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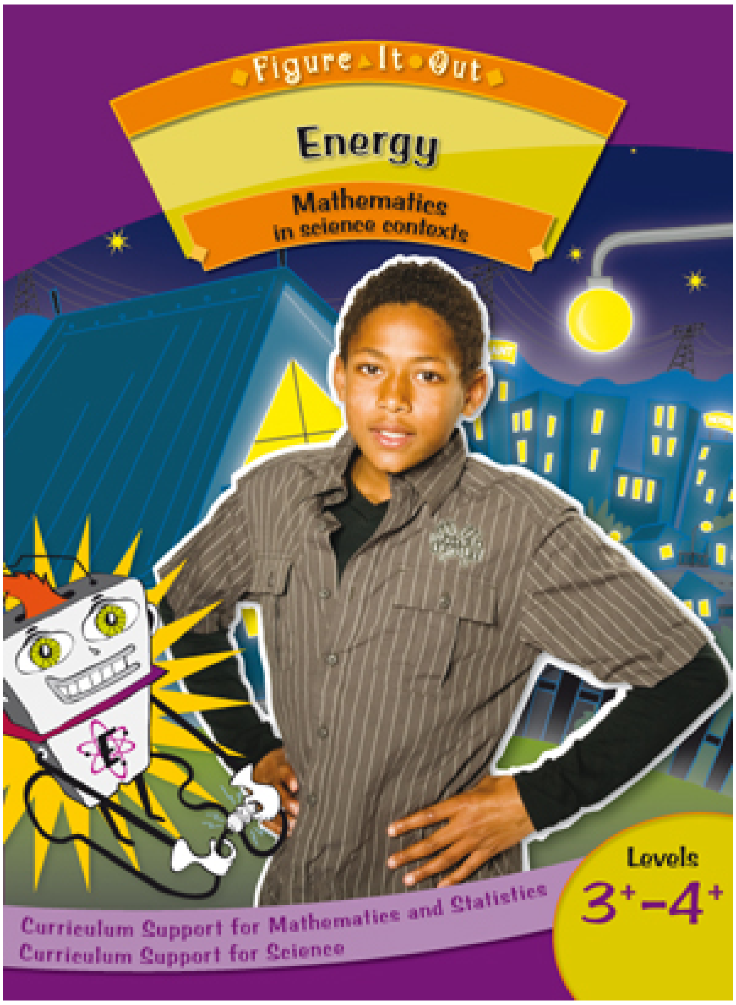
Teacher Support Material
(including Answers)



MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga

Contents

Introduction

The books in the Figure It Out series are issued by the Ministry of Education to provide support material for use in New Zealand classrooms. The achievement objectives for mathematics and statistics and for science and the key competencies referred to in this *Teacher Support Material (including Answers)* are from *The New Zealand Curriculum*.

Student books

The activities in the Figure It Out student books are written for New Zealand students and are set in meaningful contexts, including real-life and imaginary scenarios. The contexts in the level 3+–4+ *Energy* book reflect the ethnic and cultural diversity and the life experiences that are meaningful to students in years 5–8. However, you should use your judgment as to whether to use the students' book with older or younger students who are also working at these levels. Figure It Out activities can be used as the focus for teacher-led lessons, for students working in groups, or for independent activities. You can also use the activities to fill knowledge gaps (hot spots), to reinforce knowledge that has just been taught, to help students develop mental strategies, or to provide further opportunities for students moving between strategy stages of the Number Framework.

Teacher Support Material (including Answers)

In this new format, the answers are placed with the support material that they relate to. The answers are directed to the students and include full solutions and explanatory notes. Students can use these for self-marking, or you can use them for teacher-directed marking. The teacher support material for each activity, game, or investigation includes comments on mathematics and science ideas, processes, and principles, as well as suggestions on teaching approaches. The *Teacher Support Material (including Answers)* for *Energy* can also be downloaded from the nzmaths website at www.nzmaths.co.nz/node/1995

Using Figure It Out in the classroom

Where applicable, each page of the students' book starts with a list of equipment that the students will need in order to do the activities. Encourage the students to be responsible for collecting the equipment they need and returning it at the end of the session.

Many of the activities suggest different ways of recording the solution to the problem. Encourage your students to write down as much as they can about how they did investigations or found solutions, including drawing diagrams. Discussion and oral presentation of answers is encouraged in many activities, and you may wish to ask the students to do this even where the suggested instruction is to write down the answer.

Students will have various ways of solving problems or presenting the process they have used and the solution. You should acknowledge successful ways of solving questions or problems, and where more effective or efficient processes can be used, encourage the students to consider other ways of solving a particular problem.

Figure It Out

Energy

Mathematics in science contexts

Teacher Support Material (including Answers)

Overview of Energy, Levels 3^+–4^+

Title	Focus	Page in students' book	Page in support material
Energy Stations	Investigating energy	1	8
Playing with Energy	Categorising forms of energy	2–3	13
Measuring Potential	Measuring potential energy	4–5	19
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Using Electricity	Calculating with rates	22–24	51

Introduction to Science

> Science is a way of investigating, understanding, and explaining our natural, physical world and the wider universe.
>
> *The New Zealand Curriculum,* page 28

Inquiry in science is called investigating. Science investigations can take many forms, including classifying and identifying, pattern seeking, exploring, investigating models, fair testing, making things, and developing systems. Investigating in science may involve more than one type of investigation; each investigation can share elements with other investigations. Scientists choose the appropriate type of investigation to answer their question(s). Science investigations also provide students with rich contexts for mathematical opportunities as they decide what and how to measure, what units to use, and how to record findings as they identify trends and patterns and describe relationships. See www.tki.org.nz/r/science/science_is/dssa/focus_07_approach_e.php for examples of different types of science investigations and activities that illustrate them.

This Figure It Out students' book reinforces concepts in physics and chemistry, especially motion, heat transfer, and electricity. Energy is abstract – students can't see the difference between 5 and 10 joules as they can between 5 and 10 centimetres. The investigations in this book are designed to make energy concrete. Students make meaningful comparisons between different quantities of energy through indirect measurement, graphical data representations, energy unit conversions, and relative rates. This book strongly supports the following areas of emphasis in the mathematics and statistics learning area of *The New Zealand Curriculum*: gathering and interpreting data, identifying relationships, using and converting between appropriate metric units, and applying linear proportions or rates of change. For example, students compare the amount of chemical energy in different foods by interpreting a table of joule values and also by measuring energy released during combustion.

Several of the investigations in this book introduce concepts that will be explored in levels 5–6 and beyond in the science learning area, for example, the relationship between force and energy.

The teacher support material for the students' book includes conceptual background material and suggestions for wider and deeper exploration. However, you are the best judge of how far to take a particular idea with your students. For example, while the potential energy investigation on pages **6–7** of the students' book is suitable for students working at level 3, it could also be extended to higher levels through a discussion of Hooke's law and plastic deformation (once stretched beyond a certain limit, objects don't return to their original length). Similarly, the game on page **2** introduces students to potential and kinetic energy; this can be concluded in a single class or used as the starting point for an investigation into more complex ideas, such as why thermal energy is a measure of the kinetic energy of atomic particles.

Notes:

- Terms in the glossary are bolded the first time that they appear in the notes for each activity title.
- Internet links: on the downloadable version of this support material (www.nzmaths.co.nz/node/1995), all the Internet links can be activated by clicking on a hyperlink.

Investigating in Science

EXPLORING A SITUATION

A problem, question, situation, phenomenon, artefact, model, event, story

I wonder why ...?

I wonder how ...?

OBSERVE

What is happening?

What changes happen?

What materials are involved?

What are the main parts?

What are the key aspects?

What do these parts do?

ASKING QUESTIONS

Why? How? What? When? Where?

PLANNING AN INVESTIGATION

What will we observe/measure? What do we want to find out? How can we find out? What can we do to find out? Are there things we need to change or keep the same?

MAKING PREDICTIONS

What do we think will happen and why?

GATHERING DATA

Find out, measure, compare, verify, test, clarify, identify

PROCESSING AND INTERPRETING

Creating personal explanations supported by evidence

What is the cause and effect of change?

What patterns keep occurring?

What parts are interacting with other parts?

What are the outcomes of these interactions?

EVALUATION

What do the results mean?

Does our investigation answer our question?

Do our results support or challenge our predictions?

Is there another explanation for what we found out?

What do other people think about our investigation?

What have other people found?

APPLICATION AND SHARING OF NEW THINKING

How could we use our idea or explanation?

Does it explain other things?

What next? Where to now?

FURTHER INVESTIGATION

Do we have another question to investigate?

Is there another idea or explanation that needs testing?

Glossary of related terms

Arc: a portion of the circumference of a circle

Energy: the capacity of matter to do work. Energy can be kinetic or potential (see below). If an engine lifts 1 kg by 1 m against gravity, it does 10 joules (J) of work because the potential energy of the kilogram has been increased by 10 J.

Kinetic energy: energy of motion. The kinetic energy of a moving object is equal to $\frac{mv^2}{2}$, where m is mass and v is velocity (how fast it is moving). In other words, this is the amount of work or additional energy needed to change an object's speed from zero (stopped) to its current velocity.

Potential energy: stored energy, or the amount of work you could do if you tap into the energy contained in that object. For example, you could tap stored energy by dropping an object from a height onto one side of a see-saw – the stored potential energy due to the height and mass of the object will be converted into motion, which will transfer a force to the see-saw and move the other side of the see-saw up. As another example, you could do work by connecting a battery to a circuit, which would allow the electrons stored as potential energy in the battery to move through the wire and light up a light bulb.

- **Chemical energy**: the potential energy stored in the molecules of an organic substance, for example, food, which can be released by burning or by digestion. For example, the carbohydrates in an apple contain energy that your body uses to fuel the motion of your cells.
- **Elastic potential energy**: the energy stored inside a stretched or compressed spring. For example, if you stretch a rubber band, the work you do on the rubber band is stored in the band as elastic potential energy. This stored energy will be converted into motion if you let go.
- **Gravitational potential energy**: the energy stored in an object because of its relative height and gravity, or the amount of work performed against the force of gravity to lift an object to its current height. Gravitational potential energy can be thought of as the height of an object times the force of gravity acting on it (height x force). This energy is converted to kinetic energy if an object falls. For example, a 1 kg weight balanced on top of a 10 m high roof has more potential energy than that same weight balanced on top of your desk. If the weight fell off your desk onto your foot, it would hurt a little bit, but if that same weight fell on your foot from a distance of 10 m, it would probably break a bone!

Electrical energy: the energy of an electric charge, either kinetic (flowing current) or potential (a battery). Electrical energy is a measure of the flow of electrons, for example, from the mains outlet through a glowing light bulb, or from the anode to the cathode when you connect a battery into a circuit.

Mechanical energy: the sum of the potential and kinetic energy of a movable object. For example, a chair in a ski-lift will have mechanical energy equal to the gravitational potential energy of its height off the ground plus the kinetic energy of its motion through the air.

Conservation of energy: a natural law that states that energy can only be transferred from one object to another, not destroyed. For example, when the driver of a moving car applies the brakes, the energy of the car doesn't disappear – it is converted into heat by the friction of the brake pads.

Energy density: the amount of stored energy in a substance per unit volume. For example, petroleum has a much higher energy density than wood. Petroleum will release much more heat when burned than an equal volume of wood, which is why the petrol tanks of cars are small enough to fit inside the car, while steam trains powered by burning wood needed an entire carriage of fuel!

Gravity/force of gravity: the force caused by the attraction of mass. For example, the mass of the Sun pulls the mass of Earth into an orbit around it. All masses attract each other; bigger, closer masses attract more strongly. The pull of the mass of Earth on your mass is the force of gravity. (Your mass also pulls on the mass of Earth, but because your mass is very small compared with the mass of Earth, this force is negligible.)

Force: something that causes a change in the motion of an object (acceleration). For example, you exert a force on a ball when you kick it, and the speed and/or direction of the ball changes.

Friction: a force caused by the rubbing of two surfaces against each other. Friction resists (acts against the direction of) motion and is proportional to the force that presses the two surfaces together. For example, the more weight on top of a piece of paper, the harder it is to slide it along the top of a desk.

Joule (J): a measure of energy. One joule is the work required to lift 100 g about 1 m against the force of gravity.

Kilojoule (kJ): one thousand joules

Mass: a measure of how much matter is in an object

Newton: a measure of work (force x distance). In science, force (for example, weight) is measured in newtons, but in mathematics, weight is more commonly described in terms of kilograms.

Glossary of related terms

Pendulum: a weight hanging from a fixed point that swings freely back and forth due to gravity

Proportional: in a fixed ratio to something else. For example, the amount of money a person on wages gets paid is proportional to the number of hours they work, and how long it takes a person to walk 1 km is proportional to how fast they walk.

Variable: something that can change or be changed, for example, the temperature of a bowl of water or the height of a swinging pendulum

Controlled variable: a variable in an experiment that is kept the same in order to prevent it from affecting other variables of interest

Dependent variable: a variable in an experiment that changes because of a change made to an independent variable

Independent variable: a variable in an experiment that is changed in order to measure the effect on other variables

For example, in an experiment measuring how far a wooden block travels when struck by a pendulum, if you control the size of the block by always using the same one (the control variable), then the dependent variable is how far the block moved, and the independent variable is how high you lifted the pendulum on the release swing.

Watt (W): A measure of power, equal to 1 joule per second. Power is energy divided by time. For example, lifting 1 kg a vertical distance of 1 m requires 10 J of energy. If you lift that kilogram in 1 second, you have a power of 10 W. If you lift it in half a second, you have a power of 20 W (10 J ÷ 0.5 seconds = 20). A less powerful person might need 10 seconds to lift the weight that distance, so the power is 10 J ÷ 10 seconds = 1 W.

Kilowatt (kW): one thousand watts

Kilowatt-hour: the energy of 1 000 W of power used continuously for an hour (power x time)

Weight: the force of gravity acting on mass (in other words, a measure of how hard gravity is pulling on an object). This is measured in grams and/or kilograms.

Wind chill: an approximate measure of the cooling effect of the wind, or how cold you will feel if you are out in the wind at a given temperature

Work: a change in energy, measured as force x distance (see newton)

Teacher Support Material (including Answers)

Page 1: Energy Stations

Mathematics and Statistics Achievement Objectives

- Number strategies: Use a range of multiplicative strategies when operating on whole numbers (Number and Algebra, level 4)
- Measurement: Convert between metric units, using whole numbers and commonly used decimals (Geometry and Measurement, level 4)
- Statistical literacy: Evaluate statements made by others about the findings of statistical investigations … (Statistics, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Communicating in science: Begin to use a range of scientific symbols, conventions, and vocabulary (Nature of Science, levels 3–4)
- Investigating in science: Ask questions, find evidence, and explore simple models, and carry out appropriate investigations to develop simple explanations (Nature of Science, levels 3–4)
- Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as … heat (Physical World, levels 3–4)

Mathematics and statistics context

Students will:

- estimate the energy change of a system
- calculate the amount of energy converted by different activities
- use rates to determine inputs and/or outputs.

Students should discover that:

- energy transfer is proportional to work (the more force x distance, the more energy)
- different forms of energy are measured in different ways; we can use equivalent rates and units to convert from one form to another.

Science context

Students will:

- investigate the energy changes taking place at each station
- use the experiments to test whether energy is used up or conserved.

Students should discover that:

- energy is conserved, not used up
- energy changes take place all the time, in a variety of contexts
- whenever you do work (by exerting force), energy is changed from one form to another.

Answers

Activity

1. i.–ii. Answers for each station are listed below.

Station 1: Rubbing Hands

Experiment: When you rub your hands together vigorously, you should notice that your hands warm up. The more you rub, the warmer your hands get and the more tired you get! The motion of your muscles and the friction on your skin produces heat energy. In other words, you're converting your energy into heat. You eat food to get energy, so by rubbing your hands you're converting the energy of the food you have eaten into motion, and friction converts motion into heat energy.

Question: 1 250 rubs. 1 rub is 0.8 joules (J), so divide 1 000 by 0.8. Another way to think about it is that 1 rub = 0.8 J, 10 rubs = 8 J, 100 rubs = 80 J, and 1 000 rubs = 800 J, so 1 250 rubs = 1 000 J (the extra 200 J added to 800 J to make 1 000 J is $\frac{1}{4}$ [0.25] of 800; $\frac{1}{4}$ of 1 000 rubs is 250, so 1 250 rubs = 1 000 J).

