Interesting Science fact #8

Copper is the only metal that is naturally antibacterial.

PHYSICAL SCIENCES

Content Booklet: Targeted Support

GRADE 11 TERM 2

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.

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

What are the learning programmes?

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

The programme began in 2015 with a small group of schools called the Fresh Start Schools (FSS). 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 scale-up process in its Universalisation Programme and in its Provincialisation Programme.

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

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PROGRAMME ORIENTATION

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

- A Content Booklet: Targeted Support
- Worksheet Booklet
- A Planner & Tracker to help you plan lessons and monitor curriculum coverage
- A Practical Booklet and Videos
- A Set of Posters
- A Formal Assessment Support Booklet

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 memoranda 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 assessment practicals, together with worksheets and memoranda.
9. Providing guidance on how to structure formal assessment tasks.
10. Providing a 'bank' of questions and memoranda that may be used to structure formal assessment tasks.
11. Providing a set of posters with key information to display in the classroom.

PROGRAMME ORIENTATION

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*** to the topic that states how long the topic runs for 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 practise 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 explicitly teach the words and their meanings 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 Booklet.

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 c**oncepts 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 Booklet.
      - 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 Booklet. 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.

PROGRAMME ORIENTATION

THE WORKSHEET BOOKLET

1. The Worksheet Booklet has different worksheets and corresponding memoranda for each topic.

2. First, there is a ***practise 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 ***memorandum*** supplied. Either do this together as a whole class, or display copies of the memorandum 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 memorandum, so that they fully understand how to answer questions in tests and exams.

5. At the end of each topic, there is a ***consolidation worksheet*** and memorandum. This worksheet is a consolidation exercise of all the calculations covered in the topic. The consolidation worksheet is NOT scaffolded and it 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 memorandum.

PROGRAMME ORIENTATION

THE PRACTICALS BOOKLET AND VIDEOS

1. The following practicals 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: Relationship between force and acceleration
   e. Grade 11 Term 2: The effects of intermolecular forces on: BP, MP, surface tension, solubility, capillarity
   f. Grade 12 Term 1: Preparation of esters
   g. Grade 12 Term 2: 1) Titration of oxalic acid against sodium hydroxide
      i. 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 practicals 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 practical worksheets. Learners should complete the worksheet whilst watching the video.

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 videos and posters once.
   a. Make sure you store the videos safely.
   b. It is also important for you to make these posters as durable as possible. Do this by:
      - Writing your name on all posters
      - 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 BOOKLET

1. A separate Assessment Booklet is provided for Grade 10, Grade 11 and Grade 12.

2. These booklets first show you how to structure the formal assessment tasks for each term, according to CAPS requirements.

3. Next, the booklets provide you with a ‘bank’ of sample assessment questions for each topic.

4. This is followed by the memoranda for all the different questions that details the allocation of marks.

5. This booklet gives you all the support required to structure and design different tests and exams correctly.

PHYSICAL SCIENCES 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 Booklet
   d. The Practicals Booklet and Videos
   e. 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, 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 Worksheet Booklet for the topic, including the Consolidation Worksheet.
      - Check your solutions against the memorandum.
      - Make notes in your Planner & Tacker to show where you will include the targeted support teaching and activities.
   c. Now, 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.
      - Make careful notes in your Planner and Tracker of which sections and activities you will teach from the Textbook, and which you will teach from the Content Booklet: Targeted Support.
      - It will strengthen your teaching to use a combination of the two resources, but be careful not to leave anything out!
   d. If the Topic includes one of the Practicals for formal assessment, then consult the Practical Booklet and Video.
      - Complete the worksheet for the practical, whilst watching the video.
      - •Try by all means to set up the practical and to conduct it with your learners. However, if this is not possible, ensure that learners see the video and complete the worksheet

e. 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.

f. 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 practise exercises for each key concept
   - Time to correct and remediate each key concept
   - Time for a consolidation worksheet
   - Time to complete the required practicals

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 PLANNING

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:

EXAM PREPARATION

Note: It is important to start preparing learners for their **exam from the beginning of the term**.

1. Make sure that your learners know exactly when their Physical Science exam will be written.
2. Ask learners to take out their exercise books, and to mark off what must be studied.
    a. Go through all their written work, and get them to tick off the work that they must study and practise.
    b. If learners are missing notes, they must copy the missing work from another learner.
    c. 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.
3. 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 exam. 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 exam.
    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 Booklets**
    a. THE Assessment Booklets that form part of this series may be used as a very useful exam preparation tool.
    b. These booklets include 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. **DBE Grade 12 'Mind the Gap' Study Guides**
    a. Grade 12 learners can access the 'Mind the Gap' Study Guides on the DBE website: https://www.education.gov.za/Curriculum/LearningandTeachingSupportMaterials(LTSM)/MindtheGapStudyGuides.aspx
    b. This series includes Grade 12 study guides for:
        - Physical Science: Physics
        - Physical Science: Chemistry
    c. These guides include an overview of the Grade 12 exam structures, useful study techniques, a guide to questions types, a comprehensive list of question words / terms, as well as a summary of key content and skills.
    d. Consider downloading a copy of these guides, and making copies for Grade 12 learners if possible.
    e. Alternately, tell learners how to access this useful resource.

3. **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 5: Geometrical Optics

A INTRODUCTION

- This topic runs for 10 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 Waves, Sound & Light (Physics).
- Waves, Sound & Light counts as 21,3% in the final exam.
- Geometrical optics counts approximately 12% to 16% of the final examination.
- This is an enjoyable section, with some relatively easy experiments, some challenging calculations, but with a limited number of equations, which makes it easier for the learners.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 11 Physics Examination Data Sheet.
4. Highly recommended: Ray box; rectangular glass block, glass blocks of other shapes, water, paper, pencil, ruler, protractor. If you do not have a ray box, a laser pointer works very well instead.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. A4, 3 Quire exercise book, for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended. Ensure that these are set to 'degrees', not radians or grads.
3. Pen.
4. Additional paper.
5. Pencil and ruler.
6. Protractor.

B SEQUENTIAL TABLE

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
Grade 10	**Grade 11**	**Grade 12**
• Transverse pulses. • Transverse waves. • Longitudinal waves. • Sound. • Electromagnetic radiation.	• Geometrical Optics. • 2D & 3D wavefronts.	• Doppler effect.

C GLOSSARY OF TERMS

TERM	DEFINITION
Law of reflection (from gr 10)	The angle of incidence equals the angle of reflection. $\angle_i = \angle_r$ or $\theta_i = \theta_r$ Also, the incident ray, the reflected ray and the normal all lie on the same plane.
The speed of light (c)	The speed of light is constant in a medium and has a maximum value of $3 \times 10^8 m \cdot s^{-1}$
Refraction	The change of direction of a light ray because its speed changes when it passes from one medium into another. (There are equivalent definitions – but all have three parts i) change in in direction ii) change in speed iii) change in medium.)
Refractive index (n)	$n = \frac{c}{v}$
Optical density	An indication of the ease (speed) with which light travels through a medium. (Note that this is not the same as, or related to, density ($\frac{m}{V}$).
Normal	The line perpendicular to the surface.
Angle of incidence	The angle between the incident ray and the normal.
Angle of refraction	The angle between the refracted ray and the normal.
Snell's Law	$n_1 \sin \theta_1 = n_2 \sin \theta_2$
Critical angle	The angle of incidence which will give an angle of refraction of 90° and the refracted ray is parallel to the boundary between the media.
Medium	The substance through which an energy form (e.g. a wave) passes. The plural is mediums or media.
Transparent medium	A medium through which light can travel.
Opaque medium	A medium through which light cannot travel
Reflection (from gr 10)	When all or part of a pulse or wave changes direction at a boundary between two media and returns into the original medium.
Total internal reflection	When light in a medium of higher optical density reflects off a boundary with no refraction occurring.

D ASSESSMENT OF THIS TOPIC

- This topic is assessed through class tests and/or in the Term 4 examination.
- There may be multiple-choice type questions, match the phrase type questions, or problems to solve, where the learners are expected to show their method, give some explanation and/or write down definitions or laws.
- The determination of critical angle is a recommended informal experiment.

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	Refraction	76	**1. Key concepts and possible misconceptions are clarified and explained:** a. The speed of light b. Refraction c. Optical density and refractive index **2. Calculations, questions and ray diagrams are modelled and practised at different levels:** a. Introduction level calculations involving $n = \frac{c}{v}$; introductory ray diagrams and questions b. Challenge level calculations involving $n = \frac{c}{v}$; ray diagrams and questions
4 hours	Snell's Law	77	**1. Key concepts and possible misconceptions are clarified and explained:** a. Snell's law **2. Calculations, questions and ray diagrams are modelled and practised at different levels:** a. Introduction level calculations involving $n_1 \sin\theta_1 = n_2 \sin\theta_2$; introductory ray diagrams and questions b. Challenge level calculations involving $n_1 \sin\theta_1 = n_2 \sin\theta_2$; ray diagrams and questions
3 hours	Critical angle and total internal reflection	77	**1. Key concepts and possible misconceptions are clarified and explained:** a. Total internal reflection **2. Calculations, questions and ray diagrams are modelled and practised at different levels:** a. Introduction level calculations involving $n_1 \sin\theta_1 = n_2 \sin 90$. b. Challenge level calculations involving $n_1 \sin\theta_1 = n_2 \sin 90$.

F TARGETED SUPPORT PER SUB TOPIC

1. REFRACTION

INTRODUCTION

Before starting refraction, reflection and the law of reflection is revised. While both reflection and refraction are wave properties, it is important to note that particles will undergo similar effects. It is really diffraction and interference (see topic 6) that will prove the wave nature of light. This background may help prepare learners for the concepts in the photo-electric effect in grade 12.

It is very useful to demonstrate this section both with practical demonstrations and experiments (like a pencil in a glass of water) and with a ray box. When dealing with a ray box you will often see both reflection and refraction occurring at the same time – and it is useful to prepare the learners that this can happen. (Sometimes learners think only the one of the other happens.) It is useful to make the room as dark as possible when using a ray box. If you do not have access to a ray box a 'laser pointer' can be used, often they work better in fact.

CONCEPT EXPLANATION AND CLARIFICATION: SPEED OF LIGHT

The <u>speed of light in a vacuum</u> is a constant, normally given as $3 \times 10^8 m \cdot s^{-1}$. However, light changes its speed when it changes media. So it is not actually correct to say that the 'speed of light' is a constant.

CONCEPT EXPLANATION AND CLARIFICATION: REFRACTION

A ray of light will refract towards the normal when entering a more dense optical medium. A ray of light along the normal will not refract. It can be useful to use an analogy here, like a lawn mower going from a patch of short grass (medium 1) to longer grass (medium 2.) the wheel that enters the long grass first is slowed, and so the direction of the lawn mower's movement will change 'towards the normal.' If both front wheels enter at the same time (movement along the normal) they slow down equally and the direction of movement is unaffected, although the lawn mower slows down.

It is important to note that with refraction the speed changes, but the frequency does not. This means that the wavelength has changed. This is different to the Doppler effect (grade 12) where the frequency changes, not the speed.

TOPIC 5: Geometrical Optics

CONCEPT EXPLANATION AND CLARIFICATION: OPTICAL DENSITY AND REFRACTIVE INDEX

Optical density is more of a qualitative comparative concept (glass is optically more dense than water) while the refractive index is a quantitative measure of this. The higher a material's refractive index, the more optically dense it will be. It is important to know that optical density is independent of physical density (the relationship between mass and volume.) For example, sunflower oil (0,9 $g.cm^{-3}$) is less dense than water (1,0 $g.cm^{-3}$), but has a higher refractive index (1,47) than water (1,33) and so sunflower oil is optically more dense.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions with recall of information and calculations that learners will be required to perform at this stage in the 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.

d. Introductory ray diagrams are modelled.

