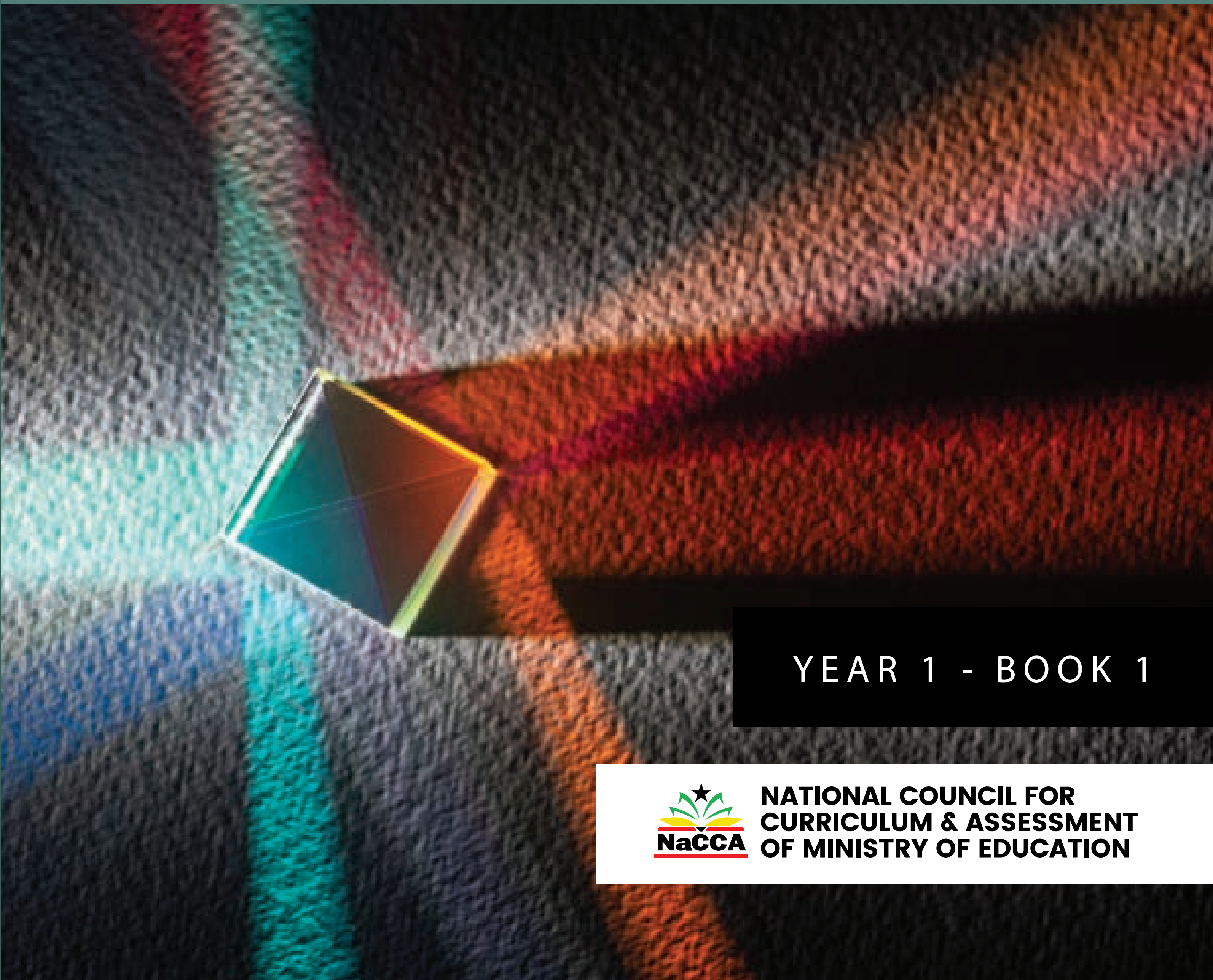
MINISTRY OF EDUCATION

Physics

TEACHER MANUAL



YEAR 1 - BOOK 1

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION

REPUBLIC OF GHANA

Physics

Teacher's Manual

Year One - Book One

NATIONAL COUNCIL FOR
CURRICULUM & ASSESSMENT
OF MINISTRY OF EDUCATION

GEOGRAPHY TEACHER'S MANUAL

Enquiries and comments on this manual should be addressed to:
The Director-General
National Council for Curriculum and Assessment (NaCCA)
Ministry of Education
P.O. Box CT PMB 77
Cantonments Accra

Telephone: 0302909071, 0302909862
Email: info@nacca.gov.gh
website: www.nacca.gov.gh

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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 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 this information for the first 12 weeks of Year One, with the remaining 12 weeks contained within Book Two. 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:

- 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.
- 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.

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The writing team was made up of the following members:

Subject	Writer	Institution
Home Economics	Grace Annagmeng Mwini	Tumu College of Education
	Imoro Miftaw	Gambaga Girls' SHS
	Love Boateng	Juaso SHS
	Jusinta Kwakyewaa (Rev. Sr.)	St. Francis SHTS
Religious Studies	Richardson Addai-Mununkum	University of Education Winneba
	Dr. Bonsu Osei-Owusu	West Africa SHS
	Prince Osei Adjei	Adventist SHS, Bantama
	Dr Francis Opoku	Valley View University College
	Yaw Sarkodie Agyemang	University of Cape Coast
	Aransa Bawa Abdul Razak	Uthmaniya SHS
	Godfred Bonsu	Prempeh College
RME	Anthony Mensah	Abetifi College of Education
	Joseph Bless Darkwa	Volo Community SHS
	Clement Nsorwineh Atigah	Tamale SHS
Arabic	Murtada Mahmoud Muaz	AAMUSTED
	Abas Umar Mohammed	University of Ghana
	Adam Abubakar	Uthmaniya SHS
	Mahey Ibrahim Mohammed	Tijjaniya Senior High School
French	Osmanu Ibrahim	Mount Mary College of Education
	Maurice Adjetey	
	Mawufemor Kwame Agorgli	Akim Asafo SHS
Performing Arts	Latipher Osei Appiah-Agyei	University of Education Winneba
	Desmond Ali Gasanga	Ghana Education Service
	Yaw Owusu Asiamah	Adventist SHS, Bantama
	Chris Ampomah Mensah	Bolgatanga SHS, Winkogo

Subject	Writer	Institution
Art and Design Studio and Foundation	Dr. Ebenezer Acquah	University for Education Winneba
	Dr. Osuanyi Quaicoo Essel	University for Education Winneba
	Seyram Kojo Adipah	Ghana Education Service
	Jectey Nyarko Mantey	Kwame Nkrumah University of Science and Technology
	Yaw Boateng Ampadu	Prempeh College
	Kwame Opoku Bonsu	Kwame Nkrumah University of Science and Technology
	Dzorka Etonam Justice	Kpando SHS
Applied Technology & Design and Communication Technology	Joseph Asomani	AAMUSTED
	Dr. Prosper Mensah	AAMUSTED
	Dr. Sherry Kwabla Amedorme	AAMUSTED
	Esther Pokuah	Mampong Technical College of Education
	Wisdom Dzidzienyo Adzraku	AAMUSTED
	Kunkyuuri Philip	Kumasi SHTS
	Antwi Samuel	Kibi SHTS
	Gabriel Boafo	Kwabeng Anglican SHTS
	Josiah Bawagigah Kandwe	Walewale Technical Institute
	Emmanuel Korletey	Benso SHTS
	Isaac Buckman	Armed Forces SHTS
	Daniel K. Agbogbo	Kwabeng Anglican SHTS
	Tetteh Moses	Dagbon State SHS
	Awane Adongo Martin	Dabokpa Technical Institute
Business Studies	Emmanuel Kodwo Arthur	ICAG
	Dr. Emmanuel Caesar Ayamba	Bolgatanga Technical University
	Ansbert Baba Avole	Bolgatanga SHS, Winkogo
	Faustina Graham	Ghana Education Service, HQ
	Nimako Victoria	SDA SHS, Akyem Sekyere
Agriculture	Dr Esther Fobi Donkoh	University of Energy and Natural Resources
	Prof. Frederick Adzitey	University for Development Studies
	Eric Morgan Asante	St. Peter's SHS

Subject	Writer	Institution
Agricultural Science	David Esela Zigah	Achimota School
	Prof J.V.K. Afun	Kwame Nkrumah University of Science and Technology
	Dr. Kwadwo Amankwah	Kwame Nkrumah University of Science and Technology
	Alex Adu Frimpong	Benso SHTS
	Mrs. Benedicta Foli	
Government	Josephine Akosua Gbagbo	Ngleshie Amanfro SHS
	Augustine Arko Blay	University of Education Winneba
	Samuel Kofi Adu	Fettehman SHS
Economics	Peter Anti Partey	University of Cape Coast
	Charlotte Kpogli	Ho Technical University
	Joseph Agbevanu	Kinbu SHS
	Adams Abdul-Somed	Kalponin SHS
	Benjamin Agyekum	Mangoase SHS
Geography	George Boateng	Berekum College of Education
	Dr. Esther Yeboah Danso-Wiredu	University of Education Winneba
	Dr. Matthew Krusah	University of Education Winneba
	Raymond Nsiah Asare	Methodist Girls' High School
History	Kofi Adjei Akrasi	Opoku Ware School
	Anitha Oforiwah Adu-Boahen	University of Education Winneba
	Prince Essiaw	Enchi College of Education
Ghanaian Language	David Sarpei Nunoo	University of Education Winneba, Ajumako
	Catherine Ekua Mensah	University of Cape Coast
	Ebenezer Agyemang	Opoku Ware School
Physical Education and Health	Paul Dadzie	Accra Academy
	Sekor Gaveh	Kwabeng Anglican SHTS
	Anthonia Afosah Kwaaso	Junkwa SHS
	Mary Aku Ogum	University of Cape Coast
Social Studies	Mohammed Adam	University of Education Winneba
	Simon Tengan	Wa SHTS
	Jemima Ayensu	Holy Child School

Subject	Writer	Institution
Computing and Information Communication Technology (ICT)	Victor King Anyanful	OLA College of Education
	Raphael Dordoe Senyo	Ziavi SHTS
	Kwasi Abankwa Anokye	Ghana Education Service, SEU
	Millicent Heduvor	STEM SHS, Awaso
	Mohammed Abdul-Samed	Dagbon State SHS
	Dr. Gaddafi Abdul-Salaam.	Kwame Nkrumah University of Science and Technology
English Language	Esther Armah	Mangoase SHS
	Kukuaa Andoh Robertson	Achimota School
	Cecilia Amponsah	Presbyterian Boys' SHS
	Alfred Quaittoo	Kaneshie SHTS
	Benjamin Orsoo	Islamic SHS
	Fuseini Hamza	Tamale Girls' SHS
Intervention English	Roberta Emma Amos-Abanyie	Ingit Education Consult
	Prof. Charles Owu-Ewie	University of Education Winneba
	Perfect Quarshie	Mawuko Girls SHS
	Sampson Dedey Baidoo	Benso SHTS
Literature in English	Blessington Dzah	Ziavi SHTS
	Angela Aninakwah	Ghana Education Service
	Dr. Emma Sarah Eshun	University of Education Winneba
	Samuel Kwame Kassah	St. Peter's SHS
	Juliana Akomea	Mangoase SHS
General Science	Dr. Comfort Korkor Sam	University for Development Studies
	Saddik Mohammed	Ghana Education Service
	Robert Arhin	SDA SHS, Akyem Sekyere
Chemistry	Ambrose Ayiku	St. Francis College of Education
	Awumbile Patrick Nsobila	Bolgatanga SHS, Winkogo
	Bismark Tunu	Opoku Ware School
	Gbeddy Neurus Anthony	Ghanata SHS
Physics	Linus Labik	Kwame Nkrumah University of Science and Technology
	Henry Benyah	Wesley Girls' SHS
	Sylvester Affram	Kwabeng Anglican SHS

Subject	Writer	Institution
Biology	Damoah Paul	Prempeh College
	Maxwell Bunu	Ada College of Education
	Ebenezer Delali Kpelly	Wesley Girls' SHS
	Doris Osei-Antwi	Ghana National College
Mathematics	Edward Dadson Mills	University of Education Winneba
	Zacharia Abubakari Sadiq	Tamale College of Education
	Faustina Nana Ackob	Mfantsiman SHS
	William Ababu	Swedru SHS
	Collins Kofi Annan	Mando SHS
Additional Mathematics	Dr. Nana Akosua Owusu-Ansah	University of Education Winneba
	Gershon Mantey	University of Education Winneba
	Very Rev. Prof. William Obeng Denteh	Kwame Nkrumah University of Science and Technology
	Charles B. Ampofo	Kibi College of Education
	Bismark Twum	SDA SHS, Akyem Sekyere
	Innocent Duncan	KNUST SHS
Intervention Mathematics	Florence Yeboah	Assin Manso SHS
	Mawufemor Adukpo	Ghanata SHS
	Jemima Saah	Winneba SHS
	Mohammed Shani Abdulai	Yendi SHS
Robotics	Dr. Eliel Keelson	Kwame Nkrumah University of Science and Technology
	Dr. Nii Longdon Sowah	University of Ghana
	Kwabena Osei-Kusi	Prempeh College
	Michael Wilson	CSIR
	Isaac Nzoley	Wesley Girls' SHS
Engineering	Daniel K. Agbogbo	Kwabeng Anglican SHTS
	Prof. Abdul-Rahman Ahmed	Kwame Nkrumah University of Science and Technology
	Dr. Griffth Serlorm Klogo	Kwame Nkrumah University of Science and Technology
	Japheth Kwadwo Bumusi	Mawuli School
	Valentina Osei-Himah	Atebubu College of Education

Subject	Writer	Institution
Aviation and Aerospace Engineering	Opoku Joel Mintah	Altair Unmanned Technologies
	Dr. Eunice Akyereko Adjei	Kwame Nkrumah University of Science and Technology
	Dr. David Kofi Oppong	Kwame Nkrumah University of Science and Technology
	Sam Ferdinand	Afua Kobi Ampem Girls' SHS
Biomedical Science	Dr. Dorothy Yakoba Agyapong	Kwame Nkrumah University of Science and Technology
	Jennifer Fafa Adzraku	Université Libre de Bruxelles
	Dr. Isaac Acquah	Kwame Nkrumah University of Science and Technology
	David Ayah	St. John's Grammar School
	Dr. Eric Worlawoe Gaba	Br. Tarcisius Prosthetics and Orthotics Training College
Manufacturing Engineering	Benjamin Atribawuni Asaaga	Kwame Nkrumah University of Science and Technology
	Dr. Samuel Boahene	Kwame Nkrumah University of Science and Technology
	Issahaku Iddrisu	Ada SHS
	Dr. Mizpah Ama D. Rockson	Kwame Nkrumah University of Science and Technology
	Prof Charles Oppon	Cape Coast Technical University
Spanish	Setor Donne Novieto	University of Ghana
	Franklina Kabio	University of Ghana
	Mishael Annoh Acheampong	University of Media, Art and Communication
Assessment	Benjamin Sundeme	St. Ambrose College of Education
	Victor Gideon Obeng	Retired
	Prof. Eric Francis Eshun	Kwame Nkrumah University of Science and Technology
	Dr. Ruth Annan-Brew	University of Cape Coast
	Dr. Isaac Amoako	Atebubu College of Education

