PHYSICAL SCIENCES
Grade10
TERM 1
Content Booklet
TARGETED SUPPORT

Contents

A Message from the NECT

NATIONAL EDUCATION COLLABORATION TRUST

DEAR TEACHERS

This learning programme and training is provided by the National Education Collaboration Trust (NECT) on behalf of the Department of Basic Education (DBE)! We hope that this programme provides you with additional skills, methodologies and content knowledge that you can use to teach your learners more effectively.

WHAT IS NECT?

In 2012 our government launched the National Development Plan (NDP) as a way to eliminate poverty and reduce inequality by the year 2030. Improving education is an important goal in the NDP which states that 90% of learners will pass Maths, Science and languages with at least 50% by 2030. This is a very ambitious goal for the DBE to achieve on its own, so the NECT was established in 2015 to assist in improving education.

The NECT has successfully brought together groups of people interested in education so that we can work collaboratively to improve education. These groups include the teacher unions, businesses, religious groups, trusts, foundations and NGOs.

WHAT ARE THE LEARNING PROGRAMMES?

One of the programmes that the NECT implements on behalf of the DBE is the 'District Development Programme'. This programme works directly with district officials, principals, teachers, parents and learners; you are all part of this programme!

The programme began in 2015 with a small group of schools called the Fresh Start Schools (FSS). The FSS helped the DBE trial the NECT Maths, Science and language learning programmes so that they could be improved and used by many more teachers. NECT has already begun this scale-up process in its Provincialisation Programme. The FSS teachers remain part of the programme, and we encourage them to mentor and share their experience with other teachers.

Teachers with more experience of using the learning programmes will deepen their knowledge and understanding, while some teachers will be experiencing the learning programmes for the first time.

Let's work together constructively in the spirit of collaboration so that
we can help South Africa eliminate poverty and improve education!

www.nect.org.za

PROGRAMME ORIENTATION

Programme Orientation

Welcome to the NECT Physical Sciences learning programme! This CAPS compliant programme consists of:

- A Content Booklet: Targeted Support
- A Resource Pack Booklet which consists of worksheets, a guide to formal experiments and/or investigations, formal assessment support.
- A DVD with a video of the formal experiments and/or investigation.
- A set of posters.

OVERVIEW AND APPROACH OF PROGRAMME

The FET Physical Sciences curriculum is long and complex. There are many quality textbooks and teachers' guides available for use. This programme does not aim to replace these resources, but rather, to supplement them in a manner that will assist teachers to deliver high quality Physical Sciences lessons.

Essentially, this programme aims to provide targeted support to teachers by doing the following:

1. Clarifying and explaining key concepts.
2. Clarifying and explaining possible misconceptions.
3. Providing worked examples of questions at an introductory level.
4. Providing worked examples of questions at a challenge level.
5. Providing the key teaching points to help learners deal with questions at challenge level.
6. Providing worksheet examples and corresponding marking guidelines for each topic.
7. Providing a Planner & Tracker that helps teachers to plan their lessons for a topic, and track their progress, pacing and curriculum coverage.
8. Providing videos of formal experiments and/or investigations, together with learners' worksheets and marking guidelines.
9. Providing guidance on how to structure formal assessment tasks.
10. Providing a 'bank' of questions and marking guidelines that may be used to structure formal assessment tasks.
11. Providing a set of posters with key information to display in the classroom.

CONTENT BOOKLET: TARGETED SUPPORT

1. The booklet starts with a ***contents page*** that lists all the topics for the term.
2. Every topic begins with a ***general introduction*** that states for how long the topic runs and the value of the topic in the final exam. It also gives a general idea of what is covered in the topic, and why this is important for our everyday lives.
3. This is followed by a ***list of requirements*** for the teacher and the learner. Try to ensure that you have all requirements on hand for the topic, and that your learners always have their requirements ready for each lesson. This is a simple classroom management practice that can improve your time-on-task and curriculum coverage significantly!
4. Next, you will see a ***sequential table*** that shows the prior knowledge required for this topic, the current knowledge and skills that will be covered, and how this topic will be built on in future years. Use this table to give learners an informal quiz to test their prior knowledge. If learners are clearly lacking in the knowledge and skills required, you may need to take a lesson to cover some of the essential content and skills. It is also useful to see what you are preparing learners for in the years to follow, by closely examining the 'looking forward' column.
5. This is followed by a ***glossary of terms***, together with an explanation of each term. It is a good idea to display these words and their definitions somewhere in the classroom, for the duration of the topic. It is also a good idea to allow learners some time to copy down these definitions into their books. You must teach the words and their meanings explicitly as and when you encounter these words in the topic.

   Once you have taught a new word or phrase, try to use it frequently in statements and questions. It takes the average person 20 – 25 authentic encounters with a new word to fully adopt it and make it their own.
6. Next, there are some very brief notes about the ***assessment*** of this topic. This just informs you of when the topic will be assessed, and of the kinds of questions that are usually asked. Assessment is dealt with in detail in the Assessment Section of the Resource Pack.
7. The next item is very useful and important. It is a table showing the ***breakdown of the topic and the targeted support offered.***

   This table lists the ***sub-topic***, the classroom ***time allocation*** for the sub-topic, and the ***CAPS page reference***.

   The table also clearly states the ***targeted support*** that is offered in this booklet. You will see that there are three main kinds of support offered:
   a. Key concepts are clarified and explained.
   b. Possible misconceptions are clarified and explained.

   c. Questions are modelled and practised at different levels (introductory level and challenge level).

8. After this introduction, the ***targeted support for each sub-topic*** commences. This generally follows the same routine:
   a. A key concept or key concepts are clarified and explained. It may be useful for you to work through this carefully with learners, and do any demonstrations that are included.
   b. Questions related to the key concepts are worked and explained.
      - These questions may be done at introductory level, at challenge level, or both.
      - It is important to expose learners to **challenge level questions**, as this is often how questions are presented in exams.
      - These questions also challenge learners to apply what they have learnt about key concepts. Learners are, essentially, challenged to think at a critical and analytical level when solving these problems.
      - Please note that when calculations are done at challenge level, the key teaching points are identified.
      - Make sure that you effectively share these key teaching points with learners, as this can make all the difference as to whether learners cope with challenge level questions or not.
   c. At key points in the topic, checkpoints are introduced.
      - These checkpoints involve asking learners questions to check that they understand everything to that point.
      - The checkpoints also refer to a worksheet activity that is included in the Worksheet Section of the Resource Pack.
      - Use checkpoints to ascertain whether more consolidation must be done, or if your learners are ready to move to the next key concept.
9. Every topic ends with a ***consolidation exercise*** in the Worksheet Section of the Resource Pack. This exercise is not scaffolded as a test, it is just a consolidation of everything covered in this programme for that topic.
10. Finally, a section on ***additional reading / viewing*** rounds off every topic. This is a series of web links related to the topic. Please visit these links to learn more about the topic, and to discover interesting video clips, tutorials and other items that you may want to share with your learners.

THE WORKSHEET SECTION OF THE RESOURCE PACK

1. The Worksheet Booklet has different worksheets and corresponding marking guidelines for each topic.
2. First, there is a ***practice worksheet***, with questions that learners must complete during the topic. These are referred to in the checkpoints.
3. Once learners have completed these calculations, it is important to mark their work, using the ***marking guidelines*** supplied. Either do this together as a whole class, or display copies of the marking guidelines around the classroom, in spaces where learners can go and mark their work for themselves.
4. It is important that learners see how marks are allocated in the marking guidelines, so that they fully understand how to answer questions in tests and exams.
5. At the end of each topic, there is a ***consolidation exercise*** and marking guidelines. This worksheet is a consolidation exercise of all the concepts covered in the topic. The consolidation exercise is NOT scaffolded and it is not designed to be used as a formal test. The level of the worksheet will be too high to be used as a test.
6. Again, it is important for learners to mark their work, and to understand how marks are allocated for each question.
7. Please remember that these worksheets do not replace textbook activities. Rather, they supplement and extend the activities that are offered in the textbook.

THE PLANNER & TRACKER

1. The Planner & Tracker is a useful tool that will help you to effectively plan your teaching programme to ensure that it is CAPS compliant.
2. The Planner & Tracker has a section for every approved textbook, so that regardless of the textbook that you use, you will be able to use this tool.
3. It also has space for you to record all lessons completed, which effectively allows you to monitor your curriculum coverage and pacing.
4. In addition, there is space for you to reflect on your progress and challenges at the end of each week.
5. At the end of the Planner & Tracker, you will find a series of resources that may be useful to you when teaching.
6. You will also find a sample formal assessment and marking guidelines.

THE FORMAL EXPERIMENTS AND/OR INVESTIGATIONS AND DVD

1. The following experiments or investigations must be completed as part of the formal assessment programme:

a.	Grade 10 Term 1:	Heating and cooling curve of water
b.	Grade 10 Term 2:	Electric circuits with resistors in series and parallel – measuring potential difference and current
c.	Grade 10 Term 3:	Acceleration
d.	Grade 11 Term 1:	Verification of Newton's 2nd Law: Relationship between force and acceleration
e.	Grade 11 Term 2:	The effects of intermolecular forces on: BP, MP, surface tension, solubility, capillarity
f.	Grade 12 Term 1:	Preparation of esters
g.	Grade 12 Term 2:	1) Titration of oxalic acid against sodium hydroxide 2) Conservation of linear momentum
h.	Grade 12 Term 3:	a) Determine the internal resistance of a battery b) Set up a series-parallel network with known resistor. Determine the equivalent resistance using an ammeter and a voltmeter and compare with the theoretical value.

2. Videos of all the listed experiments and investigations are supplied as part of this programme.

3. These videos should ideally be used as a teacher's guide. After watching the video, set up and complete the practical with your learners. However, if this is not possible, then try to show the video to your learners and allow them to record and analyse results on their own.

4. The videos should be used in conjunction with the experiment (or investigation) learners' worksheets. Learners should complete the observations and results section of the worksheet while watching the video, and then work on their own to analyse and interpret these as instructed by the questions that follow on the worksheet.

THE POSTERS

1. Every FET Physical Sciences teacher will be given the following set of five posters to display in the classroom:
    - a. Periodic Table
    - b. Chemistry Data Sheet
    - c. Physics Data Sheet Part 1
    - d. Physics Data Sheet Part 2
    - e. Chemistry Half Reactions
2. **Please note that you will only be given these posters once**. It is important for you to make these posters as durable as possible. Do this by:
    - a. Writing your name on all posters
    - b. Laminating posters, or covering them in contact paper
3. Have a dedicated wall or notice board in your classroom for Physical Sciences, per grade:
    - Use this space to display the posters
    - Display definitions and laws
    - Display any additional relevant or interesting articles or illustrations
    - Try to make this an attractive and interesting space

THE ASSESSMENT SECTION OF THE RESOURCE PACK

1. A separate Assessment Section is provided for Grade 10, Grade 11 and Grade 12.
2. This section provides you with a 'bank' of sample assessment questions for each topic.
3. These are followed by the marking guidelines for all the different questions that details the allocation of marks.
4. The level of cognitive demand is indicated for each question (or part of a question) in the marking guidelines as [CL1] for cognitive level 1 etc.

Planning and Preparation

1. Get into the habit of planning every topic by using the following documents together:
   - a. The Physical Sciences Planner & Tracker
   - b. The Content Booklet: Targeted Support
   - c. The Worksheet Section of the Resource Pack
   - d. Your textbook
2. Planning should always be done well in advance. This gives you the opportunity to not only feel well-prepared but also to ask a colleague for help if any problems arise.
3. Follow these steps as you plan to teach a topic:
   - a. **Turn to the relevant section in the Planner & Tracker for your textbook.**
     - Look through the breakdown of lessons for the topic.
     - In pencil, fill in the dates that you plan to teach each lesson. This will help with your sequencing.
   - b. **Next, turn to the relevant section in your Textbook.**
     - Read through each key concept in the Textbook.
     - Complete as many examples as possible. This will also help in your teaching – you will remember more points to share with the learners if you have done all of the work yourself.
   - c. **Finally, look at the topic in the Content Booklet: Targeted Support.**
     - Read through all the introduction points, including the table that shows the breakdown of lessons, and the targeted support offered.
     - Take note of the targeted support that is offered for each section.
     - Read through the whole topic in the Content Booklet: Targeted Support.
     - Complete all the examples in the Worksheets for the topic, including the Consolidation Exercise.
     - Make notes in your Planner & Tacker to show where you will include the targeted support teaching and activities. You may choose to replace some textbook activities with work from the targeted support programme, but, be careful not to leave anything out!
   - d. **Document your lesson plans in the way that you feel most comfortable.**
     - You may like to write notes about your lesson plans in a notebook.
     - You may like to use a standardised template for lesson planning. (A template is provided at the end of this section).
     - Remember to make notes about where you will use the textbook activities, and where you will use the targeted support activities.

e. **Ideally, Lesson Planning for a topic should include:**
  - Time to introduce the topic to learners.
  - Time to establish the learners' prior knowledge.
  - If required, time to address critical gaps in learners' prior knowledge.
  - Introduction of terminology (glossary words).
  - Time to introduce and teach each key concept.
  - Time for learners to complete practice exercises for each key concept.
  - Time to correct and remediate each key concept.
  - Time for a consolidation exercise.

Note: Avoid giving learners an exercise to do that you haven't already completed yourself. This is useful for when the learners ask questions or get stuck on a question, you will be ready to assist them immediately instead of wasting time reading the question and working it out then.

PREPARATION AND ORGANISATION

1. Once you have completed your planning for a topic, you must make sure that you are properly prepared and organised to teach it.
2. Do this by completing all the steps listed in the planning section, including completing all the textbook and worksheet examples.
3. Have your lesson plans or teaching notes ready to work from.
4. Next, make sure that you have all resources required for the lesson.
5. Prepare your notice board for the topic, to give learners something visual to anchor their learning on, and to generate interest around the topic.
6. Print copies of the worksheets for all learners.

SAMPLE TEMPLATE FOR LESSON PREPARATION

PHYSICAL SCIENCES LESSON PLAN

School	
Teacher's name	
Grade	
Term	
Topic	
Date	
Lesson Duration	

1. CONCEPTS AND SKILLS TO BE ACHIEVED:

By the end of the lesson learners should know and be able to:

2. RESOURCES REQUIRED:

3. HOMEWORK REVIEW / REFLECTION:

Exercises to be reviewed and notes:

4. LESSON CONTENT / CONCEPT DEVELOPMENT

Explanation and examples to be done:

5. CLASSWORK ACTIVITY

Resource 1	
Page	
Exercise	
Resource 2	
Page	
Exercise	

Notes:

6. HOMEWORK ALLOCATION

Resource 1	
Page	
Exercise	
Resource 2	
Page	
Exercise	

7. LESSON REFLECTION:

What went well:
What could have gone better:

Creating a Positive Learning Environment

The best learning takes place when learners feel safe and confident enough to participate. It is up to you, as the teacher, to create the kind of atmosphere that will promote discussion and learning. Below are some tips to help you with this important challenge:

1. **Work constantly to create the atmosphere that you want.** It takes time for teachers and learners to understand and adopt the behaviours required for a safe, positive classroom. Don't give up if it doesn't happen straight away – keep working towards creating a feeling of emotional safety in your classroom.
2. **Take an interest in learners' work.** Most of the time, you will probably get learners to correct their own work, either by working through the solutions on the chalkboard, or by posting up the marking guidelines for learners to see. However, it is a good idea to look through learners' exercise books from time to time. This allows you to verify that your learners are doing their work, and are on track. It is also a time for you to show interest in learners' progress. Tell learners when you are pleased or impressed with their progress or efforts. This shows learners that you are interested, supportive, and that you value their work.
3. **Establish and implement ground rules.** Work out a set of ground rules for your classroom – it is a good idea to do this together with the learners.
    - Tell learners that you need a set of ground rules to set the tone for the classroom, and to manage how you work together.
    - Ask learners to contribute their ideas for the ground rules. As a learner makes a suggestion, write it down. Do not reject anyone's suggestion at this point.
    - When everyone has contributed their ideas, read through the list together. Eliminate duplicate ideas. If there are key rules missing, ask prompting questions, to try and get learners to suggest them.
    - Finally, ask learners if they are all prepared to accept and live by these rules. If there is a rule that needs to be adjusted or removed, do so. Make it clear that these are their rules, and that they have accepted them, and must therefore abide by them.
    - Also talk to learners about self-moderation. This means that you accept that they are young adults, and that they should not need a teacher to tell them how to behave. By this stage of their lives, they should be able to assess if their behaviour is out-of-line, and to adjust or self-moderate their behaviour.
    - Whilst you should expect learners to self-moderate their behaviour by the FET stage, if a learner behaves really badly, particularly in a way that makes another learner feel bad or unsafe, you need to implement consequences.
    - Learners need to know that you will take action against harmful behaviour. If you do not do this, it will be difficult for learners to trust you.

4. **Correct mistakes clearly, but without derision.** When learners make mistakes, thank them for trying, but point out that a mistake has been made. Correct the mistake clearly and quickly, and then move on. Do not labour the point – learners must see that it is perfectly acceptable to make mistakes as long as one tries.

5. **Tell learners if you do not know something.** Learners appreciate it when teachers are honest, and say things like, 'I'm not really sure. Does anyone else know? Should we look up the answer?'

6. **Model the kind of behaviour you expect in your class.** We often hear the phrase 'respect is earned', or 'respect is a two-way street', but we don't always think about what that means.
   - The simplest explanation is to model the behaviour that you expect from your learners, and to treat them the way that you want to be treated.
   - Be punctual and prepared for lessons; work diligently; keep your space clean, tidy and organised; never use your cell phone in class; look after your apparatus and resources; greet learners; be considerate of their feelings; praise learners for a job well done; thank learners for going the extra mile; and go the extra mile yourself.
   - This may not be reciprocated immediately, but in time, learners will learn from your model, and will begin to behave as you do within your environment.
   - Feel free to hold an open, honest discussion with learners about this concept. Let learners know that you will try to always treat them with consideration and respect, and that you will always work hard for them.
   - Let your learners know that you will appreciate them trying to do the same.

7. **Move around the classroom.** As learners work, walk around the classroom. Use this opportunity to stop and look at individual learner's work. Stop and discuss challenges – help individual learners as much as you can. Look out for problems between learners, and deal with issues that arise. Get to know your learners better. If tension is building between learners, put a stop to the argument. Then, if appropriate, find time for the learners to talk it out while you mediate.

8. **Laugh with your learners.** If you can find something to laugh about with your learners, do so! This is an excellent way to bond with learners, and to make them feel closer to you. Laughter is also an excellent way to break down tensions, and to get learners to relax.

9. **Leave your problems outside of the classroom.** Learners pick up on your stress, anxiety and unhappiness, and this can affect them negatively. Try your best to be in the habit of leaving your problems at the classroom door, and to focus on your learners once you are inside the classroom.

10. **Praise your learners for their efforts.** This is one of the easiest and most effective behaviours that you can implement.
    - Praise learners not for their achievements, but for their efforts. This will encourage learners to try and do more.
    - This is known as building a 'growth mindset'. This means that learners believe that they can learn and progress.
    - The opposite of a growth mindset is a 'fixed mindset', where learners believe they are born with a certain ability, and that they cannot change this.

TOPIC 1:

Matter and Classification

A Introduction

- This topic runs for 2 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Matter and Classification forms part of the content area Matter and Materials (Chemistry).
- Matter and Materials counts 46,67% in Grade 10 Paper 2 (Chemistry) examination.
- Matter and Classification provides a basic foundation for all concepts related to Matter and Materials. It could count 4% of the final Paper 2 (Chemistry) examination.
- The classification of matter helps learners to identify the nature of materials according to their properties. This will be of benefit in later topics such as chemical bonding. It will also help learners in the understanding of everyday materials and their uses.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. A Periodic Table of the Elements (Poster supplied with the NECT reources).
4. The tables of common cations and anions (polyatomic ions) (as specified on pages 161–163 of CAPS).

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book for notes and exercises.
2. Scientific calculator – highly recommended Sharp or Casio.
3. Pen, pencil, ruler.
4. A Periodic Table of the Elements (copied from page 29 of the 2015 Grade 10 Examination Guidelines).
5. The tables of common cations and anions (polyatomic ions) (as specified on pages 161 – 163 of CAPS).

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7-9	**GRADE 10**	**GRADE 11-12**
• Physical properties of materials. • Separation of mixtures. • Pure and impure substances. • Elements and compounds. • The Periodic Table. • Names of compounds.	• The materials of which substances are made. • Homogeneous and heterogeneous mixtures. • Pure substances, elements and compounds. • Names and formulae of substances. • Metals, metalloids and non-metals. • Electrical conductors, semiconductors and insulators. • Thermal conductors and insulators. • Magnetic and non-magnetic materials.	• Writing chemical formulae. • Physical properties of substances.

C Glossary of Terms

TERM	DEFINITION
Element	A pure substance consisting of one type of atom.
Compound	A pure substance consisting of two or more elements that are always present in the same ratio.
Mixture	A mixture consists of two or more pure substances that are combined in any proportions and do not react chemically with each other.
Homogeneous	A mixture of uniform composition in which all components are in the same phase.
Heterogeneous	A mixture of non-uniform composition in which the components can be easily identified.
Pure substance	A pure substance is one that cannot be separated into simpler components by physical methods.
Thermal conductivity	The ability of a material to allow thermal energy (heat) to be transmitted through it.
Brittle	A hard substance that is likely to break easily.
Malleable	A material that can be hammered or pressed into shape without breaking or cracking.
Ductile	A material that can be stretched into a wire.
Melting point	The constant temperature at which a solid, given sufficient heat, becomes a liquid.
Boiling point	The temperature of a liquid at which its vapour pressure equals the external (atmospheric) pressure.
A thermal conductor	A material that allows heat to pass through easily.
A thermal insulator	A material that does not allow heat to pass through it.
Metalloids	Substances that have properties of metals and properties of non-metals.
Electrical conductor	A material that allows the flow of charge.
Semiconductors	A substance that can conduct electricity under some conditions, but not under others, making it a good medium for the control of electric current.
Electrical insulators	A material that prevents the flow of charge.

D Assessment of this Topic

This topic is assessed by informal and control tests as well as in the midyear and end of year examinations.

- There can be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.
- Recommended experiment for informal assessment: *Testing various materials for physical properties*.

E Breakdown of Topic and Targeted Support Offered

TIME ALLOCATION	SUB-TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
15 minutes	The material(s) of which an object is composed	15	Key concepts and possible misconceptions are clarified and explained: a. The similarity between thermal and electrical conductivity needs to be explained. b. The meanings of the terms brittle, malleable and ductile must be clearly understood.
15 minutes	Mixtures: heterogeneous and homogeneous	16	Key concepts and possible misconceptions are clarified and explained: a. The difference between homogeneous and heterogeneous mixtures must be clearly understood.
15 minutes	Pure substances: elements and compounds	16	Key concepts and possible misconceptions are clarified and explained: a. The concept of what pure substances are made up of is often confusing and needs to be explained carefully. b. The application of the concept of a pure substance being an element or a compound and not a mixture must be understood.
15 minutes	Names and formulae of substances	17	Key concepts and possible misconceptions are clarified and explained: a. Learners often get confused when naming substances and when they write chemical formulae – there is a need to eliminate the confusion. b. Learners must understand the prefixes and the endings in the names of substances.
15 minutes	Metals, metalloids and non-metals	17	Key concepts and possible misconceptions are clarified and explained: a. Learners must be able to identify the nature of an element by its position in the Periodic Table.
15 minutes	Electrical conductors, semiconductors and insulators	18	Key concepts and possible misconceptions are clarified and explained: a. Learners must understand the differences in the properties of metals, non-metals and semiconductors with reference to their ability to conduct an electric current.

15 minutes	Thermal conductors and insulators	18	Key concepts and possible misconceptions are clarified and explained: a. The difference in properties of thermal conductors and insulators needs to be clarified.
15 minutes	Magnetic and non-magnetic materials	19	Key concepts and possible misconceptions are clarified and explained: a. The importance of magnetic materials and their uses.

F Targeted Support per Sub-topic

1. THE MATERIAL(S) OF WHICH AN OBJECT IS COMPOSED

INTRODUCTION

The classification of matter, i.e. being in a position to identify materials as being of a particular type, is important. It enables us to predict the properties of the material and its suitability for certain uses.

CONCEPT EXPLANATION AND CLARIFICATION

Learners need to be aware of the physical properties of matter which are used to classify materials. The best way to do this is to provide learners with a sample of everyday objects that are made from different materials. You can include natural materials such as grass, stones or wood and materials for re-cycling like paper and plastic. Learners can record their observations of these materials and then ask them to think about what makes each material different. In this way you can establish criteria for testing materials. It is important that you allow learners to tests different materials so that those with similar properties can be grouped together. This is the process of classification.

A list of questions about selected materials and a summary of their properties is provided on the next page as an exemplar of this activity.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the question and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

INVESTIGATION OF PROPERTIES OF DIFFERENT MATERIALS

AIM: **Classify materials based on their strength, thermal and electrical conductivity, brittleness, malleability, ductility, magnetism, density and melting point.**

MATERIAL REQUIRED

Objects made from different materials, such as

- Copper
- Paper
- Ceramic tea cup
- Steel
- PVC (plastic pipe)

INSTRUCTIONS

Tabulate your observations of the properties of the material you are given. Answer the following questions to help you complete the table.

- Is the material strong – meaning that when a force is applied to it, is it able to withstand a force without breaking or fracturing?
- The thermal and electrical conductivities of the material. Do they conduct thermal energy and/or electricity?
- The brittleness of the material – does it shatter easily when a force is applied or it is dropped onto a hard surface?
- Is the material malleable – can it be made into sheets without breaking?
- Is the material ductile – can it be drawn into wire?
- Is the material magnetic or non-magnetic?
- Does the material have a high or low density? (i.e. does it have a high or low mass for it's size?)
- Are the melting point and the boiling point of the material high or low?

Solution

Material	Strength	Thermal/ electrical conductivity	Brittle	Malleable /ductile	Magnetic	High density	High m.p/b.p.
Copper	✓	✓		✓		✓	✓
Paper				✓(Mall.)			
Ceramic tea cup			✓				✓
Steel	✓	✓		✓	✓	✓	✓
PVC (plastic) pipe	✓		✓				✓

2. MIXTURES: HETEROGENEOUS AND HOMOGENEOUS

INTRODUCTION

A lot of everyday substances are mixtures of one type or another, e.g. milk and tap water. It is important to be able to identify such substances as one type of mixture or another.

CONCEPT EXPLANATION AND CLARIFICATION

Learners need to understand the properties of mixtures. It must be stressed that mixtures consist of at least two pure substances and that they can be mixed in any proportion. The components of a mixture do not combine chemically. Also, mixtures can be separated by physical means, such as filtration and distillation.

Examples:

- Soil can be separated from water by passing the mixture through filter paper in a funnel.
- A mixture of water and alcohol can be separated by distillation because these liquids boil at different temperatures. The alcohol boils first and evaporates; it can be collected by condensing it.

We can make a mixture of table salt and water by mixing a spoonful of salt in a glass of water. At first the salt was a solid and the water was a pure liquid but after we have mixed these two substances we cannot see differences between them. We say we have formed a solution and it looks like all the salt and water are both in the liquid phase.

If we take a sample of the solution from the top or bottom of the glass it will taste exactly the same. If we could see the particles of salt and water there would be no difference in the way the particles are spread out in the two test samples. We say the particles in the solution are spread out uniformly. A salt water solution is an example of a homogeneous solution.

You can also make homogeneous mixtures by combining gases. Air is a homogeneous mixture of nitrogen, oxygen and a large number of other gases including carbon dioxide and water vapour.

Remember in a homogeneous mixture, the particles are spread out uniformly. This is also true of homogeneous mixtures made from solids. We can combine two or more metals to make alloys like stainless steel, brass or bronze. In a sample of any alloy you cannot see where the particles of one particular metal are. The particles in every part of the sample are spread out in exactly the same way.

In a heterogeneous mixture the particles of the mixture are not spread out uniformly. You can often see the boundary of where one component ends and the other starts. In a mixture of sand and water, different parts of the mixture will be different. Some large particles will settle at the bottom of the glass and smaller particles will float in the water near the surface.

The following mixtures can be observed:

- Sand and water (heterogeneous)
- Potassium dichromate and water (homogeneous)
- Iodine and ethanol (homogeneous)
- Iodine and water (heterogeneous)
- Air is a mixture of different gases (homogeneous)

In the mixture of sand and water, both the sand and the water are visible.

In the case of potassium dichromate and water, the mixture is uniformly orange in colour and the potassium dichromate cannot be distinguished from the water.

In the case of iodine and alcohol, the mixture is uniformly purple in colour and the iodine cannot be distinguished from the alcohol.

In the case of iodine in water, the iodine crystals lie at the bottom of the container and are very distinct from the water.

In the case of air, we cannot distinguish between nitrogen and oxygen gases by sight.

The point must be stressed that solutions are not only solid in liquid solutions. There are many different types of solutions:

1. Solid in solid solutions, e.g. metal alloys
2. Gas in gas solutions, e.g. the air
3. Liquid in gas solutions, e.g. mist

These are but a few examples.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the question and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

2. Explain whether each of the following is a homogeneous or heterogeneous mixture and explain how you made your decision.
   - a. Sand and water
   - b. Salt and water
   - c. Oil and vinegar
   - d. Iodine and water
   - e. Beans and peas

Solution

a. Heterogeneous. The sand and the water are in two different phases. The one can easily be distinguished from the other.
b. Homogeneous. Once the salt is dissolved in the water, we cannot distinguish the solvent (water) from the salt (solute).
c. Heterogeneous. The vinegar and the oil do not mix. The two different portions are clearly visible even though they are both liquids. The oil floats on the vinegar.
d. Heterogeneous. The iodine crystals (solid) are at the bottom of the water (liquid).
e. Heterogeneous. The beans and peas are easily visible as separate substances, as they are both solids.

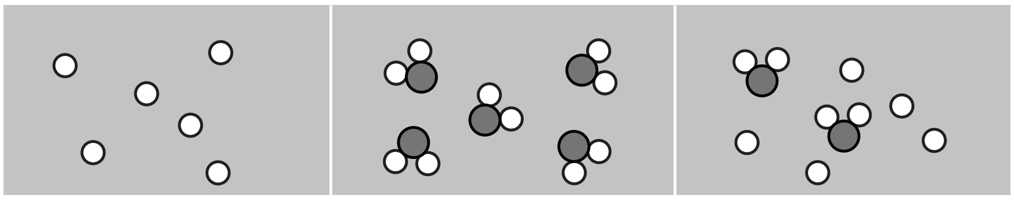
3. PURE SUBSTANCES: ELEMENTS AND COMPOUNDS

INTRODUCTION TO THE TOPIC

It will become increasingly important in the Chemistry sections of the work in grade 11 and grade 12 for learners to be able to distinguish between elements and compounds and then to calculate percentage purity. This sub-topic is a good grounding for what will follow.

CONCEPT EXPLANATION AND CLARIFICATION

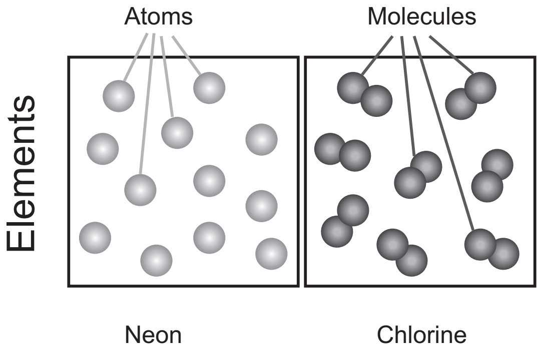
Learners must be familiar with diagrams of microscopic representations of atoms and molecules, pure and impure substances and how to interpret them. Teachers are advised to use different colour and sized circles to represent different combinations.



This illustration is an example of the type of diagram mentioned above. The diagrams represent, from left to right respectively, an element (pure substance), a compound (pure substance) and a mixture.

It is important that learners fully understand the concepts of an element and a compound. Compounds consist of more than one type of atom bonded together – in both the microscopic representation and in the chemical formulae.

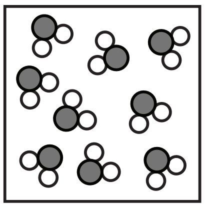
An element can be made up of single atoms or molecules consisting of atoms of the same element.



The chemical formulae for neon and chlorine are:

Ne	$C\ell_2$
Single atoms	Two atoms in a molecule

Compounds are made up of atoms of two or more elements.



Molecules of water

The chemical formula for water is H_2O.

This molecule contains two atoms of hydrogen and one atom of oxygen.

It must emphasised that both elements and compounds are pure substances. If a substance consists of only one type of molecule made up of atoms of different elements, then it is a compound and it therefore a pure substance too.

Boiling points, melting points and density are physical properties which can be used to determine purity. Pure substances melt at a unique and constant temperature. Similarly, pure substances boil at a constant unique temperature.

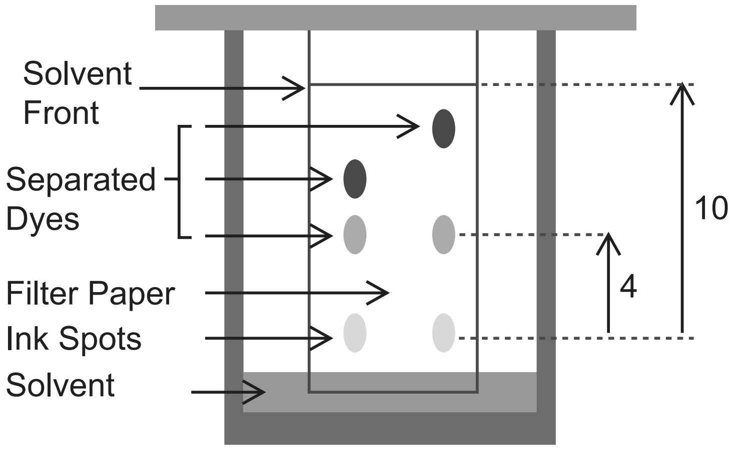
Density is a measure of how the particles of a substance are packed together. A pure substance has a unique and constant density because it has a uniform arrangement of the same type of particles in it. Impure substances melt (and boil) over a range of temperatures and they have a range of densities too.

Mixtures are impure substances. Apart from looking at the melting point, boiling point and density of a mixture, you can try to separate a mixture into it's components. One of the most interesting separation techniques is chromatography. It is easy to demonstrate paper chromatography and it can confirm if a substance is pure or whether it is a mixture of a number of substances which each have different colours.

INSTRUCTIONS FOR PAPER CHROMATOGRAPHY INVESTIGATION

- Cut a strip of filter paper that is 3 cm wide and long enough to stick out of a small beaker. The filter paper must not to touch the beaker's sides.
- Attach the top of the filter paper to a pencil or glass rod, using Sellotape. The bottom of the paper must rest just above the bottom of the beaker. Remove the filter paper from the beaker.
- Use two different green pens to make two dots about 1 cm from the bottom of the filter paper and at least 1 cm apart.
- Pour ethanol into the beaker to a depth of about 0,5 cm.
- Place the filter paper into the beaker and make sure the bottom of the filter paper is dipped into the ethanol.
- Watch what happens as the ethanol (solvent) is drawn up into the filter paper.

