Natural Sciences Teacher's Guide

Grade 7-B (CAPS)

sasol
reaching new frontiers

basic education
Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71 La-Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103 Ac-Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

No
Element

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

- Transition Metal
- Metal
- Metalloid
- Non-metal
- Noble Gas
- Lanthanide
- Actinide

Natural Sciences

Grade 7-B

CAPS

developed by

SIYAVULA
TECHNOLOGY-POWERED LEARNING

funded by

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AUTHORS' LIST

This book was written by Siyavula with the help, insight and collaboration of volunteer educators, academics, students and a diverse group of contributors. Siyavula believes in the power of community and collaboration by working with volunteers and networking across the country, enabled through our use of technology and online tools. The vision is to create and use open educational resources to transform the way we teach and learn, especially in South Africa.

Siyavula Coordinator and Editor
Megan Beckett

Siyavula Team
Ewald Zietsman, Bridget Nash, Melanie Hay, Delita Otto, Marthélize Tredoux, Luke Kannemeyer, Dr Mark Horner, Neels van der Westhuizen

Contributors
Dr Karen Wallace, Dr Nicola Loaring, Isabel Tarling, Sarah Niss, René Toerien, Rose Thomas, Novosti Buta, Dr Bernard Heyns, Dr Colleen Henning, Dr Sarah Blyth, Dr Thalassa Matthews, Brandt Botes, Daniël du Plessis, Johann Myburgh, Brice Reignier, Marvin Reimer, Corene Myburgh, Dr Maritha le Roux, Dr Francois Toerien, Martli Greyvenstein, Elsabe Kruger, Elizabeth Barnard, Irma van der Vyver, Nonna Weideman, Annatjie Linnenkamp, Hendrine Krieg, Liz Smit, Evelyn Visage, Laetitia Bedeker, Wetsie Visser, Rhoda van Schalkwyk, Suzanne Grové, Peter Moodie, Dr Sahal Yacoob, Siyalo Qanya, Sam Faso, Miriam Makhene, Kabelo Maletsoa, Lesego Matshane, Nokuthula Mpanza, Brenda Samuel, MTV Selogiloe, Boitumelo Sihlangu, Mbuzeli Tyawana, Dr Sello Rapule, Andrea Motto, Dr Rufus Wesi

Volunteers
Iesrafeel Abbas, Shireen Amien, Bianca Amos Brown, Dr Eric Banda, Dr Christopher Barnett, Prof Ilsa Basson, Mariaan Bester, Jennifer de Beyer, Mark Carolissen, Tarisai Chanetsa, Ashley Chetty, Lizzy Chivaka, Mari Clark, Dr Marna S Costanzo, Dr Andrew Craig, Dawn Crawford, Rosemary Dally, Ann Donald, Dr Philip Fourie, Shamin Garib, Sanette Gildenhuys, Natelie Gower-Winter, Isabel Grinwis, Kirsten Hay, Pierre van Heerden, Dr Fritha Hennessy, Dr Colleen Henning, Grant Hillebrand, Beryl Hook, Cameron Hutchison, Mike Kendrick, Paul Kennedy, Dr Setshaba David Khanye, Melissa Kistner, James Klatzow, Andrea Koch, Grove Koch, Paul van Koersveld, Dr Kevin Lobb, Dr Erica Makings, Adriana Marais, Dowelani Mashuvhamele, Modisaemang Molusi, Glen Morris, Talitha Mostert, Christopher Muller, Norman Muvoti, Vernusha Naidoo, Dr Hlumani Ndlovu, Godwell Nhema, Edison Nyamayaro, Nkululeko Nyangiwe, Tony Nzundu, Alison Page, Firoza Patel, Koebraa Peters, Seth Phatoli, Swasthi Pillay, Siyalo Qanya, Tshimangadzo Rakhuhu, Bharati Ratanjee, Robert Reddick, Adam Reynolds, Matthew Ridgway, William Robinson, Dr Marian Ross, Lelani Roux, Nicola Scriven, Dr Ryman Shoko, Natalie Smith, Antonette Tonkie, Alida Venter, Christie Viljoen, Daan Visage, Evelyn Visage, Dr Sahal Yacoob

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To learn more about the project and the Sasol Inzalo Foundation, visit the website at:

www.sasolinzalofoundation.org.za

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Curious? Discover the possibilities!

VISIT

Carl Sagan was an astronomer, astrophysicist, cosmologist, author, science popularizer and science communicator. Watch one of his most pertinent messages for humanity here bit.ly/1bbVDqg

Asking questions and discovering our world around us has been central to human nature throughout our history. Over time, this search to understand our natural and physical world through observation, testing and refining ideas, has evolved into what we loosely think of as 'science' today. Key to this, is that science is a continuous revision in progress, it is a mechanism rather than a product, it is a way of thinking rather than a collection of knowledge, whose driving force is not certainty in a truth, but rather being comfortable with uncertainty, thereby cultivating curiosity.

However, as Carl Sagan famously said in 1994:

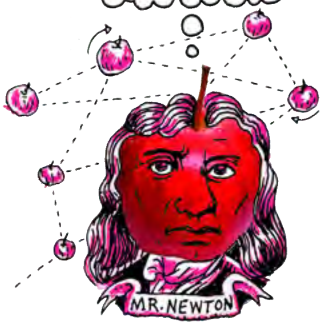
> *"We live in a society absolutely dependent on science and technology, and yet have cleverly arranged things so that almost no one understands science and technology. That's a clear prescription for disaster."*

We need to replace fear of the unknown and the difficult with curiosity, as Marie Curie said:

> *"Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less."*

DID YOU KNOW?

Marie Curie was a chemist and physicist famous for becoming the first person to be awarded two Nobel Prizes.



We would like to instill this sense of curiosity and an enquiring mind in learners. Science, technology, engineering and mathematics are not subjects to be feared, rather they are tools to unlock the potential of the world around you, to create solutions to problems, to discover the possibilities.

But, how do we practically do this in our classrooms? We would like this workbook to become a tool that you can use to do this. The theme for the presentation of this content in Gr 7-9 Natural Sciences is 'Curious? Discover the possibilities.' We have shown everyday science and objects with 'doodles' over them to show how if you are curious, intrigued and investigate the world around you, there are many possibilities for discovery. Sometimes these doodles are science or technology related, and sometimes they are more fantastical and fun. Learners should be inspired to discover, but also imagine the possibilities, as Freeman Dysan said:

> *"The glory of science is to imagine more than we can prove."*

Learners must be encouraged to 'doodle' themselves, take notes during your class discussions, write down their observations, reflect on what they have learned. They must not be afraid of drawing and writing in these books. Science is also about being creative in your thinking.

We have aimed to present the content in an investigative, questioning way. At the beginning of each chapter, the topics are introduced by asking questions to which you will discover the answers as you go through the chapter. In teaching learners to ask questions, make observations, think freely and creatively, they will be rewarded. Although, possibly not every time - it requires patience and determination. Although your learners will be exploring science and the world around us within a classroom context where assessment is integral, keep in mind this idea from Claude Levi-Strauss, when instilling the ethos of science in your learners:

> *"The scientist is not a person who gives the right answers, but one who asks the right questions."*

Science is relevant to everyone. Scientific principles, knowledge and skills can be applied in creative and exciting ways to solve problems and advance our world. It is not just a subject restricted to our classrooms, but reaches far beyond, and within. Ultimately, we also want learners to embark on a personal discovery and be curious about their own potential and possibilities for the future.

Albert Einstein certainly did this when he observed:

> *"The most beautiful experience we can have is the mysterious - the fundamental emotion which stands at the cradle of true art and true science."*

TAKE NOTE

Albert Einstein repeatedly did poorly at school, dropped out at 16 and failed his first university entrance examinations. Every child deserves a chance to become someone, sometime in some place.

The Natural Sciences curriculum

As learners enter the Senior Phase in their schooling, the focus is now purely on Natural Sciences within this subject, and Technology is a separate subject. However, there are close links between the content in both of these subjects as they complement each other. The Natural Sciences curriculum also links to what learners cover in Social Sciences and Life Orientation. Whether you are a subject specialist teacher, or a class teacher, it is worthwhile to take note of where Natural Sciences overlaps with and integrates with some of the other subjects that learners are covering.

Organisation of the curriculum

In the Natural Sciences curriculum, the knowledge strands below are used as a tool for organising and grouping the content.

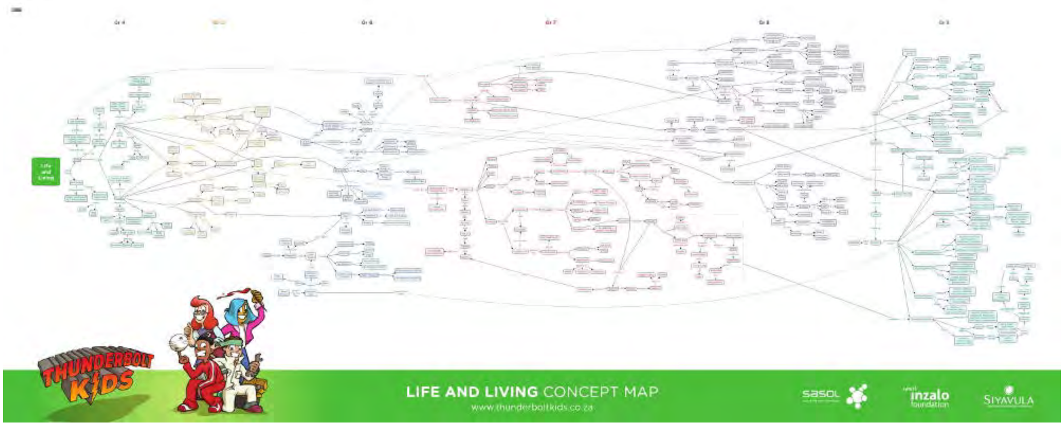
Natural Sciences Knowledge Strands
Life and Living
Matter and Materials
Energy and Change
Planet Earth and Beyond

These knowledge strands follow on from Gr 4-6. The strands also link into each other, and these have been pointed out both within the learners' workbook and here in the teachers guide.

We have also produced **concept maps** which show the progression of concepts across the grades, within a strand, and how the build upon each other. These concept maps are useful tools for teaching to see what learners should have covered in previous grades, and where they are going in the future.

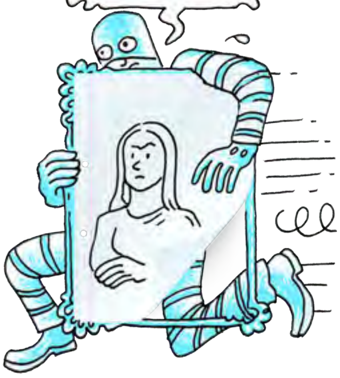
VISIT

If you would like to see what learners covered in **Gr 4-6 with the Thunderbolt Kids**, visit www.thunderboltkids.co.za



TAKE NOTE

You can download the concept maps from our website, or order large printed versions for your classroom, as well as other **posters** to brighten up your classroom.



Allocation of teaching time

The time allocation for Natural Sciences is as follows:

- 10 weeks per term with 3 hours per week
- Grades 7, 8 and 9 have been designed to be completed within 34 weeks
- Terms 1 and 3 work will cover 9 weeks each with 3 hours (1 week) allocated to assessment within each of these terms
- Terms 2 and 4 work will cover 8 weeks each, with 2 weeks allocated to revision and examinations at the end of each of these terms

Below is a summary of the time allocations per topic in Grade 7. This time allocation is a guideline for how how many weeks should be spent on each topic (chapter).

Life and Living

Chapter	Time allocation
1. The biosphere	1 week
2. Biodiversity	3.5 weeks
3. Sexual reproduction	3.5 weeks
4. Variation	1 week

Matter and Materials

Chapter	Time allocation
1. Properties of metals	2 weeks
2. Separating mixtures	2 weeks
3. Acids, bases and neutrals	2 weeks
4. The Periodic Table of Elements	2 weeks

Energy and Change

Chapter	Time allocation
1. Sources of energy	1 week
2. Potential and kinetic energy	2 weeks
3. Energy transfer: Heat	2 weeks
4. Insulation and energy saving	2 weeks
5. Energy transfer to surroundings	1 week
6. The national electricity supply system	1 week

Planet Earth and Beyond

Chapter	Time allocation
1. Relationship of the Sun to the Earth	4 weeks
2. Relationship of the Moon to the Earth	2 weeks
3. Historical development of astronomy	2 weeks

We have provided a finer breakdown of the time into the number of hours to spend on each section within a chapter in the Chapter overviews in the Teacher's Guide. However, again, this is a guideline or suggestion and should be applied flexibly according to circumstances in the classroom and to accommodate the interests of your learners.

Specific aims

There are three specific aims in Natural Sciences which are covered in these workbooks in the range of tasks provided and in the way the content is presented.

Specific Aim 1: 'Doing Science'

Learners should be able to complete investigations, analyse problems and use practical processes and skills in evaluating solutions.

There are many practical tasks within this workbook that provide the opportunity to conduct investigations to answer questions using the scientific method, to use scientific apparatus, instruments and materials and to develop a range of process skills, such as observing, measuring, identifying problems and issues, predicting, hypothesizing, recording, interpreting and communicating information. The skills associated with each task in this workbook have been identified in the chapter overviews in this Teacher's Guide.

Learners also need to be aware of the ethical concerns and values that underpin any science work that they do, as well as health and safety precautions. Where appropriate, these have been pointed out in the learners workbook and in this Teacher's Guide.

Specific Aim 2: 'Knowing the subject content and making connections'

Learners should have a grasp of scientific, technological and environmental knowledge to be able to apply it in new contexts.

In teaching and discovering the content in Natural Sciences, the aim for learners is not to just recall facts, but to also use the knowledge to make connections between the ideas and concepts in their minds. Most of the activities in this workbook have questions at the end which aim to consolidate the knowledge and skills learned in the task, and also help learners to make connections with what they have previously learned.

There are many opportunities for discussion when going through the content in these workbooks. This is often highlighted in the Teacher's Guide with suggestions for how to lead the discussion and what questions to ask your learners to stimulate their minds and create links between what they are learning. There are often questions within the learners' workbooks which relate what they are learning at that point to previously acquired knowledge and experience.

Many of the links between content and also between strands and grades are pointed out within this Teacher's Guide. We suggest also making use of the concept maps when creating a clear picture in your own mind of the framework of knowledge that learners should have up to that point about a particular topic.

Specific Aim 3: 'Understanding the uses of Science'

Learners should understand the uses of Natural Sciences and indigenous knowledge in society and the environment.

There is a strong emphasis in these workbooks to show that science is relevant to our everyday lives, and it is not restricted to what we learn within the classroom. Rather, we are learning about the natural and physical world around us and how it works, as well as how our own bodies function.

These workbooks aim to show learners that many of the issues in our world can be solved through scientific discovery and pursuit. For example, improving water quality, conserving our environment, finding renewable energy sources and medical research into cures for diseases. Where appropriate, the history of various scientific discoveries and inventions, as well as the scientists involved, have been discussed.

These workbooks also aim to highlight the beauty, diversity and scientific achievements, discoveries and possibilities in our country, South Africa. An appreciation of local indigenous knowledge is very important. When going through particular topics in class, encourage your learners to talk about their own experiences so that learners are exposed to the indigenous knowledge of different cultures, to different belief systems and worldviews.

Understanding how scientific discovery has shaped and influenced local and global communities will enable learners to see the connections between Science and Society. This will help to reinforce that Science is practical and relevant, and it can be used as a tool together with other subjects like Mathematics and Technology to find solutions and understand our world.

How to use this workbook

We would like these Curious workbooks and Teacher's Guides to become a tool for you in your classrooms to teach, explore and discover Natural Sciences.

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- **Revise** - the right to adapt, adjust, modify, or alter the content itself (for example if you want to modify an activity to suit your learners' needs o translate the content into another language)
- **Remix** - the right to combine the original or revised content with other content to create something new (for example if you want to include one of your own activities or content into this existing content)
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We would also love it if you told us how you are using this content as it helps us refine our processes.

Structure of the book

There is an A and a B book for the Natural Sciences content.

The A book covers term 1 and 2:

- Life and Living
- Matter and Materials

The B book covers terms 3 and 4:

- Energy and Change
- Planet Earth and Beyond

These books are an amalgamation between workbooks and textbooks. They have spaces for learners to write and draw whilst completing their tasks. Learners must be encouraged to write in these books, take notes, and make them their own. These workbooks also contain the content to support the various tasks. This makes these books slightly longer than usual.

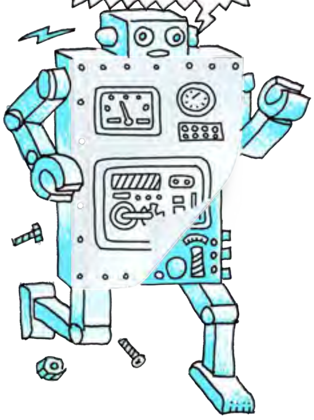
The beginning of each chapter starts off with **KEY QUESTIONS.** These introduce the content that will be covered in the chapter, but rather phrased as questions. This reinforces the idea of questioning, being curious and the investigative nature of science to discover the world around us and how it works.

The content and various **ACTIVITIES** and **INVESTIGATIONS** follow:

- **Investigations** are those tasks where learners will be using the scientific method to answer a question, test a hypothesis, etc. These are science experiments.
- **Activities** are all other tasks where the learner is required to do something

TAKE NOTE

A suggestion is to use the concept maps as a self-study homework exercise for learners to go over what they have learned in the chapter.



whether it is making a model, researching a topic, discussing an idea, doing calculations, filling in a table, doing a play, writing a poem, etc.

At the end of each chapter there is a **SUMMARY**, where the **KEY CONCEPTS** highlight the main points from the chapter. Following this, there is a **CONCEPT MAP** for each chapter. One of the aims for these workbooks is to also teach various methods of studying and taking notes. Producing concept maps is one way to consolidate information. Throughout the year, the skill of making concept maps will be taught as the maps have more and more for the learners to fill in themselves as the year progresses.

Lastly, there is **REVISION** at the end of each chapter. There are mark allocations for these questions. These revision exercises can be used as formal or informal assessment.

At the end of each strand there is a **GLOSSARY** which contains the definitions for all the **NEW WORDS** which are highlighted throughout that strand.

Going through the content

These workbooks are a tool for you to use in your classroom and to assist you in your teaching. You will still need to plan your lessons and decide which activities you would like to do. there are sometimes more activities provided than what is possible within the time allocation. We have specifically done this to give teachers a choice, providing different levels of tasks.

The tasks which are suggested in CAPS have been identified here in the teachers guide, and we have marked those that are **optional** or **extensions**.

When going through the content in class and you are using the workbook, there are various questions within the content. These questions are aimed at stimulating class discussions where learners can take notes, or they link back to what learners have already done. The answers are provided in the Teacher's Guide. Use these questions to check learners understanding and keep engaged with the content.

The various activities and investigations often contain questions at the end. The questions can often be used as a separate activity, even the next day in class or as homework, to reinforce what was learned.

Teacher's notes

The way this Teacher's Guide is structured to provide the content of the learner's book, but with all the model solutions written in italic blue text, and with many **Teacher's notes** embedded within the content.

An example of a teacher's note:

TEACHER'S NOTE

This is an example of what a teacher's note looks like. It can contain:

- chapter overviews
- suggestions on how to introduce a topic
- guidelines for setting up or demonstrating a practical task
- general tips for teaching the content
- extra background information on a topic
- misconceptions which can easily be introduced to learners, or which learners might already have

At the beginning of each chapter, there is a **CHAPTER OVERVIEW**. This is crucial for your planning. This overview contains:

- the number of weeks allocated to the chapter, as suggested in CAPS
- an introduction to the chapter, highlighting any links to previous content that learners have already covered, or anything to be aware of when going through the content
- tables highlighting the various tasks for the chapter

The tables for each section can be used to plan your lessons. We have suggested an **hours break down** to spend on each section within the chapter, based on how much content there is to cover, and the number of tasks. This is only a suggested guideline.

Within each table, we have listed the different Activities and Investigations and the **process skills** associated with each task.

The third column contains the Recommendation for the task. These recommendations are, in order of priority:

- **CAPS suggested** (a task suggested in CAPS)
- **Suggested** (a task we suggest doing doing, but is not suggested in CAPS)
- **Optional** (an additional activity which is optional if you have time or would rather do this than the other suggested tasks)
- **Extension** (an additional activity which is optional and also an extension)

An example of one of these tables is given below:

1.1 Cell structure (2.5 hours)

Tasks	Skills	Recommendation
Activity: Brainstorm the Seven Functions of Life	Recalling information	Optional (Revision)
Activity: Summarise what you have learnt	Recalling information, identifying, writing	Suggested
Activity: Cell 3D model	Planning, identifying, describing	CAPS suggested

You will need to look at how many hours you have for each section, and then decide which tasks you would like to do with your learners. These tables provide a useful overview and will also help you choose tasks so that you cover a range of process skills and specific aims.

Assessment

The assessment guidelines for Gr 7-9 Natural Sciences are outlined in CAPS on page 85.

There are many opportunities for informal assessment within these workbooks. Any of the tasks can be chosen to continuously monitor your learners' progress as well as checking the short answers they provide to questions interspersed in the content.

At the end of each strand in the CAPS document, there is a section on assessment guidelines. There is a column entitled 'Check the learner's knowledge and that they can:' and there is a list. These items are included within the content for that strand and can be used for assessment.

The questions in the revision exercises at the end of each term can be used as formal assessment and you can use these questions, as well as your own, to make class tests and examinations.

At the end of the Teacher's Guide, there is an appendix with Assessment Rubrics. These rubrics are a guideline for assessment for the different tasks which you would like to assess, either informally (to assess learners' progress) or formally (to record marks to contribute to the final year mark).

NEW WORDS

- cell
- atom
- energy
- telescope

The various rubrics provided are:

- Assessment Rubric 1: Practical activity
- Assessment Rubric 2: Investigation
- Assessment Rubric 3: Graph
- Assessment Rubric 4: Table
- Assessment Rubric 5: Scientific drawing
- Assessment Rubric 6: Research assignment or project
- Assessment Rubric 7: Model
- Assessment Rubric 8: Poster
- Assessment Rubric 9: Oral presentation
- Assessment Rubric 10: Group work

Margin boxes

You may have already noticed some of the margin boxes in this Teacher's Guide overview so far. These boxes contain additional information and enrichment.

The **NEW WORDS** highlight not only the new words used, but also the key words for the chapter or section. The definitions for all these new words are listed in the glossary at the back of the strand.

DID YOU KNOW has some fun, interesting facts relating to the content.

TAKE NOTE points out useful tips, with a special focus on language usage and the origins of words. This may be useful to second language learners.

The **VISIT** boxes contain links to interesting websites, videos relating to the content or simulations. This enrichment is also aimed to encourage learners to be curious about their subject in their own time by discovering more online. We feel it is important for learners to be aware that science is a rapidly advancing field and there are many exciting, innovative and useful discoveries being made all the time in science, mathematics and technology research.

To access the links in the VISIT boxes, you will see there is a bit.ly link. This is a shortened link that we created, as sometimes the website links to Youtube videos can be very long! You simply need to type this whole link into the address bar in your internet browser, either on your PC, tablet or mobile phone, and it will direct you to the website or video.

For example, in this Teacher's Guide overview, there is the link to a video about why open education matters. It is `bit.ly/17yW5Lj` Simply type this into your address bar as shown below and press enter.

This will either direct you to a website page, or to our website where you can watch the video online.

Discover more online at `www.curious.org.za`

Get involved

When we first embarked on this journey to create these books, our first step was to hold a workshop with volunteer teachers to get their perspective, suggestions and experience. Just turn to the front cover of this book to see how many people contributed in some way to these books! At Siyavula, we believe in openness and transparency and we would love your input in the next phase.

These books are not perfect and we will be continuously improving them. We would find your input and experience as a teacher crucial and highly beneficial in this process.

- Do you have any feedback about the books?
- Do you have suggestions?
- Would you like to share how you use these books in your classroom?
- Have you found any errors you would like to point out so we can fix them?
- Have you tried an activity and found a better way of doing it?
- What more would you like to see in these workbooks?

Get involved and let us know!

Find out more about our Siyavula Community at
projects.siyavula.com/community

And sign up by following this link bit.ly/15eiA6u. Specify Gr 7-9 Natural Sciences to stay informed about this process going forward in the future.


LOGIK
CB
B10
B10

ENERGY AND CHANGE

Sources of energy

TEACHER'S NOTE

Chapter overview

1 week

This chapter builds on the energy concepts developed in Grades 4 and 5. We extend the idea of renewable and non-renewable energy sources by detailing the different types and classifying them. This chapter also introduces the idea of fossil fuels, which links to what learners will do next term in Earth and Beyond.

An interesting article on how to encourage learners to pursue STEM careers: bit.ly/19Bpoip

1.1 Renewable and non-renewable sources (3 hours)

Tasks	Skills	Recommendation
Activity: Classify sources of energy	Identifying, classifying, explaining	CAPS suggested
Activity: Nuclear fuels - debate	Researching, reading, evaluating, writing, discussing	Suggested
Case Study: Biofuels	Reading, answering, reasoning	Suggested
Activity: What are the advantages and disadvantages?	Thinking, discussing, reasoning, writing	CAPS suggested

KEY QUESTIONS:

- Why do we need energy?
- What do we mean by renewable and non-renewable energy sources?
- Why should we use non-renewable energy sources?
- What are fossil fuels?

1.1 Renewable and non-renewable energy

TEACHER'S NOTE

The concept of renewable versus non-renewable energy sources was introduced in Grade 6. Remind the learners of the meanings of the terms and then use the activity to see how much they remember from Grade 6. This will give you an indication of how well they remember the work. If they cannot answer the questions you will need to spend some extra time revising.

All living things need energy. We learnt in Life and Living that energy is one of the requirements for life. However, it is not only living things which need energy to move and carry out various processes. The machines and appliances in our world around us also need energy to do work. Where does the energy come from?

Many substances and organisms store energy which can then be used. We call them **energy sources**. Energy sources have energy that is stored within them and can be used to make something happen, for example, energy stored in petrol can be used to make a car go. In Grade 6 you learnt about the two main sources of energy: **renewable** and **non-renewable sources**. Do you remember what these terms mean?

Renewable sources are ones which can be recycled or reused. Non-renewable sources cannot be reused and so there is a limited amount available and when that runs out there will be none left. Let's do a quick revision to see how much you remember from Grade 6.

ACTIVITY: Classify sources of energy

INSTRUCTIONS:

1. Study the following images which show different sources of energy.
2. Use the images to answer the questions that follow.

Natural gas - gas burning on a stove top.

Oil - An oil rig sinks a drill into the ocean floor to reach the oil deposits.

Sunlight - The Sun is a source of energy.

Biofuel- manure decomposes to produce methane gas.

Wood.

Coal - A coal mine.

Wind - wind turns this windmill.

Uranium - mining for uranium underground.

Hydropower - A large hydroelectric power station.

TAKE NOTE

Uranium is the source of energy for nuclear power stations.

QUESTIONS:

1. Draw a table in the following space to classify the energy sources in the images as either renewable or non-renewable. Give your table a heading.
Different renewable and non-renewable energy sources

Renewable energy sources	*Non-renewable energy sources*
wind *sunlight* *wood* *hydropower* *biofuel*	*coal* *oil* *natural gas* *uranium*

NOTE:
Learners may find it confusing that wood is a renewable energy source. Explain to them that it is renewable in terms of the time it takes to grow more trees and produce wood to generate the fuel. The time to renew this source is short, compared to non-renewable sources, for example, fossil fuels take millions of years to form. Some learners may also confuse 'deforestation' with the sustainable use of wood as a fuel for cooking or heating.

2. What do we mean when we say that something is renewable or non-renewable? Explain this in your own words.
Renewable energy sources can be used again or recycled or replaced. There is an unlimited supply of the energy source. Non-renewable energy sources cannot be used again or recycled. There is a limited supply of the energy source.
3. Why do you think we mostly use non-renewable energy sources?
Non-renewable energy sources usually have a large amount of energy stored in them and the energy is easier to harness than that of renewable sources.

Let's now have a closer look at some of the most common sources of energy.

Non-renewable sources

TEACHER'S NOTE

South Africa uses a variety of different energy sources for generating electricity. Most of the South African power stations are coal-fired power stations. We only have one nuclear power station, Koeberg near Cape Town. The South African government is encouraging the development of alternative energy sources but does not currently have any that are connected to the main grid.

In the 4th term, we will look at how the fossil fuels are formed under the section 'Stored solar energy'. This is an introduction to the different sources to link back to later.

The non-renewable energy sources most commonly used in our world today are **fossil fuels**. Fossil fuels are the non-renewable sources, oil, coal and natural gas. Why do you think they are called **fossil** fuels?

TEACHER'S NOTE

Coal, oil and gas are called **fossil** fuels because they have been formed from the remains of prehistoric plants and animals (fossils) over millions of years.

Fossil fuels

Where do we most often see fossil fuels in our everyday lives? Look at the following images for a clue.

Putting petrol into a car at a petrol station. Petrol is made from crude oil.

Coal is used in most of our power stations in South Africa.

Petrol and diesel are used mainly as fuel for cars, trucks and motorbikes. They are produced from **crude oil**, which is a fossil fuel formed from the remains of dead prehistoric animals. Crude oil contains a lot of energy which can be used. Crude oil is a non-renewable energy source because it takes millions of years to produce crude oil and so we cannot produce more when the existing reserves are finished.

VISIT

The story of petroleum (video). bit.ly/19iQ31o

Coal is most commonly used as a source of energy by power stations to generate electricity. We will learn more about this later in the term. Coal can also be burned in fires to keep warm or in coal stoves to cook our food.

Natural gas is the common name used to describe a mixture of gases. Natural gas is found in deep underground rock formations and usually with other fossil fuels, such as oil and coal. The biggest part of the gas mixture is a gas called **methane**. Methane is a gas which burns easily and releases a lot of energy when it is burnt. Natural gas is used for cooking, heating and producing electricity.

Natural gas has to be reached in underground reservoirs by drilling down wells such as these.

When talking about the methane component of natural gas, we are talking about non-renewable resources. Gas formed over thousands of years as organic matter decayed and the gas became trapped in wells which we now mine. However, as we we will see later, methane can also be considered a renewable resource. This is when methane is produced from degrading organic matter, such as animal waste, with the help of microorganisms.

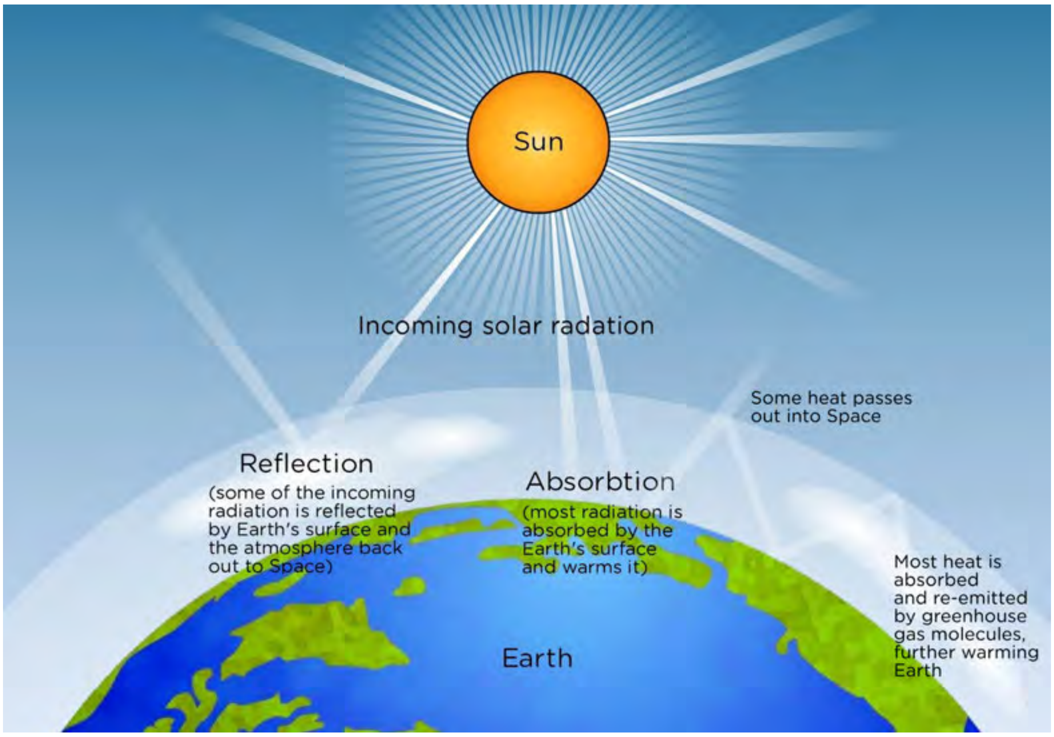
Non-renewable energy sources play a huge role in our lives and the way our world works today. However, there are some major concerns about our reliance on non-renewable energy sources. Firstly, there is only a limited supply, so these energy sources will run out one day. We will then need to find alternative energy sources. Currently alternative energy sources are being explored, and used in a small scale in some places.

VISIT

The formation of coal.

bit.ly/14Z0Oqv

Another major disadvantage of burning of fossil fuels is that it releases **greenhouse gases** into our atmosphere. Greenhouse gases are present in our atmosphere and help to control the Earth's temperature. The Sun's radiation enters Earth's atmosphere. Some of the radiation is reflected by the atmosphere and Earth's surface. Most of the solar radiation is absorbed by the Earth's surface and converted to heat to warm the Earth. The Earth's surface emits heat. Some heat escapes out into space, but most is absorbed and re-emitted by the greenhouse gases to further warm the atmosphere and Earth's surface. This natural process is called the **greenhouse effect**.



Do you know what an actual greenhouse is? It is normally a house made of glass, used to grow plants in. The glass also traps the Sun's energy and keeps the internal environment warm enough for the plants to grow. This is the same effect of the gases in the atmosphere.

A glass greenhouse traps the Sun's energy and provides a warm environment for the plants, just as the greenhouse gases in our atmosphere do.

But, our use of fossil fuels has released even more greenhouse gases, such as carbon dioxide. There is now an **excess** of greenhouse gases in the atmosphere. This reduces the amount of heat which escapes into Space and traps more heat within the Earth's atmosphere than before. This is causing the temperature of the atmosphere to rise, known as global warming.

VISIT

Play a simulation to learn more about the greenhouse effect bit.ly/15vNiyQ

Find out what else, besides burning fossil fuels, is contributing to an increase in greenhouse gases and write it below.

TEACHER'S NOTE

Other sources that contribute to an increase in greenhouse gases are:

- **Deforestation** which is the clearing of large areas of natural forest such as in the Amazon, Central Africa and Southeast Asia. These forests are cut down to provide farmland and the large trees, which have taken hundreds of years to grow, are used for making wood products. Forests usually act as a sink, absorbing CO_2 from the atmosphere, therefore deforestation contributes to an increase in greenhouse gases.

- **Agriculture** as greenhouse gases are given off from livestock such as cows, the soil and rice production.
- **Certain products** also give off greenhouse gases.

Nuclear fuels

TAKE NOTE

When nuclei are broken apart, it is called **nuclear fission** and when two nuclei combine to form one nucleus, it is called **nuclear fusion**.

Energy can be produced by nuclear reactions. Do you remember that we spoke about the atom last term in Matter and Materials? Within the atom, the nucleus is held together by very strong forces. When the nucleus is broken apart, a huge amount of energy is released. This energy can be used in nuclear power plants to generate electricity. Two different nuclei can also collide at very high speeds to form a new atomic nucleus. The energy released is also used in nuclear power plants, however on a smaller scale than when nuclei are broken apart.

Some materials are better to use than others as nuclear fuels. One such substance is uranium. Uranium is an element. Find it on the Periodic Table and write its symbol and atomic number below.

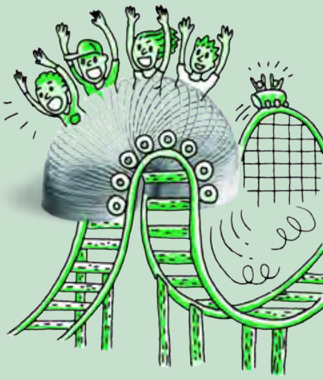
TEACHER'S NOTE

Uranium has the symbol U and atomic number 92. It is located at the bottom in the Actinides. This question is a revision of what learners covered last term in Matter and Materials and serves to reinforce learning.

This is the international symbol for radioactivity.

There is limited supply of uranium in the world, which is why we classify it as a non-renewable source. But there is enough uranium for nuclear energy to be used for a very long time because you need small amounts to produce lots of electricity. Therefore, many people see nuclear fuels as an alternative to fossil fuels. But there is a huge debate about this and many people also disagree about the use of nuclear fuels. Let's find out why.

ACTIVITY: Nuclear fuels - a debate



TEACHER'S NOTE

Get your learners to first do some of their own research about nuclear power and write down their own points. Then hold a class discussion where you compile the list of advantages and disadvantages and then discuss and debate the use of nuclear fuels. Encourage learners to give their own opinion.

This website provides a list of many of the arguments both for and against the use of nuclear power. Have a look at this website to help guide the discussion at the end of this activity. bit.ly/16sqS2d

INSTRUCTIONS:

1. You will need to do some research and extra reading to answer these questions.
2. Then you will have a class discussion about the topic.

QUESTIONS:

1. What are some of the advantages of using nuclear fuels instead of fossil fuels? Write down your own findings below and then add to it when you have a class discussion.
   Some of the advantages are listed here (there are others):
   - *There are almost no greenhouse gas emissions (no carbon dioxide gas is given off)*
   - *There is no smoke pollution*
   - *A very small amount of radioactive material can be used to generate a very large amount of energy as it is an efficient fuel*
   - *Nuclear power plants require less space, than for example a wind farm or coal station*
   - *It produces small amounts of waste (although it is radioactive, which is a disadvantage - see below)*
   - *The price of uranium does not fluctuate (go up and down) as much as coal and oil does, so it is more reliable*
2. Find out why many people, especially environmental activists are opposed to nuclear power. In other words, what are the disadvantages?
   Some of the disadvantages are listed here (there are others):
   - *The nuclear waste produced is dangerous as it is radioactive and needs to be stored for long periods of time as the used fuel remains radioactive for hundreds of years. There are environmental concerns about what is done with the radioactive waste as it damages plant and animal life.*
   - *The nuclear power plants are expensive to build.*
   - *There are many safety concerns about what happens if a plant is not maintained properly and there is a meltdown (such as what happened at the Fukushima nuclear reactor in Japan in 2011), or a reactor leaks. This is dangerous to the workers and the environment. An accident or mishap can have devastating effects for years, decades or even longer.*
   - *There are concerns about the general health of employees who work at nuclear power plants for extended periods.*

3. Although there are many disadvantages to nuclear fuels and power plants, many environmentalists and other people are now starting to change their minds and think that the advantages outweigh the disadvantages. This is happening as concern about climate change is increasing. Some people think the nuclear fuel is a more realistic alternative to fossil fuels than renewable energy sources, such as solar and wind power, which will not provide us with the energy to replace coal and oil. What do you think? Which side of the debate do you support? Discuss this with your class and then write down your thoughts below.
Learner-dependent answer. Make sure that learners offer their opinions during the class discussion and that they are then able to justify their choices in their written answers.

VISIT

Read more about renewable energy in South Africa.
bit.ly/15VuZ4n

Renewable sources

Let's now take a closer look at some of the renewable energy sources that we have mentioned so far.

Wind is moving air and it can be used as a source of energy. The energy from moving air particles is used to turn large turbines. The turbines are connected to a generator which produces electrical energy.

Wind turbines use wind to generate electricity.

You need a steady, strong wind blowing in order to produce a large, consistent amount of electricity. This means that wind farms cannot be put up in areas where there is not a lot of wind. Wind farms are noisy and many people do not like the look of them.

Water can also be used as an energy source. This is called **hydropower**. The energy from falling water is used to drive turbines in a power station. Unlike coal power stations, the water does not need to be heated and the water can be reused. These power stations must be at waterfalls or dams because there needs to be a strong flow of water to harness the energy.

Hydropower - A large hydroelectric power station.

VISIT

How does hydroelectricity work? bit.ly/15G1FAJ

Explain why you think we can classify wind and hydropower as renewable energy sources.

TEACHER'S NOTE

The wind and water is not used up in the process, the source of water or wind is continuously being replenished, the water can be reused, so it is renewable.

There is a lot of energy in sunlight. Solar panels are used to absorb the radiant energy from the Sun and to transform the energy from the Sun into stored potential energy. The Sun is a star and the lifetime of a star is measured in billions of years. This means that our Sun can provide energy to the Earth for millions of years to come. Sunlight is considered a renewable energy source because it will not run out in the foreseeable future.

TAKE NOTE

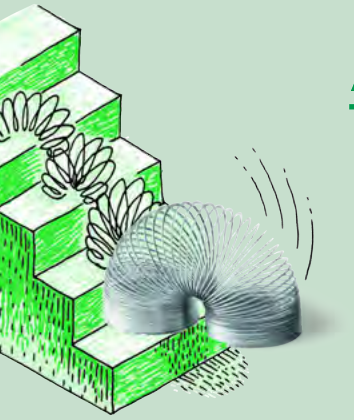
You will learn more about the Sun and its relationship to the Earth later in the year.

Solar panels on a rooftop.[1]

VISIT

Solar technology (video). bit.ly/1hh2L5Y

A **biofuel** is any fuel which is produced from plant or animal waste. Methane can be produced by decomposing plants and animal waste. This is useful for farms as they can produce enough methane gas to help run their farms. The most common biofuels are made from maize, sugarcane and sorghum. The biofuels that are made can be used in vehicles or heating and cooling systems.



ACTIVITY: A case study on biofuels

INSTRUCTIONS:

Read the following article about biofuels and answer the questions that follow.

Dairy finds a way to let cows power trucks

27 March 2013

A large dairy farm, Fair Oaks Farms, in the United States of America has found a way to use the endless supply of manure from the cows to generate electricity. This electricity is in turn used to run the equipment that milks about 30 000 cows, three times a day.

For several years, the farm had been using the waste from the cows to create natural gas. The cow manure is swept up from the barn floors each day. The manure is then allowed to decompose in a digester and as it does so, it releases methane gas. The gas is collected and stored and used to power their buildings and barns. This gas is enough to power 10 barns, a cheese factory, a small restaurant, a gift shop and even a 4D movie theatre in the kids entertainment area.

Fair Oaks Farms was doing all of this, but only using about half of the manure they swept up from the cows each day. But, they have now become even more energy efficient.

Fair Oaks Farms is now using the rest of the manure and turning it into fuel to power its delivery trucks and tractors. This is the largest group of vehicles on the roads in the US using livestock waste to power them. This is a huge saving in the amount of diesel which would otherwise be used. Gary Corbett at Fair Oaks said "We are taking about half a million litres of diesel off the roads each year." Another advantage is that natural gas is about half the price of diesel fuel for the same amount of power.

Mike McCloskey, a co-owner of Fair Oaks, said he first started looking into renewable energy options for the farm more than a decade ago. This was a way to become more energy efficient, save money and he also said the smell of the manure, used as fertilizer on the fields, started to make some neighbours complain! The leftover byproducts from producing the natural gas is still spread over the fields as fertilizer, but it has much less of a smell. This shows that nothing goes to waste.

Other farmers, landfill management companies and other large industries that produce large amounts of methane-rich material are now also starting to take interest. If used, this could provide an endless supply of 'biogas', a cleaner, safer, sustainable alternative which also reduces greenhouse gas emissions.

A digester used to decompose manure to produce methane gas.

This has been adapted from an article which appeared in the New York Times on 27 March 2013.

TAKE NOTE

The world could never produce enough biodiesel to replace fossil diesel. But it can be a part of the solution.

VISIT

Find out more about how a digester works to produce biogas. bit.ly/184BGkj

QUESTIONS:

1. What is the name of the farm in the article and in which country is it based?
   Fair Oaks Farms in the United States of America.
2. What made the owners of Fair Oaks Farm decide to use manure as a form of energy?
   They wanted to be more energy efficient, save money and also the neighbours were complaining about the smell of the tons of manure on the farm.
3. In the article, the renewable energy source referred to is an example of a biofuel. What is this renewable energy source and why can we call it a biofuel?
   The renewable energy source is methane gas. It is a biofuel as it is obtained from animal waste and turned into a fuel source. It is renewable.
4. How does the farm harvest methane from manure?
   The farm sweeps up the manure from the barn floors. As the manure decomposes, it releases methane gas. The methane gas can be collected and stored.
5. Why is it a good thing that the farm is taking "about half a million litres of diesel off the roads each year"?
   Diesel is a fossil fuel which is a non-renewable energy source. Using less diesel means that the supply will last longer. The biofuel is renewable and so it is a more sustainable source.
6. What is another advantages of using the biogas to power the delivery trucks and tractors?
   The biogas/natural gas is about half the price of diesel, so it is much cheaper.
7. Do you think that South Africa could benefit from a setup such as the one at Fair Oaks Farms? Explain your answer.
   Learner-dependent answer.

TEACHER'S NOTE

Make sure that learners justify their answers. Essentially, South Africa could benefit as we have multiple livestock farms and agricultural areas which produce a lot of manure and other methane-rich material, which mostly just goes to waste at the moment and is not used. Investing in processes that harness the natural gas to use it to power the farms and delivery trucks would help save money, be more energy efficient and also have less of an effect on the environment than using petrol and diesel.

Now that we have looked at non-renewable and renewable energy sources, let's summarise the disadvantages and advantages of each.

ACTIVITY: What are the advantages and disadvantages?

TEACHER'S NOTE

While the learners are discussing in their groups, walk around and listen to some of the discussions. Try to make sure that each learner gets a chance to speak and that they are not being overshadowed by more confident learners. If groups are sitting quietly, ask leading questions to give their discussion direction.

If you can, give the learners some newsprint and pens so that they can write down their main ideas. They can then use these newsprints as visual aids during their report back. You can also extend this activity by comparing all the newsprints from the different groups at the end of the report back. Learners can then choose what they consider to be the best responses and a summary can be written down. You can display the summary in the classroom so that the learners can refer to it again.

INSTRUCTIONS

1. Sit in groups of 3 or 4.
   Discuss, in your groups, the advantages and disadvantages of using non-renewable energy sources.
   A major advantage of non-renewable energy sources is the massive amounts of energy that they contain which is relatively easy to access. A disadvantage is that they produce excess greenhouse gases when they are burnt and that the supply is limited.

2. Discuss, in your groups, the advantages and disadvantages of using renewable energy sources.
   A major advantage of renewable energy sources is that the supply will not run out and so their use is sustainable. They are more environmentally friendly. A disadvantage of renewable energy sources is that they store smaller quantities of energy than non-renewable sources and so it takes more effort to access the stored energy.
3. Why do you believe that fossil fuels are still burnt as a source of energy? Write your own answer below.
   Learners will provide their own interpretation of the information gathered in this discussion. They should mention the disadvantages of burning fossil fuels and then explain that it is often cheaper, and certainly easier to access large amounts of energy from burning fossil fuels than it is to use renewable sources. Wind, solar and hydroelectric power are expensive and sometimes the yield of energy from those sources is less cost-effective than using fossil fuels.
4. Choose a spokesperson for your group and share your ideas with the rest of the class.
   Choose two of the sources of energy discussed so far in this chapter. Use your school library or the internet to find more information about how they are used to generate electricity in South Africa.
   This answer depends on which 2 sources the learner chooses. Learners will discover that renewable sources are not used for large scale electricity production in South Africa. In fact most renewable sources are used in homes to run geysers and swimming pools. Coal is the main source of electricity in South Africa. Nuclear power is used to supplement coal fired power stations in South Africa.

VISIT

You can make your own house more efficient in its use of waste. Have a look at this website. bit.ly/1dL9CEQ

VISIT

Six myths about renewable energy sources. bit.ly/1bmufX1

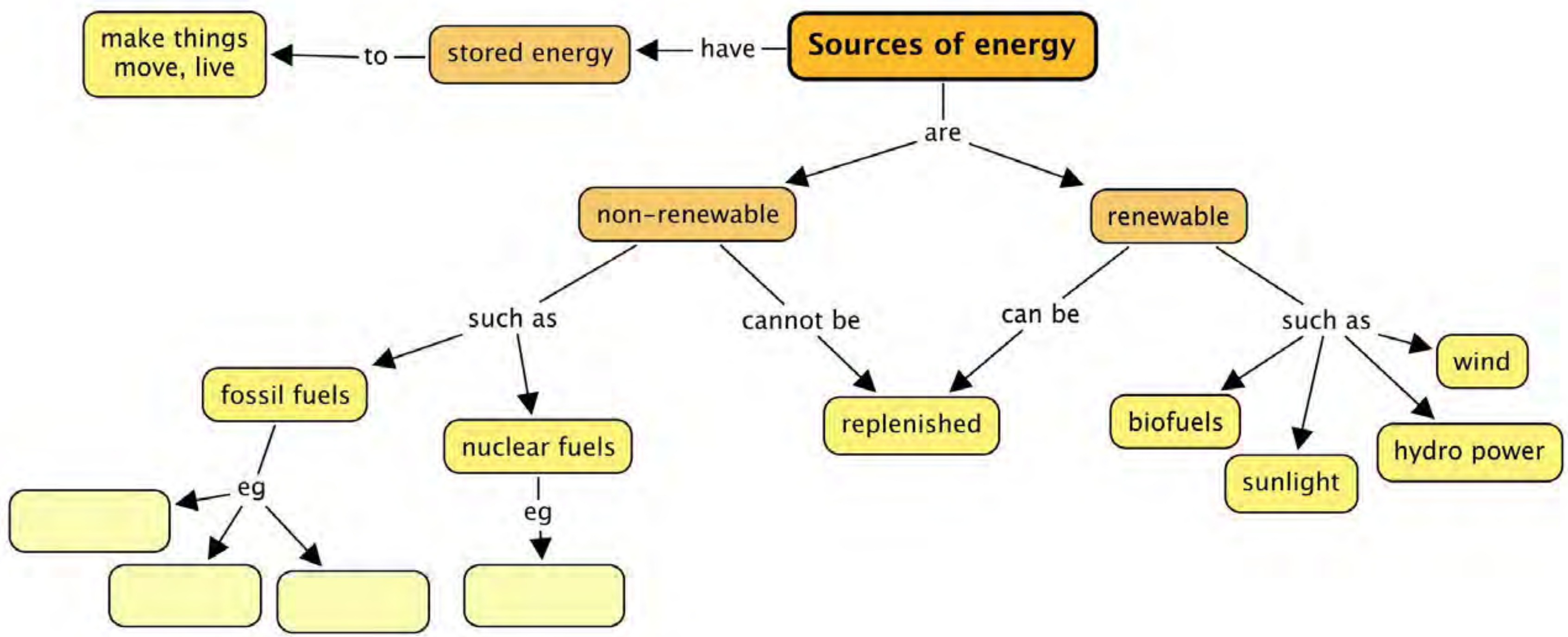
SUMMARY:

Key Concepts

- Energy is one of the requirements for life on Earth.
- Energy is needed to make things move.
- Sources of energy have energy stored within them that is used make something happen.
- Non-renewable energy sources cannot be recycled or reused. There is a limited supply.
- Examples of non-renewable energy sources are fossil fuels (coal, oil and natural gas) and nuclear fuels.
- Burning of fossil fuels releases greenhouse gases into our atmosphere.
- Renewable energy sources can be recycled or reused. There is an unlimited supply.
- Examples of renewable energy sources are wind, hydropower, solar power and biofuels.

Concept Map

This is our first concept map for Energy and Change. Complete it by filling in the three types of fossil fuels, and give an example of a nuclear fuel which was discussed in this chapter.


Sources of energy
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stored energy
to
make things move, live
are
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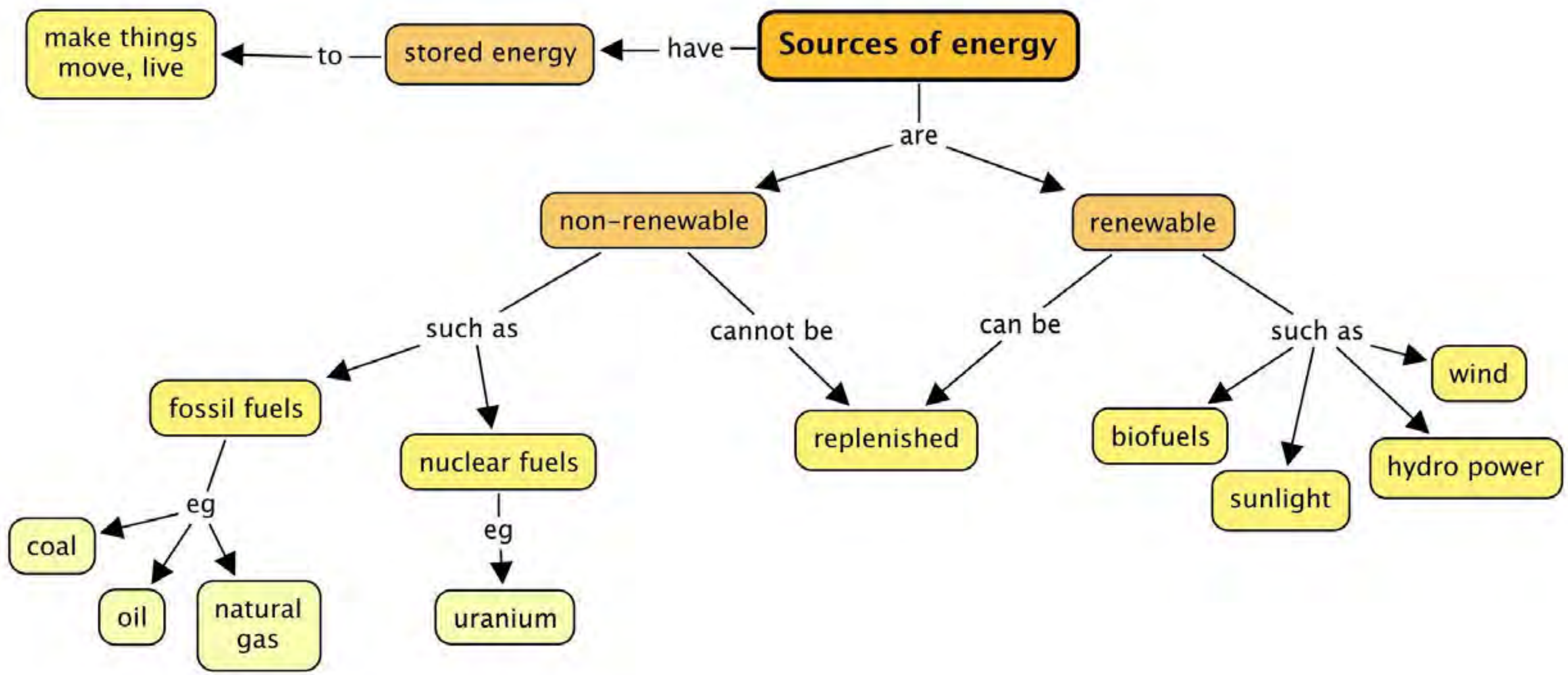
biofuels
sunlight
hydro power
wind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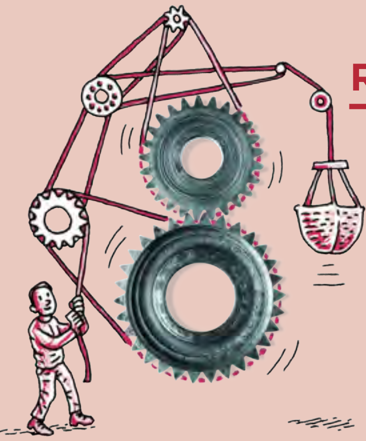


REVISION:

1. What do we need to make things move? [1 mark]
   Energy
2. What does it mean when we say something is 'a source of energy'? [1 mark]
   It is something which has energy stored in it which can be used.
3. Which of the following are sources of energy? [1 mark]
   a) Sun
   b) waves
   c) wind
   d) coal
   e) all of them
   e
4. What does it mean if something is a non-renewable source of energy? [2 marks]
   Non-renewable energy sources cannot be reused or replenished. There is a limited supply.
5. Which of these are renewable energy sources. [1 mark]
   a) coal
   b) natural gas
   c) sunlight
   d) wind
   e) crude oil
   c and d
6. Which type of renewable energy uses the movement of air to generate electricity? [1 mark]
   Wind
7. Complete the following sentences. Write them out in full on the lines provided and underline your answers. [5 marks]

   Coal, natural gas and oil are all examples of __________ (renewable/non-renewable) energy resources. When they are burned, they release __________ (energy/electricity). Coal, natural gas and oil are also known as __________ (nuclear fuels/fossil fuels). Wind and solar energy are examples of __________ (renewable/non-renewable) energy sources because they __________ (can/cannot) be replaced.
   Coal, natural gas and oil are all examples of renewable energy resources. When they are burned they release energy. Coal, natural gas and oil are also known as fossil fuels. Wind and solar energy are examples of renewable energy sources because they can be replaced.
8. How does the burning of fossil fuels contribute to global warming? [2 marks]
   Burning fossil fuels releases greenhouse gases into the atmosphere, causing an excess in the atmosphere. These gases then trap more of the Sun's energy causing the Earth to warm up even more, and results in global warming.

9. Complete the following table. [18 marks]

Energy source	***Renewable or non-renewable***	***Disadvantage***	***Advantage***
Wind	*Renewable*	*Wind farms are noisy and take up a lot of space; Need strong winds*	*No greenhouse gases produced*
Coal	*Non-renewable*	*Burning releases greenhouse gases into the environment*	*Coal stores a lot of energy which is relatively easy to access*
Uranium	*Non-renewable*	*Production of nuclear waste which needs to be stored*	*Uranium has a vast amount of energy stored within*
Water (Hydroelectric)	*Renewable*	*Dams must be built and this damages/changes the landscape and affects ecosystems; Expensive to set up and maintain*	*Sustainable. No harmful emissions; Can be utilised anywhere there is enough water*
Solar power	*Renewable*	*Need a sunny climate all year round; expensive to set up*	*Non-polluting (no greenhouse gases) and renewable*
Biofuels	*Renewable*	*May affect food production and supply*	*Uses renewable biomass for energy*

The advantages and disadvantages in the table are just some examples. Learners may write other reasonable answers.

Total [30 marks]

2 Potential and kinetic energy

TEACHER'S NOTE

Chapter overview

2 weeks

This chapter builds on the basic concept of energy. The chapter explains the difference between kinetic and potential energy. The law of conservation of energy is also introduced: Energy cannot be created or destroyed, but can be transferred from one part of the system to other parts. This is a crucial concept in Physics and it is important to make sure that the learners understand it.

We have also not made mention of the different "forms of energy" within this content. There is disagreement about what the "forms of energy" are, and how long the list should be or could be. The "forms of energy" language is a problem when teaching learners about energy. For example, learners can be asked to name the "form of energy" in various examples and often learners are just told which one and have to memorise the answer. They are disempowered by the question. Learners are still unable to work out what happens. Furthermore, not remembering the correct "form of energy" can cost them marks in a test, but remembering the "form" correctly does not add anything to their understanding of energy or systems.

What we must focus on is systems which have different parts that learners can examine. It is sufficient to say that the potential energy in a system becomes the kinetic energy of some part of the system. We can have energy in a system in two forms - it can be stored in the system (potential energy) and it can cause changes in the system (kinetic energy). Therefore, the key concepts to focus on within these sections are: potential and kinetic energy, systems, transfer of energy between parts of a system and the conservation of energy.

2.1 Potential energy (1.5 hour)

Tasks	Skills	Recommendation
Investigation: How can we make the foam cup move further?	Planning investigation, doing investigation, hypothesising, identifying variables and controls, measuring, recording, drawing graphs, analysing	Suggested
Activity: Elastic bands	Raising questions, carrying out instructions, measuring, recording, interpreting information	CAPS suggested
Activity: Reading a cereal box	Observing, comparing, interpreting information, drawing graphs	CAPS suggested

2.2 Kinetic energy (1 hour)

Tasks	Skills	Recommendation
Activity: Which objects have kinetic energy?	Observing, comparing, sorting and classifying	Suggested

2.3 Law of conservation of energy (0.5 hours)

2.4 Potential and kinetic energy in systems (3 hours)

Tasks	Skills	Recommendation
Activity: Identifying energy transfers in mechanical systems	Observing, interpreting, identifying and classifying	CAPS suggested
Investigation: The energy transfers when boiling water	Doing investigation, hypothesising, observing, identifying variables, recording, drawing graphs	CAPS suggested
Activity: An electric fan system	Building a circuit, identifying components and features	CAPS suggested
Activity: Flow diagrams for energy transfers	Identifying types of energy transfer, describing, drawing flow diagrams, communicating information	CAPS suggested

KEY QUESTIONS:

- What is potential energy?
- What is kinetic energy?
- Where do we get energy from?
- How much energy do I need?
- Can energy be created or destroyed?
- What is a system?

Renewable and non-renewable sources are where we get our energy **from** but what **types** of energy do we find in the world?

All energy can be placed into two main groups:

1. Potential energy
2. Kinetic energy

So what are these different types of energy and what does it mean if an object has potential energy or kinetic energy? Let's investigate!

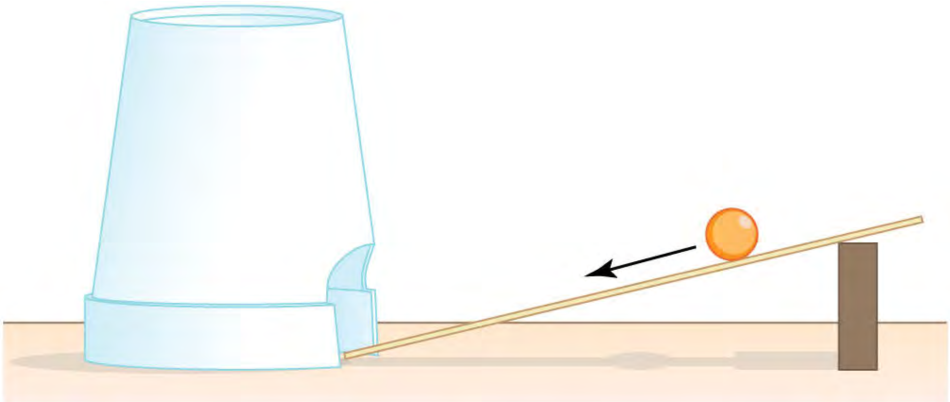
2.1 Potential energy

TEACHER'S NOTE

Start this section by doing the investigations first and allowing the learners to draw their own conclusions. This will lead them to a better understanding of what energy is and what it can do rather than a verbal explanation. There are several activities which deal with potential energy. If you do not have enough time to do all of them, then choose at least one of them. You can base your choice on the resources that you have available at your school. Do not completely ignore the other activities, though. Take some time to talk through what the outcomes would have been and then you could ask the learners to answer the questions at home.

Throughout our investigation and learning about the concepts surrounding energy, we will be talking about systems and how energy is transferred within a system. A system is a set of parts that work together as a whole. A change in one part of the system will affect the other parts. This will become more clear as we see some examples throughout this term.

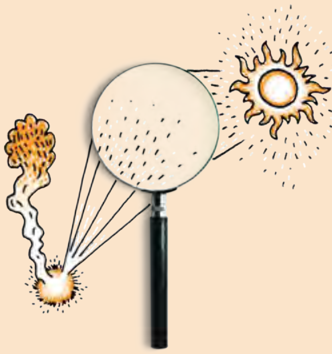
We are going to find the difference between potential and kinetic energy. Look at the following diagram which shows a ramp with a marble rolling down into a foam cup. The marble will knock the cup and make it move.



A marble rolling down a ramp.

When the marble is released, it rolls down the ramp and transfers some of its energy to the cup. This transfer of energy is what makes the cup move. But where did the marble get energy from? Do you think you can make the cup move more or less depending on how far up the ramp you start the marble? Let's do an investigation to find out.

INVESTIGATION: How can we make the foam cup move further?



TEACHER'S NOTE

It is important to emphasise the importance of independent and dependent variables. Take special care to explain the difference between the two variables. The **independent variable** is the variable that you chose to change while doing the experiment. The **dependent variable** is what result you measure in your experiment. Learners would have encountered variables in the previous strands by now. Each group will need a set up and they will roll the marble from different heights into the cup. The higher up the ramp the marble starts, the further the cup will move.

INVESTIGATIVE QUESTION: If we roll a marble down a ramp and into a cup, how does the starting position of the marble affect how far the cup moves?

VARIABLES:

1. What will we change when performing this investigation?
   The height from which the marble is released to roll down the ramp. This is the independent variable because the learners are changing it to see how far the cup moves.
2. What will we be measuring in this investigation?
   The distance that the cup moves. This would be the dependent variable because the distance depends on how high the marble was before it was released.
3. Which things must stay the same?
   The size of the marble must stay the same.

HYPOTHESIS:

Write a hypothesis for this investigation. When you do this, you need to write what you expect to observe. It does not have to be the correct answer to the investigative question.

TEACHER'S NOTE

The hypothesis should mention how the distance the cup moves would change if the height of the marble changes. Here are two possible examples:

- "The higher the marble is on the ramp, the further the cup will move."
- "The higher the marble is on the ramp, the less the cup will move"

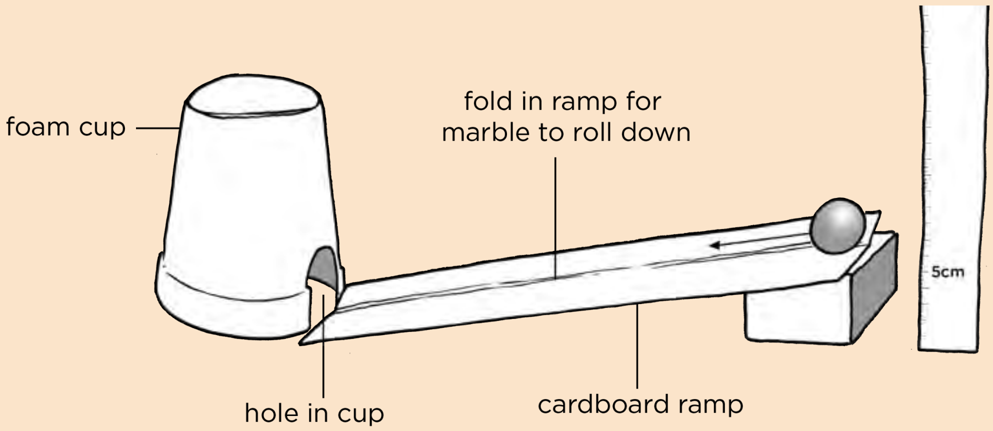
Both of the above hypotheses mention how the height of the marble is expected to affect the distance the cup moves.

MATERIALS AND APPARATUS:

- a styrofoam cup
- a marble
- a pair of scissors
- a ramp (this can be a plank of wood or stiff card)
- books or wooden blocks to prop up the ramp
- rulers

METHOD:

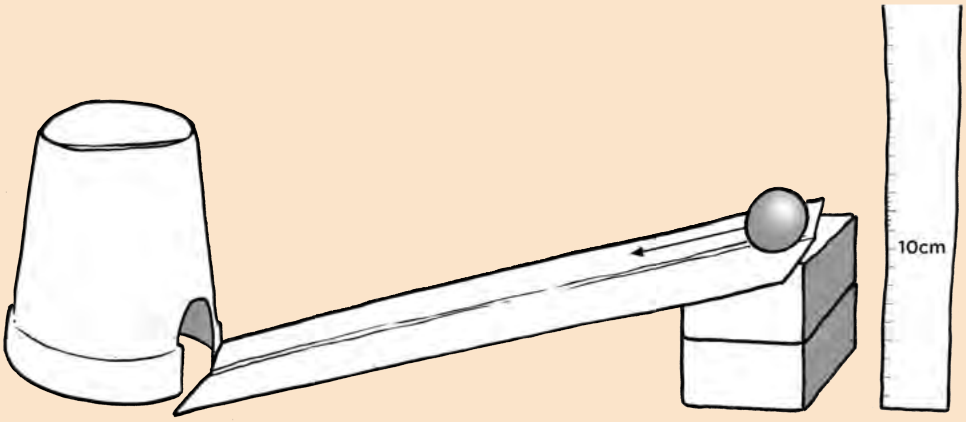
1. Work in groups of 3 or 4.
2. Cut a hole in the lip of the cup so that when you turn it over on a table, there is a hole which a marble can now fit through, as shown in the previous diagram.
3. Build the setup as shown in the following diagram. Place the cup upside down on the table surface. Place the ramp so that it ends at the hole in the cup. Prop up the ramp with blocks or books. You will adjust the height of the ramp using different books or wooden blocks. Otherwise you can just hold the top of the ramp at the specified height.



4. Practice rolling the marble down the ramp and into the cup. You can use two rulers to create a path down the ramp to guide the marble into the hole so that it does not roll off the side of the ramp. Or else you can bend the cardboard so that the marble rolls down the middle on the fold. You can also try a cardboard tube like a roller towel inner. You will need to practice to see what works best with the materials that you have available.
5. Once you have found the best way to do this, you can start the measurements.
6. First set up the ramp so that the top of the ramp is at a height of 5cm. Roll the marble from a height of 5 cm and then measure how far the styrofoam cup moves.
7. Next adjust the height of the ramp by increasing by 5 cm each time. Each time place the marble at the top of the ramp and roll it down, measuring how far the cup moves.

TEACHER'S NOTE

The height of the ramp at each step will depend on what you use to prop it up with. Try and get blocks or books of equal thickness so that at each step the height increases by the same amount.



8. Repeat the measurements until you have at least 6 recordings.
9. Record your measurements in the table and draw a graph with a line of best fit.

TEACHER'S NOTE

If you make bigger ramps, you can also perform more measurements at different positions up the ramp.

RESULTS AND OBSERVATIONS:

Record your results in this table.

Height of marble up the ramp (cm)	Distance the cup moves (cm)

Use the information in your table to draw a graph of the height of the marble up the ramp versus the distance the cup moves. Before you draw the graph, answer the following:

1. Which is the independent variable? This is the value which you changed in the investigation. The independent variable is written on the x-axis (horizontal axis).
   The height of the marble on the ramp.
2. Which is the dependent variable? This is the variable you measured. The dependent variable is written on the y-axis (vertical axis).
   The distance the cup moves.

TEACHER'S NOTE

The independent variable is plotted on the horizontal axis. In this example the scale could be increments of 5 cm. The dependent variable is always plotted on the y-axis.

CONCLUSION:

1. Write a conclusion for this investigation. Remember to refer to your graph and hypothesis when writing your conclusion.
   The conclusion should mention that as the height of release increases, the distance that the cup moves increases.
2. Was your hypothesis shown to be true or false?
   This answer will depend on what the learner wrote for their hypothesis. If their hypothesis stated that the greater the height, the further the cup moves, then their hypothesis is shown to be true. If their hypothesis stated that the greater the height, the less the cup moves then their hypothesis has been proved to be false.

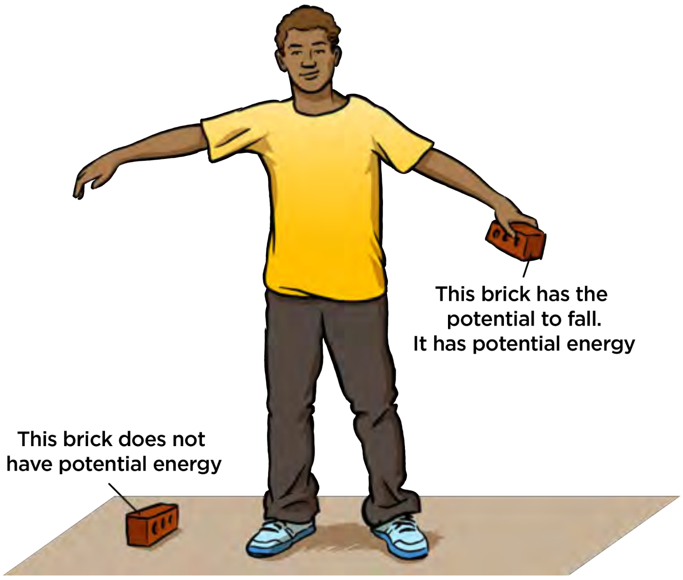
When you hold the marble at a distance up the ramp, you are preventing it from rolling down the ramp. This means that the marble has the potential to roll down and knock the cup. So, YOU gave the marble **potential energy** by picking it up and holding it at the top of the ramp. When the marble hits the cup, the marble transfers energy to the cup which then moves. The cup then comes to a stop after a while. Do you have any guesses about why the cup stops after a while?

TEACHER'S NOTE

Discuss this with your class. The cup moves along the surface and it experiences friction as it rubs along the ground. This causes it to come to a standstill. Friction will only be covered in more detail in Gr. 8 when learners look at friction in terms of static electricity and how rubbing objects transfers electrons resulting in a charge. A small demonstration that learners can do to briefly look at friction is to rub their hands together and observe that their hands become warm. When surfaces in contact with each other move against each other, the friction between them transfers kinetic energy to heat.

Your investigation will have shown you that the greater the vertical height of the marble, the further the cup moved. This tells us that lifting the marble to a higher position means that it has more potential energy than if it was released from a lower position.

So the higher an object is above a surface, the more potential energy it has. Think of another example of picking up a brick, as shown in the diagram. Here we are looking at a system consisting of: the arm, the brick and the Earth that pulls on the brick.



When the brick was on the floor, it had no potential energy. But when it is lifted up, it has potential energy. Where did the potential energy come from?

TEACHER'S NOTE

The potential energy came from the arm which lifted it.

The boy now lets go of the brick and it falls down to the ground and makes a hole in the sand. What received the energy of the falling brick?

TEACHER'S NOTE

Discuss this with your learners. The answer is the sand which goes flying up. Ask your learners where is the energy now? The answer is the molecules of the sand are moving faster. A sensitive thermometer would show that the sand is a little warmer than it was. Also, the energy went into disturbing the air and your eardrums got that energy when you heard the bang.

Do you think the hole in the sand pit will be deeper if we drop the brick from a higher point? Why?

TEACHER'S NOTE

Yes it will be as it has more potential energy at a higher point so by the time it hits the ground it will be moving faster (more kinetic energy).

So what we have seen is that the energy is all still there within this system, but it is not easy to use anymore. The sand is warmer but we can not actually use that energy for anything because the temperature increase was so small. So the energy in the system has not been destroyed, but it is less available for us to use.

Let's look at another example of stored energy and energy transfers within a system.

ACTIVITY: Elastic bands

TEACHER'S NOTE

Try to get elastic bands of equal length and thickness. It is the only variable which really needs to be kept constant. If you are running short on time you can leave out this activity. Rather just discuss the conclusions one would draw from such an activity.

1. We are going to be shooting match boxes with elastic bands by stretching the bands and releasing them to hit the matchbox. What are the parts making up this system?
   The parts of the system are the stiff fingers, rubber band, matchbox, table.
2. What is the energy input into this system?
   Stretching the elastic band so the movement of the fingers transfers potential energy to the elastic band which is now stretched.

Do you think there is a relationship between how far the matchbox travels and the energy that the hand puts in at each try? Let's find out.

MATERIALS:

- empty matchbox
- elastic band
- ruler

INSTRUCTIONS:

1. Place the empty match box on a desk, mark the spot with a piece of paper.
2. First, practice shooting the matchbox with the elastic band. Each time, place the elastic band and matchbox in the same starting position and distance from each other.
3. Once you feel comfortable doing this, stretch the elastic band by a different amount each time and measure how far the matchbox moves with each try.
4. Place a ruler next to your elastic band and first stretch it by a small amount. For example, if your elastic band is 5 cm long when held pulled tight, but not stretched, between your fingers, then stretch it to 8 cm.
5. Release the elastic band so that it hits the matchbox across the desk.
6. Measure the distance that the match box moves across the desk.
7. Record the distance in the table below.
8. Put the empty match box back in its original position on the desk.
9. Repeat the experiment several times but stretch the elastic band a bit more than before each time.

TEACHER'S NOTE

The distances moved will depend on the type of elastic bands used and how rough the surface of the desk is. What is important is that the learners see that the small stretch moves the match box the shortest distance and the largest stretch moves the matchbox the furthest.

Record your measurements in the following table.

Elastic stretch (cm)	Distance moved (cm)

QUESTIONS:

1. Does the distance moved by the matchbox increase or decrease as you stretch the elastic band more? State the relationship between these two measurements.
   The distance the matchbox moves increases as you stretch the elastic band more.
2. What did you have to do in order to stretch the elastic band and keep it stretched?
   The elastic band had to be pulled hard by the learners and they cannot let go if they want to keep it stretched.
3. Energy is transferred from the elastic band to the matchbox and the matchbox moves. But, then it comes to a stop after a while. Where did the matchbox transfer its energy to?
   The matchbox transfers energy to the air and the table.

When the elastic band was stretched it gained potential energy. We know this because your hand had to do some work to stretch the elastic band, and now the elastic band can snap back and move the matchbox. The elastic band needs energy to make the matchbox move, and it got that energy from your hand.

The further we stretched the elastic, the further it could push the matchbox. This tells us that the more we stretch the elastic band, the more energy is transferred from the elastic band to the match box.

Energy transfers have taken place within this system: Energy is transferred from the hand, to the elastic band, to the matchbox, to the air and the table surface. The table ends up a little warmer than it was as it now has most of the energy and the air has the rest. The energy has not gone, but again it's not available to use.

*A **stretched** elastic band has potential energy.*

So did you notice that both the marble and the elastic band had potential energy? But we didn't do the same thing to give them that energy. We **lifted** the marble but we **stretched** the elastic. This means that there is more than one way to give something potential energy. **Potential energy is energy that is stored within a system.**

Now that you understand a bit more about potential energy, can you think of some more examples of things which contain potential energy? Think in terms of things which have the **potential or the ability to change something or make something move.**

What about some of the fossil fuels that we discussed in the last chapter, such as coal and oil? Do you think these have potential energy? Yes they do. For example, coal is burned in power stations to generate electricity (you will learn more about this later on in the term). So, we can say the coal has stored energy which is used to generate electricity. Coal has potential energy. This is the same for other fuels as well.

Do you remember making electric circuits in Gr. 6 last year? Do you remember using batteries? The batteries are the source of energy for the circuit. The batteries store energy. In other words, they have potential energy.

Batteries are a source of potential energy for electric circuits.

Where do we get our energy from? As we learnt in Life and Living, nutrition is one of the 7 life processes. We have to eat food. Food is the fuel for our bodies.

Have you ever had a look at all the small writing on food packaging? The information gives us nutritional information about the food. It also gives us the amount of **energy** stored in the food. Have you noticed that this is often given in **joules**?

So what is a joule? How do we measure energy?

We can measure energy, just as we can measure the mass of an object or how fast a car is going. The mass of an object is given in grams or kilograms, the speed of a car is given in kilometers per hour (km/h). In the same way, energy is measured in joules. There are 1000 joules in a kilojoule.