Subject	Writer	Institution
Curriculum Writing Guide	Paul Michael Cudjoe	Prempeh College
	Prof. Winston Abroampa	Kwame Nkrumah University of Science and Technology
	Cosmos Eminah	University of Education Winneba
	Ahmed Amihere	University of Education Winneba
	Evans Odei	Achimota School
	Ellen Abakah	CEGENSA, University of Ghana
	Hasiyatu Abubakari	CEGENSA, University of Ghana
	Eyram Eric Kwasi Fiagbedzi	CEGENSA, University of Ghana
	Deborah Atobrah	CEGENSA, University of Ghana
	Ayine Akoglo	CEGENSA, University of Ghana
	Theodora Akweley Asiamah	CEGENSA, University of Ghana
NaCCA	Matthew Owusu	Ebenezer Ankamah
	Reginald Quartey	Alice Abbiw Donkor
	Rebecca Abu Gariba	Abigail Birago Owusu
	Anita Collision	Samuel Owusu Ansah
	Joachim Honu	Richard Teye
	Joana Vanderpuije	Joseph Barwuah
	Uriah Otoo	Anthony Sarpong
	Nii Boye Tagoe	Jephtar Adu Mensah
	Eric Amoah	Nancy Aseiduwaa Gyapong
	Francis Agbalanyo	Godwin Senanu
	Dennis Adjasi	Godfred Mireku
	Samuel Amankwa Ogyampo	Juliet Owusu-Ansah
	Sharon Antwi Baah	Thomas Kumah Osei
	Ayuba Sullivan	Seth Nii Nartey

SCOPE AND SEQUENCE

Physics Summary

S/N	STRAND	SUB-STRAND	YEAR 1			YEAR 2			YEAR 3		
			CS	LO	LI	CS	LO	LI	CS	LO	LI
1. 2. 3. 4.	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
5. 6.	Energy	Heat	1	1	4	1	1	4	1	1	3
		Waves	3	3	10	2	2	8	2	2	6
7. 8. 9. 10.	Electro-magnetism	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
11.	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 1: INTRODUCTION TO PHYSICS AND MATTER

Strand: **Mechanics and Matter**

Sub-Strands:

1. **Introduction to Physics**
2. **Matter**

Content Standards:

1. Recognise aspects and branches of Physics as exhibited in everyday life.
2. Classify quantities into fundamental, derived, scalars and vectors.
3. Demonstrate knowledge and understanding of physical quantities.
4. Demonstrate knowledge and understanding of matter.

Learning Outcomes:

1. *Explain how physics is applied in some sectors of the 'glocal' (global and local) economy.*
2. *Classify quantities into fundamental, derived, scalars and vectors.*
3. *Describe the various states of matter and the differences in their structure.*

INTRODUCTION AND SECTION SUMMARY

The weeks covered by the section are:

Week 1: Careers in Physics, basic mathematical concepts and units in Physics

This section looks at Physics as a branch of science and identifies some careers that rely on principles and laws of Physics. It also looks at physical quantities and their classification into fundamental, derived, scalars and vectors. Mathematics as a subject is needed in the study of Physics and therefore it is required that learners have a very good knowledge of some basic Mathematical concepts such as trigonometric ratios, Pythagoras's theorem, the sine and cosine rules and indices.

Week 2: Dimensions, measurement and errors in measurement

The section covers dimensional analysis, before moving on to highlight the importance of recognising and rectifying errors in both analogue and digital measuring tools and to categorise errors into systematic, random and parallax types.

Week 3: Scientific notations, scalars and vectors

Scientific notations and unit multipliers are discussed for simplifying numerical expressions. The distinction between scalars and vectors is highlighted, emphasising their qualitative differences. Understanding these concepts is essential for accurate experimentation and analysis in Physics.

Week 4: Matter

The section also looks at matter which is one of the fundamental concepts studied in the field of Physics. Understanding the properties and interactions of matter is essential for various branches of Physics, including mechanics, thermodynamics, electromagnetism and quantum physics.

SUMMARY OF PEDAGOGICAL EXEMPLARS

The topics in Section 1 lend themselves to a variety of teaching methods, including:

- Discussions in pairs or groups in order to allow students to build on one another's' understanding or consider concepts from a different perspective, e.g.

• Which career they would be interested in pursuing and why? Invite guest speakers from relevant industries to share their career experiences and insights.

- Where possible, engage learners through hands-on activities and inquiry-based learning. Where this is not possible, photographs and videos of the demonstrations should be shown. E.g.

• Identify and measure basic physical quantities using standard units (e.g., meter, kilogram, second).

• Demonstrate proper use of measurement tools (e.g., meter rule, vernier calliper) and common errors that may occur. Engage learners in error analysis activities where they identify and explain errors in measurement techniques. Provide opportunities for learners to practice using measurement tools accurately through hands-on experiments and laboratory activities.

• Conduct experiments or demonstrations to observe and classify the various states of matter (solid, liquid, gas).

- Integration of technology for research tasks, videos and simulations where appropriate, e.g.

• Use molecular models or animations to illustrate differences in molecular arrangements between states of matter.

- Encourage learners to notice the relevance of physics to the world around them in order to whip up learners' interest in studying the subject.

As always, implement differentiation strategies to accommodate diverse learning needs. In this document, some activities are given additional direction for how to support those 'less able' or 'more able', which refers only to their ability level in that given task / proficiency.

ASSESSMENT SUMMARY

The assessments to be used to monitor learning progress during instruction should be formative assessments and these include quizzes, mathematical problem solving, short written responses to questions and laboratory work.

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 1

Learning Indicators:

1. *Identify careers that are related to Physics in various sectors of the economy.*
2. *Use basic mathematical concepts to solve problems i.e. trig ratios, Pythagoras theorem, sine and cosine rule, indices.*
3. *Identify the basic units in Physics.*

THEME OR FOCAL AREA 1: APPLICATIONS OF PHYSICS IN VARIOUS SECTORS OF THE ECONOMY AND CAREER EXPLORATION

When we observe the careers within our own community and more widely, such as carpentry, masonry, welding, vulcanising, trading in the market, engineering, meteorology, medicine, teacher etc., physics is applied in many ways. By understanding the applications of physics in different sectors, individuals can make informed choices about their future career paths.

Physics is divided into several subfields, each focusing on specific aspects of the physical universe including classical mechanics, thermodynamics, electromagnetism, quantum mechanics, relativity, optics, nuclear physics and particle physics. Each branch focuses on specific aspects of the physical universe, from the motion of macroscopic objects to the behaviour of particles at the atomic and subatomic levels. These branches collectively provide a comprehensive framework for understanding the fundamental principles that govern the universe.

Note that students will have an understanding, to some degree, of topics such as mechanics, optics, electricity etc, but will be very unfamiliar with (e.g.) quantum mechanics which may therefore need some brief explanation in order for them to identify related careers.

LEARNING TASKS

1. Identify Physics-related careers across the various sectors of the economy.
2. Identify a selection of branches of Physics.
3. Give further explanation as to the scope of some of the branches of Physics.
4. Link the branches of Physics to examples of careers.

PEDAGOGICAL EXEMPLARS

1. Learners could watch a documentary that illustrates how physics plays a vital role in shaping the world. Let learners identify Physics-related careers linking to branches of physics that the learner may have met before e.g. mechanics, electricity, waves.
2. In groups, learners should be given a list of Physics-oriented careers, including some or all of: masonry, welding, vulcanising, trading in the market, engineering (mechanical, civil, geomatic, electrical), medicine, geophysics, materials science, metallurgy, laser physics, radiology, astrophysics, meteorology, climate science, computing, etc. Learners should be asked to discuss:
   a. What branch of Physics does this career relate to? Is there more than one?
   b. What level of Physics education might a person need to have in order to do this job?
   c. Could this job be done by people with a disability of some kind? If not; how could the job be adapted in order to make it accessible?
   d. Which of the jobs would you most like to do? Why?

3. Organise a career panel with guest speakers from various Physics-related professions. Learners should prepare questions and engage in discussions with the panelists.
4. Learners could do a research task to find out more about one of the careers mentioned previously and could be asked to volunteer to present their finding in a short oral presentation (or could alternatively produce a written piece of work). Note that more able learners should be encouraged to research a job that links to a branch of Physics which may be new to them (electromagnetism, nuclear physics, astronomy, etc.) whereas less able learners may find the task more accessible if a more recognisable branch of Physics or career is suggested to them.

KEY ASSESSMENT

Assessment Level 1: Identify at least five Physics related careers in your community.

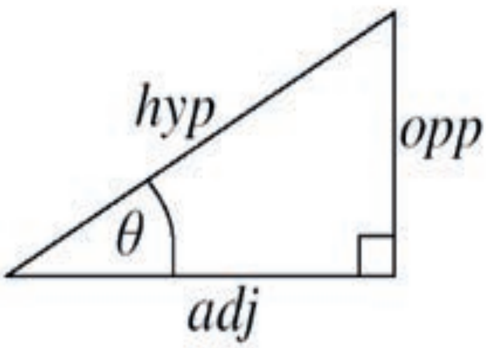
Assessment Level 2: Describe at least three branches of Physics and give examples of careers which utilise the study of these.

Assessment Level 1: Discuss the application of the principles of Physics in any industry of your choice.

THEME OR FOCAL AREA 2: THE INTERPLAY OF MATHEMATICS AND PHYSICS IN CONCEPTUAL UNDERSTANDING AND REAL-WORLD APPLICATIONS

Appreciating Physics concepts and applications requires a strong foundation in Mathematics that is as expansive as possible. This mathematical skill will serve as a solid bridge, allowing learners to seamlessly delve into the captivating world of Physics and fully thrive in their Physics courses.

Applying basic Mathematical concepts in Physics allows us to address real-world challenges and better understand the world. Trigonometric ratios, Pythagoras's theorem, the sine and cosine rules and indices are essential Mathematical tools in Physics.



Pythagoras theorem

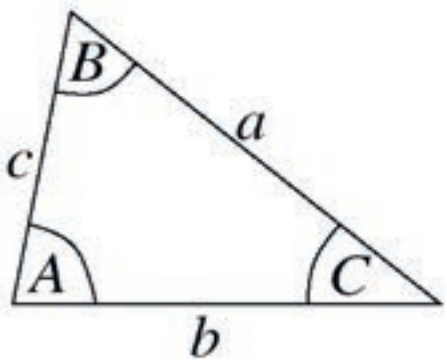
$$opp^2 + adj^2 = hyp^2$$

Trigonometric Ratios

$$\sin\theta = \frac{opp}{hyp}$$

$$\cos\theta = \frac{adj}{hyp}$$

$$\tan\theta = \frac{opp}{adj}$$



Sine Rule

$$\frac{a}{sin\,A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Cosine rule

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

Rules of indices

$$x^m \times x^n = x^{m+n}$$

$$x^m \div x^n = x^{m-n}$$

$$x^0 = 1$$

$$x^{-m} = \frac{1}{x^m}$$

$$(x^m)^n = x^{m \times n} = x^{mn}$$

$$x^{\frac{m}{n}} = \sqrt[n]{x^m}$$

LEARNING TASKS

1. Solve for missing sides or angles of right-angled triangles using trigonometric ratios.
2. Use Pythagoras' theorem to find the length of a missing side in a right-angled triangle.
3. Solve problems involving indices.
4. Apply the Sine and Cosine rules to solve for missing values when given various combinations of sides and angles.

PEDAGOGICAL EXEMPLARS

1. Using classroom discussion, learners recall their previous knowledge of plane geometrical figures, such as triangles and trapeziums, and their corresponding area formulas.
2. Teacher-led worked examples of Pythagoras' theorem, trigonometric ratios, Sine and Cosine rules and indices rules presented to class.
3. Worksheet: Learners should apply the Sine and Cosine rules in deducing the sides and angles within triangles.
   - Less able learners should be given the worksheet of examples to try but should also be provided with a worked solution to the first example in each section.
   - Some learners should be given the sheet of questions with no additional scaffolding.
   - More able learners should be encouraged to 'skip' to more challenging questions and is provided with a more complicated example of using trigonometry in a Physics context, e.g. calculating the resultant velocity and direction of a boat crossing a river which is flowing at a given velocity.
4. Worksheet: Learners utilise Pythagoras's theorem to deduce angles of inclined objects in real-life scenarios. See suggestions for differentiation above.
5. Learners work in mixed-ability groups (where the more able learners can support the less able learners) to use exponent rules to solve some real-world problems presented to the class, e.g. determine the number of teams remaining at various knockout stage in a tournament.

KEY ASSESSMENT

Assessment Level 2: A 4.2 m long ladder leans against a wall. If the bottom of the ladder is 3.8 m from the wall, draw a diagram to represent the scenario.

Assessment Level 2: A 4.2 m long ladder leans against a wall. If the bottom of the ladder is 3.8 m from the wall, calculate the angle the ladder makes with the wall.

Assessment Level 3: In the given scenario, supposing the ladder is moved further away from the wall, increasing the distance, how will this change the angle the ladder forms with the ground? Support your answer with reference to a relevant trigonometric function.

THEME OR FOCAL AREA 3: BASIC AND DERIVED UNITS

A solid understanding of basic units in Physics is crucial for comprehending scientific concepts and their practical applications.

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

The seven fundamental/basic quantities and their respective units are length (metre), mass (kilogram), time (second), temperature (Kelvin), electric current (Ampere), amount of substance (mole) and luminous intensity (candela).

Derived units are units formed from the combination of two or more fundamental units. Examples of some derived quantities and their units: Force (Newton), Work/Energy (Joule), Velocity (metre per second) etc.

LEARNING TASKS

1. Categorise quantities and units as basic or derived.

PEDAGOGICAL EXEMPLARS

1. Guide learners to brainstorm and derive units by evaluating real-world scenarios, e.g. scenario of an athlete running a race.
2. Give a list of physical quantities and their units (e.g., force [N], energy [J], power [W]) in a mixed-up order. Ask the learners to match the correct quantity with its corresponding unit.
3. Alternatively, treat this as a competition; how many units can you think of? (it doesn't matter if they are fundamental or derived). One point per correct answer.
4. Ask learners if they can categorise these units in any way (some may recognise that some units are capitalised as they are named after people etc. If a student already recognises that they can be categorised into fundamental and derived units, ask them to explain what they mean to the class).

KEY ASSESSMENT

Assessment Level 1: What are basic quantities and give three examples.

Assessment Level 1: Explain the difference between basic and derived quantities, providing examples of each.

Assessment Level 2: Categorise the following quantities as basic or derived; temperature, displacement, time, force, distance, acceleration, mass.

Week 2

Learning Indicators:

1. *Determine the dimensions of common quantities, e.g. velocity, acceleration, mass, length, time, weight, energy and force.*
2. *Identify the errors in the use of a metre rule, protractor, electronic balance, vernier calliper, micrometer screw gauge, voltmeter and ammeter.*
3. *Explain the types of errors; systematic, random and parallax.*

THEME/FOCAL AREA 1: DIMENSION

The dimension of a physical quantity is an expression of the relationship between the physical quantity and the fundamental quantities (mass, length and time in mechanics).