Results



Above is an example of a paper chromatogram, showing the separation of the dyes making up green ink.

- **For the benefit of teachers:** Paper chromatography relies on how strongly the molecules of substances of different colours are attracted to the molecules of the medium (filter paper). A solvent is used as a transport mechanism. The solvent moves up the filter paper by means of capillary action. The molecules of different coloured substances move up the filter paper with the solvent. The stronger the intermolecular forces between the filter paper and the 'coloured' molecules, the lower down on the filter paper the molecules will stop rising and so on.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the question and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

3. Which of the following substances are pure substances?

a. Tap water

b. Bronze

c. Aluminium

d. Oxygen

e. Milk

f. Air

Solution

a. This is a mixture. Tap water contains many dissolved salts and chemicals used to purify it.

b. This is a mixture. Bronze is a metal alloy. It is a mixture of copper and tin.

c. Pure substance

d. Pure substance

e. Milk is a mixture. It contains fats such as cream and other solids.

f. Air is a mixture. It is made up of many gases such as nitrogen, oxygen, carbon dioxide, hydrogen, argon, dust particles, etc.

4. NAMES AND FORMULAE OF SUBSTANCES

INTRODUCTION

Being able to give the names of chemical formulae correctly and being able to write chemical formulae from names are two extremely important skills that learners need to have. Once again these skills are vital for performing well in Chemistry at grade 11 and 12 levels.

CONCEPT EXPLANATION AND CLARIFICATION: RULES FOR NAMING AND WRITING FORMULAE OF SUBSTANCES

Example of a chemical formula

- **Clarifying what information is given by a chemical formula, e.g. H_2SO_4**

This formula tells us that the compound contains three different elements: hydrogen (H), sulfur (S) and oxygen (O). The chemical formula represents one molecule of the compound. There is an unwritten large 1 to the left of the H in the formula.

The small number after the H tells us that there are 2 atoms of hydrogen in this molecule.

This small number written after the O tells us that there are 4 atoms of oxygen in the molecule.

Naming compounds

When compounds are made up of two elements, we write down the first part of its name as the name of the first element. For the second part of the name of the compound, we change the name of the second element slightly. The second element's name is changed to end in -ide.

Examples are:	HCℓ	NaF
	hydrogen chloride	sodium fluoride

When non-metal elements combine to form compounds there is often more than one atom of an element in the molecule. To help us include the number of atoms of each non-metal in the compound we use the following prefixes:

mono	1
di	two
tri	three
tetra	four

Examples: CO_2 – carbon dioxide, NH_3 – nitrogen trihydride

- **Some compounds contain positively and negatively charged particles called ions.**

Positively charged ions are called cations and negatively charged ions are called anions. The cation is usually a simple metal ion (the ammonium ion NH_4^+ is the only positive polyatomic ion and it is an exception). The anion can be a non-metal ion or complex polyatomic ion, which is made up of more than one atom. Tables of transition element cations and polyatomic ions are provided in the CAPS document (pages 161 and 162) and in textbooks.

Transition metal cations (except zinc and silver) can have a number of different positive charges (valencies). Zinc is always Zn^{2+} and silver is always Ag^+. To show the different positive charges we use Roman numerals in brackets after the name of the ion. Examples are: Fe^{2+} – iron (II) and Fe^{3+} – iron (III).

Polyatomic ions that contain oxygen have names that end in -ate or -ite. The first ending is given to the ion that contains more oxygen, e.g. SO_4^{2-} is called sulfate and SO_3^{2-} is called sulfite. NO_3^- is called nitrate and NO_2^- is called nitrite.

When naming compounds, the name of the more positive element or ion is given first followed by the name of the negative ion or the more negative element. It must be remembered that elements generally become more negative in going from left to right across a period in the Periodic Table.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the question and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

4. Write down the names of the compounds represented by the following chemical formulae:

a. $KMnO_4$

b. K_2SO_3

c. CrF_3

d. $FeCO_3$

e. $Zn(HCO_3)_2$

Solution

a. Potassium permanganate – The potassium ion is K^+ and the permanganate ion (ends in -ate because of 4 oxygen atoms) is MnO_4^-. The charges balance when they combine in a 1:1 ratio.

b. Potassium sulfite – The sulfite anion (SO_3^{2-} as opposed to SO_4^{2-} ends in -ite) has a charge of −2 so it requires two potassium ions, K^+, for the charges to balance.

- **c.** Chromium (III) fluoride – Chromium can have a charge of +3 or +2. In this case +3 hence chromium (III).
- **d.** Iron (II) carbonate – CO_3^{2-} has a charge of −2, so the iron must have a charge of +2.
- **e.** Zinc hydrogen carbonate – The zinc ion is Zn^{2+} and the hydrogen carbonate ion is HCO_3^{-}. It thus requires two of these ions to balance the charge on the zinc ion. *Note that the charges on ions should be written as 2+ or 2− and NOT as +2 or −2.*

5. Write down the chemical formula for each of the following substances:

- **a**. Silver sulfate
- **b.** Lead(IV) oxide
- **c.** Ammonium carbonate
- **d.** Iron(III) sulfide
- **e.** Sodium hydrogen carbonate

Solution

a.	Ag_2SO_4	The silver ion is Ag^+ and the sulfate ion is SO_4^{2-}, so it requires two positive silver ions to balance the negative charge.
b.	PbO_2	The (IV) means that the lead ion is Pb^{4+}, the oxide ion is O^{2-}, so it requires two oxide ions to balance the positive charge on the lead ion.
c.	$(NH_4)_2CO_3$	The carbonate ion is CO_3^{2-} and the ammonium ion is NH_4^+, so it requires two ammonium ions to balance the charge on the carbonate ion.
d.	Fe_2S_3	The (III) means that the iron ion is Fe^{3+} and the sulfide ion is S^{2-} (its name ends in -ide so it is the element), so to balance the charges it requires two iron ions for every three sulfide ions, to make total charges of 6+ and 6−.
e.	$NaHCO_3$	The sodium ion is Na^+ and the hydrogen carbonate ion is HCO_3^-, so it requires one of each for the charges to balance.

5. METALS, METALLOIDS AND NON-METALS

INTRODUCTION

When writing chemical formulae, the symbols of metals are written first and then the non-metals. When doing this it is thus important to know what category the elements fall into.

CONCEPT EXPLANATION AND CLARIFICATION

Learners must be able to classify these elements according to their positions on the Periodic Table. The vast majority of elements are metals and they are on the left-hand side of the Table. The elements on the extreme right are non-metals. Those elements that are on the border between metals and non-metals are called the metalloids.

Learners must be able to identify non-metals from their properties. The non-metals are located in groups 14 to 18 on the Periodic Table except for hydrogen which is found at the top of group 1. When the non-metals are at the top of a group you don’t find non-metals all the way down the group, except for the noble gases in group 18.

It must be noted that metalloids mainly have properties of non-metals in that they tend to bond covalently, but they generally differ in one important aspect from non-metals; they conduct electricity under certain conditions. Unlike metals they become better conductors at higher temperatures. The most commonly used metalloid is silicon, which is the basis for computer components.

Introductory Level Questions

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the question and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

6. Classify the following elements as metals, non-metals or metalloids:
    - **a.** silver
    - **b.** silicon
    - **c.** copper
    - **d.** iodine
    - **e.** sulfur

    ### Solution

    - **a.** Metal
    - **b.** Metalloid
    - **c.** Metal
    - **d.** Non-metal
    - **e.** Non-metal

6. ELECTRICAL CONDUCTORS, SEMICONDUCTORS AND INSULATORS

INTRODUCTION

Electrical conductors, semiconductors and insulators play an extremely prominent role in our lives today. It is important to be aware of how each of these types of materials is used in everyday life.

CONCEPT EXPLANATION AND CLARIFICATION

It is important to understand the role of each type of material:

- **a.** Conductors always allow an electric current to pass through them.
- **b.** Semiconductors only allow a current to flow through them under certain conditions.
- **c.** Insulators do not allow an electric current to flow through them at all.

Ask learners to state which type of material is most suitable for particular everyday appliances.

Examples are:

- **a.** Copper is a good conductor – It needs to be, in order to bring electricity to our homes and to allow a current to flow freely to appliances, lights, etc.
- **b.** Semiconductors are particularly suitable for electronic devices and their circuitry.
- **c.** Electrical insulators are suitable for use where it is necessary to prevent a current from flowing – the copper wiring in a home cannot be bare, because we will then

be constantly exposed to the danger of electric shock. Copper wire is coated with plastic, which is an electrical insulator, so as to avoid this danger.

It is recommended that the experiment described in the CAPS document for testing materials for electrical conductivity, be carried out in class. It would be preferable for learners to do it themselves.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the question and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

7. Classify the following materials as conductors, semiconductors or insulators:

a. Rubber

b. Aluminium

c. Perspex

d. Silver

e. Silicon

Solution

a. Insulator – Rubber does not allow an electric current to pass through it. Thick rubber boots are often worn as protection by electricians.

b. Conductor – It is a metal and thus it is a good conductor of electricity.

c. Insulator – It a type of plastic and it does not allow a current to pass through it.

d. Conductor – It is a metal and thus it is a good conductor of electricity.

e. Semiconductor – It is the most extensively used material in the electronics industry. It is used in computer chips.

7. THERMAL CONDUCTORS AND INSULATORS

INTRODUCTION

The properties of thermal insulators and conductors are important because they help us to decide what materials are suitable for a particular purpose.

CONCEPT EXPLANATION AND CLARIFICATION

Substances that are good thermal insulators do not allow thermal energy to pass through them. Insulating materials are important for our buildings because they keep homes warm in winter and cool in summer.

Examples of thermal insulators are:
- Fibreglass
- Cellulose
- Polyurethane foam
- Polystyrene

Substances that are good thermal conductors allow thermal energy to pass through them. Good thermal conductors are useful for making pots for cooking food, for example.

It is recommended that the experiment described in the CAPS document for testing materials for thermal conductivity, be demonstrated in class.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:
- Learners must copy the question and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

8. Classify the following materials as thermal insulators or conductors:

- **a.** Wood
- **b.** Air
- **c.** Aluminium
- **d.** Glass
- **e.** Copper

Solution

- **a.** Insulator – Wood does not allow thermal energy to pass through it, because it contains lots of air pockets.
- **b.** Insulator – Gases generally are insulators. They do not allow thermal energy to pass through easily because their particles are far apart and do not transmit energy readily.
- **c.** Conductor – It is a metal and it readily allows thermal energy to pass through it. Generally, materials that are good electrical conductors are also good thermal conductors.
- **d.** Insulator – Generally non-metals are good insulators.
- **e.** Conductor – It is a metal; same as for aluminium.

8. MAGNETIC AND NON-MAGNETIC MATERIALS

INTRODUCTION

Magnetic materials are important because they play a big role in many of the modern appliances that we use every day.

CONCEPT EXPLANATION AND CLARIFICATION: MAGNETIC AND NON-MAGNETIC MATERIALS

Learners need to be able to classify materials as magnetic or non-magnetic according to the properties that they display. Magnets are used in many applications today, e.g. telephones, speakers, electric motors and generators, etc. It is recommended that the experiment described in the CAPS document for testing materials for magnetic and non-magnetic properties, be demonstrated in class.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the question and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

9. Classify the following materials as magnetic or non-magnetic:

a. graphite

b. iron

c. copper

d. glass

e. plastic

Solution

a. Non-magnetic – Graphite (carbon) is a non-metal although it conducts electricity. It is not affected by a magnet.

b. Magnetic – Iron is affected by a magnet and is the most commonly used material for making magnets today.

c. Non-magnetic – Even though copper is a metal it is not affected by a magnet and it cannot be used to make magnets.

d. Non-magnetic – Glass is a non-metal; it is not affected by a magnet.

e. Non-magnetic – Plastic is a non-metal; it is not affected by a magnet.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic questions, they are ready to deal with more challenging questions.

b. These questions require learners to be creative and to think independently about possible solutions.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

a. For these more challenging examples learners must be encouraged to think independently.

b. Learners must be able to analyse the properties of various materials and be able to choose their suitability for various purposes.

10. Which one of the following properties is applicable to graphite, found in pencil lead? It ...

A. is a conductor of electricity.

B. is a metal.

C. is magnetic.

D. has a low melting point.

Solution

A. Graphite is a non-metal but it does conduct electricity. It is also non-magnetic and it has a high melting point.

11. Which one of the following is NOT a property of iron? It ...

A. conducts electricity.

B. can be magnetised.

C. is a mixture of materials.

D. is an element.

Solution

C Iron is an element and consequently it is a pure substance. It is also a metal so it will conduct electricity and it can be magnetised.

12. Which one of the following would be most suitable to use for electrical wiring?

A. Glass

B. Plastic

C. Graphite

D. Aluminium

Solution

D Aluminium is a good conductor of electricity. Graphite also conducts electricity but it cannot be drawn into wire (ductile) as it is brittle. Glass and plastic are electrical insulators not conductors.

13. Which one of the following is not a pure substance?

A. Copper

B. Air

C. Oxygen gas

D. Sodium chloride

Solution

B Air is a mixture of a number of gases and consists of many different molecules and atoms. Copper, oxygen gas and sodium chloride all consist of one type of particle only and so are pure substances.

14. Which one of the following is the best thermal insulator?

A. Steel

B. Iron

C. Air

D. Water

Solution

C Air is the best thermal insulator because it is a gas. Water is also an insulator but it is liquid, so it is not as good an insulator as air. Iron and steel are good thermal conductors.

CHECKPOINT

At this point in the topic, learners should have mastered the following:

1. the ability to identify types of materials from their properties.
2. the skill of being able to choose a material that is suitable for a specified purpose.
3. the knowledge required to recall properties related to certain types of materials.

Check learners' understanding of these concepts by getting them to work through:

Topic 1 Worksheet from the Resource Pack: Matter and its classification: Questions 1–6. (Pages 4–5).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing: **Topic 1 Consolidation Exercise on Matter and its Classification from the Resource Pack. (Pages 6–7).**
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation exercise should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It should not be administered as a test, as the level of the work is altogether of a higher level of thinking.**

ADDITIONAL VIEWING / READING

In addition, further viewing or reading on this topic is available through the following web links:

1. https://www.youtube.com/watch?v=Hx9rRnxckwc
   This video is too long to show in class, and is suitable for teachers – the whole of classification of matter is covered here. Teachers might want to show short clips from the video.
2. https://www.youtube.com/watch?v=C4pQQQNwy30
   Physical properties of matter – for learners.
3. https://www.youtube.com/watch?v=x2AqHiZXdBI
   This is a very short video on conduction of electricity – for learners.
4. https://www.youtube.com/watch?v=RHQ17S72ON4
   This is a very short video on conduction of thermal energy – for learners.

TOPIC 2:

States of Matter and the Kinetic Molecular Theory

A Introduction

- This topic runs for 2 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- States of Matter and the Kinetic Molecular Theory forms part of the content area Matter and Materials (Chemistry).
- Matter and Materials counts 46,67% in the final Grade 10 Paper 2 (Chemistry) examination.
- States of Matter and the Kinetic Molecular Theory counts approximately 6% of the final Grade 10 Paper 2 (Chemistry) examination.
- States of Matter and the Kinetic Molecular Theory also helps in the classification of matter. The kinetic molecular theory, together with intermolecular forces are used to explain the three states of matter and change of state e.g. boiling.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard
2. Chalk and duster, pens.
3. Scientific calculator – highly recommend Sharp or Casio.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended.
3. Pen.

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7-9	**GRADE 10**	**GRADE 11-12**
• Atoms – the building blocks of matter. • Sub atomic particles. • The particle model of matter. • Changes of state.	• The particle nature of matter as illustrated by Brownian motion. • The three states of matter • Definitions of freezing point, melting point and boiling point. • Identify substances from their melting points and boiling points. • Melting, freezing, evaporation, condensation and sublimation as changes of state. • Demonstrating changes of state. • Description of a solid, a liquid and a gas according to the kinetic molecular theory in terms of the particles of matter.	• The application of intermolecular forces in explaining both high and low melting points and boiling points.

C Glossary of Terms

TERM	DEFINITION
Freezing point	The temperature at which a liquid changes to a solid by the removal of heat.
Melting point	The temperature at which a solid, given sufficient heat, becomes a liquid.
Boiling point	The temperature of a liquid at which its vapour pressure equals the external (atmospheric) pressure.
Melting	The process during which a solid changes to a liquid by the application of heat.
Evaporation	The change of a liquid into a vapour at any temperature below its boiling point.
Freezing	The process during which a liquid changes to a solid by the removal of heat.
Sublimation	The process during which a solid changes directly into a gas without passing through an intermediate liquid phase..
Deposition	The change of state that occurs when a substance changes directly from a gas to a solid (This is the opposite of sublimation).
Condensation	The process during which a gas or vapour changes to a liquid, either by cooling or by being subjected to increased pressure.
Diffusion	The movement of atoms or molecules from an area of higher concentration to an area of lower concentration.
Brownian motion	The random movement of microscopic particles suspended in a liquid or gas, caused by collisions between these particles and the motion of the liquid or gas.
Ion	A charged particle made from an atom by the loss or gain of electrons.
Intermolecular forces	The forces of attraction between the molecules making up a substance..
Fluid	A state of matter, such as liquid or gas, in which the particles that make up the substance (most often molecules) can move freely past one another.

D Assessment of this Topic

This topic is assessed by means of informal and control tests, and midyear and final examinations.

- There can be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.
- Prescribed experiment for formal assessment: *The heating and cooling curves of water*. [Refer to Grade 10 Term 1 Resource pack and the video supplied on the DVD].

E Breakdown of Topic and Targeted Support Offered

- Please note that this booklet does not address the full topic – only targeted support related to common challenges is offered.
- For further guidance on full lesson planning, please consult CAPS, the NECT Planner & Tracker and the textbook.

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
1 hour	Three states of matter	19	Key concepts and possible misconceptions are clarified and explained: a. The explanation for Brownian motion and diffusion. b. Full understanding of the meaning of the temperature at which the respective changes of state occur. c. Full explanation of cooling and heating curves of water.
1 hour	Kinetic molecular theory	19	Key concepts and possible misconceptions are clarified and explained: a. Full understanding of the link between intermolecular forces and change of state.

F Targeted Support per Sub-topic

1. THREE STATES OF MATTER

INTRODUCTION

Understanding the three states of matter and explaining the changes of state between them is an important foundation for work that follows in grade 11 and 12. It is essential that learners fully understand these basic concepts.

CONCEPT EXPLANATION AND CLARIFICATION: THREE STATES OF MATTER

The explanation of Brownian motion and diffusion

When a smoke cell is observed under a microscope, what is seen is tiny bright spots that are moving around randomly. It must be explained clearly to learners that what they are observing is not atoms or molecules moving around, but rather solid particles in the smoke that are being bumped by particles of the air in the smoke. This illustrates that the particles of air themselves are in continuous random motion and that is why they constantly bump into the microscopic solid particles of smoke. This is evidence for the fact that particles of matter are in constant motion.

Video number 1 (referenced at the end of this topic) can be shown at this stage. Explain what a fluid is before watching this video.

The explanation for the phenomenon of diffusion of fluids (gases and liquids) is also given in terms of the constant random motion of the particles making up the fluid.

Diffusion in liquids can be illustrated by putting some potassium permanganate crystals in a test tube and gently adding some water. After some time, all the water has a purple colour. The purple colour of the solution comes from the permanganate ions.

When the crystals dissolve in water, it is initially the potassium and the permanganate ions of the solid that are in contact with the water that go into solution. The water molecules are in contact with the surface of the crystal and become attracted to the ions.

A large number of water molecules exert a stronger force of attraction on the ions than the attraction between the ions in the crystal. The water molecules are in constant motion and they move the ions away from the solid crystal until they are spread out through the entire volume of water.

Diffusion occurs in gases by a similar process. If a bottle of perfume is opened at one end of the room, the smell eventually spreads to the entire room. This occurs because the moving air particles constantly bump into perfume molecules and spread them far and wide.

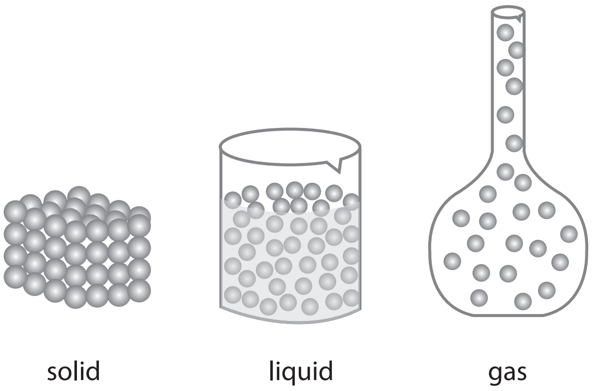
Note that diffusion always occurs from an area (or region) of higher concentration to one of lower concentration.

Video number 2 (referenced at the end of this topic) may be shown at this point.

Understanding of the meaning of the temperature at which the respective changes of state occur

1. First discuss with the learners what characterises each state of matter:
   - Solids have a fixed shape and a fixed volume.
   - Liquids have a fixed volume but take up the shape of their container, filling it from the bottom upwards.
   - Gases have neither a fixed shape nor a fixed volume. They fill the entire container.
2. Then emphasise that the state of a substance at a given temperature is dependent on:
   - The strength of the intermolecular forces between the particles making up the substance.
   - The amount of translational kinetic energy (motion from one point to another) of the particles of the substance.

   The diagram below shows the arrangement of particles in the three states of matter.

   Note further that temperature is a measure of the average kinetic energy of the particles making up a substance. The molecules of a gas have more kinetic energy than the molecules of a substance when it is in the solid state as the gas must be at a higher temperature than the solid.
3. Give definitions of freezing point, melting point and boiling point. When defining these, ensure that learners realize that changes of phase for pure substances occur at a constant temperature. So, the freezing point is the constant temperature at which a substance changes from the liquid state to the solid state.

   Make learners aware of the fact that evaporation occurs at any temperature and that it occurs only from the surface of the liquid. When boiling occurs, the change of liquid to gas takes place within the body of the liquid and it occurs at a specific temperature. Bubbles are seen forming during boiling, but not during evaporation.

Learners must be able to identify the state of a substance at room temperature (about 25°C) when given melting points and boiling points. They need to understand that:

- A substance is a solid at a temperature below its melting point.
- A substance is a liquid at any temperature between its melting point and its boiling point.
- A substance is a gas at a temperature above its boiling point.

Make learners aware of the fact that melting and freezing occur at the same temperature. Sublimation is the process that occurs when a solid changes directly to a gas when it is heated, without going through the liquid state. The reverse of sublimation is called deposition.

Recommended experiment: Demonstrate the changes of phase using water.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the question and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. The process involved when a solid changes directly to a gas is called ...

A. evaporation

B. melting

C. sublimation

D. boiling

Solution

Answer C

2. Select the correct statement. While a substance changes from solid to liquid ...

A. it gives off energy.

B. the average kinetic energy of the particles does not change.

C. the average kinetic energy of the particles increases.

D. the particles begin to move more slowly.

Solution

Answer B

While a substance changes phase there is no change in temperature. This means that the average kinetic energy of the particles remains constant, because a change in kinetic energy is related to a change in temperature.

3. Consider the following statements:

I. Evaporation of a liquid occurs at any temperature.

II. When a liquid evaporates at any temperature below its boiling point, the particles evaporate from the surface and the body of the liquid.

III. When a liquid evaporates at any temperature below its boiling point, the particles evaporate from the surface of the liquid only.

Which of the statements are true (correct)?

A. I only

B. I and II only

C. I and III only

D. III only

Solution

Answer C

Evaporation of a liquid is not the same as boiling; it does not occur at a specific temperature. The particles that leave the liquid during evaporation escape only from the surface of the liquid.

4. Brownian motion and diffusion are two pieces of evidence that the particles of matter are in constant random motion? Explain how each piece provides this evidence.

Solution

a) Brownian motion. This is shown by solid particles in smoke or in a liquid moving about randomly. This occurs because they are constantly being bumped into by other gas particles or liquid particles, which are moving about randomly. The actual particles of the gas or liquid are much too small to be seen directly.

b) Diffusion is the movement of particles from a high concentration to a region of lower concentration. The particles of the liquid bump into soild particles that have been placed there and eventually the solid particles spread throughout the liquid.

5. Define the following terms:

- **a.** boiling point
- **b.** melting point
- **c.** freezing point

Solution

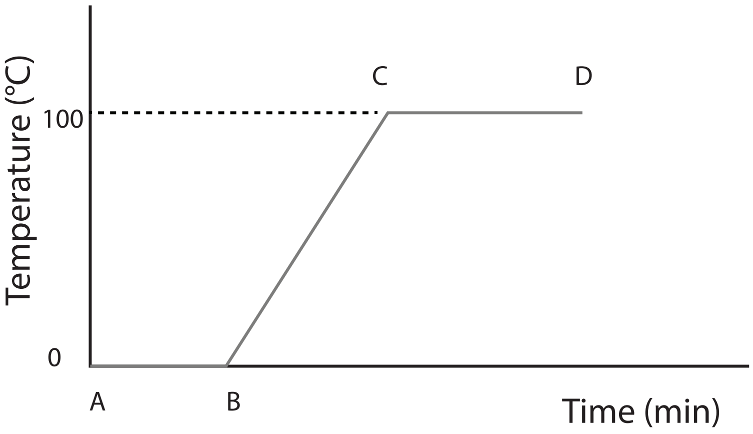
- **a.** The temperature of a liquid at which its vapour pressure equals the external (atmospheric) pressure.
- **b.** The temperature at which a solid, given sufficient heat, becomes a liquid.
- **c.** The temperature at which a liquid changes to a solid by the removal of heat.

Remind learners that freezing and melting occur at the same temperature for a particular substance.

FULL EXPLANATION OF COOLING AND HEATING CURVES OF WATER

- A heating curve for water can be obtained by putting some crushed ice in a beaker. Stir the ice with a thermometer and read the temperature of the water every minute. When all the ice has melted start to heat the water gently and continue taking readings until the water boils. Continue taking readings for about 3 minutes while the water is boiling.
- The readings are recorded and a graph of temperature vs time is plotted. The graph obtained should look like the following:

Heating curve for water



The shape of the graph needs to be explained carefully in terms of energy changes.

- Between A and B the temperature remains constant while the ice is melting. This indicates that a change of state is taking place. As the ice melts, the energy that is being supplied is not used to increase the kinetic energy of the molecules but rather it is used to move the molecules further apart from one another, in order to change water from solid ice to its liquid. Once this process is complete, the temperature begins to rise as the kinetic energy of the molecules is now increasing.

- Between B and C the temperature keeps increasing as the water is heated and the kinetic energy of the molecules keeps increasing. Most of the particles remain in the liquid state during this period of time. The only change of state occurs at the surface of the liquid, due to evaporation. This increases the pressure of the vapour above the surface.
- Between C and D, the water is boiling. At this point the vapour pressure exerted by the liquid is equal to the atmospheric pressure. So, there is another change of state – all the water molecules form gas. The temperature of the water stays constant even though you are still supplying heat. The energy supplied is now used to separate the molecules completely so that the water can change from a liquid to a gas.

Wherever the graph is a straight line, parallel to the time axis, this represents that a change of state is occurring.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

6. How can the melting point or boiling point of a substance be identified on a heating curve of the substance?

A. It is the steepest part of the graph.

B. It is the least steep part of the graph.

C. It is those parts of the graph which are parallel to the time axis.

D. It is those parts of the graph which are parallel to the temperature axis.

Solution

Answer C.

Whenever a change of state takes place, the temperature remains constant. That is why the graph is parallel to the time axis during these periods.

7. Explain why there is no change in temperature until all of a solid has turned into liquid.

Solution

The intermolecular forces (forces between the particles) in solids are very strong. In order for the solid to turn to liquid, all the intermolecular forces have to be weakened sufficiently to allow the particles to be able to flow over one another. For this to happen, energy is required.

While the forces are being weakened, even though energy is being supplied, the average kinetic energy of the molecules does not increase. Because the average kinetic energy of the particles is related to the temperature of a substance, the temperature must remain constant.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic questions, they are ready to deal with more challenging questions.

b. These questions require learners to be creative and to think independently about possible solutions.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

a. For these more challenging examples learners must be encouraged to think independently.

b. Learners must be able to explain changes of phase and the energy changes involved.

8. Which one of the following has the greatest density?

- **A.** Ice
- **B.** Water
- **C.** Oil
- **D.** Water vapour

Solution

Answer B.
This is a bit of a trick question. Under most circumstances, solids have a greater density than liquids and then gases. Although ice is solid, its molecules are arranged in such a way that there is a lot of space between them, so water is denser than ice; ice floats in water. Oil floats on water so it is less dense than water. Water vapour is a gas so the particles are very far apart, consequently it has a low density. Therefore, water has the greatest density out of all 4 substances given.

9. Temperature is a measure of ...

- **A.** the average kinetic energy of the particles.
- **B.** the potential energy of the particles.
- **C.** the strength of the intermolecular forces between the particles.
- **D.** the number of particles in the substance.

Solution

Answer A.
The average kinetic energy of the particles making up a substance changes when its temperature is changed.

10. Consider the following facts about the boiling point of a substance:

- **I.** It depends on the amount of substance present.
- **II.** It depends on the strength of the intermolecular forces between the particles of the substance.
- **III.** It is the temperature of a liquid at which its vapour pressure equals the external (atmospheric) pressure.

Which of these statements is true (correct)?

- **A.** I only.
- **B.** I and III only.
- **C.** I and II only.
- **D.** II and III only.

Solution

Answer D.
Statement I is incorrect. It does not matter how much of tthe substance is present, its boiling point doesn't change. The stronger the intermolecular forces, the more energy is needed to separate the particles, so it does affect the boiling point. Statement III is the definition of boiling point.

11. Explain, in terms of the forces between the particles, why it is possible to pour liquids.

Solution

The forces between the particles of a liquid are strong but flexible. This enables particles to flow over each other. Thus it is possible to pour liquids.

12. What information does Brownian motion provide regarding the motion of the particles of matter?

Solution

Brownian motion can be observed in liquids or gases. In a smoke cell observed under a microscope, tiny points of light are seen jumping around continuously. These specks of light are actually tiny solid particles that make up the smoke. The fact that they are constantly moving means that there invisible particles around them, causing them to move in that way. The invisible particles are particles of the air, thus showing that the molecules of the air are in constant random motion.

CHECKPOINT

At this point in the topic, learners should have mastered the following:

1. the concepts and implications of Brownian motion and diffusion.
2. what is meant by freezing point, melting point and boiling point.
3. describing the energy changes involved in changes of phase.
4. how to interpret heating and cooling curves of substances.

Check learners' understanding of these concepts by getting them to work through:

Topic 2 from the Resources Pack: States of Matter and the Kinetic Molecular Theory Worksheet: Questions 1–5. (Page 11).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

2. KINETIC MOLECULAR THEORY

INTRODUCTION

The kinetic molecular theory of matter is used to explain the arrangement of particles in the three states of matter in terms of the particle model.

CONCEPT EXPLANATION AND CLARIFICATION: FULL UNDERSTANDING OF THE LINK BETWEEN INTERMOLECULAR FORCES AND CHANGE OF STATE

- Intermolecular forces are the forces of attraction or repulstion that exist between molecules that make up a substance. There are also similar forces between particles that are not molecules.
- Intermolecular forces vary in strength from substance to substance. The stronger the forces are, the higher the melting point and boiling point will be.
- When energy is given to a substance, the molecules making up that substance tend to move apart and this leads to the weakening of the intermolecular forces. When enough energy is supplied to weaken the forces sufficiently, the molecules are able to flow over one another and the solid becomes a liquid.
- When the energy is sufficient to completely separate the molecules of a liquid from one another and the intermolecular forces are further weakened. More molecules can escape from the surface of the liquid. This increases the pressure the vapour can exert on the atmosphere. When the vapour pressure above a liquid equals the external atmospheric pressure all the liquid molecules move apart from each other; the liquid becomes a gas. We observe this in the formation of gas bubbles inside the body of the liquid and say that the liquid is boiling.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the basic facts.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

14. Choose the correct statement. When a substance changes state from a liquid to a solid ...

- **A.** the particles move closer together.
- **B.** the temperature of the substance increases.
- **C.** the forces between particles become weaker.
- **D.** the particles vibrate more strongly.

Solution

Answer A.

A substance changes state from liquid to solid when the temperature decreases. The particles thus vibrate less vigorously, they move closer together and the forces between them become stronger.

15. When a pure substance undergoes a change of state, the temperature ...

- **A.** increases.
- **B.** remains constant.
- **C.** decreases.
- **D.** fluctuates (i.e. changes randomly).

Solution

Answer B.
A change of state always occurs at a constant temperature.

CHALLENGE LEVEL QUESTIONS

- **a.** Now that learners have mastered the basic questions, they are ready to deal with more challenging questions.
- **b.** These questions require learners to be creative and to think independently about possible solutions.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

Learners need to be certain of the changes occurring in the intermolecular forces during changes of state.

16. Choose the correct statement. When a substance changes state from a liquid to a gas:

A. the temperature of the liquid decreases.

B. the intermolecular forces become stronger.

C. the molecules move further apart.

D. the particles vibrate less strongly.

Solution

Answer C.

A liquid changes to a gas when its temperature increases. The intermolecular forces are completely overcome and the particles become totally free to move.

17. Which one of the following is NOT a change of state?

A. Ice melts.

B. Snow forms in the clouds.

C. Sulfur is heated from 20°C to 40°C.

D. Alcohol boils.

Solution

Answer C.
Sulfur melts at 115,2°C, so in going from 20°C to 40°C it is simply being heated. There is no change of state taking place.

18. Consider the following statements regarding melting and/or boiling points of substances.

I. They depend on the initial temperature of the substance.

II. They depend on the amount of kinetic energy that the particles of the substance possess.

III. They depend on the amount of substance present.

Which statement(s) is/are correct?

A. I only

B. II only

C. III only

D. I and II only

Solution

Answer B.
The other statements are incorrect: it doesn't matter what temperature the substance is to begin with; it will melt or boil at the same temperature as always. The amount of substance present has no effect on either melting or boiling points.

19. What comment can be made about the melting point and boiling point of a substance if it is always a liquid at 25°C?

Solution

Its melting point must be below 25°C and its boiling point must be above 25°C. A substance is always liquid between its melting point and its boiling point.

20. Pure sulfur has a melting point of 115,2°C and a boiling point of 444,6°C. In what state is sulfur at a temperature of 100°C? Give a reason for your answer.

Solution

It will be solid. A substance will always be a solid at any temperature below its melting point.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. interpreting heating and cooling curves for substances.
2. explaining changes of state in terms of intermolecular forces.

Check learners' understanding of these concepts by getting them to work through:

Topic 2 from the Resources Pack: States of Matter and the Kinetic Molecular Theory Worksheet: Questions 6 and 7. (Page 11).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing: **Topic 2 from the Resource pack: Kinetic Molecular Theory Consolidation Exercise. (Pages 12–13).**
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.