Station 2: Beating Water

Experiment: Make sure that you leave the thermometer fully immersed in the water long enough to get an accurate reading. You should find that the water in the bowl becomes hotter as the egg beater moves, as long as the egg beater is moving fast enough for long enough. You will probably be unable to sustain the speed of the egg beater for an indefinite amount of time because your muscles will need time to recover; the heat in the water soon transfers to the outside air after the beating has stopped. Energy is required to move the egg beater, and this energy is converted into heat.

Question: About 25 000 turns. To find the answer, make a list of equivalent quantities (how much of one thing is equal to another). Heating 1 litre (L) of water by 1°C is equal to the work of 1 kg x 400 m. 5°C is therefore equal to lifting 1 kg x 2 000 m. 1 L of water weighs 1 kg, so you need to lift the water in the bowl about 2 000 m or 200 000 cm (1 m = 100 cm). The egg beater lifts water at a rate of 8 cm per turn.
200 000 ÷ 8 = 25 000 (so 25 000 turns x 8 cm per turn = 200 000 cm).

Station 3: Rolling a Can

Experiment: The weight causes the rubber band to twist as the can rolls forward. Friction and the resistance of the rubber band eventually cause the can to stop rolling, at which point the rubber band starts to unwind. The stored energy in the rubber band is transferred back into the can, which rolls back towards you.

Question: About 90 cm. $\frac{2}{3}$ of a full turn makes the can roll 10 cm, so $\frac{1}{3}$ of a turn will roll it 5 cm and 1 full turn ($\frac{3}{3}$) will roll it 3 x 5 = 15 cm. This means 6 full turns will roll it 6 x 15 = 90 cm.

Station 4: Bending a Paper Clip

Experiment: Metal is a good conductor of heat, so it should feel cool to the touch when you first pick it up (try it against your cheek). (By contrast, wool is not a good conductor and usually feels warm when you put it on.) As you work it back and forth, you should find that the portion of the paper clip that you are bending gets warmer (if it doesn't, bend it quickly back and forth a bit more). Your muscles add energy into the paper clip. The paper clip releases this energy back into the atmosphere as heat.

Question: Answers will vary. The number of joules (J) should be equal to the number of times you bent the clip. If 1 bend requires you to lift 10 kg up 1 cm, you use 1 J every bend because 10 kg x 1 cm is the same as 1 kg x 10 cm.

Station 5: Lifting a Weight

Experiment: It might not seem that anything happens to the weight of the barbell when you lift it, but you're actually increasing the gravitational potential energy. When you increase the height of the energy, you work against gravity. Your work is stored in the weight as gravitational potential energy. You can tell this is true because the higher you lift it, the more energetically (harder) it will hit the ground when you drop it. Your arms tire when continually lifting and lowering the weight because it takes energy to move it. The energy stored in your body is converted into kinetic energy as you move your muscles, and this kinetic energy is converted into potential energy in the lifted weight.

Question: Answers will vary depending on the weight. For example, if you lift 10 kg by 100 cm, you do 100 J of work because you're lifting 10 x 1 kg a distance of 10 x 10 cm or 100 x 1 J.

Station 6: Playing a Guitar

Experiment: The harder you strum a guitar, the louder the sound it makes. The pitch and tune of the note shouldn't change, just the volume.

Question: The table has a linear pattern, going up by 0.4 J per setting. At the lowest setting, it probably uses 3.0 J.

Volume setting	Low	2	3	4	5	6	7	8	9	Max
Energy used per hour (J)	3.0	3.4	3.8	4.2	4.6	5.0	5.4	5.8	6.2	6.6

2. a. Discussion may vary. However, energy doesn't get "used" up; rather, it changes from one form to another.

   b. i. The law of conservation of energy states that energy is neither created nor destroyed, just transferred from one form to another.

   ii. Answers will vary. You may be surprised that energy is never destroyed because it seems as if energy gets used up in many situations. However, you can usually find out where the energy goes. For example, when you use the brakes on a bicycle, friction changes the energy of your motion into heat and the brake pads get warm.

Notes

Preparation and points to note

The materials you will need for each station are:

Station 1: none

Station 2: plastic bowl, water, egg beater, thermometer

Station 3: round tin or can with lid, rubber band, toothpicks, tape, washers or lead sinker, instructions (see websites below)

Station 4: metal paper clips

Station 5: a weight or barbell

Station 6: a guitar or other simple stringed instrument, for example, a rubber band stretched around an open cardboard box.

Each station has an experiment and a related mathematics problem (provided on the copymasters). Think about how to set up the stations: for example, the paper clips need to be metal and you may need quite a few of them because some of them will break. Be specific about how you wish the students to record their observations and calculations and how they should present their answers. Decide whether you want more than one of each station and how you will signal the move from one station to the next.

Assemble the roll-back can ahead of time or ask some students to build it. Instructions can be found at the following sites:

www.acgilbert.org/Toys/media/Day08.pdf
www.raft.net/ideas/Rollback%20Can.pdf
www.youtube.com/watch?v=3BfQ-etVywU

Avoid over-explaining the activities – leave the students something to discover. Keep the big question to the fore: "Does **energy*** get used up, or does it just go somewhere else?"

Be clear about how the students should record their observations. It may be best to have them do the calculations when they have completed the entire series of experiments.

Leave time for a closing session. After the students have completed the activities and calculations, they are asked to discuss competing statements about energy and to find out what "**conservation of energy**" means. At the outset, it is likely that some will have the view that energy can be "used up". By the end, all should be clear that energy cannot be created or destroyed, just changed from one form to another.

These activities require students to interact, share ideas, and work effectively with others, so the key competency *relating to others* is a suitable focus.

Points of entry: Mathematics

See the answers section for comments on the mathematics for each station.

Most of the experiments are *qualitative*. In other words, they don't lead to numerical data. Encourage the students to think about trends, relationships, and limits. For example, ask *What would happen to the water if you continued to turn the egg beater (at the same speed) for 5 minutes?* (The water would continue to warm up until the heat being added equalled the amount being lost to the environment.) Similarly, *Is there a limit to how far the roll-back can can go and still roll back?* (At some point, the rubber band will snap or the weight will wrap around the band.)

With any activity involving estimation, encourage the students to discuss the difference between guesswork and estimation. Challenge them to think about how they could gather data to answer the experimental questions quantitatively (with numbers).

Unlike the experiments, the mathematics questions associated with the various energy stations are *quantitative* and require numerical answers. The students have to convert from one unit to another (much like energy is converted from one form to another). They also need to apply rates in simple ways. A rate is a specified quantity of one **variable** for every unit of another (for example, $120 dollars per day, 11.3 kilometres per hour, or 33 **joules** per second).

[***Note for teachers***: For the rubbing hands experiment, skin has a coefficient of **friction** of about 0.8. As a rough guide, the distance that fingers move per rub is about 10 cm. You need to press your hands together with a force of 10 **newtons** and rub them about 10 cm (0.1 m) to perform 0.8 J of **work**.]

The problems use very approximate numbers ("1 J is about 1 kg x 10 cm") and require assumptions to be made ("if the egg beater lifts the water about 8 cm each turn …"). This means that the students' answers are in fact only estimates of the energy transfer involved. The students need to understand that estimating is a very important mathematical process and that there is a world of difference between estimation and guesswork. A guess can be entirely random, but an estimate is always arrived at via some kind of calculation and always based on some information or data.

At this level, avoid expressing rate problems as strings of fractions and operators. These will only confuse. All rates can be modelled using double number lines (see NDP *Book 7: Using Fractions, Decimals, and Percentages*).

Points of entry: Science

The aim of this activity is that students will discover or begin to understand the law of conservation of energy. Give them as few directions as possible, but try to ensure that they focus on the energy changes that are going on at each station.

Each activity and mathematics question involves a different set of energy changes:

- The roll-back can activity illustrates that the **kinetic energy** of motion can be stored in a spring (the rubber band) and then converted (by the unwinding of the rubber band) back into motion.

** For bolded terms, see glossary, pages 6–7.*

- The egg beater illustrates how kinetic energy (**mechanical energy**) can be converted into heat.
- The rubbing hands and paper clip activities show how mechanical energy can produce heat (through friction).
- The weightlifting is an example of how we can use the **chemical energy** of food to do work. It introduces students to the term "**gravitational potential energy**", which will be explored in more detail in the activities on pages **4–5** and **14–15**.
- As the guitar is strummed, the vibrating strings transfer the kinetic energy of the motion of your hand into sound waves that travel through the air.

Different groups will get quantitively different results for the experiments. This is inevitable, given the relatively uncontrolled conditions. What matters is that each group discovers the qualitative change that takes place as a result of the action.

Each of the stations is designed to prompt extension questions, for example, *What are the variables in this investigation? What data needs to be measured and recorded? Is this a fair and repeatable experiment?* Encourage students who finish early to consider other variables, for example, *Will doubling the size of the egg beater double the rate at which the temperature increases?* (Probably, depending on the outside air temperature and the rate at which heat is being lost from the water)

A broad extension question is *If energy is conserved (not lost), why is there so much talk about an energy crisis?* The issue is that much of our stored energy is converted into wasted heat. For example, some of the energy released by burning petrol in a car's engine goes into producing mechanical energy, but a lot of it goes out into the atmosphere as hot exhaust fumes. That energy might eventually create wind gusts and be converted into useful energy through a wind turbine, but the work done in digging for oil, refining the petroleum, or transporting the petrol to a pumping station will have been wasted. An understanding of energy changes will give students a better understanding of how energy is wasted (converted into unusable forms) and how they can go about conserving it.

In the next activity, students will explore the difference between kinetic and potential energy and classify examples of each form.

Pages 2–3: Playing with Energy

Mathematics and Statistics Achievement Objectives

- Number strategies and knowledge: Use a range of multiplicative strategies when operating on whole numbers (Number and Algebra, level 4)
- Statistical literacy: Evaluate statements made by others about the findings of statistical investigations and probability activities (Statistics, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Communicating in science: Begin to use a range of scientific symbols, conventions, and vocabulary (Nature of Science, levels 3–4)
- Investigating in science: Build on prior experiences, working together to share and examine their own and others' knowledge (Nature of Science, levels 3–4)

Mathematics and statistics context

Students will:

- solve problems using rates and unit conversions.

Science context

Students will:

- categorise activities and forms of energy as potential or kinetic.

Students should discover that:

- potential energy is stored energy; kinetic energy is the energy of motion
- there are many different forms of potential and kinetic energy.

Related information

Connected 3 2007: "A New Life for Old Machines" (focus: types of energy, renewable and non-renewable resources)

Connected 3 2008: "Planning a Playground" (focus: nature of science, properties of materials, movement and forces); "Jumping for Joules" (focus: forces, gears, electricity generation, properties of materials)

Answers

Activity

Example of energy	Type of energy (potential or kinetic)
Petrol	Potential
A stretched rubber band	Potential
A battery	Potential
2 billiard balls colliding	Kinetic
An apple about to fall from a tree	Potential
An apple falling from a tree	Kinetic
A flying rubber band	Kinetic
A child riding a bicycle	Kinetic
A vibrating bass drum	Kinetic
Air blowing out of a hairdryer	Kinetic
Hot springs	Potential

Game

The type of energy for each space

Space	Type of energy
Banana	Potential
Wind	Kinetic
Petrol tank	Potential
Lump of sugar	Potential
Hydroelectric dam	Answers can vary. A dam stores water, which is potential. The power station uses the flow of water to generate electricity, which is kinetic.
Rolling skateboard	Kinetic
Rain	Kinetic
Coiled spring	Potential
Jogging	Kinetic
Wound-up yo-yo	Potential
Earthquake	Kinetic
Charcoal	Potential
Boiling kettle	Answers can vary. The steam coming from the kettle is kinetic. The heat stored in the water is potential.
Shaken-up soft drink can	Potential
Spinning wheel	Kinetic
Tornado	Kinetic
Ball at the top of the stairs	Potential
Speeding car	Kinetic
Diver on a high diving board	Potential. (It only becomes kinetic when the diver actually jumps.)
Ball rolling downhill	Kinetic
Kicking a soccer ball	Kinetic
AA battery	Potential
Stretched rubber band	Potential
A shout	Kinetic
Dried fruit and nuts	Potential
Compressed air	Potential (as long as it remains in the tank)
Person skiing downhill	Kinetic

Answers for energy game cards

Card	Answers	Spaces to move if your answer is correct	Method
1. Wind	5 metres per second	5	300 m per minute is 300 m in 60 seconds. 300 ÷ 60 = 5
2. Tornado	1 year	1	There are 365 days in a year (excluding leap years). 28 kilowatt-hours per day x 365 = 10 220 kilowatt-hours per year, so a small tornado is roughly equivalent to 1 household's energy use for 1 year.
3. Rain	3 millimetres per minute	3	180 mm per hour is 180 mm in 60 minutes. 180 ÷ 60 = 3
4. Running	2 kilometres	2	5 km in 30 minutes is 10 km/h. 12 minutes is $\frac{1}{5}$ of an hour. 10 ÷ 5 = 2
5. Earthquake	4.0	4	3.0 is 10 times more powerful than 2.0. 4.0 is 10 times more powerful than 3.0, so it's 100 times more powerful than 2.0.
6. Cycling	4 kilometres	4	10 minutes is $\frac{1}{6}$ of an hour. 24 ÷ 6 = 4
7. Car travel	6 hours	6	It takes a car 6 hours to travel 420 km at 70 km/h because 420 ÷ 70 = 6.
8. Kicks	3 kicks	3	1 kick is 33 m. 2 kicks is 66. 3 kicks is 99, which is about the length of a soccer field.
9. Sound	3 kilometres	3	If sound travels at 0.340 km in 1 second, multiply by 9 to get the distance in 9 seconds. 0.340 x 9 = 3.06 km
10. Ski-lift	2 people	2	7 200 people per hour is 7 200 in 3 600 seconds (60 seconds in a minute x 60 minutes in an hour = 3 600). 7 200 ÷ 3600 = 2
11. Penalty: cellphone	n/a	n/a	n/a
12. Penalty: lunch	n/a	n/a	n/a
13. Bonus: surfing	n/a	5	n/a
14. Wind speed	5 knots	5	9.5 is half of 19. If 19 km/h is about 10 knots, 9.5 km/h is about 5 knots (half of 10).
15. Tornado	4 minutes	4	The tornado travels at 30 km/h, or 30 km in 60 minutes. In 1 minute, it travels 0.5 km (30 ÷ 60 = 0.5), so it will take 4 minutes (4 x 0.5 = 2) to travel 2 km.
16. Skateboarding	6 minutes	6	500 kJ in 10 minutes is the same as 50 kJ per minute (500 ÷ 10 = 50). 300 kJ ÷ 50 kJ per minute = 6 minutes.

Card	Answers	Spaces to move if your answer is correct	Method
17. Rain	4 millimetres	4	There are 4 hours between 8 a.m. and noon (12 p.m.) 16 mm ÷ 4 hrs = 4 mm /h on average.
18. Jogging	3 minutes	3	250 kJ in 5 minutes is 50 kJ per minute (250 ÷ 5 = 50). 150 kJ ÷ 50 kJ per minute = 3 minutes
19. Earthquake	4.0	4	2.0 is 10 times more powerful than 1.0. 3.0 is 10 times more powerful than 2.0, or 100 times more powerful than 1.0. Since 4.0 is 10 times more powerful than that, it is 1 000 times more powerful than a 1.0 earthquake.
20. Boiling water	1 minute	1	If a half-full kettle boils in 90 seconds, a full kettle should boil in 180 seconds (twice as much water, twice as much time.) $\frac{1}{3}$ of 180 seconds is 60 seconds or 1 minute.
21. Cycling	2 minutes	2	500 kJ in 10 minutes is the same as 50 kJ per minute (500 ÷ 10 = 50). 100 kJ ÷ 50 kJ per minute = 2 minutes.
22. Car travel	3 hours	3	A car moving at 60 km/h will travel 180 km in 3 hours because 180 ÷ 60 = 3.
23. Ball speed	5 seconds	5	In the first second, the ball travels 2 m. In the next second, it travels 4 m, for a total of 6 m. In the next second, it goes 6 m more, for a total of 12. Then another 8 m, for a total of 20 m, then another 10 m, for a total of 30 m after 5 seconds.
24. Soccer	5 minutes	5	1 kJ per second is the same as 60 kJ per minute (60 seconds in a minute). 300 kJ ÷ 60 kJ per minute = 5
25. Skiing	4 kilometres	4	30 km/h is 0.5 km per minute (60 minutes in an hour, and 30 ÷ 60 = 0.5). After 8 minutes, the skier would travel 8 x 0.5 = 4 km.
26. Penalty: friction	n/a	n/a	n/a
27. Bonus: skateboard	n/a	4	n/a
28. Bonus: wind	n/a	3	n/a
29. Penalty: rubber band	n/a	n/a	n/a
30. Bonus: cellphone	n/a	n/a	n/a

Notes

Preparation and points to note

This activity familiarises students with the terms **kinetic energy*** and **potential energy** in a fun way. To progress in the game, the students are required to solve simple problems based on kinetic energy contexts (for example, a radio broadcast, a rolling skateboard, or a boiling kettle). When any student encounters a kinetic card, all players should work out the problem and confirm the answer. (The answers are provided as a copymaster. You will need to decide who has the answer sheet for students to check against.)

