Centre for Renewable and Sustainable Energy Studies

Renewable Energy
Mathematics Activities and Projects
Senior Phase

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Introduction

What is climate change?

Climate change refers to significant and lasting changes in long-term weather patterns in a specific region or across the entire Earth. It describes changes in overall weather patterns, including precipitation, temperatures and cloud cover. Climate change can cause an increase or a decrease in the incidence of extreme weather conditions in an area, or result in a shift in an area's traditional weather patterns.

Why has climate change become an issue?

Scientists are more and more convinced that human activities play a substantial role in our climate and cause the climate to undergo changes. The natural environment finds it difficult to adapt to the rate of these changes. Some of the effects of climate change include more extreme weather events, increased floods and droughts, reduced agricultural yields, melting polar ice caps and the extinction of plant and animal species. These changes may have further significant impacts on both the natural world and our human societies. Learners will need the mathematical and geographical knowledge and skills that are fundamental to understanding climate processes and climate change in order to respond effectively to these changes.

The greenhouse effect

In order to understand how climate change works and the impact it has on humankind, we first need to understand how it works naturally. The greenhouse effect is a natural process that plays an important role in moderating the planet's temperature. Energy from the sun enters the atmosphere and is absorbed by the surface of the Earth, warming it. Some of the energy is reflected off the Earth's surface (especially at the poles and in other snow- or ice-covered areas), while some is radiated back from the surface as heat. A percentage of the heat is trapped by gases in the atmosphere. Heat-trapping gases are known as greenhouse gases and include carbon dioxide, methane, nitrous oxide and, importantly, water vapour. They act as heat absorbers keeping the Earth warm. Without them, Earth would be about 35°C colder.

Unfortunately, many human activities (such as burning of fossil fuels for energy, transportation and deforestation by burning) release stored carbon dioxide and other greenhouse gases into the atmosphere. The effect of these 'extra' gases is to absorb and retain more heat, keeping Earth a little warmer than it would otherwise have been. A global average temperature rise of even 1°C has huge implications for Earth's systems and therefore for life on the planet.

Our role as teachers

The human (anthropogenic) causes of increased carbon dioxide levels and the resultant changing climate are huge causes for concern. Our individual decision-making capacity has the potential to play an important role in whether we manage to reach mitigation goals or not. We need learners to understand the science behind climate, comprehend what is driving current climate change, and grasp why this is unusual. We also need learners to understand the impact that climate change may have on their lives and how the decisions they make could become part of a solution, or at least help to alleviate the problem.

How can renewable energy help?

The most cost-effective solution to climate change is to reduce our energy consumption by becoming more energy efficient, while at the same time reducing our dependence on fossil fuels and switching to more environmentally friendly forms of energy generation.

What mathematics knowledge and skills can help?

1. Learners require key knowledge and skills concerning data handling, data representation in graphs and graph interpretation to make sense of what scientists are saying about climate change. They also

need to understand some of the science and challenges of renewable energy technology.

2. Moreover, learners require the skill to apply their mathematical knowledge to problem-solving situations.

Where does this mathematics appear in the Curriculum and Assessment Policy Statement (CAPS)?

The Mathematics Senior Phase CAPS provides for the following specific aims and specific skills (the particularly relevant parts are printed in bold):

“2.3 SPECIFIC AIMS

The aims of teaching and learning Mathematics are to develop:

- **a critical awareness of how mathematical relationships are used in social, environmental**, cultural and economic relations;
- confidence and competence to deal with any mathematical situation without being hindered by a fear of Mathematics;
- an appreciation for the beauty and elegance of Mathematics;
- a spirit of curiosity and a love for Mathematics;
- recognition that Mathematics is a creative part of human activity;
- **deep conceptual understandings in order to make sense of Mathematics**; and
- **acquisition of specific knowledge and skills necessary for**:
  - **the application of Mathematics to physical, social and mathematical problems**
  - **the study of related subject matter (e.g. other subjects)**
  - further study in Mathematics.

2.4 SPECIFIC SKILLS

To develop essential mathematical skills the learner should:

- develop the correct use of the language of Mathematics;
- develop number vocabulary, number concept and calculation and application skills;
- learn to listen, communicate, think, reason logically and apply the mathematical knowledge gained;
- **learn to investigate, analyse, represent and interpret information**;
- **learn to pose and solve problems**; and
- **build an awareness of the important role that Mathematics plays in real life situations** including the personal development of the learner.”

These specific aims and specific skills echo the fifth principle of our South African curriculum, namely:

> “Human rights, inclusivity, environmental and social justice: infusing the principles and practices of social and environmental justice and human rights as defined in the Constitution of the Republic of South Africa.”

Further study in mathematics

In our country, we need many more mathematicians with an interest in mathematical modelling to join the field of renewable energy technology and to contribute to our understanding of climate change.

1. Global graphs

Progression of the Graphs topic in CAPS

Our focus here is on the subsection of the Graphs topic, namely Global graphs. In Grade 7 Term 3, this topic has 6 hours allocated to it; in Grade 8 Term 4, this topic has around 5 out of 9 hours allocated to it; and in Grade 9 Term 3, this topic has around 3 out of 12 hours allocated to it (predominantly as revision), with all new work relating only to linear graphs.