- The consolidation exercise should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It is important to note that this consolidation exercise is NOT scaffolded.**
- **It should not be administered as a test, as the level of the work may be too high to be used in its entirety.**

ADDITIONAL VIEWING / READING

In addition, further viewing or reading on this topic is available through the following web links:

1. https://www.youtube.com/watch?v=UDj7BXA1CHU
   Brownian motion – suitable for learners.
2. https://www.youtube.com/watch?v=55CPfc9ij48
   This is a very short video showing the diffusion of potassium permanganate crystals in water.
3. https://www.youtube.com/watch?v=oT-mXy0Hc08
   This is a useful video for learners – it shows the melting of ice in time lapse and produces a graph at the same time.
4. https://www.youtube.com/watch?v=HYrQv-cF2YU
   This video is about heating and cooling curves – suitable for both teachers and learners. May be a bit long to show to learners.

TOPIC 3:

The Atom – Basic Building Block of All Matter

A Introduction

- This topic runs for 4 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- The Atom: Basic Building Block of all Matter forms part of the content area Matter and materials (Chemistry).
- Matter and materials counts 46,67% in the final Grade 10 Paper 2 (Chemistry) examination.
- The Atom: Basic Building Block of all Matter counts approximately 10% of this final examination.
- All matter is made up of atoms. Atomic structure is the foundation for understanding all interactions of matter and the formation of molecules and compounds

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk and duster, pens.
3. A Periodic Table of the Elements (Poster supplied with the NECT resources).

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended.
3. Pen, pencil, ruler.
4. A Periodic Table of the Elements (copied from page 29 of the 2015 Grade 10 Examination Guidelines).

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7-9	**GRADE 10**	**GRADE 11-12**
• Atoms – the building blocks of matter. • Sub atomic particles.	• Models of the atom. • Atomic mass and diameter. • Structure of the atom: protons, neutrons and electrons. • Isotopes. • Electron configuration.	• Concepts of relative atomic mass, isotopes. • Chemical calculations.

C Glossary of Terms

TERM	DEFINITION
Atomic number	The number of protons in the nucleus of an atom of an element.
Isotopes	Atoms of the same element having the same number of protons but different numbers of neutrons.
Relative atomic mass	The mass of a particle on a scale where an atom of carbon-12 isotope has a mass of 12.
Mass number	The number of protons and neutrons in the nucleus of an atom of an element.
Orbital	The region around the nucleus of an atom in which there is a high probability of finding an electron.
Electron configuration	The arrangement of electrons in the orbitals of an atom.
Ground state	The arrangement of electrons around a nucleus so that all the electrons occupy the lowest possible energy levels.
Energy levels	The regions around the nucleus where electrons are located.
Core electrons	The electrons around the nucleus of an atom which are not in the outermost energy level.
Valence electrons	The electrons around the nucleus of an atom which are in the outermost energy level.
Sub-atomic particles	Tiny particles that make up an atom.
Abundance (of isotopes)	The percentage of each isotope of an elementthat is found in an element in nature.
Hund's Rule	There is no pairing of electrons in p orbitals before there is at least one electron in each orbital.
Pauli's Exchange Principle	A maximum of two electrons per orbital is allowed, provided the electrons have spin in popposite directions.

D Assessment of this Topic

This topic is assessed by means of informal and control tests, and midyear and final examinations.

- There can be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.
- Recommended activity for informal assessment:
  - Have learners make a poster of the various models of the atom.
  - Have learners research the contributions of a number of scientists to the development of models of the atom. Choose from the list in the CAPS document page 20.
  - Do flame tests to identify some metal cations.

E Breakdown of Topic and Targeted Support Offered

- Please note that this booklet does not address the full topic – only targeted support related to common challenges is offered.
- For further guidance on full lesson planning, please consult CAPS, the NECT Planner & Tracker and the textbook.

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
0,5 hours	Models of the atom	20	a. Understanding the critical differences between models of the atom.
0,5 hours	Atomic mass and diameter	21	b. The meaning of relative atomic mass.
1 hour	Structure of the atom: protons, neutrons and electrons	21	a. The concepts of atomic number, mass number and the standard notation.
1 hour	Isotopes	22	a. The meaning and significance of the existence of isotopes. b. Understanding the difference between mass number and relative atomic mass.
1 hour	Electron configuration	22	a. Understanding how electrons are distributed into energy levels and orbitals. b. The meaning of the term orbitals.

F Targeted Support per Sub-topic

1. MODELS OF THE ATOM

INTRODUCTION

‘Models of the atom’ is a very suitable topic for demonstrating the concept of models in Science and how scientific theories are developed.

CONCEPT EXPLANATION AND CLARIFICATION: MODELS OF THE ATOM

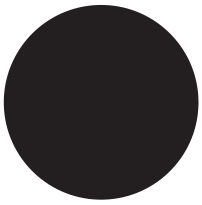
Understanding the critical differences between models of the atom

Learners need to understand the concept of a model in Science. A model is often used when the exact nature of something is not known to help us work with the concept and to help us explain observed phenomena. In the case of atomic models, they help us visualise something that cannot be seen. A model will change from time to time as new discoveries are made. In this sub-topic we will study the major stages in how scientific theories were developed and improved over time.

Historically there are five major contributions to the development of models of the atom made by the following scientists:

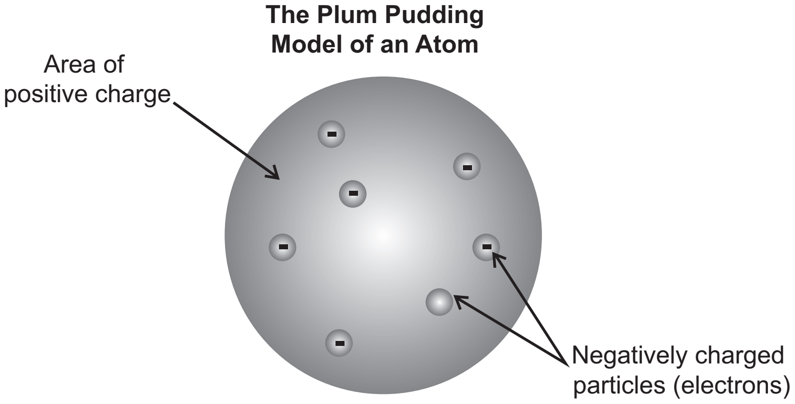
1. Democritus
2. Dalton
3. Thomson
4. Rutherford
5. Bohr

- Democritus did not develop any model of the atom – he was the first to suggest the existence of atoms.
- Dalton proposed the ‘billiard ball’ model of the atom. According to this model, the atom is indivisible – meaning that it cannot be broken down any further.



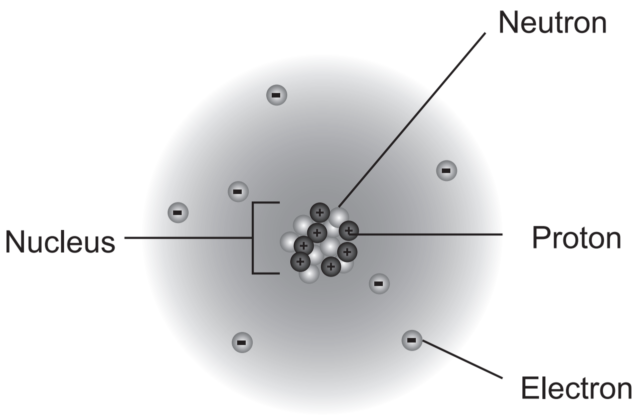
Dalton
“Billard Ball” Model

- Thomson's model suggested that atoms are not indivisible, which opposed Dalton's idea of an atom. Thomson proposed that there were charged particles smaller than atoms that together made up atoms. His idea was that there was a spongy positive mass in which negative charges were embedded. This is the 'plum pudding' or 'currant bun' model of the atom.



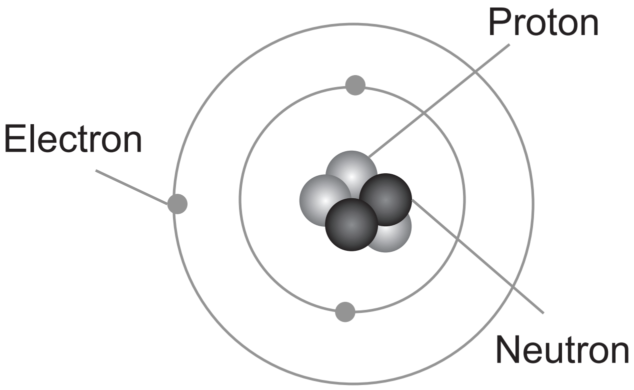
- Rutherford devised an experiment by which he could investigate whether Thomson's model was correct. This became one of the most famous experiments ever carried out and is called Rutherford's gold foil experiment or the alpha particle scattering experiment. Rutherford used a radioactive source, that produced positively charge alpha particles identical to the nucleus of the helium atom, to bombard a thin sample of gold foil. Rutherford expected most of the alpha particles to bounce off the atoms of gold. However, he found most of the alpha particles passed straight through the gold foil.

  Rutherford concluded, in fact, that the positive and negative charges in atoms are separate. The positive charges made up what he called the nucleus of an atom and the negative charges, called electrons, moved around the nucleus in orbits at a relatively large distance from the nucleus. He used this model to explain how most of the alpha particles passed straight through the gold foil. This was the critical difference to Thomson's model – the separation of charges. This model became known as the 'nuclear' model of the atom.



- The next significant model was Bohr's model of the atom. This model improved on Rutherford's model in that Bohr's idea was that electrons do not move around the nucleus in orbits, all the same distance from the nucleus. According to Bohr's model, electrons have different energy and so are arranged in shells that are at different distances from the nucleus. The shell closest to the nucleus has the lowest energy and the shell furthest away from the nucleus has the highest energy.

  Bohr's model was called the 'solar system model'.



- The modern model of the atom was developed by numerous scientists and is called the wave mechanical model. The big difference is that today, electrons are regarded as having wave properties rather than being particles and that the places where electrons are found around the nucleus are called orbitals. An orbital is a region in space where we are most likely to find electrons with a certain energy. Orbitals are not all the same – they have different shapes and size because they have different energy.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the basic facts.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. Which scientist's model was known as the nuclear model of the atom?

- **A.** Thomson
- **B.** Dalton
- **C.** Rutherford
- **D.** Bohr

Solution

Answer C.
Rutherford was the first scientist to propose a positive nucleus at the centre of all atoms.

2. What is the significant difference between the Thomson model of the atom and the Rutherford model?

- **A.** The Thomson model of the atom saw the atom as being indivisible, while the Rutherford model saw atoms as divisible.
- **B.** Rutherford's model had charges while Thomson's did not.
- **C.** Thomson's model incorporated a nucleus while Rutherford's did not.
- **D.** Rutherford's model incorporated a nucleus while Thomson's did not.

Solution

Answer D.
Rutherford was the first scientist to propose the existence of a nucleus.

3. Dalton's model of the atom was called the:

- **A.** billiard ball model.
- **B.** nuclear model.
- **C.** solar system model.
- **D.** plum pudding model.

Solution

Answer A.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic questions, they are ready to deal with more challenging questions.

b. These questions require learners to apply their knowledge.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

In these more challenging examples, learners must think carefully before applying their knowledge in the required way.

4. List the most important aspects of the five major contributions to the development of the model of the atom, up to Bohr's ideas about the atom.

Solution

- According to Dalton the atom could not be broken down to any smaller particles.
- Thomson discovered that the atom, in fact, consisted of smaller negative charges embedded in a positive mass.
- Rutherford's model separated the charges by finding that there was a positive central mass (the nucleus) surrounded by negative charges moving in orbits around the nucleus.
- Bohr improved on this by saying that the negative charges could only exist in shells of different energy, at different distance, around the nucleus like the planets around the Sun.

5. Give two significant ways in which the modern model of the atom differs from the Bohr model.

Solution

- Today electrons are regarded as predominantly having a wave nature rather than a particle nature.
- Electrons are found in regions called orbitals rather than in 'orbits'.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. being able to describe the five major models of the atom up to the Bohr model.
2. knowing and understanding the critical differences and improvements in the models as they were developed.

Check learners' understanding of these concepts by getting them to work through:

Topic 3 from the Resource Pack: The Atom: Building Block of All Matter: Questions 1 and 2. (Page 17).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

2. ATOMIC MASS AND DIAMETER

INTRODUCTION

The actual masses of atoms are so small that the numbers are very cumbersome to work with. The relative atomic scale was introduced to simplify calculations by turning the numbers into ordinary numbers.

CONCEPT EXPLANATION AND CLARIFICATION

The meaning of relative atomic mass

Actual masses of atoms are extremely small numbers, e.g. the mass of a hydrogen atom is $1{,}67 \times 10^{-27}$ kg. When this is written as a decimal, it is a number that has 26 zeros after the decimal comma. The relative atomic mass is a way of simplifying these very small numbers to numbers that are easier to work with. This is done by comparing the masses of atoms with a common standard. This standard is the isotope of carbon called carbon-12. On this scale the isotope carbon-12 has a mass of exactly 12,00 units.

Relative atomic mass is obtained by using a ratio of two masses and thus it has no units. The relative atomic mass of magnesium is 24. This means that the average mass of a magnesium atom is 24 times the mass of $\frac{1}{12}$ of the mass of a carbon-12 isotope.

The diameters of atoms are of the order of 10^{-10} m. Most of the atom is empty space with the mass concentrated in the tiny nucleus at the centre of the atom.

3. STRUCTURE OF THE ATOM: PROTONS, NEUTRONS AND ELECTRONS

INTRODUCTION

We now start a discussion about sub-atomic particles, which we will confine to protons, neutrons and electrons (in fact there are over 100 sub-atomic particles). This will enable us to understand how atoms of different elements are made up.

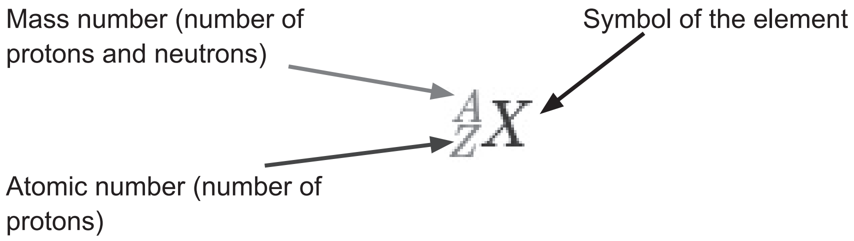
CONCEPT EXPLANATION AND CLARIFICATION

The concepts of atomic number, mass number and the standard notation.

The Atomic number is the number of protons in the nucleus of an atom of an element. This is how atoms are identified as belonging to a particular element. All atoms of the same element have the same number of protons in their nuclei. **The symbol for atomic number is the letter Z**.

The Mass number is defined as the number of protons and neutrons in the nucleus of an atom of an element. It is possible to have different atoms of the same element with different mass numbers. N.B. Mass number applies to specific isotopes of an element only – not to the element as a whole. **The symbol for mass number is the letter A**.

There is a standard way to summarise this information in a short-hand way. This standard notation is as follows:



This notation gives the following information:

1. What the element is.
2. The symbol that identifies the element.
3. The number of protons and neutrons (also called nucleons) in the nucleus of an isotope of the element.
4. It also gives the number of electrons in a neutral atom of the element. It is the same as the number of protons. The number of neutrons is given by A – Z.

Learners must be aware of the fact that an atom is electrically neutral when there are equal numbers of protons and electrons. However, the number of electrons may change. An atom may lose electrons, in which case it will become positively charged (cation) or gain electrons, in which case it will become negatively charged (anion). In the standard notation, the charge is indicated in the top right hand space above the symbol of the element.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. The mass number of an isotope is ...

A. the number of protons in its nuclei.

B. the number of neutrons in its nuclei.

C. the number of protons and neutrons in its nuclei.

D. the number of electrons around its nuclei.

Solution

Answer C.
This is the definition of mass number.

2. The atomic number of an element is ...

A. the number of protons in its nuclei.

B. the number of neutrons in its nuclei.

C. the number of protons and neutrons in its nuclei.

D. the number of electrons around its nuclei.

Solution

Answer A.
This is the definition of atomic number.

3. The letter Z represents ...
   - **A.** the atomic number.
   - **B.** the mass number.
   - **C.** the number of electrons.
   - **D.** the charge on an atom.

Solution

Answer A.

4. A symbol is written as Ca^{2+}.
   - **a.** What does this mean?
   - **b.** What name is given this sort of particle?

Solution

- **a.** It means that a neutral calcium atom has lost two electrons and now has an excess positive charge, due to the fact that the number of protons has not changed.
- **b.** This is a positively charged ion and is called a cation. (All positive ions are called cations.)

5. What property of the nucleus of an element is used to identify it?

Solution

All atoms are identified by their atomic number, i.e. the number of protons in their nucleus.

CHALLENGE LEVEL QUESTIONS

- **a.** Now that learners have mastered the basic concepts, they are ready to deal with more challenging questions.
- **b.** These questions require learners to apply the concepts that they have discussed.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

In these more challenging examples, learners must think carefully before applying their knowledge in the required way.

6. Which one of the statements is correct about $^{20}_{10}Ne$? It has:

- **A.** 20 neutrons.
- **B.** 20 electrons.
- **C.** 10 protons.
- **D.** 10 nucleons.

Solution

Answer C

The number on the bottom left is the atomic number, which is the number of protons.
The number of electrons is equal to the number of protons – 10.
The number of neutrons is 20 – 10 = 10.

7. The number of electrons in $^{41}_{20}Ca^{2+}$ is:

- **A.** 18
- **B.** 20
- **C.** 21
- **D.** 41

Solution

Answer A.

In a neutral atom of calcium there are 20 electrons, the same as the atomic number. However; this atom has lost 2 electrons (it has a charge of +2). So, it has 18 electrons.

8. How many neutrons are there in $^{48}_{23}X$? Show how you arrived at your answer.

Solution

Number of neutrons = A – Z = 48 – 23 = 25

9. Define relative atomic mass.

Solution

The mass of a particle on a scale where an atom of carbon-12 isotope has a mass of 12.

10. Copy and complete the table by filling in the number of particles in each atom in the blocks.

ATOM	PROTONS	NEUTRONS	ELECTRONS IN NEUTRAL ATOM
$^{11}_{5}B$			
$^{31}_{15}P$			
$^{40}_{18}Ar$			

Solution

ATOM	PROTONS	NEUTRONS	ELECTRONS IN NEUTRAL ATOM
$^{11}_{5}B$	5	6	5
$^{31}_{15}P$	15	16	15
$^{40}_{18}Ar$	18	22	18

The number of neutrons is obtained by doing the calculation A – Z.

The number of electrons in a neutral atom is the same as the number of protons.

11. Determine the number of electrons in $^{24}_{12}Mg^{2+}$. Explain how you arrived at your answer.

Solution

The atomic number of magnesium is 12. This tells us that the number of protons and electrons in a neutral atom is 12. In this positively charged cation, the overall charge is +2. This means that the atom lost two electrons to form the cation. So the number of electrons is 12 – 2 = 10 electrons.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. knowing and understanding the definitions of atomic number and mass number.
2. knowing and understanding the standard notation $^{A}_{Z}X$.
3. knowing how to determine the numbers of protons, neutrons and electrons in a particular atom or ion.

Check learners' understanding of these concepts by getting them to work through:

Topic 3 from the Resource Pack: The Atom: Building Block of All Matter: Questions 3–6. (Pages 17–18).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

4. ISOTOPES

INTRODUCTION

Learners must understand that not all of the atoms of an element have exactly the same numbers of protons and neutrons but that it is possible for atoms to differ by the number of neutrons in their nuclei. These different atoms are called isotopes.

CONCEPT EXPLANATION AND CLARIFICATION

The meaning and significance of the existence of isotopes.

- The definition of isotopes is:
  Isotopes are atoms that have the same atomic number but different mass numbers.
- From the definition it is implied that if the atoms have the same atomic number they must be atoms of the same element. The mass numbers differ because not all of the atoms have exactly the same number of neutrons.
- Isotopes of an element all behave in the same way chemically. The only way in which they differ is in their mass.

Understanding the difference between mass number and relative atomic mass

Relative atomic mass and mass number are not the same thing. Mass number is the sum of the protons and the neutrons present in the nucleus of an atom and it must be a whole number since there cannot be fractions of protons and neutrons. The mass number can only be used in conjunction with a particular nuclide (isotope) of an element. The relative atomic mass as it appears on the Periodic Table is the weighted average of the masses of all the isotopes that make up an element. This number has fractions of a whole. The proportion of each isotope present in each element in nature is called the abundance of the isotopes. The relative atomic mass can be calculated if the percentage of each isotope present in the element is known (see examples).

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the concepts.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

12. Consider the following isotope: $^{14}_{8}O$

Which one of the following could be the mass number for another isotope of oxygen?

A. 6

B. 7

C. 8

D. 12

Solution

Answer D
This isotope has 8 protons. The mass number must always be greater than 8.

13. Consider the following statements about isotopes of the same element:

I. They have different value of Z.

II. They have the same number of neutrons.

III. They have the same number of protons.

Which statement(s) is/are correct?

A. I only

B. III only

C. I and III only

D. II and III only

Solution

Answer B
If atoms have the same number of neutrons that does not make them isotopes of each other. If they have different values of Z, they are atoms of different elements and they cannot be isotopes. Isotopes of the same element will always have the same number of protons.

14. Define the term isotopes.

Solution

Atoms of the same element having the same number of protons but different numbers of neutrons.

15. Explain how it is possible for isotopes of an element to exist.

Solution

Atoms of the same element (with the same atomic number), can have different numbers of neutrons (and thus a different mass number). This means that isotopes of an element have different masses. Their chemical properties are always the same.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic concepts, they are ready to deal with more challenging questions.

b. These questions require learners to do calculations on relative atomic mass and answer more complex questions.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

In these more challenging examples, learners must manipulate the data and/or interpret the given information before answering the questions.

16. Which of the following pairs are isotopes of the same element?

A. $^{24}_{12}W$ and $^{27}_{13}X$

B. $^{24}_{12}W$ and $^{25}_{12}Z$

C. $^{25}_{12}Z$ and $^{25}_{11}Y$

D. $^{27}_{13}X$ and $^{25}_{12}Z$

Solution

Answer B

Only W and Z have the same atomic number (12).

17. In what way do isotopes of an element differ from each other?

Solution

Isotopes of the same element only differ in mass. Neutral atoms of isotopes of the same element have different numbers of neutrons. The mass number of these isotopes will therefore also be different..

18. Explain the difference between mass number and relative atomic mass.

Solution

Mass number is the sum of the number of protons and neutrons in the nucleus of a particular nuclide (isotope). Remember that this number must always be a whole number because you cannot get fractions of a proton or a neutron. The relative atomic mass is a comparison of the mass of a particle to the mass of carbon-12. The relative atomic mass of an element as it appears on the Periodic Table, is the weighted average of the masses of all the isotopes of that element, found in any naturally occurring sample of an element. This number can be written as a decimal fraction.

19. Calculate the relative atomic mass of magnesium given that the abundance of its isotopes are:

Mg –24 = 78,99%

Mg –25 = 10,00%

Mg –26 = 11,01%

Solution

$$\text{Relative atomic mass} = \frac{(24 \times 78{,}99) + (25 \times 10{,}00) + (26 \times 11{,}01)}{100}$$

$$= 24{,}32$$

We assume that we are dealing with a sample of 100 atoms and that is why we divide by 100. In the calculation we have multiplied 24 (mass number of isotope 1) by its percentage. Then the mass number of isotope 2 by its percentage and then the mass number of isotope 3 by its percentage.

20. Calcium consists of three naturally occurring isotopes: Ca – 40, Ca – 42 and Ca – X. They occur in the following abundance:

%Ca – 40 = 96,94%

%Ca – 42 = 1,00%

%Ca – X = 2,00%

The relative atomic mass of calcium is 40,08. Calculate the mass number of Ca – X.

Solution

$$\begin{aligned}\text{The total mass of a sample of 100 calcium atoms} &= \text{Relative atomic mass} \times 100\\ &= 40{,}08 \times 100\\ &= 4\ 008\end{aligned}$$

Mass of Ca^{-40} atoms $= 40 \times 96{,}94 = 3\ 878$ (Round off to the closest whole number)

Mass of Ca^{-42} atoms $= 42 \times 1{,}00 = 42$

Mass of Ca^{-X} atoms $= X \times 2{,}00 = 2X$

$4\ 008 = 3\ 876 + 42 + 2X$

$2X = 88$

$X = 44$

Mass number = 44

CHECKPOINT

At this point in the topic, learners should have mastered:

1. an understanding of why isotopes exist.
2. knowing how to calculate the relative atomic mass of an element, given its isotopes and their abundance.

Check learners' understanding of these concepts by getting them to work through:

Topic 3 from the Resource Pack: The Atom: Building Block of All Matter: Question 7. (Page 18).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

5. ELECTRON CONFIGURATIONS

INTRODUCTION

The arrangement of electrons around the nucleus is a key to understanding the reactivity of the elements and how they react with each other.

CONCEPT EXPLANATION AND CLARIFICATION

Understanding how electrons are distributed into energy levels and orbitals

The term 'electron configuration' refers to the way that electrons are arranged around the nucleus. Remind learners that according to the Rutherford model of the atom, electrons move in orbits a relatively long way from the nucleus. Bohr changed that model by proposing that electrons move around the nucleus in shells with specific energy. Today these shells are called energy levels. Tell learners that are three 'rules' that we use to work out the distribution of electrons into energy levels:

1. Energy levels are filled from the lowest energy to the highest energy (Aufbau principle).
2. There can only be two electrons of opposite spin in any one orbital (This rule is called Pauli's exclusion principle).
3. When there is more than one orbital of the same energy, each orbital must be filled singly before it can be occupied by two electrons (This is called Hund's rule).

Before going any further some of the terms need to be clarified.

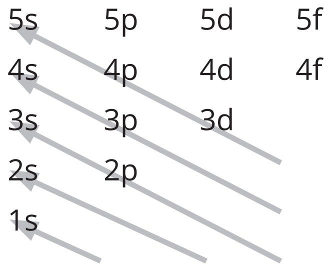
The meaning of the term 'energy levels'

Energy levels are arranged around the nucleus in order of increasing energy, with the lowest energy level being the one closest to the nucleus. The energy levels are labelled simply 1,2,3…..starting at the one closest to the nucleus.

The meaning of the term 'orbitals'

Each energy level is split into orbitals, called s,p,d and f orbitals.

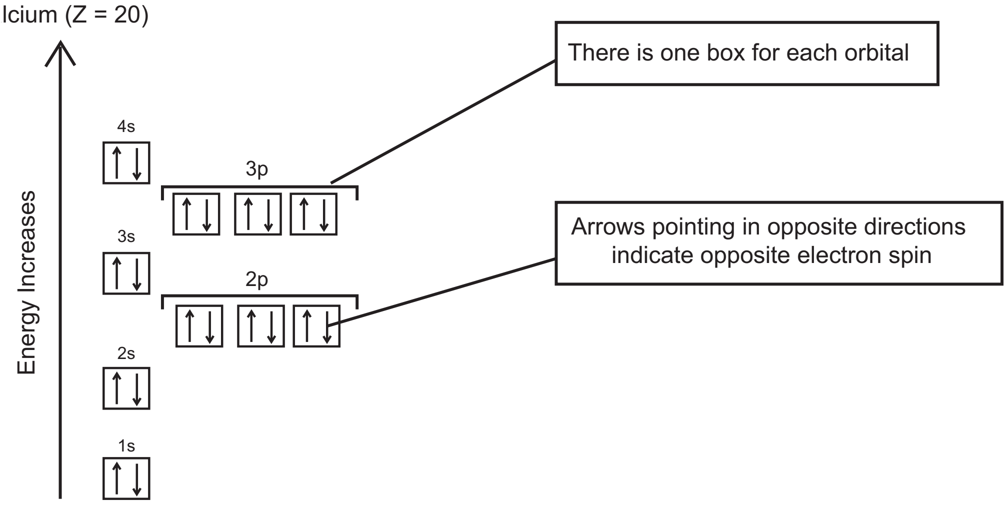
- In the first energy level there is only an s orbital. In every energy level after that there will be an s orbital. We distinguish s orbitals by putting the number of the energy level in front of the orbital symbol, e.g. 1s, 2s and so on.
- The second type of orbital is called a p orbital and this type of orbital first appears in the second energy level. The important thing about p orbitals is that they occur in groups of 3. So there are three 2p orbitals placed at right angles to each other.
- When electrons are distributed around the nucleus, it is done according to the 'Aufbau Principle', in the following order of orbitals:



This diagram shows that we fill the energy levels from the lowest energy 1s then 2s then 2p sub-level followed the 3s orbital. Next, we fill the 3p and then the 4s. The next sub-level that fills is the 3d sub-level. We do not study the way electrons are arranged in the 3-d orbital or higher energy levels at school level.

There are other ways in which the arrangement of electrons around the nucleus can be represented:

1. Orbital box diagrams (Energy Level Diagrams)



There is one box for each orbital

Arrows pointing in opposite directions indicate opposite electron spin

2. The spectroscopic electron configuration notation (just called electron configuration). Using the same element (calcium) as in the above illustration, this is as follows:

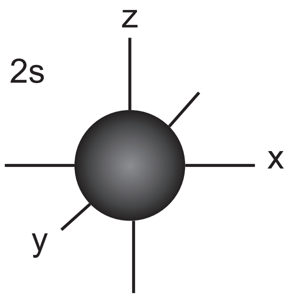
   Electron configuration of calcium: $1s^2\ 2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^2\ 3s^2\ 3p_x^2\ 3p_y^2\ 3p_z^2\ 4s^2$

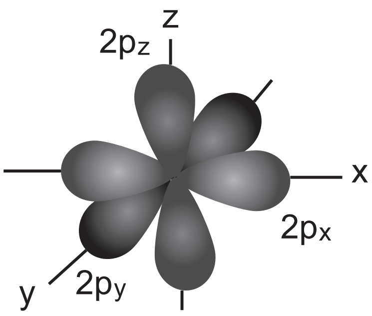
   This is often simplified to show all the p orbitals as one sub-level:

   Electron configuration of calcium: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

An orbital is a region in space in which there is a high probability of finding an electron. So, unlike an orbit or a shell, an orbital is not a fixed path, but rather a shape in which there is a high probability of finding an electron.

s and p orbitals have the following shapes:





The arrangement of electrons around a nucleus when all the electrons occupy the lowest possible energy levels is called the ground state of the atom. However, electrons may gain energy and move up to an orbital which is not their ground state orbital, but one of higher energy. The outermost electron will usually jump up to a new energy level. This is known as an excited state. However, this is an unstable state and the electron will return to its ground state.

INTRODUCTORY LEVEL CALCULATIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the concepts.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. Which one of the following rules or theories is not used to work out the distribution of electrons around the nucleus?

A. Hund's rule

B. The kinetic molecular theory

C. The Aufbau principle

D. Pauli's exclusion principle

Solution

Answer B

All of the other 'rules' are used to determine the electron distribution of an atom.

2. Which one of the following is the correct electron configuration for nitrogen?

A. $1s^2\ 2s^2\ 2p_x^1\ 2p_y^1\ 2p_z^1$

B. $1s^2\ 2s^2\ 2p_x^1\ 2p_y^2$

C. $1s^2\ 2s^2\ 2p_x^2\ 2p_y^1$

D. $1s^2\ 2s^2\ 2p_y^2\ 2p_z^1$

Solution

Answer A

There are seven electrons to be distributed. The first four electrons fill s-orbitals. (Apply Pauli's exclusion principle). The last three electrons (in the 2p orbitals) must follow Hund's rule. Each orbital must have one electron before any of them can have two.

3. Write down the electron configurations for:

3.1 aluminium

3.2 oxygen.

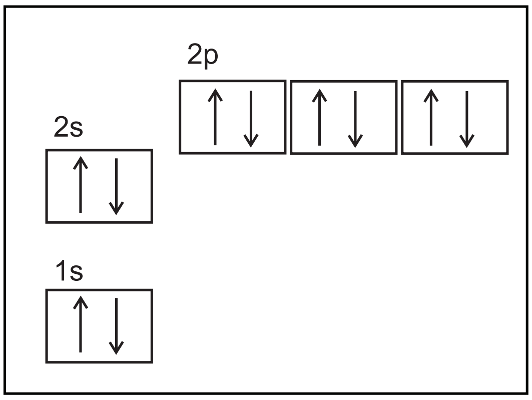
Solution

3.1 Aℓ: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

3.2 O: $1s^2\ 2s^2\ 2p^4$ or $1s^2\ 2s^2\ 2p_x^{\ 2}\ 2p_y^{\ 1}\ 2p_z^{\ 1}$.

4. Draw an orbital box (energy level) diagram to represent the electron distribution of neon.

Solution



All the orbitals are filled. Notice that paired electrons (spinning in opposite directions) occupy every orbital.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic concepts, they are ready to deal with more challenging questions.

b. These questions require learners to apply their knowledge, rather than simply recalling facts.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

a. Learners must have a thorough understanding of the rules for distributing electrons into orbitals, in particular Hund's rule.

b. Learners must know how to to draw diagrams to represent different orbitals.

5. Write down the electron configuration of a potassium atom in an excited state.

Solution

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^0\ 3d^0\ 4p^0\ 5s^1$

An atom of potassium has 19 electrons. This information is obtained from the Periodic Table (atomic number). The orbital normally occupied after 3p is the 4s orbital. The fact that the outer electron is in the 5s orbital, means that it is in an excited state. Transitions of electrons to higher energy levels are governed by complex rules of quantum mechanics.

For learners at school an excited state could be one where an electron has moved from the ground state to any unoccupied higher energy level or orbital within the same energy level:

e.g. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^0\ 3d^1$ would also have been correct.

6. Explain the difference between the terms orbit and orbital.

Solution

The term orbit refers to an object moving in a fixed path around another. A good analogy is the movement of planets around the Sun. We can tell where the Earth is in its orbit around the Sun at any given time.

An orbital is a region in space with a specific shape where there is a high probability of finding an electron. This means that the electron is somewhere in that space but we don't know exactly where it is.

7. What is meant by the excited state of an atom?

Solution

An excited state occurs when energy is supplied to an atom and an electron in the outer energy level of the atom absorbs a certain amount of energy which enables it to occupy an orbital further away from the nucleus than when it is in the ground state. The excited state is unstable and the electron will quickly return to its ground state and release energy in the process.

CHECKPOINT

At this point in the topic, learners should have mastered the following:

1. knowing and applying the rules used in distributing electrons around the nucleus.
2. knowing how to draw orbital diagrams and electron configurations.
3. knowing and understanding the difference between the terms ‘orbit’ and ‘orbital’.

Check learners’ understanding of these concepts by getting them to work through:

Topic 3 from the Resource Pack: The Atom: Building Block of All Matter: Questions 8–10. (Page 18).