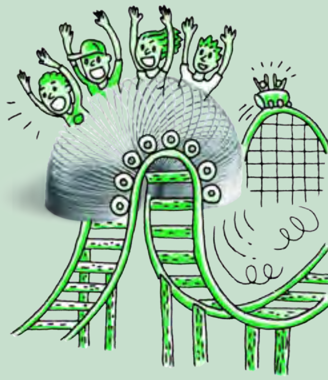
TEACHER'S NOTE

At this point it is important to note that the joule is a measure of energy. It is just a number that we calculate after a lot of careful measurements on changes in a system. A food joule is not different to an electrical joule, nor different to a joule that heats water, or a joule that comes from the Sun. It is important that learners realise that joules of energy from food are no different to joules of energy from Eskom. But, if we reinforce the concept of different "forms" of energy, then learners are given the reason to think that energy from food must be different to energy from Eskom, whereas it is not.

The main idea is to simplify the concepts around energy for learners by eliminating the long lists of "forms" of energy that appear in tests and rather shift the focus to systems, which have parts that learners can examine and understand. It is sufficient to say that the potential energy in a system becomes the kinetic energy of some part of the system.

Let's have a look at the energy content for some of the cereals that we eat for breakfast.

ACTIVITY: Reading a cereal box



TEACHER'S NOTE

Encourage the learners to bring in old cereal boxes well in advance of doing this activity. It would be a good idea to find some extras to bring to class for those who forget. You can even photocopy some of the cereal boxes and keep them for the following year.

If you want to extend this exercise you could ask the learners to compare their cereal with the rest of the class. Draw a table on the board with the different cereals and their energies. Get the class to draw a bar graph comparing the energies in the different cereals.

MATERIALS:

- cereal box
- pair of scissors
- calculator

INSTRUCTIONS:

1. Read the nutritional information on your cereal box.
2. Answer the questions that follow.

TEACHER'S NOTE

Each learner's answers will depend on the type of cereal that they have chosen. Make sure that the learners have kept their cereal box so that you can check their answers against the box details.

QUESTIONS

1. What is the amount of energy per 100 g for your cereal? Write your answer in kilojoules and in joules
   Learner-dependent answer. For example, Oats contains 1528 kJ per 100 g. This is 1528 000 J.
2. The cereal boxes often indicate an amount per 100 g and then an amount per serving, which is normally less. What is the amount of energy per serving on your cereal box? Remember to include how many grams the serving is.
   Learner-dependent answer. For example, Oats contains 611 kJ per 40 g serving. This is 611 000 J. Weetbix cereal contains 529 kJ (529 000 joules) of energy per serving.
3. Look at the following table which gives the recommended daily amount of energy for an individual depending on your age and level of activity. This is a guideline as to how much energy you should consume in food in one day.

TAKE NOTE

Sedentary means that you lead an inactive lifestyle and do not do any exercise.

Gender	Age (years)	Sedentary (kJ)	Moderately Active (kJ)	Active (kJ)
Female	9 - 13 14 - 18	8 000 8 500	8 000 - 9 000 8 500 - 10 000	8 500 - 9 500 9 500 - 10 500
Male	9 - 13 14 - 18	8 500 10 000	8 500 - 10 000 10 000 - 11 500	9 500 - 11 000 11 000 - 13 000

   According to the table, what is the recommended daily amount of energy for your age and level of activity?
   Learner-dependent answer. For example, a female learner who is 13 and moderately active needs between 8 000 and 9 000 kJ per day.
4. What percentage of your recommended daily energy is being supplied by one serving of your cereal? Show your calculations below.
   Learner-dependent answer. Learners must choose the row which corresponds to their age and gender. They must then consider, honestly, how active they would consider themselves to be. They can then use their cereal to calculate the percentage.
   Example calculation:
   Lets assume we have a male, aged 15 who is very active. His recommended daily allowance (RDA) would be between 11 000 - 13 000 kJ.
   A serving of Nestle Milo Cereal contains 477 kJ.
   The percentage of RDA = 477/13 000 x 100 = 3,7%

TAKE NOTE

The joule is a measure of energy. A food joule is not different to an electrical joule, nor different to a joule that heats water, nor a joule that comes from the Sun.

TEACHER'S NOTE

An additional question to ask learners and have a class discussion is:

Based on the percentage worked out in question 3, do you think this is a good cereal to eat for breakfast? Why do you think it's a good/bad cereal for breakfast?

The learners should decide whether their calculated percentage is low or high. If it is low, they could decide that it is better to eat a high energy meal for breakfast and then lower energy meals throughout the day, or they might indicate that they are hoping to lose/maintain weight and so a low percentage is a good thing.

TEACHER'S NOTE

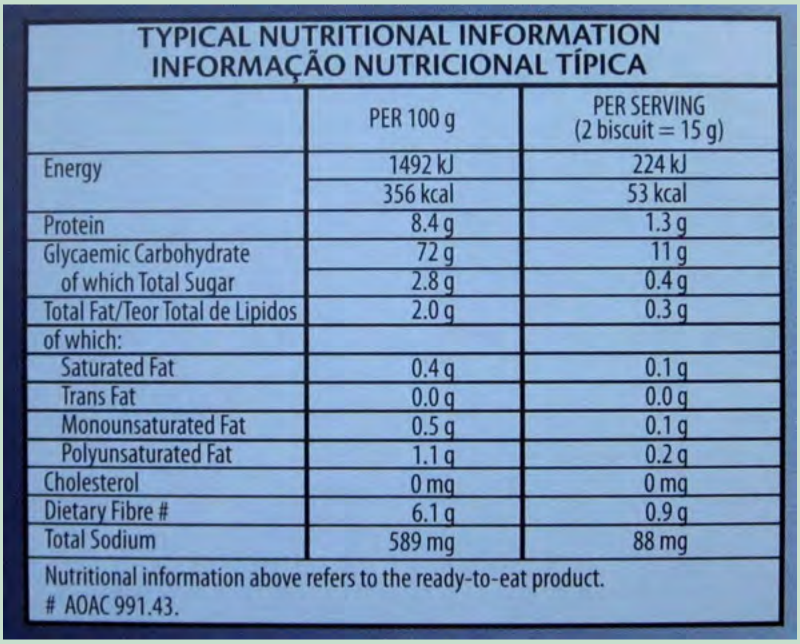
If their calculated percentage is high, they could indicate that it is better to spread out their energy intake over the entire day rather than concentrate it in one meal.

The nutritional value of a cereal also does not only depend on how much energy it provides, but also what other nutritional ingredients it offers.

There are no incorrect answers to this question. It is based entirely on their own interpretation of their needs. This can be a very sensitive topic, don't spend too much time discussing weight loss programmes as this is not a weight counselling session and learners could get confused between healthy eating and excessive dieting.

Alternatively, ask several learners what the energy content is for their cereal and then ask which one provides the most potential energy and which one the least.

5. The following photograph shows the nutritional information on a box of cracker biscuits. Study it and then answer the questions that follow.



TYPICAL NUTRITIONAL INFORMATION
INFORMAÇÃO NUTRICIONAL TÍPICA

	PER 100 g	PER SERVING (2 biscuit = 15 g)
Energy	1492 kJ	224 kJ
	356 kcal	53 kcal
Protein	8.4 g	1.3 g
Glycaemic Carbohydrate	72 g	11 g
of which Total Sugar	2.8 g	0.4 g
Total Fat/Teor Total de Lipidos	2.0 g	0.3 g
of which:		
Saturated Fat	0.4 g	0.1 g
Trans Fat	0.0 g	0.0 g
Monounsaturated Fat	0.5 g	0.1 g
Polyunsaturated Fat	1.1 g	0.2 g
Cholesterol	0 mg	0 mg
Dietary Fibre #	6.1 g	0.9 g
Total Sodium	589 mg	88 mg

Nutritional information above refers to the ready-to-eat product.
AOAC 991.43.

a) What is the energy content per 100g in **joules**?
The values given on the box are in kJ and kcal so learners must convert the values by multiplying by 1000. The answers are 1492 000 J (1492 kJ)

b) What is the mass of **one** biscuit?
The mass is 7.5 g, as the mass given on the box of 15 g is for 2 biscuits.

c) The nutritional information gives the serving size of 2 biscuits, but you want to know what the energy content will be if you only eat one biscuit. Write down the answer below.
Energy for one biscuit = 224/2 = 112 kJ per biscuit.

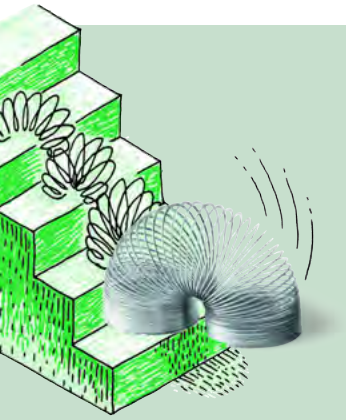
d) You now decide that you want to eat 5 biscuits. What is the energy content for this serving of 5 biscuits?
Energy content for 5 biscuits = 112 x 5 = 560 kJ.

Do you now see why we can say that food has potential energy? We need energy to make our bodies function. We get our energy from the food we eat. The molecules which make up our food have energy stored inside them. We eat the food and use the stored energy to move our muscles and perform all our bodily functions. This stored energy is potential energy.

2.2 Kinetic energy

Think back to the last activity where we used elastic bands to move matchboxes. The stretched elastic band had potential energy. When the elastic band was released, it moved and snapped back and then hit the matchbox and caused it to move. So what do we call this energy that the moving elastic band and moving matchbox have? We call it **kinetic** energy.

Kinetic energy is the energy that an object or system has because it is moving.



ACTIVITY: Which objects have kinetic energy?

INSTRUCTIONS:

1. Think about the definition of kinetic energy
2. Decide which of the objects in the following table have kinetic energy.
3. Give a reason for your answer.

TEACHER'S NOTE

Object	Does it have kinetic energy? (Yes or no)	Give a reason for your answer.
 A lady running.	Yes	The lady is running and moving so she has kinetic energy.
 A bird in flight.	Yes	The bird is flying and moving in the air so it has kinetic energy.

TEACHER'S NOTE

Object	Does it have kinetic energy? (Yes or no)	Give a reason for your answer.
 A stop street sign.	No	The sign does not move and so does not have kinetic energy.
 A roller coaster.	Yes	The roller coaster is moving and so has kinetic energy.
 Two chairs.	No	The two chairs are stationary and so do not have kinetic energy.
 An apple.	No	The apple is still on the surface - it is not moving so does not have kinetic energy.
 A helicopter.	Yes	The helicopter is flying and so it is has kinetic energy.

QUESTIONS:

1. Which bucket has more potential energy, the one sitting on the bottom step of a ladder, or the one sitting on the top step of the ladder?
The bucket at the top of the ladder has more gravitational potential energy than the one at the bottom.
2. Does a car travelling at 100 km/h or at 200 km/h have more kinetic energy?
The car travelling at 200 km/h has more kinetic energy than when it is travelling slower.
3. When the wind blows, it is actually the air particles moving. What type of energy do the air particles have? Why?
It is kinetic energy as the air particles are moving.
4. You have a bucket full of water and you are about to tip the water out. What type of energy does the water have at this point? Explain why.
It has potential energy as it has the potential to fall back down to the ground.
5. When you tip the water out and it falls to the ground, what type of energy does it have now?
Now it has kinetic energy as it is moving.

VISIT
A short video about kinetic energy bit.ly/15Vfjyf

TEACHER'S NOTE

At this level in Gr. 7, it is acceptable to state that the water has kinetic energy as it falls down (as it is moving). However, the water also still has potential energy as it falls. This is because as the water falls, it loses potential energy and gains kinetic energy as potential energy is transferred to kinetic energy. The total energy within the system is equal to the potential energy plus the kinetic energy as energy is conserved.

What have we learnt so far?

- Potential energy is the energy that an object has because of its position in a system. In the brick activity, the brick had potential energy when it was lifted away from the surface of the Earth. The brick and the Earth attract each other so they are a system. The higher you lift the brick, the more potential energy you give it.
- We know that moving objects also have energy, we call the energy of moving objects kinetic energy.

But, we have also seen something else. Think again of the marble activity:

- The marble at the top of the ramp has potential energy.
- When the marble was released, it rolled down the ramp and knocked the cup causing it to move.
- The marble therefore **transferred** energy to the cup.

We also saw this in the match box activity:

- The stretched elastic band had potential energy.
- When the elastic band was released, it moved and snapped back and then hit the matchbox and caused it to move. This means that the match box now has energy.
- Energy was therefore transferred from the stretched elastic band to the matchbox.

So, the potential energy in the elastic band is not lost. It is transferred to the matchbox. This brings us to our next section.

2.3 Law of conservation of energy

TEACHER'S NOTE

In CAPS, this section comes after the potential and kinetic energy in systems. However, it is more logical to first discuss how energy is conserved within systems and to then look at the examples of the systems in the next section.

Take time to make sure that the learners understand the difference between laws and theories. Scientific theories are subject to development and new ideas are being developed all the time. Learners should be encouraged to see science as a developing discipline and not a static set of ideas. However, the science knowledge that we teach at school level is not in doubt. Most of it has been tested and known since the 1800's. You are encouraged to tell your learners something of the arguments and confusion among the people who were the first to investigate this knowledge, and also that current science in the academic world is constantly evolving.

The **Law of Conservation of Energy** states that energy cannot be created or destroyed, it can only be transferred from transferred from one part of the system to other parts. This means that we keep recycling all the energy in the universe all the time!

TAKE NOTE

Scientific laws and theories are not set in stone, they are just the best explanation for how the world works based on the information we have now. Scientific knowledge is constantly growing and changing as new discoveries are made.

Why are we talking about laws in science? Did you think laws were just for lawyers? Well, you would be wrong. In science we talk about **laws** and **theories**.

Scientific laws predict **what** will happen in a particular situation. The law has been tested repeatedly (often) and the results do not change. A law does not explain **why** something happens, it just says what **should** happen. Theories explain **how** or **why** things happen. Theories are also tested over and over again to make sure that they are valid.

Now that we know about the Law of Conservation of Energy, this matches our own observation that the energy in the elastic and matchbox example was not lost, rather it was transferred from the elastic to the matchbox. We can say that the elastic band and matchbox form a system. This is also true for the marble and cup example. Remember, a **system** is made up of different parts that work together or affect each other. Let's now look at some more examples of how energy is transferred within systems.

VISIT

A PhET simulation to explore energy systems and energy conservation.

bit.ly/19HdkuW

2.4 Potential and kinetic energy in systems

Remember, energy cannot be created or destroyed. It is transferred from one part of the system to other parts. When it is transferred it can be stored or used to make something move and so potential energy can be transferred to kinetic energy in a system.

VISIT

A song about kinetic and potential energy

bit.ly/16KvQ4x

We can look at how energy is transferred within different systems to show that energy is conserved. There are many different types of systems that we can look at to see how energy is transferred through the systems.

VISIT

A video explaining how pulleys work.

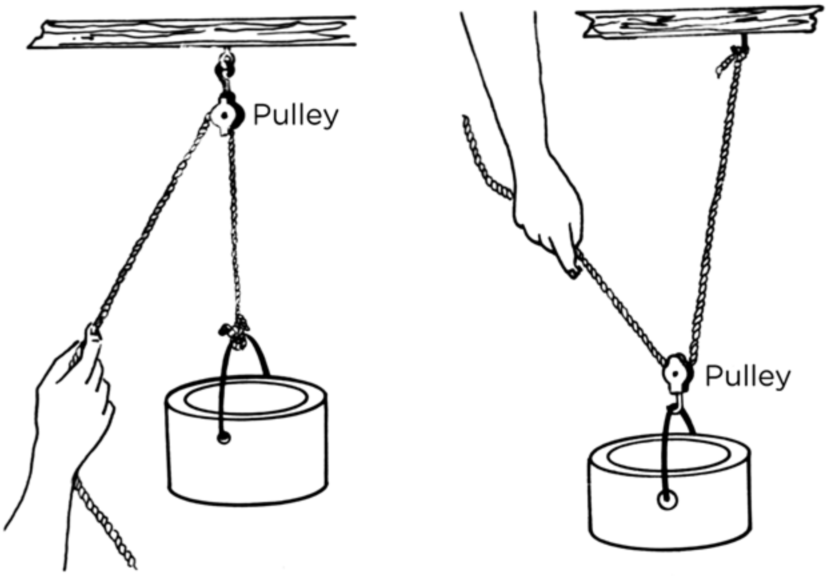
bit.ly/15vmL4R

Mechanical systems

A mechanical system is one which is based on mechanical principles and the different parts interact in a mechanism. A mechanical system usually involves movement of some kind. It is often a group of simple machines working together.

Do you remember the elastic bands pushing the matchboxes? Do you think that was a system? You are right. It is a mechanical system. The hand, elastic band and matchbox all form part of a mechanical system. Your hand transfers potential energy to the elastic band, this is the input energy. The potential energy of the elastic band was transferred to the matchbox as kinetic energy. No energy was created or destroyed. We experienced the Law of Conservation of Energy without even realising it.

Another simple example if a pulley and rope system, such as at a construction site where the builders want to lift heavy objects up to a higher floor. The construction worker will pull on the rope which goes up over a pulley and to lift the heavy object higher.



A pulley system is an example of a mechanical system.

What is the input energy in this system?

TEACHER'S NOTE

The input energy is the movement (kinetic energy) of the worker's arms as he pulls on the rope

What are the different parts making up this mechanical system?

TEACHER'S NOTE

The different parts are the worker's arms pulling on the rope. the rope, the pulley, the heavy object and the surface of the Earth.

What is the input energy transferred to within this system?

TEACHER'S NOTE

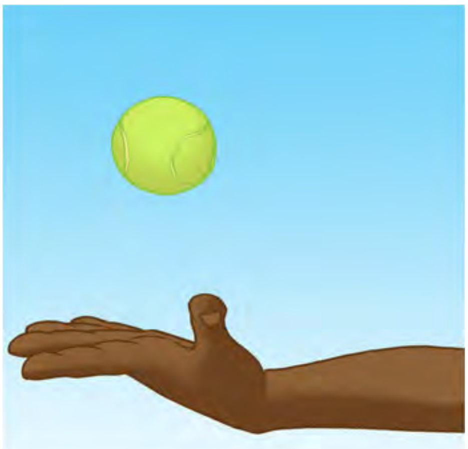
The kinetic energy is transferred to potential energy as the object is raised higher.

A swing or a seesaw are examples of mechanical systems.

A swing is a simple mechanical system.

Did you realise that when you were swinging on the park swings that you were a part of a mechanical system? When you are at the top of the swing's arc, you and the swing have potential energy because the Earth is pulling you and you are going to start moving down. The **potential energy** becomes **kinetic energy** as you swing through the arc.

What about when you throw a ball up into the air? Do you think this is a mechanical system?



When you throw a ball upward it slows down as it moves upwards, stops for an instant and then speeds up as it falls back down to your hand. Your hand moves to throw the ball and transfers energy to the ball which allows it to move upwards. Does this also follow the Law of Conservation of Energy? Yes, it does. No energy was created or destroyed. The kinetic energy was transferred from your hand to the ball which then starts to move. As the ball moves upwards, kinetic energy is transferred to potential energy as it moves further away from the ground.

As the ball moves back down again, the potential energy is transferred to kinetic energy.

What are the parts involved in this mechanical system?

TEACHER'S NOTE

The hand throwing and the ball are the parts involved.

What is the input energy in this mechanical system?

TEACHER'S NOTE

The kinetic energy of your moving arm and hand as you throw the ball.

When does the ball have the most potential energy?

TEACHER'S NOTE

It is important to note that potential energy is relative to a reference point. So, in this example, if we consider the ground to be the reference point, then if you throw a ball upwards and catch it again in your hand, it always has potential energy as it is above the ground. Therefore, the ball has most potential energy when it is at the top of the throw when it stops briefly, before coming back down to the ground.

When does the ball have kinetic energy?

TEACHER'S NOTE

The ball has kinetic energy as it is moving upwards and then falling back downwards.

Let's have a look at some more examples.

ACTIVITY: Identifying energy transfers in mechanical systems

TEACHER'S NOTE

Learner might battle to do this at first, so you can go through one or two of the examples with them, and if possible, also perform the demonstration of bending the wire back and forth. The key is to first identify the parts that are involved and then how the energy is transferred from one part to another within the system.

MATERIALS:

- a piece of wire

We are first going to perform a simple demonstration to identify the energy transfers within mechanical systems. Take a length of wire and touch it to your lips. How does it feel?

TEACHER'S NOTE

Learners should note that the wire feels cold.

Then, bend the wire into a U-shape and bend it back and forth 10 times quickly. Now, feel the temperature again at the bend. How does it feel?

TEACHER'S NOTE

Learners should note that it feels warm.

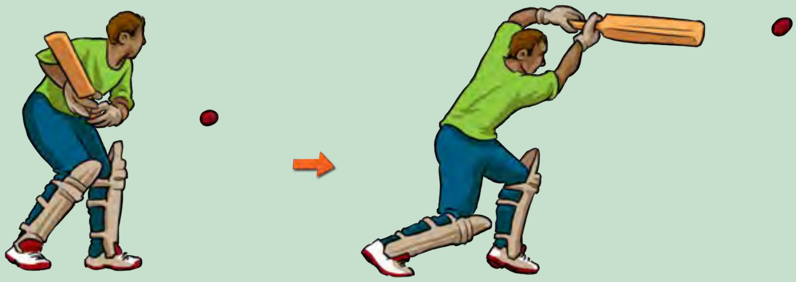
This is an example of a mechanical system. We can describe the transfer of energy as the potential energy within your arms is transferred to kinetic energy as you move them back and forth. This is transferred to kinetic energy in the wire which is then transferred to the lips as heat.

INSTRUCTIONS:

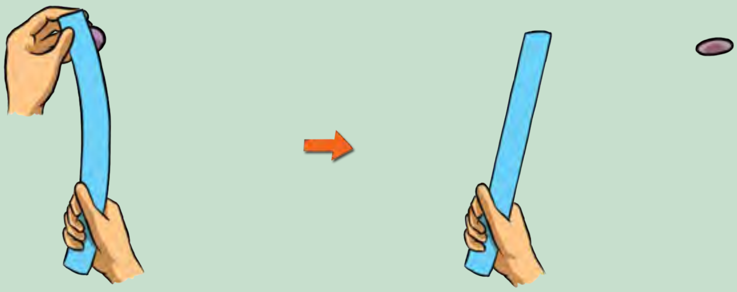
1. Look at the following pictures of different mechanical systems.
2. Identify the different parts in the system and then how energy is transferred from one part to another. You can discuss this with your partner.
3. Then write a few sentences to describe the energy transfers within each system.

QUESTIONS:

1. The girl uses the energy in her muscles and pulls her leg back. When her leg is at its highest point, what energy does it have?
   It has potential energy.
2. As she swings her leg back down towards the ball, describe the transfer of energy.
   The potential energy becomes kinetic energy.
3. When her foot hits the ball, and the ball moves off, describe the transfer of energy in the system.
   The kinetic energy from her leg is transferred to the ball and makes the ball move. The ball now has kinetic energy.



4. The muscles in the cricketer's arm pull the cricket bat upward. Describe the transfer of energy.
   This movement transfers potential energy to the bat.
5. Describe the transfer of energy as the bat swings down and then hits the moving ball.
   As the bat swings down the potential energy becomes kinetic energy as the bat moves. When the bat hits the ball, it transfers the kinetic energy to the ball. The kinetic energy allows the ball to move through the air.



6. Now that you have had practice with the other examples, use the following space to describe the transfer of energy within the above system as a ruler is pulled back and then flicks a pellet across the room.
   When the ruler is pulled back, the movement of the hand has kinetic energy which is transferred to the ruler. The ruler has gained potential energy and when it is released, the potential energy becomes kinetic energy as the ruler flicks backwards. The kinetic energy is transferred to the pellet and so the pellet moves across the room.

Thermal systems

TAKE NOTE

We will learn more about how particles behave next year when we look at the particle model of matter.

Did you know that the particles that make up a substance or object, such as atoms or molecules, also have kinetic energy? Particles which have more kinetic energy will move faster than particles which have less kinetic energy. When the particles are moving very fast, we feel the substance and say "That's hot!". This is because the temperature of a substance depends on the kinetic energy of the particles.

The thermal energy can be transferred from one object to another in a thermal system. When thermal energy is transferred, this is called heat. We will look more at this in the next chapter, but for now let's look at some simple examples of energy transfers within thermal systems (heating).

TEACHER'S NOTE

We will look more at heat as a form of energy transfer in the next chapter.

INVESTIGATION: The energy transfers when boiling water

TEACHER'S NOTE

This investigation works best with water placed in a beaker and heated over a Bunsen burner using a tripod. However, if you don't have a Bunsen burner you can use a candle and a tin can. The candle will not provide a large amount of heat energy and so you should use a small amount of water in order for it to reach boiling point within the lesson time. Remember to use an alcohol thermometer rather than a mercury thermometer.

Although this may seem like a very simple investigation, and learners have heated water before, the focus here is different in that we are investigating the energy transfers. This is also an opportunity for learners to practice recording, observing and translation skills, such as drawing a graph.

INVESTIGATIVE QUESTION:

What happens to the temperature of water when it is heated over a flame?

VARIABLES:

We will be measuring the change in the water temperature over time.

1. Which quantity/variable are you in control of? This is the independent variable.
   Time is the independent variable
2. Which variable are you measuring in response to the independent variable? This is the dependent variable.
   The temperature of the water is being measured.
3. Which variable are you keeping constant?
   The amount/volume of the water must be kept constant

HYPOTHESIS:

Write a hypothesis for this investigation. (Hint: What do you think will happen to the temperature of the water. Will it go up or down?)

TEACHER'S NOTE

The hypothesis should mention how the dependent variable would change with a change in the independent variable and should mention which variables must remain constant.

In this investigation a suitable hypothesis could read: 'The temperature of the water will increase as time increases if the amount of water is kept constant' or 'The temperature of the water will decrease as time increases if the amount of water is kept constant.'

TEACHER'S NOTE

Remember that a hypothesis doesn't have to be correct. It is a prediction made before any investigation is done and so the outcome is not necessarily known beforehand. Do not discourage learners from developing their own hypotheses. Emphasise that a hypothesis is just as valuable if it is rejected after the investigation.

MATERIALS AND APPARATUS:

- 150 ml or 250 ml beaker
- tripod
- gauze
- Bunsen burner
- matches
- thermometer
- stopwatch
- retort stand
- clamp

TEACHER'S NOTE

If you don't have Bunsen burners you can use spirit burners or a candle.

METHOD:

1. Pour 200 ml of water into a beaker.
2. Place the beaker onto the wire gauze on the tripod.
3. Carefully place the thermometer into the water. When you take the readings, the thermometer should not be touching the sides of the beaker. Alternatively, if you have a retort stand and clamp, the thermometer can be clamped in the stand with the bulb in the water.
4. Light the Bunsen burner.
5. Measure the temperature of the water every 30 seconds until the water starts to boil.
6. Once the water starts to boil, take 3 to 5 more readings.
7. Write down your observations in the table.
8. Once finished, turn off the Bunsen burner and leave the beaker of water to stand.
9. Plot a graph showing the relationship between the time and the temperature.

TEACHER'S NOTE

Make sure that learners observe that the temperature remains constant once the water starts to boil. Once the learners have completed their measurements, turn off the Bunsen burner and leave the water to cool while they carry on with the rest of the task and questions. They will then have to observe what happened to the water once it was left to stand.

RESULTS AND OBSERVATIONS:

A table to record your observations:

Time (seconds)	Temperature (°C)
30	
60	
90	
120	
150	
180	

TEACHER'S NOTE

If the water takes longer than to boil, ask the learners to add rows to the bottom of their tables. If it takes less, ignore the rest of the table. Each row must represent half a minute (30 seconds).

Use the following space to draw a line graph for your results.

1. First, think about what will go on your horizontal, x-axis? This is what you changed.
   Time goes on the x-axis as this is the independent variable.
2. What will go on the vertical, y-axis? This is what you measured.
   Temperature is the dependent variable.

TEACHER'S NOTE

Learners must provide a heading for their graph. for example "The change in water temperature over time". The graph must show data points with a line of best fit drawn through them. The graph must also flatten out at the end as the water boils.

3. The temperature of the water kept increasing, until it started to boil. What temperature did the water boil at?
   This might vary slightly depending on your area and altitude, but it is around 100 °C.
4. What did you observe in the temperature when the water started to boil?
   When the water reaches boiling point, the temperature remains constant while the water is changing state from a liquid to a gas.

TAKE NOTE

Do you remember that we learnt about boiling and melting points last term in Matter and Materials in Properties of Materials? If you do not have your previous workbook with you, you can always visit the website at http://www.curious.org.za.

TEACHER'S NOTE

The reason we do a boiling point curve like this is so that the learners can see that the curve flattens out and temperature remains constant. This is how we find the boiling point of a liquid. It is useful to do a boiling point curve of another liquid as well, such as Coca Cola or orange/apple juice to get a similar shaped curve so that learners understand that at boiling point of that liquid the temperature remains constant for while. If you leave it longer still the temperature will begin to fall as more water particles move into the atmosphere.

This links back to what was covered in the previous term in Matter and Materials in Chapter 1 on the Properties of Materials.

CONCLUSION:

1. What can you conclude from your results?
   Learner-dependent answer. The learners should conclude that the longer you keep the water over the flame, the higher the temperature of the water, until it reaches boiling point. At boiling point, the temperature remains constant as the water is changing state from a liquid to a solid.
2. Can you accept or reject your hypothesis?
   Learner-dependent answer.

QUESTIONS:

1. In order for the water to boil, the thermal energy of the water must increase. Where do you think the energy came from to make the water boil?
   The energy for the temperature increase came from the burning gas in the Bunsen burner.
2. Describe the transfer of energy within this thermal system as the water is heated.
   The thermal energy (kinetic and potential energy) of the flame in the Bunsen burner/candle is transferred to the water. The thermal energy of the water therefore increases and the temperature rises.

TEACHER'S NOTE

Remember that temperature is a measure of the average kinetic energy of the particles.

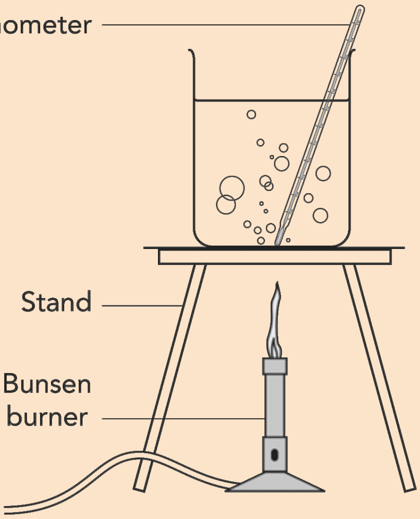
3. After the water has boiled, and you then turn off the Bunsen burner, what happened to the water in the beaker?
   It cooled down.

TEACHER'S NOTE

This is because once the Bunsen burner is switched off, no more energy is supplied to the system and so the loss of energy is greater than the gain and the temperature decreases.

4. What do you think happened to the thermal energy of the water? Describe the transfer of energy.
   The thermal energy was then transferred from the water to the surrounding air.

5. A Gr. 7 learner is conducting the investigation and read the temperature off the thermometer as it is set up in the diagram below. What is wrong with this set-up? What is your advice to the learner?



The thermometer is resting on the bottom of the beaker and touching the side. This could give an inaccurate reading. The thermometer should either be held by the learner so that it does not touch the sides while they take the reading, or else clamped in a retort stand with the bulb in the water.

VISIT

Build your own skate park with this simulation and see what happens to the potential, kinetic, and thermal energy of the skateboarder.

bit.ly/18qYcmq

So, what have we discovered? The temperature of the water increased. This means that the water particles must have been given more **kinetic energy**. The energy must have come from the Bunsen burner flame. The flame is there because we are burning gas so the energy must have been stored in the gas. If it is stored energy then it is **potential energy**.

TEACHER'S NOTE

This is a fun simulation that learners can use to investigate potential and kinetic energy. There is the example in the introduction that can be used to show them how to use it, and then there is the track playground that allows you to create your own track. Click on the bar graph, or pie chart menu options for a real-time display of the fluctuations in potential, kinetic and thermal energy.

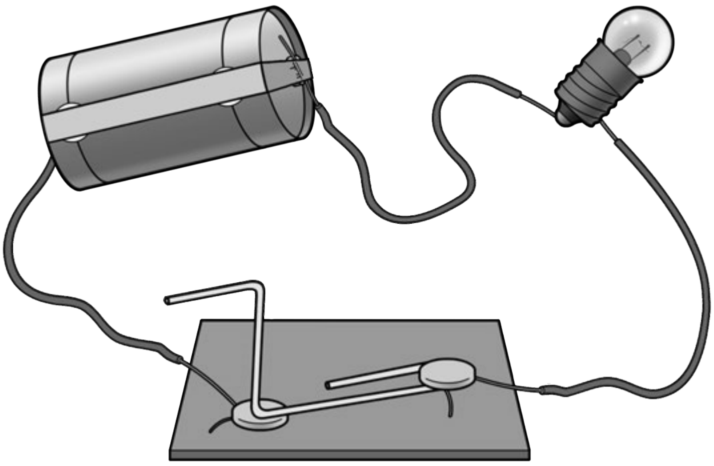
Once they have mastered the basics, and if there is more time you can show learners the more advanced skate park simulation. The graphs in this version do become slightly more involved but represent the features of the energy system beautifully. bit.ly/1fp5Oxk

PhET tips for teachers are available here: bit.ly/16B8r4D

So, we have discovered that the potential energy stored in the gas has been transferred to the water particles as kinetic energy. No energy has been **created**, it has been **transferred** from the gas to the water. The energy of the system has been **conserved**.

Electrical systems

Do you think an electric circuit is a system? Look at the following image and discuss this with your partner. Write down whether you think it is a system or not and why.



TEACHER'S NOTE

An electric circuit is a system as it consists of different parts that do something, ie. make the light bulb glow. Ask learners to identify the different parts in this system. They are: the battery, the light bulb, the switch (paperclip) and the conducting wires.

What is the source of energy is this electric circuit? In other words, what is the input energy in this system?

TEACHER'S NOTE

The battery is the source of energy, potential energy is the input energy in this system.

What is the result of the energy transfer in the system? In other words, what is the energy output?

TEACHER'S NOTE

The output is that the light bulb lights up/glows.

Let's look at another example of an electrical circuit which makes a motor turn to see the different energy transfers within the system.

ACTIVITY: An electric fan system

TEACHER'S NOTE

If possible, make this circuit in class with your learners so that they can observe the changes in the circuit and the movement of the fan. You can use any small device that rotates, such as a fan or a small motor. If you do have a small motor, you can attach a sucker stick to the rotating shaft with a piece of Prestik to make a fan.

MATERIALS:

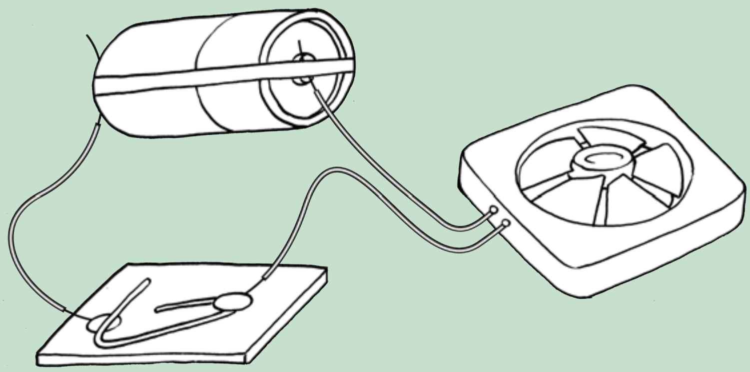
- small electric fan or motor
- conducting wires
- battery
- switch

TEACHER'S NOTE

You can also make your own switch, as described below.

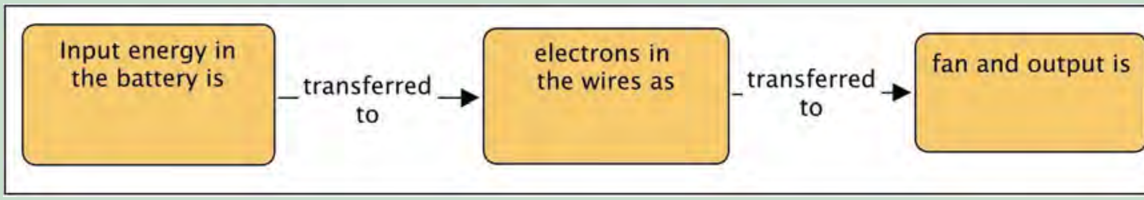
INSTRUCTIONS:

1. If possible, make the following circuit in class. However, if you do not make the actual circuit, study the image and answer the questions.
2. To make the circuit, attach a small fan or motor to a battery using the conducting wires.
3. Attach a switch in the circuit as shown in the image. You can make your own switch using a piece of board and pressing two metal pins into it. Then, bend a metal paper clip and attach it to the one drawing pin as shown below.
4. Close the switch and observe what happens to the fan.

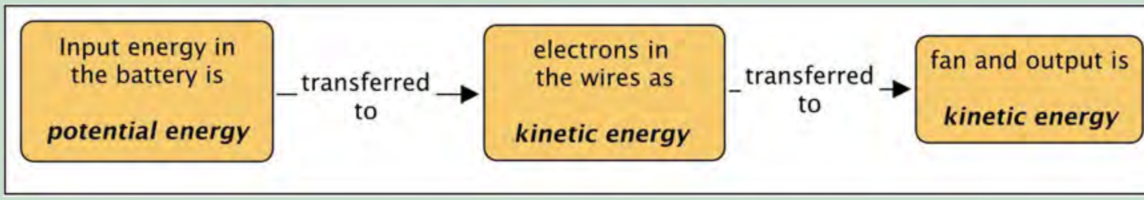


QUESTIONS:

1. What are the parts making up this electrical system?
   The battery, the fan/motor, the switch, the wires.
2. Which part of the system provides the input energy to the system?
   The battery provides the input energy (potential energy).
3. What happens to the fan or motor when you close the switch?
   The fan starts to turn/rotate/move.
4. What type of energy does the fan now have?
   Kinetic energy.
5. Using your answers to the previous questions, complete the following flow diagram which describes the energy transfers within this electrical system. You need to fill in the type of energy at each step.



The following shows the completed diagram with the answers learners should supply:



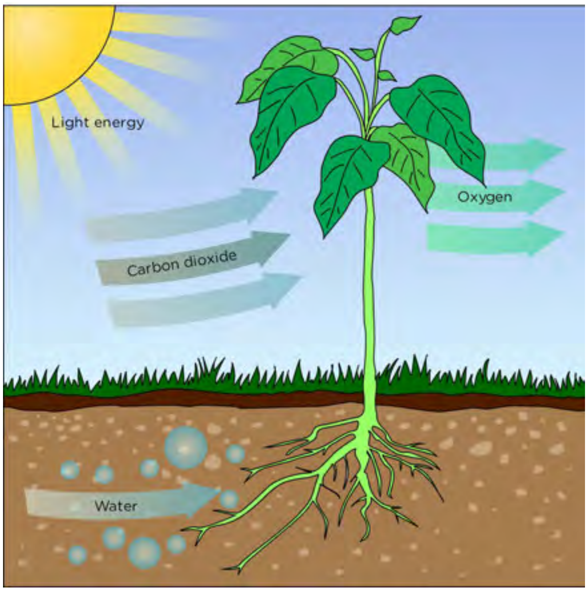
The battery has potential energy which is transferred to the electrons in the circuit. The electrons have kinetic energy which they transfer to the motor. The motor uses the kinetic energy to turn. The turning motor turns the blades of the fan.

Biological systems

Do you know that we also get biological systems? You have come across these types of systems before in Life and Living, but now we are going to talk about them in terms of how the energy is transferred within these systems, and conserved.

Do you remember learning about photosynthesis and food chains in Life and Living? This is an example of a biological system. Let's find out why.

A plant uses the radiant energy from the Sun to make its own food through the process of photosynthesis. The energy from the Sun is stored as potential energy in plants, mainly as starch. Have a look at the following image to remind you.



What process is being shown in the diagram? Write a sentence to describe the requirements for this process.

TEACHER'S NOTE

The diagram is showing photosynthesis. The plant uses water, carbon dioxide and sunlight energy to produce glucose and oxygen.

When an animal eats the plant it uses the potential energy in the food which is released during respiration. This is then used by the animal to move and for all its life processes. So the potential energy in the food which the animal eats is transferred to kinetic energy. Energy has been transferred from the Sun to the plant to the animal.

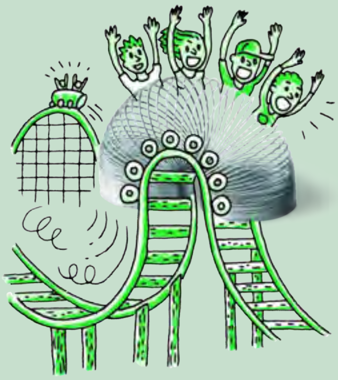
An impala eats the grass and stores the energy in its muscles. When the impala runs, the stored energy becomes kinetic energy.

When we eat plants or animals we are able to use the stored potential energy to make our bodies function.

Our food provides the input energy for our bodies to work and move. The food contains potential energy.

Is the energy conserved in a biological system? Yes, it is! The plants change the Sun's energy into **potential** energy which it stores inside itself. Animals then eat the plants and the stored potential energy is transferred to them. The animals use the stored energy to enable them to move. This means the potential energy within the animal has been transferred kinetic energy. As the animal moves and performs its functions, this kinetic energy is transferred to the surroundings. No energy has been created or destroyed, just transferred from the Sun to the plant to the animal.

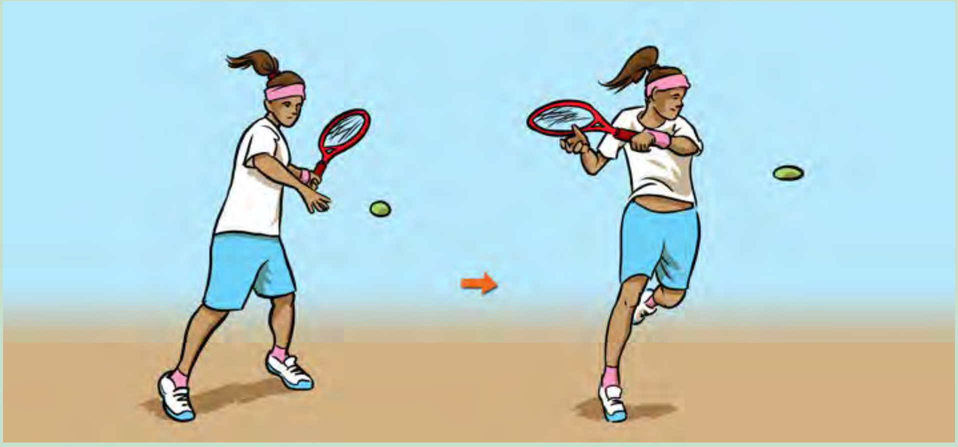
Let's revise the energy transfers within some systems by studying and drawing flow diagrams.



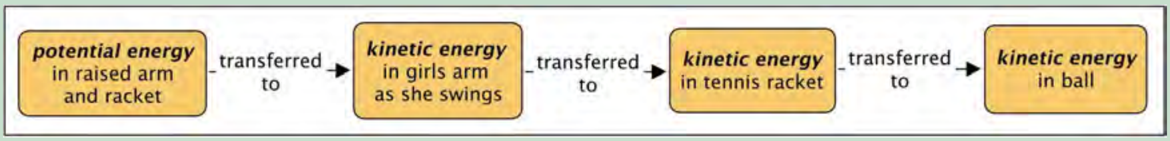
ACTIVITY: Flow diagrams for energy transfers

INSTRUCTIONS:

1. Study each of the following diagrams which show different systems.
2. Draw a flow diagram, similar to the one you did for the electric fan in the space provided.
3. Then write a few sentences underneath on the lines to describe how energy is transferred between the different parts in each of these systems.
4. The first one has been done for you.



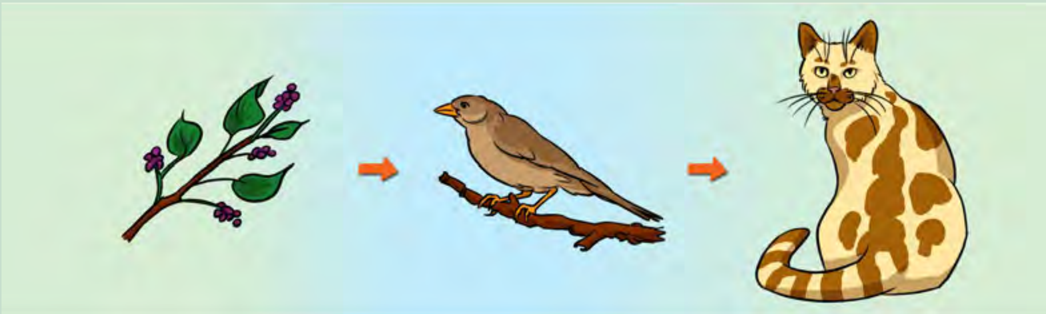
This flow diagram describes the transfers of energy.



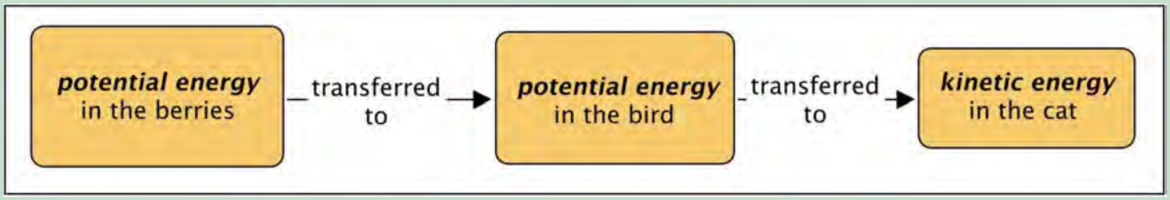
The tennis player's arm and racket have potential energy as they are raised. As the girl swings her arm, this potential energy is transferred to the tennis racket as kinetic energy. The tennis racket transfers energy to the ball as kinetic energy which enables the ball to move through the air.

QUESTIONS:

1. This drawing shows a food chain.



   Draw a diagram showing the energy transfers in this biological system.
   An example of the flow diagram learners could produce:

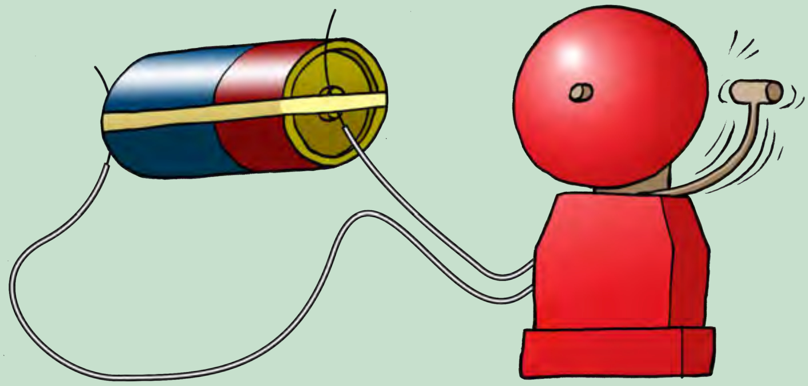


2. Write a description of the energy transfers below.
   The berries have potential energy in them. The bird eats the berries and this energy is transferred to the bird as potential energy. Most of the energy is used by the bird and transferred as kinetic energy as it moves around. The bird is then eaten by a cat and the potential energy in the bird's flesh is transferred to the cat as potential energy which is then transferred to kinetic energy as the cat moves around and performs its life processes.

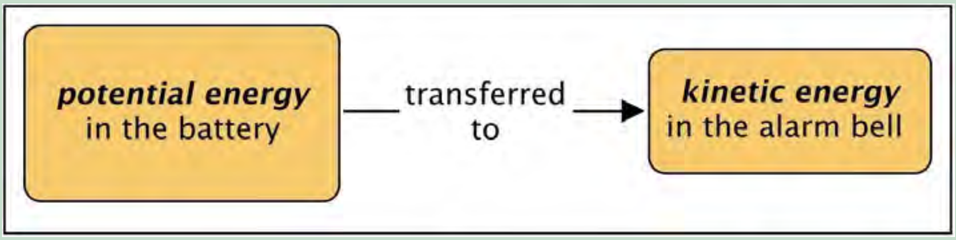
TEACHER'S NOTE

Although learners will only look at food chains and energy pyramids in more detail next year in Life and Living, this is an introduction to how not all the energy is transferred onto the cat as most of it is used by the bird as it moves around and performs its functions and processes.

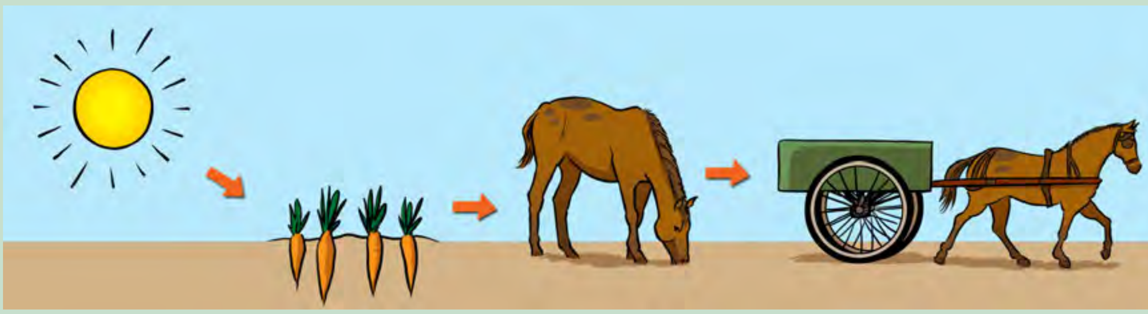
3. Draw a diagram showing the energy transfers in this electrical system.



An example of the flow diagram learners could produce:

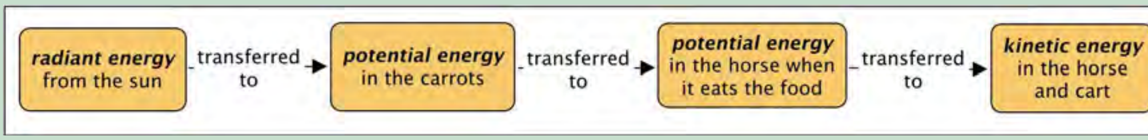


4. Write a description of the energy transfers below.
   The battery/cell has potential energy which is transferred to kinetic energy in the alarm bell as the hammer moves back and forth to produce sound.
5. In the previous example showing the berries, the bird and the cat, we saw an example of a food chain. Do you remember learning about food chains in Gr. 6? A food chain only shows the transfer of energy between organisms, and does not include the Sun. So, it always starts with a producer. Is the image below an example of a food chain? Why or why not?



No, this is not a food chain, as a food chain only shows the transfers of energy between organisms, highlighting the feeding relationships. This diagram also includes the Sun, as well as showing the horse moving a cart.

6. We can rather call this an energy transfer sequence. Draw a flow diagram to explain the energy transfers in this biological and mechanical system.
   An example of the flow diagram learners could produce:

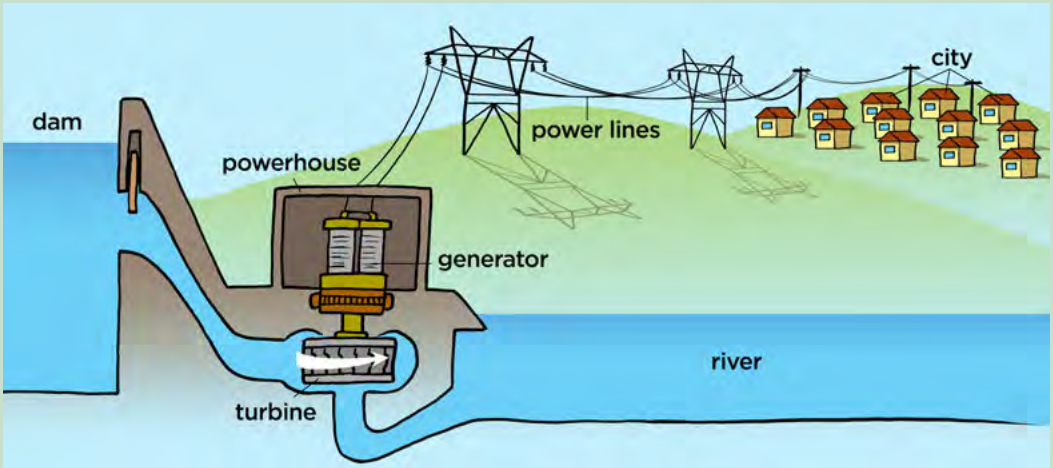


7. Write a description of the energy transfers below.
   The energy from the Sun is transferred to potential energy within the carrots as they photosynthesise and produce food. The horse then eats the carrots and this potential energy is transferred to potential energy within the horse. The horse then moves and pulls a cart, so the potential energy in the horse is transferred to kinetic energy in the horse and in the cart as it moves along.
8. Let's now look at a more complex system which involves many different parts working together. Do you remember learning about hydropower as an source? Is it renewable or non-renewable?
   Renewable.

TAKE NOTE

We will learn more about food chains and the interactions between organisms next year in Gr. 8 Life and Living.

9. Study the following diagram which shows a hydropower plant at the edge of a dam. Then answer the questions that follow.



   a) The water in the dam on the left is high up. It has the ability to fall down. What kind of energy does the water have?
      The water has potential energy.
   b) As the water flows down the outlet from the dam, describe the transfer of energy.
      The potential energy is transferred to kinetic energy as the water moves/flows down.
   c) The flowing water then turns the turbine. This is a mechanical system. What energy does the turbine have?
      It has kinetic energy.
   d) The generator then transfers the energy between two systems. The kinetic energy in the mechanical system is transferred to kinetic energy in the electrical system as it generates electricity. What parts make up the electrical system in the diagram?
      The electrical system is made up of the generator, the power lines and then the houses/ buildings in the city.
   e) What is the output from this whole system? In other words, what does the city get?
      The city gets electricity to run appliances, machines, equipment, lights and heating systems.

TAKE NOTE

We will study the national electricity grid in more detail at the end of the term.

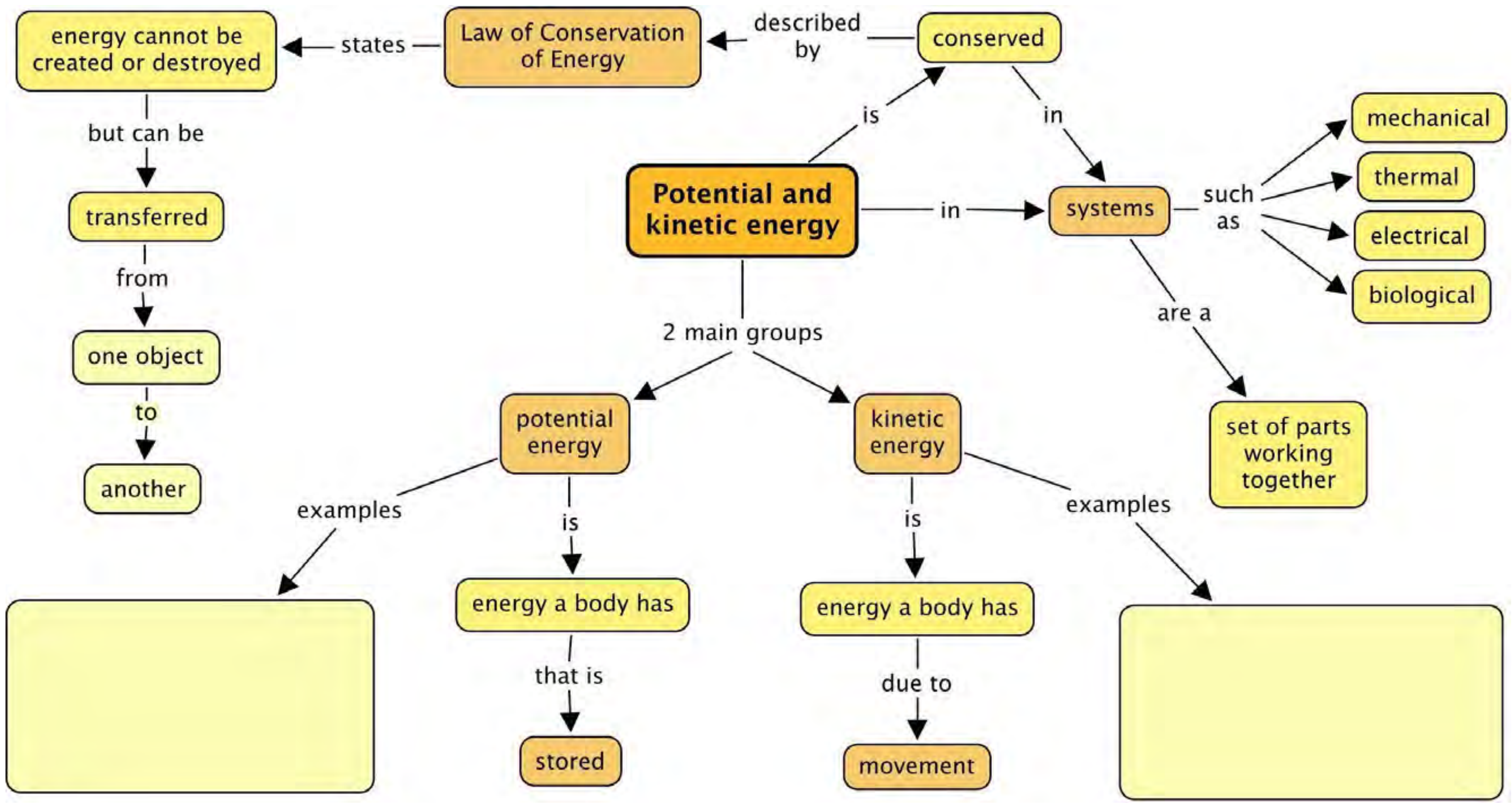
SUMMARY:

Key Concepts

- Potential energy is energy which is stored in a system.
- Kinetic energy is energy which an object has because it is moving.
- Energy is measured in joules (J).
- Energy cannot be created or destroyed. It can only be transferred from one part of a system to another. This is the Law of Conservation of Energy.
- Energy is transferred within systems. The input energy is transferred through the system and energy is conserved.
- There are various energy systems, such as:
  - mechanical systems
  - thermal systems
  - electrical systems
  - biological systems
- Energy is also transferred between different systems.

Concept Map

Complete the concept map below by filling in some examples of objects with either potential energy or kinetic energy that you learnt about in this chapter.


Potential and kinetic energy
is
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energy cannot be created or destroyed
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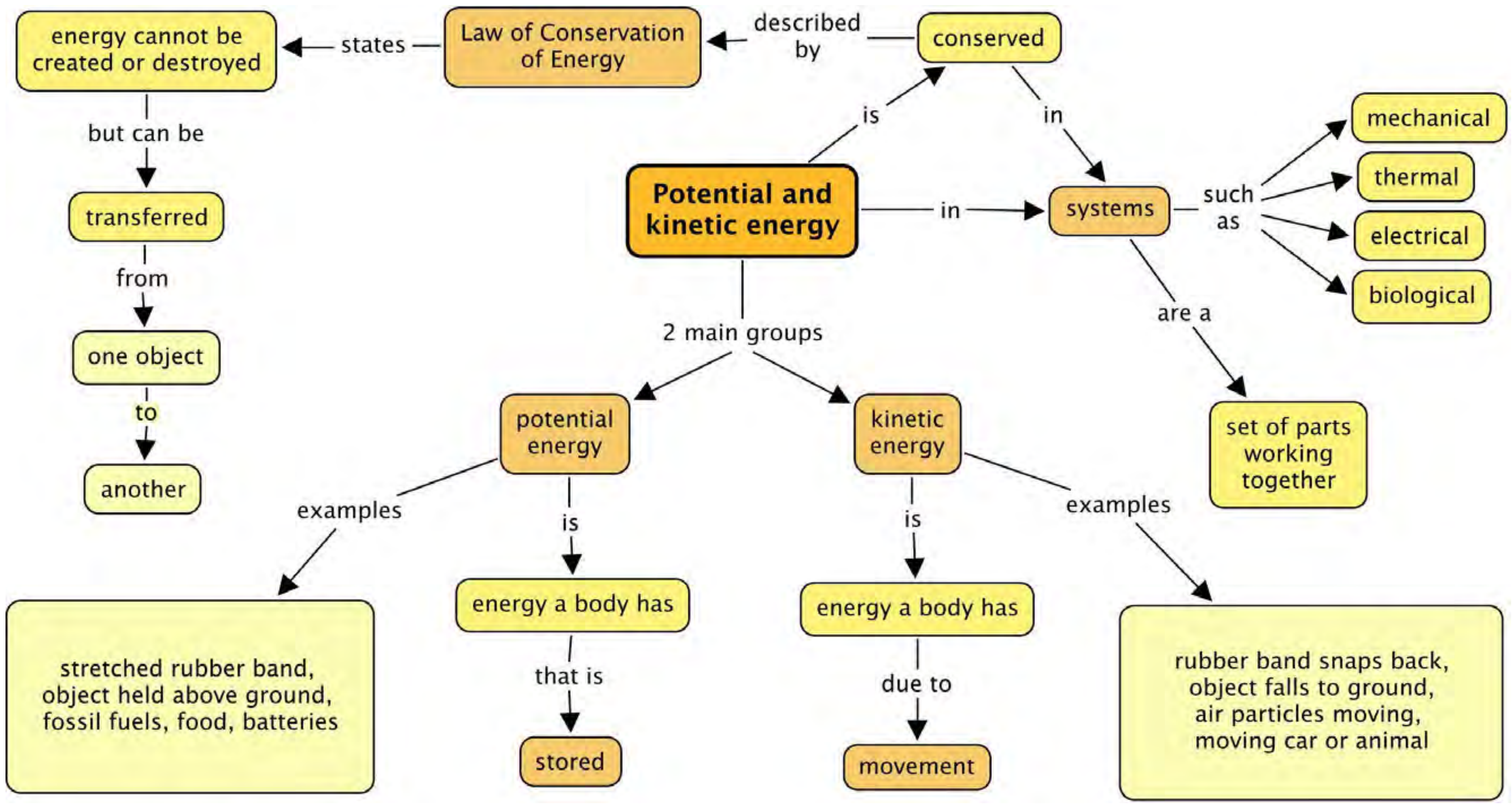
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set of parts working together
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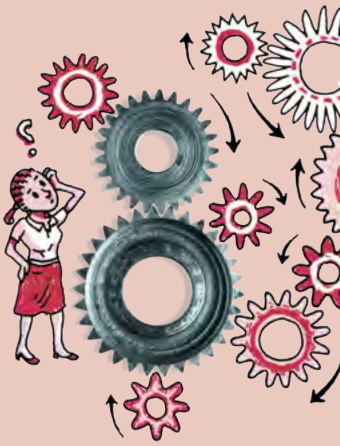
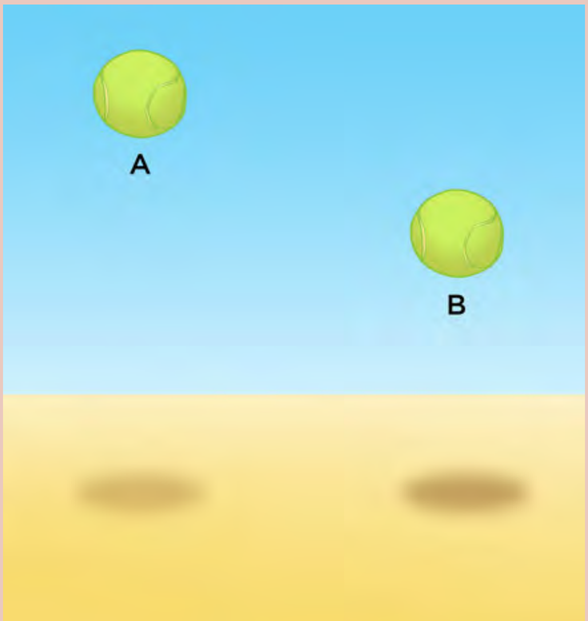
potential energy
is
energy a body has
that is
stored
examples
stretched rubber band, object held above ground, fossil fuels, food, batteries
kinetic energy
is
energy a body has
due to
movement
examples
rubber band snaps back, object falls to ground, air particles moving, moving car or animal

REVISION:



1. What is potential energy? Give two examples of systems which have potential energy [3 marks]
   It is the energy stored inside a system. There are many different examples of potential energy. Some examples are: objects which are held above a surface, elastic bands which have been stretched, batteries contain potential energy.
2. What is kinetic energy? Give two examples of systems which have kinetic energy? [3 marks]
   It is the energy a system has because it is moving. There are many different examples of kinetic energy. Learners can use any moving object as an example.
3. What does the Law of Conservation of Energy state? [1 mark]
   Energy cannot be created or destroyed. It is transferred from one part of a system to another.
4. Look at the picture below.



   a) Which ball has the most potential energy? [1 mark]
   b) Explain your choice. [1 mark]
   a) Ball A has more potential energy.
   b) Ball A is higher than ball B relative to the ground and so it has more stored energy.
5. Complete the sentences by filling in the missing words. Write the sentence out in full and underline your answers.

   a) A plant receives energy from __________ and uses the energy to make __________. The plant then changes some of the sugar into __________ and stores it in leaves, fruit and other parts. The plant has __________ energy which you can get when you eat the plant. [4 marks]
   b) When a plane carries skydivers high into the sky, it is giving them __________ energy. When they jump out and free-fall, they have __________ energy. [2 marks]

These army skydivers have just jumped out the back of a plane.

a) *A plant receives energy from the Sun and uses the energy to make food/sugar/glucose. The plant then changes some of the sugar into starch and stores it in leaves, fruit and other parts. The plant has potential energy which you can get when you eat the plant.*

b) *After skydivers jump out of a helicopter or plane, potential energy is transferred to kinetic energy as they fall.*

6. Draw an energy transfer flow diagram to show how energy gets from the Sun into your food and then to you. [3 marks]
   Learners must draw a Sun then a plant then either a person, or another animal which eats the plant and then a person which eats the animal.
7. A high jumper starts running. As she approaches the bar, she pushes off the ground and lifts her body off the ground and flies over the bar. She then falls down into a large padding on the ground.

A high jumper going over the bar.

Think about her jumping, from the moment her feet leave the ground. She goes up in the air, she almost stops as she goes over the bar, and then she comes down again.

a) Where does she have the most potential energy? [1 mark]
b) Where does she have the most kinetic energy? [1 mark]
c) Does she have some potential energy and some kinetic energy at any point in her jump? If you say yes, name one point where it is true. [2 marks]

a) *At the top of her jump (as this is when she is the highest above the ground).*

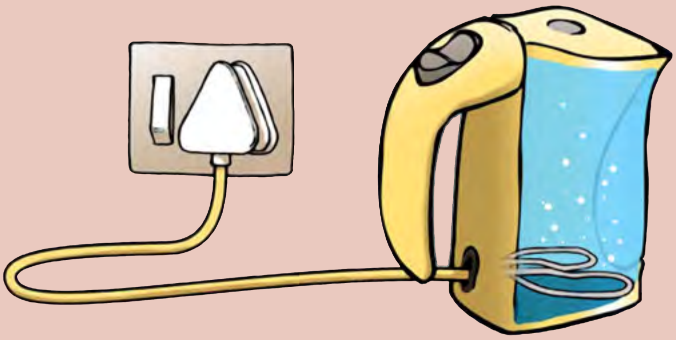
b) *She has the most kinetic energy just before she touches the ground/pad again (as this is where she will be moving the fastest).*

c) *Yes, she does have both kinetic energy and potential energy at points during her jump. They are on the way up / on the way down (either).*

8. Which type of energy do each of the following systems contain (kinetic or potential or both types)? [6 marks]

   a) A mountain biker at the top of the mountain.
   b) Petrol in a storage tank.
   c) A race-car travelling at its maximum speed.
   d) Water flowing down a waterfall before it hits the pond below.
   e) A spring in a pinball machine before it is released.
   f) A running refrigerator motor.
   a) Potential energy
   b) Potential energy
   c) Kinetic energy
   d) Both
   e) Potential energy
   f) Kinetic energy

9. Study the following image and answer the questions.



   a) There are two systems involved in this image of heating water in a kettle that is plugged in. What are they? [2 marks]
   b) Describe the energy transfers within and between these two systems. [2 marks]
   a) They are an electrical system and a thermal system.
   b) The electric current transfers energy to the hot-wire in the kettle, which transfers energy to the water and so the water molecules get more and more kinetic energy until the water starts to boil.

Total [32 marks]

3 Heat: Energy transfer

TEACHER'S NOTE

Chapter overview

2 weeks

In the last chapter we looked at thermal systems which transfer energy. This chapter expands on this and looks at the different ways that thermal energy is transferred between different objects.

It is important to understand the difference between heat, as a concept, and temperature. Temperature is a measure of how hot or cold an object is; it is a measure of the average kinetic energy of the particles of a substance. Heat is the energy transferred between two objects as a consequence of the temperature difference between them. It is also true when energy is transferred between a system and the environment as a consequence of the temperature difference between them. Temperature is measured in degrees Celsius (°C) or degrees Kelvin (K) while heat is measured in joules (J).

3.1 Heating as a transfer of energy (0.5 hours)

3.2 Conduction (2 hours)

Tasks	Skills	Recommendation
Activity: Conduction through a metal rod	Experimentation, observation	Suggested
Investigation: Do all materials conduct heat in the same way?	Hypothesising, investigating, evaluating	Suggested
Investigation: Which metals are the best conductors of heat?	Identifying, hypothesising, observation, writing, recording, drawing graphs, evaluating	CAPS suggested

3.3 Convection (2 hours)

Tasks	Skills	Recommendation
Activity: Convection in water	Experimenting, observation, comparing	CAPS suggested
Activity: Does smoke move up or down?	Observing, explaining	Suggested
Activity: Where do I put my radiator and air-conditioner?	Evaluating, drawing, discussing	CAPS suggested

3.4 Radiation (1.5 hours)

Tasks	Skills	Recommendation
Activity: Radiation from a candle	Observing, examining, explaining	CAPS suggested
Investigation: Which surfaces absorb the most radiation?	Measuring, recording, hypothesising, identifying, observing, drawing graphs	CAPS suggested

KEY QUESTIONS:

- What is the difference between heat and temperature?
- How does a heater warm up a cold room?
- Why can the Sun make us warm?
- Why does my cold drink become warm?

3.1 Heating as a transfer of energy

In the last chapter we looked at thermal systems. The thermal energy of an object is the amount of energy it has inside of it, in other words, its internal energy. In a thermal system, thermal energy is transferred from one object to another. Heat is the transfer of thermal energy from a system to its surroundings or from one object to another. This transfer of energy is from the object at a higher temperature to the object at a lower temperature.

It is very important to know that, in science, heat and temperature are not the same thing.

- **Heat** is the transfer of thermal energy from a system to its surroundings or from one object to another as a result of a difference in temperature. Heat is measured in joules (J). This is because heat is a transfer of energy.
- **Temperature** is a measure of how hot or cold a substance feels and it is measured in degrees Celsius (°C). Temperature is a measure of the average kinetic energy of the particles in an object or system. We use a thermometer to measure the temperature of an object or substance.

Complete the following table to summarise the differences between heat and temperature

TEACHER'S NOTE

Here is the completed table:

	Heat	**Temperature**
Definition	The transfer of energy from a hotter object to a colder object, or from a system to its surroundings	A measure of how hot or cold a substance feels. A measure of the average kinetic energy of the particles of a substance.
Unit of measurement	Joules	degrees Celsius
Symbol for unit	J	°C

Heat is the transfer of energy. During energy transfer, the energy moves from the hotter object to the colder object. This means that the hotter object will cool down and the colder object will warm up. The energy transfer will continue until both objects are at the same temperature.

VISIT
A rap song to introduce you to (and help you remember!) conduction, convection and radiation. bit.ly/1h3Plok

There are 3 ways in which thermal energy can be transferred from one object/substance to another, or from a system to its surroundings:

1. Conduction
2. Convection
3. Radiation

Let's have a look at these in more detail.

3.2 Conduction

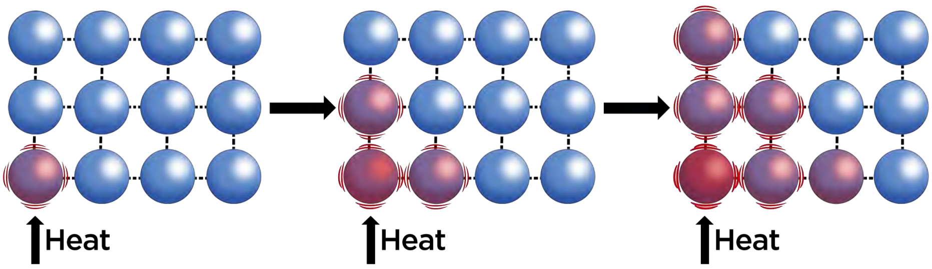
TEACHER'S NOTE

A suggestion to introduce this topic is to ask learners what happens to a metal teaspoon when they put it in their hot beverage. If possible, demonstrate this briefly in class, even with a hot glass of water and a metal rod. In addition, use a plastic teaspoon to demonstrate the difference as plastic is an insulator.

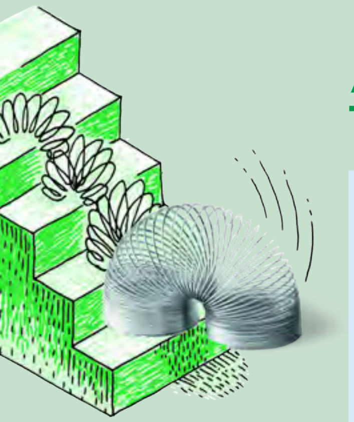
Have you noticed that when you put a cold, metal teaspoon into your hot cup of tea, the teaspoon handle also warms up after a while? Have you ever wondered how this warmth "moved" from the hot tea to the cold teaspoon and warmed it up? This is one way in which energy is transferred and this is called **conduction**. Let's find out how it works.

How does the handle of the metal teaspoon become hot when in a cup of tea?

When energy is transferred to an object, the energy of the particles increases. This means the particles have more kinetic energy and they start to move and vibrate faster. As the particles are moving faster they "bump" into other particles and transfer some of their energy to those neighbouring particles. In this way, the energy is transferred through the substance to the other end. This process is called **conduction**. The particles conduct the energy through the substance, as shown in the diagram.



Let's demonstrate this practically.



ACTIVITY: Conduction through a metal rod

TEACHER'S NOTE

Set this demonstration up in front of the class as you start to talk about conduction.

MATERIALS:

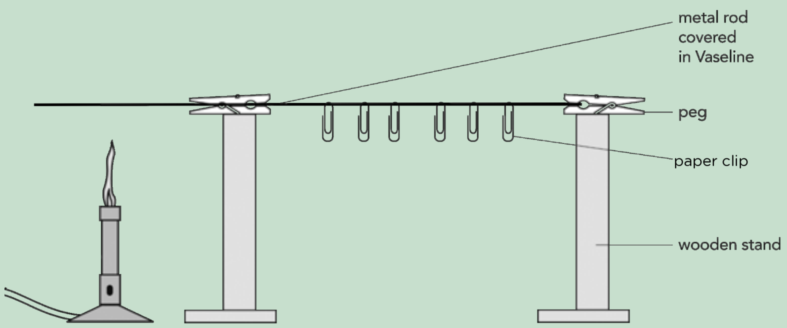
- Bunsen burner
- metal rod
- Vaseline
- paper clips, drawing pins or safety pins
- two wooden stands, or a stack of books or blocks of wood to create the two stands on either side
- 2 pegs

INSTRUCTIONS:

1. Set the apparatus up as shown in the diagram.
2. Cover the rod in Vaseline and place it between the two stands with pegs to prevent it from rolling and hold it in place. The rod must be extending past the left hand upright and the Bunsen burner placed here so that the Vaseline does not melt due to radiation from the Bunsen burner, but rather conduction along the metal rod.
3. Attach the paper clips or drawing pins to the rod by sticking them into the Vaseline.
4. Light the Bunsen burner and heat the one end of the rod.
5. Watch as the paper pins or pins drop off one by one as the energy is conducted through the rod.

INSTRUCTIONS:

1. Your teacher will set up the demonstration as in the diagram below.
2. Observe what happens to the pins or paper clips as the Bunsen burner is lit and heat is applied to one end of the metal rod.



TEACHER'S NOTE

As an extension exercise you could include another investigation in which you measure the rate of energy conduction along a metal rod. Repeat the experiment placing drawing pins at 5 cm intervals on a long metal rod. Clamp the metal rod and heat one end over a Bunsen burner. Use a stopwatch to time how long it takes for each drawing pin to drop and record the results on a graph. This could be further extended by using different metals and putting all the results on a single set of axes. The gradient of the graphs would give the rate of heat conduction.

QUESTIONS:

1. When the Bunsen burner is lit, what happens to the rod just above it?
   Energy is transferred to the metal of the rod just above it. The thermal energy of this part of the rod increases and the rod becomes hot.
2. Which pin or paperclip dropped off the metal rod first? The one closest to or furthest from the Bunsen burner?
   The one closest to the Bunsen burner dropped off first.
3. What does this tell us about the way in which heat is conducted along the rod?
   The heat is transferred from where it is hottest to the colder end of the rod.

Let's think about the teaspoon in the tea again. The tea is hot and the metal spoon is cold. When you put the metal teaspoon into the hot tea some of the thermal energy from the tea is transferred to the metal particles. The metal particles start to vibrate faster and collide with their neighbouring particles. These collisions spread the thermal energy up through the teaspoon. This makes the handle of the teaspoon feel hot.

Conduction is the transfer of thermal energy between objects that are touching. In the teaspoon example, the particles of the tea are touching the particles of the metal spoon, which in turn are touching each other, and this is how heat is conducted from one object to the other.

Do all materials conduct heat in the same way? Let's find out.

TEACHER'S NOTE

In response to the video in the margin box about why your carpet feels warmer than the tiles in winter, you can come back to this question after you have performed the following investigation, and also looked at the example of the cake tin and the cake straight out of the oven. You can lead the discussion in the following way:

- Start off by asking learners why they would prefer to stand on a carpet in winter rather than the tiles. They would probably answer that the carpet feels warmer.
- Follow this up by asking them what they think the temperatures of each surface is. Learners might say that they think the tiles are at a lower temperature than the carpet because it feels colder. This is incorrect as the tiles and the carpet will be at the same temperature as they have both

been in the same environment for a while and so will be at the same temperature.

- However, if you pose this question to learners again after doing the following investigation and also after looking at the cake and cake tin example, they might then realise that this is another example of a difference in conductivity.
- Namely, the tiles and the carpet are both at the same temperature, but the tiles are a better conductor of energy and so they conduct heat at a faster rate away from your feet than the carpet would, making the tiles feel colder, when in actual fact they are at the same temperature.

INVESTIGATION: Do all materials conduct heat in the same way?

TEACHER'S NOTE

This investigation will show the learners that metals conduct heat better than non-metals. If possible, watch the Veritasium video provided in the visit link before class about the misconceptions surrounding temperature and which demonstrates this activity. Start off by asking learners to feel the blocks and ask which one feels colder. The aluminium block will feel colder. Then ask them which block they think will melt the ice cube the fastest. as in the video, most people think that the ice cube will melt faster on the plastic block as it feels warmer than the aluminium block. However, this is a misconception, and will be demonstrated in the activity that it is in fact the aluminium block which causes the ice cube to melt faster as metals are a better conductors of heat.