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 the question as well as the solution into their workbook.

1. Define the term refraction.

   Solution

   The change of direction of a light ray because its speed changes when it passes from one medium into another. (The definition must have three parts i) change in in direction ii) change in speed iii) change in medium.)

2. The speed of light in a vacuum in various media is given in the table below:

MATERIAL	SPEED OF LIGHT [$m{\cdot}s^{-1}$]
Vacuum	$3{\times}10^{8}$
Air	$3{\times}10^{8}$
Water	$2,25{\times}10^{8}$
Glass	$1,97{\times}10^{8}$

a. Does light slow down significantly when it enters our atmosphere?

b. Calculate the refractive index for water

c. Calculate the refractive index for glass

d. Which of the three materials (air, water, glass) has the highest optical density?

Solution:

a. No — (in fact it decreases by about 90 km.s^{-1}, a factor of about 0,03%, which is insignificant.)

b. $c = 3\times10^{8}\,m\,s^{-1}; v = 2,25\times10^{8}\,m\,s^{-1}$

$n = \frac{c}{v}$ — Use the formula for n.

$= \frac{3\times10^{8}}{2,25\times10^{8}}$ — Substitute the values.

$= 1,33$ — Calculate the answer. Ensure that the learners enter the values correctly on their calculators (use the 'exponent' button. If they are making errors, it will be more obvious in later calculations, if they have the wrong power of 10.) There is no unit for this answer.

c. $c = 3\times10^{8}\,m\,s^{-1};\ v = 1,97\times10^{8}\,m\,s^{-1}$

$n = \frac{c}{v}$ — The same steps as in part (b.) so the learners can work more independently.

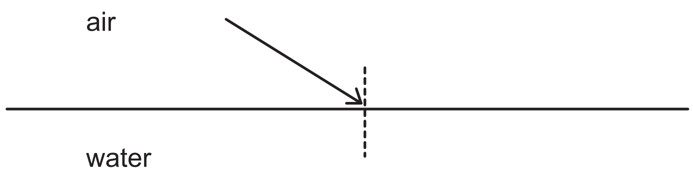
$= \frac{3\times10^{8}}{1,97\times10^{8}}$ — Substitute the values.

$= 1,52$ — There is no unit for this answer. Ensure that the answer is given to two decimal places.

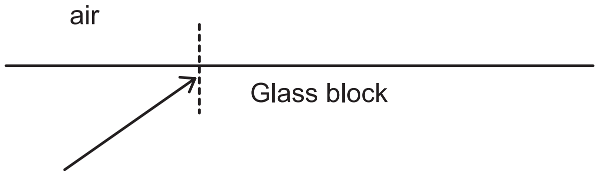
d. Glass — The optical density is related to the refractive index. However, you can point out that the density ($\frac{m}{V}$) is not the same as the optical density.

3. Complete the diagrams

a.

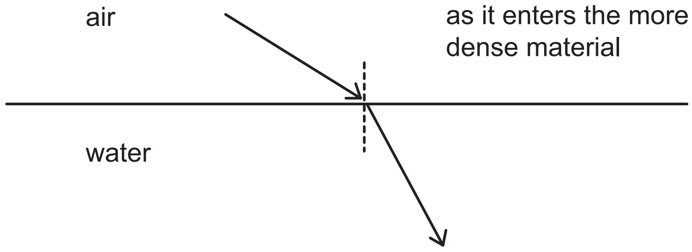


b.



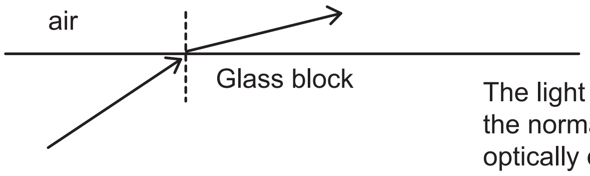
Solution:

a.



It is almost important to see that the ray bends towards from the normal as it enters the more optically dense material

b.



The light ray bends away from the normal as it enters the less optically dense material.

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 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 both the question and the solution into 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 speed of light in the medium.

b. It is often easier for learners to substitute the values into the equation first, for example: $n = \frac{c}{v}$.

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

4. The refractive index for paraffin is 1,44. What is the speed of light in paraffin?

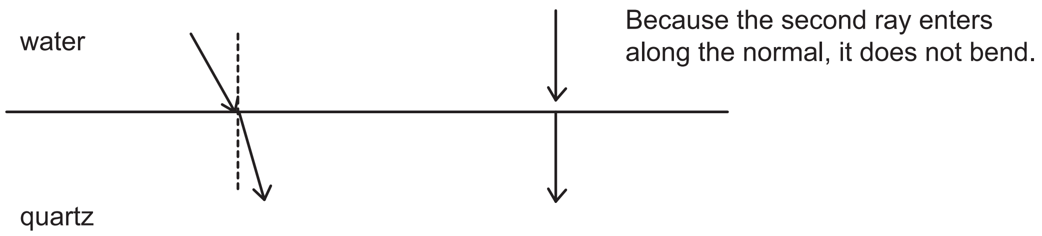
Solution:

$c = 3\times10^{8} m\ s^{-1};\ n = 1,44$

$n = \frac{c}{v}$	Use the formula for n
$1,44 = \frac{3\times10^{8}}{v}$	Substitute the values, they can re-arrange and then substitute, or substitute and then re-arrange, as done here.
$v = \frac{3\times10^{8}}{1,44}$	
$v = 2,08\times10^{8} m\ s^{-1}$	Calculate the answer. Ensure that the learners enter the values correctly on their calculators (use the 'exponent' button. If they are making errors, they will have the wrong power of 10.) Ensure that answer is quoted in scientific notation to 2 decimal places. Use the SI unit for the answer.

5. The refractive index for water is 1,33 and for quartz is 1,46. Complete the following ray diagram:

Solution:



CHECKPOINT

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

1. The calculation of refractive index.
2. The manipulation of the equation to calculate one of the other variables in the equation.
3. The drawing of ray diagrams.

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

WORKSHEET PACK: GEOMETRICAL OPTICS: QUESTIONS 1-5

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

2. SNELL'S LAW

This topic introduces an unusual relationship, which is neither directly proportional nor indirectly proportional, but rather based on a trigonometric function. This relationship is not as easy for the learners to see, so if the angle of incidence is halved, the angle of refraction does not halve, but it does decrease. Further, the learners must be reminded to ensure that their calculators are on "degree" mode (not radian or gradient).

TOPIC 5: Geometrical Optics

INTRODUCTORY LEVEL QUESTIONS AND CALCULATIONS

a. These are the basic questions with recall of information and calculations that learners will be required to perform at this stage in the topic.

b. 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 the question as well as the solution into their workbook.

6. Light goes from air (refractive index of 1,00) into water (refractive index on 1,33). The angle of refraction is 17°, what was the angle of incidence.

Solution:

n_1 = 1,00 (air); n_2 = 1,33 (water); θ_2 = 17°; θ_1 = ?

$n_1 \sin\theta_1 = n_2 \sin\theta_2$	Use the correct formula.
$1,00 \times \sin\theta_1 = 1,33 \times \sin 17°$	Substitute values
$\sin\theta_1 = 1,33 \times 0,2923$	Ensure that they get the same value for sin17° on their calculators
$\sin\theta_1 = 0,3889$	Simplify
$\theta_1 = 22,88°$	Use the "shift" "sin" and "answer" buttons

7. A ray of light, at an angle of incidence of 35°, goes from sunflower oil to air (refractive index =1,00) at a refracted angle of 57,5°. What is the refractive index of the sunflower oil?

Solution:

$\theta_1 = 35°; \theta_2 = 5°7,5; n_2 = 1,00;; n_1 = ?$

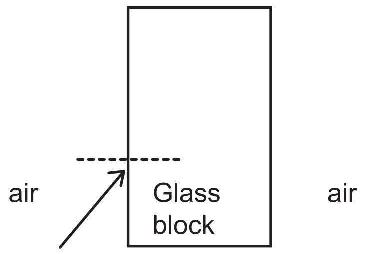
$n_1 \sin\theta_1 = n_2 \sin\theta_2$	Use the correct formula
$n_1 \sin 35 = 1,00 \times \sin 57,5$	Substitute the values
$n_1 \times 0,574 = 0,843$	Simplify

$$n_1 = \frac{0,843}{0,574}$$

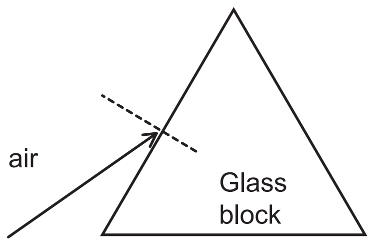
$$= 1,47$$ There is no unit for this answer.

8. Complete the diagrams

a.

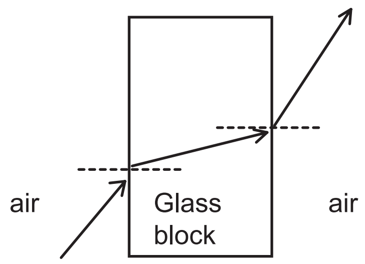


b.



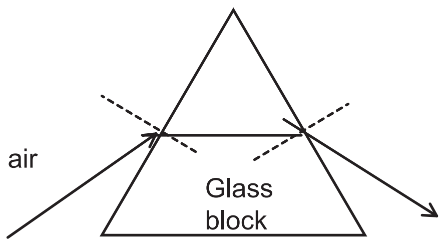
Solution:

a.



It is important to see that the ray bends towards the normal as it enters the more optically dense material, and away from the normal as it exits. Because the block has parallel sides, the incident and emergent rays are parallel.

b.



Again, the ray bends towards the normal as it enters the more optically dense material, and away from the normal as it exits. Because the block doesn't have parallel sides, the incident and emergent rays are not parallel.

CHALLENGE LEVEL QUESTIONS

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

b. These questions require learners to manipulate more data.

How to tackle these questions in the classroom:

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

Key Teaching:

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for mass, or the change in height.

b. It is often easier for learners to substitute the values into the equation first, for example: $n_1 \sin\theta_1 = n_2 \sin\theta_2$.

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

9. The refractive index for paraffin is 1,44 and for water it is 1,33.

   a. If light goes from paraffin to water with an incident angle of 45°, what is the angle of refraction?

   b. If light goes from water to paraffin with an incident angle of 40°, what is the angle of refraction?

Solution:

a. $\theta_1 = 45°; \quad \theta_2 = ?; \quad n_1 = 1,33; \quad n_2 = 1,44$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ Use the correct formula

$1,33 \times \sin 45 = 1,44 \times \sin\theta$ Substitute the values

$0,940 = 1,44 \sin\theta$ Simplify

$\sin\theta = \dfrac{0,940}{1,44}$

$\sin\theta = 0,277$

$\theta = 16,13°$

b. $\theta_1 = 40°; \quad \theta_2 = ?; \quad n_1 = 1,44; \quad n_2 = 1,33$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ Use the correct formula

$1,44 \times \sin 40 = 1,33 \times \sin\theta$ Substitute the values

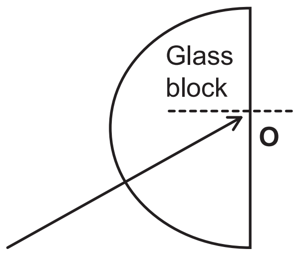
$0,9256 = 1,33 \sin\theta$ Simplify

$\sin\theta = \dfrac{0,926}{1,33}$

$\sin\theta = 0,696$

$\theta = 44,10°$ It is important to see that in a.) the angle of refraction was smaller than the incident angle, but greater in b.)