- Check learners’ understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topic 3 from the Resource Pack: The Atom: Building Block of All Matter Consolidation Exercise. (Pages 19–20).**
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation exercise should be marked by the teacher so that she/he is aware of each learner’s progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- It is important to note that this consolidation exercise is NOT scaffolded.
- It should not be administered as a test, as the level of the work may be too high to be used in its entirety.

ADDITIONAL VIEWING / READING

In addition, further viewing or reading on this topic is available through the following web links:

1. https://www.thoughtco.com/protons-neutrons-and-electrons-in-an-atom-603818
   This is reading material on atomic structure suitable for learners.
2. https://www.thoughtco.com/write-the-nuclear-symbol-of-an-atom-609562
   This is reading material on writing standard notation suitable for learners.
3. https://www.thoughtco.com/definition-of-isotopes-and-examples-604541
   This is reading material on isotopes suitable for learners.
4. 4. https://www.youtube.com/watch?v=Ewf7RlVNBSA
   This is a video on orbitals which is suitable viewing for teachers.

TOPIC 4:

The Periodic Table

A Introduction

- This topic runs for 4 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- The Periodic Table forms part of the content area Matter and materials (Chemistry).
- Matter and materials counts 46,67% in the final Grade 10 Paper 2 (Chemistry) examination.
- The Periodic Table counts approximately 10% of this final examination.
- The Periodic Table is fundamental to all of Chemistry. It is an extremely useful tool and contains vast amounts of information, both obvious and deduced.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. A Periodic Table of the Elements (Poster supplied with the NECT resources).
4. The tables of common cations and anions (polyatomic ions) (as specified on pages 161 – 163 of CAPS).

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises.
2. Scientific calculator – highly recommended Sharp or Casio.
3. Pen, pencil, ruler
4. A Periodic Table of the Elements (copied from page 29 of the 2015 Grade 10 Examination Guidelines).
5. The tables of common cations and anions (polyatomic ions) (as specified on pages 161 – 163 of CAPS).

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7-9	**GRADE 10**	**GRADE 11-12**
• Arrangement of elements in the Periodic Table. • Some properties of metals, semi-metals and non-metals.	• The position of the elements in the Periodic Table related to their electronic arrangements. • Similarities in chemical properties among elements in groups 1, 12 and 18. • Chemical bonding. • Particles substances are made from. • Quantitative aspects of chemical change.	• Quantitative aspects of chemical change. • Basic to everything in Chemistry. • Intermolecular forces. • Atomic combinations: molecular structure.

C Glossary of Terms

TERM	DEFINITION
Groups	The vertical columns in the Periodic Table. Some groups have names e.g alkali metals (group 1), alkaline earth metals (group 2), halogens (group 17) and noble gases (group 18).
Periods	The horizontal rows in the Periodic Table.
Atomic radius	The radius of an atom i.e the mean distance from the nucleus of an atom to the border of the outermost energy level.
Ionisation energy	The energy needed per mole to remove electrons from atoms in the gaseous phase.
1st Ionisation Energy	The energy needed per mole to remove the 1st electron from an atom in the gaseous phase.
Electron affinity	The energy released when an electron is attached to an atom or molecule to form a negative ion.
Electronegativity	A measure of the tendency of an atom in a molecule to attract bonding electrons.
Periodicity	The repetition of similar properties in chemical elements, as indicated by their positioning on the Periodic Table.
Chemical properties	This refers to the way in which an element will react with other elements.
Valence electrons	These are the electrons which occupy the outermost energy level in an atom.
Halides	These are compounds formed when halogens (elements in group 17) react with metals
Oxides	These are compounds formed when oxygen combines with metals or other non-metals.
Anomaly	An event/observation that does not follow the norm or trend.
Monatomic	Substances consisting of molecules made up of one atom, e.g. the noble gases
Diatomic	Substances consisting of molecules made up of two atoms, hydrogen (H_2), nitrogen (N_2), oxygen (O_2), fluorine (F_2), chlorine ($C\ell_2$), bromine (Br_2) and iodine (I_2).

D Assessment of this Topic

This topic is assessed by means of informal and formal tests, and midyear and final examinations.

- There can be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.
- Recommended activity for informal assessment: Have learners research and present a report on information on the elements and the development of the Periodic Table.

E Breakdown of Topic and Targeted Support Offered

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
2 hours	The position of the elements in the Periodic Table related to their electronic arrangements	23	**a.** The Periodic Table is a systematic way of arranging the elements. **b.** Relate the position of elements to electron structure. **c**. Understanding periodicity and trends in the Periodic Table
2 hours	Similarities in chemical properties among elements in Groups 1, 12 and 18	24	**a.** The chemical properties of the elements in groups 1,2, 17 and 18 related to electron arrangement. **b.** Predicting chemical properties of unfamiliar elements. **c**. Sectioning of the Periodic Table into metals, non-metals and transition metals.

F Targeted Support per Sub-topic

1. THE POSITION OF THE ELEMENTS IN THE PERIODIC TABLE RELATED TO THEIR ELECTRONIC ARRANGEMENTS

INTRODUCTION

The Periodic Table is arranged with the elements in order of increasing atomic number. Elements having similar chemical properties are placed in the same groups of the Periodic Table. On the modern Periodic Table this results in elements with the same electron arrangements in the outermost energy level, being in the same group.

CONCEPT EXPLANATION AND CLARIFICATION

The Periodic Table is a systematic way of arranging the elements

- The elements are arranged in order of increasing atomic number in the Periodic Table.
- Learners must understand that the way that the elements are arranged in the Periodic Table results in elements with similar properties ending up one below the other in groups.
- Groups are the vertical columns in the Periodic Table. All the elements in each group have the same number of valence electrons.
- Valence electrons are all the electrons in the outer **energy level**. It is these electrons from the valence energy level (the valence electrons) that can participate in interactions (bonding) with other atoms. Learners must be aware that sometimes all of the valence electrons take part in bonding with other atoms, and in other cases only some of them are involved.
- The number at the top of each group is called the group number. The groups are numbered 1 to 18 from left to right across the Periodic Table.

Relate the position of elements to electron structure

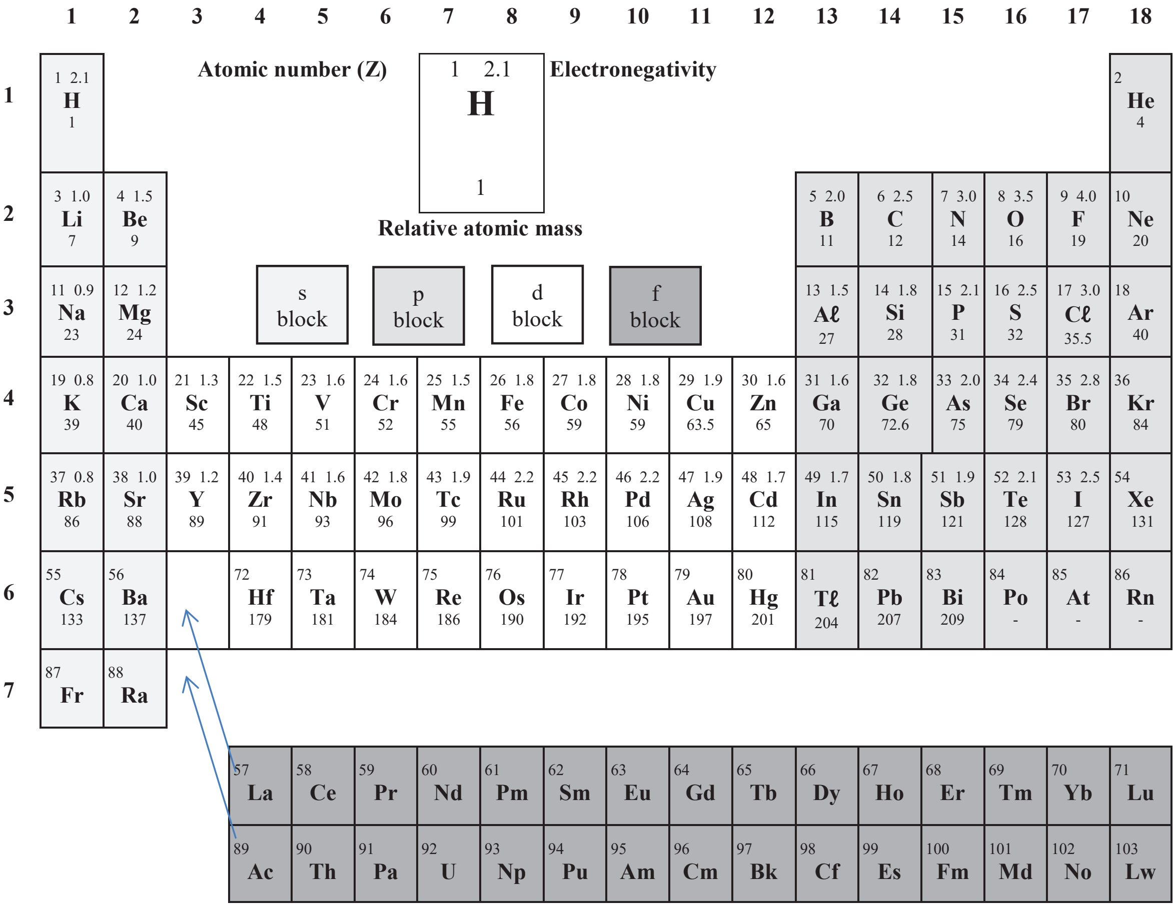
The elements in groups 1 and 2 have one and two valence electrons respectively. The rest of the elements, i.e. groups 13 to 18 have a number of valence electrons which is the same as the second digit of the group number, so group 1$\underline{3}$ elements have three valence electrons. e.g. phosphorus (element no. 15) is in group 15 and so it will have five valence electrons.

The rows across the Periodic Table are called periods. The period number which appears on the left-hand side of the table in front of each row (period) is the number of the energy level in which the valence electrons are found for s and p orbitals. The element aluminium, for example, is in period 3, which means that its valence electrons are in the third energy level.

Blocks of the Periodic Table

Have you ever wondered why the Periodic Table has such an unusual shape? It's because of the arrangement of electrons in the different orbitals of different energy levels. The diagram below shows how the Periodic Table is divided into three main blocks, the s-block (on the left), the p-block in the right and the d-block in the middle. Helium is an exception as it belongs in the empty space in the s-block.

The Periodic Table



Atomic number (Z) | 1 2.1 H 1 | Electronegativity

Relative atomic mass

s block | p block | d block | f block

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 2.1 H 1																	2 He 4
2	3 1.0 Li 7	4 1.5 Be 9											5 2.0 B 11	6 2.5 C 12	7 3.0 N 14	8 3.5 O 16	9 4.0 F 19	10 Ne 20
3	11 0.9 Na 23	12 1.2 Mg 24											13 1.5 Aℓ 27	14 1.8 Si 28	15 2.1 P 31	16 2.5 S 32	17 3.0 Cℓ 35.5	18 Ar 40
4	19 0.8 K 39	20 1.0 Ca 40	21 1.3 Sc 45	22 1.5 Ti 48	23 1.6 V 51	24 1.6 Cr 52	25 1.5 Mn 55	26 1.8 Fe 56	27 1.8 Co 59	28 1.8 Ni 59	29 1.9 Cu 63.5	30 1.6 Zn 65	31 1.6 Ga 70	32 1.8 Ge 72.6	33 2.0 As 75	34 2.4 Se 79	35 2.8 Br 80	36 Kr 84
5	37 0.8 Rb 86	38 1.0 Sr 88	39 1.2 Y 89	40 1.4 Zr 91	41 1.6 Nb 93	42 1.8 Mo 96	43 1.9 Tc 99	44 2.2 Ru 101	45 2.2 Rh 103	46 2.2 Pd 106	47 1.9 Ag 108	48 1.7 Cd 112	49 1.7 In 115	50 1.8 Sn 119	51 1.9 Sb 121	52 2.1 Te 128	53 2.5 I 127	54 Xe 131
6	55 Cs 133	56 Ba 137		72 Hf 179	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 Tℓ 204	82 Pb 207	83 Bi 209	84 Po -	85 At -	86 Rn -
7	87 Fr	88 Ra																
				57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
				89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lw

When you recognise these blocks on the Periodic Table it makes writing the electron configuration very easy.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions into their workbooks.

1. What are the names given to the following in the Periodic Table?

a. The horizontal rows across the table.

b. The vertical columns down the table.

Solution

a. The rows across the table are called periods.

b. The columns in the table are called groups.

2. What feature concerning their atoms have all these elements in common?

a. All the elements in the same period.

b. All the elements in the same group.

Solution

a. All the elements in the same period have valence electrons in the same outermost energy level when these valence electrons are in s and p orbitals.

b. All the elements in the same group have the same number of valence electrons.

3. Write down the number of valence electrons that each of the following atoms has and in which energy level they are found.

a. silicon

b. calcium

c. krypton

d. chlorine

e. oxygen

Solution

a. Silicon:4 valence electrons in energy level 3 (Group 14 and period 3)

b. Calcium: 2 valence electrons in energy level 4 (Group 2 and period 4)

c. Krypton: 8 valence electrons in energy level 4 (Group 18 and period 4)

d. Chlorine: 7 valence electrons in energy level 3 (Group 17 and period 3)

e. Oxygen: 6 valence electrons in energy level 2 (Group 6 and period 2)

CHECKPOINT

At this point in the topic, learners should have mastered the following:

1. knowing that elements are arranged in the Periodic Table in order of increasing atomic number.
2. knowing and understanding the relationship between the position of elements on the Periodic Table and their electron structure.
3. knowing and understanding the meaning and significance of the terms group and period and the significance of the group and period numbers.

Check learners' understanding of these concepts by getting them to work through:

Topic 4 from the Resource Pack: The Periodic Table: Questions 1–3. (Page 25).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

Understanding periodicity and trends in the Periodic Table

The term 'periodicity' refers to the repetition of similar properties in chemical elements, as indicated by their positioning on the Periodic Table. One example of this repeated pattern is the number of valence electrons in each group of the Periodic Table. Chemists found that the physical and chemical properties of elements follow repeated patterns according to their position on the Periodic Table too.

In order to make the term periodicity more relevant, we will refer to a number of properties of the elements.

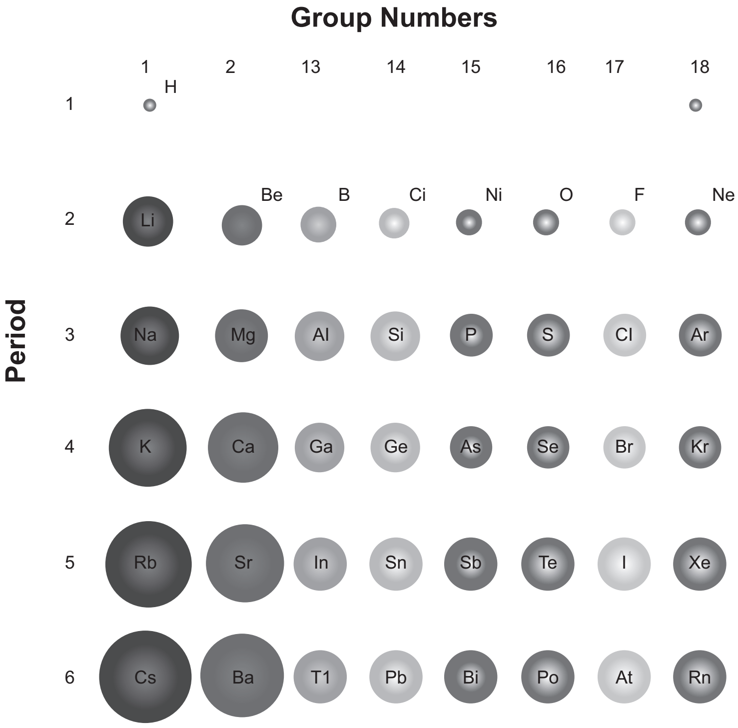
Atomic radius

Atomic radius is defined as the mean distance from the nucleus of an atom to the border of the outermost energy level. It measures the size of atoms.

- The atomic radius increases from top to bottom within a group because new energy levels are added as the period number increases.
- Atomic radius decreases in going from left to right across a period. This occurs because the number of protons in the nucleus increases from left to right making the attraction of the nucleus on the electrons stronger. The extra electrons being added to atoms with increasing atomic number are added to the same energy level.

It must be noted that the previously mentioned changes in properties are called trends. A trend is a pattern of how a property generally changes. There may be deviations at times but the trend remains as stated. This will apply to all the other properties that we discuss. It is important to understand the nature of a trend, and not to concentrate only on individual values. When an individual example does not follow the trend, we call it 'an anomaly'.

Below is a table showing the way in which the atomic radius changes within groups and across periods.



Melting and boiling points

- The trend for boiling points and melting points is that they increase across a period up to group 14. From group 15 there is a sudden drop and then a decrease to the end of the period.
- Melting and boiling points decrease when going from top to bottom down a group. The table that follows shows the melting points of elements in group 2 of the Periodic Table. The values show that the trend is for the melting points to decrease in going down the group. Magnesium is an anomaly to the trend because it has a lower melting point than calcium.

ELEMENT	ATOMIC NUMBER	SYMBOL	MELTING POINT (°C)
beryllium	4	Be	1 278
magnesium	12	Mg	649
calcium	20	Ca	839
strontium	38	Sr	769
barium	56	Ba	725

- The following table displays the trends in melting and boiling points of the elements in period 3 of the Periodic Table.

ELEMENT	ATOMIC NUMBER	SYMBOL	MELTING POINT (°C)	BOILING POINT (°C)
sodium	11	Na	98	883
magnesium	12	Mg	639	1 090
aluminium	13	Al	660	2 467
silicon	14	Si	1 410	2 355
phosphorus	15	P	44	280
sulfur	16	S	113	445
chlorine	17	Cℓ	−101	−35
argon	18	Ar	−189	−186

The table shows that the melting point of sulfur is an exception to the trend and so is the boiling point of aluminium, but this does not change the trend.

Periodicity in the formulae of the halides and oxides

First remind learners about how chemical formulae are worked out and written.

- Halides are compounds formed when the halogens combine with metals. When the metals of groups 1, 2 and 13 combine with chlorine, for example, the formulae of their respective chlorides are $NaC\ell$, $MgC\ell_2$ and $A\ell C\ell_3$ because the metals form cations with charges of $+1$, $+2$ and $+3$ respectively. Halogens form anions with a charge of -1. The positive and negative charges on ions must balance each other, to make a neutrally charged compound.
- Oxides are compounds formed when oxygen combines with metals. When the same metals as above combine with oxygen, the formulae of the respective compounds are Na_2O, MgO and $A\ell_2O_3$. This is because oxygen forms ions with a charge of -2 and when compounds form the positive and negative charges on ions must balance each other.

Periodicity of ionisation energy

The electrons moving around the nuclei of atoms are held there by the attraction of the nucleus. Ionisation energy is the energy needed per mole to remove electrons from atoms in the gaseous phase. Ionisation energy is measured in $kJ{\cdot}mol^{-1}$.

The definition of ionisation energy given here is a general definition. A more specific and useful definition is the definition of the first ionisation energy. This is the energy needed per mole to remove the 1st electron from an atom in the gaseous phase. The trend for first ionisation energy is that it increases from left to right across a period. You can refer back to atomic radius here and link the two concepts. The atomic radius of elements decreases from left to right across a period. As the atoms become smaller, the outer electrons are closer to the nucleus and held more tightly. It requires more energy to remove the electrons.

The table shows the changes in ionisation energy for the elements in period 2:

ELEMENT	FIRST IONISATION ENERGY (kJ·mol^{-1})
Li	520
Be	899
B	800
C	1 086
N	1 402
O	1 314
F	1 680
Ne	2 080

There are a couple of inconsistencies (B and O) but otherwise the trend is as stated.

Ionisation energy decreases from top to bottom within a group. From top to bottom within a group, the atomic radius increases and the valence electrons are further from the nucleus. The valence electrons are thus held less tightly and therefore less energy is needed to remove them. The ionisation energies of the elements in group 1 (from top to bottom) are shown in the table below.

ELEMENT	FIRST IONISATION ENERGY (kJ·mol^{-1})
Li	520
Na	496
K	419
Rb	408
Cs	376

Clearly, the 1st ionisation energy decreases when going down a group.

Periodicity and electron affinity and electronegativity

Electron affinity is the amount of energy released when an electron is attached to an atom or molecule to form a negative ion. The higher the electron affinity, the more likely atoms of the element are to attract electrons. When going from left to right across a period, the amount of energy released by an atom accepting an electron to form a negative ion increases. This means that elements on the right-hand side of the Periodic Table attract electrons more readily than those on the left.

The noble gases do not fit in with this trend as they have completed outer energy levels. They do not gain or lose electrons.

Electronegativity is the tendency of an atom in a molecule to attract bonding electrons. The electronegativity scale was drawn up by Linus Pauling. It does not consist of measured values. Pauling allocated values ranging from the highest value of 4 for fluorine to 0,7 for the element caesium. Electronegativity generally increases from left to right across a period.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions into their workbooks.

1. **Explain** what is meant by the following terms:
   a. First ionisation energy
   b. Atomic radius
   c. Electronegativity

Solution

Note that the question does not ask for definitions, so the learners need to do more than just quote definitions they have learned. They must give more than that by writing an explanation of the term.

a. Electrons are held in place around an atom by the attraction to their nucleus. To remove electrons from the influence of their nucleus requires energy. The energy that is needed per mole of the element, to remove the outermost electron is called the first ionisation energy.

b. Atoms have a generally spherical shape, so the radius of atom is actually the radius of the sphere. The radius of a sphere is measured from the centre of the sphere to its outermost boundary; i.e. the border of the outermost energy level.
Note that the definition says average or mean distance because we don't know exactly where an electron is at any given time.

c. Electronegativity measures the ability of an atom to attract bonding electrons in a molecule. The higher the value of the electronegativity, the more strongly an atom will attract a pair of bonding electrons.

2. Which of the pairs of elements given will have the higher melting point? Give an explanation for your answer.
   - a. Ca and Sr
   - b. Mg and Cℓ

Solution

a. Ca will have the higher melting point. It is higher up in the group than Sr and the trend is for melting points to decrease from top to bottom.

b. Magnesium will have the higher melting point because it is further to the left in period 3. Melting point decreases from left to right across a period.

3. Write down chemical formulae for each of the following substances:
   - a. Magnesium chloride
   - b. Aluminium fluoride
   - c. Calcium oxide
   - d. Boron trioxide

Solution

a. $MgC\ell_2$

b. $A\ell F_3$

c. CaO

d. B_2O_3

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic concepts, they are ready to deal with more challenging questions.

b. These questions require learners to apply their knowledge and think critically in order to answer the questions.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

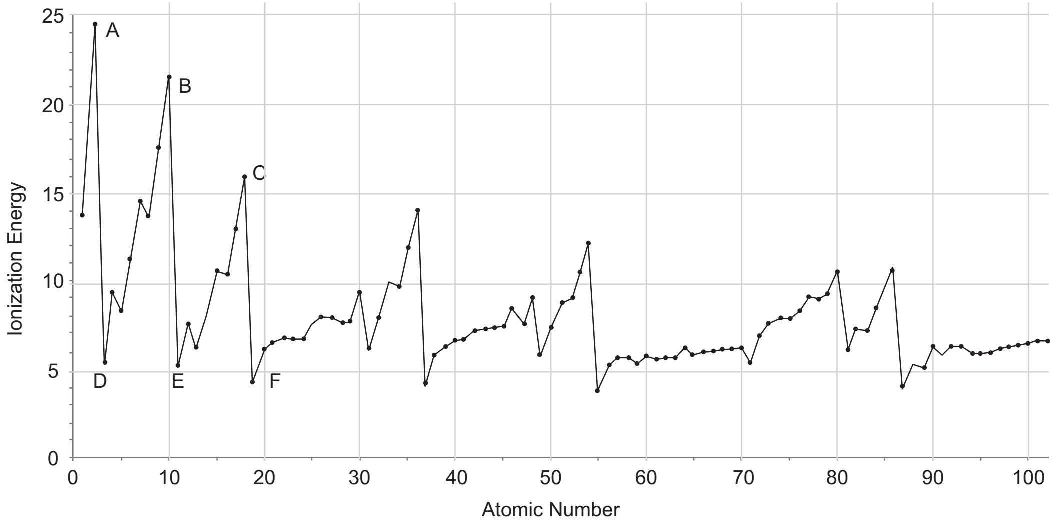
a. In these more challenging examples, learners must think critically before applying their knowledge in the required way.

b. They must understand trends in the Periodic Table and periodicity and not simply learn definitions in parrot fashion.

4. Below is a graph of the 1st ionisation energy against atomic number. Use the graph to help you answer the questions that follow.

  a. Name the elements (A, B and C) that occupy positions at the first three peaks of the graph. Give reasons for your answers.

  b. Name the elements (D, E and F) that occupy positions at the first three troughs on the graph. Give reasons for your choice.



Solution

a. A = helium

B = neon

C = argon

The peaks of the graph represent the elements with the highest ionisation energies in each period. These are the noble gases (group 18).

b. D = lithium

E = sodium

F = potassium

These are the lowest points on the graph (troughs). These represent the elements with the lowest ionisation energies in each period. These are the elements in group 1 (known as the alkali metals).

5. Arrange these elements in order of decreasing (highest to lowest) electronegativity:
    - a. magnesium, calcium, beryllium
    - b. sulfur, silicon, sodium
    - c. fluorine, iodine, bromine

Solution

- a. beryllium, magnesium, calcium
  (Electronegativity decreases in going down a group.)
- b. sulfur, silicon, sodium
  (Electronegativity increases from left to right across a period.)
- c. fluorine, bromine, iodine
  (Electronegativity increases from bottom to top in a group.)

6. Which of these elements has the highest ionisation energy? Give a reason for your choice:

magnesium, chlorine, silicon

Solution

Chlorine. Ionisation energy increases from left to right across a period.

CHECKPOINT

At this point in the topic, learners should have mastered the following:

1. the concept of the periodicity of the properties of elements.
2. being able to explain the trends of properties of the elements in groups and periods.

Check learners' understanding of these concepts by getting them to work through:

Topic 4 in the Resource Pack: The Periodic Table: Questions 4–6. (Pages 25–26).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

2. SIMILARITIES IN CHEMICAL PROPERTIES AMONG ELEMENTS IN GROUPS 1, 2, 17 AND 18

INTRODUCTION

We have discussed periodicity and the trends of various properties on the Periodic Table. In this section we will illustrate how some of these properties are relevant to elements in certain groups of the Periodic Table.

CONCEPT EXPLANATION AND CLARIFICATION

The chemical properties of the elements in groups 1,2, 17 and 18 related to electron arrangement

- The elements in **group 1** (the alkali metals) have a valence electron configuration of s^1, i.e. a single valence electron in an s orbital. This electron can easily be removed because the ionisation energy is low. This means that group 1 elements are very reactive.
- The elements in **group 2** (alkaline earth metals) have two valence electrons in an outer s orbital. They are also very reactive and form cations with a charge of +2, e.g. Mg^{2+}.
- Elements in **group 17** (the halogens) have seven valence electrons and need to gain just one electron to have a complete outermost energy level. This makes them very reactive. They form anions with a charge of −1, e.g. F^-.
- The elements in **group 18** (the noble gases) all have complete outer energy levels. They will not gain or lose electrons and compounds of these elements are virtually unknown. They are extremely unreactive. All elements try to attain the valence configuration of noble gases. A full outer energy level is a very stable arrangement of electrons.

Predicting chemical properties of unfamiliar elements

Ask learners to predict the reactivity of the elements rubidium (Rb) and caesium (Cs) in **group 1** of the Periodic Table. They have very similar chemical properties to those of the better-known elements such as sodium and potassium.

All the elements in group 1 have one valence electron in an s orbital. This makes them very reactive. This means that reactants form products quickly and there is a release of large amounts of energy too. We can see examples of these when group 1 metals react readily with oxygen and with cold water. The elements lower down in the group are more reactive than those above them. This means that potassium is more reactive than sodium, which is more reactive than lithium.

Prediction: Rubidium will react with oxygen and water in the same way as the other group 1 metals but will be more reactive than potassium.

The word equation for the reaction between rubidium and water is:

rubidium + water → rubidium hydroxide + hydrogen gas

In this reaction, when the metal just touches the water, enough heat is released almost immediately and the hydrogen gas ignites. The hydrogen reacts with the oxygen in the air explosively making a very loud bang. This reaction is too dangerous to do in a school classroom or laboratory. There are video clips on Youtube which you can watch and/or show the learners.

Prediction: Caesium will react with oxygen and water in the same way as the other group 1 metals but will be more reactive than rubidium.
Note all the alkali metals will react with water to form the metal hydroxide and release hydrogen gas.

Ask learners to predict the reactivity of elements in group 2, such as strontium and barium. They have very similar chemical properties to those of the better-known elements such as magnesium and calcium. The alkaline earth metals all have two valence electrons in an outer s orbital. This makes them reactive but not as reactive as the alkali metals. The trend in reactivity is the same as for the alkali metals when going down a group. The group 2 elements become more reactive the lower down in the group they are.

All the elements in group 2 react readily with oxygen to form the metal oxide. The general chemical equation is:

metal + oxygen → metal oxide

The group 2 elements also react with cold water to form hydrogen gas but the reaction is very slow for magnesium (to collect hydrogen gas from magnesium use warm water) and much quicker for calcium. The reactions are not as vigorous as the alkali metals.

Prediction: The metals lower down the group such as strontium and barium react with water to form the metal hydroxide and hydrogen gas, like the group 1 metals do. These reactions will occur more vigorously than those of calcium and magnesium.

Ask learners to predict the reactivity and physical properties of less familiar elements in **group 17**, such as bromine and iodine. They have very similar chemical properties to fluorine and chlorine, but they are not as reactive because they are non-metals which are lower down in the group. In terms of physical properties both fluorine and chlorine are gases at room temperature. Bromine is a reddish-brown liquid and iodine is made up of dark purple crystals. All of these elements are highly toxic. All of the halogens occur in nature as diatomic molecules.

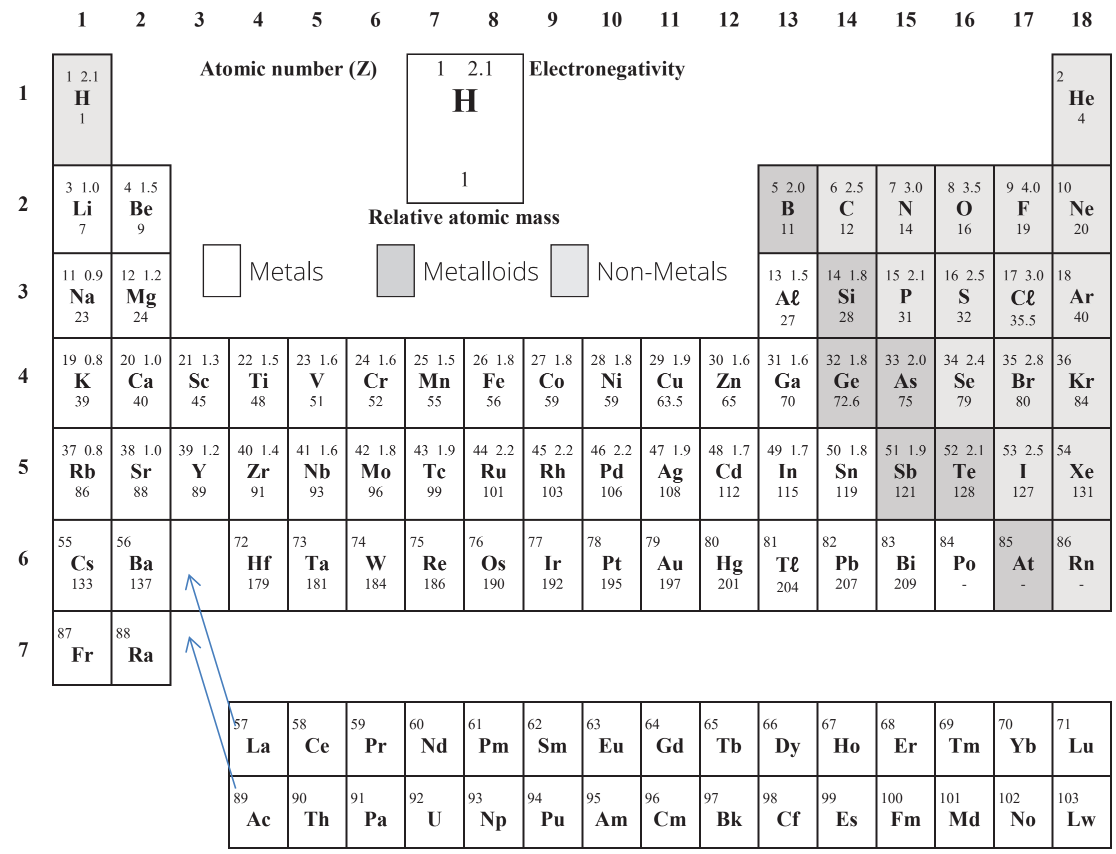
Ask learners to predict the properties of the elements krypton and xenon in group 18 of the Periodic Table. Like the other noble gases, they are unreactive and exist in nature as atoms, i.e. they are monatomic.

Sectioning of the Periodic Table into metals, non-metals and transition metals

- Besides being split into groups and periods, the Periodic Table can be sectioned into larger subdivisions for metals, non-metals and transition metals.

- The Periodic Table below shows the subdivisions mentioned using a grey scale key. The medium grey diagonal between the white metals and light grey non-metal highlights the metalloids or semi-metals.

The Periodic Table



Atomic number (Z) | 1 2.1 H 1 | Electronegativity

Relative atomic mass

☐ Metals ▨ Metalloids ░ Non-Metals

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 2.1 H 1																	2 He 4
2	3 1.0 Li 7	4 1.5 Be 9											5 2.0 B 11	6 2.5 C 12	7 3.0 N 14	8 3.5 O 16	9 4.0 F 19	10 Ne 20
3	11 0.9 Na 23	12 1.2 Mg 24											13 1.5 Aℓ 27	14 1.8 Si 28	15 2.1 P 31	16 2.5 S 32	17 3.0 Cℓ 35.5	18 Ar 40
4	19 0.8 K 39	20 1.0 Ca 40	21 1.3 Sc 45	22 1.5 Ti 48	23 1.6 V 51	24 1.6 Cr 52	25 1.5 Mn 55	26 1.8 Fe 56	27 1.8 Co 59	28 1.8 Ni 59	29 1.9 Cu 63.5	30 1.6 Zn 65	31 1.6 Ga 70	32 1.8 Ge 72.6	33 2.0 As 75	34 2.4 Se 79	35 2.8 Br 80	36 Kr 84
5	37 0.8 Rb 86	38 1.0 Sr 88	39 1.2 Y 89	40 1.4 Zr 91	41 1.6 Nb 93	42 1.8 Mo 96	43 1.9 Tc 99	44 2.2 Ru 101	45 2.2 Rh 103	46 2.2 Pd 106	47 1.9 Ag 108	48 1.7 Cd 112	49 1.7 In 115	50 1.8 Sn 119	51 1.9 Sb 121	52 2.1 Te 128	53 2.5 I 127	54 Xe 131
6	55 Cs 133	56 Ba 137		72 Hf 179	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 Tℓ 204	82 Pb 207	83 Bi 209	84 Po -	85 At -	86 Rn -
7	87 Fr	88 Ra																
				57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
				89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lw

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions into their workbooks.