AIM: To investigate which materials are the best conductors of heat.

In this investigation, we will be placing an ice cube on a plastic block and on an aluminium block and observing which ice cube melts the fastest.

HYPOTHESIS:

Write a hypothesis for this investigation. Which block do you think will melt the ice cube the fastest?

TEACHER'S NOTE

Learners might hypothesise that the ice cube will melt faster on the plastic than the aluminium block. If they do, make sure that they come back to reject their hypothesis and revise it.

MATERIALS AND APPARATUS:

- a plastic block
- an aluminium block
- ice cubes
- a plastic ring to keep the ice cube in place on the block

TEACHER'S NOTE

You can use any piece of plastic and aluminium (or other metal) that you can find. if possible, use a circular ring to stop the melted water from spilling.

METHOD:

1. First feel the plastic block and the aluminium block. Describe how they feel. *Learners will note that the plastic block feels warmer than the metal block.*
2. Place an ice cube onto each block and observe what happens.

VISIT
Misconceptions about temperature. Why do you think your carpet feels warmer than tiles in winter? Watch this video to find out.
bit.ly/16KVia5

OBSERVATIONS:

1. Which ice cube starts to melt first and the fastest? *The ice cube on the aluminium/metal block melts first.*
2. Is this what you thought would happen? Refer back to your hypothesis. *Learner-dependent answer. Most people generally have the misconception that the ice cube will melt faster on the plastic block, rather than the metal block.*

CONCLUSIONS:

What can you conclude about which material (the plastic or the metal) is the best conductor of heat?

TEACHER'S NOTE

Metal is a better conductor of heat than plastic as the ice cube on the metal melted first.

We will discuss this in the next paragraph about why this happens.

So how does this work? This is to do with **thermal conductivity**, the rate at which heat is conducted from one object to another.

When you originally felt the blocks, you felt that the plastic block was warmer. But, what we observed is that the aluminium or metal block melted the ice cube faster. This is because the metal block is conducting the heat faster to the ice cube. The plastic block is a worse thermal conductor so less heat is being transferred to the ice cube and so it does not melt as fast.

Why then does the aluminium block feel colder than the plastic block?

This is because the aluminium conducts heat faster away from your hand than the plastic does. Therefore the aluminium block feels colder and the plastic block feels warmer. When you touch something, you do not actually feel the temperature. Rather you feel the rate at which heat is either conducted away from or towards you.

VISIT
Misconceptions about heat: Why is a cake tin more likely to burn you than the actual cake? bit.ly/GL81CW

Let's think of another example of baking a cake. Imagine you have just finished baking a cake in the oven at 180 °C.

A cake baking in the oven in a metal tin.

When you remove the cake from the oven, which is more likely to burn you more, the metal cake tin, or the cake?

TEACHER'S NOTE

The most likely answer is that the cake tin will give you a more serious burn.

For the next question, get learners to speculate about what they think about the **temperature** of the cake tin and the actual tin. Many people have the misconception that the tin is hotter than the cake as it **feels** hotter. They are actually at the same temperature as they have both been baking at 180 °C.

TAKE NOTE

Remember, just because a material **feels** colder, does not mean it has a lower temperature. It may just be that it is conducting heat faster away from your hand.

Do you think the cake and the tin are at the same temperature when you remove them from the oven? Why?

TEACHER'S NOTE

Yes, the cake and the tin are both at the same temperature as they have been baking at 180 °C. Learners might be inclined to say that the tin is at a higher temperature than the cake as it feels hotter and the metal tin will give you a more serious burn than the actual cake. This is a misconception and you must discuss this. As with the example of the aluminium and plastic block, the cake tin and the cake are at the same temperature. But, the metal tin conducts heat faster towards your hand than the cake does. Therefore, the metal tin will feel hotter and is more likely to give you a serious burn than the cake does. When you touch something, you do not actually feel the temperature. Rather you feel the rate at which heat is either conducted away from or towards you.

What we have seen here is another example of thermal conductivity. The tin will conduct heat much faster to your hand than the cake, so the tin will burn you, but the cake will not. The tin and the cake are at the same temperature.

So what have we learnt? Metals conduct heat better than non-metals.

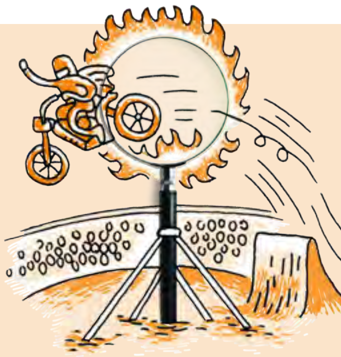
- There are substances that allow thermal energy to be conducted through them and so they are called **conductors**.
- There are substances that do not allow thermal energy to be conducted through them and so they are called **insulators**.

TEACHER'S NOTE

This links back to what we learnt in Matter and Materials about the properties of materials and how their properties determine their uses. Remind learners of the activities they did in Matter and Materials, especially linked to conductivity.

Now that we know that metals are good conductors of heat, do you think all metals conduct heat equally well? Let's investigate which metals are better conductors.

INVESTIGATION: Which metals are the best conductors of heat?



We are going to see which metal is the better conductor of thermal energy. To do this we will see which metal becomes hot first.

TEACHER'S NOTE

Now that we have established that metals conduct heat energy better than non-metals, the learners will investigate which metals are the best conductors of heat. This investigation requires more heat than the previous one and so the learners should not test the conduction with their fingers.

Spend a few minutes before the learners begin by demonstrating the correct procedure for lighting a Bunsen burner. There are many different instructional videos on the internet, such as the one identified in the visit box in the margin. Here are a list of instructions for your reference:

1. Ensure that you are working on an appropriate surface, such as a fireproof mat, and that it is clean and uncluttered.
2. Make sure that the gas tube is in good condition and not perishing.
3. Connect the to the gas outlet securely and make sure it won't easily come off if moving the Bunsen burner around.
4. Make sure that the collar at the base of the Bunsen burner and the air hole are closed.
5. First light your match, holding it away from the Bunsen burner.
6. Turn on the gas with your other hand and bring the match to the Bunsen burner to light it.
7. Adjust the air hole by opening it so that the flame becomes hotter.
8. Adjust the intensity of the flame using the collar at the bottom.

You can ask the learners to draw posters explaining how to light a Bunsen burner as an additional exercise if you feel they need the extra practice and reminders.

Remember that the tripods and metal rods that the learners use will get quite hot during this experiment. Make sure to allow the apparatus to cool before packing it away.

AIM: To identify whether some metals are better conductors of heat than other metals.

IDENTIFY VARIABLES:

Read through the method and look carefully at the diagram for the investigation to identify the different variables required.

VISIT

Make sure you know how to use a Bunsen burner safely.

bit.ly/1734sCb

1. Which variable are you going to change?
   Material being tested i.e. iron, copper, brass or aluminium
2. What do we call the variable that you are going to change?
   This would be the independent variable
3. Which variable are you going to measure?
   Time taken for the drawing pin to drop.
4. What do we call the variable that you are going to measure?
   The dependent variable
5. Which variables must be kept the same?
   Length and thickness of the material should be the same for each material used. Distance of the drawing pin from the heat source.
6. What do we call the variables which must be kept the same?
   Constants

HYPOTHESIS:

Write a hypothesis for this investigation.

TEACHER'S NOTE

Learner-dependent answer. Learners can hypothesise about which metal they think will be the best conductor, for example, the copper rod will be the best conductor.

MATERIALS AND APPARATUS:

- Bunsen burner
- Vaseline
- copper, iron, brass and aluminium rod
- stopwatch
- drawing pins
- tripod
- cardboard or paper
- matches

TEACHER'S NOTE

The materials listed here are a suggestion. You can use alternative apparatus to still do this investigation. For example, a spirit burner could also be used to heat the rods. If you do not have a tripod stand, you can place the metal rods on another stand, such as a block of wood, with the ends sticking out one side to still reach over the Bunsen burner. Paper clips can also be used instead of drawing pins. The type of metals are not important as long as you have different metals of the same length.

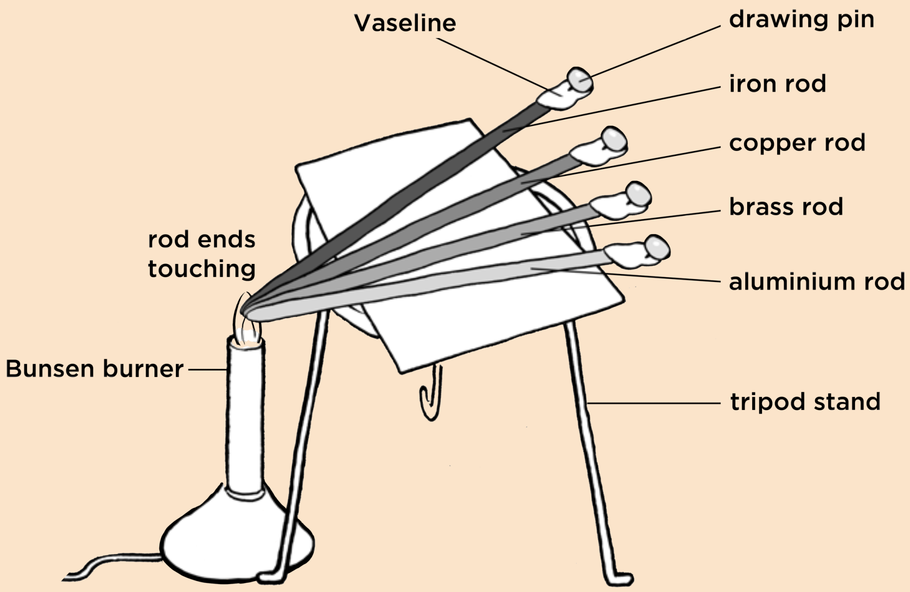
METHOD:

1. Stick the flat end of a drawing pin to the end of each of the metal rods using the Vaseline. Try to use the same amount of Vaseline for each drawing pin.

2. Place the cardboard on the tripod.
3. Balance the metal rods on the cardboard so that one end of each is over the Bunsen burner.
4. Light the Bunsen burner.
5. Using a stopwatch, measure how long it takes for each of the pins to drop off.
6. Record your results in the table.
7. Draw a bar graph to illustrate your results.

TEACHER'S NOTE

The cardboard is an insulator and will stop the heat from the rods transferring to the tripod itself. The loss of heat from the rods could affect the results.



RESULTS AND OBSERVATIONS:

Record your results in the following table.

Type of metal	Time taken for pin to drop off (seconds)
iron	
copper	
brass	
aluminium	

Now draw a bar graph to show your results. Do not forget to give your graph a heading to describe what it represents.

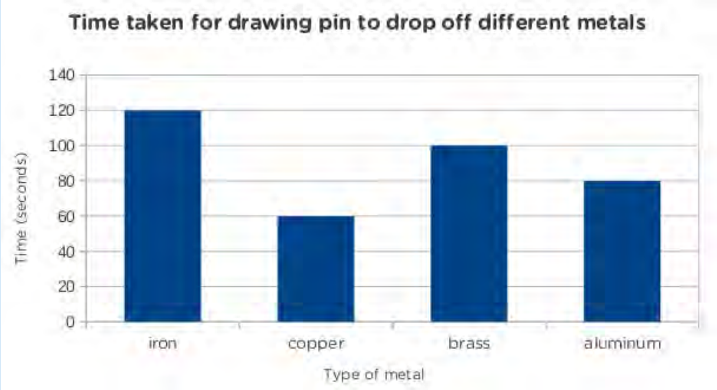
1. Which variable should be on the horizontal x-axis?
   The type of material should be on the horizontal axis. This is the independent variable.
2. Which variable should be on the vertical axis?
   The time taken for the drawing pin to to fall off should be on the vertical axis. This is the dependent variable.
3. Why do you think that a bar graph is suitable for this investigation?
   The independent variable/type of material is not a number value and so it does not need a number line. A bar graph is used to represent non-number or non-continuous data.

TEACHER'S NOTE

The independent variable is always drawn on the x-axis with the dependent variable on the y-axis. Both axes must be labelled and show the units of measurement. The graph should have a heading.

An example set of data is given here with the accompanying bar graph as a reference. Your results may vary from these presented here.

Type of metal	Time taken for pin to drop off (seconds)
iron	60
copper	30
brass	50
aluminium	40



ANALYSIS:

1. Which bar on your graph is the longest?
   The longest bar should be the iron.
2. Which bar is the shortest?
   The shortest bar should be the copper.

3. Write down the materials in order of how fast they conducted heat from the quickest to the slowest.
   Activity-dependent answer.
4. Why does the Vaseline melt?
   The heat is transferred by conduction through the metal rod and to the Vaseline causing an increase in its temperature and then a change of state (solid to liquid).
5. Why do you think it was necessary to place the piece of cardboard or paper on the tripod stand underneath the metal rods. Hint: The tripod stand is also made of metal.
   The cardboard acts as an insulator to prevent heat from transferring to the stand from the rods. For the purpose of this experiment, the heat should transfer down to the different metal rods only.
6. Why do you think it is necessary to use the same amount of Vaseline on the ends of each rod?
   This is so that the test is fair, otherwise some drawing pins might be stuck on better than others, leading to inaccurate results.
7. Do you think we could have performed this investigation if our rods were of different lengths? Why?
   No, otherwise it would not be a fair test as the heat will have to be conducted further in some rods than in others, leading to inaccurate results.

EVALUATION:

It is always important to evaluate our investigations to see if there is anything we would change or improve on.

1. Is there anything that went wrong in your investigation that you could have prevented?
   Learner-dependent answer.
2. If you were to repeat this investigation, what would you change?
   Learner-dependent answer. Examples include: repeating the same experiment three times and averaging the results, increasing the number of metals tested.

CONCLUSIONS:

1. Write a conclusion for this investigation about which metal is the best conductor of heat.
   This answer will depend on their experimental results, and the exact metals which you used in the investigation.

In this section we looked at how heat is conducted through metal rods and other objects. These were all *solid* objects. How is energy transferred through liquids or gases? Let's find out in the next section.

3.3 Convection

TEACHER'S NOTE

As an introduction to this section, you can simulate the "sitting in a bath" concept by filling a rectangular plastic tub or small water tank with cold water and then pouring hot water into one side. Invite the learners to feel the cold side of the tub and then feel it a few minutes later.

If you can get hold of a lava lamp, this can make a very exciting introduction to the lesson. You can turn the lights off and place the lava lamp on your desk for when learners come into the class. You can then explain that you are going to find out why the blobs rise and then fall back down in the lava lamp. If you do not have a lava lamp, you can also play this video: [1] bit.ly/19BpDKm

Think of a pot of water on a stove. Only the bottom of the pot touches the stove plate, but all of the water inside the pot, even the water not touching the sides, becomes warmer. How does the energy transfer throughout the water in the pot? The transfer of energy is because of **convection**.

Let's do an activity that will help us to visualise how convection occurs.

ACTIVITY: Convection in water

MATERIALS:

- 200 ml glass beaker
- potassium permanganate
- Bunsen or spirit burner, tripod stand, wire gauze

TEACHER'S NOTE

Take note that you only need a few grains of potassium permanganate, otherwise you will not see anything.

An alternative to the above materials is the following:

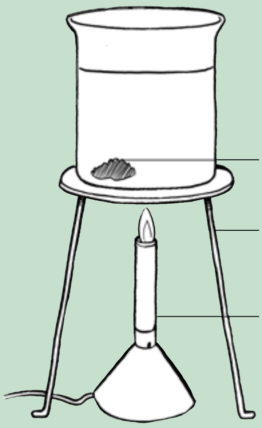
1. Cut the neck of a transparent 4 or 5 l container.
2. Fill the container three quarters with cold tap water.
3. Put coloured hot water (can be coloured with food colouring) into a small bottle with a lid that is easy to remove. Close the lid.
4. Lower the small bottle into the container.
5. Gently open it once lowered, then gently take out your hand from the container, with the lid.
6. Observe that the coloured hot water rises from the small bottle, through the cold water, then drops down again as it cools on its way up - observe the convection currents.

INSTRUCTIONS:

TEACHER'S NOTE

Learners must not just throw the potassium permanganate into the water. It is important that they place it carefully in one side of the bottom of the beaker so that they can see how the currents in the water move.

1. Half fill the beaker with cold tap water.
2. Carefully put a small amount of potassium permanganate on one side of the beaker. DO NOT STIR.
3. Heat the water directly under the side of the beaker with potassium permanganate with a Bunsen/spirit burner and observe what happens.
4. Set up a control experiment and place a few grains of potassium permanganate into the bottom of a beaker filled with water. Do not heat this beaker and observe what happens.



QUESTIONS:

1. What did you see as the water started to warm up in the beaker that was heated? Draw a picture to show what you see.
   Learners should see the purple from the dissolved potassium permanganate moving in a circle upwards through the water.
2. What is happening to the potassium permanganate in this beaker?
   As the potassium permanganate dissolves in the water it is being dragged through the water.
3. Can you explain the pattern you saw?
   The warm water is rising and being replaced by cooler water.
   NOTE:
   At this point the learners are not aware of the theory behind convection currents and so their answers will be quite simple.
4. Compare this to the beaker which was not heated. What did you observe in this beaker?
   The potassium permanganate will dissolve, but it will not form rising currents. It will diffuse evenly and densely at the bottom of the beaker. Over a long time it will spread out evenly throughout the water.

VISIT
Colourful convection currents (video)
bit.ly/1fpFCm0

Let's now explain what we observed in the last activity. Convection is the transfer of thermal energy from one place to another by the movement of gas or liquid particles. How does this happen?

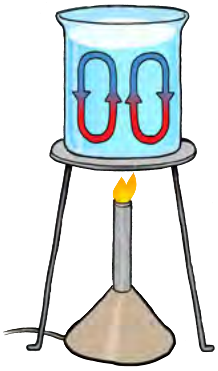
As a gas or liquid is heated, the substance expands. This is because the particles in liquids and gases gain kinetic energy when they are heated and start to move faster. They therefore take up more space as the particles move further apart. This causes the heated liquid or gas to move upwards and the colder liquid or gas moves downwards. When the warm liquid or gas reaches the top it cools down again and therefore moves back down again.

TAKE NOTE

We then say that the heated liquid or gas is less dense as the same particles are now taking up a larger space. We will learn more about density next year in Grade 8.

In the last activity, the water particles gained kinetic energy and moved apart from each other, therefore taking up more space. This water then moves upwards as it is less dense than the cold water, meaning it it lighter than the cold water. We were able to observe this as the potassium permanganate dissolved in the water and moved with the water particles, and then moved downwards again as the water cooled.

This movement of liquid or gas, is called a **convection current**, and energy is transferred from one area in the liquid or gas to another. Have a look at the diagram which shows a convection current.



ACTIVITY: Does smoke move up or down?

TEACHER'S NOTE

The learners need to be careful with this experiment. It is easy to set the T-shaped cardboard alight with the candle and they should be careful not to burn their fingers when lighting the candles as well.

MATERIALS:

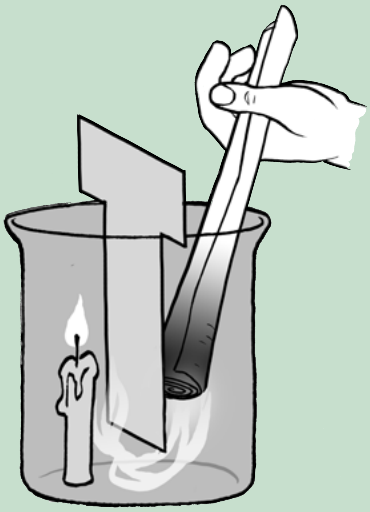
- T-shaped cardboard
- candle
- twist of paper or splint
- beaker
- box of matches

INSTRUCTIONS:

TEACHER'S NOTE

You can drip some wax onto the base and then stick the candle onto this to make it stand.

1. Light the candle and place it inside the beaker, to the side of the beaker.
2. Put the T-shaped cardboard into the beaker so that there is a small gap between the bottom of the beaker and the cardboard.
3. Light the twisted roll of paper and hold it in the beaker on the opposite side to the candle as shown in the diagram.
4. Observe what happens to the smoke.



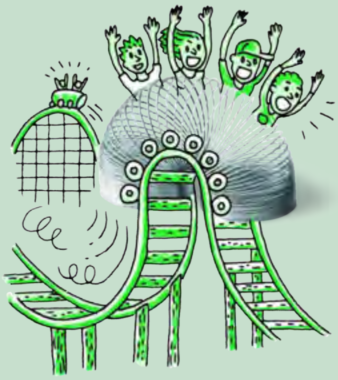
QUESTIONS:

1. What happens to the smoke from the paper?
   The smoke is drawn down under the cardboard and up next to the candle.
   NOTE:
   Some of the smoke particles may move upwards.
2. Why do you think the smoke moves in this way?
   The candle heats the air above it which creates a convection current which draws the cooler air on the other side of the cardboard towards the candle. This movement of the air particles pulls the smoke particles with it. The smoke particles allow us to visualise the convection current.

In the last two activities, we have observed convection currents in a liquid and in a gas. Convection currents can only form in gases and liquids as these particles are free to move around. They are not held in fixed positions like in a solid. Solid particles are held together too tightly for them to move when heated. Solid particles will only vibrate faster when heated but will not move from their positions.

The blobs in a lava lamp move up and down showing us the convection currents as the lamp provides the source of heat at the bottom.

Now that we have learned about convection, how can we apply this in the world around us? It is interesting to learn about concepts and theories in science, but it is even more interesting when we discover how this has an influence in our daily lives.



ACTIVITY: Installation of air heating and cooling systems

This is an photo of an air conditioner.

Imagine that your teacher has been given a heater and an air-conditioning unit for your classroom. The heater will warm your classroom in winter and the air-conditioner will keep you cool in summer. You need to help you teacher decide where each item should go in the classroom. Should they go on the wall near the ceiling or near the floor? Should they go next to a window?

INSTRUCTIONS:

1. Get into groups of 2 or 3.
2. Discuss where in your classroom you would place a heater so that it can effectively heat up the room. Draw a diagram to explain your choice.
   A heater should be placed near the floor. As it heats the air around it, the warm air will rise and be replaced by cool air. The cool air is then warmed and rises. This creates a convection current which will warm the entire room. The diagram should show the upward circulation of the warm air.
3. Discuss where in your classroom you would install the air-conditioner so that it can effectively cool the room. Draw a diagram to explain your choice.
   An air-conditioner should be placed near the ceiling. As it cools the warm air near the ceiling the cool air moves downward towards the floor and is replaced by warm air from below. The warm air is then cooled by the air-conditioner. This creates a convection current which will cool the entire room. The diagram should show the downward circulation of the cool air.

Try to find an air-conditioner or heating specialist who you can interview. Ask them to explain the best way to install the air-conditioner and a heater.

We have now looked at how energy is transferred through different materials, whether they are solids (conduction) or liquids and gases (convection). But, what about if there are no particles to transfer the thermal energy? Is there still a way for energy to be transferred?

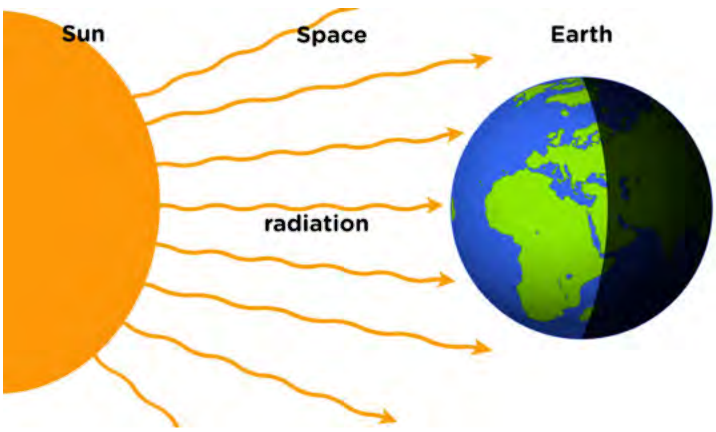
3.4 Radiation

Have you ever wondered how the Sun is able to warm us even though it is so far away? The energy is transferred from the Sun to everything on the Earth. The Sun does not need to be touching the Earth for the energy to be transferred. Also, there is space in between the Earth and the Sun. The energy from the Sun is able to warm us without the Sun ever touching us.

This transfer of energy is called **radiation**. It is different to conduction or convection as it does not require objects to be touching each other or the movement of particles.

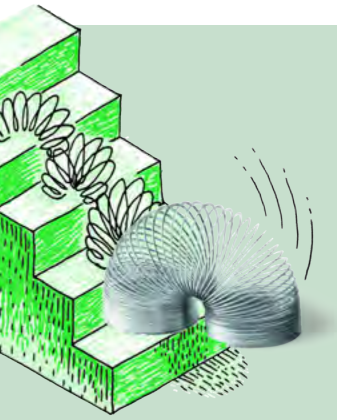
TAKE NOTE

Radiation comes from the Greek word *radius*, meaning a beam of light.



The Sun radiates heat in all directions. Energy is transferred through space to Earth

We can also see how heat is transferred by radiation here on Earth, and not just between the Sun and the Earth. Let's demonstrate the difference between radiation and convection using a candle.



ACTIVITY: Radiation from a candle

TEACHER'S NOTE

A suggestion is to do this as a demonstration and get learners to come up in small groups. You can then control how close they put their hands to the flame. Take note that heat radiates **in all directions** around the source of thermal energy (including the top of the candle). What makes us feel the heat more at the top is the effect of convection currents of the hot air moving up. They should first hold their hands above the flame to feel the heat from convection. Then they should hold their hands next to it to feel the heat transfer from radiation. Finally, you can also demonstrate conduction using a metal spoon and holding it in the flame.

MATERIALS:

- candle in a holder
- metal spoon or metal rod
- matches

INSTRUCTIONS:

1. Light a candle and place it in a holder. Your teacher might do this and get groups of you to come up at a time to the demonstration.
2. First hold you hand above the candle.
3. Then hold your hand on the side of the candle.
4. Answer the following questions.

QUESTIONS:

1. We know now that heat from a candle will be transferred to the air around it. These will warm up. Where will this air move to?
   The air particles will move upwards.
2. What is this called?
   Convection.
3. So, when you hold your hand above the candle, what do you feel and why?
   When you hold your hand above the candle, the warm air particles transfer the energy to your hand causing your hand to warm up and you feel the increase in temperature.
4. But, what about when you hold your hand on the side of the candle? Could you also feel warmth from the candle?
   Yes
5. This is not convection as the air particles do not travel sideways when they warm up from the flame. So, how is energy transferred to your hand when you feel the warmth on the side of the candle?
   The energy is transferred by radiation.
6. Lastly, if your teacher placed a metal spoon in the candle flame and you felt the end, how would it feel after a little while?
   It would also feel warm.

7. How was the energy transferred from the flame to the end of the spoon?
   The energy was transferred by conduction.

8. This photo shows all three forms of how heat is transferred.

   Explain which type of heat transfer is represented by each hand.

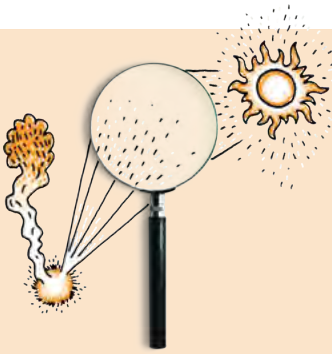
Energy is transferred in three ways.

The hand on the right holding the spoon represents conduction as the heat is transferred from the flame through the metal of the spoon. The hand above the candle represents convection as heat is transferred from the flame by moving air particles which warm up and rise. The hand above the candle will also experience heat from radiation as heat is radiated in all directions. The hand on the left next to the candle represents radiation as energy is transferred from the source through space to the hand.

As we saw in the last activity, energy is transferred from the candle to your hand by convection and by radiation. Have you ever stood next to a huge fire? You will feel the radiating heat even though the air might be very cold. This is because the energy is transferred to you by radiation through the spaces between the particles in air.

What about if you touch a black wall or a white wall? Do you think there is a difference in how different surfaces **absorb** and **reflect** radiation? Let's find out by doing an investigation.

INVESTIGATION: Which surfaces absorb the most radiation?



TEACHER'S NOTE

This investigation looks at the way different materials absorb radiation or reflect it. It is important that the surface area of each material is kept the same so that the results are reliable. This investigation will work best on a hot, sunny day. Try to find the sunniest place you can on the school grounds in order to conduct this investigation.

We are going to investigate which surfaces absorb the most heat, using dark coloured paper, light coloured paper and shiny paper, such as aluminium foil. We will use the temperature inside an envelope made from each kind of paper as a measure of the amount of heat the paper absorbed. Why do you think we can do this?

TEACHER'S NOTE

Discuss this with your class as it is important that the understand why they are doing the investigation. When the paper envelope absorbs heat, the energy will then be transferred to the air inside the envelopes. This will then cause a rise in temperature which the thermometer will show. The more energy that is absorbed, the more that is transferred to the interior, and the higher the temperature. The paper that reflects the most energy will show the smallest increase in temperature.

INVESTIGATIVE QUESTION:

Which surfaces will absorb the most radiation from the Sun and therefore increase in temperature the fastest?

VARIABLES:

1. Which variable are you going to measure?
   The temperature of the substance.
2. What do we call the variable you have measured?
   The dependent variable.
3. Which variable are you going to change?
   The type of material.
4. What do we call this variable?
   Independent variable.
5. What must be kept the same for all the different materials?
   The surface area of each substance which is exposed to the Sun must be the same (ie. the size of the envelope). The length of time that the materials are exposed to the Sun.

HYPOTHESIS:

Write a hypothesis for this investigation.

TEACHER'S NOTE

Learner-dependent answer. The hypothesis could be: 'The shiny surface will absorb the least heat, and the black/dark coloured paper will absorb the most.'

MATERIALS AND APPARATUS:

- matt black paper
- white paper
- aluminium foil
- 3 alcohol thermometers
- stopwatch or timer
- glue or adhesive tape

TEACHER'S NOTE

You can also extend the investigation by testing more colours, such as red and yellow to see how they compare.

METHOD:

1. Fold each piece of paper and aluminium foil into the shape of an envelope.
2. Put a thermometer into each of the envelopes and record the starting temperature.
3. Put all the envelopes outside in the Sun.
4. Check the temperature on the thermometers every 2 minutes for 16 minutes.
5. Record your results in the table.
6. Draw a line graph for each envelope on the same set of axes.

RESULTS AND OBSERVATIONS:

TEACHER'S NOTE

The results for this experiment are dependant on the size of the paper envelope that the learners make as well as the amount of sunlight falling on the envelopes. The readings may also fluctuate from time to time as a result of cloud covering.

Record your results in the following table.

Time (minutes)	Temperature in black paper envelope (°C)	Temperature in white paper envelope (°C)	Temperature in aluminium foil envelope (°C)
0			
2			
4			
6			
8			
10			
12			
14			
16			

Draw a line graph for each of the envelopes in the space below. Do not forget to give your graph a heading.

TEACHER'S NOTE

Time should be plotted on the horizontal axis with temperature on the vertical axis. Draw three different graphs for the three different materials. Comparing the slopes of the three graphs will allow the learners to determine which material warmed up fastest. The line with the steepest slope heated the fastest.

The black paper should increase in temperature the fastest and so it would have the steepest curve. The aluminium envelope should increase in temperature the slowest and have the shallowest curve, with the white paper in between.

The graph should have a title. An example of a suitable title would be 'A comparison of the rate of temperature increase of different surfaces.'

ANALYSIS:

1. What do you notice about the shapes of the graphs you drew? Are the graphs straight lines or curves?
   Activity-dependent answer. The values obtained will depend on the size of the envelopes the learners make as well as the amount of sunlight to which the envelopes were exposed. It is important that they should see an increasing trend in the lines of the graph.
2. Which line on your graph is the steepest? What does this tell us?
   The graph representing the black paper should be the steepest graph. This means this envelope increased in temperature the fastest. This is because the black, matt colour absorbs the most radiation.
3. Compare your results for the white paper and the shiny surface. What does this tell you.
   The envelope made out of aluminium foil should show the smallest increase in temperature as shiny surfaces reflect heat.

EVALUATION:

1. Did the investigation run smoothly? Or is there anything you would change?
   Learner-dependent answer. Learners should discuss the quality of their method and whether they got the results that they expected to get. They could suggest repeating the experiment three times and getting an average increase over time.
2. Did you get any results which did not seem to fit the overall pattern?
   Learner-dependent answer. Some learners may get outliers but others may have clear results with a clear patterns.

CONCLUSION:

Write a conclusion for your investigation. Remember to refer back to the investigative question that we wanted to answer.

TEACHER'S NOTE

Learners should conclude that black surfaces absorb the most radiation and therefore show the biggest and fastest increase in temperature, whereas shiny surfaces absorb the least, as they reflect the most.

The investigation showed that the dark envelope showed the biggest increase in temperature. The lighter coloured envelope showed a smaller increase in temperature. The envelope made out of a shiny material showed the smallest increase in temperature.

So what have we learnt? Dark colours seem to absorb more of the Sun's radiation than light or reflective colours. So, if you want to stay warm on a cold day, dark clothing will absorb more of the available warmth from the Sun's radiation than light colours.

The average summer temperature in Hotazel, a town in the Northern Cape is about 34 °C. If you lived in Hotazel and needed to buy a new car, would you buy a light or dark-coloured car? Explain why.

TEACHER'S NOTE

The best colour to buy would be a white car because, as seen in the investigation, light colours absorb less heat than dark colours. So a light-coloured car will ideally remain the coolest on the inside.

TAKE NOTE

Radiation from the Sun is essential to life on Earth, but ultraviolet radiation from the Sun can also be very damaging our skin. Remember to wear suncream and a hat when outside and avoid being in direct sunlight between 11am and 2pm.

You have the option of getting the car sprayed to make the surface more shiny. Do you think this will help keep the car cool in hot, summer months? Explain why.

TEACHER'S NOTE

Yes, it will help, as shiny surfaces are more reflective and so more radiant heat is reflected rather than absorbed, keeping the inside of the car cooler.

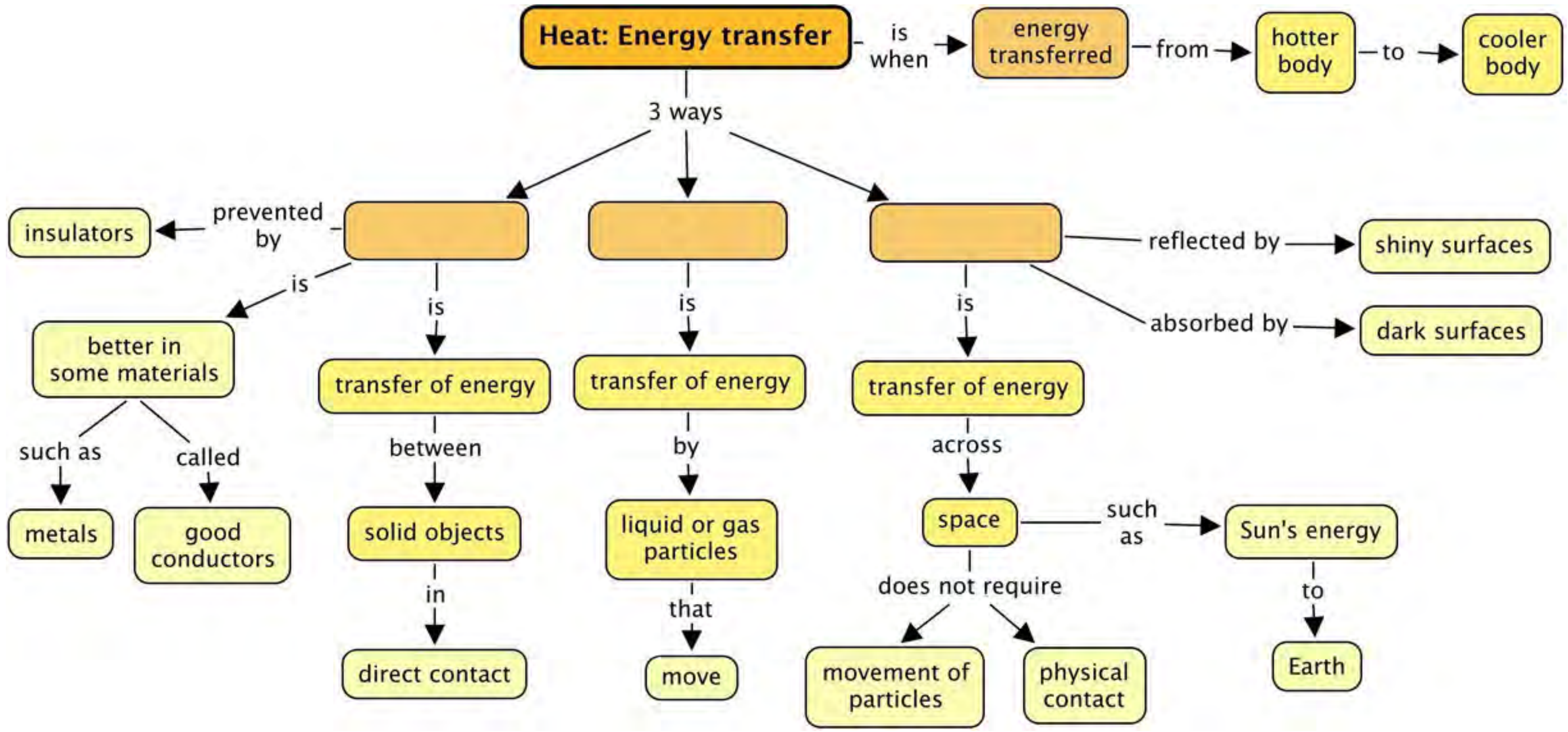
SUMMARY:

Key Concepts

- Heat is energy that is transferred from a hotter to a cooler object.
- Temperature is a measure of how hot or cold a substance feels.
- Heat (energy transfer) occurs in three ways: conduction, convection or radiation.
- During conduction, the objects must be touching each other for energy transfer to take place.
- Some materials, such as metals, conduct heat well. They are called conductors of heat.
- Some materials, such as plastics and wood, slow down or prevent conduction. They are called insulators.
- Convection is the transfer of energy within liquids or gases.
- A convection current refers to the movement of a liquid or gas during energy transfer. The liquid or gas moves upwards from the heat source (as it expands) and then downwards when the liquid or gas cools (as it contracts).
- Radiation is the transfer of energy where objects do not have to be physically touching. Radiation does not require a medium and can take place through empty space.
- The Sun's energy is transferred to Earth by radiation.
- Dark, matt surfaces are good absorbers of radiant heat
- Light and shiny surfaces are poor absorbers of radiant heat. Light, shiny surfaces reflect more radiant heat than they absorb.

Concept Map

Below is a concept map showing how the different topics about heat together. You need to fill in the three different ways that energy can be transferred, as discussed in this chapter, but you cannot just put anyone into any box. You need to study the concepts which come after and explain each way of transferring energy during heating.



Heat: Energy transfer
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to
cooler body
3 ways
prevented by
insulators
is
better in some materials
such as
metals
called
good conductors
is
transfer of energy
between
solid objects
in
direct contact
is
transfer of energy
by
liquid or gas particles
that
move
reflected by
shiny surfaces
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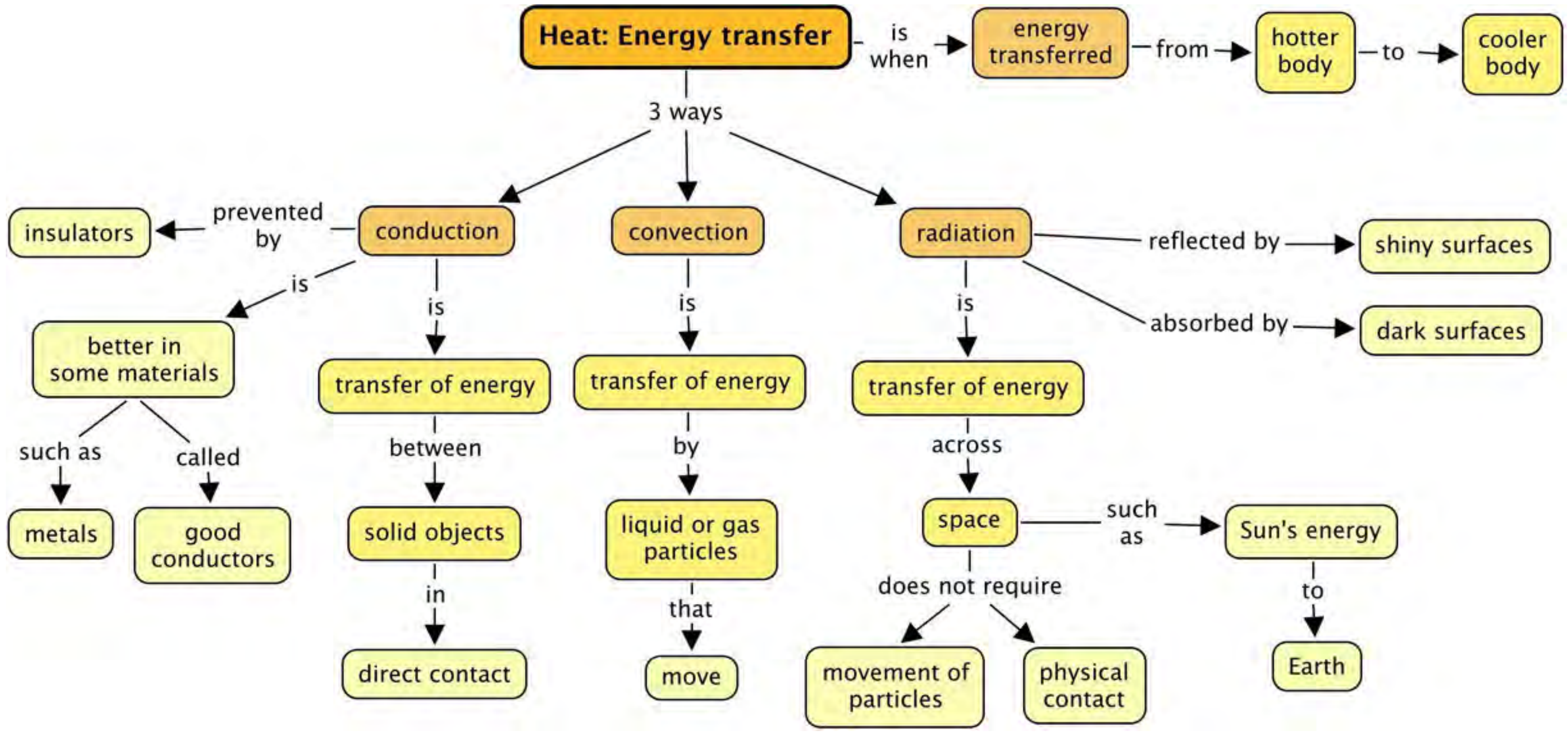

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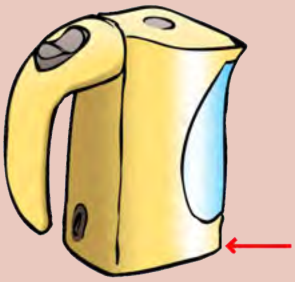
REVISION:

1. How is energy being transferred in the following photos showing different heating processes? Write down conduction, convection or radiation. Some illustrations may show more than one form. [4 marks]

 *The heat from the Sun travels to Earth.*	 *Cooking food on a braai or fire.*
Radiation	*Convection (and also some radiation)*
 *Boiling water in a metal pot.*	 *A heater in a room.*
Conduction (through the metal) and convection (in the water)	*Radiation and convection*

2. In each of the following situations, identify the method of energy transfer taking place (conduction, convection, radiation).
   a) A fireplace has a glass screen in front of it. The person sitting in a chair next to the fireplace chair feels hot due to _______________. [1 mark]
   b) When you stir your tea with a metal spoon the handle gets hot because of _______________. [1 mark]
   c) When you are lying on the beach your skin feels hot because of _____________. [1 mark]
   a) radiation
   b) conduction
   c) radiation
3. Draw energy transfer flow charts for the following: You buy a cup of hot chocolate and hold it in your hands on a cold winter day. [2 marks]
   The energy is transferred from the cup to the hands by conduction.
   NOTE:
   One of the marks is for choosing the correct direction of the energy transfer. The second mark is for drawing it in the form of a flow chart.

4. Your parents have a metal hot water geyser and they are complaining about the amount of energy needed to keep the water hot. What can you recommend your parents could do to prevent energy loss from the geyser? Explain your answer. [4 marks]
   Metals are good conductors of heat and so the heat from the water is transferred out of the geyser. A (shiny foil) insulating blanket could be used to wrap around the geyser. The air between the blanket and the geyser is a poor conductor of heat so the heat loss will be slower.
5. Explain why the heating element for a kettle is at the bottom and not at the top. [3 marks]

   The heating element is at the bottom because as the element transfers energy to the water, the water expands and moves upwards and the colder water (slower moving particles) will sink to the bottom, forming a convection current This cycle will ensure that all the water is heated as quickly as possible. If the element was at the top, the water at the bottom would take much longer to boil.
   NOTE:
   Learners must mention the term convection current.
6. Explain why you think the water boils throughout the kettle pot and not just at the bottom? [2 marks]
   The water at the bottom of the pot gets hot and then moves to the top of the pot because of convection. This allows the cold water to sink to the bottom and heat up. This constant circulation allows all of the water to heat up and boil.
7. Explain why you think take-away coffee is sold in styrofoam cups rather than ceramic cups. [2 marks]
   Normal ceramic cups are good conductors of heat and so the energy from the coffee is transferred quickly through the cup to the surroundings. The styrofoam is a poor conductor of heat and so it does not allow the energy from the coffee to move quickly to the surrounding air, so the coffee stays warmer for longer.
8. Explain why you think two thin blankets can sometimes be warmer than one thick blanket. [2 marks]
   Air is trapped between the two blankets. The air is a very poor conductor of heat and so it becomes an extra insulating layer which slows down the loss of energy from your body. One blanket cannot trap as much air and so isn't as warm as two blankets.
9. Explain why birds fluff up their feathers to stay warm, especially in winter. [2 marks]
   Birds fluff up their feathers so that more air gets trapped between the feathers. The air is a poor conductor of heat and so the energy from the birds body is not transferred to the surroundings.
10. Why should you place an air conditioner at the top of a room, near the ceiling, rather than at the bottom near the floor? [2 marks]
    This is because cold air will move downwards, therefore cooling the room, and the hot air will rise and can therefore be removed by the air conditioner at the top of the room, near the ceiling.

11. Imagine you want to build a small enclosure for some chickens on your property. You have an outside area for them that is made from barbed wire, and you have made a small inside, covered enclosure for them out of bricks and cement which you would like to paint. You know that it can get quite cold in winter in your area so you want the house to be as warm as possible for the chickens. What colour paint are you going to choose to paint the outside of chicken house? Will it be a dark-coloured paint, such as brown or black, or a light-coloured paint, such as white or yellow? Explain your choice. [4 marks]
The best choice to keep the house as warm as possible on the inside is a dark-coloured paint. This is because the dark colours absorb more radiant heat from the Sun during the day, than the light colours, which reflect heat. The dark paint will absorb the heat and it will be transferred to the air inside of the house, making it warmer, especially during winter.

Total [30 marks]

Heat insulation and energy saving

TEACHER'S NOTE

Chapter overview

This chapter expands on the idea of energy transfer that the learners discovered in the previous chapter. It is very important to reinforce the idea that heat is the transfer of energy from a warm object or system to a colder object or the surroundings. It is to retard this process that we need insulation.

The previous chapter introduced the concept of heat and temperature and the different ways in which energy is transferred between objects. This chapter deals with the practical applications of heat, showing how we can harness the transfer of energy in order to warm our homes and to stop energy being transferred away from our homes in winter. Similarly, insulation is required to keep objects cool, for example a cooler box. The learners will investigate different materials in order to discover which materials are better insulators or conductors.

1.1 Why do we need insulating materials? (1 hour)

Tasks	Skills	Recommendation
Activity: How do solar water heaters work?	Examining, observing, explaining	CAPS suggested

1.2 Using insulating materials (5 hours)

Tasks	Skills	Recommendation
Activity: Keep your coffee hot and your cold-drink cold	Designing, group work, hypothesising, making, drawing, labelling,	Suggested
Investigation: Which is the best insulating material?	Observing, measuring, recording, plotting graphs, interpreting data	CAPS suggested
Activity: Building a hot box	Drawing, designing, labelling, making, observing	CAPS suggested
Activity: Keeping our homes warm	Making, measuring, recording, plotting graphs, interpreting data	CAPS suggested

Note that CAPS suggests making a hot box OR building a model home. We have included both here for you to make a choice. There is also a substantial amount of time for this chapter, so you could also do both tasks with your learners.

KEY QUESTIONS:

- How can you keep your tea warm?
- Can you use the same materials to keep your house warm in winter and cool in summer?
- How do insulating materials assist with saving energy?

4.1 Why do we need insulating materials?

Heat is the transfer of energy by conduction, convection or radiation, as we learnt in the previous chapter. Often, we want this energy to be transferred for heating. For example, when you place a heater in a room, you want the energy to be transferred through convection and radiation to the room so that the room becomes warmer.

In other situations, you want to prevent energy transfer. For example, on a cold winter's day, we need to minimize heat loss from the house, so that it stays warm. Other objects, such as electric geysers, need to prevent energy transfer to the surroundings so that the water inside stays warm. Materials which are insulators can slow down or prevent energy transfer.

An example of where we want the transfer of energy to take place in some parts of the system but prevent it in other parts, is in a solar water heater. The use of a solar water heater helps to save energy. This is not only because the system is efficient at warming water, but we also use solar power which is free, whereas we pay for electricity from the national grid and it puts demands on the national demand for electricity.

We use different materials in different situations depending on whether or not we want energy transfer to take place. Let's find out why, and discover how a solar water heater works.

ACTIVITY: How do solar water heaters work?

TEACHER'S NOTE

Learners can discuss this in groups and then write down their own answers or do it individually.

INSTRUCTIONS:

1. Study the following diagrams which show how a solar water system works.
2. Answer the questions which follow.

There are several different types of solar water heaters. We will be looking at the most efficient heater, which uses evacuated tubes.

A solar water heater on top of a corrugated iron house.

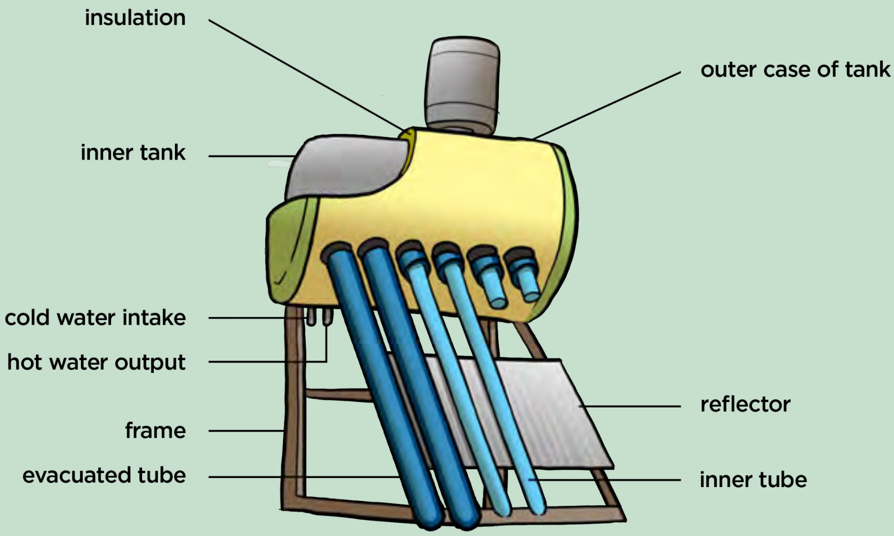
A close up photo of a solar water heater.

The following diagram shows the different parts of the solar water heater to which we will be referring. Cold water flows in the cold water intake pipe and then down the long tubes, called **evacuated tubes**. The water warms up due to energy transfer from the Sun and it then flows into the storage tank at the top. When someone wants hot water in the house, the hot water flows out of the hot water output and down into the house.

VISIT

A simple demonstration showing how a solar water heater works.

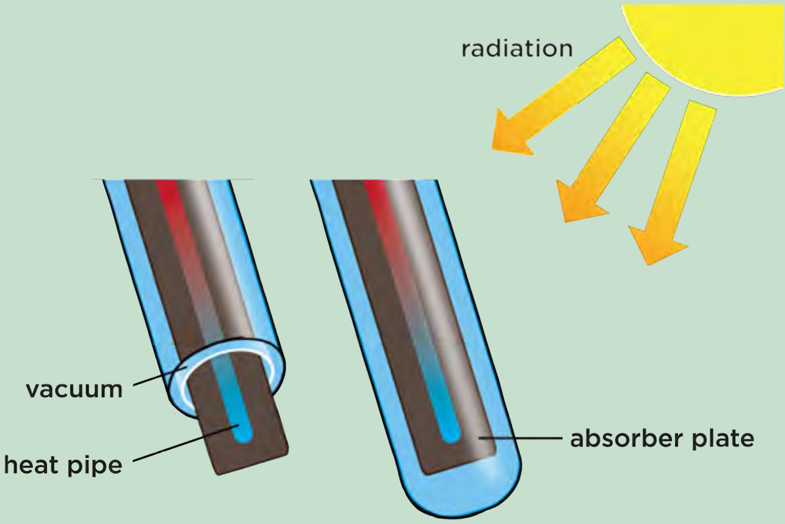
bit.ly/1h3TNbU



QUESTIONS:

1. Is solar power an example of a renewable or non-renewable energy source?
   A renewable energy source.
   NOTE:
   This links back to what learners covered in Chapter 1.
2. When the cold water flows down the tubes, energy is transferred to the water from the Sun. What type of heating is this?
   Radiation.

3. In the tubes part of the system, we want energy transfer to take place, so specific materials are used to make energy transfer as efficient as possible. There is a shiny surface underneath the tubes called a **reflector**. How does this help to increase the amount of energy that the water in the tubes receive?
   The reflector is a shiny surface so it does not absorb the heat, but reflects the Sun's radiant energy back up and onto the tubes, increasing the amount of energy that the water in the tubes receive.
4. Do you see that there is a tank at the top to store the hot water? In this part of the system we want to prevent energy transfer to the outside. This tank consists of an inner tank and an outer case. If there were just these two layers, made of metal, how could heat loss from the hot water to the external environment occur?
   By conduction.
5. However, something has been done to help prevent this transfer of energy. What have they done to help keep the water warm while it is stored?
   In between the inner and outer tank there is a thick layer of insulation. This does not conduct heat. The insulation helps to prevent the transfer of energy to the surroundings by conduction as the insulation material is a poor conductor of heat.
6. Let's now take a closer look at the evacuated tubes in a solar water heater. Study the following diagram. The water runs down the central **heat pipe**. There is an absorber plate below each pipe and this is enclosed within two layers of tube.



Can you see that there is an inner and an outer tube? Between these tubes there is a **vacuum**. This means that the Sun's energy can still pass through to warm the water. However, when the energy is transferred to the water, and it warms up, the vacuum prevents energy from transferring back out by conduction or convection. Why is this so?
For energy to be transferred by conduction or convection, it requires a medium, such as air particles. However, there is a vacuum, so it helps to insulate the inner pipe.

7. Underneath the heat pipe there is a plate which helps to absorb radiant energy from the Sun and transfer it to the heat pipe. Why is it made of a dark material and not a light material?
   This is because the dark material is much better at absorbing radiant heat and transferring it to the pipe, than a light material would be.
8. Do you see that the water at the bottom is cooler, indicated by the blue colour, and the water at the top of the tube is warmer, indicated by the red colour? When the cooler water moves to the bottom and the warmer water moves to the top, what is this called?
   A convection current.
9. This movement of water helps to move the hot water out of the tubes and into the tank so that cold water can replace it.
10. Do you think the solar water heater is an energy efficient system? Why?
   It is a very efficient system as all the materials are carefully chosen to either enhance energy transfer or prevent it, depending on what is needed in that part of the system. This helps to save electricity as solar power is used to heat water instead of relying on an electrical geyser. It is also cheaper as solar power is free, except for the installation of the actual solar heater.

Now that we have looked at how different materials are used in different situations depending on whether we want to prevent energy transfer or allow it to take place, we are going to take a closer look at how we use those materials that prevent energy transfer.

4.2 Using insulating materials

Before we start, write down your own definition for an insulator of heat.

TEACHER'S NOTE

Learners should write something about it being a poor conductor of heat, or preventing energy transfer.

Which materials work well as insulators of heat? Let's first do a fun activity.

ACTIVITY: Keep your coffee hot and your cold-drink cold

TEACHER'S NOTE

Learners must use their knowledge of the ways energy is transferred in order to come up with their own method for insulating their drinks. Let the learners be creative here, don't give them too many hints or suggestions. The activity will show you which learners have understood the energy transfer concepts from the previous chapter and which of them need more help.

There are different ways to manage this activity. You can provide the learners with a selection of materials that you want them to use or you can ask them to bring in their own materials. Making the learners bring in their own materials makes it more challenging for the learners. If you provide a selection of insulating materials then the learners will have a base from which to work and they are more likely to insulate the drink correctly the first time.

This activity is meant as an introduction to using insulating materials. The learners need to consider what they have learnt about conduction, convection and radiation in order to choose different materials for their activity.

Get the learners to develop a plan for their design before they insulate their cup. Ask them to come up with a hypothesis that they can test. Here are several hypotheses which the learners may come up with:

- "Wrapping aluminium foil around the cup will prevent energy transfer".
- "Covering the cup with cardboard will slow down heat loss."
- "Using corrugated cardboard as an insulator will slow down heat loss"
- "Wrapping a cup in layers of newspaper will prevent energy transfer."

The learners can then test their hypothesis and decide at the end whether or not it is true or false.

An additional exercise to do is to use the same size tins and wrap them in 3, 6 and 9 layers of newspaper. This clearly shows that newspaper is a very effective insulator, especially if layered.

MATERIALS:

- kettle
- 2 identical mugs, metal or ceramic
- tea or coffee
- alcohol thermometer
- various insulating materials
- timer or stopwatch

INSTRUCTIONS:

1. Get into groups of 3 or 4.
2. Design a method to keep a cup of tea warm for as long as possible. You may use any materials that you have at home or provided by your teacher.
3. Make your design.
4. Write a hypothesis for your planned design.
5. Fill your insulated cup with boiling hot tea.
6. Measure the temperature with a thermometer.
7. Keep the thermometer in the cup and time how long it takes to reach room temperature (approximately 25 °C)
8. Fill the uninsulated cup with boiling hot tea and time how long it takes to reach room temperature.
9. Repeat this activity using a cold drink in the cups.

QUESTIONS:

TEACHER'S NOTE

These answers are learner-dependent because they are based on the learner's own choice of materials and the ambient temperatures at the time of the experiment.

1. What materials did you use to keep your tea warm?
   Learner-dependent answer.
2. Why did you choose those particular materials?
   Learner-dependent answer.
3. How did you attach the materials to the mug?
   Learner-dependent answer.
4. Draw a labelled diagram of your design to keep your tea warm.
   Learner-dependent answer.
5. How long did it take your tea to reach room temperature (25 °C)?
   Learner-dependent answer.
6. What materials did you use to keep your cold drink cold?
   Learner-dependent answer.
7. Why did you choose those particular materials?
   Learner-dependent answer.
8. How did you attach the materials to the mug?
   Learner-dependent answer.
9. Draw a labelled diagram of your design to keep your cold drink cold.
   Learner-dependent answer.
10. How long did it take your cold drink to warm up to room temperature (25 °C)?
    Learner-dependent answer.
11. Why did you also time the uninsulated cups?
    The uninsulated cups acts as controls for the activity. Without testing the uninsulated cups we cannot be sure of whether or not the tea would have cooled down (or the cold drink warmed up) at the same rate without the extra insulating materials.
12. Was your hypothesis shown to be true or false?
    This answer will depend on the learners' hypotheses. If they hypothesise that their material will decrease heat loss and they can show that it does then their hypothesis is true. If they hypothesise that their material will decrease heat loss but the tea cools at the same rate as the control then their hypothesis is false.

What have you learnt from your attempts at keeping your hot drink warm and your cold drink cool? Some materials trap heat really well and others do not. Let's now do a more formal investigation of some of the different materials to find out which is the best insulating material.

INVESTIGATION: Which is the best insulating material?

AIM: Write down an aim for this investigation.

TEACHER'S NOTE

To investigate which materials is the insulator of heat.

MATERIALS AND APPARATUS:

- 4 beakers or tins
- 4 alcohol thermometers
- aluminium foil
- fabric
- newspaper
- plastic
- kettle
- timer or stopwatch

METHOD:

TEACHER'S NOTE

Make sure that the layers of newspaper, plastic and fabric are the same thickness so that the thickness of the material does NOT vary in the investigation.

1. Wrap one beaker with newspaper, one beaker with plastic, one beaker with aluminium foil and the fourth beaker with fabric.
2. Boil water in a kettle.
3. Pour 250 ml of boiling water into each beaker.
4. Put a thermometer in each beaker.
5. Measure the starting temperature of the water and then measure the temperature of the water every 5 minutes for half an hour.
6. Write the measurements in the table in the results section.
7. Draw a graph representing the data you have collected.

RESULTS AND OBSERVATIONS:

Record your results in the following table.

Time (minutes)	Temperature of aluminium foil beaker (°C)	Temperature of newspaper (°C)	Temperature of plastic (°C)	Temperature of fabric (°C)
0				
5				
10				
15				
20				
25				
30				

VISIT

Do you surf? Find out how a wetsuit works.

bit.ly/184Extr

Use the following space to draw a line graph for each type of material. You must plot each graph on the same set of axes.

First, we need to think about which data is put on each axis.

1. What will you plot on the horizontal x-axis? This is the independent variable.
   Time
2. What will you plot on the vertical y-axis? This is the dependent variable.
   Temperature
3. How are you going to show a difference between the lines for each type of material on one graph?
   Learners can use different colours for each type of material used.

TEACHER'S NOTE

The independent variable (time) must be plotted on the horizontal x-axis and the dependent variable (temperature) must be plotted on the vertical y-axis. The learners should plot each of the four graphs one-by-one in a different colour in order to distinguish between the lines. If they cannot use colour then make sure that they label each line carefully. The actual temperature of the water before it starts to cool will affect the results. Also, the ambient temperature of the room will also affect the temperature drop. What is important to notice is that the initial temperature drop is fast but then the rate of temperature drop decreases. This means that the shape of the graph will be a decreasing curve. Learners must provide a heading for the graph, such as "Graph showing the decrease in temperature over time when using different materials as heat insulators."

You can use Assessment Rubric 3 at the back of your Teacher's Guide if you wish to assess this graph.

ANALYSIS:

1. Which of your graphs has the steepest curve?
   The aluminium foil has the steepest curve. This might vary though depending on the actual foil and other materials which you used.
   NOTE: *The answers here must correlate to the learner's results.*

2. What does the steepness of the curve tell you about how quickly the material allows heat to leave the water?
   The steeper the curve the faster the temperature has dropped. The steep curve shows that heat has left the water quickly.
3. Arrange the materials in order from very good insulator to poor insulators of heat.
   Activity-dependent answer.
4. Which material was the best conductor of heat? Explain your choice.
   This depends on the learner's results. Whichever material allowed the fastest decrease in temperature is the best conductor of heat as it means that heat was easily conducted out of the warm water.
5. Which material was the best insulator of heat? Explain your choice.
   The graph with the shallowest curve is the best insulator. This depends on what the learner's observed during their investigation.
6. If you had to keep a bottle of water cold for as long as possible, which of the 4 materials would you choose? Explain your choice.
   Learners must suggest the insulator which had the shallowest curve on their graph.

VISIT

Read more about how insulating materials are used in NASA's Webb Space Telescope. bit.ly/1be3J5v

CONCLUSION:

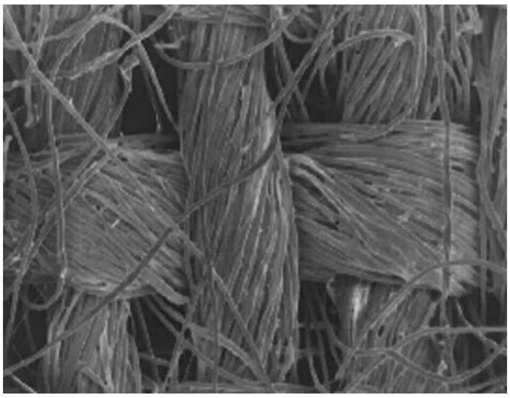
Write a conclusion for this investigation.

TEACHER'S NOTE

Learners must answer the question which was which is the best insulator. So, they can conclude, from their results, which is the best.

Why is fabric a good insulator? The woven fibres of the fabric trap air between them. Air is a poor conductor of heat and so it slows heat loss through the fabric.

Here are some different fabrics.



And here is a close up of the fibres making up the fabric.

Fabric is not generally used to keep our hot drinks warm. In fact, most take-away cups are made from styrofoam. Styrofoam is a good insulator of heat. It is made from polystyrene which has had air pumped through it. This makes

VISIT

Learn more about aerogel, a space-age insulating material bit.ly/192HJTA

styrofoam extremely light and the air pockets make it a very good insulator.

A very useful application of the use of insulating materials is the cooler box and hot box. Look at the following photo of a cooler box.

A cooler box.

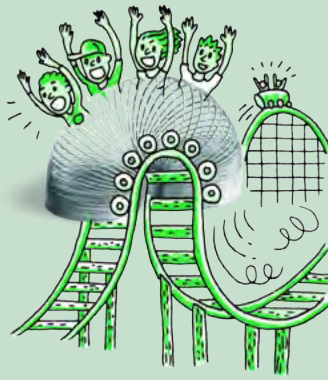
Cooler boxes are used to keep food cold. You need to put ice blocks in with the food to do so. The cooler box is made from a thick layer of plastic. How does this help to keep the contents cool inside?

TEACHER'S NOTE

The thick layer of plastic acts as an insulator so heat from the surroundings is prevented/minimized from entering into the cooler box and the contents stay cold inside.

A hot box works in a similar way, but can be used to keep food warm for long periods of time. There are many ways to construct a hot box.

ACTIVITY: Building a hot box



TEACHER'S NOTE

It would be best to do this activity as a demonstration. The quantity of blankets and towels required may be difficult for each learner to bring in to school. If you want the learners to try it then let them do it in groups. Ask learners to each bring in a towel or a blanket to school to make sure that each group has enough materials. A couple of old pillows in a box also works very well. You can also make smaller hotboxes with smaller boxes and strips of fabric rather than blankets and towels. The smaller hotboxes may not be sufficient insulation to keep a meal cooking so you could use an ice cube and try to keep that cold. A hot box can keep cold items cold as it also prevents the transfer of heat from the surroundings into the box.

This activity provides one way to make a hotbox. You can also do this as a project where learners must design and build their own hot boxes and they can also do this in groups.

The materials and instructions for building this hotbox are provided only here in the Teachers Guide in case you want learners to design, make and test their own hot box, rather than one that you have made as a demonstration.

MATERIALS:

- large cardboard box
- medium cardboard box (must fit inside the larger box)
- blankets
- towels
- rice and water brought to the boiling point for about five minutes. This will continue cooking if well insulated and the rice will be completely cooked after about 40 min.

INSTRUCTIONS:

1. Line the inside of the larger cardboard box with towels and blankets. Make sure that there is still room for the medium cardboard box to fit inside.
2. Put the medium cardboard box in the middle of the larger cardboard box.
3. Put a few small towels and blankets around the outside of the medium box. Pack the towels and blankets snugly so that the medium cardboard box cannot move around.
4. Put a pot of partially cooked rice inside the medium cardboard box, Wrap newspaper, towels and a blanket around the pot.
5. Close the lid of the medium cardboard box.
6. Put a layer of towels and blankets on top of the closed medium cardboard box and then close the large cardboard box as well. Put some more towels or blankets on top.
7. The rice will continue to cook in the hot box.

INSTRUCTIONS:

1. Depending on your teacher, he or she will either make a hot box as a demonstration in class, or else you are required to design and make your

own hot box.
2. The hot box needs to keep a pot of rice and water brought to boiling point hot enough so it finishes cooking.
3. If you are designing and making the hot box yourself or in a group, you need to think about which materials will be the best insulators for the hot box.

QUESTIONS:

1. Draw a labelled diagram of the hot box design that either you, your group or your teacher made.
   Learner-dependent answer. This links in with what learners do in Technology in terms of drawing their designs. Make sure that it is labelled and specifies the materials used.
2. Why did you or your teacher use the specific materials to make the hot box?
   This answer depends on the materials used. For example, towels and blankets are good insulators because air is trapped between the woven fibres as well as between the layers of the fabric. The cardboard box is also a better insulator than for example a metal box or container.
3. Why did you put rice with the water boiling, instead of cold water, in the hotbox?
   The food needs to be hot when it is put in so that the hotbox can trap the heat. If the food and water was cold then the hotbox would keep the heat out and the rice would not cook.
4. If you had something cold and you wanted to keep it cold, could you use your hotbox? Explain your answer.
   The hotbox can keep cold items cold for a longer period of time. This is because the insulating layers will prevent energy from the outside from entering the hotbox and so the interior can stay cool.

VISIT
A video on solar cooking
bit.ly/GzvzLr

Keeping our homes warm in winter is also very important and there are different ways to do this. Let's look at how our homes are insulated.

ACTIVITY: Keeping our homes warm

The following image shows how heat is lost from a house, using a colour scale to represent how much heat is lost. Red represents areas of high energy transfer, yellow is medium and green and blue are areas of low energy transfer.

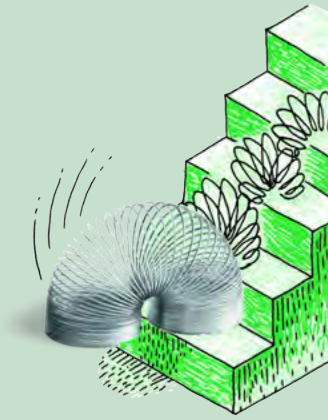
1. Which parts of the house lose the most heat?
   The windows, door and roof.
2. How is heat lost through these places?
   By conduction.

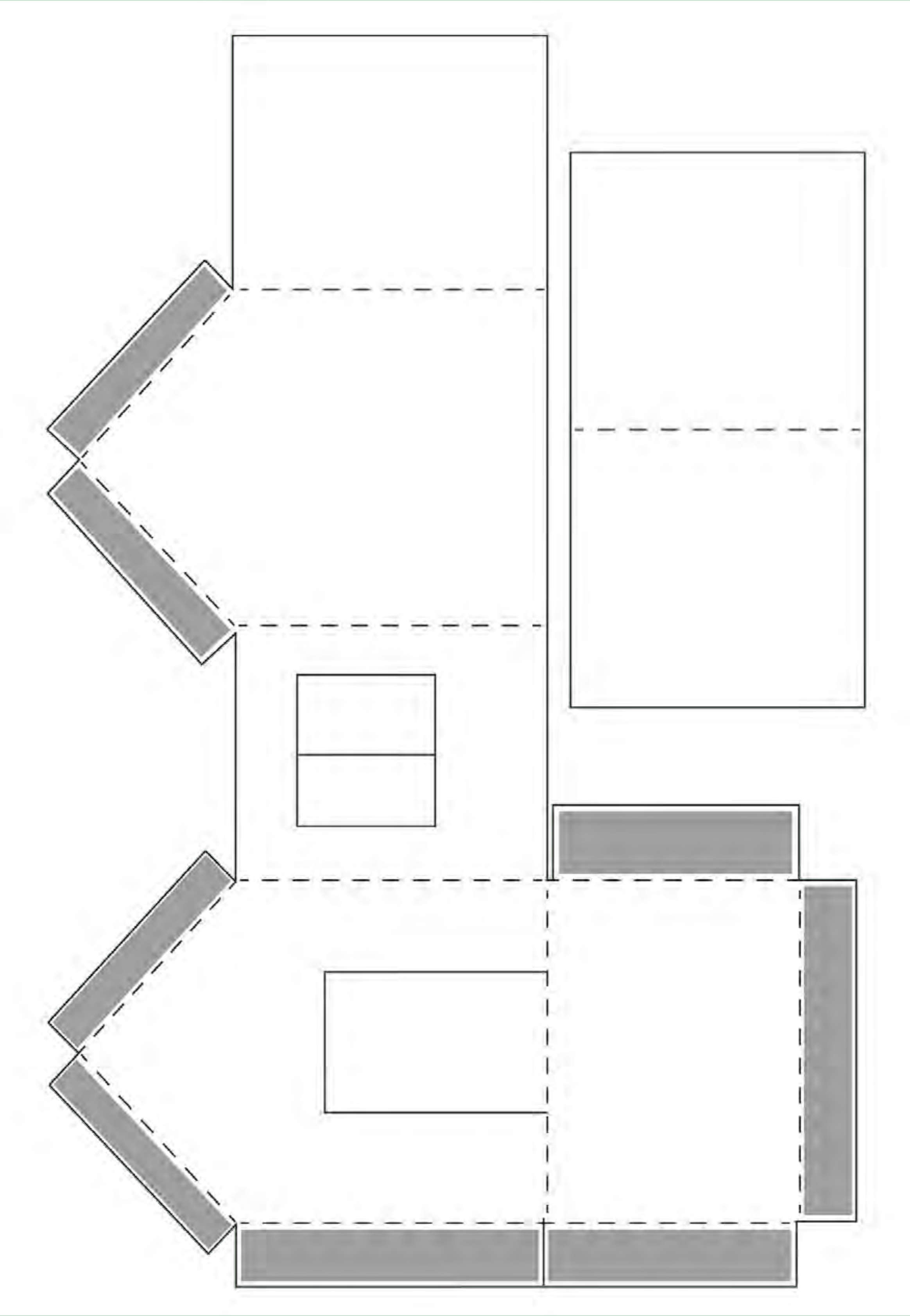
Convection also cools down a house, cold air is drawn in through gaps in doors and windows and is circulated through the house. Some of the heat is lost by radiation through the walls, roof and windows. Let's now make our own model houses to see how we can prevent heat loss.

TEACHER'S NOTE

The learners will now make model houses. The template is included below. If you can, photocopy the template for the learners as this would save some class time, preferably A3 size paper. If you cannot photocopy the template have the learners trace it onto a piece of paper. The learners can choose the number of windows in the house. The learners may choose to use thicker or thinner cardboard for the walls and roof. They may use fabric or cotton wool on the roof and the floor. They should try different things to regulate the internal temperature of their model house. The holes for the windows could be covered over with sellotape to simulate glass.

As an extension exercise, if you have enough class time, it would be a good idea to have each learner or group of learners make several different models. Each model can have a different number of windows and have used different insulating methods. If you do not have enough class time for each group to do more than one model then encourage different learners or groups of learners to do different models and then have the groups compare their results with other groups.



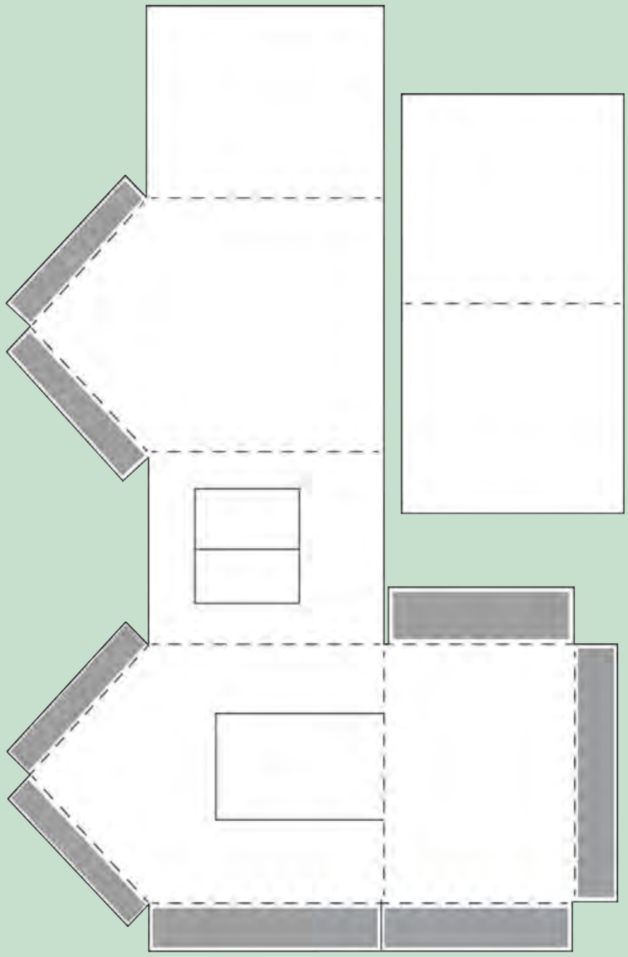


MATERIALS:

- model house template
- paper and cardboard
- glue
- sellotape
- pieces of fabric or cotton wool
- hole punch
- pair of scissors
- thermometer
- lamp (to simulate sunlight)
- timer or stopwatch

INSTRUCTIONS:

1. Your teacher might provide you with a large model house template for you to cut out. If not, copy the following template onto a large piece of cardboard or design your own template for making a house.



1. Cut a small hole in the roof using the hole punch. This is for the thermometer.
2. Choose the number of windows you would like your house to have.
3. Cut out the windows. Use sellotape across the hole to act as glass.
4. Cut out a piece of fabric for the floor.
5. Glue the fabric to the floor of your model house.
6. Fold along the dotted lines and then glue the shaded flaps together to make the house. Place the roof on top.

7. Insert the thermometer through the roof.
8. Set up the lamp so that it is shining directly onto your model house. An alternative is to put the houses in a sunny place. This will depend on the weather.
9. Take temperature readings every 5 minutes for half an hour.
10. Switch off the lamp, or bring your model out of the Sun, and measure the temperature as the house cools down, measure every 5 minutes for half an hour.

TEACHER'S NOTE

As an extension exercise, ask learners what they can do to their model houses to prevent heat loss? Try it out and test it. An example of what learners could do is to line the inside of the house with cotton wool and then repeat the experiment to see if it makes a difference.

Time (minutes)	Temperature (°C)
0	
5	
10	
15	
20	
25	
30	
35	
40	
45	
50	
55	
60	

Draw a line graph of temperature versus time. Do not forget to include a heading for your graph.

TEACHER'S NOTE

This graph is a line graph. The time should be on the horizontal axis and the temperature on the vertical axis. The temperature should rise and then reach a steady temperature. When the lamp is switched off the temperature should decrease and then reach a steady temperature again.

QUESTIONS:

1. Why did your model house warm up when the lamp was shining on it, or when it is placed in the Sun? Use your knowledge of radiation, conduction and convection in your explanation.
   The energy from the lamp (Sun) transferred by radiation to the model house. The walls of the house conducted the energy through to the interior of the house. Convection of the warmer air inside the house made sure that the entire interior of the house warmed up.
2. Why did your model house cool down when the lamp was switched off, or you brought your model back inside out of of the Sun? Use your knowledge of radiation, conduction and convection in your explanation.
   The warm air inside the model house rises towards the roof because of convection. The energy from the warm air is transferred to the outside because it is conducted through the roof, walls and windows.
3. What could you have changed in your model house in order to slow down the energy transfer so that the house is not too hot or too cold?
   Learner-dependent answer. Each model house would need different interventions in order to improve their insulation. Some may suggest fewer windows, some may suggest using fabric on the walls or thickening the walls by using cardboard.
4. Think about your own home. What do you think you could do to improve the insulation of your home in winter?
   Learner-dependent answer. The answers will depend on the socio-economic circumstances of the learners. Suggestions may vary from fitting carpets and double glazing to using cloth or cardboard to seal gaps under doors.
5. Will the suggestions you made in the previous question also work for summer? Explain your answer.
   Insulators prevent heat from leaving the house but, at the same time, they also prevent heat from entering a house. This means that the house should not take in as much heat during summer but in winter the heat is trapped inside.

