PHYSICAL SCIENCES

Grade 11

TERM 3

Content Booklet

TARGETED SUPPORT

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 their end of year examinations from the start of the 3rd term as their midyear exams will be 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 9:
Electrostatics

A Introduction

- This topic runs for 6 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Electrostatics forms part of the content area Electricity and Magnetism.
- Electricity and Magnetism counts as 33 % in the final Physics examination.
- Electrostatics counts approximately 11 % of the final Paper 1 (Physics focus) examination.
- This section is examined in the grade 12 final examination.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 11 Physics Examination Data Sheet.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises.
2. Scientific calculator is essential – Sharp or Casio calculators are highly recommended.
3. Pen.
4. Grade 11 Physics Examination Data Sheet.

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B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 10	**GRADE 11**	**GRADE 12**
• Magnetism • Electrostatics	• Electrostatics • Coulombs' Law • Electric field Prior knowledge of the following topics from Grade 11 is also required. • Vectors • Newton's 3rd Law • Newton's Law of Gravitation	• Electrodynamics This topic is examined in the NSC Paper 1 (Physics) examination.

C Glossary of Terms

TERM	DEFINITION
Coulomb's Law	The magnitude of the electrostatic force exerted by two point charges (Q_1 and Q_2) on each other is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them.
Electric field	A region in space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.
The electric field strength at a point	The electric field strength at a point is the electrostatic force experienced per unit positive charge placed at that point. $E = \frac{F}{Q}$ Note that E is a vector quantity.
Charge	The intrinsic property of matter responsible for all electric phenomena, in particular for the electromagnetic force. It occurs in two forms arbitrarily designated *negative* and *positive*.
Electric field lines	A method of representing the field around a charge. The closer the field lines, the stronger the field.
Principle of conservation of charge	Charge cannot be created or destroyed, but charge can be transferred from one object to another.

D Assessment of this Topic

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

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

E Breakdown of Topic and Targeted Support Offered

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

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
3 hours	Coulomb's Law	84	1. Key concepts and possible misconceptions are clarified and explained: a. A general introduction highlighting areas of weakness experienced by the candidates in gr 12 examinations. b. Coulomb's Law: conversion of SI units, the approach to solving problems and the application of this law in conjunction with Newton's 3rd law. 2. Calculations and questions are modelled and practised at different levels: a. Introduction level calculations involving Coulomb's Law in 1 D and 2 D. b. Challenge level calculations involving Coulomb's Law in 1 D and 2 D, including solving for charge and distance.
3 hours	Electric field	85	1. Key concepts and possible misconceptions are clarified and explained: a. Electric fields. b. Electric field lines. 2. Calculations and questions are modelled and practised at different levels: a. Introduction level calculations involving electric fields, and forces. b. Challenge level calculations involving electric fields, and forces including solving for charge and distance.

F Targeted Support per Sub-topic

1. COULOMB'S LAW

INTRODUCTION:

Coulomb's Law describes the force that arises between charged objects. It is similar to gravitational force which is the force of attraction between objects with mass. Both the electrostatic force and the gravitational force are governed by 'inverse square laws', so that as the distance between the centres of the objects halves, the force increases four times ('double squared.') However, gravitational forces are always forces of attraction, whereas electrostatic forces can be forces of attraction or repulsion. From the diagnostic reports on the gr 12 exams, we know that many learners confuse Coulomb's law with Newton's law of universal gravitation.

CONCEPT EXPLANATION AND CLARIFICATION: COULOMB'S LAW

The equation $F = \frac{kQ_1Q_2}{r^2}$ will be used frequently. However, do not use the signs of the charges when substituting into this equation. A positive and negative sign in a vector implies a direction, but with the scalar charges, it simply implies 'the opposite.' Many learners will misinterpret the final sign if they substitute the sign of the charge into the equation. Rather, they must decide, before doing the calculation, if the force will be attractive or repulsive. Then they must substitute positive values and interpret the direction of force at the end.

This section also involves changing values into SI units. Charges are often very small, and can be expressed as mC; μC, nC or pC. These should be changed as follows:

$\text{mC} = 10^{-3}\,\text{C};\ \mu\text{C} = 10^{-6}\,\text{C};\ \text{nC} = 10^{-9}\,\text{C};\ \text{pC} = 10^{-12}\,\text{C}.$

Calculations involving more than two charges may be asked. These are solved by calculating the force from each pair of charges in turn, and adding the forces using vector methods. The calculations will be limited to forces acting along one straight line (one dimension) or at right angles to each other.

This section can be used to revise Newton's 3rd law – if charge A exerts a force *F* on charge B, then B exerts a force of equal size, but in the opposite direction on A, the size of both forces coming from $\frac{kQ_1Q_2}{r^2}$.

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 in straight-forward calculations.

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. Two charges, 5 μC and −9 μC respectively, are placed 40 cm apart from each other.

a. State Coulomb's law.

b. Would the 5 μC charge experience a force of attraction or of repulsion?

c. Calculate the magnitude of the force experienced by the 5 μC charge.

Solution:

a. The force that two charges exert on each other is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

b. Attraction — The charges have opposite signs.

c. $Q_1 = 5 \times 10^{-6}$ C; $Q_2 = 9 \times 10^{-6}$ C; $r = 0,4$ m — Convert the given charges and distances into SI units.

$F = \frac{kQ_1Q_2}{r^2}$ — Write down the equation.

$= \frac{9 \times 10^9 \times 5 \times 10^{-6} \times 9 \times 10^{-6}}{(0,4)^2}$ — Substitute the values, do not substitute the "-ve" of the charge into the equation.

$= 2,53$ N

2. A charge of 65 nC is 35 mm from a charge of 95 nC.

a. Calculate the magnitude of the force that the 65 nC charge exerts on the 95 nC charge.

b. Without further calculation, give the magnitude of the force that the 95 nC charge exerts on the 65 nC charge.

Solution:

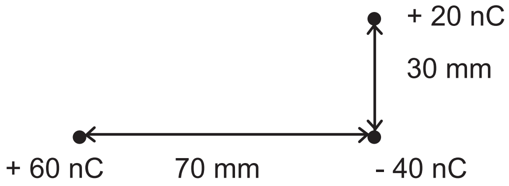
a. $Q_1 = 65 \times 10^{-9}$ C; $Q_2 = 95 \times 10^{-9}$ C; $r = 0{,}035$ m — Convert the given charges and distances into SI units.

$F = \frac{kQ_1Q_2}{r^2}$ — Write down the equation.

$= \frac{9 \times 10^9 \times 65 \times 10^{-9} \times 95 \times 10^{-9}}{(0{,}035)^2}$ — Substitute the values, do not substitute the "-ve" of the charge into the equation.

b. 0,045 N — This is from Newton's 3rd Law.

3. Three charges are placed at three corners of a rectangle as shown:



a. Calculate the force (magnitude and direction) that the +60 nC charge exerts on the -40 nC charge.

b. Calculate the force (magnitude and direction) that the +20 nC charge exerts on the -40 nC charge.

c. Calculate the net electrostatic force on the 40 nC.

Solution:

a. $Q_1 = 60 \times 10^{-9}$ C; $Q_2 = 40 \times 10^{-9}$ C; $r = 0{,}070$ m — Convert the given charges and distances into SI units.

This is an attractive force (to the left) — Opposite charges attract each other.

$F = \frac{kQ_1Q_2}{r^2}$ — Write down the equation.

$= \frac{9 \times 10^9 \times 60 \times 10^{-9} \times 40 \times 10^{-9}}{(0{,}070)^2}$ — Substitute the values.

$= 0{,}0044$ N left

Note: The charges are opposite so they will attract each other. The 60 nC force will attract the −40 nC to the left.

b. $Q_1 = 20 \times 10^{-9}$ C; $Q_2 = 40 \times 10^{-9}$ C; $r = 0,030$ m — Convert the given charges and distances into SI units

This is an attractive force (up) — Charges are opposite

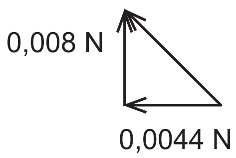
$F = \frac{kQ_1 Q_2}{r^2}$ — Write down the equation

$= \frac{9 \times 10^9 \times 20 \times 10^{-9} \times 40 \times 10^{-9}}{(0,030)^2}$ — Substitute the values, do not substitute the "-ve" of the charge into the equation

$= 0,0080$ N upward

The 20 nC charge attracts the −40 nC upwards.

c. We add these two forces using vector addition.



By Pythagoras: $F_{net} = \sqrt{F^2 + F^2}$

$= \sqrt{0,008^2 + 0,0044^2}$

= 0,0091 N

$\sin\theta = \frac{\text{opp}}{\text{hyp}} = \frac{0,008}{0,0091} = 0,0879$

$\theta = 61,54°$

So F_{net} = 0,0091 N at 61,54° up with respect to the 0,0044 N force.

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 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.

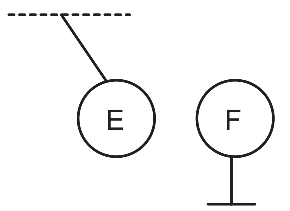
KEY TEACHING

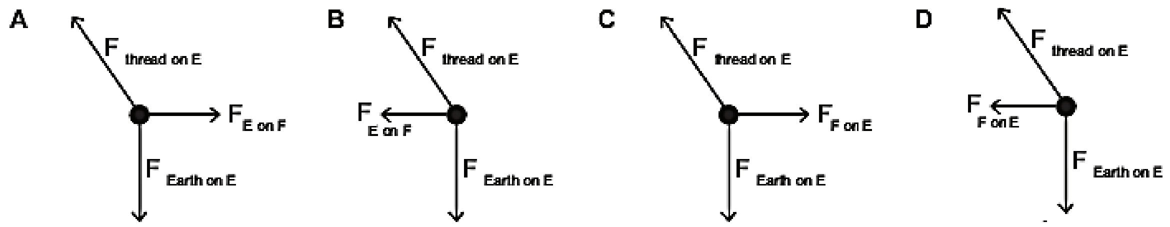
a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for charge or distance or combine sections.

b. Learners must work step by step.

c. Often it is easier to substitute the values into the equation first.

4. E and F are two oppositely-charged identical spheres. E hangs from a light silk thread and F is mounted on an insulated stand, as shown in the diagram alongside. E hangs at an angle to the horizontal. The system is in equilibrium. Which letter below gives the correct free-body diagram for E. Forces are represented to scale.

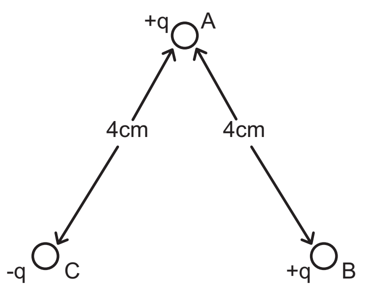




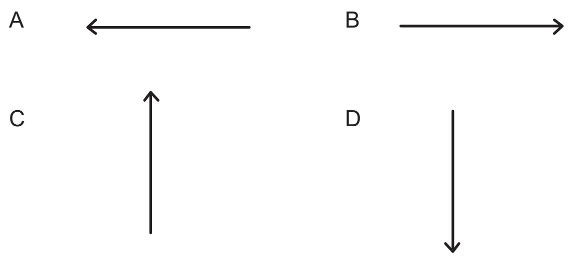
Solution:

C For A the horizontal force is labelled incorrectly; for B the horizontal force acts in the wrong direction and is labelled incorrectly; for D the horizontal force is in the wrong direction.

5. Three charges, A, B and C of equal magnitude are positioned as shown in the sketch. Charges A and B are positive, while C is negative.

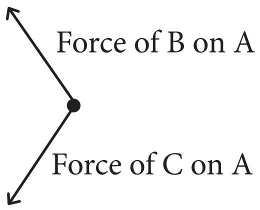


Which one of the following correctly gives the direction of the resultant force experienced by charge A?

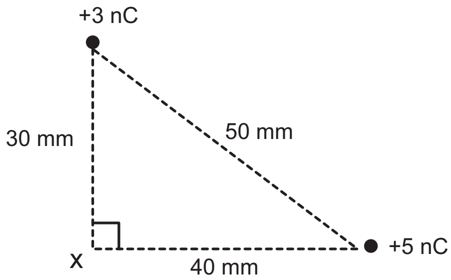


Solution:

A Charge A is attracted to C, but repelled by B. These forces are of equal magnitude, and exert forces which give a net horizontal force to the left.



6. Two small conducting spheres which carry charges of +3 nC and +5 nC respectively are placed a distance of 50 mm apart as shown in the diagram.



a. Calculate the magnitude of the electrostatic force on the +5 nC charge.

A +20 µC charge is placed at point **X**.

b. Calculate the magnitude and direction of the electric force at **X** due to the +3 nC charge only.

c. Calculate the magnitude of the net force experienced by the +20 µC charge.

Solution:

a. $F = k\frac{Q_1 Q_2}{r^2}$

$F = 9 \times 10^9 \frac{(3 \times 10^{-9})(5 \times 10^{-9})}{(0{,}05)^2}$

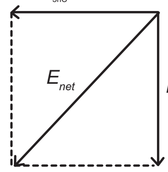
$F = 5{,}4 \times 10^{-5}$ N

b. $F_{3nC} = k\frac{Q_1 Q_2}{r^2}$

$F = 9 \times 10^9 \frac{(3 \times 10^{-9})(20 \times 10^{-6})}{(0{,}03)^2}$

$F = 0{,}60$ N away from 3 nC (or downwards or towards X)

c. $F_{5nC} = k\frac{Q_1Q_2}{r^2}$



$$F_{5nC} = 9 \times 10^9 \frac{(5 \times 10^{-9})(20 \times 10^{-6})}{(0,04)^2}$$

$$F_{3nC} = 0,56 \text{ N left}$$

$$F_{\text{net}}{}^2 = F_{\text{3nC}}{}^2 + F_{\text{5nC}}{}^2$$

$$F_{net}{}^2 = 0,60^2 + 0,56^2$$

$$= 0,6736$$

$$F_{net} = 0,82 \text{ N}$$

7. Two identical insulated metal spheres each carry charge. They are allowed to touch and then they are placed a distance of 30 cm apart. The force that they now exert on each other is 0,25 N. What is the charge on the spheres now?

Solution:

After they touch, the spheres have the same charge, as they are identical.

$F = \frac{kQ_1Q_2}{r^2}$ Write down the equation.

$F = \frac{kQ^2}{r^r}$ Simplify as $Q_1 = Q_2$.

Substitute values.

$$0,25 = \frac{9 \times 10^9 \times Q^2}{(0,030)^2}$$

$Q^2 = \frac{0,25(0,03)^2}{9 \times 10^9}$ Make Q_2 the subject of the formula.

Simplify.

$$= 2,5 \times 10^{-14}$$

$\text{Q} = 1,58 \times 10^{-7} \text{ C}$ The learners must remember this last step – take the square root.

CHECKPOINT

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

1. calculating the force exerted by pairs of charges.
2. calculating charge, when given the electrostatic force.
3. adding electrostatic forces using vector addition.

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

Topic 9 Worksheet from the Resource Pack: Electrostatics: Questions 1–4. (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.

2. ELECTRIC FIELD

CONCEPT EXPLANATION AND CLARIFICATION: ELECTRIC FIELD

An electric field is a region in space where a charge experiences an electric force. The direction of the field is determined by the direction of the force that a positive test charge (of +1 C) would experience. Often learners are confused by this detail, but they are helped if they can see that these are the obvious, easy figures to use for simplification.

CONCEPT EXPLANATION AND CLARIFICATION: ELECTRIC FIELD LINES AND ELECTRIC FIELD STRENGTH

Electric field lines are diagrammatic representations of the field. The field does not exist just along the line. The fields are 3-dimensional, although our representations are limited to two dimensions.

To represent a stronger field, we draw the lines closer.

The magnitude of the electric field is measured by the electric field strength and calculated using the formula:

$$E = \frac{F}{q}$$

The electric field is a vector quantity because it has magnitude and direction. The direction is that in which a positive test charge experiences electrostatic force.

Take time to emphasize the difference between E (the electric field strength) and F (the electrostatic force) as many learners confuse these terms when answering questions in the final Grade 12 examinations. In particular the following two formulae are frequently used incorrectly by learners who confuse these terms:

$$F = k\frac{Q_1 Q_2}{r^2} \qquad E = k\frac{Q}{r^2}$$

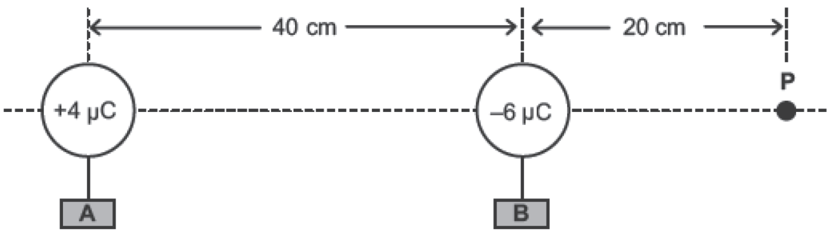
INTRODUCTORY LEVEL QUESTIONS

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

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.

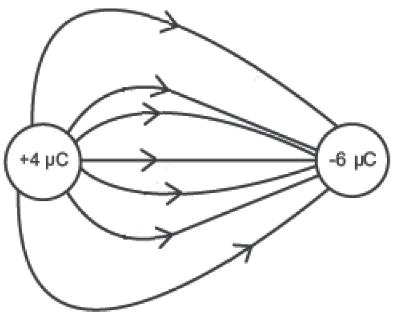
8. Two metal spheres A and B, placed on insulated stands carry charges of +4 μC and −6 μC respectively. The spheres are arranged with their centres 40 cm apart with the −6 μC charge being 20 cm from a point P, as shown in the diagram below.



a. Draw a diagram of the electric field between the two charges.
b. Calculate the electrostatic force exerted on sphere A.
c. Calculate the resultant electric field at point P.
d. Calculate the electrostatic force on a proton placed at point P.

Solution:

a.



Note that the field lines are closer together (more dense) at the -6 μC charge. The electric field is stronger around the larger charge.

Note the direction of the field and the asymmetrical shape. (The field is stronger near the -6 μC charge.)

b. $F = k\frac{Q_1 Q_2}{r^2}$

$F = (9 \times 10^9)\frac{(4 \times 10^{-6})(6 \times 10^{-6})}{(0,4)^2} = 1,35$ N to the right

c. $E_{+4\mu C} = \frac{kQ}{r^2} = \frac{(9 \times 10^9)(4 \times 10^{-6})}{(0,6)^2} = 100\ 000$ $N{\cdot}C^{-1}$ to the right.
The direction of the electric field is away from the positive charge.

$E_{-6\mu C} = \frac{kQ}{r^2} = \frac{(9 \times 10^9)(6 \times 10^{-6})}{(0,2)^2} = 1\ 350\ 000$ $N{\cdot}C^{-1}$ to the left.
The direction of the electric field is towards the negative charge

$E_{res} = 1\ 350\ 000 - 100\ 000 = 1\ 250\ 000$ $N{\cdot}C^{-1}$ to the left

d. $F = Eq = (1\ 250\ 000)(1,6 \times 10^{-19}) = 2 \times 10^{-13}$ N to the left

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 manipulate the equation in a more complex context.

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.

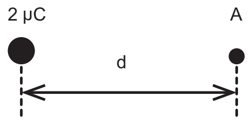
KEY TEACHING:

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for electric field, force, distance and charge.

b. It is often easier for learners to substitute the values into the equation first.

c. Once learners have done this, they should then change the subject of the formula.

9. The electric field strength of a +2 μC charge at point A is $1,8 \times 10^6$ N·C^{-1}. Point A is placed at a distance d from the charge.



