PHYSICAL SCIENCES
Grade 11
TERM 1
Content Booklet
TARGETED SUPPORT

Contents

A Message from the NECT

NATIONAL EDUCATION COLLABORATION TRUST

DEAR TEACHERS

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

WHAT IS NECT?

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

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

WHAT ARE THE LEARNING PROGRAMMES?

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

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

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

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

www.nect.org.za

PROGRAMME ORIENTATION

Programme Orientation

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

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

OVERVIEW AND APPROACH OF PROGRAMME

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

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

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

CONTENT BOOKLET: TARGETED SUPPORT

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

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

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

   The table also clearly states the ***targeted support*** that is offered in this booklet. You will see that there are three main kinds of support offered:

   a. Key concepts are clarified and explained.
   b. Possible misconceptions are clarified and explained.

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

8. After this introduction, the ***targeted support for each sub-topic*** commences. This generally follows the same routine:

   a. A key concept or key concepts are clarified and explained. It may be useful for you to work through this carefully with learners, and do any demonstrations that are included.

   b. Questions related to the key concepts are worked and explained.
   - These questions may be done at introductory level, at challenge level, or both.
   - It is important to expose learners to **challenge level questions**, as this is often how questions are presented in exams.
   - These questions also challenge learners to apply what they have learnt about key concepts. Learners are, essentially, challenged to think at a critical and analytical level when solving these problems.
   - Please note that when calculations are done at challenge level, the key teaching points are identified.
   - Make sure that you effectively share these key teaching points with learners, as this can make all the difference as to whether learners cope with challenge level questions or not.

   c. At key points in the topic, checkpoints are introduced.
   - These checkpoints involve asking learners questions to check that they understand everything to that point.
   - The checkpoints also refer to a worksheet activity that is included in the Worksheet Section of the Resource Pack.
   - Use checkpoints to ascertain whether more consolidation must be done, or if your learners are ready to move to the next key concept.

9. Every topic ends with a ***consolidation exercise*** in the Worksheet Section of the Resource Pack. This exercise is not scaffolded as a test, it is just a consolidation of everything covered in this programme for that topic.

10. Finally, a section on ***additional reading / viewing*** rounds off every topic. This is a series of web links related to the topic. Please visit these links to learn more about the topic, and to discover interesting video clips, tutorials and other items that you may want to share with your learners.

THE WORKSHEET SECTION OF THE RESOURCE PACK

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

THE PLANNER & TRACKER

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

THE FORMAL EXPERIMENTS AND/OR INVESTIGATIONS AND DVD

1. The following experiments or investigations must be completed as part of the formal assessment programme:
   a. Grade 10 Term 1: Heating and cooling curve of water
   b. Grade 10 Term 2: Electric circuits with resistors in series and parallel – measuring potential difference and current
   c. Grade 10 Term 3: Acceleration
   d. Grade 11 Term 1: Verification of Newton's 2nd Law: Relationship between force and acceleration
   e. Grade 11 Term 2: The effects of intermolecular forces on: BP, MP, surface tension, solubility, capillarity
   f. Grade 12 Term 1: Preparation of esters
   g. Grade 12 Term 2: 1) Titration of oxalic acid against sodium hydroxide
      2) Conservation of linear momentum
   h. Grade 12 Term 3: a) Determine the internal resistance of a battery
      b) Set up a series-parallel network with known resistor. Determine the equivalent resistance using an ammeter and a voltmeter and compare with the theoretical value.
2. Videos of all the listed experiments and investigations are supplied as part of this programme.
3. These videos should ideally be used as a teacher's guide. After watching the video, set up and complete the practical with your learners. However, if this is not possible, then try to show the video to your learners and allow them to record and analyse results on their own.
4. The videos should be used in conjunction with the experiment (or investigation) learners' worksheets. Learners should complete the observations and results section of the worksheet while watching the video, and then work on their own to analyse and interpret these as instructed by the questions that follow on the worksheet.

THE POSTERS

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

THE ASSESSMENT SECTION OF THE RESOURCE PACK

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

Planning and Preparation

1. Get into the habit of planning every topic by using the following documents together:
   a. The Physical Sciences Planner & Tracker
   b. The Content Booklet: Targeted Support
   c. The Worksheet Section of the Resource Pack
   d. Your textbook
2. Planning should always be done well in advance. This gives you the opportunity to not only feel well-prepared but also to ask a colleague for help if any problems arise.
3. Follow these steps as you plan to teach a topic:
   a. **Turn to the relevant section in the Planner & Tracker for your textbook.**
      - Look through the breakdown of lessons for the topic.
      - In pencil, fill in the dates that you plan to teach each lesson. This will help with your sequencing.

   b. **Next, turn to the relevant section in your Textbook.**
      - Read through each key concept in the Textbook.
      - Complete as many examples as possible. This will also help in your teaching – you will remember more points to share with the learners if you have done all of the work yourself.

   c. **Finally, look at the topic in the Content Booklet: Targeted Support.**
      - Read through all the introduction points, including the table that shows the breakdown of lessons, and the targeted support offered.
      - Take note of the targeted support that is offered for each section.
      - Read through the whole topic in the Content Booklet: Targeted Support.
      - Complete all the examples in the Worksheets for the topic, including the Consolidation Exercise.
      - Make notes in your Planner & Tacker to show where you will include the targeted support teaching and activities. You may choose to replace some textbook activities with work from the targeted support programme, but, be careful not to leave anything out!

   d. **Document your lesson plans in the way that you feel most comfortable.**
      - You may like to write notes about your lesson plans in a notebook.
      - You may like to use a standardised template for lesson planning. (A template is provided at the end of this section).
      - Remember to make notes about where you will use the textbook activities, and where you will use the targeted support activities.

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

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

PREPARATION AND ORGANISATION

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

SAMPLE TEMPLATE FOR LESSON PREPARATION

PHYSICAL SCIENCES LESSON PLAN

School	
Teacher's name	
Grade	
Term	
Topic	
Date	
Lesson Duration	

1. CONCEPTS AND SKILLS TO BE ACHIEVED:

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

2. RESOURCES REQUIRED:

3. HOMEWORK REVIEW / REFLECTION:

Exercises to be reviewed and notes:

4. LESSON CONTENT / CONCEPT DEVELOPMENT

Explanation and examples to be done:

5. CLASSWORK ACTIVITY

Resource 1	
Page	
Exercise	
Resource 2	
Page	
Exercise	

Notes:

6. HOMEWORK ALLOCATION

Resource 1	
Page	
Exercise	
Resource 2	
Page	
Exercise	

7. LESSON REFLECTION:

What went well:
What could have gone better:

Creating a Positive Learning Environment

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

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

4. **Correct mistakes clearly, but without derision.** When learners make mistakes, thank them for trying, but point out that a mistake has been made. Correct the mistake clearly and quickly, and then move on. Do not labour the point – learners must see that it is perfectly acceptable to make mistakes as long as one tries.
5. **Tell learners if you do not know something.** Learners appreciate it when teachers are honest, and say things like, 'I'm not really sure. Does anyone else know? Should we look up the answer?'
6. **Model the kind of behaviour you expect in your class.** We often hear the phrase 'respect is earned', or 'respect is a two-way street', but we don't always think about what that means.
   - The simplest explanation is to model the behaviour that you expect from your learners, and to treat them the way that you want to be treated.
   - Be punctual and prepared for lessons; work diligently; keep your space clean, tidy and organised; never use your cell phone in class; look after your apparatus and resources; greet learners; be considerate of their feelings; praise learners for a job well done; thank learners for going the extra mile; and go the extra mile yourself.
   - This may not be reciprocated immediately, but in time, learners will learn from your model, and will begin to behave as you do within your environment.
   - Feel free to hold an open, honest discussion with learners about this concept. Let learners know that you will try to always treat them with consideration and respect, and that you will always work hard for them.
   - Let your learners know that you will appreciate them trying to do the same.
7. **Move around the classroom.** As learners work, walk around the classroom. Use this opportunity to stop and look at individual learner's work. Stop and discuss challenges – help individual learners as much as you can. Look out for problems between learners, and deal with issues that arise. Get to know your learners better. If tension is building between learners, put a stop to the argument. Then, if appropriate, find time for the learners to talk it out while you mediate.
8. **Laugh with your learners.** If you can find something to laugh about with your learners, do so! This is an excellent way to bond with learners, and to make them feel closer to you. Laughter is also an excellent way to break down tensions, and to get learners to relax.
9. **Leave your problems outside of the classroom.** Learners pick up on your stress, anxiety and unhappiness, and this can affect them negatively. Try your best to be in the habit of leaving your problems at the classroom door, and to focus on your learners once you are inside the classroom.

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

TOPIC 1:
Vectors in Two Dimensions

A Introduction

- This topic runs for 4 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Vectors in two dimensions forms part of the content area Mechanics.
- Mechanics counts 45,33 % in the final Grade 11 Paper 1 (Physics) Examination.
- Vectors in two dimensions counts approximately 7,6 % of the final Paper 1 (Physics) Examination.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 11 Physics Examination Data Sheet.
4. Force board, assortment of weights (10 g to 200 g), gut or string, two pulleys.

CLASSROOM REQUIREMENTS FOR THE LEARNER

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

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 10	**GRADE 11**	**GRADE 11 – 12**
• Equality of vectors, negative vectors, addition and subtraction of vectors (in one dimension only). • Defined a resultant vector. • Found the resultant vector graphically using the tail-to-head method as well as by calculation for a maximum of four force vectors in one dimension only. • A frame of reference has an origin and a set of directions e.g. East and West or up and down. • Defined one dimensional motion. • Defined position relative to a reference point and understood that position can be positive or negative. • Defined displacement as a change in position. • Displacement is a vector quantity that points from initial to final position.	• Add co-linear vertical vectors and co-linear horizontal vectors to obtain the net vertical vector (R_y) and net horizontal vector (R_x). • Sketch R_x and R_y on a Cartesian plane. • Determine the magnitude of the resultant using the theorem of Pythagoras. • Find resultant vector graphically using the tail-to-head method as well as by calculation (by component method) for a maximum of four force vectors in both 1-dimension and 2-dimensions. • Understand what is a closed vector diagram. • Determine the direction of the resultant using simple trigonometric ratios. • Resolve a 2-dimensional vector into its perpendicular components.	• Use these methods to find the resultant of any vector quantity learnt in grades 10, 11 and 12. • Resolve any vector learnt in grades 10, 11 and 12 into its perpendicular components.

C Glossary of Terms

TERM	DEFINITION
Vector	A physical quantity which has magnitude (size) and direction.
Displacement	The change in position of a body.
Resultant (net) vector	The vector sum of two or more vectors.

D Assessment of this Topic

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

- There must be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.
- Recommended Informal Assessment Experiment: Determine the resultant of three non-linear force vectors (using a force board, assortment of weights (10 g and 20 g), gut or light inextensible string, two pulleys).

E Breakdown of Topic and Targeted Support Offered

TIME ALLOCATION	SUB-TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
2 hours	Resultant of perpendicular vectors	61	**a.** Drawing neat labelled vector diagrams to better understand the problem. **b.** The importance of assigning direction to a vector. **c.** Simplifying vector diagrams by first determining the vector sum of co-linear vectors. **d.** Practise using the tail-to-tail and tail-to-head method to find the resultant of perpendicular vectors. **e.** Practise using the theorem of Pythagoras and simple trigonometric ratios. **f.** Finding the direction of the resultant vector.
2 hours	Resolution of a vector into its horizontal and vertical components	61	**a.** Drawing a neat labelled vector diagram of a given two-dimensional vector and its horizontal and vertical components. **b.** The use of simple trigonometric ratios.

F Targeted Support per Sub-topic

1. RESULTANT OF PERPENDICULAR VECTORS

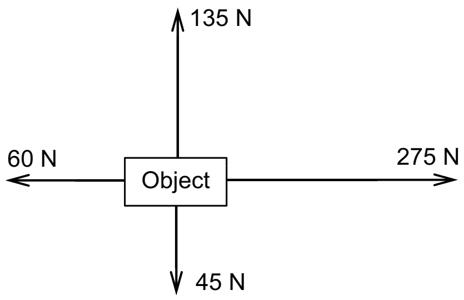
INTRODUCTION TO THE TOPIC

Learners must learn to draw neat labelled vector diagrams and simplify them. Problems involving vectors, such as forces (F) **or** displacements (Δx) can be simplified if we can place the vectors in the horizontal plane and the vertical plane.

CONCEPT EXPLANATION AND CLARIFICATION

Draw the Cartesian plane on the board and show the learners the horizontal plane (x-axis) and the vertical plane (y-axis).

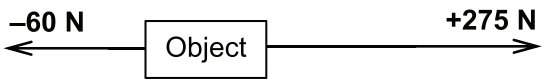
Co-linear vectors are simply vectors that lie in the same straight line. They either act in the same direction or in the opposite direction e.g. vectors pointing east or west are co-linear; vectors pointing north and west are not co-linear because they act at an angle (90°) to each other. Draw the diagram alongside, on the board, of four forces acting on an object.



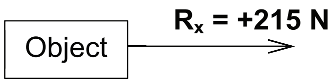
Note that we are not drawing these diagrams as scale diagrams; just a sketch diagram showing the approximate proportion of the forces will do.

The 60 N and 275 N force vectors act along the horizontal axis (x-axis). It is essential to use signs (+ and -) to indicate the direction of vectors which act in the same line.

In the Cartesian plane, right is positive (+) and left is negative (−). The 275 N force acts to the right and is therefore represented as +275 N. The 60 N force acts to the left and is therefore represented as −60 N.

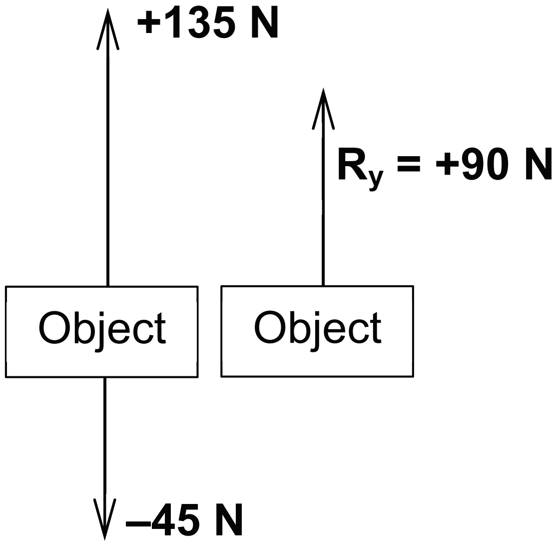


The resultant horizontal force (R_x) is the vector sum of the forces acting along the horizontal (or x-) axis: $R_x = (+275) + (-60) = +215\ \text{N}$ The positive sign (+) in the answer indicates that the resultant horizontal force acts to the right: $R_x = 215\ \text{N}$ to the right



Gr11_PS-Contents_Book_Term1.indb 26 2018/12/27 12:15:23 PM

The 135 N and 45 N forces act in the vertical direction (y-axis). In the Cartesian plane, up is positive (+) and down is negative (−). The 135 N force acts upwards and is therefore represented as +135 N. The 45 N force acts downwards and is therefore represented as −45 N.



The resultant vertical force (R_y) is the vector sum of the forces acting in the vertical direction.

$R_y = (+135) + (-45) = +90\text{ N}$

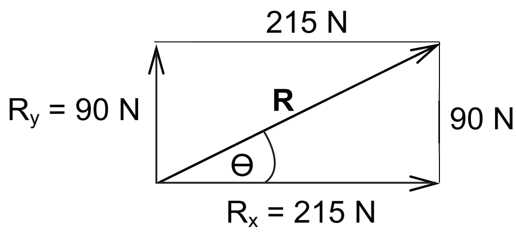
$R_y = 90\text{ N}$ upwards

CONCEPT

We have now simplified the given force diagram to just two perpendicular force vectors. The resultant force can be found by drawing a neat vector diagram using the tail-to-tail method or the tail-to-head method.

Tail-to-tail method

Place the tails of the two vectors together (tail-to-tail) in the Cartesian plane and complete the parallelogram by drawing in the opposite sides. The opposite sides are PARALLEL and EQUAL IN LENGTH to each other.



The resultant force (R) is the diagonal of the parallelogram. Draw in the diagonal of the parallelogram. The diagonal MUST start from the TWO TAILS of the given forces.

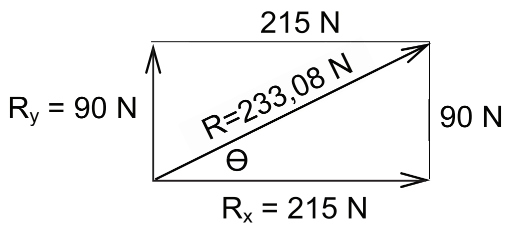
We now have two right-angled triangles to work with.
Use Pythagoras to calculate the magnitude of the resultant force (R).

$R^2 = 90^2 + 215^2$

$R^2 = 54\,325$

$R = \sqrt{54\,325} = 233{,}08\text{ N}$

This is the magnitude of the resultant force.



We now need to find the direction of the resultant force. Place a θ into your vector diagram to represent the angle between the resultant force and the horizontal plane.

Use a trig. ratio to find the angle θ: $\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{90}{215}$

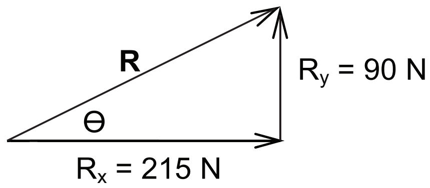
Use a calculator to find θ: Press **Shift**, then **tan**,then $\frac{90}{215}$, then **=:** θ = 22,71°

In this example, the direction is given relative to the horizontal axis (*x*-axis). Your final answer gives both the magnitude and the direction of the resultant force:

$R = 233{,}08\ \text{N}$ at 22,71° above the horizontal axis (positive *x*-axis)

Tail-to-head method

Draw the horizontal vector R_x on your page, then draw the vertical vector R_y so that its TAIL is touching the HEAD of R_x.



The resultant force (*R*) MUST be drawn from the TAIL of the first vector to the HEAD of the second vector.

As shown in the previous method, use Pythagoras to calculate the **magnitude** of the resultant force (*R*) and a trig. ratio to find the **direction** of the resultant force.

$R = 233{,}08\ \text{N}$ at 22,71° above the horizontal axis (positive *x*-axis)

INTRODUCTORY LEVEL QUESTIONS

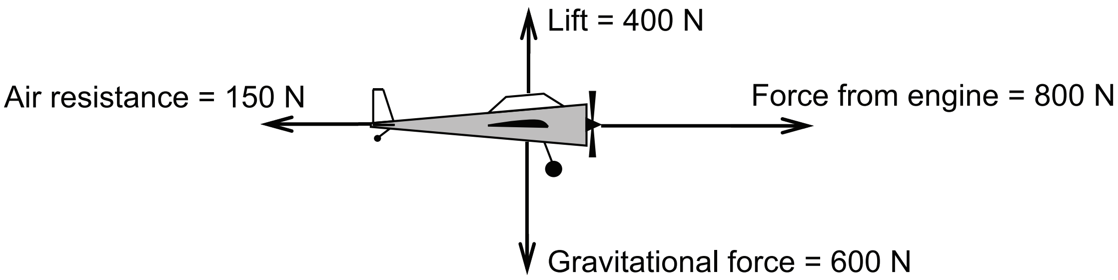
a. These are the basic calculations that learners will be required to perform at this stage in the topic.

b. Their purpose is to familiarise the learners with drawing neat labelled vector diagrams, finding the resultant of co-linear vectors and applying the methods to find the resultant of perpendicular vectors.

How to tackle these questions in the classroom:

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

1. The diagram below shows four forces acting on an aeroplane while flying.



Determine the magnitude and direction of the resultant force acting on the aeroplane.

Gr11_PS-Contents_Book_Term1.indb 28 2018/12/27 12:15:29 PM

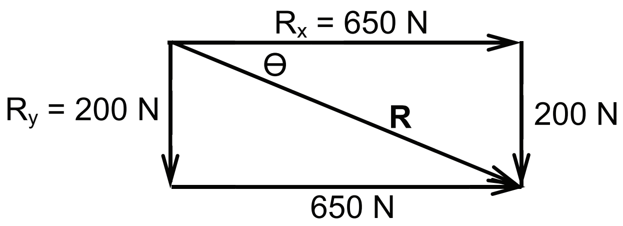
Solution

Choose "to the right" as the positive (+) direction (left is then -). Forces in the horizontal direction become +800 N and -150 N. Then the resultant force in the horizontal plane (Rx) is: $R_x = +800 + (-150) = +650\ \text{N}$. The positive sign (+) of the answer represents the direction of R_x (to the right). Therefore: $R_x = 650\ \text{N}$ to the right.

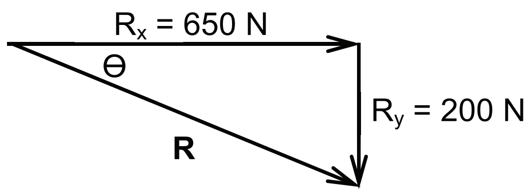
Choose "upwards" as the positive (+) direction (downwards is then -). Forces in the vertical direction become $+400\ \text{N}$ and $-600\ \text{N}$. Then the resultant force in the vertical direction (R_y) is: $R_y = +400 + (-600) = -200\ \text{N}$. The negative sign (-) of the answer represents the direction of R_y (downwards). Therefore: $R_y = 200\ \text{N}$ downwards.

Now find the resultant force (R) of the two perpendicular vectors R_x and R_y:

Tail-to-tail method:



Tail-to-head method:



Use Pythagoras: $R^2 = 200^2 + 650^2$

$R^2 = 462\,500$

$R = (\sqrt{462\,500}) = 680{,}07\ \text{N}$

$\tan\theta = \dfrac{opposite}{adjacent} = \dfrac{200}{650}$

$\theta = \tan^{-1}\left(\dfrac{200}{650}\right) = 17{,}10°$

at 17,10° below the horizontal axis (x-axis)

CHALLENGE LEVEL QUESTIONS

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

b. These questions require learners to draw neat labelled vector diagrams and to simplify the vector diagrams.

c. Apply the tail-to-head and tail-to-tail methods, use the theorem of Pythagoras and trig. ratios to find the magnitude and direction of the resultant vector.

How to tackle these questions in the classroom:

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

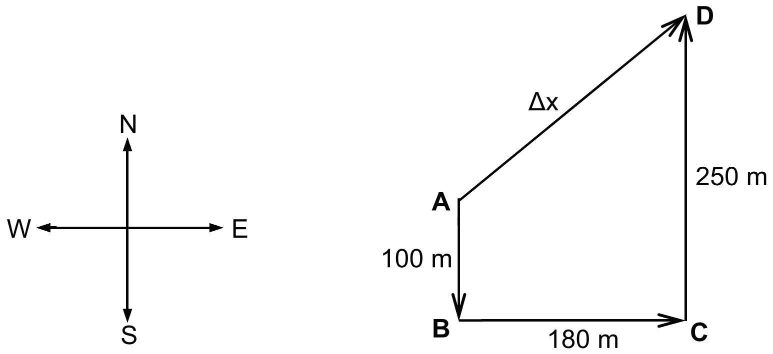
KEY TEACHING

a. Draw a neat labelled vector diagram.
b. Simplify the problem by first finding the resultant of vectors in the same and opposite directions (co-linear vectors).
c. When left with perpendicular vectors, decide on the method to use (tail-to-tail method, etc.)
d. Draw a neat vector diagram of the perpendicular vectors.
e. Use the theorem of Pythagoras and trig. ratios to find the magnitude and direction of the resultant vector.

2. An athlete on the training ground starts at point A and runs 100 m South to point B, then he runs 180 m East to point C, then 250 m North to point D. Find the athlete's resultant displacement.

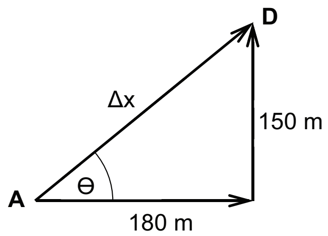
Solution

i) Using the tail-to-head method, draw a neat, fully labelled displacement vector diagram, not to scale. Draw the resultant displacement (Δx).
The resultant displacement (Δx) is drawn from the starting point (A) to the end point (D).



ii) Determine the magnitude and direction of the resultant displacement of the athlete.

Simplify the above vector diagram. Take north as the positive (+) direction, then south is the negative (−) direction. The displacements in the northerly and southerly directions can be simplified to $-100 + (+250) = +150\text{ m} = 150\text{ m}$ north. The displacement vector diagram now involves only two perpendicular vectors, 180 m east and 150 m north.



Use Pythagoras to calculate the magnitude of the resultant displacement:

$$x^2 = 180^2 + 150^2$$
$$x = (\sqrt{54\,900}) = 234,31\text{ m}$$

Now find the direction of the resultant displacement:

$$\tan\theta = \frac{opposite}{adjacent} = \frac{150}{180}$$

$$\theta = \tan^{-1}\left(\frac{150}{180}\right) = 39,81°$$

The final answer is given as a bearing from north (which has a bearing of 000°):

Bearing $= 90 - 39,81 = 50,19 = 050,19°$

$\Delta x = 234,31\ \text{m}$ on a bearing of 050,19°

CHECKPOINT

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

1. drawing a neat labelled vector diagram.
2. using signs (+ and −) to represent the direction of vectors in the same line.
3. finding the resultant of these co-linear vectors.
4. applying the tail-to-tail and tail-to-head methods, the theorem of Pythagoras and using simple trigonometric ratios.
5. stating the magnitude and direction of the resultant vector.

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

Topic 1 Worksheet from the Resource Pack:
Vectors in two dimensions: Questions 1 - 4. (Page 4).

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

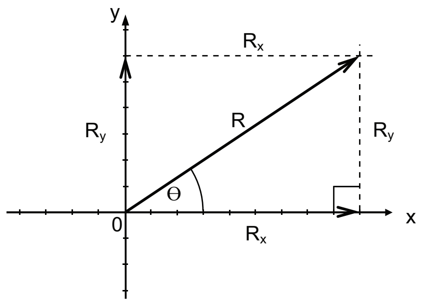
2. RESOLUTION OF A VECTOR INTO ITS HORIZONTAL AND VERTICAL COMPONENTS

INTRODUCTION TO THE TOPIC

Learners will often be faced with problems which involve 2-dimensional vectors. These problems must be simplified by resolving the 2-dimensional vector into its horizontal and vertical components.

CONCEPT EXPLANATION AND CLARIFICATION

Suppose you are given a 2-dimensional vector (R) as shown in the Cartesian plane. R can be resolved (broken down) into its horizontal and vertical components. The perpendicular components of a vector are calculated using simple trig. ratios. If θ is between R and the horizontal axis, then



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

Therefore, the horizontal component (R_x) is
$R_x = R\cos\theta$

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

Therefore, the vertical component (R_y) is $R_y = R\sin\theta$

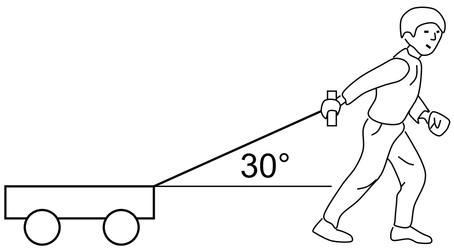
INTRODUCTORY LEVEL CALCULATIONS

This is a basic calculation in which learners are required to resolve a two-dimensional vector into its horizontal and vertical components.

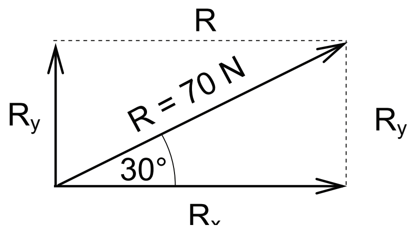
How to tackle these questions in the classroom:

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

1. A child pulls a trolley with a force of 70 N at an angle of 30° above the horizontal as shown in the diagram alongside. Determine the horizontal and vertical components of the 70 N force.



Solution



Using the tail-to-tail method, draw a neat vector diagram.

$R_x = R\cos\theta = 70(\cos 30°) = 60,62\text{ N}$ to the right
$R_y = R\sin\theta = 70(\sin 30°) = 35\text{ N}$ upwards

CHALLENGE LEVEL CALCULATIONS

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

b. These questions require learners to interpret a given diagram and identify the vectors in question, draw neat labelled vector diagrams and to simplify the vector diagrams by resolving two dimensions into their horizontal and vertical components.

How to tackle these questions in the classroom:

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

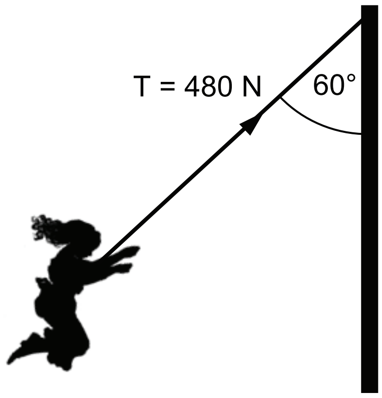
KEY TEACHING

a. Identify the vectors in the question.

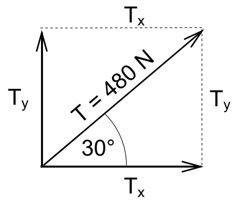
b. Draw a neat labelled vector diagram.

c. Simplify the problem by resolving any 2-dimensional vectors into their horizontal and vertical components.

2. A child is at a point in her swing when the chain makes an angle of 60° with the upright. The tension in the chain is 480 N. Determine the horizontal and vertical components of the tension in the cable (acting on the child).

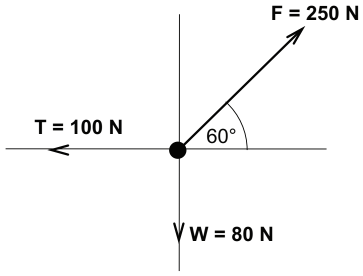


Solution



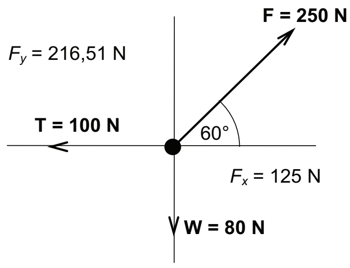
$T_x = T\cos 30° = 480(\cos 30°) = 415,69$ N to the right
$T_y = T\sin 30° = 480(\sin 30°) = 240$ N upwards

3. Three forces T, W and F act on an object. F acts at 60° above the horizontal axis (positive x-axis). Force T (100 N) is along the horizontal axis (negative x-axis) and force W (80 N) is along the vertical axis (negative y-axis). Determine the resultant force acting on the object.