TEACHER'S NOTE

At this point you can also explain some of the new building regulations, such as requiring windows to be double glazed if they take up large areas in the house. This is to prevent energy loss.

In the previous chapter you learnt that dark, matt surfaces are good absorbers of radiation. Light, shiny surfaces are poor absorbers and they can reflect some radiation. These properties are very important when choosing an insulating material. In extremely hot climates, such as Greece, the local people paint their houses white because the walls do not absorb as much heat during the day and therefore stay cooler inside. The position of the house in relation to the rising and setting of the Sun is also considered. For example, people will build their houses facing away from direct sunlight if they live in very hot areas.

Houses painted white in Greece to keep them cool in the hot summers.

Let's look at how some of the indigenous houses in Southern Africa make use of insulating materials in the house structure.

Indigenous homes

The indigenous people of South Africa have many different ways of insulating their homes. Here are some pictures of different homes from different indigenous groups.

A thatched Zulu house.

An Ndebele house.

Did you notice that the houses do not have windows, or the windows are very small? Windows allow a lot of heat to escape a building and so these designs rather leave those out. The roofs are made from thatch which is a poor conductor of heat. We know that most of the heat of a home is lost through the roof and so by using an insulating material in the roof it helps to minimise the heat loss in cold weather and heat gain in hot weather.

The roofs also extend further over the walls creating an overhang. The overhang helps to shade the walls in summer but the winter sun can still reach under the overhang. The walls are also very thick. How do you think this helps?

TEACHER'S NOTE

The thickness helps to reduce heat lost through conduction. This keeps the houses cooler in summer, but warmer in winter.

VISIT

Are you interested in energy efficient buildings? Read more about this from the Green Building Council for South Africa. bit.ly/1fpJTWy

We have now seen how our knowledge of insulating materials can be applied in the world around us to come up with solutions for preventing heat loss. Remember, be curious to discover the possibilities.

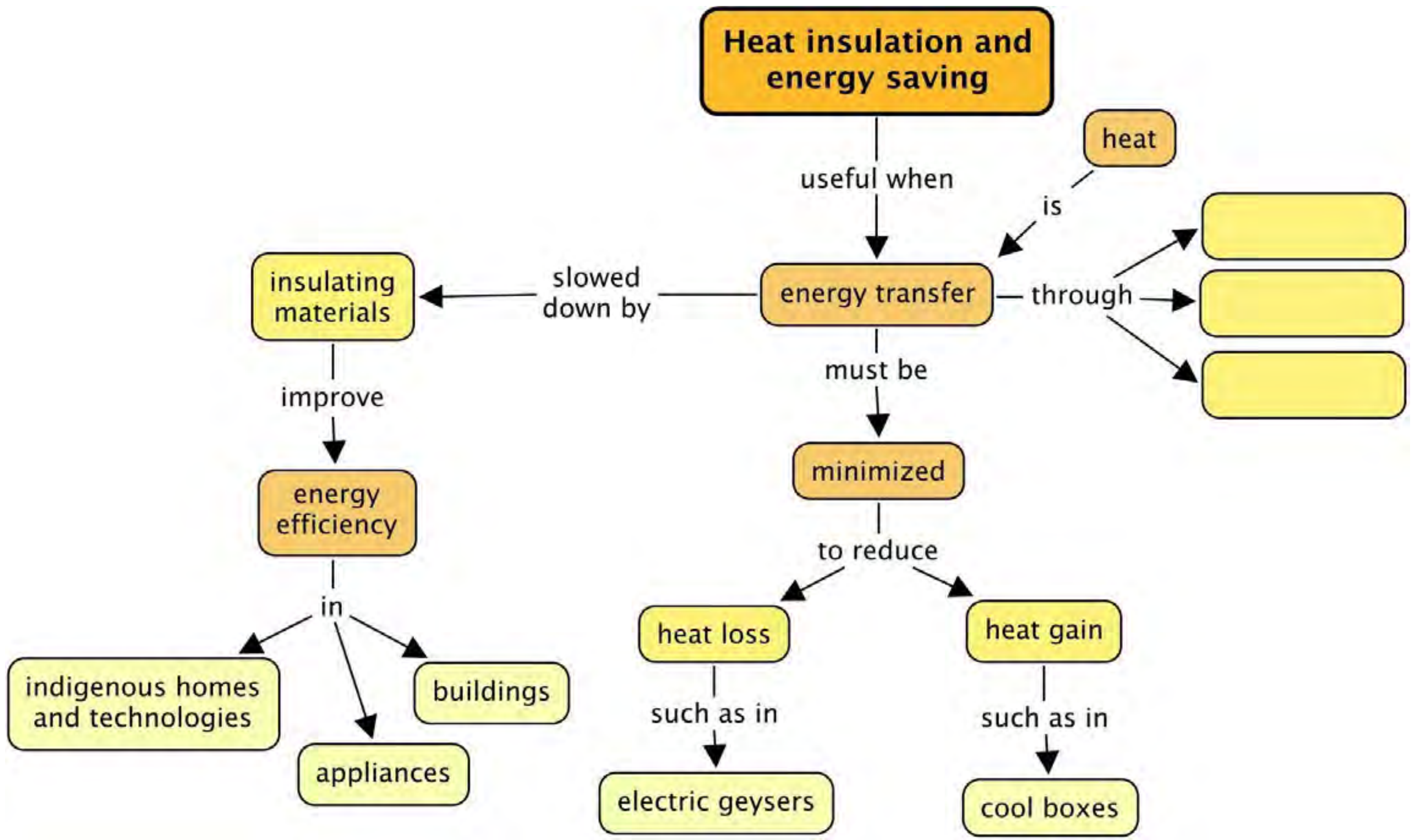
SUMMARY:

Key Concepts

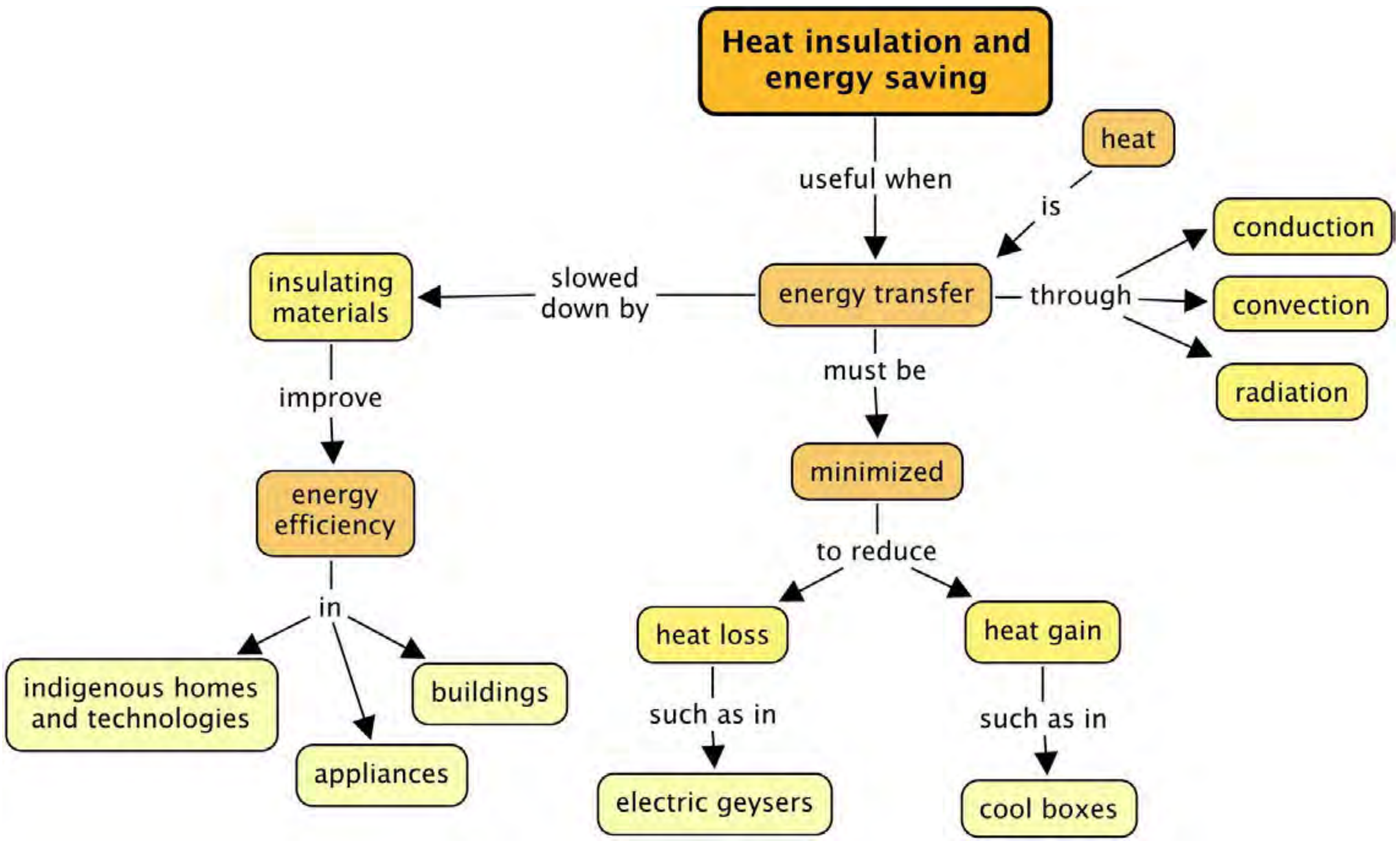
- Heat is transferred by conduction, convection and radiation
- In some cases, heat transfer is advantageous, for example from a heater to the air in a room.
- In other systems, heat transfer needs to be minimised or prevented.
- Insulating materials are used to minimise heat loss or gain from systems.
- Metals are good conductors of heat. Non-metal materials are good insulators of heat. Non-metals are used as insulating materials.
- We use insulators to keep our homes warm in winter and cool in summer. This helps to conserve energy and electricity.
- Indigenous homes in Southern Africa make use of insulating materials to be energy efficient in our climate.

Concept Map

Complete the following concept map by identifying the three ways in which energy is transferred.



Heat insulation and energy saving
useful when
heat
is
energy transfer
through
slowed down by
insulating materials
improve
energy efficiency
in
indigenous homes and technologies
appliances
buildings
must be
minimized
to reduce
heat loss
such as in
electric geysers
heat gain
such as in
cool boxes


Heat insulation and energy saving
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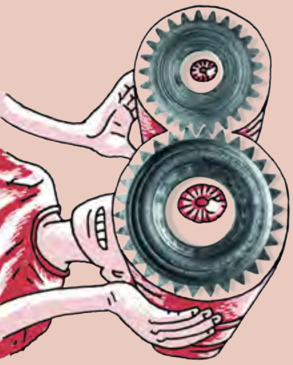


REVISION:

1. What is an insulator? [1 mark]
   An insulator is a substance which resists the transfer of energy (heat or electricity) through it.
2. Are the following statements true or false? If they are false, explain why:

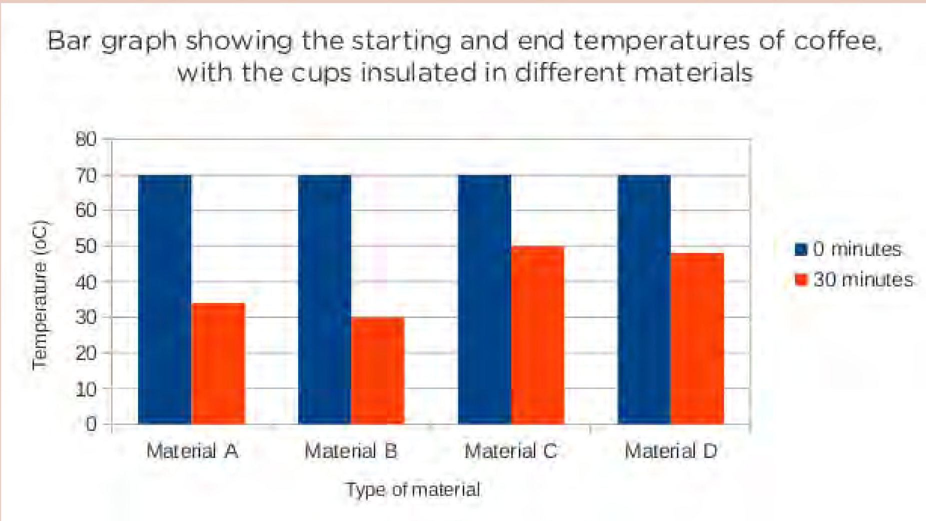
   a) A tea cosy keeps the cold out. [2 marks]
   b) Space is empty and so it is impossible for energy to transfer between the Earth and the Sun. [2 marks]
   c) On a cold day, insulating clothing reduces the energy transfer from your body to the surroundings. [2 marks]
   a) False. A tea cosy stops the heat from the tea from being transferred out of the tea to the surroundings.
   ***Note:** 'Cold' cannot be transferred. Cold is a measure of temperature.*
   b) False. The sun warms the earth through radiation which can travel through a vacuum.
   c) True
3. A man is building a wooden house. He lives in a very cold area, especially in winter. He has space for one window. He has two choices. He can put in a large window with a single pane of glass or he can put in a smaller window which has 2 panes of glass separated by a small air space trapped in between them. Which window do you think he should use? Why did you choose that window? [3 marks]
   He should use the smaller double-paned window as he needs to prevent heat loss in a cold environment. The air space slows the heat loss from conduction because the air is a poor conductor of heat. Also, the smaller window means that there is a smaller surface area for heat to escape.
4. Take away coffee is often served in paper cups with a corrugated cardboard layer on the outside. Why are these materials used? [4 marks]
   The coffee is very hot and the energy transfer to the surroundings needs to be reduced so that it stays hotter for longer. Paper is a poor conductor of heat. The corrugated cardboard allows a layer of air between the cardboard and the cup. Air is a poor conductor of heat. This means that less energy is transferred from the coffee to the person's hand and surroundings. Corrugated also means that there is less area of contact between the person's fingers and the cup. there is therefore less conduction so the person is less likely to burn their fingers.
5. You have designed a new material for insulating coffee cups. You're hoping to make money from this new material but you have to test that it works better than other materials. You arrange a blind test to convince a group of people who might invest in your new company so you can develop it. The scientist who is performing the test is given 4 different materials, labelled A, B, C and D. One of the 4 materials is your new material you have developed, but she does not know which one it is. This is called a blind test. She takes 4 beakers and wraps each one in a different material. She pours hot water into each beaker. She measures the temperature of the water at the start of the experiment and again 30 minutes later.
   The following table shows the results of her experiment.

Time (minutes)	Material A (°C)	Material B (°C)	Material C (°C)	Material D (°C)
0	70	70	70	70
30	34	30	50	48

a) What is the independent variable for this experiment? [1 mark]
b) What is the dependent variable for this experiment? [1 mark]
c) Draw a bar graph of the material collected. Show the starting temperature and end temperature for each material as separate bars. [8 marks]

d) After the experiment the results show that your material is the best insulator. Based on the results, which material (A,B,C or D) is yours? [2 marks]
e) How do you know? [2 marks]

a) The type of material is the independent variable.
b) The temperature of the water is the dependent variable.
c) Here is an example graph. Marks are allocated as follows:
0.5 marks for each of the bars [0.5 x 8 = 4 marks]
Appropriate heading [1 mark]
1 mark each of the headings for the axes [1 x 2 = 2 marks]
Putting the right variables on each axis. [1 mark]



Material C is your material.
e) Material C shows the smallest drop in temperature which means that the material prevented the most energy from transferring to the surroundings.

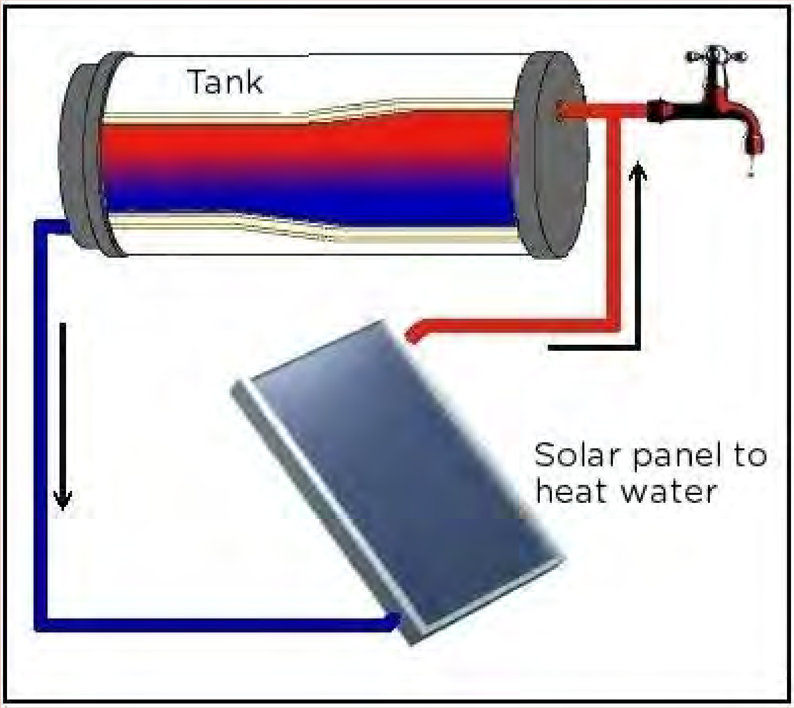
6. How does a thick woollen jersey help to prevent heat loss? [2 marks]
   The wool of the jersey acts as an insulating material as it is a poor conductor of heat. The thick jersey also traps a layer of air around the body. Energy from the body is transferred to this air via conduction. This warm air is unable to move away from the body because of the thick wool. The fibres of the wool trap air and the air is a poor conductor of heat.
7. Look at the following photo showing the inside of a ceiling in a house being constructed. Do you see the pink material?

The ceiling in a new house being built.

   a) What do you think this is for? [1 marks]
   b) How will it work? [2 marks]
   c) What type of climate do you think this house is being built in? Why? [2 marks]
   a) The pink material is an insulator to prevent heat loss.
   b) The material is a poor conductor of heat and so it minimizes heat from being transferred from the air in the house, through the roof and to the outside. The material also traps air in it, and the air is also a poor conductor of heat, increasing the insulation.
   c) It is probably being built in a cold climate as extra measures are being taken to reduce heat loss from the house.
8. Marathon runners are often given thermal blankets at the end of a long race which are made from plastic and have a shiny surface. This very thin, light blanket does not look very warm at all.

   a) How do you think it works? [2 marks]
   b) You might think that a wool blanket would be better for this purpose. why do you think the race organizers rather use these plastic blankets? [2 marks]
   a) The plastic is an insulator. The runners bodies get very hot during their race and so their bodies try to cool down by sweating. If all that heat escapes their bodies, the runners will cool down too quickly, resulting in cramps and they could get sick. The plastic traps the heat below the blanket. The reflective surface stops the blanket from emitting any heat to the surroundings.
   b) This is open to interpretation by the learners. The main reason is that the plastic blankets are much cheaper and disposable, and since they might be handing them out to many runners, it is more economical.

9. Study the following diagram showing the parts that make up a solar water heating system. This is a different type to the one we looked at in the beginning of the chapter. In this solar water heater, instead of evacuated tubes, there is a flat solar panel, called a collector.



a) What are the parts that make up this system? [3 marks]
b) Why does it make sense to have the outlet pipe for the tank to go to the solar panel at the bottom of the tank? [2 mark]
c) Why do you think the tap is at the top of the tank? [2 marks]
d) What sort of covering do you think this tank should have to make it the most efficient system? [2 marks]

a) The tank, the connecting pipes and the solar panel heater.
b) This is because as the water in the tank cools, it moves to the bottom (convection current) so the pipe at the bottom funnels this water to the heater to be warmed again.
c) Similarly to the previous question, the warm water is pumped from the solar panel heater and into the top of the tank. The warm water collects at the top of the tank as warm water rises (convection current). So, it makes sense to have the tap at the top of the tank to collect the water while it is warm. If the tap was at the bottom, the water would be colder.
d) It should be covered in an insulating material to conserve heat inside the water and reduce heat loss to the surroundings by conduction.

Total [48 marks]

5 Energy transfer to surroundings

TEACHER'S NOTE

Chapter overview

1 week

This chapter follows on from the last chapter where we mentioned that heat can be 'lost' as energy is transferred to the surroundings. This chapter now explains that within a system, there is useful energy which is transferred to the desired object or place, but no process is 100% efficient. Energy can be transferred to the surroundings rather than to the object or part of the system that you want it to transfer to. This is considered a waste of energy and systems are designed to try minimise this waste so that they are more efficient. There is always some loss of energy (wasted energy) and so there are always by-products to energy production. Some of the by-products are harmful to the environment.

Important to note is that CAPS makes the following statement:

- *'The output energy in a system is always less than the input energy, because some of the energy escapes to the environment.'*

This is **not correct** as the output energy is always equal to the input energy as energy is conserved within systems. The statement should rather state:

- *'The output energy in a system is always less than the input energy, because some of the energy escapes to the environment.'*

The wasted energy is still part of the output energy from the system, it is just not useful.

1.1 Useful and "wasted" energy (3 hours)

Tasks	Skills	Recommendation
Activity: Useful outputs from energy systems	Accessing and recalling information, identifying and classifying	Suggested
Activity: Energy transfers in systems	Accessing and recalling information, identifying and classifying	CAPS suggested
Activity: Drawing Sankey diagrams	Interpreting, sorting and classifying, communicating information graphically	Suggested
Activity: Researching energy transfers	Researching, accessing and recalling information, interpreting, sorting and classifying, communicating information; written, graphically	CAPS suggested

KEY QUESTIONS:

- What sort of useful energy output do some systems produce?
- What is meant by "wasted" energy?
- What is a Sankey diagram?
- How do we draw Sankey diagrams?

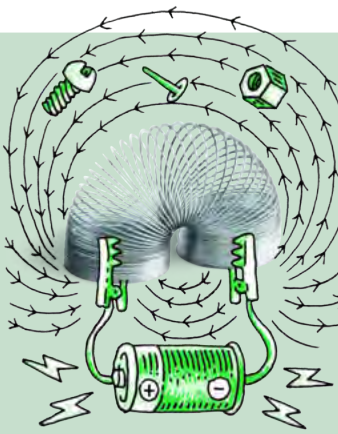
5.1 Useful and wasted energy

TEACHER'S NOTE

The learners will not have seen **Sankey diagrams** before. You should explain the usefulness of representing processes using pictures. Illustrations make a quick, visual impact on the viewer which makes it easier to understand a process. A Sankey diagram is a visual representation of an energy process showing the input energy and the output energy. Sankey diagrams should be drawn neatly and as close to scale as possible. Take the time to draw several examples on the board so that the learners see that all energy processes have more than one output energy type.

This term we have been looking at energy transfers within systems. Systems have an input energy and an output energy. Systems such as appliances, tools, vehicles and machines provide us with a useful output. Let's look at some examples to identify what these outputs are in some systems.

ACTIVITY: Useful outputs from energy systems



INSTRUCTIONS:

Look at each of the photos and identify what is useful to use from this system.

System	***What useful output does it provide us with?***
 *A light bulb.*	*Light*

VISIT

Watch how this chocolate rabbit melts beneath an energy-inefficient light bulb.
bit.ly/16s7AtK

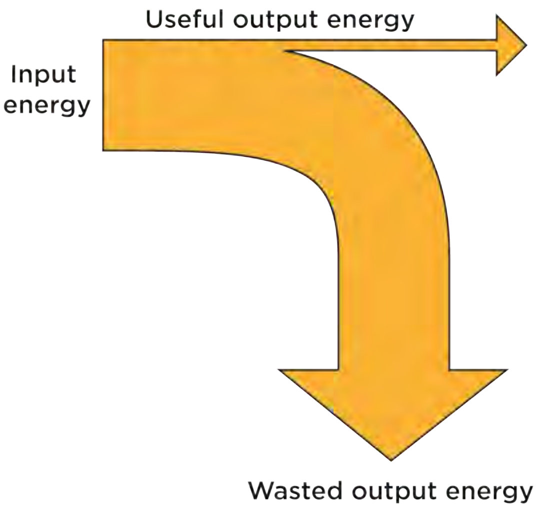
System	What useful output does it provide us with?
 An electric fan.	Movement
 An electric iron.	Thermal energy

What was the input for each of these systems?

Electricity/electrical energy.

Whenever we use an appliance or a machine we are transferring energy from one object to another. Not all the energy is transferred where we want it, a lot of it is transferred to the surroundings where it does not help us achieve our aims. The energy which is transferred to the surroundings is "**wasted**".

We can use a **Sankey diagram** to show how the energy is transferred in a system. This gives us a picture of what is happening and shows the input energy and how the output energy is made up of useful energy (arrow at the top) and wasted energy (arrow going to the bottom). Have a look at the following general example.



The width of the arrows tell us something in these diagrams. The input energy is the width of the original arrow. The width of both the output energy arrows (useful and wasted) add up to the width of the input arrow. Why do you think this is so? Think back to what you learned about energy within systems in Chapter 2.

TEACHER'S NOTE

This is because energy is neither created nor destroyed, but conserved within a system. So the input must equal the output energy in a system.

Sankey diagrams are drawn to scale so that the width of the arrows gives us a visual idea of how much energy is useful and how much is wasted. In the diagram above, you can see that only a small part of the input energy was useful and a large amount of the input was wasted by being transferred to the surroundings. An efficient system is one where the useful output energy is only slightly smaller than the input energy. An inefficient system has a lot of wasted energy. Do you think this is an efficient energy system? Why?

TEACHER'S NOTE

No, it is not efficient as a lot of the energy is wasted.

This brings us to our next point of how efficient an energy system is. If the wasted energy is much larger than the useful energy output, then the system is not energy efficient. The above Sankey diagram actually shows the energy transfers for a light bulb. You identified the useful energy output as light in the last activity. What do you think the wasted energy output is? Where does it go?

TEACHER'S NOTE

It is lost as heat, as energy is transferred to the surrounding air.

Do you see that an incandescent light bulb is actually not a very efficient system? This is because a lot of the energy is lost as heat as energy is transferred to the surroundings. Is there something more efficient? Look at the photo of a fluorescent light bulb.

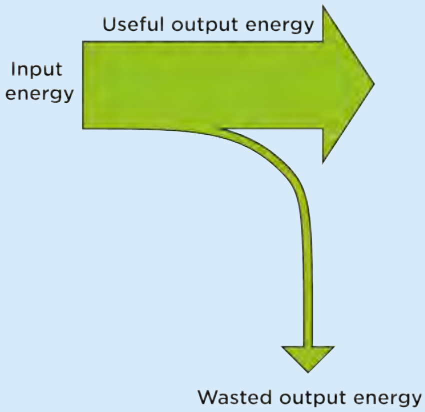

A fluorescent light bulb.

A fluorescent light bulb is much more efficient than incandescent light bulbs which use a heated wire to produce light. Most of the energy is lost as it is transferred to the surrounding air from the metal filament.

In a fluorescent light bulb, less energy is lost to the surroundings and more energy is transferred to useful light energy. Use this information to draw a Sankey diagram for a fluorescent light bulb in the space below.

TEACHER'S NOTE

Learner's diagram should look as follows:



Let's look at another example.

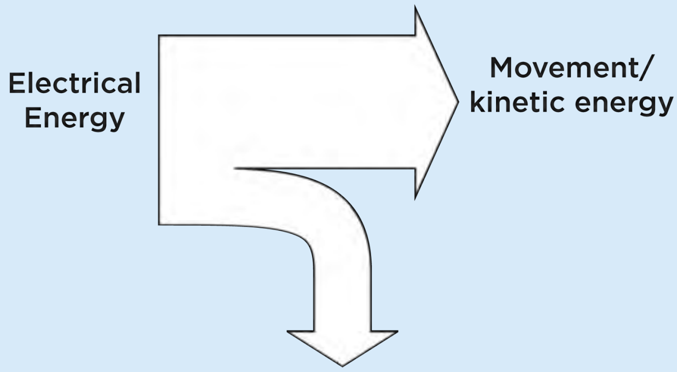
Look at the lady in the photo using an electric drill. The electrical energy from the drill is transferred to the drill bit as kinetic energy. The drill bit turns and drills into the metal. But the drill also makes a lot of noise. Energy is used to make sound and the drill bits get hot, so some of the energy is converted into thermal energy. This means that some of the electrical energy has been transferred to the surroundings as sound and thermal energy. This is energy that has been "wasted" because the sound and thermal energy are not useful to us.


A lady using an electric drill to make a hole in an aeroplane part.

Complete the following Sankey diagram by writing in what the energy input is, and then the energy outputs.

TEACHER'S NOTE

Learner's Sankey diagram should look as follows with the labels:

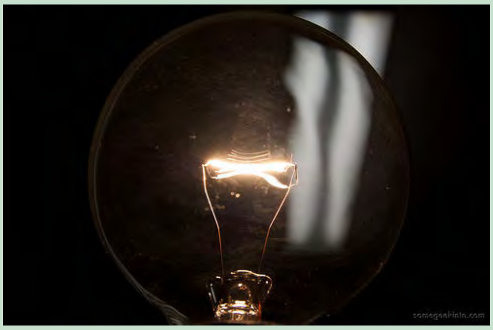


In order to draw a Sankey diagram you need to think carefully about the input energy and how the input energy is transferred to the surroundings. Let's practice this a bit more in the following activity.

ACTIVITY: Energy transfers in systems

INSTRUCTIONS :

1. Look at the following diagrams/photos of appliances.
2. Complete the tables showing the energy transfers for each diagram/photo. The first one has been completed for you.



Filament in a light bulb.

Energy INPUT	*Useful Energy OUTPUT*	*Wasted energy OUTPUT*
electricity	*light*	*thermal energy*

Burning candles.

Energy INPUT	**Useful Energy OUTPUT**	**Wasted energy OUTPUT**
potential energy in wax	*light*	*thermal energy*

An electric beater.

Energy INPUT	**Useful Energy OUTPUT**	**Wasted energy OUTPUT**
electricity	*movement/kinetic energy*	*sound, thermal energy*

A car engine.

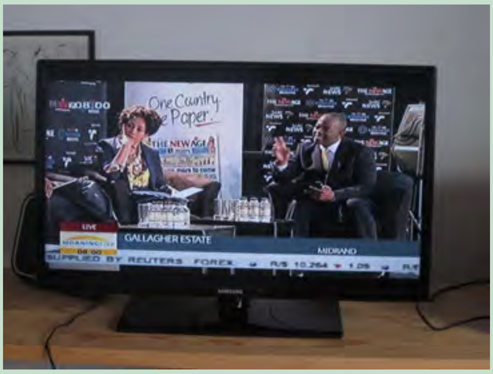
Energy INPUT	**Useful Energy OUTPUT**	**Wasted energy OUTPUT**
petrol/potential energy from burning fuel	*kinetic energy*	*thermal energy, sound*

Welding metal together.

Energy INPUT	Useful Energy OUTPUT	Wasted energy OUTPUT
electrical energy	thermal energy	light, sound

Athletes running.

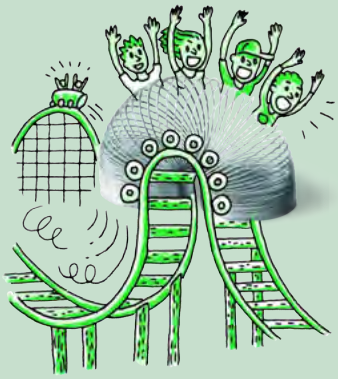
Energy INPUT	Useful Energy OUTPUT	Wasted energy OUTPUT
potential energy in food	kinetic energy	thermal energy, sound



A television.

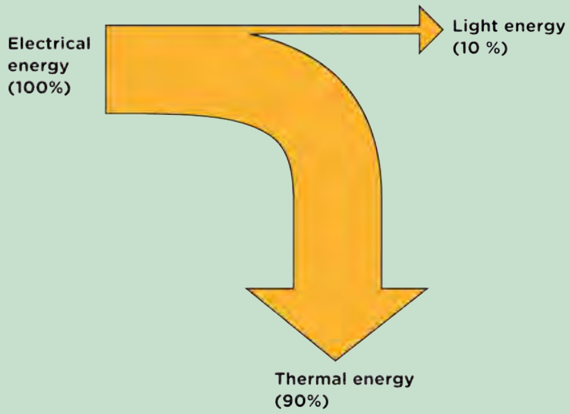
Energy INPUT	Useful Energy OUTPUT	Wasted energy OUTPUT
electrical energy	light, sound	thermal energy

Now that we have identified the energy transfers in each system and the input and output energy, let's practice drawing some more Sankey diagrams.



ACTIVITY: Drawing Sankey diagrams

Let's look at the example of a filament light bulb to draw a Sankey diagram. A filament light bulb only uses about 10% of the input energy to generate light, the rest is "wasted" because it warms up the surrounding air without producing any light. This means that our Sankey diagram must split into two parts: one for the light and one for the thermal energy which is transferred to the surroundings (heat). The thermal energy arrow must be 90% of the width of the input arrow and the light arrow must be 10% of the width of the input arrow.



VISIT

Video on drawing a basic Sankey diagram.

bit.ly/19jAwi4

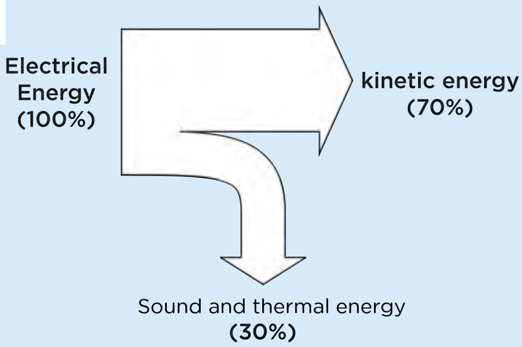
INSTRUCTIONS:

1. Now draw a Sankey diagram for some of the appliances from the last activity, which are listed below.
2. A description of the energy transfers has been provided for each appliance.
3. Concentrate on showing how the input energy is split between useful energy and wasted energy. Remember that the width of the arrow must show how much energy is transferred. A thick arrow means a large amount of energy, a thin arrow means a small amount of energy.
4. Show the various input and output energies and the percentages.

Electric beater:

The electric beater transfers 70% of the input energy to kinetic energy to beat the food and 30% is wasted output energy in the form of thermal energy and sound.

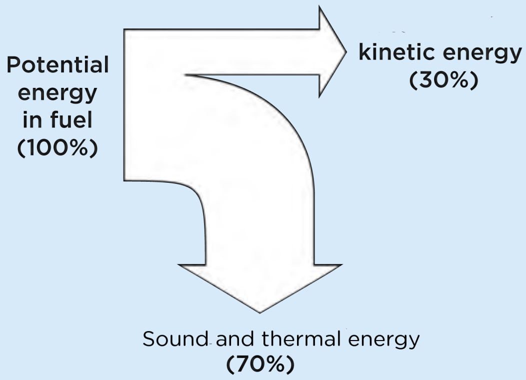
TEACHER'S NOTE



Car engine:

The car engine transfers only 30% of the input energy to move the car and 70% is wasted as sound and thermal energy.

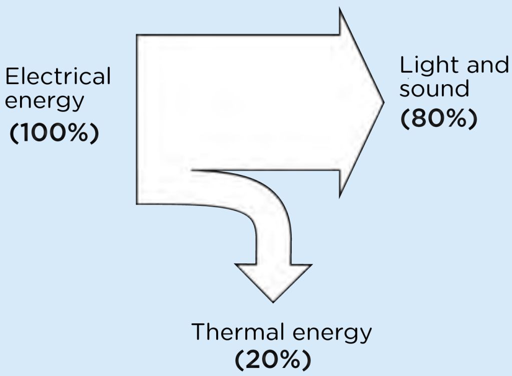
TEACHER'S NOTE



Television:

The television uses 80% of the input energy to create the images on the screen and sound and 20% is wasted as thermal energy.

TEACHER'S NOTE



QUESTIONS:

1. Which is the most efficient system in the above three examples? Why?
   The television as most of the energy input (80%) is transferred to useful output (light and sound) and only 20% is lost as thermal energy.
2. Which is the least efficient system in the above three examples? Why?
   The car engine as more of the energy input (70%) is wasted than the amount transferred to useful energy to move the car (30%).

Most of our everyday activities require some form of electrical energy. Electricity is produced by burning fuels and transforming the chemical potential energy into kinetic energy to generate electricity. Fossil fuels, such as coal, store huge amounts of energy but we can only harness a small percentage of that energy. A lot of the energy is transferred to the surroundings in the form of heat, sound and light.

ACTIVITY: Researching energy transfers

TEACHER'S NOTE

This is a research activity. If your learners have access to the internet and/or a library then allow them to spend some time researching the energy transfers in a power plant and a car engine. If your learners do not have access to the internet then it would be a good idea to print out some information from various websites that can be handed out to the class. You could let the printed information circulate through the class so that you do not need as many copies. This will save on paper and printing costs.

In this activity, they will first see how the wasted energy can be in more than one form and how to represent this in a Sankey diagram for a car engine. Learners will then research a power plant. You can get the learners to work in groups to find the information but make sure that each learner is able to write their own paragraph. This will give you a sense of whether or not the learner has understood what they have researched.

Here is a resource for reference: [1] bbc.in/15vnPFJ

TAKE NOTE

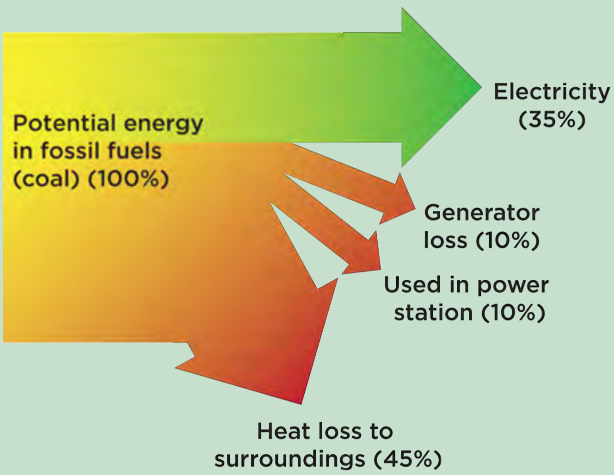
In our previous Sankey diagrams, we just had one arrow for wasted energy output, but it can split into more than one arrow to represent the different ways in which energy is wasted. There could also be more than one arrow for the useful energy, for example in the TV diagram above, light and sound are both useful and could be represented by two arrows.

In the last activity we looked at the energy transfers in a car engine. However, we only used one arrow to represent the wasted energy. We can show a difference between the ways in which energy is wasted in a Sankey diagram.

Use the following information to label the Sankey diagram:

- The input energy in a car engine is supplied by the combustion of petrol.
- Only 30% of the energy is transferred to useful output energy as movement.
- About 70% of the energy is transferred to the surroundings in the form of thermal energy and sound. Some of the energy is lost in cooling down the engine.
  - 40% is lost as thermal to the surroundings.
  - 20% is lost in cooling the engine.
  - 10% is lost as sound.

This is the labelled Sankey diagram:



In a power station, energy is transferred through the system in order to produce electricity. During the transfer of energy through the system, some of the energy is wasted.

Use the internet or other resources to find the different ways in which energy is transferred to the surroundings as wasted energy during the production of electricity in a power plant.

Write a short paragraph to explain the energy transfers. How is the input energy transferred through the system and where is the wasted energy lost?

TEACHER'S NOTE

The paragraph should include the following information:

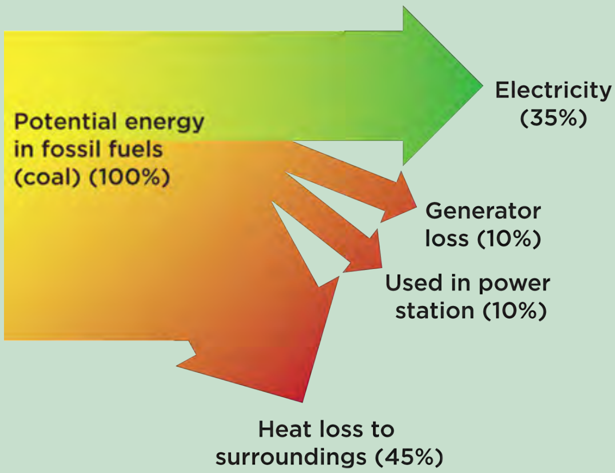
- Coal is burnt and the energy is transferred to the water and used to boil the water. Some of the energy is lost during this process.
- The steam from the boiling water is used to turn the turbine. The kinetic energy of the steam is transferred to the turbine. Some of the energy is lost to the surroundings as sound and thermal energy.
- The kinetic energy of the turbine is transferred to the generator. Some of the energy is lost to the surroundings as sound and thermal energy.
- The kinetic energy of the generator is used to generate electricity.

Draw a Sankey diagram for the energy transfers.

TAKE NOTE

Remember, energy is measured in joules (J).

An example for a Sankey diagram for a power plant is given below. You can also see what learners have found out and then draw one on the board to illustrate the transfers.



SUMMARY:

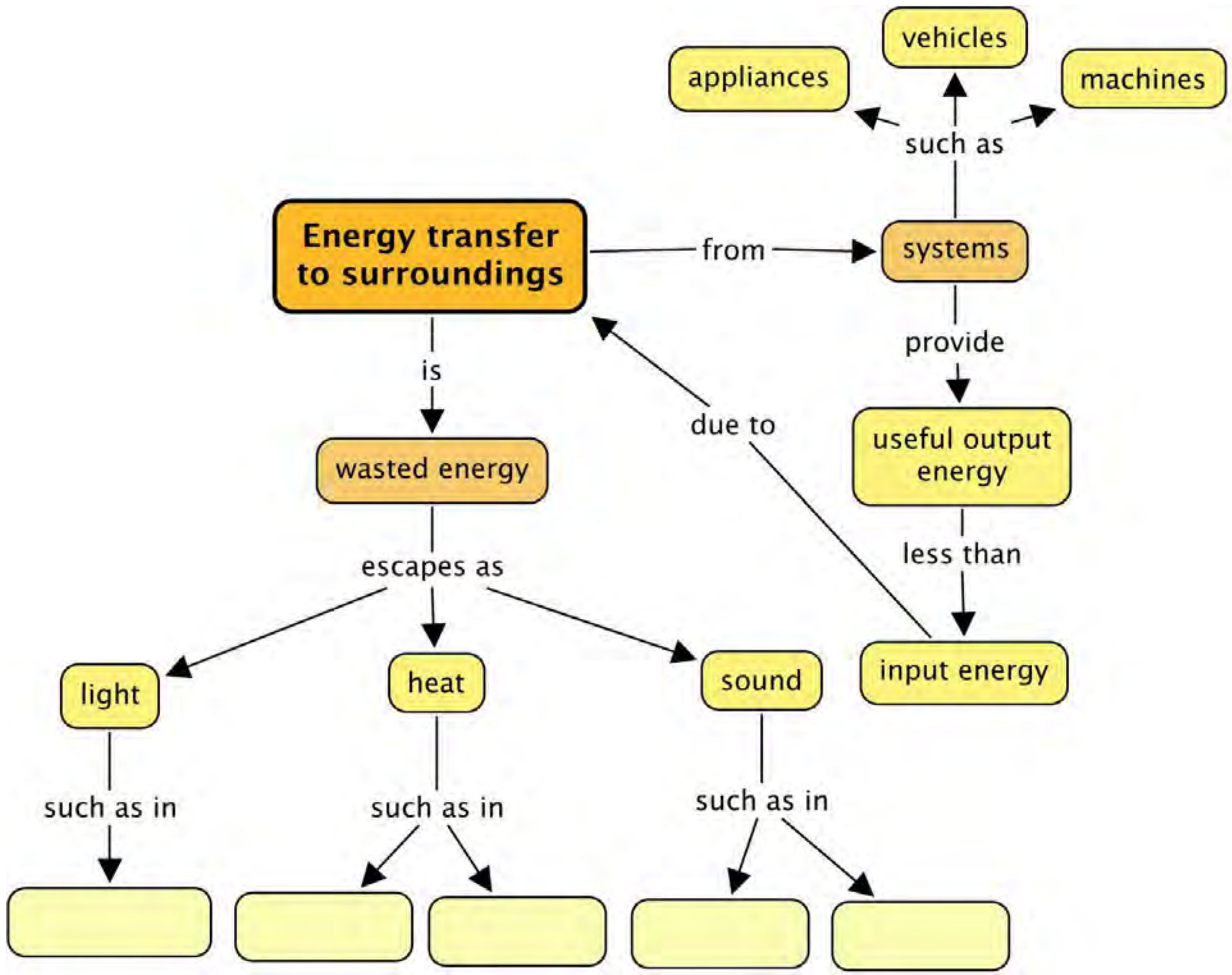
- Energy entering a system is called the input energy.
- The energy is transferred in a system to provide a useful output energy.
- Tools, appliances, vehicles and machines all provide useful energy outputs.
- Not all of the input energy is transferred to a useful output. Some of the energy is wasted or lost. The useful output is therefore less than the input energy as some of the output energy is wasted.
- An example is a light bulb where the input is electricity and the useful output is light. However, a large amount of the energy is lost to the surroundings as thermal energy.
- The efficiency of a system is determined by how much of the input energy is transferred to useful output energy. The greater the wasted output energy, the less efficient the system.
- A Sankey diagram is used to show the energy transfers in a system.
- In a Sankey diagram, the arrows represent the portion of the input energy which is transferred to useful energy output and the portion which is transferred to the surroundings and wasted.

Concept Map

Complete the concept map by giving two examples of systems where energy is transferred to the surroundings and "wasted" as sound and thermal energy, and one example of where the wasted energy output is light.

TEACHER'S NOTE

Teacher's version. The examples given here are not the only examples. Learners can use any of the examples discussed in the chapter which are appropriate.


Energy transfer to surroundings
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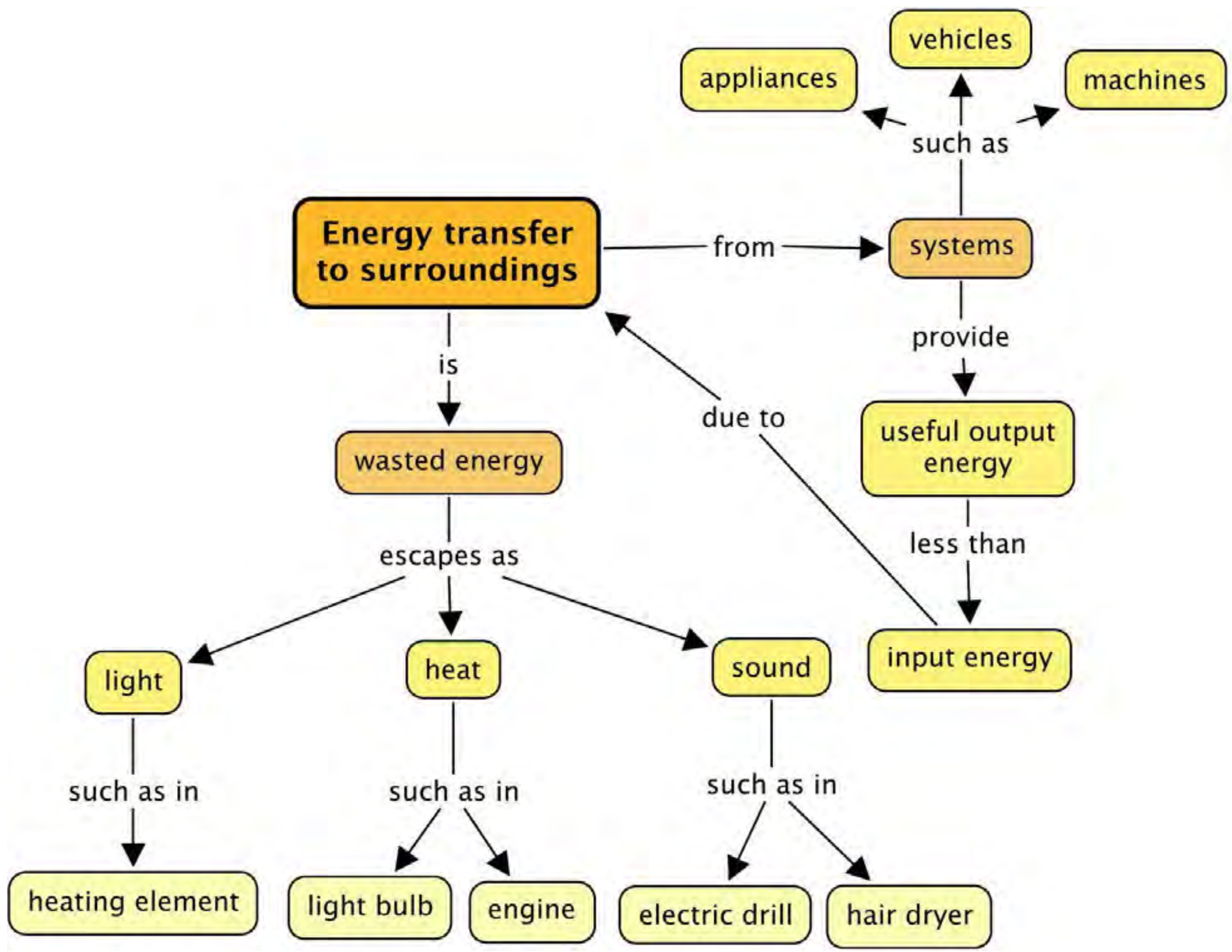
Energy transfer to surroundings
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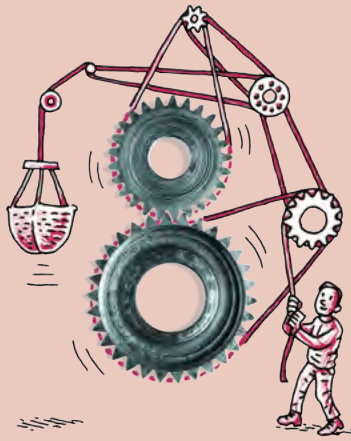
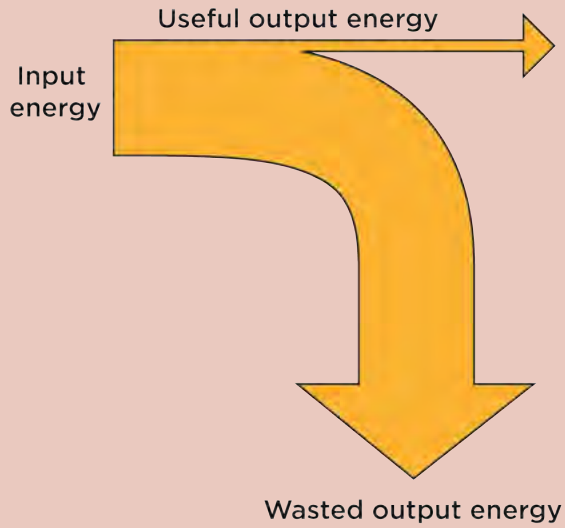
electric drill
hair dryer



REVISION:

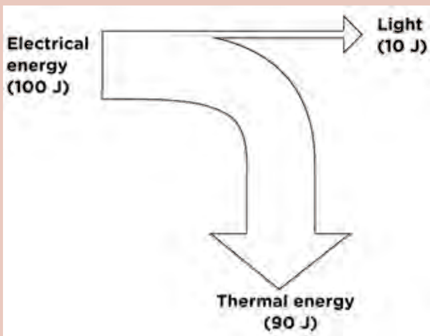
1. What is meant by "wasted" energy? [2 marks]
In an energy system, some of the energy is transferred to the surroundings in ways which we did not intend or are not useful. This amount of energy serves no useful purpose and so it is "wasted".
2. Draw a simple Sankey diagram to show the energy transfers in a system where the wasted energy output is more than the useful energy output. [4 marks]



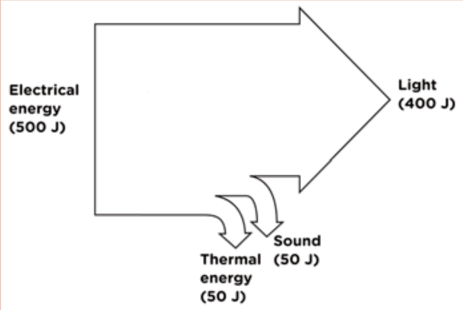
In the chapter, learners used percentages to draw their Sankey diagrams. The following is an extension and starts off with a simple example which they have already seen in the chapter, namely a light bulb, but the energy transfers were represented as percentages. In the first example here, we now start off with 100 J instead of 100%. The Sankey diagram will be straightforward to draw. However, in the subsequent examples, the input energy is more than 100 J. Learners do not need to calculate the percentages, but the thickness of the arrows should be representative of the amount transferred.

3. For each of the following situations, draw a labelled Sankey diagram to show the amount of input energy, useful energy and wasted energy.
   a) An electrical torch converts 100 joules (J) of electrical energy to 10 J of light energy and 90 J of thermal energy. [3 marks]

An electric torch.

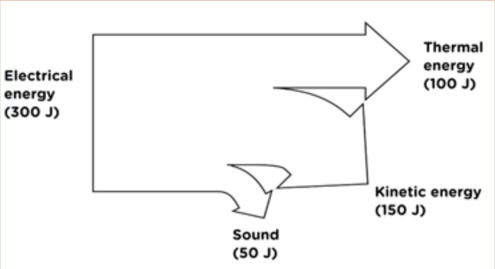


b) A television has an energy output of 500 J. 400 J is in the form of light. 50 J is in the form of sound and 50 J is thermal energy. [3 marks]



A television set.

c) A hair dryer converts 300 J of energy into 150 J of kinetic energy, 100 J of thermal energy and 50 J of sound energy. [3 marks]



A hair dryer.

4. Write a description of the energy transfers in each of the situations in question 3. [6 marks]
   a) The potential energy from the batteries in the torch is transferred to the filament of the bulb. The energy is transferred to the surroundings as thermal energy and light. Most of the energy is transferred as thermal energy which is not useful and only some of the energy is transferred as light.
   b) The energy from the TV is transferred to the surroundings as thermal energy, sound and light. The light and sound are useful because they are the images and sounds we want to hear. The heat is wasted energy.
   c) The energy from the hair dryer is used to heat the air and dry our hair. Two thirds of the energy is useful thermal energy but one third is transferred as sound, which is not useful to us.

5. What is the difference between a filament light bulb and an energy saving light bulb? [2 marks]
   A filament light bulb uses a metal filament and an energy saving light bulb uses a fluorescent gas to provide light.

6. Why is an energy saving light bulb better at saving energy than a filament light bulb? [3 marks]
   A lot of the energy used to make a filament bulb glow is used to heat the metal to make the metal glow. This means that a lot of the energy is wasted as thermal energy when we actually want light. Energy saving bulbs don't have to heat the gas before it will glow and so it wastes less energy.

7. In the last chapter we looked at insulating materials and how they help reduce energy transfer. Use this knowledge, and what you have learned in this chapter about input energy, useful output energy and wasted energy, to explain why an electric geyser should have an insulating layer on the outside. [4 marks]

An electric geyser transfers electricity to thermal energy in the water particles as the water is warmed up. The useful output is the thermal energy to warm the water. However, some of this thermal energy can escape from geyser to the surroundings. This is therefore wasted. In order to make the geyser system more efficient so that the useful energy output is greater and the thermal energy loss is minimised, the geyser should have an insulating covering, to reduce energy transfer to the surroundings by conduction.

8. In the electric geyser, the heating element is placed near the bottom of the geyser. Why is this? [2 marks]
   The heating element is placed at the bottom as this is more efficient because as the water warms up due to the transfer of energy, the heated water expands and moves upwards, and the cold water moves down in a convection current, thereby warming all the water.

TEACHER'S NOTE

This links back to the previous chapters so that knowledge is revised and reinforced.

Total [32 marks]

The national electricity supply system

TEACHER'S NOTE

Chapter overview

1 week

This chapter revises some of the concepts covered in Gr. 6 Energy and Change on the supply of electricity. The learners should already have a basic knowledge of the national grid and this chapter will expand on those ideas, and discuss how the national grid is a system to supply electricity. This chapter also introduces the concept of a dynamo and the role that Eskom plays in producing electricity. Learners will be given an opportunity to research different careers in the field of energy production.

If you only teach Natural Sciences, it is a good idea to check with the Technology teachers to see how these two curriculums complement each other, especially with regard to electricity. Some of the concepts which might be introduced for the first time in Natural Sciences, have already been covered in the Technology curriculum. Knowing what learners have already covered and been introduced to will help make your classes more efficient and more stimulating for learners.

1.1 Energy transfers in the national grid (2 hours)

Tasks	Skills	Recommendation
Activity: Overview of the national electricity grid	Accessing and recalling information, defining and describing, comparing, identifying	CAPS suggested
Activity: Turning a pinwheel	Making, observing, describing	Suggested
Activity: Energy transfers	Accessing and recalling information, interpreting, sorting and classifying, communicating information graphically	CAPS suggested

1.2 Conserving electricity in the home (1 hour)

Tasks	Skills	Recommendation
Activity: Geyser blankets and solar geysers	Accessing and recalling, explaining	Suggested
Activity: Conserving electricity	Sorting and classifying, problem-solving, describing	CAPS suggested
Activity: Writing a letter to your local newspaper	Accessing and recalling information, research, communicating in written form, identifying problems and issues, raising questions, problem-solving	Optional
Activity: Career research	Research, raising questions,	Optional

KEY QUESTIONS:

- How does Eskom produce electricity?
- What energy is transferred during electricity generation?
- How does the electricity reach our homes?
- Can we use as much electricity as we like?
- How can we save electricity?

6.1 Energy transfers in the national grid

Do you remember learning about the mains electricity supply in Gr. 6 Energy and Change? We learnt that the electricity that is used to power our homes, schools, shops and other buildings is generated in power stations and delivered to us in the **national electricity grid**. In this chapter we are going to be looking in more detail at how electricity is generated and delivered to the consumers.

TEACHER'S NOTE

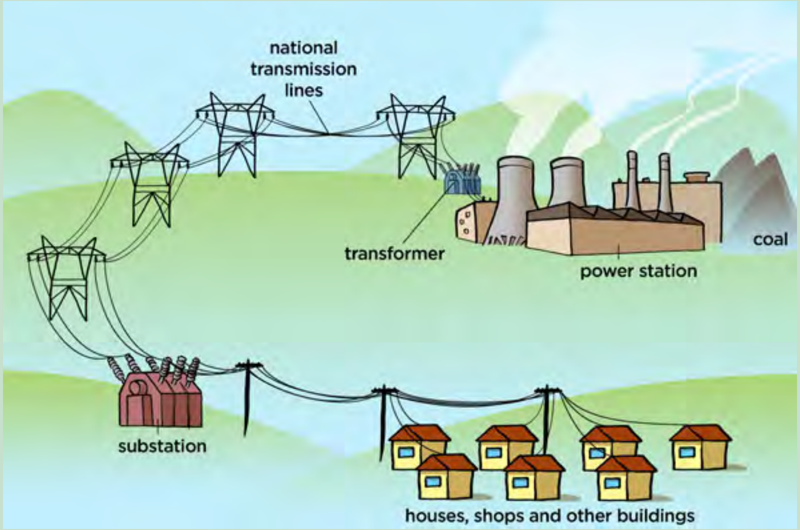
The visit box refers to an excellent video on the national grid and summarises where energy comes from, how it is harnessed, and how it is distributed. It links back to work covered in Gr. 5 and Gr. 6. It does, however, only refer to the national grid of the UK and USA. You could use this as an opportunity to discuss the South African national grid in contrast to international electricity grids and supply systems. [1] bit.ly/1hniv7m

The national grid is a system

Let's look at the different parts of the national electricity grid.

ACTIVITY: Overview of the national electricity grid

The following is a diagram of the national electricity grid. This gives you an overview of the process and different steps that we will be discussing.



QUESTIONS:

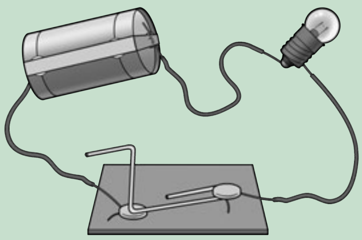
TEACHER'S NOTE

Some of the questions here link back to what was covered in the earlier chapters this term, which serves to revise concepts and also create connections between concepts. This reinforces learning.

TAKE NOTE

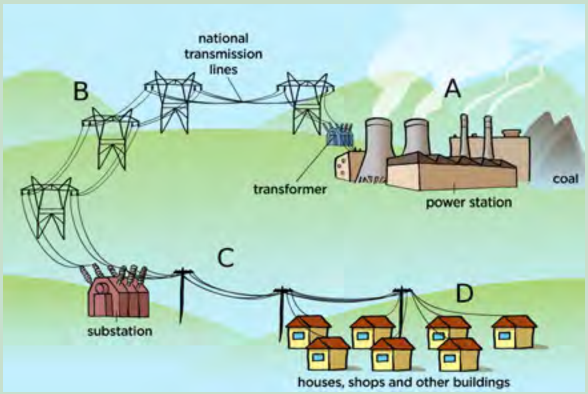
In the simple circuit, the circuit is completed as the wire goes from the bulb back to the battery. We cannot see this in the national electricity grid, but there are also power lines which connect back to the station to complete the circuit.

1. Write your own definition of a system.
   A system is a set of parts that function together as a whole.
2. What does the Law of Conservation of energy tell us about the energy in a system?
   The energy is conserved in a system, it is neither created nor destroyed.
3. Look at the diagram of the national electricity grid. Do you think it is a system? Why?
   Yes, it is a system as it is made up of different parts, such as the power station, transmission lines, buildings, which function together to generate and deliver electricity.
4. The national electricity grid is actually a big electrical circuit. Look at the following diagram of a simple electric circuit that you might have made in class and the diagram of the national grid. We can draw similarities between this circuit and the national electricity grid to understand it.



5. The battery is the source of potential energy in the simple circuit. What generates electricity in the national electricity grid?
   The power station.
6. In the simple circuit, the conducting wires transmit the electricity in the circuit. What does this job in the national electricity grid?
   The transmission power lines.
7. In the simple circuit, the useful output energy is to make the light bulb light up. What are some of the useful outputs in the buildings where the electricity is delivered to in the national electricity grid.
   There are many useful outputs, such as lights in houses, schools, heaters, warming water in geysers, running any appliances or tools, etc.
8. In Chapter 1 of this term, we discussed sources of energy. What is the source of energy for the power station in the diagram?
   Coal.
9. Is this a renewable or non-renewable energy source? Why?
   It is non-renewable as there is only a limited amount of coal on Earth. It is not being regenerated at a fast enough rate for it to be renewable.
10. We can divide the national electricity grid up into 4 main stages. These are:
    - **A: Generation** (this is where electricity is generated)
    - **B: Transmission** (the electricity enters the power lines of the national grids and is transmitted)
    - **C: Distribution** (the electricity is distributed at substations to various towns and areas)
    - **D: Consumers** (this is where the electricity is transferred to useful energy outputs)

    Use this information to write the letters A, B, C and D on the diagram of the national electricity grid to label these stages.
    The learners should write the letters in the approximate places as shown below:



VISIT
Great video that provides a comprehensive overview of where energy comes from and how it is distributed via the national grid.
bit.ly/16s7EtM

Let's now take a closer look at the first stage in the national electricity grid, namely how electricity is generated.

How electricity is generated and supplied

Do you remember that in Chapter 2 we looked at another renewable way that electricity is generated using a hydropower plant. The water in the dam was used to turn the **turbine** to generate electricity. What energy did the water have when it was at the top in the dam?

TEACHER'S NOTE

Potential energy.

What was this energy transferred to as the water fell and turned the turbine?

TEACHER'S NOTE

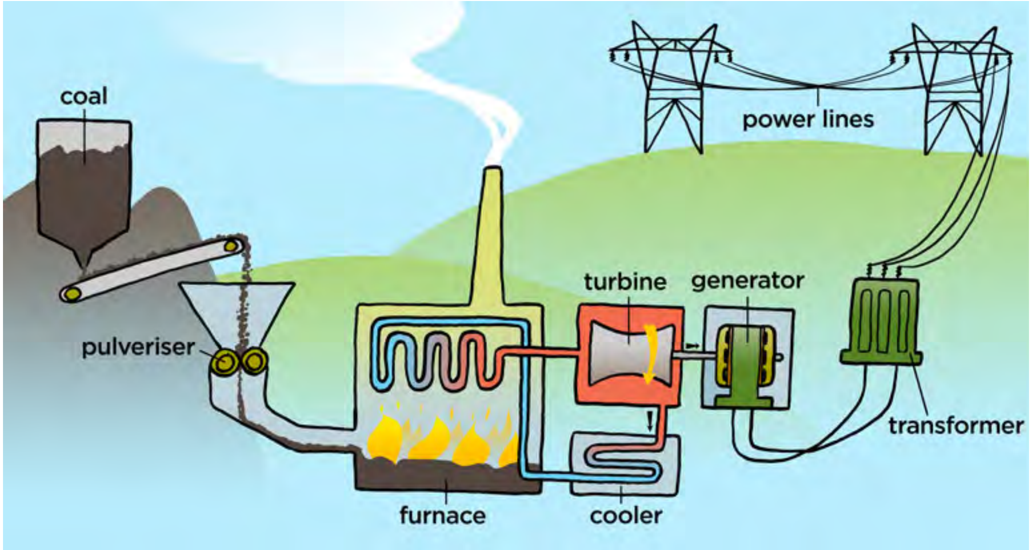
It is transferred to kinetic energy.

In South Africa most of the power stations use coal for fuel. We are therefore going to learn more about how coal-powered power stations work. The coal is mined out of the earth. The coal is transported to the power station in large trucks or trains.

This is the Orlando Power Station in Soweto which served Johannesburg for 50 years from 1951. It is not used anymore. The painted cooling towers are seen most prominently, but the building to the right is also part of the power station.

A coal-powered power station.

Let's take a closer look at what happens inside a power station. Have a look at the following diagram.



1. The large chunks of coal are first crushed into a fine powder. This is called **pulverisation**.
2. The coal is then transported to a **furnace** where it is burnt.
3. The thermal energy from the burning coal is used to boil water and generate **steam**.
4. The steam pushes the blades of the **turbine** and so the turbine spins.
5. The turbine is connected to the shaft of the **generator** which then turns large magnets within wire coils, which generates electricity.
6. The **electric current** is sent through the **power lines** to businesses and homes.

TAKE NOTE

We will learn about how coal is formed next term in Planet Earth and Beyond.

Now that we know the basic process for producing electricity, let's look more closely at how energy is transferred from one part to another in the system.

Energy transfers in the national grid

In a coal-powered power station, the potential energy stored in the coal is used to boil water to produce steam.

The thermal energy in the steam is transferred to a turbine. This allows the turbine to turn which means that the turbine now has kinetic energy. Can you see how energy is transferred from a thermal system to a mechanical system?

A steam turbine with the outer case removed.

How does the steam make the turbine turn? Let's make a simple turbine (pinwheel) and see how it works.

ACTIVITY: Turning a pinwheel

TEACHER'S NOTE

If you do not have enough time in class to have each learner make their own pinwheel then either make a few before class that the learners can use or just make one to use as a demonstration. You may also be able to purchase small pinwheels to save class time.

Some kettles may produce a weaker stream of steam and so it would be a good idea to test the kettle with a paper pinwheel before doing it with the class. You can also watch the video provided in the Visit box.

If the pin wheel which is made using the A5 paper is too large to turn in the steam from a kettle, then redo the activity using a smaller piece of paper. Starting with a smaller piece of paper will result in a smaller pinwheel. Take note that the commercial pinwheels made from plastic often curl and melt in the steam.

VISIT

How to make a pinwheel (video) bit.ly/1923wdW

MATERIALS:

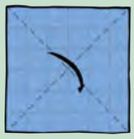
- A5 stiff cardboard
- pair of scissors
- straw
- pin
- kettle

INSTRUCTIONS:

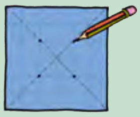
1. Start with a piece of paper. Fold the rectangular A5 page into a square.

2. Use the scissors to cut off any excess paper.

3. Fold the square corner to corner and then unfold so that you have diagonal crease marks.



4. Make a pencil mark about a third of the way from the centre along each diagonal line.



5. Use the scissors to cut along the fold lines and stop at the pencil mark.

6. Bring each point to the centre of the square and stick a pin through all four points.

7. The head of the pin forms the centre of the pinwheel.

8. Turn the pin wheel over and make sure your pin goes through the exact centre.

9. Stick the pin into a thin stick or straw. Make sure that the pinwheel is free to turn. You can also place a small bead in between the pinwheel and the stick to make sure it spins easily.

TAKE NOTE

We have mostly looked at coal-powered power stations, but other energy sources, such as hydropower or nuclear power, can also be used to transfer energy to the turbine.

10. Boil a kettle. The kettle must be full and boiling rapidly.
11. Hold the pinwheel over the spout of the boiling kettle and watch it.

TEACHER'S NOTE

Make sure to point out the thermal system (the kettle and boiling water) and the mechanical system (the turning pinwheel) and how energy is transferred between these systems.

QUESTIONS:

1. What happened to the pinwheel when it was held in the steam from the boiling kettle?
The pinwheel turned when it was placed in the steam.
2. Why did the pinwheel turn? Explain the energy transfers which are taking place.
The element in the kettle transfers energy to the water in the kettle. The water then gets to boiling point and changes phase to water vapour. The steam rises because of convection. The moving particles push against the blades of the pinwheel and cause the pinwheel to turn. The steam has a lot of kinetic energy which is transferred to the blades of the pinwheel causing it to turn. There is a transfer of energy between a thermal system and a mechanical system.

The turning turbine is attached to the axle of a generator. The turning turbine turns the generator. So the turbine transfers its kinetic energy to the generator.

A generator consists of a very large **solenoid** with a large rotating magnet. The solenoid is made up of thousands of coils of conducting wire. When the magnet is turned inside the coil, the generator produces electricity. The electricity is then sent to our homes through the national grid power lines. We use the energy in our homes to make our appliances work.

The national power lines transmit electricity across the country from the power stations.

TAKE NOTE

We will learn more about electromagnets next year in Gr. 8.

TEACHER'S NOTE

If possible, organise an excursion with your learners to a power station in your area. Here is a link to the Wikipedia article which lists all the power stations in South Africa. [2] bit.ly/15vo5Vk

Here is a table summarizing some of the various power stations in South Africa and and which province they are located in, for your reference.

Coal-powered stations

Power station	Province
Arnot Power Station	Mpumalanga
Bloemfontein Power Station	Free State
Camden Power Station	Mpumalanga
Duvha Power Station	Mpumalanga
Kelvin Power Station	Gauteng
Lethabo Power Station	Free State
Matimba Power Station	Limpopo
Pretoria West Power Station	Gauteng

Hydroelectric Power Stations

Power station	Province
Drakensberg Pumped Storage Scheme	Free State
Gariep Dam	Free State-Eastern Cape border
Ingula Pumped Storage Scheme	KwaZulu-Natal
Kouga Dam	Eastern Cape
Palmiet Pumped Storage Scheme	Western Cape
Steenbras Pumped Storage Scheme	Western Cape
Vanderkloof Dam	Northern Cape

ACTIVITY: Energy transfers

TEACHER'S NOTE

The description of the production of electricity given in the text before this activity and the videos should give the learners enough information with which to draw a simple flow diagram showing how energy is transferred through the system, from the coal to the power lines.

INSTRUCTIONS:

1. Use the information given in this chapter about how electricity is produced to draw a flow diagram of the energy transfers which take place in the production of electricity in a coal power station.
2. Start with the burning of coal and end with the transmission of electricity in the power lines.

TEACHER'S NOTE

This is an example of the type of flow diagram required. If learners are battling, start the diagram off with them by showing the first step and then they can complete it.

Dynamos

TEACHER'S NOTE

Take note that an electric generator is a device that converts mechanical energy into electrical energy, normally using electromagnetic induction. A dynamo was actually the precursor to the modern day electric generators. now, it can be considered as a type of generator that produces **direct** current, with the use of commutators. At this level though in Gr. 7, we are not explaining the difference between direct and alternating current. Generators are used all over the world now, and dynamos are considered to be an instrument of the past, however, they are still used in some instances where a low powered DC current is required, such as a bicycle light, as discussed here. Make sure that learners do not use the words generator and dynamo interchangeably as a dynamo is a type of generator, but it is incorrect to call a generator a dynamo.

TAKE NOTE

A dynamo is a type of generator, but a generator is not necessarily a dynamo.

Eskom produces electricity by using large generators but we can produce electricity on a smaller scale using a **dynamo**. A dynamo is a type of generator and they are considered to be the device that came before and led to the development of the modern day electrical generators that are used now all over the world. However, dynamos are still used in some places where a low current is needed.

A bicycle light is powered by a small dynamo. A bicycle dynamo has a small magnet which is turned inside a metal coil. The magnet is turned by the motion of the bicycle wheel.

A dynamo on the wheel of a bicycle.

Do you see the cog which turns at the top as the wheel goes around? This turns the magnet enclosed in the dynamo. Explain the transfer of energy in this system.

TEACHER'S NOTE

The movement (kinetic energy) of the wheel is transferred to electrical energy.

What is the advantage of having a dynamo on the bicycle, rather than a battery for example?

TEACHER'S NOTE

The dynamo is used to generate electricity to power a light for the bicycle. This is useful as a battery will only last for a certain amount of time and run out. But, a dynamo will work whenever you are cycling as it just needs the movement of the wheel.

Dynamos are also used in mining helmets and wind-up torches and radios. If a miner's light on his helmet goes out, he can just wind up the dynamo again to generate electricity for the light. This is very useful when miners are deep underground and they cannot afford to have no light. A battery-powered light has the risk of running out and there is no way to recharge it when underground.

Electricity is very expensive to produce and, in South Africa, we rely heavily on non-renewable sources of energy such as coal. The burning of fossil fuels releases greenhouse gases into the atmosphere, causing damage to our environment. We therefore need to conserve electricity.

VISIT
How a coal power station works (video)
bit.ly/18qGMbl

6.2 Conserving electricity in the home

In South Africa, electricity is produced by Eskom and sent to our homes through the wires of the national grid. Eskom charges us for the electricity we use. In order to save money and to preserve our environment we need to make sure that we use as little electricity as possible.

There are many ways to cut down on the amount of electricity we use in our homes. Simple things such as switching off lights when you leave a room or using extra blankets to keep warm rather than a heater. Air conditioners also use a lot of electricity so using them only when really necessary will also help to save electricity.

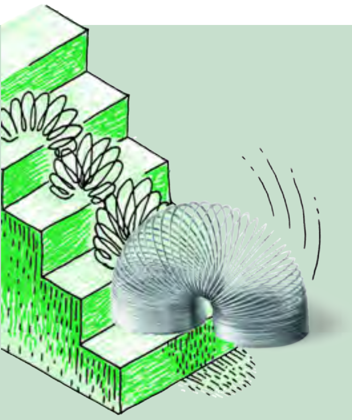
An electric oven.

There are several common household appliances which use a lot of electricity. The element of an electric stove and ovens use a lot of electricity in order to stay hot enough to cook food. Electricity can be saved by making sure that the oven is switched off as soon as the food has been cooked.

An electric stove usually has several different sizes of heating elements. In the photo there are two large plates and two smaller ones. It is important to use small pots on small elements and large pots on larger elements. Why do you think this is?

TEACHER'S NOTE

The part of the heating element which is not covered by the pot is transferring thermal energy to the air surrounding the element rather than to the pot and so a lot more energy is "wasted".



ACTIVITY: Geyser blankets and solar geysers

Any appliance that produces heat requires a lot of electricity. A **geyser** is an appliance which uses a lot of electricity. A geyser is a cylindrical tank which is used to warm and store hot water for people to use in their homes. It takes a lot of energy to warm the water and so a lot of electricity is needed. A lot of the energy transferred to the water is wasted because the air around the geyser gets warmed up as energy leaves the water and is transferred to the air. The geyser has to keep warming the water to keep the temperature constant.

One way to help reduce the energy loss to the surrounding air is to use a geyser blanket. Geyser blankets are usually between 50 mm and 150 mm thick and are often made from fibreglass and other insulating materials. They are covered with a reflective aluminium layer.

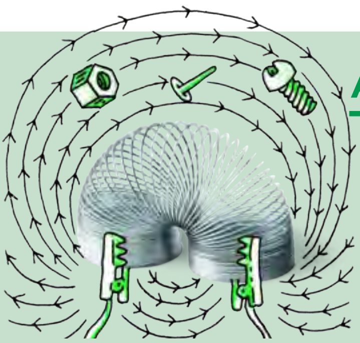
Solar geysers do not use electricity from the national grid for their energy needs. We have already learnt about how they work.

VISIT
The Eskom website has several tips on how to conserve electricity.
bit.ly/184fGpK

QUESTIONS:

1. Use your knowledge of insulating materials to explain how a geyser blanket could help reduce energy loss from the water to the surroundings, and therefore conserve electricity.
   The thick fibre layer helps to reduce the energy loss by slowing down the conduction of heat from the water to the air. The shiny aluminium layer is not a good emitter of radiation and so less energy is lost through radiation.
2. How does installing a solar geyser contribute to relieving demand placed on the national grid?
   The solar panels generate the required electricity and so it isn't generated by Eskom. It is the electricity supplied by Eskom that needs to be conserved. This also reduces the demand on non-renewable energy sources which have a negative impact on the environment.

Let's look at some more ways to conserve electricity.



ACTIVITY: Conserving electricity

INSTRUCTIONS:

Look at the grid below. If the instruction helps to SAVE electricity, colour it in BLUE. If the statement WASTES electricity, colour it in RED.