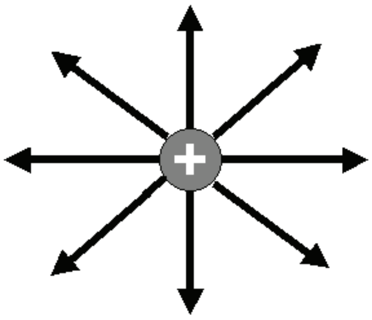
a. Sketch the shape of the electric field around the +2 μC point charge. Show the direction of the field lines.

b. Explain in terms of force and charge what is meant by an electric field strength of $1,8 \times 10^6$ N·C^{-1}.

c. Determine the magnitude of *d* in centimetres.

Solution:

a.



b. This means that a charge of 1 C will experience a force of $1,8 \times 10^6$ N.

c.
$$E = \frac{kQ}{r^2}$$
$$1,8 \times 10^6 = \frac{9 \times 10^9 \times 2 \times 10^{-6}}{d^2}$$
$$1,8 \times 10^6 = \frac{1,8 \times 10^4}{d^2}$$
$$d^2 = \frac{1,8 \times 10^4}{1,8 \times 10^6} = 0,01$$
$$d = 0,1 \text{ m}$$

10. When a charge, **X**, is placed in an electric field of 5,5 N·C^{-1}, it experiences a force of $8,8 \times 10^{-19}$ N.

a. What property of **X** enables it to experience a force in an electric field?

b. Calculate the magnitude of the charge on **X**.

c. Identify **X** if it is negatively charged.

TOPIC 9

Solution:

a. It has a charge.

b. $E = \frac{F}{q}$

$5,5 = \frac{8,8 \times 10^{-19}}{q}$

$q = \frac{8,8 \times 10^{-19}}{5,5} = 1,6 \times 10^{-19}\ \text{C}$

c. It is an electron.

CHECKPOINT

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

1. The calculation of electric field strength and electrostatic force.
2. The manipulation of the equations to calculate distances and charges

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

Topic 9 Worksheet from the Resourcce Pack: Electrostatics: Questions 5–6. (Pages 5–6).

- 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 learners time for feedback.
- Encourage the learners to learn from the mistakes they make.

CONSOLIDATION

- Learners can consolidate their learning by completing **Resource Pack: Topic 9: Electrostatics: Consolidation Exercise. (Pages 7–9).**
- 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.youtube.com/watch?v=rYjo774UpHI
A basic video covering fundamental ideas, at just under 4 minutes.
2. https://www.youtube.com/watch?v=B5LVoU_a08c
This video shows how the electrostatic force can be measured experimentally. Many learners may be interested in knowing this, and watching this 4 min 16 s video. (Radical 2, in this video, means the square root of 2.)
3. https://www.youtube.com/watch?v=LB8Rhcb4eQM
A look at electric fields, showing the 3-dimensional nature of the field. This video does go beyond the syllabus (including looking at molecules) towards the end of its 4 min 38 s, but it will really help the more capable learners to visualise the field.

TOPIC 10: Electromagnetism

A Introduction

- This topic runs for 6 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Electromagnetism forms part of the content area Electricity and Magnetism (Physics).
- Electricity and Magnetism counts as 33 % in the final Paper 1 (Physics) examination.
- Electromagnetism counts approximately 9 % of the final examination.
- This section is examined in grade 12.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 11 Physics Examination Data Sheet.
4. OPTIONAL: Simple circuit board and sensitive compasses; solenoid, magnet and a sensitive galvanometer, ammeter or voltmeter.
5. PC and data projector to show videos of experiments. (See recommended list at end.)

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended.
3. Pen, pencil and eraser.
4. Grade 11 Physics Examination Data Sheet.

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 10	GRADE 11	GRADE 12

• Magnetism.
  • Magnetic fields of permanent magnets.
  • Poles of permanent magnets
  • Attraction and repulsion
  • Magnetic field lines
• Electric circuits.
  • Emf
  • Potential difference
  • Current
  • Measurement of pd, current
  • Resistance
	• Electromagnetism (Topic 10)
	  • Magnetic field associated with current carrying wires
	  • Faraday's law of electromagnetic induction
		• Electrodynamics
		  • Electrical machines (motors and generators)
		  • Alternating current

C Glossary of Terms

TERM	DEFINITION
Magnetic flux (Φ)	The product of the component of a magnetic field perpendicular to a surface and the area of the surface. $\Phi = BA\cos\theta$ It is measured in weber (Wb).
Faraday's Law	The magnitude of the induced emf across the ends of a conductor is directly proportional to the rate of change in the magnetic flux linkage with the conductor. $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ The induced emf is meadured in volts (V).
Magnetic field (*B*)	A region where a ferromagnetic material experiences a force due to its magnetic properties. It is measured in tesla (T).
Solenoid	Many loops of wire.
Electromagnet	A coil of conducting wire (a solenoid) wrapped around a soft iron core which sets up a magnetic field when current passes through the wire.
Induced emf	An emf in a conductor caused by a changing magnetic field. It is set up so as to oppose the change in magnetic flux.

D Assessment of this Topic

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

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

E Breakdown of Topic and Targeted Support Offered

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

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
3 hours	Magnetic field associated with current carrying wire	86	1. Key concepts and possible misconceptions are clarified and explained: a. Electricity and magnetism. 2. Calculations and questions are modelled and practised at different levels: a. Introductory question on concepts, including the hand rules. b. Challenge level questions applying the concepts to a wider context.
3 hours	Faraday's Law	87–88	1. Key concepts and possible misconceptions are clarified and explained: a. Faraday's Law. b. Direction of induced current. c. Magnetic field, magnetic flux and magnetic flux linkage. d. Induced current. 2. Calculations and questions are modelled and practised at different levels: a. Introductory questions on the range of concepts and equations. b. Challenge level questions in a wider context with more re-arrangement of the equations.

F Targeted Support per Sub-topic

1. MAGNETIC FIELD ASSOCIATED WITH CURRENT CARRYING WIRES

INTRODUCTION

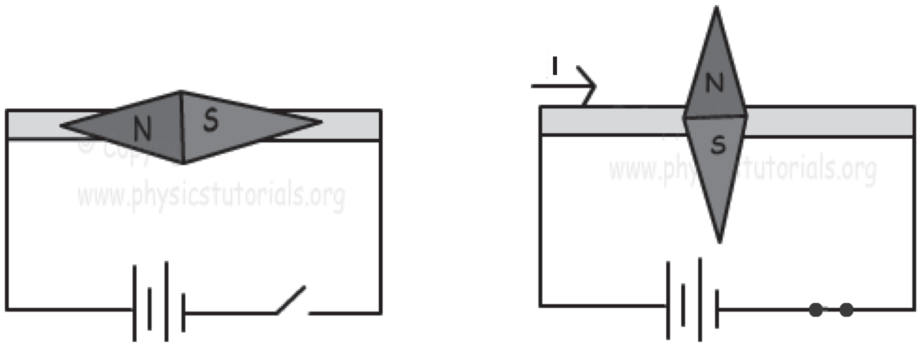
Electricity and magnetism are closely related to one another. A magnetic field is set up around a current carrying conductor (or whenever charge flows), and a spinning magnet can set up an electric current in a conductor. In this topic, learners will find out more about these phenomena, and in Grade 12 they will learn about devices which make use of electromagnetism e.g. motors and generators.

There are several simple demonstrations which will be helpful in introducing these concepts. There are also some very useful simulations which can be downloaded from the Internet for no cost (free) if you have access to a laptop and a digital projector.

The topic begins with the magnetic field around a straight current carrying conductor, and moves on to slightly more complicated arrangements such as a loop of wire and a solenoid.

CONCEPT EXPLANATION AND CLARIFICATION: THE MAGNETIC FIELD AROUND CURRENT CARRYING CONDUCTORS:

The diagram below shows how this effect can be demonstrated using a simple electric circuit and a plotting compass.



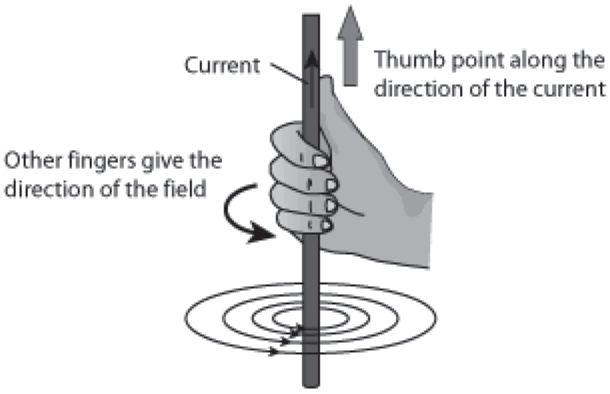
When the switch is closed, the compass needle rotates because the current sets up a magnetic field around the conductor. If the current passes in the opposite direction, the compass needle rotates in the opposite direction. The smaller the current the less the force on the compass needle.

Learners are often fascinated by these observations. They are therefore more likely to pay closer attention to this topic if they have physical proof of these effects.

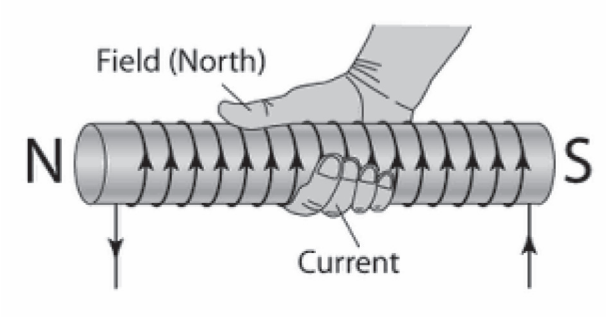
Introduce the magnetic field patterns that surround single conductors, a loop and a solenoid. The magnetic field strength decreases as distance from the current carrying conductor increases. Magnetic field strength is directly proportional to the current.

It is important that learners are able to predict the direction of magnetic fields around conductors. For this purpose we use the right hand rule, and the right hand solenoid rule. Diagrams to illustrate these rules are shown below:

RIGHT HAND THUMB RULE



RIGHT HAND SOLENOID RULE



INTRODUCTORY LEVEL QUESTIONS

a. These questions help the learners to understand and memorise the basic concepts that are required for this topic.

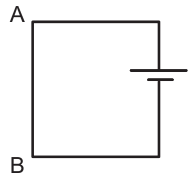
b. These are the basic questions that learners will be required to perform at this stage in the topic.

c. Their purpose is to familiarise the learners with the concepts and the hand rules.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each rule to the learners as you discuss the question with them.
- Learners must copy down the questions and answer them correctly in their workbooks.

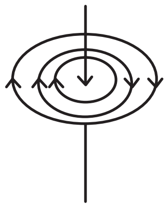
1. Consider an electric current flowing through a wire, from **A** to **B**, as shown in the diagram below.



   a. What field exists within the wire, causing the charges to move?
   b. What field exists outside the wire as a result of the movement of charge?
   c. With the aid of a drawing, describe the shape of this field mentioned in **B**.

   Solution:

   a. An electric field
   b. A magnetic field
   c. The field is circular in shape and perpendicular to the wire. It surrounds the wire as a 3-dimensional field. The field is weaker as distance from the wire increases.

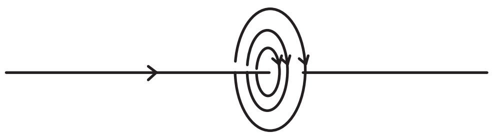


2. A wire carries a current, as shown in the diagram below.

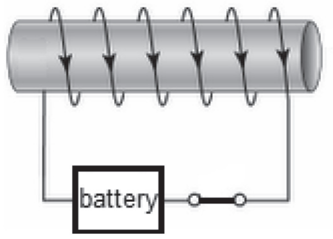
   a. Describe the magnetic field around the wire.
   b. Name and write out the "rule" you can use to predict the direction of the magnetic field.
   c. Show the direction of the magnetic field using a diagram.

   Solution:

   a. The magnetic field is a circular three-dimensional field around the wire.
   b. The 'right hand rule': If your right hand holds the wire with the thumb pointing in the direction of conventional current, then your fingers will curl in the direction of the magnetic field.
   c.



3. A solenoid carries a current, as shown in the diagram below.



a. Copy the diagram and draw in the circuit symbols for the battery, clearly showing its positive and the negative terminals.

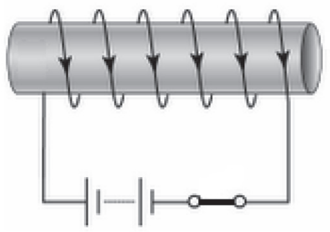
b. Describe the shape of the magnetic field around the solenoid when the current passes through it.

c. Which side of the solenoid (left or right) will be the north pole of the solenoid?

d. What rule can be used to predict the direction of this magnetic field? Describe the rule.

Solution:

a.



b. The magnetic field around a solenoid is like the magnetic field around a bar magnet, with a north pole and a south pole, and the field going from N to S outside the magnet/solenoid.

c. The right-hand side.

d. The right hand solenoid rule, where the current is in the direction of the fingers of your right hand and your right thumb points to the north pole of the solenoid.

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 explain the concepts in a greater variety of contexts.

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 apply the concepts in a wider variety of contexts.

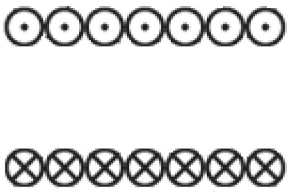
4. a. What is an electromagnet?

b. Draw the magnetic field around each of the following arrangements of wire.

(i) A straight conductor carrying current into the page

(ii) A single coil

(iii) A solenoid



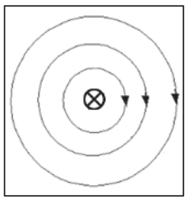
c. If the current in each of these arrangements of wire is the same, which arrangement has the greatest magnetic effect?

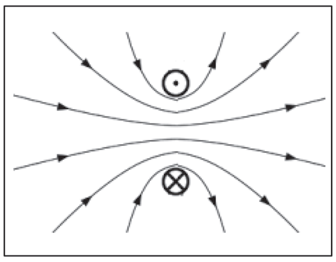
Solution:

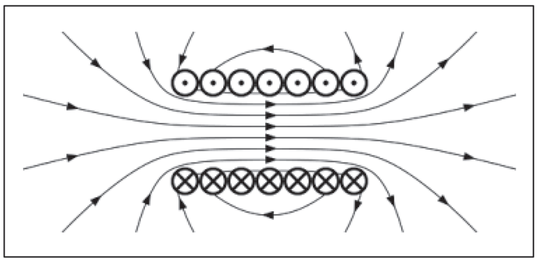
a. An electromagnet is an object that only has a magnetic field when a current is passing through it.

b.

(i) Straight conductor (ii) Single coil (iii) Solenoid







c. The solenoid (It has more coils of wire).

CHECKPOINT

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

1. drawing the magnetic fields of the following current carrying conductors: a single conductor, a single coil and a solenoid.
2. predicting the direction of the magnetic field.

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

Topic 10 Worksheet from the Resource Pack: Electromagnetism: Questions 1, 3–4 (Pages 14–15).

- 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. FARADAY'S LAW

INTRODUCTION

Faraday's law describes the relationship between the induced emf and the rate of change of magnetic flux. This section deals with Faraday's law, and calculations using Faraday's law, as well as how to determine the direction of the induced current (or emf).

This topic consists of three parts: the qualitative explanation of the induced emf and induced current, the direction of the induced current and the quantitative calculation of the induced emf.

CONCEPT EXPLANATION AND CLARIFICATION:

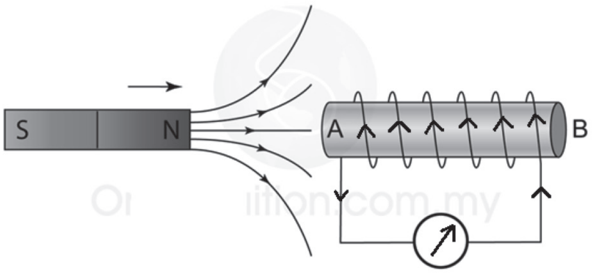
Faraday's law:

Faraday's law states that the magnitude of the induced emf across the ends of a conductor is directly proportional to the rate of change in the magnetic flux linkage with the conductor. The equation for Faraday's law is shown below:

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

Note that Faraday's law states that there must be <u>a change in magnetic flux</u> in order for an emf to be induced in a conductor.

- If there is no change in magnetic flux, the rate of change is equal to zero, therefore no emf is induced in the conductor.
- The induced emf depends on the rate of change of magnetic flux. A higher rate of change of magnetic flux induces a higher emf in the conductor, and vice versa.
- N refers to the number of turns on a coil. The greater the number of turns per unit length, the greater the induced emf in the coil.
- The negative sign refers to the direction of the induced emf (or the induced current). The induced current (emf) sets up magnetic flux to oppose the change in magnetic flux. For example, if the north pole of a bar magnet is inserted into a solenoid, the current that is induced in the solenoid, sets up a magnetic field with a north pole on the side where the bar magnet enters. Refer to the diagram below:



Magnetic flux and rate of change of magnetic flux:

The magnetic flux is a measure of the number of magnetic field lines passing through a surface placed perpendicular to it. Magnetic flux is denotd by the symbol Φ. If the magnetic field is constant, the magnetic field passing through a surface of area A is given by:

$\Phi = BA \cos\theta$ where θ is the angle between the surface and the magnetic field lines.

Φ is measured in webers (Wb); B is measured in tesla (T).

A change in magnetic flux cutting across the surface of a conductor causes an emf to be induced in the conductor.

INTRODUCTORY LEVEL QUESTIONS

- **a.** These questions help the learners to understand and memorise the basic concepts that are required for this topic.
- **b.** These are the basic calculations that learners will be required to perform at this stage in the topic.
- **c.** Their purpose is to familiarise the learners with Faraday's law and calculations of magnetic flux.

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.

5. A coil of wire of area 0,1 m^2 is at right angles to a magnetic field (B) of 0,02 T. What is the magnetic flux through the coil?

Solution:

$B = 0{,}02\ \text{T};\ A = 0{,}1\ \text{m}^2;\ \theta = 90°$

$\Phi = BA\cos\theta = 0{,}02 \times 0{,}1 \cos 90° = 0{,}002\ \text{Wb}$

6. A magnet is brought near a coil of wire as shown below.

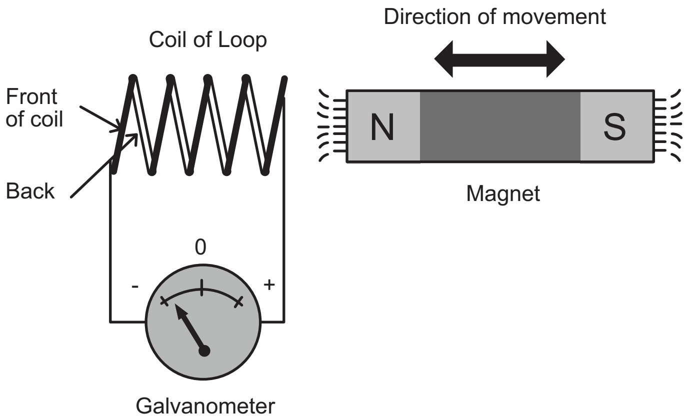


Image source: http://www.electronics-tutorials.ws/electromagnetism/electromagnetic-induction.html

- **a.** When the magnet is brought towards the coil, which side of the coil (left or right) will be a north pole?
- **b.** Which way (left to right OR right to left) will the induced current pass through the galvanometer?

c. When the magnet is stationary, what will the induced current be?

d. When the magnet is moved away from the coil, how will the direction of the current compare to that in **6b**?

Solution:

a. Right side (to oppose the inducing action.)

b. Left to right through the galvanometer. (It flows up the back of the coil and down the front.)

c. 0 A

d. The direction of the current will reverse.