Solution

We need to resolve force F into its perpendicular components:
The horizontal component F_x:
$F_x = F\cos\theta = (250)\cos 60° = 125$ N to the right
The vertical component F_y:
$F_y = F\sin\theta = F\sin\theta = (250)\sin 60° = 216,51$ N upwards



Now we have forces in the horizontal and vertical directions.

The resultant horizontal force (R_x) is:
$R_x = +125 - 100 = 25$ N to the right

The resultant vertical force (R_y) is:

$R_y = 216,51 - 80 = 136,51$ N upwards

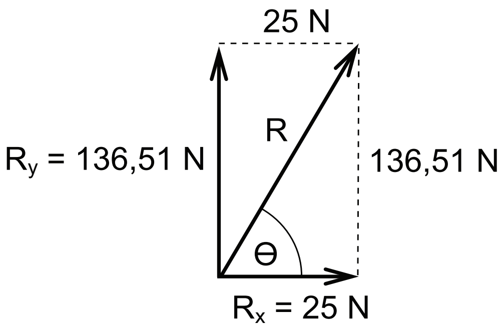
$R^2 = 25^2 + 136,51^2$

$R = \sqrt{19\,259,98} = 138,78$ N

$\tan = \frac{opp}{adj} = \frac{136,51}{25}$

$\theta = \tan^{-1}\left(\frac{136,51}{25}\right) = 79,62°$

$R = 138,78$ N at 79,62° above the horizontal



CHECKPOINT

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

1. drawing a neat labelled vector diagram from the question.
2. using simple trigonometric ratios to calculate the horizontal and vertical components of a given two-dimensional vector.
3. calculating the resultant vector along each axis, and then using the theorem of Pythagoras to calculate the resultant of the two perpendicular vectors.

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

Topic 1 Worksheet from the Resource Pack: Vectors in two dimensions: Questions 5–9. (Pages 4–5).

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

CONSOLIDATION

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

ADDITIONAL VIEWING / READING

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

1. https://www.khanacademy.org/science/physics/two-dimensional-motion/two-dimensional-projectile-mot/v/visualizing-vectors-in-2-dimensions
   The sum of vectors (tail-to-head and tail-to-tail methods)
   Resolving a two-dimensional vector into its horizontal and vertical components.
   Simple trigonometric ratios.
2. https://www.youtube.com/watch?v=w4shcAr6AR4
   Drawing vectors in two dimensions using a scale diagram.
3. https://www.youtube.com/watch?v=w4shcAr6AR4
   Adding two-dimensional vectors using a scale diagram.

TOPIC 2:

Newton’s Laws and Application of Newton’s Laws

A Introduction

- This topic runs for 23 hours.
- For guidance on how to break down this topic into lessons, please consult the NECT Planner & Tracker.
- Newton's Laws and Application of Newton's Laws forms part of the content area Mechanics (Physics).
- Mechanics counts 45,33 % in the final Grade 11 Paper 1 (Physics) Examination.
- Newton's Laws and Applications of Newton's Laws count 18,61 % of the final Paper 1 (Physics) Examination.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard.
2. Chalk.
3. Grade 11 Physics Examination Data Sheet.
4. Spring balance, several blocks (of the same material) of varying sizes with hooks attached on one end. Different textures; rough, smooth surfaces. Various surfaces at various angles of inclination, etc.
5. Trolleys, different masses, inclined plane, rubber bands, metre rule, ticker tape apparatus, ticker timer and graph paper.

CLASSROOM REQUIREMENTS FOR THE LEARNER

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

Gr11_PS-Contents_Book_Term1.indb 38 2018/12/27 12:15:40 PM

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 10	**GRADE 11**	**GRADE 12**
• Introduction to vectors and scalars • Mass and weight • Instantaneous velocity • Acceleration • Description of motion in words, diagrams, graphs and equations.	• Different kinds of forces: weight, normal force, frictional force, applied force (push or pull), tension (strings or cables) • Force diagrams, free-body diagrams • Newton's first, second and third laws. • Newton's Law of Universal Gravitation	• Momentum • Newton's second law expressed in terms of momentum • Impulse

C Glossary of Terms

TERM	DEFINITION
Weight	The gravitational force the Earth exerts on any object on or near its surface.
Normal force	The force or component of force which a surface exerts on an object that is in contact with it, and which is perpendicular to the surface.
Frictional force	The force that opposes the motion of an object and acts parallel to the surface the object is in contact with.
Acceleration	The rate of change of velocity.
Newton's first law	An object continues in a state of rest or uniform velocity unless it is acted upon by an unbalanced (net) force.
Newton's second law	When a net force, F_{net}, is applied to an object of mass, *m*, it accelerates in the direction of the net force. The acceleration, *a*, is directly proportional to the net force and inversely proportional to the mass.
Newton's third law	When object A exerts a force on object B, object B simultaneously exerts an oppositely directed force of equal magnitude on object A.
Newton's law of universal gravitation	Every object in the universe attracts every other object in the universe with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.
Static friction	Static frictional force is the force that opposes the tendency of motion of a stationary object relative to its surface.
Kinetic friction	Kinetic frictional force is the force that opposes the motion of a moving object relative to the surface.
Maximum static friction	The maximum value of the static frictional force.
Force diagram	A picture of the object(s) of interest with all the forces acting on it (them) drawn in as arrows.
Free-body diagram	The object of interest is drawn as a dot and all the forces acting on it are drawn as arrows pointing away from the dot.

Gr11_PS-Contents_Book_Term1.indb 40 2018/12/27 12:15:40 PM

D Assessment of this Topic

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

- There must be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.
- Recommended investigation for informal assessment:
  1. Investigate the relationship between normal force and maximum static friction. Investigate the effect of different surfaces on maximum static friction by keeping the object the same and/or
  2. Investigate the relationship between normal force and force of dynamic friction.
- Prescribed experiment for formal assessment: Investigate the relationship between force and acceleration (Verification of Newton's second law).

E Breakdown of Topic and Targeted Support Offered

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

TIME ALLOCATION	SUB-TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
5 hours	Different kinds of forces: weight, normal force, frictional force, applied (push, pull), tension (strings or cables)	62	Weight Normal force Forces on a horizontal and an inclined plane For an inclined plane, resolve the weight into its horizontal and vertical components Static friction, maximum force of static friction, kinetic friction
3 hours	Force diagrams, free-body diagrams	63	Fully labelled force diagrams Fully labelled free-body diagrams
11 hours	Newton's first, second and third laws	64	Explanations of each law Application of Newton's second law to horizontal planes, inclined planes and motion in the vertical plane Methods to deal with equilibrium problems Numerous problems to solve
4 hours	Newton's Law of Universal Gravitation	66	Explanations and worked examples Numerous problems to solve

F Targeted Support per Sub-topic

1. DIFFERENT KINDS OF FORCES

INTRODUCTION

Forces such as weight, normal force, static and kinetic friction, applied forces and tension all influence the motion of objects. Newton's laws of motion will be better understood if these types of forces are well taught. Learners need to clearly understand the different kinds of forces and under what circumstances they act.

Major areas of misunderstanding for learners include:

- The correct drawing of free-body diagrams
- Isolating masses in a system and drawing their individual free-body diagrams

CONCEPT EXPLANATION AND CLARIFICATION

1.1 Weight (w)

Remind your learners of the difference between mass and weight. Mass is the quantity of matter in a body. The unit for mass is the kg. Mass is a scalar quantity. Ask several students what their mass is. Emphasise the unit of mass (kg). Check if your learners know how to convert a mass in grams to kilograms. 1 000 g = 1 kg. For example 450 g = 0,450 kg (divide the mass in grams by 1 000 to get kg).

Define weight (w) as the gravitational force that the Earth exerts on any object near its surface. Make it clear that weight is a force (of attraction). Since weight is a force, its unit of measurement is the newton (N). Weight is a vector quantity. The direction of the weight is downwards (towards the Earth).

The weight of an object is calculated using: $w = mg$, where m is the mass of the object (in kg) and g is the acceleration due to gravity (in $m{\cdot}s^{-2}$). On Earth: $g = 9{,}8\ m{\cdot}s^{-2}$ downwards. Ask your learners to calculate their weight, emphasise the unit and the direction of their weight.

Make it very clear that the mass of an object does not change. However, its weight is determined by the acceleration due to gravity of the planet that it is on. For example, a 50 kg object has a mass of 50 kg on the Earth as well as on the Moon. However, the weight of the 50 kg object on the Earth is 490 N ($g = 9{,}8\ m{\cdot}s^{-2}$ downwards on Earth), whilst on the Moon its weight is 80 N ($g = 1{,}6\ m{\cdot}s^{-2}$ downwards on the Moon).

TOPIC 2

INTRODUCTORY LEVEL QUESTIONS

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

b. Ensure that a mass given in grams (g) is converted to kilograms (kg), before it is substituted into the equation $w = mg$.

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 and answer it correctly in their workbooks.

3. Calculate the weight of each of the following objects (on Earth):

a. A car of mass 800 kg.

b. A cricket ball with a mass 156 g.

Solution

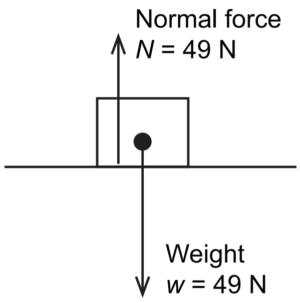
a. $w = mg = 800 \times 9,8 = 7\,840 \text{ N}$ downwards

b. $w = mg = 0,156 \times 9,8 = 1,53 \text{ N}$ downwards

1.2 Normal force (N)

Ask your learners to list the forces acting on them while sitting on a chair. They should identify their weight acting down. As a result, their body presses on the chair. There must be an upward force acting on them, otherwise they would fall to the ground. The chair surface presses back on their body (upwards). This is an example of a normal force (*N*).

Define a normal force (*N*) as the force exerted by a surface on an object which with it is in contact, and which is perpendicular to the surface. Draw the diagram on the board of a 5 kg crate resting on a horizontal surface. Explain that the crate is pulled towards the Earth with a weight of 49 N. The crate therefore presses down on the surface with a force of 49 N. At the same time, the surface presses upwards on the crate with a force of 49 N.



This upward force of the surface on the crate is known as the normal force. Your learners must know that the normal force always acts perpendicular (at 90°) to the surface it is on. The word "normal" as used in mathematics refers to lines which are perpendicular to each other; that is why this force is called the normal force.

It is important to highlight that a normal force only exists when an object is resting on a surface. Too often, in vertical pulley-type questions, learners incorrectly state that there is a normal force upwards in response to the object's weight. This is not true if the object is not on a surface, but is hanging from a cable.

INTRODUCTORY LEVEL CALCULATIONS

4. A 50 kg block is at rest on the ground.

a. Draw a diagram of the block and draw in the forces acting on the block (Label these forces).

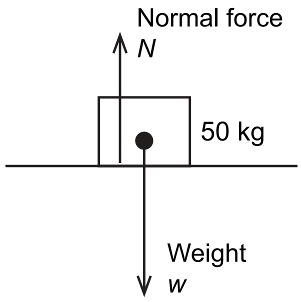
b. Determine the magnitude and direction of the weight of the block and the normal force acting on the block.

Solution

a. Diagram is shown alongside.

b. $w = mg = 50 \times 9{,}8 = 490$ N downwards

$N = 490$ N upwards (perpendicular to the ground)



1.3 Friction (f)

Ask your learners what they understand by the word "friction". Ask them to give examples of situations where a frictional force acts. When we stand, walk, drive a car, and sit on a chair, two surfaces rub against each other. Explain that friction occurs whenever two surfaces slide or try to slide across each other. The frictional force between the two surfaces depends on the roughness of both surfaces. Friction also depends on the amount of force pushing the two surfaces together.

Define a frictional force (f) as the force that opposes the motion of an object and acts parallel to the surface the object is in contact with. There are two types of frictional forces: static and kinetic friction.

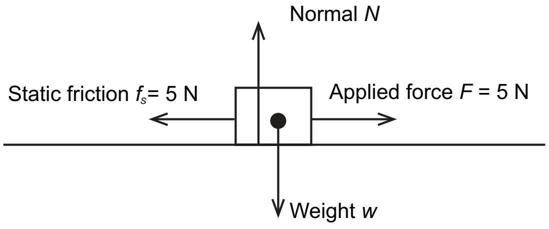
Static friction occurs between a stationary object and the surface on which it is resting: for example, when you try to push an object along a surface but there is no movement. Static friction can prevent an object from sliding down a sloped surface, by opposing its motion. Static frictional force is the force that opposes the tendency of motion of a stationary object relative to a surface.

Kinetic friction occurs when an object slides across a surface. Ask your learner's to list examples where kinetic friction occurs. Sliding a textbook across your desk top, locked tyres skidding along a road, pushing furniture across the carpet are examples of objects which experience kinetic friction, which opposes the motion. Kinetic frictional force is the force that opposes the motion of a moving object relative to the surface. (Kinetic friction is also known as dynamic friction.)

1.4 Maximum Static friction (f_s^{max})

Draw the diagram of a 3 kg brick on a horizontal wooden surface.

State that when a small horizontal force of 5 N is applied to the brick it does not move. It does not move because a 5 N static friction force (f_s) opposes the motion of the brick.



Explain that as more force is applied, the static frictional force increases until it reaches a certain maximum value. Once the horizontal applied force (F) exceeds the maximum static frictional force, the brick begins to move.

The maximum static frictional force $(f_s^{\max})$ depends on:

a. The coefficient of static friction (μ_s) between the two surfaces.

b. The normal force (N) acting on the brick.

Let us say that that the coefficient of static friction between brick and wood is 0,6. The coefficient of static friction (μ_s) is a measure of how easily the two surfaces slide across each other. (It does not have a unit). The greater the coefficient of static friction the greater the maximum force of static friction. The greater the normal force (N) the greater the maximum force of static friction.

The maximum force of static friction is calculated using the following equation:
$f_s^{\max} = \mu_s N$

The magnitude of the normal force (N) acting on the 3 kg brick is equal to the weight of the brick: $N = w = mg = (3)(9,8) = 29,4$ N

The maximum force of static friction between the 3 kg brick and the wooden surface is:
$f_s^{\max} = \mu_s N = (0,6)(29,4) = 17,64$ N

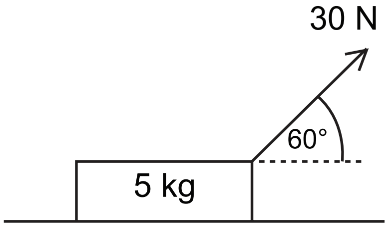
Refer to the diagram above. If the applied force (F) exceeds 17,64 N then the brick will move.

VERY IMPORTANT

If a force F acts at an angle to the horizontal, then the normal force N is **<u>NOT</u>** equal to the weight (w).

Work through the following example with your learners:

A 30 N force is applied to a block at an angle of 60° above the horizontal.



Calculate the normal force acting on the trolley.

The weight of the block is:

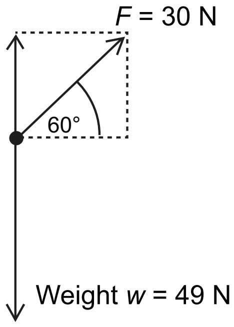
$w = mg = 5 \times 9{,}8 = 49$ N

The normal force N is **<u>NOT EQUAL</u>** to the weight of the block's weight w.

The vertical component of the applied force is:

$F_y = F \sin 60^\circ = (30) \sin 60^\circ$

$F_y = 25{,}98$ N upwards



The vertical component F_y of the applied force acts against the weight w. The upward force F_y will decrease the total downward force of the block on the ground.

$F_{\text{down on the ground}} = w - F_y$

$F_{\text{down on the ground}} = 49 - 25{,}98 = 23{,}02$ N downwards

The block exerts a downward force of 23,02 N on the ground, therefore the ground exerts an equal force of 23,02 N upwards on the block.

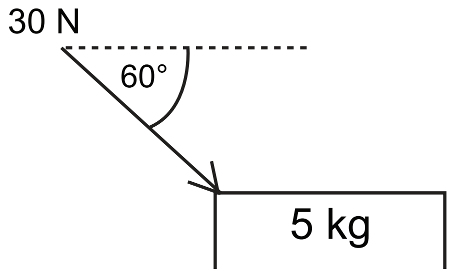
The normal force N acting on the block is: $N = 23{,}02$ N upwards on the block

Learners often **<u>INCORRECTLY</u>** ignore the vertical component of the applied force when calculating the normal force N.

Now calculate the maximum force of static friction if the coefficient of static friction is 0,4.

$f_s^{\max} = \mu_s N = 0{,}4 \times 23{,}02 = 9{,}21$ N to the left

Suppose the applied force acts downwards on an object at an angle below the horizontal as shown below:



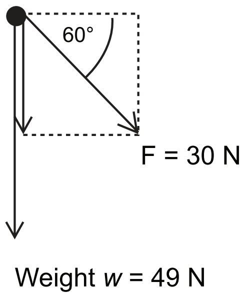
The normal force N is **NOT EQUAL** to the weight of the block w.

The vertical component of the applied force is:

$F_y = F\sin 60^\circ = (30)\sin 60^\circ$

$F_y = 25,98\text{ N upwards}$

The **vertical component** F_y of the applied force acts downwards in the same direction as the weight w. The downward force F_y will increase the total downward force of the block on the ground.



$F_{down\ on\ ground} = w + F_y$

$F_{down\ on\ ground} = 49 + 25,98 = 74,98\text{ N}$ down.

The block exerts a downward force of 74,98 N on the ground, therefore the ground exerts an equal force of 74,98 N upwards on the block.

The normal force N acting on the block is: $N = 74,98\text{ N}$ upwards on the block

Now calculate the maximum force of static friction if the coefficient of static friction is 0,4.

$f_s^{max} = \mu sN = 0,4 \times 74,98 = 29,99$ to the left

INTRODUCTORY LEVEL CALCULATIONS

5. A 6 kg block rests on a table. The coefficient of static friction between the two surfaces is 0,25.

- **a.** Calculate the normal force acting on the block.
- **b.** Calculate the maximum force of static friction.

Solution

a. $w = mg = (6)(9,8) = 58,8\text{ N}$

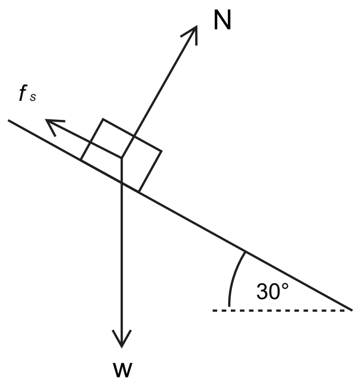
$\therefore N = 58,8\text{ N}$

b. $f_s^{max} = \mu_s N = (0,25)(58,8) = 14,7\text{ N}$

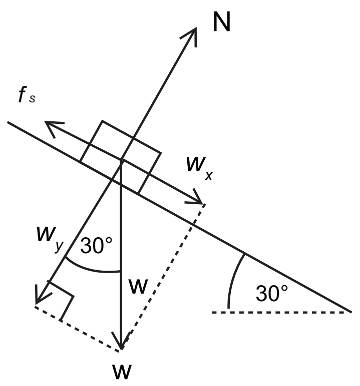
1.5 Kinetic friction (f_k)

Kinetic friction (f_k) occurs when an object slides across a surface. The magnitude of the kinetic frictional force depends on the normal force (*N*) acting on the object and the coefficient of kinetic friction (μ_k) between the two surfaces. The kinetic friction force is calculated using: $f_k = \mu_k N$ The coeffiecient of kinetic friction (μ_k) is always less than the coefficient of static friction (μ_s).

1.6 Forces on an Inclined Plane



Draw a diagram on the board of a 3 kg block at rest on an inclined plane. The plane is inclined at an angle of 30° to the horizontal. Ask your learners to identify the forces acting on the block. The normal force (*N*) always acts perpendicular (at 90°) to the inclined plane. Weight (*w*) always acts vertically downwards. The block would slide down the slope, but static friction (f_s) acts up the slope (opposing it's motion). On an inclined plane, the normal force is **NOT** equal to the weight of the block.



When dealing with an inclined plane, we must resolve the weight (*w*) of the block into its components, parallel (w_x) and perpendicular (w_y) to the inclined plane. Show the learners how to neatly draw in these components. The angle at which the plane is inclined (30°) is **always inserted** between the *w* and w_y. The <u>component of weight parallel to the surface</u> (w_x) is then: $w_x = w\sin 30^\circ = (mg)\sin 30^\circ$

$w_x = (3)(9,8)\sin 30^\circ = 14,7\text{ N}$ down the slope

The <u>vertical component of the weight</u> (w_y) is then:

$w_y = w\cos 30^\circ = (mg)\cos 30^\circ$

$w_y = (3)(9,8)\cos 30^\circ = 25,46\text{ N}$ perpendicular to the slope

w_y presses the block against the slope. The magnitude of the normal force (*N*) is equal to the vertical component of the weight (w_y): $N = w_y = 25,46\text{ N}$. Suppose the coefficient of static friction between the block and the inclined plane is 0,6. Then the maximum force of static friction $(f_s^{\max})$ is: $f_s^{\max} = \mu_s N = (0,6)(25,46) = 15,28\text{ N}$ up the slope

The component of weight, w_x tries to pull the block down the slope. Get your learners to realise that, in this example, w_x (14,7 N) is not large enough to overcome the maximum force of static friction (15,28 N). The block will not slide down the slope. In this example, the force of static friction (f_s) acting on the block is 14,7 N up the slope.

INTRODUCTORY LEVEL CALCULATIONS

6. A block of mass 5 kg is placed on a plane inclined at 35° to the horizontal. The coefficient of static friction between the block and the slope is 0,4.

a. Calculate the normal force acting on the block.

b. Calculate the maximum force of static friction.

c. Use a calculation to explain why the block slides down the slope.

d. The coefficient of kinetic friction between the block and the slope is 0,3. Determine the magnitude and direction of the force of kinetic friction acting on the block as it slides down the slope.

Solution

a. $N = w = w\cos 35° = mg\cos 35° = (5)(9,8)\cos 35° = 40,14\ \text{N}$

b. $f_s^{\max} = \mu_s N = (0,4)(40,14) = 16,06\ \text{N}$

c. $w_x = w = w\sin 35° = mg\sin 35° = (5)(9,8)\sin 35° = 28,11\ \text{N}$

d. The block will slide down the slope because w_x (28,11 N) is greater than the maximum force of static friction (16,06 N).

e. $f_k = \mu_k N = (0,3)(40,14) = 12,04\ \text{N}$ up the slope

CHALLENGE LEVEL CALCULATIONS

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

b. These questions require learners to use their understanding of the different kinds of forces on horizontal and inclined planes.

How to tackle these questions in the classroom:

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

KEY TEACHING

a. Calculate weight.
b. Calculate the normal force when an object is on a horizontal plane and an inclined plane.
c. Draw a neat, detailed, fully labelled diagram of the forces that act on an object when on a horizontal plane and an inclined plane.
d. When an object is on an inclined plane, calculate the horizontal (w_x) and vertical (w_y) components of the weight (w).
e. Understand the difference between static friction (f_s), maximum static friction f_s^{max} and kinetic friction (f_k).
f. Know how to calculate each of the different types of friction.

7. A 10 kg block rests on a horizontal surface.

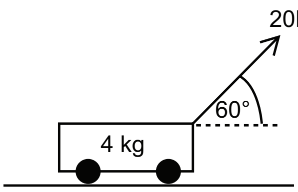
7.1 Calculate the weight of the block.

7.2 Calculate the normal force acting on the block.

7.3 A student now leans on the block applying a downward force of 60 N to the block. Calculate the normal force acting on the block.

7.4 A student applies an upward force of 60 N on the block. Calculate the normal force acting on the block.

8. A 20 N force is applied to a trolley at an angle of 60° to the horizontal as shown in the diagram. Calculate the normal force acting on the trolley if the mass of the trolley is 4 kg.



9. A 100 kg steel crate rests on a horizontal surface coated with Teflon. The coefficient of static friction between the two surfaces is 0,04.

9.1 Calculate the maximum force of static friction between the steel block and the Teflon surface.

9.2 A worker now attaches a rope to the crate and pulls with a force of 70 N at an angle of 60° to the horizontal. Will the crate move? Justify your answer.

10. A child climbs into a cardboard box which is resting on a grass bank. The bank is inclined at 30° to the horizontal. The coefficient of static friction between the two surfaces is 0,63. The total mass of the child and the box is 52 kg.

10.1 Draw a diagram showing all the forces acting on the box. Label each force.

10.2 Calculate the maximum force of static friction experienced by the box.

10.3 Will the box slide down the slope? Justify your answer.

TOPIC 2

11. Consider an empty 20 kg container placed on an inclined plane. The plane is inclined at an angle of 45° to the horizontal. The coefficient of static friction is 0,75.

11.1 Calculate the maximum force of static friction that can act on the crate.

11.2 Will the container slide down the slope if 5 kg of sand is loaded into the container?

Solutions

7. **7.1** $w = mg = 10 \times 9,8 = 98\text{ N}$ downwards

7.2 $N = 98\text{ N}$ upwards

7.3 $F_{down} = 98 + 60 = 158\text{ N}$ therefore $N = 158\text{ N}$ upwards

7.4 $N = 98 - 60 = 38\text{ N}$ upwards

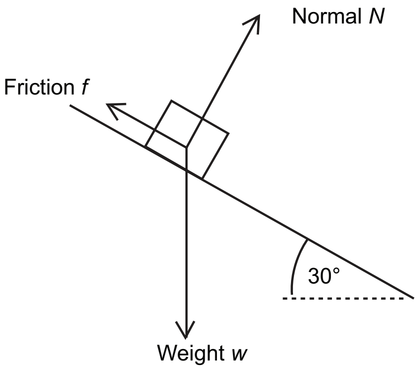
8.
$$F_y = F\sin 60^\circ = (20)\sin 60^\circ = 17,32\text{ N upwards}$$
$$w = mg = (4)(9,8) = 39,2\text{ N downwards}$$
$$F_{down} = 39,2 - 17,32 = 21,88\text{ N downwards}$$
$$N = 21,88\text{ N upwards}$$

9. **9.1** $f_s^{max} = \mu_s N = \mu_s mg = 0,4 \times 100 \times 9,8 = 39,2\text{ N}$

9.2
$$F_y = F\sin 60^\circ = (70)\sin 60^\circ = 60,62\text{ N upwards}$$
$$w = mg = 100 \times 9,8 = 980\text{ N downwards}$$
$$F_{down} = 980 - 60,62 = 919,38\text{ N downwards}$$
$$N = 919,38\text{ N upwards}$$
$$f_s^{max} = \mu_s N = 0,4 \times 919,38 = 36,78\text{ N}$$
$$F_x = F\cos 60^\circ = (70)\cos 60^\circ = 35\text{ N}$$

No, the crate will not move since $F_x\,(35\text{ N})$ is less than $f_s^{max}\,(39,2\text{ N})$.

10. **10.1**



10.2 $N = w_y = w\cos 30^\circ = mg\cos 30^\circ = (52)(9,8)\cos 30^\circ = 441,32\text{ N}$

$f_s^{max} = \mu_s N = (0,63)(441,32) = 278,03\text{ N}$

10.3 $w_x = w\sin 30^\circ = 52 \times 9,8\sin 30^\circ = 254,8\text{ N}$

Box will not slide since w_x is less than f_s^{max}

11. 11.1 $N = w_y = w\cos 45° = mg\cos 45° = 20 \times 9,8\cos 45° = 138,59\ \text{N}$

$f_s^{max} = \mu_s N = 0,75 \times 138,59 = 103,94\ \text{N}$

11.2 $N = w_y = w\cos 45° = mg\cos 45° = 25 \times 9,8\cos 45° = 173,24\ \text{N}$

$f_s^{max} = \mu_s N = 0,75 \times 173,24 = 129,93\ \text{N}$

$w_x = w\sin 45° = 25 \times 9,8\sin 45° = 173,24\ \text{N}$

The container will slide since w_x is greater than f_s^{max}.

CHECKPOINT

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

1. calculating the weight and normal force.
2. drawing, neat fully labelled force diagram for an object on horizontal and on an inclined plane.
3. for an inclined plane, resolving the weight (*w*) into its horizontal component (w_x) parallel to the slope and its vertical component (w_y) perpendicular to the slope.
4. calculating the maximum force of static friction and kinetic friction for both horizontal and inclined planes.

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

Topic 2 Worksheet from the Resource Pack: Newton's Laws and Application of Newton's Laws: Questions 1–5. (Pages 13–14).

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

TOPIC 2

2. FORCE DIAGRAMS AND FREE-BODY DIAGRAMS

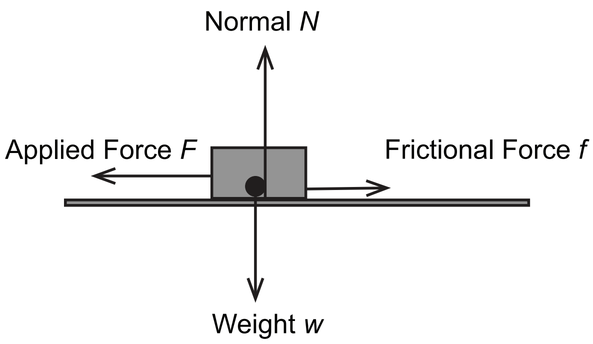
INTRODUCTION

A neat, fully labelled force diagram or free-body diagram is an essential step to simplifying the problem to gain a better understanding of all the forces present. It is vital that your learners practise drawing these diagrams.

CONCEPT EXPLANATION AND CLARIFICATION

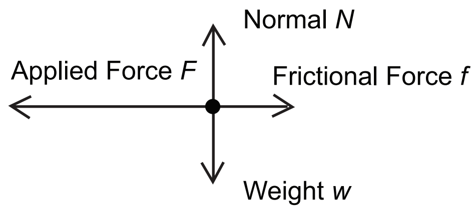
2.1 Force diagram

A force diagram is a picture or simple diagram of the object(s) showing all the forces acting on the objects using labelled arrows. Consider an object on a rough horizontal surface. A horizontal force (F) is applied to the left, friction (f) acts to the right. The weight of the object (w) acts down and the normal force (N) acts up. Forces can be drawn acting towards OR away from an object. Draw the force diagram on the board and label each force.



2.2 Free-body diagram

A free-body diagram shows the object drawn as a dot. The forces are shown as labelled arrows which act away from the dot. A free-body diagram shows all the forces acting on a single isolated body. Draw the free-body diagram of the same object on the board and emphasise how it is different from a force diagram.



