PHYSICAL SCIENCES
Grade10
TERM 3
Content Booklet
TARGETED SUPPORT

Gr10_T3-PhysicalScience_Contents.indb 1 2019/05/31 5:34:14 AM

Contents

A Message from the NECT

National Education Collaboration Trust (NECT)

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 and to help the DBE reach the NDP goals.

The NECT has successfully brought together groups of relevant people 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). Curriculum learning programmes were developed for Maths, Science and Language teachers in FSS who received training and support on their implementation. The FSS teachers remain part of the programme, and we encourage them to mentor and share their experience with other teachers.

The FSS helped the DBE trial the NECT learning programmes so that they could be improved and used by many more teachers. NECT has already begun this embedding process.

Everyone using the learning programmes comes from one of these groups; but you are now brought together in the spirit of collaboration that defines the manner in which the NECT works. Teachers with more experience 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 Section 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, surface tension, solubility, rate of evaporation
   - **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:

Examination Preparation

Note: It is important to start preparing learners for the end of year examinations from the start of the 3rd term as their midyear exams will still be quite fresh in their minds.

1. Make sure that your learners know exactly what content their Physical Science examination will cover.
2. Ask learners to take out their exercise books, and to mark off what must be studied.
3. Go through all their written work, and get them to tick off the work that they must study and practise.
    a. If learners are missing notes, they must copy the missing work from another learner.
    b. As you complete more work during the term that will be in the exam, tell learners to tick it off and to add it to their study plans.
4. If necessary, help learners to work out a study schedule.
    a. Estimate how long learners will need to study all the content required for the examination. This will differ from grade to grade, and from learner to learner.
    b. Be aware that some learners, even in the FET stage, have not yet developed these planning skills.
    c. Tell learners the number of hours that you think they need to study before the examination.
    d. Break this down into the number of hours they should study each week.
    e. Tell learners to think about their own lives and habits, and to work out when they have time to study, and when they study best.
    f. They must then use all of this information to work out their study and revision plan.

USEFUL REVISION RESOURCES

1. **Assessment Section of the Resource Pack**
    a. The Assessment Section that forms part of this series may be used as a very useful examination preparation tool.
    b. This section includes a 'bank' of questions for each topic at the different conceptual levels.
    c. If your province or district provides standardised tests and exams, use the questions in this booklet at revision and exam preparation for learners.

d. Remember to carefully explain the question structure and meaning, together with the mark allocation.

2. **Vodacom e-school**

   a. If learners have a Vodacom number, they are eligible to use the Vodacom e-school as a free service, i.e. no data costs:
   http://www.vodacom.co.za/vodacom/test-templates/eschool-two

   b. This e-school includes Physical Science lessons as part of its curriculum.

   c. Tell learners how to access this useful resource.

TOPIC 17:

Reactions in Aqueous Solutions

A Introduction

- This topic runs for 8 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT
- Planner & Tracker.
- Reactions in aqueous solutions forms part of the content area Chemical change (Chemistry).
- Chemical change counts as 40 % in the Paper 2 (Chemistry) examination.
- Reactions in aqueous solutions counts approximately 10 % to 12 % of the final examination.
- Many chemical reactions occur in solution. Most reactions carried out in a school laboratory occur in solution. In nature, too, reactions occur in solution, e.g. plants absorb their nutrients from the soil in the form of aqueous solutions.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Periodic Table.
4. Tables of cations and anions as shown on page 161 and 162 in CAPS.
5. Table of Solubilities Page 163 CAPS.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises.
2. Pen.
3. Periodic Table.
4. Tables of cations and anions as shown on page 161 and 162 in CAPS.
5. Table of Solubilities Page 163 CAPS.

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7 – 9	**GRADE 10**	**GRADE 11 – 12**
• Chemical equations to represent reactions. • Balanced equations. • Acids and bases.	• Ions in aqueous solution: their interaction and effects. • Electrolytes and extent of ionisation as measured by conductivity. • Precipitation reactions. • Other chemical reaction types in water solution.	• Reaction rates. • Chemical equilibrium. • Solutions. • Acids and bases.

C Glossary of Terms

TERM	DEFINITION
Aqueous solution	A solution in which the solvent is water.
Polar molecule (dipole)	A molecule with two oppositely charged poles. (Also known as a dipole).
Dissociation	The process in which solid ionic crystals are broken up into ions when dissolved in water e.g. $NaC\ell(s) \rightarrow Na^{+}(aq) + C\ell^{-}(aq)$.
Solubility	The maximum amount of a substance (the solute) that may be dissolved in another (the solvent).
Solution	A homogenous mixture of two or more substances.
Solute	The dissolved substance in a solution – usually the substance present in lesser amount.
Solvent	The substance in a solution in which the solute is dissolved - usually the substance present in greater amount.
Hydration	The process in which ions are surrounded with water molecules.
Conductivity	The ability of a material to conduct electricity.
An electrolyte	A solution that conducts electricity through the movement of ions.
Concentration	The number of moles of solute per unit volume of solvent.
Mole	The amount of substance having the same number of particles as there are atoms in 12 g carbon-12. The mole is the SI unit for an amount of substance.
Precipitation reactions	Reactions in which an insoluble product forms when solutions are mixed. The insoluble product is called the precipitate.
Gas-forming reactions	Reactions in which the driving force is the formation of a gas as one of the products.
Acid-base reactions	Reactions in which a hydrogen ion (H^{+} ion) is transferred from one of the reactants to another.
Redox reactions	Reactions in which an electron transfer takes place. One reactant gains electrons and another loses electrons.
Spectator ion	An ion that undergoes no change during a chemical reaction.
Salts	Ionic compounds formed as products of acid-base reactions.

D Assessment of this Topic

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

- There may be multiple-choice type questions and problems to solve, where the learners are expected to show their method, give some explanation and/or write down definitions or laws.
- Prescribed practical activities: A Physics or Chemistry project:
  If the Chemistry project is chosen the topic can be either of the following:
  - Purification and quality of water.
  - Any other topic based on Grade 10 chemistry content.
- Recommended informal assessment: Practical activity:
  Reaction types: precipitation, gas-forming, acid-base and redox reactions.

D Breakdown of Topic and Targeted Support Offered

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
2 hours	Ions in aqueous solution: Their interaction and effects	46	a. Explaining the mechanism of solution. b. Representing the dissolution process by using balanced equations.
1 hour	Electrolytes and extent of ionisation as measured by conductivity	47	a. A circuit for measuring conductivity. b. Relate conductivity to certain factors.
3 hours	Precipitation reactions	48	a. Writing balanced equations. b. Tests for anions.
2 hours	Other chemical reaction types in water solution	49	a. Types of reactions.

E Targeted Support per Sub-topic

1. IONS IN AQUEOUS SOLUTION: THEIR INTERACTION AND EFFECTS

INTRODUCTION

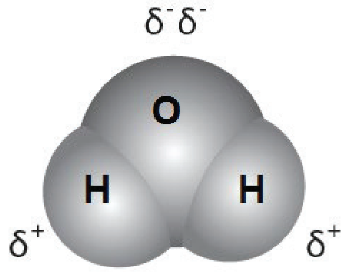
For substances to dissolve in water, their particles have to interact with the water (or any solvent). The results of this process are important as they help us work out what is actually in the solution.

CONCEPT EXPLANATION AND CLARIFICATION: IONS IN AQUEOUS SOLUTION: THEIR INTERACTION AND EFFECTS

Explaining the mechanism of solution

- The explanation of how solution in water occurs lies in the polarity of the water molecule.
- The oxygen-hydrogen covalent bonds in water are very polar because of the large difference in electronegativity between hydrogen (2,1) and oxygen (3,5). This means that the shared electrons in each bond spend more time over the oxygen end of the molecule than they do over the hydrogen ends of the molecule.

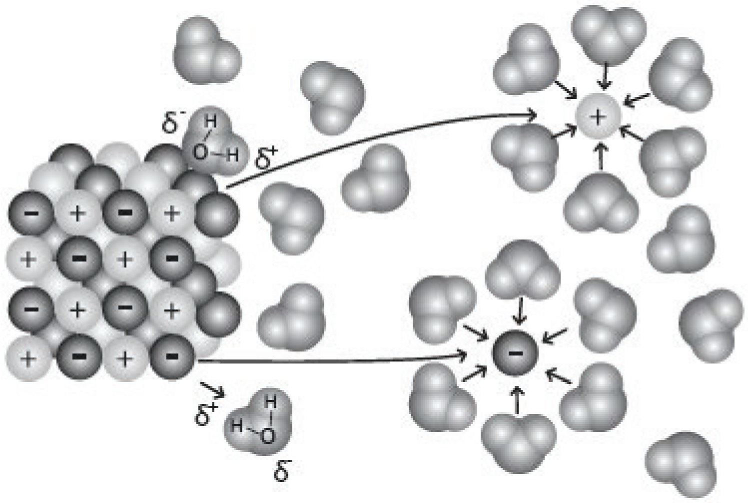
The water molecule has an angular shape, and together with its polar bonds this gives rise to a molecule in which one end is partially positively charged and the other end has a partial negative charge.



Representation of a water molecule showing the shape and the partially charged ends

- The symbol δ is used to indicate a partial charge. The diagram shows that the hydrogen ends of the water molecule are partially positive and the oxygen end is partially negative.
- A molecule with two oppositely charged poles is known a a polar molecule (or as a dipole).
- When an ionic compound is placed in water, the positive ends of the water molecules are attracted to the negative ions and the negative end is attracted to the positive ions.

- There are many water molecules that are attracted to each ion. The electrostatic forces of attraction that come about between the molecules and the ions are strong enough to break the ionic bonds between the ions, and thus remove ions from the lattice. The diagram shown below represents this process:



The dissolution of an ionic compound in water and subsequent hydration

- The ions from the solid are surrounded by water molecules and the layer that they form around the ions prevents the ions from returning into the solid phase. This process is called **hydration**.
- The process that occurs when the ions separate from other ions in the lattice and go into solution is called **dissolving**.
- Make it clear to the learners that not all ionic compounds dissolve readily in water. Some do not dissolve at all – they insoluble. This occurs because the forces between the ions making up the ionic bonds are stronger than those of the water molecules attempting to pull them out of the crystal lattice.
- For a table of the solubility of compounds in water refer to the CAPS document, page 163.

REPRESENTING THE DISSOLUTION PROCESS BY USING BALANCED EQUATIONS

- The dissolving process can be represented by a reaction equation. Ensure that learners understand that this is a physical process. Although ionic bonds are broken during solution, no new bonds are formed. The ions are said to have **dissociated**.
- Some examples of equations follow below:

$$KC\ell(s) \xrightarrow{H_2O} K^+(aq) + C\ell^-(aq)$$

$$Na_2SO_4(s) \xrightarrow{H_2O} 2Na^+(aq) + SO_4^{2-}(aq)$$

$$A\ell F_3(s) \xrightarrow{H_2O} A\ell^{3+}(aq) + 3F^-(aq)$$

- The 2 in Na_2SO_4 refers to the fact that there are 2 Na^+ ions in the crystal lattice. It does not mean a molecule of Na. That is why we write the two separate ions in the equation.
- Remind learners of the need to put phase symbols in their equations. Note that all ionic compounds are solid, so their formula should be followed by (s).
- H_2O may be placed over the arrow, but it is not necessary to do so. However H_2O must NOT form part of the balanced equation.

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:

- Work through these examples with learners.
- Explain each step of the question to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

1. Write down balanced reaction equations for each of the following substances dissolving in water:

a. $Ca(NO_3)_2$

b. $A\ell_2(CO_3)_3$

c. $(NH_4)_3PO_4$

Solution:

a. $Ca(NO_3)_2(s) \rightarrow Ca^{2+}(aq) + 2NO_3^-(aq)$
Remind learners that the charge on the cation is obtained from the periodic table. NO_3^- is a polyatomic ion and as such must not be broken up in any way.

b. $A\ell_2(CO_3)_3(s) \rightarrow 2A\ell^{3+}(aq) + 3CO_3^{2-}(aq)$

c. $(NH_4)_3PO_4(s) \rightarrow 3NH_4^+(aq) + PO_4^{3-}(aq)$

KEY TEACHING:

a. In writing these equations, learners must remember the basic principles of charges on ions and must know the formulae of the polyatomic ions.

CHECKPOINT

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

1. understanding the mechanism of solution of ionic compounds in water.
2. writing balanced reaction equations for the dissolution process.

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

Topic 17 Worksheet from the Resource Pack: Reactions in Aqueous Solutions: Questions 1–3. (Page 4)

- 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 it and place these on the walls of your classroom.
- Allow time for feedback.
- Encourage the learners to learn from the mistakes they make.

2 ELECTROLYTES AND EXTENT OF IONISATION AS MEASURED BY CONDUCTIVITY

INTRODUCTION

When compounds dissolve in water and form ions, the resulting solution becomes an electrical conductor. This property is extremely useful for a large number of industrial processes.

CONCEPT EXPLANATION AND CLARIFICATION: ELECTROLYTES AND EXTENT OF IONISATION AS MEASURED BY CONDUCTIVITY

A circuit for measuring conductivity

- To help us determine how good a conductor a certain solution is, we use a circuit such as the one below.

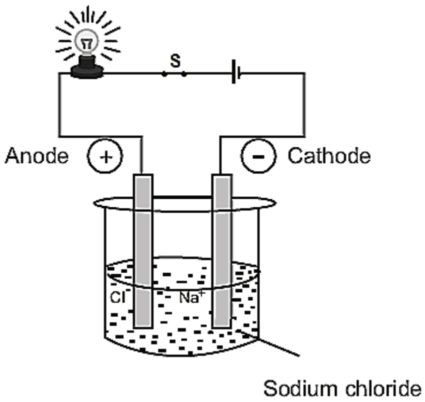


Diagram showing the apparatus to determine electrical conductivity of solutions

- The solution to be tested is placed in the beaker. The switch is closed and if the solution conducts electricity, the light bulb will light up. The brighter the bulb glows, the more conductive the solution.
- It is recommended that this experiment is demonstrated to the class.

RELATE CONDUCTIVITY TO CERTAIN FACTORS

- The conductivity of the solution is determined by the concentration of the ions in the solution. This, in turn, depends on:
  - The type of substance in the solution, and
  - The degree of solubility of the solute in the solution.
- This means that we can use the degree of conductivity as an indicator of how soluble a substance is.
- A solution that conducts electricity through the movement of ions is called an **electrolyte**.
- A word of warning: Not all soluble substances give rise to electrolytes. Sugar, for example is very soluble in water, but a sugar solution does not conduct electricity.
- Conversely, learners need to know that there are some molecular substances that also dissolve in water to form ions. A good example of these is the strong acids. Their solutions in water are very good conductors of electricity. The way in which these substances give rise to ions in water is different to what happens with ionic compounds.

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 concept of electrolytes and their conduction of electricity.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the question to the learners as you complete it on the chalkboard.
- Learners must copy down the question and answer it correctly in their workbooks.

2 Explain how it is possible for an electrolyte to conduct electricity.

Solution:

Remind learners that in order for a substance to conduct electricity, there need to be charged particles present that are free to move as charge carriers. In the case of solids there have to be delocalised electrons present. This is not the case in electrolytes. The charge carriers here are the ions that are in the solution.

The positive ions in the solution are attracted to the negative electrode and the negative ions are attracted to the positive electrode. In this way charge is carried through the solution and so the solution conducts electricity.

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 the facts that they have learned.

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 able to relate the degree of conductivity to the extent of solubility of a substance in water.

3. Give an explanation for how the degree of conductivity of an electrolyte is linked to the extent of solubility of the substance being tested.

Solution:

Remind learners of the definition of current; it is the rate of flow of charge.

The brightness with which the bulb glows in the circuit used to test for conductivity, depends on the current in the external circuit. This, in turn, depends on the number of ions arriving at the electrodes per unit time. The number of ions arriving at the electrode per unit time is directly proportional to the concentration of the ions. The concentration of the ions is dependent on how soluble the substance making up the electrolyte is.

CHECKPOINT

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

1. the concept of an electrolyte.
2. understanding and explaining how the electrical conductivity of an electrolyte relates to the extent of solubility of a substance.

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

Topic 17 Worksheet from the Resource Pack: Reactions in Aqueous Solutions: Question 4. (Page 4)

- 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 it and place these on the walls of your classroom.
- Allow time for feedback.
- Encourage the learners to learn from the mistakes they make.

3 PRECIPITATION REACTIONS

INTRODUCTION

Precipitation reactions are among the most important reactions that occur in solution. In this sub-section we discuss how precipitation can come about as a result of ion exchange reactions.

