valuable materials efficiently.



Magnetic field around a bar magnet



Iron filings create a pattern around a bar magnet.

Learning Tasks

1. Define what a magnetic field is and how it is produced.
2. Represent magnetic fields visually using field lines and interpret field line patterns.
3. Explore the application of magnetic fields in navigation.

Pedagogical Exemplars

1. To understand their properties, guide learners to visualise and map magnetic fields using iron filings and bar magnets. Learners in groups sprinkle iron filings on a piece of paper placed over the magnet to observe the pattern of the magnetic field lines. Also, set up a circuit with a straight conductor passing through a piece of paper sprinkled with iron filings. When current flows through the conductor, the filings align along the magnetic field lines created by the current, visually demonstrating the field's shape and direction. Learners sketch the observed patterns and discuss how the field lines provide insights into the force exerted. They should comment on a) the shape of the field and b) the direction of the field; does it have one? Do the iron filings show this?
2. Students research an alternative method for plotting the shape and direction of a magnetic field (using a small plotting compass). Students should write a step-by-step method and then carry out the method if the equipment is available.
3. Discuss the history of magnetic navigation, emphasising how explorers used the Earth's magnetic field to travel across oceans. Conduct an outdoor activity where learners use compasses to find directions based on magnetic north. Link this to the concept of magnetic declination and its importance in accurate navigation.

Key Assessment

Assessment level 1: What is a magnetic field?

Assessment level 2: Explain how a compass works using Earth's magnetic field.

Assessment level 3: Describe how a compass needle aligns itself in the Earth's magnetic field and how this helps in finding direction

Theme or Focal Area: Magnetisation And Demagnetisation

Magnetisation and demagnetisation are not just scientific concepts but integral processes affecting many everyday applications. Magnetisation involves inducing a magnetic field in a material, enabling it to interact with other magnetic fields. This process is crucial in creating compass needles, which are essential for navigation by aligning with Earth's magnetic field. Furthermore, magnetisation plays a significant role in data storage devices like hard drives, which use magnetic fields to store and read data.

Demagnetisation, on the other hand, is crucial for eliminating unwanted magnetic fields that can interfere with electronic devices. This process is vital in recycling electronic components, where residual magnetic fields must be removed before reuse. Additionally, security uses demagnetisation to erase magnetic strips or RFID tags to prevent unauthorised use or access via contactless payments using credit or debit cards and security doors.

Learning Tasks

1. Identify everyday items that utilise magnetisation.
2. Define magnetisation and demagnetisation.
3. State methods of magnetisation and demagnetisation.

Pedagogical Exemplars

1. Learners explore household items like doorbells, speakers and microwaves to identify components that rely on magnetisation, such as electromagnets in doorbells and magnets in speakers. They create a visual presentation or a physical exhibition explaining how magnetisation is essential for the functionality of these devices.
2. Conduct a class discussion on the importance of demagnetising tools and devices used in electronic repairs to prevent damage to sensitive components. Guide learners in discussing recycling electronic devices like hard drives where demagnetisation is necessary to prevent access to old data before dismantling and recycling.
3. Demonstrate the magnetisation process using a bar magnet and a ferromagnetic material (e.g., iron nail). Show how rubbing the magnet along the material in one direction creates a magnetic field. Provide learners with a needle and a bar magnet. Instruct them to magnetise the needle using the rubbing method and test its magnetic properties. Show learners how to demagnetise a magnetic material using various techniques (e.g., heating, hammering, or exposing it to a strong alternating magnetic field). Ask them to explain the results of each method.
   - More able students should conduct further research into ferromagnetism and the property of an iron atom that makes it magnetic. They should present their findings to the class, being encouraged to consider their wording such as to make the information accessible to less able students.
4. Through gamification, learners construct a simple compass using a needle, a magnet to magnetise the needle, a piece of cork, and a bowl of water. Learners in groups of mixed abilities use this compass to determine directions from a given treasure map. Learners write a brief report on how the Earth's magnetic field interacts with a compass needle to show direction.

Key Assessment

Assessment level 1: What is magnetisation?

Assessment level 1: State three methods of demagnetising magnets.

Assessment level 2: Describe some applications of magnetisation and demagnetisation.

Assessment level 3: Design a safe procedure for demagnetising electronic devices such as mobile phones and laptops before disposal. Explain why demagnetisation is necessary and how your method will prevent damage to other electronic devices during disposal.

Section 6 Review

Learners should develop the ability to use gold leaf electroscope for charge detection. Learners should effectively communicate their understanding of electrons as charge carriers and their significance in conducting electricity. Learners should understand how electrical currents can flow through conductive materials. Learners should gain a deeper understanding of how the abundance and mobility of charge carriers contribute to the distinct properties of conductors, semiconductors and insulators.

Learners should be able to draw diagrams to visualise the distribution of charges on spherical, pear-shaped and sharp point surfaces. Learners should comprehend that electric charge is a fundamental property of matter, similar to mass, and it is one of the fundamental properties of subatomic particles, such as protons, electrons and neutrons. Learners should also comprehend that the total electric charge in an isolated system remains constant over time. Electric charge cannot be created or destroyed; it can only be transferred from one object to another. Learners should understand that electric charge can be positive or negative, representing an excess or deficiency of electrons in an object. Learners should develop observational skills to identify magnetic behaviour in various objects. Learners should be able to visualise the behaviour of magnetic fields in space. Learners should understand how magnetic materials can be turned into magnets and how magnets can lose their magnetic properties.

References

1. Althaus, C. W. (2006). Mobile phones are not lightning strike risk: Injury from lightning strike while using mobile phone. BMJ. British Medical Journal, 333(7558), 96.2. https://doi.org/10.1136/bmj.333.7558.96-a
2. An Overview of Magnetic Field Lines and its Characteristics | ET Blog. (n.d.). Electronics Technican Training. https://www.etcourse.com/news-blog/magnetic-field-lines
3. Basic(?) Electroscope/Electrometer question. (2015, February 15). Physics Forums: Science Discussion, Homework Help, Articles. https://www.physicsforums.com/threads/basic-electroscope-electrometer-question.797883/
4. Electrostatics II - High School Physics Form 3 - ESOMA-KE. (n.d.). https://esomake.co.ke/secondary/physics/electrostatics-2-form-three/
5. Ibn Saul discovers the Law of Refraction : History of Information. (n.d.). https://www.historyofinformation.com/detail.php?id=2048
6. Magnetic direction: Understanding the direction of magnetism. (n.d.). https://www.aimmagnetic.com/Magnetic-direction
7. Subatomic science: JJ Thomson's discovery of the electron | Royal Institution. (n.d.). Royal Institution. https://www.rigb.org/explore-science/explore/blog/subatomic-science-jj-thomsons-discovery-electron
8. World Health Organization: WHO. (2023, July 25). Drowning. https://www.who.int/news-room/fact-sheets/detail/drowning

SECTION 7: SEMI CONDUCTORS, TRANSDUCERS AND THEIR APPLICATIONS

Strand: **Electromagnetism**

Sub-Strand: Analogue Electronics

Content Standards:

1. Demonstrate knowledge and understanding of the development and functions of diodes.
2. Demonstrate knowledge and understanding of the input and output processes of a transducer.
3. Demonstrate knowledge and understanding of the processes and functions of the bipolar junction.

Learning Outcomes:

1. *Explain the basics and working principles of semiconductor structure and their applications in LEDs and Zener diodes.*
2. *Distinguish between input and output of transducers and show their applications in thermistors, light-dependent resistors, infra-red diodes, microphones, buzzers, loudspeakers and electromechanical relays.*
3. *Explain the structure and operations of bipolar junction transistors and their applications.*

INTRODUCTION AND SECTION SUMMARY

The weeks covered by the section are:

Week 17: Types of semiconductors and PN junction diodes

The section begins by explaining the formation of the two types of semiconductors: n-type and p-type. It then discusses the basic structure and applications of PN junction diodes used in reverse and forward-biased circuits. These diodes allow current to flow and block it in one direction, making them essential components in electronic circuits.

Week 18: LEDs, Zener diodes and the effect of temperature changes on resistance

Next, the section analyses the benefits of using LEDs and explores the I-V characteristics of Zener diodes, including their applications in voltage regulation and protection. The concept of transducers is introduced, explaining the terminologies "input" and "output" with examples such as microphones and loudspeakers. It also covers the effects of temperature changes on resistance using devices like thermistors and light-dependent resistors (LDRs), as well as analysing their characteristic graphs.