Turning off appliances when on holiday	Leaving lights on in an empty room	Using an electric blanket	Using fluorescent lights	Using filament lights
Wearing jerseys and warm clothes in winter	Leaving outside lights on during the day	Using an electric toothbrush	Running full loads in the washing machine	Switching off the geyser during the day
Boiling a full kettle	Using a gas heater	Hanging clothes outside to dry	Turning the TV off when no one is watching	Using a geyser blanket
Running half loads in a dishwasher	Leaving the oven on when nothing is cooking	Using an electric can opener	Running an air conditioner with the windows open	Using a tumble dryer

1. Look at all of your red blocks. Rewrite each statement so that it changes from a waste of electricity to a method of saving electricity.
   The blocks which learners should identify as energy wasting are listed below, with a suggestion for how it can be rewritten to be energy saving:
   - ***Leaving lights on in an empty room*** *- Switch off lights in an empty room*
   - ***Using an electric blanket*** *- Use extra fabric blankets*
   - ***Using filament lights*** *- Use fluorescent lights*
   - ***Leaving outside lights on during the day*** *- Switch off outside lights during the day*
   - ***Using an electric toothbrush*** *- Use a non-electric toothbrush*
   - ***Boiling a full kettle for one cup of tea*** *- Only boil the amount of water that you intend using*
   - ***Running half loads in a dishwasher*** *- Only run the dishwasher when it is full*
   - ***Leaving the oven on when nothing is cooking*** *- Switch off the oven as soon as the food is cooked*
   - ***Using an electric can opener*** *- Use a non-electric can opener*
   - ***Running an air conditioner with the windows open*** *- Keep windows and doors closed when running an air conditioner*
   - ***Using a tumble dryer*** *- Rather hang washing than use a tumble dryer*

QUESTIONS:

1. Make a list of the electrical appliances in your home. Walk through your home and make sure to count every item. What could you do, in your home, to help your family conserve electricity?
   Learner-dependent answer.
2. Our country relies heavily on fossil fuels for our energy supply. Eskom power stations use coal, which is a non-renewable energy source. How can saving electricity in our homes help to reduce our negative impact on the environment?
   This question links back to what learners covered in Chapter 1 on sources of energy. Burning fossil fuels releases greenhouse gases which contribute to the greenhouse effect in the atmosphere. This contributes to global warming. If we use electricity in our homes wisely and save electricity, we reduce the load on the coal-powered stations, and therefore help to reduce the emission of greenhouse gases.

3. What renewable energy alternatives could your family use in your house to reduce your use of electricity supplied by coal-powered stations through the national electricity grid?
Learners can suggest installing solar panels on the roofs of their house to rather make use of solar power as it is a renewable energy source. Electric geysers also use a huge amount of electricity to warm water, therefore installing a solar water heater (as discussed in Chapter 4), the family will reduce their load on the national supply system by rather using alternative energy sources.

ACTIVITY: Writing a letter to your local newspaper

TEACHER'S NOTE

This is an optional activity aimed at creating awareness amongst learners about our country's reliance on fossil fuels and the negative environmental impact. This can also be done as a homework task.

Learners will need to write a letter to their local newspaper. Encourage learners to do some extra research about the area in which you live. For example, looking at the direct impacts of a coal station on your area, such as the possible effects of acid rain. Learners should research the renewable energy power stations that might already be in the area which could rather be expanded.

This is a creative writing piece but also a research task. Learners must reference any sources that they use. Learners must include in their letter, their motivation for why renewable energy sources should rather be explored. The scientific accuracy of their letters must also be assessed.

The purpose of this activity is to engage learners in constructive, problem-solving thinking.

You have just found out that there are plans to build a new coal-powered power station just outside your home town. Your local community is upset about this due to the effects of the pollution on the environment. Your community also feels that greater measures are needed to change the way we rely so heavily on non-renewable sources. We should rather be looking at alternative ways of generating electricity. You decide to do some research about the best possible solution for a power station, other than one which uses fossil fuels.

INSTRUCTIONS:

1. You decide to write a letter to your local newspaper explaining your findings, your community's concerns and your alternative suggestion.
2. Use your knowledge from this term's work and think about the best possible solution for your area. For example, perhaps there is a dam nearby which could be used for a hydroelectric power plant? Perhaps there is a wind power farm close by which could be expanded?

3. You need to think critically and present a constructive solution to the problem.
4. Use the following space to write your letter.
5. Reference any sources which you use.

VISIT

Want to take part in some real science research? Check out these citizen science projects to easily get involved. bit.ly/15VgBsY

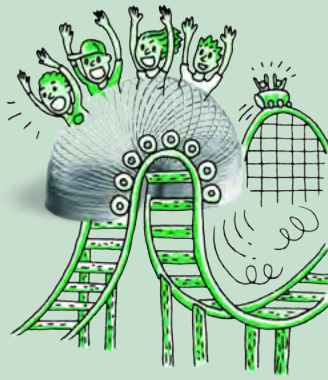
TEACHER'S NOTE

Learner-dependent answer.

Careers in electricity

There are many different careers in the field of electricity generation. Engineers, both mechanical and electrical, are needed to help design and run the processes of electricity generation. Technicians and artisans are needed to build and maintain the power generators. Research scientists are also needed to help test and develop new technologies.

ACTIVITY: Career research



INSTRUCTIONS:

Choose an electricity related career which you find interesting and research the career. You can do this by searching on the internet or in books. Some careers to find out about are those in the field of electricity generation, including engineers, scientists, artisans and technicians.

TEACHER'S NOTE

Learners can also make a poster about the career and put them up for display in the classroom.

You can also contact some the engineering associations listed below:

Engineering Council of South Africa (ECSA)

Tel: (011) 607-9500 Fax: (011) 622-9295

E-mail: engineer@ecsa.co.za

South African Institute of Electrical Engineers

Tel: (011) 487-3003/6 / (011) 487-3002

http://www.saiee.org.za

Electrical Contractors Association of SA

Tel: (011) 392 0000

What does a day in the life of this career involve?

TEACHER'S NOTE

Learner-dependent answer.

TEACHER'S NOTE

The Zooniverse website provides a great overview of the various citizen science projects that learners can get involved in. There is a huge variety of projects, from helping to identify possible planets around stars, analysing real life cancer data, looking at tropical cyclone data, or listening to the calls from whales or bats. And there are also many others. Citizen science is scientific research which is conducted in whole or in part by nonprofessional scientists, specifically the general public. Encouraging learners to get involved in some of these projects will open their eyes to the possibilities out there, and also add meaning and value to what they learn within the Natural Sciences classroom. bit.ly/14JxLsw

Remember to discover more online by visiting http://www.curious.org.za and by typing the links in the Visit margin boxes into your Internet browser to watch any videos, play with simulations or read an interesting article.

Type the bit.ly link for the video or site that you want to visit into the address bar of your browser on your computer, tablet or mobile phone.

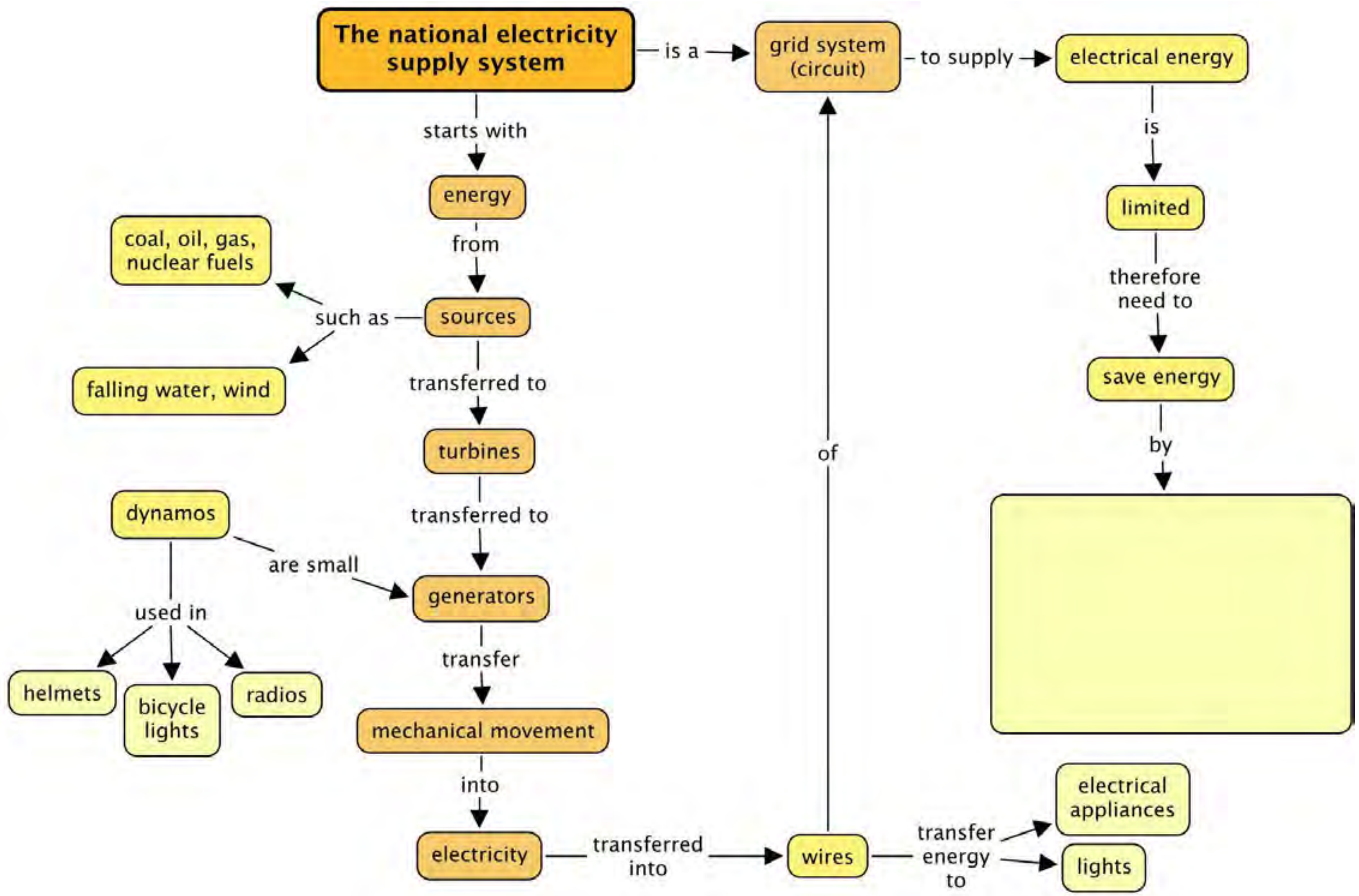
SUMMARY:

Key Concepts

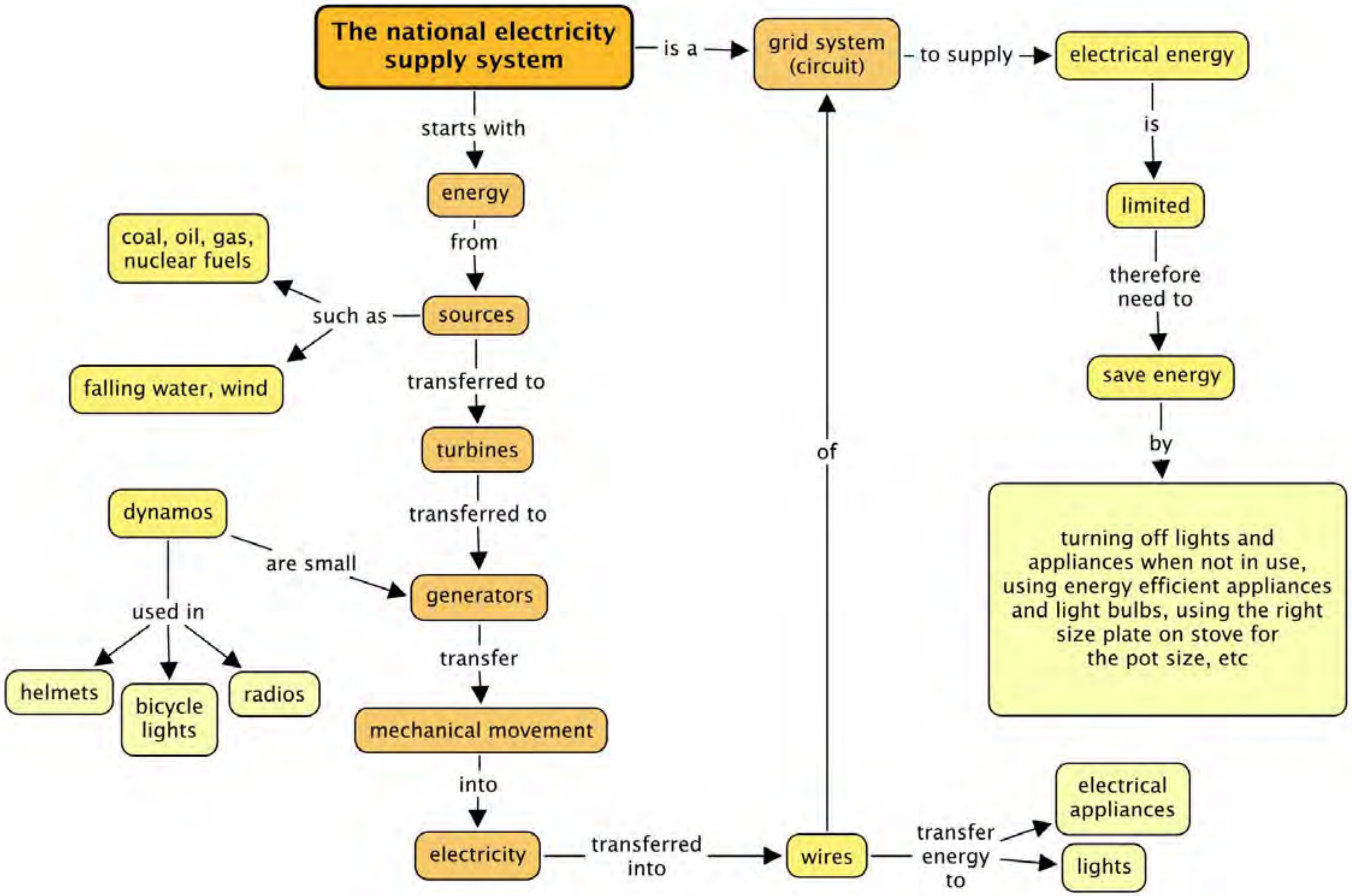
- The national electricity grid is a system in which the energy is conserved. It makes a complete circuit.
- In a coal power station, the coal is burned and steam is produced. The steam turns a turbine. The turbine turns a generator which produces electricity. This is transferred to the powerlines in the national grid.
- Eskom uses coal powered stations and generates electricity using generators.
- Dynamos are a type of generator that can be used to produce small amounts of electricity, such as a for a bicycle lamp.
- Electricity is expensive and we need to conserve electricity to reduce our household costs.
- Fossil fuels are burnt to generate electricity. When fossil fuels are burnt they release greenhouse gases into the atmosphere. We need to reduce our electricity consumption in order to reduce pollution.
- There are many practical ways to conserve electricity within our homes.

Concept Map

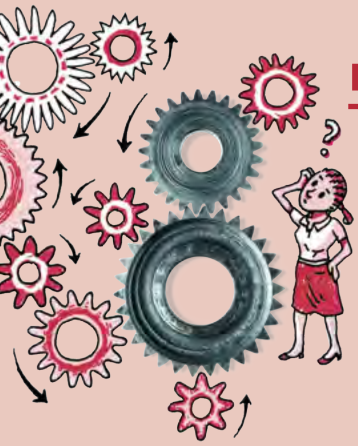
Complete the concept map below by filling in some of the ways to save energy.



The national electricity supply system
is a
grid system (circuit)
to supply
electrical energy
is
limited
therefore need to
save energy
by
starts with
energy
from
sources
such as
coal, oil, gas, nuclear fuels
falling water, wind
transferred to
turbines
transferred to
generators
dynamos
are small
used in
helmets
bicycle lights
radios
transfer
mechanical movement
into
electricity
transferred into
wires
of
transfer energy to
electrical appliances
lights

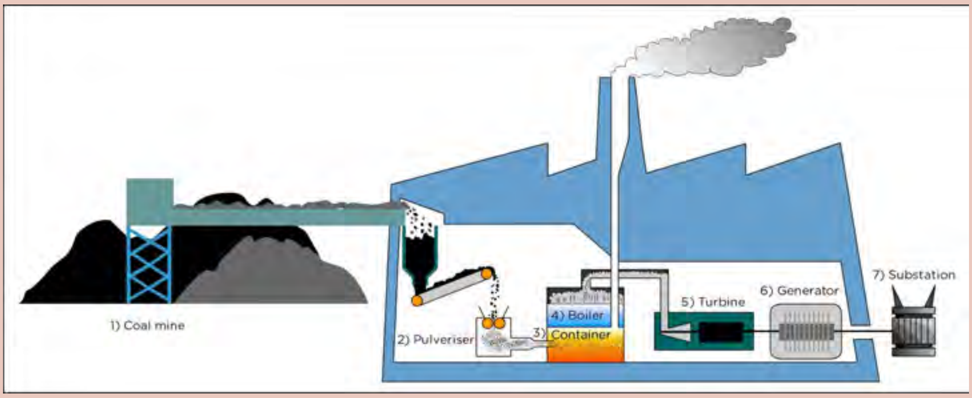


The national electricity supply system
is a
grid system (circuit)
to supply
electrical energy
is
limited
therefore need to
save energy
by
turning off lights and appliances when not in use, using energy efficient appliances and light bulbs, using the right size plate on stove for the pot size, etc
starts with
energy
from
sources
such as
coal, oil, gas, nuclear fuels
falling water, wind
transferred to
turbines
transferred to
generators
dynamos
are small
used in
helmets
bicycle lights
radios
transfer
mechanical movement
into
electricity
transferred into
wires
of
transfer energy to
electrical appliances
lights



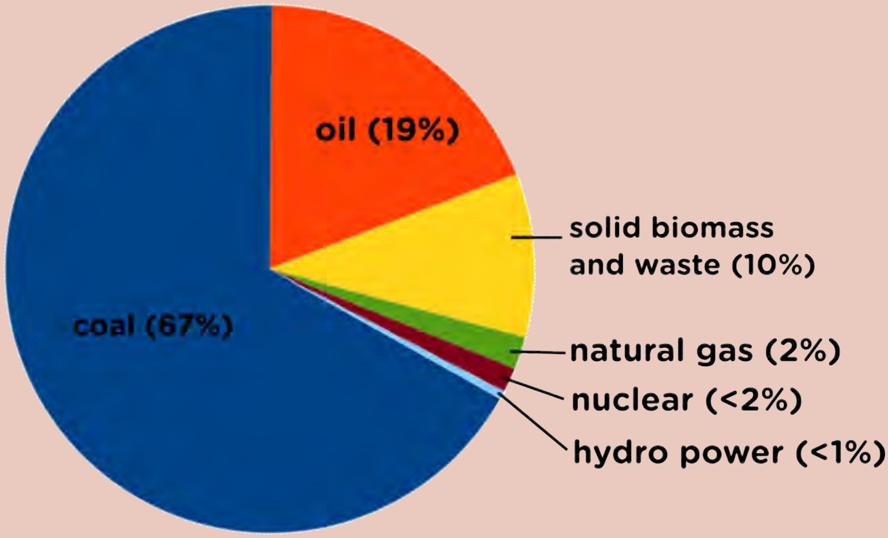
REVISION:

1. Why do you think we can refer to the national electricity supply as a **grid**? [2 marks]
   This is because the power lines make up a grid across the country which is a closed circuit. It is a system.
2. What is the main source of energy for power stations in South Africa? [1 mark]
   Coal.
3. What is Eskom? [1 mark]
   Eskom is South Africa's public utility which produces the largest amount of electricity in South Africa.
4. Look at the diagram of a power station. Write a paragraph to describe the process by which electricity is produced in a coal power station. [7 marks]



   The paragraph must contain the following points:
   - *coal is mined and then delivered to the coal station*
   - *the coal is pulverised to make it finer*
   - *the coal is burned in a furnace*
   - *the energy is used to boil water*
   - *the steam turns the turbine*
   - *the turbine turns a generator which produces electricity*
   - *the electricity enters the wires of the national grid.*
5. We have mostly looked at coal power stations and how energy from coal is transferred to the turbine. What other energy sources can be used? [3 marks]
   Any of the fossil fuels (natural gas and oil too), falling water in a hydropower plant, a wind turbine, or nuclear fuel.

6. The following graph shows the energy supply in South Africa from the various sources of energy. These percentages include the electricity production, consumption and export for each source in 2010. Answer the questions that follow.



a) What type of graph is this? [1 mark]
b) What do all the percentages add up to in this type of graph? [1 mark]
c) What percentage of our energy supply comes from coal, as shown in 2010? [1 mark]
d) What percentage of our energy supply came from fossil fuels in total in 2010? [2 marks]
e) Does South Africa rely more on renewable or non-renewable energy supply? [1 mark]
f) What energy source is the smallest supply in South Africa, as in 2010? [1 mark]
g) What is the impact of our country's reliance on non-renewable energy sources? [3 marks]

a) A pie chart.
b) 100%
c) 67%
d) Learners must add up the percentages for coal, oil and natural gas which is 67 + 19 + 2 = 88%
e) Non-renewable, as this makes up 88% of our energy supply.
f) Hydropower.
g) Learners need to justify their answers. You should assess their reasoning and explanations of answers. Some points for answers in this question: Non-renewable energy sources are not sustainable in the long term as there is only a limited supply, they are not renewable. South Africa needs to think ahead to plan for when the supply of non-renewable energy sources runs out, by looking at alternative renewable solutions. The use of non-renewable energy sources has a negative impact on the environment due to the emission of greenhouse gases which contribute to global warming and acid rain which ruins crops and buildings.

7. Use the chart to draw a table showing this data in the space below. [6 marks]

   An example of a table is given below. Learners must provide a heading for the table [1 mark] and column headings [1 mark each]. 2 marks are awarded to the correct data. 1 mark is for putting the percentage sign in the heading and not in each row.

   Table showing the percentage breakdown for each source of energy supply in South Africa in 2010

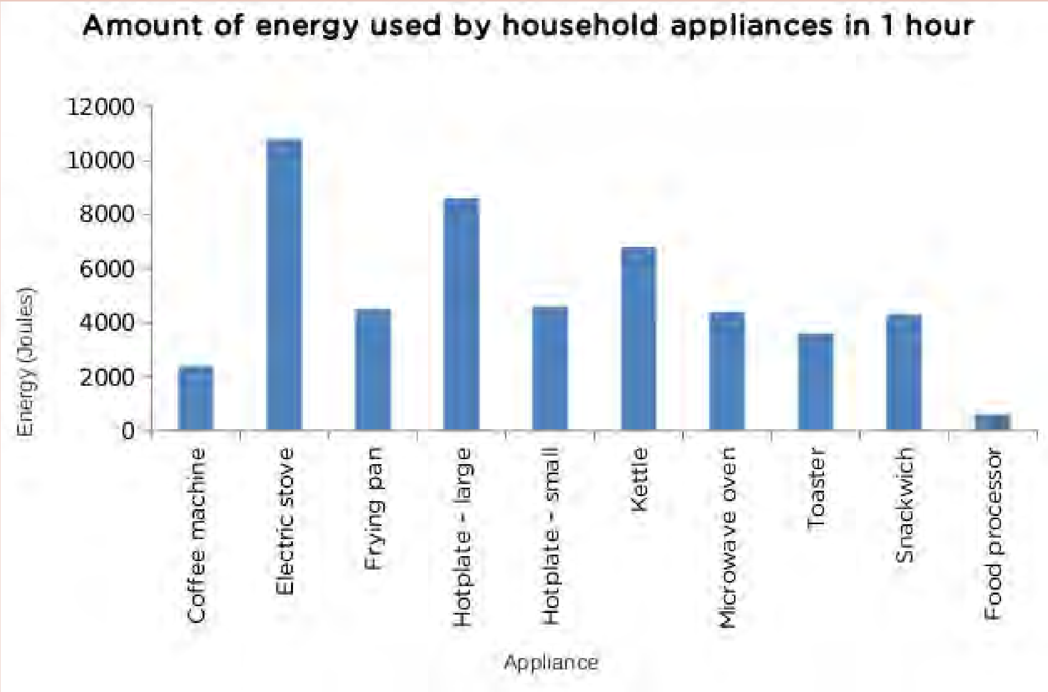
Energy supply source	***Percentage of energy supply in South Africa (%)***
Coal	*67*
Oil	*19*
Solid biomass and waste	*10*
Natural gas	*2*
Nuclear	*<2*
Hydro power	*<1*

8. Why does a miner need a dynamo instead of a battery for his helmet light? [2 marks]
   Batteries run out quite quickly. Miners are underground for long periods of time and a dynamo does not run out of energy. The miner can just wind up the dynamo by hand again as soon as the electric light in the helmet begins to fade.
9. List 3 ways in which you could save electricity in your home. [3 marks]
   Learner-dependent answer. Possible answers include: switching off appliances after use. Switch off lights of unoccupied rooms. Switch off geyser. Use a geyser blanket. Install solar geysers.
10. The following table shows the amount of energy used by some kitchen appliances in one hour.

Appliance	**Kilojoules**
Coffee machine	2 400
Electric stove	10 800
Electrical frying pan	4 500
Hot plate - large	8 600
Hot plate - small	4 600
Kettle	6 800
Microwave oven	4 400
Toaster	3 600
Snackwich	4 300
Food processor	600

a) Use the table to draw a bar graph. [5 marks]
b) Which appliance uses the most electricity? [1 mark]
c) How could you conserve electricity by continuing to cook your food in another system, once it has warmed up? Hint: You might have made one of these in a previous activity! [1 mark]

*a) **Note:** The bar graph should have a heading [1 mark] which indicates what the bar graph represents. An example heading could be "Amount of energy used by common household appliances in one hour.".*
The type of appliance should be listed on the horizontal x-axis [1 mark].
The number of kilojoules should be plotted on the vertical y-axis [1 mark].
The height of each bar should be correct according to the scale of the vertical axis [1 mark].
There should be gaps between the bars of the graph [1 mark].



The electric stove.
b) Use a hot box to continue cooking the food once it has warmed up.

Total [42 marks]

GLOSSARY

absorb: to take in

biofuel: a fuel made from biological materials such as soya, maize or sugar cane; examples of these fuels are biodiesel and methanol

conduction: the transfer of energy between objects that are in direct contact with each other

conductor: a substance which allows heat, sound or electric charge to pass through it easily; a good conductor alls free passage whilst a poor conductor allows partial passage

conservation: a quantity stays constant; something is not lost or destroyed

conserve: to make something last longer by using it carefully

consistent: reliable and predictable

consumption: using up a resource

convection current: the movement of liquid and gas particles as the substance warms up and rises and then cools and moves down again to form a current

convection: transfer of energy through a liquid or gas by the movement of liquid or gas particles

dynamo: a small generator that can be used for powering a bicycle light, a mine helmet or a wind up torch

fossil fuel: non-renewable energy sources, namely coal, oil and natural gas

generator: a machine used to convert mechanical energy into electrical energy

geyser: a cylindrical tank that is used to warm and store hot water

greenhouse gases: gases in the atmosphere that contribute to the greenhouse effect; these gases include carbon dioxide and methane

heat: heat is the energy transferred between two objects as a result of the temperature difference between them; it is also when energy is transferred between a system and the environment as a result of the temperature difference between them; it is measured in joules (J).

hydrocarbon: a molecule which consists of hydrogen and carbon atoms bonded together

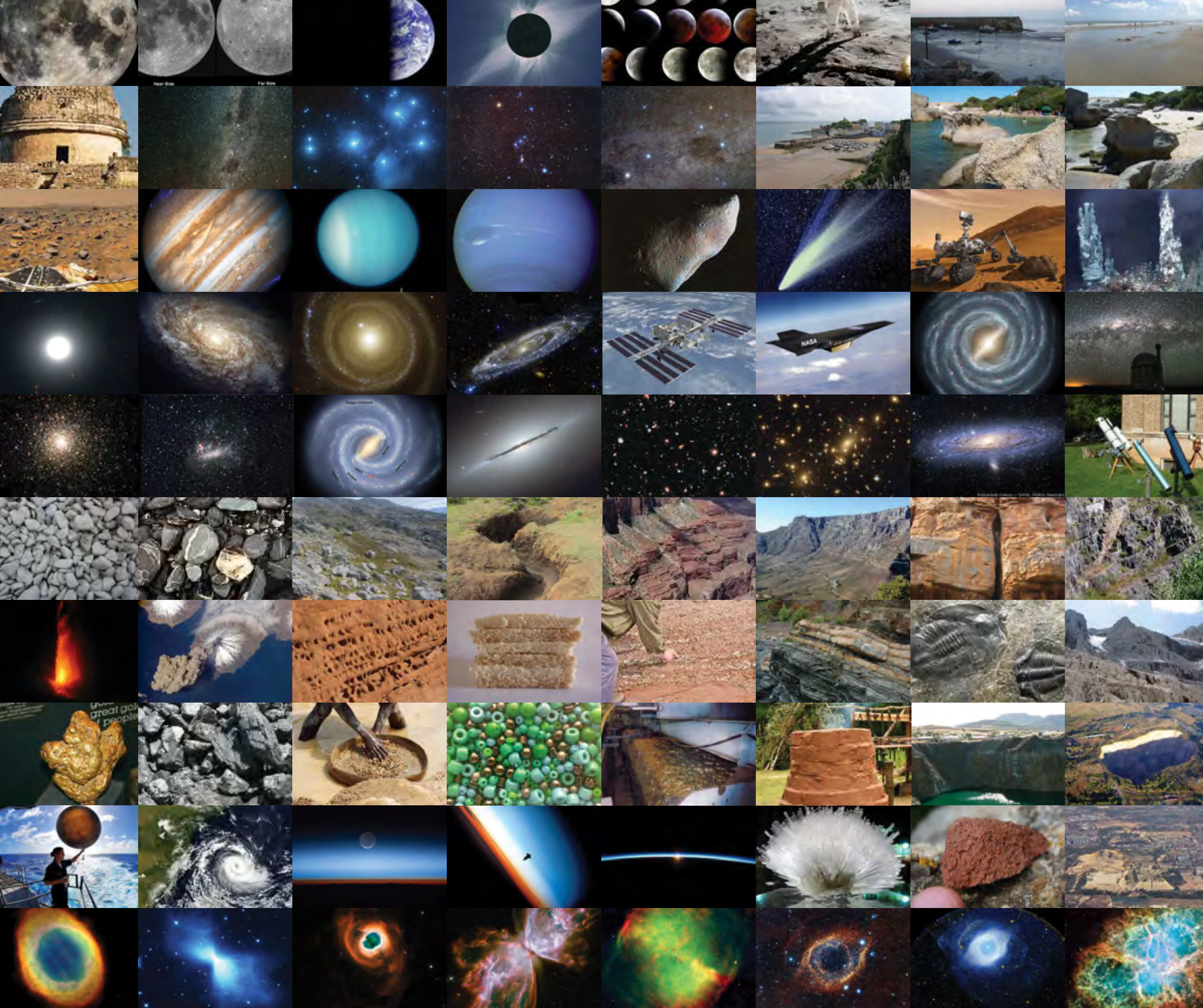
hydropower: the energy harnessed from a moving water source, like a river or a waterfall

input: something that enters a system and is altered by the system to produce an output

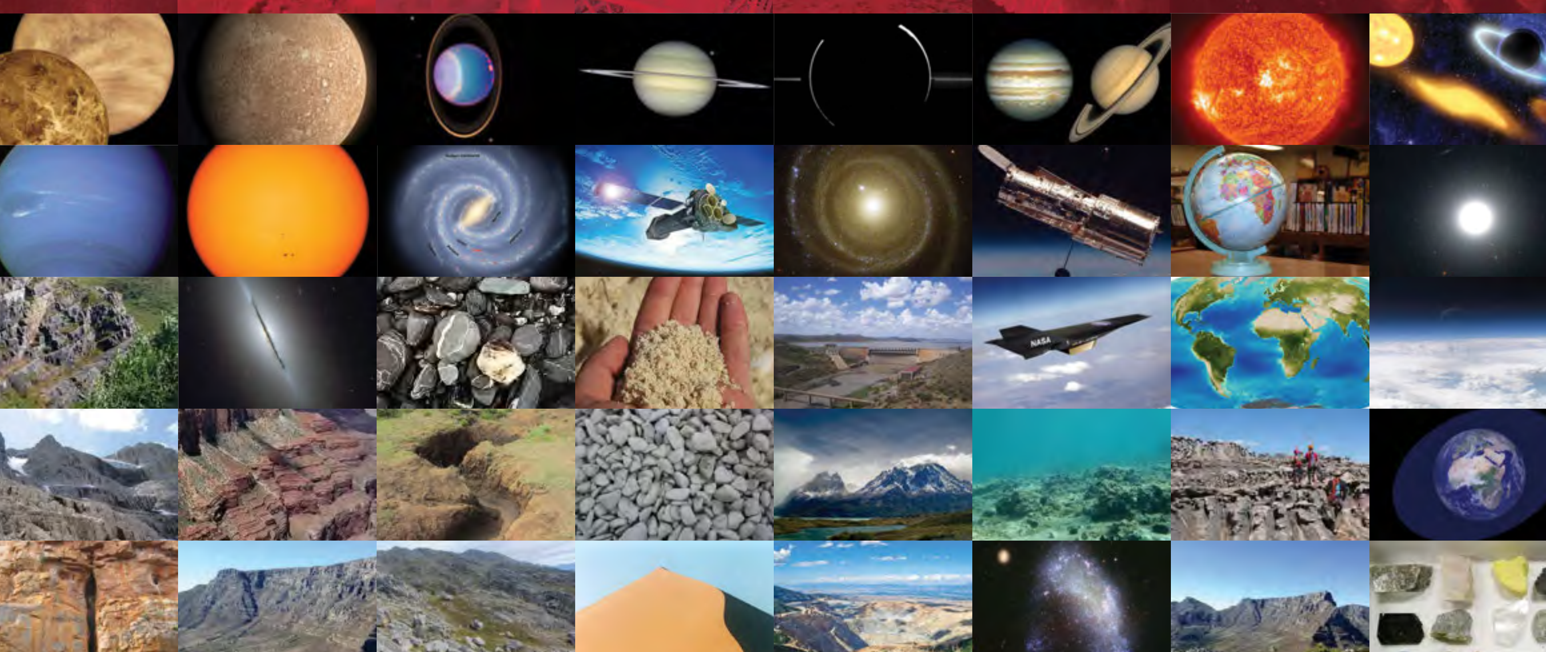
insulator: a substance which resists the movement of heat, sound or electric charge through it

joule: the standard, international unit of measurement for energy

kinetic energy:	energy that a body has when it is moving
law:	in science, a law is a statement of what happens and it is based on repeated experiments and observations
matt:	not glossy or shiny
methane:	a colourless, odourless gas which is often called natural gas
national electricity grid:	the network of cables, pylons and transformers which transfer electricity throughout the country
non-renewable:	a resource, such as coal, that can not be replenished or there is a limited supply of it
nuclear:	the type of energy released when a large atomic nucleus breaks up or two smaller ones combine
output:	the end result of a process
potential energy:	energy that is stored in a system
pylon:	a large vertical steel tower which supports electrical power cables
radiation:	the transfer of energy from a source that does not require physical contact or movement of particles
reflect:	to throw back heat light or sound without absorbing it
renewable:	something which is continuously replenished or there is an unlimited supply of it
reservoir:	a large container or space in which a gas or liquid can be stored
Sankey diagram:	a Sankey diagram is used to show the difference between input and output energy
solenoid:	a current carrying coil or coils of conducting wire
system:	a system is any set of parts working together to carry out a particular function
temperature:	a measure of how hot or cold a substance feels; it is measured in degrees Celsius (°C).
theory:	in science, a theory is an explanation of why or how something happens
thermal:	relating to heat
transfer:	to move from one object or place to another; in an energy system, we say energy is transferred from one object to another
transformer:	an electrical device to transfer energy between two parts of the circuit in the national electricity grid
turbine:	a set of curved blades on a central, rotating spire



PLANET EARTH AND BEYOND



1 Relationship of the Sun to the Earth

KEY QUESTIONS:

- Why do we have night and day?
- Why do we experience seasons on Earth?
- Do other planets have seasons too?
- How does the Sun influence life on Earth?

TEACHER'S NOTE

Chapter overview

4 weeks

In Grade 6 learners covered material explaining how the spin of the Earth on its axis causes day and night. They also learnt that the Earth revolves around the Sun, completing one orbit every year. In this chapter we begin by reviewing this material before moving on to look at solar energy and the Earth's seasons. The main aims of this chapter are to ensure that learners understand the following:

- The Earth revolves (orbits) around the Sun in one year.
- The Earth's rotation axis is tilted relative to the plane of its orbit around the Sun.
- This tilt of the Earth is responsible for the seasons as the Earth orbits the Sun.
- The Sun provides energy that sustains all life on Earth.

Learners often battle with distinguishing between revolves and rotates as they confuse the words. If you find learners are battling with this, sometimes it helps to replace the word 'revolves' with 'orbits' so that the concept is clear and the learners are not confused by semantics. We have used the rotate and revolve here, as required by CAPS, but you can introduce this more slowly if you feel the wording is hindering your learners grasp of the concept.

It is important to address any misconceptions that learners may have regarding the cause of the seasons. Some common misconceptions are identified in section 1.1 and explanations are given.

At the end of section 1.1 there is a sub-section that covers the **Seasons on other planets.** It is included as an interesting and challenging extension. However, this section could cause confusion if the learners have not fully grasped why seasons occur on Earth, so do not attempt to include it if you have doubts about learner's comprehension of the previous material. This section is useful however as it helps learners to apply the knowledge they've gained about Earth to the other planets and gives learners a sense of the Earth's place within our solar system.

Concept maps: The concept maps in these workbooks were created using an open source programme called CMapTools. You can download it from this link if you would like to use it to create your own concept maps. `bit.ly/1fMyJsQ`

Do you think it is important to teach astronomy to learners at school? Read this interesting and informative article detailing the benefits and applications of astronomy. bit.ly/17iVgpw

1.1 Solar energy and the Earth's seasons? (7 hours)

Tasks	**Skills**	**Recommendation**
Activity: Day and night revision exercise	Stating, remembering	Optional revision
Activity: Movement of a classroom Sun	Investigating, observing, analysing	Suggested
Activity: Daytime and nighttime	Investigating, observing, analysing	CAPS suggested
Activity: Which way does the Earth rotate?	Observing, analysing	Extension
Activity: Label the Earth	Identifying	CAPS suggested
Activity: What causes the seasons? Guesses.	Listing	Optional
Activity: The Earth's tilt	Investigating, observing, analysing	Suggested
Activity: Direct and indirect light	Working in pairs, investigating, observing, analysing, evaluating	CAPS suggested
Investigation: Direct and indirect light and its effect on temperature	Investigating, observing, taking measurements, recording, analysing	Suggested
Activity: Looking at sunlight hitting the Earth	Observing, analysing	CAPS suggested
Activity: Earth's seasons summary	Recalling, summarising	Optional

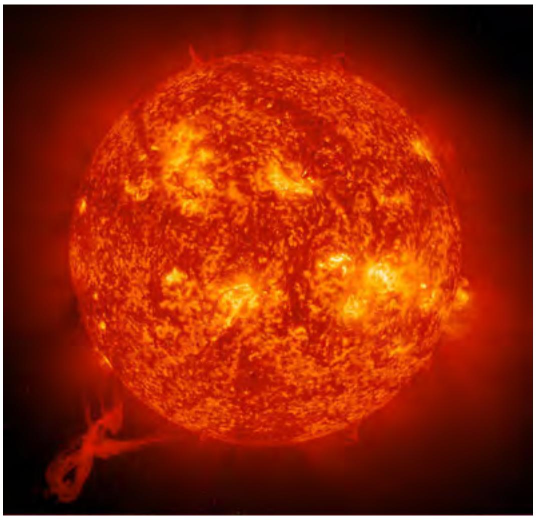
1.2 Solar energy and life on Earth (1 hour)

Tasks	**Skills**	**Recommendation**
Activity: Capturing the Sun's energy	Writing, interpreting, giving opinions	Suggested
Activity: What happens if the Sun stops shining?	Application, synthesis	Optional extension

1.3 Stored solar energy (4 hours)

Tasks	Skills	Recommendation
Activity: Going back in time	Recall, listening skills, comprehension	Optional
Activity: Coal formation flow diagram	Writing, ordering information, translating information	CAPS suggested
Activity: Forming coal	Translating information, comprehension	CAPS suggested
Activity: Explaining the flow of energy	Application, synthesis, comprehension	CAPS suggested
Investigation: The use of fossil fuels in my home	Gathering data, collecting data, reporting findings	Suggested **(This can be used as a possible project)**

The Sun is our closest star. It is a huge ball of very hot gas in space which radiates heat and light in all directions. All the planets, including our home, the Earth, travel around the Sun in orbits. As we will see in this chapter, the Sun is incredibly important: it provides us with light and warmth and its apparent motion across our sky causes day and night and the passage of the seasons.



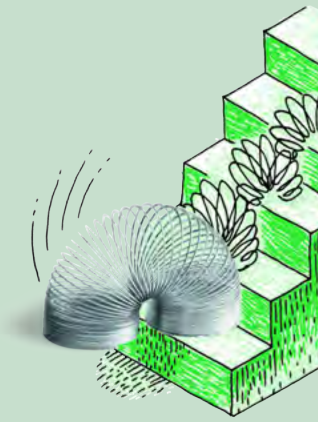
Our Sun.

1.1 Solar energy and the Earth's seasons

Earth's rotation

Let's start off with seeing what you can remember learning about **day** and night in Gr. 6.

ACTIVITY: Day and night revision exercise



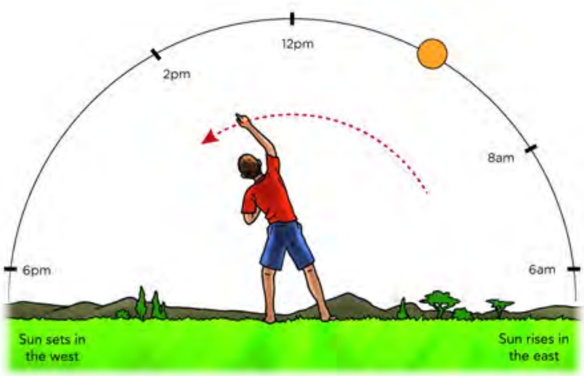
INSTRUCTIONS:

1. Answer the questions in the table below.

QUESTIONS:

In which direction would you have to look to see the Sun rising?	*To the East*
In which direction would you look to see the Sun setting?	*To the West*
At what time is the Sun at its highest point in the sky?	*At midday*
At midnight, where is the Sun in relation to your position on the Earth?	*Directly opposite your position on the other side of the globe*
How long does it take the Earth to complete one rotation on its axis?	*24 hours (1 day)*

If you follow the path of the Sun during the day you will see that it rises in the east and sets in the west. The Sun reaches its highest point at noon (midday). Why do you think it looks as though the Sun moves across the sky during the day?



The Sun is at different positions in the sky during the day. But is it the Sun that is moving?

Let's do an activity to find out!

ACTIVITY: Movement of a classroom Sun

TEACHER'S NOTE

This is an active group activity for the whole class. Ensure that the balloon or ball you use can be seen clearly by all learners. The learners will be standing up and turning around on the spot so ensure that they have enough room to turn without hitting each other or falling over their chairs. If space is cramped it might be a good idea to stack all the chairs away for the activity, or else ten or so children can stand up at a time and move and after that they sit down and the next ten take a turn.

Ensure that the learners know the difference between turning in a clockwise and anti-clockwise direction before they complete the activity.

MATERIALS:

- yellow round balloon or ball which can be hung from the ceiling
- string for hanging the ball or balloon

INSTRUCTIONS:

VISIT
The story of our planet
(video) bit.ly/1bLAXbE

1. Hang up the balloon or ball from the ceiling using the string close to one of the corners in your classroom. Make sure that the balloon/ball is high up and visible from the back of the classroom. The balloon/ball represents the Sun.
2. Stand up in your classroom and face the balloon/ball.
3. Now slowly turn on the spot in a clockwise direction keeping your head still, completing two or three turns.
4. Repeat the activity but this time turn in an anti-clockwise direction.

QUESTIONS:

1. As you turned clockwise what direction did the hanging balloon/ball appear to move?
   From right to left.
2. As you turned anti-clockwise what direction did the hanging balloon/ball appear to move?
   From left to right.
3. Did the hanging Sun actually move?
   No it was hanging in place.
4. Why do you think we see the Sun move across the sky?
   The Sun appears to move from our perspective, but really we are moving. The Earth is spinning on its axis and the Sun appears to move in the opposite direction from our spin.

As you can see the hanging Sun is not really moving, it just appears to move because you are turning. This is also true for the real Sun in the sky. The Sun does not really move, it just appears to move because the Earth is turning on its **axis**. So, it is the Earth's **rotation** that causes the apparent movement of the Sun across the sky during the day.

ACTIVITY: Daytime and nighttime

TEACHER'S NOTE

This is an active group activity for the whole class. Ensure that the balloon or ball you use can be seen clearly by all learners. They will have to walk around the globe so ensure that there is space to do this. Ensure that the lamp or torch you use fully illuminates one half of the globe. If only a small portion of the globe is lit up, move the lamp further away and if necessary use a stronger light source.

MATERIALS:

- a globe (or a ball/balloon with the shapes of the continents drawn on it) which can be hung from the ceiling
- string for hanging the globe
- non-permanent marker or sticker
- desk lamp or torch
- black bin bags or curtains to darken the room

INSTRUCTIONS:

1. If you do not have a globe, you can make a model of the Earth yourself in class. Use any ball. Draw the Equator and mark the North and South Poles.
2. Mark with a dot/sticker your position on the globe.
3. Hang the globe from the ceiling near the middle of the class. It should be at about eye level height. The globe represents the Earth.
4. Darken the room.
5. Shine a desk lamp or torch on the globe facing Africa and keep the lamp/torch steady in this position. The torch represents the Sun.
6. Walk around the globe so that you can see all of it. Is it all lit up by the torch? How much of it is lit and how much is dark?
   Half of the globe is lit and half is dark.
7. The lit area represents daytime and the dark area represents nighttime. Is your dot/sticker in daytime or nighttime?
   The dot is in daytime as it is facing the lamp.
8. Now turn the globe anti-clockwise, half a turn. Is your dot/sticker in daytime or nighttime?
   The dot is now in nighttime as it is facing away from the lamp.
9. Where is it now daytime?
   Learner dependent answer. Accept any answer where there is light shining onto the globe. (i.e on the half of the globe now facing the lamp).
10. Keep turning the globe anti-clockwise until your dot/sticker is back in its original position and lit again. How long would it take on the real Earth for the dot to complete one rotation like this?
    24 hours, or one day.

TAKE NOTE

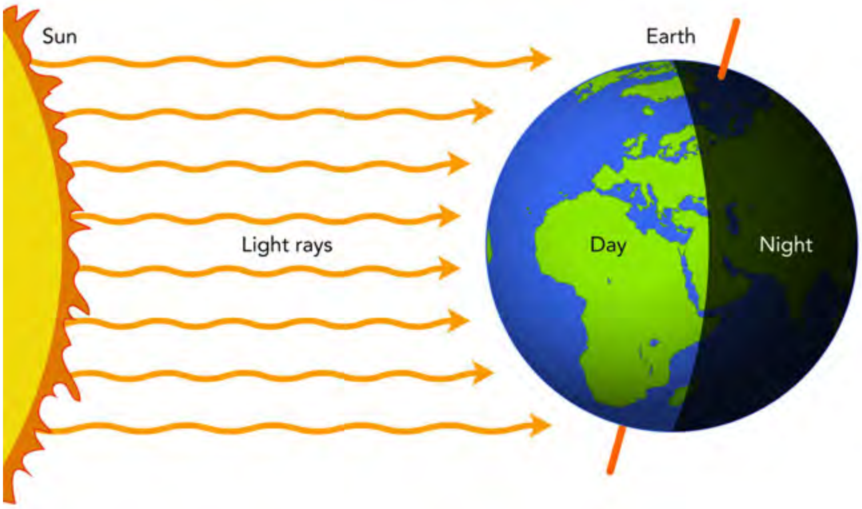
It is incorrect to talk about the Sun 'burning'. The Sun is not 'burning' in the way a fire does. Remember, a fire burning on Earth requires oxygen and there is no oxygen in space. Rather, the gas is very hot and glowing as a result.

So, now you can see how the Earth's rotation about its axis causes day and night. When one half of the Earth is lit up by the Sun, the other half is in darkness. It is daytime in the lit half and nighttime in the dark half. As the Earth spins you move from light to shadow and back to light again over the course of

VISIT

Video of the Earth spinning on its axis causing day and night. bit.ly/1h8mMeM

one day (24 hours).



During the night you cannot see the Sun move across the sky, but if you look carefully you will notice that the stars move across the sky, just like the Sun does. It takes the Earth 24 hours to make one complete turn (called a rotation) on its axis, so an Earth day is 24 hours long.

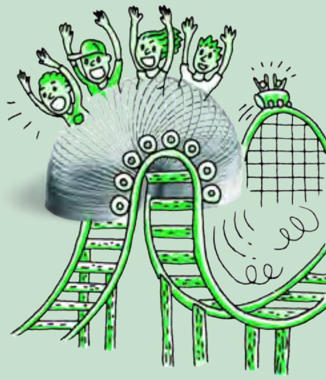
This picture of the SALT telescope near Sutherland was taken at night with the camera shutter left open. You can see the star trails due to the Earth's rotation.

VISIT

Why does the Earth spin? (video) bit.ly/16ORlvF

You now know that the Earth rotates on its axis completing one turn every 24 hours. But which way does it turn? Let's see if you can figure it out.

ACTIVITY: Which way does the Earth rotate?



TEACHER'S NOTE

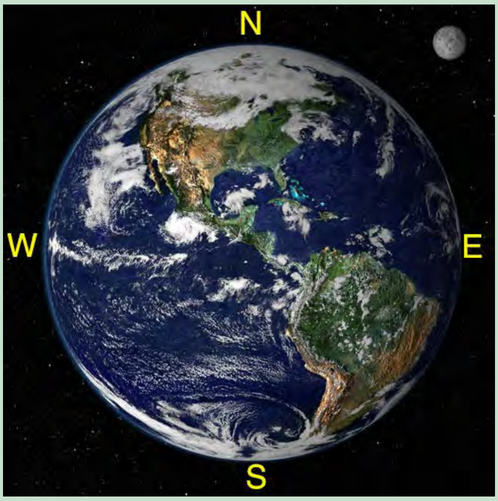
This is a slightly more difficult activity. Ensure that the balloon or ball you use can be seen clearly by all learners. The learners will be standing up and turning around on the spot, ensure that they have enough room to turn without hitting each other or falling over their chairs. If space is cramped it might be a good idea to stack all the chairs away for the activity. Ensure that the learners know the difference between turning in a clockwise and anti-clockwise direction before they complete the activity.

MATERIALS:

- a ball or balloon
- string for hanging the ball

INSTRUCTIONS:

1. Hang up the balloon or ball from the ceiling using the string close to one of the corners in your classroom. Make sure that the balloon/ball is high up and visible from the back of the classroom. The ball represents the Sun.
2. Stand up in your classroom and face the balloon/ball.
3. Now slowly turn on the spot in a clockwise direction keeping your head still, completing two or three turns. Are you turning to your left or right? Note what happens to the hanging balloon or ball.
   You are turning to your right. The ball appears to be moving from right to left.
4. Now repeat the activity but this time turn in an anti-clockwise direction. Are you turning to your left or right? Note what happens to the hanging balloon or ball.
   You are turning to your left. The ball appears to be moving from left to right.
5. What do you notice about the direction that you turn (left or right) and the direction that the hanging Sun appears to move?
   The directions are opposite to each other.
6. Which direction does the Sun appear to move across the sky, east to west or west to east? Given your answer to question 5 which way do you think the Earth is really turning?
   The Sun appears to move from east to west. So the Earth is really moving west to east.
7. Look at the following picture showing the Earth from space. Using your answer to question 6, is the Earth spinning in a clockwise or anti-clockwise direction? Draw the direction on the picture below.
   Anti-clockwise direction (as viewed from the North Pole).



This colour image shows North and South America (green and brown continents) as they would appear from space.

Earth's revolution

The Earth revolves around the Sun in an almost perfect circle, completing one **revolution** (**orbit**) around the Sun per year (or 365 $\frac{1}{4}$ days to be precise). As the Earth revolves around the Sun it also rotates (spins) on its axis at the same time. Having two words both beginning with "r" relating to movement can be confusing! Let's check now that you know what they mean before we continue.

In your own words explain what is meant by the Earth's **rotation**.

TEACHER'S NOTE

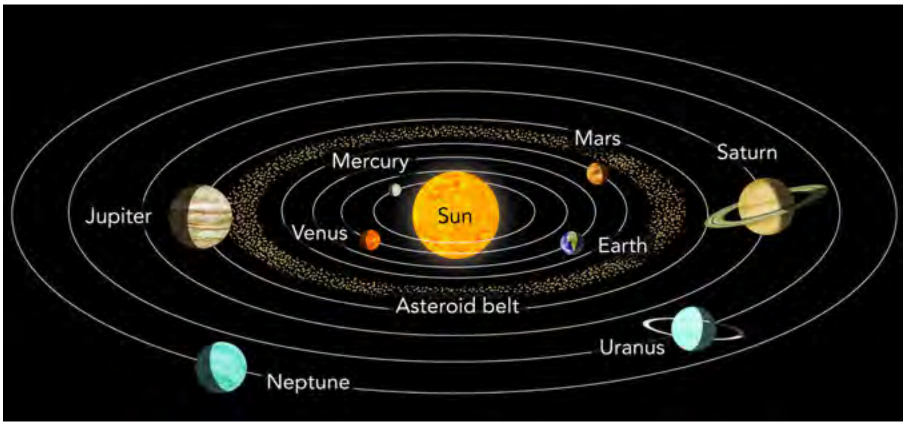
It is the spinning of the Earth on its own axis. This axis is called the rotation axis.

In your own words explain what is meant by the Earth **revolving**.

TEACHER'S NOTE

This refers to the Earth travelling around the Sun in its orbit. One complete orbit is called a revolution.

Different planets take different amounts of time to make one complete revolution around the Sun and so their years have different lengths. The planets further from the Sun will have bigger orbits, as shown in the diagram, and therefore take longer to revolve around the Sun.



Our solar system.

Why do we have seasons?

TEACHER'S NOTE

A good way to introduce the concept of seasons is to have learners identify the traditional four seasons (spring, summer, autumn and winter). Ask them to describe the differences in weather and environment during the four seasons and ask them about the different activities they like to do in the different seasons (for example going to the beach in summer). You could then ask them roughly how long each of the seasons lasts and at what time of the year the different seasons occur. In a country as large as South Africa the climate varies considerably from place to place and while it may for example be spring-like in Pretoria, it could still be frosty in the Eastern Cape. Therefore, keep in mind that the four seasons (each lasting 3 months) have been defined mainly for temperate regions and the weather expected for "spring" (mild!) might not correspond exactly to the weather experienced in a given place in South Africa at a given time. Discussions in the chapter are therefore kept as general as possible focusing on average temperatures in summer and winter for the northern and southern hemispheres.

Before investigating what causes the seasons on Earth you could ask learners what they think causes the seasons and list all the answers on a blackboard, perhaps taking a class vote for each reason. After doing the activities listed in section 1.1 you should ask the learners to recast their votes. It is important that any misconceptions that learners may have regarding the cause of the seasons be addressed and some common misconceptions are explained in the teachers notes in section 1.1.

As the Earth travels around the Sun it receives **solar energy** in the form of light and heat, emitted from the Sun. Do you remember that in Energy and Change last term, we spoke about how heat is transferred from the Sun through space, to Earth? What is this called?

TEACHER'S NOTE

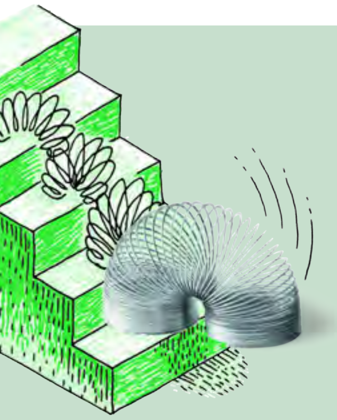
Radiation.

We are very lucky to have our Sun! if the Earth did not receive any energy from the Sun the Earth would be cold and lifeless. Have you noticed that the average temperature is not the same all year round? We experience the **seasons**: winter, spring, summer and autumn. It is generally much warmer in summer and cooler in winter, why do you think that is?

TEACHER'S NOTE

Learners will most probably have lots of different answers, accept all the answers and then carry out the activities in the chapter to investigate the true cause of the seasons.

Let's first make sure that we know some of the terminology about Earth before continuing.



ACTIVITY: Label the Earth

TEACHER'S NOTE

If possible, bring some oranges to class and get learners to draw the different lines of latitude onto the oranges using a permanent marker and marking the North and South Pole and the Northern and Southern Hemisphere.

INSTRUCTIONS:

Using the word bank, label the diagram of the Earth below.

Word bank:
- Northern Hemisphere
- Southern Hemisphere
- Equator
- North Pole
- South Pole

TAKE NOTE

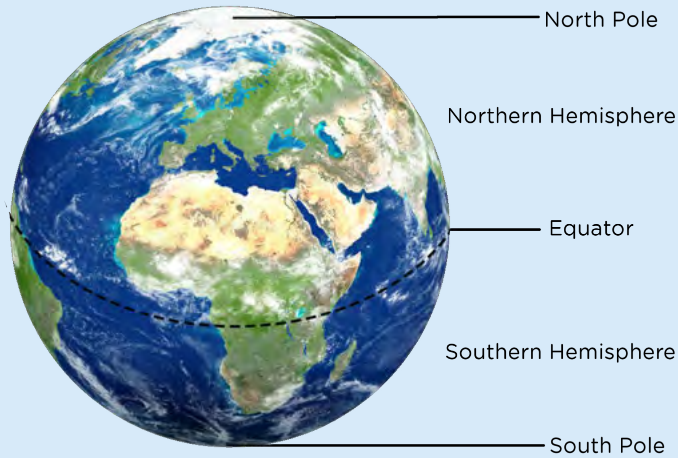
The amount of solar energy the Earth receives is called **insolation** which comes from the words: **in**coming **sol**ar radi**ation**

TEACHER'S NOTE

See Take Note: Insolation is not to be confused with insulation.

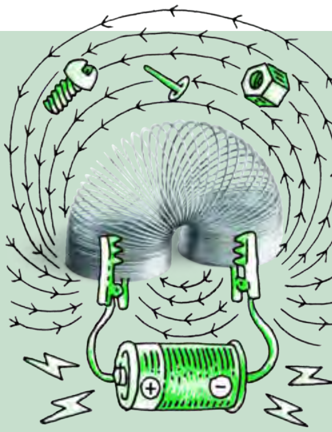
TEACHER'S NOTE

Here is the labeled diagram:



You might already have some thoughts about why we get different seasons throughout the year.

ACTIVITY: What causes the seasons? Guesses!



INSTRUCTIONS:

1. Which of the statements in the table do you think are true and which do you think are false? Put your answers in the right hand column.

Statement	***True or False***
We experience winter because the Sun emits less energy in winter.	*False*
We experience summer because we are closer to the Sun during summer.	*False*
If it is winter in the Northern Hemisphere it is winter in the Southern Hemisphere too.	*False*
Daytime is longer in the summer because the Earth spins more slowly in the summer months.	*False*

ALL the statements in the "What causes the seasons?" activity are false! The amount of energy emitted by the Sun is the same all year round. Also the Earth spins on its axis at the same rate all year. When it is summer in Cape Town it is winter in Paris and when it is spring in London it is autumn in South Africa. The seasons are reversed in the Northern and Southern **Hemispheres**. If it can both be winter and summer on different parts of the Earth at the same time, the seasons cannot be caused by our distance to the Sun. If that were the case, then the whole of the Earth would experience summer and winter at the same time.

TEACHER'S NOTE

Two common misconceptions about the seasons to be aware of whilst going through this content with learners:

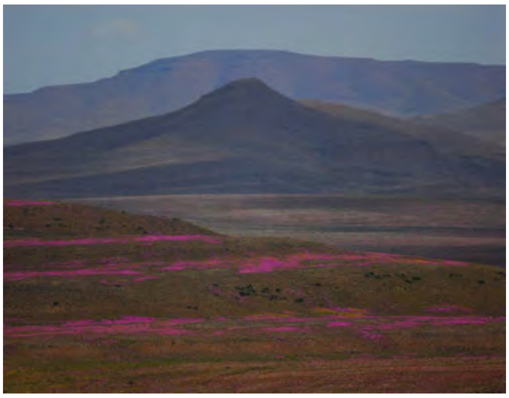
1. **Seasons are caused by the Earth being closer to the Sun in the summer and farther in the winter due to the Earth's oval orbit**.

NO: IN FACT, the Earth's orbit around the Sun is elliptical but it is nearly a perfect circle; it is off by only 4%. Astronomers have calculated the resulting difference in incoming solar energy: it is only 7% which is very small and not sufficient to cause the variations in the temperatures associated with the seasons. If this change in distance were responsible for the seasons, then

the Southern and Northern Hemispheres would experience summer and winter at the same time, which is not the case.

2. **The Earth's tilt brings the Earth significantly nearer to the Sun during the hotter times of the year.**

NO: IN FACT, the tilt of the Earth is the cause of our seasons, but this tilt does not bring us significantly closer to the Sun. The distance from the Sun to the Earth is on average 149 000 000 km and any difference caused by the Earth's tilt is tiny (the change in distance is only about 0.003% of the distance between the Sun and the Earth). This is not sufficient to cause any differences in temperature.



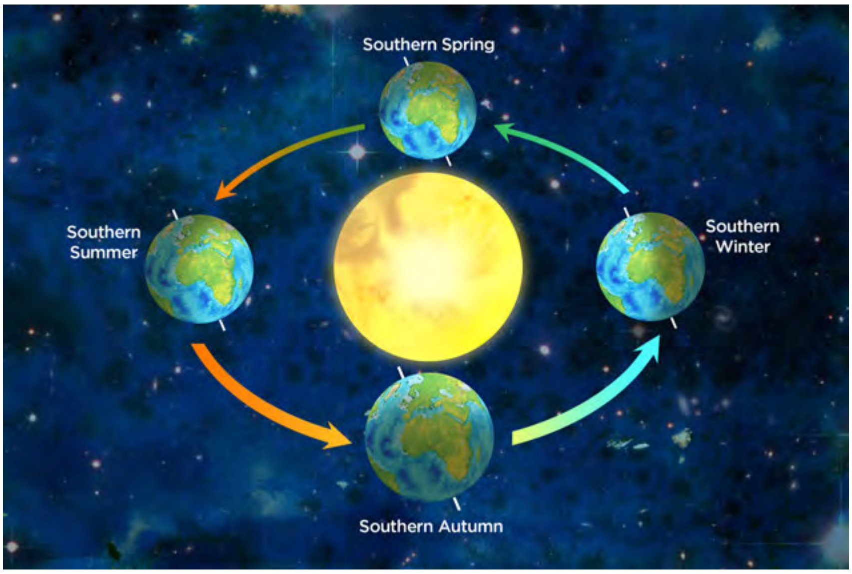
Springtime in the Northern Cape, the flowers are out in bloom.

Winter time in the Northern Cape. In Sutherland, temperatures can go below 0°C and it often snows.

TAKE NOTE

The relative position of the Earth around the Sun is not drawn to scale. If it was drawn to scale, the Earth would not fit on this page!

Let us now find out what causes the seasons. The seasons don't just divide up the year into quarters, they tell us where the Earth is in its path around the Sun. Have a look at the following diagram which shows how the Earth revolves (orbits) around the Sun and the different seasons experienced by the Southern Hemisphere.



The relative positions of the Earth and Sun during the course of a year. It takes one complete year for the Earth to revolve (orbit) around the Sun. It takes six months for the Earth to travel halfway around the Sun.

Look at the picture showing the position of the Earth as it orbits the Sun during a year. The Earth travels around the Sun in an almost perfect circle. If you look closely, you can see that the Earth's axis is not pointing straight up, but is slanted, or tilted in the picture. This is because the Earth is actually tipped over slightly relative to the plane of its orbit. The Earth's axis always tilts in the same direction in space: the North Pole points towards the star Polaris.

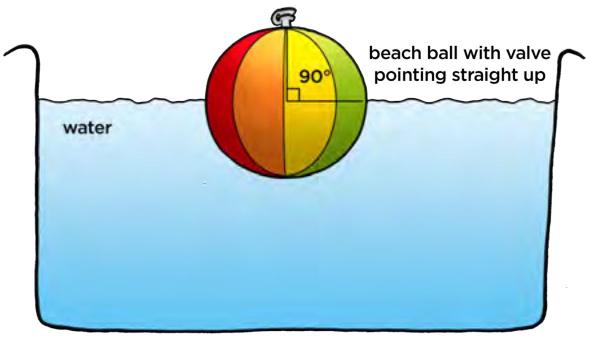
What do we mean when we say that the Earth's axis is tilted relative to the **plane** of its orbit? A plane is a flat surface, for example a flat piece of card or the surface of still water. The plane of the Earth's orbit is an imaginary flat surface that contains the Earth as it revolves around the Sun.

TAKE NOTE

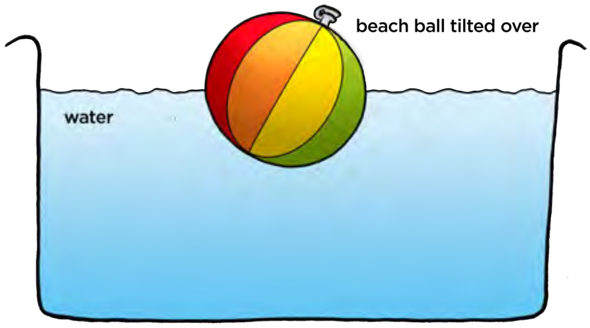
The Earth's orbit is actually very slightly elongated but very close to a circle, called an ellipse.

Imagine that the Earth is a beach ball floating on the surface of water in a swimming pool with half the ball submerged so that you can only see the top half of the ball poking out of the water. Now imagine that the ball is moving around in a circle on the surface of the water but it is not moving up or down. This is what we mean when we say that the Earth travels in a circle in a plane. In this example the Earth's orbital plane is the surface of the water. In space there is no surface of water, the plane is just an imaginary flat surface!

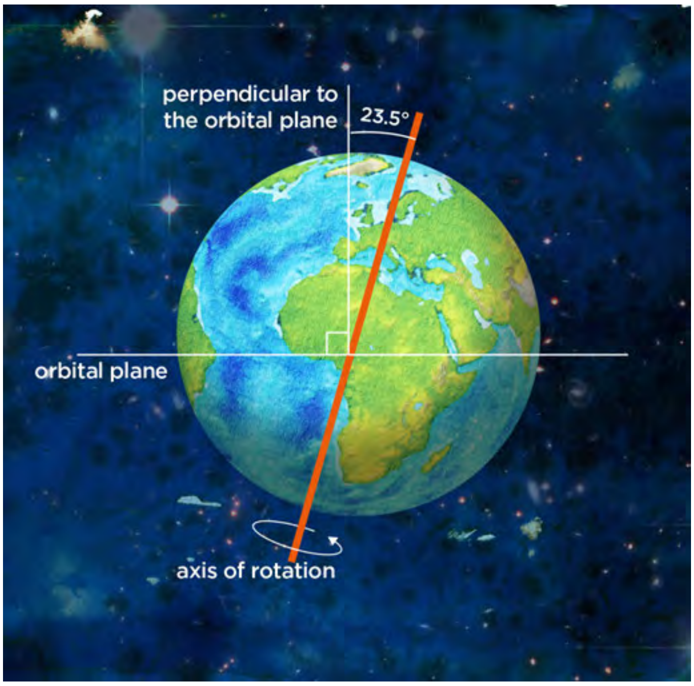
Now imagine that the valve where you blow up the beach ball is pointing straight up towards the sky. This valve represents the Earth's North Pole. In this case the valve and the plane are **perpendicular** to each other and the angle between them is 90 degrees.



However, if you push the ball over slightly so that the valve no longer points straight up, then the valve (representing the Earth's North Pole) and the water surface will not be perpendicular to each other.



The Earth's rotation axis is tilted over by an angle of 23.5 degrees (23.5°) from the vertical. As the Earth travels around the Sun its North and South Poles constantly point in the same direction in space.



The Earth's rotation axis is tilted by 23.5° from the vertical as it orbits the Sun.

Let's model the Earth's tilt.

ACTIVITY: The Earth's tilt

TEACHER'S NOTE

This activity is designed to reinforce the idea that the Earth's axis always points in the same direction in space. The North Pole points towards the star Polaris (North Pole Star) and you can mention this to learners. Unfortunately, there is no southern equivalent of the North Pole Star.

MATERIALS:

- globe or ball/balloon
- non-permanent marker or stickers
- card and tin foil to make a star
- string
- scissors
- glue

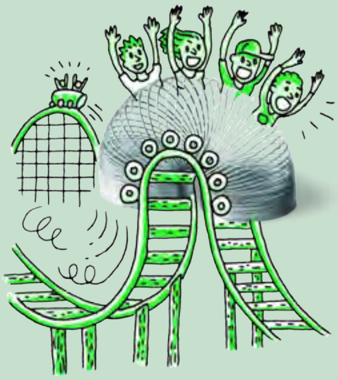
INSTRUCTIONS:

1. Mark on the globe the position of the North and South Pole with a marker or stickers. If using a ball or balloon mark the positions of two points directly opposite each other on the surface of the ball/balloon which will be used to represent the North and South Poles of the ball/balloon.
2. Using the scissors, cut the card into the shape of a star.
3. Cover the star in foil, using the glue if necessary to stick it to the card.
4. Hang the star up from the ceiling using the string. Make sure it is high up and clearly visible from the whole of the class.
5. Sit in a circle with the rest of your class, your class teacher should sit or stand in the middle of the circle representing the Sun.
6. Select one member of your class in the circle to start the activity and pass the globe to them.
7. Tilt the globe away from the vertical, pointing the North Pole towards the hanging star.
8. Pass the globe around the circle keeping the North Pole pointed in the same direction towards the hanging star. *Remember to keep the globe spinning on its axis as it is passed around!*
9. Note how as the globe moves around the circle, sometimes the Northern Hemisphere is tilted more towards the Sun, sometimes the Southern Hemisphere is pointed more towards the Sun and sometimes neither hemispheres are tilted towards the Sun.

QUESTIONS:

1. For roughly what fraction of the orbit did the Southern Hemisphere point towards the Sun?
   $\frac{1}{4}$ *of the orbit.*
2. For roughly what fraction of the orbit did the Northern Hemisphere point towards the Sun?
   $\frac{1}{4}$ *of the orbit.*
3. What length of time do these fractions correspond to for the real Earth's orbit around the Sun?
   Both represent 3 months.

Let's see now what effect this tilt has on the Earth.



ACTIVITY: Direct and indirect light

TEACHER'S NOTE

Before starting this activity, explain what is meant by direct and indirect. The aim of this activity is to see how the energy from a torch is spread out when the light is shone directly and indirectly onto card. In this activity students will need to shine a torch onto black card. Learners will need to work in pairs so that one person can hold the torch and the other one can draw an outline of the beam of light.

This activity works best when the room is darkened, as it is easier to see the torch light. Some torches produce concentric rings rather than a smooth light distribution. If this is the case the learners should pick a given ring (say the outside one, or the one immediately inside this, whichever is easier to see) and stick to observing this ring in both cases. Learners should find that the direct light is more concentrated (spread over a smaller area) than indirect light.

MATERIALS:

- A4 sized or larger piece of black card, one per pair
- torch, one per pair
- bin bags to darken the room if necessary
- pencil or pen, one per pair

INSTRUCTIONS:

1. You will need to work in a pair for this activity.
2. Place the card flat on a desktop or table.
3. Darken the room using curtains or bin bags.
4. One person should hold the torch about 25 cm above the card pointing straight down onto the card. Shine the light onto the card.
5. Look at the beam shining on the black card and note its size. The person in the pair not holding the torch should draw around the edge of the beam with a pen or pencil.
6. Swap places and point the torch towards the card at an angle of 45°, keeping it at the same distance from the card as before. Shine the light onto the card.
7. Look at the beam shining on to the card, draw around the edge of the beam with a pen or pencil.

QUESTIONS:

1. In which case is the light more concentrated? (direct or indirect)
   Direct.
2. In which case is the light more spread out? (direct or indirect)
   Indirect.
3. If the light is more concentrated, does this mean that the energy from the torch is more concentrated or spread out?
   If the light is more concentrated, energy from the torch is more concentrated, and spread over a smaller area.
4. In which case did the light look brighter? Why is this?
   Direct. Because the energy from the light is spread over a smaller area, so

each unit area receives more energy compared with the indirect case. As the brightness is proportional to the amount of energy received, so areas which receive more energy per unit area are brighter.

The energy is spread out over a larger surface area when the light is shone at a slanting (**oblique**) angle relative to the card than when it is shone **directly** onto the card. Similarly, when light from the Sun hits the Earth directly, the solar energy is spread over a smaller surface area and is more **intense** (concentrated) than when light hits the Earth **indirectly**. Do you think this has an effect on the temperature? Let's investigate.

INVESTIGATION: Direct and indirect light and its effects on temperature

Scientists often use models to recreate the real world in a laboratory. In this investigation, you will use a model to simulate how sunlight strikes the surface of the Earth. You will use a torch to represent the Sun. You will change the angle at which light strikes a flat surface and see what effect this has on the heating of the surface. This will model how sunlight strikes the surface of the Earth at different angles.

TEACHER'S NOTE

The aim of this investigation is to demonstrate that direct light heats up an area more quickly than indirect light. It is assumed that this experiment will be a teacher led demonstration but with measurements taken by the learners, however, if you have enough equipment there is no reason why the learners cannot set up the experiment themselves. Strip thermometers are often used for taking children's temperatures and are available in most chemists. You can extend this activity if you wish by changing the angle at which the "indirect light" lamp points at the card in steps. Learners should find that shallower angles with respect to the surface produce lower temperature readings.

Ensure that the two lamps have bulbs of the same power installed in them. During the experiment the strip thermometers may become too hot. If this happens turn both the lamps off for about 5 minutes and let them cool down, then start the observation again.

INVESTIGATIVE QUESTION:

Does direct light heat an area more quickly or slowly than indirect light?

HYPOTHESIS:

What do you think will happen?

TEACHER'S NOTE

Learner-dependent answer. Learners could state 'The direct light will heat the area more quickly.'

IDENTIFY VARIABLES:

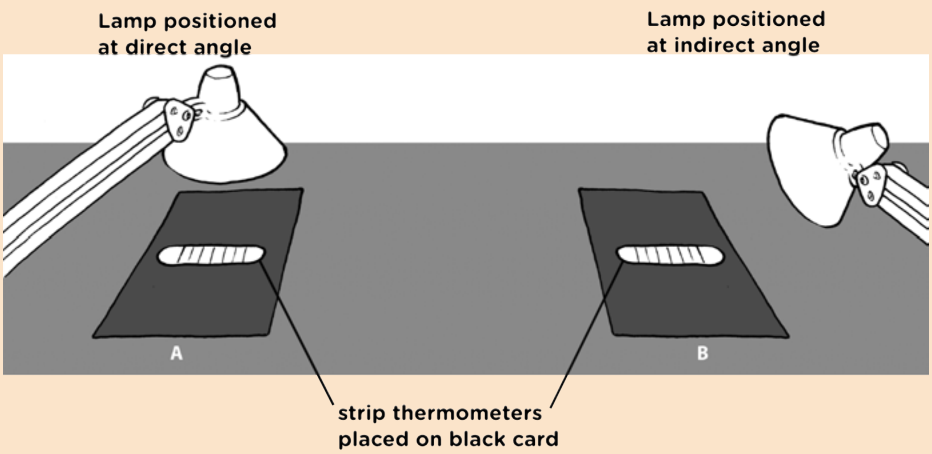
1. What are you keeping constant in this experiment?
   The distance of the lamp from the thermometer is kept constant. Also the power of the light bulbs used in the lamps are kept constant. The amount of time that light is shone on each thermometer is also kept constant. These are called control variables.
2. What are you changing in this experiment?
   The angle at which the light hits the card is changing, in the first case, A, the light is direct. In the second case, B, the light is indirect. This is the changing independent variable.
3. What are you going to be measuring in this investigation?
   The temperature. This is the dependent variable.

MATERIALS AND APPARATUS:

- two desk lamps
- two pieces of black card/paper
- two strip thermometers
- watch or clock
- marker pen and/or sticker to label the cards

METHOD:

1. Place the two desk lamps on a table or desk about 1 metre apart from each other.
2. Point one of the desk lamps directly downwards towards the table, at a height of about 30 cm.
3. Place the black card under the light and label it "A".
4. Place the thermometer strip in the centre of the black card. The light bulb should be directly above the thermometer strip.
5. Adjust the second desk lamp so that it is at the same height as the first one, but instead of pointing it directly down at the table, tilt it slightly to one side (left-right direction).
6. Place the second piece of black card under this lamp and label it "B".
7. Place the second thermometer strip in the centre of the black paper. This light should shine indirectly over the thermometer.
8. Record the temperature of both thermometers in the table below.
9. Turn on both lights at the same time. Wait for about 30 seconds and then record the temperatures of the thermometers in the table below.



RESULTS AND OBSERVATIONS:

Card	Initial temperature (°C)	Final temperature (°C)	Temperature difference (°C)
Card A (direct light)			
Card B (indirect light)			

TEACHER'S NOTE

The temperatures recorded are learner dependent. However, all learners should agree on the initial temperature of the thermometers. The thermometers should indicate the same initial temperature if they are calibrated correctly. The final temperature should be higher than the initial temperature, and the temperature of A should be higher than B. They should then work out the temperature difference by subtracting the initial temperature from the final temperature.

1. Is light hitting the card from lamp A direct or indirect light?
   Direct light.
2. Is light hitting the card from lamp B direct or indirect light?
   Indirect light.
3. Which card has the hottest final temperature? Why is this?
   Card A, this is because the light is shining directly onto it and so the energy is more concentrated.

EVALUATION:

How could you have improved this experiment?

TEACHER'S NOTE

Learner-dependent answer. Learners should clearly explain the reasoning behind their answers. Examples could include using more sensitive thermometers, repeating the observations and taking an average value for the temperatures.

CONCLUSION:

What do you conclude about the heating effects of direct and indirect light? Why do you think this is the case?

TEACHER'S NOTE

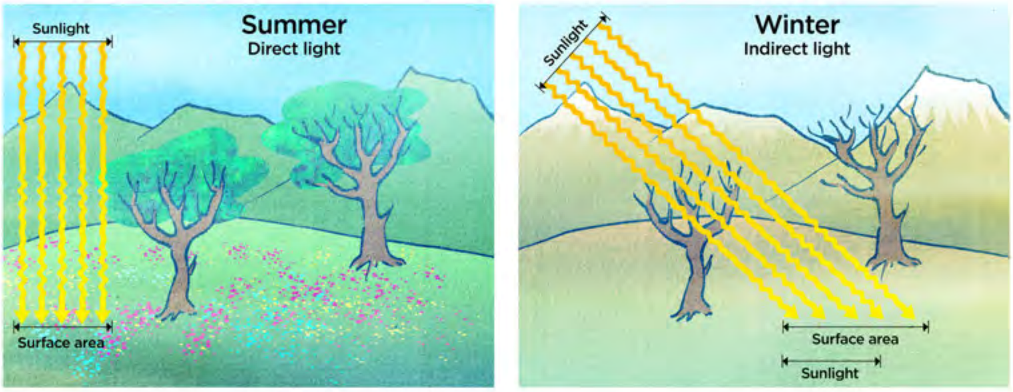
Direct light heats the card more quickly as light is more concentrated and so more energy per unit area falls onto the card. This energy is what causes the heating and so if there is more energy per unit area falling on a surface then there will be more heating of that surface.