CONCEPT EXPLANATION AND CLARIFICATION: PRECIPITATION REACTIONS

Writing balanced equations

- There are numerous types of chemical reactions that occur in solution. Among these, the most important are:
  - ion exchange reactions
  - redox reactions
- Ion exchange reactions include:
  - precipitation reactions
  - gas forming reactions
  - acid-base reactions

- There is more than one way of representing precipitation reactions on paper:
  - Reaction equations can be written in the normal way, with phase symbols and the symbol for solid (s) is placed next to the substance that is precipitated.
    $2AgNO_3(aq) + BaC\ell_2(aq) \rightarrow \mathbf{2AgC\ell(s)} + Ba(NO_3)_2(aq)$

  The fact that AgCℓ is solid, means that it has precipitated. The equation could also be written as:

  $2AgNO_3(aq) + BaC\ell_2(aq) \rightarrow \mathbf{2AgC\ell}\downarrow + Ba(NO_3)_2(aq)$

  - The equation can be written as an ionic equation:
    $2Ag^+(aq) + 2NO_3^-(aq) + Ba^{2+}(aq) + 2C\ell^-(aq) \rightarrow \mathbf{2AgC\ell(s)} + Ba^{2+}(aq) + 2NO_3^-(aq)$
  - A third way is to leave out the ions that are unchanged on either side of the equation. These are called spectator ions. This type of equation is called a net ionic equation. It shows only the ions that actually react:
    $2Ag^+(aq) + 2C\ell^-(aq) \rightarrow \mathbf{2AgC\ell(s)}$
  - Learners will identify the precipitate by referring to the table of solubilities (CAPS p. 163)

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 writing of the equations for ion exchange reactions.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the question to the learners as you complete it on the chalkboard.
- Learners must copy down the question and answer it correctly in their workbooks.

4. Write down a balanced reaction equation for the reaction between solutions of lead(II) nitrate and potassium iodide.

Solution:

When ion exchange occurs in this reaction, the anions present are exchanged. The possible substances that are formed are lead iodide and potassium nitrate. Potassium nitrate is soluble but lead iodide is not – this will be the precipitate. Learners need to go through this process before writing down the equation.

The equation is:

$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow 2KNO_3(aq) + PbI_2(s)$

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 go one step further into writing net ionic equations.

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 question and answer it correctly in their workbooks.

KEY TEACHING:

In this slightly more complicated example, the learners not only have to identify the precipitate but also the spectator ions.

5. **a.** Write down a balanced reaction equation for the reaction that occurs when solutions of silver nitrate and sodium chloride are mixed togather.

b. Identify the spectator ions in the mixture.

c. Write down the balanced net ionic equation for this reaction.

Solution:

a. The precipitate can be identified as silver chloride.

$AgNO_3(aq) + NaC\ell(aq) \rightarrow AgC\ell(s) + NaNO_3(aq)$

b. The spectator ions will be $Na^+(aq)$ and $NO_3^-(aq)$.

c. Balanced net ionic equation:

$Ag^+(aq) + C\ell^-(aq) \rightarrow AgC\ell(s)$

CHECKPOINT

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

1. identifying the precipitate in an ion exchange reaction.
2. writing balanced reaction equations in both complete form and in the form of an ionic equation.

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

Topic 17 Worksheet from the Resource Pack: Reactions in Aqueous Solutions: Questions 5–8. (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 it and place these on the walls of your classroom.
- Allow time for feedback.
- Encourage the learners to learn from the mistakes they make.

Tests for anions

- It is recommended that the tests for anions are done at least as a demonstration in the laboratory.
- The tests for the following anions will be discussed:
  - chloride
  - bromide
  - iodide
  - sulfate
  - carbonate
- The strategy for testing chloride ions:
  A colourless solution of suspected chloride ions is to be tested. Add a few drops of dilute silver nitrate solution. If a white precipitate forms, it could confirm the presence of chloride ions.
- However silver carbonate also forms a white precipitate. We have to be sure which ion is present. To confirm the presence of chloride ions, we add a few drops of dilute nitric acid. If the white precipitate does not dissolve, this confirms that the anions in the original solution were chloride ions.

Testing for the chloride ion

Add $AgNO_3$ solution to the test solution and a white precipitate is formed:

$$AgNO_3(aq) + C\ell^-(aq) \rightarrow \underset{\text{white precipitate}}{AgC\ell(s)\downarrow} + NO_3^-(aq)$$

When dilute HNO_3 is added to this solution and the white precipitate does not dissolve, it confirms the presence of chloride ions.

If the white precipitate was silver carbonate, the reaction equation would be:

$$2AgNO_3(aq) + CO_3^{2-}(aq) \rightarrow Ag_2CO_3(s)\downarrow + NO_3^-(aq)$$

When dilute nitric acid is added to this solution, the white precipitate dissolves, according to:

$$Ag_2CO_3(s) + 2HNO_3(aq) \rightarrow 2Ag^+(aq) + 2NO_3^-(aq) + CO_2(g) + H_2O(l)$$

Silver nitrate is soluble in water and carbon dioxide gas is released, so the white precipitate disappears.

Testing for the bromide ion

Add $AgNO_3$ solution to the test solution and a light yellow precipitate is formed:

$$AgNO_3(aq) + Br^-(aq) \rightarrow \underset{\text{light yellow precipitate}}{AgBr(s)\downarrow} + NO_3^-(aq)$$

When dilute HNO_3 is added to this solution and the yellowish precipitate does not dissolve, it confirms the presence of bromide ions.

Testing for the iodide ion

Add $AgNO_3$ solution to the test solution and a yellow precipitate is formed:

$$AgNO_3(aq) + I^-(aq) \rightarrow \underset{\text{yellow precipitate}}{AgI(s)\downarrow} + NO_3^-(aq)$$

When dilute HNO_3 is added to this solution and the yellow precipitate does not dissolve, it confirms the presence of iodide ions.

Testing for the sulfate ion

Add a few drops of barium nitrate solution to the test solution.

The reaction that occurs is represented by the reaction equation:

$$Ba(NO_3)_2(aq) + SO_4^{2-}(aq) \rightarrow \underset{\text{white precipitate}}{BaSO_4(s)\downarrow} + 2NO_3^-(aq)$$

If this white precipitate is formed, add a few drops of dilute nitric acid. If the precipitate does not dissolve, the test solution contained sulfate ions.

Testing for the carbonate ion

The test is exactly the same as for the sulfate ion. The balanced reaction equation is:

$$Ba(NO_3)_2(aq) + CO_3^{2-}(aq) \rightarrow \underset{\text{white precipitate}}{BaCO_3(s)\downarrow} + 2NO_3^-(aq)$$

The solution is now tested with dilute HNO_3, but in this case, the white precipitate dissolves. The reaction equation for this reaction is:

$$BaCO_3(s) + 2HNO_3(aq) \rightarrow Ba_2^{+}(aq) + 2NO_3^{-}(aq) + CO_2(g) + H_2O(l)$$

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 tests for anions.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the question to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

6. Describe the test for the iodide ion and provide the necessary balanced reaction equation to justify your answer.

Solution:

A few drops of silver nitrate solution are added to the test solution. If a yellow precipitate forms, add a few drops of dilute nitric acid. If the precipitate does not dissolve, the test solution contains iodide ions.

$$AgNO_3(aq) + I^{-}(aq) \rightarrow \underset{\text{yellow precipitate}}{AgI(s)} + NO_3^{-}(aq)$$

7. Describe a test that can be carried out to test for the presence of carbonate ions in a solution. Give two appropriate reaction equations to justify your answer.

Solution:

A few drops of barium nitrate solution are added to the test solution. If a white precipitate is formed, add a few drops of dilute nitric acid. If the precipitate dissolves, the test solution contained carbonate ions.

To form the white precipitate:

$$Ba(NO_3)_2(aq) + CO_3^{2-}(aq) \rightarrow BaCO_3(s) + 2NO_3^{-}(aq)$$

For the precipitate to dissolve:

$$BaCO_3(s) + 2HNO_3(aq) \rightarrow Ba^{2+}(aq) + 2NO_3^{-}(aq) + CO_2(g) + H_2O(l)$$

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 the facts to more complex problems.

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 question and answer it correctly in their workbooks.

KEY TEACHING:

In these more challenging questions, learners must be able to apply the actual tests for anions to identifying anions contained in solutions.

8. A few drops of barium nitrate solution are added to a solution containing either sulfate or carbonate anions. A white precipitate forms when the barium nitrate is added, which dissolves when a few drops of dilute nitric acid are added.

a. Which ion did the solution contain?

b. Justify your answer by writing down relevant balanced, reaction equations.

Solution:

a. The solution contained carbonate ions.

b. The process and observations described are consistent with the presence of carbonate ions.

Equations

For the white precipitate:

$Ba(NO_3)_2(aq) + CO_3^{2-}(aq) \rightarrow BaCO_3(s) + 2NO_3^-(aq)$

For the white precipitate dissolving:

$BaCO_3(s) + 2HNO_3(aq) \rightarrow Ba_2+(aq) + 2NO_3^-(aq) + CO_2(g) + H_2O(l)$

- The other types of ion exchange reactions will be discussed in the next sub-topic, together with redox reactions.

4 OTHER CHEMICAL REACTION TYPES IN WATER SOLUTION

INTRODUCTION

Precipitation reactions are not the only ion exchange reactions. In the previous sub-section, gas forming reactions and acid base reactions were mentioned and these will be discussed here. Also, besides ion exchange reactions, we will discuss redox reactions.

CONCEPT EXPLANATION AND CLARIFICATION: OTHER CHEMICAL REACTION TYPES IN WATER SOLUTION

Types of reactions

- Under the heading of ion exchange reactions, we discussed precipitation reactions in the previous sub-section. The tests for anions are all carried out with ion exchange precipitation reactions.
- **Gas forming reactions are also ion exchange reactions**.
- A typical gas forming reaction is the reaction of acids with carbonates:

$$CaCO_3(aq) + 2HC\ell(aq) \rightarrow CaC\ell_2(aq) + CO_2(g) + H_2O(l)$$

As a full ionic equation:

$$Ca_2+(aq) + CO_3^{2-}(aq) + 2H^+(aq) + 2C\ell^-(aq) \rightarrow Ca^{2+}(aq) + 2C\ell^-(aq) + CO^2(g) + H_2O(l)$$

The net ionic equation is:

$$CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$$

- **Acid base reactions are ion exchange reactions, too.**
- An example of an acid base reaction is:

$$NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

The full ionic equations is:

$$Na^+(aq) + OH^-(aq) + H^+(aq) + NO_3^-(aq) \rightarrow Na^+(aq) + NO_3^-(aq) + H_2O(l)$$

The net ionic equation is:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

- **Redox reactions are reactions which involve the transfer of electrons**.

An example of a redox reaction is the reaction between magnesium and sulfuric acid:

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

The full ionic equation is:

$$Mg(s) + 2H^+(aq) + SO_4^{2-}(aq) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq) + H_2(g)$$

The net ionic equation is:

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

From these two half-reaction equations shown below, it can be seen that the magnesium transfers 2 electrons to the H^+ ions.

$Mg(s)$	$\rightarrow$	$Mg^{2+}(aq) + 2\ e^-$	Magnesium atoms lose two electrons.
$2H^+(aq) + 2\ e^-$	$\rightarrow$	$H_2(g)$	Each H+ ion gains one electron.
$Mg(s) + 2H^+(aq)$	$\rightarrow$	$Mg^{2+}(aq) + H_2(g)$	This is the net ionic equation.

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:

- Work through these examples with learners.
- Explain each step of the question to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

9. Sodium carbonate reacts with hydrochloric acid.

a. Write down a balanced reaction equation for this reaction.

b. Write down the net ionic equation for this reaction.

Solution:

a. $Na_2CO_3(aq) + 2HC\ell(aq) \rightarrow 2NaC\ell(aq) + CO_2(g) + H_2O(\ell)$

b. $CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(\ell)$

10. Iron filings react with hydrochloric acid to produce iron(II) chloride and hydrogen gas.

a. Write down a balanced reaction equation for this reaction.

b. Write down the net ionic equation for this reaction.

c. What type of reaction is this?

Solution:

a. $Fe(s) + HC\ell(aq) \rightarrow FeC\ell_2(aq) + H_2(g)$

b. $Fe(s) + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2(g)$

c. This is a redox reaction.

The iron transfers electrons to the H^+ ions.

CHALLENGE LEVEL QUESTIONS

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

b. These questions require learners to apply their knowledge of different types of reactions.

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 need to analyse the given equations in order to determine what types of reactions they represent.

11. Consider the following three equations:

I $K_2SO_4(aq) + Ca(NO_3)_2(aq) \rightarrow 2KNO_3(aq) + CaSO_4(s)$

II $FeS(s) + 2HNO_3(aq) \rightarrow Fe(NO_3)_2(aq) + H_2S(g)$

III $2A\ell(s) + 3H_2SO_4(aq) \rightarrow A\ell_2(SO_4)_3(aq) + 3H_2(g)$

a. Identify the type of reaction represented by each equation.

b. Write down balanced net ionic equations for each of these reactions.

c. Why are some ions left out in the net ionic equations?

Solution:

a.	**I**	Precipitation.	$CaSO_4$ is formed which is a solid that is insoluble in water.
	II	Gas forming reaction.	H_2S is formed which is a gas.
	III	Redox reaction.	Aluminium transfers electrons to the H^+ ions.

b. When identifying the type of reaction, learners must look for:

- a solid in the products – this will tell them that it is a precipitation reaction.
- a gas in the products – this will tell them that it is a gas forming reaction.
- a salt and water in the products – this will tell them that it is an acid base reaction.
- electron transfer, which will tell them that it is a redox reaction.

A salt is an ionic compound formed by a cation and an anion.

I $Ca^{2+}(aq) + SO_4^{2-}(aq) \rightarrow CaSO_4(s)$

II $S^{2-}(aq) + 2H^+(aq) \rightarrow H_2S(g)$

III $6H^+(aq) + 2A\ell(s) \rightarrow 2A\ell^{3+}(aq) + 3H_2(g)$

c. The ions that are left out are spectator ions. These are ions that do not change during the reactions.

CHECKPOINT

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

1. knowing and understanding how each of these different types of reaction occur.
2. identifying each type of reaction.
3. writing balanced reaction equations, full ionic equations and net ionic equations.

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

Topic 17 Worksheet from the Resource Pack: Reactions in Aqueous Solutions: Questions 9–10. (Page 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 it and place these on the walls of your classroom.
- Allow time for feedback.
- Encourage the learners to learn from the mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing: **Topic 17 Consolidation Exercise from the Resource Pack: Reactions in Aqueous Solutions: (Page 6).**
- 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.bbc.co.uk/schools/gcsebitesize/science/add_ocr_21c/natural_environment/hydrosphererev4.shtml

   This is extra reading – suitable for teachers, precipitation reactions and equations.

2. https://www.slideshare.net/LKOTZE/6-gr-10-reactions-in-aqueous-solutions

   This is a slide show summarising all the important aspects of this topic – suitable for learners.

3. https://www.youtube.com/watch?v=A1QIq9n55n8

   This video is suitable for leaners. It deals with the concept of electrolytes.

TOPIC 18:

Quantitative Aspects of Chemical Change

A Introduction

- This topic runs for 8 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Quantitative aspects of chemical change forms part of the content area Chemical change (Chemistry).
- Chemical change counts as 40% in the Paper 2 (Chemistry) examination.
- Quantitative aspects of chemical change counts approximately 12% to 15% of the final examination.
- Chemical change has been discussed qualitatively up till now. In this topic the quantitative aspect of chemical change is introduced. The mole concept lies at the heart of most calculations in Chemistry and this concept forms the foundation of quantitative Chemistry.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Periodic Table.
4. Scientific calculator.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises.
2. Pen.
3. Periodic Table.
4. A scientific calculator (Sharp or Casio calculators are highly recommended).

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 7 – 9	**GRADE 10**	**GRADE 11 – 12**
• Reactants and products. • Chemical equations to represent reactions. • Balanced equations. • Names of compounds.	• Atomic mass and the mole concept. • Molecular and formula masses. • Determining the composition of substances. • Amount of substance (mole), molar volume of gases, concentration of solutions. • Basic stoichiometric calculations.	• Applications of calculations from chemical equations, including reaction rates, chemical equilibrium, acids and bases, electrochemistry.