7. A coil with an area of 0,25 m^2 is at 45º to a magnetic field with a flux density of 0,04 T. What is the magnetic flux through the coil?

Solution:

$$B = 0,04 \text{ T}; A = 0,25 \text{ m}^2; \theta = 45^\circ$$
$$\Phi = BA\cos\theta = 0,04 \times 0,25\cos 45^\circ = 0,0070 \text{ Wb}$$

8. A magnetic field of 0,05 T passes through a single loop of area 10 cm^2. The field lines are at 20^0 to the normal of the plane of the loop.

a. Calculate the magnetic flux linkage.

b. Calculate the average induced emf if the loop is removed from the magnetic field (to where the flux linkage is 0) in 0,02 s.

c. If the total resistance of the circuit is 0,5 Ω, what will the current be?

d. What does the negative sign in the equation $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ mean?

Solution:

a. $\Phi = BA\cos\theta = 0,05 \times 0,0001 \times \cos 20^\circ = 4,7 \times 10^{-5}$ Wb

b. $\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = \frac{-1 \times 4,7 \times 10^{-5}}{0.02} = 2,35 \times 10^{-3}$ V

c. $I = \frac{V}{R} = \frac{2,35 \times 10^{-3}}{0,5} = 4,7 \times 10^{-3}$ A

d. The negative sign ($-N$) shows that the induced current opposes the changing flux.

TOPIC 10

CHALLENGE LEVEL QUESTIONS

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

b. These questions require learners to explain the concepts in a greater variety of contexts, re-arranging of the equations when needed.

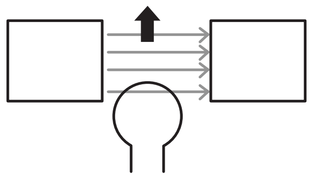
How to tackle these questions in the classroom:

- 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 apply the concepts in a wider variety of contexts and re-arrange equations where appropriate.

9. A single coil of wire is moved into the area between magnets as shown below. The coil, which has an area of 0,02 m^2 moves from an area where the magnetic field is zero to where the magnetic field is 1,5 T in 0,025 s. The plane of the coil is at 90° to the magnetic field.



a. Calculate the change in the magnetic flux linkage of the coil.

b. Calculate the induced emf in the coil.

Solutions:

a. $\Delta\Phi = \Delta BA\cos\theta = (1,5 - 0) \times 0,02 \times \cos 0^\circ = 0,03 \text{ Wb}$

b. $\varepsilon = \dfrac{-N\Delta\Phi}{\Delta t} = \dfrac{-1 \times 0,03}{0,025} =- 1,2 \text{ V}$

10. The coil used in (8) above is now rotated so that the plane of the coil changes from "perpendicular to the field" to "parallel to the field".

a. Will this action induce an emf in the coil? Explain your answer.

b. If the coil rotates through 90° in 0,1 s, calculate the induced emf.

c. If the coil has a resistance of 0,2 Ω, calculate the induced current.

Solutions:

a. Yes, because changing the angle of the plane changes the magnetic flux linkage (from 0,03 Wb to 0 as it goes through 90°)

b. $\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = \frac{-1 \times 0,03}{0,1} = 0,3 \text{ V}$

c. $I = \frac{V}{R} = \frac{0,3}{0,2} = 1,5 \text{ A}$

11. A coil with 20 windings (turns) has an induced emf of 2,25 V. What is the rate of change of the magnetic flux linkage?

Solutions:

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$2,25 = \frac{-20\Delta\Phi}{\Delta t}$$

$$\frac{\Delta\Phi}{\Delta t} = 0,113 \text{ Wb·s}^{-1}$$

CHECKPOINT

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

1. knowing and understanding electromagnetic induction.
2. calculating magnetic flux linkage.
3. calculations involving Faraday's law.

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

Topic 10 Worksheet from the Resource Pack: Electromagnetism: Questions 2, 5–7. (Pages 14–16).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- 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 time for feedback.
- Encourage the learners to learn from the mistakes they make.

TOPIC 10

CONSOLIDATION

- Learners can consolidate their learning by completing; **Resource Pack: Electromagnetism: Consolidation Exercise (Pages 17–18).**
- 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.youtube.com/watch?v=wBdzoePJPe0
   3 minutes 40 seconds. This is a good, simple introduction to electromagnetism including some applications (which go beyond the grade 11 syllabus, but are interesting.)
2. https://www.youtube.com/watch?v=KGTZPTnZBFE
   This slightly interactive video of 6 minutes is a good, simple animated video lasting 6 minutes, with a brief mention of a dynamo.
3. https://www.youtube.com/watch?v=GVABAaAivwQ
   This Mindset video at almost 13 minutes is a good overview, especially of flux. However, the grade 11 syllabus does not use Lenz's law (which the video references).

TOPIC 11:
Electric Circuits

A Introduction

- This topic runs for 6 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Electric circuits form part of the content area Electricity and Magnetism (Physics).
- Electricity and Magnetism counts 33 % in the final Paper 1 (Physics) examination.
- Electric circuits counts approximately 11 % of the final examination.
- This section will be examined in the final grade 12 examinations.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 11 Physics Examination Data Sheet.
4. Highly recommended: circuit boards or equivalent, ammeters, voltmeters, batteries or power packs, resistors and light bulbs.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended.
3. Pen, pencil and eraser.
4. Grade 11 Physics Examination Data Sheet.

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 10	**GRADE 11**	**GRADE 12**

• Electric circuits
  • Emf
  • Potential difference
  • Current
  • Measurement of pd & current
  • Resistance
  • Resistors in series and in parallel
	• Electric circuits
	  • Ohm's law
	  • Energy and power
		• Electric circuits
		  • Internal resistance
		  • Series-parallel networks

C Glossary of Terms

TERM	DEFINITION
Ohm's Law	The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature.
Ohmic conductors	Obey Ohm's law.
Resistance	The ratio of the potential difference across a resistor to the current in the resistor. Resistance is measured in ohms (Ω).
Voltage (potential difference)	The difference in energy per coulomb of charge.
emf	The emf of a battery is work done per unit charge by the source (battery). It is equal to the potential difference measured across the terminals of a battery when no charges are flowing in the circuit.
Terminal potential difference	The terminal potential difference is the voltage measured across the terminals of a battery when charges are flowing in the circuit.
Current	The rate of flow of charge. Current is measured in amperes (A). $1 \text{ A} = 1 \text{ C}\cdot\text{s}^{-1}$.
1 coulomb	One coulomb is defined as the charge transferred in a conductor in one second if the current is one ampere.
Series circuit	A circuit with a single path for the current. The current is the same everywhere in a series circuit.
Parallel circuit	A circuit with more than one path for the current to follow. The potential difference is the same across all components that are parallel to each other.
Power	The rate at which work is done or energy is transferred. Power is measured in watts (W). $1 \text{ W} = 1 \text{ J}\cdot\text{s}^{-1}$
Kilowatt hour (kW·h)	One kilowatt hour is the electrical energy used in one hour at a rate of 1 kilowatt. 1 kW·h is an amount of electrical energy also known as one unit of electricity. 1 kW·h = 3 600 000 J

D Assessment of this Topic

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

- There must be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.
- Informal assessment: A practical investigation to determine which of a resistor and a filament light bulb obeys Ohm's law.

E Breakdown of Topic and Targeted Support Offered

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

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
4 hours	Ohm's Law	88	1. Key concepts and possible misconceptions are clarified and explained: a. Relationship of V, I and R. b. Ohmic and non-Ohmic conductors. c. $R = \frac{V}{I}$ in series and parallel circuits. 2. Calculations and questions are modelled and practised at different levels: a. Introductory questions on Ohm's law, Ohm's law experiments and applying Ohm's law in circuit problems. b. Challenge level questions applying the concepts to a wider context and more complex circuits.
4 hours	Power, Energy	89	1. Key concepts and possible misconceptions are clarified and explained: a. Power. b. Electrical energy. c. Cost of electricity. 2. Calculations and questions are modelled and practised at different levels: a. Introductory question on concepts, building on circuit questions from earlier sections. b. Challenge level questions applying the concepts to more complex circuits.

F Targeted Support per Sub-topic

1. OHM'S LAW

INTRODUCTION

Electric circuits will be examined from this term until the end of matric. The grade 12 diagnostic reports show that learners do not perform as well as they should in this topic. This module will concentrate extensively on graphing (a very important general skill) with Ohm's law, and on the essential concepts around electric circuits to prepare the learners for the end of the year and the end of grade 12 examinations.

CONCEPT EXPLANATION AND CLARIFICATION:

The relationship between current (I), voltage (potential difference) (V) and resistance (R): Resistance is defined by $R = \frac{V}{I}$ .This formula becomes very important in the calculations in this section.

Ohmic and non-ohmic conductors: If the ratio of V to I is constant, the resistor is said to be ohmic; that is, it obeys Ohm's law. Many resistors do not obey Ohm's law either because the conditions are not maintained (e.g. the temperature of a filament bulb or the heating element of a kettle changes) or because the material just doesn't obey Ohm's law. We consider mainly ohmic conductors.

R = V/I: This formula will be used time and again and it will apply in all manner of situations. However, it is important to use the appropriate values of voltage, current and resistance for each situation. Often the learners have to use the fact that the current is the same everywhere in a series circuit to determine the current through a resistor, or that the voltage across a set of parallel resistors is the same as the voltage across each of the parallel resistors. A series circuit divides the voltage but the current is the same everywhere. The voltage is the same across parallel resistors, but the current divides between them.

In series, resistances are added up as $R_{total} = R_1 + R_2 + R_3 + \ldots$

In parallel, resistors are added up as $\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$ The learners must remember to invert the final answer, to get R_{total}, not $\frac{1}{R_{total}}$.

Often there are many values for R, V and I, so the learners will find it very useful to use subscripts to label each of these.

Lastly, in grade 11, the internal resistance of the cells or battery is treated as zero. Internal resistance will be dealt with in grade 12.

INTRODUCTORY LEVEL QUESTIONS

- **a.** These questions help the learners to understand and memorise the basic concepts that are required for this topic.
- **b.** These are the basic calculations that learners will be required to perform at this stage in the topic.
- **c.** Their purpose is to familiarise the learners with the equation, but not to change the subject of the formula.

How to tackle these questions in the classroom:

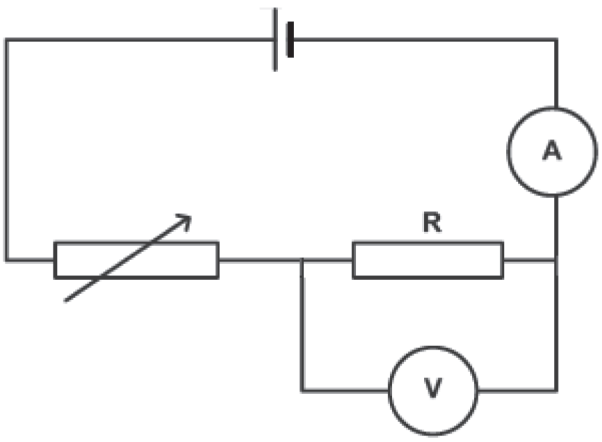
- Work through these examples with learners.
- Explain each step of the calculation to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

1. You are required to conduct an experiment to verify that a given resistor obeys Ohm's law. You are provided with the resistor, a source of potential difference, a switch, a rheostat and enough connecting leads.

- **a.** List two other pieces of apparatus that you will require to conduct the experiment.
- **b.** State Ohm's law.
- **c.** Draw a circuit diagram that can be used to verify whether the given resistor obeys Ohm's law.
- **d.** Name the variable that must be kept constant when conducting this experiment.
- **e.** Name the dependent variable in this investigation.

Solution:

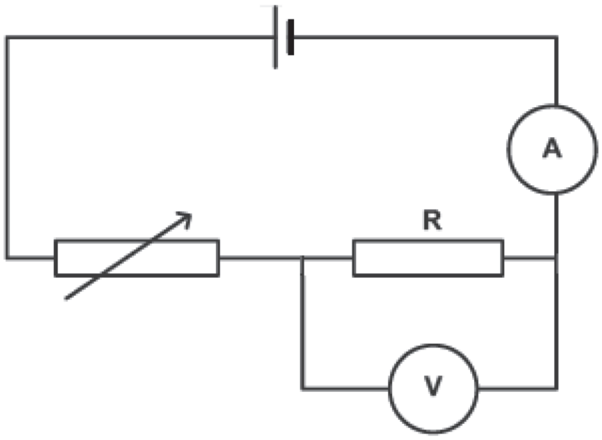
- **a.** Voltmeter and ammeter
- **b.** The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature.
- **c.**



d. Temperature of the resistor.

e. Current (or potential difference).

2. An investigation was conducted to verify whether a given resistor obeys Ohm's law. The circuit diagram that was used in shown below.



The table below shows the results that were obtained from the investigation.

POTENTIAL DIFFERENCE (V)	CURRENT (A)
0,0	0,00
1,5	0,26
3,2	0,55
4,4	0,76
5,6	0,97

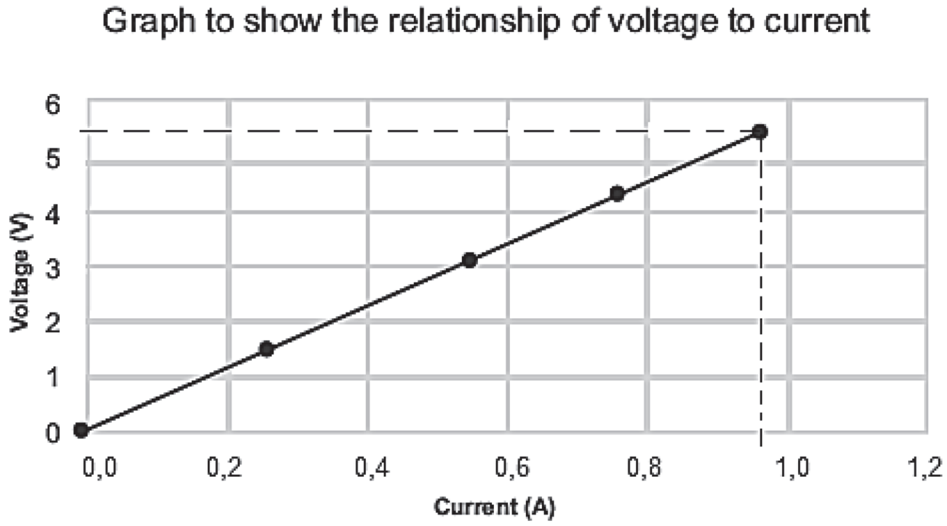
a. Plot a graph of potential difference (y-axis) versus current (x-axis).

b. Write a suitable conclusion for this investigation.

c. Use the **graph** to calculate the resistance of the given resistor. Clearly show which points (on the graph) you used to calculate your answer.

Solution:

a. Note: Heading; Both axes correctly labelled: **V (V)** and **I (A)**; Good choice of scales on both axes; Points are correctly plotted; Straight line through the origin

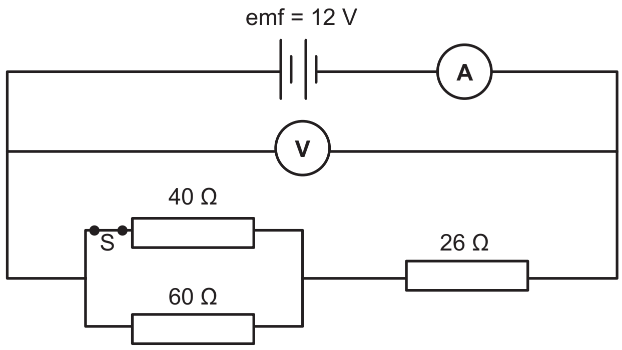


b. The resistor in question obeys Ohm's law. The resistor is ohmic.

c. $\text{Resistance} = \text{gradient} = \frac{\Delta V}{\Delta I} = \frac{5,6 - 0,0}{0,97 - 0,00} = 5,77\ \Omega$

Other values could be used to calculate the gradient. Show the points used on the graph.

3. A battery of emf 12 V and negligible internal resistance is connected to the circuit shown below.



a. State Ohm's law in words.

b. Calculate:

i. the ammeter reading.

ii. the voltmeter reading.

iii. the current in the 60 Ω resistor.

c. How would the reading on the voltmeter change if switch **S** was opened (increase, decrease or remain the same)? Explain your answer.

Solution:

a. Current through a conductor is directly proportional to the potential difference across the conductor at constant temperature. (Current and potential difference can be interchanged).

b. i) $R_p = \frac{40 \times 60}{40 + 60}$ **OR** $\frac{1}{R_p} = \frac{1}{40} + \frac{1}{60} = \frac{1}{24}$

$R_p = 24\ \Omega$

$R_T = 24 + 26 = 50\ \Omega$

$I = \frac{emf}{R_T} = \frac{12}{50} = 0,24\ \text{A}$

ii) 12 V

iii) $I_{60\Omega} = \frac{40}{100} \times (0,24) = 0,096\ \text{A}$

OR

$V_{60\Omega} = R_p I = (24)(0,24) = 5,76\ \text{V}$

$I_{60\,\Omega} = \frac{V}{R} = \frac{5,76}{60} = 0,096\ \text{A}$

c. Remains the same. The voltmeter reads the (terminal) potential difference across the battery (and over all the resistors) and this remains constant.

CHALLENGE LEVEL QUESTIONS

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

b. These questions require learners to explain the concepts in more complex circuits.

c. The learners must ensure that they use subscripts or other methods to label currents, voltages and resistances whenever needed.

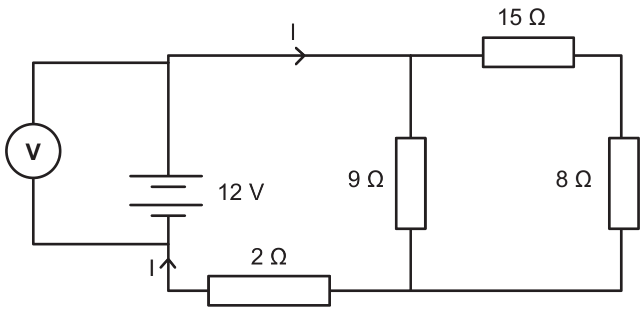
How to tackle these questions in the classroom:

- 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 apply the concepts in more complex circuits.

4. The battery in the circuit below has a voltage of 12 V and no internal resistance. The resistance of the connecting wires can also be ignored.



a. Calculate the current, *I*, that passes through the battery.

b. How will the resistance of the circuit and the current in the circuit be affected if the 9 Ω resistor is removed and replaced with a conducting wire of negligible resistance?

Solution:

a. $\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_1} = \frac{1}{9} + \frac{1}{15+8}$

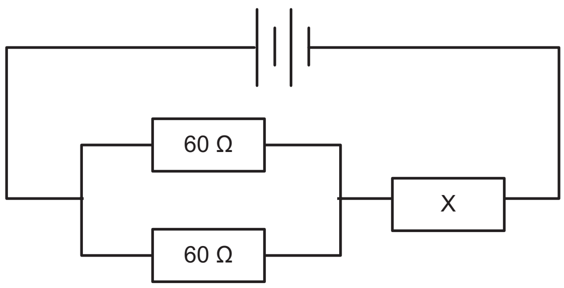
$R_{eff} = 6,47\ \Omega$

$R_{tot} = R_{eff} + R_{2\Omega} = 6,47 + 2 = 8,47\ \Omega$

$I = \frac{V}{R} = \frac{12}{8,47} = 1,43\ \text{A}$

b. No current will pass through the 15 Ω and 8 Ω resistors. All the current will pass through the conducting wire (because it causes a short circuit). The total resistance of the circuit will now be 2 Ω therefore the current will increase.