1. Explain why the elements in groups 1 and 2 in the Periodic Table are so reactive.

Solution

Elements in group 1 have one valence electron in their outer energy level, while the elements in group 2 have two valence electrons. Both sets of elements have low ionisation energies which means that it is easy to remove their valence electrons. When they lose these valence electrons they have a stable electron configuration, with a filled outer energy level, just like the noble gases. Hence their high reactivity.

2. Explain why

- **a.** group 17 elements are so reactive.
- **b.** group 18 elements are so unreactive.

Solution

- **a.** The halogens all have seven valence electrons in their outer energy level. They need one electron to complete the outer energy level (valence shell). They have a high electron affinity and so they readily gain that single electron. This makes them very reactive.
- **c.** The noble gases have complete outer energy levels. They all have a so-called octet of electrons in their valence shells. They have no need to gain or lose electrons and so they are very unreactive.

3. Write down a word equation for each of the following reactions:

- **a.** lithium reacts with water
- **b.** aluminium reacts with oxygen
- **c.** calcium reacts with fluorine

Solution

- **a.** lithium + water → lithium hydroxide + hydrogen gas
- **b.** aluminium + oxygen → aluminium oxide
- **c.** calcium + fluorine → calcium fluoride

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic concepts, they are ready to deal with more challenging questions.

b. These questions require learners to apply their knowledge and to think critically before answering.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

a. Learners must understand the relationship between electron configuration and reactivity.

b. Learners must be able to apply their understanding in predicting properties of unfamiliar elements.

4. By looking at following electron configurations of elements, predict which element has the lowest first ionization energy.

A. $1s^2\ 2s^2\ 2p^6$

B. $1s^2\ 2s^2\ 2p^4$

C. $1s^2\ 2s^2\ 2p^6\ 3s^2$

D. $1s^2\ 2s^2\ 2p^6\ 3s^1$

Solution

Answer D

D has only one valence electron which is fairly far from the nucleus and so it is the easiest electron to remove.

5. Describe the trends of each of the following in the groups and periods of the Periodic Table:

  a. ionisation energy.

  b. electron affinity.

Solution

a. Ionisation energy decreases from top to bottom in a group and increases from left to right across a period.

b. Electron affinity decreases from top to bottom in a group and increases from left to right across a period.

6. Caesium (Cs) and fluorine (F) are said to be the most reactive elements. Do you agree with this statement or not? Give reasons for your answers.

Solution

The statement is correct. Cs is at the bottom of group 1 in the Periodic Table. Ionisation energy decreases from top to bottom in a group, so the ionisation energy of Cs is the lowest on the Periodic Table. This makes it the most reactive metal. Fluorine is at the top of group 17 in the Periodic Table. Electron affinity increases from left to right across a period and decreases from top to bottom in a group. Fluorine's electron affinity is the highest so it attracts an electron very readily. It is the most reactive non-metal.

7. Ionisation energy changes depending on an element's position in a period and/or in a group. Answer the following questions about ionisation energy.

  a. Define the term 'first ionisation energy'.

  b. What is the trend for ionisation energy from left to right across a period? Explain this trend.

  c. What is the trend for ionisation energy from top to bottom in a group? Explain this trend.

Solution

a. First ionisation energy is the energy needed per mole to remove the 1st electron from an atom in the gaseous phase.

b. Ionisation energy increases from left to right across a period. In moving across a period, each successive element has one more proton in its nuclei than the preceding element. As the number of protons increases so does the number of electrons, but they are all filling the same energy level. So, as the attraction of the nucleus increases it requires more energy to remove the outermost electron and the ionisation energy increases.

c. Ionisation energy decreases from top to bottom in a group. Each element below another in a group has an extra energy level compared to the one preceding it. This means that the valence electron(s) are further and further from the nucleus. So, less energy is needed to remove the valence electron(s) from elements when going down the group; therefore the ionisation energy decreases.

CHECKPOINT

At this point in the topic, learners should have mastered the following:

1. knowing how to relate chemical properties of elements to their electron configuration.
2. knowing how the reactivity of elements relates to their position in the Periodic Table.
3. knowing how to predict properties of unfamiliar elements.

Check learners' understanding of these concepts by getting them to work through:

Topic 4 in the Resource Pack: The Periodic Table: Question 7. (Page 26).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing: **The Periodic Table Consolidation Exercise from the Resource Pack**. **(Pages 27–28).**
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation exercise should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It is important to note that this consolidation exercise is NOT scaffolded. It should not be administered as a test, as the level of the work may be too high to be used in its entirety.**

ADDITIONAL VIEWING / READING

In addition, further viewing or reading on this topic is available through the following web links:

1. https://www.khanacademy.org/science/biology/chemistry--of-life/electron-shells-and-orbitals/v/periodic-table-groups
   This video isabout the groups of the Periodic Table that is very suitable for teachers and after seeing it, teachers might want to show their learners. (It does include a short discussion on the d-block elements).
2. https://www.chemicool.com/the-periodic-table.html#continued
   This consists of reading material for teachers.
3. http://www.rsc.org/periodic-table
   This Periodic Table is interactive and can be downloaded onto phones or tablets from google play or the google app store. It is suitable for both teachers and learners.
4. https://www.youtube.com/watch?v=J2K3mAKr67U
   Understanding the Periodic Table suitable for learners.

TOPIC 5:

Chemical Bonding

A Introduction

- This topic runs for 4 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Chemical Bonding forms part of the content area Matter and materials (Chemistry).
- Matter and materials counts 46,67% in Grade 10 Paper 2 (Chemistry) examination.
- Chemical Bonding provides a basic foundation for all concepts related to Matter and Materials. It could count 7% of the final Paper 2 (Chemistry) examination.
- Chemical Bonding reflects on everything in Chemistry. It is essential to know what holds atoms together to make up different substance with a wide variety of properties. There are three types of bonds that will be discussed in this topic: covalent bonding, ionic bonding and metallic bonding.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard
2. Chalk
3. A Periodic Table of the Elements (Poster supplied with the NECT resources)
4. The tables of common cations and anions (polyatomic ions) (as specified on pages 161 – 163 of CAPS)

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises
2. Scientific calculator – Sharp or Casio calculators are highly recommended
3. Pen
4. A Periodic Table of the Elements (copied from page 29 of the 2015 Grade 10 Examination Guidelines)
5. The tables of common cations and anions (polyatomic ions) (as specified on pages 161 – 163 of CAPS)

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7-9	**GRADE 10**	**GRADE 11-12**
• Atoms and subatomic particles. • Basic knowledge of the Periodic Table.	• Understanding of the Periodic Table. • Lewis diagrams. • Covalent bonding. • Ionic bonding. • Metallic bonding.	• Intermolecular forces. • Molecular structure. • Quantitative aspects of chemical change.

C Glossary of Terms

TERM	DEFINITION
Chemical bond	A mutual attraction between atoms resulting from the simultaneous attraction between the nuclei and the outer electrons. (The energy of the combined atoms is lower than that of the individual atoms resulting in higher stability.)
Covalent bond	The sharing of electrons between atoms to form a molecule.
Ionic bond	The transfer of electrons to form cations (positive ions) and anions (negative ions) that attract each other to form a formula unit.
A formula unit	The simplest empirical formula that represents a compound.
An ion	A charged particle made from an atom by the loss or gain of electrons.
An anion	A negatively charged particle made from an atom by the gain of electrons.
A cation	A positively charged particle made from an atom by the loss of electrons.
Metallic bond	The chemical bond brought about by the attraction between positive ions (atomic kernels) and delocaliszed valence electrons in a metal.
Lewis dot diagram (Also known as: Electron dot formula or Lewis formula)	A structural formula in which valence electrons are represented by dots or crosses.
Valence electrons (outer electrons)	Electrons in the highest energy level on an atom in which there are electrons.
Delocalised electrons	Valence electrons that are distributed over a whole structure and not associated with any particular atom.
Relative formula mass	Relative mass of a single unit of an ionic compound.
Relative molecular mass	Relative mass of a molecule of a substance.
Crystal lattice	An orderly three-dimensional arrangement of particles (ions, molecules or atoms) in a solid structure.
Molecule	A group of two or more atoms that are covalently bonded and that functions as a unit.
Single covalent bond	A bond formed by the sharing of one pair of electrons.
Double bond	A bond formed by the sharing of two pairs of electrons.
Triple bond	A bond formed by the sharing of three pairs of electrons.
Electrostatic force	A force that exists between charged objects.

D Assessment of this Topic

This topic is assessed by means of informal and control tests, and midyear and final examinations.

- There can be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.
- Recommended informal assessment: Use polystyrene spheres to make models of crystal lattices.

E Breakdown of Topic and Targeted Support Offered

- Please note that this booklet does not address the full topic – only targeted support related to common challenges is offered.
- For further guidance on full lesson planning, please consult CAPS, the NECT Planner & Tracker and the textbook

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
4 hours	Covalent bonding, ionic bonding and metallic bonding	25	**a.** Lewis diagrams. **b.** The essentials of covalent bonding. **c.** The essentials of ionic bonding. **d.** The essentials of metallic bonding. **e.** Calculating relative molecular and formula mass.

F Targeted Support per Sub-topic

1. COVALENT BONDING, IONIC BONDING AND METALLIC BONDING

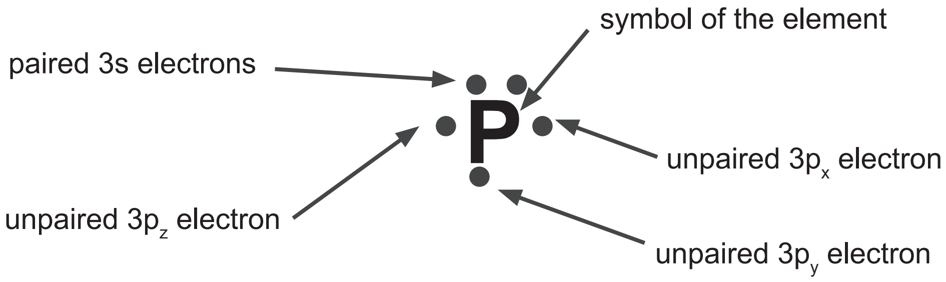
INTRODUCTION

Chemical bonding comes about as a result of electrostatic forces between particles. There are three types of chemical bonding: covalent, ionic and metallic. The type of bonds formed depends on the type of particles present.

CONCEPT EXPLANATION AND CLARIFICATION: COVALENT BONDING, IONIC BONDING AND METALLIC BONDING

Lewis diagrams

- A Lewis diagram is a diagrammatic representation of an atom and its valence electrons.
- A Lewis diagram is started by writing down the symbol of the element. Around that symbol, electrons, represented by dots or crosses, are arranged in the same way that they are in the valence electron configuration of the element.
- Drawing a Lewis diagram:
  Let us represent an atom of phosphorus by means of a Lewis diagram. The electron configuration of phosphorus is: : [Ne] $3s^2\ 3p_x^{\ 1}\ p_y^{\ 1}\ p_z^{\ 1}$
  The valence electron configuration is the part after [Ne] which represents the core electrons and the symbol of the element in the Lewis diagram. The Lewis diagram of phosphorus below shows these features.



INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1 Write down the valence electron configuration together with the symbol of the noble gas that represents the core electrons and then draw Lewis diagrams for atoms of each of the following elements:

a. Mg

b. Ne

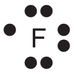
c. F

Solution

a. Mg : [Ne] $3s^2$

b. Ne : [He] $2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^2$

c. F : [He] $2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^1$



CHECKPOINT

At this point in the topic, learners should have mastered:

1. knowing how to draw Lewis diagrams for atoms.

Check learners' understanding of these concepts by getting them to work through:

Topic 5 in the Resource Pack: Chemical bonding Worksheet: Questions 3, 4, 8. (Pages 33–34).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from the mistakes they make.

The essentials of covalent bonding

- Covalent bonding generally occurs between atoms of non-metals.
- Covalent bonding is characterised by the sharing of electrons.
- The atoms in the bond are held together by the attraction between both nuclei and both sets of valence electrons.
- The result of a covalent bond between atoms is a molecule.

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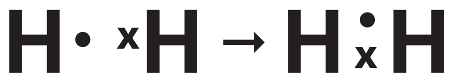
- both sets of valence electrons.
- The result of a covalent bond between atoms is a molecule.

Types of Covalent bonds

There are two types of covalent bonds:

- Pure polar covalent bonding – electrons are shared equally. Pure covalent bonding always occurs between atoms of the same elements e.g the diatomic elements such as H_2, O_2, etc. Pure covalent bonds are also called non-polar covalent bonds.
- Polar-covalent bonds arise when electrons are shared unequally. Polar covalent bonds usually form when a hydrogen atom shares a pair of electrons with a non-metal atom to form a molecule. The ends of the molecule develop opposite charges. The hydrogen end of the molecule is slightly positively charged and the non-metal end is negatively charged. This kind of molecule which has a separation of charge within it, is called a dipole.

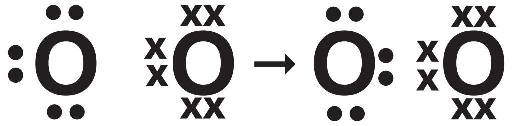
Look at the Lewis diagram showing the formation of a hydrogen molecule below:



Before formation of bond After the formation of bond

Before the formation of the bond each hydrogen atom has an unpaired electron represented by the dot and cross. During the formation of the bond, the two s-orbitals overlap and the two unpaired electrons form a shared pair. The shared pair of electrons are attracted to both nuclei and give each of the atoms a filled outer energy level.

- When there is only one shared pair of electrons in a bond, the bond is called a single covalent bond.
- The shared pair of electrons (bond pair) are shared equal between the two hydrogen nuclei. The molecule has an equal distribution of electrons so the molecule is non-polar.
- It is possible for the same atoms to have two pairs of shared electrons. In this case the bond is called a double bond. For example, oxygen (O_2)

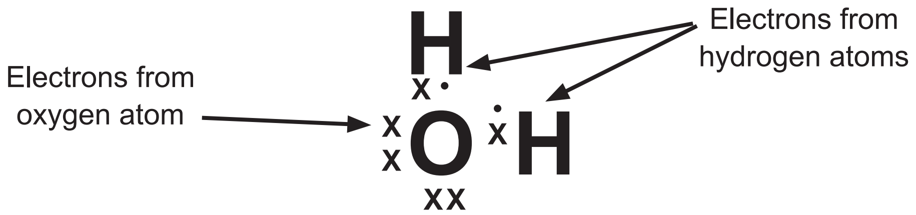


Before formation of bond After the formation of bond

The unpaired electrons before the formation of the bond are in two different p orbitals. These p-orbitals overlap to form two separate covalent bonds. This is also a non-polar molecule because the bonding pairs of electrons are shared equally

If there are three shared pairs of electrons, the bond is a triple bond. eg. nitrogen

- Lewis diagrams can be drawn for molecules formed from atoms of different atoms too. Example: Water (H_2O)

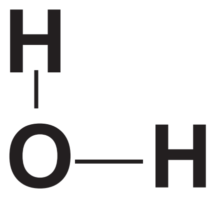


The oxygen atom has two unpaired electrons and each hydrogen atom has one unpaired electron. So, it takes two hydrogen atoms to pair with both of the oxygen's unpaired electrons. After the formation of the bonds that there are two pairs of electrons shared between the oxygen atom and the two different hydrogen atoms. So this is not a double bond but two single covalent bonds.

The electrons are not shared equally between the oxygen and hydrogen atoms. The shared pair of electrons are closer to the oxygen atom and not close to the hydrogen. The hydrogen end of the molecule becomes slightly positive and the oxygen end slightly negative. The molecule has two oppositely charged ends (poles). The molecule is a dipole and the bond is called a polar covalent bond.

- We can also represent molecules by means of Couper diagrams, in which each shared pair is represented by a line.

The Couper diagram for water is:



The Couper notation for a molecule of nitrogen is:

$$N \equiv N$$

- At this point revise the naming and chemical formulae of covalent substances.

Note that polar covalent bonding is discussed in more detail in the topic: Particles Substances Are Made Of.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:
- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. **a.** What types of elements bond covalently with one another?

   b. What characterises covalent bonding?

Solution

a. Covalent bonding occurs between atoms of non-metals.

b. Covalent bonding is characterised by the sharing of electrons.

2. Write down the valence electron configuration and then draw Lewis diagrams for atoms of:

   a. He

   b. N

   c. Aℓ

Solution

a. He: $1s^2$

b. N: [He] $2s^22p_x^12p_y^12p_z^1$

c. Aℓ [Ne] $3s^23p^1$

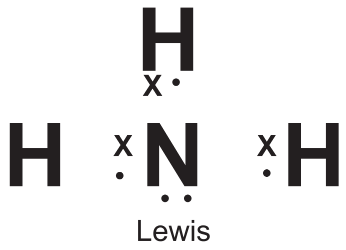
3. Draw Lewis and Couper diagrams for the molecules:

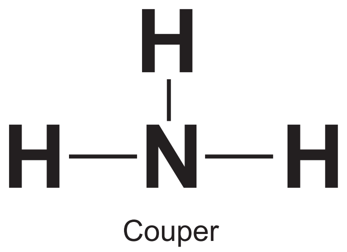
   a. NH_3

   b. O_2

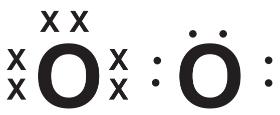
Solution

a.





b.



CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic concepts, they are ready to deal with more challenging questions.

b. These questions require learners to apply their knowledge and to think critically.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING

a. In these more challenging examples, learners must sharpen their application skills.

b. Learners must learn to use valence electron configurations to work out their Lewis diagrams.

c. When working with more complex molecules, they must learn to make use of unpaired electrons to work out the bonds.

4. Give the chemical names of the substances represented by the following chemical formulae:

a. CO_2

b. H_2S

c. NH_3

Solution

a. carbon dioxide (there are two oxygens, hence dioxide).

b. dihydrogen sulphide (two hydrogens, hence di-)

c. nitrogen trihydride (ammonia) – three hydrogens, hence **tri**hydride.

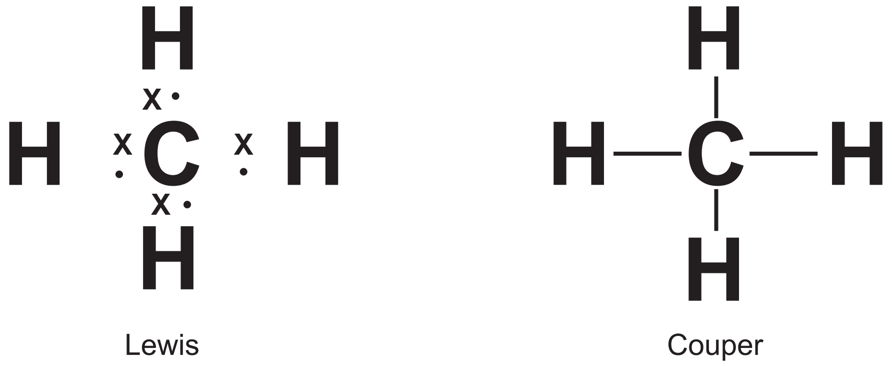
5. Draw Lewis and Couper diagrams for:

a. CH_4

b. C_2H_4

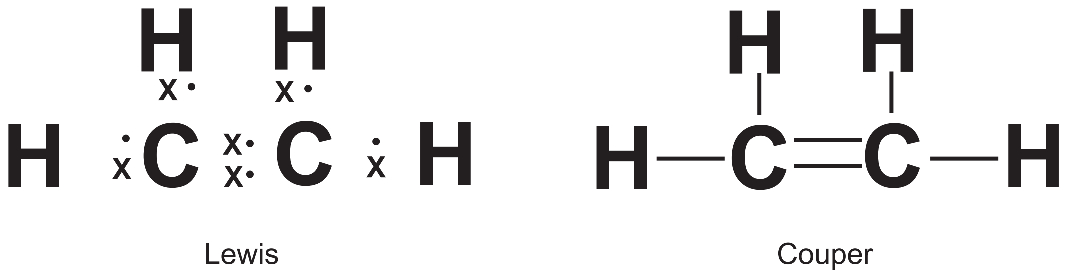
Solution

a.



The carbon atom has 4 unpaired electrons because when carbon reacts it undergoes a rearrangement of its orbitals so that it ends up with 4 unpaired electrons. Each of those electrons pairs up with the single unpaired electron in each hydrogen atom.

b.



Each carbon has 4 unpaired electrons. 2 of those in each carbon share with an unpaired electron in each hydrogen. That leaves two unpaired electrons in each carbon. The only way to pair up those two electrons is for them to share the two pairs with each other to form a double bond.

CHECKPOINT

At this point in the topic, learners should have mastered the following:

1. knowing and understanding the nature of covalent bonding.
2. the drawing of Lewis and Couper diagrams for atoms and molecules.
3. naming covalent compounds.

Check learners' understanding of these concepts by getting them to work through:

Topic 5 in the Resource Pack: Chemical bonding Worksheet: Questions 2, 3, 5, 8. (Pages 33–34).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from the mistakes they make.

The essentials of ionic bonding

- Ionic bonding generally occurs between atoms of metals and atoms of non-metals.
- Ionic bonding is characterised by the transfer of electrons.
- Electrons are transferred from a metal to a non-metal.
- The crystal lattice that is formed is held together by the attraction between positive and negative ions.

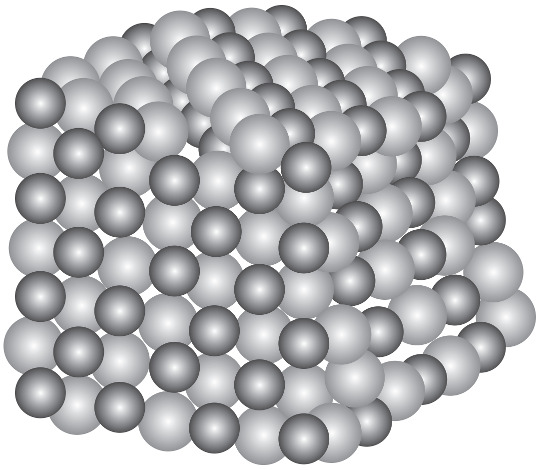
Representing ionic bonds

Before formation of bond

After the formation of bond

In the Lewis diagram the sodium atom before the formation of the bond has one valence electron and the chlorine atom has seven valence electrons. The electron from the sodium atom is transferred to the chlorine atom. The sodium atom becomes a positively charge ion as it has more protons than electrons and the chlorine atom becomes a negatively charge ion as it has more electrons than protons. The ions of opposite charge are attracted to each other.

The result of ionic bonding between cations and anions is a crystal lattice.



The larger lighter grey spheres represent the negative chloride ions (anions) and the smaller darker grey spheres represent the positively charged smaller sodium ions (cations).

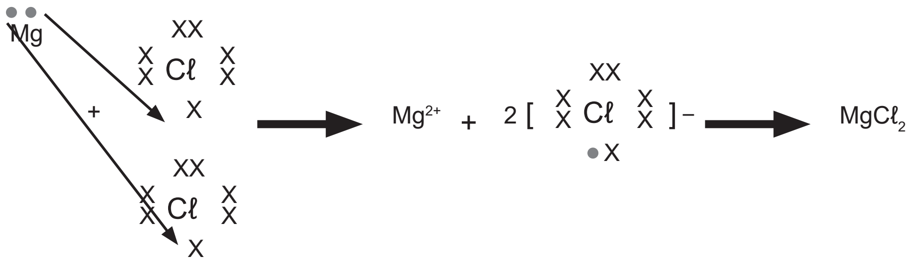
A single sodium chloride molecule consisting of one sodium ion and one chloride ion of $NaC\ell$ does not exist. The formula of an ionic compound tells the ratio in which the ions occur in the crystal lattice. It is not the formula of a single molecule.

Ionic bonding can be formed when the ratio is not 1:1 as for sodium chloride. Consider the formation of magnesium chloride:

> Magnesium atoms have two valence electrons. When magnesium reacts with chlorine it releases two electrons to become an Mg^{2+} cation.

One chlorine atom can only accept one electron to become a chloride ion ($C\ell^-$) anion. This means you need two chlorine atoms to each gain one electron to form It means that it requires two chloride anions. Together these anions can neutralise the positive charge on one magnesium cation., Thus the ratio between magnesium cations and chloride anions is 1:2 so the chemical formula for magnesium chloride is $MgC\ell_2$,

Lewis diagram:



Ionic compounds are also formed between metals and polyatomic ions or between two polyatomic ions, e.g. $Mg(OH)_2$, $A\ell(NO_3)_3$, $(NH_4)_2SO_4$. Remind learners about the table of polyatomic ions (CAPS document p 162).

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the content.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. Write down chemical formulae for the following:

a. ammonium carbonate

b. calcium sulfide

c. aluminium sulfate

d. iron(II) nitrate

e. potassium phosphate

Solution

a. $(NH_4)_2CO_3$

b. CaS

c. $A\ell_2(SO_4)_3$

d. $Fe(NO_3)_2$

e. K_3PO_4

2. **a**. Between which types of elements does ionic bonding occur?

b. What characterises ionic bonding?

c. What type of structure results from ionic bonding?

Solution

a. Ionic bonding occurs between metals and non-metals.

b. Ionic bonding is characterised by the transfer of electrons.

c. A crystal lattice.

Note that the term molecules should never be mentioned in conjunction with ionic bonding.

3. What are the positive and negative ions that form when each of the following react? Explain briefly.

- **a.** Potassium and oxygen
- **b.** Aluminium and sulfur
- **c.** Magnesium and nitrogen
- **d.** Calcium and chlorine

Solution

a. Potassium forms K^+ ions and oxygen forms O^{2-} ions.
Potassium atoms have 1 valence electron in their outer shell, which they will lose.
Oxygen atoms have 6 valence electrons, so they will accept 2 electrons.

b. Aluminium forms $A\ell^{3+}$ ions and sulfur forms S^{2-} ions.
Aluminium atoms have 3 valence electrons, which they will lose.
Sulfur atoms have 6 valence electrons, so they will accept 2 electrons.

c. Magnesium forms Mg^{2+} ions and nitrogen forms N^{3-} ions.
Magnesium atoms have 2 valence electrons, which they will lose.
Nitrogen atoms have 5 valence electrons, so they will accept 3 electrons.

d. Calcium forms Ca^{2+} ions and chlorine will form $C\ell^-$ ions.
Calcium atoms have 2 valence electrons, which they will lose.
Chlorine atoms have 7 valence electrons, so they will accept 1 electron.

CHECKPOINT

At this point in the topic, learners should have mastered the following:

1. the concept of ionic bonding.
2. understanding the formation of ions resulting from electron transfer.
3. drawing Lewis diagrams to represent the process of ionic bonding.

Check learners' understanding of these concepts by getting them to work through:

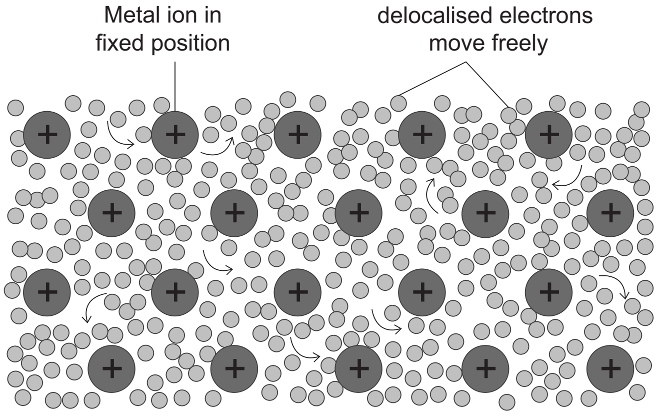
Topic 5 in the Resource Pack: Chemical bonding Worksheet: Questions 1, 4, 6. (Pages 33–34).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from the mistakes they make.

The essentials of metallic bonding

- Metallic bonding occurs between atoms of the same metal.
- Metallic bonding is characterised by delocalised electrons.
- The valence orbitals of metals overlap. Because of this the electrons in metals don't necessarily occupy their own valence orbitals but move into the valence orbitals of neighbouring atoms. They do this all the time in a random way. So, the valence electrons do not belong to any particular atom, but rather belong to the metal structure as a whole. These electrons are called **delocalised electron**s.
- The metal structure is held together by the attraction between the metal ions and the delocalised electrons.

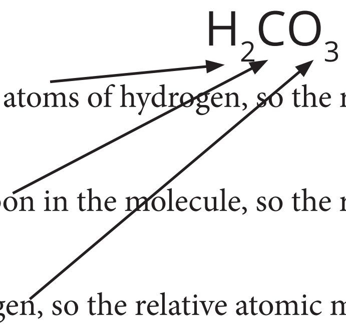
A diagram of the structure of a metal is shown below.



When different metals are mixed together they form alloys, such as steel, brass and bronze. The bonding in metal alloys is the same as in pure metals. The metals are heated until they are both liquids. This means that the atoms of each metal are evenly spread through the mixture. When cooled the nuclei and core electrons of the atoms (positive metal ions) form a lattice and the delocalised electrons spread out between the positive ions. The different ions are held in position in the lattice by the forces of attractive between the positive ions and the delocalised electrons

Calculating relative molecular and formula mass

Recall the meaning of relative atomic mass as obtained from the Periodic Table. When the relative mass of a molecule is to be found, the relative atomic masses of the atoms making up the molecule are used, multiplied by the number of atoms in the molecule. This is called relative molecular mass.



$$H_2CO_3$$

This molecule contains 2 atoms of hydrogen, so the relative atomic mass of hydrogen (1) is multiplied by 2.

There is one atom of carbon in the molecule, so the relative atomic mass of carbon (12) is multiplied by 1.

There are 3 atoms of oxygen, so the relative atomic mass of oxygen (16) is multiplied by 3.

The relative molecular mass is $[2 \times A_r(H) + 1 \times A_r(C) + 3 \times A_r(O)]$

Relative molecular mass = 62

The symbol for relative molecular mass is M_r and it has no units.

INTRODUCTORY LEVEL CALCULATIONS

a. These are the basic calculations that learners will be required to perform at this stage in the topic.

b. Their purpose is to familiarise the learners with the method by which these calculations are done.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. Determine the relative molecular mass of the following:

a. HNO_3

b. CO_2

c. NH_3

Solution

a. $M_r(HNO_3) = (1 \times 1) + (1 \times 14) + (3 \times 16)$
$= 63$

b. $M_r(CO_2) = (1 \times 12) + (2 \times 16)$
$= 44$

c. $M_r(NH_3) = (1 \times 14) + (3 \times 1)$
$= 17$

Relative formula mass refers to the relative mass of a single formula of an ionic compound. Effectively it is found in exactly the same way as relative molecular mass, but it cannot be called that because there no molecules in ionic compounds. The symbol for relative formula mass is also Mr and because it is relative, it has no units.

2. Determine the relative formula mass of each of the following:

a. $CuSO_4$

b. K_2CO_3

c. NH_4NO_3

Solution

a. $M_r(CuSO_4) = (1 \times 63{,}5) + (1 \times 32) + (3 \times 16)$
$= 143$

b. $M_r(K_2CO_3) = (2 \times 39) + (1 \times 12) + (3 \times 16)$
$= 138$

c. $M_r(NH_4NO_3) = (1 \times 14) + (4 \times 32) + (3 \times 16)$
$= 80$

Note that in this last example, the two nitrogen atoms can be added together and then multiplied.

CHECKPOINT

At this point in the topic, learners should have mastered the following:

1. the concept of metallic bonding.

2. knowing how to calculate relative molecular masses and formula masses.

Check learners' understanding of these concepts by getting them to work through:

Topic 5 from the Resource Pack: Chemical bonding Worksheet: Question 7 (Page 34) For relative molecular/formula mass see Consolidation Exercise Question 8. (Page 36).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topic 5 from the Resource Pack: Chemical Bonding Consolidation Exercise. (Pages 35–36).**
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation exercise should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It is important to note that this consolidation exercise is NOT scaffolded. It should not be administered as a test, as the level of the work may be too high in its entirety.**

ADDITIONAL VIEWING / READING

In addition, further viewing or reading on this topic is available through the following web links:

1. https://www.visionlearning.com/en/library/Chemistry/1/Chemical-Bonding/55
   This is reading for teachers on chemical bonding in general.
2. https://www.youtube.com/watch?v=ZxWmyZmwXtA
   This is a video on covalent bonding. Suitable for learners.
3. https://www.youtube.com/watch?v=Qf07-8Jhhpc
   This is a video on ionic bonding. Suitable for learners.
4. https://phet.colorado.edu/en/simulation/legacy/build-a-molecule
   pHet simulation on covalent bonding.

TOPICS 6 & 7:

Transverse Pulses and Transverse Waves

A Introduction

- These two topics run for 6 hours in total.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Transverse Pulses and Transverse Waves form part of the content area of Waves, Sound and Light (Physics).
- Waves, Sound and Light counts 26,67% in the final Grade 10 Paper 1 (Physics) examination.
- Transverse Pulses and Transverse Waves provides a basic foundation for all concepts related to Waves, Sound and Light. This topic could count about 8% of the final Paper 1 (Physics) examination.
- Understanding waves as a means of energy transfer is very important in modern Physics. Communication systems work by transmitting and receiving signals via waves and/or pulses. Both transverse and longitudinal waves transmit information in modern telecommunications, radio, TV and digital systems. Medical technologies use ultrasound, MRI, X-rays and gamma radiation. The electromagnetic spectrum with its diverse range of characteristics and uses forms an integral part of everyday life in the 21st century.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 10 Physics Examination Data Sheet.
4. OPTIONAL: A slinky and/or a medium-weight 3 m length of rope.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended.
3. Pen.
4. Grade 10 Physics Examination Data Sheet.

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7-9 QUALITATIVE ASPECTS	**GRADE 10 QUALITATIVE AND QUANTITATIVE ASPECTS**	**GRADE 11-12 FURTHER APPLICATIONS**
• Light energy: White light as a combination of colours: • travels through space. • is transferred by radiation. • passes through transparent materials and is absorbed and reflected by opaque materials. • Seeing: • vision (the eye), • seeing colour, • reflected light. • Dispersion: • colours of the visible spectrum. • infrared waves. • Transfer of energy: • heating by conduction, convection and radiation.	• Transverse pulses on a string or spring. • Transverse waves. • Longitudinal waves. • Sound. • Electromagnetic radiation.	• Geometrical Optics: • Refraction. • Snell's Law. • Critical angle. • Total internal reflection. • 2D &3D Wave fronts. • Diffraction. • Doppler Effect (either moving source or moving observer): • with sound and ultrasound. • with light - red shifts in the universe. • Optical phenomena and properties of materials: • The photo-electric effect. • Emission and absorption spectra.