GUIDELINES FOR LEARNERS ON HOW TO DRAW FREE-BODY DIAGRAMS

1. The object must be drawn as a dot, NOT a circle or box.
2. The forces are shown as labelled arrows which act away from the dot.
3. Forces must have arrows on them.
4. Forces must make contact with the dot. Do not have a small space between the dot and the arrow.
5. Make sure to LABEL every force. For example, 'N' is not a label. Use 'N' on the free-body diagram, but then make use of a key next to the free-body diagram and say N = normal force etc.
6. If one force is greater than another, it should be drawn as a longer vector (arrow).
7. When drawing the free-body diagram for an object on an inclined plane, do NOT draw the components of the weight on the diagram.

VERY IMPORTANT

When teaching free-body diagrams involving 2 or more objects that are connected, spend time on isolating the masses and discussing the forces acting on each individual object. Isolating masses and drawing free-body diagrams is a major problem area in final exams, as learners lack the skill to isolate the bodies.

INTRODUCTORY LEVEL QUESTIONS

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

b. Learners must identify the forces acting on an object to draw a fully labelled force diagram or free-body diagram.

How to tackle these questions in the classroom:

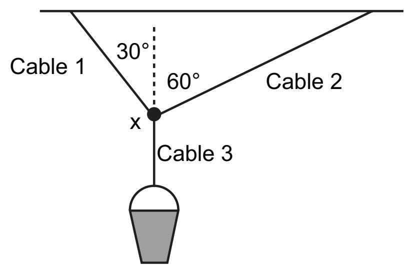
- Work through these examples with learners.
- Explain each step of the answer to the learners as you complete it on the chalkboard.
- Learners must copy down the questions and answer them correctly in their workbooks.

1. A trolley is pulled to the right along a rough horizontal surface with a rope at an angle of 60° to the horizontal.

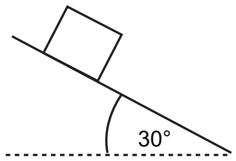
1.1 Draw a fully labelled force diagram for the trolley.

1.2 Draw a fully labelled free-body diagram of the forces acting on the trolley.

2. A 3 kg bucket is hung from the ceiling using three very light inextensible cables as shown in the diagram. The cables are attached at point X. Draw a fully labelled free-body diagram of all the forces acting at point X.



3. Consider a brick which is sliding down a rough inclined plane. The plane is inclined at 30° to the horizontal.

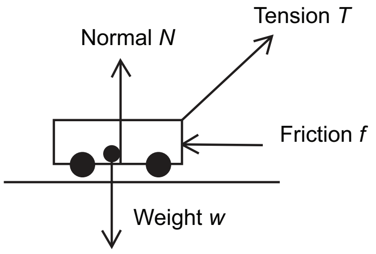


3.1 Draw a fully labelled force diagram for the brick.

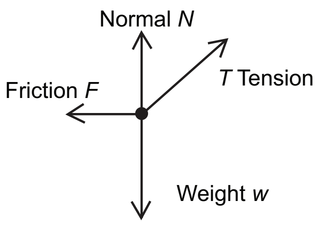
3.2 Draw a fully labelled free-body diagram for the brick.

Solutions

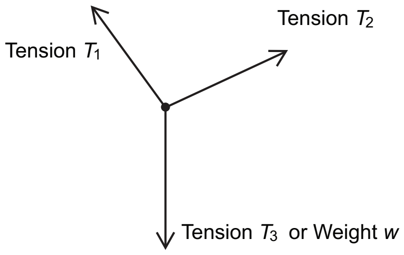
1. 1.1



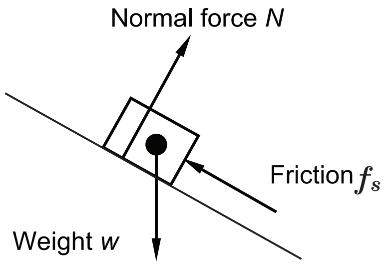
1.2



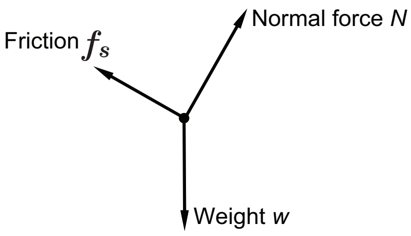
2.



3. 3.1



3.2



CHALLENGE LEVEL QUESTIONS

a. These questions will require more discussion about the forces present.

b. Remember that when two objects press against each other, then an action-reaction pair is present. This concept will be covered in more detail in Newton's third law but can be discussed now.

How to tackle these questions in the classroom:

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

KEY TEACHING

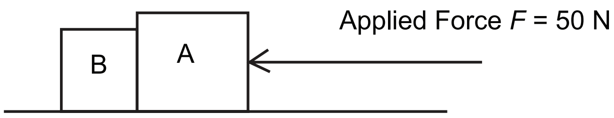
a. Know the difference between a force diagram and a free-body diagram.

b. Label your forces with a "word" (e.g. Weight) and a symbol (e.g. *w*).

c. If one force is greater than another, it should be drawn as a longer vector (arrow). All forces drawn must have arrow heads.

d. DO NOT show the horizontal and vertical components of a force in a free-body diagram.

4. Consider two blocks, A (mass 2 kg) and B (mass 5 kg) resting against each other on a rough horizontal surface. A horizontal force of 50 N is applied to block A as shown in the diagram.

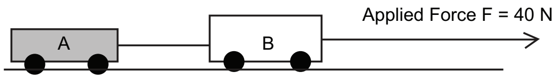


4.1 Draw a fully labelled free-body diagram of all the forces acting on block A.

4.2 Draw a fully labelled free-body diagram of all the forces acting on block B.

Gr11_PS-Contents_Book_Term1.indb 57 2018/12/27 12:15:58 PM

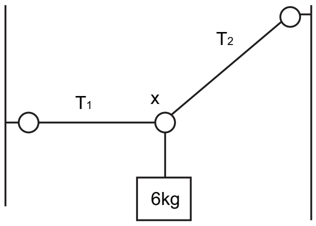
5. Two trolleys, A (of mass 2 kg) and B (of mass 4 kg) are joined together by a light inextensible string as shown in the diagram. A force 40 N is applied to trolley B which moves the trolleys to the right.



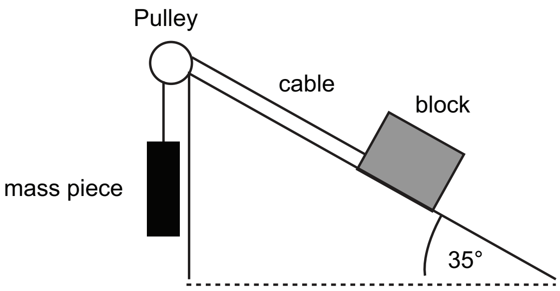
5.1 Draw a fully labelled force diagram for trolley A.

5.2 Draw a fully labelled free-body diagram for trolley B.

6. A 6 kg crate is hanging from three chains which are connected to a ring X as shown in the diagram. Draw a fully labelled free-body diagram of all the forces acting on ring X.



7. A 4 kg block is pulled up an inclined plane at constant velocity using a cable which runs over a frictionless pulley and is connected to an unknown mass piece as shown in the diagram below.

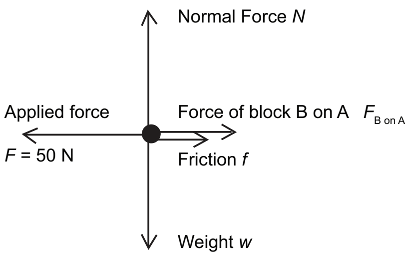


7.1 Draw a fully labelled free-body diagram for the mass piece.

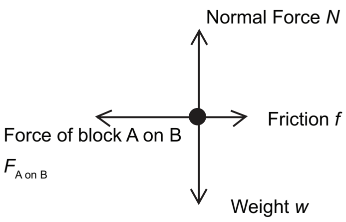
7.2 Draw a fully labelled force diagram for the block.

Solutions

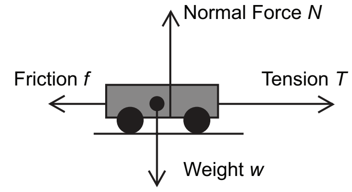
4.1



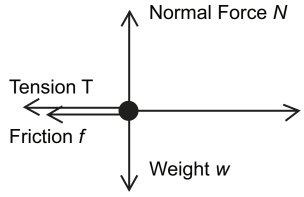
4.2



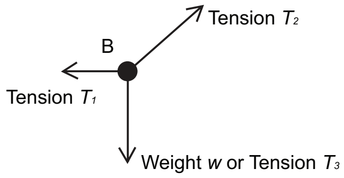
5.1



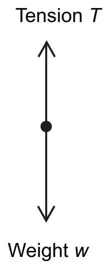
5.2



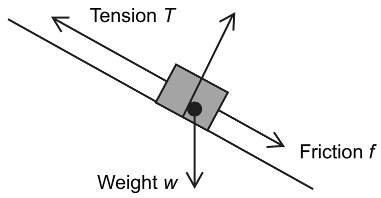
6



7.1



7.2



CHECKPOINT

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

1. knowing the difference between force diagrams and free-body diagrams.
2. drawing and labelling force diagrams and free-body diagrams.

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

Topic 2 Worksheet from the Resource Pack: Newton's Laws and Application of Newton's Laws: Questions 6–7. (Page 14).

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

TOPIC 2

3. NEWTON'S FIRST LAW

INTRODUCTION

Learners must understand the difference between the following types of motion:

- remaining at rest (stationary),
- moving at constant (uniform) velocity,
- accelerating.

They must understand how a net (resultant) force affects the motion of an object.

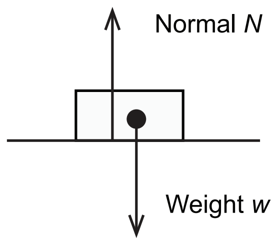
CONCEPT EXPLANATION AND CLARIFICATION

Write Newton's first law on the board: **An object continues in a state of rest or uniform velocity unless it is acted upon by an unbalanced force.**

To develop an understanding of this law you should break it up into smaller parts. Firstly focus on the words "**continues in a state of rest**". "At rest" simply means not moving. The word "**continues**" means that the object remains at rest. Ask your learners to give examples of objects around them that remain in a state of rest.

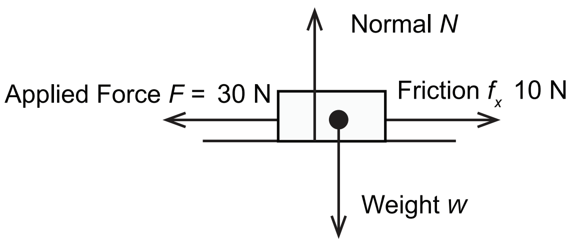
A parked car, a desk, a school bag on the floor are examples of objects that remain at rest. When an object remains at rest, **all** the forces acting on that object are balanced. In other words, the resultant (net) force (F_{net}) acting on the object is **zero**.

Consider the school desk. The weight of the desk (downwards) is balanced by the upward force of the floor on the desk (normal force). Since these two forces are equal in magnitude and opposite in direction, the net force in the vertical direction is zero. The vector sum of the forces in the vertical direction is zero. There are no forces acting on the desk in the horizontal direction.



Suppose the maximum force of static friction between the desk and the floor is 25 N. Draw the following diagram on the board.

If we apply a horizontal force of 20 N to the desk, it will not move (remain at rest). Suppose we now apply a horizontal force of 30 N to the left. The desk will slide across the floor because the applied force is greater than f_s^{max} which is 25 N.



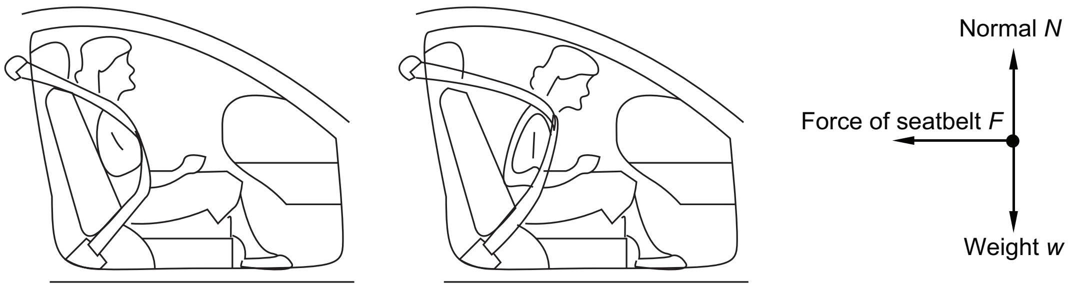
Suppose the force of kinetic friction is 10 N. The forces in the horizontal direction are not **balanced**.

There is now a net horizontal force (F_{net}) acting on the desk. Take the learners back to the first part of the statement of Newton's first law: "**An object continues in a state of rest unless it is acted upon by a net force**". The applied force of 30 N (to the left) is greater than kinetic friction (10 N). $F_{net} = +30 + (-10) = 20\ \text{N}$ to the left

Now get the learners to consider the words "**constant velocity**". Ask them what they understand by these words. A car travels at **constant velocity** if its velocity does not **change** (e.g. a car moving at 20 $m \cdot s^{-1}$ in a straight line). If the car travels at the same speed around a corner, then its velocity is <u>not constant</u>! Velocity is a vector quantity, so a change in direction will mean a change in velocity. So "constant velocity" means that the car is travelling "**at the same speed in a straight line**".

Let's take a look at the second part of Newton's first law: "**An object continues moving at constant velocity unless it is acted upon by a net force**." Use this example with your learners: A passenger (not wearing a seatbelt) is travelling in a car. The car is travelling in a straight line at 100 $km \cdot h^{-1}$. The car is involved in a collision and comes to rest very quickly. What will happen to the motion of the car? What will happen to the motion of the passenger?

During the collision, the car experiences a massive **net force backwards,** bringing it to rest. The passenger does NOT experience this net force and will keep moving forward at a constant velocity of 100 $km \cdot h^{-1}$. There is **ZERO** net force acting on the passenger. He/she will keep moving forward at constant velocity until he/she collides with the windscreen. A seat belt would exert a **net force backwards** on the passenger slowing him/her down rapidly, preventing him/her from colliding with the windscreen. Draw the following free-body diagram of the forces acting on the passenger (wearing a seat belt).



Before the collision　　　　During/after the collision

A **common mistake** made by learners is to think that there is a forward force on the passenger keeping him/her moving forward. When the car collides, there is **NO** forward force on the passenger.

"**Inertia**" is a property of a body that resists any change in its motion. The greater the mass of an object the more inertia it has and the more it resists any change in its motion. It is correct to say that the moving passenger has inertia and therefore continues to move in a straight line until the seatbelt exerts the net backward force. It is **INCORRECT** to say that "there is a force of inertia pushing the passenger forward". Inertia is **NOT** a force!

KEY TEACHING

- For an object that **remains** at rest, the net force on that object is **ZERO** ($F_{net} = 0$). It will remain at rest until acted on by a net force.
- For an object that is moving at **constant velocity**, the **net force** on that object is **ZERO** ($F_{net} = 0$). It will continue to move at constant velocity until acted on by a net force.
- For an object that is **speeding up, slowing down or changing direction (accelerating)**, the net force on that object is **NOT** zero.

INTRODUCTORY LEVEL QUESTIONS

a. Questions involving Newton's first law require an explanation. Learners often struggle to apply this law.

b. Get your learners to identify which object is experiencing the net force and which object does not experience the net force.

c. The object that does experience a net force will speed up, slow down or change direction.

d. The object that does not experience the net force will remain at rest or keep moving at constant velocity (this object will keep doing what it was doing).

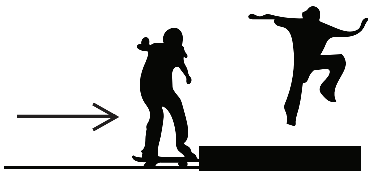
How to tackle these questions in the classroom:

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

1. A skater is moving to the right at 2 m·s^{-1} when his skateboard collides with the curb. Use Newton's first law to explain:

1.1 why the skateboard comes to rest.

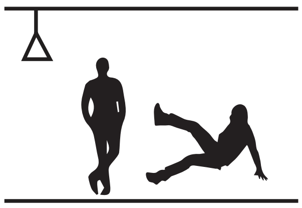
1.2 why the skater lands further along the curb.



2. A passenger standing in a stationary bus is not holding onto the overhead handles. The bus suddenly pulls off and the passenger falls backwards relative to the bus.

2.1 Use Newton's first law to explain why the passenger "falls backwards".

2.2 How would holding onto the overhead handles prevent the passenger from falling over?



3. Use Newton's first law to explain why the passengers on a bus move forward when the bus suddenly stops.

Solutions

1. **1.1** The curb exerts a net force backwards on the skateboard.

   1.2 The net backward force applied by the curb does not act on the skater. According to Newton's first law, the skater will continue moving forwards at constant velocity.

2. **2.1** The passenger is at rest. His feet are in contact with the bus. As the bus pulls off, his feet experience a net force forwards. The feet move forward. This net forward force is not applied to his upper body. According to Newton's first law, his upper body will remain at rest. His feet move forward however his upper body is left behind.

   2.2 The overhead handles now exert a net forward force on his upper body too.

3. A net force acts backwards on the bus, slowing the bus down rapidly. This backward net force does not act on the passengers. According to Newton's first law, the passengers will continue moving forward at constant velocity.

CHALLENGE LEVEL QUESTIONS

a. Now that learners have understood Newton's first law, they are ready to deal with more challenging explanations.

a. Get learners to read out their explanations to the class. Listen carefully to their explanations and make corrections verbally to the entire class. This will help all your learners.

How to tackle these questions in the classroom:

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

4. **4.1** State Newton's first law.

   4.2 Use Newton's first law to explain why passengers get thrown to the side when the car they are driving in suddenly goes around a corner.

5. Use Newton's first law to explain why seat belts are important for the safety of the passengers in a car.

6. Use Newton's first law to explain why a rocket continues to move at constant velocity in space when the engines are switched off.

7. Use Newton's first law to explain why a skater who jumps off a moving skate board has to run forwards to stop himself from falling over.

8. An ornament hangs from the roof of a car which is moving with constant velocity to the right.

   8.1 Use Newton's first law of motion to explain the position of the ornament if the car is speeding up.

   8.2 Use Newton's first law of motion to explain the position of the ornament if the car is slowing down.

   8.3 Use Newton's first law of motion to explain the position of the ornament if the car is travelling at constant velocity.

Solutions

4. 4.1 An object continues in a state of rest or constant velocity unless it is acted upon by a net (or unbalanced) force.

   4.2 A net force acts on the car, changing its direction. This net force does not act on the passengers. According to Newton's first law, the passengers will continue to move forward at constant velocity. The car has changed direction, however the passengers keep moving in a straight line.

5. When a car is involved in a collision, a net backward force acts on the car. If the passenger is not wearing a seatbelt, he/she will not experience this net force. According to Newton's first law, he/she will continue moving forward at constant velocity and collide with the wind shield. If the passenger was wearing a seat belt, it would exert a net backward force on the passenger causing the passenger to slow down with the car.

6. There is no air friction in the vacuum of space. When the engine is switched off, there is no net force acting on the rocket. According to Newton's first law, the rocket will continue moving forward at constant velocity.

7. The skater is moving forwards when he jumps off. His feet make contact with the ground. The ground exerts a net backward force on his feet slowing them down. This net force does not act on his upper body. According to Newton's first law, his upper body will continue to move forward at constant velocity. He therefore needs to run so that his feet keep up with his upper body.

8. **8.1** A net forward force acts on the car speeding it up. For a short time interval (until the string tension tightens), this net force does not act on the ornament. According to Newton's first law, the ornament will continue moving at a constant velocity forwards. The ornament travels at a lower speed than the car. The ornament will swing backwards relative to the car.

8.2 A net backward force acts on the car slowing it down. For a short time interval, this net force does not act on the ornament. According to Newton's first law, the ornament will continue moving at a constant velocity forwards. The ornament travels at a higher speed than the car. The ornament will swing forwards relative to the car.

8.3 The car and the ornament do not experience a net force. According to Newton's first law, they will both travel at the same constant velocity forward. The ornament will hang vertically.

CHECKPOINT

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

1. stating Newton's first law.
2. correctly deciding when an object is experiencing a net force and when an object is not experiencing a net force.
3. using Newton's first law to explain the motion of the different objects.

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

Topic 2 Worksheet from the Resource Pack: Newton's Laws and Application of Newton's Laws: Questions 8–13. (Page 14).

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

4. NEWTON'S SECOND LAW

INTRODUCTION

Newton's first law allows us to describe and predict the motion of an object when the net force is zero (remains at rest or moves at constant velocity). Newton's second law governs the motion of an object which DOES experience a net force.

CONCEPT EXPLANATION AND CLARIFICATION

Write Newton's second law on the board: When a net force (F_{net}) is applied to an object of mass (*m*), it accelerates in the direction of the net force. The acceleration (*a*) is directly proportional to the net force and inversely proportional to the mass.

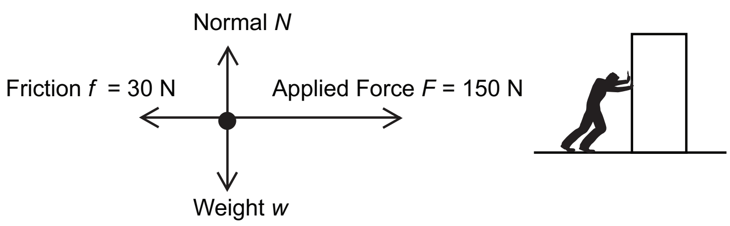
$$F_{net} = ma$$

1. **Apply Newton's second law to motion along a HORIZONTAL PLANE**

   Work through the following example to develop the learners' understanding of Newton's second law.

   1.1 **A man applies a horizontal force of 150 N in order to move an 80 kg cupboard across the carpet. A frictional force of 30 N exists between the carpet and the cupboard.**

Ask your learners to draw a fully labelled a free-body diagram for the cupboard.



Ask the learners if there is a net force in the vertical direction. The answer is NO. The weight down is balanced by the upward normal force.

Ask the learners if there is a net force in the horizontal direction. The answer is YES.

The net force is the vector sum of the forces in the horizontal direction.

If we choose "to the right" as the positive direction, then:

$F_{net} = F - f = 150 - 30 = 120\ \text{N}$ to the right

The direction of the net force on the cupboard is to the right; it follows then that the cupboard will accelerate to the right. Repeat this statement to your learners: "**The direction of the acceleration of the object is always in the same direction as the net force acting on the object**."

Now we can calculate the acceleration of the cupboard using the equation for Newton's second law. Get your learners to set out their answer as shown below:

$F_{net} = ma$	1. Write down the equation.
$F - f = ma$	2. Write down an expression for the net force on the left hand side.
$150 - 30 = (80)\,a$	3. Now substitute any known values.
$120 = 8a$	
a = 1,5 m·s^{-2} to the right	4. The sign of the answer (+) for acceleration, indicates its direction.

The magnitude of the net force on the cupboard is 120 N. Suppose we doubled the net force on the cupboard (240 N), how would this affect the acceleration of the cupboard?

According to Newton's second law, "**the acceleration is directly proportional to the net force**". In symbols: $a \propto F_{net}$

If the mass is kept constant, then **doubling** the net force will **double** the acceleration:

The original acceleration is: $a = \frac{F_{net}}{m}$

The new acceleration is: $a_{new} = \frac{2F_{net}}{m} = 2\left(\frac{2F_{net}}{m}\right) = 2a = 3{,}0 \text{ m·s}^{-2}$

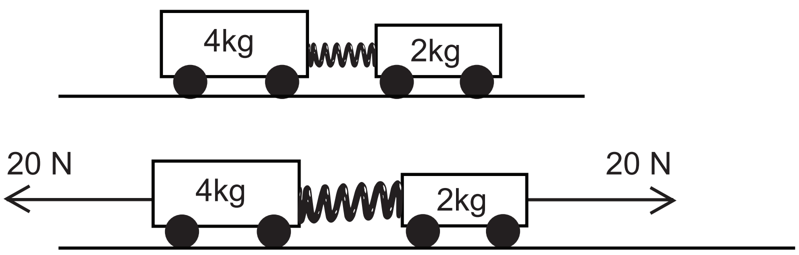
If the mass is kept constant, then **halving** the net force will **halve** the acceleration:

The original acceleration: $a = \frac{F_{net}}{m}$

The new acceleration: $a_{new} = \frac{\frac{1}{2}F_{net}}{m} = \frac{1}{2}\left(\frac{F_{net}}{m}\right) = \frac{1}{2}a = 0{,}75 \text{ m·s}^{-2}$

Work through the following example to continue to develop the learners understanding of Newton's second law.

1.2 A spring is compressed between two trolleys of different mass as shown in the diagram. When the spring is released, it applies a force of 20 N on each trolley. Assume that the surface is frictionless.



Since there is no friction present, the magnitude of the net horizontal force on each trolley is 20 N.

Calculate the acceleration of each trolley. Take "to the right" as the positive direction.

2 kg trolley:	**4 kg trolley:**
$F_{net} = ma$	$F_{net} = ma$
$20 = (2)a$	$-20 = (4)a$
a =1,5 m·s^{-2} to the right	$a = -5 = 5$ m·s^{-2} to the left

The magnitude of the acceleration of the 2 kg trolley is 10 m·s^{-2}. Notice that when the mass is doubled (4 kg), the acceleration is halved (5 m·s^{-2}). According to Newton's second law, "the acceleration is inversely proportional to the mass". In symbols: $a \propto \frac{1}{m}$

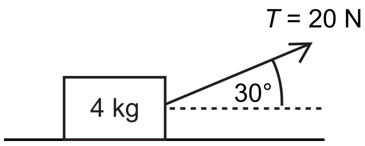
If the net force is kept constant, then doubling the mass will halve the acceleration:

The original acceleration is: $a = \frac{F_{net}}{m}$

The new acceleration is: $a_{new} = \frac{F_{net}}{2m} = \frac{1}{2}\left(\frac{F_{net}}{m}\right) = \frac{1}{2}a$

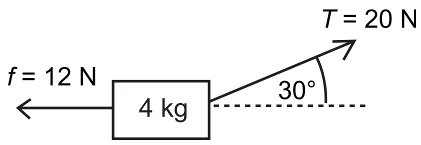
Work through the following example to continue to develop the learners' understanding of Newton's second law.

1.3 A 4 kg crate is pulled along a rough horizontal surface by a light inextisible rope which makes an angle of 30° to the horizontal. The tension in the rope is 20 N and a frictional force of 12 N is present.



When asked to calculate the acceleration of the crate, learners should draw a force diagram to identify all the forces acting on the crate.

The crate accelerates along the horizontal plane. We must therefore resolve the tension force T into its horizontal component (T_x):



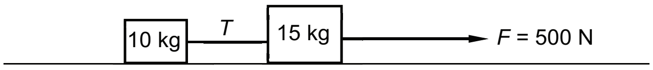
$T_x = T\cos 30° = (20)\cos 30° = 17,32$ N

Now apply Newton's second law to the crate: (Take "to the right" as positive)

$F_{net} = ma$	1. Write down the equation.
$T_x - f = ma$	2. Write down an expression for the net force on the left hand side.
$17,32 - 12 = (4)a$	3. Now substitute any known values.
$5,32 = 4a$	
$a = 1,33$ m·s^{-2} to the right	

Work through the following example to continue to develop the learners understanding and ability to apply Newton's second law.

1.4 Two crates, 10 kg and 15 kg respectively, are connected by a light inextensible rope as shown in the diagram below. A force of 500 N is applied to the 15 kg crate. The frictional force acting on the 10 kg crate is 150 N and 300 N on the 15 kg crate. Calculate the acceleration of the system and the tension in the rope.



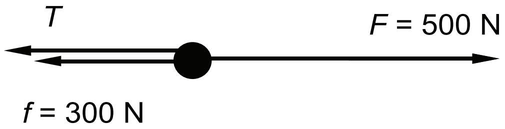
To calculate the acceleration (a) of this system and the tension (T) get your learners to:

1. Draw a neat a free-body diagram for each crate.
2. Apply Newton's second law to each crate separately.
3. Solve the two equations simultaneously to calculate the acceleration (a) and tension (T).

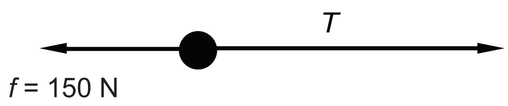
Remind your learners that this system of crates does NOT accelerate upwards (in the vertical direction). Therefore the vector sum of the forces in the vertical direction is ZERO. In other words the net force in the vertical direction is ZERO.
The system of crates DOES accelerate in the horizontal direction.

1. Draw a neat fully labelled free-body diagram for each crate.

15 kg crate:



10 kg crate:



The tension T in the rope acts on BOTH crates but in opposite directions. The tension T in the rope acts to the right on the 10 kg crate and the tension T in the rope acts to the left on the 15 kg.

2. Apply Newton's second law to each crate separately.

15 kg crate:

Choose right as positive.

$F_{net} = ma$

$F - T - f = (15)a$

$500 - T - 300 = 15a$

$200 - T = 15a$

$T = 200 - 15a$ (i)

10 kg crate:

$F_{net} = ma$

$T - f = (10)a$

$T - 150 = 10a$

$T = 10a + 150$ (ii)

We now have two equations (i) and (ii) in two unknowns (a) and (T).

3. Solve the two equations simultaneously to calculate the acceleration (a) and tension (T).

Set equation (i) equal to equation (ii)

$200 - 15a = 10a + 150$

$200 - 150 = 15a + 10a$

$50 = 25a$

$a = 2\ \text{m·s}^{-2}$ to the right

Now solve for T by substituting $a = +2\ \text{m·s}^{-2}$ into any of the two equations:

$T = 200 - 15a$

$T = 200 - 15(2) = 200 - 30 = 170\ \text{N}$ to the left on 15 kg crate

$T = 170\ \text{N}$ to the right on 10 kg crate

INTRODUCTORY LEVEL QUESTIONS

a. These are the basic questions 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 board.
- Learners must copy the questions and answer them correctly in their workbook.

1. State Newton's second law of motion.

2. Define acceleration.

3. State whether or not there is a net force acting on the bike in each of the following situations. Give the direction of the acceleration and the net force.

3.1 A girl rides her bike along a straight road at a constant speed.

3.2 She makes a right turn into another street without changing her speed.

3.3 She free-wheels down a hill increasing her velocity.

3.4 She applies the brakes and slows down as she approaches a robot.

3.5 She waits stationary at a red robot.

4. Use words to describe the relationship between the acceleration of an object and the net force acting on the object.

5. Suppose an object is accelerating forwards at 1,5 m·s^{-2} due to a net force F acting on it. Determine the net force acting on the same object (in terms of F) if it accelerates forward at 0,75 m·s^{-2}.

6. Use words to describe the relationship between the acceleration of an object and the mass of the object.

7. Suppose a trolley of mass *m* is accelerating forwards at 2 $m{\cdot}s^{-2}$. Determine the acceleration (in terms of *a*) of another trolley of double the mass which experiences the same net force.