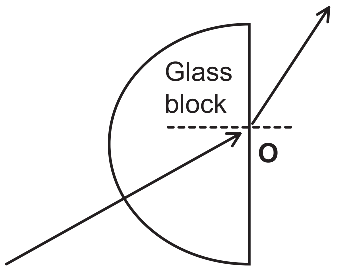
10. a. Complete the following ray diagram:



b. The ray does not bend when it enters the semi-circular block. What does this tell you about the angle of incidence, and the point **O**?

Solution:

a.



b. The angle of incidence is zero (0°)

Otherwise the ray would bend towards the normal.

The point **O** is the centre of the diameter of the circle.

If the incident ray is along the normal, the 'refracted' ray in the block must be along a radius of the circle and so **O** must be the centre.

CHECKPOINT

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

1. The calculations involving Snell's law.
2. Drawing of ray diagrams.

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

WORKSHEET PACK: GEOMETRICAL OPTICS: QUESTIONS 6-7

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

3. CRITICAL ANGLE AND TOTAL INTERNAL REFLECTION

INTRODUCTION

This section provides an easy and enjoyable experiment for informal assessment. For extension, you could ask the more able learners to compare the calculated values (from Snell's Law) to the measured values from the experiment.

CONCEPT EXPLANATION AND CLARIFICATION: TOTAL INTERNAL REFLECTION

If a ray of light enters a medium with a lower refractive index (less optically dense), it bends away from the normal. However, the angle of refraction normally cannot be greater than 90°, because then it has not exited or refracted. Hence, as the angle of incidence increases, there will come a stage when there is no refraction and only reflection (total internal reflection). Total, because all the light is reflected, internal, because the ray remains inside the more optically dense material.

Please note that in these experiments there will be both reflection and refraction, with the reflected ray becoming more dominant as the angle of incidence increases. The reflected ray will obey the law of reflection and the refracted ray will obey Snell's Law until $\theta=90°$, after which the law can no longer apply.

Total internal reflection has many uses, especially in high speed communication (optical fibres/ cables.)

INTRODUCTORY LEVEL QUESTIONS

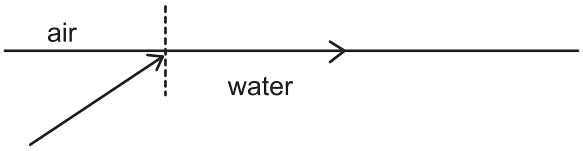
a. The basic questions are to ensure that the learners understand the concept of total internal reflection and the conditions required for total internal reflection to occur.

b. 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 the question as well as the solution into their workbook.

3. A ray of light is going from water to air, as shown in the diagram.



The angle of refraction is 90°.

a. What is the angle of incidence called?

b. What happens if the angle of incidence is increased?

c. What are the conditions that are required for this total internal reflection to occur?

Solution:

a. The critical angle

b. Total internal reflection

c. Light goes from more optically dense to less optically dense material (or from higher to lower refractive index); the angle of incidence is greater than the critical angle.

4. Light travels from a diamond (refractive index =2,42) to air (refractive index =1,00). What is the maximum that the angle of incidence can be before total internal reflection occurs?

Solution:

$\theta_1 = ?;\quad \theta_2 = 90°;\quad n_1 = 2,42;\quad n_2 = 1,00$	Note that the angle of refraction is 90°.
$n_1 \sin\theta_1 = n_2 \sin\theta_2$	Use the correct formula.
$2,42 \times \sin\theta = 1,00 \times \sin 90°$	Substitute the values.
$\sin\theta = \frac{1,00}{2,42}$	Simplify.
$\theta = 24,41$	This small critical angle is part of the reason that diamonds have their sparkle.

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 both the question and the solution into their workbooks.

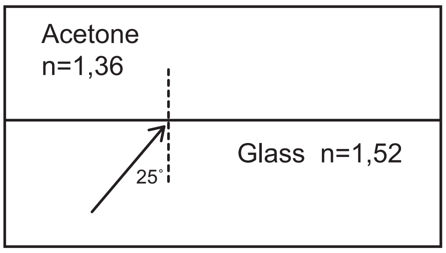
Key Teaching:

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for mass, or the change in height.

b. It is often easier for learners to substitute the values into the equation first, for example: $n_1 \sin\theta_1 = n_2 \sin 90$.

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

5. In the diagram below (not to scale), a ray of light is travelling from glass towards the boundary with acetone



a. Write down the equation for Snell's Law.

b. Calculate the critical angle for light going from glass into ice.

c. The angle of incidence is 25°. Copy and complete the ray diagram for the ray at the boundary of the glass and acetone.

d. How does the speed of light in the glass compare to speed of light in acetone?

Solution:

a. $n_1 \sin\theta_1 = n_2 \sin\theta_2$

b. $\theta_1 = ?; \quad \theta_2 = 90°; \quad n_1 = 1{,}52; \quad n_2 = 1{,}36$ Note that the angle of refraction is 90°.

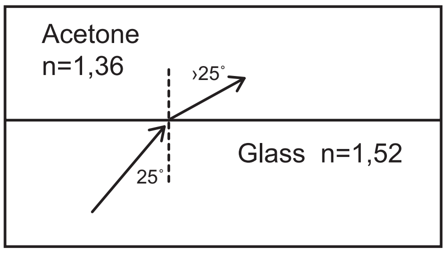
$n_1 \sin\theta_1 = n_2 \sin\theta_2$ Use the correct formula.

$1{,}52 \times \sin\theta = 1{,}36 \times \sin 90°$ Substitute the values.

$\sin\theta = \dfrac{136}{1{,}52}$ Simplify.

$\theta = 63{,}5°$

c.



d. Light travels slower in glass.

CHECKPOINT

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

a. The calculation of critical angle
b. The drawing of ray diagrams with critical angles
c. The practical application of total internal reflection, especially in optical fibres.

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

WORKSHEET PACK: GEOMETRICAL OPTICS WORKSHEET: QUESTIONS 8-9

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

CONSOLIDATION

- Learners can consolidate their learning by completing; **Worksheet Pack: Geometrical Optics: Consolidation Exercise**.
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation worksheet should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It is important to note that this consolidation exercise is NOT scaffolded.**
- **It should not be administered as a test, as the level of the work may be too high to 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=fjv6gWj1hx4

   Video of refraction experiment with ray box and ripple tanks (about 2 min 30 s)

2. https://www.youtube.com/watch?v=XTMbYDrMr0w

   A useful video to show how to draw ray diagrams from a ray box experiment (about 3 min 30 s)

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

   Video showing a Snell's Law experiment (2 min 55 s.) You can use the measurements to draw up a table and do the analysis of the data.

4. https://www.youtube.com/watch?v=NAaHPRsveJk

   A silent video showing a critical angle experiment (1 min 43 s). You can use the measurements to draw up a table and do the analysis of the data.

TOPIC 6: 2D and 3D Wavefronts

A INTRODUCTION

- This topic runs for 3 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- 2D and 3D wavefronts form part of the content area Waves, Sound & Light (Physics).
- Waves, Sound & Light counts as 21,3% in the final exam.
- 2D and 3D wavefronts counts approximately 7% of the final examination.
- This section forms the basis of understanding diffraction and interference, which are the properties of waves, and prove that light behaves as a wave. This can be compared with the photo-electric effect in grade 12, where is it shown that light can also behave like a particle.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 11 Physics Examination Data Sheet.
4. OPTIONAL: Ripple tank set up with a single slit and/or ray box and diffraction grating with a very dark room.
5. PC or data projector to show videos of experiments (see recommended list at end.)

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. A4, 3 Quire exercise book, for notes and exercises.
2. Scientific calculator – Sharp or Casio calculators are highly recommended.
3. Pen, pencil and eraser.

B SEQUENTIAL TABLE

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
Grade 10	**Grade 11**	**Grade 11-12**
• Transverse pulses. • Transverse waves. • Longitudinal waves. • Sound. • Electromagnetic radiation	• Geometric Optics (topic 5) • Refraction • Snell's Law • Critical angles and total internal reflection	• Doppler effect
• See above	• 2D and 3D wavefronts • Diffraction	• Photoelectric affect

C GLOSSARY OF TERMS

Please note: The highlighted definitions and laws are ones that learners must be able to state and are given in the CAPS document. For examination purposes, learners must know these definitions and laws by heart, and must write them exactly as they appear here.

TERM	DEFINITION
Wavefront	An imaginary line that connects waves that are in phase (e.g. all at the crest of their cycle.)
Huygens' principle	Every point on a wavefront acts as the source of secondary wavelets that spread out in the forward direction with the same speed as the wave.
Diffraction	The ability of a wave to spread out in wavefronts as they pass through a small aperture or around a sharp edge OR The bending of a wave around an obstacle or the corners of a narrow opening.
Superposition	Two (or more) waves that meet at the same point at the same time.
Destructive interference	Two (or more) waves that are totally out of phase meet at a point.
Constructive interference	Two (or more) waves that are exactly in phase meet at a point.
Nodal line	A line in an interference pattern where destructive interference takes place.

D ASSESSMENT OF THIS TOPIC

- In the midyear and final examinations
- Possibly in a control test

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	Diffraction	78	**1. Key concepts and possible misconceptions are clarified and explained:** a. Huygens' principle b. Diffraction **2. Calculations, questions and ray diagrams are modelled and practised at different levels:** a. Introductory question on concepts, including a revision of interference, also diffraction and Huygens' principle. b. Challenge level questions applying the concepts to a wider context with both water and light waves.

TOPIC 6: 2D and 3D Wavefronts

F TARGETED SUPPORT PER SUB TOPIC

1. 2D AND 3D WAVEFRONTS

INTRODUCTION

In this topic, waves are typically depicted quite differently from how they are shown in Geometric Optics. There, the emphasis was on ray diagrams and not on the ‘wave-nature’ of the light ray. In this section, learners will examine the wave nature of the light, and view waves both from a ‘side-view’ and look at wave patterns from ‘above.’ Making this difference explicit will help some learners, especially the more advanced learners.

CONCEPT EXPLANATION AND CLARIFICATION:

Huygens’ Principle: each wave front is seen as being made up of an infinite number of mini-waves, each *cancelling each other* (by destructive interference) for most of the wave, but *reinforcing each other* (by constructive interference) where they are in phase, giving rise to a single wave front. Formally, this is stated as “*every point on a wavefront acts as the source of secondary wavelets that spread out in the forward direction with the same speed as the wave.”* However, its importance is seen when the wavelet is removed from an area, for example by the wave going through a slit.

Diffraction: the spreading of a wave which has passed through an aperture, or past a sharp edge. Diffraction gives rise to a typical diffraction pattern, which can be seen with both water waves and light, and thus demonstrates the wave nature of light. The extent or degree of diffraction depends upon both the wavelength and the width of the slit giving rise to the diffraction. The degree of diffraction is directly proportional to the wavelength of the wave and inversely proportional to the width of the slit. Different colours of light (with different wavelengths) will thus show differing degrees of diffraction, with the colours with a longer wavelength diffracting more.

TOPIC 6: 2D and 3D Wavefronts

INTRODUCTORY LEVEL QUESTIONS

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

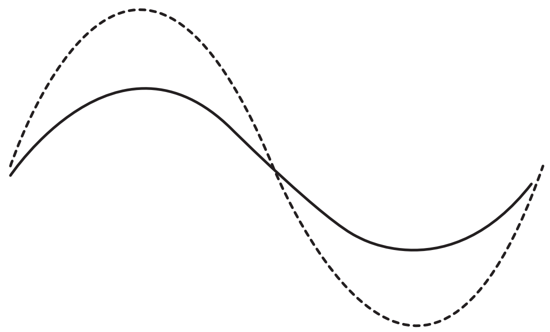
b. These are the basic calculations that learners will be required to perform at this stage in the topic.