Students need to be able to distinguish between potential and kinetic energy to play the game. Before introducing it to your students, review the answers so that you can provide guidance if called upon.

Preferably, the students will play the game with a minimum of introduction but, if they are confused about what to do, walk them through a few turns.

All players start with their counters on the banana. They should discuss whether a banana is potential or kinetic energy. When each student starts, they collect 2 potential energy tokens (thanks to the banana being a potential energy square). They can then either trade in 2 tokens and end their turn on the petrol tank, trade in 1 token and end their turn on the wind (retaining 1 token), or stay on the banana and keep both tokens. In the next round, students on the petrol tank or the banana will collect 2 more tokens. Students on the wind (kinetic energy, because it is air in motion) don't collect any tokens; they must pick up an energy card and try to solve the problem on it. If another student disputes their answer and it differs from that on the answer sheet (see copymaster), they lose their turn and stay on the wind square. On their next turn, they pick up another kinetic card and try to answer the question on it.

The game provides natural opportunity to mix up groups so that the students work with a diversity of classmates. By being actively involved in a group with a common interest and focus, they are using and further developing the key competency *participating and contributing*.

Points of entry: Mathematics

There are two types of kinetic problem cards: rate conversions and number patterns.

The rate conversion problems require the students to convert from one unit to another closely related unit as in the Energy Stations problems on page **1**. For example,

> "Sefo burns 1 kilojoule per second playing soccer. Move forward 1 square for each minute he needs to burn 300 kilojoules."

To solve this problem, students need to convert **kilojoules** per second (kJ/s) into kilojoules per minute (kJ/min) and calculate the number of minutes it will take to burn 300 kJ. If students are not sure how to approach a problem like this, prompt them to think about equivalent quantities: 60 seconds is the same as 1 minute, so 1 kJ/s is the same as 60 kJ/min. Similarly,

> "A skier is travelling downhill at 30 kilometres per hour. Move forward 1 square for each kilometre he travels in 8 minutes."

In this case, the conversion is from kilometres per hour to kilometres per minute: 30 km/h = 30 km/60 min = 1 km/2 min = 4 km/8 min. Once the hour has been converted to 60 minutes, doubling and halving type strategies are all that is needed.

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* *For bolded terms, see glossary, pages 6–7.*

The Richter scale problem, the ball rolling downhill, and other similar problems involve number patterns. Students may find that it helps to put the given information into a table. For example, knowing that an earthquake that measures 2.0 on the Richter scale is 10 times as powerful as one that measures 1.0 or that an earthquake that measures 6.0 is 100 times as powerful as one that measures 4.0 is sufficient to identify the pattern in this table:

Scale	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
Multiple	1	10	100	1 000	10 000	100 000	1 000 000	10 000 000

Similarly, the ball rolling downhill problem can be represented by and solved using this table:

Elapsed time	1 s	2 s	3 s	4 s	5 s
Speed	2 m	4 m	6 m	8 m	10 m
Total distance	2 m	6 m	12 m	20 m	30 m

Total distance is the distance travelled in the previous seconds plus the distance travelled in the current second.

Points of entry: Science

As the students work through the examples of energy listed on the copymaster, the aim should be for them to come up with their own everyday language definitions for potential and kinetic energy. The different examples should enable them to test and refine their definitions as they go.

As the students play the game, they may not always readily agree on whether a particular space represents potential or kinetic energy. Encourage them to debate the subject and justify their decisions. For example, the spinning wheel of a bike translates energy into forward momentum (kinetic), but a spinning flywheel mounted on a stationary block is also a source of stored (potential) energy.

Prompt students to think about how, in each situation, the energy could be changed from potential to kinetic or vice versa. For example, the coiled spring is potential energy, but when it expands, it converts its potential energy into motion (kinetic).

Pages 4–5: Measuring Potential

Mathematics and Statistics Achievement Objectives

- Number strategies: Use a range of additive and simple multiplicative strategies with numbers, fractions, decimals, and percentages (Number and Algebra, level 3)
- Patterns and relationships: Use graphs, tables, and rules to describe linear relationships found in number and spatial patterns (Number and Algebra, level 4)
- Measurement: Interpret and use scales … and charts (Geometry and Measurement, level 4)
- Statistical investigation: Plan and conduct investigations using the statistical enquiry cycle:
  - determining appropriate variables and data collection methods
  - communicating findings, using appropriate displays (Statistics, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Understanding about science: Appreciate that science is a way of explaining the world and that science knowledge changes over time (Nature of Science, levels 3–4)
- Investigating in science:
  - Build on prior experiences, working together to share and examine their own and others' knowledge
  - Ask questions, find evidence and explore simple models, and carry out appropriate investigations to develop simple explanations (Nature of Science, levels 3–4)
- Physical inquiry and physics concepts: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as movement, forces … (Physical World, levels 3–4)

Mathematics and statistics context

Students will:

- carry out a statistical investigation into the relationship between weight, height, and potential energy
- measure and record weight, height, and energy data
- identify relationships in their data, judge their accuracy, and use the relationships to make predictions.

Students should discover that:

- potential energy is proportional to weight x height
- friction and experimental error affects this relationship.

Science context

Students will:

- perform a simple experiment in order to learn how to measure potential energy
- learn the meanings of dependent, independent, and controlled variables.

Students should discover that:

- the potential energy of the pendulum swing is determined by its weight and the height of its release
- a heavier pendulum with less swing may or may not have more potential energy than a lighter pendulum with more swing; both variables are important.

Related information

Connected 3 2007: "A New Life for Old Machines" (focus: types of energy, renewable and non-renewable resources)

Connected 3 2008: "Planning a Playground" (focus: nature of science, properties of materials, movement and forces); "Jumping for Joules" (focus: forces, gears, electricity generation, properties of materials)

Answers

Activity

1. Practical activity
2. Results will vary. Increasing the height or the weight will increase the distance that the wood block travels. For example, if 2 weights released from a height of 30 cm move the block 5 cm, then 3 weights released from the same height should move the block *more* than 5 cm. Similarly, 2 weights released from a height of 40 cm should move the block more than 5 cm.
3. **a.** The pendulum with the greatest weight released from the greatest height would transfer the most energy.

   b. The pendulum with the least weight released from the least height would move the block the least distance.

   c. i. If you double the weight of the bob, the block should move double the distance.

   ii. If you double the height of the back swing, the block should move double the distance.
4. **a.** Answers will vary. A light pendulum released high or a heavy pendulum released low can have similar energy, so the block could move about the same amount.

   b. You should be able to prove your prediction by experimentation.
5. **a.** Results should be similar to those in the table in question **2**.

   b. The energy value should be a good predictor of distance.

   c. Energy will be lost in friction as the block slides along the floor. Also, if the bob does not strike the block cleanly in the centre of its mass, some of the pendulum's energy will not transfer to the block.

Notes

Preparation and points to note

Ensure that there is enough working space for each group to work comfortably. Choose and brief the groups carefully. Consider setting up a demonstration **pendulum*** so that the students are clear about what to do.

Your students may not be familiar with the terms **arc**, pendulum, and **proportional**. Revise these as needed.

Encourage the students to discuss their results with other groups. This will reinforce the key competency *thinking* by providing opportunities for students to learn from their mistakes, improve their processes, and refine their conclusions.

Note that **weight** is the correct term in relation to the action of the bob. (**Mass** is a measure of how much matter is in an object. Weight is the **force of gravity** acting on mass – in other words, a measure of how hard gravity is pulling on an object. For more information, see the teacher support material for Figure It Out, *Forces*, levels 2+–3+.

Points of entry: Mathematics

This activity is about the relationship between weight, height, and potential energy. Relationships are the foundation of algebra and are responsible for all patterns. For example, the numbers in the sequence 3, 6, 9, 12, 15 … conform to a pattern: each is 3 greater than the number before it, and each is 3 times its position in the sequence ($3n$). Wherever we can find and describe a pattern (that is, form a generalisation from particular instances), we can make predictions with confidence.

** For bolded terms, see glossary, pages 6–7.*

Discuss what **variables** are (see the definitions on page **5** of the students' book) and why they are important. (They tell other people who might like to repeat the experiment exactly what was changed and what was measured.) Discuss what the variables are in questions **2** and **3** and what type of variable they are in this context.

Reinforce the notions of **dependent** and **independent variables** and focus the students on finding relationships between them. (If there is no relationship, the dependent variable is not actually dependent!) Ask: *What did we change? What did we keep the same? What conclusion(s) can we reach?*

[***Note for teachers***. The relationship being explored here is $E = mgh$ where E is **potential energy**, mg is the weight of the bob (mass x gravity), and h is the height. There are *two* independent variables (weight and height). If height stays the same and weight doubles, energy doubles; if weight stays the same and height doubles, energy doubles. If both weight and height are doubled, energy increases by a factor of $2 \times 2 = 4$.]

Careful measurement is the key to getting meaningful results in this activity. To make measurement easier, encourage the students to make significant changes in height and weight, as opposed to small changes. For example, they will probably get better data using bobs of 10 washers, 20 washers, and 30 washers than trying to precisely measure the differences between results from bobs of 5, 6, and 7 washers. It is therefore important that students work out a method that allows them to take consistent measurements to a good level of accuracy. As always, encourage the students to take multiple measurements for each combination of variables and average them in order to reduce the impact of measurement variation. And, as with any statistical investigation, reinforce the phases of the statistical enquiry cycle: problem, plan, data, analysis, and conclusion.

You could challenge the students to create a visual representation of their data – one that clearly shows the relationship between the variables.

Points of entry: Science

Use Sefo's question as an entry into this activity. All students will have had experiences with falling objects, and they may already have theories about the relative influence of weight and height. Ask them to share their examples and express their views. Ask *What evidence do you have (to support your theory)?*

Potential energy is an abstract quantity (the product of weight [mass x acceleration due to gravity] and height). But if students can link it to their own experience, they can give it meaning. Suggest: *Pain is also an abstract quantity, but you can be sure that getting hit by a heavier pendulum will hurt more.*

The pendulum experiment is an ideal classroom investigation. It provides a great opportunity for students to learn how to devise and run a good experiment that will give them data on which to base a valid conclusion. While it is important that students know what they are about to do and why, avoid over-specifying and thereby denying them the chance to develop their own methodology and do their own learning.

The students will probably introduce considerable error into their data; treat this as a learning opportunity, not a negative. Encourage them to track down the possible sources of error and to evaluate the impact of these on their data. They need to understand that error is something that prevents them from clearly identifying what is really happening. It can be difficult to eliminate all sources of error, especially in simple experimental set-ups like this one, so the emphasis needs to be on reducing/minimising them.

Additionally, in energy experiments, it is impossible to get "perfect" data because energy is always lost to **friction**.

Pages 6–7: Bungy Jump Energy

Mathematics and Statistics Achievement Objectives

- Statistical investigation: Conduct investigations using the statistical enquiry cycle:
  - gathering, sorting, and displaying multivariate category and whole-number data and simple time-series data to answer questions
  - identifying patterns and trends in context, within and between data sets
  - communicating findings, using data displays (Statistics, level 3)
- Patterns and relationships: Use graphs, tables, and rules to describe linear relationships found in number and spatial patterns (Number and Algebra, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Physical inquiry and physics concepts: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena … (Physical World, levels 3–4)
- Investigating in science: Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations (Nature of Science, levels 3–4)

Mathematics and statistics context

Students will:

- measure, record, and average data for 2 variables (number of marbles and bungy cord stretch)
- plot a scatter graph using appropriate scales (independent variable on *x*-axis [number of marbles]; dependent variable [overall length] on *y*-axis)
- use tables and graphs to identify patterns/ relationships
- use the relationship between weight and stretch to make predictions.

Students should discover that:

- the more marbles there are in the bag, the greater the stretch. (This relationship is reasonably linear.)
- averaging helps smooth out inconsistencies and reveal patterns. (Rubber bands don't all have the same stretch, and stretch is hard to measure, so predictions are necessarily estimates.)

Science context

Students will:

- perform a scientific experiment that measures energy transfer from gravitational potential energy to elastic potential energy (stretch).

Students should discover that:

- to jump safely, bungy jumpers of different weights need bungy cords of different lengths
- elastic potential energy (stretch) transferred to a rubber band is roughly proportional to gravitational potential energy (weight of marbles)
- rubber bands aren't perfect springs – they obey an approximation of Hooke's Law: stretch is roughly linearly proportional to force, with some plastic stretching at a low elastic limit. (In other words, bands don't always bounce back to their original dimensions, and sometimes they snap.)

Answers

Activity One

1. **a.–b.** Practical activity. Results, tables, and graphs will vary.

2. **a.** Your graph should show that stretch depends on weight (as weight increases, so does stretch). With weight plotted on the *x*-axis and stretch on the *y*-axis, the data points on your graph should head towards the top right-hand region.

   b. **i.–ii.** Predictions and results will vary. You could draw a trend line on your graph to help you with your prediction.

Activity Two

1. a.–c. Practical activity. Results, comments, and predictions will vary. The new bands will make your bungy cord longer, so you should get more stretch for the same amount of weight. The length of the cord will affect the slope of your graph: a longer cord will have a steeper trend line.

Instead of adding the extra bands to the end of your bungy, you could add them in parallel (doubling the thickness). The bungy will be less stretchy than before, so the trend line of your graph will be less steep.

2. a. All you can be sure of is that the cord will stretch more than 9 m because the weight is greater.

Assuming that stretch is roughly proportional to weight, 100 kg will probably stretch the cord to a length greater than 40 m. (100 kg is 143% of 70 kg, and 143% of 9 m is a stretch of 12.9 m, for a total of about 42.9 m.)

b. i. Approximately 35 m, if stretch is roughly proportional to weight.

The 70 kg person stretched the 30 m bungy 9 m. At half this weight, a 35 kg person should stretch the same cord about half as much (approximately 4.5 m, which represents 1.5 m of stretch for each 10 m of cord or 0.75 m of stretch for each 5 m of cord).

To just touch the river 40 m below, the cord should be about 35 m long. (The stretch would be about 4.5 [for the 30 m] + 0.75 [for the 5 m] = 5.25 m. Added to the unstretched length of 35 m, this gives a fall of 40.25 m.)

ii. Approximately 28 m, if stretch is roughly proportional to weight. 105 kg is 150% of 70 kg. The 70 kg person stretched a 30 m bungy 9 m. Assume a 105 kg person would stretch the 30 m bungy 150% x 9 = 13.5 m or 4.5 m per 10 m of cord or 45 cm per metre.

Bungy length (105 kg weight) if length is roughly proportional to weight		
Unstretched length of cord (m)	Stretch (m)	Total length when stretched (m)
30	13.5	43.5
29	13.1	42.1
28	**12.6**	**40.6**
27	12.2	29.2

iii. David made at least two mistakes:

Given that the 30 m cord stretched 9 m for a 70 kg person, it is unlikely that it would stretch 4 times that amount (36 m) for a person who was slightly less than 3 times the weight (200 kg).

He calculated that the 30 m cord would stretch to 30 + 36 = 66 m (220%). Even if the 18 m cord were able to stretch by 220%, the total length would be 18 x 2.2 = 39.6 m, so the 200 kg person would not reach the water.