C Glossary of Terms

TERM	DEFINITION
Stoichiometry	The quantitative aspect of chemical change, when chemical reactions go to completion.
A mole	The amount of substance having the same number of particles as there are atoms in 12 g carbon-12.
Avogadro's constant, NA	The number of particles (atoms, molecules, formula-units) present in a mole ($N_A = 6{,}022 \times 10^{23}\ mol^{-1}$).
Relative atomic mass	The mass of a particle on a scale where an atom of carbon-12 has a mass of 12.
Molar mass	The mass of one mole of a substance measured in $g{\cdot}mol^{-1}$.
Molar volume	At STP: 1 mole of any gas occupies 22,4 dm^3 at 0 °C (273 K) and 1 atmosphere (101,3 kPa). Thus the molar gas volume, V_M, at STP = 22,4 $dm^3{\cdot}mol^{-1}$.
Relative molecular mass	This the sum of the relative atomic masses of all the atoms making up a molecule.
Relative formula mass	This is the sum of the relative atomic masses of all the atoms making up a formula unit (ionic compounds).
Empirical formula	The simplest whole-number ratio of atoms in a compound.
Amorphous	A substance is amorphous when it does not have a crystal structure.
Hydrates	Compounds containing water of crystallisation.
Anhydrous substances	Compounds from which water of crystallisation has been removed.
Concentration	The number of moles of solute per cubic decimetre of solution.
Yield	The theoretical yield is the calculated yield of a product in a chemical reaction. Actual yield is the quantity physically obtained from a chemical reaction.
Percentage composition	The mass of each atom present in a compound expressed as a percentage of the total mass of the compound.
Avogadro's law	One mole of any gas occupies the same volume at the same temperature and pressure.

D Assessment of this Topic

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

- There may be multiple-choice type questions and problems to solve, where the learners are expected to show their method, give some explanation and/or write down definitions or laws.
- Prescribed practical activities: A Physics or Chemistry project:
  If the Chemistry project is chosen the topic can be either of the following:
  - Purification and quality of water.
  - Any other topic based on Grade 10 chemistry content.

D 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	Atomic mass and the mole concept	50	a. The definition of a mole. b. Molar mass. c. Molar mass calculations.
2 hours	Molecular and formula masses	51	a. Relationship between mass, molar mass and moles. b. Empirical formula. c. Water of crystallisation.
2 hours	Determining the composition of substances	51	a. Percentage composition of substances. b. Concentration. c. Calculations on molar concentration.
1 hour	Amount of substance (mole), molar volume of gases, concentration of solutions	51	a. Molar volume. b. Calculations on molar volume.
2 hours	Basic stoichiometric calculations	52	a. Calculations using all aspects of molar quantities. b. Theoretical yield and calculations.

E Targeted Support per Sub-topic

ATOMIC MASS AND THE MOLE CONCEPT

INTRODUCTION

The mole concept is used in Chemistry to deal with the extremely large numbers of atoms and molecules etc. Learners must grasp the actual size of the number called the mole. It is a very important concept and learners need to understand it well. It simplifies all aspects of calculations in Chemistry, which involve what is known as stoichiometry, or calculations involving mole ratios.

CONCEPT EXPLANATION AND CLARIFICATION: ATOMIC MASS AND THE MOLE CONCEPT.

Definition of a mole

- The numbers of particles involved in chemical reactions are so enormous that to express them as ordinary numbers would make calculations in Chemistry clumsy and time consuming.
- So, the concept of an amount of particles called a mole made calculations simpler. The mole is a very large number like any other number in common usage such as a million or a trillion.
- The mole is defined as: the amount of substance having the same number of particles as there are atoms in 12 g carbon-12.
- Elementary particles may be atoms, molecules, formula units, etc. This depends on the particular substance concerned. It refers to the basic units that a substance is made up of.
- **The mole is the SI unit for the amount of substance.** Its abbreviation is mol. The symbol used for amount of matter is the letter *n*.
- The number of atoms in 12 g of carbon-12 is called the Avogadro constant (N_A) and has the value $6{,}022 \times 10^{23}$ elementary particles. (The term Avogadro's number is a historical term, which represents the same number of particles but was defined differently to the Avogadro constant. The number, as defined here, is the Avogadro constant.)
- If we write out the Avogadro constant in full it is 602 200 000 000 000 000 000 000, so it a huge number. Do this to give learners a better idea of the size of this number. If there was a mole of Rand (money) available to divide among all the people on earth (about 7 billion), each person would receive R$8{,}57 \times 10^{13}$, which means 8 570 million billion Rand. Still an enormous sum of money.
- The definition of a mole in terms of the relative atomic mass of carbon. This means that we can take the relative atomic mass of carbon (which is 12) and express it in grams, i.e. 12 grams and this mass of carbon contains exactly one mole of atoms of carbon.
- If we extend this thinking to the whole periodic table, it means that if we take the relative atomic mass of an element (remember this is based on carbon-12) and express it

TOPIC 18

in grams, that mass of the element will contain 1 mole of atoms. For example: one mole of magnesium will have a mass of 24 g and one mole of phosphorus will have a mass of 31 g.

Molar mass

- We use the term molar mass when we are dealing with one mole of a substance.
- We define molar mass as: molar mass is the mass of one mole of any substance expressed in grams. This means that unit of molar mass is $g·mol^{-1}$.

Molar mass calculations

- **Relative molecular mass** is the sum of all the relative atomic masses of the atoms making up the molecule.
- **Relative formula mass** is the sum of all the relative atomic masses of the atoms making up an ionic substance.
- **Molar mass** is the relative molecular mass of one mole of a substance, expressed in grams and is the relative formula mass of one mole of a substance expressed in grams. We can also say that the molar mass of an element is the relative atomic mass (if the element is atomic) expressed in grams.

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 content.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the question to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

1. **a.** What is meant by the term mole?

b. What is the difference between relative molecular mass and molar mass?

Solution:

a. One mole is the amount of substance having the same number of particles as there are atoms in 12 g carbon-12.

b. Relative molecular mass is the mass of a molecule relative to the mass of a carbon-12 isotope. Molar mass is the relative molecular mass expressed in $g·mol^{-1}$.

2. Calculate the relative molecular mass of:

- **a.** H_2SO_4
- **b.** N_2O_4

Solution

a. $M_R(H_2SO_4) = (2 \times 1) + 32 + (4 \times 16)$

$= 98$ (no units – this is relative molecular mass)

b. $M_R(N_2O_4) = (2 \times 14) + (4 \times 16)$

$= 92$ (no units)

CHALLENGE LEVEL QUESTIONS

Now that learners have mastered the basic questions, they are ready to deal with more challenging 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. Learners need to have understood the concept of the mole.

b. Learners must be well aware of the differences in terminology and their meanings.

3. **a.** Calculate the molar masses of each of the following:

I Na_2CO_3

II HNO_3

b. Say what type of molar mass each one is.

Solution:

a. **I** $M(Na_2CO_3) = (2 \times 23) + 12 + (3 \times 16)$
$= 106\ g{\cdot}mol^{-1}$ (Note the unit for molar mass)

II $M(HNO_3) = (2 \times 1) + 14 + (3 \times 16)$
$= 63\ g{\cdot}mol^{-1}$

b. **I** (Molar) formula mass (This is an ionic compound)

II (Molar) molecular mass (This is a molecular compound)

CHECKPOINT

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

1. knowing and understanding the mole concept.
2. knowing the definitions of the various terms and understanding the differences in their meaning.
3. calculating relative molecular and formula masses and molar masses.

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

Topic 18 Worksheet from the Resource Pack: Quantitative Aspects of Chemical Change: Questions 1–3. (Page 10)

- 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 it and place these on the walls of your classroom.
- Allow time for feedback.
- Encourage the learners to learn from the mistakes they make.

MOLECULAR AND FORMULA MASSES

INTRODUCTION

Molecular and formula masses are used to calculate number of moles and vice versa. These calculations also lead to calculating empirical formulae.

CONCEPT EXPLANATION AND CLARIFICATION: MOLECULAR AND FORMULA MASSES

Relationship between mass, molar mass and moles

- The number of moles of a substance can be calculated by using the following equation:

$$n = \frac{m}{M}$$

where n = number of moles, m = given mass in grams and M = molar mass in g·mol^{-1}.

> **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 equation, but not to change the subject of the equation.
>
> **How to tackle these questions in the classroom:**
>
> - Work through these examples with learners.
> - Explain each step of the calculation to the learners as you complete it on the chalkboard.
> - Learners must copy down the questions and answer them correctly in their workbooks.

1. Calculate the number of moles of each of the following substances:

a. 11 g of carbon dioxide (CO_2)

b. 200 g of magnesium carbonate ($CaCO_3$)

Solution:

a.

$$\begin{aligned} M(\mathrm{CO_2}) &= 2 + (2 \times 16) \\ &= 44\ \mathrm{g{\cdot}mol^{-1}} \\ n = \frac{m}{M} &= \frac{11}{44} = 0{,}25\ \mathrm{mol} \end{aligned}$$

b.

$$\begin{aligned} M(\mathrm{CaCO_3}) &= 40 + 12 + (3 \times 16) \\ &= 100\ \mathrm{g{\cdot}mol^{-1}} \\ n = \frac{m}{M} &= \frac{200}{100} = 2{,}0\ \mathrm{mol} \end{aligned}$$

Empirical formula

- The empirical formula is the chemical formula showing the simplest whole-number ratio of atoms in a compound.
- The empirical formula can be calculated from the percentage composition of a compound, or from the masses of each element present in a sample of the compound.

TOPIC 18

- Point out to learners that the ratio of atoms of each element is a mole ratio, so to get the empirical formula, we first need to find the number of moles of each element present.

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 method of finding empirical formulae.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the calculation to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

2. A compound has the following percentage make up by mass:

K 38,61%

O 47,52%

N 13,86%

Determine the compound's empirical formula.

Solution:

If we assume that we have a 100 g sample of the compound, then the percentages will be numerically equal to masses.

$$n_K = \frac{m}{M} = \frac{38,61}{39} = 0,99$$

$$n_O = \frac{m}{M} = \frac{47,52}{16} = 2,97$$

$$n_N = \frac{m}{M} = \frac{13,86}{14} = 0,99$$

We now have a mole ratio of each element, but we need to make it a whole number ratio. This is done by dividing each number of moles by the lowest number. In this case, we divide by 0,99.

Ratio: $0,99\ : 2,97; 0.99 = \frac{0,99}{0,99} \cdot \frac{2,97}{0,99} \cdot \frac{0,99}{0,99} = 1\ : 3\ : 1$

Hence the empirical formula is KNO_3.

Remind learners that when we write chemical formulae, the order of the elements is as they occur from left to right on the Periodic Table.

WATER OF CRYSTALLISATION

- When some ionic compounds form a crystal lattice there are water molecules that form part of that crystal lattice. In fact, without the water, the crystal structure collapses and the compound becomes amorphous.
- Water of crystallisation is the number of water molecules that combine chemically in definite molecular proportion, with the ionic compound in its crystalline state. This water is responsible for the geometric shape and colour of the crystals.
- This fact can be demonstrated by strongly heating some blue copper sulfate crystals in a crucible. As the crystals are heated, the blue colour disappears, and the substance becomes a greyish-white powder. If the powder is allowed to cool, and then water is added, the blue colour returns.
- Water of crystallisation is displayed in a chemical formula as follows:
  e.g. $CuSO_5{\cdot}5H_2O$ and $Na_2CO_3{\cdot}10H_2O$
  The correct chemical name for the first is copper(II) sulfate pentahydrate and the second is sodium carbonate decahydrate. So, these compounds are called hydrates or hydrated compounds.
- When the water of crystallisation has been removed, we talk about anhydrous sodium carbonate.
- It is possible to calculate the number of moles of water of crystallisation in a compound, when we are given the related masses.

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 method of calculating water of crystallisation.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the calculation to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

TOPIC 18

3. To determine the number of moles of water of crystallisation in $A\ell C\ell_3{\cdot}nH_2O$, i.e. the value of *n*, some of the hydrate was heated. The mass of hydrate heated was 4,31 g. This solid was allowed to cool after heating, and then its mass was found to be 3,38 g.

Mass of water lost = 4,31 – 3,38 = 0,93 g

$$\begin{aligned} n(\mathrm{H_2O\ lost}) &= \frac{m}{M} \\ &= \frac{0,93}{18} \\ &= 0,05\ \mathrm{mol} \\ M(\mathrm{AlCl_3}) &= 27 + (3 \times 35,5) = 133,5\ \mathrm{g{\cdot}mol^{-1}} \\ n(\mathrm{AlCl_3\ after\ heating}) &= \frac{m}{M} \\ &= \frac{3,38}{133,5} \\ &= 0,025\ \mathrm{mol} \end{aligned}$$

Thus, ratio of $A\ell C\ell_3$: H_2O = 0,025: 0,05 = 1:2

Thus $n = 2$

The formula of the hydrate is $A\ell C\ell_3{\cdot}2H_2O$.

DETERMINING THE COMPOSITION OF SUBSTANCES

INTRODUCTION

In this sub-section learners determine how to calculate the percentage of each element making up a particular compound and also how to determine the concentration of solutions.

CONCEPT EXPLANATION AND CLARIFICATION: DETERMINING THE COMPOSITION OF SUBSTANCES

Percentage composition of substances

- The percentage composition refers to the percentage of each element by mass that makes up that substance.
- First find the molar mass of the compound. Then determine the mass contribution to the 'total' mass by multiplying the number of atoms of an element by its relative atomic mass. This is then expressed as a percentage of the total.

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 method of determining percentage composition.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the calculation to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them in their workbooks.

3. Calculate the percentage composition by mass of:

a. K_2SO_4

b. $A\ell_2(CO_3)_3$

Solution:

a. $M(K_2SO_4) = (2 \times 39) + 32 + (4 \times 16) = 174 \text{ g·mol}^{-1}$

$$\%K = \frac{2 \times 39}{174} \times 100 = 44{,}83\ \%$$

$$\%S = \frac{32}{174} \times 100 = 17{,}39\ \%$$

$$\%O = \frac{4 \times 16}{174} \times 100 = 36{,}78\ \%$$

b. $M(Al_2(CO_3)_3) = (2 \times 27) + (3 \times 12) + (9 \times 16) = 234 \text{ g·mol}^{-1}$

$$\%Al = \frac{2 \times 27}{234} \times 100 = 23{,}08\ \%$$

$$\%C = \frac{3 \times 12}{234} \times 100 = 15{,}38\ \%$$

$$\%O = \frac{9 \times 16}{234} \times 100 = 61{,}54\ \%$$

Concentration

- The (molar) concentration of a solution is the number of moles of solid per unit volume (in dm^3) of solution.
- If mass is given rather than number of moles, then this has to be converted to moles before the concentration can be calculated. The volume, if not given in dm^3, must be converted to that unit.
- The equation for calculating molar concentration is:

  $c = \frac{n}{V}$

  where:

  c is the concentration in $mol{\cdot}dm^{-3}$

  n is the number of moles of solute

  V is the volume of the solution in dm^3.

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 equation for and the method of calculating molar concentration.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the calculation to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

4. Calculate the molar concentration of a solution that is made up by dissolving 5,85 g of NaCℓ in enough water to make up 0,5 dm^3 of solution.

Solution

$$\boxed{\begin{aligned} M(\text{NaC}\ell) &= 23 + 35,5 \\ &= 58,5\ \text{g}{\cdot}\text{mol}^{-1} \end{aligned}}$$

$$\begin{aligned} n &= \frac{m}{M} \\ &= \frac{5,85}{58,5} \\ &= 0,1\ \text{mol} \end{aligned}$$

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{0,1}{0,5} \\ &= 0,2\ \text{mol}{\cdot}\text{dm}^{-3} \end{aligned}$$

CHALLENGE LEVEL QUESTIONS

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

a. 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.

KEY TEACHING:

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula.

5. A solution of sodium hydroxide has a concentration of 0,25 mol·dm^{-3}. Calculate the mass of sodium hydroxide required to make up 0,8 dm^3 of this solution.

Solution:

First calculate the number of moles of sodium hydroxide that are present in the solution.

$$\begin{aligned} c &= \frac{n}{V} \\ n &= c \times V \\ &= 0{,}25 \times 0{,}8 \\ &= 0{,}2 \text{ mol} \end{aligned}$$

Now calculate the mass of sodium hydroxide corresponding to this:

$$\boxed{\begin{aligned} M(\text{NaOH}) &= 23 + 16 + 1 \\ &= 40 \text{ g·mol}^{-1} \end{aligned}}$$

$$\begin{aligned} n &= \frac{m}{M} \\ m &= n \times M \\ &= 0{,}2 \times 40 \\ &= 8 \text{ g} \end{aligned}$$

CHECKPOINT

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

1. the relationship between moles, mass and molar mass.
2. calculating the number of moles, using the equation $n = m/M$.
3. knowing what is the empirical formula, and being able to calculate it when given sufficient data.
4. knowing the meaning of water of crystallisation and calculating quantities or finding formulae concerning this concept.
5. calculating percentage composition.
6. knowing and understanding the concentration of solutions, and managing calculations of concentration.