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 the question as well as the solution into their workbook.

1. Consider the wave patterns given below:

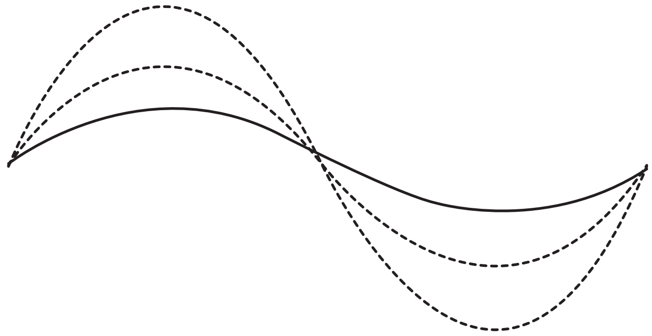


a. Draw the resulting wave pattern from these two waves, which are in phase with each other.

b. What is the interaction of these waves called?

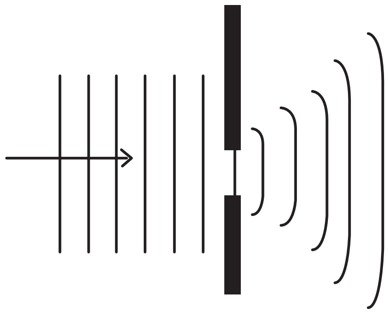
Solution:

a. Although destructive and constructive inference are not directly examined in this section, it is very useful to do some easy revision examples. These are needed to explain Huygens' principle, and especially the diffraction pattern of light. These examples will help the learners to understand these concepts. Thus, the resultant wave will be bigger than the other 2.



b. Constructive interference

2. A wave passes through a narrow gap as pictured below.

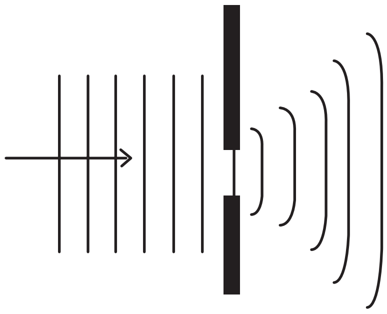


a. Using the diagram above, explain the concept of diffraction

b. The wavelength of the incoming waves is decreased. Would the waves bend more or less? Use a mathematical expression to explain your answer.

c. From the original diagram, the size of the gap is decreased. Would the waves bend more or less? Use a mathematical expression to explain your answer.

Solution:

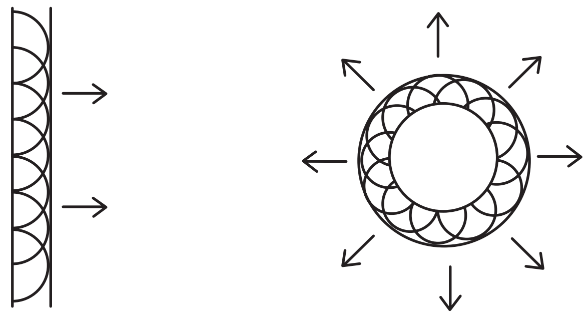


a. Diffraction is the bending of a wave around an obstacle or the corners of a narrow opening. As the waves pass through the narrow gap the 'ends' of the wave start to bend. This causes the wave to spread and to go into the area 'behind' the obstacle.

b. As wavelength decreases, the degree of diffraction decreases, so the waves bend less. Degree of diffraction $\alpha \frac{1}{\lambda}$.

c. If the width if the gap is decreased, the degree of diffraction increases. Thus, the waves would bend more. Degree of diffraction $\alpha\ width$.

3. Huygens stated that a wavefront can be considered to be made of an infinite number of mini-wavelets, as pictured below.



Picture source https://www.ux1.eiu.edu/~cfadd/1160/Ch25WO/Huygn.html

a. Why are the circular waves not seen behind the wavefront?

b. How can these circular waves produce a straight wavefront?

c. How does this explain the bending of a wave around an edge?

Solution:

a. The wavelets have destructive interference everywhere behind the wavefront. Thus, the wavelets ‘cancel’ each other out behind the wavefront and are not seen.

b. The wavefronts do not interfere with each other on the wavefront – thus it maintains its shape (in this case from a straight source) giving a straight wavefront.

c. Every point on the wavefront is a wavelet. The wavelets destructively interfere with each other except on the wavefront. However, when the wavefront passes through a slit, the wavelets on each side are removed, which means that the wavelets spread out and cause interference.

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.

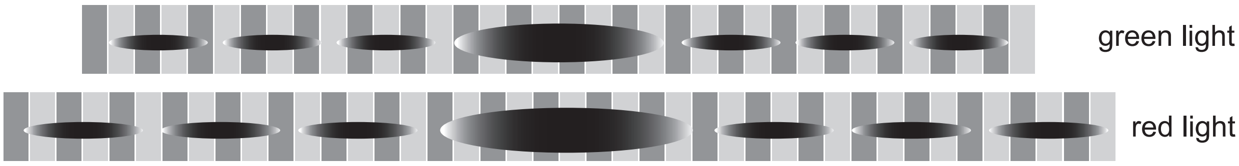
How to tackle these questions in the classroom:

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

Key Teaching:

In these more challenging examples, learners must apply the concepts in a wider variety of contexts.

4. Consider the two diffraction patterns for green and red light, respectively, given below. The patterns were generated with the same diffraction grating.



a. What does the fact that light diffracts prove about the nature of light?

b. Compare the two diffraction patterns – how are they different?

c. In what ways are they the same?

d. What can you conclude about the wavelength of green light compared to the wavelength of red light?

Solution:

a. The diffraction of light shows that it has a <u>wave nature.</u>

b. The second diffraction pattern (red, the lower one) is wider and shows a greater degree of diffraction.

c. They both have a central band and 3 bright bands on either side, which grow fainter as they get further from the centre.

d. Green light has a shorter wavelength than red light (degree of diffraction $\alpha\ \lambda.$)

5. A learner conducts an experiment with light and obtains a diffraction pattern. How will the pattern change if:

   a. The wavelength of the waves is doubled?

   b. The width of the gap is doubled?

   c. Both the wavelength and the width are doubled?

Solution:

a. The diffraction will increase (double).

b. The diffraction will decrease (halve).

c. The diffraction will remain exactly the same (degree of diffraction $\alpha\ \frac{\lambda}{width}$).

6. A girl is standing in the corner of a room, cannot see the speaker in the room next door through the door. But she can still hear the sound. Explain this observation.

Solution:

The sound will diffract as it passes through the doorway. However, light has a much, much shorter wavelength than sound and so the diffraction of the light is negligible. The speaker cannot be seen because there is no clear direct line from the girl through the door to the speaker, but the sound bends to enable her to her the speaker.

TOPIC 6: 2D and 3D Wavefronts

CHECKPOINT

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

a. The factors affecting diffraction.

b. Huygens' principle and how this can explain diffraction.

c. The application of diffraction to water waves (in a ripple tank), sound waves and light.

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

WORKSHEET PACK: 2D AND 3D WAVEFRONTS: QUESTIONS 1-6

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

CONSOLIDATION

- Learners can consolidate their learning by completing; **Worksheet Pack: 2D and 3D wavefronts: Consolidation Exercise.**
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation worksheet should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It is important to note that this consolidation exercise is NOT scaffolded.**
- **It should not be administered as a test, as the level of the work may be too high to in its entirety.**

TOPIC 6: 2D and 3D Wavefronts

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=vqa4L0DuWbM
   Mindset video 8 minutes 22 seconds.
2. https://www.siyavula.com/science/grade-11/06-2d-and-3d-wavefronts/06-2d-and-3d-wavefronts-05.cnxmlplus
   This explanation by Siyavula goes beyond the syllabus but is good further reading to give extra background for a teacher.
3. https://www.youtube.com/watch?v=egRFqSKFmWQ
   This shows single slit diffracting in a ripple tank. The 1st 1:45 is about single slits, and it shows the effect very well, even showing nodal lines (best seen at about 1:27 and 1:35).
4. https://www.youtube.com/watch?v=RXMofhv3JwE
   This video shows the results of single slit light of various widths and also for circular slits (3:18).

TOPIC 7: Ideal Gases and Thermal properties

A INTRODUCTION

- This topic runs for 8 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Energy forms part of the content area (Chemistry).
- Matter & Materials counts as 15% in the final examinations.
- The chemistry part of Matter & Materials (molecular structure, intermolecular forces, and ideal gases) counts approximately 11 % of the final examinations, or 22 % of the chemistry examination. Thus, Ideal gases will count about 13% of the chemistry paper.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 11 Chemistry Examination Data Sheet.
4. Optional Practical requirements: although optional it is highly recommended that some of the experimental work is done. A Boyle's law apparatus may be used, or Charles' law can be shown with a good, well-sealed graduated syringe and ice and water baths, with a thermometer.

CLASSROOM REQUIREMENTS FOR THE LEARNER

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

B SEQUENTIAL TABLE

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
Grade 10	**Grade 11**	**Grade 12**
• States of Matter and Kinetic Molecular theory.	• Ideal Gases. • Motion of particles: kinetic theory of gases • Ideal gas law • Temperature and heating, pressure	• Although not directly related, many of the kinetic theory concepts used here carry forward into Rates of Reactions and Chemical Equilibrium

C

GLOSSARY OF TERMS

Please note: The highlighted definitions and laws are ones that learners must be able to state and are given in the CAPS document. For examination purposes, learners must know these definitions and laws by heart, and must write them exactly as they appear here.

TERM	DEFINITION
Boyle's Law	For a fixed amount of gas, at a constant temperature, volume is inversely proportional to pressure.
Charles' Law	For a fixed amount of gas, at a constant volume, pressure is inversely proportional to absolute temperature.
Gay Lussac's Law	For a fixed amount of gas, at a constant pressure, volume is inversely proportional to absolute temperature.
The Ideal gas law	The amount of a gas is determined by its pressure, volume and temperature. In symbols, PV = nRT.
Ideal gas	A gas which fulfils a number of assumptions and obeys the equation PV = nRT.
Real gas	A gas that occurs in nature and will not obey PV =nRT, especially at high pressure and low temperatures.
Kelvin temperature	0 K is absolute zero, and 273 K = 0°C; T K= t°C +273
particle	The smallest unit in a chemical reaction or physical process.
Pressure	Pressure arises from the collisions of the particles with the walls of the container. It depends on the frequency of the collisions per unit area
Temperature	A measure of hotness or coldness, usually measured with a thermometer. *A measure of the average kinetic energy of the particles.*

D ASSESSMENT OF THIS TOPIC

- This topic is assessed through class tests and/or in the Term 2 examination.
- There may be multiple-choice type questions, match the phrase type questions, or problems to solve, where the learners are expected to show their method, give some explanation and/or write down definitions or laws.
- There are several experiments available, and it is recommended that the Boyle's law experiment is done as an informal assessment.