Investigation

Investigations and presentations will vary. However, each presentation should discuss gravity, energy, and energy loss. These points could be made:

- A person bounces back up again because their gravitational potential energy is converted to kinetic energy as they fall, and this kinetic energy is stored as elastic potential energy in the bungy cord.
- At the bottom of a jump, potential energy from the person's height at the top of the jump has been transferred to the cord. The person stops for a brief moment in mid-air. The cord is stretched, so it contains a lot of energy, but the jumper's kinetic energy is now zero.
- All that keeps the cord from bouncing straight back is the force of the jumper's weight. This weight is absorbed by the stretch. During their fall, the jumper has lost gravitational potential energy. This extra energy now sends them upwards as the cord unstretches.
- A bungy jumper doesn't bounce all of the way back up because some energy is lost to friction in the cord and air resistance.

Notes

Preparation and points to note

The students need to understand that stretch is the difference in length, not the total length. In other words, they should treat the length of the unstretched bungy as 0 and focus on the increase in length as marbles are added to the bag.

Dynamic stretch is the difference between the length of the rubber band when unstretched and the length reached when the bag is first dropped. *Static* stretch is the difference between the unstretched length of the rubber band and its length after it has come to a complete stop. The students should try to measure the dynamic rather than the static stretch of their "bungy" because this is what matters with a real bungy. But they will have to be quick.

Use identical, thin rubber bands (rather than thick ones) so that they stretch similarly when the marble bag is added.

As with the pendulum experiment on pages **4–5**, choose groups carefully and ensure that there is enough working space for each group to work comfortably.

As well as fostering *thinking*, the challenges in Bungy Jump Energy will build new knowledge and require the use of precise language and appropriate tools – all part of the key competency *using language*, *symbols, and texts*.

Points of entry: Mathematics

The core of this activity is the relationship between **force*** (the weight caused by **gravity** acting on the **mass** of marbles) and **elastic energy** (measured as stretch). Reinforce the meaning of **dependent** and **independent variables** and focus the students on finding the relationship between force and stretch. They should do this by looking at overall or average patterns and trends.

As with any statistical investigation, reinforce the elements of the statistical enquiry cycle: problem, plan, data, analysis, conclusion.

Prompt the students to think about why they are asked to average multiple trials instead of using the data from a single trial. (All measurement is subject to error. Particularly as this task involves speed and line-of-sight measuring, the likelihood of significant error is considerable. Averaging smoothes out the overs and unders and gives a more genuinely representative measurement.)

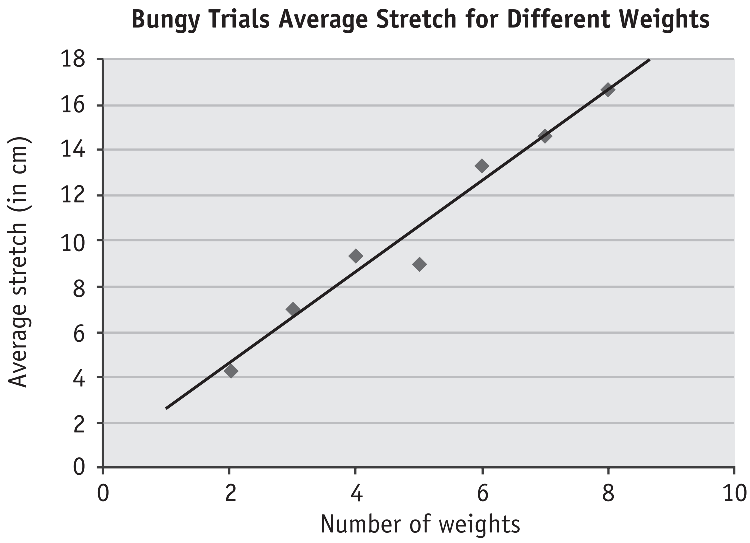
** For bolded terms, see glossary, pages 6–7.*

Note that the relationship between force and stretch is NOT linear (perfect data would not give a straight-line graph) – it is actually quadratic ($mgh = \frac{kx^2}{2}$). Nevertheless, a straight line gives a surprisingly useful approximation. Without going into detail, explain this to your students.

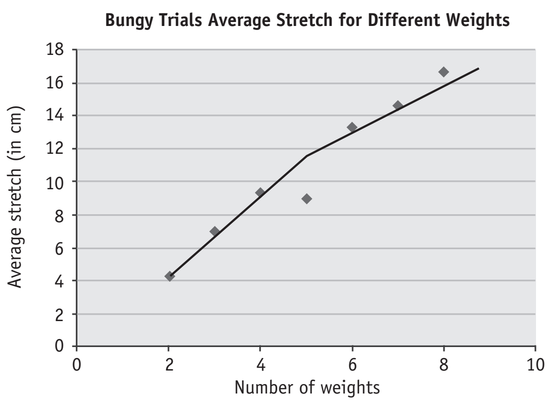
Introduce or reinforce the concept of rate of change and the slope of a graph as a measure of rate of change. If 5 rubber bands stretch 8 cm for 6 marbles, they will stretch about 16 cm for 12 marbles (2 cm for every 3 marbles). In **Activity Two**, link question **1c** to David's question: "Does the length of the bungy cord affect the slope of the graph?" on page **7**. In other words, will a longer cord stretch the same amount as a shorter cord for the same weight? (Probably not – it will stretch more! A longer cord will be less stiff, so it will stretch more for each increment of weight, which means that the slope of the line will be greater [the same increase in weight will give a larger increase in stretch on a longer cord]).

When graphing their data, the students should follow protocol, putting the independent variable (weight) on the *x*-axis and the dependent variable (stretch) on the *y*-axis. Discuss the shape of the graph and why it has that shape.

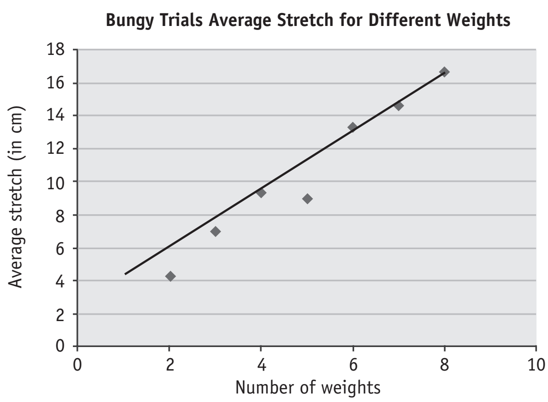
Suggest that your students draw a line of best fit (trend line) to help them make predictions. This does not mean connecting the dots! The trend line should follow the direction of the trend, going through the "middle" of the data points with about half on either side, as shown in the sample graph below:



The trend line below is invalid. While it does have about the same number of points above and below the line, it isn't straight and the distance of the points below the line from the trend is much greater than the distance of the points above the line.



The trend line below is also invalid. It is too high; most points are below the line.



Points of entry: Science

This activity is similar to the pendulum activity on pages **4–5**. The force of gravity acting on a mass is converted into elastic potential energy as it stretches the cord. Discuss the energy changes with the students; for example, the stretch is converted back into **kinetic energy** when the bungy rebounds.

Discuss good experimental technique with the students. For example, they should drop the bag of marbles the same way for each trial.

Encourage the students to research the force of gravity, elastic potential energy, rubber band elasticity, and Hooke's Law.

Hooke's Law states that, for perfect springs, force = the spring constant x distance, where the spring constant is a property of the material. The spring constant of typical rubber bands varies widely, between about 8 and 60 **newtons** per metre.

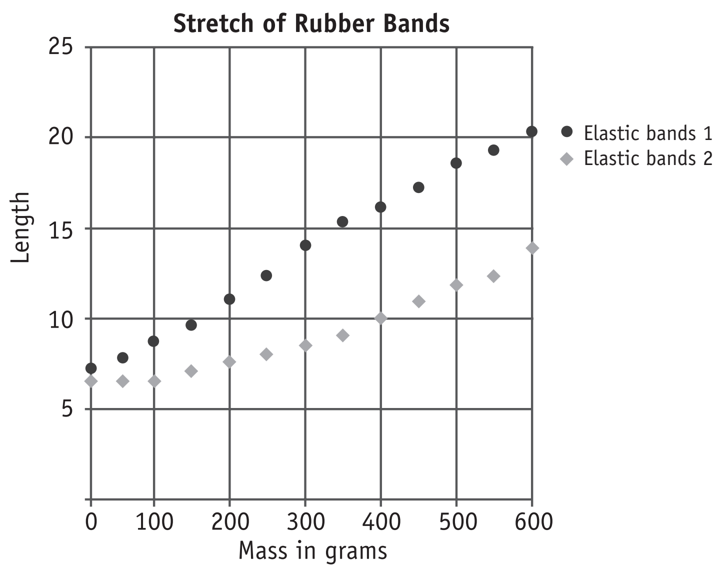
An experiment on Hooke's Law can be found at: www.practicalphysics.org/go/Experiment_1024.html.

An experiment with detail on the **energy** transfers that take place in bungy jumping can be found at http://stokes.byu.edu/bungee.html)

Rubber bands are not perfect springs. Ask *What might be the consequences of too little weight or too much weight?* (With too little weight, rubber bands won't stretch at all; with too much weight, they may deform [stretch permanently] or snap.)

Tap into your students' prior knowledge of springs and energy. Ask, for example, *Do car springs compress more when the car is full or empty?* (A car suspension will "bottom out" [compress to the limit] if you try and cram too many passengers in the vehicle.)

To make the comparison between **Activity One** and **Activity Two** easier, suggest that the total number of bands used in the second activity is a multiple of the number of bands used in the first activity (that is, if you start with 3 bands in **Activity One**, then use either 6 or even 9 bands in **Activity Two**).
A sample comparison graph is shown here:



As an extension, encourage the students to experiment with a variety of types of bands, number of bands, number of twists, and what effect putting the bands side-by-side (in parallel) or end-to-end (series) has on the overall stretch.

Pages 8–9: Food Energy

Mathematics and Statistics Achievement Objectives

- Measurement: Use appropriate scales, devices, and metric units for … weight (mass), temperature … and time (Geometry and Measurement, level 4)
- Number strategies: Use a range of … multiplicative strategies … (Number and Algebra, level 3)
- Number strategies and knowledge: Apply simple linear proportions … (Number and Algebra, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Physical inquiry and physics concepts: Explore, describe, and represent patterns … for everyday examples of physical phenomena … For example, … identify and describe everyday examples of sources of energy, forms of energy, and energy transformations (Physical World, levels 3–4)

Mathematics and statistics context

Students will:

- measure and record data on temperature change
- convert between temperature change and food energy units
- calculate the total energy needs and intake for sample menus, using food energy unit values
- investigate the relative proportions of energy provided by different foods in their diet.

Students should discover that:

- sugars tend to have a high energy density (make up a large portion of energy intake by mass of food consumed).

Science context

Students will:

- investigate which foods store the most energy
- use appropriate apparatus safely, carefully, and effectively
- use a range of scientific symbols, conventions, and vocabulary
- relate energy in food to life processes.

Students should discover that:

- different food types usually have different energy values
- the amount of energy in food can be estimated via combustion and temperature change
- a healthy diet includes diverse food types, with some being foods rich in energy.

Related information

Connected 3 1998: "Cooking with Biogas in India" (focus: combustion, burning, chemical changes)

Answers

Investigation

Answers will vary. Ultimately, the energy in food comes from the Sun. Photosynthetic plants use the radiation from the Sun to make sugars. We take in this energy either by eating plants and/or their fruit or eating animals that feed on those plants.

The amount of energy in food varies widely. In general, fats provide more energy for a given amount of food than do proteins or carbohydrates. Examples of healthy, high-energy, high-density foods include peanut butter and dried fruits.

Activity One

1. Practical activity
2. **a.** Approximate the energy calculation using the conversion factor 1°C air temperature change = 1 kJ. For example, if burning half the sugar cube raised the air temperature by 8°C, then half the sugar cube has approximately 8 kJ of energy. The whole cube would therefore have 16 kJ.

b. The heat generated from the energy did not all migrate to where you had the thermometer bulb; it was lost in all directions. Some would have also gone into heating the stand.

c. Answers will depend on the peanut calculation in **2a**. Compare your peanut energy calculations with the 20 kJ per peanut figure and then multiply the sugar cube energy by the same factor. For example, if you calculated that a whole peanut has 10 kJ, this means that your calculation for the peanut was too low by half. You should therefore double the amount of energy you calculated for sugar as well.

Activity Two

1. Suggested daily energy intakes will vary depending on your age and level of activity.

2. a.–b. Menus and comments on usefulness will vary. Hopefully you will have aimed for an overall healthy menu rather than just high-energy foods. Two sample 9 050 kJ menus are listed below:

Menu 1

	kJ per 100 g	Grams consumed	Total kJ
Bananas	400	400	1 600
Wheat bread	1 040	400	4 160
Orange juice	240	275	660
Peanut butter	2 630	100	2 630
	Total	**1 175**	**9 050**

Menu 2

	kJ per 100 g	Grams consumed	Total kJ
Chocolate	2 400	100	2 400
Soft drink	190	330	627
Potato chips	1 900	275	5 225
Bacon	800	100	800
	Total	**805**	**9 052**

Both menus have about the same kilojoules. However, menu 1 is much healthier because fruits and nuts contain more vitamins and minerals than do fats and sugars. In menu 1, you actually eat more food (1 175 g instead of 805 g). If you ate 1 175 g of menu 2, you would eat over 13 000 kJ.

3. a.–b. Energy calculations and menus will vary.

Notes

Preparation and points to note

Some children have serious allergies to nuts and food products, so you need to check this out for your class and exercise caution. Good substitutes for the peanuts are potato chips, banana chips (dried), or crackers.

As with any experiment involving potentially dangerous equipment, start by setting safety expectations and reviewing emergency procedures. For **Activity One**, set up the apparatus carefully and safely, as shown in the illustration in the students' book. The students should wear safety glasses when carrying out the experiment. The bulb of the thermometer will get hot; students should not touch it during or immediately after the experiment.

Instead of measuring the temperature directly above the burning peanut or sugar cube, the students could suspend a tin (a good conductor of heat) containing 100 mL of water securely over the burning food and then use the thermometer to measure the temperature rise of the water. To find the exact **energy*** given off by the burning food, they would need to multiply the temperature rise by 4.2 (specific heat of water).

In these activities, students need to make sense of information, draw on their own experiences, and debate their ideas, all of which use and further develop the key competency *thinking*.

Points of entry: Mathematics

These activities have three mathematical components: measuring temperature change, converting temperature change to energy in **joules** (J), and adding up food energy values to reach an appropriate daily intake target.

Confirm that the students know how to safely use and read your particular model of thermometer. Remind them that, like the bungy jump stretch on page **6**, they are trying to find the amount of change, not the overall value.

Measurements should be consistent; for example, have the students mark a reference point for the height of the thermometer. Encourage them to think about the surrounding temperature and its impact on their measurements. They need to wait for the thermometer to return to the ambient (room) temperature before burning the second food and, if they are heating water instead of air, they need to change the water.

Consider the different **variables** involved in this experiment. The two foods will probably have different **masses** and volumes, the food may not all burn, the foods will burn at different rates, and the thermometer may not measure all the energy of the burned food.

Challenge the students to factor these variables into their energy calculations, for example, by estimating the total energy change in relation to the volume of the food burned. If only half the sugar cube burns, then the total amount of energy in the cube is, at minimum, twice the amount recorded by the thermometer. For more precise results, consider asking the students to measure the mass of the food samples before and after burning and use the mass difference in their calculation and/or give each group food samples of approximately the same size.

The thermometer cannot accurately measure energy change (due to heat loss into the surrounding atmosphere and variance in the combustion of the foods), so have the students use **Activity One**, question **2c**, to estimate measurement error and calibrate their answers. A typical peanut, if burned completely, releases **kilojoules** [kJ] of energy that equal a 20°C air temperature change. (1 g of potato or banana chips also contains about 20 kJ of energy.) If the experimental peanut increases the air temperature by 5°C, then the measured energy value is only $\frac{1}{4}$ of the actual. If the sugar cube and the peanut burn in a similar way, the students should then multiply by 4 to get the real amount of energy in the sugar cube.

Encourage the students to repeat their experiments using the same foods and to work out the average temperature rise for each type. The results from different groups could then be collated on a spreadsheet, from which comparisons could be made and conclusions drawn.

As an extension, give the students different-sized samples of the same foods and ask them to find out if the temperature rises more for larger samples.

For **Activity Two**, students should find the amount of energy per serving (from nutrition labels, a photocopied table of food energy values, or an appropriate website), multiply these by the number of servings they expect to eat per day, and add up the subtotals to get a total daily intake. Alternatively, they can use size of serving (in grams) together with kJ per 100 g data. They may find it useful to structure their calculations using a table.