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

Topic 18 Worksheet from the Resource Pack: Quantitative Aspects of Chemical Change: Questions 4–6. (Page 10)

- 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 it and place these on the walls of your classroom.
- Allow time for feedback.
- Encourage the learners to learn from the mistakes they make.

4 AMOUNT OF SUBSTANCE (MOLE), MOLAR VOLUME OF GASES, CONCENTRATION OF SOLUTIONS

INTRODUCTION

This sub-section revolves around the concept of molar volume and calculations relating to this concept.

CONCEPT EXPLANATION AND CLARIFICATION: AMOUNT OF SUBSTANCE (MOLE), MOLAR VOLUME OF GASES, CONCENTRATION OF SOLUTIONS

Molar volume

- The molar volume of a gas is defined as the volume occupied by one mole of any gas at STP.
- The value of this volume is 22,4 dm^3 at STP.

- STP refers to the conditions known as Standard Temperature and Pressure. These conditions are:
  - a temperature of 0 °C
  - a pressure of 1 atmosphere or 101,3 kPa (The pascal – Pa is a unit of pressure.)

CALCULATIONS ON MOLAR VOLUME

- An equation that can be used to calculate molar volume is:

  $$n = \frac{V}{V_m}$$

  where:

  n is the number of moles (mol)

  V is the volume of a gas in dm^3

  V_m is the molar volume of a gas in $dm^3 \cdot mol^{-1}$.

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 equation.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the calculation to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

6. Calculate the number of moles in:

a. 120 dm^3 of neon at STP.

b. 5,6 dm^3 of helium at STP.

Solution:

a.
$$\begin{aligned} n &= \frac{V}{V_m} \\ &= \frac{120}{22,4} \\ &= 5,36 \text{ mol} \end{aligned}$$

b.
$$\begin{aligned} n &= \frac{V}{V_m} \\ &= \frac{5,6}{22,4} \\ &= 0,25 \text{ mol} \end{aligned}$$

5 BASIC STOICHIOMETRIC CALCULATIONS

INTRODUCTION

In this sub-section we will bring together all the quantities and calculations that have been dealt with in the entire section and apply them to calculations involving chemical equations.

CALCULATIONS USING ALL ASPECTS OF MOLAR QUANTITIES

- When doing calculations from chemical equations, learners must first ascertain that the equation is balanced.
- Point out to learners that the coefficients in front of chemical formulae and symbols (balancing numbers) represent the number of moles of each substance present in the reactants and the products.
- The coefficients represent the mole ratio which in which the reactants combine with each other. This doesn't mean that there will always be a number of moles that corresponds to those numbers. However, the ratio in which they react will never change.
- The mole ratios carry through to the products as well.
- From the numbers of moles in the mole ratios we can calculate the masses involved in the reactants and the products formed.
- Inform learners that they needn't calculate the masses of everything in the balanced equation but just deal with one reactant and one product at a time in order to avoid confusion. So, they must focus on only what is given and what is required.
- If the mass of a reactant is given in grams, learners should calculate the number of moles of that substance.
- The next step is to determine the number of moles of the product that they are required to find.
- Finally, the number of moles of the product is converted into mass or volume to get the answer.

THEORETICAL YIELD AND CALCULATIONS

- The theoretical yield is the maximum yield (i.e. amount of product) that can be obtained when all the reactants react completely. This is calculated from the balanced chemical equation.
- In practice, the theoretical yield may not always be obtained because there may be impurities present in the reactants.
- At this point we will work with stoichiometric quantities, i.e. based on the assumption that all the reactants are pure and they will all react to form products.

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 method used to solve this type of problem.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step of the calculation to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

7. Sodium hydroxide solution reacts with sulfuric acid to produce sodium sulfate and water according to the following balanced reaction equation:

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$$

If 20 g of sodium hydroxide reacts completely with sulfuric acid, calculate the mass of sodium sulfate produced.

Solution:

First calculate the number of moles of sodium hydroxide

$$n_{NaOH} = \frac{m}{M} = \frac{20}{40} = 0,5 \text{ mol}$$

$$M(\text{NaOH}) = 23 + 16 + 1 = 40 \text{ g·mol}^{-1}$$

Tell learners that it is advisable to indicate the substance for which the number of moles or molar mass is being calculated.

According to the mole ratio, 2 mol of NaOH produces 1 mol of Na_2SO_4

Thus, number of moles of Na_2SO_4 produced $= \frac{1}{2} \times 0,5 = 0,25 \text{ mol}$

Now we calculate the mass of Na_2SO_4

$$n = \frac{m}{M}$$
$$m = n \times M = 0,25 \times 142 = 35,5 \text{ g}$$

$$M(\text{Na}_2\text{SO}_4) = (2 \times 23) + 32 + (4 \times 16) = 142 \text{ g·mol}^{-1}$$

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 perform more complex calculations.

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 be able to apply the basic principles to more complex examples of the problems.

8. Magnesium metal reacts with nitric acid to produce magnesium nitrate and hydrogen gas, according to the following balanced reaction equation:

$$Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$$

0,02 dm^3 of nitric acid of concentration 0,5 $mol\cdot dm^{-3}$ reacts completely with magnesium metal. Calculate:

a. the mass of magnesium that reacts.

b. the mass of magnesium nitrate that is produced when the acid reacts completely.

c. the volume of hydrogen gas that is produced at the same time, calculated at STP.

Solution:

a. Calculate the number of moles of nitric acid.

$$c = \frac{n}{V}$$

$$\begin{aligned} n &= c \times V \\ &= 0,5 \times 0,02 \\ &= 0,01 \text{ mol} \end{aligned}$$

2 mol of nitric acid reacts completely with 1 mol of magnesium, so number of moles of magnesium reacting $= \frac{1}{2} \times 0,01 = 0,005 \text{ mol}$.

Now calculate the mass of magnesium.

$$n = \frac{m}{M}$$

$$\begin{aligned} m &= n \times M \\ &= 0,005 \times 24 \\ &= 0,12 \text{ g} \end{aligned}$$

b. First calculate the number of moles of magnesium nitrate produced.
2 mol of nitric acid produces 1 mol of magnesium nitrate.
0,01 mol of nitric acid produces 0,005 mol of magnesium nitrate.
Now calculate the mass of magnesium nitrate:

$$n = \frac{m}{M}$$

$$\begin{aligned} m &= n \times M \\ &= 0,005 \times 148 \\ &= 0,74 \text{ g} \end{aligned}$$

$$\begin{aligned} M[\text{Mg}(\text{NO}_3)_2] &= 24 + (2 \times 14) + (6 \times 16) \\ &= 148 \text{ g·mol}^{-1} \end{aligned}$$

c. First determine the number of moles of hydrogen gas produced.
2 mol of nitric acid produces 1 mol of hydrogen gas.
0,01 mol of nitric acid produces 0,005 mol of hydrogen gas.
Now calculate the volume of the hydrogen gas:

$$n = \frac{V}{V_m}$$

$$\begin{aligned} V &= n \times V_m \\ &= 0,005 \times 22,4 \\ &= 0,112 \text{ dm}^3 \end{aligned}$$

TOPIC 18

CHECKPOINT

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

1. the concept of molar volume
2. calculations involving molar volume.
3. working out stoichiometric calculations

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

Topic 18 Worksheet from the Resource Pack: Quantitative Aspects of Chemical Change: Questions 7–10. (Pages 10–11).

- 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 it and place these on the walls of your classroom.
- Allow time for feedback.
- Encourage the learners to learn from the mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topic 18 Consolidation Exercise from the Resource Pack: Quantitative Aspects of Chemical Change (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 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/chemistry/atomic-structure-and-properties/introduction-to-the-atom/v/the-mole-and-avogadro-s-number

   This video covers the mole concept and is suitable for learners.

2. https://www.youtube.com/watch?v=lyWAGMEKzSY

   Video about empirical formula suitable for learners.

3. https://www.youtube.com/watch?v=BD1A6nzsnE4

   Video on stoichiometric calculations – for learners.

TOPIC 19:
Vectors and Scalars

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.
- These topics form part of the content area of Mechanics.
- Mechanics counts 50 % of the Paper 1 (Physics) examination.
- Introduction to vectors and scalars counts about 14 % in this examination.
- Mechanics was the first branch of Physics to be developed, and it is the foundation on which all other branches of Physics are built. It deals with the motion of objects and the forces which act on them when at rest or in motion. This introduction to vectors and scalars forms the basis for the study of one-dimensional motion.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Mathematical instruments to draw on the chalkboard e.g. ruler and protractor.
4. Scientific calculator.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book for notes and exercises.
2. Pen.
3. A set of mathematical instruments with at least a protractor and a ruler.
4. A scientific calculator (Sharp or Casio are highly recommended).

B Sequential Table

<table>
<tr><th>PRIOR KNOWLEDGE</th><th>CURRENT</th><th>LOOKING FORWARD</th></tr>
<tr><th>GRADE 7 – 9
QUALITATIVE ASPECTS</th><th>GRADE 10
QUALITATIVE AND QUANTITATIVE ASPECTS</th><th>GRADE 11 – 12
FURTHER APPLICATIONS</th></tr>
<tr><td>• Forces.
  • Force as a push or a pull.
  • Contact and non-contact forces.
  • Force fields (gravitational, electric and magnetic).
  • Weight is the force of gravity (Weight = mg).
  • Electrostatics.
  • Magnetism.</td><td>• Introduction to vectors and scalars.
• Motion in 1-D
• Reference frame, position,
• displacement and distance.
• Average speed, average
• velocity, acceleration.
• Instantaneous speed and velocity and the equations of motion.
  • Instantaneous velocity, instantaneous speed,
  • Description of motion in words, diagrams, graphs and equations.</td><td>• Vectors in 2-D.
  • Resultant of two perpendicular vectors
  • Resolution of vectors into horizontal and vertical components.
• Newton's Laws and application of Newton's Laws.
  • Different kinds of forces.
  • Force diagrams and free-body diagrams.
  • Newton's 1st, 2nd and 3rd laws.
• Momentum and impulse.
  • Momentum.
  • Newton's 2nd law expressed in terms of momentum.
  • Conservation of momentum and elastic and inelastic collisions.</td></tr>
</table>

TOPIC 19

C Glossary of Terms

TERM	DEFINITION
Scalar	A physical quantity that has magnitude only.
Vector	A physical quantity that has magnitude and direction.
Resultant vector	The single vector having the same effect as two or more vectors together.
Distance	The length of the path travelled.
Displacement	The change in position.
Average speed	The distance divided by the time taken.
Average velocity	The displacement divided by the time taken.
Average acceleration	The change of velocity divided by the time taken.

D Assessment of this Topic

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

- There may be multiple-choice type questions and problems to solve, where the learners are expected to show their method, give some explanation and/or write down definitions or laws.
- Prescribed practical activities: A Physics or Chemistry project:
  - If the Physics project is chosen the topic is the following:
  - Roll a trolley down an inclined plane with a ticker tape attached to it, and use the data obtained to plot a position-time graph.

E Breakdown of Topic and Target Supported 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 h	Vectors and scalars	53	Vectors differ from scalar quantities.

F Targeted Support per Sub-topic

1 VECTORS DIFFER FROM SCALAR QUANTITIES.

INTRODUCTION

Vectors are physical quantities which have magnitude and direction, whereas scalars are physical quantities with magnitude only. The concept of a physical quantity which requires both magnitude and direction is novel to the learners. In the past, the learners have dealt with concepts such as force, energy, distance, and speed, without being asked to distinguish which of these is a vector quantity. In fact, the learners have generally not learned anything about vectors or scalars.

The novelty of this new concept can be quite daunting. Just the fact that there is much more to the idea of force than it just being a force of 5 N, can challenge the learner's prior understanding of what (s)he has learnt so far.

CONCEPT EXPLANATION AND CLARIFICATION

Scalar quantities are added, subtracted, multiplied and divided by well-known rules of algebra which learners have been using ever since they began learning mathematics. Vector quantities obey the mathematical rules of vector algebra. They require different processes when they are added or subtracted from one another.

The first task is to help the learners choose whether a physical quantity is a scalar or a vector quantity. This is a good opportunity to check whether the learners are able to define terms such as mass, volume and weight, as well as to apply the descriptions "scalar" or "vector" to each of these quantities.

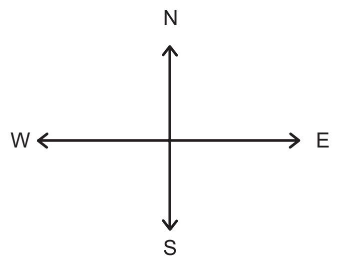
One way to start these types of tasks is to give a list of quantities with their definitions and ask learners to decide whether each quantity requires both magnitude and direction, or not. They can then classify the quantities as vector or scalar quantities.

The learners can then progress further by learning the definitions of these quantities and their classifications as scalars or vectors.

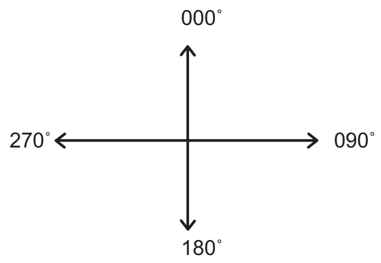
The second task is to represent a vector quantity as an arrow. The length of the arrow gives an indication of its relative magnitude, and the direction of the arrow shows the direction of the vector. Learners draw vectors to scale to represent quantities such as force and/or velocity.

Direction can be represented in a number of different ways.

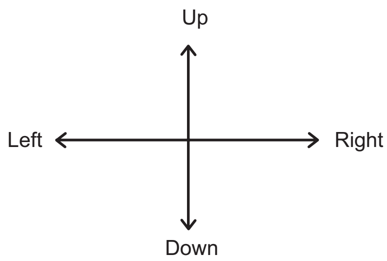
1. Cardinal points



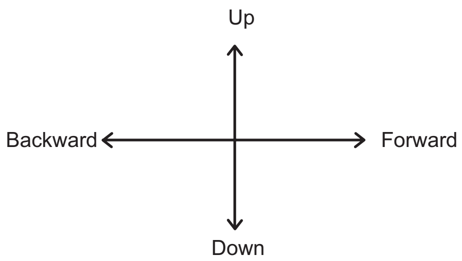
2. Bearing



3. Left & right, up & down

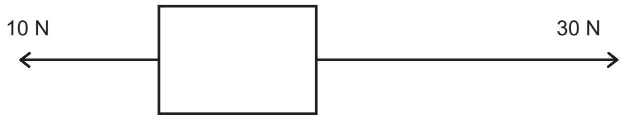


4. Forward, backward, up and down



The third task is to assign one direction as having positive values and the opposite direction will then have negative values. For example, the forward direction can be chosen as the positive direction. Forces with positive values will then be pulling (or pushing) the object forward. Forces with negative values will be pulling (or pushing) the object backward.

Clearly one force can pull an object forward, and another force can act on the same object in the opposite direction, so the fourth task is to add vector quantities.



The resultant vector is that single vector that represents the effect in magnitude and direction of all the vectors acting on the object.

Vectors are added geometrically to give the resultant vector. The tail of the second vector is placed at the head of the first vector, and so on. The resultant vector is given by drawing the straight line from the tail of the first vector to the head of the last vector.

In this particular case, the resultant vector is 20 N to the right.

Finally, learners need to pay attention to what is required when answering questions. If the question asks for the velocity of an object, the answer should state the magnitude of the velocity and its direction because velocity is a vector quantity.

Sometimes a question will specify that only the magnitude of the force is required. In these cases, there is no need to specify the direction of the force (or any other vector).

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, describing directions in terms of cardinal points and bearings, and finding the resultant of two (or more) vectors acting in the same straight line.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them in their workbooks.

1. Write down the definitions or descriptions of each of the following quantities, and classify each as a scalar or a vector quantity.