E

BREAKDOWN OF TOPIC AND TARGETED SUPPORT OFFERED

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

TIME ALLOCATION	SUB TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
1 hour	Motion of particles: Kinetic theory of gases	79	**1. Key concepts and possible misconceptions are clarified and explained:** a. The ideal gas model, and scientific models in general. b. The relationship between temperature and the motion of the particles. c. The relationship between pressure and the motion of the particles.
6 hours	Ideal gas law	80	**2. Key concepts and possible misconceptions are clarified and explained:** a. The three gas laws, which can be combined into the Ideal gas law. b. The importance of the kelvin scale of temperature. **3. Calculations are modelled and practised at different levels.** a. Introductory calculations, largely derived from $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ b. Challenge level calculations, based on PV = nRT and more difficult $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$. c. The conversion of units as needed.
1 hour	Temperature and heating, pressure	81	**4. The relationship between temperature, pressure and the motion of the particles is revised.**

F TARGETED SUPPORT PER SUB TOPIC

1. MOTION OF PARTICLES: KINETIC THEORY OF GASES

INTRODUCTION TO THE ENTIRE TOPIC

These three sections (*Motion of particles*; *Ideal gas law* and *temperature and heating, pressure*) must be taught in an integrated fashion.

This topic relates strongly back to the Kinetic theory of matter from earlier grades, and even to Intermolecular forces from earlier in the grade 11 year. (Real gases deviate from ideal gases when the intermolecular forces become significant).

This topic also allows for the differentiation in the learners' minds between the sub-microscopic world of particles (in this topic a particle is usually a molecule or the atom of a noble gas) and the macroscopic world of our experience. For example, we experience temperature as a perceived coldness or heat, but the explanation for that is found in the average kinetic energy of the particles.

This section also allows learners to refine their idea of a scientific model. The *Ideal gas* is a scientific model which is very useful and enables us to do a number of calculations. However, the model has its limitations (such as conditions of low temperature and high pressure) when the real gas will deviate from the predictions of the ideal gas model. It is important for the learners to note that the model is not wrong, but rather that the limits of the model have been exceeded.

This topic has place for doing good practical work, including analysis of data and graphing, both very important skills for the final grade 12 examination. It may also be useful to point out to learners the advantage of having directly proportional relationships. So, working in Kelvin in Gay Lussac's law (relationship of P to T) enables the direct proportionality $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ to be used.

Note: the CAPS document uses P as the abbreviation for pressure, but some textbooks use p. We will use the CAPS notation.

CONCEPT EXPLANATION AND CLARIFICATION: MOTION OF PARTICLES: KINETIC THEORY OF GASES

This section uses the sub-microscopic world to explain real life phenomena. It is very useful to distinguish clearly between macroscopic events (pressure, temperature) and the sub-microscopic kinetic theory explanation. The learners can see and engage in the one world, and have to imagine the other. If you have access to the internet, it is very useful to show them animations, such as listed in the website(s) at the end of this module.

Pressure is explained by the particles colliding with the walls of the container. Pressure will be increased by increasing the frequency of those collisions (more collisions per second) or the force exerted by the particles on the walls, which is related to their momentum (a greater momentum means that as they change direction when bouncing off the walls, there is a greater nett force exerted on the particles (F_{net} = change in momentum/time) and by the particles on the walls of the container. The average momentum of the particles is proportional to their average kinetic energy, which is measured in the macroscopic world by temperature.

CONCEPT EXPLANATION AND CLARIFICATION: IDEAL AND REAL GASES

The idea of an ideal gas is a theoretical model, which enables us to make accurate predictions about the behaviour of a gas. It makes certain assumptions, the most important of which are:

1. *The particles are identical and are in constant motion.* This assumption makes the mathematics behind the ideal gas theory easier to work with, but doesn't really affect the learners' understanding.
2. *The gas particles are small and their volume is negligible*. This is an important assumption – it is true for real gases at high temperatures and low pressures.
3. *There are no intermolecular forces between the particles and they move in a straight line between collisions.* The lack of intermolecular forces is true in real gases at high temperatures and low pressures.
4. *The collisions between the particles, or the particles and the walls of the container are perfectly elastic* i.e. there is no loss of total kinetic energy.
5. *The gas fills the whole space available to it.* This will be important in some calculations, such as when a balloon or syringe expands.

The Ideal gas model works well at high temperatures and low pressures. The value of the 'high' temperature and 'low' pressure will depend on each gas. As long as a gas is quite far from liquefying (this depends on temperature as well as pressure), it will behave ideally. A gas will not behave like an ideal gas at low temperature and high pressure. There are two primary reasons for this:

- The intermolecular forces become significant and can no longer be ignored (which is obviously what happens when a substance liquefies).
- The volume of the particles becomes significant. The volume of the particles is most significant at high pressures.

TOPIC 7: Ideal Gases and Thermal properties

CHALLENGE LEVEL QUESTIONS

a. These are the basic questions with recall of information that learners will be required to perform at this stage in the topic.

b. Their purpose is to familiarise the learners with the assumptions and definitions used in this section, 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 the question as well as the solution into their workbook.

1. State the assumptions of the Ideal gas model

   Solution:

   - The particles are identical and are in constant motion.
   - The gas particles are small and their volume is negligible.
   - There are no intermolecular forces between the particles and they move in a straight line between collisions.
   - The collisions between the particles, or the particles and the walls of the container are perfectly elastic.

2. The temperature of a sample of gas is increased.

   a. Explain, using the kinetic theory, what happens to the average speed of the molecules of the gas.

   b. State what happens to the pressure, assuming the volume of the container remains constant.

   c. Explain your answer to (b) above, in terms of the kinetic theory.

   Solution:

   a. The average speed of the molecules will increase. (This is because temperature is a measure the average kinetic energy, which is $\frac{1}{2}mv^2$)

b. The pressure will increase.

c. The molecules will move more quickly, so they will collide with the walls of the container more frequently (i.e. more collisions per unit time.) Also, because their speed, on average, is higher, they will have a greater average momentum and change in momentum - so exert a greater force of the walls of the container. (Note it is very important that the learners understand that it is not sufficient to speak of the 'number of collisions' but the 'number of collisions per unit time' or 'frequency of collisions' is required. These ideas are also important in the Rate of reactions section in grade 12.)

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 give explanations in greater detail.

How to tackle these questions in the classroom:

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

Key Teaching:

a. In these more challenging examples, learners must see the limitations of scientific models.

b. Learners also are encouraged to predict the cause of a scientific model not being valid under certain conditions.

3. The Ideal gas model is a simplification that we use in science.

   a. Under what conditions will a real gas condense into a liquid?

   b. Will a liquid behave like an ideal gas? Explain.

   Solution:

   a. Low temperature and high pressure.

   b. No, except that both flow, otherwise they behave fairly differently.

4. The volume of an enclosed mass of gas is decreased.

   a. Predict what will happen to the pressure of the gas.

   b. Explain your answer to (a), using the kinetic theory.

   Solution:

   a. The pressure will increase.

   b. Because the volume has decreased, the molecules have less space to move and so they collide more frequently with the wall of the container. Thus, the pressure increases.

CHECKPOINT

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

1. The ideas of the kinetic theory of matter for gases.
2. The relationship between temperature, pressure and the behaviour of the molecules.

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

WORKSHEET PACK: IDEAL GASES AND THERMAL PROPERTIES WORKSHEET: QUESTIONS 1-2

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

TOPIC 7: Ideal Gases and Thermal properties

2. IDEAL GAS LAWS

CONCEPT EXPLANATION AND CLARIFICATION: THE IDEAL GAS LAW

There are 3 gas laws, which can be combined into the ideal gas law, $PV = nRT$. The units for these are interesting, in that temperature must always be measured in kelvin (K) where 0 K = -273°C, but there is variance with the other physical quantities. If R is used, then everything must be measured in SI units (Pa, m^3, mol, K) but in an equation without R consistent and appropriate units can be used. So, volume can be measured as dm^3 or ml or any appropriate unit, as long as the same unit is used for V_1 and V_2. But it may be better, when using the ideal gas law equation, especially for the weaker learners, to select one set of values for pressure and volume for this equation and say that learners must always convert to these units first before using the equation. This is to prevent 'mixing' of incorrect units with one another.

This is a section with strong ties to mathematical concepts such as graphs and the shapes of graphs, direct proportionality and inverse proportionality. All of these proportions can be derived from the Ideal gas law, or from the appropriate specific law. So, considering the relationship between pressure and volume (all other variables will be kept constant, we get $PV = k$. If this is plotted as a pressure against volume graph, we can easily see that the shape is a hyperbola (like xy = k.) From this we can see that pressure is inversely proportional to volume $(P = \frac{1}{V} or\, P \propto \frac{1}{V})$. This means that if pressure doubles, volume halves (or vice-versa).

A very useful form of the equation in solving problems is $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$. This can be used in almost any problem with 'initial and final' conditions, with the variable that doesn't change eliminated, as it is a constant.

Lastly, at least one of the gas laws should be used as the basis for an informal assessment as a practical. Really good data can be obtained and, fairly often, questions will be set on the basis of experimental data.

CHALLENGE LEVEL QUESTIONS

a. These are the basic questions with recall of information and calculations that learners will be required to perform at this stage in the 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.

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 the question as well as the solution into their workbook.

5. Which of the following statements is true for a real gas?

   A There are no forces of attraction between the particles.

   B Collisions between the particles are perfectly elastic.

   C All motion of particles ceases at 0 ˚C.

   D The particles have real volume.

   Solution:

   D – all the other statements (A-C) apply to ideal gases.

6. The kelvin temperature of 80 cm^3 of gas is halved. What will the final volume (in cm^3) of gas be at the new temperature?

   A 20

   B 40

   C 80

   D 160

Solution:

B – V is proportional to T, if T halves, so will V.

7. A test tube contains 5,0 cm^3 helium and is sealed with a moveable wax head. This volume was recorded at sea level when the surrounding temperature was 293 K and the pressure was 100 kPa. A student, keen to study the effect of altitude, carefully drives inland where the pressure is 85 kPa, but the temperature was still 293 K.

   a. Helium is said to display near ideal gas properties. Give two reasons for this.

   b. Calculate the volume of the gas in the test tube inland.

Solution:

a. The volume of the He atoms (molecules) is extremely small; the force of attraction between the atoms is extremely small.

b. $\mathrm{P_1 V_1} = P_2 \mathrm{V_2}$

$$\mathrm{V_2} = \frac{(100)(5,0)}{85}$$

= 5,88 cm^3

8. A particular gas cylinder will explode if the pressure exceeds 14 x 103 kPa. The cylinder has a capacity of 20 dm^3 and it contains 100 mol of a propane and butane mixture. Using appropriate gas law equations, calculate the maximum temperature that the cylinder can be exposed to.

Solution:

$$PV = nRT$$

$$T = \frac{PV}{nR}$$

Note that everything must be in SI units. Here we have used Pa for pressure and m^3 for volume. Consider making this a rule for this equation for learners, to prevent incorrect mixing of units.

$$T_{\max} = \frac{14 \times 10^6 \times 20 \times 10^{-3}}{100 \times 8,31}$$

$$T_{\max} = 337K$$

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 both the question and the solution into their workbooks.

Key Teaching:

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula. They also need to convert to the correct units in certain examples.

b. Learners must convert units if needed. Often it is easier to substitute the values into the equation first before rearranging the equation.

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

d. Learners must be able represent the relationships graphically.

9. Assume that oxygen is an ideal gas and complete the following sketch graph of PV against T for various values of temperature and pressure.

This particular sample of gas has a volume of 3,60 dm^3 at STP.

a. Calculate the value that the slope of the graph should have.

b. At very high pressures, it is found that the PV values for oxygen no longer agree with those expected for an ideal gas. Assuming that no condensation has taken place, how would those PV values deviate?

c. Mention one factor to which the deviation, given above, can be attributed.