** For bolded terms, see glossary, pages 6–7.*

Points of entry: Science

These activities should help students make the link between energy (as measured by heat), food, and eating. Check that they understand that we get energy from food and then convert that energy into **kinetic energy** with our muscles. Activity requires more energy; energy without activity stores **potential energy** in our bodies as fat.

Like other forms of energy, food energy is expressed in joules (1 kJ is simply 1 000 J). Students may come across the term calorie, which is a non-SI unit for food energy. The kilojoule is the unit officially recognised by the World Health Organisation (1 kcal = 4.1868 kJ).

Ask the students to present the results of their investigations. Many facts about food energy are surprising. Only about 85% of the total energy in food is available to humans because 15% is lost in the digestive process and other bodily functions. Certain types of food contain more food energy per gram than others. Fats have particularly high **energy density** (energy per gram), while sugars and proteins have less. Water, non-digestible fibre, minerals, and vitamins are essential for a healthy diet but do not contribute to energy values.

Possible discussion questions include: *Why does the body need energy, and where do we get it from? What does it mean when we say we don't have any energy? What is energy used for, and how does it get used up?* When discussing "Where does the energy in food come from?", look at the relationship between the transfer of energy through the food chain and the Sun's role as the ultimate source of most of our food energy.

Discuss the importance of a healthy diet. Ask *What are the ingredients of a healthy diet?* We need vitamins for health and fitness, fats for stored energy, proteins for cell growth and development, carbohydrates for quick energy in the form of glucose, and roughage (fibre), to help keep the body system operating properly (like oil in a car engine).

A useful table of food energy values can be found at:
www.hc-sc.gc.ca/fn-an/alt_formats/hpfb-dgpsa/pdf/nutrition/nvscf-vnqau-eng.pdf

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** For bolded terms, see glossary, pages 6–7.*

Pages 10–11: Energy Density

Mathematics and Statistics Achievement Objectives

- Number strategies and knowledge:
  - Use a range of multiplicative strategies when operating on whole numbers
  - Find … percentages of amounts expressed as whole numbers (Number and Algebra, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Participating and contributing: Explore various aspects of an issue and make decisions about possible actions (Nature of Science, levels 3–4)
- Investigating in science: Ask questions, find evidence … to develop simple explanations (Nature of Science, levels 3–4)

Mathematics and statistics context

Students will:

- investigate the meaning of derived quantities, such as energy density
- calculate energy and mass totals using energy density, percentage of water content, and mass
- predict and calculate the reduction of mass through dehydration.

Students should discover that:

- energy is the product of energy density x mass or, alternatively, energy density is the ratio of energy to mass
- energy density increases as total mass decreases through dehydration
- percentage loss of water = (original mass – final mass) ÷ (original mass) x 100.

Science context

Students will:

- learn the difference between hydrated and dehydrated food
- appreciate that different foods provide the human body with different amounts of energy
- identify what makes a food a good choice for dehydration and/or tramping trips.

Students should discover that:

- the amount of water in a food can contribute significantly to the overall mass of the food, with no extra food energy value
- dried food has the same food energy value as hydrated food
- some foods are more appropriate than others to take on a tramp.

Answers

Activity One

1. **a.** Yes. (Henry needs 11 000 kJ and has 11 426 kJ, which is the total from column D in the table for question **4**.)

   b. Beef, at 4 860 kJ
2. 8.7 kg (his menu of 2 900 g x 3 days)
3. Dehydrated foods have more energy per gram than the same food with its normal water content. Water is not a source of energy, but it does have mass, so if you remove the water, the energy stays the same but the number of grams goes down.

4. **a.** The completed table (including column H from question **6a**) is:

Water Content and Energy Density							
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Food	**Original mass (g)**	**Energy density in kJ/g (not dehydrated)**	**Energy (kJ)**	**Normal water content (% by mass)**	**Dry mass (g)**	**Mass saved (g)**	**Energy density (kJ/g, dehydrated)**
Apples	450	1.5	675	85	68	382	10.0
Bananas	610	3.4	2 074	76	146	464	14.2
Beef	540	9	4 860	54	248	292	19.6
Carrots	420	0.8	336	88	50	370	6.7
Peas	450	2	900	89	50	400	18.0
Rice	280	5.2	1 456	10	252	28	5.8
Dried fruit and nuts	150	7.5	1 125	0	150	0	7.5
Total	2 900		11 426		964	1 937	
			Col B x col C		**(100% – water content %) x col B**	**Col B – col F**	**Col D ÷ col F**

Columns A, B, C, and E are given.

Column D is the total energy provided by the food in kilojoules. Find it by multiplying the energy density (number of kilojoules per gram) by the number of grams.

Column F is the dry mass (mass once water is removed). Calculate how much of the food is *not* water (using the normal water content percentage) and then multiply the dry percentage by the original mass (column B). For example, if apples are 85% water, then the dry mass is 15% (100 – 85). Multiply 450 g by 0.15 (15%) to get a dry mass of 68 g.

Column G is the mass of the water content. Find it by subtracting the dry mass (column F) from the original mass (column B). For example, if the apples were originally 450 g and now weigh 68 g, Henry saves 450 – 68 = 383 g of mass by dehydrating them.

Column H is the energy density of the dried food. Energy density is how much energy each food contains per gram. As water contributes no kilojoules, the foods contain the same energy as before. To find the energy density of the dehydrated food, divide the energy (column D) by the new mass (column F).

b. 5.8 kg over 3 days (1 937 x 3, rounded, using daily total from column G in the table above)

5. **a.** About 600 g. (Beef is 54% water, which means it's about half (50%) water and half dry mass. You can work out the amount of normal beef required by estimating: if about half of normal beef is dry mass, then to get 300 g of dehydrated beef, you'll need about 600 g of normal beef because 300 is $\frac{1}{2}$ of 600. Calculating exactly, the mass of dehydrated beef is 46% [100 – 54] that of normal beef. Dividing 300 by 46% [0.46] gives 652 [reverse to check: 0.46 x 652 = 299.92].)

b. 88%. ($\frac{24}{200}$ = 12%. 100 – 12 = 88)

6. **a.** Rice. (See the calculated values on the table above.)

b. Bananas have a higher energy density than peas, but peas contain relatively more water (89% compared with 76%). When you remove the larger amount of water, the remaining dry mass actually has more energy per gram.

c. Beef, peas, and bananas

Activity Two

1. a. Suggestions and predictions will vary.
2. a. Practical activity
   b. In order to find the water content, you need to measure the normal mass of the food, remove the water, and then measure its mass with the water taken out. Methods may vary, for example, you can dry food in an oven, in the sun, in a microwave, or freeze-dry it.
      i. Percentage loss of water = (original mass – final mass) ÷ (original mass) x 100
      ii. When there is no further change in mass if you continue drying
3. a.–b. Answers will vary.

Activity Three

Menus and discussion will vary. Your food choices need to have good food value in relation to their mass (because they are to be carried).

Notes

Preparation and points to note

This activity builds on the ideas in the activities in Food Energy and develops in a more formal way the idea of **energy density***. Given the nature of the calculations, it is preferable that students use calculators (or spreadsheets). They can then focus on what they are trying to achieve, look for patterns, and maintain enthusiasm and involvement, without being tied up by the calculations themselves.

For **Activity Two**, the students need to dehydrate food items. You may need to discuss with them what items are suitable and whether they are able (with permission) to bring them from home. It may be impractical for the whole class to use an oven or dehydrator. If this is an issue, consider assigning different foods to different groups, dehydrating the foods over a period of time, and sharing the results.

These activities are ideal for focusing on the key competency *thinking* because students will be exploring energy density by using their own experiences and ideas and the information that they research.

Points of entry: Mathematics

This activity focuses students' attention on a real-life problem: "What food should Henry pack to go on a 3 day tramp?" The food that students think Henry should take on the tramp should be based on sound mathematical and scientific evidence, from both what the students have calculated and any research they may have done.

The students should fill in the blank columns on their copy of the water content and energy density table as they work through the questions in **Activity One**, rounding appropriately. You may need to review rounding principles.

Question the students about what the table is showing and how they should use the data. Ask *What do the columns actually show and mean?* Make sure all the students understand why **energy** is the product of **mass** and energy density (column D = B x C). You can use the idea of ratio to help students, for example, *If 1 g of apple has 1.5 kJ, how many **kilojoules** do 670 g have?*

See the notes in the bottom row of the water content and energy density table for question **4** for explanations of the equations used.

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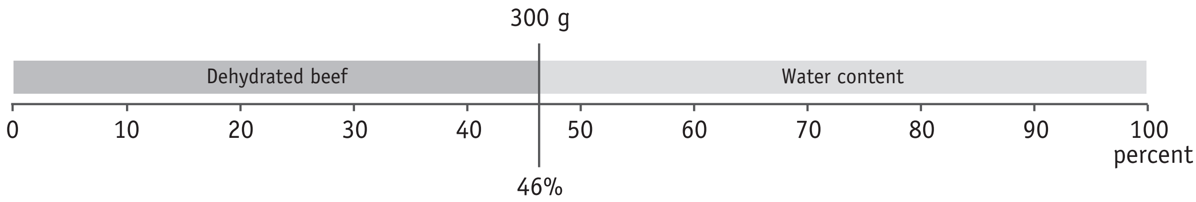
* *For bolded terms, see glossary, pages 6–7.*

Ensure that the students also set up the calculation properly for question **5** because the questions invert the relationships in the table. For example, beef is 54% water, so dry beef is 100 – 54 or 46% of the original. If 300 g of dehydrated beef is 46% of the original amount, that amount equals 300 ÷ 0.46. This is not intuitive and needs to be taught with care. A diagram can help:

Dehydrated Beef



If 46% of the original beef equates to 300 g, then 1% of the original beef must equate to a tiny part of that, namely $\frac{300}{46}$ g. If this is 1% of the original, then the original must weigh 100 times as much, namely $100 \times \frac{300}{46} = 652$ g.

There is huge scope to develop this topic further. You could encourage the students to produce graphic displays that show, for example, energy levels compared with food types or water content as a percentage for a variety of foods.

Points of entry: Science

Find out what your students already know. Ask *Which foods are probably high in water content?* (Most fruits and vegetables)

Water provides absolutely no **food energy**, so removing water does not reduce the available energy. Energy density is energy divided by mass, so when mass is reduced, energy density increases. Water is surprisingly heavy (1 L weighs 1 kg). This means that any reduction in water content can be helpful where mass is an issue.

Like **potential energy**, energy density is an abstract quantity (energy per gram). Abstractions tend to be hard to understand. Clear-cut examples can help: *Will you have more energy after eating 500 g of celery or 500 g of sugar?*

As an extension, ask the students to research the energy densities (kJ ÷ 100 g) of a variety of foods and drinks from the supermarket, especially those that are marketed as good sources of energy. Link the amount of energy Henry uses while hiking (11 000 kJ per day) to the suggested intakes from the previous activity (Food Energy). Compare the level of activity and the amount of energy in sports foods and discuss the implications of eating or drinking high-energy foods without exercising.

At the end of these activities, the students should be able to clearly identify good choices of foods to take on a tramp (high in energy, low in mass). Make sure you have enough time for a closing session to ensure that all students are clear about this.

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* *For bolded terms, see glossary, pages 6–7.*

Pages 12–13: Wind Chill

Mathematics and Statistics Achievement Objectives

- Number strategies: Use a range of additive and simple multiplicative strategies with whole numbers, fractions, decimals, and percentages (Number and Algebra, level 3)
- Measurement: Interpret and use scales … and charts (Geometry and Measurement, level 4)
- Statistical investigation: Conduct investigations using the statistical enquiry cycle:
  - gathering … and displaying … whole-number data and simple time-series data to answer questions
  - identifying patterns and trends in context, within and between data sets (Statistics, level 3)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Investigating in science: Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations (Nature of Science, levels 3–4)
- Physical inquiry and physics concepts: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as … heat (Physical World, levels 3–4)

Mathematics and statistics context

Students will:

- accurately measure, record, and average data with 2 variables (water temperature is the dependent variable; wind is the independent variable)
- use a table to identify patterns and/or relationships and calculate the heat energy effect of wind.

Students should discover that:

- the rate of cooling is proportional to the wind (the greater the wind, the faster the water cools down).

Science context

Students will:

- investigate the effect of wind chill
- set up and conduct a scientific experiment measuring heat energy loss for different amounts of wind
- use their results to formulate a conclusion that relates their experiment to a real tramping scenario.

Students should discover that:

- wind does not actually change the air temperature, but it does change the rate of energy loss
- wind chill can have a big impact on heat energy, to the point of being dangerous if not taken into account.

Related information

Connected 3 2010: Wind Power

Answers

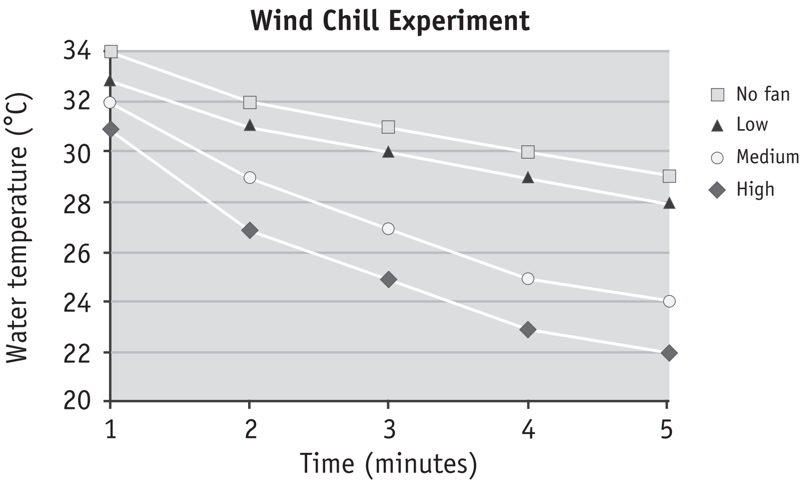
Activity

1. a.–b. Practical activity and recording of results. Question **1a**, without "wind", is the control experiment. The rate of cooling in each trial will depend on many factors, including the strength of the fan, the room temperature, and the shape and thickness of the bowl. Here is a possible data set:

Wind Chill Experiment

"Wind"	Water temperature (C°)				
	1 min	**2 min**	**3 min**	**4 min**	**5 min**
No fan	34	32	31	30	29
Low	33	31	30	29	28
Medium	32	29	27	25	24
High	31	27	25	23	22

c. Graphs will depend on the data. Here is a line graph for the above data:



d. Answers will depend on the actual data. However, more "wind" should cool the water faster. For example, the water will be closer to room temperature after 3 minutes for the high-fan setting than for the medium-fan setting. But once the water reaches room temperature, it will not cool further.

2. a.–b. Answers will depend on the actual data. The following table shows temperature loss over 5 minutes and energy transferred from water to air for the sample data listed above (question **1a–b**).

Wind Chill Experiment		
"Wind"	Water temperature (C°)	
	Loss over 5 min (°C)	Energy transferred from water to air (J)
No fan	37 – 29 = **8**	8 x 4 180 = 33 440
Low	37 – 28 = **9**	9 x 4 180 = 37 620
Medium	37 – 24 = **13**	13 x 4 180 = 54 340
High	37 – 22 = **15**	15 x 4 180 = 62 700

3. Answers will depend on your data. Subtract the control (no fan) energy loss from the high-fan energy loss. For the sample data, 62 700 J is lost with high fan and 33 440 J is lost with no fan, so 29 260 J (62 700 – 33 440 = 29 260 J) is due to the "wind".

4. a. Estimates will vary. You will need to assume that energy loss in a 30 km/h wind is roughly 3 times as great as in a 10 km/h wind (the high-fan setting). Also note that the estimate required is for 1 hour, which is 12 times as long as the period in your experiment (12 x 5 = 60 minutes). This means you should multiply your answer to question **3** by 3 x 12 = 36 to get an estimate.

For example, if the high-fan setting causes a net energy loss of 29 260 joules (J) in 5 minutes, a 30 km/h wind might cause an energy loss of 29 260 x 3 x 12 = 1 053 360 J (1 053 kJ). Given that this is a very rough estimate, it should be rounded to 1 000 kJ.

b. Answers will depend on your estimate in **4a**. If Henry loses about 1 000 kJ per hour due to the wind, then he will lose 1 000 ÷ 150, or about 7 apples' worth, of energy per hour.