	QUANTITY	DEFINITION (OR DESCRIPTION)	SCALAR OR VECTOR QUANTITY
1.1	Mass		
1.2	Weight		
1.3	Volume		
1.4	Area		
1.5	Force		
1.6	Position		
1.7	Distance		
1.8	Displacement		
1.9	Time		
1.10	Direction		

Solution:

	QUANTITY	DEFINITION (OR DESCRIPTION)	SCALAR OR VECTOR QUANTITY
1.1	Mass	The amount of matter in an object.	Scalar
1.2	Weight	The force of the earth on the object OR the force due to (the earth's) gravity.	Vector
1.3	Volume	The amount of space occupied by an object.	Scalar
1.4	Area	The measurement of a surface.	Scalar
1.5	Force	A push or a pull.	Vector
1.6	Position	The location of an object.	Vector
1.7	Distance	The total path length travelled.	Scalar
1.8	Displacement	The difference in position in space.	Vector
1.9	Time	The duration of an event or moment.	Scalar
1.10	Direction	A course along which something moves or is located.	Scalar

2. Draw the following force vector to scale: 10 mm : 10 N on the axes of the cardinal points (N, S, E and W).

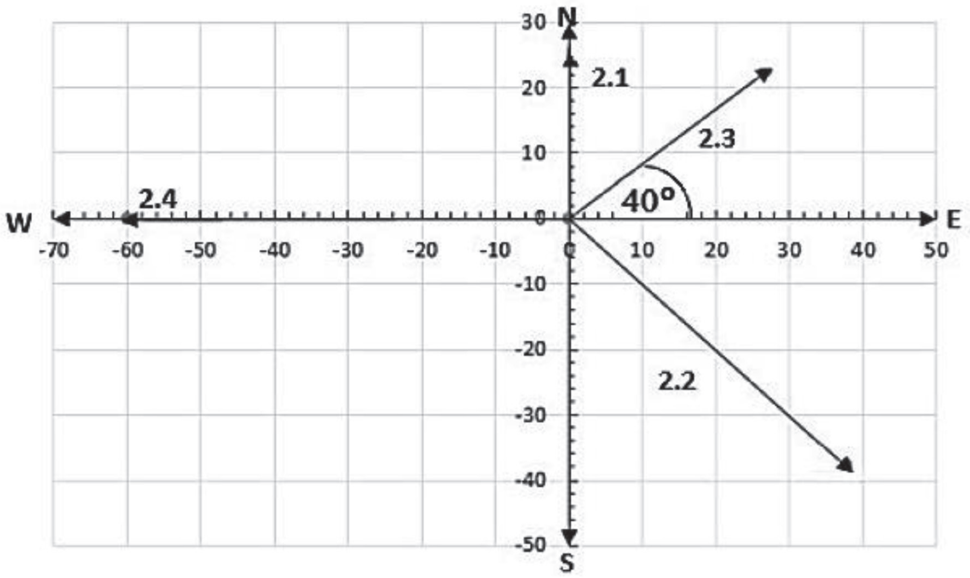
2.1 25 N north

2.2 55 N south-east

2.3 35 N 40° north of east

2.4 60 N west

Solution:



3. Write down the bearings of the force vectors of Question 2, given that a bearing due north is 000°, and east is 090°.

Solution:

3.1 25 N 180°

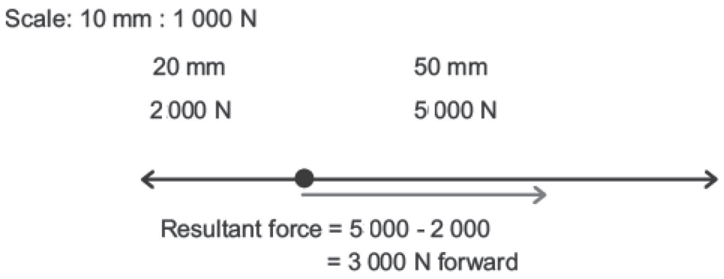
3.2 55 N 135°

3.3 35 N 050°

3.4 60 N 270°

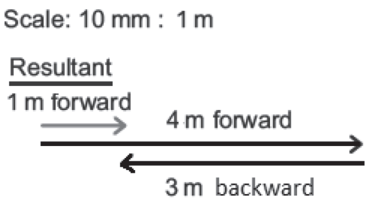
4. The driving force on a car is 5 000 N, and the resistive forces are 2 000 N. Draw a scale diagram showing the car as a "dot" and the action of these forces on the car. Determine the resultant force acting on the car.

Solution:



5. A ball rolls forward on a smooth horizontal surface for 4 m. It strikes the wall and rolls 3 m back along the same straight line. Draw a scale diagram to show the path of the ball, and determine is displacement.

Solution



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 facts and terminology and to apply these to solving problems.

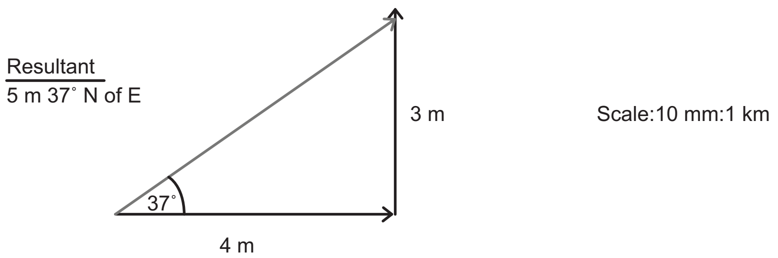
c. Although learners will not be asked to determine the resultant of two vectors acting at 90º to one another, challenge level questions can include a few examples of these types of questions, so that learners are encouraged to apply geometry when adding vectors.

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 man walks 4 km east and 3 km north. Construct a scale diagram to show where he walked, and determine his resultant displacement.

Solution:



NB. Grade 10 learners are only expected to add vectors acting along the same straight line. They do not need to add vectors acting at 90° to one another. However, it can be helpful for learners to work through this kind of exercise so that they understand that vectors are added geometrically. We are only asking the learners to draw the vectors to scale in a tail to head arrangement. And we ask them to draw the resultant displacement, which is the change in position of the object, and to measure its resultant magnitude and direction.

7. Peter walks to school 400 m eastwards down the street, and then he turns north and walks another 300 m due north.

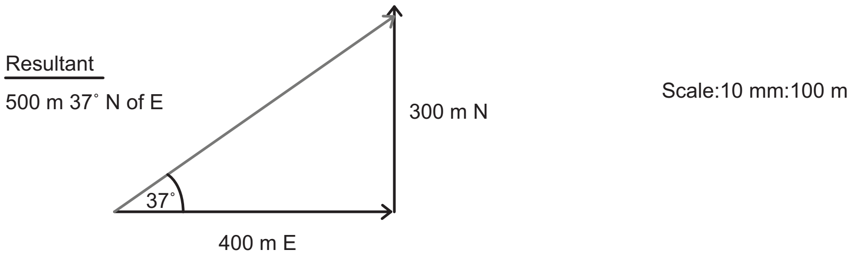
7.1 What is the displacement of the school from his house?

7.2 How far does he walk to school?

7.3 When he returns home in the afternoon, what is his displacement?

Solution:

7.1



7.2 Distance = 400 + 300 = 700 m

7.3 Zero (He has not changed his position!).

KEY TEACHING:

a. In these more challenging examples, learners must apply their knowledge of terminology and analysis of data to solving the problems.

b. It is good practice for the learners to draw diagrams of the vector quantities when finding the resultant so that they are able to show their reasoning clearly.

CHECKPOINT

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

1. knowing and understanding the terminology associated with vectors and scalars.
2. defining the resultant vector.
3. drawing scale diagrams of vectors, and using these to find the resultant vector.

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

Topic 19 Worksheet from the Resource Pack: Vectors and Scalars: Questions 1–6. (Pages 21–23).

- 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 it and place these on the walls of your classroom
- Allow time for feedback.
- Encourage the learners to learn from the mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topic 19 Consolidation Exercise from the Resource Pack: Vectors and Scalars (Page 24).**
- 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://people.ucalgary.ca/~alphy/MAP/workinprogr/Vec/ItemDescr.htm
   Teacher's resource: Outlining misconceptions that learners have about vectors and vector quantities.
2. http://www.physicsclassroom.com/class/1DKin/Lesson-1/Scalars-and-Vectors
   Teacher's and learners' resource: introducing vectors and scalars with examples and exercises for learners.

TOPIC 20:

1-Dimensional Motion, Speed, Velocity and Acceleration

A Introduction

- This topic runs for 8 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 Mechanics.
- Mechanics counts 50 % of the final Paper 1 (Physics) examination.
- 1-Dimensional motion counts about 28 % in this examination.
- Mechanics was the first branch of Physics to be developed, and it is the foundation on which all other branches of Physics are built. It deals with the motion of objects and the forces which act on them when at rest or in motion. The topic introduces one-dimensional motion, average speed and velocity, and acceleration.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Scientific calculator.

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 QUALITATIVE ASPECTS	**GRADE 10 QUALITATIVE AND QUANTITATIVE ASPECTS**	**GRADE 11 – 12 FURTHER APPLICATIONS**

• Forces.
  • Force as a push or a pull.
  • Contact and non-contact forces.
  • Force fields (gravitational, electric and magnetic).
  • Weight is the force of gravity (Weight = mg).
  • Electrostatics.
  • Magnetism.
	• Introduction to vectors and scalars.
	• Motion in 1-D.
	• Reference frame, position,
	• displacement and distance.
	• Average speed, average.
	• velocity, acceleration.
	• Instantaneous speed and velocity and the equations of motion.
	  • Instantaneous velocity, instantaneous speed,
	  • Description of motion in words, diagrams, graphs and equations.
		• Vectors in 2-D.
		  • Resultant of two perpendicular vectors.
		  • Resolution of vectors into horizontal and vertical components.
		• Newton's Laws and application of Newton's Laws.
		• Different kinds of forces.
		  • Force diagrams and free-body diagrams.
		  • Newton's 1st, 2nd and 3rd laws.
		• Momentum and impulse.
		  • Momentum.
		  • Newton's 2nd law expressed in terms of momentum.
		  • Conservation of momentum and elastic and inelastic collisions.

TOPIC 20

C Glossary of Terms

TERM	DEFINITION
Scalar	A physical quantity that has magnitude only.
Vector	A physical quantity that has magnitude and direction.
Resultant vector	The single vector having the same effect as two or more vectors together.
Distance	The total path length travelled.
Displacement	The difference in position in space.
Average speed	The total distance travelled per total time.
Average velocity	The rate of change of position.
Acceleration	The rate of change of velocity.
Instantaneous velocity	The displacement divided by an infinitesimal time interval. The change in position divided by a very small time interval.
Instantaneous speed	The rate of change in position, i.e. the displacement divided by a very small time interval or the velocity at a particular time.
A frame of reference	A coordinate system used to represent and measure properties of objects, such as position.
1-D motion	Motion along a straight line.
Positive acceleration	An object moving in the positive direction is experiencing an increase in speed and an object moving in the negative direction is experiencing a decrease in speed.
Negative acceleration	An object moving in the positive direction is experiencing a decrease in speed and an object moving in the negative direction is experiencing an increase in speed.
Deceleration	An object is experiencing a decrease in speed.
Stopping distance	The total distance the car travels from the time the driver decides to stop the car. NB. The stopping distance may include the "thinking distance" which is the distance travelled during the time it takes the driver to react and apply the brakes. The stopping distance may only refer to the "braking distance" which is the distance travelled by the car from the moment the brakes are applied. You have to read the problem carefully to decide what information you have been given, and then deal with it appropriately.
Reaction time	The time taken for the driver to be able to respond to an emergency situation after seeing a hazard in front of the car, and applying the brakes. During the reaction time the car continues travelling at its initial velocity. The distance that it travels during this time is called the "thinking distance".

D Assessment of this Topic

This topic is assessed by informal class tests and/or control tests, and in the Term 4 examination.

- There should be multiple-choice type questions, and problems to solve, where the learners are expected to show their method, give some explanation and/or write down definitions or laws.

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	
3 h	Reference frame	54	Measurements of position take place relative to the origin of a frame of reference.
	Displacement and distance	54	Distinguishing between displacement and distance.
5 h	Average speed, average velocity and acceleration	55	Distinguishing between speed and velocity, and between velocity and acceleration.

TOPIC 20

F Targeted Support per Sub-topic

1 MEASUREMENTS OF POSITION TAKE PLACE RELATIVE TO THE ORIGIN OF A FRAME OF REFERENCE.

INTRODUCTION

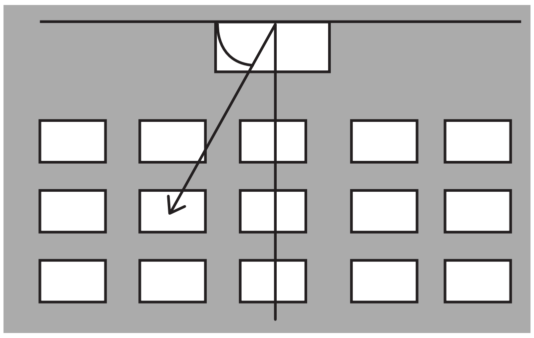
The position of an object describes its location. To be able to locate an object we need to be able to say how far it is from a reference point, and in what direction it is away from a reference line (or axis).

CONCEPT EXPLANATION AND CLARIFICATION

Very often the reference point is taken as the position of the observer. It is where you are located. An object near to you would be assigned a magnitude as to how far away it is from you, and in what direction you would have to move towards it.

In the case of 1-dimensional motion, the direction that you move will be forwards or backwards, or it may be up or down, or left and right.

If we consider the layout of a classroom with desks placed in rows and lines all facing the chalkboard, we have a 2-dimensional frame of reference. We can choose the position of the teacher's desk as the origin of the frame of reference. The position of a particular desk (for a particular learner) will be the magnitude of the straight line drawn from the teacher's desk to the learner's desk. The direction will be referenced by an angle drawn from the teacher's "chalkboard" axis to the learner.



The frame of reference is an arbitrary set of axes chosen to describe the location of a point on a line or on a plane surface, or even in 3-dimensional space.

From this discussion it is clear that position is a vector quantity. To describe an object's position, we need to know the magnitude of how far it is from the origin of the frame of reference, and in what direction it is located relative to an axis of the reference frame.

2 DISTINGUISHING BETWEEN DISTANCE AND DISPLACEMENT.

INTRODUCTION

It is critical that learners are able to clearly distinguish between displacement (change in position) and distance (length of path travelled). Spending a little longer on checking the learners understanding can be very helpful, because the definitions of speed and velocity depend on these two concepts.

CONCEPT EXPLANATION AND CLARIFICATION

Displacement is a vector quantity which represents change in position. It does not depend on the path which was used to change position – it only depends on the initial and final position of the object.

$$\overrightarrow{\Delta x} = \vec{x}_f - \vec{x}_i$$

For example, a ball moves 4 m towards the wall. It bounces back travelling 3 m from the wall. What is its displacement?

$\overrightarrow{\Delta x} = \vec{x}_f - \vec{x}_i$ = 4 m forwards – 3 m backward
= 1 m forward

In this case, the path length travelled by the ball is 4 m forward, and 3 m backward = 7 m.

Distance = path length = 7 m but displacement = change in position = 1 m forward.

Clearly these two quantities measure completely different things.

3 DISTINGUISHING BETWEEN AVERAGE SPEED, AVERAGE VELOCITY AND ACCELERATION.

INTRODUCTION

The terms “speed”, “velocity” and “acceleration” are frequently interchanged. This confusion can be a huge obstacle to overcome in moving forward with physics. It is therefore crucial to introduce these terms clearly and unambiguously, and to continue to check the learners’ understanding of them, through classroom discussions, problem solving and class tests.

CONCEPT EXPLANATION AND CLARIFICATION

“Speed” and “velocity” are related to each other, in that they both measure the rate of change of a quantity with respect to the time taken.

“Speed” is related to “distance”; and “velocity” is related to “displacement”.

Average speed is defined as The total distance travelled per unit time.

Average velocity is defined as The rate of change of position.

However concise and unambiguous a definition is, learners need to match the definition to their internal understanding of what the definition means to each of them. It is always good practice to remind the learners of the definition of each of the terms – but it is not always useful to the learners to hear the definition as a means of explaining why, or what or how to solve a problem. The learners need to work with the definitions in various contexts to build a resilient knowledge base on which to hang these ideas.

Problem scenarios which relate to their understanding of everyday situations can also help them to build a robust mental picture of each concept.

For example, the distance that each learner travels to school and home each day is different from the displacement of the learner's home from the school. Some learners walk to school; others ride on bicycles, in buses, in taxis or in a car. These different modes of transport open up a wide range of speeds and velocities for learners to calculate.

The speed of high performance cars, airplanes and rockets, and athletes in sport are topics which could spark the learners' interest and motivate them to seek answers to problems.