TOPIC: 2.5 GRAPHS		
Grade 7	**Grade 8**	**Grade 9**

Interpreting graphs
• Analyse and interpret global graphs of problem situations, with a special focus on the following trends and features:
  o linear or non-linear
  o constant, increasing or decreasing
	Interpreting graphs
	• Revise the following done in Grade 7:
	• Analyse and interpret global graphs of problem situations, with a special focus on the following trends and features:
	  o linear or non-linear
	  o constant, increasing or decreasing
	• Extend the focus on features of graphs to include:
	  o maximum or minimum
	  o discrete or continuous
		Interpreting graphs
		• Revise the following done in Grade 8:
		• Analyse and interpret global graphs of problem situations, with a special focus on the following trends and features:
		  o linear or non-linear
		  o constant, increasing or decreasing
		  o maximum or minimum
		  o discrete or continuous
		• Extend the focus on features of linear graphs:
		  o *x*-intercept and *y*-intercept
		  o gradient

Drawing graphs
• Draw global graphs from given descriptions of a problem situation, identifying features listed above
	Drawing graphs
	• Draw global graphs from given descriptions of a problem situation, identifying features listed above
	• Use tables or ordered pairs to plot points and draw graphs on the Cartesian plane
		Drawing graphs
		• Revise the following done in Grade 8:
		• Draw global graphs from given descriptions of a problem situation, identifying features listed above
		• Use tables or ordered pairs to plot points and draw graphs on the Cartesian plane
		• Extend the above with special focus on:
		  o drawing linear graphs from given equations
		  o determining equations from given linear graphs

This section has three activities:

Activity 1: Matching descriptions to graphs

Activity 2: Interpreting graphs

Activity 3: Showing increase and decrease on graphs

The activities in this section were all adapted from the Grade 8 and Grade 9 Mathematics books of the Department of Basic Education (DBE) and the Sasol Inzalo Foundation.

1.1 ACTIVITY 1: MATCHING DESCRIPTIONS TO GRAPHS: TEACHERS' NOTES

Purpose

The first activity gives learners an opportunity to work in groups to solve the problem of matching graphs to their descriptions. The main purpose of the activity is to assist learners to develop an awareness of the rate of change (gradient); and to recognise the rate of change that is visible in the graph. Try to keep the groups sizes small; have no more than four learners in a group.

Preparation

You will need to photocopy the page of graphs and descriptions on the next page and cut them up so that each group has a complete set.

The instructions to learners are:

- You are given descriptions of the temperature changes on five different days.
- You are also given five different graphs showing the temperature changes from morning to evening.
- As a title for each graph, write down which of the above days is possibly represented by the graph.

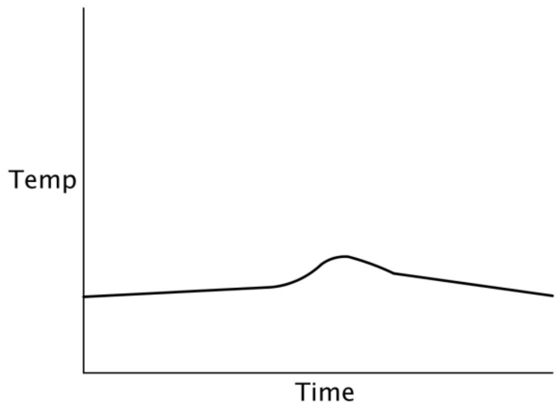
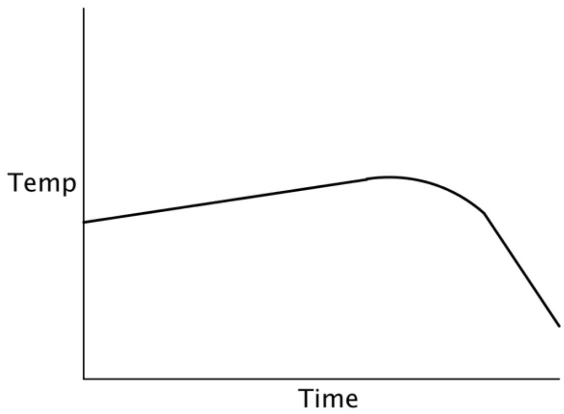
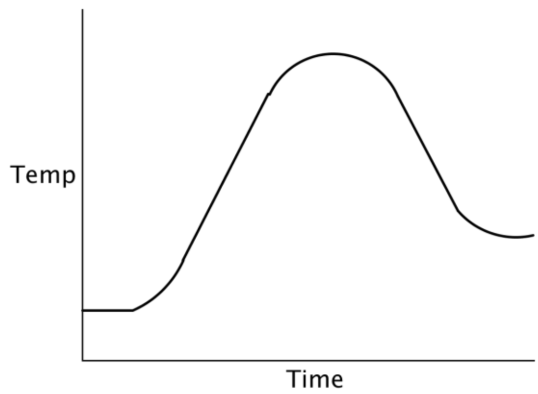
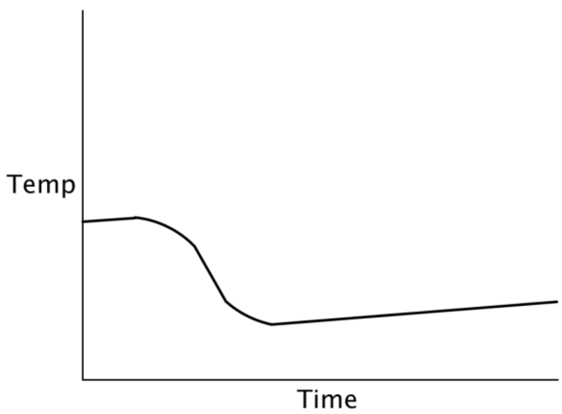
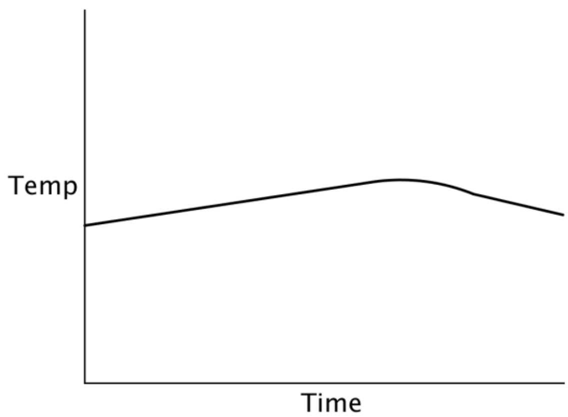
Points for discussion:

- How did they work out which description matched which graph? What were the 'clues' in the descriptions that helped them to do so?
- The axes of the graphs were labelled, but there was no scale given. What would they suggest as a scale for the axes?