Investigation

Research results will vary, but you should discover that Emperor penguins huddle together to conserve energy. Those on the outside lose energy much more rapidly than those on the inside. To ensure that all survive, they systematically shuffle. Every penguin takes a turn at bearing the brunt of the wind before returning to the warmth of the huddle.

Notes

Preparation and points to note

If you don't have a 3-speed fan, use multiple fans to increase the amount of wind for the experiment. Before the students start the experiment, relate it to their prior knowledge of **wind chill***. Ask *Which feels colder, a windy 20°C day or a calm 20°C day?* Ask the students to blow on the back of their hand and then say what they feel. Then have them moisten the back of their other hand using a wet cloth and blow over the wet area. Ask *Was there a difference between what you felt blowing over the dry hand compared with the wet hand?* (The wet hand should feel cooler because the water evaporates from the surface of the skin and, in doing so, cools the body. This is the principle behind sweating. You may wish to point out that the wind on the dry hand had very little cooling effect because wind by itself doesn't change the temperature.)

There are common misconceptions about wind chill, for example, that wind makes the air colder. Be careful to differentiate between *feeling* colder (losing heat faster) and being colder (lower body temperature). Wind chill is dangerous because the wind causes us to lose more heat **energy**, especially if we are wet and experiencing evaporative cooling. A simple way to demonstrate that wind does not affect air temperature is to take 2 readings with a thermometer: one in front of a fan and another out of its airstream.

Investigations should be structured so that the students can draw meaningful results. Prompt them to apply the results of their investigation. (This can be linked to thinking in flexible ways, an aspect of the key competency thinking.)

Points of entry: Mathematics

This activity is a controlled experiment to measure the (rate of) energy loss associated with wind chill. Direct the students as little as possible; instead, encourage them to apply the various stages of the statistical enquiry cycle (problem, plan, data, analysis, conclusion) on their own. Prompt them to think about the **variables** involved (**dependent**, **independent**, and **controlled**). Encourage them to consider how they will standardise their investigation: *How far are you going to put the fan away from the bowl? Will its distance make any difference? What else about the fan might make a difference? Why is it important to use the same amount of water in each trial?* (Less water may have less surface area exposed to the wind and will therefore cool differently.) *Why should we record the temperature every minute and not just after 5 minutes?* (Depending on the fan speed and the room temperature, the water may reach room temperature in less than 5 minutes. The additional readings give the students more information about the cooling.)

After the students have collated their data, they should examine it for relationships, preferably with the aid of suitable graphs. They should find that the more wind, the faster the water cools. The slope of the graphs should make this clear.

All estimates will be very rough. Discuss why. (The wind speed [10 km/h] given for the fan is an estimate. The cooling effect of wind is not linear: a 50 km/h wind does not feel twice as cold as a 25 km/h wind. The cooling effect of the wind depends on air temperature as well as wind speed.)

As always with an activity involving estimation, remind your students that an estimate is different from a guess; estimates should always be based on data.

Points of entry: Science

This activity introduces the idea of heat transfer. Heat energy tends to move from a warm body to a cold body, so a bowl of hot water in a cool classroom will lose heat energy to the atmosphere.

As with any experiment, challenge the students to describe what makes the experiment scientific and to identify possible sources of error. For example, if the thermometer is touching the bowl, they may be measuring the temperature of the bowl, not the water. Ask *Why did we record the cooling for "no fan"?* (Only by knowing how much the water cools without assistance can we work out how much of the cooling is caused by the fan.)

** For bolded terms, see glossary, pages 6–7.*

Encourage the students to relate their data to real-life contexts. Ask: *Why are windbreaker jackets thin?* (You only need a thin windproof layer to prevent wind chill. For cold air temperatures, you need insulation, regardless of whether there is wind or no wind.)

Discuss the dangers of drawing universal conclusions from the experiment. (The data is very limited, may contain errors, and may not be valid across a range of temperatures.)

The students may be familiar with wind-chill charts or charts in newspapers showing temperatures adjusted for wind chill. Wind-chill charts are subjective; there are several competing methods of equating wind speed to apparent temperature difference. Remind the students that the cooling effect of wind depends on air temperature as well as wind speed because the wind doesn't actually change the temperature. Reinforce the idea that being outside in windy, wet, and cold conditions can be deadly and that even experienced trampers can suffer from wind chill (see the later investigation on hypothermia).

Pages 14–15: Tramping against Gravity

Mathematics and Statistics Achievement Objectives

- Number strategies: Use a range of additive and simple multiplicative strategies with whole numbers, fractions, decimals, and percentages (Number and Algebra, level 3)
- Measurement: Interpret and use scales … and charts (Geometry and Measurement, level 4)
- Patterns and relationships: Use graphs, tables, and rules to describe linear relationships found in number and spatial patterns (Number and Algebra, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objective

- Physical inquiry and physics concepts: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena … (Physical World, levels 3–4)

Mathematics and statistics context

Students will:

- read elevation values off a contour map and a line graph
- calculate potential energy
- sketch a graph of potential energy.

Students should discover that:

- there is a relationship between potential energy, mass, and height gained
- a graph of potential energy looks the same as a graph of elevation, with a scale factor of about 10 x mass.

Science context

Students will:

- quantify the relationship between mass, height, and potential energy in joules (J)
- understand that the amount of potential energy trampers have depends both on their overall mass and how high up the mountain they are.

Students should discover that:

- potential energy is the result of mass x gravity x height (in this activity, height above sea level)
- a gain in potential energy from tramping requires a loss of food energy
- mass and weight are different and are used in specific contexts in science (weight is the force of gravity acting on mass)
- the greater the overall mass, the greater the force of gravity acting on that mass
- the overall potential energy that a "body" has is dependent on both its mass and its height above the ground (sea level in this activity). Therefore, a tramper with a greater overall mass will have a greater potential energy than a tramper with less overall mass. (The trampers will lose potential energy when they remove their packs.)

Answers

Activity

1. a. 400 m

   b. 264 kJ. (Henry has climbed 400 m. His total mass with a pack on is 66 kg. 10 x 66 kg x 400 m = 264 000 J)

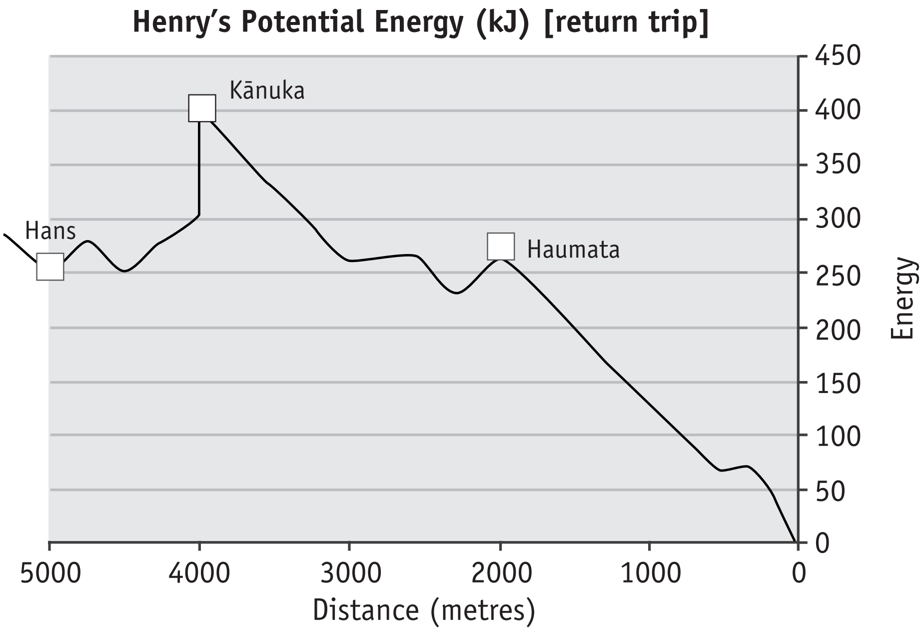
   c. Rua. (All three boys climbed the same amount, and Rua [with his pack] lifted the greatest mass.)

2. a. 188 kJ. (Rua lifted a total of 94 kg: his body [65 kg], his pack [19 kg], and the 10 kg transferred from Mukasa. The height increase from Haumata Hut to Kānuka Lodge was 200 m. 10 x 94 kg x 200 m =188 000 J.)

   b. 58 kJ. (Rua's pack is now 29 kg. 10 x 29 kg x 200 m = 58 000 J.)

3. 173 kJ (descent). (Without their packs, Henry, Rua, and Mukasa have a total weight of 173 kg. They descend 100 m from Kānuka Lodge to Hans Hut. 10 x 173 kg x $^{-}100$ m = $^{-}173$ 000 J.)

4. Your graph should be similar to this:



Henry's potential energy at Hans Hut is 10 x 51 kg x 500 m = 255 kJ. When he reaches Kānuka Lodge, his elevation has gone up by 100 m, so his potential energy has increased to 10 x 51 kg x 600 m = 306 kJ. Then he puts on his pack, increasing his potential energy to 10 x 66 kg x 600 m = 396 kJ, as shown by the vertical increase in energy at Kānuka Lodge on the graph. As he descends, his potential energy goes down, reaching 10 x 66 kg x 400 m = 264 kJ at Haumata Hut, and 0 at sea level. Henry's potential energy graph is similar in shape to his elevation graph, but it is reversed along the horizontal (distance) axis because he is returning to the start of the track.

5. a. Kānuka Lodge (because that's the point of greatest height x mass)

   b. Henry gets the greatest boost when he is losing potential energy the fastest, in other words, on the steepest descent on the track (below Haumata Hut). (This is why it's easier to run downhill.)

Notes

Preparation and points to note

Be careful not to confuse **mass*** and **weight**. Although *weight* is often used in everyday conversation to mean *mass*, mass and weight have specific and very different meanings. Mass is a measure of how much matter is in an object. Weight is the **force of gravity** acting on mass (in other words, a measure of how hard gravity is pulling on an object). Imagine taking a 1 kg object to the Moon. The object will have exactly the same mass there as here (it is the same object, after all), but because gravity on the Moon is about $\frac{1}{6}$ of Earth's gravity, it will weigh about $\frac{1}{6}$ as much. For more information, see the teacher support material for Figure It Out, *Forces*, levels 2^+–3^+.

The activity provides an opportunity to focus on the key competency *using languages*, *symbols*, *and texts* because it encourages students to build new knowledge, find ways to describe their thinking, and use tables and graphs to display their findings.

Points of entry: Mathematics

In this activity, students interpret a map and a line graph, calculate **gravitational potential energy** using the equation E = 10 mh, for different masses and heights, and use the results to sketch a graph of **potential energy**.

[***Note for teachers***. The equation for potential energy is E = mgh, where *m* is mass, *g* is acceleration due to gravity, and *h* is height. Acceleration due to gravity (g) is actually 9.8 metres per second squared (9.8 m/s^2) but has been rounded to 10 to keep it simple.]

Contour maps can be difficult to interpret. Make sure that all students are able to relate the contours to elevation. "Walk" them along the track. Ask them to describe what is going on in terms of their height above sea level (elevation).

Ask the students to explain in their own words what the contour map and the line graph show and to explain how the information in the one relates to the information in the other. *How does the elevation graph help you to understand how hard the tramp is? Why does the graph start at (0,0)? Why is this relevant? What do the numbers on the x and y axes refer to?* As a class or in small groups, connect features on the contour map with points on the line graph, for example, the large flat meadow at 400 m elevation between Haumata Hut and Kānuka Lodge or the small peak between Kānuka Lodge and Hans Hut.

Potential energy is always calculated from a reference point, in this case, height above sea level. If students struggle to calculate potential energy, illustrate with sample calculations. For example, at 100 m above sea level, Mukasa's potential energy would be 10 x 77 kg x 100 m = 77 000 J, or 77 kJ.

The final part of the activity, which involves drawing a graph of potential energy, is highly conceptual. The *x*-axis scale is reversed from the elevation graph because the boys are tramping back down the trail to sea level. Specific data points will simplify the drawing, for example, ask the students to plot the calculated potential energy values for Henry at each hut and at the bottom. Discuss what happens at Kānuka Lodge when Henry puts on his pack (his mass increases, so his total potential energy increases.) From these few points, they should be able to see that the shape of the graph is roughly mirroring the shape of the elevation graph on the previous page.

Extension activities could include discussing the question of gradients (steepness of the climb). Ask: *What is a negative gradient and where do you find one on the graph? How would you measure the gradient on the mountain? What do gradients have to do with the distance between contour lines on a map?* (There is a difference in elevation of 20 m between any two contour lines. The closer the contour lines, the steeper the gradient.)

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* *For bolded terms, see glossary, pages 6–7.*

Points of entry: Science

Ask the students to think about what happens when people climb mountains. *What does it feel like when climbing? Where do the trampers get their* **energy**? *Which of the three boys (in the activity) will require most energy?* As they study the elevation graph, get them to discuss where the trampers will have to expend most energy. Ask: *How will the terrain change as they climb higher? How might the weather, especially wind chill, affect their climb?*

This activity focuses on **work** (the change in potential energy). Note that in this scenario, it's only when gaining or losing height that the boys fight gravity or gain its assistance. Help the students to link the ideas of force, acceleration, mass, and energy. The acceleration due to gravity on all objects on Earth is about 10 metres per second squared (m/s^2). This acceleration gives us weight, where the force of our weight (in newtons) is equal to 10 metres per second squared times our mass in kilograms. It's this force that we fight against when we climb, which is why the energy used in climbing is 10 times our height times our mass. In equations, F = ma, where F is force, m is mass in kilograms, and a is the acceleration due to gravity (also known as g) and E = mgh or Fh, where h is height.

Pages 16–17: Hypothermia

Mathematics and Statistics Achievement Objectives

- Measurement: Interpret and use scales, measurements, and charts (Geometry and Measurement, level 4)
- Statistical investigation: Conduct investigations using the statistical enquiry cycle:
  - gathering, sorting, and displaying multivariate category and whole-number data and simple time-series data to answer questions
  - identifying patterns and trends in context, within and between data sets (Statistics, level 3)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Chemistry and society: Relate the observed, characteristic chemical and physical properties of a range of different materials to technological uses and natural processes (Material World, levels 3–4)
- Participating and contributing: Explore various aspects of an issue and make decisions about possible outcomes (Physical World, levels 3–4)
- Investigating in science: Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations (Nature of Science, levels 3–4)

Mathematics and statistics context

Students will:

- measure and record data relating to two variables (the dependent variable is the mass of an ice cube; the independent variable is the type of clothing)
- use data to decide which clothing will best guard against hypothermia when tramping.

Students should discover that:

- they can use experimental models and results to draw conclusions about real (tramping) scenarios.

Science context

Students will:

- investigate the insulating effect of different clothing types, including the effect of mass
- set up and conduct a controlled scientific experiment measuring insulation (reduction in loss of heat energy).

Students should discover that:

- layers and survival blankets are probably a better choice than bulky clothes.

Related information

Connected 2 2004: "Of Elbows and Eels" (focus: electrical energy generated by living things)

Connected 2 2003: "Fabulous Felt" (focus: changing properties of materials)

Answers

Activity

1.–2. Practical activity. Answers will vary. A sample table is shown below.

To find the energy transferred, multiply the mass lost by 355 joules per gram [J/g]; to find the insulating effect, subtract the energy transferred for that clothing type from the energy transferred by a bare hand.

Clothing type	2 ice cubes, starting mass (g)	2 ice cubes, final mass (g)	Mass lost (g)	Energy transferred (J)	Clothing mass (g)	Insulating effect (J) [energy from bare hands minus energy for this type], for question 2	Energy savings by mass (insulating effect ÷ clothing mass)
Bare hand	40	21	19	6 745	0	0	0
Thick glove	40	30	10	3 550	120	3 195	27
Aluminium foil "survival blanket"	39	33	6	2 130	30	4 615	154
Plastic and paper layers	40	32	8	2 840	25	3 905	156

3. Answers will depend on the actual data. For the sample data above, the plastic and paper layers were the most efficient by mass, preventing the transfer of 156 J of heat energy per gram of mass. Overall, the "survival blanket" insulated the most (4 615J), but its mass was greater than that of the plastic and paper layers. The paper/plastic was more efficient per gram than the survival blanket, even though the survival blanket was better overall.