5. In the circuit represented below, two 60 Ω resistors connected in parallel are connected in series with an unknown resistor X. The battery has an emf of 12 V and negligible internal resistance.



Calculate the:

a. equivalent resistance of the parallel combination.

b. current in 60 Ω resistor if the potential difference across the parallel combination is 9 V.

c. the resistance of the unknown resistor X.

Solution:

a. $\frac{1}{R} = \frac{1}{60} + \frac{1}{60}$

$\therefore R = 30\ \Omega$

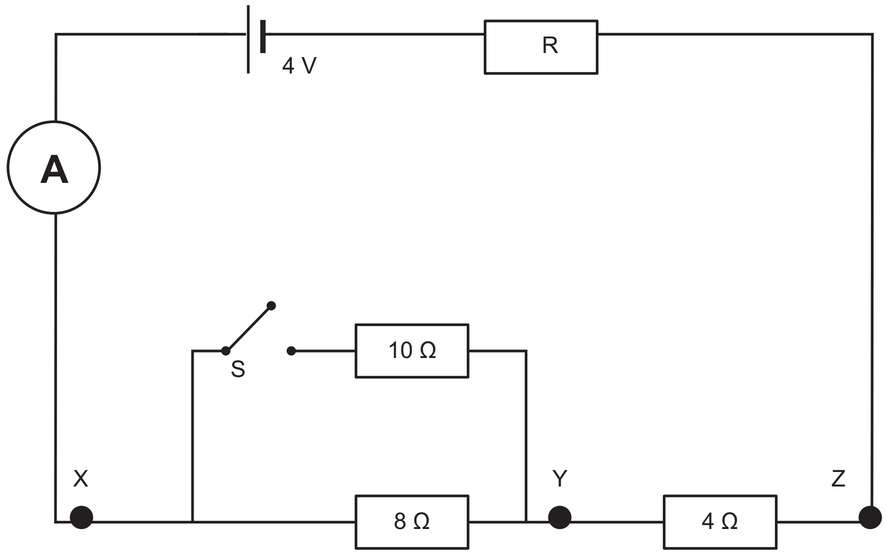
b. $I = \frac{V}{R} = \frac{9}{60} = 0{,}15\ \text{A}$

c. $V_{unknown} = 12 - 9 = 3\ \text{V}$

$I_{unknown} = 2 \times 0{,}15 = 0{,}3\ \text{A}$

$R = \frac{V}{I} = \frac{3}{0{,}3} = 10\ \Omega$

6. The circuit diagram below represents a combination of resistors in parallel and series.



With switch S OPEN, ammeter A reads 0,32 A.

a. Calculate the potential difference between **X** and **Z**.

b. Calculate the resistance of **R**.

Switch S is now CLOSED.

c. How will the potential difference between **X** and **Z** be affected when switch S is closed? Write INCREASE, DECREASE or REMAINS THE SAME.

d. Explain your answer to question **c**.

TOPIC 11

e. A conducting wire of negligible resistance is now connected between points **Y** and **Z**. What effect will this have on the ammeter reading? Write down only INCREASE, DECREASE or REMAINS THE SAME.

Solution:

a. $V_{XZ} = R \times I = (12)(0,32) = 3,84\ \text{V}$

b. $V_{unknown} = 4 - 3,84 = 0,16\ \text{V}$

$R = \frac{V}{I} = \frac{0,16}{0,32} = 0,5\ \Omega$

c. Decreases.

d. R_{total} decreases; I increases; $V_{over\ R}$ increases therefore $V_{Y\text{-}Z}$ decreases.

e. Increases.

CHECKPOINT

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

1. calculating the resistance of series and parallel components in basic and more complex circuits.
2. calculating voltage, current and/or resistance using Ohm's Law.
3. Questions dealing with Ohm's Law experiments.
   Check learners' understanding of these concepts by getting them to work through:

Topic 10: Worksheet from the Resource Pack: Electric Circuits: Questions 1–6 (Pages 23–26).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of 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. POWER, ENERGY

CONCEPT EXPLANATION AND CLARIFICATION:

Power is the rate of conversion of (electrical) energy. There are four equations which can be used here, and the learners must choose the equation according to the information that they have. Note that as there are often multiple approaches to solve a problem in the electrical circuits section, so learners may use slightly different information when solving circuit problems. The equations are:

$$P = VI; \quad P = I^2R; \quad P = \frac{V^2}{R} \quad \text{and} \quad P = \frac{E}{t}.$$

Electrical energy: E, older textbooks sometimes use W in this context.

Cost of electricity and the kilowatt hour: Energy supplied to consumers is normally measured in the units of kilowatt hours (kWh or kW·h). This comes from $E = Pt$ where power is measured in kW and time in hours. One kilowatt hour is equal to 3 600 000 J.

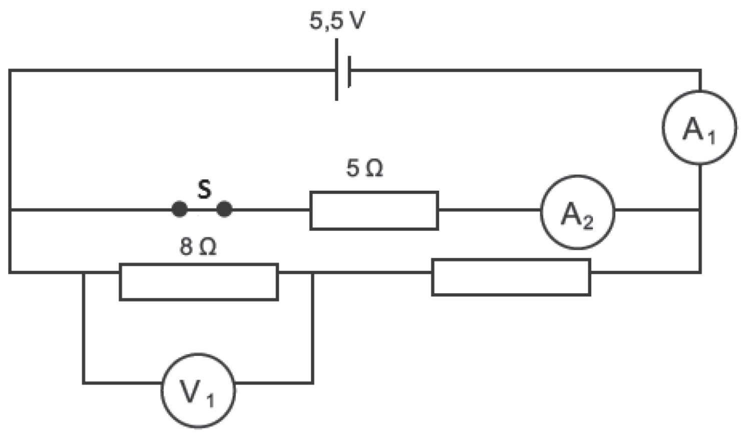
INTRODUCTORY LEVEL QUESTIONS

1. These questions help the learners to understand and memorise the basic concepts that are required for this topic.
2. These are the basic calculations that learners will be required to perform at this stage in the topic.
3. Their purpose is to build energy or power calculations into circuit questions, based on the Ohm's law section already covered.

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. A cell with an emf of 5,5 V and negligible internal resistance is connected to three resistors as shown in the circuit diagram below.



   a. Calculate the effective resistance of the external circuit.
   b. Calculate the reading on A_1.
   c. Calculate the reading on ammeter A_2.
   d. Calculate the reading on voltmeter V_1.

e. Calculate the power dissipated in the 2 Ω resistor in 5 minutes.

f. Switch **S** is now opened. Indicate whether the following will **increase**, **decrease** or **remain the same**:

i. The effective resistance of the external circuit.

ii. The reading on ammeter A_1.

Solution:

a. $\frac{1}{R_{parallel}} = \frac{1}{5} + \frac{1}{10}$

$\therefore R_{parallel} = 3,3\ \Omega$

b. $I = \frac{V}{R} = \frac{5,5}{3,3} = 1,65\ \text{A}$

c. $I_5 = \frac{V}{R} = \frac{5,5}{5} = 1,10\ \text{A}$

d. $I_8 = 1,65 - 1,1 = 0,55\ \text{A}$

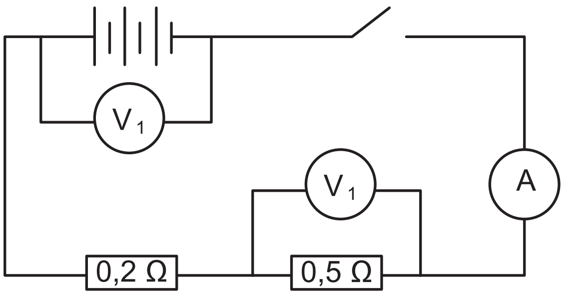
$V = IR = 0,55 \times 8 = 4,4\ \text{V}$

e. $P = I^2R = 0,55^2 \times 2 = 0,605\ \text{W}$

f. **i.** increase

ii. decrease

8. Study the circuit diagram below. Each cell has an emf of 0,5 V.



a. Determine the emf of the battery.

b. With the switch closed, calculate the:

i. total resistance of the circuit.

ii. ammeter reading.

iii. reading on voltmeter V_2.

iv. amount of energy generated in the battery in 10 seconds.

Solution:

a. $V = 3 \times 0,5 = 1,5\ \text{V}$

b. **i.** $R_t = 0,7\ \Omega$

ii. $I = \frac{V}{R} = \frac{1,5}{0,7} = 2,14\ \text{A}$

iii. $V_2 = IR = 2,14 \times 0,5 = 1,07\ \text{V}$

iv) $E = VIt = 1,5 \times 2,14 \times 10 = 32,1\ \text{J}$

9. A 1 200 W oven element runs for 2 hours.

- **a.** Calculate the energy used (in kilowatt hours).
- **b.** Calculate the cost of electrical energy which is charged at R2.80 per kW·h.

Solution:

- **a.** $E = Pt = 1,200 \times 2 = 2,4 \text{ kW·h}$
- **b.** Cost = 2,8 × 2,4 = R 6,72

CHALLENGE LEVEL QUESTIONS

- **a.** Now that learners have mastered the basic questions and calculations, they are ready to deal with more challenging questions.
- **b.** These questions require learners to explain the concepts in more complex circuits.

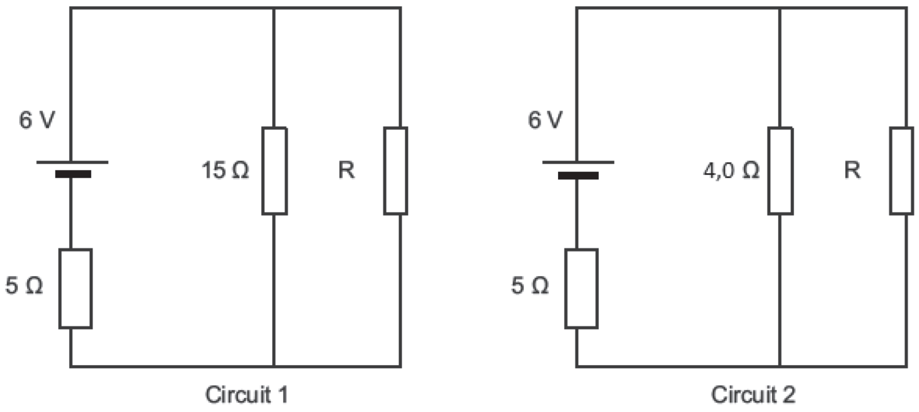
How to tackle these questions in the classroom:

- 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 apply the concepts in more complex circuits.

10. In the circuit diagrams shown below, each cell supplies power to a 5 Ω resistor which is connected in series with it and to a pair of resistors in parallel. The battery in each circuit provides a voltage of 6 V.



When maximum power is dissipated in the parallel resistors, the resistance of the parallel combination is equal to the resistance of the 5 Ω resistor.

a. For circuit 1, determine the value of R which results in the maximum power being delivered to the external circuit.

b. Calculate V, the potential difference, across the parallel combination of circuit 1, under the conditions described in part **a**.

c. Calculate the power that is dissipated by the 15 Ω resistor when delivering maximum power is delivered to the external circuit.

d. In circuit 2, explain why the supply cannot deliver maximum power in this circuit for any value of the resistor R.

Solution:

a. $\frac{1}{R_{parallel}} = \frac{1}{15} + \frac{1}{R}$

$\frac{1}{5} = \frac{1}{15} + \frac{1}{R}$

$\frac{1}{R} = \frac{1}{5} - \frac{1}{15} = \frac{2}{15}$

∴ R = 7,5 Ω

b. $I_{circuit} = \frac{V}{R} = \frac{6}{5+5} = 0,6 \text{ A}$

$V_{parallel} = IR = 0,6 \times 5 = 3 \text{ V}$

Or you could say that the parallel combination is half of the total resistance and so has half of the total voltage.

c. $P = \frac{V^2}{R} = \frac{9}{15} = 0,6 \text{ W}$

d. Using the method used in (**a.**)

$$\frac{1}{R_{parallel}} = \frac{1}{4} + \frac{1}{R}$$

$$\frac{1}{5} = \frac{1}{4} + \frac{1}{R}$$

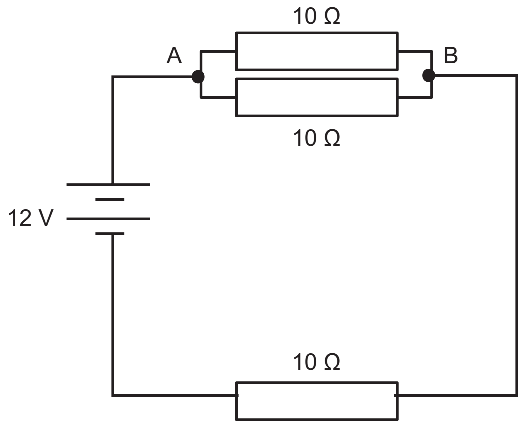
$$\frac{1}{R} = \frac{1}{5} - \frac{1}{4} = \frac{-1}{20}$$

$R = -20\ \Omega$ but R cannot be less than 0.

OR

The effective resistance of resistors connected in parallel is always less than the smallest resistor in the parallel combination, therefore it will always be less than 4 Ω for every value of R.

11. A battery of emf 12 V and negligible internal resistance is connected in a circuit with three resistors each having a resistance of 10 Ω as shown.



Calculate the:

a. potential difference between the points A and B in the circuit.

b. total energy supplied by the battery in 5,0 s.

Solution:

a. $$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{10} + \frac{1}{10} = \frac{1}{5}$$

$$R_{parallel} = 5\ \Omega$$

ALTERNATIVE 1

$R_{circuit} = 5 + 10 = 15\ \Omega$ $\qquad I_{circuit} = \frac{V}{R} = \frac{12}{15} = 0{,}8\ \text{A}$

$$V_{parallel} = IR_{parallel} = 0{,}8 \times 5 = 4{,}0\ \text{V}$$

ALTERNATIVE 2

Series circuits are potential dividers

therefore the potential difference of 12 V will divide in the ratio of 5 : 10

$$V_{parallel} = \frac{5}{5+10} \times 12 = 4\ \text{V}$$

TOPIC 11

b. ALTERNATIVE 1

$$E = VIt = 12 \times 0,8 \times 5 = 48 \text{ J}$$

ALTERNATIVE 2

$$E = \frac{V^2 t}{R} = \frac{12 \times 12 \times 5}{(5 + 10)} = 48 \text{ J}$$

CHECKPOINT

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

1. calculating the resistance of series and parallel components in basic and more complex circuits.
2. calculating voltage, current and/or resistance using Ohm's law.
3. calculating energy and power in circuits.

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

Topic 11: Worksheet from the Resource Pack: Electric Circuits: Questions 7–8. (Pages 26–27).

- 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; **Resource Pack: Topic 11: Electric Circuits: Consolidation Exercise. (Pages 28–31).**
- 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.youtube.com/watch?v=WEqu2vxjyFc
A Cape Town Science Centre video 3 minutes 14 seconds. This video deals with how to set up an Ohm's law experiment using school equipment and gives some simple readings.
2. https://phet.colorado.edu/en/simulation/ohms-law
This is a simulation – very useful to do as an additional experiment. You can change the voltage or the resistance (which f=goes beyond Ohm's law).
3. https://www.youtube.com/watch?v=iLzfe_HxrWI
An amusing 6 minute animation of Ohm's law.
4. http://www.eskom.co.za/CustomerCare/TariffsAndCharges/Pages/Tariffs_And_Charges.aspx
This site gives the up-to-date costs of electricity and a pricing tool.

TOPIC 12:
Energy and Chemical Change

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.
- Energy forms part of the content area Chemical Change (Chemistry).
- Chemical change counts 46 % in the final Paper 2 (Chemistry) examination.
- Energy and chemical change counts approximately 10 % of the final examination.
- Chemical reactions all involve the change of reactants into products. Whenever a chemical reaction occurs, there have to be changes in energy as well. Either energy is released from the reaction or energy is absorbed by the reaction to get the reaction going and sustain it. This topic will look to explain the important concepts surrounding the fundamental principles of energy changes that occur during chemical reactions.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. List of bond energies for the most common chemical bonds.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises.
2. Scientific calculator — Sharp or Casio calculators are highly recommended.
3. Pen, pencil and eraser.
4. List of common bond energies as provided by the teacher.

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 10	**GRADE 11**	**GRADE 12**
• Endothermic and exothermic reactions • Covalent bonding • Couper notation	• Energy changes relating to bond formation and bond breaking • Exothermic and endothermic reactions • Graphical representations of energy changes • Activation energy and the activated complex	• Rates of chemical reactions • Molecular Collision theory

C Glossary of Terms

TERM	DEFINITION
Exothermic reaction	Reactions that release energy. ($\Delta H < 0$ for exothermic reactions.)
Endothermic reaction	Reactions that absorb energy. ($\Delta H > 0$ for endothermic reactions.)
Bond energy	The amount of energy required to break a particular bond in a molecule or the amount of energy released when a new bond is formed.
Enthalpy (heat (energy) of a substance)	The total amount of energy within a substance, either a reactant or a product.
Heat of reaction/change in enthalpy (ΔH)	The energy absorbed or released per mole in a chemical reaction. $\Delta H = H_{products} - H_{reactants}$, where $H_{products}$ and $H_{reactants}$ are the heat (energy) of the products and reactants.
Law of conservation of energy	In an isolated (closed) system, energy cannot be created or destroyed; it can only be transferred from one form to another.
Activation energy	The minimum energy needed for a reaction to take place.
Energy profile	Graphical representation of exothermic and endothermic chemical reactions.
Collision theory	The theory that explains the criteria that must be met before a chemical reaction will takes place. It describes what must happen when two reacting particles collide.
Effective/successful collision	A collision between two reacting particles that will start the process of bond breaking to form new products.
Collision frequency	The measure of the amount of collisions per unit time between reacting particles.
Activated complex	The unstable transition state from reactants to products.

D Assessment of this Topic

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

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

E Breakdown of Topic and Targeted Support Offered

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

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
2 hours	Energy changes in reactions related to bond energy changes	90	**a.** Explaining the concept of enthalpy and it's relationship to heat of reaction. **b.** Explaining that bond breaking requires energy and bond formation releases energy. **c**. Classification of various reactions as either exothermic or endothermic.
1 hour	Exothermic and endothermic reactions	90	**a.** Looking at graphical representations of exothermic and endothermic reactions.
1 hour	Activation energy	91	**b.** The concept of activation energy and the formation of the activated complex.

F Targeted Support per Sub-topic

1. ENERGY CHANGES IN REACTIONS RELATED TO BOND ENERGY CHANGES

INTRODUCTION

All chemical reactions involve change in the structure and composition of the reactants to form new products. This is done through the breaking of "old" bonds in the reactants and the formation of "new" bonds in the products. From an understanding of these concepts, the concepts of exothermic and endothermic reactions can be explained. This sub-topic will teach learners these processes and how using bond energies we can determine whether a reaction is exothermic or endothermic.

CONCEPT EXPLANATION AND CLARIFICATION: EXPLAINING THE CONCEPT OF ENTHALPY AND IT RELATION TO HEAT OF REACTION.

In this new topic, explain to the learners that we are going to be examining the changes in energy that take place during a chemical reaction when reactants form products. There are energy changes in **every** chemical reaction that takes place. Learners must understand that when chemical reactions take place, that the reactant particles will have their bonds broken and that product particles will have new bonds formed. In terms of energy changes, there are two important things for the learners to know at this stage:

- Energy is absorbed to break the bonds of the reactant particles.
- Energy is released when new bonds form in the products.

In other words, whenever there is bond breaking or bond formation, energy is either released or absorbed. This energy, known as bond energy, is the measure of the amount of energy either released or absorbed when either breaking or forming a chemical bond. These bond energies are measured in $kJ \cdot mol^{-1}$.