The answers are:

A – 2. B – 3. C – 5. D – 1. E – 4.

ACTIVITY 1: MATCHING DESCRIPTIONS TO GRAPHS

Day A: It is already warm early in the morning. The temperature does not change much during the day, but late in the afternoon, a breeze causes the temperature to drop quite sharply.	**Day B**: It is very cold early in the morning, but it gets quite hot soon after the sun gets up. By midday, a cold wind comes up and the temperature drops until late in the afternoon. The wind then stops and it gets warmer again into the evening.
Day C: It is warm in the early morning and the temperature remains about the same until midday, then the temperature drops slowly during the afternoon.	**Day D**: It is cold in the early morning and it remains cold for the whole day, except for a short time after lunch when the sun comes out for a while.
Day E: It is warm early in the morning, but the temperature drops sharply soon after sunrise and remains low until mid-afternoon, when it slowly warms up a little.	 1.
 2.	 3.
 4.	 5.

1.2 ACTIVITY 2: INTERPRETING GRAPHS: TEACHERS' NOTES

Background information

Every year, as the seasons change, the number of hours of daylight changes too. In the summer, our days are long. In the winter, our days are shorter. The amount of daylight is different from place to place, depending on how far the place is from the equator. At the equator, the days and nights are almost exactly 12 hours each all year round. It may be useful to have a globe of the Earth to show learners why the amount of sunshine changes at different latitudes.

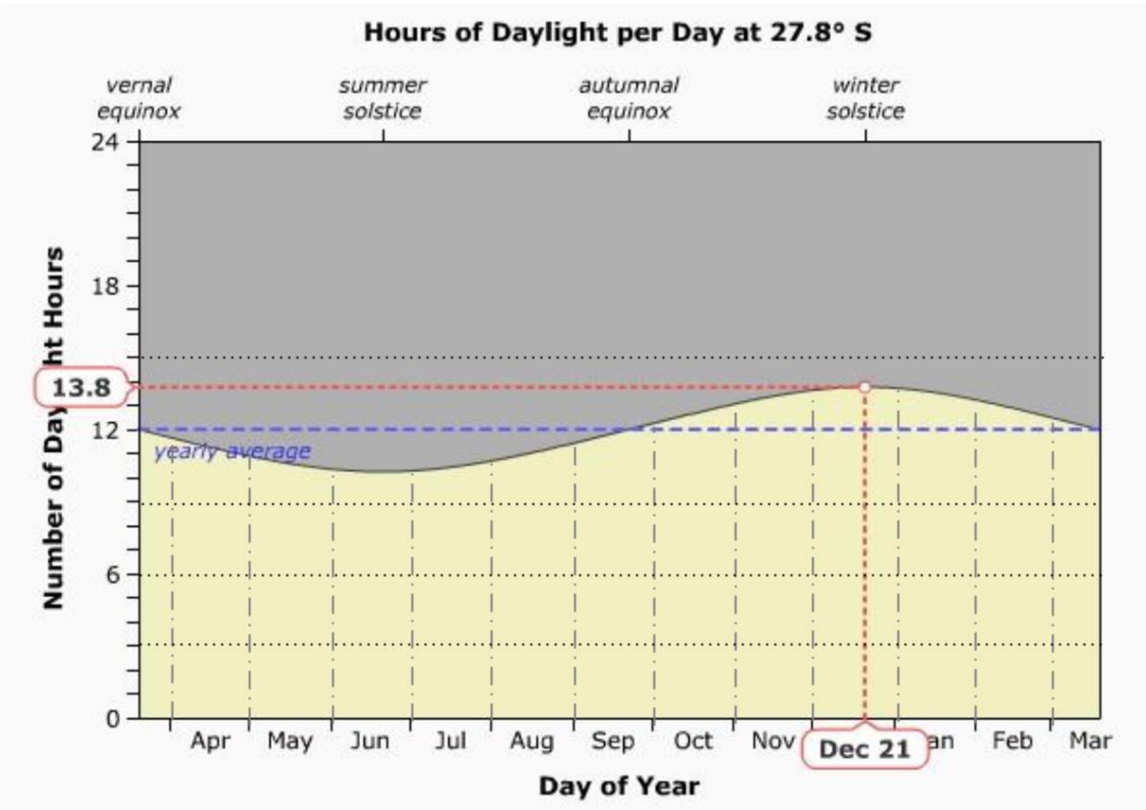
Graph from website:

http://astro.unl.edu/classaction/animations/coordsmotion/daylighthoursexplorer.html

For the second question, show learners where the two places mentioned are on a world map or globe.

ACTIVITY 2: INTERPRETING GRAPHS

1. The graph below shows the number of hours of daylight per day in Sishen throughout the year. Sishen is 27,8° south of the equator.



(a) The number of daylight hours reaches a maximum on 21 December of 13,8 hours. This is shown by the white dot where the red lines meet. Estimate the number of daylight hours when the graph is at its minimum.

………………………………………………………………………………………………

(b) The average number of daylight hours over the year is 12 hours, shown by the blue line. Which months have a higher number of daylight hours than the average?