C Glossary of Terms

TERM	DEFINITION
Pulse	A single disturbance in a medium.
Amplitude	The maximum disturbance of a particle from its rest (equilibrium) position.
Transverse pulse	A pulse in which the particles of the medium move at right angles to the direction of motion of the pulse.
The principle of superposition	When two pulses occupy the same space at the same time the displacement of the particles of the medium is found by adding the displacement of the two disturbances.
Constructive interference	The phenomenon where the crest of one pulse overlaps with the crest of another pulse to produce a pulse of increased amplitude.
Wavelength	The distance between two successive points on a wave which are in phase.
Frequency	The number of complete waves that pass a point in one second.
Period	The time taken for one complete wave to pass a point.
Transverse wave	A wave in which the particles of the medium vibrate at right angles to the direction of motion of the wave.
Speed (velocity) of the wave	The product of the frequency and wavelength of a wave. $v = f\lambda$ velocity = frequency × wavelength The speed of the wave is defined as the distance travelled by a point on a wave per unit time. $v = \frac{distance}{time}$
Crest	The highest point on a wave.
Trough	The lowest point on a wave.
Vibration or oscillation	One complete “to and fro” motion of a medium. Note: The word “vibration” has the same meaning as the word “oscillation”.
Wave	A series of pulses.
In phase	Two points in phase are separated by a whole number (1; 2; 3; ...) multiple of complete wavelengths OR Two points on a wave are in phase when they move simultaneously with the same speed in the same direction.

Exactly out of phase	Two points on a wave are exactly out of phase when they move simultaneously with the same speed in opposite directions.
Out of phase	Points that are not separated by a whole number multiple of complete wavelengths.
The wave equation	$v = f\lambda$ velocity = frequency × wavelength

D Assessment of this Topic

This topic is assessed by means of informal and control tests, and midyear and final examinations.

- There can be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.

E Breakdown of Topic and Targeted Support Offered

- Please note that this booklet does not address the full topic – only targeted support related to common challenges is offered.
- For further guidance on full lesson planning, please consult CAPS, the NECT Planner & Tracker and the textbook

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
2 h	Pulse, amplitude	25	**a.** Introducing Physics. **b.** The importance of learning and understanding the definitions. **c.** Displacement and distance. **d.** The relationship between amplitude and energy of the pulse. **e.** Distinguishing between the displacement of the particles and the direction of propagation.
2 h	Superposition of pulses	25	**a.** The principle of superposition. **b.** Drawing the resultant pulse when two pulses interfere.
2 h	Wavelength, frequency, amplitude, period, wave speed	26	**a,** Waves transmit energy from one place to another. **b.** The factors that affect the speed of the wave. **c.** Superposition of waves. **d.** Calculations of frequency, period, speed and wavelength.

F Targeted Support per Sub-topic

1. PULSE AND AMPLITUDE

INTRODUCTION

There are quite a few new terms and ideas which the learners need to master before they can move on to study wave motion. It is worth taking the time to teach these new concepts systematically and patiently to lay a solid foundation.

CONCEPT EXPLANATION AND CLARIFICATION

A. Introducing Physics

This is the first Physics topic introduced to the Grade 10 learners. Physics is very different from Chemistry.

Chemistry focuses on how substances interact with each other and with energy (heat and light). Physics also studies the behaviour of matter, but its scope and its approach are different. Chemistry describes matter by considering the particles and molecules that it's made of, and how these interact with each other.

Physics describes the fundamental principles of physical phenomena and the basic forces of nature. It also deals with aspects of space and time, and with the basic principles that explain matter and energy.

Some topics of Physics and Chemistry overlap one another e.g. atomic physics deals with the physics of the atom and how its electrons are able to orbit the nucleus, and yet in chemistry we study how electrons are rearranged during and after chemical reactions. Because these two disciplines are so closely related to one another we have combined them together in this subject which we call Physical Sciences.

In Physics, the learners are required to measure physical characteristics, e.g. the length of the pulse, amplitude, and speed of the pulse. They perform calculations based on measurements, and explain how and why matter behaves as it does in terms of laws and principles of physics.

B. Definitions

Definitions are always very specific. It is no use asking learners to just memorise definitions, and to write them down "word perfectly" if they don't know what it is that is being described. Introduce each new term carefully. Explore what its definition actually means.

For example, "A pulse is a single disturbance". A pulse refers to one disturbance that's why we say it's "a single" disturbance. A "disturbance" refers to an abrupt movement which moves through the medium (the string (rope) or the spring). To create a pulse, we jerk the rope or spring once and we see how the disturbance moves along the rope or the spring.

It may take you a little longer to introduce each new word and its meaning, but the time spent in clarifying terms pays off in the long run. If learners recall a physical action and relate it to the definition, they have a better chance of internalising and dealing with their new knowledge.

C. Displacement and distance

Some of the terms used in describing pulses and waves are defined later, when we deal with kinematics e.g. “Displacement” is the “change in position”. It is better to just define displacement in this simple (and accurate) way, than to call “displacement” distance. The magnitude of the change in position is measured as distance from the start position to the end position, whereas if we talk about distance, we would measure the whole path length, and get a different answer! Don’t introduce the idea of vector and scalar quantities at this stage. Just let the learners know that we call “the change in position of an object” its displacement. You can even include as a “by the way” piece of information, that “the pulse was displaced by 20 cm forward” from its original position. But don’t overemphasise the extra bit of information. The learners have enough to deal with in starting to learn how to enjoy studying Physics.

D. The amplitude of the pulse

Demonstrate a transverse pulse, using a slinky or 2 – 3 m length of flexible rope or ribbon. Secure the slinky or rope at one end, and apply a little tension to it. Jerk your hand at right angles to the length of the slinky or rope, and allow the pulse to travel down its length. Describe the “direction of propagation” of the pulse as it travels along the slinky or rope. Also describe the direction of disturbance, at right angles to the direction of propagation. The fact that these two directions are at right angles to one another makes this “a transverse pulse”.

Repeat the demonstration by beginning with the slinky or rope “in its rest position”. Now define the amplitude of the pulse. Ask the learners how you can increase the amplitude. And hopefully they realise that you need to move your hand further left and right of the rest position. Relate this increased movement to the amount of energy you are giving the pulse. Greater energy input gives the pulse greater amplitude.

A common misconception about waves and pulses concerns amplitude. It is a faulty idea that pulses and waves of greater amplitude move with greater speed through the medium. The speed of the pulse or wave depends on the tension in and weight of the medium – not on the amplitude.

E. Distinguishing between the displacement of the particles and the direction of propagation.

We can measure the length of the pulse from its start position to its end position. We can see the pulse moving along the slinky or rope but we can't see the particles of the medium moving inside the slinky or rope.

To study the motion of the particles inside the medium, firmly tie a ribbon to a coil of the slinky, or a section of the rope. Tell the learners that you are now going to study the motion (movement) of that 'particle' (which is tagged) as the pulse travels along the medium.

The tagged 'particle' moves in the direction of the disturbance – at right angles – to the direction of propagation of the pulse. It doesn't move along the slinky or rope. It moves up and then down, and then it returns to its rest position. The particles of the medium move at right angles to the direction of the pulse.

An analogy that you can also use here could be if learners have ever seen surfers on their boards bobbing beyond the breakers, waiting to surf in to the shore. As a wave approaches, the surfers rise and fall with the wave, but once the wave has passed, they remain in the same place, where they started. It is only when they move to "catch" the breaker that the water pushes the surfer forwards.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic calculations that learners will be required to perform at this stage in the topic.

b. Their purpose is to familiarise the learners with the terminology of transverse pulses.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. A pulse is generated in a rope by jerking the free end of the rope from left to right. The pulse travels along the rope to a fixed end. Draw a diagram of the pulse as it travels along the rope. Label the following:

  1.1 the direction of propagation of the pulse.

  1.2 the rest position of the particles of the rope.

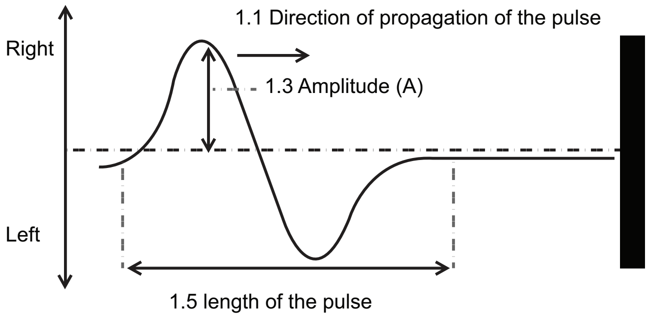
  1.3 the amplitude of the pulse.

1.4 the direction of disturbance.

1.5 the pulse length.

Solution

1.4 Direction of the disturbance is left then right



2. Explain why a transverse pulse is produced when the rope is jerked at right angles to the direction of propagation of the pulse.

Solution

A transverse pulse is generated (produced) when the movement of the disturbance is at right angles to the direction in which the pulse travels. When the rope is jerked at right angles to its length, the pulse is only able to travel along the rope – so it moves at right angles to the direction of disturbance. It must be a **transverse** pulse.

3. **3.1** Define the amplitude of a pulse.

3.2 Explain why and how the amplitude of a pulse is related to the energy of the disturbance.

3.3 What happens to the speed of the pulse when its amplitude is increased? Explain briefly.

Solution

3.1 The amplitude is the maximum disturbance of a particle from its rest position.

3.2 The greater the displacement of the particles (amplitude of the pulse) the greater the amount of energy that it transfers through the medium. It takes more energy to displace the particles further from their rest positions, so the greater the energy of disturbing the particles of the medium, the greater the amplitude.

3.3 The speed is not changed. The amplitude does not determine the speed of the pulse in the medium. The tension of the rope (or spring) and its weight determine the speed of the pulse along the rope.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic terminology, they are ready to deal with more challenging questions.

b. These questions require learners to **explain** the relationship(s) between various changes to frequency, period, speed, energy and amplitude.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

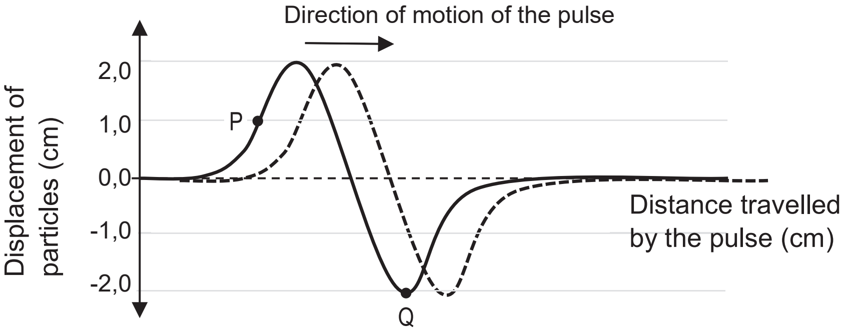
4. Give two ways to change the speed of the pulse in a slinky or rope. Explain briefly.

Solution

The speed of the pulse is measured by the distance that it travels along the rope (or slinky) per second. The speed of the pulse depends on the tension in the medium, and on its weight.

1. At higher tension, the particles of the medium exert greater force on each other. When one particle moves the other adjacent particles respond to changes in force more quickly – they respond quicker than they would do under lower tension. The speed of the pulse in the medium increases when the tension is increased.
2. A heavier rope is more difficult to move (disturb) than a lighter rope because it resists changes in its motion more than the lighter rope does. The greater the weight of the medium the slower the pulse is able to move through it.

5. Study the diagram of a pulse in a rope (shown below).



Label the following:

5.1 the amplitude.

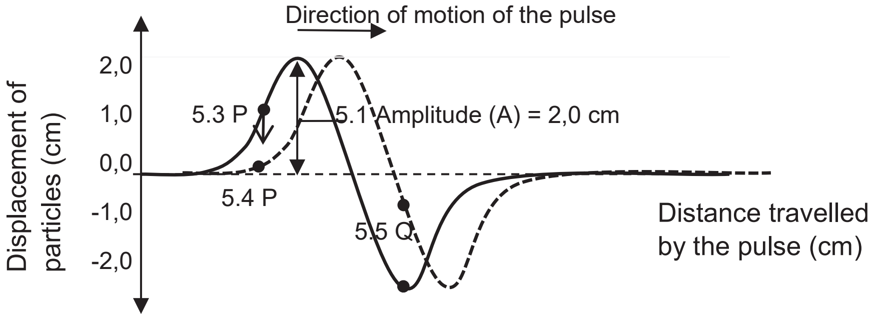
5.2 the direction of the disturbance.

5.3 an arrow to show the direction in which particle P is moving.

5.4 the position of particle P in the next 0,1 s.

5.5 the position of particle Q in the next 0,1 s.

Solution



KEY TEACHING

a. In these more challenging examples, learners must describe how the particles of the medium move while the pulse travels through it, and/or identify factors that affect the speed of a pulse.

b. It is often easier for learners to grasp these concepts by discussing the motion of a ribbon tied to the rope or the slinky – so that they can build a mental picture of the motion of the particles.

c. It is important that learners clearly distinguish between the direction of motion of the particles of the medium and the direction of transfer of energy by the pulse.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. knowing and understanding the terminology associated with a transverse pulse.
2. extracting information from a diagram of a transverse pulse.
3. labelling diagrams of transverse pulses.

Topics 6 and 7 from the Resource Pack: Transverse Pulses and Transverse Waves Worksheet: Questions 1–5. (Page 42).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

2. THE PRINCIPLE OF SUPERPOSITION

INTRODUCTION

A unique property of waves and pulses is the way in which they interfere constructively and destructively when two or more waves or pulses meet each other in the same medium. Particles collide with one another – often distorting their shape, deflecting each other on to different paths. Waves and pulses interfere, and then they continue onwards in the same way that they were travelling initially. Interference of pulses and waves is governed by the principle of superposition.

CONCEPT EXPLANATION AND CLARIFICATION

A. The principle of superposition

Send a pulse of large amplitude along the slinky or rope. Focus the learners' attention on the behaviour of the pulse when it reflects from the fixed end. Ask them to draw the new shape of the pulse – and to try to explain what has happened and why it happened. The pulse should invert itself – keep the same shape, same speed. A pulse reflects at the fixed end. By the time it reaches the fixed end it may have "lost" (i.e. transferred) some of its energy to its surroundings – mechanical energy transferred to heat as the rope of the slinky rubs against the table top (experiencing the action of frictional forces). It will have smaller amplitude if a lot of energy has been transferred.

Now the question crops up. What happens when two pulses travelling in different directions meet each other in the slinky? Will they bounce back again like two balls would do?

Unhinge the end of the slinky or rope. Ask two learners each to hold an end of the slinky or rope, and to give it a bit of tension. They will each simultaneously (if possible) send a pulse down the medium. Record the outcomes: i) both pulses interfering constructively when they meet each other ii) both pulses "destroying each other" when they meet each other.

Repeat the procedure a couple of times focusing on the shape of the resultant pulse when the pulses meet each other.

Repeat the procedure a couple more times focusing on how the pulses move after they have crossed over each other.

The results should demonstrate constructive interference when the two pulses arrive at the same position with their disturbances moving in the same direction (both up or both down). The resulting pulse is bigger than either of the two pulses by themselves.

When the two disturbances in the medium meet up and their displacements are moving in opposite directions, destructive interference occurs. The resultant pulse has an amplitude less than either of the two pulses.

It is then time to introduce the principle of superposition, and to put it to practise by working through graphic examples.

INTRODUCTORY LEVEL QUESTIONS

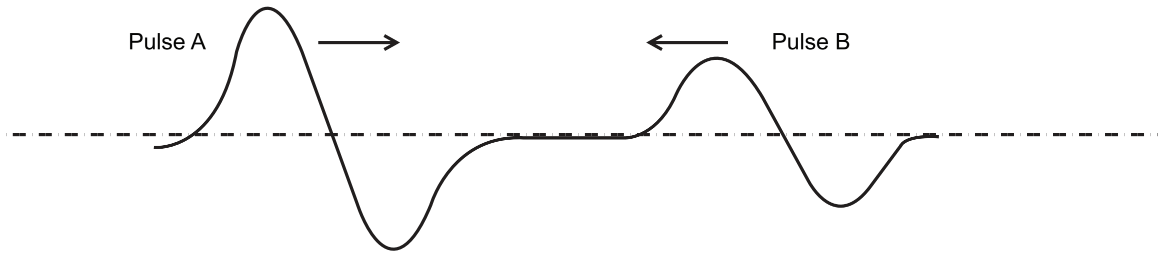
a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with terminology: constructive and destructive interference, and the principle of superposition.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

6. Pulse A travels along the rope towards Pulse B, while Pulse B travels towards Pulse A, as shown in the diagram below.



6.1 Name the phenomenon which occurs when Pulse A meets Pulse B.

6.2 State the principle of superposition.

6.3 The amplitude of Pulse A is 20 cm, and that of pulse B is 10 cm.

a. What is the maximum amplitude of the resultant pulse?

b. What is the minimum amplitude of the resultant pulse?

c. Briefly explain your answers to (a) and (b).

Solution

6.1 Interference.

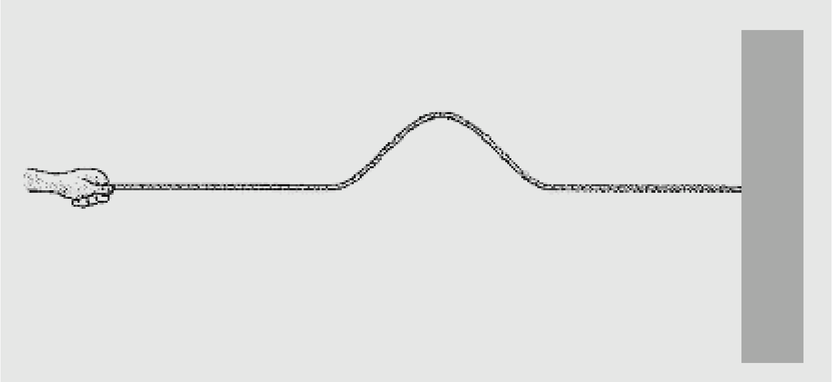
6.2 The Principle of Superposition states that the amplitude of the resultant pulse is the algebraic sum of the amplitudes of two pulses that occupy the same space at the same time.

6.3 **a.** 30 cm

b. 10 cm

c. The principle of superposition states that the amplitude of the two pulses is the algebraic sum of the displacements of the two pulses. If the two pulses are both going up at the same time when they meet each other, their amplitudes will add, to give a maximum value of 20 + 10 = 30 cm.
If the pulses are going in the opposite directions when they meet each other, their amplitudes with be either -20 + 10 = -10 cm OR they will be 20 + (-10) – 10 cm. The minimum amplitude is therefore 10 cm.

7. A demonstrator wanted to increase the speed of the pulse as it travels along the rope from her hand to the wall.



Which of the following actions (A–L) will cause the pulse to travel faster?

You can choose one or more than one of the following actions.

A	Move her hand more quickly	**G**	Decrease the tension
B	Move her hand more slowly	**H**	Increase the tension
C	Move her hand a larger distance in the same amount of time	**J**	Put more force into the pulse
D	Move her hand a smaller distance in the same amount of time	**K**	Put less force into the pulse
E	Use a heavier string of the same length	**L**	None of the above
F	Use a lighter string of the same length		

Solution

Only options E, F, G and H will change the speed of the pulse in the string.

Since we are increasing the speed, options F and H are the correct responses.

If your learners choose other options, they are possibly confusing the motion of the particles in the string, and the motion of the pulse along the string. Many learners struggle to relate the way in which the pulse (wave) is created to the way in which it travels in the medium. Options A, B, C, D, J and K all act to increase the amplitude of the pulse.

CHALLENGE LEVEL CALCULATIONS

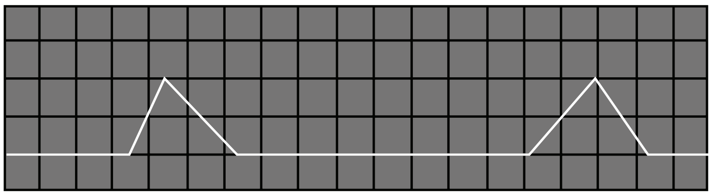
a. Now that learners have mastered the basic principles, they are ready to deal with more challenging questions.

b. These questions require learners to manipulate the information and to draw the shape of the resultant pulse at various stages during interference.

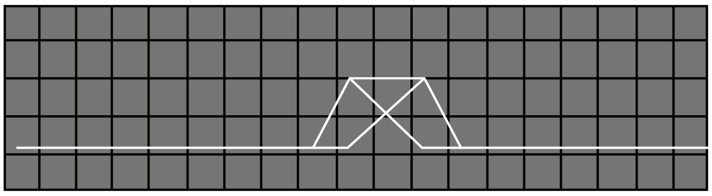
How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

8. Two pulses travel in opposite directions towards each other along the same string. The pulses move at
10 cm·s^{-1}. Draw the resultant pulse after they have travelled for 0,5 s. (Each block represents 1 cm).

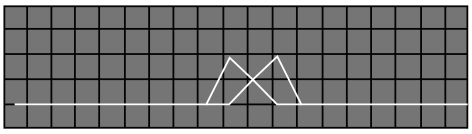
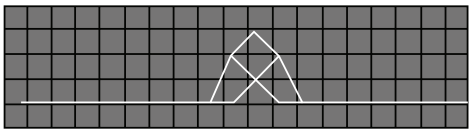


Solution



The correct response is given by point-by point addition of the amplitudes of both pulses.

However learners may give you the following types of responses.

	No addition of displacement where pulses overlap. "The pulses only add when the amplitudes meet".
	Amplitudes add even though they don't overlap. "Because the pulses are on top of each other, the amplitudes add up."

KEY TEACHING

a. In these more challenging examples, learners must manipulate the data and draw the smooth curve of the resultant pulse.

b. The learners must be able to recognise the difference between constructive interference and destructive interference. If the resultant pulse has a smaller displacement than the larger pulse, the two pulses are interfering destructively.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. applying the principle of superposition to calculate the resultant displacement of particles in the medium.
2. drawing a smooth curve to show the resulting pulse.
3. identifying constructive and destructive interference.

Topics 6 and 7 from the Resource Pack: Transverse Pulses and Transverse Waves Worksheet: Questions 11–13. (Pages 43–44).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

3. TRANSVERSE WAVES

INTRODUCTION

Many learners struggle to form an appropriate mental model of how waves transmit energy. One of the most common difficulties is distinguishing between the motion of the particles of the medium and the motion of the wave fronts through the medium. Another common misconception is that big waves travel faster than small waves in the same medium however the amplitude of the wave does not affect its speed (velocity).

CONCEPT EXPLANATION AND CLARIFICATION: TEACHING GUIDELINES

1. Waves transmit energy from one place to another.

In a transverse wave these motions occur at right angles to one another. The particles move up and down, and the wave moves perpendicular to the direction of disturbance.

Many learners mistakenly believe that waves transport matter from one place to another. The most effective way to help learners replace any misconception is to give them an experience that directly challenges it. Tie different coloured ribbons to the coils of a slinky (or along the rope). Ask the learners to describe the direction in which the ribbons move. The particles of the medium move in the same way as the ribbons. They vibrate (oscillate; move to and fro) about their rest positions. These particles move in the direction of the disturbance e.g. up and down, for a transverse wave, but the wave itself moves forward through the medium. The wave transmits energy e.g. from one end of the slinky (rope) to the other. The particles of the slinky (rope) vibrate about their rest positions.

2. The factors that affect the speed of the wave.

The amplitude is determined by the amount of energy that the wave transmits. The speed depends on the physical characteristics of the medium itself (e.g. its density, the tension in the rope or slinky). A pulse travels slower in a heavier rope than it does in a lighter one. The pulse (or wave) travels faster when the rope (or slinky) is under greater tension.

3. Superposition of waves

The superposition of waves can also present conceptual problems. The amplitudes of the two waves are added together algebraically to give the amplitude of the resultant wave at any moment.

TOPICS 6 & 7

INTRODUCTORY LEVEL CALCULATION

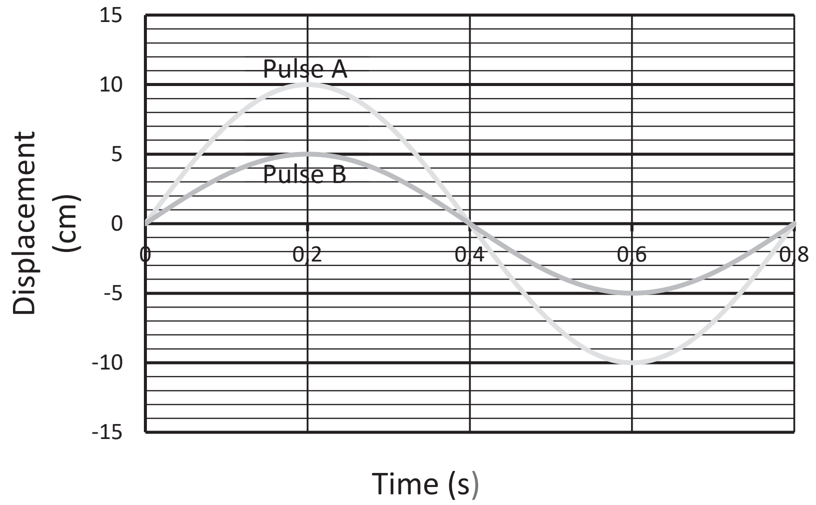
a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with terminology.

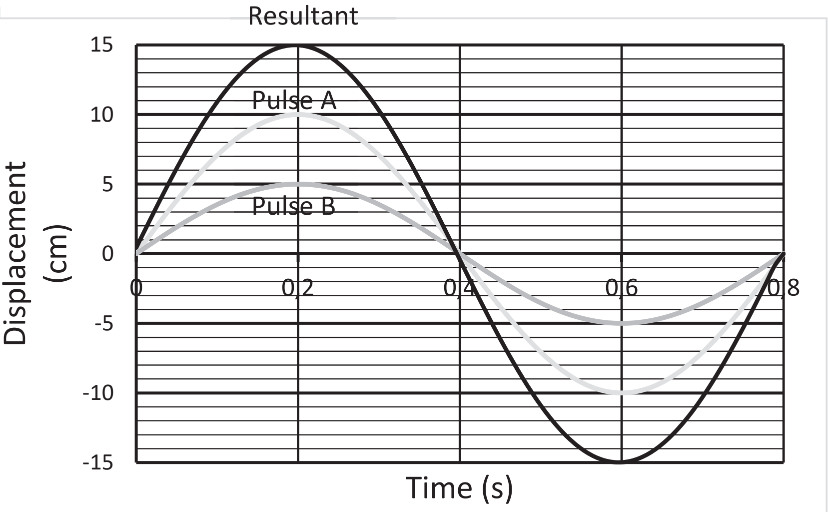
How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

9. Two pulses interfere with each other. Draw their resultant amplitude, and name the type of interference which occurs.



Solution



The resultant pulse is found by adding the amplitudes of both pulses together, and drawing a smooth curve through the answers e.g. at 0,2 s the amplitudes are 5 and 10; the resultant amplitude is 15 cm.

CHALLENGE LEVEL CALCULATIONS

a. Now that learners have mastered the basic principles, they are ready to deal with more challenging questions.

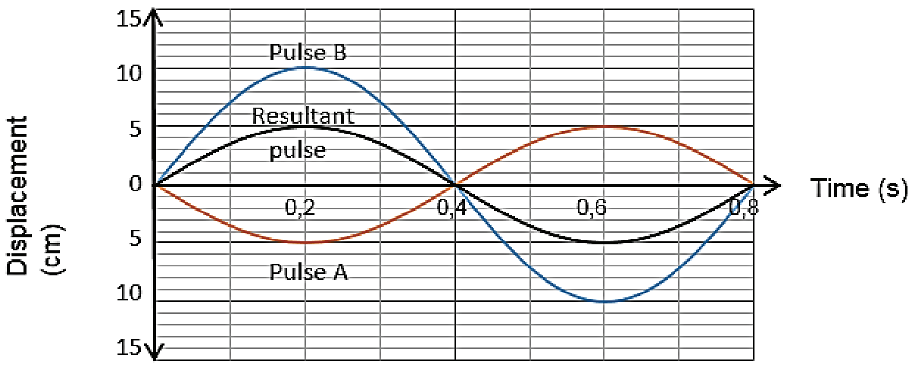
b. These questions require learners to **manipulate** the equation to change the subject of the formula.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

10. Two pulses interfere destructively with one another. Pulse A is exactly out of phase with Pulse B. Pulse has an amplitude of 5 cm; Pulse B has an amplitude of 10 cm. Draw a labelled diagram to show each pulse (A and B) and their resultant pulse when they interfere. Each pulse has a period of 0,8 s.

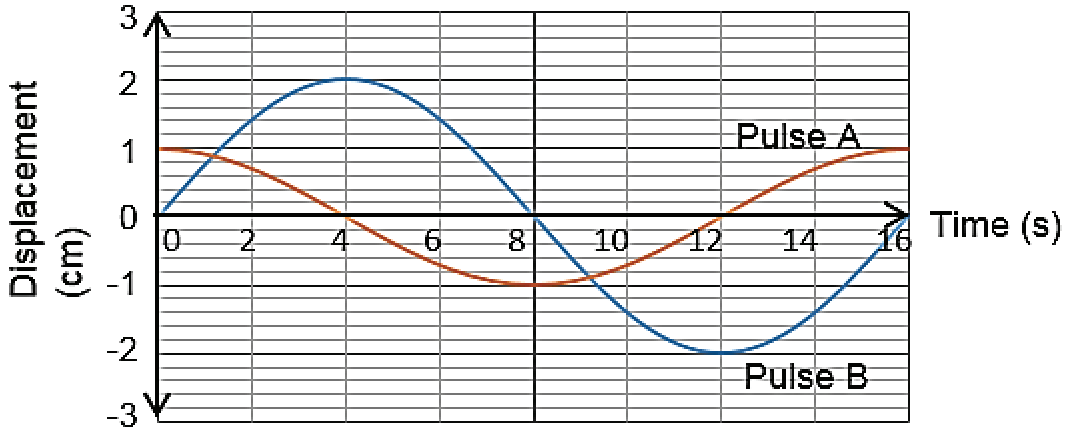
Solution



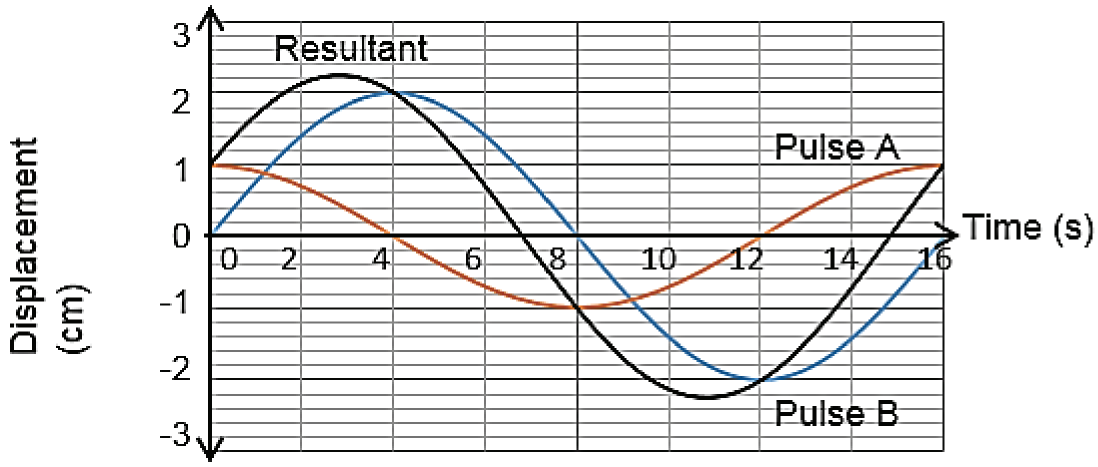
The resultant pulse is found by adding the amplitudes of both pulses together, and drawing a smooth curve through the answers e.g. at 0,2 s the amplitudes are -5 and 10; the resultant amplitude is 5 cm.

11. Two waves, labeled C & D, meet up with one another as shown in the diagram below.

- **a.** Draw the resultant pulse (on a copy of the diagram.)
- **b.** Determine the time periods when constructive interference takes place (on the resultant pulse).



Solution



Constructive interference takes place when the particles of the pulses are moving in the same direction i.e. when both waves are above the horizontal axis or both are below it. Constructive interference: from 0 s to 4 s and from 8 s to 12 s.

KEY TEACHING

- **a.** In these more challenging examples, learners must apply the principle of superposition.
- **b.** They must realise that they need to add the displacements of the particles at each position to obtain the resultant pulse or wave.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. the concept of a transverse wave as opposed to a transverse pulse.
2. the principle of superposition applied to waves.

Topics 6 & 7 from the Resource Pack: Transverse Pulses and Transverse Waves Worksheet: Questions 6–10, 14. (Pages 42–44).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

4. CALCULATIONS

INTRODUCTION

This is the first time that learners are calculating values to solve problems in Physics and using formulae to do so. It is time to encourage systematic reasoning and how to substitute values into formulae, as well as teaching the learners to visualise the situation. Sometimes it is helpful to draw a sketch of the wave so that the learners can "see" what is required of them.

CONCEPT EXPLANATION AND CLARIFICATION:

The frequency (f) of waves is related to the period (T) by the equations: $f = \frac{1}{T}$ and $T = \frac{1}{f}$

The wave equation relates the velocity of the wave to its frequency and wavelength: $v = f\lambda$

However the velocity (v)of the wave is also measured by its rate of change in position:

$$v = \frac{displacement}{time}$$

Since the wave travels in a straight line along a slinky or rope or through the water, the magnitude of its speed equals the magnitude of its velocity. The words "speed" and "velocity" can be interchanged without changing the magnitude of either. So we can refer to the pre-knowledge which learners bring to this topic:

$$speed = \frac{distance\ travelled}{time\ taken} \text{ and } v = \frac{d}{t}$$

INTRODUCTORY LEVEL CALCULATION

a. These are the basic calculations that learners will be required to perform at this stage in the topic.

b. Their purpose is to familiarise the learners with the equation, but not to change the subject of the formula.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

12. A transverse wave of amplitude 20 cm, travels at 5 m·s^{-1}. The frequency of the vibration is 10 Hz.

12.1 Calculate:

12.1.1 how far the wave travels in 15 s.

12.1.2 the period of the wave.

12.1.3 the wavelength of the wave.

12.2 Draw a diagram of the wave showing the following: the direction of disturbance, the direction of propagation, the wavelength, the amplitude, a crest, a trough, the rest position of the particles of the medium.