Now the learners need to understand that whenever a chemical reaction takes place, there is a change in energy when reactants react to form products. This change in energy is called the heat of the reaction. It is important for the learners to understand what is meant by enthalpy. Enthalpy is the total amount of energy that the reactants or products possess and it is represented by the symbol "H" or "E"**.** This means that when it comes to measuring the heat of reaction, we are in fact measuring the **change in enthalpy** (ΔH) of the system. In other words, **change in enthalpy/heat of reaction** is the measure of the amount of heat energy transferred during a chemical reaction. This can be calculated as follows:

Enthalpy change = enthalpy of products - enthalpy of reactants

$$\Delta H = H_{products} - H_{reactants} \quad \text{(measured in kJ·mol}^{-1}\text{)}$$

At this point, it is advised to give learners a table of bond energies of common chemical substances as these bond energies can be used to calculate the enthalpies of reactants and products:

BOND	BOND ENERGY ($kJ \cdot mol^{-1}$)	BOND	BOND ENERGY ($kJ \cdot mol^{-1}$)
C — H	413	O – H	463
C — C	348	O — O	495
C — N	293	C — C	614
C — O	358	C — O	799
C — F	485	F — F	155
C — Cl	328	Cl — Cl	242
C — Br	276	Br — Br	193
H — H	436	H — Cl	431
H — F	567	N = N	941

CONCEPT EXPLANATION AND CLARIFICATION: EXOTHERMIC AND ENDOTHERMIC REACTIONS

These concepts were introduced in Grade 10 but it is important to revise them to ensure that all learners are familiar with these terms.

Exothermic reaction: Chemical reactions that release energy in the form of heat and/or light to the surroundings.

Endothermic reaction: Chemical reactions that absorb or take in energy from the surroundings.

What is vital for the learners to grasp is the concept that energy is not created in an exothermic reaction nor is it destroyed in an endothermic reaction. This is a common misconception that teachers should be aware of. Energy can only be transferred from one form to the other. This means that the total energy in the system has to remain constant. This is known as the Law of Conservation of Energy and the learners should be able to state it.

Law of Conservation of Energy: In an isolated (or closed) system, energy cannot be created or destroyed; it can only be transferred from one form to another.

This law can also be stated as: The total energy in an isolated (or closed) system remains constant.

CONCEPT EXPLANATION AND CLARIFICATION: IDENTIFYING THAT BOND BREAKING ABSORBS ENERGY AND BOND MAKING (FORMATION) RELEASES ENERGY

We are now going to look at how chemical reactions take place in terms of the breaking of bonds in reactants and formation of bonds in products. Learners must understand that both these processes involve energy and that to break a bond, energy is absorbed from the surroundings (endothermic process). When bonds are formed, energy is released into the surroundings (exothermic process).

The energy involved in the bond breaking/bond forming process can be calculated by looking at the balanced chemical equation for a reaction and determining which bonds are breaking, and then finding the bond energies of those bonds from a table of bond energies (as shown on page 87). The amount of energy needed to break a bond is exactly the same as the energy released when a new bond is formed. Do the following worked example with the learners.

Example:

Consider the following chemical reaction that shows the formation of water from its individual elements:

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Step 1: Identify the bonds that make up the reactants. In the reactants, there are 2 $\times$ H_2 molecules (H $-$ H) and 1 $\times$ O_2 molecule (O $=$ O).

Step 2: Identify the bonds that make up the products. In the products there are 2 $\times$ O $-$ H bonds formed per H_2O molecule, and there are 2 molecules formed.

Step 3: Using the bond energy table, determine the total energy required to break the bonds.

H $-$ H: 436 kJ·mol^{-1}, thus with 2 moles of H_2 present, total energy required $=$ 872 kJ

O $=$ O: 495 kJ·mol^{-1}, thus with 1 mole of O_2 present, total energy required $=$ 495 kJ

TOTAL ENERGY to break bonds $= 872 + 495$
$= 1\ 367$ kJ

Step 4: Using the bond energy table, determine the total energy released when new bonds are formed.

O $-$ H: 463 kJ·mol^{-1}, thus with two O $-$ H bonds per molecule, 926 kJ·mol^{-1} released on bond formation. However, there are 2 moles of H_2O formed, thus:

TOTAL ENERGY released on new bond formation $= 926 \times 2$
$= 1\ 852$ kJ

Step 5: Calculate the change in energy/change in enthalpy (ΔH) by subtracting the total energy of new bond formation from the total energy required to break the old reactant bonds.

$$\Delta H = E_{reactant\ bonds} - E_{product\ bonds}$$
$$= 1\ 367 - 1\ 852$$
$$\Delta H = -485\ kJ$$

Please note that in this reaction, a negative value is obtained which means that excess energy is released from the reaction; that is, the reaction is exothermic.

Note: Learners will not be examined or tested on this type of calculation. However working through this example explains how the heat of reaction is determined for a reaction. It may help learners to understand the process of energy being absorbed to break bonds, as well as energy being released during bond formation.

CONCEPT EXPLANATION AND CLARIFICATION: CLASSIFICATION OF VARIOUS REACTIONS AS EITHER EXOTHERMIC OR ENDOTHERMIC

Now that the learners have been shown the concept of bond breaking and bond formation, as well as how to calculate the change in enthalpy of the reaction to see whether it is exothermic or endothermic, learners must look at a few reactions in everyday life to see how they are classified.

Photosynthesis: This is an example of an endothermic reaction in which plants absorb energy from the sun and use it to convert CO_2 and H_2O into glucose and oxygen.

$$6CO_2 + 6H_2O + \text{sunlight} \longrightarrow C_6H_{12}O_6 + 6O_2$$

Cell respiration: This is an exothermic reaction from which animals and plants obtain energy to be able to grow. In this reaction, glucose reacts with oxygen to produce CO_2, H_2O and energy. In other words, it is the exact opposite of photosynthesis reaction.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

Combustion of fuels: These are exothermic reactions where fuels are used by humans to obtain warmth, to power cars or motorbikes and to keep engines/industrial equipment running. Propane and butane are natural gases that are used as fuels. Explain to the learners that this is what we call LPG (liquid petroleum gas) and it is the gas that is used to provide heat and for cooking. Propane and butane are mixed together to form commercial LPG.

Propane: $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O + \text{energy}$

Butane: $2C_4H_{10} + 13O_2 \longrightarrow 8CO_2 + 10H_2O + \text{energy}$

INTRODUCTORY LEVEL QUESTIONS

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

b. Their purpose is to familiarise the learners with the terminology and energy changes that take place during chemical reactions.

How to tackle these questions in the classroom:

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

1. For each of the following physical or chemical changes, say whether it involves an exothermic or endothermic change/reaction. Briefly explain your answer.

a. Combustion of fuel in a car engine

b. Boiling water

c. Evaporation

d. LPG gas burning in a gas stove

e. Cell respiration

Solution

a. Exothermic: Fuel burns to release heat energy which is used to drive the engine.

b. Endothermic: Electrical energy is used to add heat energy to water to raise the temperature to the boiling point.

c. Endothermic: Energy from the sun is absorbed by water particles which will result in a change of phase from liquid to gas.

d. Exothermic: Gas burns to release heat energy which is used to cook food.

e. Exothermic: Cells release energy to the living organism by converting glucose and oxygen into carbon dioxide and water.

2. Define the following terms:

a. Exothermic reaction

b. Endothermic reaction

c. Law of conservation of energy

d. Change in enthalpy/heat of reaction

Solution

a. A chemical reaction that releases excess energy into the environment.

b. A chemical reaction that absorbs energy from the environment.

c. Energy cannot be created or destroyed. It can only be converted from one form to another.

d. The measure of the amount of heat energy transferred during a chemical reaction.

3. Consider the following reaction:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

a. Draw the Couper notation for the reactants and products showing the bonds in each substance.

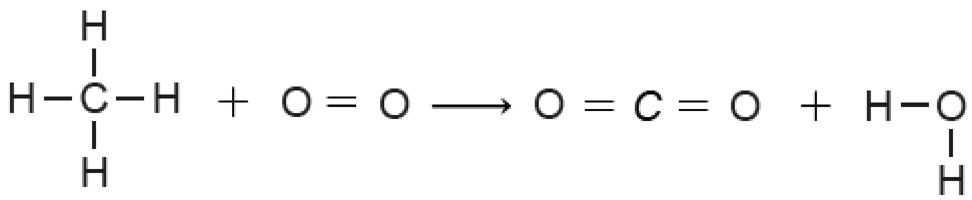
b. Describe the energy changes that take place during

i) bond breaking and

ii) bond formation.

Solu

a.



b. i) Energy is absorbed when bonds are breaking e.g. energy is taken in to break the covalent bonds between carbon and hydrogen atoms, and between the two oxygen molecules.

ii) Energy is released when bonds are forming e.g. when carbon atoms combine with oxygen atoms to form CO_2 and when hydrogen atoms combine with oxygen atoms to form water.

KEY TEACHING:

a. Learners need to have a good grasp of the important concepts regarding enthalpy and heat of reaction (change in enthalpy).

b. They must be able to define exothermic and endothermic reactions.

c. Learners must be able to recall different reactions in the real world as to whether they are exothermic or endothermic.

CHECKPOINT

At this point in the topic, learners should be able to:

1. explain the meaning of enthalpy(H) and the change in enthalpy (ΔH) also known as the heat of reaction.
2. explain that bond breaking requires absorption of energy (an endothermic process), whilst bond formation releases energy (an endothermic process).
3. The difference between an exothermic and an endothermic reaction.
4. recall various reactions in the real world and know which of these reactions are exothermic and which are endothermic.

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

Topic 12: Worksheet from the Resource Pack: Energy and Chemical Change: Questions 1–3 (Page 36).

- Check learners' understanding by marking their work with reference to the marking guidelines.
- If you cannot photocopy the marking guidelines for each learner, make three or four copies of 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. EXOTHERMIC AND ENDOTHERMIC REACTIONS

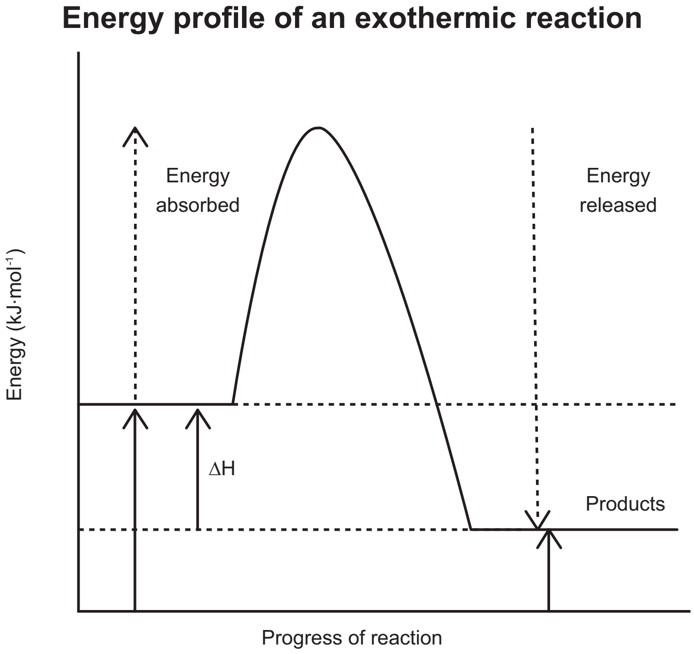
INTRODUCTION

In this sub-topic, learner will be introduced to the graphical representation of exothermic and endothermic reactions known as energy profiles. Learners must be able to draw and label these graphs correctly.

CONCEPT EXPLANATION AND CLARIFICATION: GRAPHICAL REPRESENTATIONS OF EXOTHERMIC AND ENDOTHERMIC REACTIONS.

Learners are required to represent energy changes in reactions on **energy profiles** or **enthalpy diagrams.**

Energy profiles are graphs that are drawn to show how the energy changes from reactants to products for the duration of the reaction.



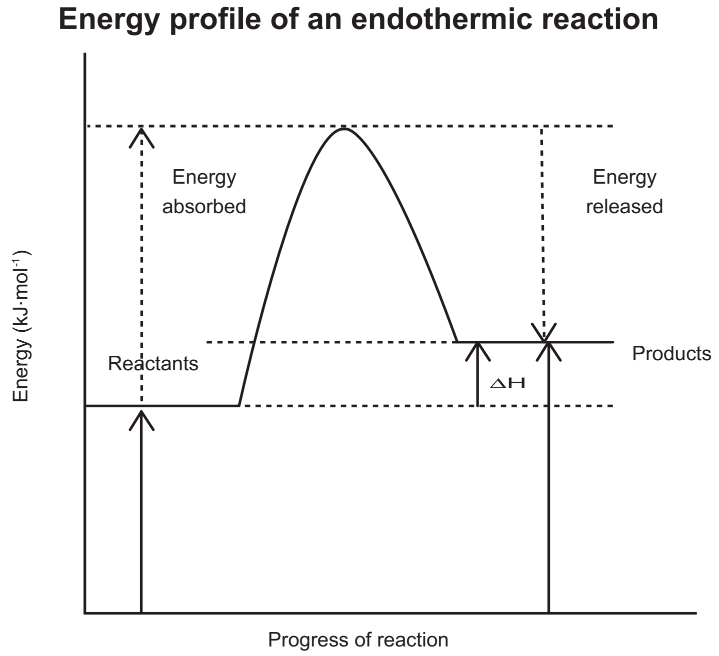
This is an energy profile of an exothermic reaction which shows the energy change from the reactants to products. At the start of the reaction, the reactants have a certain amount of energy. When the reaction starts, energy is absorbed causing the energy of the system to increase. The graph shows a steep increase in energy per mol. As new bonds start to form the energy of the system decreases. The graph shows a steep decrease in energy per mol. If the total energy released is greater than the total energy absorbed, then the final energy of the products is less than the initial energy of the reactants. Thus it is an exothermic reaction and the energy profile is as represented above.

The heat of the reaction, ΔH, is equal to the difference between the energy of the products and the energy of the reactants.

$$\Delta H = E_{Products} - E_{Reactants}$$

For an exothermic reaction $\Delta H < 0$ because the energy of the products is less than the energy of the reactants.

TOPIC 12



This is an energy profile of an endothermic reaction which shows the energy change from the reactants to products. At the start of the reaction, the reactants have a certain amount of energy. When the reaction starts, energy is absorbed so the energy of the system increases. As bonds in the reactants are broken, new bonds start to form and the energy of the system decreases as energy is released. If the total energy released is less than the total energy absorbed, then the final energy of the products is greater than the initial energy of the reactants. Thus, it is an endothermic reaction and the energy profile is represented above.

The heat of the reaction, ΔH, is equal to the difference between the energy of the products and the energy of the reactants.

$$\Delta H = E_{Products} - E_{Reactants}$$

For an endothermic reaction $\Delta H > 0$ because the energy of the products is greater than the energy of the reactants.

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INTRODUCTORY LEVEL QUESTIONS

1. These are the basic questions that learners will be required to answer at this stage in the topic.
2. Their purpose is to familiarise the learners with terminology and energy profiles of reactions.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Explain each part of the answers 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 definitions for the following terms:
   a. Bond energy
   b. Endothermic reaction
   c. Exothermic reactions
   d. Enthalpy

   Solution

   a. The amount of energy required to break a particular bond in a molecule or the amount of energy released when a new bond is formed.
   b. A reaction in which energy is absorbed by the reaction from its surroundings.
   c. A reaction in which excess energy is released into the surroundings.
   d. The total amount of energy within a substance, either a reactant or a product.

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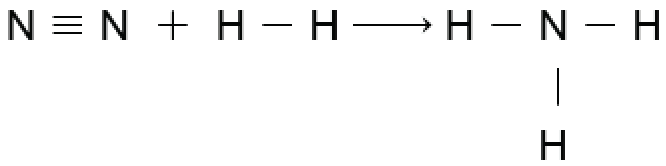
2. Consider the following balanced chemical equation which represents the industrial preparation of ammonia gas from nitrogen and hydrogen.

   $N_2 + 3H_2 \longrightarrow 2NH_3 \qquad \Delta H < 0$

   a. Draw the Couper notations for the reactants and products showing the bonds that make up these molecules.
   b. Is this reaction exothermic or endothermic? Explain briefly.
   c. Draw a labelled energy profile for this reaction. On the diagram indicate the following: energy of the reactants, energy of the products, energy absorbed, energy released and ΔH.
   d. Draw a labelled energy profile for this reaction.

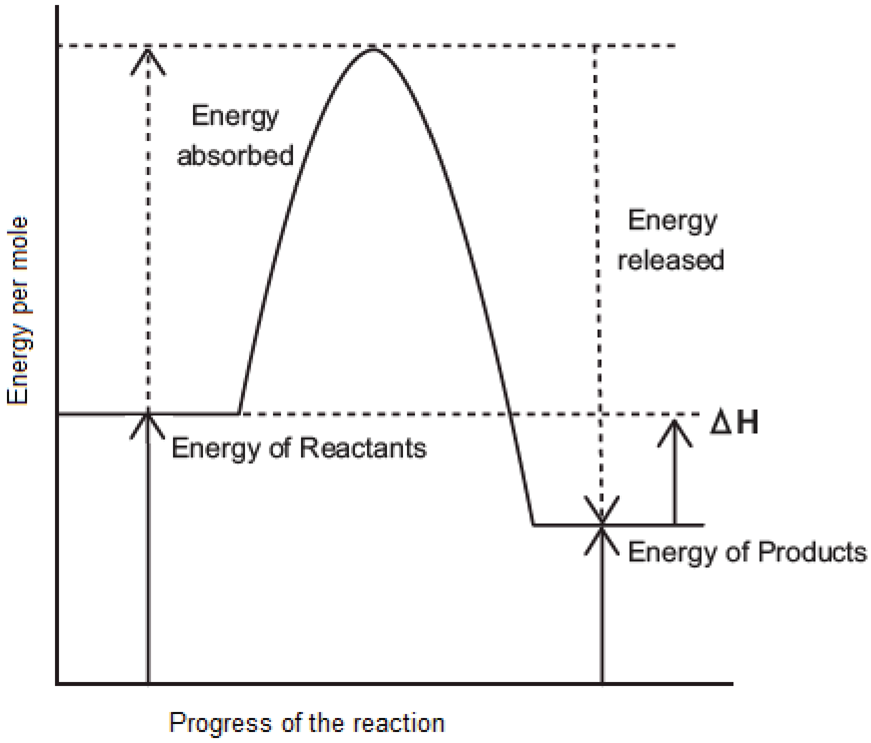
Solution

a.



b. The reaction is exothermic, because the heat of reaction is less than zero (negative). This shows us that the energy of the products is less than the energy of the reactants.

c.



KEY TEACHING:

a. Ensure learners are able to correctly draw the energy profiles for both exothermic and endothermic reactions.

b. Make sure that they are able to label them correctly.

CHECKPOINT

At this point in the topic, learners should be able to:

1. recognise, recall and draw the energy profiles of both exothermic and endothermic reactions.
2. recognise, recall and draw these energy profiles showing energy of reactants, energy of products and indicating where energy is absorbed and where energy is released.

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

Topic 12: Worksheet from the Resource Pack: Energy and Chemical Change: Questions 1–5 and 7 (Page 37).

- 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 ACTIVATION ENERGY

INTRODUCTION

For any reaction to begin, molecules must be able to collide effectively to start the chemical reaction. This sub-topic will introduce the concept of the collision theory which will explain the essential criteria necessary for reactions to take place. It will also introduce the concepts of activation energy and the activated complex.