Week 19: Processes of some transducers

The section describes various transducers and their processes, including microphones, loudspeakers, buzzers, low-voltage DC motors, electromagnetic relays, and infrared diodes. It highlights their construction and actions.

Week 20: Bipolar junction transistor (BJT) and transistor biasing

The section covers the construction and action of the bipolar junction transistor, including its use in amplifying and switching electronic signals. Transistor biasing, an essential process for proper transistor function, is also explained.

Week 21: Transistor configurations

Finally, the section discusses the distinct characteristics and advantages of the three primary transistor configurations: common emitter, common base and common collector, highlighting their suitability for diverse applications.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Pedagogical exemplars for teaching Section 7 should engage learners and promote understanding:

- Conduct experiments and demonstrations:
    - o Conduct demonstrations of PN junction diodes in forward and reverse bias conditions and provide circuit analysis exercises.
    - o Enable hands-on activities with LEDs and Zener diodes in circuits.
    - o Use examples and demonstrations to explain input and output in transducers such as microphones, loudspeakers and LDRs.
    - o Conduct experiments and analyse graphs to observe the effects of temperature and light on resistance in thermistors and LDRs.
- Use visual aids such as diagrams and animations to:
    - o Explain the formation and properties of n-type and p-type semiconductors.
    - o Explain the construction and operation of BJTs and illustrate their applications in amplifiers and switches.
- Provide interactive tutorials and circuit design activities to help learners understand different types of transistor biasing.

ASSESSMENT SUMMARY

Use Multiple Choice Questions to test learners on key concepts and terminologies. Questions can include distinguishing between types of semiconductors (n-type and p-type), different types of diodes (PN junction, Zener diodes), transducer operations, and thermistor/LDR characteristics. Make sure the questions are not purely recall-based but involve application and interpretation.

Using short answer questions, ask learners to describe concepts in their own words, such as the formation and properties of semiconductors and transistors.

Conduct laboratory or simulation-based assessments where learners work with diodes, transistors and transducers. Have them set up and measure characteristics such as the I-V curves of Zener diodes and perform experiments to observe the effect of temperature changes on thermistors.

Organise group discussions or presentations on areas like the construction and action of the bipolar junction transistor, the applications of different types of transducers, or the benefits of using certain semiconductors.

Present learners with case studies involving real-world applications of the topics covered, such as the use of LEDs in various lighting applications or the use of Zener diodes in voltage regulation circuits. Ask them to analyse the scenarios and suggest improvements or alternatives based on their understanding.

Develop rubrics to provide clear criteria for assessing student work across different assessment tasks. Use rubrics to evaluate not only content knowledge but also skills such as critical thinking, communication and problem-solving.

Keep track of learners' scores and any feedback on their understanding of key concepts. Note areas where learners are struggling or excelling for targeted instructional support.

Week 17

Learning Indicators:

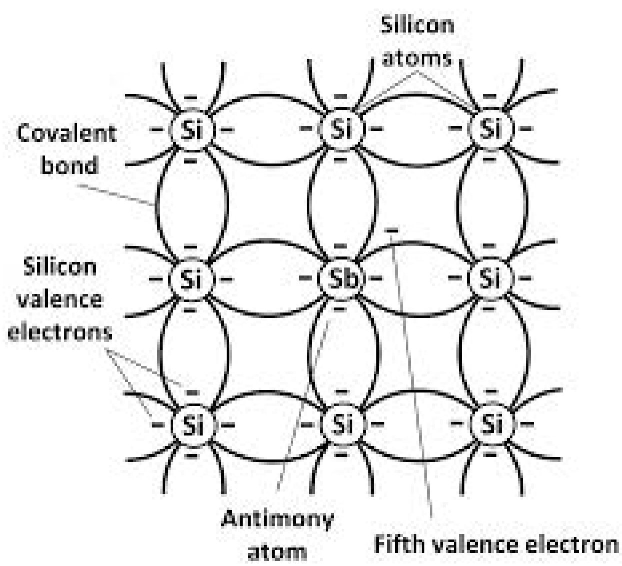
1. *Describe the formation of the two types of semiconductors: n-type and p-type.*
2. *Describe the basic structure and applications of the PN junction diodes in reverse and a forward-biased circuit.*

Theme or Focal Area: N-Type And P-Type Semiconductors

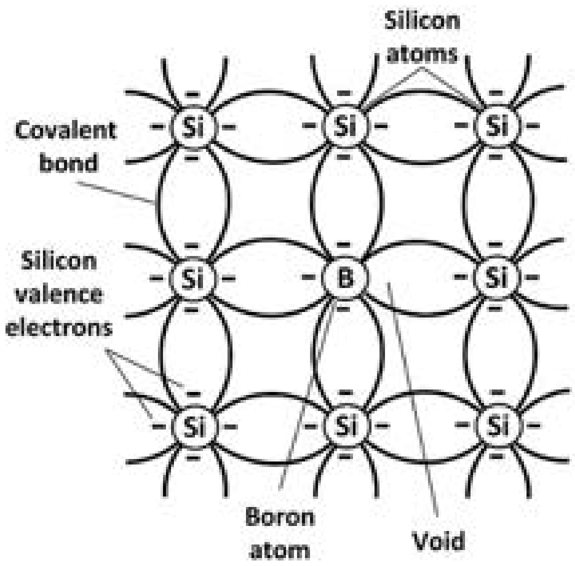
Semiconductors are crucial components in modern electronics, bridging the gap between conductors and insulators in their ability to conduct electricity. Semiconductors are used in everyday life in many devices like transistors, Zener diodes, solar panels, switches, electric circuits, etc.

The journey of semiconductor technology began in the early 19th century by observing the unique conductive properties of certain materials. In 1833, Michael Faraday discovered that the electrical conductivity of silver sulphide increased with temperature, which contrasted with the behaviour of metals. This marked the first documented observation related to semiconductor materials. The term "semiconductor" was first used in the early 20th century, but a deeper understanding of these materials began in the 1930s and 1940s when quantum mechanics was applied to explain their behaviour. The turning point came in 1947 when John Bardeen, Walter Brattain, and William Shockley invented the transistor at Bell Laboratories. This invention showcased the practical application of semiconductors and paved the way for the development of modern electronic devices.

Semiconductors are categorised into intrinsic and extrinsic types based on purity and doping. Intrinsic semiconductors are pure forms without added impurities, exhibiting minimal conductivity under normal conditions. Extrinsic semiconductors, however, are enhanced by adding specific impurities, increasing their conductivity significantly and making them practical for various electronic applications. Extrinsic semiconductors are further divided into n-type and p-type semiconductors, each with distinct charge carriers predominating. In n-type semiconductors, a pentavalent impurity (an atom with five valence electrons) is added, resulting in excess free electrons that serve as the majority charge carriers. Conversely, p-type semiconductors are created by doping the semiconductor with a trivalent impurity (an atom with three valence electrons), leading to more "holes" or spaces where an electron could exist; these holes act as the majority charge carriers.



N-type semiconductor



P-type semiconductor

Learning Tasks

1. Distinguish between n-type and p-type semiconductors and their charge carriers.
2. Explain the doping process and its effects on the properties of a semiconductor.
3. Explore the application of n-type and p-type semiconductors.

Pedagogical Exemplars

1. Use a simple animated simulation, diagrams or marbles and beans to show how doping changes the structure of pure semiconductors to form n-type and p-type materials. Demonstrate the movement of electrons and holes in these materials.

- Learners may subsequently produce a stop-motion animation or video using their marble and bean model to demonstrate the action of n- and p- type semiconductors while they describe it in the audio.

2. Provide learners with basic diode circuits to assemble using n-type and p-type semiconductors. Guide them in observing the direction of current flow and relating it to the type of semiconductor used.
3. Facilitate a discussion or presentation on the structure of solar cells, emphasising the role of n-type and p-type semiconductors in creating a junction that facilitates the flow of electricity when exposed to sunlight.
   - Pupils should be guided towards resources to use in their research which provide an appropriate level of challenge and interest for them; for example, a more able pupil may be interested in resources targeting University students.

Key Assessment

Assessment level 1: What are the majority charge carriers in n-type and p-type semiconductors?

Assessment level 2: Explain how impurities affect the electrical conductivity of semiconductors.