8. A horizontal force of 40 N is applied to the left on a 5 kg trolley which moves along a frictionless horizontal track.

8.1 Calculate the acceleration of the trolley along the frictionless track.

8.2 Suppose the trolley now moves along a rough part of the track and experiences a frictional force of 10 N. The horizontal force of 40 N is still being applied to the left on the trolley. Draw a neat fully labelled free-body diagram for the trolley and calculate the acceleration of the trolley.

8.3 Suppose the trolley now moves along a rougher part of the track and experiences a frictional force of 40 N. The horizontal force of 40 N is still being applied to the left on the trolley. Draw a neat fully labelled free-body diagram for the trolley and calculate the acceleration of the trolley.

Solutions

1. When a net force is applied to an object of mass (*m*), it accelerates in the direction of the net force. The acceleration (*a*) is directly proportional to the net force and inversely proportional to the mass.

2. The rate of change of velocity.

3. **3.1** Her velocity is constant. The bike is not accelerating, therefore $F_{net} = 0$.

3.2 The direction of her velocity is changing, therefore the bike is accelerating to the right. The net force acts to the right.

3.3 Her velocity is changing (increasing). The bike is accelerating down the hill, therefore there is a net forward force on the bike down the hill.

3.4 Her velocity is changing (decreasing), therefore the direction of the acceleration is backwards. A net force acts backwards on her bike.

3.5 She remains at rest, therefore the bike is not accelerating. $F_{net} = 0$.

4. The object will accelerate in the same direction as the net force. The acceleration is directly proportional to the net force.

5. $F_{net} = ma$

The original net force is: $F_{net} = ma$

The new net force is: $F_{net} = m\left(\frac{1}{2}a\right) = \frac{1}{2}ma = \frac{1}{2}F$

6. The acceleration is inversely proportional to the mass of the object.

7. The original acceleration is: $a = \frac{F_{net}}{m}$

The new acceleration is:

$$a_{new} = \frac{F_{net}}{2m} = \frac{1}{2}\left(\frac{F_{net}}{m}\right) = \frac{1}{2}a = \frac{1}{2}(2) = 1\ \text{m·s}^{-2} \text{ in the same direction}$$

8. **8.1** There is no friction, therefore $F_{net} = 40\,\text{N}$ to the left

$a = \frac{F_{net}}{m} = \frac{40}{5} = 8\ \text{m·s}^{-2}$ to the left

8.2 Choose left as positive:

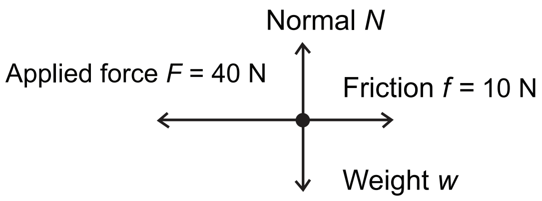
$F_{net} = ma$

$F - f = ma$

$40 - 10 = (5)a$

$30 = 5a$

$a = 6\ \text{m·s}^{-2}$ to the left



8.3 Choose left as positive:

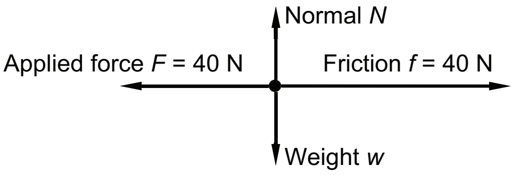
$F_{net} = ma$

$F - f = ma$

$40 - 40 = (50)a$

$0 = 5a$

$a = 0\ \text{m·s}^{-2}$

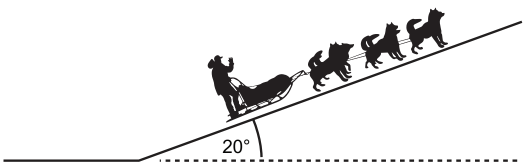


The trolley moves continues to move to the left at constant velocity.

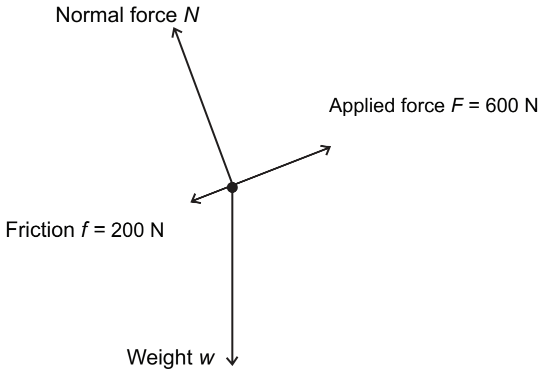
2. **Apply Newton's second law to motion along an INCLINED PLANE**

Work through the following example to continue to develop the learners' understanding and ability to apply Newton's second law.

2.1 A moving sled pulled by dogs begins to climb a slope which is inclined at 20° to the horizontal. The total mass of the sled and the two passengers is 150 kg. The sled experiences a frictional force of 200 N. The dogs exert a combined force of 600 N on the sled. Calculate the acceleration of the sled.

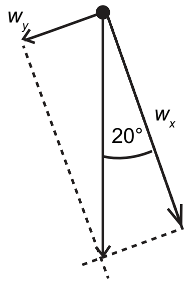


1. Draw a neat fully labelled free-body diagram for the sled.



2. Resolve the weight w into its horizontal component (w_x) parallel to the inclined plane.

The motion of the sled is parallel to the slope; therefore we must consider all the forces parallel to the slope. We need to find the component of the weight parallel to the slope w_x:

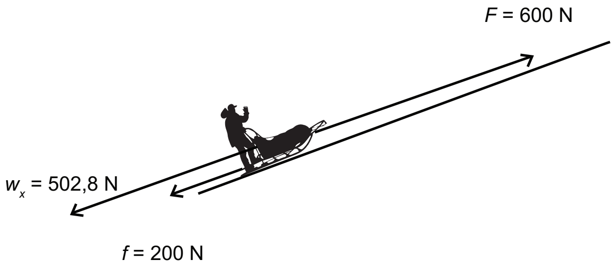


$w = mg = (150)(9{,}8) = 1\,470\ \text{N}$

$w_x = w\sin 20° = 1\,470\sin 20° = 502{,}8\ \text{N}$ down the slope

The horizontal component of the weight ALWAYS acts DOWN a slope.

We have found all the forces acting parallel to the slope:



Choose up the slope as positive.
Applying Newton's second law:

$F_{net} = ma$

$F - w_x - f = (150)a$

$600 - 502{,}8 - 200 = (150)a$

$-102{,}8 = (150)a$

$a = -0{,}69$

$a = 0{,}69\ \text{m·s}^{-2}$ down the slope

The sled is moving up the slope, however the direction of the acceleration of the sled is down the slope. It will slow down.

CHALLENGE LEVEL QUESTIONS

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

b. These questions require a good understanding of Topic 1 (Vectors in two dimensions), force and free-body diagrams and Newton's second law.

c. Get your learners to refer back to the worked examples in this topic to remind themselves of the steps required for a successful solution.

How to tackle these questions in the classroom:

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

KEY TEACHING

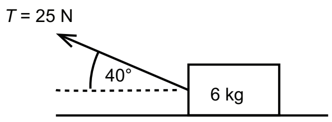
a. Always draw neat, fully labelled force or free-body diagrams to simply the question.

b. Forces that act perpendicular to the plane of motion are balanced. The net force perpendicular to the plane of motion is ZERO.

c. If the object is accelerating, then the forces that acts parallel to the plane of motion are not balanced. There is a net force acting in this plane of motion.

d. When there is more than one object, apply Newton's second law to each object separately.

1. A 6 kg crate is pulled along a rough horizontal surface by a light inextensible rope which makes an angle of 40° to the horizontal. The tension in the rope is 25 N and a frictional force of 10 N is present.



1.1 Draw a neat fully labelled force diagram for the 6 kg crate.

1.2 Calculate the horizontal acceleration of the crate.

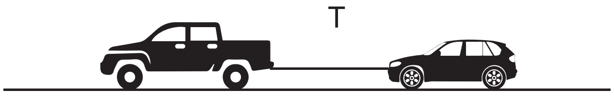
2. A horizontal force of 300 N is applied to a 29 kg crate (to the right) to accelerate it across the floor. The crate experiences a frictional force of 215 N.

2.1 Calculate the acceleration of the crate.

2.2 By what factor would the acceleration change if the mass of the crate was doubled and all forces on the crate remained the same?

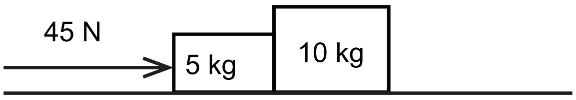
3. During rugby training, a scrum pushes the coach on a scrum machine. The combined mass of the scrum machine and the coach is 300 kg. The coefficient of kinetic friction between the scrum machine and the grass is 0,8. The acceleration of the scrum machine is 0,58 $m{\cdot}s^{-2}$ forwards. Calculate the force applied by the players.

4. A truck (mass 4 000 kg) tows a car (mass 1 600 kg) using a chain. The turning wheels exert a force of 25 000 N on the truck. The force of friction acting on the truck is 3 000 N and 1 500 N on the car.



Calculate the acceleration of the truck and car as well as the tension in the chain.

5. A 5 kg and a 10 kg box are touching each other. A 45 N horizontal force is applied to the 5 kg box in order to accelerate both boxes across the floor. The coefficient of kinetic friction is 0,2.

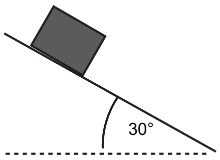


5.1 Draw a free-body diagram for each box.

5.2 Calculate the acceleration of the boxes.

5.3 Calculate the force that the 10 kg box exerts on the 5 kg box.

6. A 4 kg block slides down a rough plane inclined at 30° to the horizontal. The coefficient of kinetic friction between the block and the inclined plane is 0,3.

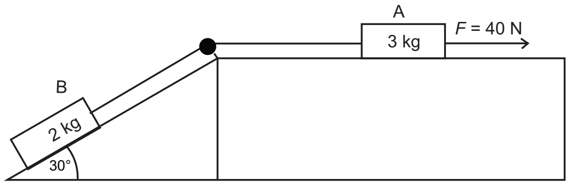


6.1 Calculate the force of kinetic friction acting on the block as it slides down the slope.

6.2 Calculate the acceleration of the block.

TOPIC 2

7. Consider the forces acting on the blocks in the diagram shown below.



Block A (3 kg) and block B (2 kg) are attached by means of a thin cord than doesn't stretch. The cord is passed over a frictionless pulley. A horizontal force *F* of 40 N is applied to block A.
Block A slides along a rough horizontal surface and block B slides up a rough plane inclined at 30° to the horizontal. Block A experiences a frictional force of 14,7 N.

7.1 Draw a fully labelled free-body diagram for block B.

7.2 Calculate the magnitude of the frictional force acting on block B if the coefficient of kinetic friction is 0,5.

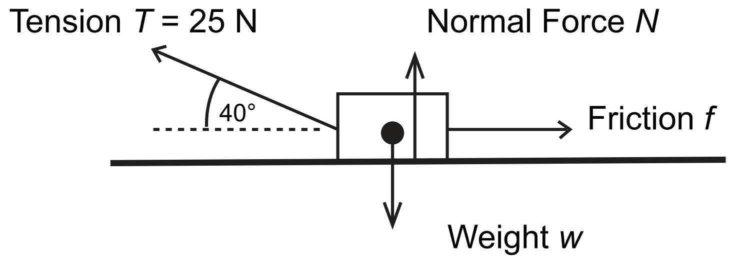
7.3 State Newton's second law of motion.

7.4 If the system accelerates at 1,4 $m{\cdot}s^{-2}$ (from left to right), calculate the magnitude of the tension *T* in the cord.

7.5 While block B is accelerating up the slope, the cord snaps. How does the acceleration of block A change after the cord snaps? Write INCREASE, DECREASE or REMAIN THE SAME. Explain the answer.

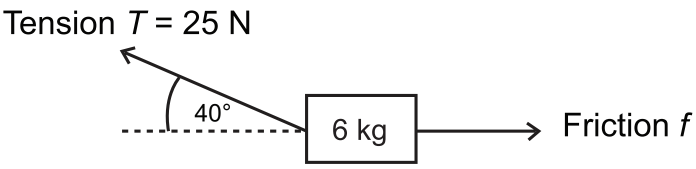
Solutions

1. **1.1**



1.2 $T_x = T\cos 40° = 25\cos 40° = 19,15\ \text{N}$

Choose left as positive



$F_{net} = ma$

$T_x - f = ma$

$19,15 - 10 = 6a$

$9,15 = 6a$

$a = 1,53\ \text{m}{\cdot}\text{s}^{-2}$ to the left

2. **2.1** Choose to the right as positive:

$F_{net} = ma$

$F - f = ma$

$300 - 215 = (29)a$

$85 = 29a$

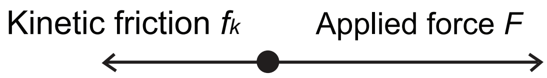
$a = 2{,}93\ \text{m·s}^{-2}$ to the right

The original acceleration is: $a = \dfrac{F_{net}}{m}$

The new acceleration is: $a_{new} = \dfrac{F_{net}}{\frac{1}{2}m} = 2\left(\dfrac{F_{net}}{m}\right) = 2a$

2.2 The acceleration is doubled.

3. $w = mg = 300 \times 9{,}8 = 2\,940\ \text{N}$



$N = 2\,940\ \text{N}$

$f_k = \mu_k N = 0{,}8 \times 2\,940 = 2\,352\ \text{N}$

$F_{net} = ma$

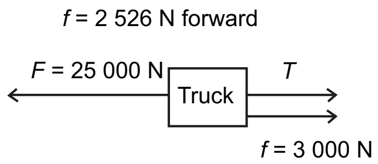
$F - f_k = ma$

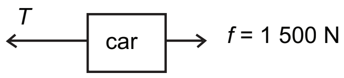
$F - 2\,352 = 300 \times 0{,}58$

$F = 2\,352 + 174$

$F = 2\,526\ \text{N}$ forward

4.





Truck:

Choose left as positive.

$F_{net} = ma$

$F - T = f = (4\,000)a$

$25\,000 - T - 3\,000 = 4\,000a$

$T = 22\,000 - 4\,000a$ (i)

Car:

$F_{net} = ma$

$T - f = (1\,600)a$

$T - 1\,500 = 1\,600a$

$T = 1\,600a + 1\,500$ (ii)

Set equation (i) equal to equation (ii)

$22\,000 - 4\,000a = 1\,600a + 1\,500$

$20\,500 = 5\,600a$

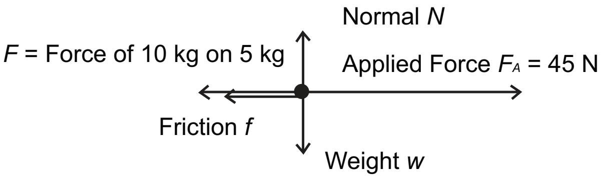
$a = 3{,}66\ \text{m·s}^{-2}$ to the left

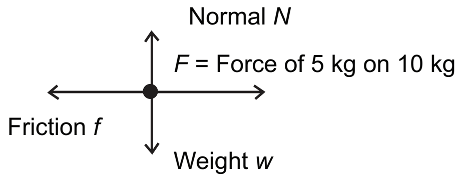
$T = 22\,000 - 4\,000a$

$T = 22\,000 - 4\,000(3{,}66) = 22\,000 - 14\,640 = 7\,360\ \text{N}$ to the right on truck

$T = 7\,360\ \text{N}$ to the left on the car

5. **5.1** **5 kg box** **10 kg box**





5.2 **5 kg box**

$w = mg = 5 \times 9,8 = 49\ \text{N}$

$N = 49\ \text{N}$

$f_k = \mu_k N = 0,2 \times 49 = 9,8\ \text{N}$

10 kg box

$w = mg = 10 \times 9,8 = 98\ \text{N}$

$N = 98\ \text{N}$

$f_k = \mu_k N = 0,2 \times 98 = 19,6\ \text{N}$

Choose right as positive.

5 kg box		10 kg box	
$F_{net} = ma$		$F_{net} = ma$	
$F_A - F - f = (5)a$		$F - f = (10)a$	
$45 - F - 9,8 = 5a$		$F - 19,6 = 10a$	
$F = 35,2 - 5a$	(i)	$F = 19,6 + 10a$	(ii)

Set equation (i) equal to equation (ii)

$35,2 - 5a = 19,6 + 10a$

$15,6 = 15a$

$a = 1,04\ \text{m·s}^{-2}$ to the right

5.3 $F = 35,2 - 5a$

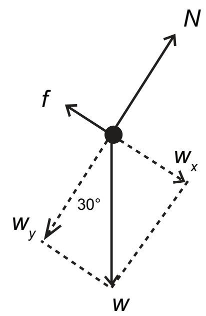
$F = 35,2 - 5(1,04) = 35,2 - 5,2 = 30\ \text{N}$ to the left

6. **6.1** $w = mg = 4 \times 9,8 = 39,2\ \text{N}$

$w_y = w \cos 30° = (39,2) \cos 30° = 33,95\ \text{N}$

$N = 33,95\ \text{N}$

$f_k = \mu_k N = 0,3 \times 33,95 = 10,19\ \text{N}$



6.2 $w_x = w\sin 30° = (39,2)\sin 30° = 19,6\text{ N}$

Choose down the slope as positive.

$F_{net} = ma$

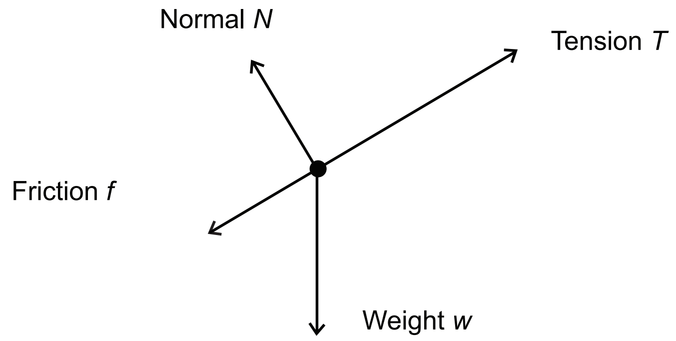
$w_x - f = ma$

$19,6 - 10,19 = (4)a$

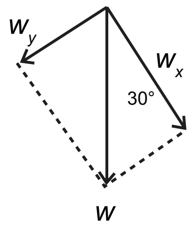
$9,41 = 4a$

$a = 2,35\text{ m·s}^{-2}$ down the slope

7. **7.1**



7.2 $w = mg = 2 \times 9,8 = 19,6\text{ N}$



$w_y = w\cos 30° = (19,6)\cos 30° = 16,97\text{ N}$

$N = 16,97\text{ N}$

$f_k = \mu_k N = 0,5 \times 16,97 = 8,49\text{ N}$

7.3 When a net force is applied to an object of mass (*m*), it accelerates in the direction of the net force. The acceleration (*a*) is directly proportional to the net force and inversely proportional to the mass.

7.4 <u>2 kg</u>:

$w_x = w\sin 30° = (19,6)\sin 30° = 9,8\text{ N}$

$F_{net} = ma$

$T - f - w_x = 2(1,40)$

$T - 8,49 - 9,8 = 2,8$

$T = 21,1\text{ N}$ up the slope

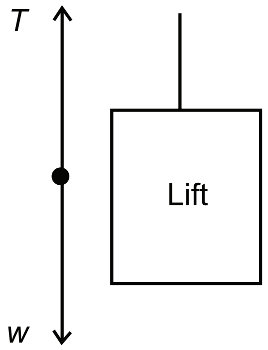
7.5 Increases. *T* becomes zero. The net force on block A increases.

TOPIC 2

3. Apply Newton's second law to motion in the VERTICAL PLANE

Work through the following example to continue to develop the learners' understanding and ability to apply Newton's second law in the VERTICAL PLANE.

3.1 A lift with passengers is stationary at the third floor of a tall building. The total mass of the lift and passengers is 800 kg.



Consider the following **types of motion:**

a. The lift is stationary.

Determine the tension T in the cable.

Since the lift is stationary (remains at rest), the **net force acting on the lift is zero**. The tension (T) in the cable upwards exactly balances the weight (w) of the lift downwards.

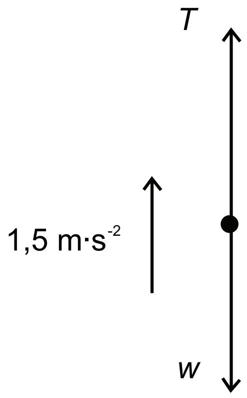
$w = m.g = 800 \times 9{,}8 = 7\ 840\ \text{N}$ downwards

Therefore: $T = 7\ 840\ \text{N}$ upwards

b. The lift is moving upwards while accelerating upwards at 1,5 m·s^{-2}.

Determine the tension T in the cable.

Since the lift is accelerating upwards, the net force (F_{net}) acting on the lift is also upwards. The magnitude of the tension T in the cable is **greater than** the magnitude of the weight w of the lift.



Choose upwards as positive.

Apply Newton's second law:

$F_{net} = ma$

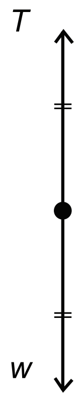
$T - w = (800)(+1{,}5)$

$T - 7\ 840 = 1\ 200$

$T = 9\ 040\ \text{N}$ upwards

c. The lift moves at a constant velocity (up or down)

Determine the tension T in the cable.



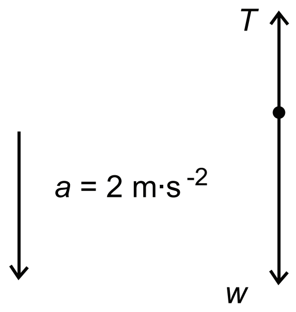
If the lift moves at constant velocity, the acceleration of the lift is zero. According to Newton's second law, the **net force** acting on the lift is **zero**.

The tension (T) in the cable upwards exactly balances the weight (w) of the lift downwards.

$w = mg = 800 \times 9{,}8 = 7\ 840\ \text{N}$ downwards

Therefore: $T = 7\ 840\ \text{N}$ upwards

d. The lift is <u>moving downwards</u> while accelerating downwards at 2 m·s^{-2}.



Determine the tension T in the cable.

Since the lift is accelerating downwards, the net force(F_{net}) acting on lift is also **downwards**. The magnitude of the weight w of the lift is **greater than** the magnitude of the tension T in the cable.

Choose down as positive.

Apply Newton's second law:

$F_{net} = ma$

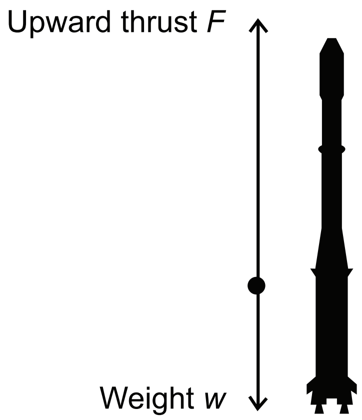
$w - T = (800)(2)$

$7\,840 - T = 1\,600$

$-T = -6\,240$

$T = 6\,240$ N upwards

Consider the forces acting on a rocket moving vertically upwards.



The weight w of the rocket pulls down on the rocket.

The upward thrust F of the rocket engines pushes the rocket upwards.

During **launch**, the magnitude of the upward thrust F must be g**reater than** the magnitude of the weight w of the rocket. This will result in a **net force upwards** and therefore an **upward acceleration.**

3.2 A rocket is launched vertically upwards with an acceleration of 20 m·s^{-2}. If the mass of the rocket is 5 000 kg, calculate the magnitude and direction of the thrust of the rocket engines.

$w = mg = (5\,000)(9,8) = 49\,000$ N downwards

The acceleration is upwards; therefore the net force acting on the rocket is also upwards. F is greater than w.

Choose upwards as positive:

Applying Newton's second law:

$F_{net} = ma$

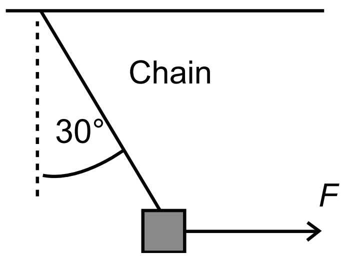
$F - w = (5\,000)(+20)$

$F - 49\,000 = 100\,000$

$F = 149\,000$ N upwards

4. Forces in Equilibrium (Components method)

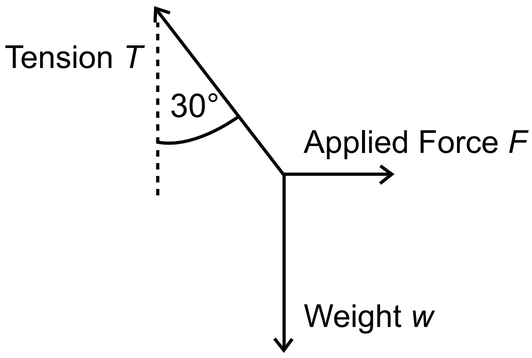
Work through the following example to develop the learners' understanding of forces in equilibrium.



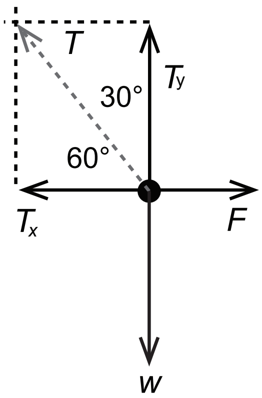
4.1 Consider a car engine which hangs from a chain. A mechanic pulls the engine sideways by applying a force of 100 N to the right. The engine is held in such a position that the chain makes an angle of 30° to the vertical.

Calculate the tension T in the chain.

1. Draw a free-body diagram of the forces acting on the engine.



2. Resolve the tension T into its horizontal component T_x and vertical component T_y.



The engine **remains at rest** therefore the net force in the horizontal direction is **zero**.

This means that the magnitude of the applied force F must **exactly balance** the horizontal component of the tension T_x.

F and T_x are equal in magnitude but opposite in direction.

$F = 100\text{ N}$ to the right

Therefore $T_x = 100\text{ N}$ to the left

$T_x = T\cos 60°$

$100 = T\cos 60°$

$T = \frac{100}{(\cos 60°)} = 200\ \text{N}$

Calculate the mass of the engine.

The engine **remains at rest** therefore the net force in the vertical direction is **zero.**

This means that the magnitude of the weight *w* must **exactly balance** the vertical component of the tension T_y.

w and T_y are equal in magnitude but opposite in direction.

$T_y = T\sin 60°$

$T_y = (200)\sin 60°$

$T_y = 173,21\ \text{N}$ upwards

Therefore $w = 173,21\ \text{N down}$

$m = \frac{w}{g} = \frac{173,21}{9,8} = 17,67\ \text{kg}$

Your learners must remember and understand the following facts:

An object that **remains at rest** or is moving at **constant velocity** has **zero acceleration**, $(a = 0)$.

According to Newton's second law, the **net force** acting on this object is **zero**, ($F_{net} = 0$).

The forces acting on an object are said to be in **equilibrium** if the **net force is zero**.

Conditions for equilibrium

a) All the forces acting parallel to the line of motion of an object must be balanced (i.e. The vector sum of these forces is zero), and

b) All the forces acting perpendicular to the line of motion must be balanced (i.e. The vector sum of these forces is zero).

5. Triangle of forces law

Remind your learners that the **tail-to-head** method can be used to find the resultant of any number of vectors.

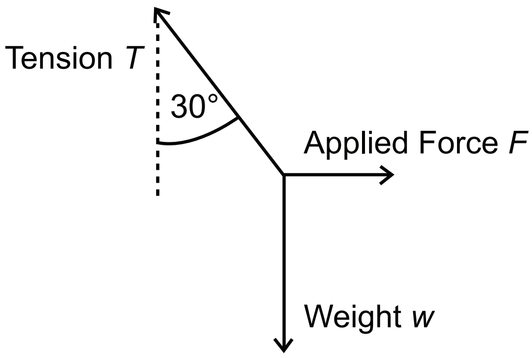
If three forces act on an object AND the three forces are in equilibrium then the net force is ZERO and the three forces drawn tail-to-head will form the **three sides of a closed triangle.**

We will now work through the previous example to equip your learners with another method of dealing with three forces in equilibrium.

TOPIC 2

5.1 Consider a car engine which hangs from a chain. A mechanic pulls the engine sideways by applying a force of 100 N to the right. The engine is held in such a position that the chain makes an angle of 30° to the vertical. Calculate the tension *T* in the chain.

1. Draw a free-body diagram of the forces acting on the engine and fill in any known angles.

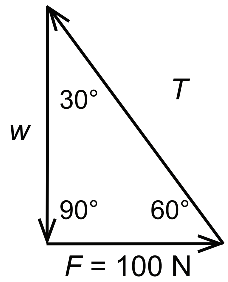


2. Draw the three forces tail-to-head to form a closed triangle and fill in the known angles.

The engine **remains at rest,** therefore the net force acting on the engine is ZERO.

If we draw the three forces tail-to-head (IN ANY ORDER) they must form the three sides of a closed triangle.

In this example, we have formed a right angled triangle.



We can use simple trig. ratios to find *T* and *w*.

$$\sin 30° = \frac{opposite}{hypotenuse} = \frac{100}{T}$$

$$T = \frac{100}{(\sin 30°)} = 200 \text{ N}$$

Calculate the mass of the engine.

$$\tan 30° = \frac{opposite}{adjacent} = \frac{100}{w}$$

$$w = \frac{100}{(\tan 30°)} = 173{,}21 \text{ N}$$

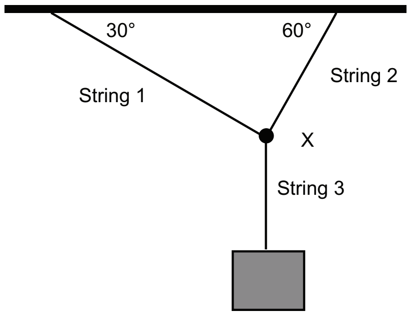
$$m = \frac{w}{g} = \frac{173{,}21}{9{,}8} = 17{,}67 \text{ kg}$$

The Triangle of forces law:

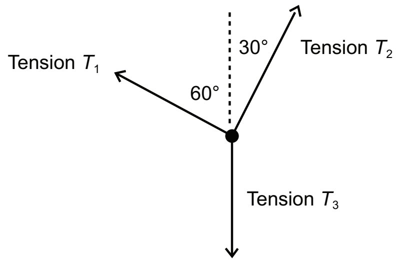
If three forces acting at a point are in equilibrium, they can be represented in magnitude and direction by the sides of a triangle taken in order.

Work through the following example to develop your learners' ability to apply the triangle of forces law.