QUESTIONS:

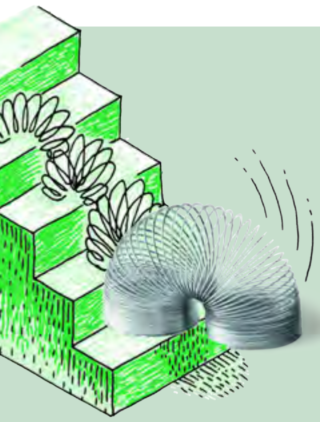
Imagine that the lamps represent sunlight and the cards represent the surface of the Earth.

1. What season on Earth do you think corresponds to case A, and why do you think this?
   Summer because it is warmer.
2. What season on Earth do you think corresponds to case B, and why do you think this?
   Winter because it is cooler.

Areas of the Earth that are hit by direct sunlight are therefore warmer than areas that are hit by indirect sunlight. In the summer, the Sun is high in the sky and we receive more direct sunlight than in winter when the Sun is lower in the sky and we receive more indirect sunlight. This explains why summer is warmer than winter.



But why do we receive more direct light in summer? And why is it always warmer at the equator than at the North and South Poles? Let's do an activity to find out.



ACTIVITY: Looking at sunlight hitting the Earth

TEACHER'S NOTE

The aim of this exercise is to introduce learners to the concept that sunlight hits the Earth at varying angles across the Earth's surface because it is curved. At the equator you can see that sunlight hits the Earth almost straight on, this is called direct light. Areas close to the equator are warm as the Sun's energy is concentrated in these regions. As the Earth is curved, not all of the Sun's rays hit it directly. Areas that are hit by indirect sunlight are cooler because the Sun's energy is spread out over a large area. The poles are always hit by indirect light which explains why it is cold at the North and South Poles.

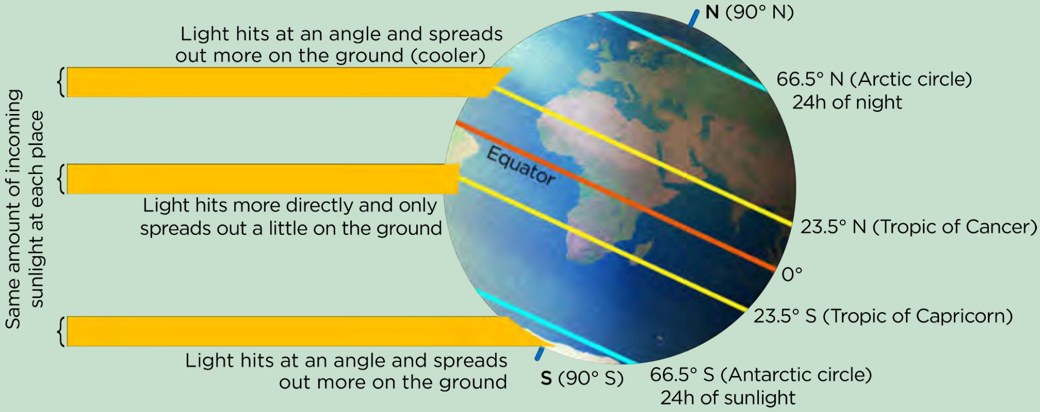
TEACHER'S NOTE

In this example, the Southern Hemisphere is tilted towards the Sun. In the Northern Hemisphere most of the sunlight hits the surface of the Earth at a shallow slanted (oblique) angle relative to the Earth's surface, and so it receives more indirect light. The Southern Hemisphere receives lots of sunlight straight on (directly) and a little also hits at an oblique angle (indirectly) close to the South Pole. As the Southern Hemisphere receives more direct light it is summer there.

This exercise may prove a little harder for the learners as they have to visualise the angle at which the Sun's rays strike the Earth along a curved surface. Encourage them to rotate the book around if needed so that the surface of the Earth is always horizontal.

INSTRUCTIONS:

1. Look at the example picture below. It shows sunlight hitting the Earth.
2. Look at the Sun's rays and see how the angle at which they hit the Earth's surface changes at different points along the surface of the Earth because of its curved shape.
3. Answer the questions below.

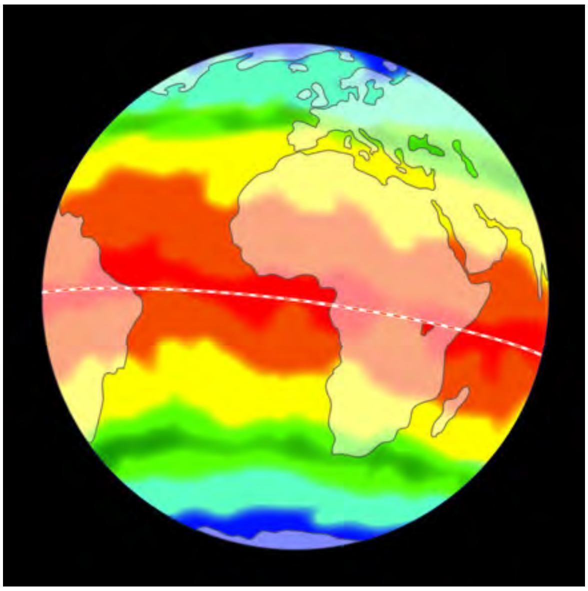


QUESTIONS:

1. Does the equator receive more or less direct light than the poles?
   More direct light.
2. Which hemisphere receives more direct light in the picture? Why is this?
   The Southern Hemisphere receives more direct light as it is tilted towards the Sun.
3. Which hemisphere in this diagram receives more indirect light? Why is this?
   The Northern Hemisphere receives more indirect light as it is tilted away from the Sun.
4. Why do you think it is warmer at the equator than at the poles?
   Because the equator receives more direct light where the solar energy is more concentrated and the poles receive only indirect light where solar energy is more spread out.
5. Is it summer or winter in the Southern Hemisphere in this example?
   Summer.

6. Is it summer or winter in the Northern Hemisphere in this example?
   Winter.
7. What would happen to the seasons if the Earth was tilted in the opposite direction, with the Northern Hemisphere tilted towards the Sun instead?
   The seasons would be reversed, it would be summer in the Northern Hemisphere and winter in the Southern Hemisphere.

The light falling on the Equator always hits at angles very close to 90° (almost direct), so it stays almost the same temperature all year round.



The areas around the Equator are warmer than at the poles throughout the year, as light falls almost directly on the Earth's surface between the Tropic of Cancer and Tropic of Capricorn.

TAKE NOTE

Another way to say that the light falls indirectly is to say **obliquely.** Oblique means it is not at a right angle (90°), but slanted.

Areas that are hit by indirect sunlight are cooler because the Sun's energy is spread out over a larger area than at the equator. The poles are always hit by indirect sunlight which explains why it is cold at the North and South Poles.

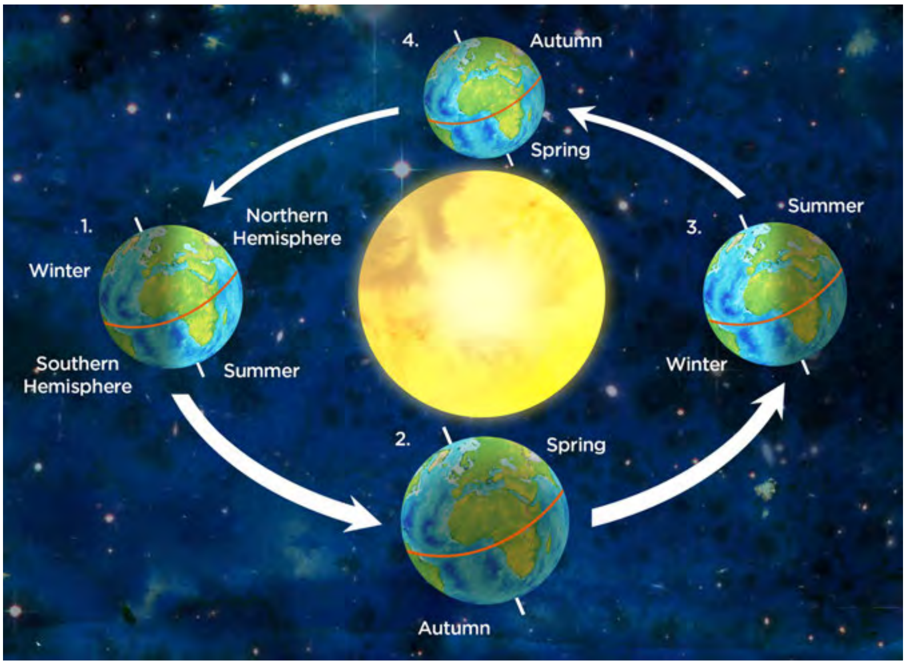
TEACHER'S NOTE

Having discovered that the Earth is warmer close to the equator and cooler towards the poles you could start discussions related to this. For example, why is the world's population distributed the way it is? How long is the growing season for each region of the world? Tundra, Desert, Deciduous versus Coniferous versus Rain Forest. Why?

We experience the different seasons because of the varying amount of direct and indirect sunlight we receive. When the Southern Hemisphere is tilted towards the Sun it receives more direct sunlight (more radiant energy) and temperatures increase: it is summer in the Southern Hemisphere.

The opposite hemisphere is tilted away from the Sun and receives less direct sunlight, it receives less energy and temperatures decrease, so it is winter in the

Northern Hemisphere. When the Northern Hemisphere is tilted towards the Sun we have the opposite case and it is summer in the Northern Hemisphere and winter in the Southern Hemisphere.



The seasons as the Earth revolves around the Sun.

TEACHER'S NOTE

A nice arts and craft activity to reinforce the idea that the tilt of the Earth's rotation axis is responsible for the seasons is to have learners make a poster of the above figure, labelling the Earth and Sun, the equator, hemispheres, poles, tilt (towards, away, neither) and resulting seasons for each hemisphere at each position.

In the picture above you can see the Earth travelling around the Sun in its orbit. The Earth's axis always points in the same direction in space. Because of this, sometimes the Southern Hemisphere is tilted towards the Sun and sometimes it is tilted away from the Sun. Let's follow the path of the Earth around the Sun as it completes one revolution from points 1 to 4.

At position 1 the light falls directly on the Tropic of Capricorn (23.5° S). This occurs when we, in the Southern Hemisphere, are having summer, and is called a **solstice**. The day of the summer solstice is the longest day in the year. In the Southern Hemisphere, this is usually around 21 December. At position 3, the light falls directly on the Tropic of Cancer (23.5° N). This occurs during our winter, whilst the Northern Hemisphere is having summer. This is called the winter solstice in the Southern Hemisphere and occurs around the 21 June. The winter solstice is the shortest day of the year.

At position 2 and 4, the equator receives direct sunlight. This is called an **equinox**. An equinox occurs twice a year, around 20 March (when our autumn equinox occurs at position 2) and 22 September (when our spring equinox occurs at position 4).

TAKE NOTE

The term 'equinox' comes from the Latin words *aequus* (equal) and *nox* (night), because around the equinox, night and day are about the same length.

ACTIVITY: Earth's seasons summary

INSTRUCTIONS:

1. Refer to the previous diagram showing the Earth's seasons.
2. Fill in the blanks in the sentences below.
3. Write out the paragraph in full and underline your answers.

QUESTIONS:

1. At position 1, the Southern Hemisphere is tilted towards the Sun and experiences summer. This is called the summer __________ in the Southern Hemisphere and occurs around the date, __________. The Northern Hemisphere is tilted __________ from the Sun and experiences winter. This is called the winter __________ in the Northern Hemisphere.
   At position 1, the Southern Hemisphere is tilted towards the Sun and experiences summer. This is called the summer solstice in the Southern Hemisphere and occurs around the date, 21 December. The Northern Hemisphere is tilted away from the Sun and experiences winter. This is called the winter solstice in the Northern Hemisphere.
2. At position 2, __________ months later, neither hemisphere is tilted more toward the Sun. Direct sunlight only hits the Earth near the __________ and indirect sunlight hits nearly everywhere else. This is called an __________. This causes mild temperatures in the north and south away from the equator.
   At position 2, three months later, neither hemisphere is tilted more toward the Sun. Direct light only hits the Earth near the equator and indirect light hits nearly everywhere else. This is called an equinox. This causes mild temperatures in the north and south away from the equator.
3. Six months later, the Southern Hemisphere is tilted __________ from the Sun and experiences __________. This is called the winter __________ in the Southern Hemisphere and occurs around the date, __________. The Northern Hemisphere is tilted the Sun and experiences __________. This is called the summer __________ in the Northern Hemisphere.
   Six months later, the Southern Hemisphere is tilted away from the Sun and experiences winter. This is called the winter solstice in the Southern Hemisphere and occurs around the date, 21 June. The Northern Hemisphere is tilted towards the Sun and experiences summer. This is called the summer solstice in the Northern Hemisphere.
4. Nine months later, neither hemisphere is tilted more toward the Sun. Direct light only hits the Earth near the __________ and indirect light hits nearly everywhere else. This causes mild temperatures in the north and south away from the equator.
   Nine months later, either hemisphere is tilted more toward the Sun. Direct light only hits the Earth near the equator and indirect light hits nearly everywhere else. This causes mild temperatures in the north and south away from the equator.
5. The Earth is now back to its starting point again, having completed one revolution of the Sun in __________ months.
   The Earth is now back to its starting point again, having completed one revolution of the Sun in twelve months
6. Why do you think it is important to know about the seasons? Think about how people used the knowledge of the seasons to organise their lives and mark the passage of time. Discuss this with your class and take some notes

below.
Learner-dependent answer

TEACHER'S NOTE

It is important that we relate the learning in class to learners' everyday lives so that it is applicable to them. You can have a class discussion on this topic, but learners must also write down their own thoughts. Start off by asking learners what do they think we can learn from learning about the seasons?

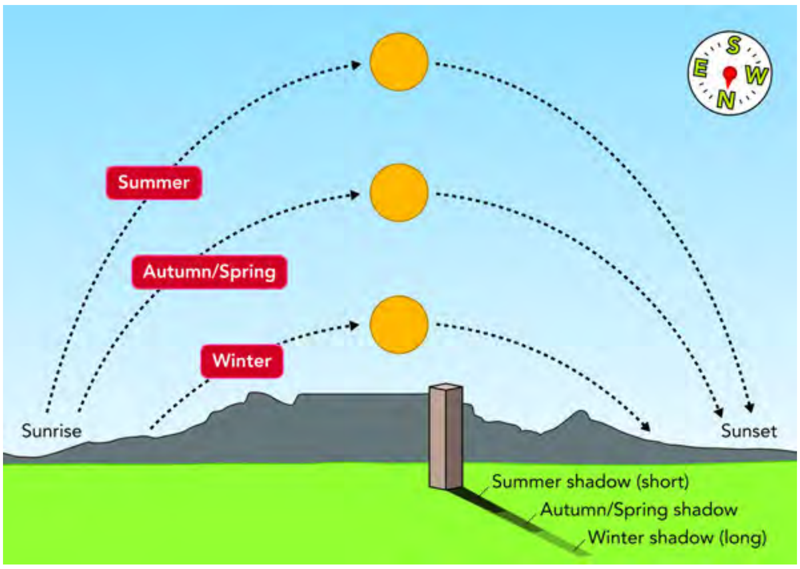
Some of the benefits of learning about the seasons relate to indigenous knowledge, such as knowing when to plant crops, when to harvest and when to store food for the winter months. Before people had calendars, they used the seasons to mark the passage of time and know when a year had gone by and the cycle repeated again.

So you now know that temperatures (and therefore the seasons) on Earth are determined by the angle at which sunlight hits the Earth. In summer, the Sun is high in the sky and sunlight hits the Earth directly. In winter, the Sun is low in the sky and the Sun's rays strike the Earth indirectly at an oblique (shallow) angle. The seasons occur because *the Earth's axis is tilted relative to the path of its orbit around the Sun* and not because the distance between the Earth and the Sun vary as the Earth revolves around the Sun.

VISIT
The reason for the seasons (video) bit.ly/1dNUVRa

Viewed from the Earth's surface, the Sun appears higher in the sky in summer. As the

Sun travels higher in the sky it takes more time to travel across the sky from sunrise to sunset. Therefore, daytime is longer in summer than in winter. The change in the length of daytime during the year also occurs because of the tilt of the Earth's rotation axis in space.



The apparent path of the Sun across the sky in winter and summer. The Sun travels higher and further across the sky in summer, and so days are longer.

TAKE NOTE
Remember that it is NOT actually the Sun that moves, but Earth's rotation which makes it look as though the Sun moves across the sky.

TEACHER'S NOTE

The following questions are challenging and can be used to test the most able learners and extend their thinking.

What do you think would happen to the seasons if the Earth were not tilted by 23.5^{o}, but instead were pointed straight up relative to the path of its orbit?

TEACHER'S NOTE

You can discuss this with your class. The Sun's path across the sky would be the same all year round and there would no longer be seasons as we know them. It would still be warm at the equator and cold at the poles however. The biggest impact on temperatures would be at the poles. Presently they have dark winters with extremely low temperatures followed by warmer temperatures and constant light in the summer. If there were no tilt, the polar regions would have much more uniform temperatures all year round and the Sun would always be low on the horizon. Across the Earth it would be like it is in the middle of autumn or spring all year.

There would still be some slight changes during the year. This is because the Earth-Sun distance varies during the year as the Earth's orbit around the Sun is not a perfect circle (it is *slightly* elliptical). Currently, the Earth is closest to the Sun in January and furthest away in July. With no tilt, this change in Earth-Sun distance during the year would produce a slight impact on the weather pattern. It must be emphasised that the effect would be tiny as the Earth-Sun distance does not vary significantly different during the year (147 million km in January 2013 compared to 152 million km in July 2013).

The Southern Hemisphere receives the greatest amount of solar energy around the 21st of December each year. However, the hottest days of the year are generally a month or so afterwards. Why do you think this is?

VISIT
A year of the sky on Earth (video) bit.ly/16vU8Fr

TEACHER'S NOTE

This is because it takes time for the land and sea to heat up or cool down. This is also explains why the seasons change gradually.

TEACHER'S NOTE

The video showing a year of the sky is very interesting. Each panel shows one day so there are 360 movie panels playing at once to show the sky over almost a whole year, as recorded in San Francisco. 28 July is shown in the upper left and January 1 is about half way down. The camera recorded an image every 10 seconds from sunrise to sunset. You can see the time going by in the bottom right. This video is useful to show learners how although each day lasts 24 hours, the amount of sunlight changes depending on the season. Although this video is for the Northern Hemisphere and we are in the Southern Hemisphere, it is still very interesting and can be used to demonstrate the difference in daylight hours very eloquently. You can ask the learners why they think the bottom videos (and soon the top videos) are the first to light. This is because it is dawn and the Sun rises earlier in the summer months of June, July and August in the Northern Hemisphere, so these panels light up earlier than the others for the winter months. The initial darkness in the middle depicts the delayed dawn and fewer daylight hours of winter.

Seasons on other planets

TEACHER'S NOTE

This section is an extension which is not required by CAPS, but offers an opportunity to extend your learner's thinking, if you feel you have time in class and you need to assess the capabilities of your learners. Alternatively, learners can read it themselves in their own time.

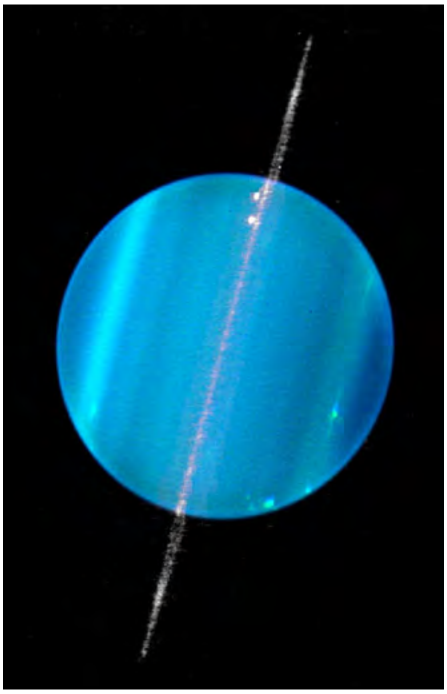
Do you think that other planets experience seasons too?

Yes they do! Every planet in the solar system has seasons, but they are nothing like the seasons we experience on Earth. Seasons pass very quickly on some planets like Venus, yet last decades on others like Uranus. Unlike the Earth's seasons, which are caused *only* by the tilt of the Earth's axis in space, seasons on other planets can be caused by:

1. The tilt of the planet's rotation axis.
2. The variable distance of the planet from the Sun during its orbit. This is because some planets have extremely oval shaped orbits around the Sun unlike Earth.

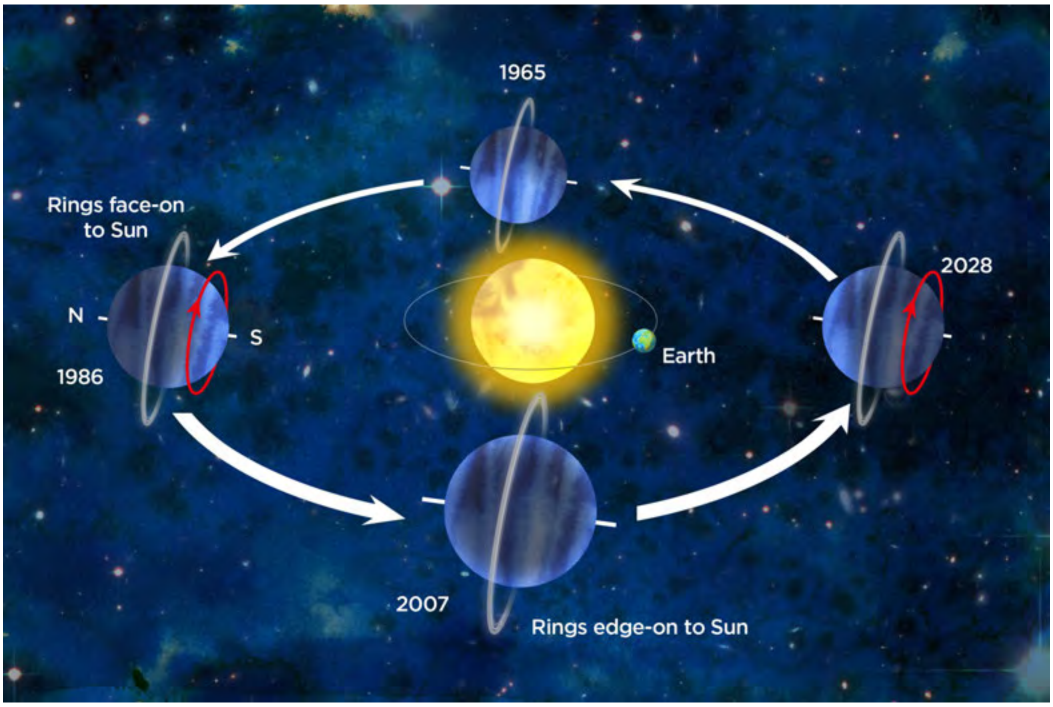
The planets Venus and Jupiter have very small tilts compared with Earth. Their rotation axes are only tilted by 3° compared with the Earth's 23.5° tilt and so Venus' and Jupiter's seasons are hardly noticeable. Venus does have interesting weather however! Venus's surface is a whopping 460 °C all year round because Venus has an atmosphere made of dense acidic clouds which trap sunlight leading to a runaway greenhouse effect.

Mars' tilt is 25°, very close to the Earth's 23.5°. Because of this tilt, Mars has seasons, just like the Earth. As Mars takes two Earth years to orbit the Sun, the seasons on Mars are twice as long. The rotation axis of Mars does not point toward Polaris, our North Star, but points towards the star Alpha Cygni. Because of this, Martian seasons are out of step with the seasons on Earth. Mars also has a distinctly oval-shaped orbit. When Mars is further away from the Sun in its orbit it is cooler, which leads to long, extreme southern winters. The northern winters are not so long and extreme because they occur when the planet is closer to the Sun.



Uranus.

The planet with the most extreme seasons in the solar system is Uranus. Like Earth, the orbit of Uranus is nearly circular, however, Uranus's rotation axis is tilted by a massive 98°. Uranus is on its side! Uranus completes one revolution around the Sun every 84 Earth years, giving rise to seasons which last 21 years each! For two of the seasons, one pole is pointed directly at the Sun and the opposite hemisphere does not see the Sun because Uranus spins on its side. The hemisphere facing away from the Sun experiences a long (around 21 years!) dark, bitterly cold winter and doesn't see the Sun until the planet has travelled on in its orbit, to a point in its orbit where Uranus's rotation axis no longer points directly at the Sun.



The seasons on Uranus: In 1986 the south pole was facing the Sun and so its Northern Hemisphere was in total darkness. In 2028 the North Pole of Uranus will face the Sun and the Southern Hemisphere will be in total darkness. Presently, neither pole is facing the Sun directly.

1.2 Solar energy and life on Earth

TEACHER'S NOTE

This section builds on what was done in Grades 4-6 on energy and photosynthesis to expand learners' understanding of these concepts and include the concept that the Sun's energy can be captured through photosynthesis and stored as carbohydrates to sustain life on Earth.

Earlier in Grade 7, in the Energy and Change section, the concept of fossil fuels was discussed with a focus on renewable versus non-renewable energy sources. This is extended here by looking into how fossil fuels were formed and how they captured the Sun's energy for use millions of years later. Learners need to realise how crucially important the Sun is for life on Earth.

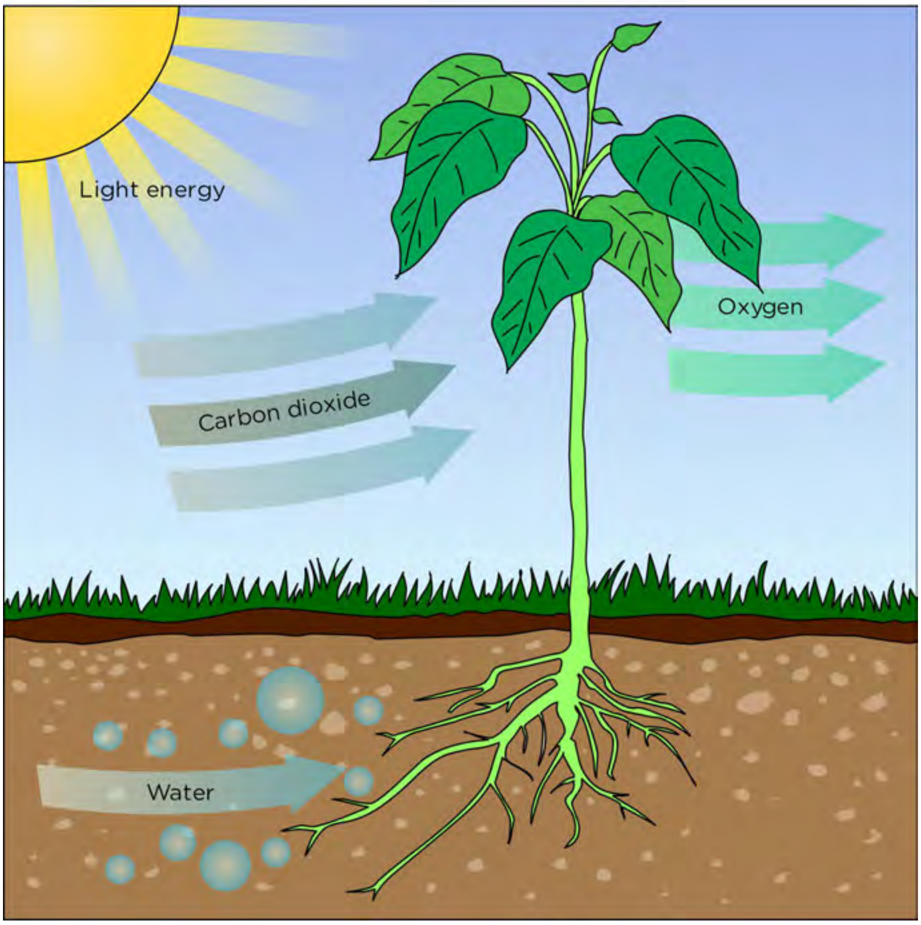
In earlier grades energy transfer from producers to consumers, in food chains and food webs, were discussed. Here we look at capturing the energy from its source, the Sun, and storing it for later use. The overarching concept that energy cannot be created or destroyed, it can only be transferred from one form to another, should come through strongly in this section and the next one.

Misconception: The carbon in plants comes from the soil.

This could be used as an introduction to the section. Ask learners what wood is made of (mainly carbon) and where the carbon comes from that a tree is made of. Learners might say the soil (which is incorrect). This could then lead into a discussion of photosynthesis (revision) and how energy is captured by plants. Learners could be lead to discover that plants take up atmospheric carbon from the carbon dioxide air and not from the soil - wood is composed mainly of carbon atoms which come from atmospheric carbon dioxide. This is how plants capture carbon and store it so that human and animals are able to use it. The take-up of carbon by plants is also important as it controls the amount of greenhouse gases in the atmosphere (CO_2 is a problematic greenhouse gas when in excess). When plants die and decompose to eventually form coal, the carbon remains in the fossil fuel which we harness later on. The same applies for oil and natural gas.

So far this term you learnt about how the Sun and Earth interact to form day and night, and the seasons. In this section we are going to look further at how important the Sun is for us on Earth, and more specifically at how the energy from the Sun is essential for life on Earth.

In Grade 6 you learnt how plants produce food through the process of **photosynthesis**. Plants absorb light energy from the Sun and use the energy to make food. In this way the Sun's energy is captured and stored so that it can be used later on.



The process of photosynthesis to produce carbohydrates which are stored in the plant.

TAKE NOTE

Plants also take up minerals from the soil, which are necessary for their functioning.

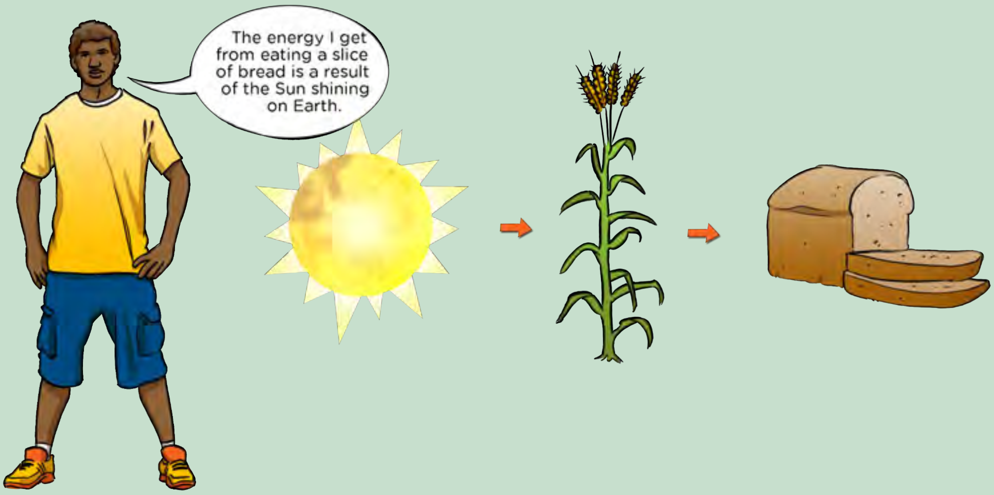
In photosynthesis the energy from the Sun is to used to change carbon dioxide and water into **carbohydrates** (for example **cellulose**, **starch** or **glucose**). The carbohydrates are stored in fruits, leaves, wood or bark. When we eat the plant, for example an apple, our bodies are able to release the energy stored in carbohydrates. In the same way animals, for example cows, use the Sun's energy when they eat the grass.

ACTIVITY: Capturing the Sun's energy

Study the following flow diagram and answer the question below.

QUESTION:

A boy says: 'The energy I get from eating a slice of bread is a result of the Sun shining on Earth.' Do you agree with this statement? Use the flow diagram provided, and write a paragraph to explain why you agree or disagree with the statement. Use the words in the word bank in your explanation.



Word bank:

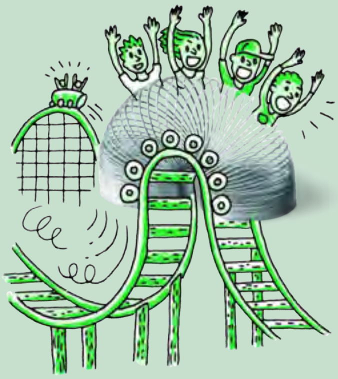
- capture
- release
- store
- energy
- photosynthesis
- Sun
- wheat
- bread

TEACHER'S NOTE

Learner-dependent answer. It is not important whether the learner agrees with the statement or not, but rather what they write in their explanation. A possible explanation could be:

The Sun's energy is captured through a process called photosynthesis. Wheat plants use the energy to make carbohydrates which they store in their wheat kernels. The wheat kernels are ground to make flour for bread. The Sun's energy is therefore captured in the carbohydrates found in bread, so when the boy eats the bread, the energy from the carbohydrates is released.

All plants and animals depend on photosynthesis for their energy. In previous grades, you learnt about energy transfer between producers, for example grass, and consumers, for example a buck or lion. You used food chains and food webs to show how energy is transferred. Plants play a vital role in life on Earth as they form the basis of food chains. Without plants, life on Earth would not survive. Plants are completely dependant upon the Sun for survival and would die out without its energy which allows them to photosynthesise. Let's investigate this in the following activity:



ACTIVITY: What would happen if the Sun's rays are blocked from reaching Earth?

Imagine a world without the Sun. How can this happen? It has happened before in Earth's history.

Dinosaurs lived on Earth millions of years ago. They were the dominant terrestrial vertebrates until about 65 million years ago, when there was a massive extinction. There are several theories about what caused this mass extinction. The most supported theory is that a massive asteroid hit Earth. It entered Earth's atmosphere with a brilliant flash of light and crashed into a shallow sea. Huge pieces of red-hot rock and steam exploded into the sky, causing raging fires which destroyed everything in their path. The asteroid's impact also caused giant waves, called tsunamis which swept across the coastal lands. Scientists think that the impact could have started a series of volcanic eruptions. This sent huge clouds of ash and dust into the atmosphere, blocking the sunlight. These huge clouds of ash, dust and steam quickly spread all over Earth and blocked the warm rays of the Sun. Scientists hypothesise that this cold, dark environment could have lasted for months, or even years.

An artist's depiction of the asteroid impact 65 millions years ago, which scientists think is the most direct cause of the dinosaur's sudden, mass extinction.

Much more recently in Earth's history, there was a supervolcanic eruption at the present site of Lake Toba in Indonesia. This occurred about 70 000 years ago when Mount Toba erupted and sent a huge volcanic ash cloud into the atmosphere. The eruption was followed by a six year long volcanic winter as the ash blocked out the sun's rays, and a 1000-year-long Ice Age. Following the eruption, mount Toba collapsed inwards and today the site can be seen at Lake Toba.

VISIT

The 10 biggest volcanic eruptions in recorded human history. bit.ly/14OGuK3

A satellite image of Earth's largest caldera (30 x 100 km), partially filled by Lake Toba.

Let's now pretend that another event occurs in present day, blocking the Sun's rays from reaching Earth. What would happen to the people, animals and plants on Earth? Discuss this with a friend and then complete the table by writing down the things that you think would happen if the Sun's rays are blocked from reaching Earth for an extended period.

TAKE NOTE

A caldera, meaning *cooking pot* in Latin, is a large volcanic feature usually formed by the collapse of land after a volcanic eruption.

TEACHER'S NOTE

For this activity let the learners first discuss what they think would happen in pairs. Then give them time to write their answers down. Afterwards a class discussion could follow. Another suggestion is to have the learner discussion at the end of a lesson and then give them the exercise for homework. The class discussion could follow in the next lesson when the homework is checked. The answers to this activity will be learner-dependent, however, some suggestions are provided. The purpose of the activity is to generate discussion and not to have right and wrong answers. The suggestions provided here are based on what scientists believe happened after the major volcanic eruptions (for example, Mount Toba), in the past.

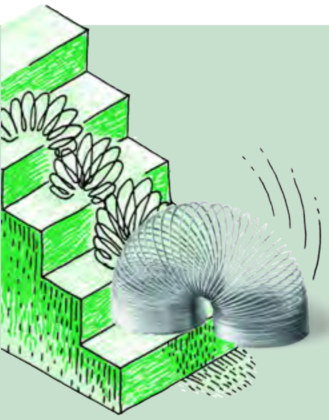
Something else to discuss, which links back to what learners covered briefly in Matter and Materials, is that the atmospheric dust and ash forms poisonous acid rain, which contaminates rivers, lakes and oceans, causing many plants and animals to die.

TEACHER'S NOTE

	What do you think would happen?
On the first day	It would be overcast as the ash and dust would block out the Sun's rays. It would be much cooler.
One week later	It would still be dark, where people have electricity they would have light. Fossil fuels will provide heat and light. Animals might die because of the cold. Plants would be affected as they would not be able to photosynthesise which would start to affect the quality of food higher up the food chain.
One month later	Most food crops will fail and plants that manage to fruit and seed will have lower abundance. All stored foods will be used until they run out. Animals will die when there are no more plants available. Weather patterns will have changed. Rainfall will change drastically and will be hugely reduced.
One year later	Many animal and plant species in the land and sea would have decreased in number, severely so in the case of animals or plants reliant on heat and rainfall for reproducing. People and animals will be struggling to find food and will have to expand their diet to include foods not usually eaten. There will be great competition for food at levels in the food chain where similar food types are eaten.

1.3 Stored solar energy

Earlier this year you learnt about **renewable** and **non-renewable** energy sources. **Fossil fuels** are examples of non-renewable energy sources. In this section we are looking at the relationship between the Earth and the Sun and how solar energy is stored on Earth. We have learnt that plants store the Sun's energy and we are able to use that energy later on. But what happens to the stored energy when plants die? To answer this question we need to go back in time. Millions of years back in time...



ACTIVITY: Going back in time

TEACHER'S NOTE

This is an optional activity. This video is only 9 minutes long and gives a useful link between the Sun's energy and how it was captured long ago. It gives the conditions for the formation of fossil fuels and explains how coal was formed. Play this video to your learners and let them answer the questions afterwards.

If video facilities are not available in your classroom, try to watch this video yourself and then use it to talk to the learners about the formation of fossil fuels. Alternatively, the text provides the information as well and can be used to facilitate a discussion before the activity is done.

The following video tells the story of how fossil fuels were formed millions of years ago and how we are able today to use the energy captured at the time: `bit.ly/19FdvrQ`.

Watch the video and answer the questions below.

QUESTIONS:

1. What are fossil fuels?
   A source of fuel/energy made from the fossilised remains of ancient plants and sea animals.
2. Are fossil fuels renewable or non-renewable? Give a reason for your answer.
   Non-renewable, it cannot be replaced once used up.
3. What conditions are needed for fossil fuels to form?
   Saturated environment (lots of water), anaerobic conditions (lack of oxygen), increased/high pressure, increased/high temperature.
4. How were each of these conditions met at the time when fossil fuels were formed?
   Swamps created areas of saturation and lack of oxygen (anaerobic conditions). As the plants died and layers upon layers were formed, the pressure on the lower layers increased. As the layers moved deeper in the Earth, they were subjected to increasingly high temperatures (it gets hotter the further down in the Earth's crust that you go).
5. Why are fossil fuels important?
   Fossil fuels are important as they form a vital part of the economies and lifestyles of all people on Earth. They have stored energy which we now use to drive many machines, vehicles and processes in our lives.
6. Why can't we make fossil fuels today?
   Fossil fuels need millions of years to form.

Fossil fuels were formed millions of years ago. **Coal, crude oil** and **natural gas** are examples of fossil fuels. The different fossil fuels were all formed in slightly different ways. Let's look at how they were formed.

Formation of coal

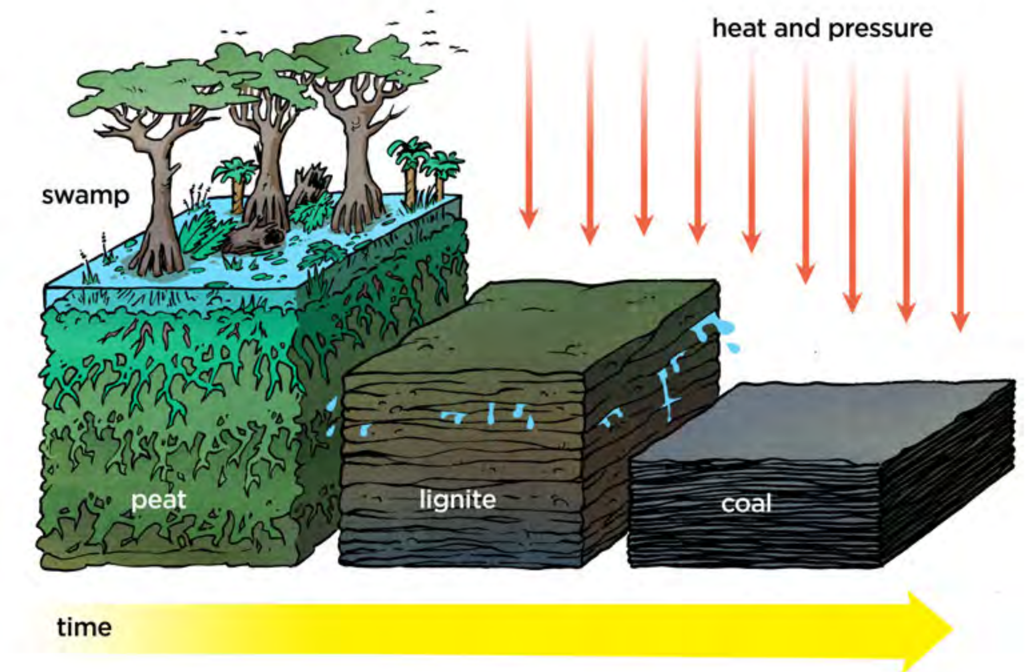
Millions of years ago the Earth was covered with fern-like plants. The plants captured the Sun's energy and manufactured carbohydrates through the process of photosynthesis, just like plants do today. Through changes in the conditions on Earth, the land was increasingly covered by water, forming swamps. Over time the plants died, forming a thick layer of dead **vegetation** on swamp bottoms.

As more water covered the land, sand and silt were washed in and covered the dead vegetation, enabling more and more plants to grow. These plants eventually died as well and more layers of plant material formed. Again they were was covered with water, sand and soil. This process repeated itself for millions of years building up massive layers of dead plant material, called **peat**. The peat layers eventually became buried and compressed by further layers of sediment forming above them.

Deep in the Earth the peat was subjected to pressure and heat, and turned into **lignite**, a porous type of coal. Upon further pressurisation and heating, more moisture was squeezed out of the lignite until it became soft, bituminous coal and eventually anthracite, the hardest type of coal available.

TAKE NOTE

Bituminous coal is a soft coal, containing bitumen, a sticky, black tar-like substance. Bituminous coal is of a lower quality than **anthracite** coal, which is a hard, compact coal with the highest carbon content out of all the coal types.



Coal was formed from the remains of ancient plants over millions of years.

ACTIVITY: Coal formation flow diagram

INSTRUCTIONS:

1. Read the above section on the formation of coal and summarise it in a flow diagram.
2. The following tips will help you draw your flow diagram:
    a) Underline the most important key words.
    b) Write a short sentence on each event.
    c) Identify the order in which events took place.
    d) Link the sentences using arrows.

TEACHER'S NOTE

The purpose of this activity is to practice the skill of identifying the most important facts from text and translating the information into a flow diagram. Learners also need to be able to extract the order of events from a paragraph.

Fernlike plants lived on Earth millions of years ago

Plants captured the Sun's energy through photosynthesis

Earth became wetter and swamps formed

Plants died forming thick layers of peat

Water washed in silt and sand

More plants grew and died

More layers formed

Layers were compressed and heated, squeezing out more and more moisture

Peat turned into lignite

Lignite turned into bituminous coal

Bituminous coal turned into anthracite coal

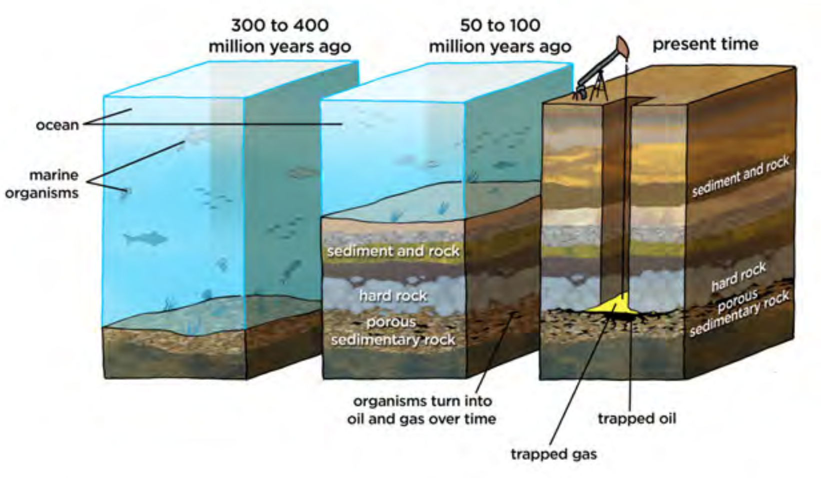
Coal is found in a number of different areas in South Africa. Study the map to see where the coal deposits are located in South Africa. Millions of years ago the interior of South Africa was a large swamp where many plants grew and died, eventually forming coal.

Coal deposits in South Africa.

Formation of crude oil and natural gas

Oil, also known as crude oil, and natural gas were also formed millions of years ago by processes similar to those leading to the formation of coal. Sea animals and plants died in the oceans and were deposited on the ocean floor. Over millions of years, layer upon layer of marine deposits formed and were covered by sand and silt.

Through the actions of temperature and pressure, the deposits were changed into crude oil and natural gas. Today, oil and gas are trapped under layers of rocks and sediment and have to be drilled and pumped out of the Earth. South Africa has some gas fields off the coast of Mossel Bay, but we do not have any oil reserves.



Crude oil and gas were formed millions of years ago.

Crude oil is a thick, dark, sticky substance when it comes out of the ground. Crude oil has many uses, but has to be refined first to obtain different a number of different products. These different products have different boiling points, which is how they can be separated from each other. Do you remember that we learnt about this in Matter and Materials when looking at how to separate mixtures? What is the name of this technique where different components, which have different boiling points, are separated by evaporating and collecting them?

TEACHER'S NOTE

We call the separated components fractions, and the process, fractional distillation.

Crude oil is refined to make a number of different products such as motor oil, petrol, lighter fuel, aeroplane fuel, diesel and tar, Vaseline and other waxes. The components of crude oil are evaporated at different temperatures, starting with lighter fuel (which has the lowest boiling point), then jet fuel, then petroleum, then motor car oil, until only tar is left. When crude oil is refined, some of the raw materials extracted from this process are then used to make plastics and various chemicals.

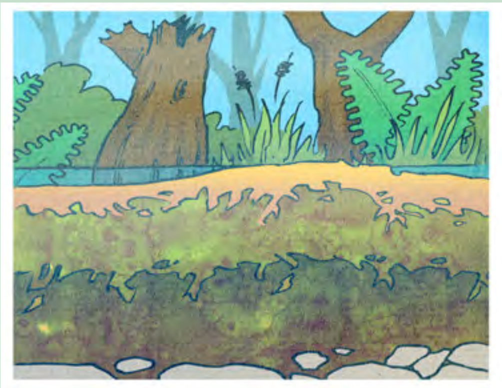
ACTIVITY: Forming coal

TEACHER'S NOTE

The purpose of this activity is to support learners in making sense of information. Here they need to put information in order by applying what they know about the process of coal formation. If there are learners struggling to find the correct order, guide them by telling them to look at number of layers of coal formed. The learners should use the pictures to guide their discussion in the paragraph.

INSTRUCTIONS:

1. The following pictures explain the formation of coal. The pictures are not in the correct order.
2. Study the pictures and order them in the correct order to show how coal is formed.
3. Write a paragraph explaining the formation of coal.



Picture 1.

Picture 2.

Picture 3.

Picture 4.

TEACHER'S NOTE

The correct order is: 4, 1, 3, 2

Millions of years ago ferns and trees grew in swamps. As they died, they formed thick layers of vegetation in the swamps. Rain and rivers washed in sand and soil, which covered the dead plant material. More plants grew, died and formed layers of dead plant material called peat. Over millions of years the peat layers got buried deeper within the Earth's crust, subjecting the layers to high temperatures and pressure. Over time, the peat turned into lignite. High temperatures and pressure squeezed and squeezed more water from the lignite and layers of bituminous coal and later anthracite was formed.

The video resource on the formation of fossil fuels from the activity done earlier in this section (`bit.ly/1h8ncSi`) can also be used here to help learners by providing them with a visual picture of how coal was formed. As an extension of this activity, learners could be asked to make up their own drawings for the formation of oil or gas.

VISIT

The formation of coal (video). bit.ly/188KxS7

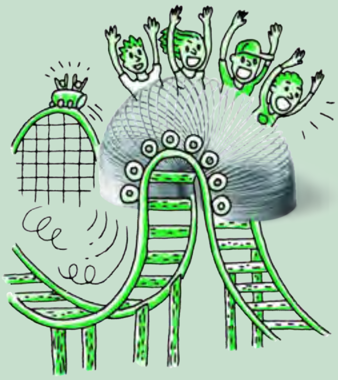
Fossil fuels store and transfer solar energy

What type of energy is stored in fossil fuels?

TEACHER'S NOTE

The energy is stored in the form of potential energy in fossil fuels.

When we use fossil fuels, the stored energy is transferred to another part in the system, for example as kinetic energy. We already saw this in Energy and Change last term when looking at how a coal-powered power station works to generate electricity. In a coal-powered station, coal is burned and used to boil water. The steam produced then turns the turbine, which in turn causes the generator to turn to produce electricity. In the next activity we will investigate how the Sun's energy is transferred through fossil fuels.



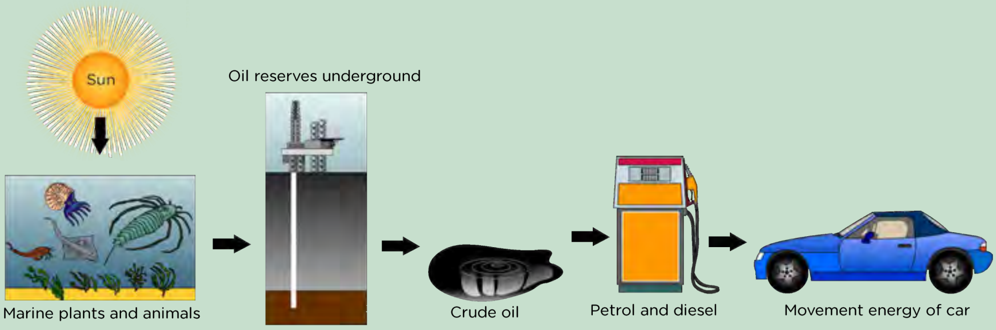
ACTIVITY: Explaining the flow of energy

TEACHER'S NOTE

This activity can be used to link what was done in the previous term on energy transfers within a system, with the content from this term. This will also give the learners the opportunity to revise what was done earlier in the year.

INSTRUCTIONS:

Petrol is made from crude oil, a fossil fuel. Use the diagram below to answer the questions about how the Sun's energy is captured in petrol and how this helps life on Earth.



QUESTIONS:

1. Using the diagram, explain how the Sun's energy is captured in petrol and used in cars.
   The energy from the Sun (or solar energy) was captured through the process of photosynthesis by sea plants. The marine animals obtained energy by eating the plants. Millions of years ago the sea animals and plants died in the oceans and were deposited on the ocean floor. They were covered with sand and silt and formed layers and layers of dead matter. Over time, and through the working of temperature and pressure, the remains were changed into crude oil and natural gas. Crude oil was extracted from the ground by mining and refined to make petrol, which is then used to fuel cars.
2. What transfer of energy takes place within the system?
   The Sun's radiant energy is transferred to chemical potential energy in the marine organisms and then stored within the oil. The potential energy in the oil/petrol is transferred to kinetic energy when the car moves.
3. Why is petrol important in our lives?
   We use petrol for transport, for example, to transport food from farms to cities (or any other link between transport and food can be supplied). Any appropriate answer of how we use petrol to sustain life can also be accepted.
4. Draw a labelled flow diagram to show the transfer of energy from the Sun to a fire made from burning anthracite, a type of coal.

The learners should draw the Sun with an arrow going to trees and other plants with an arrow going to coal with an arrow going to a fire with the burning coal. Each picture should have a label.

5. For each label write a sentence explaining how the energy is transferred. Also give an example of how this energy can be used in human activity.
   A possible answer could be: The Sun is the source of solar energy. Plants capture the energy through photosynthesis. Ancient plants formed coal which stored the energy from the Sun. When the coal is burned, the energy which was stored millions of years ago, is released. This energy can be used for human activities, for example cooking. In this way the Sun's energy was transferred through plants and coal to be released from the coal by burning.

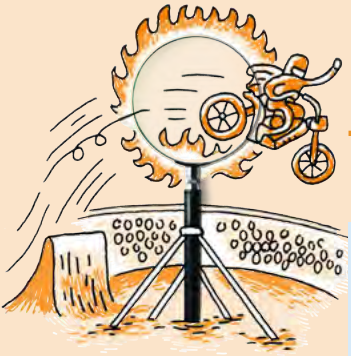
TAKE NOTE

We also rely on crude oil for many products besides as a source of energy, such as producing plastics, lubricating waxes and oils and other materials and chemicals.

TEACHER'S NOTE

1. How did people react immediately, one year later, and 40 years after all the oil disappeared?
2. How would this affect you?
3. How would this affect South Africa? How is South Africa different to the United States of America?
4. How would you and your family survive?
5. What jobs would be important in a world without oil?
6. Do you think countries should grow crops for fuel or food?
7. What is the effect on the animal populations?
8. What effect would this have on disease and combating diseases in hospitals?
9. How important is fuel for life on Earth?
10. What would the effect be on recycling? Do you think we should recycle? What should we recycle and why?

This stored energy is not in limitless supply. It will run out at some point so we need to be very careful how we use it, and we need to find alternatives to using fossil fuels for our energy supply. Do you think that people on Earth are using our fossil fuels wisely? Let's investigate how fossil fuels are used in our homes.



INVESTIGATION: The use of fossil fuels in your home

TEACHER'S NOTE

Learners should not only focus on the use of fossil fuels as an energy source, but they should also look at the many other ways that we use fossil fuels in our daily lives, such as our use and reliance on plastics, various chemicals, lubricating substances, etc. This has an impact when talking about our reliance on fossil fuels.

Provide some guidelines on the format of the reporting required. You can decide whether it must be a written report, a project to complete over the course of this chapter or term, a poster, an oral presentation, or a combination. You can use the various Assessment Rubrics at the back of your Teacher's Guide to assess learners reports, projects or posters.

If time permits, a general class feedback discussion could follow when the learners hand in their reports. This would close the chapter reinforcing our responsibility to use fossil fuels wisely.

For this task, you need to find out how much your household makes use of fossil fuels in one month.

INSTRUCTIONS:

1. Make up a question that you would like to answer. You teacher will help you formulate this. Write your question below.
   Learner-dependent answer.
2. Think about what information you need and design a table where you will gather this information.
3. Research information about fossil fuels and their uses.
4. Report the information in the format that your teacher specified (either a written report, a poster or a project):
   a) Do a write-up which clearly shows how your findings are linked to fossil fuels, and how you collected your data.
   b) What have you found? Write a paragraph on your findings.
   c) Write a conclusion. Answer the question you posed in step 1.
   d) Make some recommendations on what you have found. Does your family use a lot of fossil fuels? Is this good or bad? Why do you think so? Give your own opinion here.

TEACHER'S NOTE

Discuss the formulation of an investigative question in class. Examples are: How much electricity does my household use in a month? How much petrol does my household use in a month? (In this case, public transport should also be included.) What other products do we use at home that are derived from fossil fuels? If learners choose to use electricity as a measure of the fossil fuel use, then they need to clearly state how this is related to fossil fuels, for example the burning of coal to generate electricity.

Below are some exemplar tables. These are not complete and should only be used to help learners think about what information they need. It might be necessary to discuss this in class before learners start working on it on their own.

Appliance	Power (Watts)	Time used	Consumption (kWh)	Price per unit
Geyser				
Stove				
Kettle				
Light bulbs				
etc.				

Mode of transport	Distance	Fuel consumption*	Litres of petrol used	Price per litre of petrol
Car				
Bus				
Taxi				

* Take note that the average fuel consumption can be calculated as litres per 100 km. You can also then discuss with learners that more fuel is used, the more you accelerate.

Household product	Fossil fuel source	Method of manufacture

Learners will need about a week to plan this investigation and gather the information. The activity can be handed out in the beginning of the section to allow enough time for learners to complete this investigation.

SUMMARY:

Key Concepts

- The Earth revolves around the Sun completing one orbit every $365 \frac{1}{4}$ days. As the Earth revolves around the Sun it also spins on its axis completing one rotation in 24 hours.
- The Earth's rotation axis is tilted in space. The North Pole points towards the star Polaris and the axis is offset from the vertical by 23.5°.
- The tilt of the Earth's rotation axis is responsible for the seasons on Earth.
- Areas near the equator are warmer than areas near the poles because they receive more direct sunlight.
- The Sun's energy is captured and used by plants to produce carbohydrates, which the plant uses and stores. Plants form the basis of food chains.
- The energy stored by plants millions of years ago is available to us today in fossil fuels. The energy however is non-renewable.
- Coal, crude oil and natural gas was formed millions of years ago from the remains of dead animals and plants.
- Life on Earth depends on the Sun's stored energy in fossil fuels.

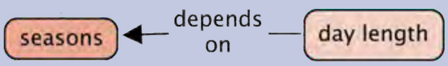
Concept Map

Look at the concept map below which shows what we have learnt in this chapter about the relationship between the Sun and the Earth.

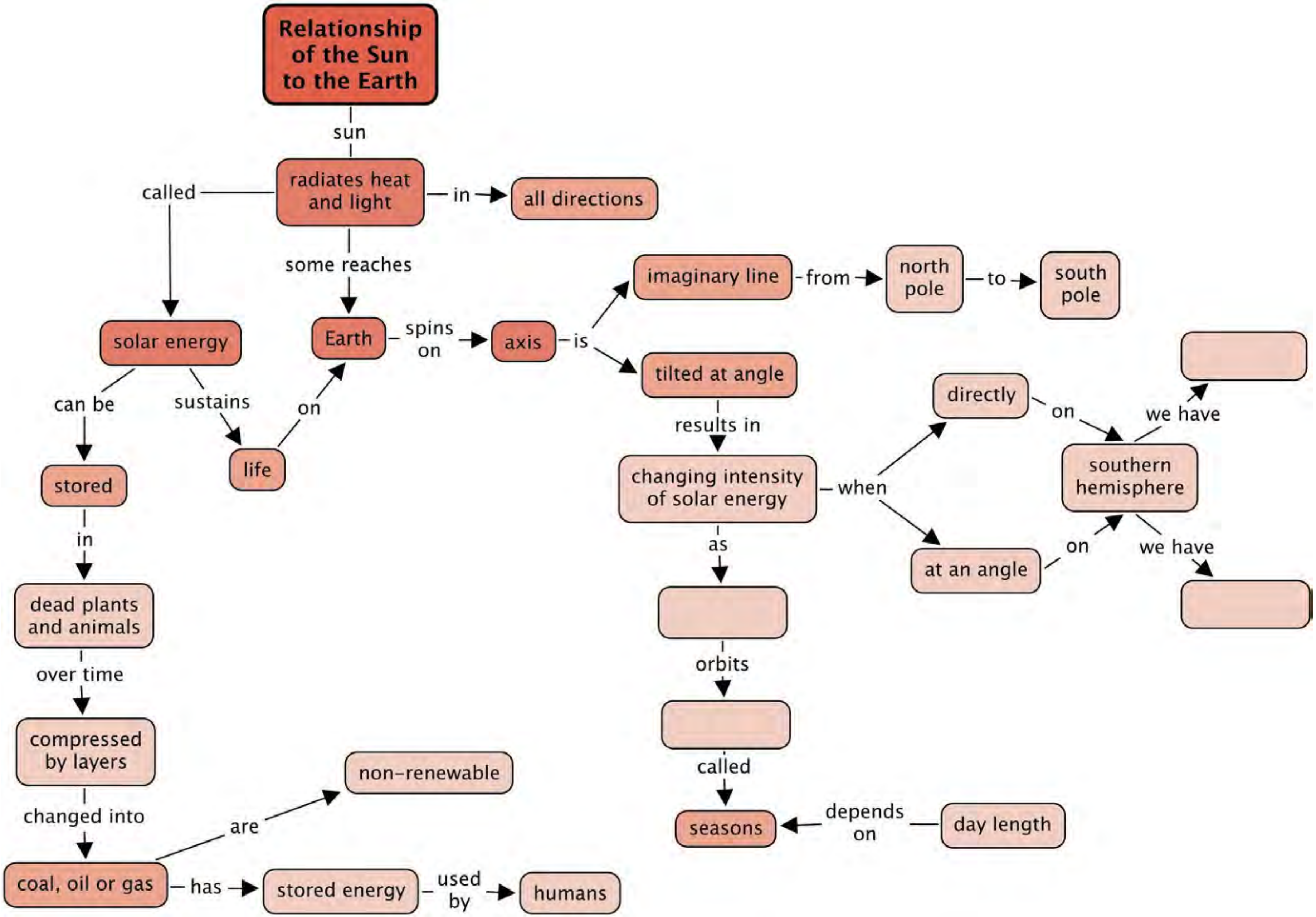
Fill in the blank spaces to complete the concept map. You need to fill in two of the seasons. To do this, read the concept map and complete the sentence. For example 'when **solar energy** falls **directly** on the **Southern Hemisphere**, we have __________'.

There are also two blank spaces to fill in about what orbits what in terms of the Sun and the Earth.

It is important to take note of which direction the arrows are pointing in a concept map so that you know which way to read it. For example, below where we have:



The arrow is pointing to the left so this reads, 'Day length depends on seasons' and NOT the other way around 'seasons depends on day length'.


Relationship of the Sun to the Earth
sun
radiates heat and light
in
all directions
called
solar energy
some reaches
Earth
spins on
axis
is
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from
north pole
to
south pole
tilted at angle
results in
changing intensity of solar energy
when
directly
on
at an angle
on
southern hemisphere
we have
we have
as
orbits
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seasons
depends on
day length
sustains
life
on
can be
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in
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are
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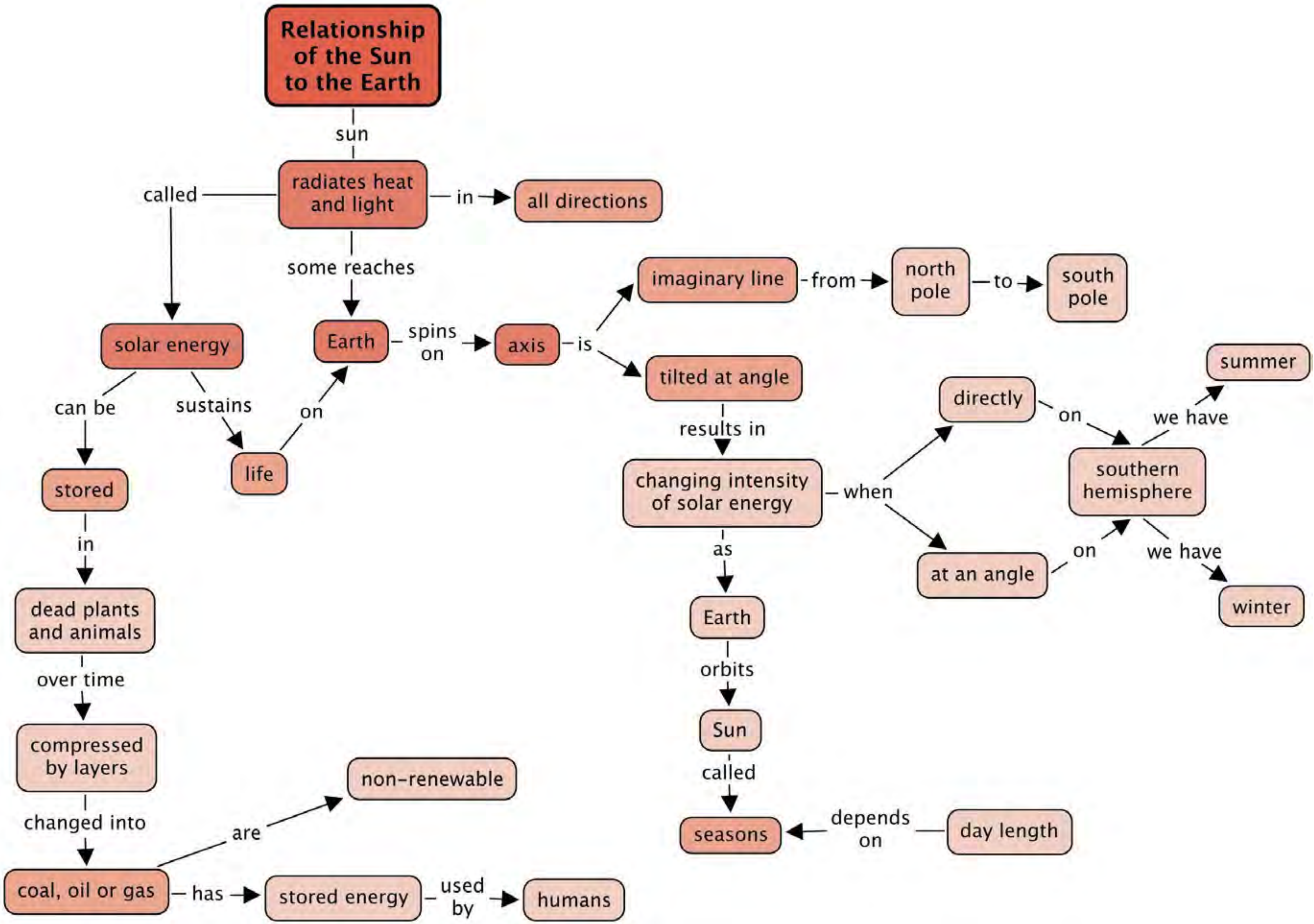
used by
humans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REVISION:

1. What causes day and night? [2 marks]
   We have day and night because the Earth rotates on its axis. The side of the Earth facing the Sun is lit up it is daytime for this side. The side not facing the Sun is dark. It is night time for this side. Because the Earth is continually rotating each point on the Earth experiences successive daytime and nighttime.
2. The Sun appears to move across the sky during the day moving from east to west. What is really happening? [2 marks]
   The Earth is spinning on its axis west to east (anti-clockwise). The Sun does not move, but it is rather due to the Earth's rotation.
3. What is the difference between rotation and revolution? [2 marks]
   Rotation is when an object spins around on its own axis. Revolution is when an object moves around (orbits/revolves) another object, such as the planets around the Sun.
4. How long does it take the Earth to complete one rotation? [1 mark]
   24 hours (actually 23 hours and 56 minutes!)
5. How many days does it take for the Earth to complete one revolution around the Sun? [1 mark]
   $365\frac{1}{4}$.
6. Why do you think we have leap years every 4 years, when there is an 'extra day', 29 February? [1 mark]
   Because of the extra $\frac{1}{4}$ *days, which every 4 years adds up to a whole day.*
7. What does sunlight do for the Earth? [2 marks]
   It provides radiant energy to the Earth in the form of heat and light.
8. Why is it hotter at the equator than at the poles? [4 marks]
   As the equator is always hit by direct rays from the Sun it is always warm as the solar energy is spread over a small surface area (intense). Areas that are hit by indirect light are cooler because the Sun's energy is spread out over a large area. The poles are always hit by indirect rays which explains why it is cold at the North and South Poles.
9. What causes the seasons on Earth? [5 marks]
   The seasons are caused by the tilt of the Earth's rotation axis relative to the Earth's orbital plane as it travels around the Sun. If the Northern Hemisphere is tilted towards the Sun at a particular point during the Earth's orbit, it receives more direct sunlight. In this case the solar energy is spread over a smaller area, is more intense and thus temperatures are warmer and it is summer. Meanwhile the Southern Hemisphere is tilted away from the Sun and receives indirect sunlight. In this case the solar energy is spread out over a larger area, it is less intense and thus temperatures are lower and it is winter in this hemisphere. Because the Earth's axis always tilts in the same direction in space, six months later the opposite hemisphere is tilted towards the Sun and the seasons are reversed in the two hemispheres.
10. Explain why the seasons cannot be caused by the change in the Earth's distance from the Sun as it travels along its slightly oval (elliptical) orbit. [2 marks]
    If the change in distance were responsible for the seasons, then the Southern and Northern Hemispheres would experience summer and winter at the same time, which is not the case. The Earth's orbit around the Sun is elliptical but it is nearly a perfect circle; it is off by only 4% and the resulting difference in incoming solar radiation is only 7% which is very small and not

sufficient to cause the variations in the temperatures associated with the seasons.

11. Where does crude oil come from? [2 marks]
Crude oil was formed millions of years ago from the remains of sea animals and plants through the action of high temperature and pressure.
12. Why are the coal deposits found mostly in the same area in South Africa? [1 mark]
Millions of years ago interior areas of South Africa used to be a large inland lake which became a swamp.
13. Compare the formation of natural gas, crude oil and coal by completing the following table. [5 marks]

	When was it formed?	***What was it formed from?***	***What conditions were need for its formation?***	***Does South Africa have this natural resource?***	***Renewable or non-renewable resource?***
Coal	*Millions of years ago*	*Remains of dead plants*	*High temperature and pressure*	*Yes*	*Non-renewable*
Oil	*Millions of years ago*	*Remains of dead sea animals*	*High temperature and pressures*	*No*	*Non-renewable*
Natural Gas	*Millions of years ago*	*Remains of dead sea animals*	*High temperature and pressures*	*Yes*	*Non-renewable*

14. Explain how fossil fuels are able to store the Sun's energy. [4 marks]
Millions of years ago ancient plants used the Sun's energy, carbon dioxide and water to produce energy-rich glucose through photosynthesis. The glucose was stored in the plants. As the plants died their energy was transferred to the coal, natural gas or crude oil that was formed.
15. The Sun's energy is essential for life on Earth. Draw a flow diagram to show how the Sun's energy is transferred through natural gas and used in gas cooker in a household. Use appropriate labels to explain the diagram. [4 marks]
Learners should draw a flow diagram from the Sun to sea plants and sea creatures to natural gas (drawing can be an underground gas chamber) to a gas cooker showing the flame. Labels that should be included are: Sun (solar energy); Sea plants (capture the Sun's energy through photosynthesis); natural gas (formed over millions of years, stores the Sun's energy); gas cooker (releases the energy when the gas is burned)

Total [38 marks]

Just a plain flask from an experiment? What are the possibilities? Be curious here.

2 Relationship of the Moon to the Earth

TEACHER'S NOTE

Chapter overview

2 weeks

In Gr. 4 learners covered the basic facts about the Moon: its lack of air and water, size relative to the Earth and its position with respect to the Sun. They also observed the Moon's phases. In Gr. 6 learners learnt about the Moon's motion in space: it revolves around the Earth whilst rotating on its spin axis. In this chapter, learners will develop an understanding of how the phases of the Moon are related to the relative positions of the Earth, Moon and Sun. They will also be introduced to the concept of gravity, (covered in more detail in Gr. 9: Energy and Change strand), and the influence of the Moon's and Sun's gravitational pulls on the Earth's oceans which result in tides.

The main aims of this chapter are to ensure that learners understand the following:

- The Moon is smaller than the Earth and orbits around the Earth in 27.3 days as the Earth revolves around the Sun.
- The Moon is held in orbit around the Earth by the force of gravity. In turn the Earth and all the other planets in the solar system are held in orbit around the Sun by the force of gravity.
- All masses experience the force of gravity, and the size of the force exerted is dependent upon the mass of the objects and their distance from each other.
- The combined gravitational pull of the Moon and the Sun on the Earth's oceans cause the ocean tides.

2.1 Relative positions (1.5 hours)

Tasks	Skills	Recommendation
Activity: Moon revision quiz	Recalling, stating	Optional revision
Activity: Observe the Moon	Observing	Suggested
Activity: Total Solar Eclipse	Observing, analysing	Suggested

Note: There are three additional activities included only in the Teacher's Guide in this section. They are:

- Activity: Google the Moon (Replacement activity for "Observe the Moon" if computers and internet are available.)
- Activity: Hands-on Moon Phases (Optional extension activity, revision of Gr. 6 material.)
- Activity: Month Long Moon Observation (Optional extension activity. This is a repeat of an activity done in Gr. 6. This reminds learners of the Moon's phases but does not yet link them to the relative positions of the Sun/Earth/Moon.)

2.2 Gravity (2 hours)

Tasks	Skills	Recommendation
Activity: Demonstrating the Moon's orbit around the Earth	Investigating, observing	CAPS suggested
Activity: How heavy would you be on other planets?	Calculating, measuring	Suggested

Note: There is an additional investigation included only in the Teacher's Guide in this section. It is:

- Investigation: Dropping objects (Optional extension activity)

2.3 Tides (2.5 hours)

Tasks	Skills	Recommendation
Activity: Reading a tide chart	Reading graphs	Suggested
Activity: Dance of the tides	Working in groups, investigating, analysing	Suggested
Activity: Spring and neap tides	Observing, analysing	CAPS suggested
Activity: The effect of tides on shoreline ecosystems	Researching, analysing, writing	CAPS suggested
Activity: How good a fisherman are you?	Analysing data	Suggested

Note: There are two additional activities included only in the Teacher's Guide in this section. They are:

- Activity: Tides poster (Optional, fun activity)
- Activity: Make a tide wheel (Optional activity)

KEY QUESTIONS:

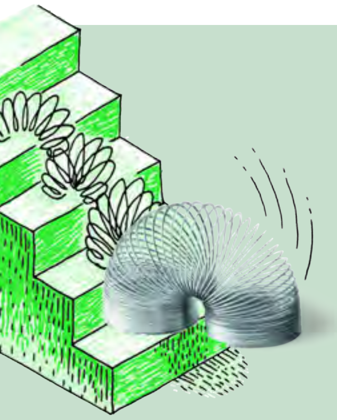
- How long does it take for the Moon to orbit the Earth?
- What keeps the Moon in orbit around the Earth?
- What causes tides on Earth?

The Moon is the most obvious feature in our night sky and has captivated people for thousands of years. Ancient cultures recorded the apparent motion of the Moon through the sky and made calendars which used the phases of the Moon to mark the months. In fact some religious calendars still use a lunar (Moon) based calendar rather than the official solar (Sun) based calendar used today in South Africa and most of the Western world (called the Gregorian calendar). The Moon's influence on the Earth is also important to us in other ways as you will discover in this chapter.

Our Moon.

2.1 Relative positions

You learnt about the Moon in Grades 4 and 6. Lets see what you can remember!



ACTIVITY: Moon revision quiz

TEACHER'S NOTE

This is an activity to review material covered in Grades 4 and 6. It is a short, optional activity.

INSTRUCTIONS:

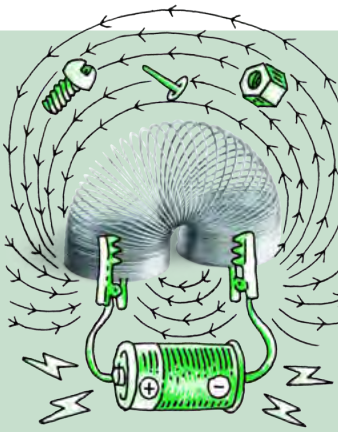
1. Fill in the gaps in the Earth-Moon comparison table below using the word bank.

Word bank:

- rock, soil and water
- rock and lunar soil
- reflects
- absorbs
- Sun
- Earth
- an
- no
- larger
- smaller
- 24
- 27.3

The Earth	*The Moon*
Surface consists of rock, soil and water.	*Surface is consists of rock and lunar soil.*
Is larger than the Moon	*Is smaller than the Earth*
Is visible because it reflects light from the Sun hitting it.	*Is visible because it reflects light from the Sun hitting it.*
Is in orbit around the Sun.	*Is in orbit around the Earth.*
Spins on its axis once every 24 hours.	*Spins on its axis once every 27.3 days.*
Has an atmosphere.	*Has no atmosphere.*

Let's now take a closer look at the surface of the Moon.



ACTIVITY: Observe the Moon!

TEACHER'S NOTE

In this activity learners look in detail at the surface features of the Moon. The photographs show images of both the near side and far side of the Moon which look quite different and learners should be encouraged to compare the two.

Images of the near side and far side of the Moon taken with NASA's Clementine spacecraft. Look at the difference between the two images, what do you notice?

INSTRUCTIONS:

1. Study the images of the Moon.
2. Answer the questions below.

QUESTIONS:

1. Does the Moon's surface have any oceans or lakes?
   No, the surface is all solid rock and lunar soil (regolith).
2. What do you notice covering much of the Moon's surface?
   Craters.
3. Some areas look dark and others look lighter, the dark areas are called maria (singular mare) meaning seas, as astronomers initially thought that these areas were seas on the surface. The bright areas are called highlands as they are higher than the maria. On what side of the Moon (near or far) are there more dark areas (maria)?
   The near side has more maria.

TEACHER'S NOTE

Activity: Google the Moon

This is an optional activity to do with your learners if you have internet access. You can use it as an alternative to the previous activity where the images are provided.

This activity is a nice way to incorporate ICT into a science lesson. The Google Earth software can be downloaded for free directly onto your computer from the following web address: `bit.ly/1h519Mj`. The software contains an interactive map of the Earth, Moon and Mars. Switching to 'Moon mode', learners can look at the surface of the Moon in amazing detail, rotating, and zooming in or out of the map. Additional information about the 6 Apollo landing sites is also available with photos and short videos. Both low and high resolution images of the Moon can be studied along with contour maps to explore the heights and depths of the craters. If you do not have access to a computer then an alternative activity is to show students a variety of photographs of the Moon.

MATERIALS:

- Computer
- Google Earth software (freely downloaded from the internet)

INSTRUCTIONS:

1. Open the Google Earth software installed on your computer.
2. Switch to Moon mode.
3. Study the images of the Moon, rotating, zooming in and out to look at the surface features.
4. Read the information about the Apollo missions and other missions to the Moon.

QUESTIONS:

Use the Google Earth Moon images to answer the following questions.

1. Does the Moon's surface have any oceans or lakes?
   No, the surface is all solid rock.
2. What do you notice covering much of the Moon's surface?
   Craters.
3. Some areas look dark and others look lighter, the dark areas are called maria (singular mare) meaning seas, as astronomers initially thought that

these areas were seas on the surface. The bright areas are called highlands as they are higher than the maria. Rotate the image of the Moon around. On what side of the Moon (near or far) are there more dark areas (maria)?
The near side has more maria.

4. In what mare or sea did the Apollo 11 mission land?
Sea of Tranquility. (Latin: Mare Tranquillitatis).

TAKE NOTE

The time that it takes an object to make one complete orbit around another object, relative to the stars, is called the orbital period or synodic period.

The Earth, just like all the other planets in the solar system, travels around the Sun, completing one revolution every year. As the Earth travels around the Sun it has a companion in space: our Moon!