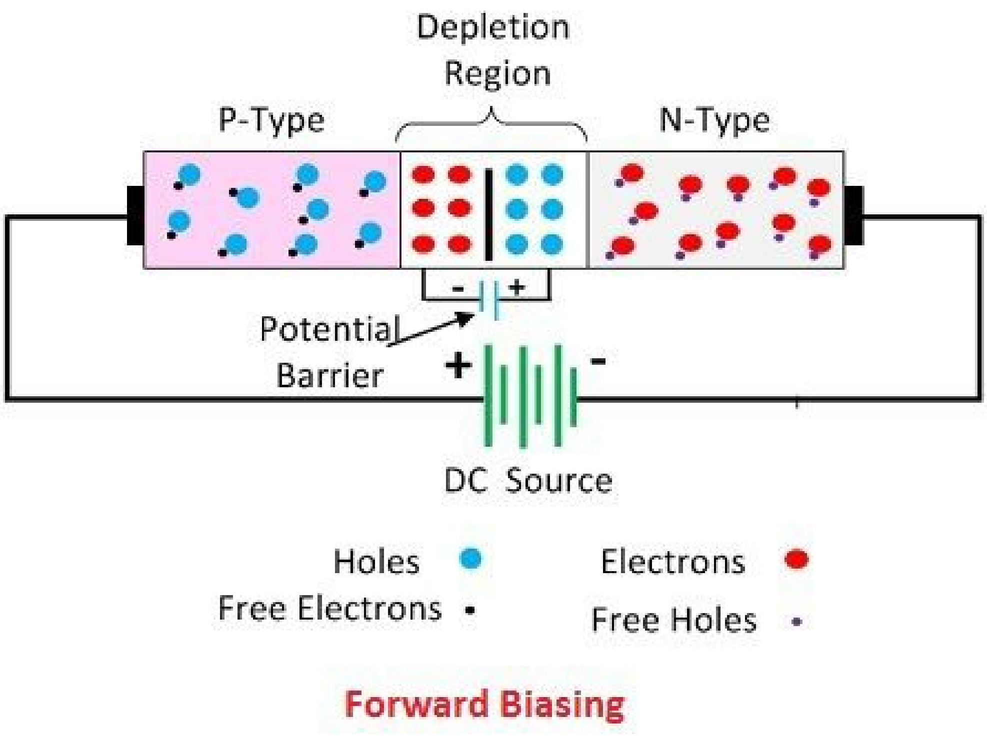
Assessment level 3: Create a circuit diagram with an n-type and a p-type semiconductor. Explain how each affects the direction of current flow in your circuit and why this is beneficial in electronic design.

Assessment level 3: Discuss the role of majority and minority charge carriers in n-type and p-type semiconductors and how these carriers influence the electrical properties of the material.

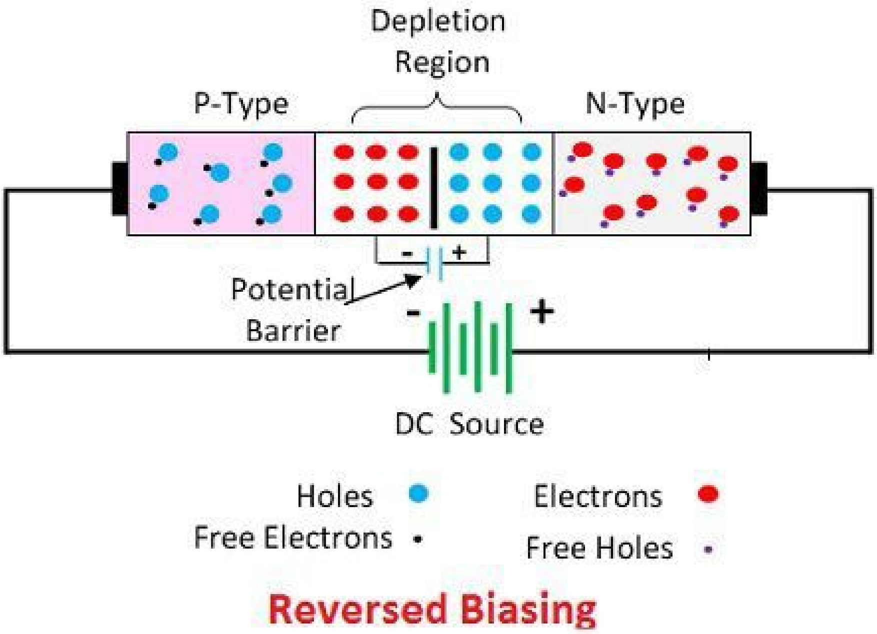
Theme or Focal Area: P-N Junction Diodes

The p-n junction diode is a cornerstone of modern electronics, formed by combining p-type and n-type semiconductor materials. This fusion creates a unique interface, or junction, where charge carriers (electrons from the n-type and holes from the p-type) can flow across to enable distinct electronic behaviours.

When a p-n junction diode is forward-biased (positive terminal connected to the p-type and negative terminal to the n-type), it allows current to flow freely across the junction, reducing the inherent electric field at the interface and enabling devices like LEDs and amplifiers to function. In contrast, when reverse-biased (positive terminal connected to the n-type and negative to the p-type), the diode blocks current, effectively acting as an insulator until a specific threshold voltage is reached. This is crucial for applications like voltage regulation and circuit protection. The versatility of p-n junction diodes makes them essential components from rectifiers that convert AC to DC and to intricate parts of integrated circuits that protect against voltage spikes.



P-N junction for a forward biased circuit



P-N junction in a reversed biased circuit

Learning Tasks

1. *Define a p-n junction diode.*
2. *Describe the structure of a p-n junction diode and explain how it is formed.*
3. *Differentiate between forward-biased and reverse-biased p-n junction diodes.*
4. *Explore how diodes are used in everyday electronic devices.*

Pedagogical Exemplars

1. Show the class a diagram of a p-n junction diode and ask them to discuss how they think the electrons and holes would behave when forward- and reversed-biased. Guide their discussion and, using targeted questioning to eventually engage the more able students, come up with a definition of a p-n junction diode.
2. Provide learners with actual p-n junction diodes or images of diodes. Ask them to observe the physical structure of the diode and identify the p-type and n-type regions as well as the depletion region. Learners should sketch and label a diagram, as well as note the circuit symbol.
3. Conduct a simple experiment using batteries, LEDs (a type of diode), and resistors to demonstrate the effect of increasing the voltage across diodes (in forward-biased settings and in reverse-biased settings) on the current.
   - Less able students could be provided with a method.
   - More able students should be able to design their own experiment and be asked to discuss how to improve its accuracy and precision.

Key Assessment

Assessment level 1: What is a p-n junction diode?

Assessment level 2: Explain the terms “p-type” and “n-type” in relation to a p-n junction diode.

Assessment level 3: Describe what happens to the electric field across a p-n junction when forward-biased and how this affects current flow.

Assessment level 4: The Electricity Company of Ghana (ECG), as part of its consulting and specialised technical training sessions, provides consulting and specialised training programmes in surge protection system designs. As the lead facilitator for the next training session, create a circuit diagram incorporating diodes for voltage spike protection. Explain your choice of components and the expected behaviour of the circuit during a spike, as well as the concept of reverse-biasing and its impact on the behaviour of a p-n junction diode.

Week 18

Learning Indicators:

1. *Analyse the benefits of LEDs and I-V characteristics of Zener diodes and their applications.*
2. *Explain the effect of temperature changes on resistance using a thermistor, light-dependent resistor (LDR), infra-red diode and the microphone and analyse the characteristic graphs of thermistors and LDRs.*

Theme or Focal Area: Leds and Zener Diodes

Light-emitting diodes (LEDs) and Zener diodes are pivotal components in modern electronics, offering distinct benefits and functionalities that have revolutionised various industries. LEDs are highly efficient, durable, and eco-friendly light sources that have transformed lighting technology with low energy consumption and long lifespan. Their flexibility in design allows them to be integrated into countless applications, from residential lighting to advanced medical devices.

On the other hand, Zener diodes are specialised in their function and designed to operate reliably in reverse-bias mode, allowing current to flow in the opposite direction once a specific threshold voltage, known as the Zener voltage (V_z), is reached. This unique property makes Zener diodes ideal for voltage regulation and circuit protection, ensuring that sensitive components operate within safe voltage levels.

Both types of diodes utilise semiconductor properties to fulfil their roles, making them essential for basic educational purposes and advanced technological applications.