The dimension of a physical quantity is crucial because it provides essential information about the nature of the quantity being measured.

Dimensions can be used, for the verification of equations, to find the units of quantities and to derive an equation between quantities. Dimensional analysis is a tool in Physics and Engineering, helping learners develop a better understanding of physical relationships and units, but does not allow for numerical constants.

LEARNING TASKS

1. Determine fundamental units of quantities using dimensions.
2. Evaluate the usefulness of dimensional analysis.

PEDAGOGICAL EXEMPLARS

1. Opportunity for some lesson interactivity/quiz; "if this is the formula, what is the quantity?" Or "if this is the definition, what is the quantity?". Help learners to recall relationships that they already know as a starting point for their work on dimensional analysis.
2. Put pupils into mixed-ability groups, so that more able learners can support less able learners, with a list of quantities to write down the formula for, including units.
3. Teacher-led demonstration of how to find the unit for a quantity in terms of fundamental units, followed by the students practicing the skill:
   - Less able learners should be given the worksheet of simple examples to try but also should be provided with a worked solution to the first example and a list of relevant formulae.
   - Some learners should be given the sheet of questions but is expected to recall the relevant formulae.
   - More able learners should be encouraged to 'skip' to more challenging questions and should be asked to show that different quantities have the same fundamental units e.g. Gravitational Potential Energy, Kinetic Energy and work done, pressure and stress, work done and moment.
4. Introduce fundamental constants (e.g. speed of light [c], gravitational constant [G]) and ask learners to determine their dimensions and units. Learners should be provided with formulae or definitions of the constants named above.
5. Pair/group discussions about the benefits of dimensional analysis in Physics.

KEY ASSESSMENT

Assessment Level 1: Give three uses of dimensional analysis.

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

a. Acceleration
b. Force
c. Energy
d. Power

Assessment Level 3: Evaluate the usefulness of dimensional analysis.

THEME/FOCAL AREA 2: ERRORS IN THE USE OF MEASURING INSTRUMENTS

Accurate measurements are essential for Scientific research, Engineering and many other fields. Analogue instruments such as rulers, vernier callipers, micrometer screw gauges, thermometers, balances, protractors, as well as digital instruments such as voltmeters and ammeters, etc, enable us to quantify and compare physical quantities precisely. Learners will need to learn the proper usage of the instruments and also learn to overcome challenges they will encounter in the handling of the instruments.

LEARNING TASKS

1. Identify various measuring instruments.
2. Identify specific instruments for specific purposes.
3. Identify potential errors in the use of specific instruments.

PEDAGOGICAL EXEMPLARS

1. Provide students with a variety of pieces of measuring equipment, e.g. rulers, vernier callipers, protractors, analogue/digital voltmeters and ammeters. Ask students to identify the equipment and what it would be used to measure. Ask them, also, to look closely and identify the 'least count' of each piece of equipment. Can they suggest an example of a use for each item? Suggestions could be left on a post-it note near the equipment.
   - Less able learners should handle all of the equipment available and consider the use / precision of the equipment in pairs/groups. The teacher will offer support in terms of understanding the 'least count' of the equipment as they circulate the room, and could ask simple questions such as:
     a. Why is it more appropriate to use a metre ruler to measure the length of a textbook rather than vernier callipers?
     b. Do you know of a piece of equipment that could be used to measure longer distances, such as the length of a football pitch?
     c. Why should you take repeats of measurements when doing practical work?
   - Some learners should handle all of the equipment but are given less support than the less able learners. They could be encouraged to 'work it out' themselves or by using the internet to research. Targeted questioning could look like:
     a. What is the advantage of vernier callipers over a screw gauge for measuring the internal diameter of a bottle neck?
     b. When you measure an angle using a protractor, at how many different positions are you 'judging' the measurement? (Two—one at either side of the angle being measured)

c. Three results for voltage are measured. They are: 1.02V, 1.04V and 0.98V. What is the range of the repeats? What is the percentage difference between the greatest measurement of V and the average V?

- Higher ability learners should complete the work as above, but should also be given a 'challenge' such as to estimate the width of a single sheet of a textbook using an appropriate piece of equipment. They could be prompted to consider various ways in which this could be achieved.

  Targeted questioning could look like:

  a. What is the difference between an accurate and a precise measurement?
  b. Which piece of equipment gives the most precise reading for length?
  c. What is the advantage of using digital equipment vs analogue equipment?

2. In pairs/groups, and encouraging everybody to have a turn, provide a set of objects or drawings of lines with varying lengths. Ask the learners to measure each length using a meter rule (ideally with cm, not mm) markings and record their measurements. Then, identify any potential errors in their measurements.
3. Repeat task above, but using vernier callipers instead.
4. Provide a set of objects with known masses. Ask the learners to weigh each object using an electronic balance and record their measurements. Then, identify any errors in their readings.

KEY ASSESSMENT

Assessment Level 1: Name the instruments that are used to measure the following quantities:

a. thickness of a blade
b. mass of a stone
c. volume of a stone

Assessment Level 1: Determine the least count of the following instruments used in the laboratory.

a. Micrometer screw gauge
b. Metre rule
c. Vernier calliper
d. Protractor
e. Voltmeter

THEME/FOCAL AREA 3: ERRORS IN MEASUREMENT

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

1. **Systematic error:** This is an error that consistently deviates from the true value in the same direction. It often arises due to zero-errors in the equipment or by errors in the scales on the equipment (e.g. a ruler with 1mm markings which are, in reality, 1.1mm apart).
2. **Random errors:** These are errors made by the person carrying out the measuring or as a result of experimental conditions. Sources of random errors include incorrect timing, or inaccurate reading of instrument. Factors such as unpredictable fluctuations in temperature, voltage supply, mechanical vibrations of experimental set-ups can also result in random errors.
3. **Parallax error**: This is the error that occurs due to incorrect positioning of the eyes while taking a reading on a measuring scale.

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

LEARNING TASKS

1. Use various pieces of measuring equipment and identify whether any/what type of errors are present in the results.
2. Create a written summary of the results from each piece of measuring equipment.

PEDAGOGICAL EXEMPLARS

1. Ask students to think for 30 seconds about whether 'accuracy' and 'precision' are the same. Then, discuss with a partner for 30 seconds. Then, share with the class.
2. Prepare a set of measurement instruments, such as a ruler, protractor and weighing scale, along with objects to measure (e.g., various lengths, angles and masses). Make sure some of the instruments have errors or calibration issues (e.g. a non-zeroed set of weighing scales, or a homemade ruler marked incorrectly), while others are accurate. Ask learners to measure the lengths of different objects. Instruct them to identify and describe any patterns or inconsistencies in their measurements.
   - Let learners handle all of the equipment available and consider the use/precision of the equipment in pairs/groups. The teacher should offer support in terms of proper usage of the instruments and could ask less able learners simple questions such as:
     a. How appropriate can you use an instrument to avoid the introduction of errors?
     b. Can you provide examples of systematic errors?
     c. How do random errors differ from systematic errors?
   - Some learners could be given less support than this. They could be encouraged to 'work it out' themselves or by using the internet to research. Targeted questioning could look like:
     a. How can we eliminate systematic and random errors in an experiment?
     b. How can we prevent or minimize parallax errors in measurements?
   - More able learners should be given an extension question on the effect of a random error on a subsequent calculation, for example:

     "When a set of scales has nothing on it, it reads a value of 2g. A student measures the mass of a rock using these scales as 154g. What type of error has occurred? How would this error affect the students' measurement of the density of the object after its volume has also been measured?"
3. Ask learners to measure the angles of different shapes or drawn angles. Encourage them to take multiple measurements and analyse the variations they observe.
4. Let learners discuss in a collaborative manner, the errors made in their readings. Give them the keywords 'systematic, random and parallax' with their definitions. Can they identify any of these in their results? Promote open-mindedness and integrity with respect for one another.

KEY ASSESSMENT

Assessment Level 2: What are the sources of random and systematic errors? Give ways to reduce or eliminate them.

Assessment Level 2: With examples of random and systematic errors each from real-life experimental situations, explain the difference between random error and systematic error.

Assessment Level 3: A reading can be precise but inaccurate. Discuss.

Week 3

Learning Indicators:

1. *Explain scientific notations and their unit multipliers.*
2. *Distinguish scalars from vectors (qualitative treatment)*

THEME/FOCAL AREA 1: SCIENTIFIC NOTATIONS AND THEIR UNIT MULTIPLIERS

Scientific notation is a way to express numbers that are very large or very small. It consists of two parts: a coefficient and a power of 10. The coefficient is a number between 1 and 10 and a power of 10 indicates how many places the decimal point should be moved. The purpose of scientific notation is to represent numbers in a concise and standardised format, making it easier to work with extremely large or small values. By using scientific notation and unit multipliers, we can more easily compare and perform operations on numbers with different magnitudes.

LEARNING TASKS

1. Identify some scientific notation and their unit multipliers
2. Express quantities in scientific notation to standard units
3. Convert other units into SI units

PEDAGOGICAL EXEMPLARS

1. Opportunity for interactive element/quiz: Ask students to estimate the sizes of some very small and very large things (diameter of a proton, width of human hair, distance from Ghana to England, distance from Earth to Pluto etc.). Give them time to make their guesses before revealing the real answers and seeing who got the closest. Use this as an opportunity to highlight how it can be difficult to leave very large and very small numbers in their normal format and give the benefits of using standard form.
2. Provide learners with a list of numbers, some of which are extremely large and others extremely small. Ask them to convert these numbers into scientific notation. Present learners with real-life scenarios involving very large or very small quantities from various scientific disciplines (e.g. astronomy, chemistry, nanotechnology). Ask them to express these quantities using scientific notation, or vice versa.
   - Learners should be given a list of numbers in their usual format and asked to convert these into standard form and vice versa. Teacher will circulate and assist where needed, targeting students that they know may find working with numbers more challenging.
   - Some more difficult examples should be provided for learners to attempt if they have found the first task easy. E.g. ask them to adjust their answers when a unit conversion is added e.g. 10,000cm = ____ x 10^____ m. Some learners may need a unit conversion table to be provided.
   - The most able learners may be given some more complicated examples involving converting units for area and volume, or a combination of units e.g. kmh^{-1} to ms^{-1}, cm^2 to m^2.

KEY ASSESSMENT

Assessment Level 2: Define scientific notation and give an example of a number that is written in a scientific notation.

Assessment Level 2: Express 900 cm in m

Assessment Level 2: Convert the following:

a. 20 cm^2 to m^2
b. Convert 72 $kmhr^{-1}$ to ms^{-1}

THEME/FOCAL AREA 2: SCALARS AND VECTORS

Physical quantities can be distinguished into two types: scalars and vectors.

Scalar quantities refer to physical quantities that can be fully described by a magnitude or numerical value. They do not have a specific direction associated with them. Examples of scalar quantities include mass, temperature, time, speed, energy etc.

Vector quantities, on the other hand, require magnitude and direction to fully describe them. Examples include: displacement, velocity, acceleration, force and momentum etc.

Vectors play a crucial role in describing motion and navigation. When driving a car, the velocity is a vector quantity that describes both speed (scalar) and direction of the car.

LEARNING TASKS

1. State the definition of a scalar and the definition of a vector.
2. Categorise a list of physical quantities into scalars and vectors and justify your answers.

PEDAGOGICAL EXEMPLARS

1. In a collaborative manner, learners research on the differences between scalar and vector quantities.
2. In mixed-ability groups, and using their research or provided definitions to support them, ask them to categorise velocity, speed, displacement, distance, acceleration, mass, length, time, weight, energy, power and force into scalars and vectors. Note that some students will need support in understanding the difference between a) velocity and speed and b) displacement and distance; examples should be given of each.
3. Present real-life scenarios involving vector quantities. For each scenario, ask the learners to identify the vector involved and explain how both the magnitude and direction are essential in describing the physical situation.
   (a) Scenario 1: A car moving along a curved road.
   (b) Scenario 2: A person walking at a steady speed but changing direction.
4. Provide simple diagrams or sketches that represent both scalar and vector quantities. Ask the learners to label the quantities in each diagram correctly.

KEY ASSESSMENT

Assessment Level 1: What is the difference between scalars and vectors?

Assessment Level 1: Give three examples each of quantities that are vectors and quantities that are scalars.

Week 4

Learning Indicators:

1. *Identify the various states of matter.*
2. *Distinguish between the molecular arrangements of the various states of matter.*

THEME OR FOCAL AREA 1: STATES OF MATTER

Matter refers to anything that occupies space and has mass.

The states of matter are the distinct forms in which matter exists; solid, liquid, gas and plasma.

1. **Solid:** Examples include: ice, wood, metal etc.
2. **Liquid:** Examples include: water, oil and milk.
3. **Gas:** Examples include: air, oxygen, carbon dioxide etc.
4. **Plasma:** Examples include: lightning, stars, neon signs etc.

LEARNING TASKS

1. State the four states of matter.
2. Give examples of substances in the various states of matter.
3. Explain plasma as a state of matter.
4. Use the formula $\rho=m/V$ to calculate the density of regular and irregular solid objects.

PEDAGOGICAL EXEMPLARS

1. Have learners participate in a think-pair-share activity where learners list the states of matter, and classify the objects into the three primary states of matter, e.g. ice cube, water, helium in a balloon, wooden block, pencil lead etc. This should be a quick activity and accessible for all learners.
2. Learners should delve into the fourth state of matter, ‘plasma’, researching its definition and exploring diverse examples.
   - Offer learners who find independent work difficult some scaffolding to researching plasma (a list of questions about plasma to answer, for example)
   - Some learners could produce some more independent work in the form of a poster or an oral presentation.
   - More able learners could be tasked with researching a specific use of plasma and asked to present their findings to the class.

KEY ASSESSMENT

Assessment Level 1: List the three primary states of matter, commonly found in our surroundings.

Assessment Level 1: Match examples of substances to their corresponding states of matter.

Assessment Level 1: Provide examples of naturally occurring plasmas and their significance in the universe.

THEME OR FOCAL AREA 2: MOLECULAR ARRANGEMENT OF THE VARIOUS STATES OF MATTER

Molecular arrangement of matter refers to how the individual molecules or atoms are organised and positioned in a substance or material.