4. The snowman without a coat will melt faster. The coat on the snowman acts as an insulator, in this case, reducing the transfer of heat from the outside air to the snowman, just as the "survival blanket" reduced the transfer of heat from your hand to the ice cube. To test this, wrap an ice cube in fabric and compare how quickly it melts with how quickly an unwrapped ice cube melts.

Notes

Preparation and points to note

You will need enough similar-sized ice cubes for multiple trials for all groups. Melting ice cubes create a lot of water – establish expectations for handling and cleaning up.

Holding ice for a prolonged period can be painful; modify the time period if necessary. If students do this, they should ensure that they use the same period for subsequent trials (fair testing).

To get the most out of this investigation, the students will need to work co-operatively, initially in pairs. This gives them an opportunity to develop the key competency *participating and contributing*.

Points of Entry: Mathematics

This investigation is a controlled experiment to measure the insulating effect (reduction in **energy*** loss) of different types of "clothing".

Encourage the students to apply each stage of the statistical enquiry cycle: problem, plan, data, analysis, and conclusion. Before they start testing, ask them to predict which clothing type will perform best. They should also think about potential sources of error and how they can be controlled. For example, they will need to use cubes with a similar **mass** and let their hands warm up again before they start the next trial. Prompt them to think about whether they should use multiple trials or average the data from several groups, or both. (Different hands will transfer different amounts of heat, so a class average will tend to smooth out variation.)

Make sure the students draw appropriate conclusions from the data, for example, *Which is better, less melting or more melting?* (Less melting means better clothing because less heat was transferred from the hand to the ice.) Remind the students that there are two **variables** (mass and type of clothing) and encourage them to use all of the evidence to make their decision. For example, the heavy glove may reduce heat transfer the most, but it might not be as efficient as a smaller mass of layered clothing. In other words, you could get as much insulation with less mass by using layers or a survival blanket instead of a bulky glove.

At the end of the investigation, the students will have 4 pieces of data. Using the table provided (see copymaster) will help them to structure their comparisons. They need to compare the amount of energy saved (energy not transferred to the ice compared with energy transferred from bare hands) with the amount of energy transferred. A suitable way of comparing the three "clothing" types is to divide the **joules** saved by the mass. This gives the energy saved per gram for each type. A sample table is listed in the answers.

You could ask the students to pool their data and average it. They could then present their findings graphically.

Points of Entry: Science

At the end of this activity, the students should be able to identify clothing types that are suitable for tramping (high in insulating effect, low in mass). Ensure that you have enough time for a closing session so that all students are clear about what makes an item good for preventing hypothermia. Encourage discussion of ideas and findings: groups may get different results, especially if each group uses different types of gloves and different amounts of foil, plastic, and paper. What matters is that they can (begin to) identify the reasons for the different results.

Some lighter materials, such as those used in expensive ski gloves, offer better insulation than thick woollen ones, so the students need to consider thickness as well as type. Modern polypropylenes are good examples of light, very effective insulators. The order and composition of layers also matters. For example, paper over plastic will not be as effective as plastic over paper because the air gap between the plastic and the paper provides some insulation while paper on the outside will get wet and mould to the plastic, squeezing out almost all air. Encourage the students to think about the "ideal" glove, for example, a medium-weight glove made with multiple layers of waterproof material, reflective material, and cloth insulation. You may be able to cut open a real ski glove and show that it is constructed from a number of different fabrics.

Make sure that the students can transfer the results of their experiments to other contexts, such as the snowman (question **4**). Insulating materials slow the transfer of heat **energy**, so a snowman with a coat will melt (absorb heat energy) more slowly than a snowman without a coat. Similarly, a well-insulated house will heat up more slowly on a hot day.

Reinforce use of the scientific inquiry method. Ask: *What are the variables? What does it mean to do a controlled experiment? Why do the bare-hand test?* (Only when we know how much energy is lost when no clothing is worn can we determine the effectiveness of different materials.) The students should try and control as many of the extraneous variables as possible, for example, ice cube size (keep the same), time of tests (keep the same), hand(s) (use the same person and make sure that the hand is dry and about the same temperature at the start of each test).

In conclusion, ask *What further investigation could you carry out to show which type of clothing is most suitable for a tramp?* Invite students to develop additional questions or hypotheses and then answer or test them.

** For bolded terms, see glossary, pages 6–7.*

Pages 18–19: Wind Power

Mathematics and Statistics Achievement Objectives

- Measurement: Interpret and use scales, timetables, and charts (Geometry and Measurement, level 4)
- Statistical investigation: Plan and conduct investigations using the statistical enquiry cycle: gathering, sorting, and displaying multivariate category, measurement, and time-series data to detect patterns, relationships, and trends (Statistics, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Physical inquiry and physics concepts: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena … and describe everyday examples of sources of energy, forms of energy, and energy transformations (Physical World, levels 3–4)
- Participating and contributing: Explore various aspects of an issue and make decisions about possible actions (Nature of Science, levels 3–4)

Mathematics and statistics context

Students will:

- convert metric units for speed (metres per second [m/s] to kilometres per hour [km/h])
- interpret line graphs and scatter plots
- use location, wind speed, and gale frequency data to recommend a location for a wind farm
- adjust their conclusion for additional variables.

Students should discover that:

- good decisions may involve multiple variables, but data displays can only show a few of these.

Science context

Students will:

- learn that wind can generate electrical energy
- evaluate the suitability of different locations for a wind farm
- discuss or debate issues regarding wind power.

Students should discover that:

- wind power can be a good source of energy, but people object to having wind farms close to their houses
- turbines are most efficient when wind speed is consistently within a specified range
- turbines are shut down when winds exceed 90 km/h.

Related information

Connected 3 2010: Wind Power

Answers

Activity One

1. **a.** 3 metres per second (m/s)

   b. 12.5–25 m/s

2. **a.** 10.8 km/h. (There are 60 seconds in a minute, so 3 m/s is the same as 180 m/min [3 x 60 = 180]. 180 m/min is the same as 10 800 m/h [180 x 60 because there are 60 minutes in an hour]. There are 1 000 m in 1 km, so 10 800 m/h = 10.8 km/h.)

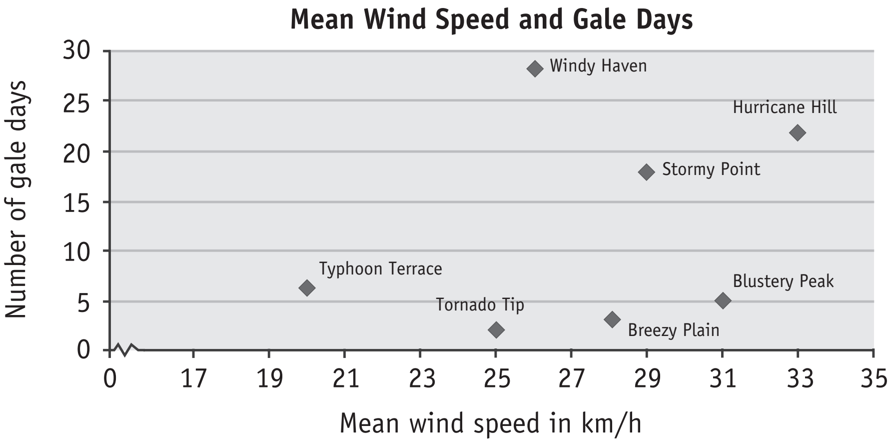
   b. 90 km/h. (Convert from seconds to hours again. 25 m/s x 60 = 1 500 m/min.
   1 500 m/min x 60 = 90 000 m/h, which is 90 km/h. Alternatively, you could use the fact that there are 3 600 seconds in an hour, and multiply directly.
   25 m/s x 3 600 = 90 000 m/h)

c. 45–90 km/h. (The graph shows that full output is reached at 12.5 m/s and shutdown at 25 m/s. Convert 12.5 m/s to 45 km/h using the method you used for **2a** and **2b** because there are 1 000 m in 1 km and 3 600 seconds in an hour. You may have noticed that 12.5 is half of 25; you have already calculated that 25 m/s is 90 km/h, so you can also halve 90 km/h to get 45 km/h.)

Activity Two

1\. a. Tornado Tip (left) and Hurricane Hill (right)

b. Your graph should be similar to this:



2\. a.–b. Answers will vary but should be backed up by evidence. Blustery Peak, Breezy Plain, Hurricane Hill, and Stormy Point all have high mean wind speeds. Hurricane Hill and Stormy Point both also have a high number of gale days, which may count against them.

c. Answers will vary. Stormy Point has the most wind for an inexpensive location, but the combination of high wind speed and few gale days may make Blustery Peak worth the extra cost.

3\. a. Answers will vary. Mean wind speed is just one statistic; it would be essential to analyse wind patterns for an extended period of time before committing to a particular location. Relevant non-weather data might include environmental impact or site access.

b. Answers will vary. You might have to rule out otherwise suitable sites because construction equipment can't access them, they are in national parks or other areas of particular cultural or ecological value, they lie in bird migration paths, or they are too close to populated centres.

Notes

Points of entry: Mathematics

This activity requires students to make decisions based on different **variables*** and data representations. They need to combine information from the line graph, the scatter plot, the table, and their own ideas and research to come up with their recommendation.

** For bolded terms, see glossary, pages 6–7.*

Tables and graphs are important tools for representing information and ideas and, as such, both use and develop the key competency *using language*, *symbols*, *and texts*.

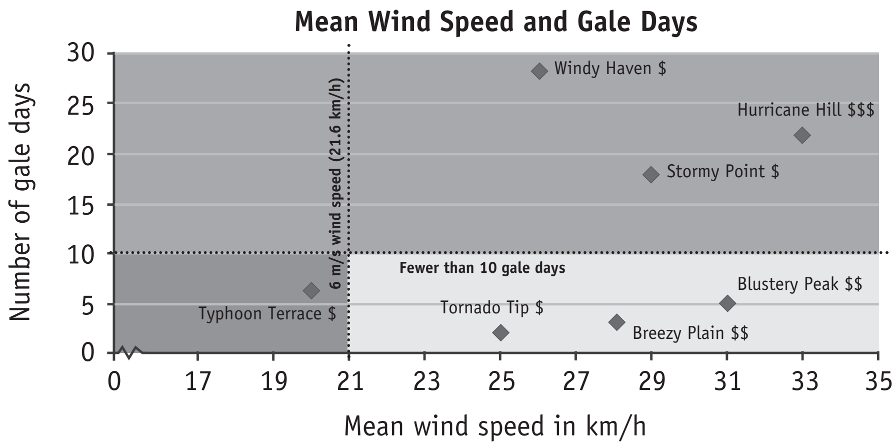
To ensure that all students can interpret the table with a minimum of teacher direction, have them study it in small groups and write down at least 5 statements that are true according to the data. For example, "Hurricane Hill is the windiest", "Windy Haven is the most stormy", "Tornado Tip is the least windy", "Hurricane Hill is the most expensive", "Windy Haven, Hurricane Hill, and Stormy Point all have quite a few gale days".

The students will realise that the difference between winds and gales is one of degree, but they are unlikely to know the technical difference, so you could challenge them to find out. (Gale-force winds are usually defined as greater than 60 km/h [17 m/s].)

The students need to understand what the line graph tells them about wind turbines. Ask: *What are the axes? What do the terms "**Watts**" and "metres per second" mean?* (1 watt is 1 **joule** per second [J/s].) Discuss the fact that the output profile of a wind turbine is not a simple straight line; it takes a certain amount of wind before the turbine will turn at all, then power increases smoothly until the limit of the generator is reached; once this limit is reached, full output is maintained until the wind drops below the optimum range or reaches gale shutdown speed (at which point, the turbine is shut off and the power output drops to zero).

Once the students have re-created and completed the scatter plot (**Activity Two**, question **1b**), they can use it to rule out locations. They can decide how many gale days are the most they can accept, draw a horizontal line through that point, and eliminate all locations above the line. Similarly, they can eliminate locations where the wind speed falls below a selected threshold. Although it is arguable whether a graph is really necessary for a small data set like this, the students should be able to see that, as a general principle, it is much easier to analyse data presented on a scatter plot than in an unsorted table.

Challenge the students to incorporate all the data in a single representation. The following scatter plot incorporates information from the power curve graph in the students' book. Based on the power curve, a reasonable power output can be obtained at 6 m/s or more (21.6 km/h), which is represented by a vertical line. (The 13 m/s [46.8 km/h] full output threshold is off the scale.) The graph also shows a selected gale-days threshold of fewer than 10 days. The graph clearly identifies 3 locations that meet the selected criteria.



This activity offers a very suitable context for exploring the notion of mean (average). The students need to realise that the mean wind speed is not the minimum wind speed on any given day: there will be days where the wind speed is greater (sometimes much greater) and days when it is less (sometimes much less). Based on the data provided, Typhoon Terrace, with a mean wind speed of 20 km/h, is likely to be a bad choice for a wind farm because the mean wind speed is very low relative to the power curve. This means that there will be many days when there won't be enough wind to generate much electricity at all. The statistics for Windy Haven and Tornado Tip are also interesting. Both have similar mean wind speeds (25–26 km/h), but Windy Haven has far more gale days. This means that, in Windy Haven, when gales are not shutting the turbines down, the winds will frequently be too light to generate much electricity.

In this activity, there are 3 **independent variables** (mean wind speed, gale days, and cost). To meet the statistics achievement objective of "gathering, sorting, and displaying multivariate category … data to answer questions", the students should factor in all 3 variables when making their recommendations for location. Scientists and mathematicians use data to make decisions. It is important that the students learn to differentiate between beliefs and evidence-based recommendations so that they select and support their proposed locations using facts. For example, Tornado Tip is a good choice in terms of cost, mean wind speed, and low number of gale days, and Blustery Peak has a considerably higher mean wind speed, although the cost is higher.

The debate could be extended to include other variables, for example, proximity to major energy users. (For example, in a New Zealand context, electricity generated in Kaitaia would have to travel some distance to reach users in Auckland.)

Points of entry: Science

Find out what your students know about wind power and how wind turbines work. Some may already have considerable relevant knowledge. Encourage them to present or explain their ideas to other students as an introduction before you introduce the graph showing wind speed and output.

Transfer the students' thinking about the selected locations to other places: *Would our area be a good location for wind generation? Are there any wind turbines nearby? What are the characteristics of areas where wind turbines are located?*

Wind turbines work by converting the **kinetic energy** of the wind into **electrical energy**. The **energy** is transferred from the moving wind to the turbine blades, which then drive the turbine (inverter), generating electricity. Electricity can be stored as **potential energy** in a battery or flow directly as current (kinetic electrical energy) to another electrical device. This simple flow chart may help:

Wind → **Blades** → **Turbine** → **Electricity**

As the power curve graph shows, not all of the energy of the wind is converted into electricity (for example, a 20 m/s wind yields the same amount of energy as a 15 m/s wind). Ask: *Is the process 100% efficient? Why not? Where is energy being wasted or lost?* (The blades are not 100% aerodynamically efficient. There are losses due to **friction** around the turning shaft.)

With fossil fuel resources becoming depleted and increasing emphasis on reducing our carbon footprint, wind power is a growth area in New Zealand. But, because of its inconsistency, wind will never be able to provide 100% of our power needs. Energy needs to be stored so that it can be drawn on as needed, not just when it happens to be available. The lakes that supply our hydroelectric systems serve this function. Unfortunately, wind energy can't be stored, so when a wind farm is idle, the electricity it would generate has to come from another energy source. In New Zealand, that other source is either water or fossil fuels.

Encourage your students to make use of the Internet and to debate the issues regarding the advantages and disadvantages of wind turbines and wind farms. Possible lines of inquiry include: *Why do we need to look at alternative sources of energy, such as wind power? How do wind turbines work? What are their limitations? What aesthetic, cultural, ecological, technological, or economic factors prevent us using otherwise suitable sites for wind farms? Which countries in the world are leaders in the use of wind generation? How does the cost of wind generation compare with other energy sources?*

Pages 20–21: Saving Power

Mathematics and Statistics Achievement Objectives

- Number strategies: Use a range of multiplicative strategies when operating on whole numbers, fractions, decimals, and percentages
- Number knowledge: Find fractions, decimals, and percentages of amounts expressed as whole numbers, simple fractions, and decimals (Number and Algebra, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objective

- Investigating in science: Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations (Nature of Science, levels 3–4)

Mathematics and statistics context

Students will:

- practise inductive reasoning
- calculate percentages and rates for savings and loans.

Students should discover that:

- small changes over time can lead to big savings.