CONCEPT EXPLANATION AND CLARIFICATION: EXAMINING THE CONCEPT OF ACTIVATION ENERGY AND ENERGY PROFILES INDICATING ACTIVATION ENERGY.

In our concluding sub-topic, learners are introduced to the concept of activation energy and the importance of this energy in getting a reaction started. What is activation energy? Learners need to learn the definition off by heart as it is a crucial concept that all reactions need to absorb energy for the reaction to take place.

Activation energy: The minimum energy required to start a chemical reaction.

The symbol for activation energy is E_A.

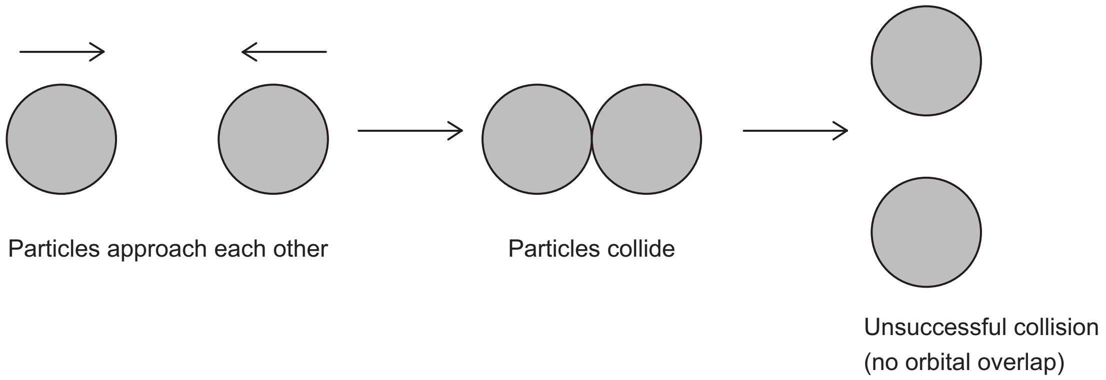
At this point, it is a good idea to explain to the learners the basic mechanism of how a reaction takes place. This is known as the **collision theory.** For a reaction to occur between any atoms, molecules or ions in a system, these particles must first collide. The rate of collision or how many particles collide per unit time is called the **collision frequency**.

Now emphasise to learners that not every collision between these particles will produce a chemical reaction. Two important factors must be present:

1. There must be enough energy in the system to produce a successful/effective collision.
2. The particles must collide in the correct orientation.

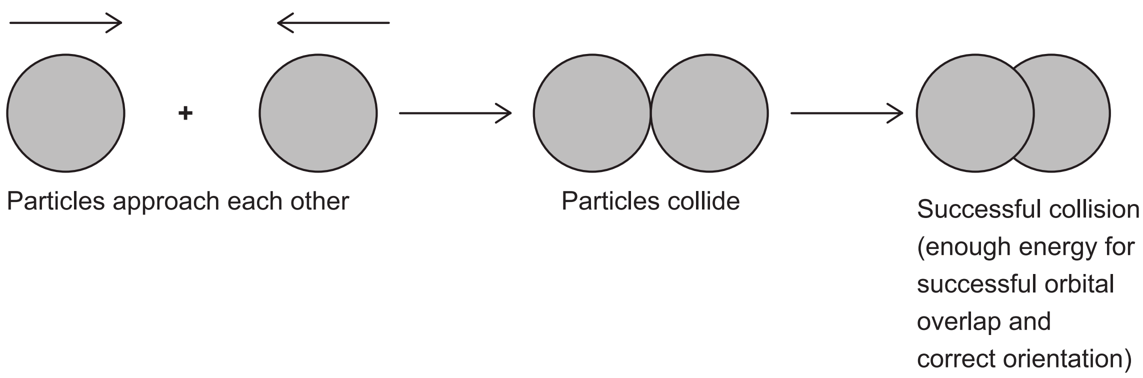
A successful /effective collision is firstly described as one when there is enough energy in the system to allow for the outermost orbitals of the reacting particles to overlap which now starts the reaction process. Secondly, the particles must be positioned in space in the correct orientation to allow for this orbital overlap to be successful. Thus the number of successful/effective collisions per unit time will be the measure of the rate of the chemical reaction. The following diagrams illustrate the concept of successful/effective and unsuccessful/non-effective collisions between particles.

Unsuccessful/non-effective collisions per unit time



With an unsuccessful collision, no orbital overlap occurs and the particles simply move away from each other.

Successful/effective collision per unit time



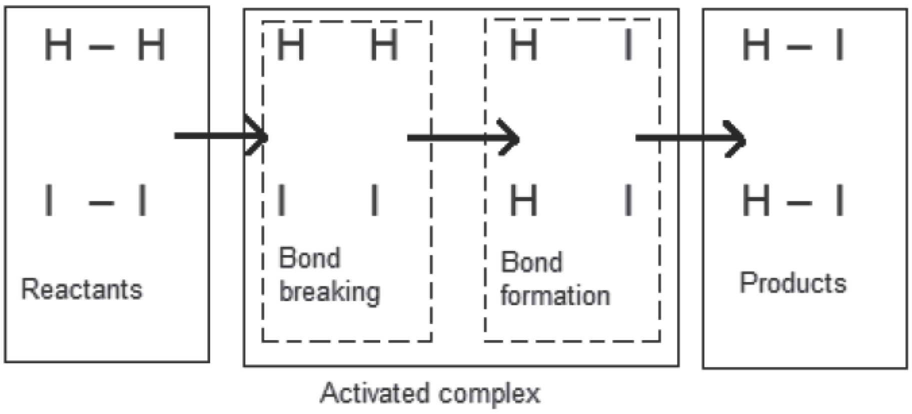
Thus, in a successful collision, particles must have enough energy to break the chemical bonds and that will only happen if there is enough energy to allow for orbital overlap to occur. **This minimum energy is the activation energy.**

Now, learners must understand that when the old reactants' bonds break and the new products' bonds form, there is a transition from reactants to products. In other words, there is an intermediate state that is formed while the reactant bonds are breaking and the product bonds are forming. This is known as the transition state complex or the **activated complex.**

Activated complex: The intermediate state in a chemical reaction that is formed while reactant bonds are breaking and product bonds are forming.

It is a highly unstable state in the reaction and energy will quickly be lost on product formation. To give the learners an idea of what the activated complex looks like, consider the following chemical reaction: $H_2(g) + I_2(g) \longrightarrow 2HI$

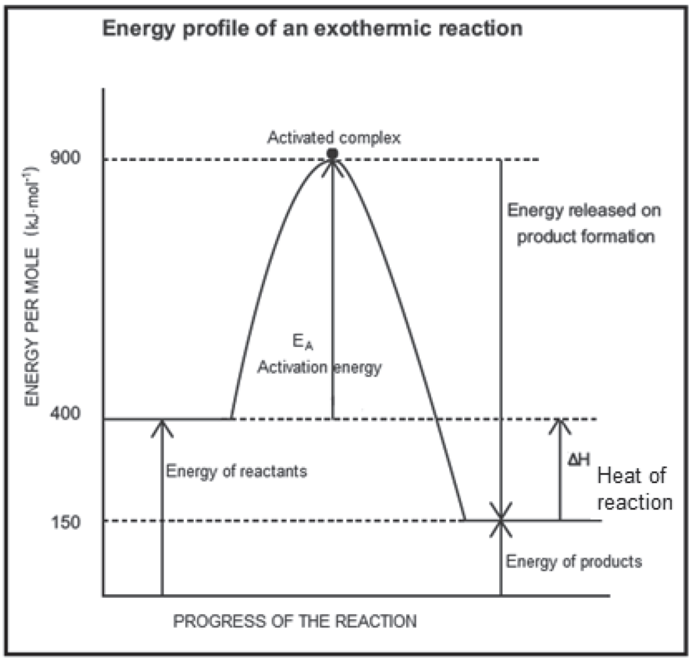
You can draw the reacting molecules H_2 and I_2 showing the covalent bonds between them. Then another diagram can be drawn showing the breaking of bonds in reactants and the formation of bonds in products using a dotted line. In other words, the complex is a transition state.



On the energy profile alongside, we can represent both the activation energy and the activated complex. The activation energy is represented by a single arrow showing the amount of energy the reactants gain to reach the activated complex.

$E_A = 900 - 400 = 500 \text{ kJ·mol}^{-1}$

The activated complex is shown as a small dot at the top of the curve.



Learners do not have to have to explain how the activated complex is formed, as shown in the diagram of the formation of HI from H_2 and I_2. They only have to be able to define the activated complex, and to show it as small dot with a label on an energy profile of a reaction.

Calculations can be done using energy values given on the graph. Using the values, learners can calculate or read from the graph:

- Activation energy as explained already.
- Energy of activated complex = 900 $kJ \cdot mol^{-1}$
- Energy released on formation of products = 150 − 900 = −750 $kJ.mol^{-1}$
- Energy of the reactants = 400 $kJ \cdot mol^{-1}$
- Energy of the products = 150 $kJ \cdot mol^{-1}$

It is also important for the learners to note that the change in enthalpy (heat of reaction), ΔH, can also be calculated from the graph. There are two ways in which this can be done:

Method 1	Method 2
$\Delta H = E_{products} - E_{Reactants}$	$\Delta H = E_A - E_{Released\ on\ product\ formation}$
$= 150 - 400$	$= 500 - 750$
$\Delta H = -250\ kJ \cdot mol^{-1}$	$\Delta H = -250\ kJ \cdot mol^{-1}$

INTRODUCTORY LEVEL QUESTIONS

1. These are basic questions that learners will be required to answer at this stage in the topic.
2. Their purpose is to familiarise learners with terminology and concepts.

How to tackle these questions in the classroom:

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

1. Define the term “activation energy”.

Solution

This is the minimum energy required to start a chemical reaction.The symbol for activation energy is E_A.

2. What name is given to the theory that explains the specific criteria that must be met in order for a chemical reaction to take place?

Solution

Collision theory

3. State the TWO criteria that must be met for a successful/effective chemical reaction to take place.

Solution

a. There must be enough energy in the system to produce a successful/effective collision.

b. The particles must collide in the correct orientation.

4. Explain what is meant by the term "activated complex".

Solution

The intermediate state in a chemical reaction that is formed while reactant bonds are breaking and product bonds are forming.

CHALLENGE LEVEL QUESTIONS

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

b. These questions require learners to apply their knowledge and understanding to solve 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 questions and answer them correctly in their workbooks.

1. Consider the decomposition of calcium carbonate to form calcium oxide and carbon dioxide as described by the following equation:

$$CaCO_3 \longrightarrow CaO + CO_2$$

The process involves the roasting of the calcium carbonate in a kiln at 500°C.

a. Is the reaction exothermic or endothermic? Give a reason for your answer.

b. Draw a labelled sketch graph of the energy profile for this reaction.

Calcium oxide is able to react with water to form calcium hydroxide according to the following equation:

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

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The temperature of the reaction mixture increases as the calcium hydroxide is formed.

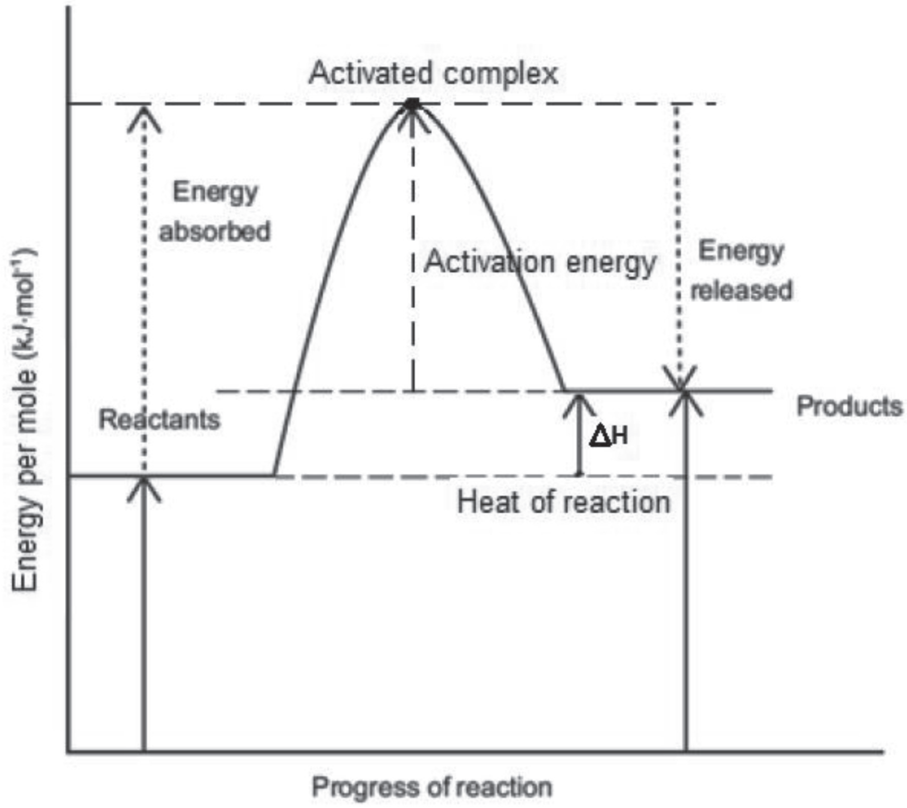
c. Indicate if this reaction is exothermic or endothermic. Explain your answer.

d. Will the bonds in $Ca(OH)_2$ be stronger or weaker than those of CaO and H_2O? Explain your answer.

Solution

a. Endothermic. The heat of reaction is positive (or $\Delta H > 0$) showing that the energy of the products is greater than the energy of the reactants.

b.



c. Exothermic. The temperature increases meaning that heat energy is released into the system.

d. Weaker.
More energy is released on bond formation than is taken in to break bonds in the reactants, therefore the chemical energy of $Ca(OH)_2$ is less than that of CaO and H_2O.
OR The energy of the products of an exothermic reaction is always less than the energy of the reactants. Therefore the bonds between the atoms in the products are weaker.

KEY TEACHING:

a. Ensure that learners are able to understand the collision theory and the importance it has in a chemical reaction.

b. Ensure learners are able to understand the concepts of activation energy and activated complex.

c. Make sure that learners are able label the energy profiles correctly indicating the activation energy and the activation complex.

d. Ensure learners can label the change in enthalpy ΔH.

CHECKPOINT

At this point in the topic, learners should have an understanding of:

1. the collision theory and the criteria that must be met for a successful/effective collisions to occur.
2. the concept of activation energy and why it is important in a chemical reaction.
3. how to draw a labelled energy profile that includes both activation energy and the activated complex.
4. how to use energy data from an energy profile to determine:
   - **a)** activation energy.
   - **b)** energy released on product formation.
   - **c)** change in enthalpy/heat of reaction ΔH.

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

Topic 12: Worksheet from the Resource Pack: Energy and Chemical Change: Questions 4–6 and 8 (Pages 36–38).

- 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; **Resource Pack: Topic 12: Energy and Chemical change: Consolidation Exercise. (Pages 39–41).**
- 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.youtube.com/watch?v=eJXL0IrbtqE&pbjreload=10
   This video explains the concepts of both exothermic and endothermic reactions and the differences between the two.
2. https://www.youtube.com/watch?v=RlF4D9rcqK8
   This video looks at bond energies and how to calculate the change in enthalpy in a chemical reaction. It is useful resource for educators, but it goes beyond the CAPS syllabus.
3. https://www.youtube.com/watch?v=pHULgFf44E8
   This video looks at exothermic and endothermic reactions, energy profiles and activation energy.

TOPIC 13:
Types of Reactions

A Introduction

- This topic runs for 12 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Types of Reactions forms part of the content area Chemical Change (Chemistry).
- Chemical Change counts approximately 45 % in the final exam.
- Types of reactions counts approximately 18,75 % of the final Paper 2 (Chemistry) examination.
- There are many different types of chemical reactions. In this Topic, we are going to examine TWO types of reactions, namely Acid-Base reactions and REDOX reactions. They are both uniquely different in that acid-base reactions involve the transfer of protons to effect chemical change whilst REDOX reactions involve the transfer of electrons to effect chemical change.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Rules to allocate oxidation numbers.
4. A Periodic Table.
5. Grade 11 Paper 2 (Chemistry) Data Sheet.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book, for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended.
3. Pen, pencil and ruler.
4. Rules to allocate oxidation numbers.
5. A Periodic Table.
6. Grade 11 Paper 2 (Chemistry) Data Sheet.

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 10	**GRADE 11**	**GRADE 12**
• Writing chemical formulae • Writing of balanced chemical equations • Reactions in aqueous solutions	• Acid and bases • REDOX reactions	• Acids and bases • Electrochemical reactions • The chemical industry

C Glossary of Terms

TERM	DEFINITION
Lowry-Brønsted acid	A proton / H^+ ion donor.
Lowry-Brønsted base	A proton / H^+ ion acceptor.
An Arrhenius acid	A substance that produces hydrogen ions (H^+) / hydronium ions (H_3O^+) when it dissolves in water.
An Arrhenius base	A substance that produces hydroxide ions (OH^-) when it dissolves in water.
Ampholytes	A substance that can act as either acid or base.
Oxidation number	The oxidation number of an element is a number assigned to each element in a compound, in order to keep track of the electrons during a reaction.
Oxidation	Oxidation: A loss of electrons. / An increase in oxidation number.
Reduction	Reduction: A gain of electrons. / A decrease in oxidation number.
Oxidising agents	A substance that is reduced/that gains electrons OR a substance whose oxidation number decreases.
Reducing agents	A substance that is oxidised/that loses electrons OR a substance whose oxidation number increases.
REDOX reaction	An oxidation-reduction reaction which involves electron transfer.
Ionisation	When a molecular substance dissolves in water to form aqueous ions for the first time.
Dissociation	When an already ionic substance dissolves in water to form aqueous ions.
Protolysis	The name given to an acid-base reaction that involves the simultaneous exchange of protons between acidic and basic substances.
Hydronium ion	The H_3O^+ ion formed when a proton, which is released by an acidic substance, reacts with water.
Conjugate acid-base pairs	When the acid, HA, loses a proton, its conjugate base, A-, is formed. When the base, A^-, accepts a proton, its conjugate acid, HA, is formed. These two are a conjugate acid-base pair.
Strong and weak acids	Strong acids ionise completely in water to form a high concentration of H_3O^+ ions. Examples of strong acids are hydrochloric acid, sulfuric acid and nitric acid.
Strong and weak bases	Strong bases dissociate completely in water. Examples of strong bases are sodium hydroxide and potassium hydroxide. Weak bases dissociate/ionise incompletely in water to form a low concentration of OH^- ions. Examples of weak bases are ammonia, calcium carbonate, potassium carbonate, calcium carbonate and sodium hydrogen carbonate.

Monoprotic acid	An acid that is able to donate only one proton upon ionisation.
Polyprotic acid	An acid that is able to release more than one proton upon ionisation.
Salt	The product formed from an acid –base reaction.
Indicator	A weak acid, or a weak base, which colour changes as the H^+ ion concentration or the OH^- ion concentration in a solution changes.
Ion-electron method	This is a method of balancing REDOX reactions that ensures that the number of electrons transferred remains constant.
Net REDOX reaction	This is the overall ionic reaction that shows both reduction and oxidation processes combined together into one equation.

D Assessment of this Topic

This topic is assessed by informal and control tests as well as in the end of year examinations, and also in grade 12.

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

E Breakdown of Topic and Targeted Support Offered

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

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
6 hours	Acids and Bases	92	a. The Arrhenius and Lowry-Brønsted acid-base models. b. Conjugate acid-base pairs. c. Ampholytes. d. Common acids and bases. e. Acid-base reactions. f. Acid-base indicators.
	Redox reactions	93	a. Oxidation numbers and the application of oxidation numbers. b. Introduction to REDOX reactions. c. The concepts of oxidising and reducing agents. d. Describing oxidation-reduction reactions in terms of involving changes in oxidation numbers. e. Balance redox reaction equations by using oxidation numbers via the ion-electron method.