The Moon orbits around the Earth completing one revolution every 27.3 days. Our Moon rotates on its own axis and experiences daytime and dark nighttime just like the Earth does. However, the Moon spins much more slowly than the Earth does and completes one rotation on its axis once every 27.3 days. Did you notice that the Moon takes the same amount of time to spin on its axis as it does to orbit completely around Earth? This means that from the Earth, we always see the same side of the Moon (called the 'nearside'). The side we do not see from Earth, called the 'farside', has been mapped during space missions to the Moon.

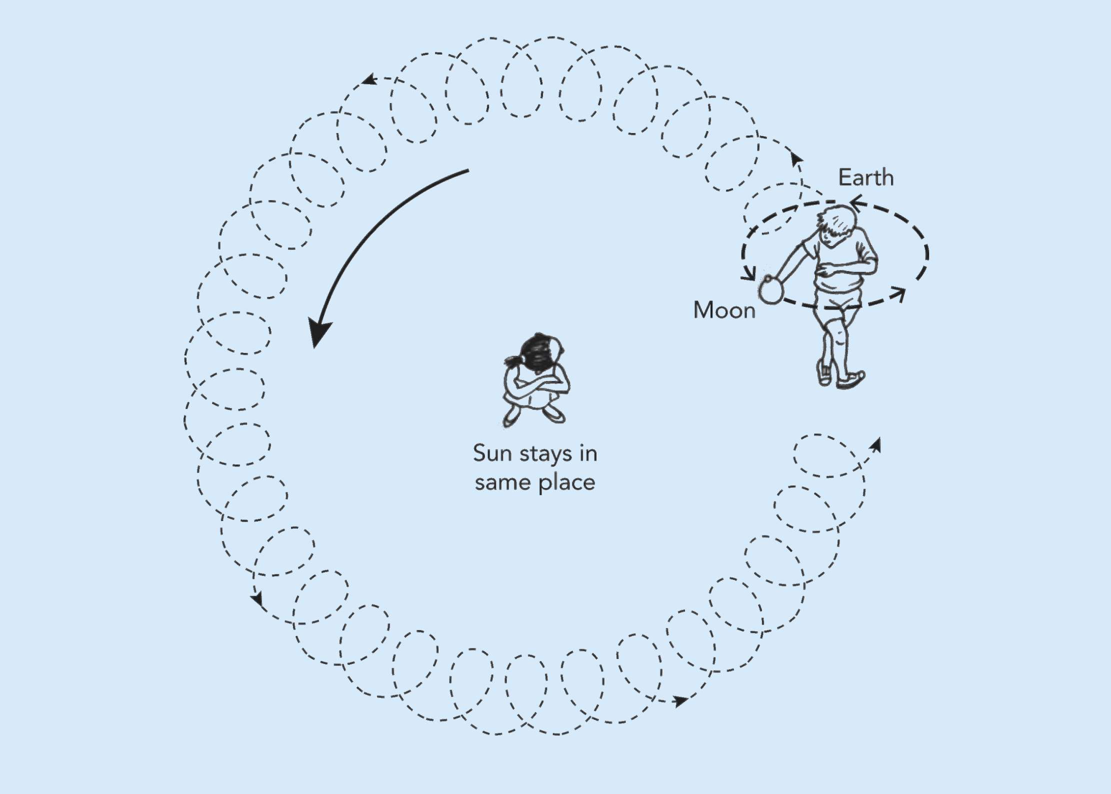
TEACHER'S NOTE

The **sidereal period** of the Moon is mentioned in the previous paragraph, namely the Moon completes an orbit around the Earth about once every 27.3 days. This is not to be confused with the Moon's **synodic period**, which is 29.5 days. The synodic period of the Moon is due to the Earth moving in its orbit about the Sun at the same time, and so it takes slightly longer for the Moon to show the same phase to Earth.

Viewed from above, the Moon moves in an anti-clockwise direction around the Earth. The Moon's orbit is not a perfect circle, it is elliptical, so its distance from Earth varies as it revolves around the Earth. The average distance is about 385 000 km, which is about 60 times the radius of the Earth itself. For comparison, the Earth's average distance from the Sun is 149 597 871 km, or about 23 481 times the radius of the Earth. You can see now why the Moon is called Earth's close companion!

TEACHER'S NOTE

In Gr. 6, learners would have done some activities to act out the revolution of the Moon around the Earth as the Earth orbits the Moon. You can view this content online at `www.thunderboltkids.co.za`. Here is a link to the actual content: `bit.ly/15wPXbE`. Here is an image of the activity if you would like to repeat it with your learners to reinforce the relative positions of the Earth, Moon and Sun.



TAKE NOTE

In the diagram, the Sun and Sun-Earth distance are not drawn to scale, the Sun would be MUCH larger than in this image and the distance between the Sun and Earth would also be MUCH larger.

VISIT

Why do we only see one side of the Moon? (video)
bit.ly/1eJOmCj

VISIT

Read more about exploring the far side of the Moon.
bit.ly/14L9X7S

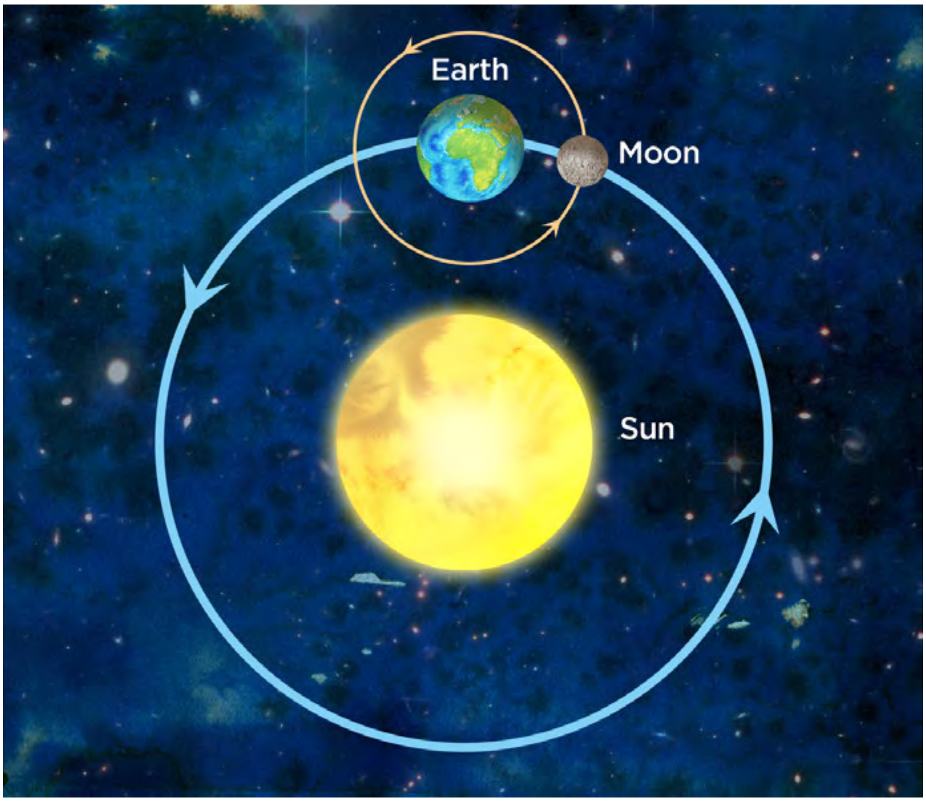
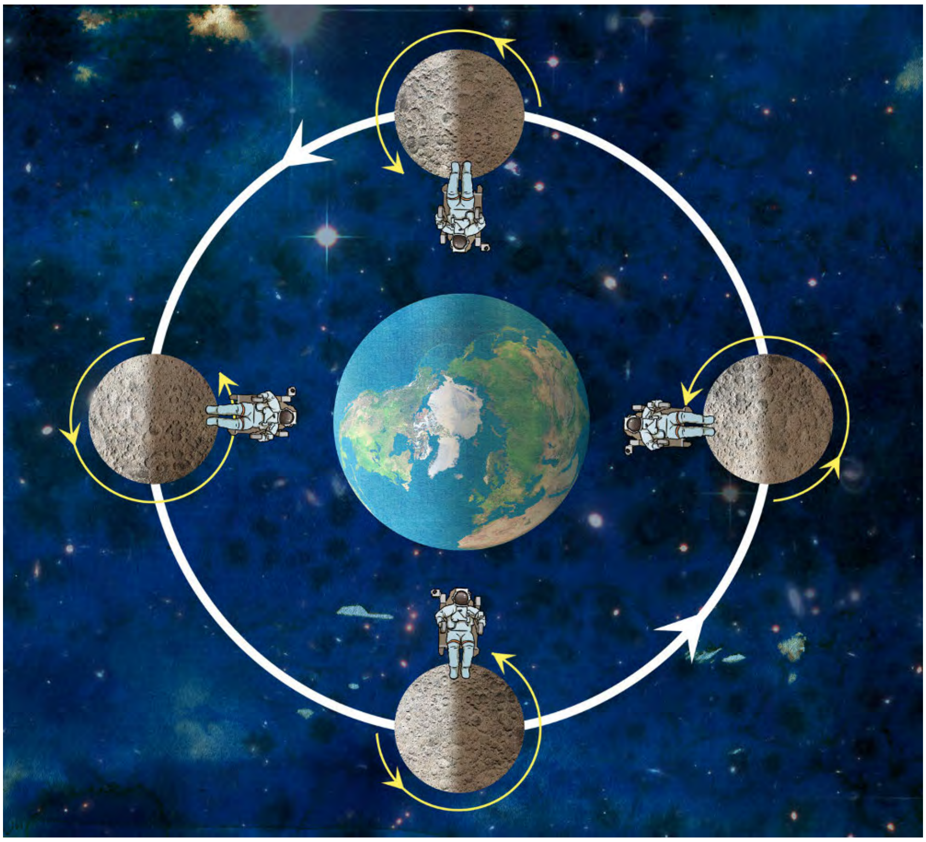


Diagram showing the Earth's motion around the Sun and the Moon's motion around the Earth.



The Moon spins on its own axis at the same rate that it revolves around the Earth. As it completes one quarter turn on its axis it also completes one quarter of its orbit. This results in the same side of the Moon always facing Earth.

An image of the Earth and Moon taken from the Galileo satellite on its way to Jupiter over 6 million km away. The Moon's diameter is just under a third of the Earth's diameter. You can see the sunlit sides of the Earth and Moon. On what side do you think the Sun is?

VISIT

A spacecraft, called Ladee, was launched in 2013 to orbit the Moon to gather information about the lunar environment. Have a look at this infographic detailing the mission. bit.ly/16C6HZ0

TEACHER'S NOTE

The Sun is on the right.

The following table summarises some useful information about the Sun, Earth and Moon.

Characteristic	Sun	Earth	Moon
Relative position	Is at the centre of our solar system	Orbits the Sun once every 365.25 days	Orbits the Earth once every 27.3 days
Rotation	Spins on its own axis roughly once every 28 days	Spins on its own axis once every 24 hours	Spins on its own axis once every 27.3 days
Distance from orbited body	-	23 481 Earth radii from the Sun	60 Earth radii from Earth
Size	Diameter is roughly 100 times the Earth's diameter	-	Diameter is roughly times the Earth's diameter

VISIT

Did the Earth have two Moons? bit.ly/1bvHqlx

We have now looked at the relative positions and movement of the Earth, Moon and Sun. Let's extend this knowledge to learn about a solar eclipse.

ACTIVITY: Total Solar Eclipse

TEACHER'S NOTE

In this activity, the idea that the apparent size of an object depends upon its distance from an observer is reinforced. Learners will find that although the Sun is much much larger than the Moon, it appears about the same size in the sky because it is much more distant than the Moon.

INSTRUCTIONS:

Look at the image below. It shows a total solar eclipse which you learnt about in Gr. 6. This happens when the Moon passes directly in front of the Sun and blocks the Sun's light. The bright light from the Sun is blocked, allowing us to see the very faint outer edge of the Sun's atmosphere, called the corona. We normally cannot see the corona as it is swamped by the bright light from the Sun. When you look at the size of the Moon in the sky compared with the size of the Sun in the sky you see that they are very similar. We call this the **angular size**. This is because the Moon is much closer than the Sun. The Moon appears large enough from Earth to totally block out the Sun's light.

A total solar eclipse. The Moon is in front of the Sun allowing us a rare glimpse of the Sun's outer corona, with thin wisps of atmosphere extending into space.

VISIT
What is a solar eclipse?
(video) bit.ly/17479mY

QUESTIONS:

1. Which in reality is larger, the Moon or the Sun?
   The Sun is larger.
2. Which is further away, the Moon or the Sun?
   The Sun is further away.
3. How do the angular sizes of the Moon and the Sun compare when viewed from the Earth's surface?
   They are almost the same.
4. Why is this the case?
   Although the Sun is much larger than the Moon, it is much more distant. As objects appear to look smaller and smaller the further away they are, the Sun appears smaller than it is in reality. The Moon also appears smaller than it is in reality, however it is much closer to the Earth than the Sun is and so its apparent size isn't reduced as much as the Sun's is. Just by chance, the Sun and moon are currently at distances where they have the same angular size viewed from the Earth's surface.

A total solar eclipse occurs when the Earth, Moon and Sun are aligned in a straight line with the Moon placed in between the Earth and the Sun. Just by chance, the Sun and Moon are currently at distances where they have the same angular size viewed from the Earth's surface. If the angular size of the Moon were smaller, it would not be large enough to completely block the Sun and we wouldn't have total solar eclipses! The picture below shows the relative alignment of the Sun, Earth and Moon during a solar eclipse.

VISIT

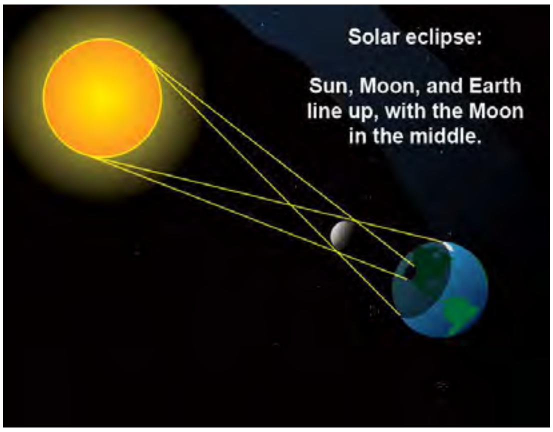
Why does the Moon sometimes appear red?

bit.ly/14LbAIV

VISIT

Read more about why the Moon can appear red during a lunar eclipse.

bit.ly/1blmuND



The Sun, Moon, and Earth all lined up during a solar eclipse. The black spot on Earth shows the location from where a total solar eclipse would be visible. This area is in the Moon's shadow. The grey area on Earth's surface indicates the location from where a partial eclipse would be visible.

We can also get a lunar eclipse. This is when the Sun, Earth and Moon line up with the Earth in the middle.

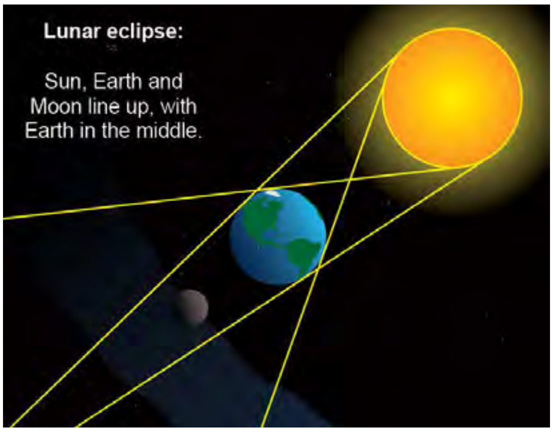
A series of images showing the Moon during a full lunar eclipse.

See how a lunar eclipse compares to a solar eclipse in the diagram. In this case, the Earth blocks the sunlight from reaching the Moon's surface, making the Moon appear dark in the night sky.

VISIT

Find out when the next lunar eclipses will take place.

bit.ly/1fHY9aX



Sun, Earth and Moon line up to form a lunar eclipse.

TEACHER'S NOTE

A note about lunar phases

Learners will most likely be familiar with the change in the Moon's appearance over the course of a month, the lunar phases. Each lunar phase cycle from New Moon to New Moon takes 29.5 days, which is slightly longer than the Moon takes to complete one revolution around the Earth (27.3 days). This is because during the 27.3 days it takes for the Moon to revolve around the Earth, the Earth is moving along in its orbit. In order for the Moon to appear at the same phase *as viewed by an observer on Earth* it needs to travel slightly further than 360 degrees around the Earth and in order for it to be aligned such that there is a New Moon it takes about an extra 2 days.

`bit.ly/16C8LQB` shows a nice animation demonstrating the difference between the orbital period of the Moon which defines the sidereal month (27.3 days) and the lunar phase cycle which defines the synodic month (29.5 days).

Observers on Earth see the same phase where ever they are positioned on Earth. However, the phases (apart from New Moon and Full Moon) look different to an observer in the Northern and Southern hemispheres. We in the Southern Hemisphere view the Moon "upside down". This is important to note because 99% of all textbooks and online references include the Northern Hemisphere view of the phases and this is *not* what learners will see when they view the Moon for themselves. An awareness of this is crucial to reduce learner confusion when looking online and in generic textbooks.

The activity below is an optional extension activity which links the relative positions of the Earth, Sun and Moon to the phases of the Moon observed.

Activity: Hands-on Moon Phases

As the Moon revolves around the Earth, the side facing the Sun is always illuminated, just as Earth's daylight side is illuminated by the Sun. However, from the Earth's surface we do not see a half Moon lit up all the time. Instead, we see a change in the amount of the Moon which is lit up by the Sun.

In this activity learners will learn that the relative position of the Earth, Moon and Sun determine what phase of the Moon is observed. Learners will use a lamp to represent the Sun. The learners will represent the Earth and a styrofoam ball stuck on a pencil will represent the Moon. If you cannot get hold of a styrofoam ball then you can use an orange instead. They will vary the location of the Moon in its orbit around the Earth and observe the phase of the Moon. A dark room is needed for this activity. If necessary darken the classroom with bin bags or curtains. In the centre of the room place an unshaded lamp to represent the Sun.

Ideally learners should work in pairs for this activity, so that one learner can draw their observations while the other learner holds the ball in place. Ensure that learners hold the balls slightly above their heads so that they do not cast shadows over the ball. In this exercise we make the assumption that the Earth remains in the same spot while the Moon orbits around the Earth.

Before starting the activity, explain to learners the names of the Moon phases and draw them on the blackboard: New Moon (entirely dark), Full Moon (entirely lit), Crescent Moon (mostly dark), Gibbous Moon (mostly lit) and First Quarter Moon (left half lit) and Third Quarter Moon (right half lit). [Note that the first and third quarter appearances listed here are for the Southern Hemisphere only.]

MATERIALS:

- pencil (2 per pair)
- one lamp that can shine in all directions (i.e., a lamp base with a bare 100 to 150 Watt bulb and no lampshade)
- styrofoam balls (1 per pair)
- black plastic bags (and tape) or curtains to darken the classroom
- sheet of paper (1 per pair)

INSTRUCTIONS:

1. You will work in pairs for this activity.
2. Place a lamp representing the Sun in the centre of the classroom. Even for a large classroom, you should only use one bright lamp placed in the middle of the classroom otherwise you will have shadowing effects that may ruin the results.
3. Darken the room if needed by taping dark plastic bags to the windows or closing the curtains.
4. Stick one of the pencils into your styrofoam ball so that you can hold the ball up by the pencil end. This ball represents the Moon.
5. All learners must stand in a circle around the central light, with your partner next to you in the circle.
6. Directly face the light in front of you. One of you should hold the ball at arms length, slightly above your head, and the other should hold the pencil and paper. The person holding the ball represents the Earth.
7. If you are holding the ball, move the ball from left to right (keeping still) and observe how much of it is lit by the light as you move it around. Now let your partner do the same.
8. Look at the different phases of the Moon drawn on the blackboard by your teacher (New Moon, Full Moon, First quarter, Third quarter).
9. One of you should now hold the ball and position it until from your point of view it looks completely in shadow. This represents New Moon.
10. The member of the pair not holding the ball should now draw the relative positions of the Sun, Moon and Earth, and write down the Moon phase corresponding to these positions.
11. Swap the person holding the ball and the pen/paper, and position the ball such that it is fully lit and looks like a Full Moon. The member of the pair not holding the ball should now write down the relative positions of the Sun, Moon and Earth.
12. Repeat this for all the phases listed in 8.
13. Look at the crescent Moon on the blackboard. Find out what positions you can place the ball in to see it lit up like a crescent (less than half lit).
14. Swap positions again and this time find out what positions you can place the ball in to see it lit up in a gibbous phase (more than half lit).

QUESTIONS:

1. In what position do you need to place the Moon in order to see a New Moon?
   The Moon needs to be placed directly in between the Sun and the Earth.
2. In what position do you need to place the Moon in order to see a full Moon?
   The ball needs to be place d directly opposite from the Sun, with the Earth in between the two.
3. In what positions can you place the Moon in order to see a crescent?
   Any position as far as 90 degrees either side of the N ew Moon position (to the left or right).

Another optional activity that learners may complete in their own time is a month long Moon observation. They may have already completed this activity in Gr. 6 but it is included here in case you wish to conduct a Moon observation as an additional activity.

Activity: Month long Moon observation

This activity can be conducted by students at home.The activity takes a month (30 days) to complete, therefore it can be done while other material is covered in class. Students may need reminding to complete their observations every day. Start the observations at New Moon so that the learners can follow the phases of the Moon in order. The dates of New Moon can be obtained online at http://aa.usno.navy.mil/data/docs/MoonPhase.php Once learners have completed all their observations you can discuss in class what they saw and ask them questions as to why they think the Moon changes its appearance.

MATERIALS:

- Moon observation chart
- pencil

INSTRUCTIONS:

1. Draw up an observation chart with blank circles to represent the moon each day.
2. Go out and observe the Moon. (You may have to do this during the day or during the night depending on when the Moon is visible).
3. Always stand in approximately the same spot and face the same direction (either south or north). Look from east to west and find the Moon.
4. Draw how the Moon looks by shading in the circles to reflect the shape of the Moon in your observation chart.
5. Note the date and time of your observation.

Help: For example, if you can see the whole Moon, you do not need to shade in any part of the circle. If you can only see half of the Moon, shade the side of the Moon that you cannot see in the circle for that day. If you cannot see the Moon at all on a day, indicate this on your journal and also write down why you could not see the Moon.

2.2 Gravity

TEACHER'S NOTE

Before introducing the concept of gravity ensure that learners fully understand what is meant by a force (a push or a pull). Run through some everyday examples of forces that learners encounter such as pushing a trolley at the supermarket, or pushing or pulling their friends!

Strictly speaking when talking about "gravity" we are specifically referring to the gravitational force of attraction that occurs between the Earth (or another celestial body like a planet) and other objects, as opposed to the gravitational force in general which acts between any two objects with mass. For example, we would refer to the gravitational force acting to attract objects to the Moon as the Moon's gravity, but we would not generally refer to the gravitational force acting to attract things to ourselves as 'our gravity'.

The word **gravity** is used to describe the **gravitational pull (force)** an object experiences on or near the surface of a planet or moon. The gravitational force is a force that attracts objects with mass towards each other. *Any object with mass exerts a gravitational force on any other object with mass*. So, the Earth exerts a gravitational pull on you, the desks in your classroom and the chairs in your classroom, holding you on the surface and stopping you from drifting off into space.

The Earth's gravity pulls everything down towards the centre of the Earth and so when you drop an object like a book or an apple it falls to the ground. However, do you know that you, your desk, your chair, and the falling apple and book exert an equal but opposite pull on the Earth? Why do you think that these pulls don't cause the Earth to move noticeably?

TEACHER'S NOTE

The Earth has a much larger mass than a person or a desk and so it is accelerated by a much smaller amount even though the force exerted on the Earth by a desk is the same size as the force exerted on the desk by the Earth (just in opposite directions). This is why the Earth does not move noticeably.

The arrows show the direction of the force of gravity by the Earth on all other objects with mass. The arrows all point towards the centre of the Earth because the gravitational force is always attractive.

VISIT

Interact with this simulation to see the relationship between gravity and the masses of the object and distance between them.

bit.ly/1dLLZMn

TEACHER'S NOTE

The PhET simulation in the visit box can be used to very easily demonstrate how the gravitational force between two objects increases with mass and decreases as the distance between the objects increases. You can turn off the values, and use the position of the little figures tugging on the ropes to qualitatively demonstrate the relationships.

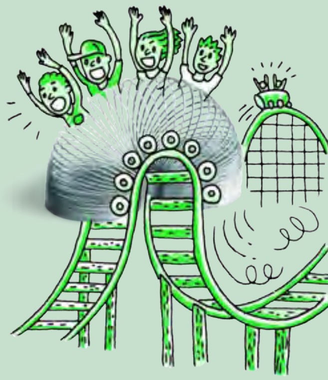
The gravitational force between two objects decreases as the objects move further apart. If you double the distance between two objects the gravitational force between them decreases by a factor of four. Similarly if you triple the distance between them, the gravitational force between them decreases by a factor of nine. This explains why we are stuck to the Earth rather than the Sun.

The Sun is 333 000 times more massive than the Earth and its gravity is much stronger than the Earth's. However, we are so far away from the Sun that the gravitational force the Sun exerts on us, is much smaller than the gravitational force the Earth exerts on us.

The Moon is held in orbit around the Earth by the gravitational force between the Earth and the Moon. Similarly, the Sun's gravity holds the Earth in orbit around the Sun. Lets do an activity to demonstrate the Moon's orbit around the Earth.

VISIT
Watch Felix Baumgartner's supersonic freefall back to Earth. bit.ly/15wRxKr

ACTIVITY: Demonstrating the Moon's orbit around the Earth



TEACHER'S NOTE

In this activity learners will demonstrate the orbit of the Moon around the Earth using a ball tied to a rope swung around their heads. They will demonstrate what would happen to the Moon if there were no gravity by letting go of the rope.

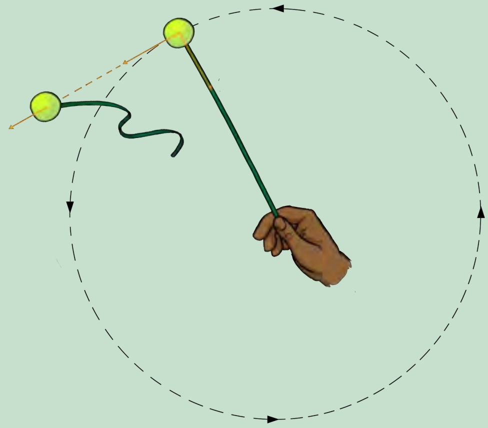
Safety tip: Do this activity outside or in the school hall if possible so that learners can spread out. This will help them avoid hitting each other when the balls are released. If this is not possible take it in turns to do this demonstration or have only a few learners do this demonstration so that no one is hit by a flying ball!

MATERIALS

- rope
- ball (tennis balls are ideal)

INSTRUCTIONS

1. Tie a ball to the end of a piece of rope. You may have to wrap the rope around the ball a few times to do this.
2. Hold the rope up high above your head and swing the rope around in a horizontal circle.
3. Let go of the rope and observe what happens.



Looking down at a ball swung in a circle after it is released.

QUESTIONS:

1. How can you describe the movement of the ball as you swing it around?
   The ball moves around in a complete circle.
2. The rope pulls the ball inwards towards the centre of the circle keeping the ball moving in a circle. What force holds the Moon in orbit around the Earth?
   The gravitational attraction between the Earth and the Moon.
3. What happens to be ball when you let the rope go?
   If the rope is released the ball flies off in the direction it was travelling in just as the rope was released.
4. What does this represent in terms of the Earth and the Moon?
   This represents that the gravity keeps the Moon in it's path around the Earth. Without it, the Moon would move away from its path.

VISIT

Move the Sun, Earth, Moon and space station to see how it affects their gravitational forces and orbital paths.

bit.ly/1fZGRGi

All the components in our Universe are held together by gravity. In summary we can say:

- The greater the mass of the objects, the stronger the gravitational pull between them.
- The closer objects are, the stronger the gravitational pull between them.

Weight

TEACHER'S NOTE

The content here on weight is not specified for Gr. 7 level in CAPS, and only appears in Gr. 9 in CAPS. However, as learners confuse mass and weight very easily, this has been included as enrichment material at this level. You can decide whether you want to cover this content with your learners or not. It is not to be assessed in Gr. 7.

The weight of an object is the force acting on it due to gravity. Weight is not the same as mass although the two words are often confused in everyday language.

The **mass** of an object is the amount of matter in the object, it tells you how many particles you have. Do you remember that we briefly spoke about atoms in Matter and Materials? So, for example, the mass of a wooden block tells us how many atoms there are. Mass is measured in kilograms (kg) and is independent of where you measure it. A wooden block with a mass of 10 kg on Earth also has a mass of 10 kg on the Moon.

However, an object's **weight** can change as it depends on the mass of the object and also the strength of gravity acting on it. Weight is measured in Newtons (N). For example the Earth exerts a gravitational force of about 10 Newtons for every kilogram of mass on its surface. So, a person with a mass of 50 kg has a weight of 500 N on the surface of the Earth.

The Moon also has its own gravity. The strength of gravity on the surface of the Moon is one-sixth that of the Earth, and so you would weigh one-sixth of what you do on Earth on the Moon. On Jupiter you would weigh 2.5 times more than you do on Earth as Jupiter's gravity is 2.5 times that of the Earth's. Even though you would weigh different amounts (and feel lighter on the Moon and heavier on Jupiter) your actual mass would stay the same in both cases.

An astronaut's mass remains the same wherever it is measured. The astronaut's weight however depends on where you measure it, as you can see the astronaut weighs 1200 N on Earth but only 200 N on the Moon.

Check your understanding of mass and weight with the following questions.

1. Lindiwe has a mass of 50 kg on Earth. What is her mass on the Moon?
   50 kg as the mass of an object is independent of position.
2. Andrew has a mass of 60 kg on Earth, what is his weight in Newtons on Earth?
   600 N (60 x 10)
3. How much would Andrew weigh on the Moon?
   100 N (60 x 10/6)
4. Would Lindiwe feel heavier or lighter on the Moon?
   She would feel lighter on the Moon, even though her mass is the same on the Moon.

ACTIVITY: How much would you weigh on other planets?

MATERIALS:

- weighing scales
- calculator

TEACHER'S NOTE

In this activity, learners calculate what their weight would be on the seven other planets in our solar system. Although their mass remains the same, they will "feel" lighter or heavier because of the differences in the gravitational field strength on the surfaces of the other planets. You should emphasise that their mass always remains the same, but only their weight varies. If you do not have access to weighing scales you can either ask learners to estimate their mass or provide them with an example number.

INSTRUCTIONS:

1. Measure your mass in kilograms using weighing scales. Record the value in the table below.
2. Look at the table below, it shows how strong the gravity is on each of the planets in our solar system.
3. Calculate your weight on each of the planets and enter it into the table below.

Hint: On Earth each kilogram weighs 10 Newtons. So if your mass is 50 kg then you weigh 50 x 10 = 500 N on Earth. If the strength of gravity on a planet is half the strength of the Earth's gravity then you would weigh half of what you weigh on Earth on that planet.

TEACHER'S NOTE

Example answers for a 50kg learner

Planet	Your mass (kilograms)	Strength of gravity relative to Earth	Your weight (Newtons)
Earth	50	1	500
Mercury	50	0.378	189
Venus	50	0.907	453.5
Mars	50	0.377	188.5
Jupiter	50	2.36	1180
Saturn	50	0.916	458
Uranus	50	0.889	444.5
Neptune	50	1.12	560

QUESTIONS:

1. On which planets would you feel heavier than you do on Earth?
   You would feel heavier on Jupiter and Neptune.
2. On which planets would you feel lighter than you do on Earth?
   You would feel lighter on Mercury, Venus, Mars, Saturn and Uranus.

TEACHER'S NOTE

A note on falling objects

A useful way to demonstrate the Earth's gravity is to look at falling objects. An optional extension activity is included below in which learners drop a variety of objects. You can take a vote from the class to see whether learners think that an apple or bag of sugar would hit the ground first. (Answer: they would hit the ground at the same time as long as air resistance is negligible.) It is very likely that learners will have the preconception that heavier items fall faster. It is not important at the moment that the learners answers are correct and do not try to lead them to the correct answer. They will hopefully discover it for themselves in the following experiment.

Investigation: Dropping objects

In this investigation learners need to work in pairs. They will initially drop a whole apple and half an apple from the same height at the same time. They will then further experiment with balls of different masses (but the same size) and balls of the same mass (but different volumes). It is very hard to drop objects at exactly the same time so that they hit the floor simultaneously so let the learners repeat the experiment several times until they are confident that they are dropping the objects at the same time. If it is hard for them to see which object hits the ground first, suggest to that learners they listen for the number of sounds they hear - one or two - when the objects hit. Learners might need to repeat this investigation many times since it most likely contradicts their preconceptions! Safety tip: It is probably a good idea to have the apples cut in half ahead of time.

Once the learners have finished their experiment you can demonstrate the effects of air resistance by dropping a hammer and a feather. Have the learners take a vote on what will happen when you drop the hammer and feather. Be ready to explain to learners that air resistance slows the fall of the feather and that if there were no air resistance the two would fall at the same rate and hit the floor at the same time.

INVESTIGATIVE QUESTION: Do different objects fall at the same rate?

HYPOTHESIS:

What do you think will happen?
Learner-dependent answer.

IDENTIFY VARIABLES:

What are you keeping constant in this experiment?
The height at which objects are dropped.

What are you changing in this experiment?
The type objects that are being dropped, in particular the mass and volume of the objects.

MATERIALS AND APPARATUS:

- hammer
- feather
- apples (one and a half per pair)
- knife (if needed to cut the apples in half)
- two balls of the same mass, different volumes (one set per pair)
- two balls of the same volume, different masses (one set per pair)

METHOD:

1. Work in pairs, take it in turns to be the person who drops an object (experimenter) and the person who observes the object dropping (observer).
2. Fill in the "prediction" column in the table below.
3. Experimenter: stand on top of a chair or desk and take an apple in one hand and apple half in the other hand.
4. Experimenter: hold the two up at the same height in front of you and drop them at exactly the same time.
5. Observer: note what happens, in particular which lands first.
6. Swap positions and repeat the experiment using two balls which have the same mass but different volumes.
7. Swap positions and repeat the experiment using two balls which have the same volume but different masses.
8. Your teacher will now do a demonstration for you and drop a hammer and a feather. Before your teacher drops the hammer and feather, fill in the prediction column for the hammer and feather drop.
9. Write down what happened with the hammer and feather and answer the questions below.

RESULTS AND OBSERVATIONS

In the table below, fill in what you think will happen in the "prediction" column before you conduct your experiment. Assuming that you drop each pair of objects from the same height at the same time, what do you think will happen? Which do you think will land first?

Objects	**Prediction**	**Observation**
Apple and half apple		
Balls: same mass, different volume		
Balls: different mass, same volume		
Hammer and feather		

EVALUATION:

How reliable was your experiment? How could you improve your method?
Learner dependent answer. Example answers could include: It is difficult to drop objects at exactly the same time. It would be better to drop the objects from a greater height. Air resistance could have affected the results and it would be better to drop the objects in a vacuum.

CONCLUSIONS:

Learners should have found that the apple and half apple hit the floor at the same time. They should also have found that the balls of the same mass hit the floor at the same time and also the balls of the same volume hit the floor at the same time. From this they should conclude that all objects dropped, fall at the same rate no matter what their shape or size if air resistance can be ignored. (Advanced: they *accelerate* at the same rate). In the case of the hammer and feather drop, learners should have found that the hammer landed first. This is because of the effects of air resistance slowing the feather's fall.

QUESTIONS:

1. Which landed first, the apple or the half apple?
   They should have both landed at the same (or close to the same) time.
2. Considering the balls of the same mass, which landed first, the larger one or the smaller one?
   They should have both landed at the same time.
3. Considering the balls of the same volume, which landed first, the heavier one or the lighter one?
   They should have both landed at the same time.
4. Why do you think the two balls dropped always landed at the same time?
   In an ideal situation, all objects dropped from the same height will land at the same time, this is because the Earth's gravity causes the same acceleration for everything no matter how heavy it is or its volume.

Advanced Teacher Note: According to the universal law of gravitation, the Earth's gravitational force pulls down on an object with a force that is proportional to the (gravitational) mass of the object and the (gravitational) mass of the Earth. In all cases the mass of the Earth is the same and so any differences in the gravitational force depends only upon the difference in the gravitational mass of the objects being dropped.

According to Newton's second law, the force exerted on an object, F, is given by F=ma where m is the inertial mass of the object and a is the acceleration produced by the force F. All objects resist movement when acted on by a force. This resistance is called inertia and arises because an object has (inertial) mass.

When dropped, a heavier object experiences a greater gravitational force as it has a greater (gravitational) mass, but also resists harder as well as its inertial mass is larger. Lighter objects experience a smaller gravitational force and a smaller inertia.

We have, Force=$m_i a$ = $m_g g$ where g is independent of the falling object, where m_i= inertial mass and m_g = gravitational mass.

So the resulting acceleration an object experiences is given by a = (m_g/m_i) x g

As the value of g is independent of the falling object, the acceleration is given by the ratio of the gravitational and inertial masses. It turns out that the measured acceleration of all objects in the Earth's gravitational field is the same, they all fall at the same rate. This implies that the ratio between the gravitational mass and inertial mass is the same for all objects. By setting the value of G, the gravitational constant appropriately we can set the two masses equal to each other, a rather remarkable result since the gravitational mass is what causes the object to accelerate and the inertial mass opposes the acceleration!

5. Why do you think that the hammer landed before the feather?
   In a real situation, the air around us affects how objects fall. As an object moves through the air, it must push the air out of the way, it experiences air resistance. The feather is much lighter than the hammer and so the effect of air resistance is much larger for the feather. The net force acting downwards on a falling object is the force due to gravity - force due to air resistance. As the feather is much lighter than the hammer, the net force acting on it will be less and so it will experience a smaller acceleration towards the ground and fall more slowly.

Advanced Teacher Note: Air resistance is a drag force acting to slow the object down. The size of the force depends upon the velocity of the falling object squared, the surface area of the falling object and the density of the fluid it is falling in (in this case air). Very light objects are slowed by air resistance, like feathers or thin sheets of paper. This is because their weight is very small compared with the air resistance. Very large objects are also slowed by air resistance. This explains why a parachute slows your fall. Before you open a parachute only a small amount of air needs to be pushed out of the way as you fall. After opening, the wide parachute must push much more air out of the way and the air resistance increases, slowing you down.

TEACHER'S NOTE

A note on weightlessness

The term weightless causes a lot of confusion for learners. The confusion of a person's actual weight with one's feeling of weight is the source of many misconceptions. Weightlessness refers only to someone's sensation of their weight, or lack thereof. Weightlessness is a feeling experienced by someone when there are no external objects touching the person exerting a push or pull upon them, (we call these contact forces because they arise due to things being in contact or touching each other).

The weight of a person is the force of gravitational attraction to the Earth, which that person experiences. Someone in free fall, feels weightless but they have not lost their weight, they are still experiencing the Earth's gravitational attraction.

Learners are also often confused as to why astronauts in orbit around the Earth float in their spacecraft. One common misconception is that there is no gravity in space and so the astronauts can float. In actual fact, in low Earth orbit the Earth's gravity is about 90% of its strength at the surface of Earth. The only reason the astronauts float is because they are in free fall and their spacecraft is also in free fall with them, falling at the same rate. Therefore, the astronauts appear to float when compared with the spacecraft because they are both falling at the same rate. Another example is how orbiting spacecraft are essentially in free fall as there is 'nothing' retarding their motion towards to centre of the Earth, but because of their orbital velocity, they never actually move closer to the Earth.

A useful link to a video of someone experiencing free fall is given below:

Watch Felix Baumbartner's skydive. He experienced free-fall or weightlessness.
bit.ly/1fHZnmv

The Moon's gravity

As you have already discovered, the Moon, like any other planet or moon, has its own gravity. The strength of gravity on the surface of the Moon is one-sixth that of the Earth, and so on the Moon you would weigh one-sixth of what you do on Earth. Due to the weak gravity on the Moon, you would be able to jump six times higher than usual! The astronauts had to learn to walk in strange ways (such as leaping or hopping) to move about on the surface of the Moon.

As we will find out in the next section, the Moon's gravity not only affects humans walking on the Moon, but also influences the Earth.

Neil Armstrong, the first man on the Moon.

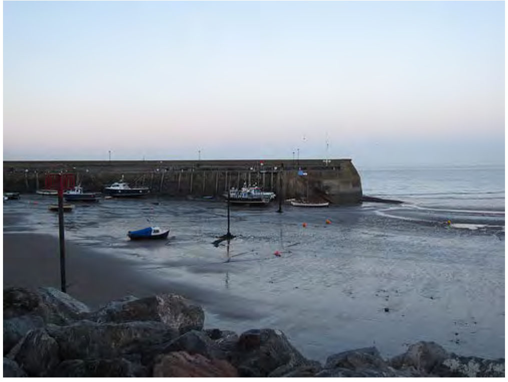
VISIT
Neil Armstrong walking on the Moon (video)
bit.ly/1eJPlwZ

2.3 Tides

TEACHER'S NOTE

Learners are often confused about the differences between waves and tides. Waves on the surface of the oceans, seas or lakes are caused by the wind and are independent of tides. Tides cause the overall water level to change with time. At high tide the sea is really high up on the beach, at low tide it is really far out. The water level gradually changes between the two and the cycle repeats daily with two high tides and two low tides at a given point in 24 hours. A tidal wave, or tsunami, is caused by a sudden disturbance, such as an earthquake and is unrelated to tides.

Tides are the predictable, repeated rise and fall of sea levels on Earth. If you look closely you will notice that the height of the surf at any beach varies slowly with time. When the sea is far out and there is lots of sand exposed, it is called low tide. You can see an example of low tide in the photo.



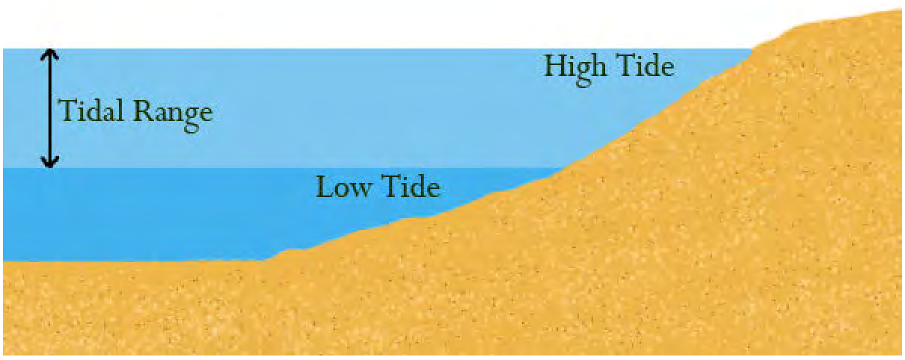
At low tide, the water is far out and the boats are resting on the sand.

Following low tide, the water gradually comes further up on the beach until it reaches its highest level, this is called high tide. After high tide the water level gradually drops again until it goes back to low tide. This pattern repeats over and over again. You can see an example of low and high tide at the same beach in the pictures below.

The same beach photographed at low tide (top) and high tide (bottom).

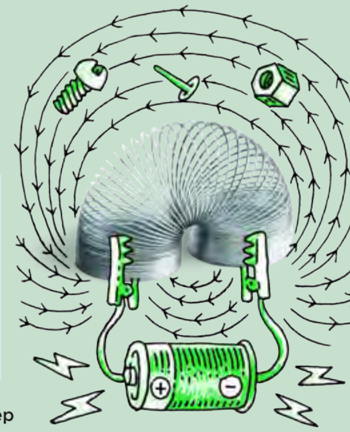
In general there are are two low and two high tides per day on the sea, which can be observed on the beaches or even in estuaries. The times of high and low tides are not exactly the same every day, they occur roughly one hour later each day.

Tides can be predicted and low and high tide times are published in tide tables. Fishermen use this information to plan when they will fish. Surfers also use this information so they can plan the best times to go surfing as each beach has a particular time when the sea level is just right for producing excellent surfing waves.



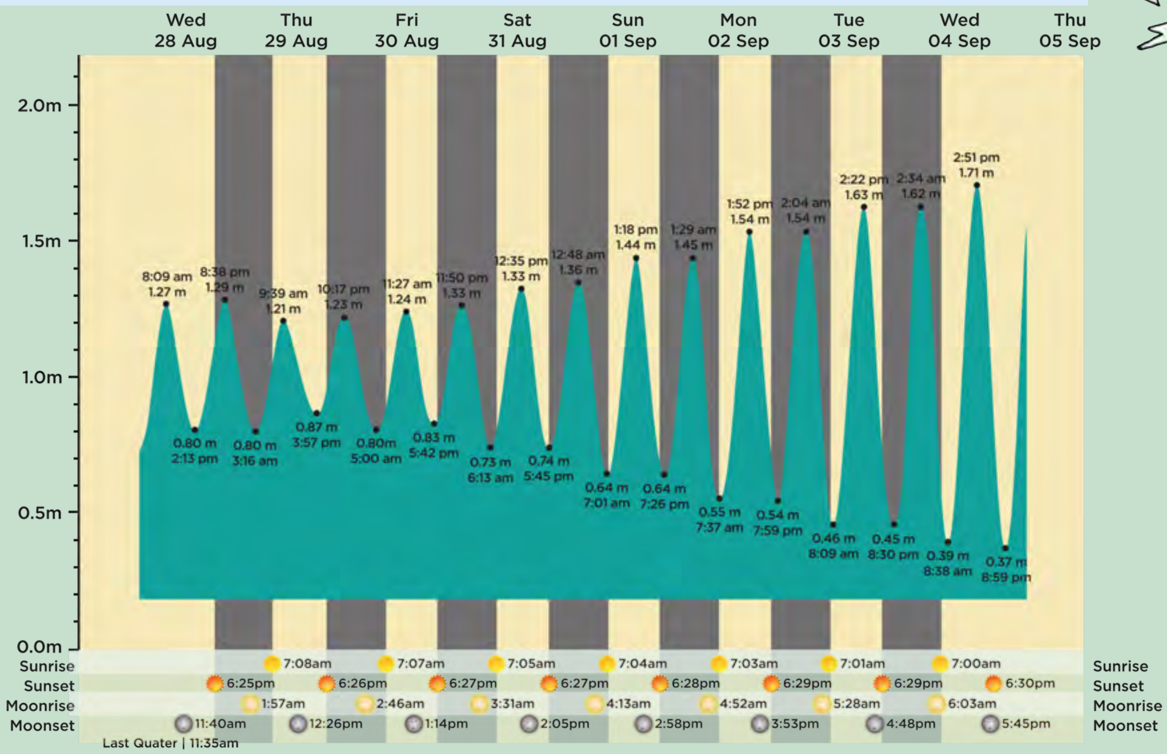
This diagram shows how the sea level differs at low and high tide at a beach. The vertical difference between low and high tide is called the tidal range.

ACTIVITY: Reading a tide chart



TEACHER'S NOTE

This activity provides a chart showing tidal data for one week in Cape Town. This activity gives learners the opportunity to read and interpret data from the chart.



This graph shows the predicted tides for a period of one week in Cape Town. Although the graph only includes data for one week, the actual pattern of high and low tides repeats every day throughout the year.

INSTRUCTIONS:

1. Look at the chart above, it shows the predicted times of low and high tide for one week in Cape Town.
2. The peaks represent times of high tide and the heights are listed in metres along with the time of high tide. The troughs represent times of low tide.
3. Answer the following questions.

QUESTIONS:

1. How many peaks appear per day in the chart?
   Two
2. What do these correspond to? High or low tide?
   High tide
3. How many troughs appear per day in the chart?
   Two
4. What do these correspond to? High or low tide?
   Low tide

5. What is the height in metres of the highest low tide during the week?
   0.7 m
6. When does the lowest high tide occur? (date and time)
   Friday 3rd May, 10.17 am
7. What height is the lowest high tide?
   1.35 m
8. The following photo is of a small harbour in Cape Town with a boat moored. These photos were taken on Monday 29 April.

Boulders Beach in Cape Town at low tide.

The same view of Boulders Beach at high tide.

   a) What time of day, was the photo taken of low tide?
   b) What time of day was the photo taken of high tide?
   a) At 11:47am
   b) At 6:05pm

VISIT
Timelapse of a shore from low to high tide.
bit.ly/1fHZYoi

So you now know that all seas have tides, why do you think this is? Lets do an activity to find out.

This picture shows a small harbour at low tide. The tide is out and the boats are stuck on the sand banks. Once the tide comes back in the boats will float on the water again.

TEACHER'S NOTE

Ask learners to give you their answer as to what causes the tides. You can write down all the answers. At this point it does not matter if the learners do not know what causes the tides, they will find out in the "Dance with the tides" activity. Once they have completed the activity, ask the learners again to see if they have changed their minds. At this point they should be aware that the gravitational pulls of the Moon and the Sun cause the tides.

ACTIVITY: Dance of the tides

TEACHER'S NOTE

This activity requires learners to work in groups of six. One learner will represent the Earth, four learners will represent the Earth's oceans and one learner will represent the Moon. You could ask learners to wear coloured T-shirts (green for the Earth, blue for the oceans, grey for the Moon) or to pin drawings or photos of the object they are representing to their school shirts with safety pins to make it clear what they are representing.

In this activity learners will model how the Moon's gravitational pull causes tides on Earth. Be sure to explain to them that the scale of the model is not correct, for example the Moon and Earth sizes are not correct in relation to each other. You can ask learners how they think the Moon can influence the Earth. Explain that moons and planets can influence each other's spins and tilts from a distance via their gravitational pull. All objects that have mass have their own gravity, but only large objects, like planets, have enough gravity to influence each other from very large distances. Explain that you are going to model what effect the Moon's gravitational pull has on the Earth. Remember that the gravitational force exerted by an object diminishes as you go further from it. Therefore, objects that are closer to the Moon experience a greater gravitational pull towards the Moon than objects that are further away.

MATERIALS:

- Four (ideally blue) scarves or strips of fabric per group, each one needs to be about a metre in length.

INSTRUCTIONS:

1. Work in groups of six, one learner represents the Earth, four learners represent the Earth's oceans and one learner represents the Moon.
2. The learner representing the Earth: stand in an open space.
3. The four learners representing the oceans: take one scarf each and stand in a circle around the learner representing Earth. (One behind, one in front and one on either side).
4. The four learners representing the oceans: link scarves with your neighbours.
5. Learner representing the Moon: stand outside the circle of "ocean" about 5 steps away from the "Earth" directly in front of one of the learners representing the ocean.
6. All learners apart from the Moon: turn to face the "Moon". You are now going to be "pulled" towards the Moon by the Moon's gravitational attraction! Remember that the gravitational pull exerted on an object by the Moon decreases with increasing distance to the Moon.
   NOTE:
   Ask the learners the following questions and discuss them as you are going through the activity.
7. Which part of the Earth and ocean is being pulled the most by the Moon?
   The learner closest to the Moon (one of the "oceans").
8. Which part of the Earth and oceans is being pulled least by the Moon?
   The learner farthest from the Moon (another "ocean".)

9. Ocean learner closest to the Moon: take three large steps towards the Moon.
10. Two ocean learners standing beside the Earth and the Earth learner: take two large steps toward the Moon.
11. Ocean learner farthest from the Moon: take one large step towards the Moon. Why have you moved towards the Moon by varying amounts?
    Because the pull of the Moon depends upon the distance to the Moon.
12. Note what happens to the shape the "oceans" now make, are you still in a circle or forming an oval shape?
    An oval.

TEACHER'S NOTE

Explain that the water from the oceans has "piled up" under the Moon and directly opposite the Moon. The two children standing beside "Earth" represent parts of the ocean where there is less water. You could ask the learners the following questions:

- Where are the oceans at the highest levels?
  At the oceans nearest and farthest from the "Moon".
- Are the coastal areas next to those "oceans" seeing a high or low tide?
  High.
- How many sides of the Earth experience high tide at the same time?
  Two (in general).
- Which parts of the Earth are experiencing high tide right now?
  The part that is under the piled up oceans.
- Where is low tide?
  Near the oceans closest to Earth on either side.

13. Note which sides of "Earth's" body is experiencing high tide. (Front and back or left and right arms).
    Front and back.

TEACHER'S NOTE

The formation of the second ocean bulge is simplified in this model and ignores subtle motions of the Earth.

14. Earth: spin around on the spot a few times stopping in a random position not directly facing the Moon. Remember that the Earth is continually spinning on its axis!
15. Note which sides of the "Earth's" body is experiencing high tide.
    Learner-dependent answer. Should be the parts of the body directly facing towards and away from the Moon.
16. Now imagine that there is no Moon, but only the Sun to exert a gravitational pull on the Earth. Because the Sun is much farther than the Moon, its gravitational pull is only one third of the Moon's pull. The team member representing the Moon must now represent the Sun instead.
17. Sun learner: take an additional 10 steps away from the Earth so that you are 15 steps away in total.
18. Ocean learners return to your starting circle positions.
19. All learners apart from the Sun: turn to face the "Sun". You are now ready to be pulled towards the Sun.
20. Ocean learner closest to the Sun: take one large step towards the Sun.
21. Two oceans learners standing beside the Earth *and* the Earth learner: take one normal step toward the Sun.

22. Ocean learner farthest from the Sun: take one small step towards the Sun.
23. Note what happens to the shape the "oceans" now make, are you still in a circle or forming an oval shape? How does the shape compare with that made when you were pulled by the Moon?
    An oval but not as elongated as before, the "oceans" facing and directly opposite the Sun are closer to the Earth than they were when the Moon was pulling on them.

TEACHER'S NOTE

Ensure that learners can still find the sides of low and high tides even though they are less extreme.

QUESTIONS

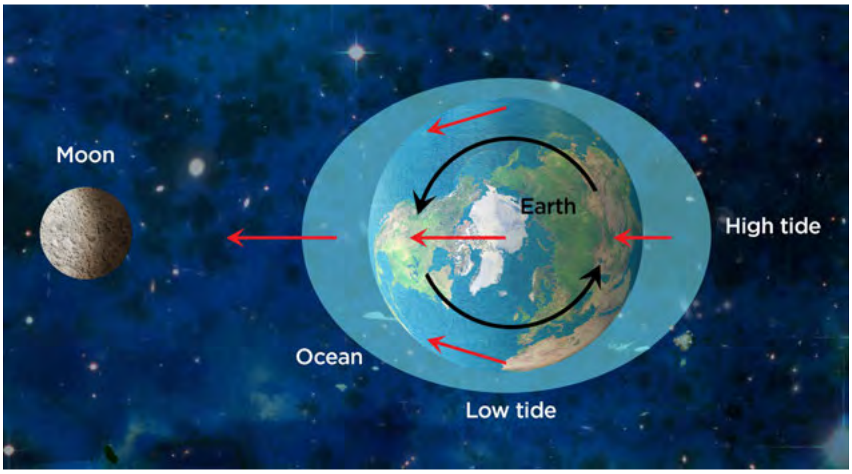
1. How many sides of the Earth experience high tide at the same time?
   Two
2. Where are they positioned in relation to the Moon?
   Under the Moon and on the side of the Earth directly opposite the Moon.
3. As the Earth spins what happens to the position of high tides in relation to the Moon?
   They remain under the Moon and directly opposite the Moon.
4. As the Earth spins what happens to the position of high and low tides on the surface of Earth?
   The high and low tide are on different parts of the surface of Earth now.
5. Besides the Moon, what pulls on the Earth?
   The Sun.
6. If there were no Moon, would we still have tides?
   Yes but the difference between high and low tide would not be as extreme. Since the Sun is so far away, the Sun's gravitational pull would give the tides only a third of their height.

TEACHER'S NOTE

In this activity we have ignored the motion of the Moon revolving around the Earth. The time of high tide changes each day because the Moon is moving around the Earth. If we had no Moon, the tide due to the Sun alone would occur at essentially the same time every day. This activity also ignores the friction between the water and solid Earth as it spins, which causes the tidal bulges (piled up ocean bulges) to lie ahead of the Earth-Moon line in the direction of the Earth's rotation.

Look at the image below. It shows how the Moon's gravity distorts the shape of the Earth's oceans into an oval shape. Do you remember how the gravitational force depends on distance? The ocean on the side of the Earth closest to the Moon experiences a greater gravitational pull towards the Moon relative to the ocean on the far side of the Earth.

This difference in gravitational pulls stretches the Earth's oceans into an oval shape. Along the Earth-Moon direction the oceans form two *tidal bulges*. At places in line with the Moon, where the oceans are experiencing a tidal bulge we have high tide. At locations which are at right angles to the Moon we have low tide.



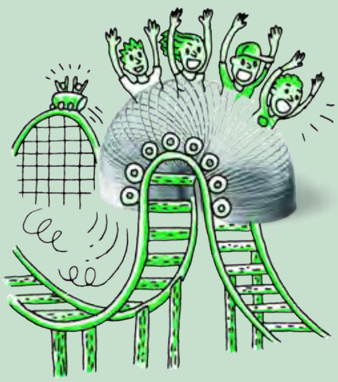
This picture shows the Earth and the Moon looking down from above. The gravitational pull experienced by different parts of the Earth towards the Moon are shown as arrows. The longer the arrow, the greater the pull. The ocean closest to the Moon experiences the greatest pull from the Moon and the ocean farthest from the Moon experiences the smallest pull towards the Moon. The differences result in the Earth's oceans being stretched to an oval shape.

Why do you think there are two low tides and two high tides at a given beach per day? Look at the diagram above again. When the Moon is directly overhead your location you experience high tide. You also experience high tide when the Moon is directly opposite your location on Earth. Remember that the Earth spins on its axis once every 24 hours and so during one day you experience two high tides at a given location: one when the Moon is directly above your location and one when the Moon is directly opposite your location roughly twelve hours later. Similarly there are two low tides per day. This cycle continues as the Earth spins.

TEACHER'S NOTE

The actual times of low and high tides at a particular place on Earth are influenced not only by the Earth's spin but also by the Moon's motion around the Earth in its orbit. As the Earth spins, the Moon also travels around the Earth. The Moon rises about an hour later each day, and high (and low) tides also occur roughly an hour later each day.

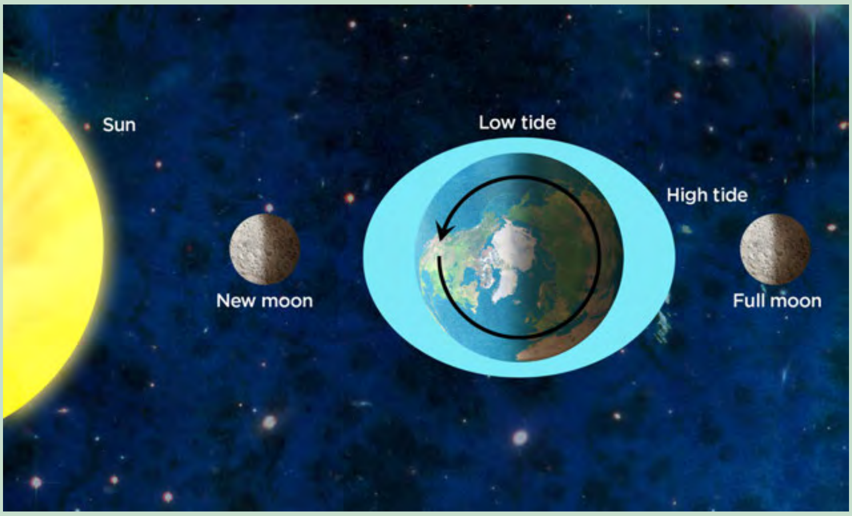
The height of the tides varies slightly with the phase of the Moon. This is *not* because the gravitational pull of the Moon is changing: the Moon has the same amount of mass and therefore exerts the same gravitational pull at all phases. Rather, the change in the heights is due to the relative alignment of the Sun and the Moon. Let's look at this further in the following activity.



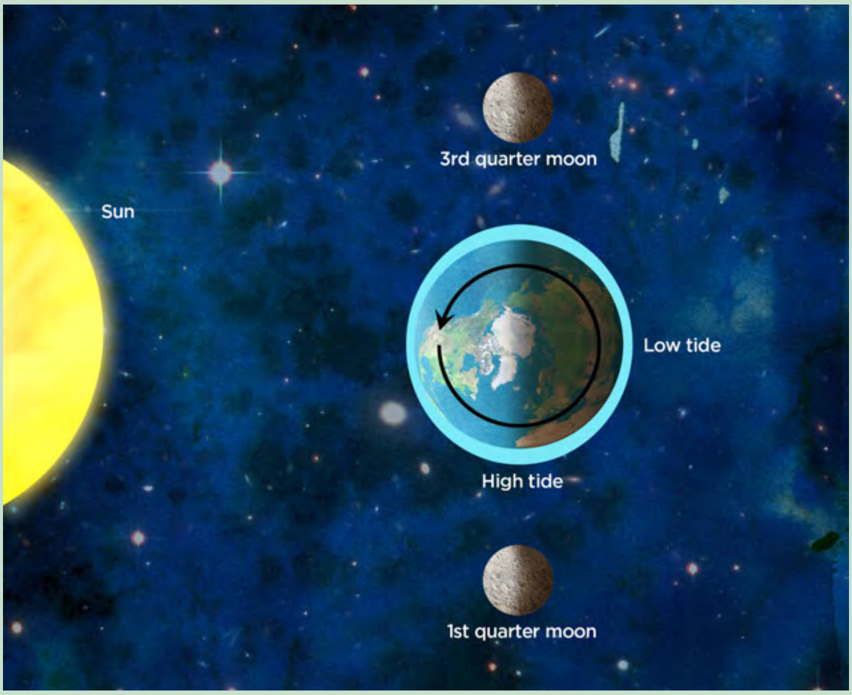
ACTIVITY: Spring and neap tides

INSTRUCTIONS

1. Look carefully at the following diagrams, it shows the size of the tides at Full and New Moon (top) and at the first and third quarter phase (bottom).
2. Answer the following questions.



Spring tide, showing the size of the tides at New moon and Full moon.



Neap tide, showing the size of the tides at first quarter and third quarter moon.

QUESTIONS

1. When the Sun, Moon and Earth are in a straight line the Sun's gravitational pull adds to the Moon's gravitational pull. What Moon phases does this correspond to?
   New and Full Moon.
2. During what phases of the Moon do the Moon's and Sun's gravitational pulls partly cancel each other out?
   First and third quarter.
3. During what Moon phases would you expect the highest high tides and the lowest low tides?
   New and full Moon.

VISIT

An animation demonstrating the tides. bit.ly/191SxEF

When the Sun, Moon, and Earth are lined up in a straight line (at the time of New or Full Moon), the pull of the Sun's gravity adds to the pull of the Moon's gravity creating extra-high high tides, and very low low tides. The difference in height between low and high tide is at its maximum at this time. These are called *spring tides*. When the Sun and Moon are at right angles to each other (during first and third quarter), the Sun's gravitational pull partially cancels out the Moon's gravitational pull and produces less extreme tides. The difference in height between the low and high tide is at its minimum at this time. These are called *neap tides*. Overall the Moon contribution to the Earth's tides is bigger than the Sun's contribution because it is much closer to Earth. If there were no Moon, the Earth's tides would be about a third of their current height.

TEACHER'S NOTE

Some additional activities are explained below.

Activity: Tides Poster

In this art and craft activity learners will make a poster to show the relative positions of the Sun and Moon producing spring and neap tides. You can use whatever art materials you have available, e.g. paint or pencils/crayons or felt pens. Ensure that you have blue, yellow and white and black colours so that the Earth's oceans, Sun and Moon can be accurately represented. Ensure that learners correctly identify which Earth-Moon-Sun alignments and Moon phases cause spring and neap tides . Ensure that learners draw the tidal bulge in the correct orientation and that the heights of their spring tides are higher at high tide and lower at low tide than their neap counterparts. Ensure that they correctly label places on Earth experiencing high and low tide.

MATERIALS:

- A3 sized poster paper
- paints, pencils or felt pens

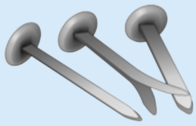
INSTRUCTIONS:

1. Draw a poster showing the alignments of the Earth, Sun and Moon for both spring tides and neap tides.
2. Label the Sun, Earth and Moon, including the Moon phase.
3. Draw and label the tidal bulge created by the Moon.
4. Label where high and low tide occur.

Activity: Make a tide wheel

This is a very simple and fun activity for learners where they make a tide wheel using a template. Internet access and access to a printer is needed for this activity. The template used in the activity can be freely downloaded from the US weather service website at `1.usa.gov/1bInzFg`.

The template file contains two pages. If available print out the template file onto thin card, this will make the tide wheel sturdier, however normal A4 paper is also fine (the learners will have to be careful not to rip the paper in this case). The printed pages will have to be secured together in the middle using a brass fastener (sometimes called a split pin). These are available from stationary stores.



Split pins or brass fasteners.

Learners can use their tide wheels to see what phases of the Moon cause spring and neap tides, and to investigate the relative contribution of the Sun and the Moon to the tidal height.

MATERIALS:

- one tide wheel template per learner
- one brass fastener per learner
- scissors

INSTRUCTIONS:

1. Cut out the two pages of the template along the dotted lines at the edge.
2. Cut out the areas marked "cut out" along the dotted lines to leave "windows" in your first sheet of paper.
3. Place the sheet of paper with the windows cut out on top of the second sheet of paper. Both pieces of paper should have their pictures facing up.
4. Align the sheets so that the black dots in the middle lie directly on top of each other.
5. Use your brass fastener to secure the two pieces of paper together at the black dot in the middle. You should still be able to rotate the bottom or top sheet around.
6. Move the top circle of card on your tide wheel and notice how the tides change with the position of the Moon.
7. Use your tide wheel to answer the questions below.

QUESTIONS:

1. During New Moon, how are the Sun, Moon and Earth aligned?
   They are in a straight line: Sun-Moon-Earth.
2. Is the tidal pull contribution from the Sun greater at Full Moon or First Quarter?
   The tidal pull contribution from the Sun is greater at Full Moon.
3. What Moon phases correspond to neap tide?

Neap tides occur at First quarter and Third Quarter (where the orange colour lines up with the neap tide marker on the front of the tide wheel)..

You can now see how important our closest neighbour the Moon is. The Moon's gravitational pull is responsible for the ocean tides!

The effects of tides on shoreline ecosystems

TEACHER'S NOTE

This section covers the effects that the tides have on marine life living in the region between low and high tide: the intertidal zone. This is a particularly harsh environment for marine animals and many have developed unique adaptations to help them thrive in their shoreline environments. A good way to introduce this topic is to ask learners about their experiences at the beach, in particular in rocky pool areas. You could ask them what sort of marine life they have seen for themselves in these areas. If learners have not visited the beach themselves you can also show colourful photographs of marine life found in the intertidal zone and explain how different animals have adapted to live in the shoreline environment.

This section links nicely with the biodiversity areas of the Life and Living strand in Gr. 7 and in particular with the Interactions and interdependence within the environment section of the Life and Living strand in Gr. 8. A class visit to an aquarium would be an ideal excursion for this section, allowing learners to see for themselves the organisms and conditions described in this section.

The intertidal zone can be seen here between the sea and the top of the sand.

The region of the beach between high tide and low tide levels is called the **intertidal zone**. The intertidal zone is a harsh environment for marine animals to live. During storms the surf can be very rough and plants and animals must be able to withstand the battering from big waves and not get washed away! Animals and plants that live here are underwater at high tide but are exposed to the air during low tide. Some organisms may stay underwater if they are in small rock pools which do not empty out when the tide goes out. Those that are exposed to air at low tide, face hot temperatures in summer and cold temperatures in winter so they must be able to adapt to different temperatures.

Animals exposed to the air at low tide may be soaked in fresh water when it rains and yet be soaked in salty sea water at high tide. Therefore, they must also be able to adapt to different salt concentrations as the tides come in and out.

Different animals have adapted to this tough environment in different ways. For example:

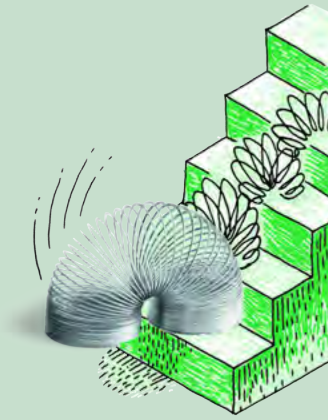
Crabs burrow into the sand to hide during low tide.

Kelp and other seaweeds are covered with thick slime to prevent them drying out.

Mussels and barnacles close their shells tightly to avoid drying out.

This oystercatcher takes advantage of low tide to feed.

ACTIVITY: The effects of tides on shoreline ecosystems



TEACHER'S NOTE

This is an activity in which learners investigate what adaptions different shoreline animals have made in order to survive in the intertidal zone and write a summary of their findings. You can ask learners to look online for images and examples if they have access to the internet. Alternatively they can consult the school or local library or you can provide them with specific examples. Some images have been provided here as a starting point. This can also be used as a research task.

MATERIALS:

- Pictures and texts about shoreline animals. (Can be textbooks, library books or online materials as directed by your teacher).

Seaweed, starfish and mussels in a rock pool.

Birds feeding on the rocks.

Eggs on some seaweed.

Green anemones in a rock pool.

Mussels growing on the rocks.

A crab in the sand.

A mother seal and pup in the waves in the intertidal zone.

Mudskippers - fish that can walk on land!

INSTRUCTIONS:

Study the pictures and texts and write a summary about how two different organisms are adapted to living in the intertidal zone. You can use the internet or other resources to do some more research.

TEACHER'S NOTE

Learners can use any of the examples given in this activity or those that they have read about. Answers could include animals that avoid drying out by burrowing, or closing their shells or plants that are covered in mucus. Answers could also include animals and plants that avoid being washed away by having strong "feet" that suck onto rocks.

High up in the intertidal zone water splashes only during high tide and the rest of the time it is dry. As you go lower down the intertidal zone, down the beach towards the sea, it gets progressively wetter for longer periods of time.

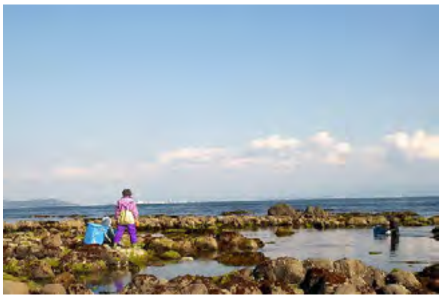
TEACHER'S NOTE

Some extra information about the different animals found in different areas in the intertidal zone:

High up in the intertidal zone (closer to the beach) the area is pounded by strong waves. Animals that live here need to be able to cling tightly to rocks to avoid being swept out to sea. Barnacles, limpets, periwinkles, and whelks cling tightly to rocks to avoid being swept out to sea. Seals and sea otters either rest or sleep above the intertidal zone so that they are not washed away or hit by the waves. If the tide comes in really high, they will move to another shoreline.

In the middle of the intertidal zone, tide pools often form and animals come to the tide pools to feed. Animals that live here can have softer bodies as this region is not so heavily pounded with waves. Sea anemones, snails, hermit crabs and starfish live in tidal pools.

In the lowest region of the intertidal zone where it is mainly wet, organisms are not well adapted to long periods of dryness. Some of the creatures found here are sea anemones, brown seaweed, crabs, green algae, limpets, mussels, sea slugs, starfish, sea urchins, shrimp, snails and sponges.

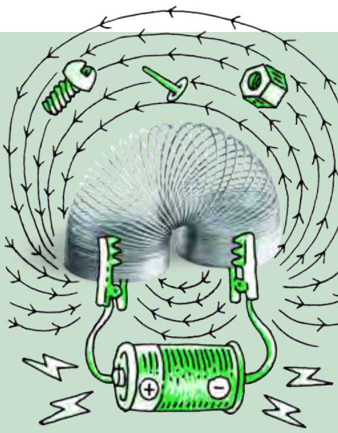


Harvesting seaweed during low tide.

Marine life in the intertidal zone have to adapt to the rise and fall of sea levels at the beach. But marine life is not the only kind of life that has to take note of the tides. Many people also use the low tide to collect seaweed. Seaweed has many uses, including being a food source for people. In some cultures seaweed is used for medicinal purposes and to make various woven products, such as rope, baskets and mats.

Fishermen looking for big catches time their fishing activities according to the tides too. Lets investigate this further.

ACTIVITY: How good a fisherman are you?



TEACHER'S NOTE

In this activity learners have to use a tide table to predict the best fishing times in Durban on a particular day. This emphasises how learning about the tides in the classroom has real world applications.

BACKGROUND:

Fish are easier to catch at times when they are feeding. The tides determine when most fish feed. When the tide is coming in or going out the moving water stimulates feeding. The fastest part of the tide is normally around two hours before and after low and high tides. These times are the best times to go fishing.

INSTRUCTIONS:

1. Look at the example tide table data for one day below and answer the following questions.

Durban - Thursday 29th August 2013

Time	Tide Height (m)	Comment
00:56		Moonrise
02:29	0.85	Low tide
06:14		Sunrise
08:41	1.26	High tide
11:42		Moonset
14:52	0.93	Low tide
17:39		Sunset
21:34	1.27	High tide

QUESTIONS:

1. Thembela wants to go fishing at the best time around the first low tide of the day. What times could she go fishing?
   00:29 or 04:29
2. Josh wants to go fishing while the Sun has set. What would be the best possible times for him to choose from?
   00:29, 04:29, 19:34 or 23:34
3. Faried wants to go fishing while the Sun is up. What would be the best possible times for him to choose from?
   06:41, 10:41, 12:52, 16:52

SUMMARY:

Key Concepts

- The Moon orbits the Earth once every 27.3 days. The Moon also spins on its own axis once every 27.3 days. Due to both these time periods being the same, we only ever see one side of the Moon from Earth.
- Gravity is a force that acts between all objects with mass. The size of the force acting on the objects is proportional to their masses and inversely proportional to their distance from each other.
- The Earth's gravity is responsible for holding the Moon in orbit around the Earth.
- The Moon's gravitational pull is mainly responsible for the tides on Earth.
- Neap tides occur when the Sun and Moon are at 90 degrees to each other.
- Spring tides occur when the Sun and Moon are in line with each other.
- The rise and fall of the tides affects marine life living along shorelines. They have adapted to this harsh environment in many ways to prevent themselves from drying out and from being washed away by strong waves.

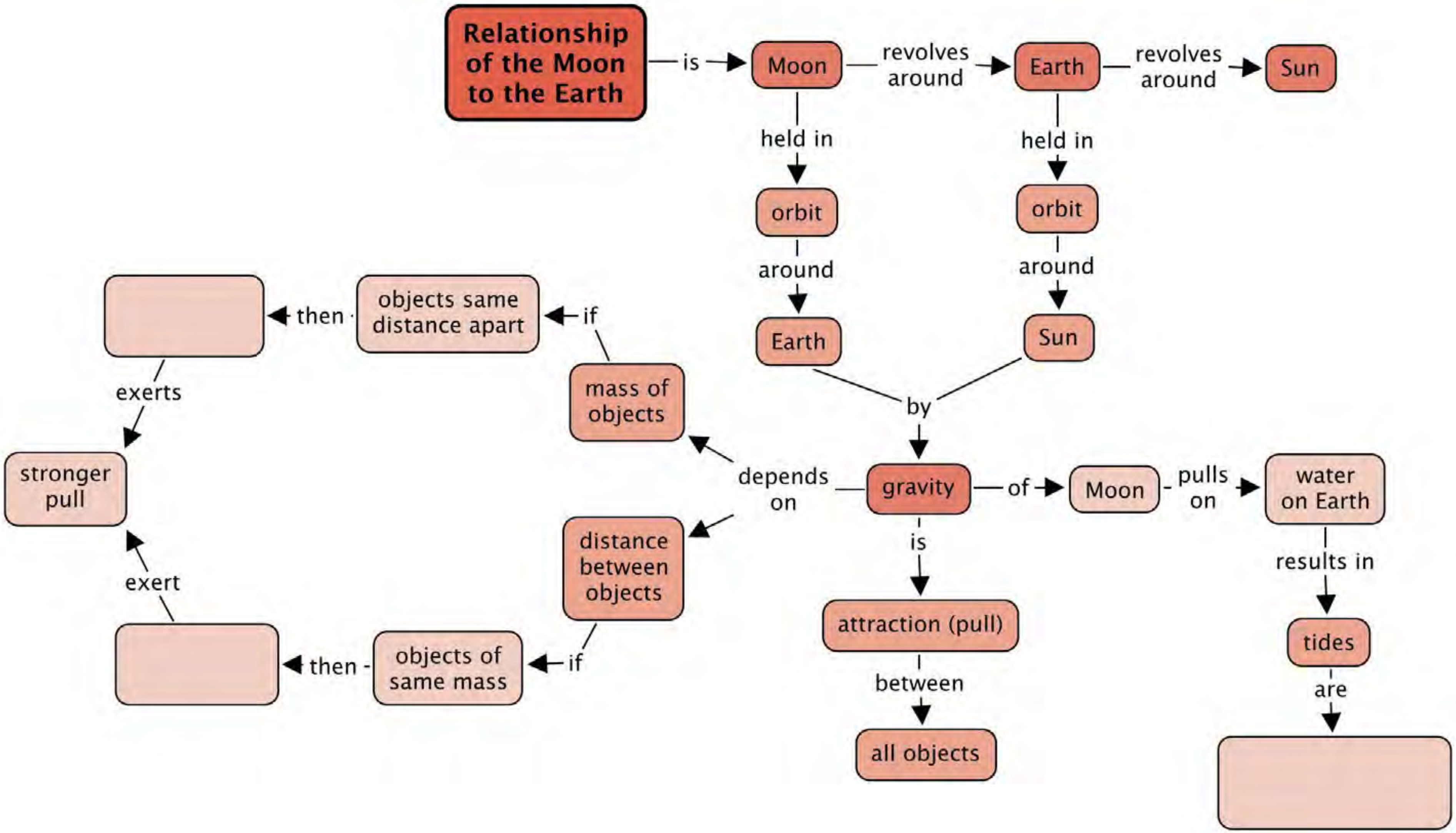
Concept Map

Complete the concept map by filling in the blank spaces. You can do this by reading the sentence that is made in the concept map. For example, "**Gravity** depends on **mass of objects**. If **objects same distance apart**, then ___________, exerts a **stronger pull**." What would the answer be? A 'bigger object' or a 'smaller object'? Fill the answer in. Also do this for the distance between objects. Would 'closer objects', or 'further away objects' exert a stronger pull? Then give a description of tides.