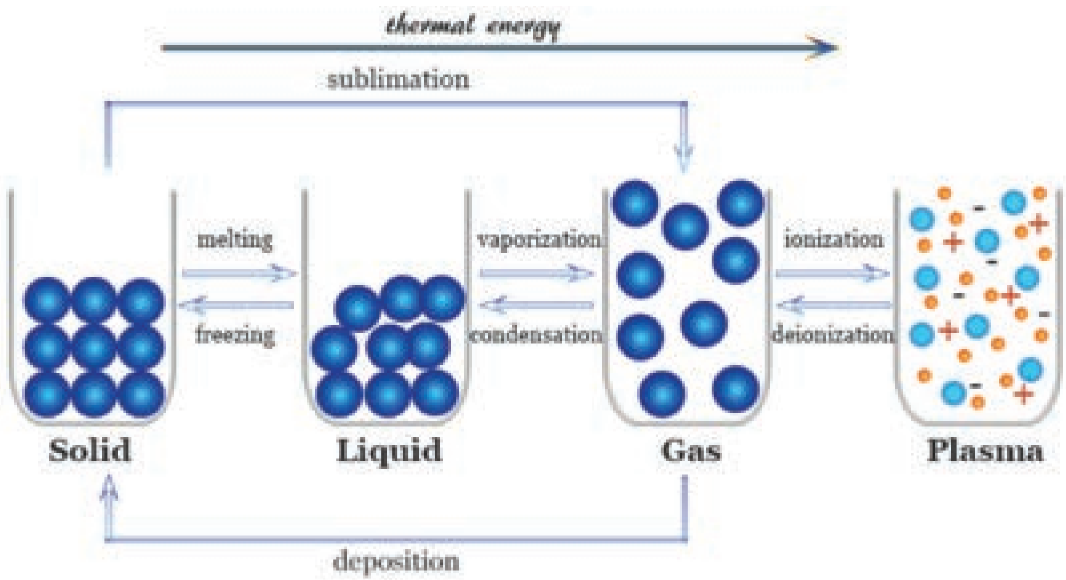
In solids, molecules are tightly packed and held together by strong intermolecular forces. The arrangement is highly organised, with molecules vibrating in fixed positions. This results in a definite shape and volume.

In liquids, molecules are still close together but have more freedom of movement compared to solids. The intermolecular forces are weaker, allowing molecules to slide past one another. Liquids take the shape of their container and have a definite volume.

In gases, molecules are far apart and move freely. The intermolecular forces are very weak, and molecules move in random, rapid motion. Gases have no definite shape or volume, as they expand to fill the available space.

In plasma, molecules are not present but rather a mixture of ions and free electrons.

It does not have a fixed molecular arrangement. The charged particles in plasma move independently and do not maintain fixed positions.



LEARNING TASKS

1. Describe the molecular arrangement of the various states of matter.
2. Draw the diagrams of the molecular arrangement of the various states of matter.
3. Explain how heating or cooling a substance affect the particles that make it up, and how this can result in a state change.

PEDAGOGICAL EXEMPLARS

1. Create a classroom discussion among small group learners to compare the molecular arrangement of various states of matter.
2. Smaller groups of students can be asked to stand up and 'behave' like the particles in each of the states of matter. The rest of the class can critique their model.

3. In groups, learners should engage in drawing molecular arrangements of states of matter.
4. Provide learners with molecular model kits or use digital simulations to represent the arrangement of molecules in each state of matter. Ask learners to build models to represent solids, liquids and gases based on their knowledge of molecular behaviour.
5. Extend the test above by asking students to describe and explain what happens when a solid is heated. Provide them with and encourage them to use the terms 'thermal energy', 'kinetic energy', 'particles', 'movement', 'intermolecular forces' etc. Guide them step-by-step through the melting and evaporating (and, if appropriate, ionisation into a plasma) processes. "Pose, pause, pounce, bounce" is a good technique for helping students to develop upon one another's answers; for example,
   - Ask the class what happens when a solid is heated (pose). Give them 30 seconds to think silently (pause).
   - Ask a volunteer to give their answer (pounce). Congratulate them on any accurate points. Then, ask the rest of the class if there is anything that they would like to add to improve the answer, and choose a new volunteer to speak (bounce). Continue in this vein until the class have fully described melting, evaporation and ionisation into a plasma if appropriate.

KEY ASSESSMENT

Assessment Level 1: Briefly describe the molecular arrangement in solid, liquid and gas.

Assessment Level 1: Draw the molecular arrangements representing the distinct states of matter.

Assessment Level 2: Plasma as a distinct state of matter is often overlooked. Discuss the unique molecular arrangement and behaviour of plasma.

SECTION 1 REVIEW

Learners should gain a deeper understanding of the wide array of career possibilities that Physics offers and should see Physics as a versatile discipline with applications in various fields beyond traditional academic research.

Learners also should acquire essential knowledge in Pythagoras theorem, trigonometry, indices and algebra.

Learners should gain a comprehensive understanding of the fundamental units of measurement used in Physics. They should also know some derived units and how to convert between different units. Learners should also understand the importance of standardising units in Physics to ensure consistency and facilitate international communication among scientists. Learners should gain a deeper conceptual understanding of physical quantities and their dimensions.

They should develop keen observation skills to detect errors and irregularities in the use of measuring instruments. They should also become increasingly proficient in carrying out experiments and investigations so that they are conducted in a way that minimises error.

Learners should also recognise matter as existing in various states in their everyday surroundings, influencing natural phenomena. They should also develop observation skills to identify and classify different states of matter based on their physical characteristics and behaviour.

Reference

1. Priyam study centre. (2024). Four states of matter. https://www.priyamstudycentre.com/science/states-of-matter

SECTION 2: MOTION AND PRESSURE

Strand: **Matter and Mechanics**

Sub-Strands:

1. **Kinematics**
2. **Dynamics**

Content Standards:

1. Demonstrate knowledge and understanding of motion and its relevance to everyday activities.
2. Demonstrate knowledge and understanding of Newton's laws of motion.
3. Demonstrate knowledge and understanding of pressure.

Learning Outcome:

1. *Explain the terminologies and measurements of distance, displacement, speed, velocity, acceleration, average velocity and instantaneous velocity and distinguish between them.*
2. *Apply the laws of motion to explain how bodies move to change their positions.*
3. *Recognise pressure as an agent of force.*

INTRODUCTION AND SECTION SUMMARY

The weeks covered by the section are:

Week 5: Motion and its type, Equations of motion and graphical representation of motion

Motion refers to the continuous change in the position of an object and can be classified into various types, i.e. circular, oscillatory, rectilinear, spin and random. The equations of motion, derived from basic principles, describes the relationships between an object's position, velocity, acceleration and time.

Week 6: Newton's laws of Motion

This section talks about Newton's three laws of motion, which explain the relationship between the motion of a physical object and the forces acting upon it.

Week 7: Pressure and Pascal's principle

Finally, this section looks at pressure which is the force exerted per unit area and is a fundamental concept in fluid mechanics and Pascal's principle which forms the basis for brake system and hydraulic press, enabling the amplification of force through confined fluids.

SUMMARY OF PEDAGOGICAL EXEMPLARS

The topics in Section 2 lend themselves to a variety of teaching methods, including:

- Where possible, engaging learners through hands-on activities and inquiry-based learning. Where this is not possible, photographs and videos of the demonstrations should be shown. E.g.
  - Using measuring equipment such as stopwatches, metre rulers, trundle wheels, measuring tapes or (if available) light gates to measure quantities such as distance, time, velocity and acceleration.

  - Setting up experiments in order to investigate Newton's 2nd law (e.g. passing a string connected at one end to a toy car over a pulley and using different hanging masses to accelerate the car, allowing objects to slide down inclined planes, etc.).
  - Observing demonstrations which show pressure varying with depth (plastic bottles with holes in them at different depths, etc).

- Practicing mathematical problem solving. Provide ample opportunities for learners to solve problems and apply theoretical concepts to real-world situations. Incorporate challenging yet relevant problems that encourage critical thinking and problem-solving skills.
- Integration of technology for research tasks, videos and simulations where appropriate, e.g.
  - Use of interactive demonstrations and simulations to illustrate different types of motion. Interactive simulations allow learners to manipulate variables and observe the effects on motion, helping them grasp concepts effectively.
- Translating written information or a table of data into a graph (or vice versa).
  - Visual representations of motion graphs, force diagrams and pressure diagrams can aid in conceptualising abstract concepts.
- Encouraging pupils to notice the relevance of Physics to the world around them in order to whip up learners' interest in studying the subject.

As always, implement differentiation strategies to accommodate diverse learning needs. In this document, some activities are given additional direction for how to support those 'less able' or 'more able', which refers only to their ability level in that given task / proficiency.

ASSESSMENT SUMMARY

The assessments to be used to monitor learning progress during instruction should be formative assessments and these include quizzes, mathematical problem solving (with varying levels of challenge and support), short written responses to questions and laboratory work.

Conduct laboratory experiments related to motion and pressure and require learners to write reports detailing their experimental procedures, observations and conclusions. Assess their ability to design experiments, collect data accurately, plot graphs and draw valid conclusions based on scientific principles.

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 5

Learning Indicator:

1. *Describe the various types of motion, i.e. circular, oscillatory, rectilinear, spin and random*
2. *Establish equations of uniformly accelerated motion and its application in daily life.*
3. *Represent the motion of objects graphically, i.e. distance-time, displacement-time and velocity-time and deductions that can be made from it.*

THEME/FOCAL AREA 1: TYPES OF MOTION

Motion means a continuous change in the position of an object.

The various types of motion are circular, oscillatory, rectilinear, spin and random.

1. **Rectilinear motion**: This refers to the movement of an object along a straight line, e.g. a person walking in a straight line.
2. **Circular motion**: This occurs when an object moves along a circular path around a fixed centre or axis, e.g. the Moon orbiting around the Earth.
3. **Rotational/Spin motion**: This involves the spinning or rotation of an object around a fixed axis. Unlike circular motion, the object itself may not move along a path, but it rotates around a center point or axis, e.g. a planet rotating on its axis, causing day and night cycles.
4. **Oscillatory motion**: This is a repetitive back-and-forth motion around an equilibrium position, e.g. a pendulum swinging from side to side.
5. **Random motion**: This is an unpredictable kind of motion where an object moves in any direction and the direction keeps changing without a pattern, e.g. the movement of smoke particles in the air.

It is a fundamental form of motion that we engage in regularly to move from one place to another, whether it is walking around our home, commuting to work or school, or simply going for a leisurely stroll. The different types of motion of other objects can be utilised to enrich and aide our daily lives, such as the constant time period of the swinging pendulum in a grandfather clock.

LEARNING TASKS

1. Define motion.
2. State the various types of motion.
3. Describe the various types of motion and give examples.

PEDAGOGICAL EXEMPLARS

1. Instruct learners to research and prepare a presentation describing an assigned type of motion. They should explore the characteristics, examples and real-life applications of the motion they are studying. Encourage them to use diagrams, graphs, animations and real-life examples to illustrate their findings.
2. Practical opportunity: Provide learners with the tools to create a model demonstrating their assigned type of motion (strings, pendulums, sprints, masses, trolleys, ramps, etc). Alternatively,

set up some demonstrations around the room to demonstrate the types of motion and allow students to use these in their presentations.

3. Have learners present their findings to the class. During the presentations, encourage learners to describe the main features and unique characteristics of the motion type they researched. Prompt them to provide clear examples to help the class understand each type better. The audience could be provided with a table in which to summarise the key points from each presentation, e.g.

Type of motion	Description/definition	Diagram	Other key information

KEY ASSESSMENT

Assessment Level 1: Define motion.

Assessment Level 1: List the five types of motion.

Assessment Level 2: Describe the various types of motion and give two examples of each.

THEME/FOCAL AREA(S) 2: EQUATIONS OF MOTION

Equations of motion formulated by Isaac Newton provide a framework for understanding and predicting how objects move and their applications extend to various aspects of our daily lives such as transportation, sports, construction, technology, etc.

The equations of motion are a set of mathematical equations that describe the motion of an object under a uniform acceleration. These equations are fundamental in classical mechanics and are used to understand the behaviour of objects in motion. There are three main equations of motion for uniformly accelerated rectilinear motion, which describes the motion of an object moving in a straight line with a constant acceleration:

$$v = u + at$$
$$s = ut + \frac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

Where:

s is the displacement or position of the object at time t.

u is the initial velocity of the object.

v is the final velocity of the object.

a is the constant acceleration.

t is the time elapsed.

LEARNING TASKS

1. Define the terminologies associated with rectilinear motion (s, u, v, a and t).
2. Establish the equations of motion
3. Solve problems associated with the equations of motion

PEDAGOGICAL EXEMPLARS

1. In mixed-ability groups, learners should brainstorm and define the terminologies; distance, displacement, speed, velocity, acceleration, average velocity and instantaneous velocity and distinguish between them in a collaborative manner.
2. The teacher presents the derivations of the equations of motion step-by-step, using algebraic principles. Encourage learners to understand each step of the derivation and the algebraic principles used by asking targeted questions throughout the explanation (e.g. 'student 1, how would I read off the initial velocity of the object from this graph?' Or 'student 2, how can you tell from the shape of this graph that the object is accelerating uniformly' etc).
3. Discuss the physical meaning of each equation and how they relate to the motion of objects under constant acceleration.
4. Provide a set of problems involving different types of motion scenarios, such as uniformly accelerated motion, free fall. Ask learners to apply the equations of motion to solve these problems and calculate the unknown quantities. These mathematical problems could be differentiated according to level of challenge, with the more able learners having to consider objects reversing direction (and therefore the use of negative values).

KEY ASSESSMENT

Assessment Level 1: Define acceleration.

Assessment Level 1: Distinguish between average velocity and instantaneous velocity.

Assessment Level 1: Name the four quantities that are associated with the equations of linear motion.

Assessment Level 2: A race car accelerates uniformly from 18 m s^{-1} to 45 m s^{-1} in 2 seconds. Determine the acceleration of the car and the distance travelled.

Assessment Level 1: Show that for a uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$.

THEME/FOCAL AREA (S) 3: REPRESENTATION OF MOTIONS OF OBJECTS GRAPHICALLY

Representing the motion of an object on a graph is highly valuable as it allows for a visual and quantitative understanding of the object's movement, aiding in analysis, comparison, predictive and scientific investigations. It enhances our understanding of the dynamics and behaviour of objects in motion.

There are several types of graphs commonly used to represent the motion of an object: distance-time graph, displacement-time graph, velocity-time graph etc, and analysing each graph of motion provides valuable deductions about an object's movement. These deductions help in understanding the characteristics of an object's motion.

For example, distance-time graphs are commonly used to analyse the speed of an object and determine whether it's moving at a constant speed, accelerating, decelerating, or at rest. Real-world applications include analysing the motion of vehicles, studying the speed of an athlete during a race etc.

LEARNING TASKS

1. Represent motion of objects on a graph.
2. Create a story that illustrate a specific motion scenario.
3. Calculate quantities from a velocity-time graph.

PEDAGOGICAL EXEMPLARS

1. Provide learners with a set of data points representing distance or velocity at different times. Ask them to plot the points on a graph and connect them to create the corresponding distance-time graph or velocity-time graph. Learners individually should deduce quantities, such as instantaneous acceleration and distance travelled, from their plotted velocity-time graph.
   - Less able learners may need assistance with their graph-plotting and in drawing information from the graph (such as the gradient at a particular point), and so should be encouraged to sit near somebody who is more confident and can help them in this area.
   - Most learners should plot graphs which go into negative y-values, i.e. v-t graphs for objects which have reversed direction or s-t graphs for objects that have moved back past their starting point.

More able learners should be challenged to take one graph of motion and use it to plot another (e.g. take a v-t graph and use it to plot a d-t graph). They should also be asked to comment on the forces acting as part of their storyboarding.