…………………………………………………………………………………………………

(c) From 21 December, the number of daylight hours decreases into January and February. Is the number of daylight hours increasing or decreasing during the month of April?

…………………………………………………………………………………………………

(d) During which months do the number of daylight hours increase?

…………………………………………………………………………………………………

(e) How does the amount of daylight in a day change from winter to summer?

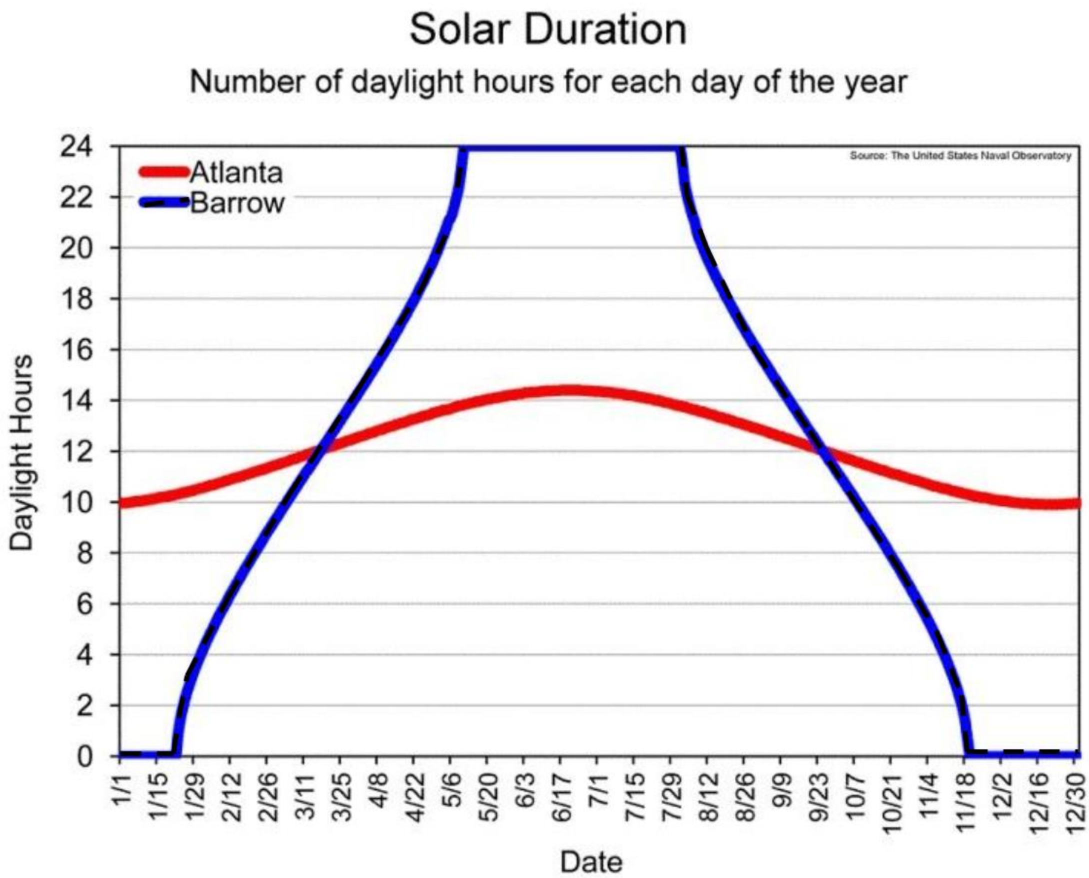
…………………………………………………………………………………………………

(f) Describe the shape of the graph, using the words increasing, decreasing, maximum and minimum.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

2. The graph below shows the number of daylight hours for two different places. Find the places on a map to see where they are. Answer the questions below:



(a) Atlanta shows a greater number of daylight hours in July. Is Atlanta in the Northern or Southern Hemisphere?

…………………………………………………………………………………………………

(b) Between which dates does Barrow have constant amounts of daylight hours?

……………………………………………………………………………………………

……………………………………………………………………………………….…

(c) How does the amount of daylight in a day change from winter to summer for Barrow?

…………………………………………………………………………………………….

(d) Is the number of daylight hours for Barrow increasing or decreasing during the month of March?

……………………………………………………………………………………………

(e) During which months do the number of daylight hours increase for Atlanta?

……………………………………………………………………………………………

(f) Describe the shape of each of the graphs, using the words increasing, decreasing, maximum and minimum.

……………………………………………………………………………………………

…………………………………………………………………………..…………….