VISIT

Watch the original footage of Apollo 11 landing on the Moon in 1969.

bit.ly/185mzXG



Relationship of the Moon to the Earth
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Moon
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Earth
revolves around
Sun
held in
orbit
around
Earth
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around
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by
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of
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pulls on
water on Earth
results in
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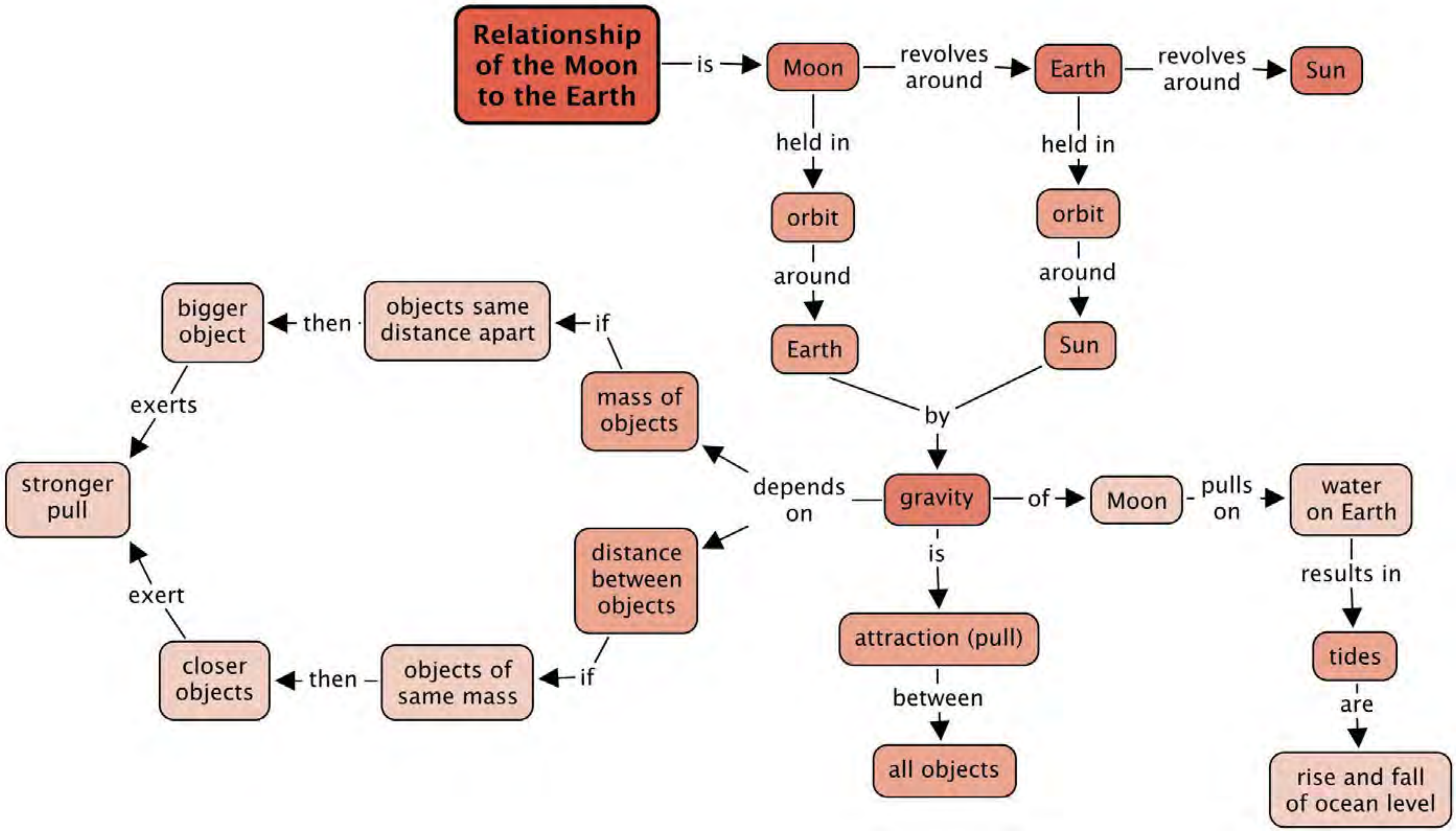
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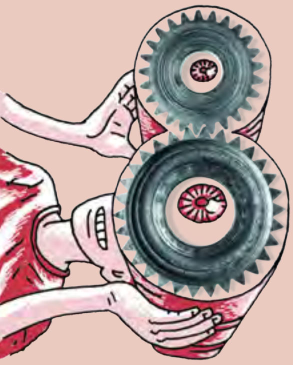


REVISION:

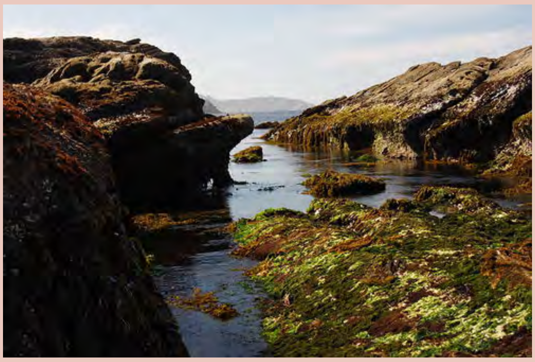
1. Why do we only see one side of the Moon from Earth? [2 marks]
   We only see one side of the Moon because the Moon rotates on its own axis at the same rate as it revolves around the Earth (27.3 days). Therefore the same half of the Moon always faces the Earth.
2. What is gravity? [1 mark]
   Gravity is the force of attraction between two objects with mass.
3. What holds the Moon in orbit around the Earth? [1 mark]
   The pull of gravity.
4. How does the gravitational force of attraction between two objects depend on their masses? [2 marks]
   The larger the masses of the objects, the larger the gravitational force of attraction between them (at a fixed distance).
5. How does the gravitational force of attraction between two objects depend upon their distance? [2 marks]
   The greater the distance between two objects with mass, the smaller the gravitational force of attraction between them (for fixed masses).
6. If you were to stand on the surface of the Moon you would experience only 1/6th the strength of gravity that you experience standing on the surface of the Earth. Why is this? [2 marks]
   This is because the Moon is less massive that the Earth and so it has less gravity.
7. What causes tides? [2 marks]
   Pull of the Moon's gravity on the Earth's oceans. And to a lesser extent the Sun's gravity.
8. Look at the following photo of boats on the sand. Do you think it is a problem that they are stuck on the sand? How will people get them into the sea?

   Boats on the sand.

   It is not a problem as it is low tide at the moment so the water has receded and the boats rest on the sand. But, when it is high tide again the water will come up and lift the boats off the sand and people will be able to get them out to sea.
9. What kind of tides occur when the Moon is inline with the Sun? [1 mark]
   Spring tides.
10. What kind of tides occur when the Sun, Earth and Moon are at right angles to each other? [1 mark]
    Neap tides.

11. At what phases of the Moon do spring tides occur? [2 marks]
    New Moon and Full Moon.
12. At what phases of the Moon do neap tides occur? [2 marks]
    First Quarter and Third Quarter.
13. What would happen to the height of the tides if there were no Moon? [1 mark]
    They would be only a third of the height that they presently are.
14. Draw a diagram to show the alignment of the Sun, Earth and Moon during neap and spring tides. [4 marks]
    You can use the image from the activity on spring and neap tides as a reference for what learners should draw.
15. Explain why spring tides are more extreme than neap tides. [2 marks]
    When the Sun, Moon, and Earth are lined up in a straight line the pull of the Sun's gravity adds to the pull of the Moon's gravity creating spring tides. When the Sun and Moon are at right angles to each other the Sun's gravitational pull partially cancels out the Moon's gravitational pull and produces less extreme tides. These are called neap tides.
16. Look at the following photo and answer the questions.



A rocky shore.

a) Do you think it is low or high tide? Give a reason for your answer. [2 marks]
b) What is the name given to this zone on the shoreline where the tides move back and forth? [1 mark]
c) What are the main risks to marine life living in this region? [2 mark]
d) How is the seaweed adapted to not dry out? [1 mark]
e) What other types of animals do you think you would find in this region? Give 4 examples. [2 marks]

a) It is low tide as there are rocks exposed which are normally underwater as they have seaweed growing on them.
b) The intertidal zone.
c) Drying out, damage by strong wave action and predation.
d) The seaweed is covered in a slimy layer which prevents it from drying out. It also clumps together.
e) Learners can list any of the animals included in this chapter, or else others which they may know about.

Total [33 marks]

TEACHER'S NOTE

Chapter overview

2 weeks

This chapter provides an overview of the key scientific discoveries that have led to our current understanding of the solar system and the Universe in general. The first part of the chapter covers early indigenous knowledge and is focused mainly on South African starlore. The second half of the chapter summarises the key astronomical discoveries made in Europe during the scientific revolution that were crucial in moving our understanding forward.

The main aims of this chapter are to ensure that learners understand the following:

- Early cultures saw that the stars formed patterns in the sky called constellations, which often had stories and myths associated with them which were passed down from generation to generation.
- Early cultures used the stars and constellations for timekeeping, direction finding and marking important religious events.
- In more recent times, astronomers tried to make sense of the motions of the stars and planets in terms of a physical model of the solar system.
- Copernicus suggested a Sun-centred model of the solar system in 1543. At the time, the generally accepted but incorrect model was an Earth-centred model.
- Johannes Kepler discovered that the planets orbit around the Sun in ellipses rather than circles.
- Galileo was the first person to use a telescope for viewing the stars and planets. He made many important discoveries using his telescope.
- Newton finally explained why planets orbit the Sun, by putting forward his theory of gravitation.

The subsection on *Modern Day Discoveries* is included as an extension to this chapter to highlight more recent exciting discoveries in astronomy. The aim here is to show learners current research in astronomy and to demonstrate that scientific discoveries are continuously being made.

You can download an open source programme called Stellarium to render 3D photo-realistic skies in real time. It displays stars, constellations, planets, nebulae and others things like the ground, landscape and atmosphere. You could use this software in your classroom to demonstrate some of the concepts in this chapter, such as constellations and the movement of planets.
bit.ly/1bHFb4d

3.1 Early indigenous knowledge (3 hours)

Tasks	Skills	Recommendation
Activity: The traditional and modern Xhosa calendar	Writing	CAPS Suggested

Tasks	Skills	Recommendation
Activity: Class discussion about different calendars	Discussion, communicating	CAPS Suggested
Activity: Create your own legend	Drawing, writing	Suggested

3.2 Modern developments (3 hours)

Tasks	Skills	Recommendation
Activity: Explaining the motions of Mars	Drawing, observing, analysing	Suggested
Activity: Interview with a revolutionary	Working in pairs, researching, describing, analysing, (writing - extension exercise)	Suggested
Activity: Research a new discovery, invention or scientist	Researching, describing, writing	CAPS Suggested
Activity: Modern day astronomers: test your knowledge	Accessing and recalling information, communicating in written, oral, or graphic form	Optional

KEY QUESTIONS:

- How did ancient astronomers use the motions of the Sun, Moon and stars for time keeping?
- How did ancient astronomers view our place in the solar system?
- Why did Copernicus think that the Earth and planets go around the Sun?
- What discoveries did Galileo make using his telescope?
- How did Newton explain Kepler's observations?

3.1 Early indigenous knowledge

TEACHER'S NOTE

In this section learners will discover how ancient civilisations viewed the stars and told stories about the stars which were passed on from generation to generation. They will also learn about the practical uses of stars for navigation and timekeeping. A special emphasis is placed on indigenous knowledge related to South Africa, however, some global comparisons are also made.

Astronomy is one of the oldest sciences. Ancient civilisations around the world watched the night skies, noting the patterns they saw in the sky. These patterns are called the constellations. A constellation is any group of stars, as seen from Earth, that seems to form a pattern or picture in the sky. Different nations, cultures and people have given different names for the different star patterns and how they interpreted the patterns.

A well known example is the Southern Cross. Have a look at the photos which show the stars in the night's sky and how to view the pattern making up the cross.

This pattern of stars is the Southern Cross.

The white lines show you how to view the Southern Cross.

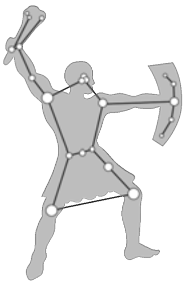
TAKE NOTE

To find south using the Southern Cross constellation, extend the long axis of the cross four times and go straight down to the horizon.

The Southern Cross, *Crux*, and the two bright Pointer stars were used by farmers to mark the beginning of the planting season. According to Sotho, Tswana and Venda traditions, these stars were called *Dithutlwa*, meaning "The Giraffes". The bright stars of *Crux* are male giraffes, and the two Pointers are female giraffes.

Another example is the constellation Orion. It is named after Orion, a supernaturally, strong hunter in Greek mythology. This is one of the most recognised constellations around the world and many cultures have identified with it, each forming their own myths, many around a strong man or hunter.

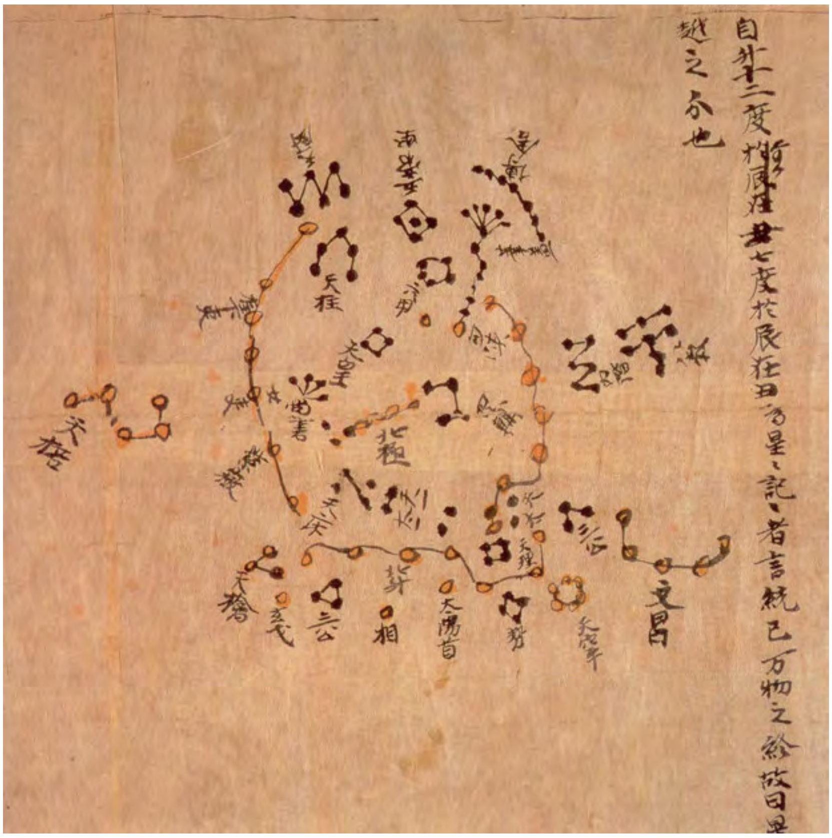
The Orion constellation, seen here as the three bright stars in the middle making up Orion's belt and the four stars in each corner.



This image shows how the pattern of stars in Orion make the image of the hunter.

People also watched the movement of the stars and planets across the sky marking the passage of time. Early cultures tended to identify the stars and planets they saw in the night sky with gods, spirits or animals. Ancient astronomers could tell the difference between stars and planets as the relative positions of the stars remain fixed in the sky whereas planets appear to move across the sky relative to the background stars. Not all the planets were known to the ancient people, rather only Mercury, Venus, Mars, Jupiter and Saturn. Uranus and Neptune were only discovered after telescopes were invented.

Ancient civilisations like the Sumerians, Babylonians and Egyptians were responsible for introducing many of the constellations that astronomers use in the West today.



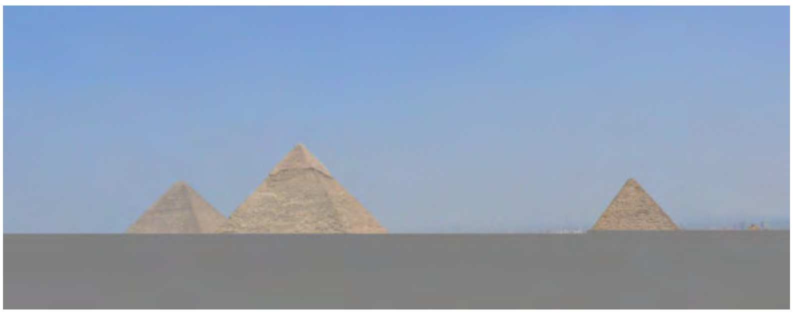
The Dunhuang Star Map from the Tang Dynasty in China (circa 700 AD) showing some of the constellations they observed.

VISIT

Read more about Chinese astronomy. bit.ly/19BmxGp

Knowledge of these constellations were later passed on and added to by later civilisations like the ancient Greeks, Romans and Arabs. Native Americans, Aboriginal Australians, Mayans, Aztecs, Polynesians and ancient Chinese and Japanese peoples took a keen interest in the stars and had their own constellations and stories about the stars.

Astronomy played an important role in religion at the time, and the dates of festivals and holy days were fixed by the alignment of the stars or the phase of the Moon. In fact, the ancient Egyptian and Mayan pyramids and temples were designed in such a way that the Sun, Moon, stars and planets would be visible from the top or through certain windows at important times of the year, such as solstices or equinoxes.



The three Great Pyramids of Giza.

VISIT

Ancient Egyptian Astronomy (video) bit.ly/1bHFeNo

Here in South Africa, early cultures also had their own constellations and stories which were passed down from generation to generation.

Early cultures used the stars for navigation. When travelling to new areas or over water they would have been unable to use familiar landmarks. When viewed from a particular location, a star always rises and sets in the same direction and follows the same path across the sky. We are familiar with this idea as the Sun is a star and we see it rise and set in the same direction every day. Early navigators learnt to use the directions of rising and setting stars to find their way.

Ancient manuscripts from Timbuktu in Mali in central Africa, documenting astronomical observations.

TAKE NOTE

In a *lunar calendar* the time between one New Moon and the next is called a *synodic month* and it is 29.5 days.

Early cultures also used the observed changes in the sky for timekeeping. A day was marked by the time between one sunrise and the next, just as it is today. The Moon's regular phases made it a very convenient "clock", and the time period between one New Moon and the next formed the basis of many of the oldest calendars.

The lunar cycle was useful because it was predictable in the same way as day and night, however, each Moon cycle was also connected to a slightly different season with its own name and activities.Tally sticks made of bones with notches etched into them have been found dating as far back as 20-30 000 years ago and are believed to mark the phases of the Moon. Today we use a **solar calendar**, a calendar in which a year is defined by the complete revolution of the Earth around the Sun, but some religious calendars still use a lunar calendar. Accurate timekeeping was particularly important for farming communities because people needed to know when to plant their seeds and when to harvest their crops.

The Lebombo Bone was discovered in the Lebombo mountains between South Africa and Swaziland in the 1970s. It is a bone from a baboon used as a Tally Stick. It is roughly 35 000 years old. It is thought to have been used for tracking lunar cycles, due to the 29 marks on it.

The *Pleiades*, also called the *Seven Sisters,* is a bright cluster of stars. Traditional farming communities in South Africa used the Pleiades to help them plan their planting. Once the constellation was visible in the early morning in June they knew it was time to start planting their crops. The Khoikhoi call the Pleiades *Khuseti* or *Khunuseh* meaning "rain stars". They are called *Selemela* in Sotho and Tswana, *Shirimela* in Tsonga, *Tshilimela* in Venda, and *isiLimela* in Xhosa and Zulu. In Xhosa the stars are called the "digging stars". In East Africa and Zanzibar the Pleiades are called *Kilimia*, which also means "ploughing stars" or " digging stars". Not only were the Pleiades used in Africa to mark planting season, they were also used by the ancient Mayans in Mexico and Central America to mark the start of their rainy season too.

The Pleiades or Seven Sisters star cluster. Although the constellation is known as the seven sisters, the star cluster actually contains hundreds of stars although only about seven are easily visible to the human eye.

VISIT

Read more about traditional African star lore.

bit.ly/1dL83Xl

ACTIVITY: The traditional and modern Xhosa calendar

In the Xhosa language, there are two ways of naming months, the modern and the traditional way. The modern names of the months are used in urban areas. However, in rural areas, in poetry, and particularly in the Eastern Cape the old names are still used. Look at the following table which shows these names.

TEACHER'S NOTE

Learners do not need to know the names of the months in Xhosa. This activity is for interest.

English	Modern Xhosa	Traditional Xhosa	Meaning of traditional name
January	uJanuwari	EyoMqungu	month of the Tambuki Grass
February	uFebhuwari	EyoMdumba	month of the swelling grain
March	uMatshi	EyoKwindla	month of the first fruits
April	uApreli	UTshazimpuzi	month of the withering pumpkins
May	uMeyi	UCanzibe	month of Canopus (Canopus is a star)
June	uJuni	Isilimela	month of the Pleiades
July	uJulayi	EyeKhala / EyeNtlaba	month of the aloes
August	uAgasti	EyeThupha	month of the buds
September	uSeptemba	EyoMsintsi	month of the coast coral tree
October	uOktobha	EyeDwarha	month of the lilypad
November	uNovemba	EyeNkanga	month of the small yellow daisies
December	uDisemba	EyoMnga	month of the mimosa thorn tree and Simba (the lion)

QUESTIONS:

1. Do you see that the modern Xhosa names are derived from the English names. The traditional names for the months mostly come from the names of plants and flowers. Why do you think certain months are given specific plants or flower names?
This corresponds to when these plants appear or grow as the seasons change throughout the year.
2. Why do you think August is called *EyeThupha*, the month of the buds?
This is because it is the start of Spring and the buds on plants start to appear at this time.
3. Why is June called *Isilimela*? Hint: Read the preceding text in your workbook.
Isilimela means 'month of Pleiades'. Pleiades is the group of seven stars which appears in the sky during June.
4. What time of year does *Isilimela* correspond to? What does this signal to traditional farmers?
It corresponds to winter, when farmers must start planting their crops so that they are ready to harvest when summer comes.
5. What month are you born in? Write down the traditional Xhosa name below.
Learner-dependent answer.

VISIT

Read more about some South African star myths.
bit.ly/14K09Lf

ACTIVITY: Class discussion about different calendars

TEACHER'S NOTE

Remind learners of the rules for debating which is that each one must be given a chance to speak and respond and learners' viewpoints must all be respected. This activity will help learners to appreciate different cultures and religions.

You can also get learners from different religions or cultures in your class to explain the different festivities, holidays or special events which they observe throughout the year.

The calendar the we use is the Gregorian calendar and is the most widely used around the world. It is also known as the "Western calendar" or "Christian calendar". It was named after the man who first introduced it in February 1582: Pope Gregory XIII. The term New Year's Day for the 1 January was adopted in Western Europe in the Middle Ages. Before this, the Roman Julian calendar (named after Julius Caesar) was used.

The Islamic year begins on the first day of the month of Muharram. It is counted from the year of the Hegira (Anno Hegirae), when Muhammad emigrated from Mecca to Medina (16 July 622 AD).

The Jewish calendar represents the number of years since they believed the world was created. This is calculated by adding up the ages of people in the Bible. So when someone of Jewish beliefs says that the year is 5763, it means 5763 years from the creation of Adam.

INSTRUCTIONS:

1. Around the world, and within South Africa, there are different calendars which are in use. Do you think it would just be easier to have one calendar?
2. Discuss this as a class.
3. You could do this as a class debate with teams debating the pros and cons of the concept.

As well as their practical uses in timekeeping, stories surrounding the Sun, Moon and constellations have been passed down from generation to generation. These mythical stories are called **star lore**. For example some believed that after sunset the Sun travelled back to the east over the top of the sky and that the stars are small holes which let the light through. Others said that the Sun is eaten each night by a crocodile and that it emerges from the crocodile each morning.

Being the most prominent object in the night sky, the Moon also has many stories and legends associated with it. If you look closely at the Moon you can see that it has lighter and darker patches. The pattern formed by the light and dark patches had been interpreted differently by different cultures: some see a rabbit, others a buffalo, others a "Man in the Moon". One urban legend that some people still incorrectly believe is that the the Full Moon is linked to insanity. There is no evidence to support the claims of increased birth rates, admissions to psychiatric hospitals, traffic accidents, homicides or suicides during a Full Moon.

The Khoikhoi called the Moon *kham*, or *khab* meaning "the Returner". The Khoikhoi also considered the Moon to be "the Lord of Light and Life" and would sing and dance at times of New and Full Moon. In /Xam San star lore, there is the following story:

The Moon is a man who has made the Sun angry. The Sun's sharp light cuts off pieces of the Moon until almost the whole of the Moon is gone, leaving only one small piece. The Moon then pleads for mercy and the Sun lets him go. From this small piece, the Moon gradually grows again until it becomes a Full Moon.

What do you think the San were observing which they explained with this story?

TAKE NOTE

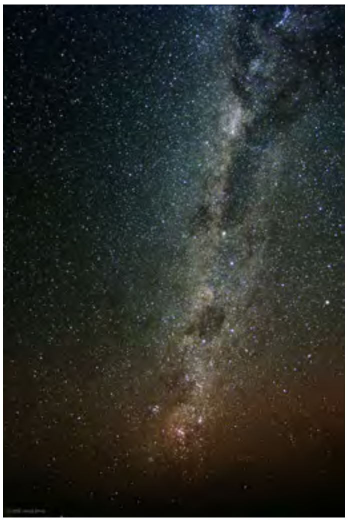
We will learn more about our galaxy, the Milky Way, and other galaxies, next year in Grade 8.

TEACHER'S NOTE

The San were observing the phases of the Moon. Throughout the month we only see certain parts of the Moon due to the relative position of the Sun, Earth and Moon and how much light is reflected from which part of the Moon.

The Xhosa considered the time of New Moon to be a time of inaction. When it reappeared as a crescent in the evening sky, it was cause for celebration. Important events were scheduled to take place around the time of Full Moon.

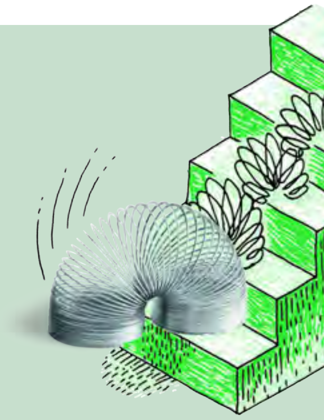
The Milky Way is also a prominent feature of the South African nighttime sky visible away from cities. Ancient peoples in South Africa described the Milky Way as as a footpath across the sky, along which the ancestor spirits walked. In San starlore, the Milky Way was created by a girl who scooped up a handful of ashes from a fire and flung them into the sky. This made a glowing path along which people could see the route to return home at night.



The Milky Way seen from Sutherland, Northern Cape, by Janus Brink (SAAO/SALT).

Meteors (also called shooting stars) and comets also feature heavily in starlore around the world. In most cultures meteors and comets were regarded as signs of important events. In Tswana starlore, a very bright meteor is an indication of a good season ahead. However, the .Xu San saw a meteor as an evil spirit racing across the sky to cause mischief among people.

The /Xam San, thought that a meteor announced the death of one of them. In Xhosa starlore, a comet, *Uzatshoba,* is associated with bad luck, wars and death. There was also a strong belief that comets predicted the death of a chief. The Sothos called comets *naledi tsha mesela*, and the Zulus called them *inkanyezi enomsile*, which means "stars with tails".



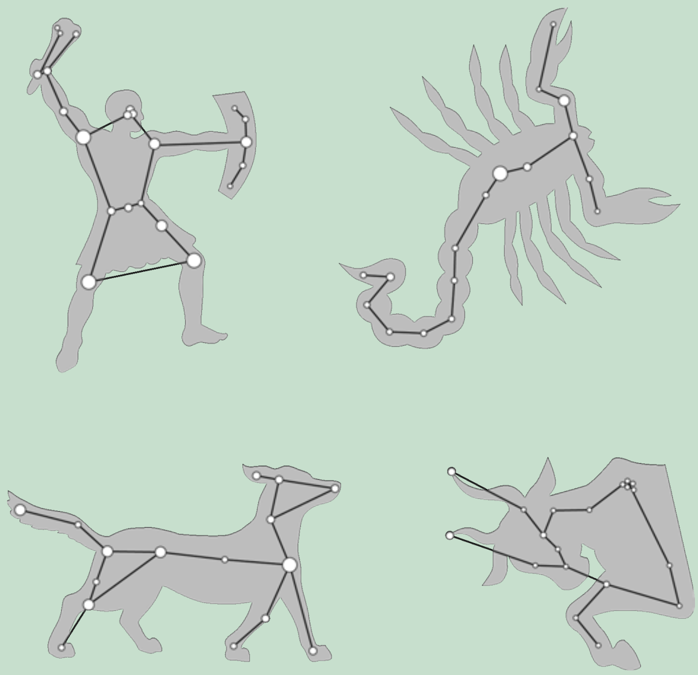
ACTIVITY: Create your own legend

TEACHER'S NOTE

In this activity learners will draw their own imaginary constellation (some examples are included for inspiration). They will then make up a story to go along with their constellation.

MATERIALS:

- pictures of famous constellations for inspiration



Some examples of constellations in the sky.

INSTRUCTIONS:

1. Make up your own pattern of stars and draw them in the box below.
2. Make up a legend (story) to go along with your new constellation.

Draw your new constellation pattern the box below.

Write your legend here.

VISIT

Curious about the universe, but don't know where to start? Have a look at this step-by-step guide to becoming an awesome amateur astronomer.

bit.ly/1aqKQHX

3.2 Modern developments

TEACHER'S NOTE

This section highlights significant discoveries about the nature of our Universe and the technology used to make those discoveries. The details about modern telescopes are kept brief, as this subject will be covered in more detail in the Grade 8 Earth and Beyond Strand: *Early viewing of space and telescopes*. Additional activities which are appropriate for this section depending upon access include visits to science centres, science museums, planetariums, observatories and amateur astronomy clubs.

The earliest astronomers had no sophisticated observatories. They studied the stars and planets using just their eyes. This is called naked eye observing. The South American Mayans, ancient Egyptians and ancient Chinese built some of the first **observatories**. These are special buildings used for studying the stars. These ancient observatories had no telescopes inside.

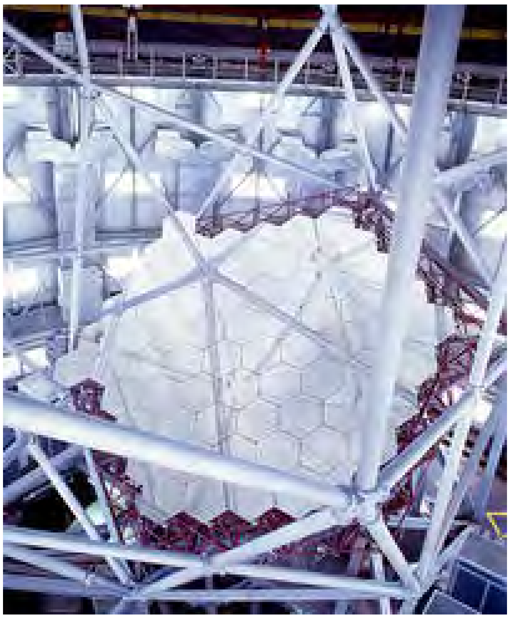
Nowadays modern observatories contain large telescopes with extremely sensitive cameras and instruments mounted on the telescopes. Astronomers use computers to move the telescopes and operate the instruments. As technology has progressed, we have been able to see a lot more and have learnt a lot more about the Universe.

Chichen-Itza observatory in Mexico. This ancient observatory was used by the Mayans, although it had no telescope inside.

VISIT
Astronomy timeline
bit.ly/1fGv8ML

South Africa currently has the largest optical telescope in the Southern Hemisphere, the Southern African Large Telescope (SALT). SALT is located just outside Sutherland in the Karoo where the skies are clear and very dark. SALT's main mirror is a hexagon shape measuring 11 x 9 metres across and is made up of 91 individual smaller mirrors which are slotted together. Its mirror is so large so it can collect a lot of light from very faint and distant objects. SALT is used to study a variety of objects including asteroids, stars and galaxies.

The Southern African Large Telescope (SALT).



SALT's huge mirror collects light from faint distant objects.

VISIT

The SALT website. bit.ly/18qWlui and a SKA video bit.ly/16soWXD

South Africa will also be hosting part of the Square Kilometre Array (SKA), the world's largest radio telescope, scheduled to be completed in 2024. The SKA will be located in the Karoo near the town of Carnarvon, far away from big towns and cities where there is little radio interference. When complete the telescope array will be 50 times more sensitive than any other radio telescope to date. The array will contain 3000 radio dishes as well as other types of radio detectors.

What the SKA will look like in the Karoo.

TAKE NOTE

An array means a large number of the same items. For example, when the desks in your classroom are all lined up neatly, we can call that an array of desks.

Astronomers plan to use the giant telescope to test the laws of gravity using black holes. They will also peer at some of the most distant clouds of gas in the Universe which formed before the first stars. Astronomers will also study how galaxies form, and change over time, and perhaps also detect life elsewhere in the Universe.

VISIT

Two thirds of the SKA will be built in Africa (mostly in South Africa), while the remaining third will be built in Australia.

Find out more about SKA. bit.ly/1eJ3JuG

We still have so much to learn about our Universe, we only understand about 5% of the content of our Universe presently. SALT and SKA will help us understand far more about our Universe, so much is still to be discovered.

VISIT

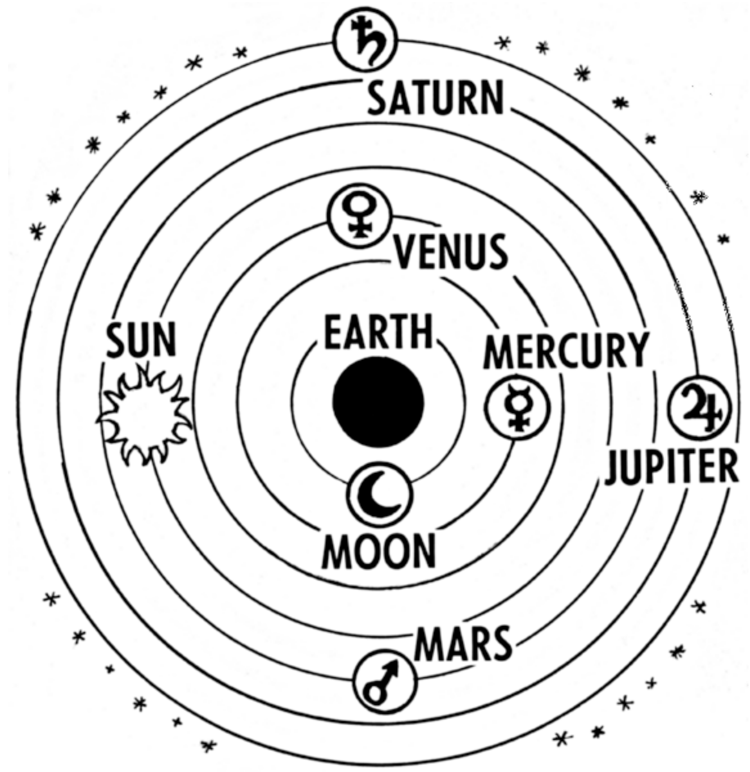
History of astronomy

bit.ly/15Vufw5 and bit.ly/16sp7Cf

Let's look at some of the highlights in our journey of scientific discovery so far.

The discovery that the Sun is at the centre of the solar system and not the Earth

Early astronomers such as the ancient Greeks believed the Earth was at the centre of the Universe, with the stars and planets orbiting around the Earth.



The ancient Greeks thought that the Earth was at the centre of the universe and believed that the planets, Sun and background stars all orbited around the Earth.

TAKE NOTE

Motion towards the east is called direct or*prograde* motion. Backwards motion is called *retrograde* motion.

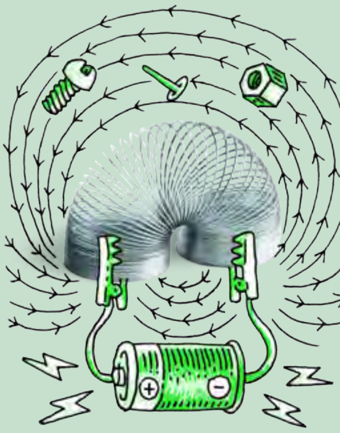
By carefully watching the motions of the planets in the sky, the Greeks saw that most of the time the planets travelled west to east across the sky relative to the background stars. However, they occasionally reversed their direction and moved backwards, from east to west relative to the background stars. The ancient Greeks' ideas about the Earth-centred Universe worked when the planets were travelling in the same direction as the background stars, but could not account for the their retrograde (backwards) motion.

In 1543, Nicolaus Copernicus, a Polish mathematician and astronomer, published his book called *De revolutionibus orbium coelestium*, or in English, *On the Revolutions of the Celestial Spheres*. In it he correctly deduced that the Sun, rather than the Earth, was at the centre of the Solar system. He based his deductions on many of his own and other people's observations.

Copernicus correctly ordered all the planets known at the time in increasing distance from the Sun. In his model, all the orbits of the planets were circular, so in this way, it was similar to the model of the ancient Greeks. But how did Copernicus's new deduction solve the problem of Mars' backwards motion?

Let's do an activity to find out.

ACTIVITY: Explaining the motions of Mars

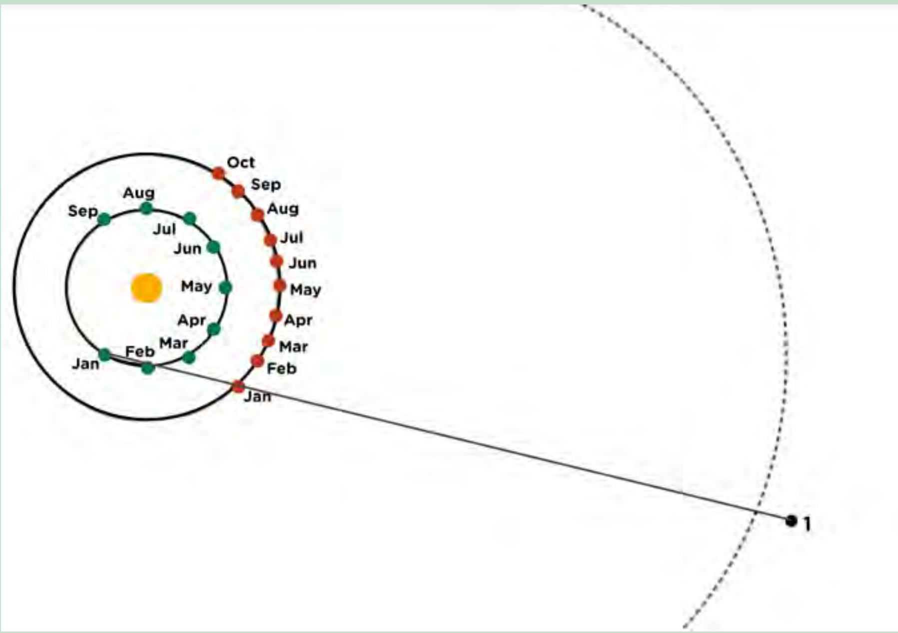


TEACHER'S NOTE

In this activity learners will discover how the retrograde (backwards) motion of Mars can be explained in a Sun-centred model of the solar system.

MATERIALS:

- pencil/pen
- ruler



Note that inner orbit is that of Earth (green) and outer is that of Mars (red). The dashed line are the background stars.

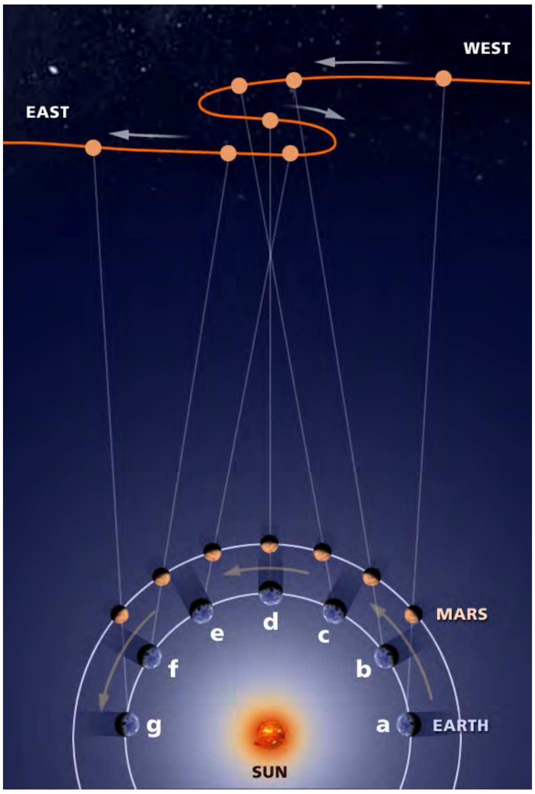
INSTRUCTIONS:

1. Draw a line from each Earth position through the Mars position for the same month. Extend the line approximately 1 cm past the dashed curve on the right which represents the background stars.
2. Place a dot at the end of the line and label the dots in order. If a new line crosses one already drawn, draw the new line slightly longer and place the dot slightly farther away than you did for the other lines. The line for January is already drawn as an example. The dots represent the positions where an observer on Earth would see Mars for the month indicated on the diagram.
3. Start with the dot number 1, and carefully connect the dots in order. This connecting line represents the path Mars appears to follow on the sky as viewed from Earth.
4. Answer the questions below.

VISIT
seven famous astronomers you should know.
bit.ly/19HJLtb

QUESTIONS:

1. How does Mars move around the Sun between January and August?
   Mars orbits around the Sun in an anti-clockwise direction.
2. To an observer on Earth, what movement does Mars appear to experience during that time period?
   It appears to initially be moving in an anti-clockwise direction, then it appears to turn around and travel in a clockwise direction before changing direction again and appearing to move in an anti-clockwise direction.
3. During which months does Mars appear to be moving backward in its orbit?
   During May, June and July.
4. Carefully observe what is happening to Earth and Mars in their orbits when Mars seems to loop "backward." What causes Mars to seem to move backward in its orbit?
   The Earth "overtakes" Mars in its orbit around the Sun.



The Earth moves faster than Mars in its orbit and catches up with Mars at point (b) before overtaking Mars at point (d). As the Earth overtakes Mars, Mars appears to travel backwards on the sky, even though Mars is not really changing direction in space.

VISIT

Retrograde motion of Mars.

bit.ly/1732x0x

How can objects appear to move backwards when they are not really moving backwards? Let's do a test right now. Hold your arm outstretched in front of you and hold up your first finger. Cover or close your left eye and note where your finger appears against the background. Now cover or close your right eye instead. What do you notice about the position of where your finger appears? It moved to the right didn't it? But did you really move your finger? No, it just appeared to move because of your change in perspective.

The discovery that the planets' orbits are elliptical

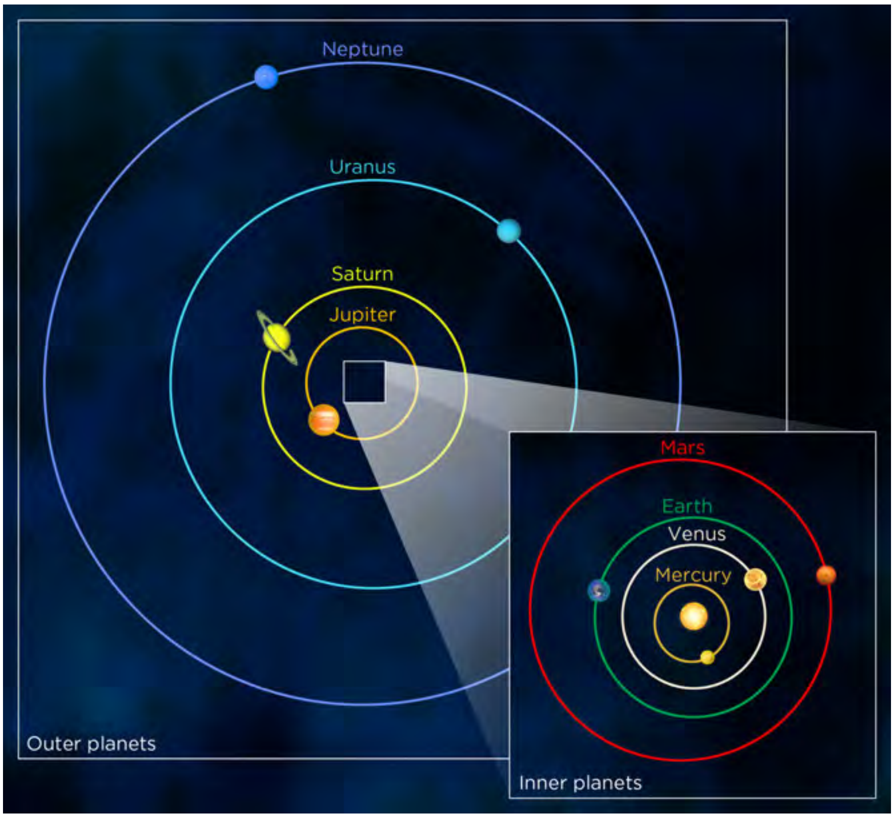
TEACHER'S NOTE

Ensure that learners are familiar with the term ellipse before starting this section. If necessary spend five minutes reviewing the properties of ellipses before continuing.

Johannes Kepler.

Johannes Kepler was a German astronomer and mathematician. He spent ten years trying to explain the motion of Mars across the sky in detail. He could only get his model of the solar system to fit the observations of the planets' motions if he assumed that rather than moving in a circle around the Sun, the planets all orbited in ellipses (ovals). He discovered that the true shape of the planets' orbits is elliptical.

The Earth travels faster in its elliptical orbit when it is closer to the Sun than when it is farther away. This is because the gravitational force of attraction between the Earth and Sun is stronger when the Earth is closer to the Sun. This is true of the orbits of all planets around the Sun.



The Earth and the other planets in our solar system orbit around the Sun in an ellipse.

Galileo's discoveries using his telescope

Galileo Galilei was an Italian physicist, mathematician and astronomer. He built his first telescope in 1609 and was the first astronomer to use a telescope. In 1610 he published a book called the *Sidereal Messenger,* listing the discoveries he had made using his telescope.

Galileo displaying his telescope.

TAKE NOTE

Although Galileo wasn't appreciated during his lifetime, his experimental and mathematical approach to physics was revolutionary and way ahead of his time.

Galileo discovered the four largest moons of Jupiter (which are now called the Galilean moons). Over several nights he watched them move and realised that they were actually orbiting around Jupiter.

The four largest moons of Jupiter, left to right in increasing distance from Jupiter: Io, Europa, Ganymede and Callisto.

He also found that Venus has phases just like the Moon (and just like all planets). He discovered that the Moon has craters and that the Sun has dark spots which are called sunspots. These imperfections on the Moon and Sun discredited the belief held by the Catholic Church at the time that the heavens were perfect and unchanging.

TAKE NOTE

Heresy is having a belief or opinion that is against the official teachings of the church at the time.

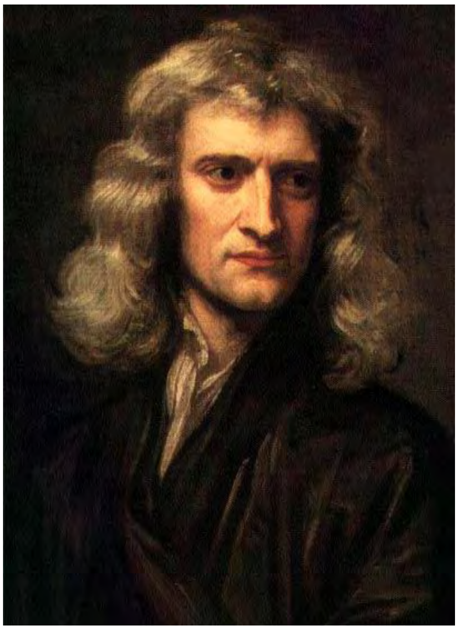
The Catholic Church allowed Galileo to conduct his research, as long as he did not openly publicise his findings. In 1632 Galileo angered the head of the Catholic Church (the Pope) when he published a book in which he stated that the Earth was moving around the Sun. He was put on trial and found guilty of heresy. He was first imprisoned and later placed under house arrest.

Newton discovers gravity

Isaac Newton was an English physicist and mathematician and is considered one of the greatest scientists of all time. He derived mathematical laws to describe the motions of objects but his greatest discovery was that of the force of gravity. In 1687 he published a book called *Philosophae Naturalis Principia Mathematica*, or in English: *Mathematical Principles of Natural Philosophy,*in which he explained his ideas about the motions of objects and gravity.

VISIT

Learn more about gravity and general relativity (video) bit.ly/1fpDg6L



Sir Isaac Newton aged 46.

There is a famous story which says that Newton was sitting under an apple tree when an apple fell on his head and he began to think about gravity and falling objects. The apple didn't really land on his head but he did watch an apple fall and began to wonder why apples always fall down. He suggested that it was the force of gravity that caused apples to fall.

Amazingly, he made the mental leap from Earth to space and realised that it was the force of gravity that was holding the Moon in its orbit around the Earth. According to Newton, gravity is the reason that objects fall to the ground when dropped and why planets orbit the Sun and why moons orbit planets. Up until Newton no one had been able to explain what held the Moon and the planets up in their orbits.

ACTIVITY: Interview with a revolutionary

TEACHER'S NOTE

In this activity learners will work in pairs to role play. One learner should imagine that they are an important early astronomer and the other learner will play the part of a journalist. The "journalist" will interview the "astronomer" in order to find out what important discoveries the astronomer has made. You may also ask the journalists to report back their findings to the class. If time permits you could ask the learners to switch places and therefore conduct two interviews in total (choosing a different astronomer each time). If you want to add a writing task to this activity you could also ask the "journalists" to write a newspaper report, detailing their interviewee's discoveries.

MATERIALS:

- reference materials about famous historical astronomers.

VISIT

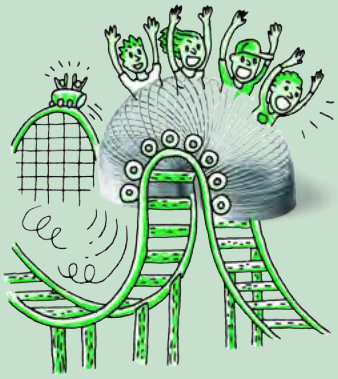
A short documentary about the search for habitable planets. bit.ly/1fpDqei

INSTRUCTIONS:

1. Work in pairs in this activity. One of you will play the role of an early famous astronomer and the other will play the role of a journalist.
2. Astronomer: Pick which famous astronomer you are going to be and answer the questions your partner asks you.
3. Journalist: Ask the "astronomer" what they have discovered and why their discoveries are important.

Modern day discoveries

Scientists are continually making new discoveries, and with every new discovery comes a new question.



ACTIVITY: Research a new discovery, invention or scientist

TEACHER'S NOTE

In this activity learners must conduct some research and then write a summary about a new discovery in astronomy, an invention in astronomy, or a particular astronomer that interests them. They can use the example material provided in this chapter, or they can conduct research online or at a local/school library. Decide how learners must present the information, either as a research project, an oral presentation or a poster.

INSTRUCTIONS:

1. Research either a recent discovery made in astronomy, or an invention used in astronomy or about a famous astronomer.
2. You can choose to write about one of the examples provided in the text below, or you can choose your own example.
3. Your teacher will inform you how you must present your work.

Some example discoveries:

Exoplanets - An exoplanet is a planet orbiting around a star other than our own Sun. The first exoplanet was discovered in 1992 when several planets were found orbiting around a small, rapidly spinning star. As of June 2013, 890 exoplanets have been discovered and more and more are being found all the time.

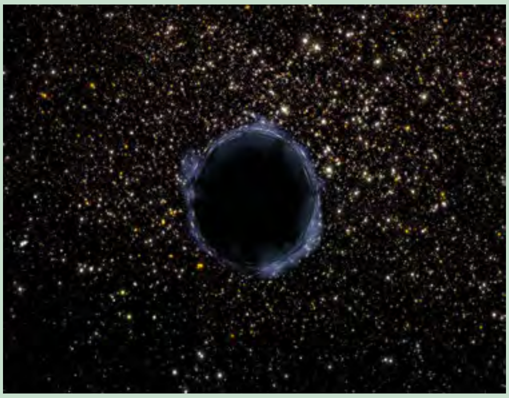
VISIT

Planet Quest - the search for another Earth.
bit.ly/1be0oDn

Citizen science - help look for other planets.
bit.ly/1dL91Tt

This image compares the smallest known exoplanets orbiting outside the solar system, to our own planets Mars and Earth.

Black holes-Black holes are super-dense regions in space which have very strong gravity, so strong that not even light can escape from them. Although you cannot see a black hole directly astronomers know they exist because of their pull on objects close to them. If you were to fall into a black hole feet first, you would be pulled apart like a piece of spaghetti.



A black hole in the universe.

An artist's drawing concept. On the left, the yellow, sun-like star comes too close to the black hole, and is stretched (middle yellow blob), until it is ripped apart. Some these remains of the star swirl into the black hole (blue-white cloudy ring on the right).

VISIT

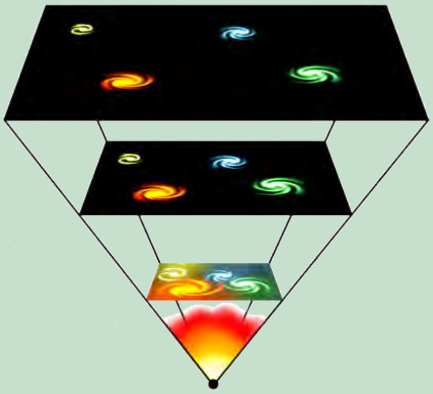
Black holes are super-dense regions in space which have very strong gravity, so strong that not even light can escape from them.

Read more about black holes. bit.ly/15vM5HU

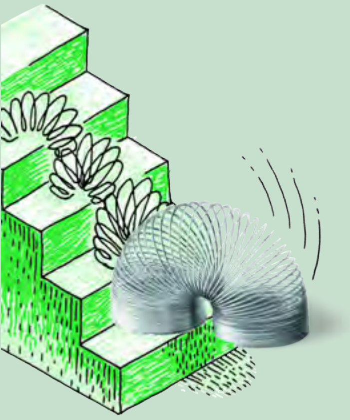
VISIT

Watch a black hole swallow a star. bit.ly/1aqMrOa

The Expansion of the Universe-In 1929, astronomer Edwin Hubble made the astonishing discovery that our universe is expanding. Looking at galaxies outside our Milky Way galaxy, he found that all the galaxies he looked at were moving away from the Earth, and that the most distant ones were moving away fastest. This implies that every galaxy is moving away from every other galaxy. In fact the space between galaxies is itself expanding.



As the Universe expands, galaxies move further and further apart.



VISIT

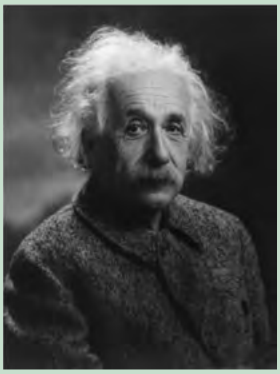
Universe awareness.

bit.ly/16Bs24C

ACTIVITY: Modern day astronomers and physicists

INSTRUCTIONS:

Look at the photographs below and match the face to the description of the person.



TEACHER'S NOTE

Stephen Hawking, Cecilia Payne-Gaposchkin, Albert Einstein.

Descriptions:

Stephen Hawking, a famous British physicist diagnosed with ALS, a form of Motor Neuron Disease, shortly after his 21st birthday. He is famous for his work on black holes.

Cecilia Payne-Gaposchkin, the astronomer responsible for discovering that stars are made up mostly of hydrogen and helium.

Albert Einstein, a German physicist famous for his work on gravity and the nature of space and time.

VISIT

The final frontier for Humans. bit.ly/16Bs3pk

SUMMARY:

Key Concepts

- People have watched the stars for thousands of years. They have created stories about the stars and constellations which have been passed on from generation to generation.
- Early scientists believed that the Earth was at the centre of the solar system.
- Copernicus found that the observations of planetary motion could be more easily explained if the Sun were at the centre of the solar system.
- Galileo was the first astronomer to use a telescope and found that Jupiter had moons orbiting around it.
- Newton discovered gravity and explained that planets and moons are held in orbit by the force of gravity.
- New discoveries are continuously made using modern telescopes.

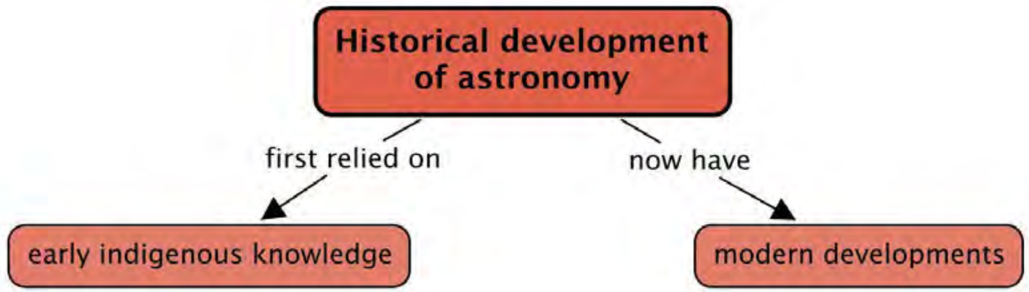
Concept Map

Throughout this year we have been looking at how to produce concept maps after each chapter. This is now your chance to make your own concept map. The concepts in this chapter about the development of astronomy can easily be divided into two main themes. Firstly, about "early indigenous knowledge" and then about the "modern developments" that people have made and are still making. The concept map has been started for you. Copy this into your notebook to first practice drawing your concept map. Once you have your final version, with the help of your teacher, draw it into the space below to act as the summary for this chapter.

VISIT

The concept maps in your workbooks were created using an open source programme. You can download it from this link if you want to use it to create your own concept maps for your other subjects.

bit.ly/16spQTO


Historical development of astronomy
first relied on
now have
early indigenous knowledge
modern developments

TEACHER'S NOTE

This is the first time the learners have to produce most of the concept map on their own. Although throughout the year we have been looking at and completing concept maps at the end of each chapter, this is quite a difficult skill to master. You will need to guide your learners through this process. It is important to do this last concept map with your learners as it will help with the development of this skill which will be very useful in high school. Remember, **learners need to learn how to learn**.

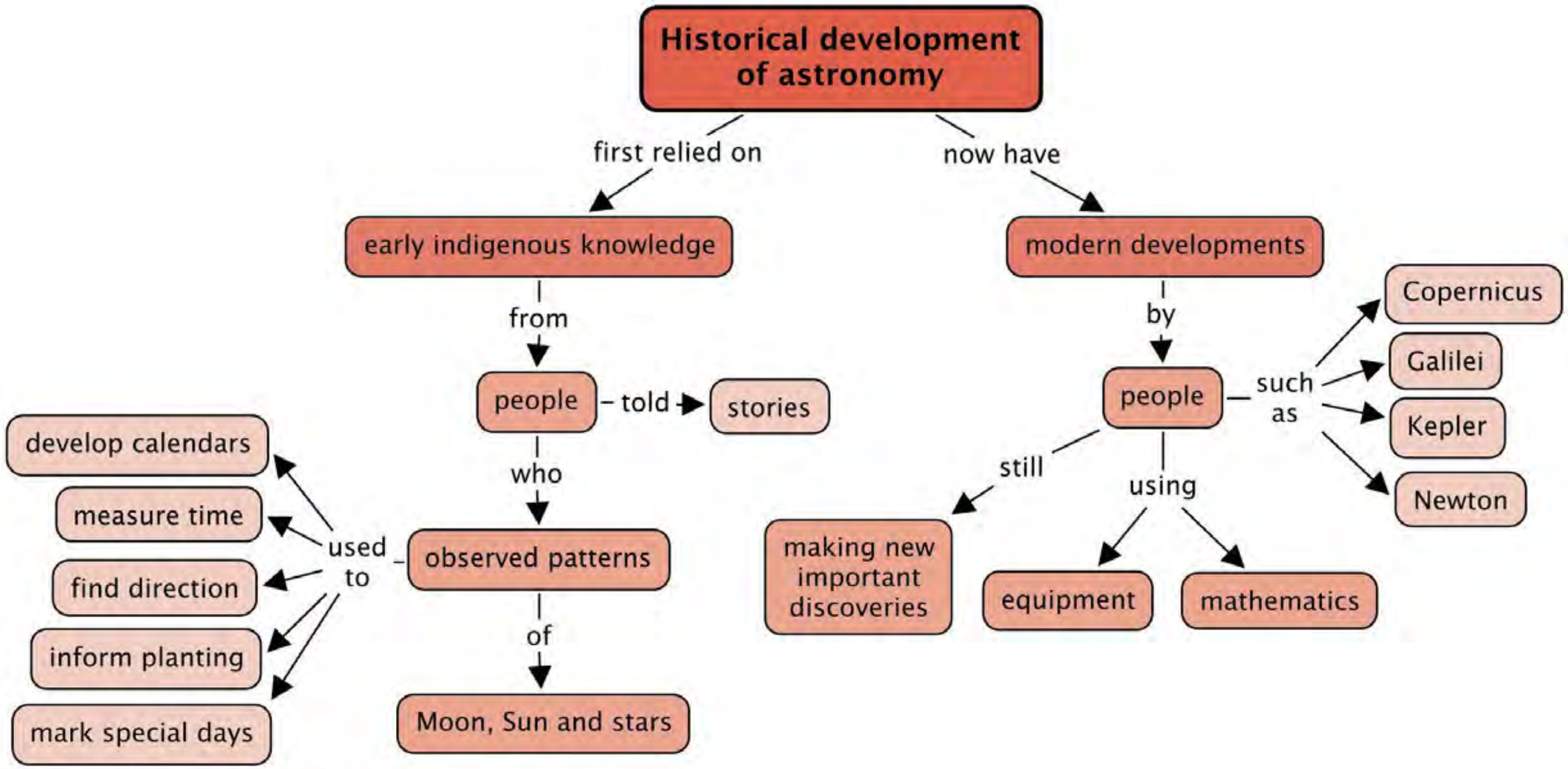
A version of a completed concept map is provided for you to reference when going through the process with your learners. Encourage them to first design their own concept maps on some scrap paper or in their notebooks. You will need to walk around the class during this time to help them and lead them through the process. For example, for the development of "early indigenous knowledge", ask questions such as:

- *Where* did this early indigenous knowledge come from? (from **people**)
- *How* did it come about it? (by **observing patterns** in the movement of the **stars, Moon and Sun**)
- *What* did they use the patterns for? (to **develop calendars, measure time, find direction**, etc.)

Also bear in mind that concept mapping is a subjective task - different learners may come up with different ways of presenting the content, and this should be encouraged, not penalised. Once the learners have had a chance to design their own concept maps, you can then do it as a class activity on the board. Ask for their input into what the next "bubbles" should be and why.

If learners are battling with this task, you can use the reference concept map given here to guide them through the process and still ask the same questions listed above. Once you have a concept map that you are all happy with, then the learners can draw it into their own books. **Please do not just copy the concept map below onto the board and instruct learners to copy it into their workbooks.** They (and you as a teacher) need to go through the process together so that the learning cycle for concept mapping is completed.

Teacher's version of the concept map follows:


Historical development of astronomy
first relied on
now have
early indigenous knowledge
modern developments
from
people
told
stories
who
observed patterns
of
Moon, Sun and stars
used to
develop calendars
measure time
find direction
inform planting
mark special days
by
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such as
Copernicus
Galilei
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making new important discoveries
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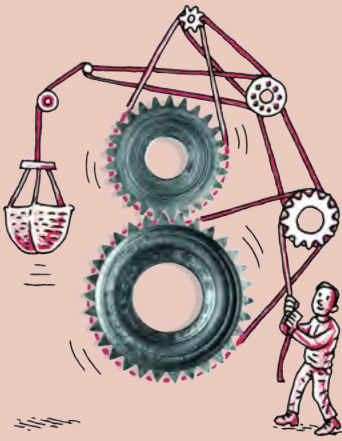
equipment
mathematics

REVISION:



1. What motions could the ancient Greek model of the solar system not explain? [2 marks]
   The ancient Greek model could not fully explain the motions of the planets. It could explain the forward or prograde motions, but could not explain the backward or retrograde motions where the planets appeared to move backwards relative to the background stars.
2. How did Copernicus's model of the solar system differ from the ancient Greek model of the solar system and how was it similar? [2 marks]
   Copernicus's model model was similar in that it assumed that the planets orbited in a circle. It was different however in that it assumed correctly that the Sun is at the centre of the solar system rather than the Earth. In Copernicus's model all the planets including the Earth orbit around the Sun. In the ancient Greek model the planets and the Sun orbit around the Earth.
3. Explain in your own words why Mars sometimes appear to move backwards relative to the motion of the background stars? [3 marks]
   Planets move in a direct (eastward) motion around the Sun. The Earth revolves around the Sun more quickly than Mars does as its orbit is smaller and on the inside of Mars's orbit. As the Earth moves faster than Mars at some point in its orbit, it catches up and then passes the slower-moving Mars. When the Earth overtakes Mars, Mars appears to be moving backwards relative to its usual motion around the sky. In this retrograde motion, neither the Earth or Mars are actually moving backwards; it only appears that way.
4. List two different discoveries that Galileo made using his telescope. [2 marks]
   The Galilean moons of Jupiter orbiting Jupiter, craters on the Moon, sunspots on the Sun, and the phases of Venus.
5. Do planets travel around the Sun in circles or ellipses? [1 mark]
   Planets travel around the Sun in an elliptical orbit.
6. How does the speed of a planet vary as it travels around the Sun? [2 marks]
   A planet speeds up in its orbit as it approaches the Sun and slows down in its orbit as it gets further away from the Sun.
7. What practical uses for the stars were used by early cultures? [2 marks]
   The stars were used for finding direction and timekeeping. They were used to mark special holidays and were also used by farmers to indicate when to plant their seeds.
8. How did early San people explain the Milky Way? [2 marks]
   In San starlore, the Milky Way was created by a girl who scooped up a handful of ashes from a fire and flung them into the sky.
9. Does the phases of the Moon have an effect on human behaviour? [1 mark]
   No, the idea that the Moon affects people's behaviour is an urban legend.

Total [17 marks]

GLOSSARY

acceleration due to gravity:	the acceleration given to an object by the attractive gravitational force of the Earth or other celestial body
axis:	a real or imaginary straight line about which something turns; the imaginary axis of the Earth passes through the North and South Pole
cellulose:	a carbohydrate which plants use to form leaves and stems
coal:	brown or black rock that can be ignited and burned, and which consists of carbonised plant matter
constellation:	a group of stars that when viewed from Earth form a pattern in the sky
crude oil:	a dark oil found in rock formations deep underground, used as fuel
day:	the length of time it takes for a planet to spin once on its axis
decompose:	to break down or decay
direct:	the shortest way
eclipse:	the blocking of light coming from a celestial object, for example, a solar eclipse or a lunar eclipse
ecosystem:	a community of living organisms and their interaction with the environment
equator:	an imaginary horizontal line around the middle of the Earth, at an equal distance from the North Pole and the South Pole
equinox:	occurs twice a year (around 20 March and 22 September) when the Sun's rays fall directly on the Earth's equator
fossil fuels:	a natural fuel such as coal, oil or natural gas, formed in the geological past from the remains of living organisms
glucose:	a carbohydrate produce by most plants, which is energy rich
gravitational force:	the force that attracts an object with mass towards another object with mass
gravity:	the force that attracts a body towards the centre of the Earth or towards any other celestial body having mass
hemisphere:	one half of a sphere or globe; the Earth is divided at the equator into the Northern and Southern hemispheres
indirect:	not direct, by a longer way
intensity:	the concentration or amount of something
intertidal zone:	an area that is above water at low tide and under water at high tide (i.e. lies between low and high tide levels)

lunar calendar:	a calendar based on lunar cycles (phases of the Moon)
lunar:	related to the Moon, e.g. lunar surface (Moon's surface), lunar day (the Moon's day)
mass:	the quantity of matter an object contains
moon:	a body that orbits around a planet or small body such as an asteroid (not a star)
natural gas:	a flammable gas, consisting largely of methane, occurring naturally underground and used as fuel
neap tides:	tides with the minimum difference between low and high tides which occur when the Moon and Sun are at right angles to each other
non-renewable:	something of which there is a limited supply, or which can only be used once
oblique:	at an angle other than 90 degrees, slanting inward
observatory:	a room or building housing a telescope or other scientific equipment for observations and research, especially of objects in space.
orbit:	the path followed by a planet , moon, or other object in space as it travels around another object; the path of the Earth around the Sun is an orbit
photosynthesis:	the process whereby green plants use sunlight (energy), water and carbon dioxide to produce glucose, which is food for the plant; oxygen is released during this process
prograde:	direct or forward motion (proceeding from west to east across the sky)
renewable:	something of which there is an unlimited supply found in nature, or which can be reused
retrograde:	reversed motion (proceeding from east to west across the sky)
revolution:	the orbit of Earth (or other object or planet) around the Sun
rotation:	the spinning of the Earth (or other object or planet) on its axis
season:	each of the four divisions of the year (spring, summer, autumn, winter) which have different weather patterns and daylight hours
solar calendar:	a calendar whose dates indicate the position of the Earth in its orbit around the Sun
solar energy:	energy from the Sun's light and heat
solstice:	occurs twice in a year (around 21 June and 21 December), when the Sun's rays strike the Tropic of Capricorn (southern summer solstice) or the Tropic of Cancer (northern summer solstice) directly
sphere:	any round object that has a surface that is the same distance from its centre at all points, for example, a ball or globe
spring tides:	extreme tides with the maximum difference between low and high tides which occur when the Earth, Moon and Sun are in alignment

star lore:	mythical stories about the stars, planets and constellations
starch:	a carbohydrate consisting of a large number of glucose units
telescope:	an instrument designed to make distant objects appear nearer and magnified
tidal bulge:	a swell in the sea level in line with the Moon on either side of the Earth (along the Earth-Moon line)
tides:	the regular rise and fall of the oceans (and some rivers and lakes) twice per day caused by the gravitational attraction of the Moon and to a lesser extent the Sun
tilt:	to slant or tip
vegetation:	the general word used for plant growing in an area or region
weight:	the force exerted on a mass due to gravity

A Assessment rubrics

The assessment guidelines for Gr 7-9 Natural Sciences are outlined in CAPS on page 85. Provided here are various rubrics as a guideline for assessment for the different tasks which you would like to assess, either **informally** (to assess learners' progress) or **formally** (to record marks to contribute to the final year mark). These rubrics can be photocopied and used for each learner.

The various rubrics provided are:

- **Assessment Rubric 1: Practical activity**
- To be used for any practical task where learners are required to follow instructions to complete the task.
- **Assessment Rubric 2: Investigation**
- To be used for an investigation, especially where learners have to write their own experimental report or design the investigation themselves.
- **Assessment Rubric 3: Graph**
- To be used for any graph or translation task you would like to assess, either on its own or within another activity.
- **Assessment Rubric 4: Table**
- To be used when learners have to draw their own table and you would like to assess it.
- **Assessment Rubric 5: Scientific drawing**
- To be used when learners have to do a drawing, particularly in Life and Living.
- **Assessment Rubric 6: Research assignment or project**
- To be used when learners have to do a research assignment or project, either outside of class or in class time, and either individually or in groups.
- **Assessment Rubric 7: Model**
- To be used when learners have to design and build their own scientific models.
- **Assessment Rubric 8: Poster**
- To be used when learners have to make a poster, either individually or in a group.
- **Assessment Rubric 9: Oral presentation**
- To be used when learners have to give an oral presentation to the class on a selected topic.
- **Assessment Rubric 10: Group work**
- To be used to assess any work where learners are required to complete the task as a group. This rubric is designed to assess the group as a whole.

A.1 Assessment Rubric 1: Practical activity

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
Following instructions	Unable to follow instructions	Instructions followed with guidance	Able to work independently	
Observing safety precautions	Unable to observe safety precautions	Sometimes does not follow safety precautions	Able to follow safety precautions completely	
Ability to work tidily	Cannot work tidily	Can work tidily		
Cleans up afterwards	Does so once reminded	Does so without reminding		
Organisation	Disorganised	Fairly organised	Organised and efficient	
Use of apparatus, equipment and materials	Always used incorrectly and materials wasted	Sometimes used correctly and aware of material usage	Apparatus and materials used correctly and efficiently	
Results or final product	No result or final product	Partially correct results or product	Results or product correct	
Answers to questions based on activity	No answers provided or most are incorrect	Can answer questions and at least 60% are correct	Can answer application and questions correctly	
			Total	/15

A.2 Assessment Rubric 2: Investigation

Name:

Date:

Task:

Assessment criteria	0	1	2	3	Comments
Aim	Not stated or incorrect	Not clearly stated	Clearly stated		
Hypothesis or prediction	Not able to hypothesise	Able to hypothesise, but not clearly	Clearly hypothesises		
Materials and apparatus	Not listed or incorrect	Partially correct	Correct		
Method	None	Confused, not in order or incorrect	Partially correct	Clearly and correctly stated	
Results and observations (recorded either as a graph, table or observations)	No results recorded or incorrectly recorded	Partially correctly recorded	accurately recorded but not in the most appropriate or specified way	Correctly and accurately recorded in the most appropriate or specified way	
Analysis or discussion	No understand-ing of the investigation	Some understand-ing of the investigation	Understands the investigation	Insightful understand-ing of the investigation	
Evaluation	No attempt	Partially correct	Correct, but superficial	Critical evaluation with suggestions	
Neatness of report	Untidy	Tidy			
Logical presentation of report	Not logical	Some of report is logically presented	Report is logically presented		
				Total	/25

A.3 Assessment Rubric 3: Graph

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
Correct type of graph	Not correct	Correct		
Appropriate heading, describing both variables	Not present	Present, but incomplete	Complete	
Independent variable on x-axis	Not present or incorrect	Present		
Dependent variable on y-axis	Not present or incorrect	Present		
Appropriate scale on x-axis	Incorrect	Correct		
Appropriate scale on y-axis	Incorrect	Correct		
Appropriate heading for x-axis	Not present or incorrect	Correct		
Appropriate heading for y-axis	Not present or incorrect	Correct		
Units for independent variable on x-axis	Not present or incorrect	Correct		
Units for dependent variable on y-axis	Not present or incorrect	Correct		
Plotting points	All incorrect	Mostly or partially correct	All correct	
Neatness	Untidy	Tidy		
Graph size	Too small	Large		
			Total	/15

A.4 Assessment Rubric 4: Table

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
Appropriate heading, describing both variables	Not present	Present, but incomplete	Complete	
Appropriate column headings	Not present or incorrect	Mostly correct	Correct and descriptive	
Appropriate row headings	Not present or incorrect	At least half correct	All correct	
Units in headings and not in body of table	None present	Present but in the body	Present and in the headings	
Layout of table	No horizontal or vertical lines	Some lines drawn	All vertical and horizontal lines drawn	
Data entered in table	Not correct	Partially correct	All correct	
			Total	/12

A.5 Assessment Rubric 5: Scientific drawing

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
Appropriate, descriptive heading	Not present	Present, but incomplete	Complete	
Appropriate size of drawing (sufficiently large on page)	Incorrect (too small)	Correct		
Accuracy of drawing (correct shape and proportion of parts)	Incorrect	Somewhat correct	Correct	
Structures or parts placed correctly in relation to each other	Mostly incorrect	Mostly correct, but some misplaced	All correct	
Diagram lines are neat, straight and done with a sharp pencil	Not clear or neat or blunt pencil	Clear and neat		
Label lines do not cross over each other	Incorrect	Correct	All correct	
Parts are labelled	Mostly incorrect	Mostly correct with some missing or incorrectly labelled	All correct and labelled	
			Total	/12

A.6 Assessment Rubric 6: Research assignment or Project

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
Group work (if applicable)	Conflict between members or some did not participate	Some conflict and some members did not always participate	Worked efficiently as a group	
Project layout	No clear or logical organisation	Some parts are clear and logical, while others are not	Clear and logical layout and organisation	
Accuracy	Many errors in content	A few errors in content	Content is accurate	
Resources used (material or media)	No resources used	Some or limited resources used	A range of resources used	
Standard	Poor standard	Satisfactory	Of a high standard	
Use of time	Did not work efficiently and ran out of time	Worked fairly efficiently	Worked efficiently and finished in time	
			Total	/12

A.7 Assessment Rubric 7: Model

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
Scientifically accurate	Model inaccurate or incomplete	Mostly accurate, but with some parts missing or incorrect	Accurate, complete and correct.	
Size and scale	Too big or too small, parts not in proportion to each other	Correct size, but some parts too big or too small	Correct size and proportional scale	
Use of colour or contrast	Dull, with little use of contrast	Somewhat colourful	Creative and good use of colour and contrast	
Use of materials	Inappropriate use or only expensive materials used	Satisfactory use of appropriate materials and recyclables where possible	Excellent use of materials and recyclables where appropriate	
Use of a key or explanation	Not present	Present but incomplete or vague	Clear and accurate	
			Total	/10

A.8 Assessment Rubric 8: Poster

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
Title	Absent	Present, but not sufficiently descriptive	Complete title	
Main points	Not relevant	Some points relevant	All points relevant	
Accuracy of facts	Many incorrect	Mostly correct, but some errors	All correct	
Language and spelling	Many errors	Some errors	No errors	
Organisation and layout	Disorganised and no logic	Organisation partially clear and logical	Excellent, logical layout	
Use of colour	No colour or only one colour	Some use of colour	Effective colour	
Size of text	Text very small	Some text too small	Text appropriate size	
Use of diagrams and pictures	Absent or irrelevant	Present but sometimes irrelevant	Present, relevant and appealing	
Accuracy of diagrams or pictures	Inaccurate	Mostly accurate	Completely accurate	
Impact of poster	Does not make an impact	Makes somewhat of an impact	Eye catching and makes a lasting impact	
Creativeness	Nothing new or original	Some signs of creativity and independent thought	Original and very creative	
			Total	/22

A.9 Assessment Rubric 9: Oral presentation

Name:

Date:

Task:

Assessment criteria	0	1	2	3	Comments
Introducing the topic	Did not do	Present, but with no clear links to content	Present, and links to content being covered	Interesting and catching introduction	
Speed of presentation	Too fast or too slow	Started off too fast or too slow but reaches optimal pace	Good speed throughout		
Pitch and clearness of voice	Too soft or unclear	Started off unclear or too soft, but improved	Speaks clearly and optimal pitch throughout		
Capturing audience's attention and originality	Did not make an impact or no attempt to capture interest	Interesting at times	Sustained interest and stimulating	Sustained interest and stimulating throughout with originality	
Organisation of content during presentation	Illogical or unclear	Clear and mostly logical	Clear and logical throughout		
Factual content	Many errors in content	Some errors in content	All correct		
Concluding remarks	No conclusion or not appropriate	Made a satisfactory conclusion	Insightful/ thought-provoking conclusion		
Answers to educator and class's questions	Was not able to answer questions or gave incorrect answers	Was able to answer recall questions only	Was able to answer recall and application questions		
			Total		/18

A.10 Assessment Rubric 10: Group work

Name:

Date:

Task:

Assessment criteria	0	1	2	3	Comments
Member participation	Very few members participated or one or two members did most of work	Only some members participated	In the beginning only some members participated but then full participation	Full participation throughout	
Discipline within the group	Lack of discipline	Some members disciplined	Most members disciplined	All members disciplined	
Group motivation	Unmotivated or lack focus	Some members motivated, but others lack focus	Most members motivated and focused	All members motivated and focused	
Respect for each other	Show disrespect to each other	Some members showed disrespect	All members are respectful		
Conflict within the group	Considerable conflict and disagreements which were unresolved	Some conflict which was either resolved or unresolved	No conflict or any issues were resolved maturely		
Time management	Disorganised and unable to stick to time frames	Mostly able to work within the given time	Effective use of time to complete the task		
			Total		/15

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