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F Targeted Support per Sub-topic

1. ACID – BASE THEORIES

INTRODUCTION

In order to understand how acids and bases work within chemical systems, it is important for learners to know what is meant by an acid and a base and how chemical compounds are classified as acids or bases.

CONCEPT EXPLANATION AND CLARIFICATION: THE ARRHENIUS AND LOWRY-BRØNSTED ACID-BASE MODELS

THE ARRHENIUS MODEL

The Swedish chemist, Svante Arrhenius, was the first person to come up with a model to explain the difference between acids and bases. According to Arrhenius's theory:

- Acids are substances that produce hydrogen ions (hydronium ions, H_3O^+) in solution.
- Bases are substances that produce hydroxide ions (OH^-) in solution.

Show learners examples:

1. ACID: $HCl \longrightarrow H^+(aq) + Cl^-(aq)$ This process is known as **ionisation.**
2. BASE: $NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq)$ This process is known as **dissociation.**

It is very important for the learners to know the difference between ionisation and dissociation.

***Ionisation*:** The process whereby covalent molecules produce ions in solution for the first time.

***Dissociation*:** The process where ionic compounds break up into their individual ions in solution.

THE LOWRY-BRØNSTED MODEL

This model followed the Arrhenius model in around 1923 where the two scientists, Thomas Lowry and Johannes Brønsted improved on the ideas of Arrhenius. Arrhenius's model is limited in that it only explains the behaviour of acids and bases when dissolved in water, whereas Lowry and Brønsted were able to explain acids and bases in all phases (solid, liquid and gases), hence the improvement.

Note: Brønsted and Lowry each worked independently, and both of them came up with the same theory which they presented to the IUPAC conference in the same year. That is why both their names are used to describe this theory.

According to the Lowry-Brønsted theory:

- Acids are proton donors
- Bases are proton acceptors

Lowry and Brønsted refined their theory based on the formation of the hydrogen ion (H^+). The hydrogen ion is essentially a proton (a hydrogen atom without an electron). Thus, if an acidic substance reacts, a hydrogen ion is released in the reaction. In other words, it is donated from the parent molecule. A proton cannot exist by itself, is highly reactive and will react with another molecule which then becomes the proton acceptor which is the base. According to the Lowry-Brønsted theory, there is a simultaneous exchange of protons (H^+ ions). Reactions of this type can be classified as **acid-base reactions** and the exchange of protons is known as **protolysis**.

Example:

$$HCl + NH_3 \rightleftharpoons NH_4^+ + Cl^-$$

Here the learners should be able to see that the HCl donates its proton to the NH_3 molecule, hence HCl is acting as the acid (proton donor) and NH_3 is acting as the base (proton acceptor). We can see many other examples of these acid-base reactions happening and it is important for the learners to recognise the proton exchange taking place.

IONISATION REACTION EQUATIONS OF MOLECULAR ACIDS AND MOLECULAR BASES IN WATER

Additional examples are the ionisation equations of acids and bases molecules in water. These form **aqueous solutions** as the products are now dissolved in water.

$$HCl(g) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$$ Ionisation Reaction 1

$$NH_3(aq) + H_2O(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$ Ionisation Reaction 2

Here the learners can see that H^+ ions are being exchanged in each of these ionisation reactions. Reaction 1 represents the ionisation of acid (HCl), whereas Reaction 2 represents the ionisation of base (NH_3).

IMPORTANT:

1. The learners need to look carefully at the ionisation of the acid. Arrhenius stated that acids release H^+ ions into solution. Here we can see that the H^+ has reacted with the H_2O molecule to produce the H_3O^+ ion as a product. This is called the **hydronium**

ion and the hydronium ion is the same as a H^+ in solution. Remember that the H^+ ion cannot exist by itself in solution, hence:

$$H^+(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq)$$

Thus, whenever learners see the presence of the hydronium ion (H_3O^+), it represents the proton (H^+) released by the acid molecule confirming the presence of an acidic solution.

2. The learners need to see that in the ionisation of the NH_3 molecule, the NH_3 accepts a proton from the water making the NH_3 a basic substance (proton acceptor). It is also important to see that the OH^- ion is present, confirming the presence of a basic solution.

CONCEPT EXPLANATION AND CLARIFICATION: CONJUGATE ACID-BASE PAIRS

In all acid-base reactions there is a simultaneous donation and acceptance of protons (H^+). From this follows **conjugate acid-base reaction pairs**. Explain to learners that the term '**conjugate**' means that a substance differs from another substance by a single proton. Thus, a conjugate acid-base pair is where the substances differ from each other by a single proton within that acid-base reaction. Consider the example below:

$$HCl(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$$

base 2 (H_2O) — acid 2 (H_3O^+)

acid 1 (HCl) — base 1 (Cl^-)

Here learners need to be shown the two conjugate acid base pairs:

HCl and Cl^- : HCl is the acid and after donating the proton, Cl^-, the conjugate base is formed. Cl^- differs from HCl by a single proton, but is known as a conjugate base as it will act as a base (proton acceptor) in the reverse reaction. (acid 1 ---base 1)

H_2O an H_3O^+: H_2O is the base and after accepting a proton, H_3O^+, the conjugate acid is formed. H_3O^+ differs from H_2O by a single proton but is known as a conjugate acid as it will act as an acid (proton donor) in the reverse reaction. (base 2---acid 2)

Example:

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

acid 2 (H_2O) — base 2 (OH^-)

base 1 (NH_3) — acid 1 (NH_4^+)

Here we can identify the conjugate acid base pairs as follows:

NH_3 and NH_4^+ : NH_3 acts as the base and after accepting the proton, NH_4^+, its conjugate acid, is formed. NH_4^+ differs from NH_3 by a single proton (H^+) and thus will act as an acid (proton donor) in the reverse reaction.
(base 1 --- acid 1)

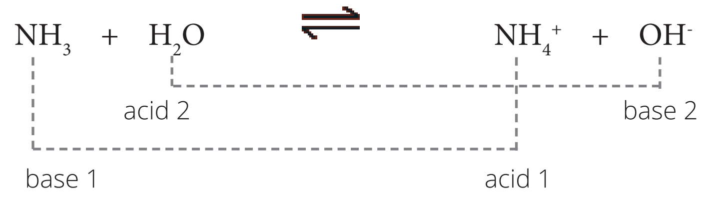
H_2O and OH^- : H_2O is acting as the acid and after donating the proton, OH^-, the conjugate base, is formed. OH^- differs from H_2O by a single proton (H^+) and thus will act as a base (proton acceptor) in the reverse reaction.
(acid 2 ---base 2).

CONCEPT EXPLANATION AND CLARIFICATION: AMPHOLYTES

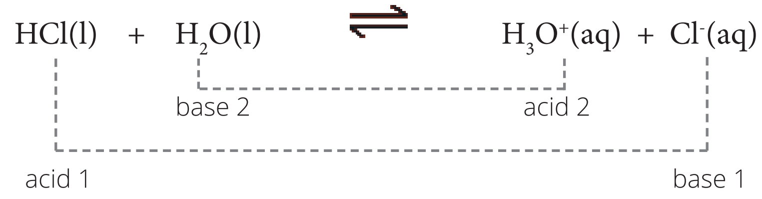
Show learners that water is used in both these acid-base reactions. and draw their attention to the fact that water is acting as a base in the one reaction, but as an acid in the other. Explain to them that substances like this are known as **ampholytes,** that is, substance that are able to act as either an acid or a base. They can either donate or accept protons.

Example:

a)



b)



In (a) H_2O acts as an acid and in (b) H_2O acts as a base.

CONCEPT EXPLANATION AND CLARIFICATION: COMMON ACIDS AND BASES

Learners should be able to differentiate between strong and weak acids or bases:

Strong acids: An acid that will ionise completely in water to produce a high concentration of H_3O^+ ions.

$$HCl(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$$

Explain to learners that the long arrow for the forward reaction implies that the reaction takes place completely. This means that there will be a high concentration of H_3O^+ ions in solution.

Weak acid: An acid that ionises only partially in water to produce a low concentration of H_3O^+ ions.

$$CHJ_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH3COO^-(aq)$$

The longer arrow for the reverse reaction implies that the forward reaction does not take place completely. This means that there will be a low concentration of H_3O^+ ions in solution.

Learners should know the names and chemical formulae of common acids and bases. The lists below show examples of such acids and whether they are weak or strong.

Common acids

FORMULA	NAME OF ACID	
HCl	Hydrochloric acid	These 3 acids are the most commonly used strong acids.
HNO_3	Nitric acid	
H_2SO_4	sulfuric acid	
HF	Hydrofluoric acid	These 4 acids are examples of weak acids.
H_2CO_3	Carbonic acid	
CH_3COOH	Ethanoic acid	
H_3PO_4	Phosphoric acid	

Learners should notice that all acids have at least one hydrogen atom in their structures. Acids can be classified according to the number of hydrogen ions that they are able to donate:

- HCl has one hydrogen in its structure, thus we classify it as a **monoprotic acid**. (mono = one, protic = proton)
- H_2SO_4 has two hydrogen atoms in its structure, thus we classify it as a **diprotic acid**. (di = two, protic = protons)
- H_3PO_4 has three protons in its structure, thus we classify it as a **triprotic acid.** (tri = three, protic = protons)

Diprotic and triprotic acids are are collectively referred to as **polyprotic acids** where the word “poly” means “many”.

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COMMON BASES

FORMULA	NAME OF BASE	
$NaOH$	Sodium hydroxide	These 3 bases are the most commonly used strong bases.
KOH	Potassium hydroxide	
$LiOH$	Lithium hydroxide	
$Ca(OH)_2$	Calcium hydroxide	These 3 bases are examples of weak bases.
$Mg(OH)_2$	Maganesium hydroxide	
NH_4OH	Ammonium hydroxide	

It is suggested that learners learn these different acids and bases and be able to classify them as strong or weak.

Learners should notice that bases have at least one hydroxide ion in their structures.

CONCEPT EXPLANATION AND CLARIFICATION: ACID-BASE REACTIONS

Once learners are comfortable with the introductory concepts of acids and bases, reactions between acids and bases can be introduced.. The general reaction is:

acid + base → salt + water

Regardless of the type of acid or base is used, the products will always be a salt and water. These reactions are known as **neutralisation reactions**.

A salt is the product of an acid-base reaction where the hydrogen in the acid molecule is replaced by the metal cation of the base. For example:

- The salt $NaCl$ is produced from the acid HCl and the base $NaOH$. The H^+ from the HCl is replaced by the Na^+ ion from the $NaOH$.
- The salt K_2SO_4 is produced from the acid H_2SO_4 and the base KOH. The H^+ ions from the H_2SO_4 are replaced by the K^+ ions from the KOH.

There are three types of acid-base reactions:

1. **Acids reacting with metal oxides. (The metal oxide is the base.)**

acid + metal oxide → salt + water

Useful metal oxides are Na_2O, K_2O and CaO.

An example of such a reaction will be: $2HCl + K_2O \rightarrow 2KCl + H_2O$ where KCl is the salt that forms.

Other examples are:

hydrochloric acid + calcium oxide → calcium chloride + water

$$2HCl + CaO \rightarrow CaCl_2 + H_2O$$

sulfuric acid + sodium oxide → sodium sulfate + water

$$H_2SO_4 + Na_2O \rightarrow Na_2SO_4 + H_2O$$

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2. Acids reacting with metal hydroxides. (The metal hydroxide is the base.)

acid + metal hydroxide → salt + water

Useful metal hydroxides are NaOH, KOH and $Ca(OH)_2$

An example of such a reaction will be:

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

where Na_2SO_4 is the salt that forms.

Other examples are:

hydrochloric acid + magnesium hydroxide → magnesium chloride + water

$2HCl + Mg(OH)_2 \rightarrow MgCl_2 + H_2O$

sulfuric acid + potassium hydroxide → potassium sulfate + water

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

3. Acids reaction with metal carbonates. (The metal carbonate is the base.)

acid + metal carbonate → salt + water + carbon dioxide

Useful metal carbonates are Na_2CO_3, $CaCO_3$ and K_2CO_3

An example of such a reaction will be:

$2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + 2H_2O + CO_2$

where $Ca(NO_3)_2$ will be the salt formed. It is important to note that in this type of reaction, CO_2 is formed as an additional product.

Other examples are:

hydrochloric acid + calcium carbonate → calcium chloride + water + CO_2

$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$

sulfuric acid + sodium carbonate → sodium sulfate + water + CO_2

$H_2SO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + H_2O + CO_2$

nitric acid + sodium carbonate → sodium nitrate + water + CO_2

$2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$

CONCEPT EXPLANATION AND CLARIFICATION: ACID-BASE INDICATORS

Indicators provide a practical way to distinguish between an acid and a base. An indicator is a weak organic dye that is able to change colour at different levels of acidity or basicity. In other words, an indicator will be one colour in an acid and another colour in a base.

The table below summarises a few indicators and their colours in acids and bases respectively.

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INDICATOR	COLOUR IN ACID	COLOUR IN BASE	COLOUR AT NEUTRAL POINT
Bromothymol blue	Yellow	Blue	Pale green
Phenolphthalein	Colourless	Pink	Very pale pink
Methyl orange	Red	Yellow	Pale orange
Universal indicator	Red/orange	Blue/purple	Light green

INTRODUCTORY LEVEL QUESTIONS

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

<u>How to tackle these questions in the classroom</u>:

- Work through these examples with learners.
- Discuss with the learners as you complete the question on the chalkboard.
- Learners must copy the questions and answer them correctly in their workbooks.

1. Define an acid and a base in terms of the Lowry-Brønsted theory

Solution

An acid is a proton donor.

A base is a proton donor.

2. Explain the difference between the terms "ionisation" and "dissociation".

Solution

Ionisation: The process whereby a molecular substance dissolves in water to form ions for the first time.

Dissociation: The process whereby an ionic substance dissolves in water to release its individual ions into solution.

3. Complete the following general equations:

3.1 acid + base $\rightarrow$ ________ + ________

3.2 acid + metal carbonate $\rightarrow$ ______ + _______ + ______

Solution

3.1 salt + water

3.2 salt + carbon dioxide + water

4. Write balanced equations for the following acid-base reactions:

4.1 H_2SO_4 + KOH

4.2 HNO_3 + Na_2CO_3

4.3 HCl + MgO

Solution

4.1 $H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

4.2 $2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + CO_2 + H_2O$

4.3 $2HCl + MgO \rightarrow MgCl_2 + H_2O$

5. Name the salts that will be formed in these reactions:

5.1 $HCl + Zn$

5.2 $HNO_3 + Na_2CO_3$

5.3 $H_2SO_4 + MgO$

5.4 $HCl + KOH$

Solution

5.1 zinc chloride

5.2 sodium nitrate

5.3 magnesium sulfate

5.4 potassium chloride

6. Explain the following terms:

6.1 Conjugate acid-base pairs

6.2 Ampholytes

Solution

6.1 A conjugate acid-base pair is where the substances differ from each other by a single proton within that acid-base reaction.

6.2 Substances that are able to act as either an acid or a base. They can either donate or accept protons.

7. What is the difference between a strong acid and a weak acid and give TWO examples of each?

Solution

Strong acid: An acid that will tend toward complete ionisation to produce a large concentration of H_3O^+ ions. e.g. sulfuric acid, nitric acid and/or hydrochloric acid

Weak acid: An acid that ionises partially in water to produce a low concentration of H_3O^+ ions. e.g. carbonic acid, oxalic acid, acetic (or ethanoic) acid, or any other organic acid.

8. What is the conjugate base of the following acids?

8.1 H_2SO_4

8.2 HF

8.3 HSO_4^-

8.4 H_2CO_3

Solution

8.1 HSO_4^-

8.2 F^-

8.3 SO_4^{2-}

8.4 HCO_3^-

9. What is the conjugate acid of the following bases?

9.1 NH_3

9.2 H_2O

9.3 NO_3^-

9.4 $H_2PO_4^-$

Solution

9.1 NH_4^+

9.2 H_3O^+

9.3 HNO_3

9.4 H_3PO_4

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CHALLENGE LEVEL QUESTIONS

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

b. These questions require learners to apply their knowledge and understanding to solve 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 encourag apply their knowledge and understanding to solve more complex problems. e critical thinking and questioning.
- Ensure that learners copy down the questions and answer them correctly in their workbooks.

KEY TEACHING:

a. It is important that learners engage with the more difficult and challenging questions as this will prepare them for the tests and examinations ahead.

b. Conjugate acid-base pairs are tested regularly in Grade 11 and Grade 12, thus practise is needed here.

c. Do not forget to reinforce the writing of balanced chemical equations for the various types of acid-base reactions.

1. Identify the conjugate acid-base pairs in the following reactions:

1.1 $CH_3COO^- + H_2O \rightarrow CH_3COOH + OH^-$

1.2 $NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

Solution

1.1 $CH_3COO^- + H_2O \rightarrow CH_3COOH + OH^-$

acid 2 (H_2O) – base 2 (OH^-)

base 1 (CH_3COO^-) – acid 1 (CH_3COOH)

1.2 $NH_4^+ + H_2O \longrightarrow NH_3 + H_3O^+$

acid 1   base 2   base 1   acid 2

2. Ammonia (NH_3) is an ampholyte. Give an equation for the reaction of ammonia with water when ammonia acts as:

2.1 An acid.

2.2 A base.

Solution

2.1 $NH_3 + H_2O \longrightarrow NH_2^- + H_3O^+$

acid 1   base 2   base 1   acid 2

2.2 $NH_3 + H_2O \quad NH_4^+ + OH^-$

base 1   acid 2   acid 1   base 2

3. Write balanced equations for the following acid-base reactions:

3.1 nitric acid + sodium oxide

3.2 hydrochloric acid + potassium carbonate

3.3 acetic acid + calcium hydroxide

Solution

3.1 $2HNO_3 + Na_2O \longrightarrow 2NaNO_3 + H_2O$

3.2 $2HCl + K_2CO_3 \longrightarrow 2KCl + CO_2 + H_2$

3.3 $CH_3COOH + Ca(OH)_2 \longrightarrow CH_3COOCa + 2H_2O$

CHECKPOINT

At this point in the topic, learners should be able to:

1. describe the acid-base models of Arrhenius and Lowry-Brønsted.
2. describe and explain that acids ionise in water while bases dissociate.
3. describe and explain the formation of conjugate acid-base pairs.
4. describe and explain ampholytes (using appropriate equations).
5. define and explain what are strong bases and weak bases and give examples of each.
6. define and explain the terms: monoprotic and polyprotic acids.
7. recall the different types of acid-base reactions and be able to write balanced equations for all of them.
8. know that acid-base indicators are used to detect acidic and/or basic solutions.

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

Topic 13: Worksheet from the Resource Pack: Types of Reactions: Acids and Bases: Questions 5–13 (Pages 48–49).

- 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 REDOX REACTIONS

INTRODUCTION

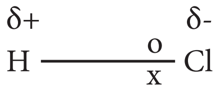
In the previous section, we looked at acid-base reactions. They are characterised by proton (H^+) transfer. REDOX reactions involve the transfer of electrons. These are known as oxidation-reduction reactions or better known as REDOX reactions.

The concept of oxidation numbers, also known as oxidation states provides a very useful technique to keep track of the movement of electrons in a REDOX reaction.

Oxidation numbers will also be used to balance REDOX reaction equations using the ion-electron method.