Learning Tasks

1. Describe the basic properties and functionalities of LEDs and Zener diodes.
2. Demonstrate the energy efficiency and versatility of LEDs.
3. Explore the functionality of Zener diodes in circuit protection.

Pedagogical Exemplars

1. Explain the construction and operation principles of LEDs and Zener diodes. Use diagrams and simple animations to illustrate how these diodes differ from typical diodes and each other.
2. Facilitate learners in identifying understanding their typical applications. Learners could be given a series of scenarios and asked whether an LED or a Zener diode would be more appropriate to use; targeted questioning or a written classification activity could be assessed.
3. Conduct an experiment comparing an LED bulb's brightness and power consumption versus a conventional incandescent bulb. Measurements can be taken using a simple multimeter. Learners should record and analyse data to see first-hand the efficiency benefits of LEDs and discuss their environmental impact.
   - Less able students could be provided with a method.
   - More able students should be able to design their own experiment and be asked to discuss how to improve its accuracy and precision.
4. Facilitate a hands-on project where learners build a basic power supply circuit incorporating a Zener diode for voltage regulation. Where possible, learners will create and test their circuits,

observing how the Zener diode maintains a constant voltage output despite variations in input voltage. This could be conducted as a demonstration in the absence of enough equipment.

Key Assessment

Assessment level 1: List the critical properties of LEDs and Zener diodes.

Assessment level 2: Explain how a Zener diode can regulate voltage.

Assessment level 3: Outline a detailed plan for an experiment to measure the energy usage of LED vs. incandescent bulbs, including the equipment you will use, the variables you will control, and how you will interpret your results.

Theme or Focal Area: Effect of Temperature Changes on Resistance

Temperature plays a critical role in influencing the resistance of various electronic components, affecting their functionality and performance. Components such as thermistors and light-dependent resistors (LDRs) exhibit a direct correlation between temperature changes and resistance. Thermistors, specifically designed to be sensitive to temperature variations, decrease in resistance as temperature increases, and vice versa. Similarly, LDRs change their resistance based on the intensity of light, which can also be indirectly influenced by temperature changes affecting light conditions.

On the other hand, infrared diodes maintain a relatively stable resistance across a broad range of temperatures, making them ideal for applications where consistent performance is necessary despite temperature fluctuations. Microphones, though not typically affected by temperature in terms of resistance, can experience performance variability due to the thermal sensitivity of their other internal components, like diaphragms, which may expand or contract slightly with temperature changes.

Understanding how temperature affects resistance in these devices is crucial for designing and troubleshooting electronic circuits, especially in environments with significant temperature variations, a common scenario in many parts of Ghana.

Learning Tasks

1. Explain how the resistance of different electronic components, such as thermistors and LDRs, responds to temperature changes.
2. Demonstrate practical applications and implications of temperature-dependent resistance changes.
3. Apply knowledge of temperature effects on resistance to solve a real-world problem.
4. Analyse characteristic graphs that plot resistance against the temperature of thermistors and LDRs

Pedagogical Exemplars

1. Conduct virtual demonstrations using simulations or provide learners with a circuit setup that includes a power supply, a thermistor, an LDR, and a multimeter. Instruct learners to measure the resistance of the thermistor as the temperature changes. You can use hot and cold water baths to vary the temperature of the thermistor. For the LDR, provide a flashlight and ask learners to measure resistance as light intensity changes. Have learners record their data in tables. Learners plot and analyse the characteristic graphs of thermistors and LDRs and interpret the data showcasing resistance changes.

2. Learners complete a differentiated worksheet about temperature-dependent resistors. Questions should increase in difficulty, and learners should be signposted to skip questions that are too easy for them (e.g. "If you found questions 1 easy, skip straight to question…")
   - Simple problems should involve:
     - o Reading data from a temperature-resistance graph for a thermistor
     - o Calculating the current in a circuit (I=V/R) containing a battery of known voltage and a thermistor at a known temperature, with its characteristic graph available.
   - More challenging problems may involve further components in series or parallel with the thermistor, and the student being asked to calculate not only the current in the circuit but also the output potential different across various components.
3. Set up a simple circuit incorporating a thermistor to control an LED or a buzzer, illustrating how changes in ambient temperature can activate or deactivate the circuit. Learners observe and discuss how the thermal properties of components can be utilised in practical applications like automatic temperature sensors or alarms.
4. Assign learners to research and present real-world applications of temperature-sensitive devices (e.g., thermistors and LDRs) in temperature measurement, climate control, and electronic circuits.

Key Assessment

Assessment level 1: List two components whose resistance is affected by temperature changes.

Assessment level 3: Describe how the resistance change in a thermistor can control a circuit to activate a fan when the temperature rises above a set threshold.

Assessment level 3: As a member of the design team for the Science Club in a competition, design a device that uses an LDR and a thermistor to maintain optimal light conditions in an agricultural greenhouse for the growing of tomatoes. Detail the role of each component in your system and discuss how they interact to maintain desired conditions.

Week 19

Learning Indicators:

1. *Explain the terminologies "input" and "output" of a transducer with examples.*
2. *Describe the processes of the following transducers: microphone, loudspeaker, buzzer, low voltage DC motor, electromagnetic relays and infra-red diodes.*

Theme or Focal Area: Transducer

Transducers are instrumental devices that convert one form of energy or physical quantity into another. By taking an input signal from the environment (light, sound, temperature, or pressure) a transducer processes this input and outputs it in a different, often more useful form. For example, in a microphone, a transducer converts sound waves (input) into electrical signals (output), which can then be amplified or recorded.

Transducers are essential for monitoring and controlling systems in everyday life and industrial applications. They are critical components in various devices, such as sensors in automotive systems, actuators in robotic arms, microphones in communication devices, and speakers in audio systems. Understanding how transducers work illuminates the seamless integration of physical sciences with technology, bridging the gap between theoretical principles and practical applications.

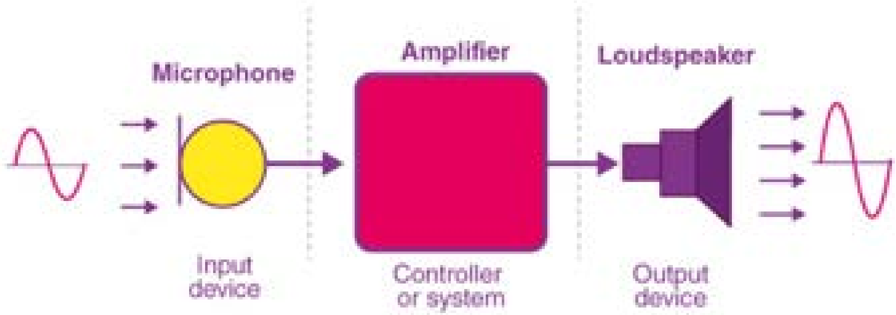


Diagram showcasing the connection between an input transducer (microphone) and an output transducer (loudspeaker)

Learning Tasks

1. Define a transducer and explain its function in converting energy between different forms.
2. Identify and categorise different types of transducers based on their input and output energies.
3. Demonstrate the function of a simple transducer.
4. Design a simple circuit that uses a transducer to perform a specific function.

Pedagogical Exemplars

1. Provide a clear and concise definition of a transducer, emphasising its role in converting one form of energy into another.
2. Give learners examples of various transducers like thermocouples, microphones, light sensors, and piezoelectric devices. Let them classify these transducers based on what type of energy or

signal they convert. They create a chart or a digital presentation that lists transducers' types, inputs and outputs.

3. Provide learners with a basic thermocouple or a microphone kit to show how temperature changes or sound waves can be converted into electrical signals. Discuss the conversion process and its significance in practical applications.
4. Guide learners in building a light-sensitive circuit using an LDR, which acts as a transducer by converting light levels into resistance changes in the circuit.
5. Assign each learner to research a different type of transistor and to produce a short presentation or poster explaining their function and examples of where they are used. Learners should be assigned tasks/themes based on their ability, with more complication applications being assigned to the more able learners.

Key Assessment

Assessment level 1: Define a transducer and give two examples.

Assessment level 2: Describe how a microphone converts sound waves into electrical signals.

Assessment level 3: SONABEL, the power utility of Burkina Faso, manages the Bagre Dam. When there is a high inflow of water into the dam, they spill, and consequently, the water levels in the White Volta also increase. Outline a plan for a transducer system to monitor water levels at the White Volta River rapids near Gambaga in the North East Region of Ghana as part of a flood warning and prevention system for the Volta River Authority of Ghana. Describe the type of transducer you would use, how it would function, and the benefits of your solution.