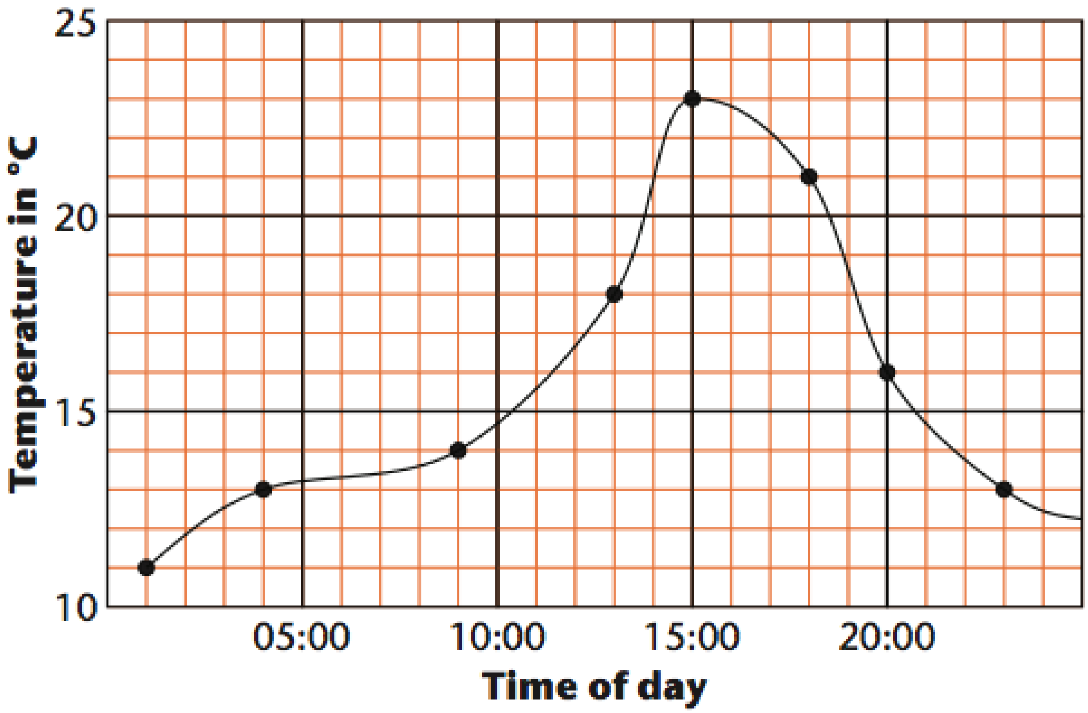
1.3 ACTIVITY 3: SHOWING INCREASE AND DECREASE ON GRAPHS: TEACHERS' NOTES

Work on vocabulary is very important for this section.

ACTIVITY 3: SHOWING INCREASE AND DECREASE ON GRAPHS

1. The graph below shows the temperature over a 24-hour period in a town in the Free State.

   The graph was drawn by connecting the points that show actual temperature readings.



(a) Do you think the above temperatures were recorded on a summer day or a winter day?

……………………………………………………………………………………

(b) At what time of the day was the highest temperature recorded, and what was this temperature?

……………………………………………………………………………………

(c) During what part of the day did the temperature rise, and during what part did the temperature drop?

……………………………………………………………………………………

……………………………………………………………………………………

(d) During what part of the period when the temperature was rising did it rise most rapidly?

……………………………………………………………………………………

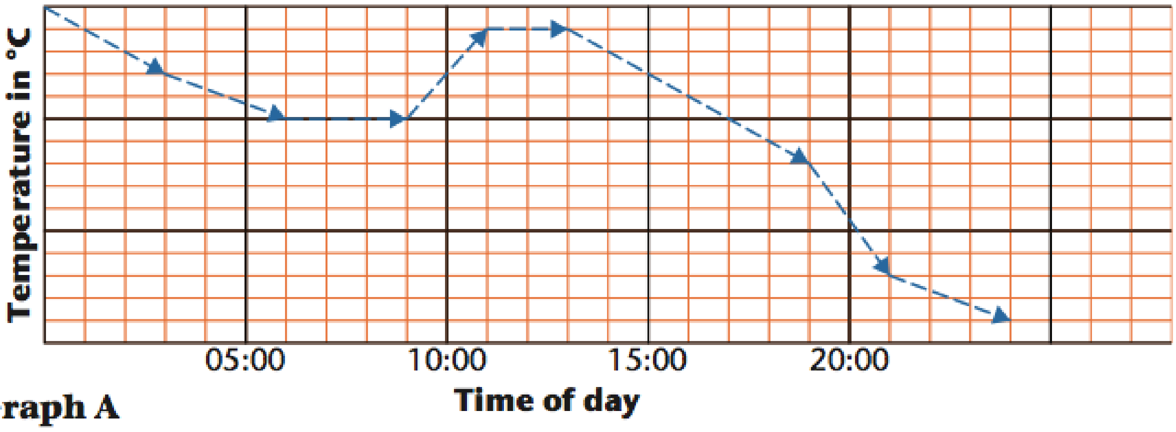
(e) During what part of the day did the temperature drop most rapidly?

……………………………………………………………………………………

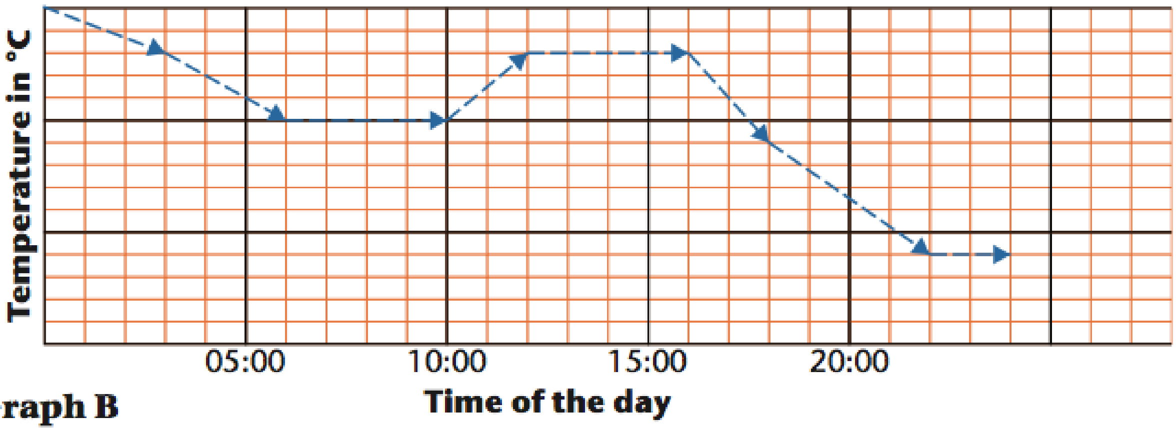
2. During a certain day, these changes occur in the temperature at a certain place.