5.2 A 2 kg mass hangs from the ceiling by means of three light extensible strings attached to point X as shown in the diagram below. Determine the magnitude of the tensions in strings 1 and 2.



1. Draw a free-body diagram of the forces acting on point X and fill in any known angles.



2. Draw the three forces tail-to-head to form a closed triangle and fill in the known angles.

The tension T_3 is equal to the weight of the block.

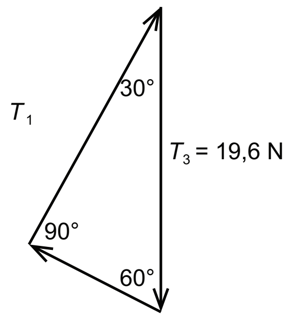
$$w = mg = (2)(9{,}8) = 19{,}6 \text{ N} = T_3$$

$$\sin 30^\circ = \frac{T_2}{19{,}6}$$

$$T_2 = (19{,}6)\sin 30^\circ = 9{,}8 \text{ N}$$

$$\cos 30^\circ = \frac{T_1}{19{,}6}$$

$$T_1 = (19{,}6)\cos 30^\circ = 16{,}97 \text{ N}$$



TOPIC 2

CHALLENGE LEVEL QUESTIONS

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

b. These questions require a good understanding of topic 1 (vectors in two dimensions), force and free-body diagrams and Newton's second law.

c. Get your learners to refer back to the worked examples in this topic to remind themselves of the steps required for a successful solution.

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

KEY TEACHING

a. Always draw neat, fully labelled force or free-body diagrams to simplify the question.

b. Apply Newton's second law to motion in the vertical plane.

c. When there is more than one object, apply Newton's second law to each object separately.

d. If an object remains at rest or moves at constant velocity, then the net force is zero and the forces are in equilibrium.

e. When three forces are in equilibrium, use the components method or the triangle of forces law to solve the problem.

1. Calculate the upward force that is required to accelerate a toy rocket of mass 0,5 kg vertically upwards at 8 $m{\cdot}s^{-2}$.

2. A lift, mass 300 kg, is initially at rest on the ground floor of a tall building. Passengers with an unknown mass, *m*, climb into the lift. The lift accelerates upwards at 1,8 $m{\cdot}s^{-2}$. The cable supporting the lift exerts a constant upward force of 8 000 N. Ignore friction.

2.1 Draw a fully labelled free-body diagram indicating all the forces acting on the lift while it accelerates upwards.

2.2 Calculate the mass, m, of the passengers.

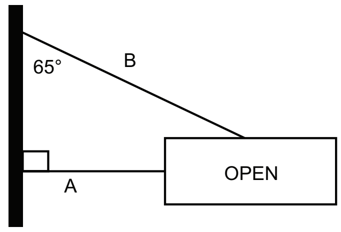
3. A rocket of mass 1 000 kg is travelling upwards with the rocket engines producing a constant upward thrust of 7 000 N.

3.1 Calculate the acceleration of the rocket.

3.2 Draw a fully labelled free-body diagram for the rocket.

3.3 How would the acceleration of the rocket change during its flight if the rocket engines continue to produce a constant upward thrust? Explain your answer. (Hint: Consider the total mass of the rocket and its fuel.)

4. A sign hanging outside a shop is attached by means of two solid struts (A and B) as shown in the diagram. Strut A exerts a horizontal force of 40 N on the sign. The force exerted by strut B is unknown.



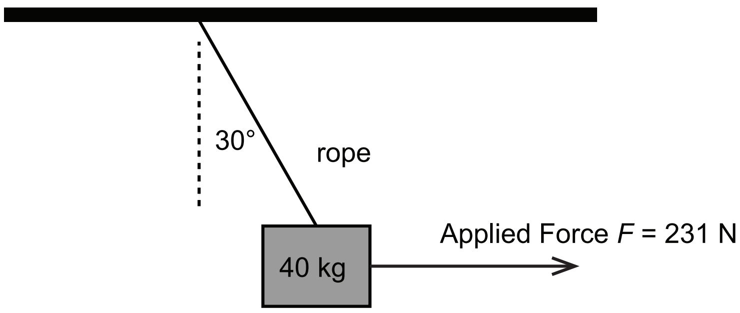
4.1 Draw a free-body diagram of the forces acting on the sign. Include any relevant angles.

4.2 Are the three forces acting on the sign in equilibrium? Explain your answer.

4.3 Determine the mass of the sign.

4.4 Determine the magnitude of the force exerted by strut B.

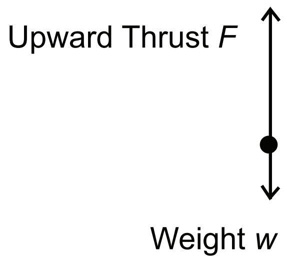
5. A mass of 40 kg is suspended from the ceiling by a length of light inextensible rope. The mass is pulled sideways by a horizontal force of 231 N until the rope makes an angle of 30° with the vertical. The mass is now stationary.



Determine the magnitude of the tension T in the rope.

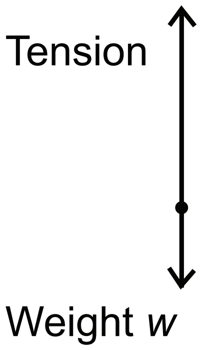
Solutions

1. Choose upwards as positive:



$$F_{net} = ma$$
$$F - w = (0,5)(8)$$
$$F - 4,9 = 4$$
$$F = 8,9\text{ N upwards}$$

2. **2.1**



2.2 Choose upwards as positive.

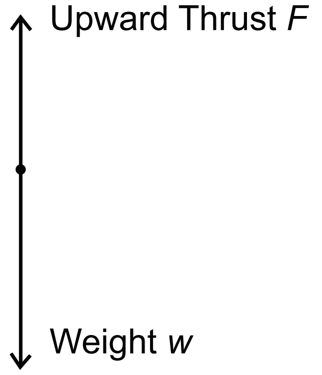
$$F_{net} = ma$$
$$T - W = m_T(1,8)$$
$$8\,000 - (m_T)(9,8) = m_T(1,8)$$
$$8\,000 - 9,8m_T = 1,8m_T$$
$$8\,000 = 11,6m_T$$
$$m_T = 689,66\text{ kg}$$
$$m = 689,66 - 300 = 389,66\text{ kg}$$

3. **3.1** Choose upwards as positive.

$$F_{net} = ma$$
$$F - w = (1\,000)a$$
$$7\,000 - 9\,800 = 1\,000a$$
$$-2\,800 = 1\,000a$$
$$a = -2,8$$
$$a = 2,8\text{ m·s}^{-2}\text{ downwards}$$

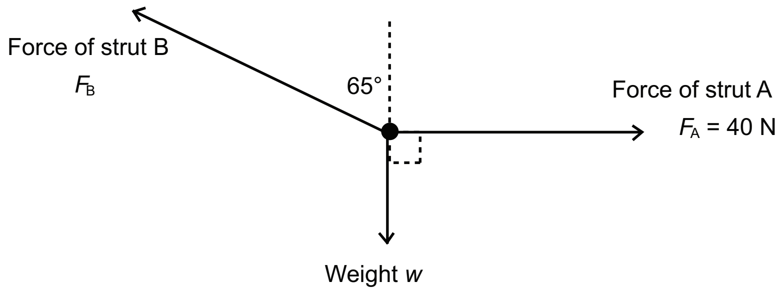
The rocket slows down at a rate of 2,8 m·s^{-2}.

3.2



3.3 The mass decreases, therefore weight decreases. The resultant force on the rocket decreases, therefore its acceleration (in the downward direction) decreases. The rocket will still be slowing down as it travels upwards, but it will be slowing down at an ever-decreasing rate. If its weight drops to be less than 7 000 N, the rocket will accelerate upwards at an ever-increasing rate until all its fuel has been burnt.

4. 4.1

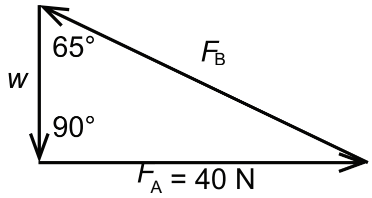


4.2 Yes. The sign remains at rest, therefore the net force is zero.

4.3 $\tan 65^\circ = \dfrac{40}{w}$

$$w = \frac{40}{(\tan 65^\circ)} = 18{,}65\ \text{N}$$

$$m = \frac{w}{g} = \frac{18{,}65}{9{,}8} = 1{,}90\ \text{kg}$$



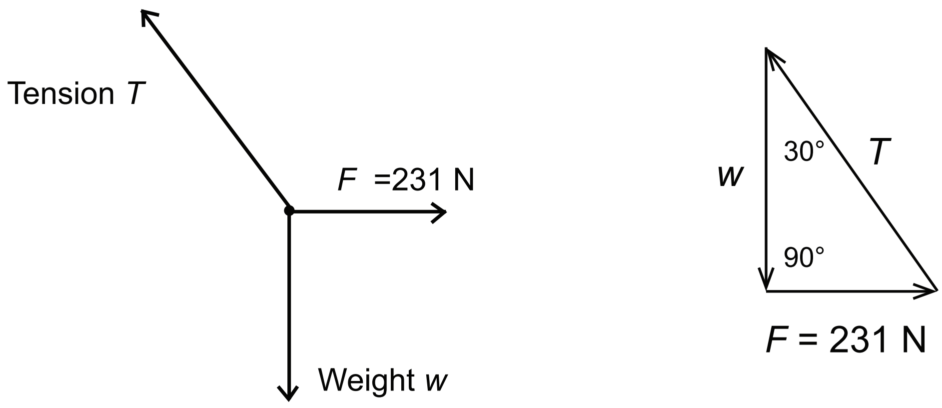
4.4 $\sin 65^\circ = \dfrac{40}{F_B}$

$$F_B = \frac{40}{(\sin 65^\circ)}$$

$$F_B = 44{,}14\ \text{N}$$

TOPIC 2

5.



$$\sin 30^\circ = \frac{231}{T}$$

$$T = \frac{231}{(\sin 30^\circ)} = 462\text{ N}$$

CHECKPOINT

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

1. applying Newton's second law to motion on a horizontal plane.
2. applying Newton's second law to motion on an inclined plane.
3. applying Newton's second law to motion in the vertical plane.

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

Topic 2 Worksheet from the Resource Pack: Newton's Laws and Application of Newton's Laws: Questions 14–20. (Pages 15–16).

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

5. NEWTON'S THIRD LAW

INTRODUCTION

Newton's third law deals with the interaction of pairs of objects.

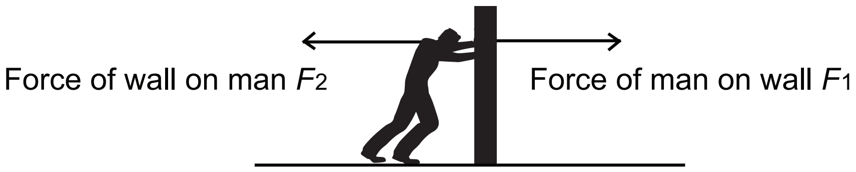
CONCEPT EXPLANATION AND CLARIFICATION

Let's begin by looking at the statement of Newton's third law. Write Newton's third law on the board.

Newton's third law: When object A exerts a force on object B; object B simultaneously exerts an oppositely directed force of equal magnitude on object A.

Get your learners to consider the following examples to better understand Newton's third law:

A man pushes against the wall as shown below, by exerting a horizontal force on the wall F_1.



The **action force** is the force of the man on the wall F_1. According to Newton's third law; the wall will exert an equal force on the man in the opposite direction. The **reaction force** is the force of the wall on the man F_2.

These forces are known as action-reaction pairs. Action-reaction pairs are **equal in magnitude** but act in **opposite directions**. Action-reaction pairs act at the SAME TIME.

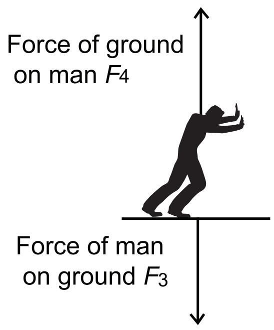
Action-reaction pairs **DO NOT** cancel each other, because they **act on different objects**. F_1 acts ON THE WALL; F_2 acts ON THE MAN.

There are other action-reaction pairs involved in this example:

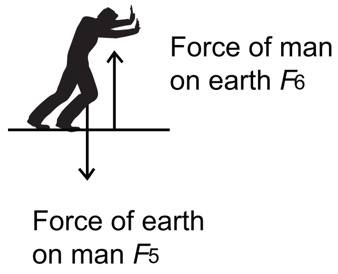
The man presses down on the ground F_3.

The ground presses up on the man F_4.

These forces act on **different bodies**.
They are equal in magnitude but opposite in direction.



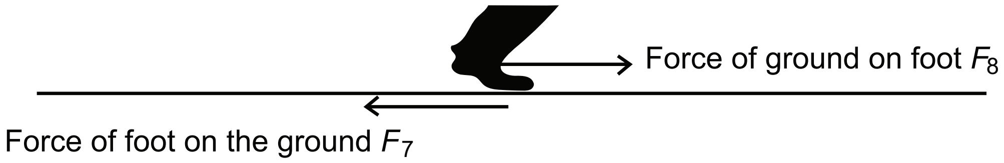
There are also **gravitational forces** of attraction involved in this example:



The Earth exerts a gravitational force of attraction on the man (his weight) F_5.

According to Newton's third law; the man will exert an equal gravitational force of attraction on the Earth (upwards) F_6.

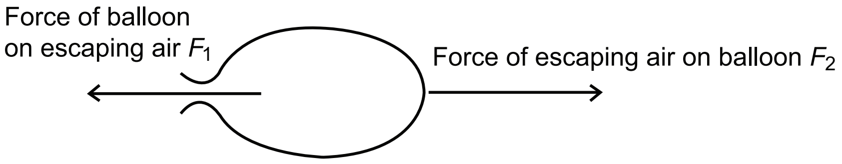
Here is another action-reaction pair in this example:



His foot exerts a backward force on the ground F_7, according to Newton's third law, the ground exerts an equal forward force on his foot F_8.

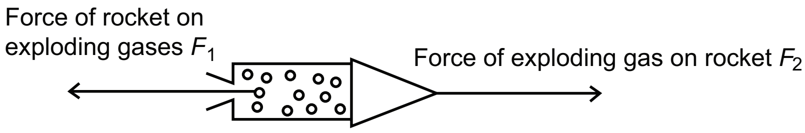
The next example is a very important one and must be discussed in class.

Imagine you blow up a balloon and release the end.



The balloon squeezes the air out of the hole. In another words, the balloon exerts a backward force on the air in the balloon F_1. According to Newton's third law, the escaping air exerts a forward force on the balloon F_2.

This is how rockets propel themselves forward. The rocket exerts a force on the exploding gases F_1, forcing the gas out the back end of the rocket. The exploding gases will then exert an equal forward force on the rocket F_2.



Note that a Newton's third law action-reaction pair will always involve the same combination of words, for example, "rocket on gases" and "gases on rocket". The objects are swapped around when naming the pairs.

Write a summary of the properties of action-reaction pairs on the board:

Properties of action-reaction pairs of forces:

1. They are equal in magnitude and opposite in direction.
2. They act on different bodies (they do not cancel each other).
3. They act simultaneously (at the same time).
4. They act along the same line.

INTRODUCTORY LEVEL QUESTIONS

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

a. Your learners should be able to identify action-reaction pairs.

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 board.
- Learners must copy down the questions and answer them correctly in their workbooks.

1. A boy presses a book against a wall. Name two action-reaction pairs of forces that are present in this situation.
2. Identify the action-reaction pairs of forces present in each of the following situations:

   2.1 A swimmer moves through the water.

   2.2 A book rests on the table.

Solutions

1. Force of hand on book towards the wall. Force of book on hand away from the wall.
2. **2.1** Force of hand backwards on water. Force of water forwards on hand.

   2.2 Downward force of book on table. Upward force of table on book.

CHALLENGE LEVEL QUESTIONS

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

b. These questions require learners to use their understanding of Newton's third law.

How to tackle these questions in the classroom:

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

KEY TEACHING

a. Identify action-reaction pairs.

b. Use the correct words to describe these forces.

c. They are equal in magnitude and opposite in direction.

d. They act on different bodies (they do not cancel each other).

e. They act simultaneously (at the same time).

1. A book rests on a table. Identify the reaction force to the weight of the book.
2. Identify the action-reaction pairs of forces present in each of the following situations:

   2.1 A rocket accelerates through space.

   2.2 A car moving at constant velocity along the road.

Solutions

1. The weight of the book in words is: The downward force of attraction of the Earth on the book. The reaction force is the upward force of attraction of the book on the Earth.
2. 2.1 Action: The rocket exerts a backward force on the exploding gases.
   Reaction: The exploding gases exert a forward force on the rocket.

   2.2 Action: Tyres exert a backward force on the road.
   Reaction: Road exerts a forward force on the tyres.

CHECKPOINT

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

1. identifying action-reaction pairs.
2. describing the action-reaction pairs.

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

Topic 2 Worksheet from the Resource Pack: Newton's Laws and Application of Newton's Laws: Questions 21–22. (Page 16).

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

6. NEWTON'S LAW OF UNIVERSAL GRAVITATION

INTRODUCTION

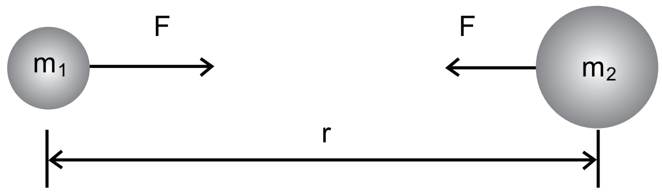
Newton's Law of Universal Gravitation describes the gravitational force of attraction between any two masses.

CONCEPT EXPLANATION AND CLARIFICATION

Write Newton's law of Universal Gravitation on the board:

Newton's Law of Universal Gravitation:
Every object in the universe attracts every other object in the universe with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

Consider any two masses m_1 and m_2:



The distance between the centres is represented by r. According to Newton's Third Law, the masses experience equal forces or attraction, F.

Let's consider each part of the statement of the law:

"the force is directly proportional to the product of their masses"

Therefore: $F \propto m_1 \times m_2$

"the force is inversely proportional to the square of the distance between their centres"

Therefore: $F \propto \frac{1}{r^2}$

This inverse square relationship was found by observing the orbit of the Moon around the Earth.

If we combine the above two relationships we get: $F \propto \frac{(m_1 \times m_2)}{r^2}$

If we introduce a proportionality constant, G, we get: $F = G\frac{m_1 m_2}{r^2}$

F is the gravitational force of attraction (measured in newtons). m_1 and m_2 are the interacting masses (measured in kilograms). r is the distance between the centres of the masses (measured in metres).

The constant G is known as the Universal Gravitational Constant.

$\mathrm{G} = 6{,}7 \times 10^{-11}\,\mathrm{N{\cdot}m^2{\cdot}kg^{-2}}$

The above equation can be used to calculate the gravitational force of attraction acting on each mass. This force is ALWAYS a force of attraction.

Work through the following example with your learners:

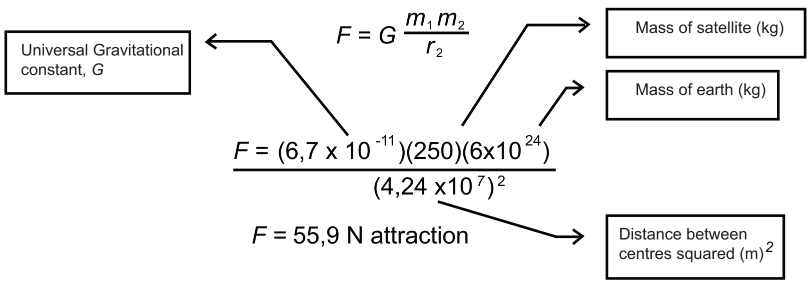
The radius of the Earth $= 6{,}4 \times 10^6$ m. Communications satellites orbit the Earth at a height of 36 000 km.

1. How far is the satellite from the centre of the Earth?
   $36\,000\ \mathrm{km} = 36\,000\,000\ \mathrm{m} = 3{,}6 \times 10^7\ \mathrm{m}$
   $r = 36\,000\,000 + 6\,400\,000 = 42\,400\,000\ \mathrm{m} = 4{,}24 \times 10^7\ \mathrm{m}$

2. If the satellite has a mass of 250 kg, calculate the force of attraction of the Earth on the satellite.

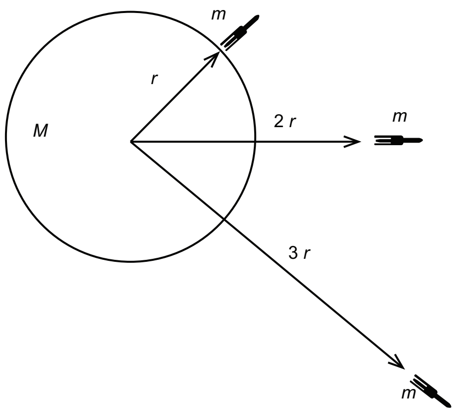
   $\mathrm{G} = 6{,}7 \times 10^{-11}\,\mathrm{N{\cdot}m^2{\cdot}kg^{-2}}$

   mass of Earth $= 6{,}0 \times 10^{24}$ kg



Newton's Law of Universal Gravitation is an example of an "**inverse square law**", so called because the force of attraction varies in inverse proportion to the square of the distance between their centres.

Consider a rocket (mass m) launched from the surface of the Earth (mass M):



When the rocket is on the surface of the Earth the gravitational force is given by:

$$F = G\frac{Mm}{r^2}$$

where r is the radius of the Earth, M is the mass of the Earth. m is the mass of the rocket.

Let's assume that the mass of the rocket $m = 2 \times 10^6$ kg.
The mass of Earth $M = 6 \times 10^{24}$ kg. The radius of the Earth $r = 6,4 \times 10^6$ m

$$F = G\frac{(Mm)}{r^2}$$

$$F = (6,7 \times 10^{-11})\frac{((6 \times 10^{24})(2 \times 10^6))}{(6,4 \times 10^6)^2}$$

$$F = 1,96 \times 10^7 \text{N attraction towards the Earth}$$

Let's now assume the rocket is now **double** its distance from the centre of the Earth ($2r$):

The new gravitational force is found from:

$$F_{new} = G\frac{mM}{(2r)^2} = G\frac{mM}{4r^2} = \frac{1}{4}\left(G\frac{mM}{r^2}\right) = \frac{1}{4}F$$

If the distance between the centres is **doubled**, then the new gravitational force is a **quarter** of the original force.

Let's now assume the rocket has now **tripled** its distance ($3r$) from the centre of the Earth:

The new gravitational force is found from:

$$F_{new} = G\frac{mM}{(3r)^2} = G\frac{mM}{9r^2} = \frac{1}{9}\left(G\frac{mM}{r^2}\right) = \frac{1}{9}F$$

If the distance between the centres **triples**, then the new gravitational force is a **ninth** of the original force.

Calculating the acceleration due to gravity (g) on any planet:

First, let's derive an equation for g on Earth.

Consider a man of mass m on the surface of the Earth:

The mass of the Earth is M_{Earth}

The distance between the centre of the Earth and the man is simply equal to the radius of the Earth, d_{Earth}.

The gravitational force exerted on the man can be expressed in **two ways**:

$w = mg$ and $F = G\frac{mM_{Earth}}{(d_{Earth})^2}$

Both these expressions represent the same gravitational force acting on the man (mass m).

Therefore they are equal: $w = F$

$$mg = G\frac{mM_{Earth}}{d_{Earth}^{\ 2}}$$

Divide both sides of the equation by m and we get:

$$g_{Earth} = G\frac{M_{Earth}}{(d_{Earth})^2}$$

We have derived an equation which can be used to calculate the acceleration due to gravity on Earth (g).

Calculate the acceleration due to gravity, *g*.

$G = 6,7 \times 10^{-11}\ \text{N}\cdot\text{m}^2\cdot\text{kg}^{-2}$

mass of Earth $= 5,97 \times 10^{24}$ kg

radius of Earth $= 6,38 \times 10^{6}$ m

$$g_{\text{Earth}} = G\frac{M_{\text{Earth}}}{(d_{\text{Earth}})^2}$$

$$g_{\text{Earth}} = \frac{(6,7 \times 10^{-11})(5,97 \times 10^{24})}{(6,38 \times 10^{6})^2}$$

$$g_{\text{Earth}} = 9,83\ \text{m}\cdot\text{s}^{-2} \text{ towards the Earth}$$

There is an **important point** to note about the gravitational field strength, g:

$$g_{Earth} = G\frac{M_{Earth}}{(d_{Earth})^2}$$

***g* does <u>not</u> depend on the mass of the man (*m*).**

Thus two objects of different mass will experience the same gravitational acceleration, but will feel different gravitational forces.

The equation for g can be used on **ANY** planet:

$$g = G\frac{M_{planet}}{(d_{planet})^2}$$

where M_{planet} = mass of the planet in question (kg)

d_{planet} = radius of the planet in question (m)

and $G = 6,7 \times 10^{-11}\ \text{N·m}^2\text{·kg}^{-2}$

Calculate the acceleration due to gravity, g, on Mars.

$G = 6,7 \times 10^{-11}\ \text{N·m}^2\text{·kg}^{-2}$

mass of Mars = $6,41 \times 10^{23}$ kg

radius of Mars = $3,39 \times 10^{6}$ m

$$g_{planet} = G\frac{M_{planet}}{(d_{planet})^2}$$

$$g_{Mars} = \frac{(6,7 \times 10^{-11})(6,41 \times 10^{23})}{(3,39 \times 10^{6})^2}$$

$g_{Mars} = 3,74\ \text{m·s}^{-2}$ towards Mars

INTRODUCTORY LEVEL QUESTIONS

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

b. The unit of mass is the kilogram (kg) and the unit of distance is the metre (m).

c. r is the distance between the CENTRES of the two masses.

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 board.
- Learners must copy down the questions and answer them correctly in their workbooks.

1. You are standing on the surface of Earth.

1.1 Calculate the force of attraction of the Earth on you.
Mass of the Earth $= 6,0 \times 10^{24}$ kg.

Radius of the Earth $= 6,4 \times 10^{6}$ m.

1.2 What do we call this force?

1.3 What is the force of attraction of you on the Earth?

1.4 Calculate the force of attraction of the Sun on you?
Mass of the Sun $= 2,0 \times 10^{30}\,\text{kg}$.
Average distance between centre of Earth and centre of Sun $= 1,5 \times 10^{11}\,\text{m}$.

1.5 How many times smaller is the force of attraction of the Sun on you than the force of attraction from the Earth on you?

2. Calculate the weight of an astronaut whose mass (including spacesuit) is 72 kg on the Moon.
Mass of the Moon $= 7,4 \times 10^{22}$ kg.
Radius of Moon $= 1,74 \times 10^{6}\,\text{m}$.

3. Calculate the acceleration due to gravity on Jupiter.
Mass of Jupiter $= 1,9 \times 10^{27}\,\text{kg}$;
Radius of Jupiter $= 7,1 \times 10^{7}\,\text{m}$; $G = 6,7 \times 10^{-11}\ \text{N·m}^2\text{·kg}^{-2}$.

Solutions

1. **1.1** Use your own mass.

$$F = G\frac{m_1 m_2}{r^2}$$

$$\text{F} = (6,7 \times 10^{-11})\left(\frac{(6 \times 10^{24})(87)}{(6,4 \times 10^{6})^2}\right)$$

$$F = 853,86\ \text{N downwards on you}$$

1.2 Your weight

1.3 $F = 853,86\ \text{N upwards on the Earth}$

1.4 $F = G\frac{m_1 m_2}{r^2}$

$$\text{F} = (6,7 \times 10^{-11})\frac{((2 \times 10^{30}) \cdot (87))}{(1,5 \times 10^{11})^2}$$

$$F = 0,52\ \text{N towards the Sun}$$

1.5 $\frac{853,86}{0,52} = 1\,642$ times smaller

2. $F = G\frac{m_1 m_2}{r^2}$

$$\text{F} = (6,7 \times 10^{-11})\frac{((7,4 \times 10^{22}) \cdot (72))}{(1,74 \times 10^{6})^2}$$

$$F = 117,91\ \text{N}\ \text{towards the Moon}$$

3. $g_{planet} = G\frac{M_{planet}}{d_{planet}^{\,2}}$

$$\text{g}_{\text{Jupiter}} = \frac{(6,7 \times 10^{-11})(1,9 \times 10^{27})}{(7,1 \times 10^{7})^2}$$

$$g_{Jupiter} = 25,25\ \text{m·s}^{-2}\quad \text{towards Jupiter}$$

CHALLENGE LEVEL CALCULATIONS

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

b. These questions require learners to draw a picture to better understand the question.

c. These questions require learners to change the subject of the formula and convert to the correct units.

How to tackle these questions in the classroom:

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

KEY TEACHING

a. Draw a picture to better understand the question.

b. Convert km to m before squaring the distance between the centres of the masses.

c. Don't forget to square the distance between the centres of the masses.

d. This is an inverse square law. The force is inversely proportional to the square of the distance between the centres of the masses.

1. Show that the unit for G, the universal gravitational constant, can be expressed as $m^3{\cdot}s^{-2}{\cdot}kg^{-1}$.

2. Consider two masses. The distance between their centres is *r*. By what factor would the gravitational force between the two masses change if each of the following changes were made one at a time:

2.1 Each mass was doubled.

2.2 The distance between their centres was doubled.

3. Calculate the distance between the centres of two equal masses of 150 kg if the force between them is 2×10^{-5} N.

4. Calculate the radius of the moon, if its acceleration due to gravity is 1,67 $m{\cdot}s^{-2}$.
Mass of Moon $= 7,4 \times 10^{22}$ kg; $G = 6,7 \times 10^{-11}$ $N{\cdot}m^2{\cdot}kg^{-2}$.

5. A satellite has a mass of 300 kg.

5.1 The satellite is on the surface of the Earth. Calculate the gravitational force of the earth on a satellite.

Radius of the Earth $= 6,4 \times 10^{6}$ m.

Mass of the Earth $= 6,0 \times 10^{24}$ kg.

$G = 6,7 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$.

5.2 Calculate the gravitational force of Earth on the satellite when it is in orbit 30 km above the surface of the Earth.

Solutions

1. $G = \dfrac{Fr^2}{m_1 m_2} = \dfrac{mar^2}{m_1 m_2} = \dfrac{[\text{kg}]\,[\text{m}\cdot\text{s}^{-2}]\,[\text{m}^2]}{[\text{kg}]^2} = \text{m}^3\cdot\text{s}^{-2}\cdot\text{kg}^{-1}$

2. **2.1** $F_{new} = G\dfrac{2m_1 2m_2}{r^2} = 4\left(G\dfrac{m_1 m_2}{r^2}\right) = 4F$

Force is 4 times greater.