2. Ask learners in groups to create a storyboard using their distance-time or velocity-time graphs to illustrate a specific motion scenario. They should be able to explain the motion of the object based on the graph they have created. As above, more able learners should also be able to comment on the forces acting.
3. Use toy cars on a marked track to measure time and distance, allowing learners to measure and calculate instantaneous speeds at different time intervals and to plot a graph of velocity against time. Note that students may wish to film their experiment in slow motion, with a stopwatch in-shot, in order to process their data more accurately.
   - Less able learners should be monitored closely during practical work in order to ensure they are correctly calculating instantaneous velocity at various times during an object's journey. They are given some guidance as to how their graph should be drawn (e.g. axes provided, step-by-step instructions on a worksheet etc). Students are also given prompts (orally or on paper) about how their graphs relate to the equations of motion (e.g. the area under a v-t graph gives the distance travelled. How could the area under your graph be calculated?)
   - Some learners will require less monitoring and may be able to complete their derivations with no prompts, or by providing them with the final equations for them to work towards.
   - More able learners should be given little to no guidance in completing their practical and deriving the equations of motion. The teacher should still monitor to ensure that they have understood the task and are making progress.

KEY ASSESSMENT

Assessment Level 1: List four quantities that can be deduced from a velocity-time graph.

Assessment Level 2: A bus starts from rest and accelerates uniformly at 2 $m\,s^{-2}$ for 10s. It maintains the maximum speed attained for further 10 s and decelerates at 1 $m\,s^{-2}$ gradually to rest

a. Draw the velocity-time graph.
b. Use velocity-time graph to determine:
   i. the maximum velocity attained.
   ii. the time taken for the bus to decelerate to rest.
   iii. the total distance covered
   iv. the average velocity

Assessment Level 2:

Time (s)	0	10	20	30	40	50	60	70	80
Velocity (m/s)	0	20	40	40	40	30	20	10	0

i. Draw the velocity-time graph of the given table.
ii. Calculate the total distance covered during the motion.

Assessment Level 3: Imagine a scenario where a car is initially at rest, accelerates uniformly for a period of time, maintains a constant velocity, then decelerates uniformly until it comes to a stop. Design a storyboard utilising either distance-time or velocity-time graphs to depict this motion scenario. Explain how your chosen graph accurately represents the motion of the car throughout the entire journey.

Week 6

Learning Indicators:

1. *State Newton's laws of motion.*
2. *Identify daily applications of Newton's laws of motion.*
3. *Apply Newton's second law to establish the relationship between force, mass and acceleration.*

THEME/FOCAL AREA 1: NEWTON'S LAWS OF MOTION

Newton's laws of motion formulated by Isaac Newton, are fundamental principles in Physics that describes the relationship between the motion of an object and the unbalanced force acting upon it.

Newton's first law (law of inertia): A body will continue in its state of rest or of uniform motion in a straight line unless it is acted upon by an unbalanced force.

This law is relevant when you are in a moving vehicle and suddenly it comes to a stop, your body tends to continue moving forward due to its inertia and you might feel a jerk.

Newton's second law (law of acceleration): The time rate of change of momentum of a body is directly proportional to the resultant force applied and it takes place in the direction of the unbalanced force.

This law is applied when you push a shopping cart. The greater the force you apply, the faster the cart accelerates.

Newton's third law (law of action and reaction): For every action, there is an equal and opposite reaction.

The law is seen in the motion of a canoe. As you push water backwards with the use of the paddle the canoe moves forward.

LEARNING TASKS

1. State Newton's first law of motion and explain the concept of inertia.
2. State Newton's second law of motion.
3. Explain Newton's third law of motion.
4. Identify application of Newton's first, second and third laws in daily life

PEDAGOGICAL EXEMPLARS

1. Using talk for learning in a collaborative and inclusive manner, let learners discuss the situations below to establish a) what forces are acting on the object and b) the motion of the object. They should draw diagrams to represent the magnitude and direction of the forces that they identify, and also the direction of motion of the object (if any). They should then share their ideas with the class.
   a. A vehicle has broken down and as responsible citizens, you know that the vehicle needs to be moved off the road to prevent other cars from crashing into it. (1^{st} and 2^{nd} laws)
   b. Learners build simple paper boats and place them in a bowl of water and using made-up paddles, try to move the paper boats. (3^{rd} law)

2. The teacher should then summarise the laws of motion for the class to be able to answer questions about the factors that affect inertia.
3. Watch videos (a good example is on YouTube: Veritasium - Best Film on Newton's Third Law. Ever.) or use interactive simulations (a good example is the PHeT simulation: Forces and Motion) to observe the effect on an object when it is a) already in motion and then experiences a resultant force, b) already in motion and experiences no resultant force, c) is stationary and experiences a resultant force and d) is stationary and experiences no resultant force.
4. Learners should research and discuss various situations in daily life where Newton's laws of motion are applied. Allow students to leave the classroom and take photos of nature/objects which they can then present to the class and describe/explain the forces at play.

KEY ASSESSMENT

Assessment Level 1: Explain inertia and state the factors that affect the inertia of a body.

Assessment Level 2: Account for changes that will occur in the motion of bodies of different masses that experience the same force.

Assessment Level 2: Identify some daily activities and explain how at least two of the 3 laws of motion is applied in each situation.

Assessment Level 3: Design an experiment with simple materials in the environment to verify Newton's third law of motion (E.g. throwing a tennis ball against a wall)

THEME/FOCAL AREA 2: RELATIONSHIP BETWEEN FORCE, MASS AND ACCELERATION USING NEWTON'S SECOND LAW

Newton's second law (law of acceleration): The rate of change of momentum is directly proportional to the unbalanced force applied and it takes place in the direction of that force.

i. e. $F \propto \frac{mv-mu}{t}$

From this equation, one can establish the relation $F = m\,a$

This law allows us to quantitatively analyse the motion of objects by considering the effects of forces on objects of different masses.

LEARNING TASKS

1. State Newton's second law of motion.
2. Represent Newton's second law of motion mathematically.
3. Combine Newton's second law with the equation of motion v = u + at to establish F = ma.

PEDAGOGICAL EXEMPLARS

1. Take into account learners with low mathematical proficiency and in ability groups guide learners to establish the equation $F = m\,a$.
2. Show learners a range of examples of force diagrams and ask them to establish whether
   a. there is a resultant force
   b. the direction and size of the resultant force.

This could be a worksheet or a class quiz, with images shown one at a time on the board.

3. Give pupils a worksheet to practice using Newton's second law.
   - There should be some scaffolding for pupils who are less mathematically able; a worked example could be given, and the examples could be fairly simple.
   - If students are more mathematically able, they could be challenged by removing the worked example, introducing some erroneous units that need converting (e.g. velocity in kmh^{-1}), given examples with multiple forces or forces which need resolving into two components (e.g. a windsurfer whose parachute applies a tension at some angle to the horizontally, whilst the drag acts horizontally backwards) etc.

KEY ASSESSMENT

Assessment Level 2: A car has mass of 2000 kg and an acceleration of 2.3 $m\ s^{-2}$

a. What resultant force is causing this?

b. If the car is at rest what is its velocity after 7 s?

c. If the car experiences a resistive force of 2.4 N, what is the driving force? How far does the car travel after 7 s?

Week 7

Learning Indicators:

1. *Explain how pressure changes with depth in a fluid.*
2. *Explain the operation of brake systems in vehicles and the operation of the hydraulic press.*
3. *State Pascal's principle.*

THEME/FOCAL AREA 1: THEME/FOCAL AREA(S) 1: PRESSURE IN A FLUID

Pressure is defined as force per unit area. Mathematically, pressure (P) is calculated as:

$$P = \frac{F}{A}$$

Where:

P is the pressure,

F is the force applied perpendicular to the surface, and

A is the area over which the force is applied.

Hydrostatic pressure specifically refers to the pressure exerted by a fluid at rest due to the force of gravity. It increases with depth in a fluid due to the increasing weight of the fluid above. The hydrostatic pressure at a certain depth h can be derived from the pressure at the surface using the equation for hydrostatic pressure:

Hydrostatic pressure equation $P = \rho g h$

Where P is the hydrostatic pressure caused by a certain depth (in Pascal Pa),

ρ (rho) is the density of the fluid (in kilograms per cubic meter, kg m^{-3}),
g is the acceleration due to gravity (in meters per second squared, m s^{-2})
h is the depth of the point within the fluid (in meters, m).

This equation helps to understand how pressure increases with depth in a fluid due to the weight of the fluid above it. For example, in a water tank, the hydrostatic pressure at the bottom is higher than at the top due to the weight of the water above pressing down on it.

LEARNING TASKS

1. Define pressure.
2. Explain factors that cause pressure to vary with depth.
3. Demonstrate how pressure varies with depth.
4. Derive the equation from P=F/A.

PEDAGOGICAL EXEMPLARS

1. Give each learner a piece of graph paper and ask them to draw around their foot. By counting squares, estimate the area of the foot. Stand on weighing scales and use your measurements to

calculate your own pressure on the ground. This could be differentiated by asking pupils to give their results in a variety of units (e.g. Nm^{-2}, Ncm^{-2} etc.), or to provide a written summary as to the effect of wearing stilettos or doing a handstand on your pressure on the ground.

2. Give learners some mathematical problems to solve using the P=F/A formula, involving different units and different rearrangements of the equation (solving for different quantities). Increase the level of challenge as the worksheet progresses and encourage higher ability students to 'skip' to more difficult questions. If they finish, they could circulate the room to support lower ability students.
3. Learners should be given a large plastic bottle with holes made at various heights. When the bottle is filled and the lid taken off, the learners should be asked to explain / comment on their observations about the path of the water at various heights. Lower ability learners could be given key words to help prompt them: can they use the terms radius, depth, force, pressure, particles etc. in their explanations?
4. Combining the P=F/A formula with the formula ρ=m/V, guide the students to derive the formula Note that students may be unfamiliar with the density formula, or may not have studied it for a long time, and so the teacher may need to do some additional teaching to explain the quantity ρ.
5. Give learners some mathematical problems to solve using the formula, involving different units and different rearrangements of the equation (solving for different quantities). As above, Increase the level of challenge as the worksheet progresses and encourage higher ability students to 'skip' to more difficult questions. If they finish, they could circulate the room to support lower ability students.

KEY ASSESSMENT

Assessment Level 1: Identify two systems that produce forces from the pressure within fluids.

Assessment Level 1: What are the factors that influence the pressure in a fluid and how do these factors affect the fluid's pressure?

Assessment Level 2: Calculate the pressure at a point 70 m below the surface of water. [g =10 m s^{-2}, density of water =1000 kg m^{-3}]

THEME/FOCAL AREA 2: PASCAL'S PRINCIPLE

Pascal's principle states that, in a confined fluid an externally applied pressure is transmitted equally in all directions.

Both hydraulic systems and brake systems work on the principle of Pascal's law, which is based on the transmission of fluid pressure.

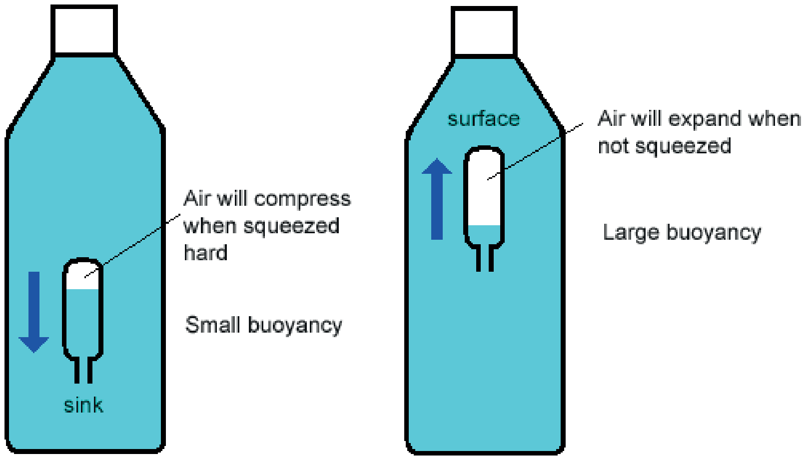
Pascal's principle plays a fundamental role in various aspects of our lives, ranging from mechanical systems to biological processes, contributing to the functioning of many everyday objects and systems.

LEARNING TASKS

1. State Pascal's principle.
2. Describe an experiment that explains Pascal's principle.
3. State applications of Pascal principle.

PEDAGOGICAL EXEMPLARS

1. Organise a hands-on activity that involves a glass barrel with a plunger, connected to a bulb/ container with pierced holes on all sides. Ask the learners to push down the plunger slowly and steadily so that water in the barrel squirts out of all the holes in the bulb simultaneously. Ask them to comment on what they observe and, if possible, explain their observations in terms of pressure and particle motion.
2. Divide the learners into small groups and provide them with scenarios or problems related to Pascal's principle. Challenge learners in groups to think of new applications of Pascal's principle in technology or everyday life that they haven't discussed yet.



3. Learners should be given the equipment to make 'Cartesian Divers' and are asked to explain their observations (written / orally – as above, a list of key words could be provided to lower ability pupils to help prompt their answers).
   - Give less able learners a list of sentences to rearrange / paragraph with gap fills which explain the various phenomena that they are observing (bottle squeezed – pressure increased – greater volume of water pushed into inverted test tube – density increase – sinks).
   - Most learners will require less support with their explanations, but perhaps provide a list of key words to include in their answers.
   - Ask some more able learners to use their observations to explain the Cartesian Divers with no scaffolding.

KEY ASSESSMENT

Assessment Level 1: State Pascal's principle.

Assessment Level 1: State at some applications of Pascal's principle in industry.

Assessment Level 2: Describe an experiment that demonstrates Pascal's principle.

THEME/FOCAL AREA 3: BRAKE SYSTEMS AND HYDRAULIC PRESS

Brake systems in vehicles are crucial for safe and controlled stopping. They work through a combination of mechanical and hydraulic components such as brake pedal, master cylinder, brake fluid, brake pad, shoes etc. The brake system's operation relies on the driver's input, which is converted into hydraulic pressure to apply friction on the wheels, allowing the vehicle to slow down or stop safely.

Hydraulic press is a machine often used in various industries for tasks like compressing materials, bending, straightening, punching and forging. It uses fluid pressure to generate a strong force. It works by applying a small force to a piston, which creates pressure in the fluid. This pressure is transmitted to a larger piston resulting in a much greater force being exerted. The force is then used for various tasks in the industries.