Before introducing the concept of acceleration, it is a good idea to give he learners opportunities to solve introductory level problems on average speed and average velocity.

Acceleration is often confused with velocity. Velocity is displacement divided by time (or change in position divided by time) whereas acceleration is the change in velocity divided by time.

A simple demonstration of a toy car running in a straight line on a track can be helpful in developing an understanding of acceleration.

- Push the car forward and release it. The car moves forward slowing down as it goes along.
- Raise the track a little at one end, until the car is able to run down the track at constant velocity. The car covers the equal distances in the same time interval. It does not gain or lose speed.
- Raise the track a little higher at one end, and the car accelerates down the track.

During this demonstration, ask the learners to describe the motion of the car at each stage. Encourage them to use the terms "speed", "velocity" and "acceleration" appropriately. And note that even when the car is slowing down, it is accelerating because its velocity is changing as it goes along.

Acceleration is a vector quantity. When calculating the value for acceleration, the value can be positive or negative.

$$a = \frac{v_f - v_i}{\Delta t}$$

A negative value does not mean that the acceleration is less than zero.

The sign of acceleration tells us only about the direction of the acceleration. A positive value of acceleration tells us that the object accelerates in the positive direction. A negative acceleration tells us that the object accelerates in the opposite direction. The sign of the acceleration does not tell us whether the object is gaining or losing velocity (or speed).

INTRODUCTORY LEVEL QUESTIONS

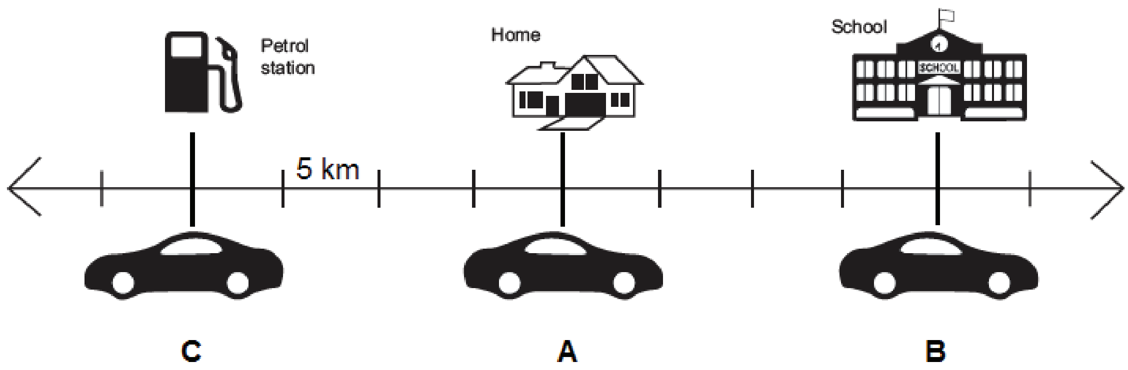
a. These are the basic questions that learners will be required to answer at this stage in the topic.

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

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

1. Ted drives his car along the road, starting at point A and driving to point B, in 30 minutes. He then stops and drives from point B to point C in 45 minutes. Take the positive direction as moving to the right.



Calculate, in $km \cdot h^{-1}$,

1.1 Ted's average speed from A to B.

1.2 Ted's average velocity from A to B.

1.3 Ted's average speed from B to C.

1.4 Ted's average velocity from B to C.

Solution:

1.1 average speed $= \frac{\text{distance}}{\text{time}}$ (method)

$= \frac{4 \times 5}{30/60}$ (substitutions; conversion minutes to hours)

$= 40\ \text{km}\cdot\text{h}^{-1}$ (accuracy; SI units)

1.2 average velocity $= \frac{\text{displacement}}{\text{time}}$ (method)

$= \frac{20}{0,5}$ (substitutions; conversion minutes to hours)

$= 40\ \text{km}\cdot\text{h}^{-1}$ right (or forward) (accuracy; SI units)
(direction)

1.3 average speed $= \frac{\text{distance}}{\text{time}}$ (method)

$= \frac{8 \times 5}{45/60}$ (substitutions; conversion minutes to hours)

$= 53{,}33\ \text{km}\cdot\text{h}^{-1}$ (accuracy; SI units)

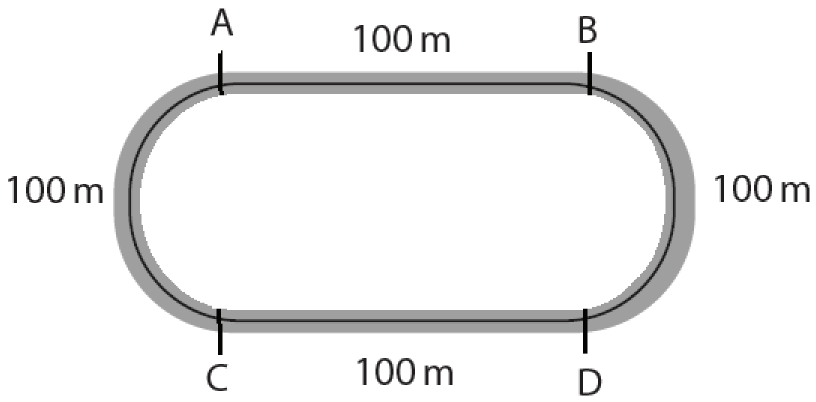
1.4 average velocity $= \frac{\text{displacement}}{\text{time}}$ (method)

$= \frac{-40}{0,75}$ (substitutions; conversion minutes to hours)

$= -53{,}33\ \text{km}\cdot\text{h}^{-1}$ (accuracy)

$= 53{,}33\ \text{km}\cdot\text{h}^{-1}$ left (backwards or in the opposite direction)
(accuracy; SI units)
(direction)

2. An athlete runs the 1 600 m race around an oval track as shown in the diagram below.



He runs four laps (from A to B to C to D and back to A, four times) and he finishes in a time of 4 minutes 10 seconds.

2.1 Clearly distinguish between average speed and average velocity.

2.2 Determine the athlete's average speed.

2.3 Determine the athlete's average velocity.

Solution:

2.1 The average speed is the distance divided by time; the average velocity is displacement divided by time.

(Speed is a scalar quantity, and velocity is a vector quantity. This answer, by itself, could be awarded 1 mark. It does not actually "distinguish" between the meanings of the terms speed and velocity, so it is not awarded full marks)

2.2 Average speed $= \frac{\text{distance}}{\text{time}}$ (method)

$= \frac{1\,600}{(4 \times 60 + 10)}$ (substitutions)
(converting minutes to seconds)

$= 6{,}4\ \text{m·s}^{-1}$ (accuracy; SI units)

2.3 Average velocity $= \frac{\text{displacement}}{\text{time}}$ (method)

$= \frac{0}{(4 \times 60 + 10)}$

$= 0\ \text{m·s}^{-1}$ (accuracy)
SI units can be ignored (Value = 0)

3. A high-performance car accelerates from rest to 108 km·h^{-1} in 8,4 s.

3.1 Show that 108 km·h^{-1} is equivalent to 30 m·s^{-1}.

3.2 Define acceleration.

3.3 Calculate the acceleration of the car.

Solution

3.1 $108\ \text{km·h}^{-1} = \frac{108 \times 1\,000}{60 \times 60}$ (method)

$= 30\ \text{m·s}^{-1}$

3.2 Acceleration is the rate of change of velocity.

3.3 $a = \frac{v_f - v_i}{\Delta t}$ (method)

$= \frac{30 - 0}{8{,}4}$ (substitutions)

$= 3{,}57\ \text{m·s}^{-1}$ forward (accuracy; SI units)
(direction)

TOPIC 20

CHALLENGE LEVEL QUESTIONS

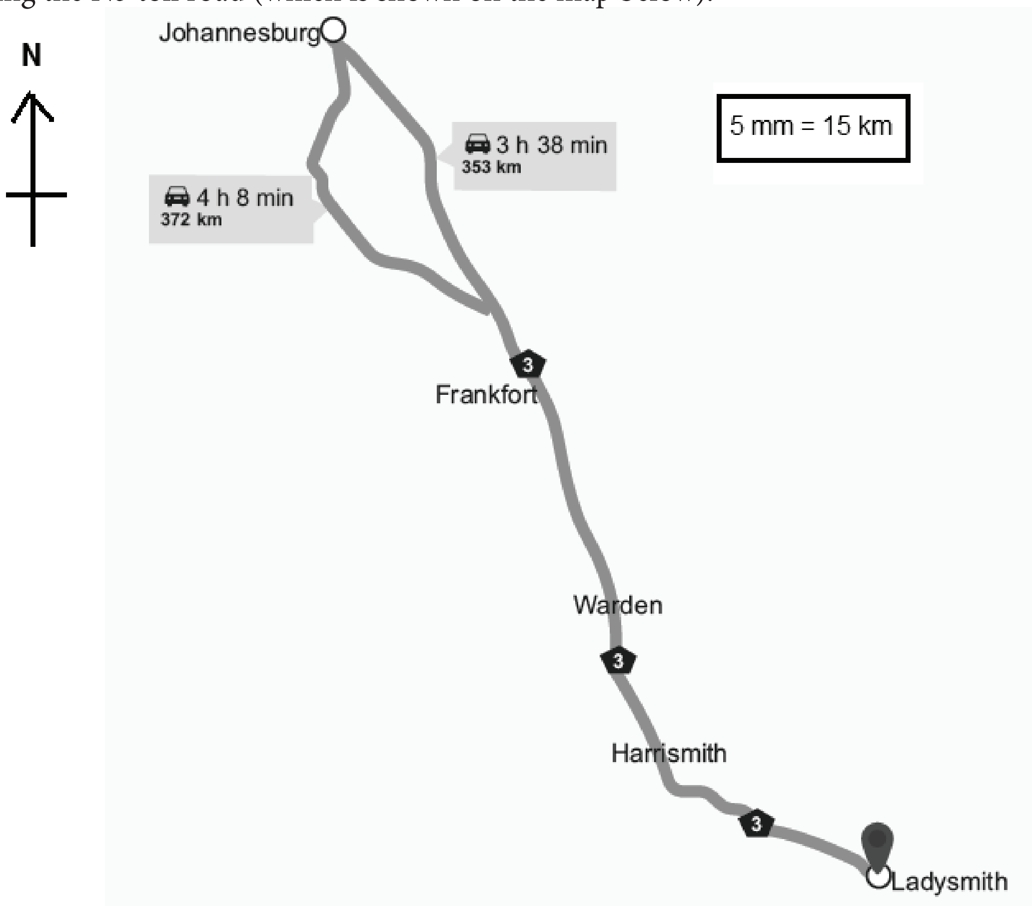
a. Now that learners have mastered the basic terminology, they are ready to deal with more challenging questions.

b. These questions require learners to use the facts and terminology and to apply these to solving problems.

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 motorist takes 3 hours 38 minutes to travel 353 km from Johannesburg to Ladysmith using the N3 toll road (which is shown on the map below).



4.1 Calculate the average speed of the car as it travelled from Johannesburg to Ladysmith.

4.2 Determine the displacement of the car from Johannesburg to Ladysmith.

4.3 Calculate the magnitude of the average velocity of the car from Johannesburg to Ladysmith.

4.4 A few days later the driver drove his car from Ladysmith back to Johannesburg, but this time he took the route through Newcastle, Ermelo and Belfast. Determine his displacement from Ladysmith to Johannesburg.

Solution:

4.1 Average speed $= \dfrac{\text{distance}}{\text{time}}$ (method)

$= \dfrac{353}{(3 + {}^{38}\!/_{60})}$ (substitution) (converting minutes to hours)

$= 97{,}16 \text{ km·h}^{-1}$ (accuracy; SI units)

4.2 On the map, draw an arrow from Johannesburg to Ladysmith.

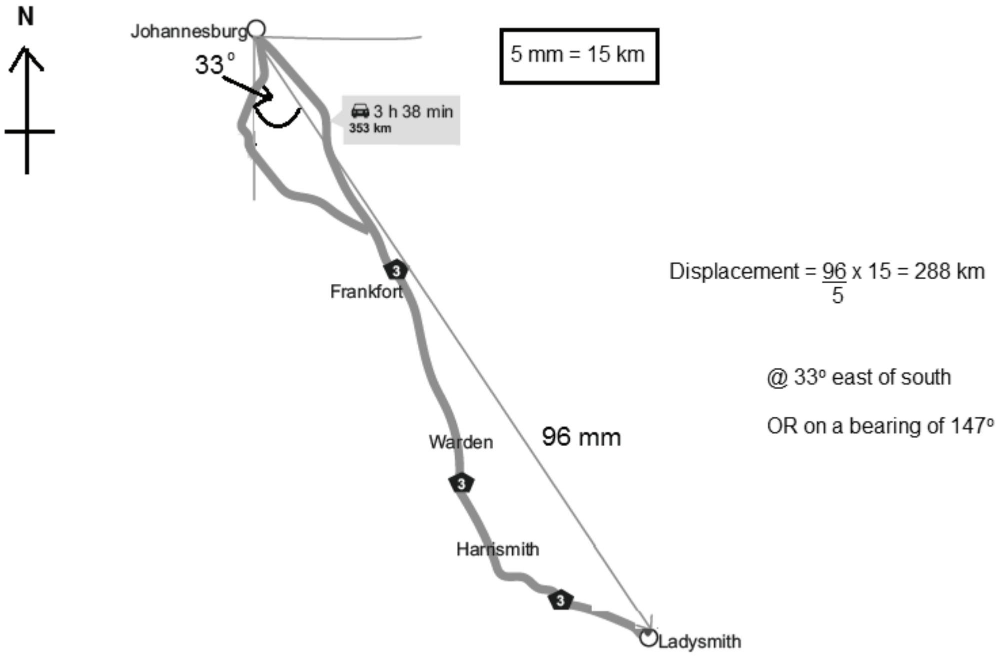
Measure the length of this line, and convert it according to the scale shown on the map.

Measure the angle between the N-S line and the displacement vector.

State the displacement correctly.

276,35 km @ 33° east of south OR on a bearing of 147°.

(Answers can vary slightly)



TOPIC 20

4.3 Average velocity $= \dfrac{\text{displacement}}{\text{time}}$ (method)

$= \dfrac{288}{3,63}$ (substitutions)

$= 79{,}34\ \text{km·h}^{-1}$ (accuracy; SI units)

4.4 Displacement from Ladysmith to Johannesburg

= 288 km @ 33° west of north

OR on a bearing of 327°

5. A stone falls off a 25 m high cliff. It hits the ground after 2,3 s.

5.1 Calculate the average speed of the stone.

5.2 Explain why the average velocity has the same magnitude as the average speed.

5.3 State the average velocity of the stone.

5.4 Explain how we know that the stone accelerates during its fall.

Solution

5.1 Average speed $= \dfrac{\text{distance}}{\text{time}}$ (method)

$= \dfrac{25}{2,3}$ (substitutions)

(converting minutes to hours)

$= 10{,}87\ \text{m·s}^{-1}$ (accuracy; SI units))

5.2 The distance that the stone falls is straight down from the cliff. Its change in position is the same straight-line length from the top of the cliff to the bottom. Therefore, their magnitudes are the same.

5.3 $10{,}87\ \text{m·s}^{-1}$ down

5.4 The stone falls from rest, and moves down to hit the ground, therefore, its velocity changes while it falls. (i.e. it accelerates).

6. An ant walks for 30 s from point A to B to C. Its average speed is $0{,}2\ \text{m·s}^{-1}$, and its average velocity is $0{,}05\ \text{m·s}^{-1}$ due east.

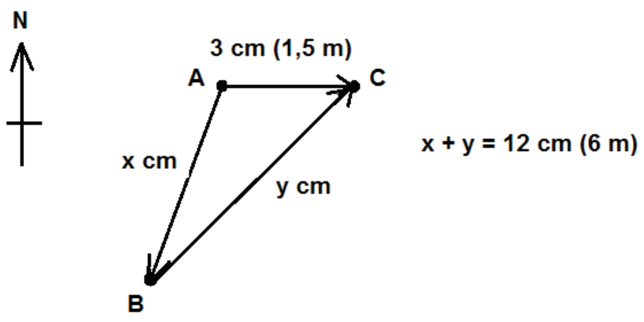
6.1 Determine the distance the ant walked in 30 s.