Theme or Focal Area: Processes of Some Transducers

Transducers play a pivotal role in converting one form of energy into another, a fundamental process in numerous everyday technologies. This transformation is crucial in microphones, loudspeakers, buzzers, low-voltage DC motors, electromagnetic relays, and infrared diodes, each serving specific functions. Microphones are used in smartphones and computers for voice communication. They convert spoken words into electrical signals that can be transmitted over communication networks or recorded as digital audio files. Loudspeakers are integral to home theatre systems and public address systems. They convert electrical audio signals from media players or microphones into audible sound waves that fill a room or an outdoor space with sound. Buzzers are commonly found in alarm clocks and alert systems. They provide audible alarms by converting electrical signals into sound, alerting individuals to specific events like wake-up times or emergencies. These motors are widely used in electric toothbrushes and automated toys. They convert battery-powered electrical energy into the mechanical motion needed to drive bristles or wheels, enhancing user convenience and entertainment. In modern vehicles, electromagnetic relays control the operation of headlights, electric windows, and air conditioners. They allow low-power switches to activate high-power circuits within the car, ensuring safe operation of critical components. IR diodes are crucial in TV remote controls. They emit infrared signals when the user presses a button. These signals are detected by the television's IR receiver, triggering specific actions such as changing channels or adjusting the volume.

Learning Tasks

1. Demonstrate how microphones and loudspeakers convert energy.
2. Analyse how buzzers and DC motors operate and their applications.
3. Demonstrate the practical applications of electromagnetic relays and infrared diodes.

Pedagogical Exemplars

1. Ask learners to create process flow diagrams or flowcharts illustrating each transducer's step-by-step processes.
2. Guide learners to create simple microphone and loudspeaker models using materials like plastic cups, string, magnets and coils to visually and practically explore how these devices convert sound to electrical signals and vice versa.
3. Engage learners in a lab activity where they disassemble and test buzzers and a simple DC motor to observe the electromechanical processes involved. Include mapping the input and output energy forms and discussing their practical applications in everyday devices. Let learners document the energy conversion processes and discuss how understanding these mechanisms can aid in troubleshooting and innovation in technology design.
4. Conduct experiments or use multimedia such as videos or images to show how electromagnetic relays can control larger circuits with small currents and how infrared diodes can be used for remote communication. This could include setting up a simple remote-control circuit. Let learners explain the importance of these components in modern electronics, particularly in automation and remote communication.

Key Assessment

Assessment level 1: What is the function of a loudspeaker?

Assessment level 2: Explain how a low-voltage DC motor converts electrical energy into mechanical motion. What roles do the electromagnet and armature play?

Assessment level 4: The Department of Urban Roads seeks to implement a real-time traffic monitoring and response system at some traffic intersections in Ghana. As part of the plan, an intelligent traffic control system will be installed to redistribute traffic efficiently, unlike the current fixed-time system. Outline a circuit that uses an electromagnetic relay as a simple switch for safely controlling red-yellow-green signals, which work on the higher power supply. Describe the components you would use and their configuration.

Week 20

Learning Indicators:

1. *Describe the construction and action of the bipolar junction transistor*
2. *Describe transistor biasing.*

Theme or Focal Area: Bipolar Junction Transistor (Bjt)

The Bipolar Junction Transistor (BJT) is a critical component in modern electronics, crafted from semiconductor materials such as silicon or germanium. It consists of three main regions: the emitter, the base and the collector, configured in either NPN or PNP form. The NPN type includes an n-type collector and emitter with a p-type base sandwiched between them, while the PNP type reverses this arrangement. The unique arrangement of these doped regions allows BJTs to amplify current, making them invaluable in various electronic applications, including amplifiers, switches and signal modulators. The functionality of BJTs as a control device in circuits stems from their ability to modulate the flow of electrons through the arrangement of their semiconductor regions. Each is delicately doped to precise levels to ensure optimal performance. Metal contacts are added to each region for external electrical connections, and a passivation layer is applied to protect the device's integrity.

Bipolar Junction Transistor

Learning Tasks

1. Identify the structure and function of NPN and PNP BJTs.
2. Apply knowledge of BJTs to design a basic electronic circuit.

Pedagogical Exemplars

1. Using videos, diagrams and physical models, demonstrate the doping configurations of NPN and PNP transistors and explain how these structures influence their function in circuits. Guide learners in creating a visual poster or digital presentation outlining the components of NPN and PNP BJTs, including diagrams and explanations of how each type functions within electronic circuits, the significance of the arrow symbol and how it represents the direction of conventional current flow.
2. Facilitate a hands-on workshop where students use BJTs to build a simple amplifier or switch circuit. Provide breadboards, BJTs, resistors and power sources. Learners are guided to construct a circuit and demonstrate its functionality, discussing how the BJT regulates current flow to achieve amplification or switching.

3. Assign each learner to research a different use of BTJs and to produce a short presentation or poster explaining their function and examples of where they are used. Learners should be assigned tasks/themes based on their ability, with more complicated applications being assigned to the more able learners.

Key Assessment

Assessment level 1: List the three main regions of a BJT and their doping types.

Assessment level 3: Describe the process by which a BJT can function as a switch, including the role of the base current in this functionality.

Assessment level 3: Provide a circuit diagram for an audio amplifier using a BJT. Explain the choice of each component in your design and how the BJT contributes to amplifying an audio signal.

Assessment level 4: You are given a broken light switch that is part of a lighting control system in your house. The BJT in the light switch is malfunctioning, and so the lights are not turning on/off as intended. Explain the potential reasons for the circuit malfunction.

Theme or Focal Area: Transistor Biasing

Transistor biasing is the controlled amount of voltage and current that must go to a transistor to produce the desired amplification or switching effect. This controlled amount of voltage and/or currents fed to the different junctions of a transistor is transistor biasing.

Without appropriate transistor biasing, the transistor may not function at all or amplify very poorly, such as produce clipping of the signal or produce too low of gain. Therefore, a transistor must be biased correctly to produce the intended output effect.

Learning Tasks

1. Describe what biasing means and why it is necessary for transistors.
2. Illustrate and label transistor biasing circuits.
3. Examine and interpret real-world examples of biased transistors in circuits.

Pedagogical Exemplars

1. Assign learners to research the historical context and significance of transistor biasing in developing electronics and communication technology.
2. Provide learners real-life examples where biasing is necessary, such as setting the correct operating conditions for electronic devices like amplifiers or transistors in radios. Instruct learners to draw a simple schematic diagram of a transistor circuit and explain the concept of biasing in their own words.
3. Let learners watch instructional videos on transistor biasing that demonstrate different biasing techniques, explain their practical applications, and show how to construct and troubleshoot biasing circuits in real-world scenarios.
4. Have learners use circuit simulation software to design and test various transistor biasing circuits, allowing them to adjust component values and observe the impact on the transistor's operation and performance in a virtual environment. Learners could conduct this as a scientific

investigation whereby they measure appropriate data with which to plot a graph and draw a conclusion.

- Less able students could be provided with a method.
- More able students should be able to design their own experiment and be asked to discuss how to improve its accuracy and precision.

Key Assessment

Assessment level 1: What is transistor biasing?

Assessment level 1: Why is proper biasing necessary in transistor circuits?

Assessment level 2: Discuss the significance of bias stability in transistor circuits.

Week 21

Learning Indicator: *Describe the various transistor configurations and use of an NPN transistor as a small signal amplifier.*

Theme or Focal Area: Various Transistor Configurations

Transistors, as fundamental components in modern electronics, can be configured in multiple ways to meet different circuit requirements. The three primary transistor configurations (common emitter, common base, and common collector) each offer distinct characteristics and advantages, making them suitable for varied applications.

The Common Emitter Configuration places the emitter as the shared connection between the input and output circuits. It is favoured in applications requiring high voltage gains, such as in audio amplifiers and RF signal amplification. It efficiently amplifies weak input signals by controlling the base current, modulating the larger current flowing from the collector to the emitter. The base is common to both the emitter and collector circuits for Common Base Configuration. Known for its high input and low output impedance, it is useful in high-frequency applications and impedance-matching tasks, enabling quick signal transmission without significant loss. In the Common Collector Configuration (Emitter Follower), the collector common to input and output, serves primarily as a voltage buffer. It offers almost unity voltage gain with good current gain, making it ideal for applications where voltage needs to be stabilised without amplification.