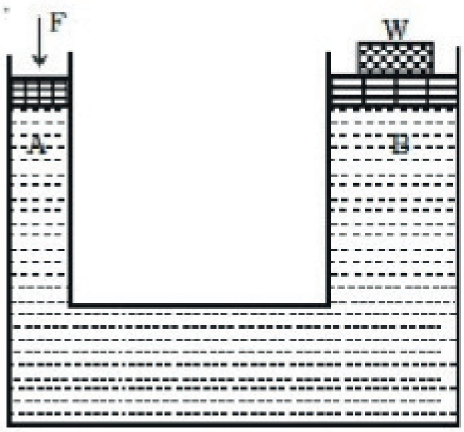


Fig. Hydraulic lift

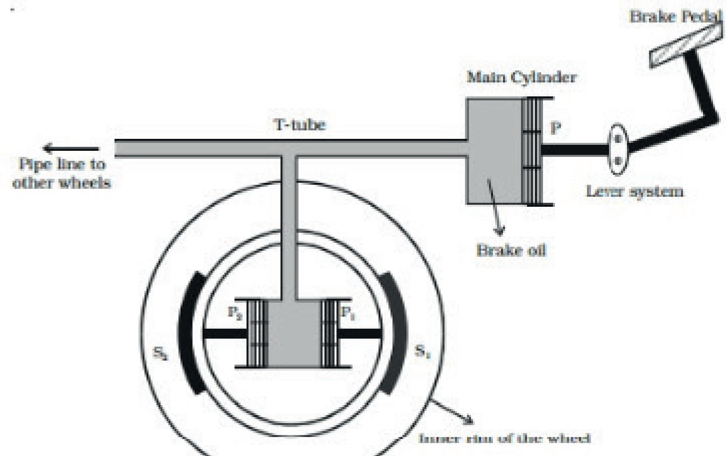


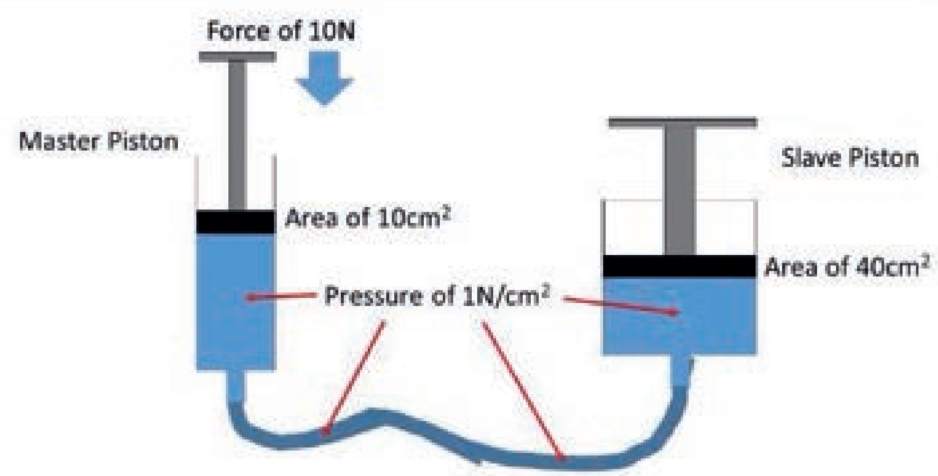
Fig. Hydraulic brake

LEARNING TASKS

1. State the purpose of brakes and hydraulic presses in various applications.
2. Explain the basic components of brake systems and hydraulic presses.
3. Describe the working principles of brake systems and hydraulic systems.

PEDAGOGICAL EXEMPLARS

1. Learners should experience the concepts through videos/virtual labs, which allow them to virtually participate in the process, simulating hands-on experiences even if they cannot physically interact with the systems.
2. Demonstrate hydraulic systems using two syringes (one large and one small) connected by a tube, filled with water, and placed vertically on a flat surface. By pushing down the plunger of the smaller syringe, water is forced through the tube into the larger syringe, which, upon repeating the action, transmits pressure equally through the fluid, causing the larger syringe's plunger to rise and lift objects placed on it.



3. If the equipment is available, learners could be asked to make observations of what happens when the system is full of water vs when the system is full of air. Then ask: Why is gas not suitable to be used as the fluid in a hydraulic system?
4. Learners could be given a differentiated series of problems to solve regarding pistons and using the formula P=F/A to deduce input and output forces.
5. Research task: Explain one use of hydraulics in an industry of your choice OR design your own hydraulic system to solve a problem that you face in everyday life.

KEY ASSESSMENT

Assessment Level 1: State two uses of the hydraulic press

Assessment Level 3: How does the concept of fluid pressure relate to the operation of both brake systems in vehicles and hydraulic presses?

Assessment Level 3: Design a model that employs the hydraulic press to solve a problem.

SECTION 2 REVIEW

Learners should have a clear conceptual understanding of equations of motion, grasping how different variables interconnect to describe the motion of objects. They should begin to develop problem-solving skills by applying equations of motion to calculate unknown quantities in different motion scenarios, with varying levels of challenge.

Learners should have acquired a solid understanding of the three laws formulated by Sir Isaac Newton and can recite them accurately and should have learned the basic concepts and principles behind each law. By applying Newton's laws to real-life situations, learners should be able to predict the motion of objects experiencing forces and anticipate outcomes in various scenarios.

Learners should have acquired essential knowledge about the concept of pressure, its relationship with depth and the principles of hydrostatics. They should have understood that pressure in a fluid increase with depth. Practical demonstrations or experiments related to the brake system and hydraulic press should have fostered learners' hands-on application of Engineering concepts. Learners should have understood the significance of pressure transmission in enclosed fluids, realising how a small force applied at one point can result in a significant force at another.

References

1. Brainkart. (2018). Applications of Pascal's law: Hydraulic lift and brake [Image] https://www.brainkart.com/article/Applications-of-Pascal-s-law--Hydraulic-lift-and-brake_3055/

SECTION 3: THERMOMETERS AND TEMPERATURE

Strand: **Energy**

Sub-Strand: Heat

Content Standard: Demonstrate knowledge and understanding of principles of thermometry.

Learning Outcome: *Apply the principles of thermometry to design a thermometer.*

INTRODUCTION AND SECTION SUMMARY

The weeks covered by the section are:

Week 8: Types of thermometers

Thermometric substances, such as mercury and alcohol, exhibit predictable changes in physical properties in response to temperature variations. Various types of thermometers, including liquid in glass thermometers, resistance thermometers, thermocouples, gas thermometers etc., are designed for specific applications and temperature ranges.

Week 9: Temperature scales

Temperature scales, such as Celsius, Fahrenheit and Kelvin, offer standardised units for expressing temperature measurements. Understanding these temperature scales and how to convert between them is crucial for accurate temperature measurement and control across different fields.

SUMMARY OF PEDAGOGICAL EXEMPLARS

The topics in Section 3 lend themselves to a variety of teaching methods, including:

- Where possible, engaging learners through hands-on activities and inquiry-based learning. Where this is not possible, photographs and videos of the demonstrations should be shown. E.g.
  - Students observe the behaviour of different thermometric substances (e.g., mercury, alcohol) as they are exposed to varying temperatures. This allows students to directly observe the principles of thermal expansion and contraction.
  - Foster collaborative learning environments where students work together to solve problems or design experiments related to temperature measurement.
- Practicing mathematical problem solving. Provide ample opportunities for learners to solve problems and apply theoretical concepts to real-world situations. Incorporate challenging yet relevant problems that encourage critical thinking and problem-solving skills.
- Integration of technology for research tasks, videos and simulations where appropriate, e.g.
  - Use interactive simulations or virtual laboratories to demonstrate how different types of thermometers work. Students can manipulate variables and observe the corresponding changes in temperature readings, enhancing their understanding of temperature measurement principles.
- Encouraging pupils to notice the relevance of Physics to the world around them in order to whip up learners' interest in studying the subject.

- Provide real-life examples of the use of thermometers in different contexts, such as weather monitoring, cooking and medical applications. Relating concepts to everyday experiences helps students grasp the practical significance of temperature measurement.

As always, implement differentiation strategies to accommodate diverse learning needs. In this document, some activities are given additional direction for how to support those ‘less able’ or ‘more able’, which refers only to their ability level in that given task/proficiency.

ASSESSMENT SUMMARY

Administer written assessments, quizzes, or tests to evaluate students’ factual knowledge of thermometric substances, types of thermometers and temperature scales. Assessments may include: multiple-choice questions, short-answer questions, or matching exercises to gauge comprehension of key concepts and terminology.

Assign problem-solving tasks or scenarios that require students to apply their understanding of thermometric substances and types of thermometers to solve practical problems.

Assess their ability to select appropriate thermometers for specific temperature ranges and interpret temperature readings accurately.

Conduct laboratory experiments related to temperature measurement and require students to write reports documenting their experimental procedures, observations and conclusions. Evaluate their ability to design experiments, collect data accurately and analyse results using appropriate scientific principles. Design performance-based tasks such as constructing a thermometer or calibrating temperature scales to assess students’ practical skills and understanding of temperature measurement principles.

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 8

Learning Indicators:

1. *Explain thermometric substances and their associated characteristics.*
2. *Describe the features and uses of different types of thermometers.*

THEME/FOCAL AREA 1: THERMOMETRIC SUBSTANCES

Thermometric substances exhibit physical changes in response to temperature variations, making them useful for temperature measurement. When subjected to temperature changes, thermometric substances undergo alterations in their physical properties or characteristics, such as expansion, contraction, change in electrical resistance, or change in thermal conductivity. These changes are then measured and correlated with temperature readings.

Common examples include: mercury, alcohol, various metals used in thermocouples, platinum used in resistance thermometers and semiconductor materials used in thermistors. The selection of a specific thermometric substance depends on factors such as temperature range, accuracy requirements, response time and the application in which temperature measurement is needed.

LEARNING TASKS

1. Define thermometric substances.
2. List thermometric substances.
3. Explain characteristics of some thermometric substances.

PEDAGOGICAL EXEMPLARS

1. Using a class discussion, learners are encouraged to recall their knowledge of heat and temperature, laying the foundation for the upcoming hands-on activities and allowing learners to connect new information with existing understanding.
2. Provide a list of common thermometric substances such as mercury, alcohol, water and bimetallic strips. Ask learners in groups to research and identify the unique properties of each substance that make them suitable for measuring temperature changes. These experiments can also be demonstrated by the teacher or been shown in videos.
3. Provide learners with thermometers for them to measure the temperature of substances to enable them observe the expansion and contraction of some thermometric substances.
4. If available, provide learners with different thermometric substances and have them experiment with the expansion of these materials when exposed to hot and cold environments. They can observe and measure the changes in length or volume as the temperature changes. In the case that this equipment is not available, show learners images or videos of the materials demonstrating their thermometric properties and then provide them with some data to analyse (e.g. a graph of temperature against change in volume for a sample of mercury; ask the students to read data off the graph and to comment on the relationship between the two variables. Are they directly proportional or not? If used as the liquid in a standard thermometer, should the markings on the thermometer be at regular intervals?)
5. If available, demonstrate the effect of temperature changes on a bimetallic strip, taken from a faulty electric iron, by positioning one end near a heat source. Allow learners to observe the

strip's behaviour when the heat source is removed. Additionally, illustrate its application in thermostats for temperature control systems.

KEY ASSESSMENT

Assessment Level 1: Define thermometric substances.

Assessment Level 1: List at least three thermometric substances.

Assessment Level 2: State the characteristics of at least two thermometric substances.

THEME/FOCAL AREA 2: THERMOMETERS

A thermometer is a device used to measure temperature. There are several types of thermometers, each utilising different principles to measure temperature. Some common types include, liquid in glass thermometers, resistance thermometers, thermocouples, gas thermometers etc.

They are widely used in a variety of settings, including weather monitoring, medical applications, industrial processes, cooking and scientific research.

LEARNING TASKS

1. List different types of thermometers.
2. State features of different types of thermometers.
3. State advantages and disadvantages of different types of thermometers.

PEDAGOGICAL EXEMPLARS

1. Individually, learners should research different types of thermometers (including liquid in glass thermometers, resistance thermometers, thermocouples, gas thermometers), examining their features, uses, advantages, disadvantages, safety considerations, environmental impacts. Their findings could be presented orally or be in a written format to submit.
2. Set up a temperature-controlled environment with different temperature sources (hot water, ice water, room temperature, etc.). Provide various types of thermometers and ask learners to measure and compare the temperatures using each thermometer. This helps them understand how different thermometers respond to varying temperature ranges.
3. For each type of thermometer, the learners could be given a list of questions such as
   a. How much does the material change (in terms of size / resistance etc) per degree Celsius? Is this hard or easy to see/measure)
   b. Is the change linear? Is there an upper or a lower limit as to the temperatures that produce a change in the material?
   c. Is the substance expensive, or dangerous to use?
4. Create role-play scenarios where learners act as professionals (e.g., weather forecaster, medical personnel, chef, scientist) who need to measure temperatures in specific situations. They should choose the most appropriate thermometer for each scenario and explain their choices.

KEY ASSESSMENT

Assessment Level 1: Define a thermometer.

Assessment Level 1: Name two common types of thermometers and briefly describe one feature of each.

Assessment Level 2: Discuss the advantages and limitations of thermocouples as temperature-measuring devices and provide examples of scenarios where they are preferred.

Week 9

Learning Indicators:

1. *Describe the various temperature scales and the construction of their corresponding thermometers.*
2. *Derive the relationship between the Celsius, Fahrenheit and the Kelvin scales.*

THEME/FOCAL AREA 1: TEMPERATURE SCALES

There are several temperature scales used around the world. The most commonly used ones are:

1. Celsius (°C): The Celsius scale is a metric temperature scale where 0 degrees represents the freezing point of water, and 100 degrees represents the boiling point of water at standard atmospheric pressure.
2. Fahrenheit (°F): On the Fahrenheit scale, 32 degrees represents the freezing point of water, and 212 degrees represents the boiling point of water at standard atmospheric pressure.
3. Kelvin (K): The Kelvin scale is an absolute temperature scale used in scientific and engineering applications. It starts from absolute zero, the theoretical point where all molecular motion ceases. One Kelvin is equal to one Celsius degree, but the Kelvin scale has no negative values.

Celsius and Kelvin are the most commonly used scales in scientific contexts.

LEARNING TASKS

1. Identify types of temperature scales.
2. Describe various temperature scales and the construction of their corresponding thermometers.

PEDAGOGICAL EXEMPLARS

1. Have learners research the origin, historical context and key reference points (freezing and boiling points of water for all temperature scales (Celsius, Fahrenheit, Kelvin)
2. Instruct learners to stand up and pretend to be particles in a gas and then ask them to behave as though their temperature is decreasing and decreasing until they form a solid and eventually stop moving. This can help them to envisage what we mean when we say that the particles have zero kinetic energy, and to understand why there are no temperatures colder than absolute zero.
3. The same activity could be extended to understanding the Celsius scale; learners behave as particles in water as it increases in temperature from (e.g.) –20 degrees to 120 degrees. Can they pinpoint exactly when they have reached 0 degrees and 100 degrees?
4. If available, learners should construct their own thermometers. This can be done by providing a bucketful of icy water (0 degrees Celsius) and a kettle of water on a rolling boil (100 degrees Celsius). Learners are given liquid in glass thermometers with no scale, or with the scale blanked out using stickers or permanent markers. They mark on their thermometers the height of the thermometric liquid at 0 degrees and at 100 degrees, before dividing the scale up into 10-degree increments. They could then remove the sticker covering the true scale and compare their experimental results with the true values.

KEY ASSESSMENT

Assessment Level 1: What is a temperature scale?

Assessment Level 1: Name two commonly used temperature scales.