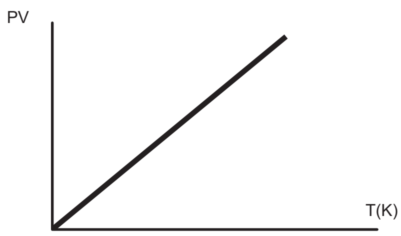
d. When the temperature of a sample of oxygen gas in a 200 cm^3 container is 27 °C, the pressure is 149,58 kPa.

  i. Calculate the number of moles of gas present.

  ii. Thus, show that oxygen gas is diatomic, if 0,348 g of gas is present.

Solution:

a. Sketch graph of PV against T



The value that the slope of the graph should have:

PV = nRT

y = m x

so the slope is nR

n = V/V_0

= 3,6/22,4

= 0,16 mol

nR = 0,16 x 8,314

= 1,34 JK^{-1}

b. At very high pressures, PV values are greater than expected.

c. The real size of the molecules.

d. T = 300 K; V = 0,2 dm^3= 0,2x10^{-3} m^3; p = 149,58 x 10^3 Pa

i. the number of moles of gas present

PV = nRT

n = $\frac{PV}{RT} = \frac{(149\ 580)(0,2x10^{3})}{(8,31)(300)}$

= 0,12 mol

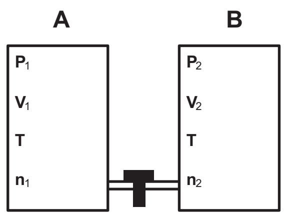
ii. oxygen gas is diatomic

M= m/n = 0,384/0,12 = 32 $g.mol^{-1}$

Therefore oxygen is diatomic as each atom has a molar atomic mass of 16 $g.mol^{-1}$ and 2 x 16 =32.

10. a. What does n represent in the equation PV = nRT?

b. Two vessels **A** and connected by a thin tube and a valve as shown in the sketch. **A** has a volume $\mathbf{V_1}$ while **B** has a volume of $\mathbf{V_2}$. **A** contains air at a pressure of $\mathbf{P_1}$ and **B** has air at a pressure of $\mathbf{P_2}$.



The valve is now opened. If the temperature **T** of the air in the vessel remains constant throughout the experiment, derive the formula for the final pressure **P** in the vessels.

Hint $\mathbf{n_1}$ + $\mathbf{n_2}$ remains constant.

c. What is the relationship between the average kinetic energy of the molecules in a gas and its kelvin temperature?

d. The mass of a helium atom is 4u and that of a methane molecule is 16u. If both gases are at the same temperature, calculate the ratio of the average velocities of their molecules i.e. $\frac{\textit{average velocity of helium atom}}{\textit{average velocity of methane molecule}}$.

Solution:

a. n stands for the number of molecules in the equation PV = nRT.

b. Hint **n1** + **n2** remains constant.

$$n_1 = \frac{P_1V_1}{RT}\, n_2 = \frac{P_2V_2}{RT}$$

$$\text{therefore } n_1 + n_2 = \frac{P_1V_1 + P_2V_2}{RT}$$

$$P_{\text{final}} = \frac{n_{\text{final}}RT}{V_{\text{final}}}$$

$$= \frac{\left(\frac{P_1V_1 + P_2V_2}{RT}\right)RT}{V_1 + V_2}$$

$$= \frac{P_1V_1 + P_2V_2}{V_1 + V_2}$$

c. Kelvin temperature is a measure of the average kinetic energy of the molecules and the kelvin temperature is directly proportional to the average kinetic energy of the molecules.

d. Since they are at the same temperature average kinetic energy of helium atom= average kinetic energy of methane molecule.

$$\frac{\frac{1}{2}mv^2_{\text{helium atom}}}{\frac{1}{2}mv^2_{\text{methane molecule}}} = 1$$

$$\frac{\frac{1}{2}4uv^2_{\text{helium atom}}}{\frac{1}{2}16uv^2_{\text{methane molecule}}} = 1$$

$$\frac{1v^2_{\text{helium atom}}}{4v^2_{\text{methane molecule}}} = 1$$

$$\frac{v^2_{\text{helium atom}}}{v^2_{\text{methane molecule}}} = 4$$

$$\frac{\text{average velocity of helium atom}}{\text{average velocity of methane molecule}} = 2$$

CHECKPOINT

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

1. The calculation involving Boyle's law, Charles' law, Gay Lussac's law and the general gas equation.
2. The manipulation of the equation to calculate one of the other variables in the equation.

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

WORKSHEET PACK: IDEAL GASES AND THERMAL PROPERTIES WORKSHEET: QUESTIONS 4-6

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

3. TEMPERATURE AND HEATING, PRESSURE

INTRODUCTION

This section reinforces the idea of temperature and pressure in terms of the movement of the particles. So doubling temperature doubles the average kinetic energy of the particles, and the average speed of the particles increases by $\sqrt{2}$.

For an explanation of pressure, see the Concept Explanation and Clarification in Motion of particles: Kinetic theory of gases.

TOPIC 7: Ideal Gases and Thermal properties

INTRODUCTORY LEVEL QUESTIONS

a. The basic questions are to ensure that the learners understand the concept how temperature and pressure are related to the behaviour of the particles.

b. There are the calculations based on work already covered, leading into explanations.

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 the question as well as the solution into their workbook.

11. The volume of a particular tyre is 9,0 dm^3. Two thirds of the contents of the tyre is nitrogen gas and one third is oxygen gas.

    a. Which gas exerts a greater pressure in the tyre? Explain your answer.

    b. The tyre is driven for 100 km at high speed and the temperature of the tyre increases. Explain why the tyre (which is slightly elastic) looks more rigid immediately after the journey than before.

    Solution:

    a. Nitrogen exerts a greater pressure because there is more nitrogen gas than oxygen gas ($n \alpha T$).

    b. As temperature increases, so does pressure in a fixed volume environment. This makes the tyre more rigid.

12. At the same temperature, the molecules of all gases have the same:

    A average kinetic energy

    B average velocity

    C average mass

    D volume

    Solution:

    A – from the concept of temperature.

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.

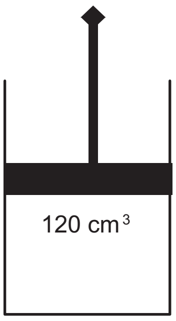
How to tackle these questions in the classroom:

- 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 both the question and the solution into their workbooks.

Key Teaching:

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

13. The sketch below is of a gas syringe. The plunger is free to move. A sample of nitrogen, initially at room temperature is trapped in the syringe at atmospheric pressure, then the end of the syringe is slowly immersed in hot water at 77 ˚C.



a. Explain why the pressure in the syringe remains at atmospheric pressure, even when the end of the syringe is immersed in hot water.

b. Explain, in terms of the kinetic model of matter, why the volume of the gas increases.

Solution:

a. Because the plunger can move, it will adjust so that the forces from inside and outside are equal i.e. the pressures will be equal.

b. As temperature increases, the average kinetic energy of the particles increases. This means that they collide with the walls of the container more frequently and with greater force. This would lead to a greater pressure, but the container can expand, so it does so to enlarge the container to reduce the frequency of the collisions per unit surface area, until the pressures inside and outside are equal.

CHECKPOINT

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

1. The calculations involving all the gas laws.
2. The manipulation of the equation to calculate one of the other variables in the equation
3. The conversion of units when needed.

As this section revises concepts already covered, there are no further worksheet questions.

CONSOLIDATION

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

ADDITIONAL VIEWING / READING

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

1. https://www.youtube.com/watch?v=whic90TMgIs

   Video of Boyle's law experiment, with data to plot (about 5 min 50 s).

2. https://www.youtube.com/watch?v=HrdQ7kJWQfc

   An animation to show how temperature affects pressure (about 30 s).

3. https://www.youtube.com/watch?v=pfxSw9SbX9o

   Video talking about temperature scales (2 min 55 s.)

4. https://phet.colorado.edu/en/simulation/legacy/gas-properties

   A simulation where you can change gas conditions, it shows the particles, but needs Java to be loaded.

TOPIC 8: Quantitative aspects of Chemical Change

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.
- Quantitative aspects of Chemical Change (also called stoichiometry) forms part of the content area Chemical Change.
- Chemical Change counts as 47% in the final chemistry exam.
- Quantitative Chemistry counts approximately 20% to 25 % of the final Chemistry examination.
- This section will be built into many topics in grade 12, and may be examined in Organic chemistry and rates of reactions; it is vital in Chemical equilibrium, especially in the equilibrium constant calculations; it will be examined in the Acids and bases section, and may be asked in the electrochemical section. Further, some aspects of this were dealt with in the previous topic, Ideal gases.

CLASSROOM REQUIREMENTS FOR THE TEACHER

- Chalkboard.
- Chalk.
- Grade 11 Chemistry Examination Data Sheet.

CLASSROOM REQUIREMENTS FOR THE LEARNER

- A4, 3 Quire exercise book, for notes and exercises.
- Scientific calculator is essential – Sharp or Casio calculators are highly recommended.
- Pen.

B SEQUENTIAL TABLE

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
Grade 10	**Grade 11**	**Grade 12**
• Stoichiometry • The mole concept • Molecular and formula masses • Determining the composition of substances • Amount of substance (mole), molar volume of gases, concentration of solutions	• Stoichiometry • Molar volume of gases. • Concentration • Limiting reagents • Volume relationships in gaseous reactions. • Previously in gr 11 in Ideal gases	• These quantitative concepts will be examined in: • Acids and bases • Equilibrium • They may be examined in: • Electrochemical reactions, • Organic chemistry • Reaction rates or • Any other section

C GLOSSARY OF TERMS

Please note: The highlighted definitions and laws are ones that learners must be able to state and are given in the CAPS document. For examination purposes, learners must know these definitions and laws by heart, and must write them exactly as they appear here.

TERM	DEFINITION
Molar volume of a gas	The volume of 1 mole of a gas at STP ($22,4dm^3$)
STP	Standard temperature and pressure $(0°C; 1atm\ pressure\ i.e. 101,3kPa)$
Relative molecular mass/ formula mass	The sum of the masses in a molecule or formula unit
The mole	The amount of substance that has the same number of particles as there are atoms in 12 g of C-12
Avogadro's number	$6,02 \times 10^{23}$
Molar mass	The mass of 1 mole of a substance
Concentration	The number of moles of solute in a given volume of solvent
Standard solution	A (stable) solution of known concentration
Empirical formula	The simplest whole number ratio of the elements making up a compound
Molecular formula	The actual number of atoms making up a molecule
Limiting reagent	The reactant that will be used up totally in a chemical reaction
Theoretical yield	The amount of product that is expected from a reaction
Percentage yield	The ratio of the actual yield to the theoretical yield, expressed as a percentage.

D ASSESSMENT OF THIS TOPIC

- This topic will be assessed in the mid-year examinations and in all examinations going forward. These concepts can be examined in a number of contexts (e.g. acid-base reactions or chemical equilibrium).