6.2 Determine the displacement of the ant in 30 s.

6.3 Draw a scale diagram of the positions of the points A, B and C relative to each other. Use the scale 1 cm: 0,5 m.

Solution:

6.1	Distance	= average speed × time	(method)
		= 0,2 × 30	(substitutions)
		= 6 m	(accuracy; SI units)
6.2	Displacement	= average velocity × time	(method)
		= 0,05 × 30	
		= 1,5 m east	(accuracy; SI units) (direction)



6.3 AC points to the east.

AC has a length of 3 cm (c.o.e. from 6.2).

AB + BC has a combined length of 12 cm (c.o.e. from 6.1).

Arrows on AB and BC are in the correct directions (from A to B, from B to C).

NB. AB and BC can be curved lines – their combined distance must add up to 12 cm (6 m).

7. A sprinter takes off from rest, accelerating along a straight track for 3 s to reach a maximum speed of 9,6 m·s^{-1}, and covering a distance of 14,4 m in this time.

7.1 Calculate his average acceleration.

7.2 Calculate his average velocity after 3 s

7.3 Calculate his maximum speed at 2 s.

Solution:

7.1 $a = \frac{v_f - v_i}{\Delta t}$ (method)

$= \frac{9,6 - 0}{3}$ (substitutions)

= 3,2 m·s^{-2} forward (accuracy; SI units)
(direction)

7.2 Average velocity $= \dfrac{\Delta x}{\Delta t}$ (method)

$= \dfrac{14,4}{3}$ (substitutions)

$= 4,8 \text{ m·s}^{-2}$ forward (accuracy; SI units) (direction)

7.3 $a = \dfrac{v_f - v_i}{\Delta t}$ (method)

$3,2 = \dfrac{v_f - 0}{2}$ (substitutions)

$v_f = 6,4 \text{ m·s}^{-1}$ forward (accuracy; SI units) (direction)

KEY TEACHING:

a. In these more challenging examples, learners must apply their knowledge of terminology and analyse the data given when solving the problems.

b. They must be able to distinguish between distance and displacement, and speed and velocity.

c. Learners must remember to include the direction of vector quantities in their final answers.

CHECKPOINT

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

1. the terminology associated with vectors and scalars, distance, displacement, speed and velocity, and acceleration.
2. calculating average speed, average velocity and average acceleration, and using these formulae to find the final or initial velocity, or the time taken to accelerate.
3. calculating the distance travelled using the average speed and time, and/or the displacement using the average velocity and time.
4. knowing that vector quantities require both magnitude and direction to be specified in the final answer.

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

Topic 20 Worksheet from the Resource Pack: 1-Dimensional motion, Speed, Velocity and Acceleration: Questions 1–7. (Pages 30–31).

- 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 it and place these on the walls of your classroom.
- Allow time for feedback.
- Encourage the learners to learn from the mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topic 20 Consolidation Exercise from the Resource Pack: 1-Dimensional motion, Speed, Velocity and Acceleration (Pages 32–33).**
- 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://apasseducation.com/4-misconceptions-students-have-about-physics/

   Teachers resource: on common misconceptions in mechanics. The section on "acceleration" is particularly informative and useful.

2. https://www.youtube.com/watch?v=FOkQszg1-j8

   Learners and teachers resource: A video lesson on acceleration from the Khan Academy.

3. https://www.youtube.com/watch?v=rZo8-ihCA9E

   Learners and teachers resource: A video lesson on speed, velocity and acceleration from Bozeman Science.

.

TOPIC 21:

Instantaneous Speed and Velocity and the Equations of Motion

A Introduction

- This topic runs for 8 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 Mechanics.
- Mechanics counts 50 % of the final Paper 1 (Physics) examination.
- Instantaneous speed and velocity and the equations of motion form 18 % of the final assessment.
- Mechanics was the first branch of Physics to be developed, and it is the foundation on which all other branches of Physics are built. It deals with the motion of objects and the forces which act on them when at rest or in motion. This introduction to one-dimensional motion, average speed and velocity, and acceleration.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Graph paper.
4. Grade 10 Examination Data Sheet.
5. Scientific calculator.

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 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**

• Forces.
  • Force as a push or a pull.
  • Contact and non-contact forces.
  • Force fields (gravitational, electric and magnetic).
  • Weight is the force of gravity (Weight = mg).
  • Electrostatics.
  • Magnetism.
	• Introduction to vectors and scalars.
	• Motion in 1-D.
	• Reference frame, position,
	• displacement and distance.
	• Average speed, average velocity, acceleration.
	• Instantaneous speed and velocity and the equations of motion.
	  • Instantaneous velocity, instantaneous speed,
	  • Description of motion in words, diagrams, graphs and equations.
		• Vectors in 2-D.
		  • Resultant of two perpendicular vectors.
		  • Resolution of vectors into horizontal and vertical components.
		• Newton's Laws and application of Newton's Laws.
		  • Different kinds of forces.
		  • Force diagrams and free-body diagrams.
		  • Newton's 1st, 2nd and 3rd laws.
		• Momentum and impulse.
		  • Momentum.
		  • Newton's 2nd law expressed in terms of momentum.
		  • Conservation of momentum and elastic and inelastic collisions.

TOPIC 21

C Glossary of Terms

TERM	DEFINITION
Scalar	A physical quantity that has magnitude only.
Vector	A physical quantity that has magnitude and direction.
Resultant vector	The single vector having the same effect as two or more vectors together.
Distance	The total path length travelled.
Displacement	The difference in position in space.
Average speed	The total distance travelled per total time.
Average velocity	The rate of change of position.
Acceleration	The rate of change of velocity.
Instantaneous velocity	The displacement divided by an infinitesimal time interval. The change in position divided by a very small time interval.
Instantaneous speed	The rate of change in position, i.e. the displacement divided by a very small time interval or the velocity at a particular time.
A frame of reference	A coordinate system used to represent and measure properties of objects, such as position.
1-D motion	Motion along a straight line.
Positive acceleration	An object moving in the positive direction is experiencing an increase in speed and an object moving in the negative direction is experiencing a decrease in speed.
Negative acceleration	An object moving in the positive direction is experiencing a decrease in speed and an object moving in the negative direction is experiencing an increase in speed.
Deceleration	An object is experiencing a decrease in speed.
Stopping distance	The total distance the car travels from the time the driver decides to stop the car. NB. The stopping distance may include the “thinking distance” which is the distance travelled during the time it takes the driver to react and apply the brakes. The stopping distance may only refer to the “braking distance” which is the distance travelled by the car from the moment the brakes are applied. You have to read the problem carefully to decide what information you have been given, and then deal with it appropriately.
Reaction time	The time taken for the driver to be able to respond to an emergency situation after seeing a hazard in front of the car, and applying the brakes. During the reaction time the car continues travelling at its initial velocity. The distance that it travels during this time is called the “thinking distance”.

D Assessment of this Topic

This topic is assessed by informal class tests and/or control tests, and in the final Term 4 examination.

- There should be multiple-choice type questions, match the phrase type questions, or problems to solve, where the learners are expected to show their method, give some explanation and/or write down definitions or laws.

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	Instantaneous speed and instantaneous velocity	56	a. Differentiating between average and instantaneous speed and velocity.
6 h	Description of motion in words, diagrams, graphs and equations.	56 - 57	b. Analysing data from graphs and descriptions of motion in order to solve problems successfully.

TOPIC 21

F Targeted Support per Sub-topic

1 DIFFERENTIATING BETWEEN AVERAGE AND INSTANTANEOUS SPEED AND VELOCITY

INTRODUCTION

The equations of motion and graphs of motion make use of instantaneous speeds and/or velocities rather than average values of these quantities. In their work and calculations up to this point, the learners have been dealing with the average values. It is important that they are able to distinguish between the value of the average speed and instantaneous speed. Similarly for average velocity and instantaneous velocity.

CONCEPT EXPLANATION AND CLARIFICATION:

The concept of average and instantaneous values may make more sense to the learners if we remind them how their marks are calculated for a term average. For example, let's say that there were 5 tests in the term, and the results were:

79 % 36 % 51 % 67 % 45 %

The report card shows the average of these results:

$$\text{Average} = \frac{(79+36+51+67+45)}{5} = 55{,}6\ \% \text{ which we round up to 57 \%.}$$

The average shows the learner's overall performance for the term. The individual test results show the learner's performance at that moment in time and in that particular task.

In a similar way the average speed of an object in motion tells us about the rate at which it covered the total distance during the journey. It doesn't tell us about individual changes in speed over very short periods of time. The instantaneous speed tells us the "exact" speed of the object over a very short time interval.

$$\text{Average speed} = \frac{(\text{total distance})}{(\text{total time})}$$

$$\text{Instantaneous speed} = \frac{(\text{distance travelled})}{(\text{very short time interval})}$$

Similarly, the average and instantaneous velocity are calculated as:

$$\text{Average velocity} = \frac{(\text{total displacement}}{(\text{total time})}$$

$$\text{Instantaneous velocity} = \frac{(\text{displacement})}{(\text{very short time interval})}$$

Learners must be reminded that average velocity and instantaneous velocity are both vector quantities. They require both magnitude and direction to be specified.

The instantaneous speed at any point in time is equal to the magnitude of the instantaneous velocity.

The instantaneous velocities that we deal with in particular are the initial and the final velocity for an object accelerating uniformly along a straight line.

Initial velocity = v_i (in a particular direction)

Final velocity = v_f (in its particular direction)

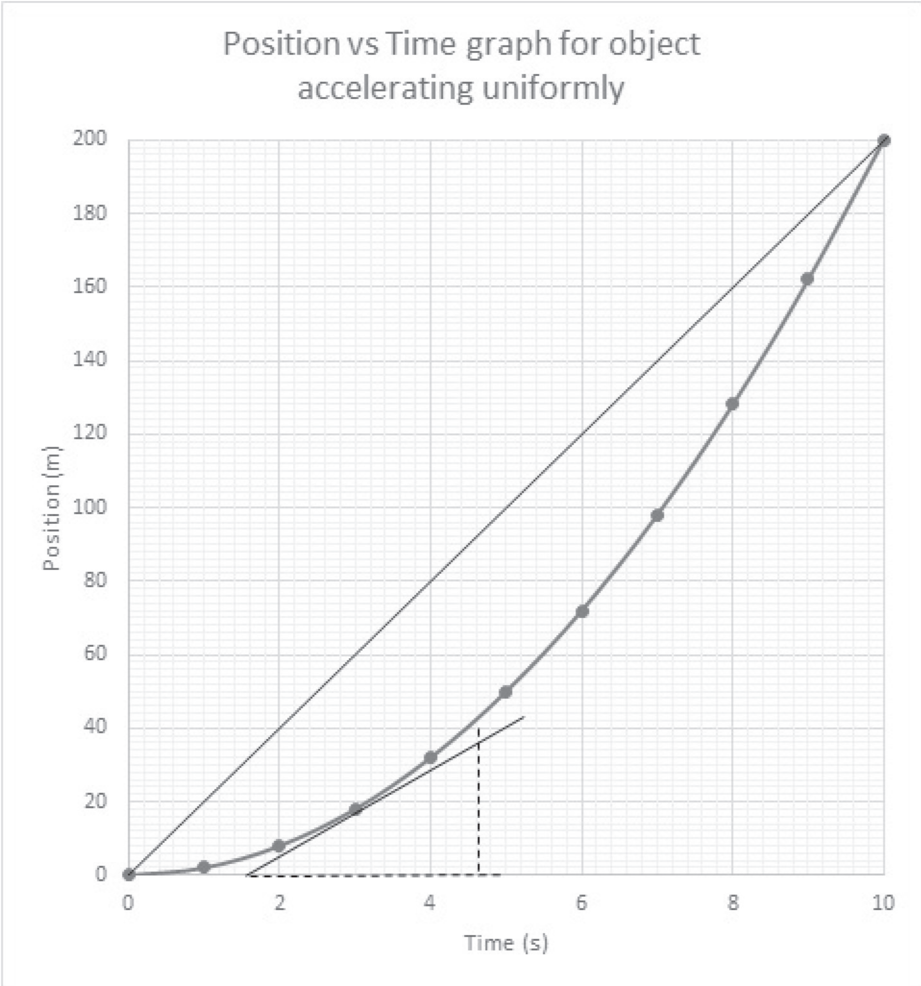
The average velocity of these two quantities is their sum, divided by 2 (because we are taking the average of two quantities.

$$\text{Average velocity} = \frac{v_i + v_f}{2} \text{ (in the appropriate direction)}$$

The uniform acceleration can be calculated using: $a = \dfrac{v_f - v_i}{\Delta t}$

Graphs of motion show the difference between average velocity and instantaneous velocity clearly.

The average velocity is calculated by the gradient of the graph from 0 s to 10 s:



$$\text{Gradient} = \frac{\Delta y}{\Delta x} = \frac{200}{10} = 20 \text{ m·s}^{-1} \text{ forward}$$

The instantaneous velocity of the object at 3 s is calculated by the gradient of the tangent to the graph at 3 s:

$$\text{Gradient} = \frac{\Delta y}{\Delta x} = \frac{36}{3} = 12 \text{ m·s}^{-1} \text{ forward}$$

TOPIC 21

2 ANALYSING DATA FROM GRAPHS AND DESCRIPTIONS OF MOTION IN ORDER TO SOLVE PROBLEMS SUCCESSFULLY.

INTRODUCTION

Many learners have difficulty organising data when asked to solve a problem. They are unsure of which quantity is the initial or final velocity, and they may not understand that acceleration is negative when an object is slowing down.

CONCEPT EXPLANATION AND CLARIFICATION:

1. Organising data to solve problems using the equations of motion.

Encourage learners to write down the list of variables, and then to read through the question collecting the values for these variables. There should be at least three values mentioned in the question, so that they can solve for the 4th and/or 5th variables.

For example: A car accelerates uniformly along a straight level road increasing its speed from 10 m·s^{1} to 30 m·s^{1} in 25 s. Calculate a) the acceleration of the car, and b) the distance travelled during these 25 s.

The learner will be able to find these three values, and then proceed to use the appropriate equation of motion.

v_i = 10 m·s^{1}

v_f = 30 m·s^{1}

a =

Δt = 25 s

Δx =

2. Choosing an appropriate equation of motion to solve a problem.

Referring to the example shown above, we note that the initial velocity, final velocity and time are values which are given in this problem.

a) The acceleration of the car must be calculated.

Possible equations are: $v_f = v_i + at$

$v_f^2 = v_i^2 + 2a\Delta x$

$\Delta x = v_i\Delta t + ½\, a\Delta t^2$

However, we must use the first of these equations because we have sufficient data to calculate an answer.

$$v_f = v_i + at$$
$$30 = 10 + a\,(25)$$
$$a = \frac{30-10}{25}$$
$$= 0{,}8 \text{ m·s}^{-2} \text{ forward}$$

b) The displacement (distance travelled) must be calculated.
Possible equations are: $v_f^2 = v_i^2 + 2a\Delta x$

$$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$$

$$\Delta x = \frac{(v_i + v_f)}{2}\Delta t$$

Any of these equations will suffice. We now know the value of the acceleration so we have sufficient data to use any of these equations.

However, if we hadn't already calculated the acceleration, we could use the last of these equations, using the data which was given in the question.

$$\Delta x = \frac{(v_i + v_f)}{2}\Delta t$$

$$= \frac{(10 + 30)}{2}25$$

$$= 500 \text{ m}$$

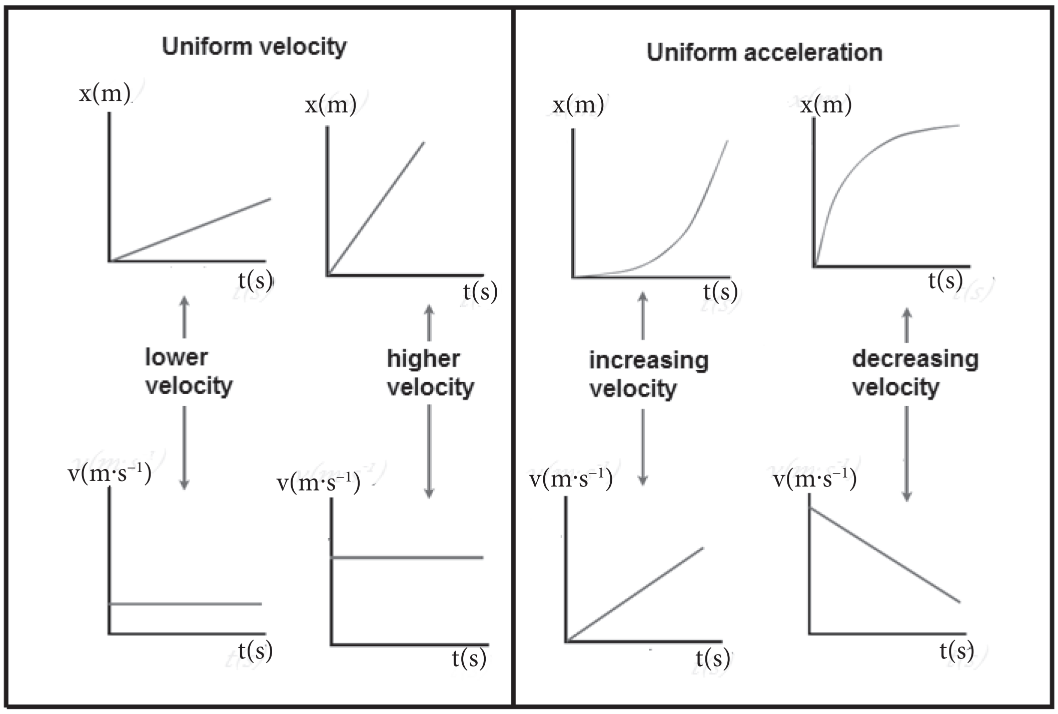
3. Describing motion using graphs of motion

Three different graphs of motion can be drawn: position-time, velocity-time and acceleration-time.