Learning Tasks

1. Identify and briefly describe the main transistor configurations: Common Emitter, Common Base, and Common Collector.
2. Using diagrams, explain each transistor configuration, detailing how the terminals (emitter, base and collector) are connected and the impact on their performance.
3. Explain how small AC signals are amplified using an NPN transistor.

Pedagogical Exemplars

1. Provide diagrams of the common emitter, common collector, and common base configurations, explaining terminal connections and their effects on input and output.
2. Conduct a practical activity or use interactive tools to help learners identify different transistor configurations, discuss the roles of the terminals in these configurations, and explore the impact of input variations on the output.
3. Explore and present the applications of transistor amplifiers in everyday devices, focusing on real-world examples to illustrate their use in technology.

Key Assessment

Assessment level 1: List the three common transistor configurations and briefly mention one key characteristic of each.

Assessment level 3: Explain the significance of different transistor configurations in electronic circuits, mainly focusing on how they affect the amplification and signal processing.

Assessment level 3: Describe the common emitter transistor configuration, including details on how it is connected within a circuit, and discuss its primary function and typical application in electronic devices.

Section 7 Review

Learners should grasp the practical applications of diodes, such as rectification in power supplies, voltage regulation, and signal demodulation. Learners should be able to design and analyse electronic circuits involving these LED and Zener diode. Learners should gain a deeper appreciation for the principle of transduction and how transducers facilitate energy conversion in diverse applications. Learners should interpret characteristics graphs to draw conclusions about the behaviour of thermistors and LDRs under different conditions. Learners should gain a deeper appreciation for the different transduction principles involved in converting energy from one form to another. Learners should recognise the practicality of using NPN transistors in common emitter configuration as small signal amplifiers in real-world applications.

References

1. Admin. (2022, July 27). Transducer - Definition, parts, types, efficiency, applications. BYJUS. https://byjus.com/physics/transducer/
2. File:Silicon doping - Type N.svg - Wikimedia Commons. (2018, November 24). https://commons.wikimedia.org/wiki/File:Silicon_doping_-_Type_N.svg
3. File:Covalent bonding in silicon.svg - Wikimedia Commons. (2018, November 17). https://commons.wikimedia.org/wiki/File:Covalent_bonding_in_silicon.svg
4. Rehmani, A. (2023, September 14). T106M1 4A 600V SCR – Datasheet. Circuits DIY. https://www.circuits-diy.com/t106m1-4a-600v-scr-datasheet/
5. T, A. (2021, February 18). Difference between forward & reverse biasing. Circuit Globe. https://circuitglobe.com/difference-between-forward-and-reverse-biasing.html

SECTION 8: FUNDAMENTAL CONCEPTS IN ATOMIC AND NUCLEAR PHYSICS

Strand: **Atomic and Nuclear Physics**

Sub-Strands:

1. Atomic Physics
2. Nuclear Physics

Content Standards:

1. Demonstrate knowledge of J. J. Thompson's, Rutherford's, Bohr's models of the atom and recognise their limitations.
2. Demonstrate knowledge and understanding of the nucleus of an atom.

Learning Outcomes:

1. *Describe the evolution of the various atomic models. i.e., J. J. Thompson's, Rutherford's and Bohr's.*
2. *Explain the factors that account for the stability of the nucleus.*

INTRODUCTION AND SECTION SUMMARY

The weeks covered by the section are:

Week 22: Atomic Models and their Limitations and Energy of a photon

The section begins by explaining different atomic models that have been proposed over time, such as Thomson's model, Rutherford's model, and Bohr's model. Each model contributed to our understanding of atomic structure but also had its limitations, leading to the development of more advanced models like the quantum mechanical model.

It then discusses how to calculate the energy of a photon during a transition, such as an electron moving between energy levels in an atom.

Week 23: Radioactivity and structure of a nucleus

The structure of the atomic nucleus is described, including the composition of protons and neutrons, as well as the forces that hold them together. The section also introduces the concept of radioactivity, which involves the spontaneous decay of an unstable atomic nucleus, leading to the release of energy in the form of radiation.

Week 24: Balancing Nuclear Reactions

Finally, the section explains how to balance basic nuclear reactions, such as alpha and beta decay, by ensuring the conservation of mass and charge. This involves understanding how the numbers of protons and neutrons change during a nuclear reaction.

SUMMARY OF PEDAGOGICAL EXEMPLARS

Pedagogical exemplars for teaching Section 8 should involve engaging instructional strategies to enhance understanding:

- Conduct safe demonstrations and explore real-world examples to help learners understand radioactive decay and its applications.

- Use visual aids and discussions to:
  - o Illustrate the composition and stability of the atomic nucleus.
  - o Illustrate the historical models of the atom.
  - o Visualise electrons moving between energy levels and absorbing or emitting a photon.
- Provide historical context and comparative analysis of atomic models.
- Worksheets and problem solving:
  - o Teach learners to derive and apply formulas for calculating photon energy during electron transitions through problem-solving exercises.
  - o Teach the principles of balancing nuclear equations through rules and practice problems.
- Implement differentiation strategies to accommodate diverse learning needs.

ASSESSMENT SUMMARY

Conduct quizzes, multiple-choice and short-answer questions at regular intervals to assess learners' understanding of different atomic models, their limitations and related concepts such as photon energy calculation and nuclear structure.

Assign tasks that require learners to calculate photon energy during transitions, and balance basic nuclear reactions.

Let learners create concept maps and diagrams that help them visually represent and connect different concepts in atomic and nuclear physics.

Develop rubrics to provide clear criteria for assessing student work across different assessment tasks. Use rubrics to evaluate not only content knowledge but also skills such as critical thinking, communication and problem-solving.

Keep track of learners' scores and any feedback on their understanding of key concepts. Note areas where learners are struggling or excelling for targeted instructional support.

Week 22

Learning Indicators:

1. *Explain various atomic models and their limitations.*
2. *Calculate the energy of a photon during a transition.*

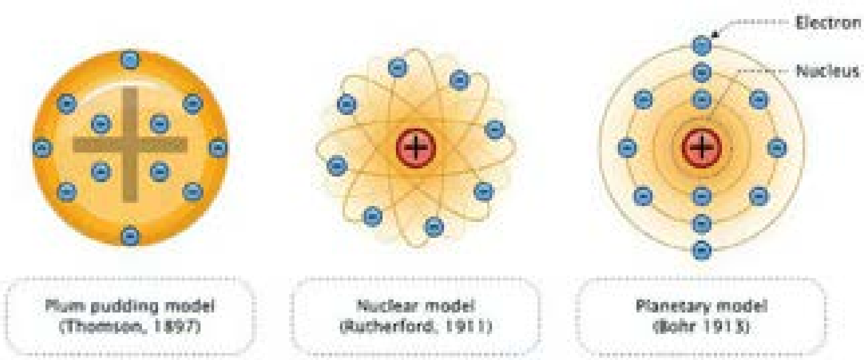
Theme or Focal Area: Atomic Models and Their Limitations

J.J. Thomson proposed the "plum pudding" model, describing the atom as a sphere of positive charge with embedded negative electrons. However, it failed to explain the nucleus and atom's stability.

Ernest Rutherford's model suggested that atoms have a dense, positively charged nucleus at their centre, surrounded by mostly empty space with electrons orbiting around it. While it addressed the nucleus, it did not explain the electrons' exact positions or the stability of atoms.

Niels Bohr expanded on Rutherford's model, introducing quantised energy levels for electrons. These quantised energy levels means that electrons could only exist in specific orbits, emitting or absorbing energy as they moved between levels. This model worked for hydrogen but had limitations with more complex atoms.

Atomic models are crucial in understanding the fundamental building blocks of matter and their interactions, which have significant implications for everyday life. The various atomic models have played a central role in shaping our understanding of matter and the universe. Their applications in everyday life are far-reaching, touching numerous aspects of technology, medicine, materials, and our understanding of the natural world.



Atomic models

Learning Tasks

1. Describe various atomic models.
2. Explain specific limitations of each atomic model.

Pedagogical Exemplars

1. Begin with a brief history of atomic theory, from early ideas about atoms to more contemporary models. Introduce learners to major atomic models, such as Thomson's, Rutherford's, Bohr's model. Discuss the key features of each model and how they improved upon previous models.