2.2 $F = G\dfrac{m_1 m_2}{r^2}$

$F_{new} = G\dfrac{m_1 m_2}{(2r)^2} = G\dfrac{m_1 m_2}{4r^2} = \dfrac{1}{4}\left(G\dfrac{m_1 m_2}{r^2}\right) = \dfrac{1}{4}F$

Force will decrease by a factor of $\dfrac{1}{4}$

3. $r^2 = G\dfrac{(M_1 m_2)}{F} = \dfrac{(6,7 \times 10^{-11})\,((150)\,(150))}{((2 \times 10^{-5}))}$

$r^2 = 0,075375$

$r = 0,27$ m

4. $g_{planet} = G\dfrac{M_{planet}}{{d_{planet}}^2}$

${d_{\text{planet}}}^2 = G\dfrac{M_{\text{planet}}}{g_{\text{planet}}} = (6,7 \times 10^{-11})\dfrac{((7,4 \times 10^{22}))}{((1,67))} = 2,97 \times 10^{12}$

$d_{planet} = 1,72 \times 10^{6}$ m

5. **5.1** $F = G\dfrac{m_1 m_2}{r^2}$

$F = \dfrac{(6,7 \times 10^{-11})\,((6 \times 10^{24})\,(300))}{(6,4 \times 10^{6})^2}$

$F = 2\,944$ N towards the Earth

5.2 $r = 6,4 \times 10^6 + 30\,000 = 6\,430\,000 = 6,43 \times 10^6$ m

$$F = G\frac{m_1 m_2}{r^2}$$

$$\mathrm{F} = \frac{(6,7 \times 10^{-11})\,((6 \times 10^{24})\,(300))}{(6,43 \times 10^6)^2}$$

$F = 2\,916,93$ N towards the Earth

CHECKPOINT

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

1. calculations using Newton's law of Universal Gravitation.
2. an understanding of an inverse square law.
3. calculating the acceleration due to gravity on a planet (g).

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

Topic 2 Worksheet from the Resource Pack: Newton's Laws and Application of Newton's Laws: Questions 23–26. (Pages 16–17).

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

TOPIC 2

CONSOLIDATION

- Learners can consolidate their learning by completing; **Resource Pack: Topic 2: Newton's Laws and Application of Newton's Laws Consolidation Exercise. (Pages 18–20)**.
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation exercise should be marked by the teacher so that she/he is aware of each learner's progress in this topic.
- Please remember that further consolidation should also be done by completing the examples available in the textbook.
- **It is important to note that this consolidation exercise is NOT scaffolded**. **It should not be administered as a test, as the level of the work may be too high in its entirety**.

ADDITIONAL VIEWING / READING

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

1. https://www.khanacademy.org/science/physics/forces-newtons-laws/newtons-laws-of-motion/v/newton-s-1st-law-of-motion
   Newton's first law of motion
2. https://www.khanacademy.org/science/physics/forces-newtons-laws/newtons-laws-of-motion/v/newton-s-second-law-of-motion
   Newton's second law of motion
3. https://www.khanacademy.org/science/physics/forces-newtons-laws/newtons-laws-of-motion/v/newton-s-third-law-of-motion
   Newton's third law of motion
4. https://www.khanacademy.org/science/physics/centripetal-force-and-gravitation/gravity-newtonian/v/introduction-to-newton-s-law-of-gravitation
   Newton's law of Universal Gravitation

TOPIC 3:

Atomic Combinations – Molecular Structure

A Introduction

- This topic runs for 6 hours.
- For guidance on how to break down this topic, please consult the NECT Planner and Tracker.
- Atomic Combinations – Molecular Structure forms part of the content area Matter and Materials (Chemistry).
- Matter and Materials counts 40 % in the final Grade 11 Paper 2 (Chemistry) examination.
- Atomic Combinations – Molecular Structure counts approximately 16,67 % in the final Grade 11 Paper 2 (Chemistry) examination.
- Atomic Combinations – Molecular Structure forms an important area within Matter and Materials. This topic will look to revise the concepts of chemical bonding and then look at how the molecules that are formed are orientated in space through the VSEPR theory. It will also look at the concept of polarity and why certain molecules are classified as polar or non-polar and then look at the strength of the chemical bond relating how much energy is need to break that bond.

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard
2. Chalk
3. SUGGESTION: A packet of jelly tots and some toothpicks or matches to demonstrate the 5 ideal molecular shapes when looking at the topic of molecular shapes due to VSEPR theory. These can be used to represent the shapes visually to the learners.
4. Grade 11 Chemistry Examination Data Sheets.

CLASSROOM REQUIREMENTS FOR THE LEARNER

1. An A4 3-quire exercise book for notes and exercises.
2. Scientific calculator – highly recommend Sharp or Casio (for calculations of electronegativity difference).
3. Pen, pencils.
4. SUGGESTION: If learners have access to coloured pencils, these may be useful in showing/colouring different atoms when drawing molecular shapes in VSEPR theory.
5. Grade 11 Chemistry Examination Data Sheets.

B Sequential Table

PRIOR KNOWLEDGE	CURRENT	LOOKING FORWARD
GRADE 10	**GRADE 11**	**GRADE 12**
• The basic structure of the atom – protons and neutrons make up the nucleus, Electrons orbit around the nucleus in energy levels. • The concepts of valence electrons and valency • The basic concepts of covalent, ionic and metallic bonding. • Ability to recognise and draw Lewis Diagrams for covalent and ionically bonded compounds. • Understanding the meaning of a crystal lattice, specifically with regards to ionic structures.	• A covalent chemical bond is formed when an electrostatic force exists between two atoms that are sharing electrons. • Molecules have different shapes depending on the number of atoms that make up the molecule and the forces that exist within the molecule due to the repulsive effects of lone pair and bonding pair electrons. • Molecules can be classified as either non-polar covalent or polar covalent due to the electronegativity of atoms within the chemical bond. • Although molecules can contain polar covalent bonds within the molecule, the molecule can be overall non-polar due to its symmetry. • The relationship between bond length and bond energy within a covalent molecule.	• Knowledge and understanding of this topic are used in organic chemistry when looking at intermolecular forces between organic molecules.

C Glossary of Terms

TERM	DEFINITION
Chemical bond	A mutual attraction between two atoms resulting from the simultaneous attraction between their nuclei and the outer electrons.
Valence electrons (or outer electrons)	The electrons in the highest energy level of an atom in which there are electrons.
Covalent bond	The sharing of electrons between two atoms to form a molecule.
Molecule	A group of two or more atoms covalently bonded and that function as a unit.
A bonding pair	A pair of electrons that is shared between two atoms in a covalent bond.
A lone pair	A pair of electrons in the valence shell of an atom that is not shared with another atom.
Electronegativity	A measure of the tendency of an atom in a molecule to attract bonding electrons.
Bond energy	The bond energy of a compound is the energy needed to break one mole of its molecules into separate atoms.
Bond length	The average distance between the nuclei of two bonded atoms.
A non-polar covalent bond	A bond in which the electron density is shared equally between the two atoms.
A polar covalent bond	A bond in which the electron density is shared unequally between the two atoms.
Core electrons	Electrons found in the energy levels below the outermost energy level.
Valence shell	The outermost energy level of an atom.
Electron configuration	A short-hand representation of the electron structure of an atom showing energy levels, orbitals and electrons found in those orbitals e.g. carbon – $1s^2\ 2s^2\ 2p^3$
Electrostatic force	The force of attraction between two oppositely charged particles, or the force of repulsion between two particles of the same charge.
Intramolecular force	The electrostatic force (of attraction) that exists within a chemical bond.
Lewis diagram (Electron diagram; electron dot formula; a Lewis formula)	A structural formula in which the electrons are represented by dots or crosses.
The 'rule of two"	States that there must be two electrons in a chemical bond.
Single bond	One chemical bond that exists between two atoms in a molecule.
Multiple bonds	Two or more bonds that exist between two atoms in a molecule.

Dative covalent bond (Co-ordinate covalent bond)	Bond formed when the lone pair of electrons from one atom are shared with the empty valence shell of another atom to create a bonding pair.
VSEPR model	Valence shell electron pair repulsion model: Model for predicting the shapes of molecules in which the electron pairs in the valence shell within the molecule are arranged to minimise the repulsive forces between them.
Electronegativity difference	The difference in the electronegativity values calculated from the electronegativity numbers of the two atoms involved in the chemical bond.
Partial charges	Small positive and negative charge created due to the uneven distribution of the shared electron pair within the chemical bond (δ^+ and δ^-).
Bond order	The number of bonds (single, double or triple) between the atoms.

D Assessment of this Topic

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

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

E Breakdown of Topic and Targeted Support Offered

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

TIME ALLOCATION	SUB-TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
2 hours	A chemical bond	67 and 68	• Chemical models • The different types of chemical bonds • The "rule of two" • Interatomic and intermolecular forces • Lone pairs and bonding pairs of electrons • Dative covalent bonding
2 hours	Molecular shapes as predicted using VSEPR theory	69	• The meaning of VSEPR as well as the different types of repulsive forces within a molecule. • Ideal and non-ideal shapes and examples of each. • How to distinguish between an ideal and a non-ideal shape
1 hour	Electronegativity of atoms to explain polarity of bonds	70	• Electronegativity and electronegativity difference. • The meaning of polarity and identifying polar and non-polar molecules
1 hour	Bond energy and length	71	• The understanding of bond energy and bond length • The relationship between bond energy and bond strength. • The relationship between bond energy and bond length. • Looking at the factors that influence bond strength

F Targeted Support per Sub-topic

1. CHEMICAL BONDS

INTRODUCTION

In this section, teachers need to revise all the bonding models that were taught in Grade 10 as well as representing the bonding models using the Lewis (electron dot) diagram. This section will then focus mainly on the covalent bonding model and look at the formation of single bonds, multiple bonds and dative covalent bond between different atoms.

CONCEPT EXPLANATION AND CLARIFICATION: MODELS OF THE ATOM

A Chemical Bond

Before you start with the topic, take time to quickly revise the concept of a scientific model. Explain to the learners that because it is impossible to see actual atoms, scientists use theoretical predictions called scientific models to create a picture or a diagram of what these atoms look like. In chemical bonding, these pictures and diagrams are representations of how scientists believe different types of chemical bonding take place and the models show how the atoms interact to form chemical bonds.

Chemical bonds within a chemical substance play a significant role with regards to chemical and physical properties of that substance. It is important to initially highlight to the learners:

a. The different types of chemical bonds that are found in chemical substances, namely, covalent bonds that occur between non-metal atoms through means of electron sharing, ionic bonds between a metal atom and a non-metal atom through means of electron transfer and metallic bonds between metal atoms through electrostatic forces of attraction between the delocalised electrons and the positive atomic residues (kernels) within the metal structure.

b. How this bonding takes place through Lewis (electron dot) diagrams specifically in covalent and ionic bonding. Firstly, get the learners to identify the correct number of valence electrons for each atom. Secondly, make the learners draw Lewis (electron dot) diagrams for each atom showing the valence electron structure. Thirdly, allow the learners to show covalent bond formation through electron sharing and ionic bond formation through electron transfer. Remind the learners of the "rule of two". Make learners identify lone pair and bonding pair electrons. Ensure learners show all the valence electrons in their final diagram.

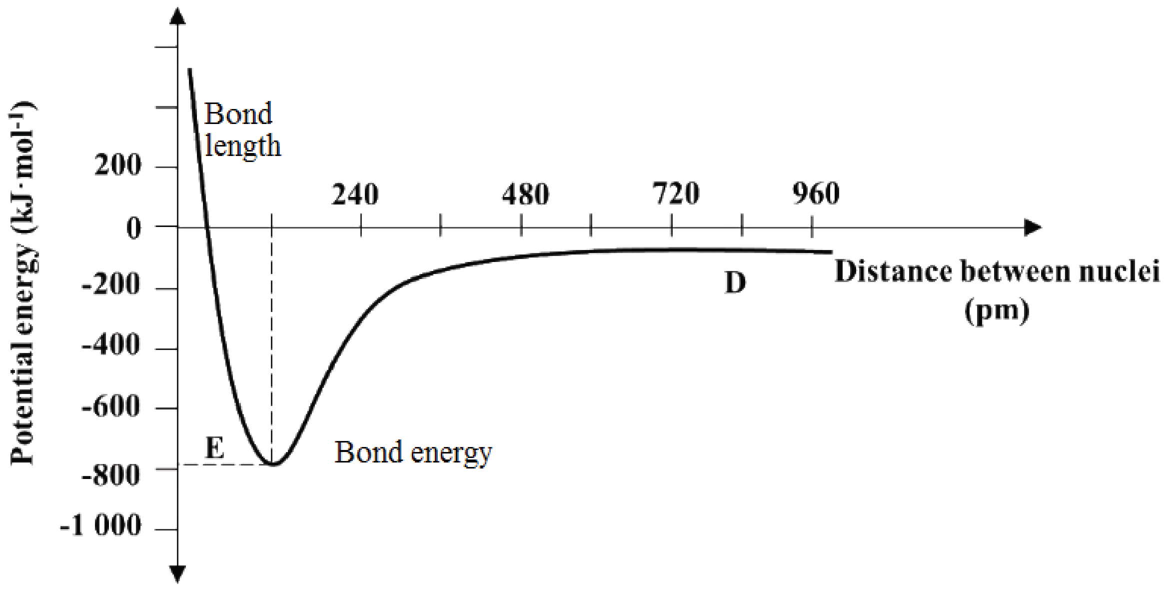
c. That the electrostatic forces of attraction that now hold the atoms or ions together make up the chemical bond and this bond is known as an <u>interatomic force</u>. The word 'inter' referring to a force that occurs between the atoms <u>within</u> the compound. This must not be confused with <u>intermolecular force</u> which is the force between molecules/ions. This will be explained in more detail in Topic 4.

When atoms bond through any of the bonding models, the resulting product ensures that they have much greater stability. Important principles that learners need to understand are:

a. Electrostatic forces – These forces of attraction and repulsion act when atoms approach each other. Attractive forces act when electrons and protons from different atoms pull the atoms together while repulsive forces act when the two sets of electrons and protons try and push the atoms apart. When these attractive and repulsive forces are balanced, then a chemical bond exists between the atoms.

b. The "rule of two" – It is important to emphasise that a chemical bond involves the formation of electron pairs known as a bonding pair, hence the name "rule of two".

c. Bond formation and stability – Use the potential energy graph to show that as the atoms approach each other, the potential energy within the system decreases. At a critical point, the potential energy will be at its lowest when the electrostatic attractive and repulsive forces as balanced. This is now when the combination is at its most stable and the distance between the nuclei of each atom is now fixed. This is known as the bond length.



Use the example of two hydrogen atoms bonding to form a hydrogen molecule to show the importance of the above principles.

Explain why He atoms do not bond as they are group 18 atoms with a full valence shell; that is, all electrons are already paired thus these atoms cannot undergo bond formation. This is true for all group 18 atoms (noble/inert gases).

Now show combinations of different atoms through Lewis diagrams forming molecular compounds. Use F_2 , H_2O , NH_3 , HF , HOCl and OF_2 as examples. Revise with the learners the concepts of lone pairs and bonding pairs. Ask the learners to identify the lone pairs in a Lewis diagram of an atom as well as both the lone pairs and bonding pairs in a Lewis diagram of a molecule.

Lone Pair - paired valence electrons that do not become involved in the chemical bonding between two atoms.

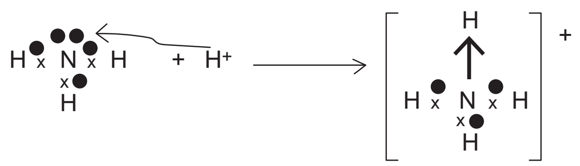
Bonding pair - pair of electrons that are formed when a chemical bond is formed.

Emphasise once again that **lone pairs** do not make chemical bonds. (The dative covalent bond is a special covalent bond formed from a lone pair. Do not complicate the matter at this stage – just say, in general, lone pairs do not make chemical bonds.)

Explain to learners that each **bonding pair** is a single bond.

More than one **bonding pair** can be formed between the same atoms. These are known as multiple bonds and are formed when each atom has two or more unpaired electrons. This leads to the formation of double and triple bonds. Use O_2 (double bond) , N_2 (triple bond) and HCN (triple bond) as examples.

The dative (co-ordinate) covalent bond must be shown using NH_4^+ and H_3O^+ as examples. Emphasise that this type of bonding occurs when an atom with an empty valence shell is able to share a lone pair from another atom which has lone pairs in its valence shell. The atom with an empty valence shell is usually a hydrogen atom which has had its single electron removed to form the H^+ ion. The H^+ ion is in fact simply a proton, and it is highly reactive. NH_3 and H_2O have lone pairs and they are able to "share" a lone pair thus placing 2 electrons in the vacant valence shell of the H^+ ion. Thus a bonding pair is established by the "rule of two". When drawing a Lewis diagram to represent a dative covalent bond, note that an arrow is used to show the bond:



Ammonium cation

INTRODUCTORY LEVEL QUESTIONS

Here are some simple questions that you can give to your learners to help them understand and identify different intermolecular forces.

How to tackle these questions in the classroom:

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

1. Explain the difference between a covalent, an ionic and a metallic bond.

Solution

- Covalent bond: the bonding between non-metal atoms through a process of electron sharing.
- Ionic bond: the bonding between a metal atom and a non-metal atom through the process of electron transfer.
- Metallic bonding: the bonding between metal atoms only through attractive forces between the delocalised electrons and the positive atomic kernels.

2. What is meant by the term 'interatomic force'?

Solution

The force of attraction between atoms or ions within a chemical bond.

3. Explain the difference between a lone pair and a bonding pair.

Solution

Lone pair: A pair of electrons in the valence shell of an atom that is not shared with another atom.

Bonding pair: A pair of electrons that is shared between two atoms in a covalent bond.

4. Draw Lewis diagrams to show valence electrons for the following atoms. Also indicate the number of lone pairs on each atom.

a. Fluorine (F)

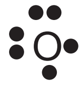
b. Oxygen (O)

c. Aluminium (Al)

d. Nitrogen (N)

Solution

3 lone pairs



2 lone pairs

1 lone pair

1 lone pair

CHALLENGE LEVEL QUESTIONS

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

How to tackle these questions in the classroom:

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

1. Draw Lewis diagrams for the following covalent molecules :

a. Hydrogen chloride (HCl)

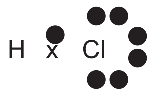
b. Ammonia (NH_3)

c. Carbon dioxide (CO_2)

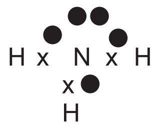
d. Methane (CH_4)

Solution

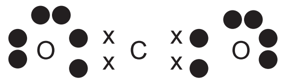
a.



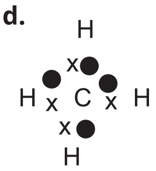
b.



c.



d.



Gr11_PS-Contents_Book_Term1.indb 115 2018/12/27 12:17:07 PM

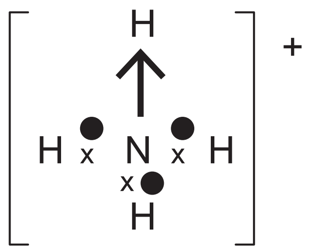
2. a. Explain what is meant by a dative covalent bond.

Solution

A dative covalent bond is formed when the lone pair of one atom is shared with the empty valence shell of another atom.

b. Draw a Lewis diagram to show the formation of a dative covalent bond in the ammonium ion (NH_4^+).

Solution



Ammonium cation

KEY TEACHING

a. In these more challenging questions, learners must be aware of representing the Lewis diagrams correctly for different molecules.

b. Learners must make sure that they place the correct number of electrons around each atom and that the lone pairs and bonding pairs are clear in the diagrams.

c. Learners need to practise working with the concept of the dative covalent bonding. Here the hydronium ion (H_3O^+) can also be used as an example of dative covalent bonding.

CHECKPOINT

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

1. knowing and understanding the difference between covalent, ionic and metallic bonding.
2. knowing and understanding the difference between interatomic and intermolecular forces.
3. knowing and understanding the difference between a lone pair and a bonding pair of electrons.
4. drawing Lewis diagrams representing the arrangement of electrons around an atom.
5. drawing Lewis diagrams representing the arrangement of electrons in molecules showing the lone pair and bonding pair electrons.
6. knowing and understanding of a dative covalent bond and being able to draw a Lewis diagram to show dative covalent bonding.

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

Topic 3 Worksheet from the Resource Pack: Atomic Combinations: Multiple Choice Question 1. (Page 33).

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

2. PREDICTED THROUGH THE VSEPR MODEL

INTRODUCTION

When atoms bond to form molecules, repulsive forces within the molecule due to the lone pair and bonding pairs of electrons become significant. This causes the molecule to alter its shape to minimise these repulsive forces, Depending on how many electron pairs are present as well as the number of atoms making up the molecule, so the magnitude of these repulsive forces vary. This causes different molecular shapes to be formed and these shapes can be explained by applying the VSEPR theory.

CONCEPT EXPLANATION AND CLARIFICATION: ATOMIC MASS AND DIAMETER

Molecular shapes

Please can teachers emphasise that learners need to appreciate molecules exist in three-dimensional space with different shapes depending on the arrangement of the atoms and number of bonds within the molecule itself. This is explained through VSEPR theory. Teachers should emphasise the following:

a. What the symbols VSEPR actually stand for.

b. Repulsive forces exist between the electron pairs that are present in the valence shells after bonding. This includes both lone pairs and bonding pairs.

c. These repulsive forces cause a build-up of stresses within the molecule and thus the electron pairs will repel each other as far away as possible to minimise the stresses. (Remember – molecules wish to be in the lowest, most stable energy state).

d. There are three possible forms of repulsive forces:

- **i** Lone pair – lone pair repulsive forces (strongest)
- **ii** Lone pair – bonding pair repulsive forces (intermediate)
- **iii** Bonding pair – bonding pair repulsive forces (weakest)

Depending on the numbers of lone pairs and bonding pairs and the respective repulsive forces, so the shape of the molecule will be determined. Tell the learners that molecular shapes can be classified into two categories, namely IDEAL and NON-IDEAL SHAPES

A. IDEAL SHAPES

a. Explain to the learners that there are five IDEAL shapes that are studied. These shapes are based on a central atom with no lone pairs surrounding them, namely:

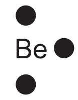
- **i.** Linear
- **ii.** Trigonal planar
- **iii.** Tetrahedral
- **iv.** Trigonal bipyramidal
- **v.** Octahedral

Emphasise to the learners that we show these shapes using a general formula to depict a central atom and then the other atoms around it. A is used to symbolise the central atom and X is used to symbolise the surrounding atoms.

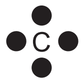
i. Linear	AX or AX_2	example	HCl, HF, CO_2 and $BeCl_2$
ii. Trigonal planar	AX_3	example	BF_3
iii. Tetrahedral	AX_4	example	CH_4
iv. Trigonal bipyramidal	AX_5	example	PCl_5
v . Octahedral	AX_6	example	SF_6

(It is vital for teachers to note here that the central atoms in these examples are in a hybridised state. This means that the valence electrons are all single and unpaired and no lone pairs are present. For example:

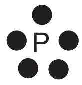
- Beryllium is in group 3 thus will have 3 valence electrons in its hybridised state (3 bonding pairs)



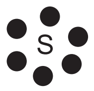
- Carbon is group 14 thus will have 4 unpaired electrons in its hybridised state (4 bonding pairs)



- Phosphorus is in group 15 and will have 5 unpaired electrons in its hybridised state (5 bonding pairs)



- Sulfur is in group 16 and will have 6 unpaired electrons in its hybridised state (6 bonding pairs)



(Hybridisation does not have to be explained in this section).

B. NON-IDEAL SHAPES

Tell the learners that there are other shapes, but these are NON-IDEAL shapes as they have lone pairs of electrons on the central atoms. These are:

i. Angular AX_2 example H_2O

Oxygen is in group 16 like sulfur but is not hybridised. There are thus 2 unpaired electrons available for bonding

ii. Pyramidal AX_3 example NH_3

Nitrogen is in group 15 like phosphorus but is not hybridised. There are now 3 unpaired electrons available for bonding.

The best way to teach these shapes is firstly by identification and then by making models as seen in the activity below.

- Identification – Identify the central atom in the molecule
  - Does it have a lone pair or not in its valence shell?
  - If answer is yes , then it will have an IDEAL shape.
  - If answer is no, then it will have a NON-IDEAL shape.
  - How may atoms surround the central atom?
  - Which general formula will it fit into?
  - Name the shape accordingly.

INTRODUCTORY LEVEL QUESTIONS

Here are some simple questions that you can give to your learners to help them understand and identify different intermolecular forces.

How to tackle these questions in the classroom:

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

1. State what the symbols VSEPR stand for.

Solution

Valence Shell Electron Pair Repulsion

2. Name the three forms/types of repulsive forces that are responsible for the valence shell repulsions in a molecule, and state which are the strongest and which are the weakest.

Solution

Lone pair – lone pair electron repulsions	strongest
Lone pair – bonding pair electron repulsions	
Bonding pair – bonding pair electron repulsions	weakest

3. Molecular shapes are classified into two categories, IDEAL shapes and NON-IDEAL shapes. Briefly explain the difference between the two types of shapes.

Solution

IDEAL SHAPES: These shapes consist of molecules whose central atom contains no lone pairs in the valence shell.
NON-IDEAL SHAPES: These shapes consist of molecules whose central atom contains lone pairs of electrons in the valence shell.

4. Name the five different IDEAL shapes that have been identified and give one example of each.

Solution

Linear	CO_2
Trigonal planar	BF_3
Tetrahedral	CH_4
Trigonal bipyramidal	PCl_5
Octahedral	SF_6

5. Name the two different types of NON-IDEAL shapes that have been identified and give one example of each.

Solution

Angular H_2O
Pyramidal NH_3

CHALLENGE LEVEL CALCULATIONS

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

How to tackle these questions in the classroom:

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

1. Consider the molecule boron tri-iodide (BI_3).

a. Draw the Lewis diagram for BI_3.

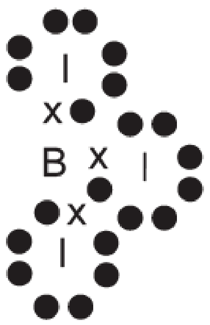
b. Identify the central atom in BI_3.

c. Are there any lone pairs around the central atom? Use this information to identify if BI_3 has an IDEAL or a NON-IDEAL shape.

d. Identify the type of molecular shape that this molecule will have.

Solution

a.



TOPIC 3

b. B – boron

c. No. This means that BI_3 has an IDEAL shape.

d. The general formula of this molecule is AX_3, thus it is trigonal planar.

2. The molecular shape of the ammonia molecule (NH_3) is trigonal pyramidal. It has a bond angle of 107,3°.

a. Draw the Lewis diagram for ammonia.

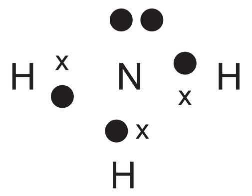
b. Is this an IDEAL or NON-IDEAL molecular shape? Briefly explain your answer.

c. How many lone pairs and how many bonding pairs of electrons are there in the ammonia molecule?

d. Explain, using VSEPR theory, why the NH_3 molecule has a trigonal pyramidal shape and the BH_3 molecule has a trigonal planar shape.

Solution

a.



b. NON-IDEAL. N is the central atom and it has a lone pair of electrons.

c. 1 × lone pair 3 × bonding pairs

d. NH_3: This is due to the electron pair repulsions that occur within the molecule. There are lone pair – bonding pair and bonding pair – bonding pair repulsions hence the combination of these repulsions gives the ammonia molecule it's pyramidal shape.

BH_3: There are no lone pairs on the central atom. There are only bonding pair – bonding pair repulsions within the molecule, hence the magnitude of these forces is different to that of NH_3. This will give BH_3 a trigonal planar shape.

KEY TEACHING

a. In these more challenging questions, learners must be aware of representing the Lewis diagrams correctly for different molecules.

b. Learners will see that a number of concepts are asked within each question and they must be aware of a number of key concepts such as molecular shapes and the difference between IDEAL and NON-IDEAL shapes.

c. Learners must be able to identify the different molecular shapes correctly from the molecular formula.

CHECKPOINT

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

1. the concepts of what causes the different repulsions to occur within a molecule.
2. the classification of IDEAL and NON-IDEAL shapes of molecules and what causes the difference between the these shapes.
3. an understanding as to which molecular shapes are IDEAL and which molecular shape are NON-IDEAL.
4. the ability to correctly predict the shapes based on the molecular formula of a compound.

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

Topic 3 Worksheet from the Resource Pack: Atomic Combinations Worksheet: Multiple Choice Question 2 and Long Questions 1 and 6. (Pages 33–35).

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

3. ELECTRONEGATIVITY AND POLARITY OF MOLECULES

INTRODUCTION

The concept of electronegativity is crucial in developing the understanding of polarity of bonds within molecules, especially the understanding of non-polar and polar covalent molecules. This is an important step to understanding intermolecular forces which will be taught in Topic 4.

CONCEPT EXPLANATION AND CLARIFICATION: STRUCTURE OF THE ATOM: PROTONS, NEUTRONS AND ELECTRONS

Electronegativity and Polarity of Molecules

Definition of electronegativity: A measure of the tendency of an atom in a molecule to attract bonding electrons. (see glossary)

It is useful to spend time with the learners making sure that they understand the meaning of the term 'electronegativity'. Once the learners have understood the concept, then ensure learners are aware of the following:

- All atoms have the ability to attract electrons towards themselves within a chemical bond.
- Different atoms will have different amounts of attraction.
- The size of the atom is an important factor in the size of the electron attraction. Small atoms exert large forces of attraction; for example, in Period 2, N, O and F are small atoms hence have large electronegativity whereas Li, Be and B in Period 2 are bigger atoms hence have smaller electronegativity . (Revise factors that affect atomic size from Grade 10 if necessary).
- Electronegativity is measured using 'electronegativity numbers' developed by American Scientist Linus Pauling who compared relative strengths of attraction on shared electron pairs. Fluorine has EN = 4,0 and hydrogen has EN = 2,1 meaning that F has approximately twice the attractive strength compared to H, and so on.

Polarity occurs within a covalent chemical bond when shared electron pairs are pulled towards one atom or the other causing an excess of electrons close to one atom and a deficiency of electrons on the other. Polarity is indicated by using δ^- to show slightly negative charge on one atom and δ^+ to show slightly positive charge on another.

Electronegativity difference is used to determine whether a covalent bond is polar or non-polar.