Assessment Level 2: Describe the Kelvin temperature scale and its significance in scientific measurements.

Assessment Level 2: Explain the concept of absolute zero and its relevance to the Kelvin temperature scale.

Assessment Level 2: Explain why the temperature of an object cannot be -50K.

THEME/FOCAL AREA 2: RELATIONSHIP BETWEEN THE CELSIUS, FAHRENHEIT AND THE KELVIN SCALES

The Celsius (θ) and the Kelvin (T) scales are related by the equation,

$$T = \theta + 273.15$$

The Celsius (θ) and the Fahrenheit (F) scales are related by the equation,

$$F = \frac{9}{5}\theta + 32$$

LEARNING TASKS

1. Derive relationships between Celsius, Fahrenheit and Kelvin scales.
2. State the impact of conversation between temperature scales on global communication, scientific research and technological applications.

PEDAGOGICAL EXEMPLARS

1. Ask learners to create a conversion chart that shows the equivalent temperature values for common points on the Celsius, Fahrenheit and Kelvin scales. These points may include freezing and boiling points of water and absolute zero. More able learners may be able to use these charts to derive the equations above, but less able learners may need to be guided through this by the teacher.
2. Learners should have a play with the PHeT simulation called 'Gas Properties'. Here they can look at the effect of cooling particles to absolute zero and can take temperature measurements using the Kelvin and Celsius temperature scales. They can also measure the pressure of the gas at different temperatures. This could be used to plot a graph of pressure against temperature and to show that at zero Kelvin there is zero pressure.
3. Provide learners with a set of temperature values in one scale and a blank puzzle where they need to fill in the equivalent values in the other two scales.
4. Assign learners to collect temperature data from different sources, such as weather websites or news reports, in one temperature scale. They must convert these temperatures into the other two scales.

KEY ASSESSMENT

Assessment Level 1: Write the relation between Kelvin scale and Celsius scale of temperature.

Assessment Level 1: Write the relation between Fahrenheit scale and Celsius scale of temperature.

Assessment Level 2: The temperature of the human body is 37. Determine this value on the Fahrenheit scale.

SECTION 3 REVIEW

Learners should have understood that thermometric substances exhibit different degrees of sensitivity to temperature changes, which makes them suitable for specific temperature ranges. Through the study of different thermometers, learners should have developed the skill of observation and description; identifying the physical features and functioning of each type and also to be able to measure temperatures using each type.

SECTION 4: MIRRORS, REFLECTION AND REFRACTION

Strand: **Energy**

Sub-Strand: Waves

Content Standards:

1. Demonstrate knowledge and understanding of reflection on plane mirrors.
2. Demonstrate knowledge and understanding of reflection on spherical mirrors.
3. Demonstrate knowledge and understanding of refraction.

Learning Outcomes:

1. *Explain the formation of images in plane mirrors.*
2. *Distinguish between images formed by converging and diverging mirrors and their characteristics.*
3. *Explain refraction and recognize its relevance in different media.*

INTRODUCTION AND SECTION SUMMARY

This section aims to explore the intricate world of optics, focusing on spherical mirrors, image formation, refraction and the laws governing light propagation. Understanding these concepts is essential for comprehending the behaviour of light rays as they interact with mirrors and pass through different mediums. From the terminology associated with spherical mirrors to the principles of refraction and total internal reflection, this section provides a comprehensive foundation in optical physics.

The weeks covered by the section are:

Week 10: Plane mirrors and reflection

We see an image of ourselves in plane mirrors every day; this section explores the mechanism by which the image is formed and describes the nature of the image.

Week 11: Spherical mirrors and image formation in spherical mirrors

Spherical mirrors come with a specific set of terms like focal point, focal length, center of curvature and mirror equation, all of which play crucial roles in understanding the properties and behaviour of light rays reflected from these mirrors. Using ray diagrams and the mirror formula, this section demonstrates how images are formed by spherical mirrors. It explores the characteristics of images formed by concave and convex mirrors, including their size, orientation and type (real or virtual).

Week 12: Refraction

Refraction occurs when light rays pass from one medium to another, causing a change in direction.

SUMMARY OF PEDAGOGICAL EXEMPLARS

The topics in Section 4 lend themselves to a variety of teaching methods, including:

- Where possible, engaging learners through hands-on activities and inquiry-based learning. Where this is not possible, photographs and videos of the demonstrations should be shown. E.g.
  - Conduct hands-on experiments with spherical mirrors and optical equipment to illustrate image formation and characteristics.
- Practicing mathematical problem solving.
  - Incorporate problem-solving activities that require students to apply the laws of reflection and refraction to solve numerical problems. Encourage critical thinking and problem-solving skills by presenting a variety of scenarios and challenges.
- Integration of technology for research tasks, videos and simulations where appropriate, e.g.
  - Utilise interactive simulations or animations to demonstrate concepts associated with spherical mirrors and refraction. Interactive visualizations allow learners to manipulate variables and observe the effects on image formation and refraction, enhancing comprehension.
- Encouraging pupils to notice the relevance of Physics to the world around them in order to whip up learners' interest in studying the subject.
  - Illustrate the practical applications of spherical mirrors and refraction in everyday life, such as in optical instruments like telescopes, microscopes and rear-view mirrors. Relating concepts to real-world scenarios enhances relevance and engagement.

As always, implement differentiation strategies to accommodate diverse learning needs. In this document, some activities are given additional direction for how to support those 'less able' or 'more able', which refers only to their ability level in that given task/proficiency.

ASSESSMENT SUMMARY

Administer written assessments such as quizzes, tests, or exams to evaluate learners' factual knowledge of terminologies, laws and formulas related to spherical mirrors and refraction. Assessments may include multiple-choice questions, short-answer questions, or problem-solving exercises. Present learners with problem-solving tasks or scenarios that require them to apply the mirror formula and laws of refraction to calculate image characteristics or refractive indices. Assess their ability to use mathematical formulas and principles to solve numerical problems accurately. Evaluate learners' ability to construct accurate ray diagrams to represent image formation in spherical mirrors and refraction phenomena. Assess their understanding of the principles of reflection and refraction and their application in creating ray diagrams. Assign laboratory experiments or demonstrations related to image formation in spherical mirrors and refraction. Assess learners' experimental design skills, data collection techniques and their ability to analyse experimental results to draw conclusions about optical phenomena. Design performance-based assessments such as oral presentations or demonstrations where students explain image formation processes or demonstrate refraction principles using real-world examples.

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 10

Learning Indicators:

1. *Deduce the laws of reflection.*
2. *Describe the processes involved in image formation in plane mirrors and their characteristics.*
3. *Determine the number of images formed by inclined mirrors.*

THEME/FOCAL AREA 1: LAWS OF REFLECTION

The laws of reflection are as follows:

1. The angle of incidence is equal to the angle of reflection;
2. The incident ray, the reflected ray and the normal to the surface, all lie in the same plane.

The laws of reflection are integral to our everyday life, influencing our vision, the design of optical devices, architectural aesthetics, safety measures and even artistic expression. Understanding these laws enhances our understanding of light and its interactions with our environment.

LEARNING TASKS

1. Describe reflection
2. State the laws of reflection
3. Draw the ray diagram showing reflection process

PEDAGOGICAL EXEMPLARS

1. Set up a plane mirror on a table and place an object in front of it. Ask learners to observe the reflection and draw the incident ray (from the object to the mirror) and the reflected ray (from the mirror to the observer's eye), for different object positions. Encourage them to look for patterns in the angles of incidence and reflection.
2. Provide learners with a protractor and a light source (such as a laser pointer). Guide them in drawing a normal to the surface and measuring the angles of incidence and reflection for light rays hitting the mirror at different positions. Discuss their findings and any observations related to the angles. Note that some students will find it difficult to a) draw a normal perpendicular to the surface and b) use a protractor to measure angles, and in this case, they should be given more one-to-one support either by the teacher or by a more proficient student.
3. In the absence of practical equipment, use interactive virtual lab simulations or online tools that allow learners to adjust the incident angle and observe the corresponding reflection angles for situations where laboratory equipment is not available. This will give them more data points to deduce the reflection laws.

KEY ASSESSMENT

Assessment Level 1: Define reflection.

Assessment Level 1: State the laws of reflection.

Assessment Level 2: A light ray is incident on a mirror at an angle of 38° to the normal, what is the reflected angle?

Assessment Level 2: A light ray is incident on a mirror at an angle of 38° to the normal, through what total angle is the ray deviated?

THEME/FOCAL AREA 2: IMAGE FORMATION IN PLANE MIRRORS

In plane mirror image formation, light rays from an object strike the mirror's flat surface and undergo reflection. As a result, the image formed in the mirror appears to be as far behind the mirror as the object is in front of it and the image is virtual, upright and laterally inverted (left-right reversed). The size of the image is the same as that of the object.

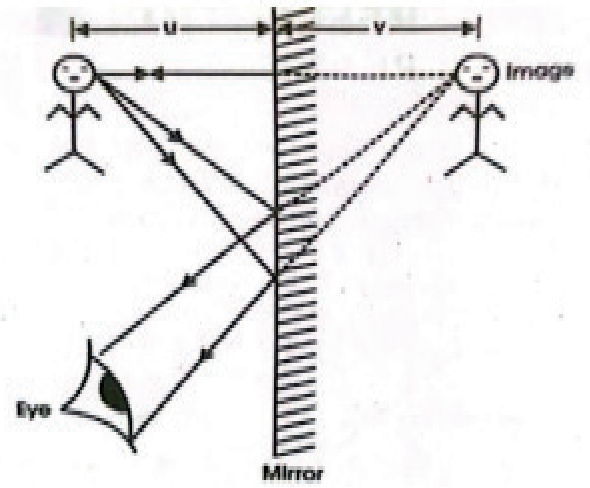


Image of an object formed by plane mirror

LEARNING TASKS

1. Describe processes involved in image formation.
2. State the characteristics/nature of images formed in plane mirrors.

PEDAGOGICAL EXEMPLARS

1. Have learners observe and identify plane mirrors in their surroundings (e.g., bathroom mirrors, dressing room mirrors). Ask them to describe how these mirrors form images and what they notice about the images. Ask students why they might often prefer how they look in the mirror compared to when they see themselves in a 'selfie' (image in a mirror is laterally inverted and so is the image of ourselves that we are familiar with seeing, compared to a photograph which is not inverted).
2. Learners should be organised into mixed-ability groups to explore the concept of reflection using a combination of plane mirrors. By manipulating the arrangement of mirrors, learners actively transmit a light source and project an image to an observer outside the classroom.
3. Learners should be given some diagrams to copy/complete. These could show an object and an eye/camera on one side of a plane mirror (see diagram above). Learners should draw rays from various point on the object entering the eye/camera at either side of the aperture. Peer or self assess:

a. Has a 'normal' to the surface been drawn at each reflection point?
b. Has each ray obeyed the law of reflection? Measure accurately with a protractor.

Ask learners to redraw their diagram if unhappy with the accuracy.

4. Ask them; where would your brain believe that these rays had come from? Where do they meet, if you track them backwards behind the mirror? What do the words 'virtual', 'real', 'upright', 'inverted', 'magnified' and 'diminished' mean? (students could independently research this),
5. What is the relationship between the object-mirror and the mirror-image distance?
6. Watch videos about some more abstract ideas around reflection in order to engage learners; VSauce "Inside a Spherical Mirror" or "If The Moon Was A Disco Ball" are interesting examples.

KEY ASSESSMENT

Assessment Level 1: State four characteristics of image formed by plane mirror.

Assessment Level 2: How are images formed in plane mirrors?

Assessment Level 2: An object of height 20 cm is placed 50 cm from a plane mirror.

a. Determine the distance of the image from the object.

b. What is the size of the image?

THEME/FOCAL AREA 3: IMAGES FORMED BY INCLINED MIRRORS

When two mirrors are inclined to each other, they can create a fascinating pattern of multiple images. The number of images formed depends on the angle between the mirrors. If the angle between the mirrors is small, such as a few degrees, only a few images may be formed. However, as the angle between the mirrors increases, the number of images grows exponentially.

Specifically, the formula to calculate the number of images formed is,

$$n = \frac{360°}{\theta} - 1$$

where θ represents the angle between the mirrors. Each image is a result of multiple reflections between the mirrors, leading to an intricate arrangement of reflected objects.

Inclined mirrors are versatile tools that play an essential role in enhancing our everyday experiences, from improving safety on the road to facilitating various daily tasks. Their ability to redirect light and expand our view has made them valuable in numerous practical applications like periscope, makeup mirrors, security cameras, telescopes and binoculars, dressing room mirrors, dance studios and gyms.

LEARNING TASKS

1. Determine the number of images when an object is placed between two inclined mirrors.
2. Draw ray diagrams of reflection process in inclined mirrors.

PEDAGOGICAL EXEMPLARS

1. Provide learners in mixed-ability groups with 2 mirrors and let them incline them to one another at a variety of angles (30 degrees, 45 degrees, 60 degrees). Initially, ask learners to observe and

comment on what they notice about the number of images seen in the mirrors as the angle is increased/decreased.

2. Ask the learners to draw ray diagrams for a ray of light incident upon one of the mirrors.
   - Most learners should be guided to draw ray diagrams when two mirrors are inclined to meet each other at an angle.
   - More able learners should extend the discussions of the ray diagrams in inclined mirror to enable them to use their knowledge in geometry and trigonometry to determine the angle of reflection.
3. Through collaborative discussions, learners arrive at a formula that allows them to calculate the number of images for any given angle. The teacher should offer some guidance to less able groups, first of all asking them to divide 360 degrees by the inclination angle and then asking them to compare this to the number of images. This activity promotes critical thinking, problem solving and collaboration among learners of different abilities, fostering an inclusive and supportive learning environment.
4. In the absence of practical equipment, use virtual lab software or online tools that allow learners to experiment with inclined mirrors and objects. They can manipulate the angles and observe how the number of images changes accordingly.

KEY ASSESSMENT

Assessment Level 2: How many images are formed when two mirrors are inclined at an angle of 45^o.

Assessment Level 3: Two mirrors are inclined to each other at angle of 90^o. If a light ray is incident on the first mirror at an angle of 42^o, draw a ray diagram to show the reflection process.

Assessment Level 3: Two mirrors are inclined to each other at an angle of 90^o. If a light ray is incident on the first mirror at an angle of 42^o, what is the angle of reflection with respect to the second mirror?

Week 11

Learning Indicators:

1. *Explain the terminologies associated with spherical mirrors.*
2. *Describe the processes involved in image formation in spherical mirrors and their characteristics using ray tracing.*

THEME/FOCAL AREA 1: TERMINOLOGIES ASSOCIATED WITH SPHERICAL MIRRORS

1. **Concave mirror**: It is an optical mirror, which is part of a sphere with reflecting inner surface.
2. **Convex mirror**: It is an optical mirror, which is part of a sphere with reflecting outer surface.