TOPIC 8: Quantitative aspects of Chemical Change

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	Molar Volume of gases and concentration of solutions	82	**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. Molar volume of gases c. Concentration of solutions **2. Calculations and questions are modelled and practised at different levels:** a. Introduction level calculations involving the mole concept, volumes of gases at STP and concentrations of solutions b. Challenge level calculations involving the mole concept, volumes of gases at STP and concentrations of solutions
6 hours	More complex stoichiometric calculations	82	**1. Key concepts and possible misconceptions are clarified and explained:** a. Empirical formulae b. Molar volume of gases **2. Calculations and questions are modelled and practised at different levels:** a. Introduction level calculations involving the mole concept, masses, volumes of gases at STP and concentrations of solutions from reaction equations b. Challenge level calculations involving the mole concept, masses, volumes of gases, and concentrations of solutions from reaction equations
3 hours	Volume relationships in gaseous calculations	83	**1. Key concepts and possible misconceptions are clarified and explained:** a. The volumes of gases produced from chemical reactions **2. Calculations and questions are modelled and practised at different levels:** a. Introduction level calculations involving the mole concept, masses, volumes of gases at STP and concentrations of solutions from reaction equations b. Challenge level calculations involving the mole concept, masses, volumes of gases, and concentrations of solutions from reaction equations

F

TARGETED SUPPORT PER SUB TOPIC

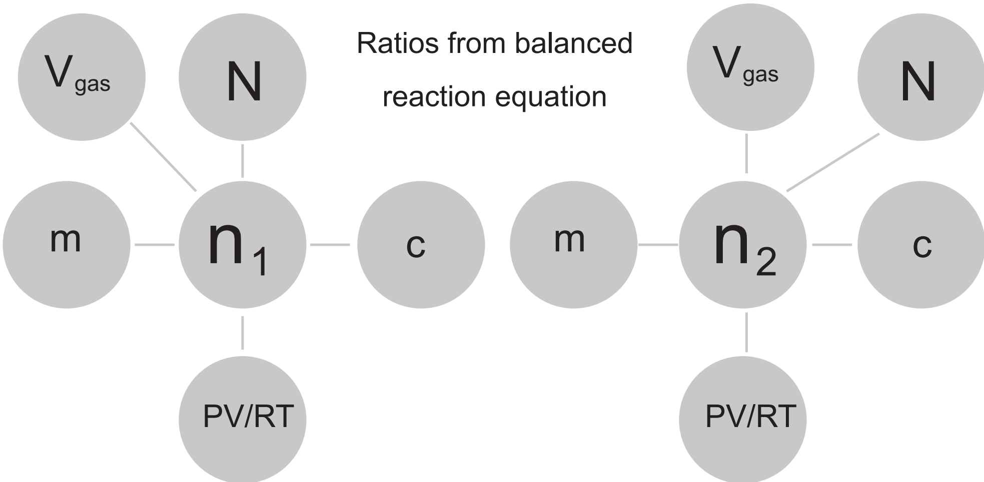
1. THE MOLE CONCEPT

INTRODUCTION

As mentioned earlier, this section is examined in many different sections in the grade 12 examination. So the learners have to be very familiar with the mole concept so that they can use it in different contexts. The mole concept was introduced in grade 10, however, learners often find it an abstract and difficult concept. Avogadro's number, which is associated with the mole, is too large for us to really understand ($6{,}02 \times 10^{23}$ marbles would be 116 times higher than Mount Everest, with a base the approximately size of the USA!) The reason that the mole is so big is because it describes atoms and molecules, which are extremely small. So the mole is a link of the world we can see and measure (like 12 g of carbon, or 22 dm^3 ($22l$) of a gas at STP, to the world we cannot see or measure the world of atoms and molecules.

The diagnostic reports from grade 12 for 2015 and 2016 both show that this section is an area of weakness for many learners, even in simpler areas like the calculation of molar masses. The correct application of ratios from reaction equations is also generally poorly handled. These notes will focus on these types of examples.

The CAPS suggest a flow diagram for stoichiometric calculations.



The word stoichiometry comes from the Greek, meaning to walk (or measure) the elements.

Usually the best way to measure the elements or compounds is by the concept of mole, which actually defines how much of a substance there is present. A good approach to most problems in this section is to convert whatever you are given to the number of moles; use the ratios (often from the chemical reaction) to find the moles of the other substance and then to convert to the desired answer.

TOPIC 8: Quantitative aspects of Chemical Change

CONCEPT EXPLANATION AND CLARIFICATION: MOLAR VOLUME OF GAS AND CONCENTRATION OF SOLUTIONS

From the Ideal gas laws, we can prove that 1 mole of any gas (that is behaving like an ideal gas) will occupy 22,4 dm^3 at STP. The STP values (273 K and 101,3 kPa i.e. 1 atm pressure) are to be learnt. But most importantly, it must be stressed to the learners that the value of 22,4 only applies to a **gas** (at STP.) Many learners try to use this value inappropriately, for example in concentration calculations.

This leads to $n = \frac{V}{22,4}$ for a gas.

CONCEPT EXPLANATION AND CLARIFICATION: GAS REACTIONS

If a there are two gases in a reaction, the ratio of their volumes will be equal to the ratio from the balanced reaction equation. For example:

$N_2(g) + 2O_2(g)\ \ 2NO_2(g)$

1 molecule of N_2 reacts with 2 molecules of O_2 to form 2 molecules of NO_2

1 mole of N_2 reacts with 2 moles of O_2 to form 2 moles of NO_2

and 1 dm^3 of N_2 reacts with 2 dm^3 of O_2 to form 2 dm^3 of NO_2.

This method can be used to solve certain calculations, or one can work out the moles in each case.

CONCEPT EXPLANATION AND CLARIFICATION: CONCENTRATION OF SOLUTIONS

The concentration of solutions is calculated in $mol.dm^{-3}$. The definition for a standard solution is also needed for this section.

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 the question as well as the solution into their workbook.

TOPIC 8: Quantitative aspects of Chemical Change

1. Carbon reacts with oxygen to form carbon dioxide, according to the equation:

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

   5,75 dm^3 of oxygen at STP reacts.

   a. How many moles of oxygen has reacted?

   b. How many moles of carbon dioxide will be formed?

   c. What volume of carbon dioxide will be formed at STP

   Solution:

   a. $n = \frac{V}{22,4} = \frac{5,75}{22,4} = 0,26 mol$

   b. The reaction gives $1O_2 \rightarrow 1\ CO_2$ so 0,26 mol CO_2 forms.

   c. $V = n \times 22,4 = 0,26 \times 22,4 = 5,75 dm^3$ OR from the reaction equation, the mole ratio is equal to the volume ratio, so VCO_2 = 5,75 dm^3.

2. A standard 0,15 $mol.dm^{-3}$ sodium carbonate solution is prepared in a 250 cm^3 volumetric flask.

   a. Give the formula for sodium carbonate

   b. How many moles of sodium carbonate are needed to prepare this solution?

   c. What mass of sodium carbonate is needed to prepare this solution?

   Solution:

   a. Na_2CO_3

   b. $n = cV = 0,15 \times 0,25$ note the conversion of cm^3 to dm^3

   $= 0,0375 mol$

   c. $m = nM = 0,0375 \times (23 \times 2 + 12 + 16 \times 3)$

   =3,975 g

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 both the question and the solution into their workbook.

Key Teaching:

a. In these more challenging examples, learners must manipulate the data and/or change the subject of the formula, to solve for mass or number of moles.

b. Learners must work step by step, often it is easier to substitute the values into the equation first.

3. 64 g of oxygen gas reacts with sulfur, according to the following equation:

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$

What volume of SO2 gas (at STP) will be produced by this reaction?

A 44,8 dm^3

B 1,2 dm^3

C 2 dm^3

D 64 dm^3

Solution:

A 2 mol ($\frac{64}{32,1}$) O_2 react, so 2 mol SO_2 forms.

4. Hydrogen and oxygen react according to the equation: $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

   a. What volume of oxygen will react with 4,0 dm³ of hydrogen at STP?

   a. What volume of water vapour will be produced?

   Solution:

   a. The ratio is 1:2 or 2:4, so 2,0 dm³ O_2 will react OR $n_{O_2} = \frac{V}{22,4} = \frac{4}{22,4} = 0,179mol$

   The ratio is 1:2 so $n_{CO2} = 0,089mol$

   $V = n \times 22,4 = 0,089 \times 22,4 = 2,0dm^3$

   b. The ratio is 2:2 or 4:4; so 4,0 dm³ H_2O will be formed OR $n_{O_2} = 0,179mol$

   The ratio is 2:2 so $n = 0,179mol$

   $V = n \times 22,4 = 0,179 \times 22,4 = 4,0dm^3$

5. A standard solution of $Mg(OH)_2$ is made up so that it will have a volume of 0,25 dm³ and a concentration of 0,5 mol.dm⁻³. The standard solution is made up using distilled water.

   a. **Name** the solute used to make this solution.

   b. Calculate the mass of solid $Mg(OH)_2$ required to make up the standard solution.

   Solution:

   a. magnesium hydroxide

   b. $n = cV = 0,5 \times 0,25\,(both\ subs) = 0,125mol$

   $m = nM = 0,125 \times 58,3 = 7,29g$

CHECKPOINT

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

1. The calculation number of moles from volumes of gases.
2. The calculation number of moles from masses of substances.
3. The use of ratios from reaction equations.
4. The calculations of concentrations of solutions..

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

WORKSHEET PACK: QUANTITATIVE ASPECTS OF CHEMICAL CHANGE WORKSHEET: QUESTIONS 1-4

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

2. STOICHIOMETRIC CALCULATIONS

CONCEPT EXPLANATION AND CLARIFICATION: STOICHIOMETRIC CALCULATIONS

Many learners find these challenging, but they can be fun. Try to link as many as possible to practical activities, by doing titrations and the recommended practical of getting PbO_2 from $Pb(NO_3)_2$.

CONCEPT EXPLANATION AND CLARIFICATION: EMPIRICAL FORMULA

This was covered in grade 10, but many learners find these calculations challenging. If no mass of the substance is given, then learners must treat the sample as if they were given 100 g of the sample, and then work out the moles of each type of element. They must work out the ratio of the elements, beginning by dividing each number of moles by the smallest number. This will give the ratio of the elements in the sample, which is called the empirical (from experiment) formula. It is called this because some chemical analysis experiments give these ratios, from which the empirical formula can be calculated.

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 and to use stoichiometric ratios in increasingly unusual or complex contexts.

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 the question as well as the solution into their workbook.

6. a. Define the term *molar mass* of a substance.

   b. Calculate the number of moles of water in 100 g of water.

   Solution:

   a. The mass of 1 mole of a substance

   b. $n = \frac{m}{M} = \frac{100}{(16+2)} = 5,56mol$

7. Methyl benzoate is a compound used in the manufacture of perfumes. It is found that a 5,325 g sample of methyl benzoate contains 3,758 g of carbon, 0,316 g of hydrogen and 1,251 g of oxygen.

   a. Define the term *empirical formula*.

   b. Determine the empirical formula of methyl benzoate.

   c. If the molar mass of methyl benzoate is 136 g·mol^{-1}, what is its molecular formula?

   Solution:

   a. The simplest whole number ratio of the elements making up a compound.

   b. $n_C = \frac{3,758}{12} = 0,3131mol$; $n_H = \frac{0,316}{1} = 0,316mol$; $n_O = \frac{1,251}{16} = 0,0,078mol$

   $n_C{:}n_H{:}n_O = \frac{0,3131}{0,078}{:}\frac{0,316}{0,078}{:}\frac{0,0,078}{0,078} = 4{:}4{:}1$

   So, the empirical formula is C_4H_4O

   c. $M_{C_4H_4O} = 68g.mol^{-1} = \frac{1}{2}(136)$ So molecular formula is $C_8H_8O_2$

8. A sample of sodium carbonate was reacted with dilute hydrochloric acid in a closed container according to the following equation:

$$Na_2CO_{3\ (s)} \ + \ 2HCl_{\ (aq)} \ \rightarrow \ 2NaCl_{\ (aq)} \ + \ CO_2\ (g) \ + \ H_2O_{\ (l)}$$

The carbon dioxide gas produced was collected at STP and occupied a volume of 0,336 dm^3.

a. Calculate the number of moles of carbon dioxide produced.

b. Calculate the number of carbon dioxide molecules in the sample collected.

c. Calculate the mass of sodium chloride formed in this reaction.

d. If the concentration of the hydrochloric acid is 0,10 $mol.dm^{-3}$ what is the minimum volume of hydrochloric acid needed for the reaction to run to completion?