- If there is an electronegativity difference equal to 0, the covalent bond is said to be non-polar covalent.
- If the electronegativity difference is between 0 and 1, then the covalent bond is said to be weakly polar covalent.
- When the electronegativity difference is greater than 1, the covalent bond is said to be polar covalent.
- If the electronegativity difference is greater than 2,1, then electron transfer will take place and the bond is said to be ionic.

Make sure that the learners realise that certain molecules may have polar bonds but are overall non-polar due to the symmetry of the molecules. For example, CO_2 and CH_4 contain polar covalent bonds within the molecule, but due to the fact that the arrangement of the bonds within the molecule is symmetrical, the molecule as a whole is non-polar.
(Symmetrical – within a molecule, there is no clear region of separation of opposite charge in the structure.)

δ^+ δ^-
H – F There is a clear region of polarity as there are two regions of opposite charge, hence the charge distribution in the molecule is not symmetrical, hence HF is a polar molecule.

δ^- δ^+ δ^-
O = C = O There are no clear regions of opposite charge, hence the CO_2 molecule is non-polar due to symmetry.

INTRODUCTORY LEVEL QUESTIONS

Here are some simple questions that you can give to your learners to help them understand electronegativity and polarity of molecules.

How to tackle these questions in the classroom:

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

1. Define the term 'electronegativity'.

Solution

A measure of the tendency of an atom in a molecule to attract bonding electrons.

2. What is meant by the Pauling electronegativity scale and why is the Pauling scale so useful?

Solution

The Pauling electronegativity scale is a scale between 0 and 4,0 which compares the electronegativity differences between atoms within a chemical bond. It is useful to see the degree of polarity within a covalent bond which can then give us an idea of the degree of polarity of the molecule.

3. Briefly explain how polarity is achieved in a molecule.

Solution

It is achieved by the measure of the amount of attraction atoms have for a shared electron pair. The greater the electronegativity of an atom, the stronger the pull will be on the shared electron pair. This causes the electron pair to move closer to that particular atom thus causing a high electron cloud density closer to that atom. This will cause a slightly negative charge on the atom (δ^-) The other atom within the bond has now a very low electron cloud density thus leaving it slightly positively charged (δ^+).

CHALLENGE LEVEL QUESTIONS

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

How to tackle these questions in the classroom:

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

1. Explain how symmetry of a molecule can affect the polarity of a molecule. Give an example of a molecule that has its polarity affected by symmetry.

Solution

If a molecule is symmetrical, it will always be non-polar, despite having polar bonds within the molecule. Symmetry ensures that the molecule will not have a distinct region of δ^+ and δ^-. Example is carbon dioxide (CO_2).

O has electronegativity of 3,5 and C has electronegativity of 2,5 – thus shared electron pairs are pulled closer to the O atoms making them δ^- leaving C as δ^+. However, CO_2 is a symmetrical molecule and thus there is no distinct side of the molecule which is δ^+ and δ^- as seen in the Lewis diagram above.

2. Methane (CH_4) is a molecule that has polar bonds, yet the overall molecule is described as non-polar. Explain why this is so.

Solution

C has electronegativity = 2,5

H has electronegativity = 2,1

Electronegativity difference = 0,4 thus there is a polar bond between C and H atoms. However, CH_4 is a symmetrical molecule, hence even though there are polar bonds, the molecule will be overall non-polar as there is no distinct region of polarity.

KEY TEACHING

a. In these more challenging questions, learners must have a good understanding of electronegativity and be able to apply the electronegativity numbers to the various bonds within a molecule.

b. Learners must be able to identify the regions of polarity with the bond and assign δ^+ and δ^- symbols.

c. Learners must understand the concept of symmetry of molecules and what makes a molecule symmetrical

d. Learners must realise that symmetrical molecules will be non-polar even if they have polar bonds because there is no distinct side of the molecule that is charged.

4. BOND ENERGY AND BOND LENGTH

INTRODUCTION

This sub-section now looks at the chemical bond in a bit more detail with respect to how to measure the strength of a chemical bond, as well as what is the length of the chemical bond. These factors are very much influenced by the types of atoms involved in the chemical bond and how many bonds have been formed; that is, is there a single, double or triple bond present in the molecule.

CONCEPT EXPLANATION AND CLARIFICATION

Begin this sub-topic by explaining to the learners that energy is needed to break chemical bonds. This is because there is an attractive force which exists between two bonded atoms so energy must be needed to separate the atoms.

Ensure that the learners are able to define bond energy and bond length.

Bond energy: The bond energy of a compound is the energy needed to break one mole of its molecules into separate atoms.

Bond length: The average distance between the nuclei of two bonded atoms.

The potential energy vs nuclei distance graph shows that bonds are formed when atoms approach each other to reach the lowest energy point where the attractive and repulsive forces are balanced. This energy point is known as the bond energy and the distance from the nuclei of each atom at this point is known as the bond length. Refer to the graph shown on page 112.

It is very important that teachers explain to the learners that the bond energy is directly related to bond strength - that is, the greater the bond energy, the stronger the chemical bond. This means that more energy will be needed in the system to break the bond by overcoming the attractive forces within the bond. Bond energy (bond strength) represents the amount of energy required to break that chemical bond OR the amount of energy released when that bond is formed. Show the learners a bond energy table to illustrate this point.

BOND	BOND ENERGY ($kJ \cdot mol^{-1}$)	BOND LENGTH (pm)
C – C	348	154
C = C	619	134
C = C	835	120
O = O	498	121
C = O	707	120
N = N	941	110

pm = picometres (10^{-12}m)

Explain to the learners that bond energies are measured in the unit "kilojoule per mole", $kJ \cdot mol^{-1}$.

This represents the amount of energy needed to break one mole of the compound into its separate atoms.

Show them a simple example of how this is calculated. Methane (CH_4) has 4 × C – H bonds in the molecule. Each C – H requires approximately 410 $kJ \cdot mol^{-1}$ of energy to break the bond, thus total amount of energy will be 4 × 410 $kJ \cdot mol^{-1}$ which is thus 1 640 $kJ \cdot mol^{-1}$.

Learners must know that the following important factors influence bond strength:

1. **Type or number of bonds** (Bond order) – Does the molecule have single or multiple bonds? Triple bonds require more energy to break the bonds compared to double bonds. Single bonds require the least amount of energy. This is because multiple bonds reduce the bond length between the atoms and the less the bond length, the greater the amount of energy needed to break the bond. This is known as the bond order. Single bonds have bond order = 1, double bonds have bond order = 2, triple bonds have bond order = 3. The reason that the bond length decreases is that there are more electrons in multiple bonds, hence greater attraction by the nuclei of the bonded atoms. Refer to the bond energy table and look at the bonds formed between C atoms. Show the learners that the bond energy values of the single, double and triple bonded C atoms increases.

2. **Length of bond** – The shorter the bond length, the stronger the bond hence more energy is required to break that bond. Thus it will also be true that the longer the bond length, the weaker the bond strength.

3. **Size of bonded atoms** – The larger the atoms involved in the bond, the less the energy required to break the bond. As one moves from left to right across the Periodic Table, the size of the atoms will decrease. Smaller atoms have higher electronegativity, thus the bond strength will increase. Larger atoms have smaller electronegativity hence do not have as great an attraction on the shared electron pair resulting in less energy being required to break the bond.

INTRODUCTORY LEVEL QUESTIONS

Here are some simple questions that you can give to your learners to help them understand bond energy and bond length.

How to tackle these questions in the classroom:

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

1. Define the following terms:
   a. Bond energy
   b. Bond length

Solution

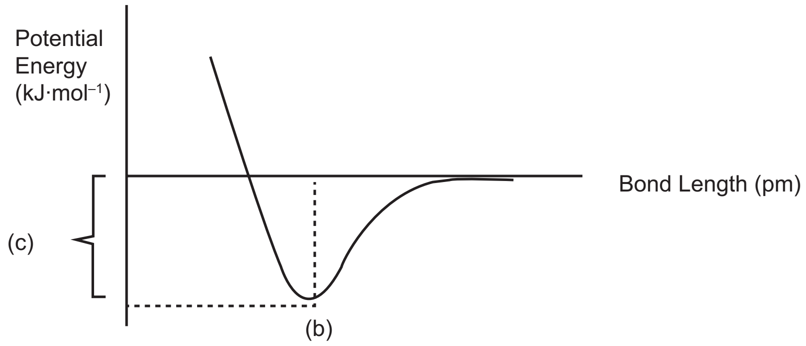
Bond energy: The bond energy of a compound is the energy needed to break one mole of its molecules into separate atoms.

Bond length: The average distance between the nuclei of two bonded atoms.

2. a. Draw a graph of potential energy vs bond length to show the relationship between bond length in the formation or breaking of a chemical bond.
   b. Show on the graph the point at which the molecule will be the most stable. Explain your answer.
   c. Show on the graph how the value of the bond energy can be determined. Explain your answer.

Solution

a.



b. At the lowest point of the curve. This is where the potential energy is the lowest and the bond is at its most stable. The point on the x-axis of the graph corresponding to this position will be the bond length.

c. The difference in the values of the potential energy read off the graph where the molecule is at its most stable, that is, at position (b).

3. State the 3 important factors that influence the strength of a chemical bond.

Solution

- Type or number of bonds
- Bond length
- Size of bonded atoms

CHALLENGE LEVEL QUESTIONS

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

How to tackle these questions in the classroom:

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

1. Consider the following chemical bonds:

C – F C – O C – N C – C

a. Which of these bonds will have the highest energy? Explain your answer.

b. Identify which of these bonds is non-polar. Explain your answer.

Solution

a. C – F. Fluorine (F) is the smallest atom of all the atoms that are bonded to carbon. It will thus have the highest electronegativity causing the strongest chemical bond. This means that more energy will be required to break the bond.

b. The C – C bond. The electronegativity difference is zero thus there will be an equal attraction on the shared electron pair. (non-polar)

2. Which of the following bonds will have the smallest bond length? Explain your answer.

   a. Cl – Cl or I – I

   b. C – C or C = C

Solution

a. Cl – Cl This is due to the fact that chlorine (Cl) is a smaller atom that iodine (I). This means that the distance between the nuclei of the atoms in the bond is shorter.

b. C = C Multiple bonds have shorter bond lengths as there is a greater attraction on the shared electrons by the atoms.

CHECKPOINT

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

1. an understanding of the concept of electronegativity and how it is related to molecular polarity.
2. calculating the electronegativity difference within a molecule.
3. the concept of molecular symmetry and how molecular symmetry plays a role in determining if a molecule is polar or non-polar.
4. understanding of the concepts of bond energy and bond length.
5. understanding how bond energy is related to bond strength and what factors are related to bond strength.

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

Resource Pack: Topic 3: Atomic Combinations Worksheet: Multiple Choice Question 4 and Long Questions 2, 3, 5–7. (Pages 33–35).

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

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topic 3 Consolidation Exercise: Atomic Combinations from the Resource Pack. (Pages 36–40)**.
- Photocopy the exercise sheet for the learners. If that is not possible, learners will need to copy the questions from the board before attempting to answer them.
- The consolidation exercise should be marked by the teacher so that he/she is aware of each learner's progress in this topic.
- Please remember that further consolidation should 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**.

ADDITIONAL VIEWING / READING

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

1. http://www.chemguide.co.uk/atoms/bonding/electroneg.html
   This link provides some good material to the teacher to gain extra insight into the concept of electronegativity.

2. http://intro.chem.okstate.edu/1314F00/Lecture/Chapter10/VSEPR.html
   This link provides some good material to the teacher to gain extra insight into the concept of molecular geometry.

3. https://www.youtube.com/watch?v=nxebQZUVvTg
   A good video which looks at VSEPR. There are a few extra aspects to VSEPR that is not in the syllabus, but there is plenty on the current curriculum to make this relevant.

4. https://www.khanacademy.org/science/biology/chemistry--of-life/chemical-bonds-and-reactions/v/electronegativity-and-chemical-bonds
   The Khan Academy provides excellent material of high quality so there should be benefit to both learners and teachers alike.

TOPIC 4:
Intermolecular Forces

A Introduction

- This topic runs for 10 hours.
- 6 hours needs to be spent on intermolecular forces.
- 4 hours needs to be spent on the chemistry of water.
- For guidance on how to break down this topic, please consult the NECT Planner and Tracker.
- Intermolecular forces forms part of the content area Matter an Materials (Chemistry).
- Matter and Materials counts 20% in the final examination. It counts 40% in the Grade 11 Physical Sciences Paper 2 (Chemistry) examination.
- Intermolecular forces counts approximately 10% in the final Paper 2 (Chemistry) examination.
- Intermolecular forces form an important area within Matter and Materials. It seeks to identify and explain the existence of matter in different phases at varying temperatures. In a liquid or a solid there must be forces between the molecules causing them to attract each other, otherwise the molecules would move apart and become a gas. These forces are called intermolecular forces (forces between molecules).

CLASSROOM REQUIREMENTS FOR THE TEACHER

1. Chalkboard / Whiteboard
2. Chalk / Board marker pens
3. Grade 11 Chemistry Examination Data Sheets.

CLASSROOM REQUIREMENTS FOR THE LEARNER

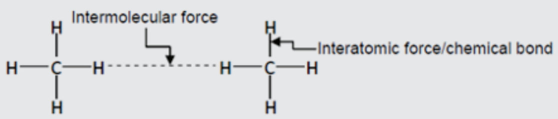
1. An A4 3-quire exercise book for notes and exercises.
2. Scientific calculator – highly recommend Sharp or Casio. (for calculations of electronegativity difference).
3. Pen, pencil.
4. Grade 11 Chemistry Examination Data Sheets.

B Sequential Table

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

• The basic structure of the atom – protons and neutrons make up the nucleus. Electrons orbit around the nucleus in energy levels.
• The concepts of valence electrons and valency.
• The basic concepts of covalent, ionic and metallic bonding.
• Ability to recognise and draw Lewis diagrams for covalent and ionically bonded compounds.
• Understanding the meaning of a crystal lattice, specifically with regards to ionic structures.
	• The difference between interatomic and intermolecular forces.
	• The five different types of intermolecular forces.
	• The special type of dipole- dipole intermolecular forces called hydrogen bonding intermolecular forces.
	• The physical properties that affect the strength of intermolecular forces such as molecular size, molecular shape and molecular polarity.
	• Compare and contrast melting and boiling points to explain different intermolecular forces and how the strength of these intermolecular forces influence these melting and boiling points.
	• Look at thermal conductivity and thermal expansion in metals and non-metals relating it to the motion of particles at different temperatures and how intermolecular forces are affected by the amount of energy in the system.
	• Explain how the density of a substance can be affected by the strength of intermolecular forces.
	• Explain the chemistry of water in terms of the influence of hydrogen bonding intermolecular forces on:
	  • the phases of water
	  • the density of water
	  • the specific heat capacity of water
	  • the heat of vapouristion of water
	  • the high boiling point of water.
		• Learners will be able to compare melting and boiling points of organic molecules in the organic chemistry section.

C Glossary of Terms

TERM	DEFINITION
Intermolecular forces	Forces of attraction between molecules.
London forces or Mutually induced dipoles	Forces between non-polar molecules.
Dipole-dipole forces	Forces between two polar molecules.
Dipole-induced dipole forces	Forces between polar and non-polar molecules.
Hydrogen bonding	Forces between molecules in which hydrogen is covalently bonded to nitrogen, oxygen or fluorine – a special case of dipole-dipole forces.
Ion-dipole forces	Forces between ions and polar molecules.
Van der Waals forces	Forces between molecules or between molecules and ions.
Intermolecular forces and Interatomic forces (or intramolecular force)	Intermolecular forces exist between molecules or between molecules and ions, but interatomic forces (chemical bonds, or intramolecular forces) exist between atoms within molecules. 
Ion	An atom which either has one or more electrons removed from it becoming positive (a cation) or one or more electrons added to it becoming negative (an anion). Some ions consist of a group of atoms which have either more electrons than protons (are negatively charged) or a group of atoms with less electrons than protons (are positively charged).
Dissociation	The process whereby ions in a crystal lattice are removed by water to form hydrated ions in solution.
Electron cloud	The region surrounding an atom or molecule which contains the electrons associated with that atom or molecule.
Kinetic energy	Energy possessed by an object due to its motion.
Aqueous solution	A solution created when a substance dissolves in water. Aqueous solutions contain ions in water.
Boiling point	The temperature at which the vapour pressure of a substance equals atmospheric pressure.
Melting point	The temperature at which the solid and liquid phases of a substance are at equilibrium.
Vapour pressure	The pressure exerted by a vapour at equilibrium with its liquid in a closed system.
Solubility	The property of a solid, liquid, or gaseous chemical substance (solute) to dissolve in a solid, liquid, or gaseous solvent to form a homogeneous solution.

Density	The ratio of mass of a substance to the volume it occupies in space.
Temperature	A measure of the average kinetic energy of the particles in a system.
Thermal expansion	The tendency of a substance to change its volume when its temperature changes.
Thermal conductivity	The ability of a substance to conduct heat.
Crystal lattice	Ordered arrangement of atoms, molecules or ions into a structured arrangement / pattern within the solid phase.
Specific heat capacity	The amount of heat required to raise the temperature of 1 g of a substance by 1°C.
Heat reservoir	A system with sufficiently large heat capacity that its temperature remains constant when it absorbs or releases heat e.g. the oceans are able to absorb vast quantities of heat (or release vast amounts of heat) without a temperature change. This is due to the high specific heat capacity of water.
Heat of vaporisation	The amount of heat energy needed to change one gram of a liquid substance to a gas at constant temperature.
Evaporation	The process in which molecules in the surface of a liquid change to the gaseous phase at temperatures below the boiling point of the substance.
Condensation	The process whereby molecules of a gas release energy to change from the gaseous phase to form the liquid.
Hydride	A binary compound formed by an element bonded to hydrogen e.g. sodium hydride NaH; water H_2O, hydrogen sulfide H_2S.

D Assessment of this Topic

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

- There must be multiple-choice type questions, problems to solve (where the learners are expected to show their method), questions that require explanation and questions that ask for definitions.
- Recommended experiment for informal assessment: Investigate the physical properties of water (density, BP, MP, effective as a solvent, ….)
- Prescribed experiment for formal assessment (which is formally assessed in Term 2): The effects of intermolecular forces: boiling points, melting points, surface tension, solubility, capillarity, ...)

E Breakdown of Topic and Targeted Support Offered

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

TIME ALLOCATION	SUB-TOPIC	CAPS PAGE NUMBER	TARGETED SUPPORT OFFERED
6 hours	Intermolecular and interatomic forces Physical state and density explain with respect to these forces Particle kinetic energy and temperature	72 and 73	• The differences between intermolecular and interatomic forces • The different types of intermolecular forces • The special type of dipole-dipole intermolecular forces, namely the hydrogen bonding intermolecular force • Explaining the concepts of molecular size, shape and polarity • Concepts of melting and boing point • Understanding density • Thermal expansion and thermal conductivity
4 hours	The chemistry of water – macroscopic properties of the three phases of water related to their sub-microscopic structure	74	• The three phases of water looking specifically at how the density of water changes. Also the significance of density in solid and very cold liquid water. • Explanation and calculation of how many water molecules there are in 1kg of water • The water molecule and heat, specifically the understanding of specific heat capacity and heat of vaporisation • Looking at heat of vaporisation in terms of evaporation and condensation. • The high boiling point of water

F Targeted Support per Sub-topic

1. INTERMOLECULAR AND INTERATOMIC FORCES

INTRODUCTION

The difference between intermolecular and interatomic forces is one of the most poorly understood and applied concepts in chemistry. Learners constantly confuse and mix up the two concepts and hence score poorly in this section in tests and examinations. It is vital that learners are able to define the two terms and then apply these definitions to a variety of examples of different intermolecular forces.

CONCEPT EXPLANATION AND CLARIFICATION: INTERATOMIC FORCE (CHEMICAL BONDS)

Interatomic forces are forces that act **within** a molecule or compound and it is these forces that hold the atoms or ions together. In other words, they are chemical bonds that allow atoms and ions to form compounds. We have already studied **covalent**, **ionic** and **metallic** bonding and seen the way electrons are shared, transferred and delocalised to create the bond. In a covalent bond, it is the shared electron pair that is attracted by each of the nuclei of the two atoms involved in the orbital overlap. This creates the attractive force between the atoms. In an ionic bond, it is the formation of positive and negative ions due to electron transfer between the atoms that creates an attractive force between the positive and negative ions. In a metallic bond, it is the attraction between the delocalised electron and the positive ion (atomic kernels) in the metal that creates the attractive forces within the metal. All of these are within the compounds and hence are called **interatomic forces** or **chemical bonds.**

CONCEPT EXPLANATION AND CLARIFICATION: INTERMOLECULAR FORCES

These are the forces that exist between molecules e.g. in a compound, and particles e.g. ions in aqueous solutions. The strength of these forces explains the physical state of a particular substance at a certain temperature. Draw the learners' attention to the fact that there are 5 different types of intermolecular forces, all different in terms of the structure and makeup of the compound and which atoms/ions make up that substance. In molecular compounds, the presence of polar or non-polar bonds plays a significant role in the type and strength of intermolecular force. Intermolecular forces also exist between molecular and ionic compounds e.g. sodium chloride dissolved in water.

The 5 types of intermolecular forces are:
- induced dipole intermolecular forces
- dipole-dipole intermolecular forces
- dipole-induced dipole intermolecular forces
- ion-dipole intermolecular forces
- ion-induced dipole intermolecular forces

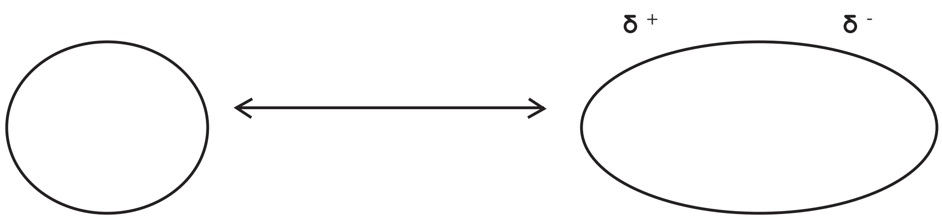
The first three intermolecular forces are known as van der Waals forces named after the Dutch scientist who identified these types of forces. Explain to the learners that van der Waals was able to identify and explain the weak intermolecular forces that exist between liquid, gas and certain molecular solids and classified them as seen in the first three examples on the list.

1. Induced dipole – induced dipole intermolecular forces (London forces)

Introduce the learners to the weakest of the van der Waals forces which exist between non-polar molecules – namely the induced dipole intermolecular forces. It is important to ask the learners to picture a perfectly symmetrical molecule with electrons spinning around the atoms in that molecule at very high speed. This is called the electron cloud and as the non-polar molecules approach each other, the electron clouds distort. This means that the electrons move to one end of the molecule creating two regions of very weak electric charge in the molecule indicated by the symbols δ^+ and δ^- . The δ^+ means that this side of the molecule has fewer electrons and thus gains a slightly positive charge where the other side of the molecule which has more the electrons gains a slightly negative charge δ^-. These dipoles are called induced dipoles as they are not permanent and occur only for a brief moment in time, hence their description as **momentary** dipoles.

Show the learners the shapes illustrated below and identify the shape which shows the distorted molecule. Stress to the learners that the side where the electrons are greater in number becomes weakly negative and the side where electrons are fewer in number becomes slightly positive. This weak polarity is indicated by the lowercase Greek letter delta, δ, which shows that there is only a very small charge.

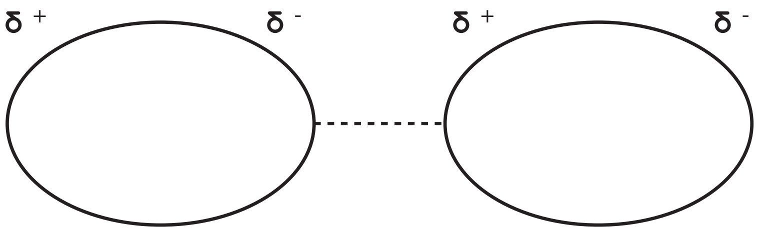
TOPIC 4



Electrons spinning symmetrically around the molecule hence non-polar.

Electrons in greater numbers on the right of molecule creating weak polarity hence δ^- on the right and δ^+ on the left. This is known as an induced dipole.

Now explain to the learners that this weak induced dipole can induce another weak dipole in a non-polar molecule through electron repulsion. Remind them that electrons are negatively charged hence they are repelled to the opposite side setting up weak polarity; that is, another induced dipole is formed.

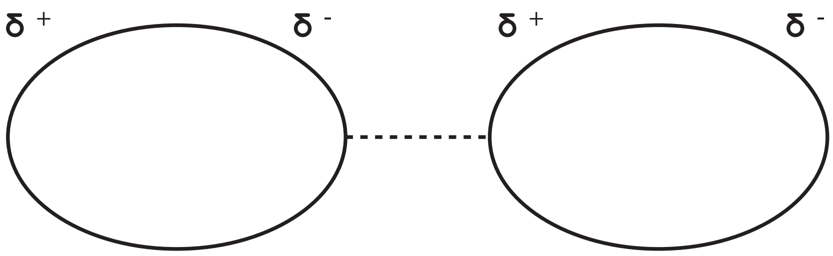


This causes a very weak electrostatic force of attraction between the two weakly induced dipoles – thus we have an induced dipole – induced dipole intermolecular force being created. These forces are also known as **dispersion forces** or **London forces**. <u>They are the weakest of all the intermolecular forces</u>. It is important to note that the larger the molecule, the larger the dispersion forces become because larger molecules have larger electron clouds that can be distorted.

Examples: All non-polar molecules such as the diatomic molecules H_2 , N_2 , O_2 and all the halogens. Also, the noble gases which exist as atoms, are subject to these dispersion intermolecular forces (London forces).

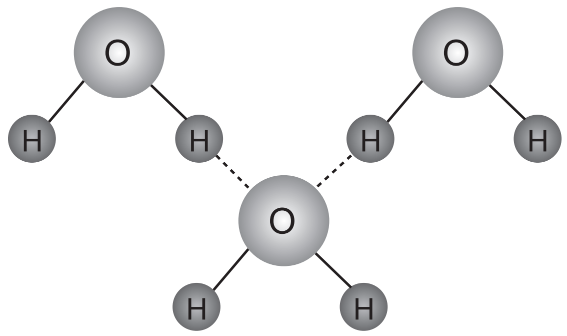
2. Dipole – Dipole intermolecular forces

Explain to the learners that this type of intermolecular force occurs between **polar covalent molecules** where permanent dipoles exist in the molecular structure and hence the areas of δ^- and δ^+ are fixed in the molecule. Once again, get the learners to understand that opposite charges attract and thus the δ^+ end of one molecule will be attracted to the δ^- end of another molecule creating a stronger intermolecular force. It is important for learners to understand that the <u>dipole-dipole intermolecular force is stronger than the induced dipole – induced dipole intermolecular force as they are permanent dipoles.</u>



Examples: HCl , ICl where these molecules have permanent dipoles due to the large electronegativity difference between the atoms in their structure.

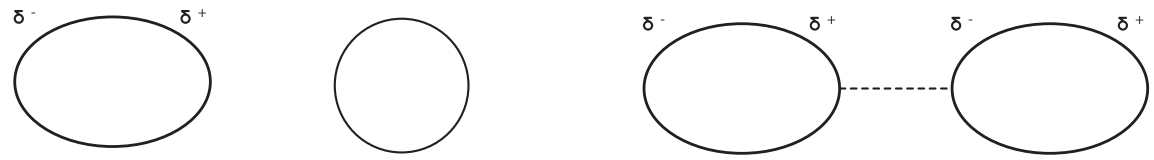
We must look at one special case of dipole-dipole intermolecular force known as a **hydrogen bonding intermolecular force**. At this point, you must say that the name itself is a bit misleading as it is NOT a bond, but still an intermolecular force. So often there is confusion with the name as many learners see a chemical bond being formed. This is not true and you must keep telling them that it is in actual fact a force of attraction between molecules (and not a chemical bond between atoms). Tell the learners that to recognise the presence of hydrogen bonding intermolecular forces, there is an attraction between a hydrogen atom of one molecule and the small, highly electronegative atom of another molecule. There are 3 atoms that are allow this to happen, namely nitrogen (N), oxygen (O) and fluorine (F) ......thus molecules NH_3, H_2O and HF are molecules where hydrogen bonding intermolecular forces exist. These intermolecular forces are much stronger than other dipole-dipole intermolecular forces.



Here we see hydrogen bonding intermolecular forces present in water. Draw attention to the dotted lines that extend from the H atom of one molecule to the O atom of another. This shows the force of attraction that exists between the water molecules. Once again repeat to the learners that the force exists between the H atom and a small atom of very high electronegativity, namely, in this case, the O atom.

3. Dipole – induced dipole intermolecular force

Learners need to have their attention drawn to the fact that these type of intermolecular forces occur between **polar molecules and non-polar molecules or atoms**. Get the learners to remember that polar molecules have permanent dipoles, that is, permanent regions of the molecule are charged whereas non-polar molecules have no region of polarity due to being symmetrical.......and it is the distortion of the electron cloud of the non-polar molecule or atom by the polar molecule when it approaches that causes the induced dipole. Remember that this is not a permanent dipole and use the term momentary dipole to also highlight that point. It is very important to tell the learners that the distortion is due to the electrons in the electron cloud of the non-polar molecule or atom either being attracted or repelled depending which side the polar molecules approaches.



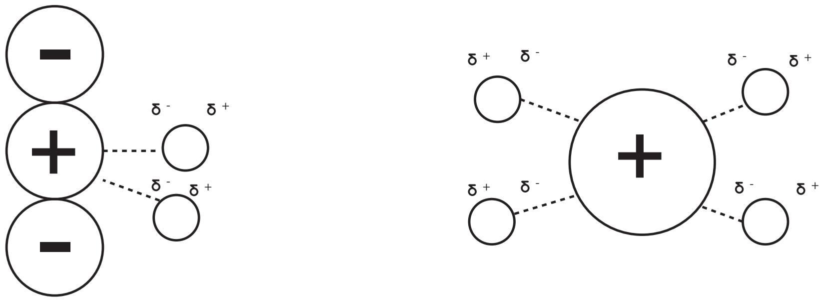
Example of this can be a HCl molecule approaching an inert gas atom such as neon (Ne)

TOPIC 4

Now that you have finished teaching learners about the three van der Waals intermolecular forces, explain to the students that there are still two more intermolecular forces that are not classified as van der Waals forces. These forces involve ions and molecules.