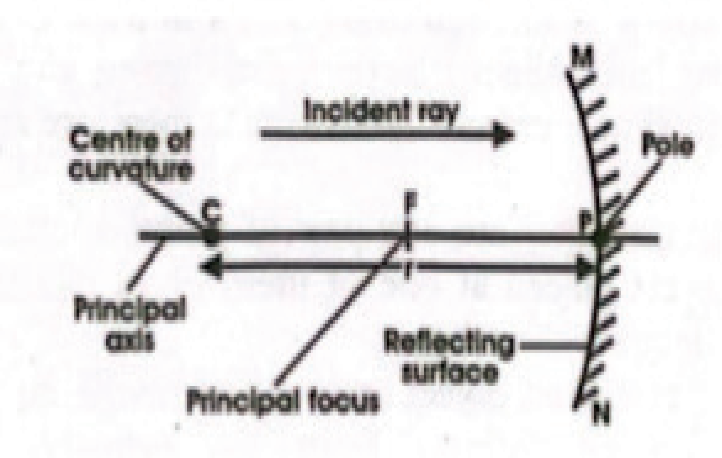


Diagram illustrating a concave mirror with accompanying terminologies

3. **Pole P**: It is the central point of a concave or convex mirror through which the principal axis passes.
4. **Principal axis** is an imaginary line joining the centre of curvature through the principal focus to the pole.
5. **Centre of Curvature C** is the centre of a sphere of which the mirror is part.
6. **Radius of curvature** is the distance from this centre of curvature to the pole of the mirror.
7. **Principal focus F** is a point on the principal axis, where all rays parallel and close to the principal axis either converge or appear to diverge after reflection from the curved mirror.
8. **Focal length of a mirror f** is the distance between the pole of the mirror and the principal focus.

LEARNING TASKS

1. Differentiate between convex and concave mirror.
2. Explain various terminologies associated with spherical mirrors.

PEDAGOGICAL EXEMPLARS

1. Provide learners with diagrams of concave and convex mirrors. Ask them to label the different parts, such as the pole, principal axis, focal point, centre of curvature and mirror surface. Learners should be tasked with conducting independent research using the internet and reference books to find the meanings and definitions of the terms related to mirrors.
2. Alternatively, for a more hands-on approach, provide a variety of spherical mirrors (concave and convex) along with labels indicating the different parts (pole, focal point).
   - Use simple language for some learners to explain each term as they label the parts of the mirrors with provided stickers or markers.
   - Ask some learners to label mirrors independently, using provided diagrams and descriptions as references.
   - Provide advanced scenarios or optical systems involving spherical mirrors and ask some learners to analyse and determine the relevant terminology.
3. Provide learners with a piece of flexible reflective material and ask them to hold it/position it so that it forms a) a convex mirror and b) a concave mirror. Shine narrow beams of light at the surface of the mirror in a direction parallel to the principal axis and use this to measure the focal length. Discuss whether the focal length is the same, or different for convex and concave mirrors of the same radius of curvature. How does the focal length compare to the magnitude of the radius?
4. Create a quiz game with questions related to the terminologies associated with spherical mirrors. Learners can answer individually or in teams, promoting friendly competition.

KEY ASSESSMENT

Assessment Level 1: What is a spherical mirror?

Assessment Level 1: Provide two examples of everyday objects that use spherical mirrors.

Assessment Level 1: Define the terms

a. Principal axis

b. Pole

c. Principal focus

in the context of spherical mirrors.

THEME/FOCAL AREA 2: CHARACTERISTICS OF IMAGE FORMATION IN SPHERICAL MIRRORS USING RAY DIAGRAM

The position, nature and size of the image formed depend on the object's location relative to the mirror. Concave mirrors can form real or virtual images, depending on the object's position.

Convex mirrors always produce virtual images that are upright, diminished and located behind the mirror.

Ray Diagram: To determine the position and nature of the image formed by a spherical mirror, the following rules are used:

1. Ray leaving the tip of the object traveling parallel to the principal axis pass through the focal point after reflection.
2. Rays leaving the tip of the object passing through the focal point and becoming parallel to the principal axis after reflection.

3. Rays passing through the centre of curvature (C) reflect back along the same path.

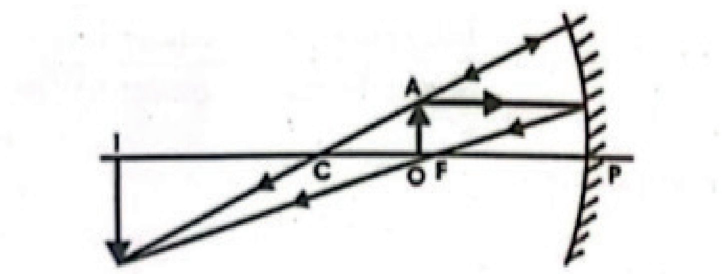


Image formed by concave mirror when the object is in between the principal focus and the centre of curvature

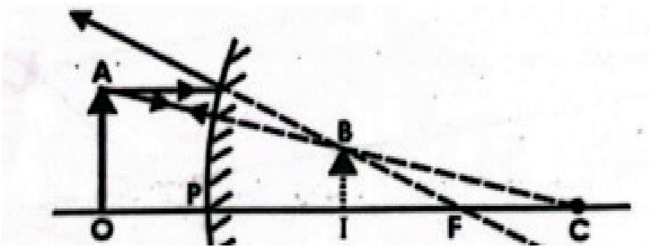


Image formed by convex mirror

LEARNING TASKS

1. Describe the three rays that could be used in locating the image formed in a spherical mirror.
2. Draw ray diagrams of image formation in spherical mirrors.

PEDAGOGICAL EXEMPLARS

1. Provide learners with a concave mirror and an object. Guide them in drawing ray diagrams to show the paths of light rays from the object to the mirror and then to the image. Ask them to observe and describe the characteristics of the image formed (e.g., real, inverted, magnified).
2. Repeat the above task, but this time, use a convex mirror. Learners should be guided to draw ray diagrams to show the paths of light rays and analyse the characteristics of the image formed (e.g., virtual, upright, diminished).
3. Challenge learners to change the position of the object in front of the concave mirror (e.g. an object in front of the mirror closer than f, at f, between f and c) and draw ray diagrams for various object distances. Have them describe how the image characteristics (size, orientation, location) change with different object positions.
   - Less able learners should be given a worked example which shows step-by-step how each ray is drawn, followed by a very similar example to practice with (e.g.) a slightly different radius of curvature. They are given the definitions of the terms magnified, diminished, inverted, upright, real and virtual, and have to select which of these is correct for a variety of examples provided.
   - Most learners should be given step-by-step instructions for how to draw a ray diagram but without a visual aid (blank diagram with object, principal axis, centre of curvature and mirror only). They have to choose words to describe the image that has been formed. They repeat the task for objects placed in a variety of positions.

- More able learners should be given a vaguer task (e.g. "deduce whether the position of an object in relation to a curved mirror affects the nature of the image produced"), alongside instructions for how to draw the three rays. They need to construct the entire diagram themselves, including drawing a mirror and a principal axis etc.

4. Provide learners with concave and convex mirrors of different focal lengths. Instruct them to use ray diagrams to determine the image distance for various object distances as above.
5. In the absence of practical equipment, utilise interactive virtual lab simulations or online tools that allow learners to manipulate object positions and mirror curvatures to observe the changes in image characteristics. Learners can record their observations and draw conclusions.

KEY ASSESSMENT

Assessment Level 1: Describe three rays that could be used in locating the image formed in a concave mirror and state how they are reflected by the mirror.

Assessment Level 2: With the aid of a diagram, show how an image may be produced by a convex mirror.

Assessment Level 2: With the aid of a diagram, show how a virtual image may be produced by a concave mirror.

Assessment Level 2: How are the laws of reflection seen in the rules applied to the formation of images in spherical mirrors?

Week 12

Learning Indicators:

1. *Determine the position and characteristics of images formed by spherical mirrors with mirror formula and magnification formula.*
2. *Explain refraction and state the laws of refraction.*

THEME/FOCAL AREA (S)1: CHARACTERISTICS OF IMAGE FORMATION IN SPHERICAL MIRRORS USING MIRROR FORMULA AND MAGNIFICATION FORMULA

The mirror formula and magnification formula are important equations used in optics to determine the position and characteristics of images formed by mirrors.

Mirror formula relates to the object distance (u), the image distance (v) and the focal length(f) of a mirror. It is expressed as,

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Magnification formula relates the height of the image () to the height of the object (). It is given by,

$$m = \frac{h_i}{h_o} = \frac{v}{u}$$

By using these formulas, along with the properties of mirrors and their focal lengths, we can analyse and predict the behaviour of light rays, determine the position and size of images formed by mirrors and understand the optics of reflective surfaces.

LEARNING TASKS

1. Determine characteristics of image using mirror formula and magnification formula.
2. Perform experiments on simple problems to prove mirror formula and magnification formula.

PEDAGOGICAL EXEMPLARS

1. Present the mirror formula to the class and emphasize the significance of the formula in understanding the behaviour of spherical mirrors and how it is used to predict the position of the image formed by such mirrors.
2. Learners should use data obtained from diagrams drawn in the previous lesson to calculate/ confirm the focal length of the mirror given.
3. Provide learners with various mirror formula problems involving concave and convex mirrors. Ask them to calculate the image distance (v) using the given focal length (f) and object distance (u). Discuss the nature (virtual or real) and characteristics (inverted or upright) of the image formed.

4. Present learners with examples where the object height is given and they need to calculate the image height and magnification using the magnification formula. Discuss the implications of magnification greater or less than 1.

   - Less able learners can be provided with simple tasks such as "If the object is 2cm tall, and the image is 4cm tall, what is the magnification? What size would the image be if the object was 4.5cm tall, for the same mirror and the same object distance?"
   - Most learners can be provided with slightly more challenging questions such as "What do you think the effect on the image height would be if this object was moved further away from the mirror? Can you be specific? If it is moved twice as far away, what would happen to the image height?"
   - More able learners can be provided with stretching questions such as "What do you think the effect on the image height would be if this object was placed in front of another mirror of a bigger focal length".

5. Assign learners to research and find real-world applications

   - of spherical mirrors (e.g., telescopes, makeup mirrors, headlights). They should determine the focal lengths, object distances and characteristics of the images formed in these applications.

6. Plot a graph with object distance (u) on the x-axis and image distance (v) on the y-axis for a concave mirror (data provided). Help learners observe the relationship between u and v to identify patterns and draw conclusions. Encourage them to consider another graph that could be plotted in order to use it to find focal length (inverse of the y-intercept for a graph of 1/v against 1/u).

KEY ASSESSMENT

Assessment Level 2: An object is placed 15 cm from a concave mirror of focal length 20 cm, if the height of the object is 7 cm,

a. Calculate the position of the image.
b. What is the nature of the image?
c. Calculate the height of the image.

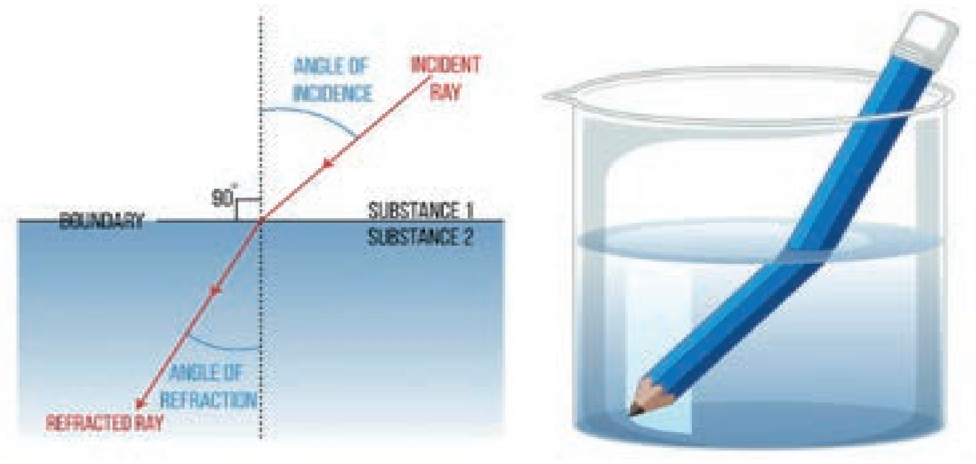
THEME/FOCAL AREA 2: LAWS OF REFRACTION

Refraction is a phenomenon where there is a change in direction and velocity of light when the light traveling in a transparent medium enters into another transparent medium of different density.

The laws governing the phenomenon of refraction are,

1. The incident ray, the refracted ray and the normal at the point of incidence, all lie in the same plane.
2. Snell's law: The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for a given pair of media.

When you place a pencil in a glass of water and look at the pencil from the side of the glass, it appears bent or broken at the water's surface. This effect is due to refraction of light.



Refraction with pencil in water beaker

LEARNING TASKS

1. Give examples of everyday phenomena involving refraction.
2. Define refraction.
3. State laws of refraction.

PEDAGOGICAL EXEMPLARS

1. Ask learners to fill a transparent glass or container with water leaving enough space at the top to submerge the pencil, then carefully place the pencil into the water, making sure it is vertically submerged and not tilted. Learners should observe the pencil and describe its position and direction while inside the water.
2. Set up an experiment using a laser pointer, a glass block and a protractor. Learners should measure the incident and refracted angles. and vary the incident angles and measure both the incident and refracted angles using a protractor. Learners should plot a graph of sine(i) against sine(r) and determine the gradient of the line, which corresponds to the refractive index of the glass.
   - Less able learners will need more support with performing the practical and with the use of the trigonometric identity (in particular: some examples and practice questions involving finding angle i or angle r using the inverse sine function) as well as choosing appropriate scale in plotting the graph.
   - Some learners should be offered support in choosing appropriate scale in plotting the graph.
   - More able learners could:
     a. Investigate refraction for waves traveling between two different mediums (NOT AIR) or
     b. research the derivation of Snell's Law and present this to the class (looking at the ratio of the speed of the wave in the two different materials and showing diagrammatically how this relates to the angles of incidence and refraction).
3. 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 refraction?

Assessment Level 2: A light ray moves from air to glass. Calculate the angle of refraction if the incident angle in air is 45 and the refractive index of glass is 1.5.

Assessment Level 2: How does the speed, wavelength and frequency of a light ray change when it enters a different medium?

SECTION 4 REVIEW

Engaging with image formation in plane mirrors should develop learners' observational skills, as they can describe the position, orientation and characteristics of images formed in different scenarios. Learners should recognise that the laws of reflection are fundamental principles in optics, explaining how light behaves when it encounters a smooth reflective surface.

Learners should also recognise that inclined mirrors can produce multiple images of a single object, depending on the number and arrangement of mirrors.

Understanding the terminologies allows learners to analyse the optical properties of spherical mirrors and predict image characteristics in different scenarios. Learners should understand that concave mirrors can form both real and virtual images and the characteristics of the images depend on the object's position relative to the focal point and also recognise that convex mirrors always form virtual images, making objects appear smaller than their actual size. Learners should interpret the numerical values obtained from calculations to determine the position and characteristics of images formed by spherical mirrors.

Learners should gain a deeper understanding of how light behaves when passing through different transparent mediums, leading to the bending of light rays. 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.

Reference

1. Freepik, (2014). Refraction [Image]. https://www.freepik.com/free-vector/refraction-science-experiment-with-pencil-water-beaker_25590906.htm