2. Divide learners into groups and assign each group a different atomic model to represent. Provide craft supplies (e.g., balls, sticks, paper) or simulation software for learners to create a visual representation of their assigned atomic model. Have each group present their model to the class and explain its features, as well as the historical context in which it was developed. Ensure that they research the key experiments that led to the development of their atomic models. For each experiment, have them explain how the results supported or challenged the prevailing atomic theory at the time.
   - More able learners should research the development of Bohr's model.
3. Use online simulations (such as PhET's "Build an Atom") to help learners visualise different atomic models and observe their limitations. Allow learners to manipulate the simulation to explore how different changes affect the model and its accuracy.
4. Organise a debate in which learners advocate different atomic models, highlighting their strengths and limitations. Encourage learners to use historical and scientific evidence to support their arguments.

Key Assessment

Assessment level 1: What is an atomic model?

Assessment level 1: Briefly describe the Bohr atomic model.

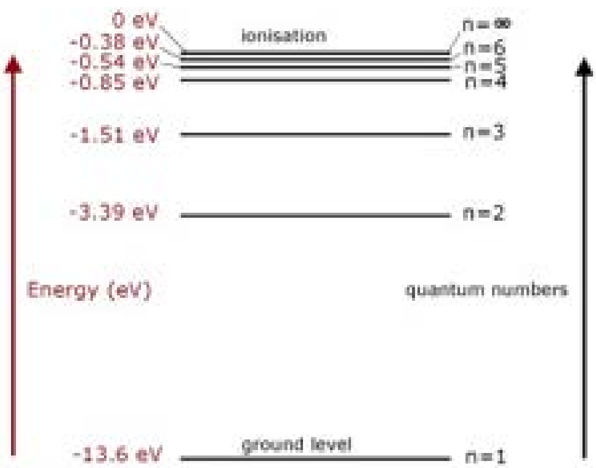
Assessment level 2: Compare and contrast the Thomson and Rutherford's atomic models, and state their main contributions to our understanding of atomic structure.

Theme or Focal Area: Transition Of An Electron

Energy is a measure of how stable a substance is. The lower the energy level of an electron, the more stable the electron is. Thus, an electron would be in its most stable state when it is closest to the nucleus (quantum number n=1). For this reason, we refer to n=1 as the ground state of the electron. If the electron is in any other shell, we say that the electron is in excited state.

The energy of a photon absorbed or emitted during a transition between two energy levels in an atom is determined by the difference in energy between those two levels. When an electron moves from a higher energy level to a lower energy level, it emits a photon with energy equal to the energy difference between the two levels, but if it moves from a lower energy level to higher energy level, it must absorb a photon with energy equal to the energy difference.

The energy difference is given as: $\Delta E=E_n-E_o$



Energy level diagram

Using the properties of de Broglie waves, we can calculate the wavelength and frequency of the following formula:

$$E = hf = \frac{hc}{\lambda}$$

where $h = 6.63 \times 10^{-34}$ Js denotes Planck's constant, f denotes frequency, λ denotes wavelength, and $c = 3.00 \times 10^{8}$ ms^{-1} denotes the speed of light.

The knowledge of photon energy and electron transitions is integral to a wide range of applications in modern technology, communication, medicine, and scientific research, impacting various aspects of our daily lives. In lighting technology, the understanding of photon energy and electron transitions is crucial in the development of lighting technologies. For example, incandescent bulbs emit light when electrons transition between energy levels in the tungsten filament. Fluorescent lights and light-emitting diodes (LEDs) work based on electron transitions in different materials, producing more energy-efficient and long-lasting lighting solutions.

Learning Tasks

1. Draw and describe the different energy levels or orbitals within an atom.
2. Draw and label diagrams of electron transitions between energy levels.
3. Use equations to calculate the energy change when an electron transitions between levels.

Pedagogical Exemplars

1. Provide learners with energy level diagrams of atoms or molecules, showing different energy levels and possible transitions. Ask them to identify the initial and final energy levels involved in a given transition.
2. Ask learners to practise converting photon energy from joules to electron volts (eV) and vice versa. Remind them that 1 eV is equivalent to 1.602 x 10^{-19}J.
   - There is no need to differentiate this worksheet.
3. Let learners watch a video or a simulation of how electrons jump from one energy level to another.
4. Provide learners with scenarios involving multi-level transitions in atoms or molecules. Ask them to calculate the energies of the photons emitted or absorbed during these transitions.
   - Less able learners should be provided with at least one worked example to help them to answer the problems.
   - More able learners should be given more challenging questions which could be linked to the various different photons that could be emitted from an atom with multiple energy level transitions. These learners should be encouraged to research 'emission spectra' in order to see how scientists actually measure the wavelength of the emitted light.

Key Assessment

Assessment level 1. Explain briefly what is meant by:

i. Ground state.

ii. First excited state.

iii. Ionisation energy.

Assessment level 2: State the equation that relates the energy of a photon to its frequency.

Assessment level 3: An electron jumps from an energy level of -1.6 eV to one of -10.4 eV in an atom. Calculate the energy of the emitted radiation.

Week 23

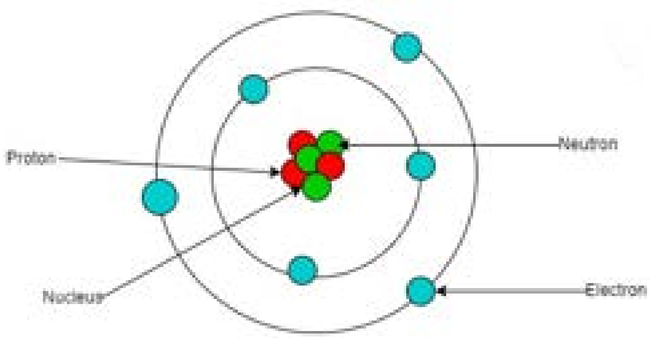
Learning Indicators:

1. *Describe the structure of the nucleus of the atom.*
2. *Explain radioactivity.*

Theme or Focal Area: The Structure Of The Nucleus

The nucleus is the central part of an atom, comprising protons and neutrons. Protons carry a positive charge of the same size as the electron's negative charge, while neutrons are neutral. The strong nuclear force holds the nucleus together overcoming the repulsion of the positive charges of protons. The nucleus is dense, occupying a very small volume compared with the volume of the atom, but containing almost all of the atom's mass. The number of protons (Z) defines the chemical element, and the total protons and neutrons determine the mass number (A). Isotopes are atoms with different numbers of neutrons (N) but the same number of protons. Protons and neutron together are called nucleons.

So, $A = Z + N$



Energies involved in dealing with nuclei are about 10^6 greater than the energies when dealing with atoms. The usual unit when dealing with nuclear energy is Mega-electron-volt, MeV.

The nucleus and its properties have far-reaching implications for various aspects of our daily lives, ranging from the energy we use, to the medical treatments we receive and the scientific understanding that shapes our knowledge of the natural world.

Learning Tasks

1. Define the nucleus of an atom.
2. Describe the structure of the nucleus of an atom.
3. Define atomic and mass number.

Pedagogical Exemplars

1. Start with an overview of the atom and its main components: protons, neutrons and electrons. Introduce learners to the nucleus as the central part of the atom, containing protons and neutrons.

2. Provide learners with materials such as modelling clay, beads, or magnets to create a physical model of the nucleus. Have learners represent protons and neutrons with different colours or shapes and arrange them to model the nucleus of different isotopes.
3. Use online simulations (such as PhET's "Build an Atom") to help learners visualise the structure of the nucleus. Have learners experiment with different numbers of protons and neutrons to create various elements and isotopes. Discuss how changing the number of protons or neutrons affects the identity and stability of the atom.
4. Provide worksheets with problems involving finding the number of neutrons in an atom, given its atomic number and mass number. Have learners work in pairs or groups to solve the problems and check their answers together. Ensure that learners are given examples of different isotopes of the same element, and that the definition of an isotope is highlighted.
   - There is no need to differentiate this worksheet.

Key Assessment

Assessment level 1: What is the nucleus of an atom?

Assessment level 1: Name the particles found in the nucleus.

Assessment level 2: Explore the concept of nuclides and how variations in the number of protons and neutrons affect the stability of nuclides.

Assessment level 2: Analyse the significance of the neutron-to-proton ratio (N/Z ratio) in determining the stability and behaviour of different nuclides.