CONCEPT EXPLANATION AND CLARIFICATION: OXIDATION NUMBERS AND THEIR APPLICATION

Introduce this section by revising a few concepts regarding the electron arrangement in a molecular structure. When a molecule is formed, the arrangement of bonded electrons in the molecule depends entirely on the type of atoms bonded in the molecule. Consider the HCl molecule:



There is an asymmetric distribution of charge in the covalent bond – hence the molecule develops two distinct regions of charge, namely δ^+ and δ^-. The molecule is considered to be POLAR.

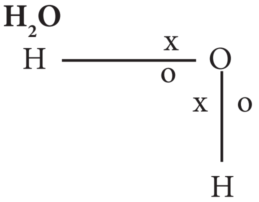
Due to its higher electronegativity, the Cl atom attracts the electrons much more strongly to itself as compared to the H atom. This means that the Cl atom will be electron rich whilst the H atom will be electron deficient. It is this measure of *electron richness or deficiency* that is referred to as the OXIDATION NUMBER (ON) of an element.

> **Oxidation number**: The oxidation number of an element is a number assigned to each element in a compound in order to keep track of the electrons during a reaction.

The Cl atom pulls the bonding pair closer to itself, and becomes "richer" by 1 electron. It therefore has an ON = −1. The H atom has the bonding pair pulled away from it, and becomes "deficient" by 1 electrons, therefore it has an ON = +1.

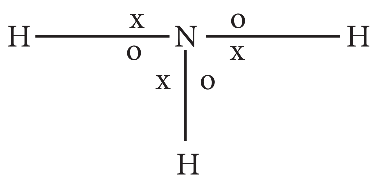
IMPORTANT NOTE: Negative oxidation numbers represent electrons pulled towards atoms; positive oxidation numbers represent electrons pulled away from atoms.

Example 1: Water – H_2O



The O atom pulls both bonding pairs towards itself as it has a higher electronegativity than the H atoms, hence O has an ON = -2 as it has two extra electrons pulled towards itself. Each H atom now has an ON = +1 because each H atom has 1 electron pulled away from itself.

Example 2: Ammonia – NH_3



The N atom has pulls all three bonding pairs towards itself. Hence N has an ON = -3

Each H atom has 1 electron pulled away from itself, thus each H atom has an ON = +1

In summary, the value of the oxidation number of an atom in a molecule is equal to the number of electron pairs it attracts within a bond or the number of electron pairs that are pulled away from it.

SIMPLE RULES FOR DETERMINING OXIDATION NUMBERS IN A MOLECULE

It is far quicker and easier to apply a few simple rules to determine the oxidation number of each atom in a molecule than to try and calculate it from a molecular diagram and comparison of electronegativity. These rules are listed below.

Rules for Oxidation Numbers

- The oxidation number of an atom in an element is zero (ON = 0).
- All Group I metals will always have ON = +1 in the combined state.
- All Group II metals will always have ON = +2 in the combined state.
- The oxygen atom in the combined state most usually has an ON = -2, except when bonded as peroxides e.g. H_2O_2 when it has an ON = -1.
- The hydrogen atom in the combined state will usually have an ON = +1, except when bonded as a hydride e.g. NaH when its ON = -1.
- The sum of all the oxidation numbers in a neutral molecule or compound always adds up to zero.
- The sum of the oxidation numbers of all the atoms in an ion adds up to the charge on the ion.

Learners should be able to apply these rules.

Example 1: What is the oxidation number of S in H_2S?

- H_2S is a molecule and thus the total oxidation number = 0.
- Assign unit oxidation numbers to each known atom in the molecule above the atom while assigning total oxidation numbers to each known atom below the atom.
- H has a unit oxidation number of +1.

Unit	+1	
	H_2S	
Total	**+2**	**= 0**

- Calculate the total oxidation number according to the number of atoms in the molecule. Here the S atom will have total oxidation number of -2 so that the total adds up to 0.

Unit	+1	
	H_2S	
Total	**+2-2**	**= 0**

- Now assign the unit oxidation number by simply dividing the total oxidation number by the total number of the atoms you are trying to determine, hence -2 ÷1 = -2.

Unit +1 <u>- 2</u> ⟵

H_2S

Total **+2-2 = 0**

Oxidation number of S = -2

Example 2: What is the oxidation number of N in N_2O?

Unit <u>+1</u> -2

N_2O

Total $+\frac{2}{2}$ -2 **= 0**

The oxidation number of N in N_2O = +1

Why do we divide by 2 …?

The total ON has been worked out to be +2. Notice that there are two N atoms in the formula. We must work only with **unit ON** – hence we must divide the **total ON** by the no. of atoms in the structure.

Example 3: What is the oxidation number of Mn in $KMnO_4$ and MnO_2?

Unit	+1<u>+7</u> -2	Unit	<u>+4</u> -2
	K Mn O_4		MnO_2
Total	+1 <u>+7</u> -8 = 0	Total	<u>+4</u> -4 = 0
The ON of Mn in $KMnO_4$ = +7		The ON of Mn in MnO_2 = +4	

It is important to note that atoms of the same element can have different oxidation numbers as these atoms can be bonded differently in different substances. Worked example 3 shows this clearly where Mn has oxidation numbers of +7 and +4 respectively.

CONCEPT EXPLANATION AND CLARIFICATION: INTRODUCTION TO REDOX REACTIONS

Explain the meaning of the terms *oxidation* and *reduction*. The easiest way is to do an experiment by burning magnesium ribbon in air and then write down the chemical equation:

$$2Mg + O_2 \longrightarrow 2MgO$$

Show learners that the neutral atoms/molecules in the reactants formed an ionic substance (MgO). Now split the reaction to show the formation of ions:

$Mg \longrightarrow Mg^{2+}$ and $O \longrightarrow O^{2-}$

Point out to learners there was ion formation, and that the ions were formed by either gaining electrons or losing electrons.

Mg^{2+} was formed when the Mg atom lost 2 electrons; O^{2-} was formed when the neutral O_2 molecule gained 2 electrons.

IMPORTANT : Ensure learners can that there was an exchange of electrons: that is, Mg lost electrons and O_2 gained electrons.

$Mg - 2e^- \longrightarrow Mg^{2+}$ and $O + 2e^- \longrightarrow O^{2-}$

This is what we call an electrochemical reaction because an electron transfer took place. In an electrochemical reaction, one element loses electrons and another gains electrons. These processes have special names:

Oxidation: The process whereby electrons are lost in a reaction.

Reduction: The process whereby electrons are gained in a reaction.

An easy way to remember these processes is OIL RIG where OIL stands for Oxidation Is Loss of electrons and RIG stands for Reduction Is Gain of electrons.

Oxidation and reduction processes are represented by half-reactions. The oxidation half-reaction will be

$Mg - 2e^- \longrightarrow Mg^{2+}$.

It can also be written in the following way:

$Mg \longrightarrow Mg^{2+} + 2e^-$.

Both representations have the same meaning, but the second method is more popularly accepted. The reduction half reaction will be:

$O + 2e^- \longrightarrow O^{2-}$.

The accepted way of writing oxidation and reduction half-reactions is as follows:

OX: $Mg \longrightarrow Mg^{2+} + 2e^-$

RED: $O + 2e^- \longrightarrow O^{2-}$

The combined electron transfer that takes place in the reaction is now called a **REDOX** reaction, where RED represents the reduction reaction and OX represents the oxidation reaction. It is important to note that you cannot have an electrochemical reaction that just has the oxidation process without the reduction process, nor a reaction that just has the reduction process without the oxidation process occurring. In other words - **both these reactions must occur simultaneously**.

CONCEPT EXPLANATION AND CLARIFICATION: OXIDISING AND REDUCING AGENTS

A substance that undergoes oxidation loses electrons. These electrons must be gained by another substance, thus we say that there must be a substance assisting the oxidation process by gaining the electrons, hence that substance must be the **oxidising agent.**
In other words, the *oxidising agent will assist the oxidation process by itself undergoing reduction.*

Cl_2 will be the oxidising agent as it assists the oxidation process by gaining 2e-, that is, undergoing reduction.

$$\mathbf{Cl_2 + 2e^- \longrightarrow 2Cl^-}$$

A substance that undergoes reduction gains electrons. These electrons can only be gained if there is another substance that loses electrons i.e. it undergoes oxidation. Thus, the substance undergoing oxidation assists the reduction process by losing electrons, hence it is called the *reducing agent*. In other words, *the reducing agent will assist the reduction process by itself undergoing oxidation*.

Na will be the reducing agent as it assists the reduction process by losing electrons i.e. undergoing oxidation.

$$\mathbf{Na \longrightarrow Na^+ + e^-}$$

CONCEPT EXPLANATION AND CLARIFICATION: DESCRIBING OXIDATION-REDUCTION REACTIONS IN TERMS OF CHANGES IN OXIDATION NUMBERS

Oxidation numbers can easily and conveniently be used to predict whether a particular chemical reaction is in fact an electrochemical (redox) reaction as well as to show how many electrons were involved in the redox reaction. This is done by comparing oxidation numbers of all the chemical species in a chemical reaction. If the oxidation number changes for a particular atom, then there must have been a transfer of electrons – either electrons lost or electrons gained.

Consider the following chemical reaction:

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

Step 1 : Assign ***unit oxidation numbers*** to all the atoms in the chemical species involved in the reaction:

$$\overset{0}{Mg} + 2\overset{1}{H}\overset{-1}{Cl} \longrightarrow \overset{+2}{Mg}\overset{-1}{Cl_2} + \overset{0}{H_2}$$

Step 2 : Identify and link those atoms whose oxidation numbers have changed

$$\overset{0}{Mg} + \overset{1}{H}\overset{-1}{Cl} \longrightarrow \overset{+2}{Mg}\overset{-1}{Cl_2} + \overset{0}{H_2}$$

Step 3 : Identify the electrochemical processes and quantify the number of electrons involved in each process

$$\overset{0}{Mg} + 2\overset{+1\,-1}{HCl} \longrightarrow \overset{+2\,-1}{MgCl_2} + \overset{0}{H_2}$$

Oxidation – loss of $2e^-$ (×1) Reduction – gain of $1e^-$ (×2)

> Cl^- will be a spectator ion in this reaction as its oxidation number does not change.

By tracking the change in oxidation number, you can now write down the half reactions:

Oxidation :	$Mg \longrightarrow Mg^{2+} + 2e^-$	(×1)
Reduction :	$H^+ + e^- \longrightarrow H_2$	(×2)
Net redox reaction:	$Mg + 2H^+ \longrightarrow Mg^{2+} + H_2$	

CONCEPT EXPLANATION AND CLARIFICATION: BALANCING OF REDOX REACTIONS USING OXIDATION NUMBERS VIA THE ION-ELECTRON METHOD

Learners find this section very demanding. It is suggested that teachers follow the steps below carefully and ensure learners practise this technique by doing examples provided in the worksheet.

What will be explained here is the **ion-electron method** of balancing REDOX reactions. It requires learners to have knowledge of:

- Oxidation numbers
- Oxidation and reduction.

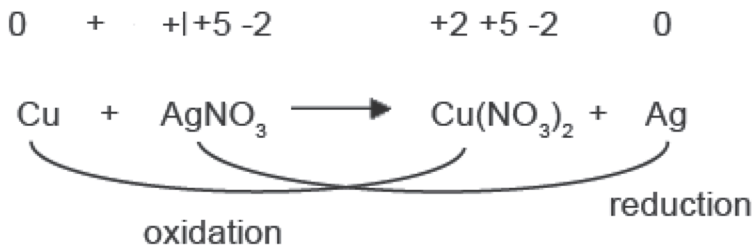
This is a method to balance REDOX reactions and the best way to approach it is to break it down into a series of steps and follow these steps carefully.

Example

Balance the following REDOX reaction using the ion-electron method:

$$Cu + Ag(NO_3)_2 \longrightarrow Cu(NO_3)_2 + Ag$$

Step1: Assign oxidation numbers to each atom in the reaction to identify where oxidation and reduction occur.



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Step 2: Separate the individual species where electron transfer took place into half-reactions.

Oxidation: $Cu \longrightarrow Cu^{2+} + 2e^-$

Reduction : $Ag^+ + e^- \longrightarrow Ag$

Step 3: Balance the half-reactions so that the number of electrons are the same in both half-reactions.

Oxidation: $Cu \longrightarrow Cu^{2+} + 2e^-$

Reduction : $2Ag^+ + 2e^- \longrightarrow 2Ag$ (×2 to balance the number of electrons transferred)

Step 4: Add the two half-reactions to give an overall balanced equation called the net REDOX reaction.

$\mathbf{Cu + 2Ag^+ \longrightarrow Cu^{2+} + 2Ag}$

You will notice that this reaction only includes the species where there is an electron transfer. The other ions in the original equation, namely the nitrate ions (NO_3^-), do not undergo a change in oxidation number, thus they do not get involved in the electron transfer process. These are known as **spectator ions**.

Additional practice examples are provided in the questions that follow this sub-topic as well as in the worksheet in the Resource Pack.

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 content and basic concepts.

How to tackle these questions in the classroom:

- Work through these examples with learners.
- Ensure learners understand each step in the balancing of reactions.
- Learners must copy down the questions and answer them correctly in their workbooks.

1. Define/Explain the following terms:

1.1 Oxidation

1.2 Reduction

1.3 Oxidising agent

1.4 Reducing agent

1.5 Oxidation number

Solution

1.1 The process whereby electrons are lost in a reaction.

1.2 The process whereby electrons are gained in a reaction.

1.3 A substance that will assist the oxidation process by itself undergoing reduction.

1.4 A substance that will assist the reduction process by itself undergoing oxidation.

1.5 The oxidation number of an element is a number assigned to each element in a compound in order to keep track of the electrons during a reaction.

2. Provide oxidation numbers for the underlined atoms in the following substances:

2.1 $H_2\underline{S}$

2.2 $H_2\underline{S}O_4$

2.3 $\underline{N}O_2$

2.4 $\underline{Mn}O_4^-$

2.5 $\underline{Cr}_2O_7^{2-}$

Solution

2.1 -2

2.2 +6

2.3 +4

2.4 +7

2.5 +6

TOPIC 13

3. Consider the following reactions. Using oxidation numbers:

- identify the oxidation and reduction half reactions.
- identify the oxidising and reducing agents.

3.1 $Mg + CrCl_3 \longrightarrow MgCl_2 + Cr$

3.2 $Al + Fe(NO_3)_3 \longrightarrow Al(NO_3)_3 + Fe$

3.3 $Cl_2 + KBr \longrightarrow Br_2 + 2KCl$

Solution

3.1 0 + 3 -1 +2 -1 0

$Mg + CrCl_3 \longrightarrow MgCl_2 + Cr$

oxidation reduction

OX: $Mg \longrightarrow Mg^{2+} + 2e^-$ Reducing agent = Mg

RED: $Cr^{3+} + 3e^- \longrightarrow Cr$ Oxidising agent = $CrCl_3$

3.2 0 +3 +5-2 + 3+5-2 0

$Al + Fe(NO_3)_3 \longrightarrow Al(NO_3)_3 + Fe$

oxidation reduction

OX: $Al \longrightarrow Al^{3+} + 3e^-$ Reducing agent = Al

RED: $Fe^{3+} + 3e^- \longrightarrow Fe$ Oxidising agent = $Fe(NO_3)_3$

3.3 0 + 1-1 0 + 1 -1

$Cl_2 + 2KBr \longrightarrow Br_2 + 2KCl$

reduction oxidation

OX: $2Br^- \longrightarrow Br_2 + 2e^-$ Reducing agent = KBr

RED: $Cl_2 + 2e \longrightarrow 2Cl^-$ Oxidising agent = Cl_2

CHALLENGE LEVEL QUESTIONS

Now that learners have mastered 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.

1. Assign oxidation numbers to the atoms that are underlined in these compounds

1.1 Fe in $\underline{Fe}O$, $\underline{Fe}Cl_3$, $\underline{Fe_2}O_3$ and $\underline{Fe}SO_4$

1.2 C in $\underline{C}O$, $\underline{C}O_2$ and $H\underline{C}O_3^-$

Solution

1.1 FeO: ON = +2 $FeCl_3$: ON = +3+ Fe_2O_3: ON = +3 $FeSO_4$: ON = +2

1.2 CO: ON = +2 CO_2: ON = +4 HCO_3^-: ON = +5

2. A learner prepares sulfur dioxide by adding concentrated sulfuric acid to copper metal according to the following balanced equation:

$$Cu + 2H_2SO_4 \longrightarrow SO_2 + CuSO_4 + 2H_2O$$

2.1 Use oxidation numbers to identify the oxidising and reducing agents in this reaction.

2.2 Write down the oxidation half-reaction.

Solution

2.1 0 +1 +6 -2 +4 -2 +2 +6 -2 +1-2

$$Cu + 2H_2SO_4 \longrightarrow SO_2 + CuSO_4 + 2H_2O$$

reduction

oxidation

ON of Cu has changed from 0 to +2, lost $2e^-$, thus it is the <u>reducing agent.</u>

ON of S in $H_2\underline{S}O_4$ has changed from +6 to +4, thus it gained 2e-; this is the <u>oxidising agent</u>.

2.2 Oxidation: $Cu \longrightarrow Cu^{2+} + 2e^-$

3. Using the ion-electron method, balance the following redox reactions:

3.1 $Mg + Fe(NO_3)_3 \longrightarrow Mg(NO_3)_2 + Fe$

3.2 $Sn + AgNO_3 \longrightarrow Sn(NO_3)_2 + Ag$

Solution

3.1

0 + 3 +5 -2 → +2 +5 -2 0

$Mg + Fe(NO_3)_3 \longrightarrow Mg(NO_3)_2 + Fe$

oxidation reduction

Oxidation: $Mg \longrightarrow Mg^{2+} + 2e^-$ (×3) Here we find the lowest common multiple = 6 electrons transferred

Reduction: $Fe^{3+} + 3e^- \longrightarrow Fe$ (×2)

Net REDOX reaction: $3Mg + 2Fe^{2+} \longrightarrow 3Mg^{2+} + 2Fe$

3.2

0 +1+5-2 → +2+5-2 0

$Sn + AgNO_3 \longrightarrow Sn(NO_3)_2 + Ag$

oxidation reduction

Oxidation: $Sn \longrightarrow Sn^{2+} + 2e^-$

Reduction: $Ag^+ + e^- \longrightarrow Ag$ (×2)

Net REDOX reaction: $Sn + 2Ag^+ \longrightarrow Sn^{2+} + 2Ag$

KEY TEACHING:

a. It is important that learners engage with the more difficult and challenging questions as this will prepare them for the tests and examinations ahead.

b. It is important for learners to keep practising how to allocate oxidation numbers as well as how to use these oxidation numbers to practise the ion-electron method of writing balanced REDOX reactions.

CHECKPOINT

At this point in the topic, learners should be able to:

1. allocate oxidation numbers to atoms in a substance (compound, atom, and/or ion).
2. recall and apply the rules on how to allocate oxidation numbers to each atom.
3. identify and describe REDOX reactions in terms of oxidation and reduction processes.
4. define and identify oxidising and reducing agents.
5. determine oxidation and reduction in a chemical reaction by looking at the change in oxidation numbers of the reactants and products.
6. use the ion-electron method to balance REDOX reactions.

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

Topic 13: Worksheet from the Resource Pack: Types of Reactions: Redox reactions: Questions 1–4 and 14–16 (Pages 47 and 49).

- 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; **Resource Pack: Topic 13: Types of Reactions: Consolidation Exercise. (Pages 50–52).**
- 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.youtube.com/watch?v=gnbuTl2ariI

   A very good video which explains the concepts of oxidation and reduction.

2. http://freesciencelessons.co.uk/aqa/chemistry/chemistry-2/acids-bases-and-salts/introduction-to-acids-and-alkalis/

   A video that teaches acids and bases/alkalis as well as acid-base indicators.