- Between 00:00 and 03:00, the temperature drops by 2 °C.
- Between 03:00 and 06:00, the temperature drops by 3 °C.
- Between 06:00 and 10:00, the temperature remains constant.
- Between 10:00 and 12:00, the temperature rises by 3 °C.
- Between 12:00 and 16:00, the temperature remains constant.
- Between 16:00 and 18:00, the temperature drops by 4 °C.
- Between 18:00 and 22:00, the temperature drops by 5 °C.
- Between 22:00 and 24:00, the temperature remains constant.

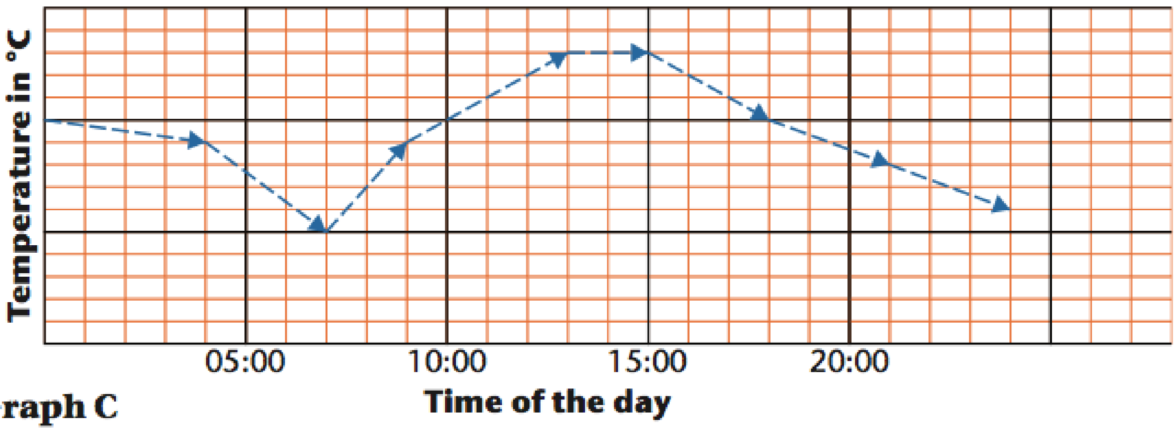
Which of the graphs below show the above temperature changes?



Graph A



Graph B



Graph C

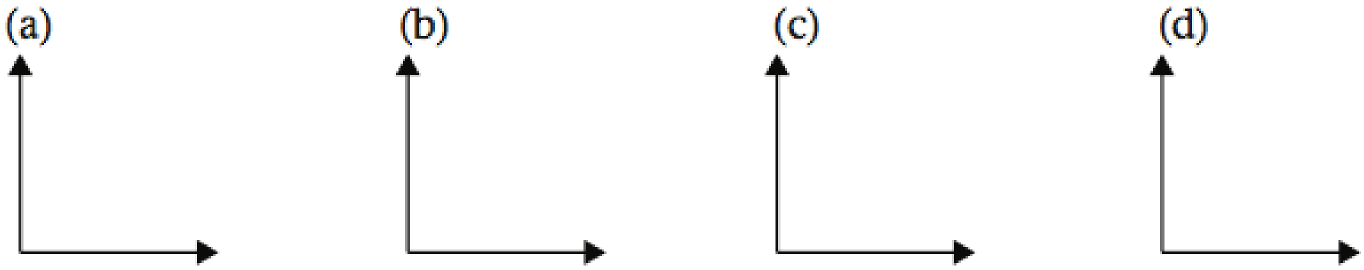
3. Draw a graph to match each of the following descriptions.

(a) The quantity increases, and increases more rapidly as time progresses.

(b) The quantity first increases slowly at a constant rate, and then increases at a faster constant rate.

(c) The quantity decreases faster and faster.

(d) The quantity increases, and the rate of increase gradually diminishes.



4. Statements and graphs about patterns of change in amount of sunlight over a 4-hour period are given below. Match each story with the appropriate graph given below. Time is represented on the horizontal axis in all these graphs, and sunlight on the vertical axis.

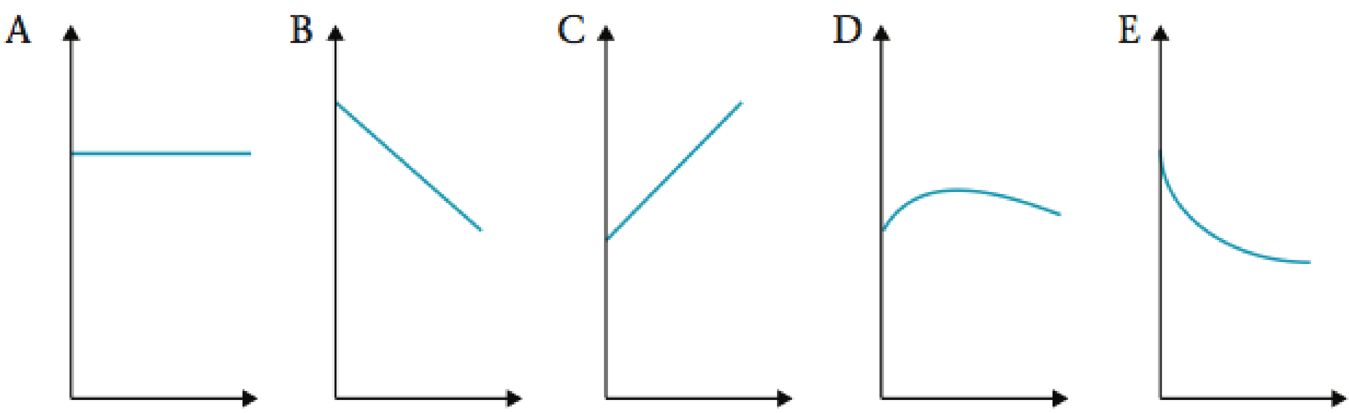
(a) There were no clouds and the amount of sunlight did not change.