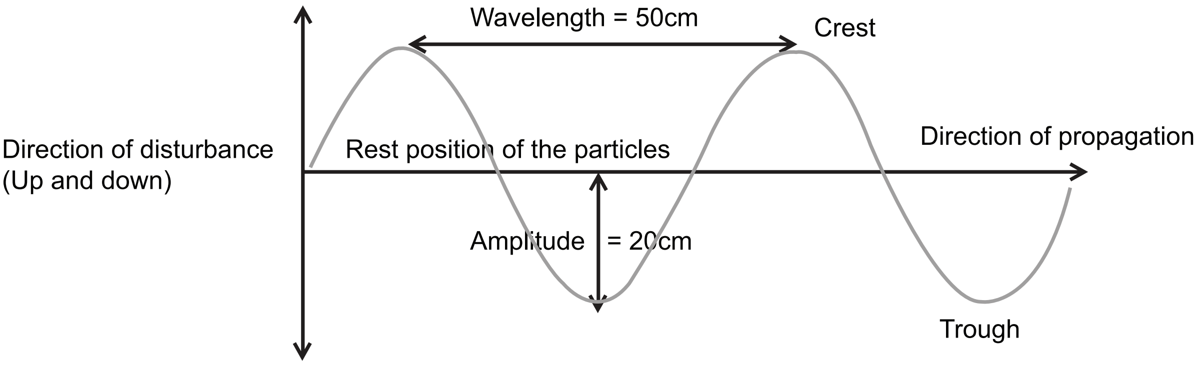
Solution

Given: A transverse wave Amplitude = 20 cm = 0,2 m
Speed = v = 5 m·s^{-1}
Frequency = f = 10 Hz

12.1.1	$v = \frac{d}{t}$	Choose the formula to calculate to the distance.
	$5 = \frac{d}{15}$	Substitute the known values.
	$d = 5 \times 15 = 75 \text{ m}$	Calculate the answer. Include the SI units.
12.1.2	$T = \frac{1}{f}$	Choose the formula.
	$= \frac{1}{10}$	Substitute the value.
	$= 0{,}1 \text{ s}$	Calculate the answer. Include the SI units.

12.1.3	$v = f\lambda$	Choose the formula.
	$5 = 10 \times \lambda$	Substitute the values.
	$\lambda = \frac{5}{10} = 0{,}5\ \mathrm{m}\ (50\ \mathrm{cm})$	Calculate the answer. Include the SI units.

12.3



CHALLENGE LEVEL CALCULATIONS

a. Now that learners have mastered the basic calculations, they are ready to deal with more challenging questions.

b. These questions require learners to **manipulate** the equation to change the subject of the formula.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

13. It takes 25 s for eleven crests to pass beneath a man standing on a pier. The waves travel at 2,0 m·s^{-1}.

13.1 Calculate the frequency of the waves.

13.2 Calculate the wavelength of the waves.

Solution

13.1 If 11 crests pass beneath the man, then 10 complete waves have passed in 25 s. The frequency is the number of waves that pass per second.

$f = \frac{number\ of\ waves}{time}$	Interpret the meaning of the word "frequency".
$= \frac{10}{25}$	Substitute the values.
$= 0,4\ \text{Hz}$	Calculate the answer. Include the SI units.

13.2

$v = f\lambda$	Choose the appropriate equation.
$2 = 0,4 \times \lambda$	Substitute the values.
$\lambda = \frac{2}{0,4} = 5\ \text{m}$	Calculate the answer. Include the SI units.

14. The frequency of vibration (oscillation; disturbance) is increased for transverse waves travelling along a rope. Briefly explain how the following quantities are affected by an increase in the frequency:

14.1 the period of the waves.

14.2 the speed of the waves.

14.3 the wavelength of the waves.

14.4 the amplitude of the waves.

Solution

14.1 $\text{Period} = \frac{1}{\text{Frequency}}$ therefore as the frequency increases, the period decreases.

14.2 The speed of the waves depends on the characteristics of the medium (rope). The same rope is used, with the same tension, therefore the speed remains the same (is constant).

14.3 Since $v = f\lambda$, then $\lambda = \frac{v}{f}$. The frequency *f* has increased, but *v* has remained constant, therefore λ decreases.

14.4 The amplitude of the waves depends on the amount of energy used to generate the waves. It remains constant.

KEY TEACHING

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for frequency, period, speed or the wavelength.

b. It is often easier for learners to substitute the values into the equation first, for example: $v = f\lambda$.

c. Once learners have done this, they should then change the subject of the formula.

d. Learners must also be able to work with and explain the relationships between these variables.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. being able to calculate speed, frequency, period and wavelength.
2. manipulating an equation to calculate one of the other variables in the equation

Topics 6 and 7 from the Resource Pack: Transverse Pulses and Transverse Waves Worksheet: Questions 15–19. (Pages 44–45).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topics 6 and 7 from the Resource Pack: Transverse Pulses and Transverse Waves Consolidation Exercise. (Pages 46–48).**
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation worksheet should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It is important to note that this consolidation exercise is NOT scaffolded.**
- **It should not be administered as a test, as the level of the work may be too high in its entirety.**

ADDITIONAL VIEWING / READING

In addition, further viewing or reading on this topic is available through the following web links:

1. https://www.brightstorm.com/science/physics/vibration-and-waves/transverse-waves/
   3 minute video about Transverse Waves.
2. https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html
   Simulation of transverse waves from pHet.
3. http://www.physicsclassroom.com/Physics-Interactives/Waves-and-Sound/Simple-Wave-Simulator
   A simulation of waves from The Physics Classroom.

TOPICS 8 & 9:

Longitudinal Waves and Sound

A Introduction

- This topic runs for 6 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- These topics form part of the content area of Waves, Sound and Light (Physics).
- Waves, Sound and Light counts 26,7% of the final Grade 10 Paper 1 (Physics) examination.
- Longitudinal Waves and Sound counts 8 % in the final examination.
- Understanding waves as a means of energy transfer is very important in Modern Physics. Communication systems work by transmitting and receiving signals via waves and/or pulses. Both transverse and longitudinal waves transmit information in modern telecommunications, radio, TV and digital systems. Medical technologies use ultrasound, MRI, X-rays and gamma radiation. The electromagnetic spectrum with its diverse range of characteristics and uses forms an integral part of everyday life in the 21st century.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 10 Physics Examination Data Sheet.
4. OPTIONAL: A slinky (Long spring).

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended.
3. Pen.
4. Ruler.
5. Grade 10 Physics Examination Data Sheet.

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7-9 QUALITATIVE ASPECTS	**GRADE 10 QUALITATIVE AND QUANTITATIVE ASPECTS**	**GRADE 11-12 FURTHER APPLICATIONS**
• Light energy: White light as a combination of colours: • travels through space. • is transferred by radiation. • passes through transparent materials and is absorbed and reflected by opaque materials. • Seeing: • vision (the eye), • seeing colour, • reflected light. • Dispersion: • colours of the visible spectrum. • infrared waves. • Transfer of energy: • heating by conduction, convection and radiation.	• Transverse pulses on a string or spring. • Transverse waves. • Longitudinal waves. • Sound. • Electromagnetic radiation.	• Geometrical Optics: • Refraction. • Snell's Law. • Critical angles and Total internal reflection. • 2D &3D Wave fronts. • Diffraction. • Doppler Effect (either moving source or moving observer): • with sound and ultrasound. • with light - red shifts in the universe. • Optical phenomena and properties of materials: • The photo-electric effect . • Emission and absorption spectra.

C Glossary of Terms

TERM	DEFINITION
Compression	A region of a longitudinal wave where the particles are closest together.
Rarefaction	A region of a longitudinal wave where the particles a farthest apart from each other.
Longitudinal wave	A wave in which the particles of the medium vibrate parallel to the direction of motion of the wave.
Pitch	The quality of a note that allows us to classify it as high or low. Pitch is related to the frequency of the sound. A high frequency vibration produces a high pitched note.
Loudness	The intensity of the sound; loudness is related to the amplitude of the sound wave.
Quality (tone)	The quality of a musical note depends on the type of instrument, e.g. a note of the same pitch played on a violin sounds difference from that same note played on a piano.
Ultrasound	Sound with frequencies higher than 20 kHz and less than 100 kHz.

D Assessment of this Topic

This topic is assessed by means of informal and control tests, and midyear and final examinations.

- There can be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.

E Breakdown of Topic and Targeted Support Offered

- Please note that this booklet does not address the full topic – only targeted support related to common challenges is offered.
- For further guidance on full lesson planning, please consult CAPS, the NECT Planner & Tracker and the textbook.

TIME ALLOCATION	SUB-TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
1 h	Longitudinal waves	27-28	Distinguishing between transverse and longitudinal waves.
1 h	Pitch, loudness, quality (tone)	28	**a.** The relationship between pitch and frequency. **b.** The relationship between the loudness of sound and the amplitude of a sound wave.
2 h	Sound waves	28	**a.** Common misconceptions related to sound. **b.** Echoes and technological applications of echoes.
1 h	Ultrasound	28	**a.** The difference between sonar and radar, and ultrasound and x-rays.

F Targeted Support per Sub-topic

A. DISTINGUISHING BETWEEN LONGITUDINAL AND TRANSVERSE WAVES

INTRODUCTION

Transverse waves are relatively easy to recognise from a diagram as they look like sine waves, which the learners learn about in mathematics. Longitudinal waves are difficult to represent as a diagram because the motion of the particles is parallel to the motion of the wave.

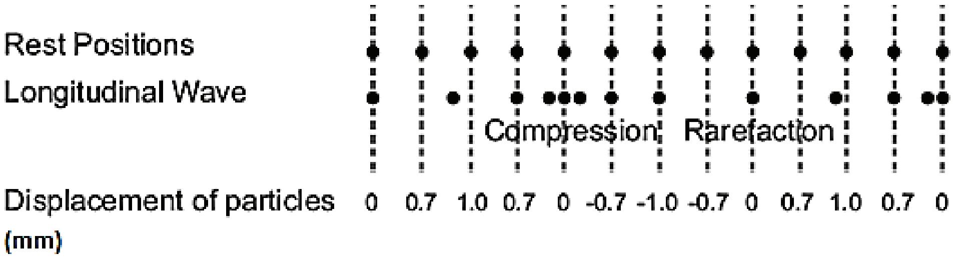
Mechanical waves require a medium in which they transmit energy. Mechanical waves set the particles of the medium into vibration to transmit energy. Longitudinal waves are mechanical waves. Some transverse waves are able to move through a medium and others can move through a vacuum, as well as through a medium.

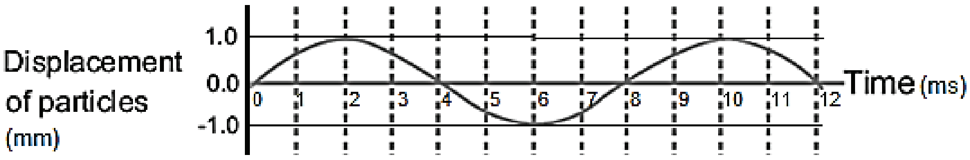
CONCEPT EXPLANATION AND CLARIFICATION

When demonstrating a longitudinal wave in a spring, attach a few coloured ribbons or pieces of cloth to the coils of the slinky, and tell the learners to describe the motion of the coloured ribbons. The ribbons move forwards and backwards about their rest positions. They do not move along the entire length of the slinky; just forwards and backwards about their rest positions.

To represent a longitudinal wave in a slinky we draw the positions of the coils as a series of lines or dots. We start with the coils as they are in their rest positions – all equally spaced – in a horizontal line.

When the wave is generated in the spring, the coils shift from their rest positions to form a series of compressions and rarefactions.





The graph of displacement of particles of the medium against time looks like the graph of displacement of particles against time for a transverse wave. But the displacement of the particles of a longitudinal wave is in the direction parallel to the direction of propagation of the longitudinal wave.

To find the amplitude of vibrations you measure the maximum displacement (change in position) of the particles from their rest positions. In the diagram above, the 2nd particle is displaced 0,7 units to the right, and the 3rd particle is displaced 1,0 units to the right, and so on.

The wavelength of a longitudinal wave consists of the length from the beginning of a compression to the beginning of another compression, or the beginning of a rarefaction to the beginning of another rarefaction. However, it is difficult to measure the wavelength in this manner because it is difficult to know where the compression (rarefaction) started. So, it is easiest to measure the wavelength of a longitudinal wave from the middle of a compression to the middle of the next successive compression.

Longitudinal waves are mechanical waves. They can only be transmitted through a medium. The particles of the medium are displaced from their rest positions parallel to the direction of propagation of the longitudinal wave.

Transverse waves can be transmitted through a vacuum and/or through a medium. Electromagnetic waves are transverse waves that can be transmitted in a vacuum. The transverse waves which are generated in a rope or a slinky are mechanical waves since they travel through a medium.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic calculations that learners will be required to perform at this stage in the topic.

b. Their purpose is to familiarise the learners with terminology.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. A wave is generated in a rope by pushing the free end of the slinky forwards and backwards along the length of the slinky. The wave travels along the slinky to a fixed end.

Draw a diagram of the wave as it travels along the slinky. Label the following:

1.1 the direction of propagation of the wave.

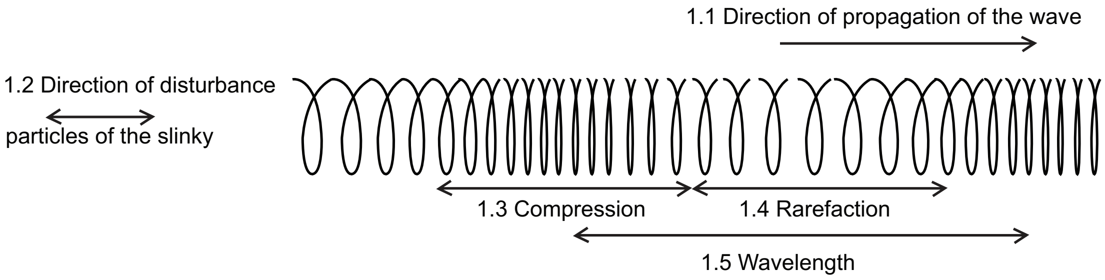
1.2 the direction of disturbance of the particles of the slinky.

1.3 a compression.

1.4 a rarefaction.

1.5 the wave length.

Solution



2. Distinguish between a transverse and a longitudinal wave, and explain how you can demonstrate their differences using a long spring (slinky).

Solution

A transverse wave is generated (produced) when the movement of the disturbance is at right angles to the direction in which the wave travels. When the spring is jerked at right angles to its length, the wave travels along the rope – the wave moves at right angles to the direction of the vibrations (disturbance).

A longitudinal wave is generated when the movement of the disturbance is parallel to the movement of the wave. Push the spring along its length, then pull it backwards to stretch it. The disturbance is forwards and backwards along its length. The wave travels forwards along the spring to the other end of the spring.

3. **3.1** Define a compression and a rarefaction of a longitudinal wave.

3.2 Explain why the wavelength of a longitudinal wave is measured from the centre of one compression to the next successive compression.

3.3 Explain how you can increase the amplitude of a longitudinal wave in a spring.

Solution

3.1 A compression is a region of a longitudinal wave where the particles are closest together. A rarefaction is a region of a longitudinal wave where the particles are farthest apart from each other.

3.2 It is easier to estimate the middle of a compression than to estimate the beginning and ending of a compression and rarefaction, so the wavelength is measured from the centre of the compression to the centre of the next compression. This includes the length of one whole compression and one whole rarefaction – that is the length of one complete wave.

3.3 The amplitude of a wave depends on the amount of energy it received from the vibrations. To increase the amplitude of a longitudinal wave on a spring push the coils together with more force and stretch the coils apart with more force – giving the vibrations more energy – and the waves a greater amplitude.

CHALLENGE LEVEL CALCULATIONS

a. Now that learners have mastered the basic terminology, they are ready to deal with more challenging questions.

b. These questions require learners to **use** the wave equation and to apply the formula which relates period and frequency.

c. The problems may also require the learners to **manipulate** a formula to change the subject of the formula.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

4. A longitudinal wave has a frequency of 20 Hz and a wavelength of 50 cm.

4.1 Calculate its period.

4.2 Calculate its speed.

4.3 If the frequency of vibration is doubled, how are the following quantities affected?

Briefly justify your answers.

a. The period

b. The speed

c. The wavelength

Solution

4.1

$$\begin{aligned} T &= \frac{1}{f} \\ &= \frac{1}{20} \\ &= 0{,}05\ \text{s} \end{aligned}$$

Unit for answer.

4.2 $v = f\lambda$

$= 20 \times 0,50$

$= 10 \text{ m·s}^{-1}$ Unit for answer.

4.3 **a.** The period is halved. $T = \frac{1}{f} = \frac{1}{40} = 0,025 \text{ s}$

b. The speed remains the same (is constant). Speed depends on the characteristics of the medium – and the wave travels through the same medium therefore the speed remains constant.

c. The wavelength is halved because $v = f\lambda$. When f doubles, λ halves.

KEY TEACHING

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for frequency, period, speed or the wavelength.

b. It is often easier for learners to substitute the values into the equation first, for example: $v = f\lambda$

c. Once learners have done this, they should then change the subject of the formula.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. the terminology associated with longitudinal waves.
2. the manipulation of the equation $v = f\lambda$ to calculate one of the other variables in the equation.
3. the calculation of period or frequency using $f = \frac{1}{T}$ and $T = \frac{1}{f}$.
4. the differences between transverse and longitudinal waves.

Topics 8 and 9 from the Resource Pack: Longitudinal Waves and Sound Worksheet: Questions 1–9. (Pages 56–57).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

B. COMMON MISCONCEPTIONS RELATED TO SOUND

INTRODUCTION

Some misconceptions with regards to sound are listed below.

- Air moves with the sound from the source to our ears.
- Sound can only travel through air.
- Sound is like light in that it cannot travel through opaque objects.
- The pitch and loudness of sounds are confused.
- When an object is struck with greater force the pitch of its sound is higher.
- The pitch of a sound is lowered as the sound dies out.
- Sound travels faster through gases than through solids.

CONCEPT EXPLANATION AND CLARIFICATION

Sound is a pressure wave which the human ear can detect. A sound wave is a longitudinal wave which is set up by the particles of air vibrating about their rest positions as compressions and rarefactions. To set the particles of air into vibration, there must be a vibrating source e.g. the membrane of a drum vibrates when it is struck with a drumstick. Compressions coincide with regions of high pressure; rarefactions are regions of low pressure.

Sound is a mechanical wave. It must travel through a material medium. Sound can travel through solids, liquids and gases. Dolphins at sea communicate with one another by making sounds. Their sounds travel through water as pressure waves move from one dolphin to the others.

Let the learners listen to sounds through their wooden desks or a table. Place the ear on the surface of the table, and knock the table top with a pencil. The learners will hear the sound through the air with one ear, and the sound through the wood with the other ear. Therefore, sound travels through air, liquids and solids.

The speed of the sound waves changes as it moves from one medium to another. Sound travel fastest through solids. This is also a challenging idea for learners who believe that because "air is thinner it forms less of a barrier to sound" and thus allowing sound to travel faster in air. To deconstruct this misconception, repeat the demonstration of the longitudinal wave – or discuss the movement of the particles of the medium. The particles set their adjacent particles into motion. In air, there are large spaces between the particles – it takes a longer time to set the adjacent particles into motion than it does for particles which are closer together, as they are in solids or liquids. You may want to explain that, if you are walking along a train track and you wish to know whether a train is approaching, place your ear to the train track. You will hear the sound of the train through the solid track before you hear the sound through the air, as sound travels faster through solids than through gases.

Be aware that some learners may have very fixed ideas of sound travelling in the space between the particles! They may say something like "sound travels between the particles and bumps into the next particle". Take the learner back to the notion that sound is a vibration – and discuss the way in which particles of the medium vibrate in a longitudinal wave.

A note with a high **pitch** has a higher frequency than one of lower pitch. High frequency vibrations generate higher pitched sounds. A typical example of high frequency vibrations is the high-pitched scream of a jet engine before take-off. And lower pitched sounds such as the sound of a jackhammer breaking up a tar road or a cement pavement.

Loudness is related to the amplitude of the sound. Its related to the amount of energy of the vibrations. A child is aware from an early age that it takes much more energy to shout to his friends than it does to whisper.

When an object such as a drum is struck it vibrates with its natural resonant frequency, so the sound that it emits has a certain pitch. If the object is struck harder, the pitch remains the same (it's the same object that is being struck), but the amplitude of the sound increases. The sound is louder.

As sounds die away they do so due to their energy being dispersed through the air or the medium in which they are travelling. The amplitude of the sound decreases as the sound dies away – the pitch remains the same because the sound is caused by vibrations of the same frequency.

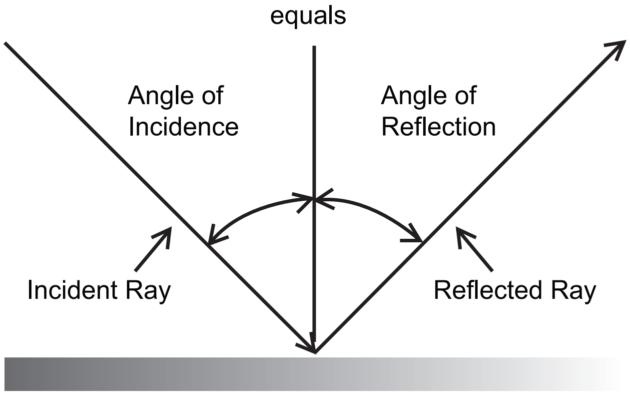
C. ECHOES AND TECHNOLOGICAL APPLICATIONS OF ECHOES

INTRODUCTION

Learners should be familiar with the phenomenon of reflection from the content which they covered in Grade 9. It would be a good idea to refresh their memories at this stage.

CONCEPT EXPLANATION AND CLARIFICATION

Reflection occurs when the sound wave hits a boundary and its direction is changed so that the angle of incidence is equal to the angle of reflection. If the angle of incidence is zero, the sound wave returns along its original path.



Echoes occur when there is more than a 0,1s delay between the “heard” sound and the “repeated” sound. If the delay is greater than 0,1 s the human ear hears two distinct sounds. It takes that minimum amount of time (of 0,1 s) because the brain holds the original sound in memory for 0,1 s – we cannot distinguish two distinct sounds in less time. The two sounds will sound like one prolonged sound.

Echoes are used in many applications – ultrasound, depth sensing, sonar – and in nature by bats for navigation.

When calculating how long it takes for an echo to return to a listener, we take into account that the distance travelled by the sound and its echo is twice as far as the reflecting surface.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic calculations that learners will be required to perform at this stage in the topic.

b. Their purpose is to familiarise the learners with the terminology and equation, but not to change the subject of the formula when calculating.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. When plucked a guitar string emits a sound with a frequency of 256 Hz. The wavelength of the sound is 1,33 m. When the tension of the string is tightened, the guitar string vibrates with a frequency of 300 Hz.

1.1 Calculate the speed of sound in air.

1.2 When the tension of the string is tightened, how are the following properties of the sound wave affected?

a. The pitch of the sound

b. The speed of the sound

c. The wavelength of the sound

Solution

1.1 $v = f\lambda$ Choose the appropriate formula

$= 256 \times 1,33$ Substitute the values

$= 340,48\ \text{m·s}^{-1}$ Calculate the answer. Insert SI units.

1.2 **a.** The frequency of the sound increases, therefore its pitch increased.

b. The speed of sound remains constant.

c. Since $v = f\lambda$ and *v* remains constant while *f* increases, the wavelength λ must decrease.

2. **2.1** State two characteristics of longitudinal wave motion.

2.2 Give evidence from everyday experience or facts that support the answer that:

a. sound travels through solids.

b. sound travels through water.

c. sound cannot travel through a vacuum.

Solution

2.1 The particles of the medium move parallel (along) the direction of wave travel (propagation).
The particles of the medium vibrate about their rest positions; the energy of the wave moves forward.
The wave is a periodic motion. (The wave form is repeated again and again at regular repeated intervals).

2.2 **a**. We can hear sounds through solids e.g. in a table top. In Western movies of the 1950's cowboys or Indians put their ears to the train tracks to hear if the train was coming. Sound travels faster in solids than it does in air. The sound of the train on the tracks would be heard earlier through listening to the sounds in the tracks than it would be heard through the air.

  b. Dolphins hear sounds through the water. They have an elaborate system of communication and they rely on the pressure waves carried through water.

  c. The classic experiment of an electric bell ringing in a bell jar, from which the air is evacuated, demonstrates that sound cannot travel through a vacuum. Other means of explaining that sound cannot travel through a vacuum are to state that sound waves are mechanical waves – they always require a medium through which to propagate.

3. A ship on the surface of the water sends a signal down to measure the depth of a shoal of fish which are located beneath it. The signal returns 4 s later. The speed of sound in water is 1 450 m·s^{-1}. At what depth below the ship are the fish?

Solution

t = 4 s		Time taken to travel down to the fish and back again.
Distance	= speed × time	Use the appropriate formula
	= 1 450 × 4	Substitute the values
	= 5 800 m	Calculate the answer
Depth	= ½ × distance	The question asked for depth (not total distance travelled)
	= ½ × 5 800	Substitute the values
	= 2 900 m	Calculate the answer. Insert the SI units.

CHALLENGE LEVEL CALCULATIONS

a. Now that learners have mastered the basic calculations, they are ready to deal with more challenging questions.

b. These questions require learners to **manipulate** the equation to change the subject of the formula.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

4. A longitudinal wave with a wavelength of 3 cm travels through air at a speed of 330 m·s^{-1}.

4.1 Calculate the frequency of this vibration.

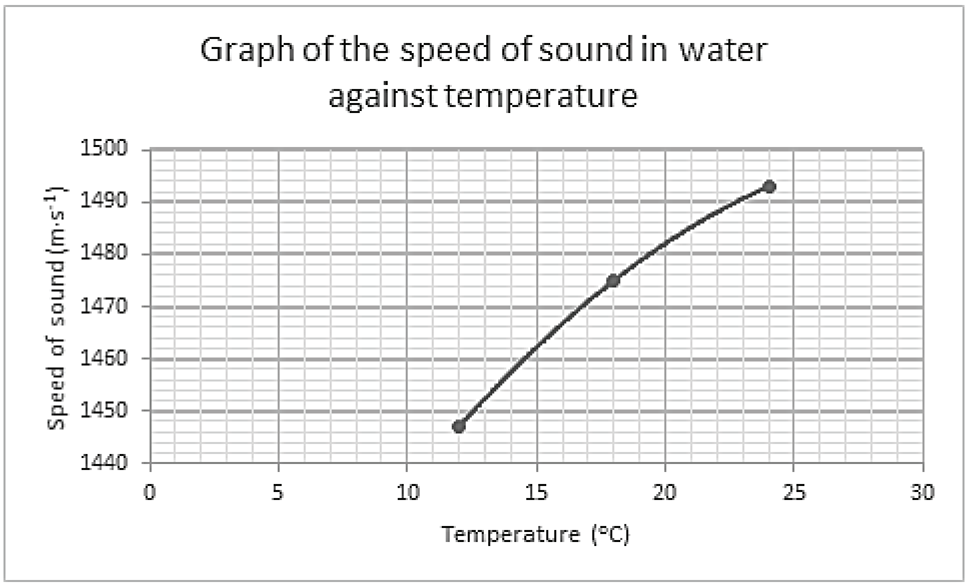
4.2 Can a person with a normal range of hearing hear the sound of this wave? Explain briefly.

Solution

4.1	$v = f\lambda$	Choose the appropriate formula.
	$330 = f \times 0,03$	Convert and substitute the values.
	$f = \frac{330}{0,03}$	Change the subject of the formula.
	$= 11\,000 \text{ Hz}$	Calculate the answer. Insert SI units.

4.2 Yes. The range of human hearing is from 20 Hz to 20 000 Hz, and this frequency fits within that range.

5. The speed of sound depends on temperature. The graph below shows the variation of the speed of sound with temperature for pure distilled water. Study the graph and answer the questions which follow.



5.1 Determine the speed of sound at ….

15°C and

20°C.

5.2 Write a general statement describing the relationship between the speed of sound and the temperature of the water.

5.3 Calculate how long it takes for sound to travel 1 000 m in water at 15°C.

5.4 Estimate the speed of sound at 30°C.

Solution

This problem includes analysis and interpretation of data, as well as calculations.

5.1 **a.** At 15°C the speed of sound is 1 462 $m \cdot s^{-1}$.

b. At 20°C the speed of sound is 1 482 $m \cdot s^{-1}$.

5.2 The speed of sound increases when the temperature increases.

NB. The graph is not a straight-line graph. It is incorrect to say that the speed of sound is directly proportional to the temperature.

Some learners may answer that "as the temperature is increased by 5°C the speed of sound increases, but by a smaller amount every 5°C." This is actually the best way to describe the relationship – but at this early stage of physics, we can be content to accept the first simple statement as sufficient.

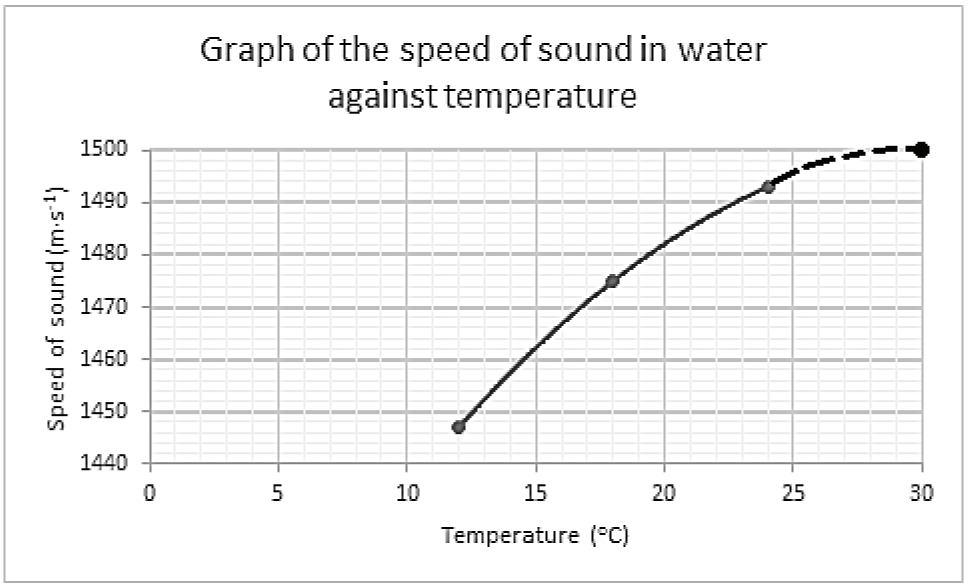
5.3 $v = \frac{total\ distance}{time}$ Choose the appropriate formula.

$1\,462 = \frac{1\,000}{time}$ Substitute the values.

$\text{Time} = \frac{1\,000}{1\,462}$ Change the subject of the formula.

$= 0,684\text{ s}$ Calculate the answer. Insert the SI units.

5.4 Refer to the graph and extend the trendline to include 30°C.
The graph should show the speed is about 1 500 $m \cdot s^{-1}$ at 30°C.



KEY TEACHING

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for distance, speed or time.

b. Learners must also interpret information from tables and/or graphs.

c. It is often easier for learners to substitute the values into the equation first, for example:

$v = \frac{distance}{time}$ or $v = f\lambda$

d. Once learners have done this, they should then change the subject of the formula.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. calculating speed, wavelength and/or frequency.
2. manipulating the equation $v = f\lambda$ to calculate one of the other variables in the equation.
3. calculating distance, speed of sound, or time when working with echoes.

Topics 8 and 9 from the Resource Pack: Longitudinal Waves and Sound Worksheet: Questions 10–13. (Pages 57–58).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

D. THE DIFFERENCE BETWEEN SONAR AND RADAR, AND ULTRASOUND AND X-RAYS.

INTRODUCTION

When sound waves meet a boundary e.g. sound travels from a solid to the air when someone knocks on the door, three things happen to the energy of the sound:

a. It is reflected.

b. It is absorbed.

c. It is transmitted.

The person on the other side of the door only hears part of the vibrations when someone knocks on a solid wooden door, because a small portion of the sound is absorbed by the material of the door. Some of the sound is reflected from the door – it never reaches the listener inside the house. Most of the sound is transmitted from the solid door into the air on the other side of the door.

Ultrasound technologies make use of the fact that sound waves are absorbed, reflected and transmitted when they meet boundaries. X-rays make use of the absorption, reflection and transmission of electromagnetic radiation when X-rays meet boundaries.

CONCEPT EXPLANATION AND CLARIFICATION

Ultrasound technologies use sound waves of frequency higher than 20 kHz but less than 100 kHz (beyond the range of human hearing). A transducer sends ultrasound waves into the body and receives echoing sound waves. (A transducer is any device which is able convert one form of energy into another form).

The sound waves bounce off internal organs, fluids and tissues. The receiver in the transducer records tiny changes in the pitch and direction of the sounds. These changes are displayed on a computer monitor as a real-time picture of the internal organs. The pictures are used to diagnose the causes of pain, swelling and infection in the body, and to examine the development of a foetus in pregnant women. Ultrasound can also be used to guide surgeons during operations, to diagnose heart conditions and to assess damage after a heart attack.

Ultrasound makes use of high frequency sound waves (pressure waves). Ultrasound waves are longitudinal waves. There is no ionising radiation associated with ultrasound technology.

X-ray technologies use small amounts of high energy electromagnetic radiation to penetrate the body. X-rays are transverse waves. They can travel through a vacuum, and through media. In a similar way to ultrasound waves, X-rays are sent by a transducer into the body and received by it when they are reflected off dense tissues. A computer monitor builds a real-time picture of the organs, and these pictures are used in diagnosis of fractures or abnormalities of dense tissues such as bone or air-filled tissues such as lungs. Ultrasound imaging is unable to produce images of these tissues.

The level of radiation exposure from an X-ray is considered safe for most adults but it is unsafe for a developing baby. Pregnant women should not be diagnosed using X-rays.

Both technologies are non-invasive (no needles or injections are required during the procedures). Ultrasound is widely available, easy-to-use and less expensive than other imaging methods. It is also very safe and uses no ionising radiation. Ultrasound gives a very clear picture of soft tissues which do not show up well with X-rays.

The term SONAR is derived from the words: **SO**und **N**avigation **A**nd **R**anging. Echo sounding to measure the depth of the ocean or locate shoals of fish uses ultrasound waves.

RADAR is a term derived from the words **RA**dio **D**etecting **A**nd **R**anging. Radar makes use of radio waves (electromagnetic waves) to locate the speed and position of distant objects e.g. aircraft. Radio waves are sent out to the object, and reflected back. The direction of the beam of radiation and the time taken to receive the reflected beam are used to calculate the position and speed of the object. Radar makes use of transverse waves, whereas sonar makes use of longitudinal waves.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the terminology.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions into their workbooks.

1. The type of tissue through which the ultrasound wave passes will NOT affect …

A. the frequency.

B. the wavelength.

C. the speed of the wave.

D. the amplitude of the wave.

Solution

Answer A.
The frequency of the wave is determined by the setting on the ultrasound machine. It remains the same when the ultrasound wave passes through tissues. The speed of the wave depends on the density (and other properties) of the tissues, therefore its wavelength will change according to $v = f\lambda$. The wave will lose energy as it is absorbed by the tissues therefore its amplitude will decrease.