Solution:

a. $n = \frac{V}{22,4} = \frac{0,336}{22,4} = 0,015 mol$

b. $N = n \times 6,02 \times 10^{23} = 0,015 \times 6,02 x 10^{23} = 9,0 \times 10^{21} molecules$

c. $n_{NaCl} : n_{CO_2} = 2:1 (from\ reaction\ equation)$

$n_{NaCl} = 0,03 mol$

$m = nM = 0,03 \square (23 + 35,45) = 1,755 g$

d. $n_{HCl} : n_{CO_2} = 2:1 (from\ reaction\ equation)$

$n_{HCl} = 0,03 mol$

$V = \frac{n}{c} = \frac{0,03}{0,1} = 0,3 dm^3$

9. 20 g of sodium hydroxide is completely reacted in excess sulphuric acid according to the following balanced equation:

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

a. Name both of the products in this reaction.

b. Calculate how many moles of sodium hydroxide were added to the sulphuric acid.

c. What mass of Na_2SO_4 is produced in this reaction?

Solution:

a. Sodium sulphate; Water

b. M_{NaOH} =23 + 16 + 1 =40 $g.mol^{-1}$

$n = \frac{m}{M} = \frac{20}{40}$ = 0,5 mol

c.

NaOH	*:*	*Na_2SO_4*
2	*:*	*1*
0,5 mol	*:*	*0,25 mol*

$M_{Na_2SO_4}$ =2(23)+32,1+4(16)=142,1 $g.mol^{-1}$

$m = n \times M$ = 0,25 ×142,1

m = 35,5 g

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 both the question and the solution into 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 mass, moles, volume, concentration or percentage yield

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.

10. 50 g of magnesium carbonate is added to 500 cm^3 of hydrochloric acid with a concentration of 0,75 mol.dm^{-3}. The equation for the reaction is given below:

$$MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$$

The carbon dioxide gas is collected at STP.

a. What are the standard conditions used when conducting an experiment at STP?

b. Determine which reactant is the limiting reactant

c. If the percentage yield of the experiment is 85%, calculate the volume of carbon dioxide collected at the end of the experiment at STP.

Solution:

a. Temperature of 0°C; Pressure of 101.3 kPa

b. M_{MgCO_3} =24,3 + 12 + 3 x 16 = 84,3 $g.mol^{-1}$

n_{MgCO_3} = m/M

n_{MgCO_3} =50/84.3

n_{MgCO_3} = 0,593 mol

M_{HCl} = 1 + 35,45 = 36,45 $g.mol^{-1}$

n_{HCl} = c × V

n_{HCl} = 0,75 × 0,5

n_{HCl} = 0,375 mol

0,593 mol $MgCO_3$ would require 1,186 mol HCl in order to completely react. $MgCO_3$ is in excess. **HCl is the limiting reagent.**

c. n_{HCl} = 0,375; so n_{CO_2} = 0,1875

$V_{CO_2} = n \times 22,4 = 4,2 dm^3$

But only 85% yield, so $V = 4,2 \times 85 = 3,57 dm^3$

11. Chlorine gas can be produced by heating calcium hypochlorite, $Ca(OCl)_2$, in dilute hydrochloric acid.

$$Ca(OCl)_2(s) + 2HCl(aq) \rightarrow Ca(OH)_2(aq) + 2Cl_2(g)$$

   a. Calculate the mass of calcium hypochlorite that would be needed to produce 0,096 litres of chlorine gas at STP.

   b. If the calcium hypochlorite used was only 76% pure, what was the mass of the original sample?

   c. What assumption do you have to make in (b) in order to determine the mass of the original sample from the given information?

Solution:

a. $n_{Chlorine} = \frac{V}{22,4} = \frac{0,096}{22,4}$ = 0,00428 mol

   $n_{Calcium\ hypochlorite} : n_{Chlorine} = 1 : 2$

   $n_{Calcium\ hypochlorite}$ = 0,5(0,00428) = 0,00214 mol

   $m_{Calcium\ hypochlorite}$ = nM = (0,00214)(143) = 0,306 g

b. $m_{original}$ = 0,306/0,76 =0,402 g

c. None of the contaminants of the original sample can produce chlorine or any other kind of gas in the above reaction. They have to be totally unreactive to hydrochloric acid.

12. An unknown mass, ***x*** g, of solid sodium hydroxide reacts with 22,18 cm^3 of 0,15 $mol.dm^{-3}$ sulphuric acid according to the equation:

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

   a. How many moles of sulphuric acid are used in this reaction?

   b. How many moles of sodium hydroxide are needed to react completely with the acid?

   c. Calculate the mass of sodium hydroxide that reacted.

Solution:

a. $n_a = c_a V_a = 0,15 \times 0,02218 = 0,0033 mol$

b. $n_b = 2 \times 0,0033 = 0,0066 mol$ *Use ratios (COE from a)*

c. $m = n.M = 0,0066 \times 40 = 0,26 g$ *(COE from b)*

CHECKPOINT

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

1. The calculation of mass, moles, volume, concentration or percentage yield.
2. The manipulation of the reaction equation to calculate ratios of moles of various substances.

3. VOLUME RELATIONSHIPS IN GASEOUS REACTIONS

Concept Explanation and Clarification:

It is remarkable how much more volume a gas takes up than a solid or a gas. 18 g of water goes from about 18 cm^3 ($3\frac{1}{2}$ teaspoons) to 22 dm^3 when going from liquid to gas at STP. It is worthwhile displaying a teaspoon and 22 $1l$ coke bottles to your learners so demonstrate this expansion.

This rapid expansion is used in airbags, where sodium azide reacts to form nitrogen gas (the sodium that forms is further reacted away into a stable compound), according to the equation: $2NaN_3(s) \rightarrow 2Na(s) + 3\ N_2(g)$. This principle is also used in explosive where the rapid formation of a heated gas is used, for example in mining.

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic calculations that learners will be required to perform at this stage in the topic.
b. Their purpose is to familiarise the learners with the equation, but not to change the subject of the 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 the question as well as the solution into their workbook.

13. Ammonium nitrate is the basis of an explosive used in mines. It can decompose according the to the following equation:

    $2NH_4NO_{3(s)} \rightarrow 2N_2 + 4H_2O + O_2$

    All the products are gases.

    a. Calculate how many moles of ammonium nitrate is found in 100 g of the solid.

    b. Find the number of moles that will be formed of:

        i. Nitrogen

        ii. Water

        iii. Oxygen

    c. Thus, calculate the total volume of gas formed at STP

    d. Calculate the total volume of gas formed at 273°C. (Hint: volume is directly proportional to temperature.)

    Solution:

    a. $n = \frac{m}{M} = \frac{100}{(14+4+14+48)} = 1,25mol$

    b. i. N_2: 1,25 mol

        ii. H_2O: 2,5 mol

        iii. O_2: 0,625 mol

    c. $n_{total} = 4,375; V = n \times 22,4 = 8dm^3$

    d. $273^{\circ}\mathrm{C} = 546K; 0^{\circ}\mathrm{C} = 273K;$ thus the temperature doubled. Thus, the volume will double to 16 dm^3.

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 both the question and the solution into 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 mass, moles, volume, concentration or percentage yield

b. Learners must appreciate the substantial increase in volume when solids or liquids react to form gases.

14. A common party trick is to fill balloons with carbon dioxide. Vinegar is poured into a small plastic bottle and the baking soda is placed into the balloon. The mouth of the balloon is then stretched over the bottle opening and the baking soda is allowed to fall into the vinegar, starting the reaction. One of the products, carbon dioxide gas, fills up the balloon, hence blowing it up.

The balanced chemical reaction that occurs when vinegar and baking soda react is as follows:

$$CH_3COOH\ (aq) + NaHCO_3\ (s) \rightarrow CH_3COONa\ (aq) + CO_2\ (g) + H_2O\ (\ell)$$

a. “Baking soda” is the common name for $NaHCO_3$. Give its full chemical name.

b. One teaspoon of baking soda is equivalent to 4 g of $NaHCO_3$. Calculate the number of moles of $NaHCO_3$ in one teaspoon of baking soda (*give your answer to 4 decimal places*).

c. 0,0377 mol of ethanoic acid (CH_3COOH) is poured into the balloon when 45 cm^3 of vinegar is added. Calculate the concentration of ethanoic acid in this sample of vinegar.

Show that if the reaction proceeds as per the quantities given, $NaHCO_3$ is in excess.

d. Assuming that the carbon dioxide gas is the only gas responsible for the filling of the balloon, calculate the expected volume in cm^3 of the balloon at room temperature once the reaction has reached completion. *(Note: V_m = 22,4 dm^3.mol^{-1} at room temperature.)*

The actual volume of the balloon that was blown up was determined to be 750 cm^3.

e. Calculate the percentage yield of the carbon dioxide gas produced in this reaction.

f. Some learners thought that these balloons would float in the same way that helium filled balloons do. Using your knowledge of molar masses, and the equation PV=nRT, predict if the balloons filled with carbon dioxide will float.

Solution:

a. sodium hydrogen carbonate (or sodium bicarbonate, not sodium bicarb)

b. $n(NaHCO_3) = \frac{m}{M}$

$= \frac{4}{84}$

$=$ 0,0476 mol

c. $c_{CH3COOH} = \frac{n}{V}$

$= \frac{0,0377}{3(0,015)}$

$=$ 0,84 mol.dm^{-3}

$n(CH_3COOH)$: $n(NaHCO_3)$

1 : 1

0,0377 : 0,0377 mol $NaHCO_3$ required if CH_3COOH reacts completely, but 0,0476 mol is available, therefore $NaHCO_3$ in excess

d. $n(CH_3COOH)$: $n(CO_2)$ need the ratio

1 : 1

$\therefore n(CO_2) = 0{,}0377$ mol

$V(CO_2)_{theor} = nV_m$

$= 0{,}0377 \times 22{,}4$

$= 0{,}8444\ dm^3$

$= 844{,}48\ cm^3$

e. % yield CO_2 $= \frac{actual\ V}{theoretical\ V} \times 100$

$= \frac{750}{844{,}47} \times 100$ (Fine to convert to other quantities, but units must cancel)

$= 88{,}81\ \%$

f. No, balloons filled with CO_2 won't float as CO_2 is more dense than air. This is because the volume of the balloon depends on the number of moles, the pressure and the temperature. (from PV = nRT.) But the same number of moles of CO_2 ($M = 44\ g.mol^{-1}$) will be much heavier than that of Helium ($M = 2\ g.mol^{-1}$)

CHECKPOINT

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

1. The calculation of mass, moles, volume, concentration and percentage yield
2. The manipulation of the reaction equation to calculate ratios of moles of various substances
3. The change in volume in reactions which produce gaseous products

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

WORKSHEET PACK: QUANTITATIVE ASPECTS OF CHEMICAL CHANGE WORKSHEET: QUESTIONS 5-8

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

CONSOLIDATION

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

ADDITIONAL VIEWING / READING

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

1. https://chem.libretexts.org/Core/Inorganic_Chemistry/Chemical_Reactions/Stoichiometry_and_Balancing_Reactions
   Has a useful, slightly different approach to stoichiometry.

2. https://www.youtube.com/watch?v=UL1jmJaUkaQ
   An unusual and fun video-clip, which deals with an introduction to stoichiometry. This is useful to watch, although long at 12:46. Some aspects are not very relevant to what is covered in this section, but is useful revision. It is best to watch just the 1st few minutes, as some the later methods are not standard in CAPS.

3. https://www.youtube.com/watch?v=XnfATaoubzA
   Also long, and not as exciting to watch (15:45) but a thorough approach, with a slightly different algebraic method.