(b) The amount of sunlight rose at a constant rate.

(c) The amount of sunlight decreased at a constant rate.

(d) The amount of sunlight dropped very fast at first as it became cloudy and then at a slower rate as the clouds started to clear.

(e) The amount of sunlight rose at a decreasing rate up to a point and then started to drop at an increasing rate as it became more and more cloudy.



2. Renewable energy-related mathematics projects

Projects in the Senior Phase Mathematics CAPS
The minimum requirements for formal assessment of Senior Phase Mathematics include a project in Term 3 of each year.

"Projects are used to assess a range of skills and competencies. Through projects, learners are able to demonstrate their understanding of different mathematics concepts and apply them in real-life situations. Caution should, however, be exercised not to give projects that are above learners' cognitive levels. The assessment criteria should be clearly indicated on the project specification and should focus on the Mathematics involved and not on duplicated pictures and facts copied from reference material. Good projects contain the collection and display of real data, followed by deductions that can be substantiated." (SP Mathematics CAPS, p 155).

Progression of the Data Handling topic in CAPS
"Progression in Data Handling is achieved primarily by:

- increasing complexity of data sets and contexts;
- reading, interpreting and drawing new types of data graphs;
- becoming more efficient at organising and summarising data; and
- becoming more critical and aware of bias and manipulation in representing, analysing and reporting data.

Learners should work through at least 1 data cycle for the year. This involves collecting and organising, representing, analysing, summarising, interpreting and reporting data. The data cycle provides the opportunity for doing projects.

Data handling contexts should be selected to build awareness of social, economic and environmental issues." (SP Mathematics CAPS, p 33)

Projects

This section covers two projects:

Project 1: Energy use in your home
This project was adapted from the *Smart Living Handbook*, City of Cape Town, 2007, p 45.

Project 2: Build a pizza box oven
This project was adapted from the US Department of Energy National Renewable Energy Laboratory booklet titled *Renewable Energy and Energy Efficiency Science Projects*, p 19.

Both projects give learners the opportunity to work with data, taking them though the data handling cycle.

2.1 PROJECT 1: ENERGY USE IN YOUR HOME: TEACHERS' NOTES

This activity can be used as a project for Grade 9 Term 3. The activity takes learners through the steps of conducting an audit of their energy usage. The activity is based on "Find out where you can save energy and money on your home" from the *Smart Living Handbook*, p 45-49, City of Cape Town, 2007.

The activity links with the CAPS Natural Science Term 3 topic: Cost of electrical power – The cost of power consumption. The Mathematics skills developed in this activity are:

- Calculating electricity consumption via an audit
- Collecting and processing data
- Calculating carbon emissions

These skills relate directly to the general aims and skills of the CAPS Senior Phase Mathematics. A core concept is that the quantity of electrical power used is measured in kilowatt-hour (kWh).

You will need to supply learners with the information sheet titled "Typical Home Appliance Electricity Consumption" from the City of Cape Town's *Smart Living Handbook* shown below.

The costs of the different forms of energy such as paraffin, gas, batteries and wood will need to be updated.

Rubric for assessment of the report in Step 4:

Criteria	1	2	3	4
Calculates energy use	No calculations	Incomplete or incorrect calculations	Correctly calculates energy use	Correctly calculates energy use
Identifies where energy saving could be made and suggests actions	Does not comment on energy saving or suggest any actions	Identifies some areas where energy saving could be made and makes some suggestions	Adequately identifies where energy saving could be made and suggests relevant actions	Makes a detailed analysis of where energy saving could be made and suggests comprehensive and appropriate actions
Comments on carbon emissions	Makes no comment on carbon emissions	Incorrectly attempts to work out carbon emissions reduction	Correctly calculates carbon emissions reduction	Correctly calculates carbon emissions reductions for various proposed energy-reducing actions

PROJECT 1: ENERGY USE IN YOUR HOME

Energy can be a big cost. It is important to know how you are using energy, as only then can you start to try to cut down on your energy use.

Step 1: Copy the format of the table below and complete your table below to audit your electricity use. Your teacher will give you a table showing "Typical Home Appliance Electricity Consumption" to help you calculate your electricity use.

Household Electric Appliance Audit Sheet					
	Daily use				**Monthly total**
Appliance	**Power use (watt)**	**Hours per day in use**	**Number of appliances**	**Average kWh per day (watt × hrs / 1000)**	**Average kWh per month**
E.g. light bulb	60 W	4 h	7	60 × 4 × 7 = 1680 $\frac{1680}{1000}$ = 1,68	1,68 × 30 = 5,04
				Monthly electricity consumption total:	

Step 2: Copy and complete the table below to audit all your energy sources such as paraffin, gas, batteries, electricity and wood. Use the second column to record the particular activity for which you require the energy, e.g. cooking, lighting, heating, music, fridge and iron. Refer to your electricity bill to estimate your electricity consumption.

Fuel type	**Activity**	**Amount per month (litre, kg, number)**	**Cost per unit (rand per litre, kg, number)**	**Fuel cost per month**
E.g. paraffin	Cooking	3 litres	R9,30 per litre	R27,90
			Total cost:	

Step 3: Identify your carbon emissions. Copy and complete the table below to calculate your household's **annual** carbon emissions.