2. What type of wave is ultrasound?

- **A.** transverse
- **B.** longitudinal
- **C.** electromagnetic
- **D.** rectangular

Solution

B. Ultrasound is a type of sound wave therefore it is a longitudinal wave.

3. Ultrasound waves cannot be heard by humans because the upper limit of human hearing is ...

- **A.** 20 Hz
- **B.** 2 000 Hz
- **C.** 20 000 Hz
- **D.** 200 000 Hz

Solution

C. Ultrasound is defined as sound waves with frequencies above 20 000 Hz, which is the upper limit of human hearing.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic facts, they are ready to deal with more challenging questions.

b. These questions require learners to **compare** (and **give reasons for**) the use of ultrasound with that of X-rays.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

4. During pregnancy, the unborn foetus is monitored using ultrasound.

4.1 Define the term "ultrasound".

4.2 Briefly explain how ultrasound waves can be used to produce an image of a foetus.

4.3 Give two reasons why ultrasound is used instead of X-rays when monitoring the development of the foetus.

4.4 Give another non-medical use of ultrasound technology.

Solution

4.1 Sound waves with frequencies higher than 20 000 Hz are called ultrasound.

4.2 A transducer sends ultrasound waves into the woman's abdomen. These waves reflect off the tissues, and are received by the transducer. A digital image of the tissues is displayed on a computer monitor. This image gives details about the unborn foetus.

4.3 **a.** Ultrasound is safe; it has no ionising radiation (which X-rays have).

b. It gives a very clear picture (image) of soft tissue which X-rays are not able to do.

4.4 SONAR uses ultrasound for depth sounding, locating shoals of fish etc.

KEY TEACHING

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for distance, speed or time.

b. They must also be able to compare ultrasound with X-rays, and distinguish between sonar and radar.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. knowing and understanding the difference between ultrasound and x-rays.
2. knowing and understanding the difference between sonar and radar.
3. knowing how to briefly explain ultrasound imaging processes.
4. knowing the benefits of ultrasound imaging.

Topics 8 and 9 from the Resource Pack: Longitudinal Waves and Sound Worksheet: Questions 14 and 15. (Page 58).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topics 8 and 9 from the Resource Pack: Longitudinal waves and sound Consolidation Exercise. (Pages 59–60).**
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation exercise should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It is important to note that this consolidation exercise is NOT scaffolded.**
- **It should not be administered as a test, as the level of the work may be too high in its entirety.**

ADDITIONAL VIEWING / READING

In addition, further viewing or reading on this topic is available through the following web links:

1. https://www.radiologyinfo.org/en/info.cfm?pg=genus
   Information on Ultrasound for the teacher.
2. https://www.youtube.com/watch?v=vloFWz-041k
   Ultrasound animation.
3. education.jlab.org/jsat/powerpoint/sound_and_waves.ppt
   Powerpoint on Sound and Waves.

TOPIC 10:

Electromagnetic Radiation

A Introduction

- This topic runs for 4 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Electromagnetic Radiation forms part of the content area of Waves, Sound and Light (Physics).
- Waves, Sound and Light counts 26,7% of the final Grade 10 Paper 1 (Physics) examination.
- Electromagnetic Radiation counts 8% in the final examination.
- Understanding waves as a means of energy transfer is very important in Modern Physics. Communication systems work by transmitting and receiving signals via waves and/or pulses. Both transverse and longitudinal waves transmit information in modern telecommunications, radio, TV and digital systems. Medical technologies use ultrasound, MRI, X-rays and gamma radiation. The electromagnetic spectrum with its diverse range of characteristics and uses forms an integral part of everyday life in the 21st century.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 10 Physics Examination Data Sheet.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended.
3. Pen.
4. Grade 10 Physics Examination Data Sheet.

B Sequential table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7-9 QUALITATIVE ASPECTS	**GRADE 10 QUALITATIVE AND QUANTITATIVE ASPECTS**	**GRADE 11-12 FURTHER APPLICATIONS**

• Light energy: White light as a combination of colours:
  • travels through space.
  • is transferred by radiation.
  • passes through transparent materials and is absorbed and reflected by opaque materials.
• Seeing:
  • vision (the eye),
  • seeing colour,
  • reflected light.
• Dispersion:
  • colours of the visible spectrum.
  • infrared waves.
• Transfer of energy:
  • heating by conduction, convection and radiation.
	• Transverse pulses on a string or spring.
	• Transverse waves.
	• Longitudinal waves.
	• Sound.
	• Electromagnetic radiation.
		• Geometrical Optics:
		  • Refraction.
		  • Snell's Law.
		  • Critical angles and Total internal reflection.
		  • 2D &3D Wave fronts.
		  • Diffraction.
		• Doppler Effect (either moving source or moving observer):
		  • with sound and ultrasound.
		  • with light-red shifts in the universe.
		• Optical phenomena and properties of materials:
		  • The photo-electric effect.
		  • Emission and absorption spectra.

C Glossary of Terms

TERM	DEFINITION
Wavelength	The distance between two successive points in phase.
Amplitude	The maximum disturbance of a particle from its rest (equilibrium) position.
Period	The time taken for on complete wave to pass a point.
Frequency	The number of waves passing a point in one second.
Relationship between frequency and period	$f = \frac{1}{T}$ and $T = \frac{1}{f}$
A photon	The smallest discrete amount (or quantum) of electromagnetic radiation.
Equation for the wave speed	$v = f\lambda$
Wave-particle duality	Some aspects of the behaviour of EM radiation can best be explained using a wave model and some aspects can best be explained using a particle model.
The dual nature of EM radiation	
The speed of light in a vacuum (The speed of EM radiation in a vacuum)	3 x 10^{8} m·s^{-1}
The EM spectrum	The range of wavelengths or frequencies over which electromagnetic radiation extends.
Energy of a photon	$E = hf$
Planck's constant (h)	6,63 x 10^{-34} J·s

D Assessment of this Topic

This topic is assessed by means of informal and control tests, and midyear and final examinations.

- There can be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.

E Breakdown of Topic and Targeted Support Offered

- Please note that this booklet does not address the full topic – only targeted support related to common challenges is offered.
- For further guidance on full lesson planning, please consult CAPS, the NECT Planner & Tracker and the textbook.

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
0,5 h	Electromagnetic radiation Dual (particle/wave) nature of EM radiation	29	**a.** Some misconceptions about the dual nature of EM radiation. **b.** Sound waves are different to radio waves.
1 h	Nature of EM radiation	29	The difference between sonar and radar, and ultrasound and x-rays. This was covered in the targeted support of Topics 8 and 9.
1 h	EM spectrum	29	**c.** The properties of EM radiation depend on its frequency.
1 h	Nature of EM as particle - energy of a photon related to frequency and wavelength	31	**d.** The particle nature of EM radiation

F Targeted Support per Sub-topic

A. SOME MISCONCEPTIONS ABOUT THE DUAL NATURE OF EM (ELECTROMAGNETIC) RADIATION

INTRODUCTION

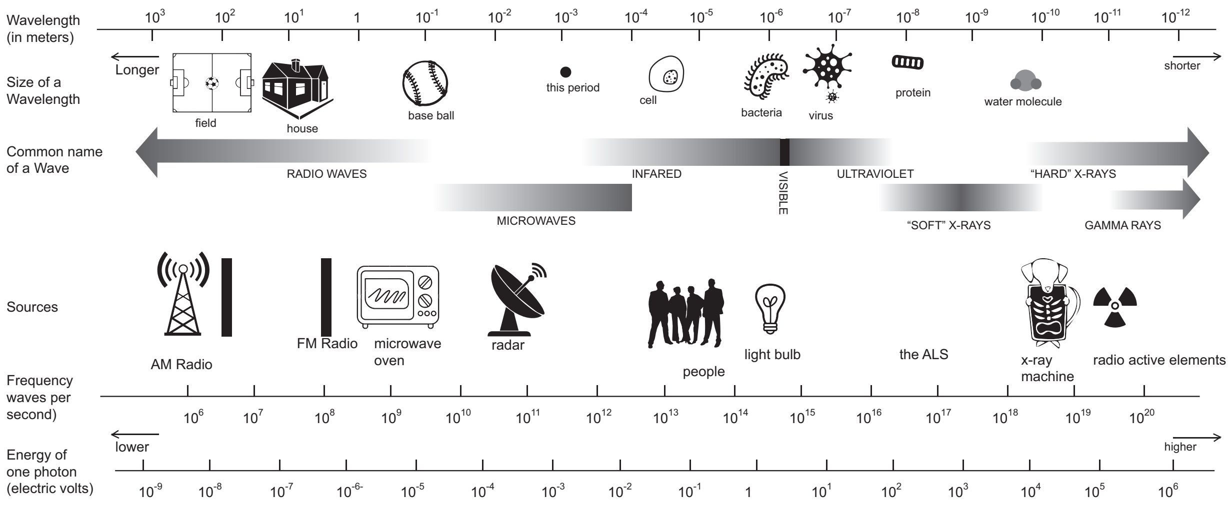
Although the idea of being both particle and wave simultaneously goes against our concept of the world as we experience it, it is a fact!

The dual nature of EM radiation is a fundamental part of modern quantum physics. This exciting new concept has opened up a wealth of knowledge regarding atoms, sub-atomic particles, the nucleus and how particles are held together, and new technologies such as nano-technology. We are still discovering many new things in these fields – and these inventions and discoveries have been possible by embracing quantum physics and mathematics – a journey into answering questions of how the very smallest of particles and electrons hold our universe together.

CONCEPT EXPLANATION AND CLARIFICATION

EM radiation consists of the full range of radiations, from radio waves to gamma rays, which are caused by oscillating (accelerating) charges. Visible light forms a small part of the EM spectrum. It falls between the infrared and ultraviolet regions. The chart shown below compares the wavelength of EM radiations in each region with the size of everyday objects. As the wavelength decreases, the energy of the radiation and its frequency increases. All EM radiation travels at the same speed (3×10^8 m·s^{-1}) in a vacuum.

[http://www2.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html]



THE ELECTROMAGNETIC SPECTRUM

The wave-particle duality theory describes EM radiation as a particle and a wave. Light is a particle and it is a wave at all times. It is never just a wave or just a particle. Many learners tend to believe that light is sometimes a particle and sometimes a wave depending on the way in which it is interacting. It is important to tell them that the dual nature of EM radiation is a property which occurs all the time.

The particle-like behaviour of EM radiation is more apparent at higher frequencies, from visible light up to gamma rays.

The concrete proof that EM radiation has both a wave and a particle nature comes from the following evidence:

1. Light waves diffract and interfere with one another.

   Diffraction occurs when a wave passes an edge. The direction of propagation of the wave changes when the wave passes an edge – it spreads out into the region behind the edge.

   If a tennis ball passes an edge it continues to travel in its straight line after passing the edge. A tennis ball can be considered to be a particle. Particles do not diffract when they pass an edge.

   Light diffracts when it passes an edge.

   Light also interferes, constructively and destructively, when two or more beams of light cross over each other. Destructive interference of light is the easiest to recognise because the absence of light is darkness. When two beams of light interfere destructively with one another dark (black) parts will be seen – that is the light waves "cancelling" each other.

   Diffraction of light can be observed when light passes through a narrow slit. The light waves bend around the edge, and an interference pattern is set up by the waves when they cross each other. The interference pattern is noticed by the dark (black) lines where destructive interference takes place.

   Hold your first two fingers close together, and within 3 to 5 cm from one eye. In the gap between your fingers you will see a pattern of light and dark lines running parallel to your fingers. The dark lines are lines of destructive interference. This demonstration proves that light is transmitted by a wave.

   Light can diffract and it can interfere. It is transmitted by waves.

2. The photoelectric effect proves the particle nature of light.

   It is not easy or useful in the short time available for teaching this concept at Grade 10 level to demonstrate the photoelectric effect to the learners. It is generally widely known that solar energy is transformed to electrical energy via solar cells. So, it can be sufficient to tell the learners that electrons are knocked off the surface of some metals by light shining on their surfaces; this is called the photoelectric effect.

> Physicists have discovered that the only way to explain the way that light frees electrons from the surface of a metal is that light consists of particles. These particles are called quanta because of each particle contains a specific quantity of energy. One particle is called "a quantum". When a quantum strikes an electron on the surface of a metal its energy is absorbed by an electron. The electron is able to move off the surface into the air.

At all times light (and all electromagnetic radiation) is a particle and a wave. It always has its dual nature. How we experience the type of radiation depends on how we see it interacting – but that does not change the fact that EM radiation is both a wave and a particle.

The dual nature of EM radiation is counter-intuitive. It does not belong in the realm of common sense, and it is often beyond the realm of common reasoning also. We introduce learners to this idea when the only experience they have of energy transfers by waves and by particles is the learning of the preceding three weeks of work on transverse and longitudinal waves. It is no wonder that learners have difficulty grasping the idea of the dual nature of EM radiation.

B. SOUND WAVES ARE DIFFERENT TO RADIO WAVES.

INTRODUCTION

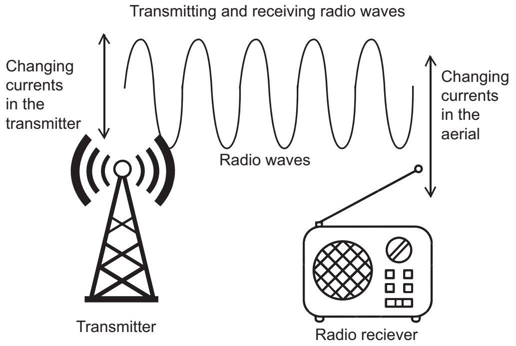
We hear radio (and TV) broadcasts. Learners are aware that radio and TV signals are transmitted from a radio station. Learners may not know how a radio works so that we can hear these broadcasts. Some learners believe that radio waves are the same as sound waves.

CONCEPT EXPLANATION AND CLARIFICATION

Sound waves are entirely different from radio waves. Sound waves are longitudinal waves which cause pressure variations in the air; radio waves are transverse electromagnetic waves which cannot be received by the human ear.

Learners will also possibly believe that radio waves travel at the speed of sound. It is useful to clearly distinguish between radio and sound waves by describing how a radio wave is generated and transmitted, and how it is received by the radio (receiver).

Radio waves are long wavelength (low frequency) EM waves. They are produced by a transmitter which sends electric charges moving rhythmically up and down in an aerial. The moving charges create a changing electric field, which sets up a changing magnetic field at right angles to the electric field. These two interacting fields propagate out from the aerial at the speed of light, forming the radio wave.



The aerial of the radio (or TV) receiver detects the electric field of the radio wave. Electrons in the aerial of the receiver are set in motion, moving up and down its length, and sending signals to the electronic circuit of the radio. The electronic circuit transforms these signals into mechanical vibrations of the loudspeaker. The vibrating cone of the loudspeaker sets air particles into motion, making the sound waves which we hear.

Radio waves belong to the same group of waves as (visible) light. When asked if visible light and radio waves travel at the same speed, a learner incorrectly said that "They should travel at the same speed, but visible light would actually travel faster than radio waves because it has more energy."

This type of response is typical of many learners who possibly have the following misconception:

- The speed of the wave depends on the energy transmitted by the wave.

In fact, the speed of the wave is equal to its frequency multiplied by its wavelength. The energy of the wave depends on its amplitude (which has no effect on the speed of the wave).

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the terminology.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

MULTIPLE CHOICE

1. Which of the following EM radiations has the longest wavelength?

A. radio waves

B. infrared waves

C. visible light

D. x-rays

2. Electromagnetic waves carry ….

A. positive charge.

B. negative charge.

C. both positive and negative charge.

D. no charge.

3. Electromagnetic waves travel …..

A. in a medium.

B. without a medium.

C. both in a medium and without a medium.

D. in a distorted path.

4. Sound waves are …..

A. electromagnetic waves.

B. electromagnetic waves of long wavelength.

C. longitudinal waves.

D. transverse waves.

5. Radio waves differ from sound waves because they …..

A. travel faster than sound waves.

B. are electromagnetic waves.

C. are transverse waves.

D. have all of the properties described in A, B and C.

Solutions

1. A Radio waves have the longest wavelength.
2. D No charge. EM waves carry energy. In fact, all waves carry energy.
3. C They consist of interacting electric and magnetic fields which can travel through a vacuum and through a medium.
4. C Sound waves are pressure waves – longitudinal waves.
5. D The speed of a radio wave is 3×10^8 m·s^{-1}; the speed of sound is about 330 m·s^{-1}. Radio waves are electromagnetic waves, but sound waves are longitudinal waves. Radio waves are transverse waves because the electric and magnetic fields vibrate at right angles to their directions of propagation.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic terminology, they are ready to deal with more challenging questions.

b. These questions require learners to use the wave equation and to apply the formula which relates period and frequency.

c. The problems may also require the learners to **manipulate** a formula to change the subject of the formula.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

6. A radio station broadcasts at a frequency of 105 kHz. What is its wavelength (in m)?

Solution:

$v = f\lambda$	Choose the appropriate formula.
$3 \times 10^{8} = (105 \times 1\,000) \times \lambda$	Insert the speed of sound. Convert kHz to Hz.
$\lambda = \dfrac{3 \times 10^{8}}{1{,}05 \times 10^{5}}$	Change the subject of the formula.
$= 2{,}86 \times 10^{-3}$ m	Calculate the answer. Insert the SI units.

(0,00286 m or 2,86 mm)

7. Radio waves are reflected from the surface of the Moon. The time elapsed between sending the signal and receiving it on Earth is 2,5 s.

7.1 How far is the surface of the Moon from the Earth?

7.2 If radio waves of twice the frequency as those that were originally sent to the Moon were reflected from its surface, how long would it take for the signal to return to Earth? Explain briefly.

Solution:

7.1

Distance $=$ speed $\times$ time	Choose an appropriate formula.
$= 3 \times 10^{8} \times \frac{1}{2} \times 2{,}5$	Insert the speed of light (EM radiation). Either half the time here, or after calculating the distance, half the distance.
$= 3{,}75 \times 10^{8}$ m	Calculate the answer. Insert the SI units.

7.2 It will take the same length of time because the speed of radio waves is fixed (all EM radiation travels) at 3×10^{8} m·s^{-1}

8. Clearly distinguish between "a sound wave" and "a radio wave".

Solution

Sound waves are longitudinal waves which are set up by vibrations which cause matter to vibrate in a series of compressions and rarefactions.

Radio waves are electromagnetic waves which are set up by electric charges accelerating. The transverse wave consists of electric and magnetic fields vibrating at right angles to each other. It can propagate through a vacuum and through materials.

KEY TEACHING

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, and choose the appropriate formula.

b. It is often easier for learners to substitute the values into the equation first, for example: $v = f\lambda$.

c. Once learners have done this, they should then change the subject of the formula.

d. Learners must be able to use the formula $v = \frac{distance}{time}$ when dealing with echoes.

e. Learners must also understand that all EM waves travel through a vacuum (or space) at a constant speed (3×10^8 m·s^{-1}).

f. Learners must be able to distinguish between sound (and ultrasound) waves and any form of EM radiation e.g. radio waves, x-rays etc. They should be able to explain the differences between them.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. the terminology associated with electromagnetic waves.
2. manipulating the equation $v = f\lambda$ to calculate one of the other variables in the equation.
3. calculating distance, time or speed when using $v = \frac{distance}{time}$.
4. knowing and understanding the differences between sound and radio waves.

Topic 10 from the Resource Pack: Electromagnetic Radiation Worksheet: Questions 1–6. (Pages 67–68).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

C. THE PROPERTIES OF EM RADIATION DEPEND ON ITS FREQUENCY

INTRODUCTION

The EM spectrum is an amazing phenomenon. The same type of wave transports so many diverse forms of radiation at exactly the same speed. There are many misconceptions which become apparent when learners first encounter this topic.

- Different kind of EM radiation travel at different speeds.
- Radio waves travel at the speed of sound.
- Visible light is fundamentally different from all the other kinds of EM radiation.
- Red light has more energy than blue light.
- All EM radiation is dangerous.
- All spectra of light are continuous.

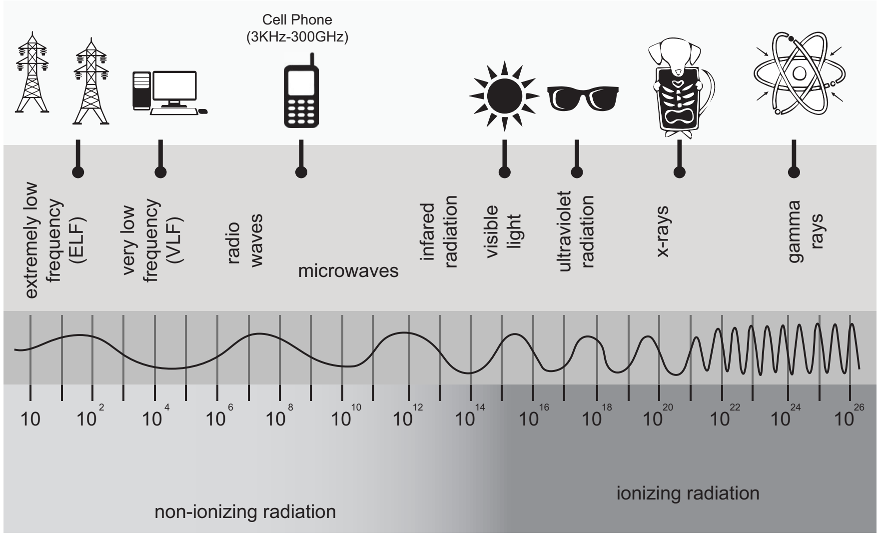
CONCEPT EXPLANATION AND CLARIFICATION

All EM radiation is created by accelerating electric charges. The alternating electric field set up by the accelerating charges, induces an alternating magnetic field at right angles to it, and this constitutes the EM wave which moves out at right angles to both fields at the speed of light (3×10^{8} m·s^{-1}).

Therefore, all EM radiations have the following common characteristics:

- Same speed in a vacuum.
- Transverse waves.
- Able to travel through a vacuum and through materials (solid, liquid and gas).
- Consist of an alternating electric field and magnetic field at right angles to each other.
- Can be reflected, refracted, diffracted, can interfere, and can be polarised.
- Show evidence of wave-particle duality.

The EM spectrum consists of a large range of waves with wavelengths of a few kilometres in length to 1×10^{-10} m. The frequencies vary from about 1×10^{9} Hz to 1×10^{19} Hz.



It is the frequency that distinguishes one kind of the EM radiation from the other. The higher the frequency, the higher the energy of the radiation. EM radiations with frequencies above those of visible light are able to ionise materials, and therefore they are dangerous to living tissues. These radiations include ultraviolet (UV), X-rays and gamma rays.

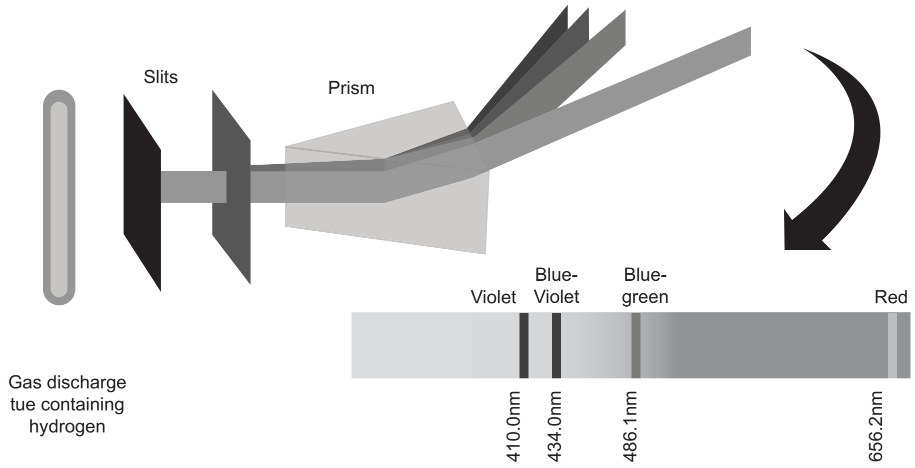
Our eyes are only able to detect radiation in the range of visible light (frequencies of $4{,}3 \times 10^{14}$ to $7{,}6 \times 10^{14}$ Hz). This does not make visible light fundamentally different from radiation in the rest of the EM spectrum; the only difference is that we can see “light”.

Red light has the lowest frequency of visible light and blue the highest, therefore blue light of the same intensity has more energy than red light.

A continuous spectrum as produced by a rainbow includes all the colours of light. It occurs when white light disperses into its colours either by raindrops (as in the formation of a rainbow) or by a prism (by refraction) or by diffraction (e.g. the “rainbows” of colour that reflect off a DVD or CD).

ENRICHMENT - Line emission spectra of elements

When a glass tube containing the vapour of a gas at low pressure e.g. hydrogen, has a high voltage applied across the tube, the tube glows with a characteristic colour.



The spectrum of a hydrogen atom is called a line emission spectrum. It shows the colours of light that are given off by hydrogen atoms when their electrons fall from higher energy states into lower energy states. This is not a continuous spectrum because there are dark gaps between the colours of light. In fact, there are specific bands (lines) of colour and the remainder of the spectrum is dark (black) with no colour. This line emission spectrum shows us that electrons in hydrogen atoms are only able to release specific amounts of energy i.e the energy of electrons in (hydrogen) atoms is quantised.

Line emission spectra also show us that not all spectra are continuous.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions that learners will be required to answer at this stage in the topic.

b. Their purpose is to familiarise the learners with the terminology and the regions of the EM spectrum.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. Arrange the following EM radiations in order of increasing wavelength:
Ultraviolet, infrared, microwaves, X-rays, radio waves.

Solution

The radiation with the longest wavelength has the lowest frequency, so we must arrange the regions in order of highest to lowest frequency (and energy).

X-rays, ultraviolet, infrared, microwaves, radio waves

2. Match the description of the use/application with an appropriate region (or regions) of EM radiation:

2.1 Identify bone fractures

2.2 Transmit and receive cell phone calls

2.3 Radiation treatment of cancer

2.4 Radiating foodstuff to kill bacteria

2.5 Photosynthesis of plants

2.6 Cooking food

2.7 Wireless broadband

2.8 Radio and TV broadcasting

2.9 Security checks of luggage at airports

Solution

2.1 X-rays

2.2 microwaves

2.3 gamma rays (sometimes high energy X-rays)

2.4 ultraviolet

2.5 visible light

2.6 infrared and microwave

2.7 microwaves (frequency = 2,4 GHz)

2.8 radio waves

2.9 X-rays

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic terminology, they are ready to deal with more challenging questions.

b. These questions require learners to manipulate the equation to change the subject of the formula.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

3. Wireless broadband signals are limited to a narrow range of frequencies between 2 400 to 2 483,5 MHz because in this region of EM radiation broadcasters and those who receive signals do not need to pay a licence fee to the radio broadcast authorities.

3.1 Which of 2 400 MHz and 2 483,5 MHz produces a wave with the longest wavelength? Explain briefly.

3.2 The upper limit of 2 483,5 MHz is chosen because microwave ovens use a frequency of 2 450 MHz to cook food. This specific frequency causes water molecules to vibrate vigorously, and their kinetic energy is transferred to food (which consists mostly of water)!

Calculate the wavelength of microwaves with a frequency of 2 450 MHz.

Solution

3.1 Because $v = f\lambda$ the greater the frequency, the shorter the wavelength. Therefore 2 400 MHz produces a wave with the longest wavelength.

3.2

$v = f\lambda$	Choose the appropriate formula
$3 \times 10^8 = 2\,450 \times 1\,000\,000 \times \lambda$	Insert the speed of EM radiation (light).
	Convert MHz to Hz (× 10^6)
$\lambda = \dfrac{3 \times 10^8}{2\,450 \times 1\,000\,000}$	Change the subject of the formula
$= 0,122$	Calculate the answer. Insert the SI units.

4. A ray of light with a frequency of 5×10^{14} Hz shines on water. When the ray passes into the water its slows down to $2{,}55 \times 10^8$ m·s^{-1}.

4.1 Calculate the wavelength of this light in air.

4.2 Explain why the frequency of the light does not change when it passes into water.

4.3 Calculate the wavelength of the light in water.

Solution

4.1

$v = f\lambda$	Choose the appropriate formula.
$3 \times 10^8 = 5 \times 10^{14} \times \lambda$	Insert the speed of EM radiation (light).
	Substitute the value for frequency.
$\lambda = \dfrac{3 \times 10^8}{5 \times 10^{14}}$	Change the subject of the formula.
$= 6 \times 10^{-7}\text{ m}$	Calculate the answer. Insert the SI units.

4.2 The light is created by an electric charge which is vibrating (oscillating) at that particular frequency (5×10^{14}Hz).

4.3

$v = f\lambda$	Choose the appropriate formula.
$2{,}55 \times 10^8 = 5 \times 10^{14} \times \lambda$	Insert the speed of EM radiation (light).
	Substitute the value for frequency.
$\lambda = \dfrac{2{,}55 \times 10^8}{5 \times 10^{14}}$	Change the subject of the formula.
$= 5{,}1 \times 10^{-7}\text{ m}$	Calculate the answer. Insert the SI units.

KEY TEACHING

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for wavelength, speed or frequency.

b. Learners must also visualise the context in which the problem is set.

c. It is often easier for learners to substitute the values into the equation first, for example: $v = f\lambda$.

d. Once learners have done this, they should then change the subject of the formula.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. the calculation of speed, wavelength and/or frequency.
2. the manipulation of the equation $v = f\lambda$ to calculate one of the other variables in the equation.
3. describing regions of the EM spectrum and their uses in everyday applications.
4. listing the regions of the EM spectrum in order of:
   a) increasing frequency
   b) increasing wavelength.

Topic 10 from the ResourcePack: Electromagnetic Radiation Worksheet: Questions 7–10. (Page 68).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

D. THE PARTICLE NATURE OF EM RADIATION

INTRODUCTION

Common misconceptions about EM radiation as a particle are listed below:

- The longest wavelength photons carry the most energy.
- Photons only behave as particles.
- Photons travel on waves.

CONCEPT EXPLANATION AND CLARIFICATION

This topic relates photon energy to the frequency of EM radiation. $E = hf$

A photon is the smallest discrete amount (or quantum) of electromagnetic radiation. It is the basic unit of all light. The energy (E) of a photon of EM radiation is given by:

$E = hf$ where h is Planck's constant ($6{,}63 \times 10^{-34}$ J·s)
and f is the frequency of the radiation (in Hz).

Photons are always moving.

In a vacuum, photons travel at the speed of light (3×10^8 m·s^{-1}).

Photons do not travel on waves. Photons are particles and they are waves.

If we know the energy of a photon, we can find its frequency using the formula: $E = hf$. And using the wave equation $v = f\lambda$, we can calculate the wavelength of the photon. The photon with the highest frequency has the highest energy. It follows then that the photon with the shortest wavelength has the highest frequency.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic calculations that learners will be required to perform at this stage in the topic.

b. Their purpose is to familiarise the learners with the terminology.

How to tackle these questions in the classroom:

- Learners must copy the questions and then answer them in their workbook.
- After a short time, work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must ensure that they have correct copies of the answers to the questions in their workbooks.

1. Calculate the energy of a photon of ultraviolet radiation with a frequency of 6×10^{15} Hz.

Solution

1. $E = hf$	Choose the appropriate formula.
$= 6{,}63 \times 10^{-34} \times 6 \times 10^{-15}$	Insert Planck's constant (h). Substitute the value for frequency.
$= 3{,}98 \times 10^{-18}$ J	Calculate the answer. Insert the SI units.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have mastered the basic calculations, they are ready to deal with more challenging questions.

b. These questions require learners to compare (and give reasons for) the use of different forms of EM radiation.

c. The calculations required learners to use any (or all) of the following formulae:

$f = \frac{1}{T}$ $v = f\lambda$ $E = hf$

and to change the subject of the formula when required.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Tell learners that this is a more challenging version of what they have been doing.
- Write the first example on the chalkboard.
- Ask learners to look at the example and see if they can work out what must be done / what is different.
- Discuss learners' ideas, and ask probing questions to extend their answers.
- Try to be positive in these interactions, to encourage critical thinking and questioning.
- Ensure that learners copy down both the question and the solution into their workbooks.

2. Ultraviolet radiation has higher energy than visible light. Give two other ways in which UV radiation differs from visible light.

Solution

2.1 UV radiation has higher frequency than visible light (since $E = hf$ and E is greater therefore f must be greater).

2.2 Visible light can be detected by humans; UV radiation is invisible – we cannot see it, and nor can we detect with our natural senses.

2.3 Both visible and UV radiation are ionising radiations – but UV ionises materials more easily than visible light does because UV photons have more energy than visible light photons do.

3. EM radiation produces photons with 4,2 × 10^{-17} J.

3.1 Calculate the frequency of this radiation.

3.2 Calculate the period of the radiation.

3.3 Calculate the wavelength of the radiation.

Solution

3.1

$E = hf$	Choose the appropriate formula.
$4,2 \times 10^{-17} = 6,63 \times 10^{-34} \times f$	Insert Planck's constant (*h*).
	Substitute the value for energy.
$f = \dfrac{4,2 \times 10^{-17}}{6,63 \times 10^{-34}}$	Change the subject of the formula.
$f = 6,33 \times 10^{16}\ \text{Hz}$	Calculate the answer. Insert the SI units.

3.2

$$T = \frac{1}{f}$$
$$= \frac{1}{6,33 \times 10^{16}}$$
$$= 1,58 \times 10^{-17}\ \text{s}$$

3.3

$$v = f\lambda$$
$$3 \times 10^{8} = 6,33 \times 10^{16} \times \lambda$$
$$\lambda = \frac{3 \times 10^{8}}{6,33 \times 10^{16}} x\lambda$$
$$= 4,74 \times 10^{-9}\ \text{m}$$

KEY TEACHING

a. In these more challenging examples, learners must integrate and explain how the technologies work.

b. They must also be able to compare ultrasound with x-rays, and distinguish between sonar and radar.

CHECKPOINT

At this point in the topic, learners should have mastered:

1. calculating the energy of a photon when given the frequency using $E = hf$.
2. manipulating the equation $E = hf$ to find the frequency when given the energy of a photon.

Topic 10 from the Resource Pack: Electromagnetic Radiation Worksheet: Questions 11–12. (Page 69).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of the marking guidelines and place them on the walls of your classroom.
- Allow time for feedback.
- Encourage learners to learn from mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topic 10 from the Resource Pack: Electromagnetic Radiation Consolidation Exercise**. **(Pages 70–71).**
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation exercise should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It is important to note that this consolidation exercise is NOT scaffolded. It should not be administered as a test, as the level of the work may be too high in its entirety**.

ADDITIONAL VIEWING / READING

In addition, further viewing or reading on this topic is available through the following web links:

1. http://www.apa.org/education/k12/misconceptions.aspx
   For teachers: A general summary of ways in which teachers can remediate learners' misconceptions (in general). Refer to the "Do's and Don'ts" for specific guidance.
2. http://www.ducksters.com/science/physics/photons.php
   For teachers and learners: Notes on the nature of photons.
3. http://www.ducksters.com/science/physics/types_of_electromagnetic_waves.php
   For teachers and learner: Notes on the different types of electromagnetic waves.
4. https://www.wired.com/2010/09/wireless-explainer/
   For extension: teachers and learners: An interesting article on the frequency of wireless broadband.
5. https://thehealthsciencesacademy.org/health-tips/microwave-radiation/
   For teachers and learners: How does a microwave work and questions related to its safety.