The first question that needs to be asked concerning any graph of motion is: "Which variable is on the y-axis?" In other words, which particular graph is this?

Thereafter, take note of the shape of the graph:

- Is it a straight-line graph, parallel to the x-axis?
- Or is it a straight-line graph passing through the origin?
- Is the graph curved, like a parabola?



4. The velocity-time graph is linked to the position-time graph in two different ways:

a) The gradient of the position-time graph at any point on the graph gives the magnitude of the velocity.

As you can see from the graphs of uniform velocity, the steeper the gradient of the straight-line graph the greater the value of the constant velocity.

b) The area under the velocity-time graph gives the displacement (change in position) of the object.

INTRODUCTORY LEVEL QUESTIONS

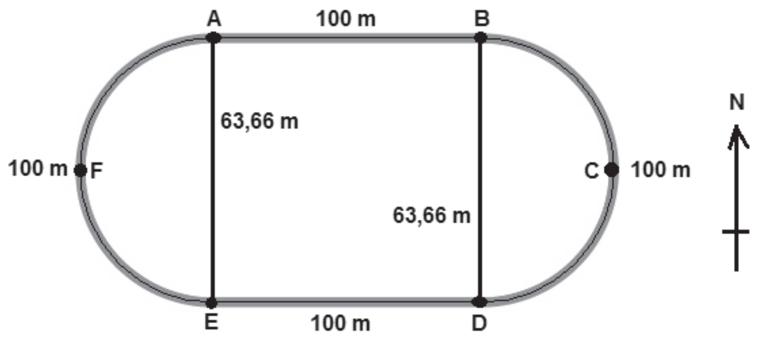
a. These are the basic questions that learners will be required to answer at this stage in the topic.

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

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each step to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

1. An athlete runs from A to B to C to D to E on an oval athletic track at a constant speed of 5 $m \cdot s^{-1}$.



1.1. How long does she take to run from A to E along the track?

1.2 Describe her displacement relative to point A when she reaches E.

1.3 Calculate her average velocity when she reaches point E.

1.4 Determine her instantaneous velocity at point C.

Solution:

1.1 Distance = 100 + 100 + 100 = 300 m (method)

Distance = average speed × time (method)

$300 = 5 \times \Delta t$ (substitutions)

Time = 60 s (accuracy; SI units)

1.2 63,66 m south

1.3 $\text{Average velocity} = \frac{\text{displacement}}{\Delta t}$ (method)

$= \frac{63,33}{60}$ (substitutions)

$= 1,06\ \text{m·s}^{-1}$ (accuracy; SI units) (direction)

1.4 $5\ \text{m·s}^{-1}$ south

2. A motorist accelerates along a straight level road from rest to a speed of $60\ \text{km·h}^{-1}$ for 8 s.

2.1 Show that $60\ \text{km·h}^{-1}$ is equal to $16,67\ \text{m·s}^{-1}$.

2.2 Calculate the acceleration of the car.

2.3 Calculate the displacement of the car.

2.4 Explain why the displacement of the car is equal in magnitude to the distance that it travelled in this time.

Solution:

2.1 $60\ \text{km·h}^{-1} = \frac{60 \times 1\,000}{60 \times 60}$ (method- shown clearly)

$= 16,67\ \text{m·s}^{-1}$

$v_i = 0\ \text{m·s}^{-1}$

$v_f = 16,67\ \text{m·s}^{-1}$

$a = ?$

$\Delta t = 8\ \text{s}$

$\Delta x = ?$

2.2 $a = \frac{(v_f - v_i)}{\Delta t}$ (method)

$= \frac{(16,67 - 0)}{8}$ (substitutions)

$= 2,08\ \text{m·s}^{-2}$ forwards (accuracy; SI units) (direction)

TOPIC 21

2.3 $\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2$ (method)

$= 0 + \frac{1}{2}(2{,}08)(8)^2$ (substitutions)

$= 66{,}56$ m forward (accuracy; SI units) (direction)

2.4 The displacement is along the same straight line as the distance travelled.

3. A car brakes (slows down) at 5,5 $m \cdot s^{-2}$ over a distance of 60 m in 3,5 s.

3.1 Calculate the initial velocity of the car.

3.2 Does the car come to a stop over this distance? Justify your answer by calculation.

Solution:

$v_i = ?$

$v_f = ?$

$a = -5{,}5\ m \cdot s^{-2}$

$\Delta t = 3{,}5$ s

$\Delta x = 60$ m

3.1 $\Delta x = v_i \Delta t + ½ a \Delta t^2$ (method)

$60 = v_i(3{,}5) + ½(-5{,}5)(3{,}5)^2$ (substitutions)

$v_i = 26{,}77\ m \cdot s^{-1}$ forward (accuracy; SI units) (direction)

3.2 $v_f = v_i + a\Delta t$ (method)

$= 26{,}77 + (-5{,}5)(3{,}5)$ (substitutions)

$= 7{,}52\ m \cdot s^{-1}$ forward (accuracy)

No. The car doesn't stop. (answers the question)

OR

$v_f^2 = v_i^2 + 2a\Delta x$ (method)

$= (26{,}77)2 + 2(-5{,}5)(60)$ (substitutions)

$= 56{,}63$ (accuracy)

Since $v_f^2 \neq 0$ the car doesn't stop. (answers the question)

CHALLENGE LEVEL QUESTIONS

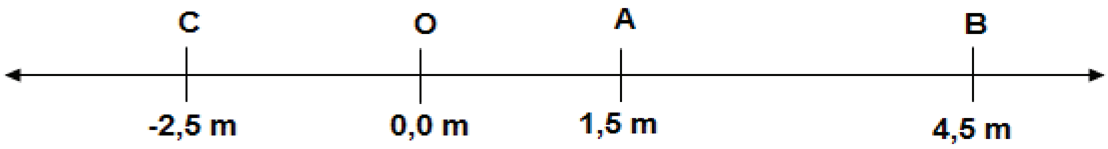
a. Now that learners have mastered the basic terminology, they are ready to deal with more challenging questions.

b. These questions require learners to use the facts and terminology and to apply these to solving problems.

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 toy car moves along a straight horizontal track.



- At time $t = 0$ s the car starts moving from position A which is located at 1,5 m from O.
- At 2 s the car is located at B, 4,5 m from O.
- At 4 s the car is located at C, -2,5 m from O.

4.1 Calculate the distance moved by the car during these 4 s.

4.2 Calculate the displacement of the car during these 4 s.

4.3 Calculate the average speed of the car during these 4 s.

4.4 Calculate the average velocity of the car during these 4 s.

4.5 If the car travels at constant speed from A to B, for this part of the journey, calculate:

a) its average speed from A to B.

b) its instantaneous velocity from A to B.

TOPIC 21

Solution:

4.1	Distance	= (4,5 – 1,5) + (4,5 – (-2,5))	(method)
		= 10 m	(accuracy; SI units)
4.2	Displacement	= 1,5 – (-2,5)	(method)
		= 4 m toward C	(accuracy; SI units)
4.3	Average speed	$= \frac{\text{distance}}{\text{time}}$	(method)
		$= \frac{10}{4}$	(substitutions)
		= 2,5 $m{\cdot}s^{-1}$	(accuracy; SI units)
4.4	Average velocity	$= \frac{\text{displacement}}{\text{time}}$	(method)
		$= \frac{4}{4}$	(substitutions)
		= 1,0 $m{\cdot}s^{-1}$ toward C	(accuracy; SI units) (direction)
4.5	**a)** Average speed	$= \frac{\text{distance}}{\text{time}}$	(method)
		$= \frac{4,5-1,5}{2}$	(substitutions)
		= 1,5 $m{\cdot}s^{-1}$	(accuracy; SI units)
	b) Instantaneous velocity	= 1,5 $m{\cdot}s^{-1}$ toward B	(accuracy; SI units) (direction)

5. A drag racer starts the race from rest and accelerates uniformly at 10 $m{\cdot}s^{-2}$ over a distance of 400 m.

5.1 How long does it take him to complete the race?

5.2 Calculate his maximum speed.

5.3 If he finished the race in 3,5 s, what would his acceleration be?

Solution:

$v_i = 0\ m{\cdot}s^{-1}$

$v_f = ?$

$a = 10\ m{\cdot}s^{-2}$

$\Delta t = ?$

$\Delta x = 400\ m$

5.1 $\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2$ (method)

$400 = 0 + \frac{1}{2}(10)\Delta t^2$ (substitutions)

$\Delta t = 8,94 \text{ s}$ (accuracy; SI units)

5.2 $v_f = v_i + a\Delta t$ (method)

$= 0 + (10)(8,94)$ (substitutions)

$= 89,94 \text{ m·s}^{-1}$ (accuracy; SI units)

OR

$v_f^2 = v_i^2 + 2a\Delta x$ (method)

$= 0 + 2(10)(400)$ (substitutions)

$= 8\ 000$

$v_f = 89.44 \text{ m·s}^{-1}$ (accuracy; SI units)

5.3 $v_i = 0 \text{ m·s}^{-1}$

$v_f = ?$

$a = ?$

$\Delta t = 3,5$

$\Delta x = 400 \text{ m}$

$\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2$ (method)

$400 = 0 + \frac{1}{2} a (3,5)^2$ (substitutions)

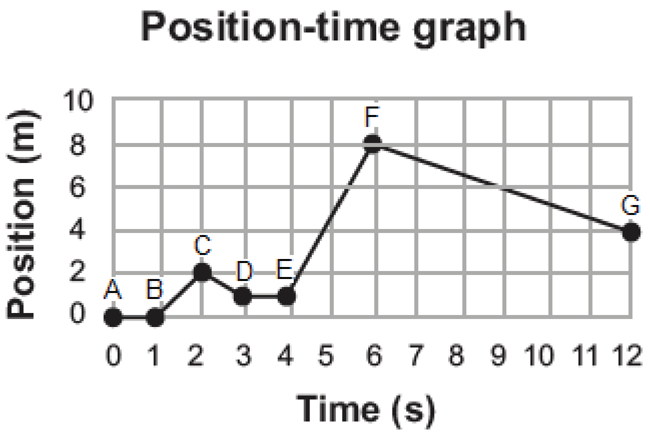
$a = 65,31 \text{ m·s}^{-2}$ (accuracy; SI units)

forwards (directions)

6. A man walks from position A to position G as shown in the position-time graph shown alongside.

6.1 Calculate his average velocity.

6.2 Calculate his average speed.



TOPIC 21

Solution:

6.1 Average velocity $= \dfrac{\text{displacement}}{\text{time}}$ (method)

$= \dfrac{4-0}{12}$ (substitutions)

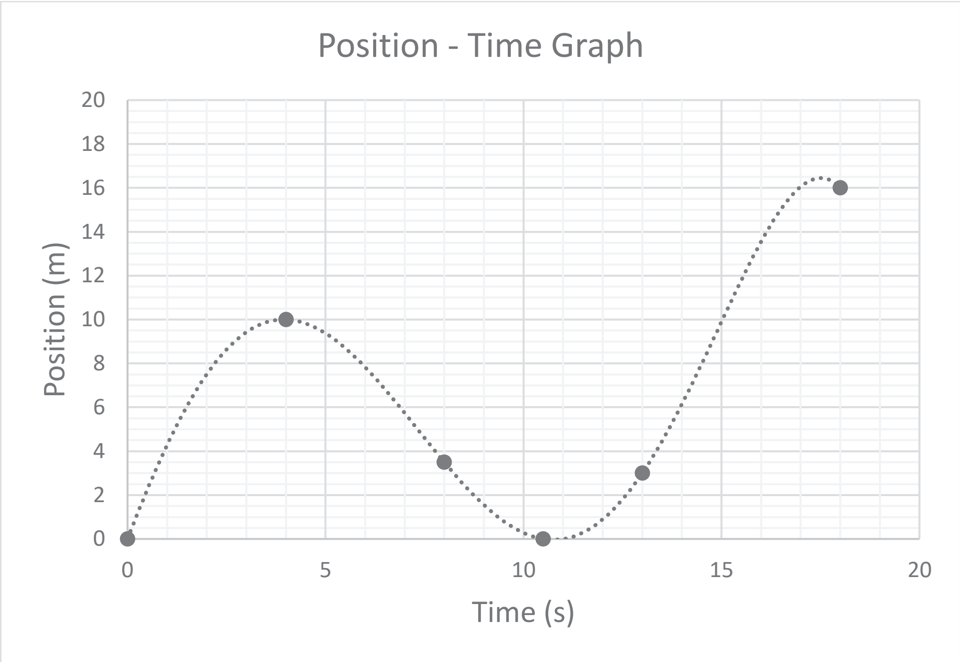
$= 0{,}33\ \text{m·s}^{-1}$ (accuracy; SI units; direction)

6.2 Average speed $= \dfrac{\text{distance}}{\text{time}}$ (method)

$= \dfrac{2+1+7+4}{12}$ (substitutions)

$= 1{,}67\ \text{m·s}^{-1}$ (accuracy; SI units)

7. The position-time graph of an object is shown below.



7.1 At what time(s) was the object at its starting position?

7.2 At what time(s) was the instantaneous velocity of the object equal to zero?

7.3 Between what time interval(s) was the object's velocity negative?

7.4 Explain what this means: "The object's velocity was negative".

7.5 Between what time interval does the object travel at maximum speed?

7.6 Calculate the average velocity of the object over 18 s.

Solution:

7.1 At 0 s and at 10,5 s

7.2 At 4 s and at 10,8 s

7.3 From 4 s to 10,5 s

7.4 The object was moving back towards the origin (the observer).

7.5 From 0 s to about 1,5 s

7.6 Average velocity $= \dfrac{\text{displacement}}{\text{time}}$ (method)

$= \dfrac{16 - 0}{18}$ (substitutions)

$= 0{,}89\ \text{m·s}^{-1}$ forward (accuracy; SI units) (direction)

KEY TEACHING:

a. In these more challenging examples, learners must apply their knowledge of terminology and analysis of data to solving the problems.

b. Learners should be able to organise data and choose an appropriate equation of motion to help them solve the problems.

c. Learners should be able to extract data from graphs to solve problems.

d. Learners should be able to describe motion by analysing the shape of the graph.

TOPIC 21

CHECKPOINT

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

1. the terminology associated with average and instantaneous speed and velocity, acceleration, displacement and distance.
2. using the equations of uniformly accelerated motion to solve problems.
3. reading and interpreting data from graphs of motion in order to describe motion, and to solve problems.

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

Topic 21 Worksheet from the Resource Pack: Instantaneous speed and velocity and the equations of motion: Questions 1–6. (Pages 39–42).

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

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topic 21 Consolidation Exercise from the Resource Pack: Instantaneous speed and velocity and the equations of motion (Pages 43–45).**
- 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.physicsclassroom.com/class/1DKin/Lesson-1/Speed-and-Velocity

   A teacher's and learner's resource which explains the concepts of speed, velocity, and the difference between instantaneous speed and velocity.

   This link also allows teachers and learners to interact with a multiple-choice test on describing motion.

2. https://www.siyavula.com/read/science/grade-10/motion-in-one-dimension/21-motion-in-one-dimension-07

   Teachers and learners resource: notes and exercises on Equations of motion from Siyavula.

3. https://www.siyavula.com/read/science/grade-10/motion-in-one-dimension/21-motion-in-one-dimension-06

   Teachers and learners resource: notes and exercises on Graphs of motion from Siyavula.