Total monthly electricity use: …………... kWh	× 1,08 kg of CO_2 per kWh	= ………..kg of CO_2 / month	× **12**	……………. kg of CO_2 / yr
Total monthly LP gas use: ………… kg	× 3,09 kg of CO_2 per kg	= ………..kg of CO_2 / month	× **12**	……………. kg of CO_2 / yr
Total monthly paraffin use: …………… litre	× 2,58 kg of CO_2 per litre	= ………..kg of CO_2 / month	× **12**	……………. kg of CO_2 / yr
			× **12**	
Total energy-related household emissions from your home per year		= ………..kg of CO_2 / month	× **12**	……………. kg of CO_2 / yr

(Adapted from p 45, *Smart Living Handbook*, City of Cape Town, 2007)

Step 4: Present your findings in the form of a report. Answer the following questions:

a) Identify where you could be saving energy.
b) What actions could you take to reduce your energy consumption?
c) By how much could you reduce your carbon emissions?

Typical Home Appliance Electricity Consumption

Appliance	Power use (watts)	Ave hrs/ day in use	Appliance	Power use (watts)	Ave hrs/day in use
Lighting			**Refrigeration**		
Incandescent bulb (40 W)	40	5	Freezer (chest)	105	4
Incandescent bulb (60 W)	60	5	Fridge with freezer	158	5
Incandescent bulb (100 W)	100	5	Fridge – no freezer	250	5
CFL (12 W)	12	5	**Home maintenance**		
CFL (18 W)	18	5	Dishwasher	2 500	0,9
CFL (20 W)	20	5	Vacuum cleaner	1 000	0,5
Security (120 W)	120	0,3	**Laundry**		
Cooking			Iron	980	0,4
Coffee machine	670	0,5	Iron (steam)	1 235	0,8
Electric stove	3 000	2	Washing machine	3 000	0,75/load
Frying pan	1 250	0,4	Tumble dryer	3 300	0,5/load
Hotplate – large	2 400	0,3	**Music, entertainment, home office equipment and other**		
Hotplate – small	1 275	0,2	**Burglar alarm**	10	24
Kettle	1 900	0,3	Cell phone charger	9	2
Microwave oven	1 230	0,8	Compact disc player	9	0,4
Toaster	1 010	0,3	Computer	134	1,5
Snackwich	1 200	0,3	**Cordless phone**	2	15
Food processor	166	0,2	Fax machine	45	13,6
Geyser			Hair drier	647	0,1
Geyser (electric)	2600	4,4	**Radio**	12	3
Geyser (solar with electric backup)	2600	1,7	M-Net decoder	28	12,1

(Source: *Smart Living Handbook*, City of Cape Town, 2009, p 47)

2.2 PROJECT 2: BUILD A PIZZA BOX OVEN: TEACHERS' NOTES

Learning objective:
To design an effective pizza box solar oven

Time:
2 ½ hours or 5 periods

Questions to start the lesson:
How can you trap the energy from the sun and turn it into something useful, like heat? What factors will affect how high the temperature will go? Why does it get hot in a car? What are the purposes of the features of a real oven?

Control and variables:
The day of the year (the season and Earth's tilt) will determine how direct the sun's rays strike the Earth; sky conditions (pollution, clouds); temperature of the air; design; and the dimensions of the oven

Materials and equipment:

pizza box	black construction paper	aluminium foil
clear plastic	scissors	stick to hold box open
clear tape	glue	oven thermometer

Safety and environmental requirements:
Never look directly at the sun. If the temperature in your oven gets too warm, you may need oven gloves. Otherwise, open the box and wait until the box cools down before you touch anything inside the box.

Instructions:

Lesson 1

1. Give each group of learners a pizza box.
2. Have available for all learners various materials such as glue, scissors, clear packing tape, new overhead transparencies, wax paper, aluminium foil, white, black, and other colours of paper/cardboard.
3. Tell the learners that their objective is to make the hottest "oven" possible using the sun.
4. In the first period, have the learners design their oven in a notebook.
5. During this lesson, work with the class to design a rubric on what is meant by the "best" oven. Options could include: hottest oven; quickest to heat; easiest design; and instructions to read.

Lesson 2

6. Learners construct their pizza box oven.

Lesson 3

7. Ask the learners what factors might affect the temperature in their oven (outside air temperature, wind, clouds). Ask them to measure these factors and the oven temperature over time. Make sure you have thermometers that can register up to 150 °C. Temperature will need to be measured every 5 minutes over a 30-minute period.

Lesson 4

8. Learners graph the temperature over time using a broken-line graph.

Lesson 5

9. Learners write a report or give a report back about their oven in which they explain why they think the best ovens worked the way they did.
10. Have learners mark their ovens based on the rubric the class created in lesson 1.

Connections to other subjects:

When learners start talking about the sun's angles, colours of the paper, ability of the sunlight to bounce, as well as the stick in the box, you can introduce the following Natural Science concepts: light, heat, and energy definitions, including reflection, absorption and motions of molecules. The discussion could also lead to topics such as energy produced by the sun and the tilt of the Earth that gives rise to different seasons.

Suggestions if learners are stuck:
1.) Cover the bottom of the box with aluminium foil and then a layer of black paper. 2.) Cut a hole in the top of the box, 2,5 cm from the edge of the box, leaving one edge on the same side as the hinge of the box. 3.) Glue aluminium foil on the inside part of the box lid. 4.) Tape clear plastic over this hole. When you glue the clear plastic to the pizza box, make sure you have a tight seal. 5.) Point the opening of the box directly at the sun and prop the lid open. 6.) Record the temperature inside the box. 7.) In addition, record any data you think might affect the temperature in the box (cloud cover, date and time, and temperature outside the box).