Assessment level 3: How do the interactions between protons and neutrons within the nucleus contribute to nuclear stability and how does this relationship influence the possible isotopes of an element?

Theme or Focal Area: Radioactivity

The history of nuclear reactions dates back to the late 19th and early 20th centuries, with pioneering work in the study of radioactivity and the structure of the atom. Early experiments by Henri Becquerel, Marie Curie, and Pierre Curie led to the discovery of radioactive decay and the identification of radioactive elements such as uranium and radium. These discoveries laid the foundation for the study of nuclear reactions and their applications.

Radioactivity is the spontaneous disintegration or decay of an unstable nucleus with the emission of radiations such as α-particles, β-particles, γ-rays, and by nuclear fission. These processes are accompanied by the release of energy to form a new nucleus. This process is random and not influenced by external factors like temperature, pressure or chemical changes.

Alpha decay is a type of radioactive decay in which an unstable atomic nucleus releases an alpha particle, which consists of two protons and two neutrons (a Helium-4 nucleus). This decay process reduces the atomic number of the original element by 2 and the mass number by 4, transforming the original element into a different element. Alpha decay is common in heavy, unstable nuclei and releases energy in the form of kinetic energy and sometimes gamma radiation. Alpha particles have low penetration power and can be easily stopped by a thin barrier such as paper or skin.

Beta decay is a type of radioactive decay in which a proton is transformed into a neutron or vice versa within the nucleus of an unstable atomic nucleus. This process results in the emission of a beta particle, which can be either a high-speed electron or positron, depending on the type of decay. Beta-minus (β^-) decay occurs when a neutron is converted into a proton, releasing an electron (beta particle) and an antineutrino. This increases the atomic number by one, transforming the element into another. Beta-plus (β^+) decay occurs when a proton is converted into a neutron, releasing a positron (beta particle) and a neutrino. This decreases the atomic number by one, transforming the element into another. Beta particles are used in medical applications, such as the treatment of certain cancers (e.g., eye and bone cancer) and as tracers in imaging techniques. The energy emitted during beta decay allows the nucleus to reach a more stable state. However, it also poses radiation risks. Beta particles have moderate penetration power and can pass through materials like paper or skin, but they are typically blocked by a few millimetres of materials such as aluminium. As such, proper shielding is necessary to protect against beta radiation.

Gamma decay is a type of radioactive decay in which an unstable atomic nucleus releases excess energy in the form of gamma rays, a highly energetic form of electromagnetic radiation. This process occurs when a nucleus transitions from a higher to a lower energy state, typically after undergoing alpha or beta decay. Gamma decay involves the release of high-energy gamma rays as the nucleus rearranges its particles to reach a more stable, lower energy state. Unlike alpha and beta decay, gamma decay does not involve a change in the number of protons or neutrons in the nucleus. The main purpose of gamma decay is to rid the nucleus of excess energy, allowing it to reach a more stable state after undergoing other types of radioactive decay. Gamma rays are highly penetrating due to their high energy and short wavelength. They can pass through many materials, including human tissue and some barriers. Protecting against gamma rays requires dense materials such as lead, steel or several centimetres of concrete to absorb or attenuate the radiation.

Radioactivity has important applications in various fields, including nuclear energy production, medical diagnostics and cancer treatment. However, it also poses potential hazards to living organisms and the environment if not handled properly, which is why safety measures are crucial when working with radioactive materials.

Learning Tasks

1. Explain radioactivity.
2. Describe the properties of alpha, beta and gamma radiation.
3. Explore the uses of radioactivity.

Pedagogical Exemplars

1. Engage learners in a discussion to define radioactivity and explore related concepts.
2. Provide a list of different types of radiation (alpha, beta, gamma) and a description of each type. Ask learners to match each type with its corresponding description and / or diagram.
3. Allow learners to use online simulations or to watch videos exploring the ionisation and penetrating power of alpha, beta and gamma.
4. Create a chart with columns for alpha, beta, and gamma radiation. Ask learners to fill in the chart with information about the particle's nature (helium nucleus, electron, high-energy photon), charge, mass, ionisation power and penetrating power.
5. Let learners research specific uses of radioactivity and prepare presentations to share their findings with the class.
6. Invite an expert working in a field that uses radioactivity to discuss their work and answer learners' questions.

Key Assessment

Assessment level 1: What is radioactivity?

Assessment level 1: Name three types of radiation associated with radioactivity.

Assessment level 2: Describe the process of alpha decay, and state the particles emitted during this type of radioactive decay?

Assessment level 2: Explore the properties of gamma radiation and its role in radioactive decay processes.

Assessment level 3: "Compare and contrast the potential environmental impacts of using radioactivity in medical treatments (such as radiation therapy) versus nuclear power generation. Consider factors such as waste disposal, radiation exposure, and regulatory measures in your answer. Provide specific examples to support your analysis."

Week 24

Learning Indicator: *Balance basic nuclear reactions.*

Theme or Focal Area: Balancing Nuclear Reactions

Nuclear reactions are processes in which the nuclei of atoms change, resulting in the transformation of one element into another or a change in the state of the nucleus. These reactions involve interactions between atomic nuclei and other particles (such as protons, neutrons, or other nuclei), and can lead to the release or absorption of energy.

Balancing a nuclear reaction involves ensuring that the total number of protons (proton number) and the total number of nucleons (nucleon number) are the same on both sides of the equation. Additionally, the sum of the charges on each side must be equal.

Balancing nuclear equations may not directly impact daily life for most people, but its significance becomes more evident when considering the broader context of nuclear science, technology and its various applications.

Nuclear reactions play a crucial role in energy production, particularly in nuclear power plants. Balancing nuclear equations is essential to ensure that the reactants and products are accurately represented, which helps engineers and scientists design efficient and safe nuclear reactors.

Learning Tasks

1. Define nuclear reactions.
2. Describe the process of balancing a nuclear reaction.
3. Solve problems involving the identification of missing particles in a nuclear equation.

Pedagogical Exemplars

1. Talk the students through the process of alpha, beta and gamma decay once more, this time focusing specifically on the changes which occur to the parent nucleus. Some student volunteers could stand up and pretend to be the various components of the reaction as a visual aid; they hold up cards showing their mass and atomic numbers, and adjust these as the teacher discusses the effect of, for example, alpha decay. Another student pretends to be the alpha particle, in this scenario.
2. Work through the steps of balancing the equations together as a class. Encourage learners to participate by suggesting which particles to balance first, while guiding the process.
3. Create cards with nuclear reactions written on them, both balanced and unbalanced. Provide the learners with a set of cards and have them sort them into two groups: balanced and unbalanced.
4. Utilise online interactive simulations or apps that allow learners to input unbalanced nuclear reactions and experiment with different ways to balance them.
5. More able students could be given an independent task to research neutrinos and the reason for their postulation. The findings could be presented to the rest of the class.

Key Assessment

Assessment level 1: What are nuclear reactions?

Assessment level 1: Describe the process of balancing a nuclear reaction.

Assessment level 2: Find the values of x and y in the nuclear equation below

$$^{14}_{x}N + ^{4}_{2}He \rightarrow ^{y}_{8}O + ^{1}_{1}H$$

Assessment level 3: Provide the balanced nuclear reaction for the following scenario: A uranium-235 nucleus absorbs a neutron and undergoes fission to produce krypton-92, barium-141, and three neutrons. Explain how you ensured the conservation of mass number and atomic number in the reaction.

Section 8 Review

Learners should gain a deeper appreciation for the historical progression of the atomic theory. Learners should understand that electrons in atoms have discrete energy levels, and when they transition between energy levels, they emit or absorb photons with specific energies corresponding to the energy difference between the levels. Learners should visualise the arrangement of protons and neutrons in the nucleus and its importance in defining the atom's properties. Learners should comprehend that radioactivity is the spontaneous emission of particles or radiation from the nucleus of an unstable atom to achieve a more stable configuration.

References

1. Atomic Structure: Over 75,719 Royalty-Free Licensable stock Vectors & Vector art Shutterstock. (n.d.). Shutterstock. https://www.shutterstock.com/search/atomic-structure?image_type=vector
2. Electricity - detailed contents. (n.d.-b). https://www.a-levelphysicstutor.com/quantphys-energy-levels.php
3. GeeksforGeeks. (2024, February 25). Structure of nucleus. GeeksforGeeks. https://www.geeksforgeeks.org/structure-of-nucleus/

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