4. Ion – dipole intermolecular force

Learners need to know that these exist when an ionic substance is dissolved in water. It is the attractive forces between the ion that is found in the ionic crystal lattice and the polar end of the water molecule that causes the ion to be removed from the lattice. Learners must also be aware it will take a combination of ion-dipole forces to remove an ion from the lattice due to the fact that the ion-ion forces within the lattice are very strong. This is why diagrams often show numerous water molecules surrounding the ion in the form of an envelope. This is known as **hydration**.



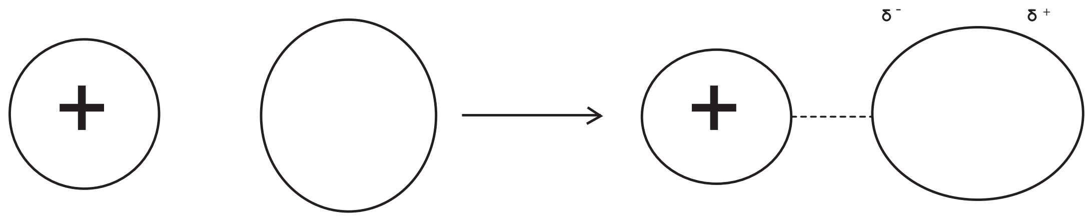
It is the accumulative ion-dipole forces that eventually will exceed the attractive forces of the ions within the lattice. The water molecule literally "rips" the ion out of the lattice and surrounds the ion in the envelope of water molecules. This envelope is what holds the ion in solution ......and we now call this an **aqueous solution.** That is why you will see the phase indicator (aq) in chemical equations.......it indicates that the ions are being surrounded by the water envelope. Exactly the same happens with an anion, except it is the δ^+ end of the polar water molecule that is attracted to the negative ion.

An example here would be the simple dissolving/dissociation of table salt (NaCl) in water

$$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$$

5. Ion – induced dipole intermolecular forces

Once again emphasise to the learners that the induced dipole is formed due to the distortion of the electron cloud of the non-polar molecule. Tell them that this occurs when an ionic substance is added to a <u>non-polar solvent</u> and it is the influence of the charged ion that will distort this electron cloud causing the temporary induced dipole to form and explain to them that this process is known as **polarisation.**



The electron cloud in the neutral molecule is distorted. Electrons are repelled by the positive ion making the one side of the molecule electron rich hence gaining a slightly negative charge δ^- leaving the side closest to the ion slightly positive δ^+ . There is now an induced dipole present and an intermolecular force is formed between the ion and the induced dipole.

An example here would be sodium chloride ($NaCl$) added to a non-polar solvent such as hexane.

INTRODUCTORY LEVEL QUESTIONS

Here are some simple questions that you can give to your learners to help them understand and identify different intermolecular forces.

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

1. Explain the difference between an interatomic and an intermolecular force.

Solution

Interatomic forces are the attractive forces that exist within a molecule that result in a chemical bond being formed. Intermolecular forces are attractive forces that exist between molecules or atoms.

2. What is the difference between covalent and ionic bonding?

Solution

Covalent bonding involves electron sharing between non-metal atoms. Ionic bonding involves electron transfer between metal and non-metal atoms.

3. Name 5 different types of intermolecular forces.

Solution

Induced dipole – induced dipole
dipole – dipole
dipole – induced dipole
ion – dipole
ion – induced dipole

4. What is the difference between a polar covalent and a non-polar covalent bond?

Solution

Polar covalent bond is a bond where electron sharing takes place between the atoms and the shared electron pair is asymmetrically positioned closer to one atom compared to the other due to the greater electronegativity of the atom. This causes one side to be slightly more negative while the other side is slightly more positive.

Non-polar covalent bond is a bond where the shared electron pair is symmetrically positioned in the middle of the bond due to there being equal electronegativity between the two atoms. There is no region of charge.

5. What is a dipole?

Solution

This is a molecule with two distinct regions of charge in the molecule indicated with a δ^+ and a δ^- on each end.

6. Explain what is meant by the following terms :

6.1 induced or momentary dipole
6.2 electron cloud
6.3 permanent dipole
6.4 dispersion or London forces

Solution

6.1 A non-polar molecule that for a brief instant in time becomes polar due to a slight shift in the electron cloud density creating a very weak temporary dipole.

6.2 This is the region surrounding the molecule that contains the electrons from the atoms making up the molecule.

6.3 This is a molecule that has two distinct region of charge that remain unchanged due to the electronegativity differences between the atoms making up the molecule.

6.4 These are very weak van der Waal's forces that exist between non-polar molecules.

7. What is the name given to the special type of dipole – dipole intermolecular force that is found in molecules containing hydrogen bonded to either nitrogen. oxygen or fluorine.

Solution

Hydrogen bonding intermolecular forces

8. Give 3 examples of molecules that will have hydrogen bonding intermolecular forces between them.

Solution

HF	hydrogen fluoride
H_2O	water (dihydrogen oxide)
NH_3	ammonia (nitrogen trihydride)

9. Explain what is meant by the term 'crystal lattice'.

Solution

The ordered regular arrangement of atoms, molecules or ions found in the solid phase.

CHALLENGE LEVEL QUESTIONS

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

How to tackle these questions in the classroom:

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

1. What type of intermolecular force exists when the substance copper sulfate ($CuSO_4$) dissolves in water? Use an equation to show how copper sulfate dissolves in water.

Solution

Ion – dipole intermolecular force

$$CuSO_4(s) \xrightarrow{H_2O} Cu^{2+}(aq) + SO_4^{2-}(aq)$$

TOPIC 4

2. What name is given to the ions that are now in solution?

Solution

Aqueous ions

3. What is the difference between an ion-dipole and an ion-induced dipole intermolecular force?

Solution

An ion-dipole intermolecular force exists between an ion and a polar molecular solvent such as water. Water molecules are permanent dipoles. An ion-induced dipole intermolecular force exists between an ion and a non-polar molecular solvent such as hexane. The electron cloud density surrounding the hexane molecule is shifted by the presence of the ionic charge. This causes a slight temporary polarity within the molecule, hence creating an induced dipole.

2. PHYSICAL STATE AND DENSITY

INTRODUCTION

In this sub-section, it is crucial to explain to the learners that we are now going to link the different types of intermolecular forces to explain the existence of the three phases of matter and what role kinetic energy plays within the system to affect the strength of these attractive forces in each different phase. Key concepts of molecular size, molecular shape and the degree of polarity will also play a significant role as to the physical state of a substance at a particular temperature.

CONCEPT EXPLANATION AND CLARIFICATION

All molecules possess kinetic energy no matter what phase these molecules are found. It is important for the learners to know that the amount of kinetic energy in the gas phase is the greatest while the amount of kinetic energy in the solid phase is the least. It is the varying amount of kinetic energy within a system that then causes intermolecular forces to be overcome, hence allowing the molecules to change phase. This kinetic energy usually comes from increasing the amount of heat within the system. The best example to use here is water as everyone has knowledge of ice (solid), water (liquid) and water vapour (gas) and then explain the phase changes as a function of adding heat energy to the system........... water placed in a freezer becomes a solid as energy is removed from the molecules and it freezes at 0°C, it melts when taken out the freezer and changes to a liquid as heat is added to the system, and then changes to the gas phase (water vapour) when boiled in a kettle at approximately 100°C. Use phase diagrams to show the spacing between the water molecules in each different phase as more energy is found in the system.

There are other factors that contribute to the strength of intermolecular forces. The most significant are size, shape and polarity of molecules.

- Molecular size is related directly to what is known as electron cloud density. The larger the molecule, the more electrons are present and hence the more easily the molecules can undergo asymmetrical electron distribution to form momentary induced dipoles, thus experience stronger van der Waals forces.
- Molecular shape influences the surface area of the molecule. The more linear or straight the molecule is, the greater the surface area. This means that the intermolecular forces can act over a much larger area as there are more points of contact where these forces can form. In spherically shaped molecules or atoms, there are fewer points of contact as the surface area is much smaller, hence the intermolecular forces will be weaker.
- Molecular polarity affects intermolecular forces due to the presence or absence of permanent dipoles in the molecule. A polar covalent molecule will exert much stronger intermolecular forces than non-polar covalent molecules as these molecules can only achieve induced polarity which is weaker than permanent dipoles. Also, the degree of polarisation is also very important as molecules made up of atoms that are very electronegative will create stronger dipoles, hence greater molecular polarity.

Melting Point and Boiling Point

So how is the strength of intermolecular forces measured? The most efficient way is to look at the **melting and boiling points** of substances. If a substance has a very low melting or boiling point, then it can be concluded that there must be very weak intermolecular forces present as very little energy is required to overcome these forces. If the melting and boiling points are much higher, then the intermolecular forces must be much stronger by comparison as more energy is required to overcome these forces. Learners can then understand that different types of intermolecular forces can be identified by comparing melting and boiling points. For example – methane (CH_4) has a boiling point of approximately -160^0C whereas hydrogen sulfide (H_2S) has a boiling point of approximately -50^0C. More energy is required to overcome the intermolecular forces in H_2S compared to CH_4 so the intermolecular forces must be stronger. Also, H_2S is a polar covalent molecule whereas CH_4 is non-polar covalent... thus it can be concluded that CH_4 will have weak London type van der Waals forces whereas H_2S will have dipole-dipole van der Waals forces.

Earlier we mentioned <u>molecular size</u> with regards to strength of intermolecular forces. This is important due to the increase in molecular size, so the electron cloud density gets larger as well. This creates stronger induced dipoles in non-polar covalent molecules. Examples of methane (CH_4), octane (C_8H_{18}) and wax ($C_{23}H_{48}$) show how as the carbon-based molecules get larger, so the melting and boiling points increase. Also with non-polar diatomic molecules such as fluorine and iodine where fluorine has a boiling point of -188^oC and iodine has boiling point of $+184^o$C. Both are composed of non-polar molecules yet the intermolecular forces between iodine molecules are significantly larger than those in fluorine.

TOPIC 4

Density

The density of a substance measures the compactness of a substance or how close together the particles of a substance are packed together which is expressed in terms of the mass of the substance per unit volume.

$$Density = \frac{mass(kg)}{volume(m^3)}$$

Learners need to understand that a high density substance will have the particles of that substance packed closely together – a large number of molecules per unit volume, whereas a low density substance will have particles of that substance spaced further apart – a low number of particles per unit volume. In the different phases of matter, the closeness of the particles of a substance and hence the density of the substance in that phase is significant. Solids generally have high density due to strong intermolecular forces holding the solid particles together because the particles are very close. There is the least amount of energy in solids thus the particles cannot escape the strong intermolecular forces. In the liquid phase, the energy in the system is greater than for solids, hence the intermolecular forces between the particles are weaker allowing the particles to slip past each other more easily whereas in gases, the energy in the system is such that the intermolecular forces are so weak that they are almost non-existent. This means that particles in the gas phase have the smallest number of particles per unit volume due to the very large spaces between particles in the gas phase.

INTRODUCTORY LEVEL QUESTIONS

Here are some simple questions that you can give to your learners to help them understand and identify different intermolecular forces.

How to tackle these questions in the classroom:

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

1. Name the 3 phases of matter.

Solution

Solids, liquids and gases

2. Explain what is meant by the term 'kinetic energy'.

Solution

This is the energy that a substance or particle possesses due to its motion.

3. What is the easiest way to increase the amount of kinetic energy in a system?

Solution

By heating the system in some way. By adding heat energy to the system, the particles absorb the extra energy and hence increase their movement, thus the average kinetic energy of the particles increases.

4. Name 3 main factors that will also contribute to the strength of intermolecular forces between molecules.

Solution

Molecular size, molecular shape and molecular polarity

5. Briefly explain how each of these factors influence the strength of intermolecular forces.

Solution

Molecular size - the bigger the molecule, the larger the electron cloud due to more electrons within the molecule. The greater the electron cloud, the greater the distortion hence the larger the polar ends will become. This leads to stronger intermolecular forces.

Molecular shape – this relates to the surface area of the molecule. The greater the surface area, the more points of contact where intermolecular forces can be formed, hence the intermolecular forces will be stronger.

Molecular polarity – this has to do with degree of polarity of the molecule. Polar covalent molecules will have much stronger intermolecular forces between molecules than non-polar covalent molecules.

6. Explain the difference between the terms 'melting point' and 'boiling point'.

Solution

Melting point – this is the steady temperature when there is enough energy in the system to allow the intermolecular forces between the particles in the solid phase to be overcome allowing for the substance to change into the liquid phase.

Boiling point – this is the steady temperature when there is enough energy in the system to allow the intermolecular forces between the particles in the liquid phase to be overcome allowing for the substance to change into the gas phase.

CHALLENGE LEVEL QUESTIONS

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

How to tackle these questions in the classroom:

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

1. Which do you think will have a higher boiling point – liquid methane (CH_4) or liquid hydrogen sulfide (H_2S)? Explain your answer in terms of molecular shape and intermolecular forces.

Solution

Methane has tetrahedral molecules which are symmetrical, hence it is a non-polar covalent substance. Thus the intermolecular forces will be very weak London/dispersion forces which means that it will have a very low boiling point. Hydrogen sulfide is an angular molecule and hence will be polar covalent due to its shape. There will be dipole-dipole intermolecular forces between the molecules which are stronger than the London/dispersion intermolecular forces. This means that hydrogen sulfide will have a higher boiling point.

2. What is meant by the term 'density'? Define density and explain the relationship between the intermolecular forces between particles and density.

Solution

Density refers to the compactness of a substance in terms of how close the particles are to each other. It is measured as a ratio of the mass of the substance and the volume that it occupies. Density can also refer to the strength of the intermolecular intermolecular forces between the particles that makeup the substance ...stronger intermolecular forces attract the molecules more, hence more compact and thus a higher density. Weaker intermolecular forces means less attraction and thus less compactness which gives a lower density.

3. How does the density of a solid compare to the density of a liquid? Explain your answer in terms of intermolecular forces.

Solution

Solids usually have a higher density compared to liquids as there are stronger intermolecular forces between the particles in the solid phase. Thus, there are a large number of particles per unit volume causing the density to be high. In liquids, the intermolecular forces are weaker due to more energy in the system, hence the particles have weaker intermolecular forces and can slip past each other. The volume occupied by the liquid particles is thus slightly more than it is by the solid and thus there are fewer particles per unit volume in the liquid, and the density is the liquid is lower than that of the solid.

CHECKPOINT

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

1. an understanding of the difference between interatomic and intermolecular forces
2. an understanding of what is meant by a van der Waals intermolecular force and the different types of van der Waals forces.
3. how the physical state of matter, namely molecular size, shape and polarity, is related to the strength of the intermolecular forces.
4. the use of melting and boiling points to give an indication as to the strength of the intermolecular forces present in the system

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

Topic 4 Worksheet from the Resource Pack: Intermolecular Forces:
Multiple Choice Questions 1–4 and Long Questions 1 and 2. (Pages 48–49).

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

3. PARTICLE KINETIC ENERGY AND TEMPERATURE

INTRODUCTION

As we have seen in the earlier sub-topic, the amount of energy in a system is directly related to the amount of movement of the molecules within the system and thus the strength of the intermolecular forces between the molecules. Learners need to be reminded that the existence of phases is a direct result of the amount of energy in the system. When we talk about the temperature of a substance, learners can thus realise that temperature is the direct link to the amount of particle kinetic energy with the system. An easy way to introduce this sub-section is to take the example of hot and cold water and ask the learners: “Why is water hot and why is water cold?” ......and then lead the discussion to the amount of heat energy within the system; how the amount of heat energy affects the particle kinetic energy and that we measure all of this by talking about the temperature of the water. This will allow you to introduce the topics of thermal expansion and thermal conductivity.

CONCEPT EXPLANATION AND CLARIFICATION – THERMAL EXPANSION AND THERMAL CONDUCTIVITY

1. Thermal expansion

Explain to the learners what the word expansion means ...to move outwards, and the word thermal ...heat energy. Thus link the two terms together to create thermal expansion and explain to the learners that as heat energy is added to the system, the kinetic energy of the particles increases and hence the particles will move faster and move outwards to occupy more space increasing the volume of the substance. Explain to them that this is how a thermometer works where the liquid inside the thermometer e.g. alcohol expands as it gets warmer as the alcohol particles move faster and further apart from each other therefore the alcohol occupies more space. This causes the alcohol to move up the thermometer tube and thus the height it reaches will indicate the temperature of that substance. Remember that the thermometer is marked in degrees celsius (^{o}C).

2. Thermal conductivity

Explain to the learners that thermal conductivity is the ability of a substance to conduct heat energy. What the learners need to understand is that when a substance is heated (in particular a metallic substance), the particles (kernels and delocalised electrons in a metal) gain kinetic energy. The particles with higher kinetic energy (e.g. the delocalised electrons in metals) transfer the kinetic energy to other particles throughout the structure. This allows the metal to transfer the heat throughout the structure. Non-metals are not able to transfer this heat energy as they do not have delocalised electrons to move and transfer this energy. Learners must be reminded that non-metals generally have covalently bonded structures where electrons are not free to move.

INTRODUCTORY LEVEL QUESTIONS

Here are some simple questions that you can give to your learners to help them understand and identify different intermolecular forces.

How to tackle these questions in the classroom:

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

1. How is the movement of molecules within a particular phase related to the amount of kinetic energy within that system?

Solution

The greater the amount of kinetic energy in the system, the faster the particles are able to move.

2. How is this movement related to the intermolecular forces within that system?

Solution

The faster the particles are able to move, the weaker the intermolecular forces between the particles are. This is because the particles are moving so fast that they are less able to interact with one another or affect one another, so the intermolecular forces decrease as temperature increases.

3. What is meant by the term 'temperature'?

Solution

Temperature is defined as the measure of the average kinetic energy of the particles within the system. The more energy within that system, the higher the temperature. In colloquial terms, temperature is a measure of the degree of "hotness" or "coldness" of a system.

4. What are meant by the terms 'thermal expansion' and 'thermal conductivity'?

Solution

Thermal expansion: This refers to the ability of particles to move away from each other as the amount of energy within the system increases and the intermolecular forces become weaker.

Thermal conductivity: This refers to the ability of a substance to conduct heat energy. This heat energy will be transferred into kinetic energy and the particles will begin to move faster within the system. Good thermal conductors will transfer heat energy easily within the system while poor thermal conductors will transfer heat energy with difficulty.

CHALLENGE LEVEL QUESTIONS

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

How to tackle these questions in the classroom:

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

1. Explain how a metallic substance is able to conduct heat energy.

Solution

Metals contain delocalised electrons which are able to move freely within the metallic structure. As heat energy is transferred to the system, so the delocalised electrons begin to move faster and thus move more quickly through the metal. The delocalised electrons collide with the kernels transferring kinetic energy to them. In this way the average kinetic energy of all the particles in the metal increases fairly quickly, thus metals are seen as good conductors of heat.

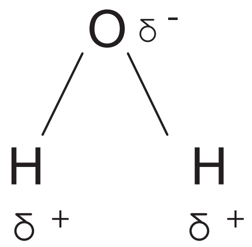
4. THE CHEMISTRY OF WATER

INTRODUCTION

Water has extraordinary physical properties and these properties give water a very unique place in nature. This topic will introduce the learner to these unique properties which are based on its molecular structure, the unique hydrogen bonding intermolecular forces that exist between the water molecules in the liquid phase as well as the macroscopic properties of water that explain the phenomena of evaporation and condensation.

CONCEPT EXPLANATION AND CLARIFICATION: THE THREE PHASES OF WATER

The first thing that learners must appreciate is the structure of the water molecule. This is a good opportunity to revise the covalent bonding model to show the interatomic forces that exist in the molecule as well as the shape of water in terms of its angular structure. Here the electronegativities of the O and H atoms can be revised to now show that it is a polar molecule and thus is dipole.



It is important now to revise hydrogen bonding intermolecular forces and tell the learners that the unique features of water are due to these hydrogen bonding forces between its molecules. This is significant in all three phases of water – solid, liquid and gas.

Begin with the solid phase (ice). Explain to the learners that in the sold phase, water molecules are arranged in a regular pattern known as a crystal lattice. Ice melts when the molecules absorb heat energy which causes them to vibrate faster (gain more kinetic energy) and overcome the forces holding them in the solid phase. The learners now need to understand about a very special unique property of water and that once in the liquid phase at temperatures of around 4°C , the strong hydrogen bonding forces attract the water molecules very strongly and thus cause the density of water at these temperatures to actually increase.....that is, for the water to become more dense that ice at 4°C. This is why ice floats......and the significance of this is that life in the oceans and rivers can still continue as the very dense cold water sinks to the bottom. Explain to the learners that because ice floats, it provides a layer on top of water which thus prevents the water underneath from freezing. This is known a “top down” freezing. If water froze from the bottom up, then ice would form at the bottom of oceans and rivers and all life in them would thus die.

As temperatures rise, there is now enough energy in the system for the molecules to begin to move faster and the effects of the hydrogen bonding forces become less. Water molecules thus move past each other freely and the density of water decreases. Explain to the learners that there are still hydrogen bonding forces present but these are not as strong as at lower temperatures hence the existence of the liquid phase. Only when the temperature rises to approximately 100°C will there be enough energy in the system for the water molecules to overcome the hydrogen bonding forces completely and for the water molecules to escape into the gas phase.

Explain how to determine the number of water molecules in 1 litre (1 dm^3) of water, by starting with the concept of the amount of molecules of water in 1 mole.

- 18 g of water is 1 mol of water and 1 mol of water contains $6{,}02 \times 10^{23}$ molecules of water
- The density of water is 1 g per millilitre(ml)
- Thus means that there are $\frac{6{,}02 \times 10^{23}}{18} = 3{,}34 \times 10^{22}$ molecules in 1 g of water
- There are 1 000 ml of water in 1 litre of water
- Thus there are $3{,}34 \times 10^{22} \times 1\,000 = 3{,}34 \times 10^{25}$ molecules of water in 1 litre of water

CONCEPT EXPLANATION AND CLARIFICATION: THE WATER MOLECULE AND HEAT

Explain to the learners that because the hydrogen bonding intermolecular forces are very strong, they require a lot of heat energy to be overcome. (Please stress to the learners that these forces do not break, but rather use the term "overcome"). This means that water has the ability to absorb a large amount of heat energy before the temperature of the water starts to rise. Tell the learners that this is known as the specific heat capacity of water and water has a very high specific heat capacity........in fact it is able to absorb 4 200 J of energy to raise the temperature of 1 kg of water by 1°C. This is a lot of energy absorption to raise the temperature by such a small amount. Also – the learners must also be made aware that the opposite is also true......that a larger amount of energy can be released into the atmosphere with only a very small decrease in temperature of the water. Both have significant benefits to our environment in that heat energy from the Sun can be absorbed in summer so that the Earth does not heat up too much, whilst in winter, heat can be released to keep the atmosphere warm so that it does not get too cold........that is, to moderate our climate. The oceans are our biggest water source thus they act as heat reservoirs.

Another good example is why water is used as a coolant in petrol and diesel engines of cars.... to absorb the large amount of heat energy produced by the internal combustion engine.

CONCEPT EXPLANATION AND CLARIFICATION: MACROSCOPIC PROPERTIES – EVAPORATION AND CONDENSATION

Learners must understand what is meant by the terms evaporation and condensation and learn the definitions of both (see glossary). In explaining evaporation, once again stress that the strong hydrogen bonding intermolecular forces, and thus the strong forces of attraction cause a high heat of vapouristion meaning lots of energy needs to be absorbed before water can evaporate into the gas phase. Once water evaporates it takes that energy into the atmosphere away from the water source which leads to a cooling effect. The learners should now understand why they feel cold when they step out of a bath or shower, or after swimming. It is also why the body perspires (produces sweat) as the water on the surface of the skin absorbs the heat produced by the body during exercise and evaporates taking the heat away from the body and cooling the person down.

Condensation is exactly the opposite of evaporation where water in the gas phases releases heat. This loss of heat allows the hydrogen bonding forces to exert greater attractive forces on the water molecules, and the water molecules attract one another forming the liquid phase.

CONCEPT EXPLANATION AND CLARIFICATION: MACROSCOPIC PROPERTIES – BOILING POINT

Explain to the learner what is meant by the term 'hydride' in terms of being molecules with H atoms in their structure. If water is compared to other hydrides (see glossary), it can be seen that the boiling point of water is much higher in comparison to these other hydrides. Once again, let the learners know that the unusually high boiling point of water is due to the presence of the strong hydrogen bonding intermolecular forces present. What is always useful is to show the learners the different boiling points of similar hydride structures and the learners will see the significant difference due to these strong intermolecular forces.

HYDRIDE	BOILING POINT (°C)
H_2O	+100
H_2S	-61
H_2Se	-41
H_2Te	-2

These are all group 16 hydrides with very similar chemical structures and thus comparative boiling point values can be seen. Notice the anomalously high boiling point of water!!!

INTRODUCTORY LEVEL QUESTIONS

Here are some simple questions that you can give to your learners to help them understand some of the basic aspects of the chemistry of water.

How to tackle these questions in the classroom:

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

1. Water is said to have polar covalent bonds. Briefly explain what is meant by this term.

   Solution

   Due to the large electronegativity difference between the H and O atoms in the molecule, the shared electron pairs are found closer to the O atom making that side of the H-O bond electron rich (δ^-) and leaving the H atoms electron poor (δ^+). This creates polarity within the covalent bond and hence the term 'polar covalent bond'

2. What is the name of the shape given to the water molecule?

   Solution

   Angular or bent

3. Give the specific name of the type of intermolecular forces that are there between water molecules.

   Solution

   Hydrogen bonding intermolecular forces

4. Why is this significant in terms of the existence of life in the oceans and in rivers?

   Solution

   Cold water is more dense than ice so it sinks to the bottom of the ocean or a river; plant and animal life can still survive as ice, with a lower density, can float on top.

TOPIC 4

5. What happens to the density of liquid water as the temperature rises? Briefly explain your answer.

Solution

As temperature rises, the internal energy of the system also rises. The water molecules will have more kinetic energy and the molecules will move further apart so the intermolecular forces become weaker. The density of the water thus decreases.

6. What is meant by the term 'specific heat capacity' and why is the specific heat capacity of water so high?

Solution

Specific heat capacity measures the amount of energy that 1 kg of a substance can absorb to raise its temperature by 1°C. Water has a high specific heat capacity as there are strong hydrogen bonding intermolecular forces... hence water is able to absorb a large amount of energy before the temperature of the water starts to increase.

7. What is the significance of water having such a high specific heat capacity?

Solution

Water in our oceans can absorb a large amount of heat energy from the Sun without increasing the ocean temperatures. This prevents the Earth from overheating and the atmospheric temperature is thus controlled.

8. Why are our oceans called "heat reservoirs" and how is this beneficial to life on Earth?

Solution

Water in the ocean stores the absorbed heat energy which helps to keep the Earth cooler, but heat energy can also be released during winter to keep the atmosphere at a reasonable temperature. Thus, water can both hold and release heat energy and thus is known as a heat reservoir.

9. What are meant by the terms 'evaporation' and 'condensation'?

Solution

Evaporation: this is the process where water molecules change phase from liquid to gas without boiling by absorbing sufficient energy to overcome the intermolecular forces.

Condensation: this is the process where water molecules change back from the gas to the liquid phase by releasing energy allowing the intermolecular forces to become stronger.

10. Explain the term 'heat of vaporisation'.

Solution

This is the measure of the amount of energy that water is able to absorb to allow it to evaporate from the liquid to the gas phase.

CHALLENGE LEVEL QUESTIONS

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

How to tackle these questions in the classroom:

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

1. Briefly explain what happens to the density of water when water melts from the solid phase to the liquid phase.

Solution

As heat energy is transferred to the solid, the intermolecular forces are overcome and the molecules change into the liquid phase. Now the strong hydrogen bonding intermolecular forces take effect and the water molecules are attracted closer together causing the density of water to increase. Thus, cold water at temperatures of around 4°C has molecules closer together than in the solid phase causing cold water to sink while the ice with less density floats on top.

2. Explain why water, with a high heat of vaporisation, is so beneficial to the human body.

Solution

The human body produces sweat which coats the skin. With a high heat of vapouristion, the water absorbs large amounts of heat energy from the body before it evaporates from the surface. This now cools the body down extremely effectively.

3. Briefly explain what is meant by the term 'hydride'.

Solution

A hydride is the term given to compounds that contain a H atom in their structure.

4. Water is an example of a group 16 hydride. Explain why water has such a high boiling point compared to the other group 16 hydrides.

Solution

Water has hydrogen bonding intermolecular forces between its molecules whereas the other Group 16 hydrides only have dipole-dipole intermolecular forces. This means that the intermolecular forces in water are much stronger and thus more energy will be required to overcome these forces hence giving water a much higher boiling point by comparison.

CHECKPOINT

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

1. an understanding of the concepts of thermal expansion and thermal conductivity.
2. an understanding of how the amount of heat energy in a system is related to the amount of kinetic energy the particles possess.
3. knowing how the average kinetic energy of the particles is related to the temperature of the substance.
4. a basic understanding regarding the chemistry of water in terms of the three phases that water is able to exist in over a relatively small difference in temperature.
5. an understanding of specific heat capacity of water and how it is related to water being called a "heat reservoir".
6. an understanding of the concepts of evaporation and condensation.
7. an understanding of where water fits into the list of group 16 hydrides with regards to intermolecular forces of the hydrides and the boiling point of the hydrides.

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

Topic 4 Worksheet from the Resource Pack: Intermolecular Forces: Long Questions 3–5. (Page 50).

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

CONSOLIDATION

- Learners can consolidate their learning by completing; **Topic 4: Consolidation Exercise: Intermolecular Forces from the Resource Pack. (Pages 51–53)**.
- 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.

Gr11_PS-Contents_Book_Term1.indb 162 2018/12/27 12:17:14 PM

- The consolidation exercise should be marked by the teacher so that he/she is aware of each learner's progress in this topic.
- Please remember that further consolidation should 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 work may be too high.**

ADDITIONAL VIEWING / READING

In addition, further viewing or reading on this topic is available through the following web links. Please note that links 1 and 2 are to videos from the Khan Academy. The Khan Academy provides excellent material in a broad variety of topics in Chemistry and can be used for additional viewing material for much of the Grade 11 and 12 syllabi.

Link 3 is a web link that provides reading material for the teacher to develop a deeper understanding of the concepts used in the 'Chemistry of water'

1. *Van der Waals forces :* https://www.khanacademy.org/science/chemistry/states-of-matter-and-intermolecular-forces#introduction-to-intermolecular-forces
2. *Intermolecular forces :* https://www.khanacademy.org/science/biology/chemistry--of-life/chemical-bonds-and-reactions/v/intermolecular-forces-and-molecular-bonds
3. *Chemistry of water:* https://www.thoughtco.com/water-chemistry-facts-and-properties-609401

TOPIC 4