Science context

Students will:

- investigate ways of using less electricity from the national grid (insulation and solar power)
- explore trade-offs between upfront costs and lifetime savings.

Students should discover that:

- New Zealand has a large potential for savings through insulating hot water cylinders
- solar panels convert solar energy into electrical energy
- alternative sources of energy come at a cost
- there is a time lag before the benefits of energy conservation measures are realised.

Answers

Activity One

1. 1 185 000. (25% of homes have insulated cylinders so 100 – 25 = 75% must have uninsulated cylinders.
0.75 x 1 580 000 = 1 185 000)

2. $83 million. (If each home saves $70 per year, total savings amount to
70 x 1 185 000 = $82,950,000.)

Activity Two

1. a. The more expensive Kiwipower bill is for Jimmy's home. (See Uncle Jack's comment. But note that while Uncle Jack thinks that the difference is due to his solar panel, there could be other factors.)

b. i. Approximately $315. The difference in the monthly bills is $148.20 – $121.90, or $26.30. $26.30 x 12 months = $315.60. (This estimate assumes the difference will be the same from month to month. In practice, winter bills are usually quite a bit more than summer bills.)

ii. Nearly 6.5 yrs. $2,000 ÷ $315.60 = 6.34

2. a.

Location	Annual sunshine hours	Blenheim's extra hours	Extra hours as % of annual sunshine hours	Blenheim's sunshine as % of annual sunshine hours
Blenheim	2 500	0	0	100
Invercargill	1 600	900	56	156
Palmerston North	1 700	800	47	147
Tauranga	2 250	250	11	111
Wellington	2 050	450	22	122

The table represents Blenheim's extra hours of sunshine in two ways:

Column 4: Blenheim gets 900 more sunshine hours than Invercargill. This amounts to 900 ÷ 1600 = 0.56 or 56% more.

Column 5: Blenheim gets 2 500 ÷ 1 600 = 1.56 or 156% of Invercargill's sunshine hours.

b. Jimmy's mum could expect to save about $385 per year, which is $69.40 more than Uncle Jack.

Blenheim gets 22% more sun than Wellington, so a solar panel in Blenheim should generate 22% more than a similar panel in Wellington. This means that, all other things being equal, Jimmy's mum should save 22% more than Jack.
1.22 x $315.60 = $385.

c. No. Sometimes the savings will be higher (for example, in February in a hot summer) and sometimes lower (for example, in the middle of a rainy winter).

3. a. $400. (5% of $2,000 is $100. $100 extra for 4 yrs is $400.)

b. $2,400

4. a. $41.67. (There are 48 months in 4 yrs. $2,000 ÷ 48 = $41.67)

b. No. Assuming that Jimmy's mum saves about $385 per year, it will take another 1.2 yrs. After 4 yrs, she will have saved $1,540. $2,000 ÷ $385 = 5.2 yrs.

Notes

Preparation and points to note

Like a number of other activities in this book, Saving Power takes students into unfamiliar territory and asks them to engage with adult scenarios – in this case, a scenario that involves power bills, loans, and savings. To get to the mathematics, they have to read and interpret the scenario and the questions.

All students bring with them a variety of experiences that will or will not have given them confidence that they can solve problems embedded in words. Problem solving can't be taught by always dissecting the information for students and rescuing them the moment they put their hand up. Students need to be given the tools, see their use modelled, and then learn how to choose and flexibly apply an increasing kit of tools to new problems. They need to learn that getting stuck is part of every problem-solving experience. (If they don't get stuck, the "problem" is not a problem!) They also need to learn that they must grapple with the difficulties until they find a way forward. Every time they do this and succeed, they strengthen their identities as learners of mathematics ("I can solve problems.")

The critical *thinking* needed for evaluating results is a suitable key competency focus for these activities.

Points of Entry: Mathematics

Several questions in this activity require inductive reasoning or leaps in thinking. Encourage the students to state in their own words exactly what it is that they are being asked to solve. Expect them to discuss their strategies and their reasoning. Get them to explain to each other, for example, how they decided which bill was which or why November is probably not an average month (higher than average sunshine in many places). Encourage them to recognise and discuss the assumptions that they have had to make when answering questions. (The scenario has been highly simplified to keep it manageable.)

Percentage is a very valuable mathematical tool. Its primary function is to enable comparisons. But percentages are used in a number of different ways (20% more, less 20%, add 20%, 20% of, 120% of, 80% of, and so on). There are usually different ways of expressing, calculating, and writing the same percentage (for example, 20% = 0.20 = 0.2, which are the same as $\frac{2}{10} = \frac{1}{5}$). Students should learn to express percentages as decimal numbers and use this format in any calculations that require use of a calculator.

You will probably need to do do some pre-teaching or revision of percentages before the students do this activity. Use examples that are similar in structure to those in the students' book, but leave those in the activity for the students to tackle themselves.

The activity requires students to think about percentages in different ways:

- **Activity One**, question **1**: Percentage as parts of 100 and as the proportional part of a whole.
- **Activity Two**, questions **2a** and **b**: Percentage as a measure of relative increase: parts per 100 more.
- **Activity Two**, question **3**: Percentage as a rate of interest: additional cost in dollars.

The activity specifies that the interest does not compound (flat rate). This is an appropriate simplification at this level.

Students who need a challenge could work out interest based on different payment schedules. For example, *If Jimmy's mum pays off $500 at the end of the year and 5% interest is added to the balance at the start of each year, what would she pay in total?*

Start of year 1: $2,000 +$100 (5% interest) = $2,100
Start of year 2: $2,100 – $500 (payment) + $80 (interest) = $1,680
Start of year 3: $1,680 – $500 (payment) + $59 (interest) = $1,239
Start of year 4: $1,239 – $500 (payment) + $37 (interest) = $776
Start of year 5: $776 – $500 (payment) + $13.80 = $289.80
End of year 5: $289.80 (final payment)
So Jimmy's mum would pay a total of $500 x 4 + $289.80 = $2,289.80

Points of Entry: Science

This activity provides another look at insulation, conservation, and alternative **energy**.* It relates back to other activities, such as Hypothermia. Use this as a starting point for more general discussions about ways of saving energy, for example, *How does insulation help to save power? Apart from the hot water cylinder, where else in the house should insulation be installed? How do double-glazed windows work?*

You could ask the students to research solar panels to find out how they work and where the best place to install one might be. Information is readily available on the Internet and in brochures at major building supplies and plumbing warehouses. Some suppliers have units on display.

This could stimulate the students' interest in eco-friendly choices and the economics of them. They could compare the costs and savings from solar panels with the savings from insulating the cylinder ($315 per year for $2,000 compared with $70 per year for $70) or the impact of other power-saving measures. Use Saving Power as a transition to the next activity, Using Electricity.

** For bolded terms, see glossary, pages 6–7.*

Pages 22–24: Using Electricity

Mathematics and Statistics Achievement Objectives

- Number strategies: Use a range of multiplication strategies when operating on whole numbers (Number and Algebra, level 4)
- Measurement: Interpret and use scales … and charts (Geometry and Measurement, level 4)
- Statistical investigation: Plan and conduct investigations using the statistical enquiry cycle:
  - gathering, sorting, and displaying multivariate category, measurement, and time-series data to detect patterns, variations, relationships, and trends;
  - communicating findings using appropriate displays (Statistics, level 4)

Mathematics standards. The approaches and thinking that students demonstrate as they engage with these tasks and problems can provide evidence in relation to the mathematics standards.

Science Achievement Objectives

- Investigating in science: Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations (Nature of Science, levels 3–4)
- Physical inquiry and physics concepts: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as … heat (Physical World, levels 3–4)
- Participating and contributing: Use their growing science knowledge when considering issues of concern to them (Nature of Science, levels 3–4)

Mathematics and statistics context

Students will:

- convert between watts (W) and joules (J)
- measure and record category data for 2 variables (the dependent variable is boiling time; the independent variable is volume of water)
- calculate energy consumption of appliances based on usage time estimates.

Students should discover that:

- small changes in usage patterns can have a big impact on energy consumption.

Science context

Students will:

- investigate how the volume of water in a kettle affects the time it takes to boil
- use their results to suggest ways to reduce electrical power consumption in their homes.

Students should discover that:

- joules (energy), watts (electrical power), and watt hours (electrical metering) have specific meanings in terms of electrical appliances and that they relate to each other
- kettles boil faster with less water in them
- electricity bills are based on energy used over time and, therefore, increased wattage means increased power consumption and higher bills
- there is a big difference in how much electrical energy one appliance uses compared with another.

Answers

Activity One

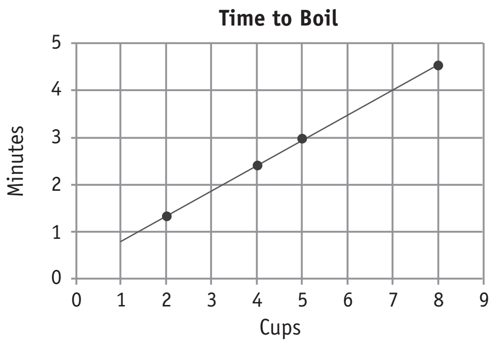
1. 18 000 kJ. (1 kWh is 3 600 kJ, so 5 kWh is 5 x 3 600 = 18 000 kJ)
2. 432 000 J (432 kJ). (60 x 3 600 x 2 = 432 000)
3. **a.** 0.042 kWh. (150 kJ ÷ 3 600 kJ = 0.042 kWh)

   b. 25 min. (A 100 W bulb uses 100 J each second (s) or 1 000 J [1 kJ] every 10 s. This equates to 150 kJ in 1 500 s or 1500 ÷ 60 = 25 min.)

4. Electricity bills are in kilowatt-hours (also called units) instead of joules because a joule (and even a kilojoule) is a very small amount of energy. The average New Zealand household uses about 900 kWh of electricity per month, which is 3 240 000 000 J, or 3 240 000 kJ. Imagine finding numbers like these on the monthly power bill!

Activity Two

1. a.–e. Practical activity and graph. The following graph is actual data from an experiment using a 2200 W jug. The graph shows that boiling time is linear: for every extra cup of water that you put in the jug, you have to add about the same amount of time.



2. Boiling a full jug for 1 or 2 cups definitely wastes energy because you are heating water that you don't need. And it is true that a full jug takes about twice as long to boil as half a jug.

3. a. Answers will vary, depending on the results of your experiment. Here is the energy usage for the data in the graph:

Cups	Seconds	2.2 kWh x seconds ÷ 3 600
2	80	0.05
4	153	0.09
5	178	0.11
8	280	0.17

b. Answers will vary. The jug used to obtain the data in the graph took 0.17 kWh of power to boil 8 cups (a full jug) and just 0.03 kWh to boil 1 cup. This means 0.14 kWh (0.17 – 0.03) was wasted.

c. Answers will vary. Using the data from the graph above, 0.14 kWh is wasted. 0.14 kWh is 140 W. This is enough power to run a 100 W bulb for 1.4 hours (1 hour 24 minutes).

4. a.–b. Practical activity. Answers will vary, but you should find that the warm (half-hot, half-cold) water boils much faster than 8 cups of cold water. In fact, it shouldn't take much more time to boil 4 hot + 4 cold than 4 cold. The hot water has already received a lot of energy and doesn't require much more to bring it to the boil again. So it's more efficient to reboil a jug containing warm water than to empty it and use fresh cold water.

Activity Three

1. Tables will vary. Here is a sample set for some data, including their energy use for question **2a**:

Appliance	Wattage	Time used (hours per week)	Energy (kWh)
100 W light bulb	100	30	3
Clock radio	4	168	0.67
Fridge or freezer	50 (average)*	$\frac{1}{4}$ of 24 x 7 = 84	2.1
Stereo	30	6	0.18
Television	300	6	1.8
Hot-water heater	5 500	$\frac{1}{2}$ hour shower x 7 = 3.5	19.25

2. a.–c. Answers and suggestions will vary. For the sample data above, weekly estimated energy use is 27 kWh; the hot-water heater used by far the most energy. A lot depends on patterns of use and the particular appliance. For example, if you spend a long time looking into the fridge with the door open but take only quick, warmish showers, fridge energy use will be higher and water-heating energy use lower.

* Note that the energy use of fridges and freezers fluctuates dramatically within a 24 hour period. These appliances have compressors that cycle on and off at intervals (you can hear them "kick in" shortly after you have had the door open) to maintain the required degree of cold (see the answer to question **3**).

d. Suggestions will vary. Possibilities could include: having showers rather than baths; reducing shower time (in many homes, this is the single greatest use of electricity); only boiling approximately the amount of water in the jug that you need (but covering the element!); putting on warmer clothes instead of switching on a heater; not using hot water when cold will do (including for washing clothes); not using an air conditioner unnecessarily; setting the thermostat of a heat pump a little lower; not leaving lights on in unoccupied parts of the house; using energy-saving bulbs in light fittings; and drying clothes on the line or on a clothes rack instead of in the dryer.

3. Estimates will vary. A suggested estimate is 700 million kWh.

The compressor in a modern fridge is typically rated 250–600 W, but it only runs at this rate intermittently. When the compressor is silent, a fridge uses a very small amount of electricitiy, typically 3–5 W. For this reason, the table provided suggests 50 W (0.05 kW) as an average rating. If a fridge is using 0.5 kW for 8 736 (24 x 7 x 52) hours per year, it will consume 437 kWh of electricity.

Using this figure, getting rid of the second appliance would save about 437 kWh per household per year. If there are 1.58 households, this equates to 437 x 1 580 000 = 690 460 000. As this figure is based on very rough data, a suggested estimate would be 700 million kWh.

Notes

Preparation and points to note

This activity brings together themes from previous activities in the book: food **energy*** values, unit conversions, relationships and trends in experimental data, rates, energy usage, and energy conservation. Make sure the students have had some exposure to **joules** as a measure of energy prior to starting the activity, and as they work, link ideas back to the related ideas in Tramping against Gravity, Wind Power, and Food Energy.

Boiling water and using electrical appliances near water is dangerous. While a jug is a common kitchen appliance, not all students will understand the potential hazards, particularly the risk of scalding by steam. Set very clear rules concerning how the jug(s) should be used. *Make sure that no one lifts the lid while the jug is boiling or immediately after it has been switched off*. Check that the jugs you use are in good order and that the cords are not frayed in any way. Also check whether the jug has an exposed heating coil. If it does have a coil, it is very important that the students don't attempt to boil very small amounts of water that won't completely cover the coil.

Much of the science language and concepts in this activity will be relatively new to students: exposure to a rich range of language strengthens the key competency of *using languages, symbols, and texts*.

Points of Entry: Mathematics

These activities look at energy usage in three different ways: converting between different measures of energy, measuring the energy use of an electric jug, and estimating the relative energy usage of different appliances. (A useful New Zealand website is www.pmb.co.nz/power_usage.htm
An American one is www.energysavers.gov/your_home/appliances/index.cfm/mytopic=10040)

Activity One requires the students to think carefully about different units and to use a known equivalence (see the energy character's speech box) such as 1 kWh = 3 600 kJ as a "bridge" between them. For example, in question **1**, the students need to be able to say "1 **kilowatt-hour** equals 3 600 kilojoules, so 5 kilowatt-hours must equal 5 times that number of **kilojoules**. That's 5 x 3 600 = 18 000 kilojoules."

Similarly, for question **2**, the students need to use as the "bridge" the information that **joules** (J) = **watts** (W) x time in seconds. 2 hours is 2 x 60 x 60 = 7 200 seconds. So the 60 W bulb uses 60 x 7 200 = 432 000 J.

* *For bolded terms, see glossary, pages 6–7.*

Check that the students can relate the different units to real life. For example, an electricity bill is a measure of how much power has been used over a set period of time because appliances continue to draw power every second they are used. When talking about energy from food, we do not factor in time because it doesn't matter how quickly or slowly we eat an apple, we get exactly the same number of joules from it.

Activity Two involves boiling water in an electric jug. Make sure that the students focus on the trend instead of the individual data values. Jugs vary in size, shape, capacity, and power. So do household cups. It doesn't matter what the capacities of the jug and cup are as long as each group uses the same jug and cup throughout the experiment. Different groups can use different equipment. If they do, results will vary but the trend should be very similar.

If your students have done other experiments in this book, they should be capable of identifying the **variables** in this one: **independent** (those that we change), **dependent** (those that change as a result of our changes), and **controlled** (those that we deliberately keep the same). Remind them that, when graphing, the independent variable (cups of water) goes on the x-axis and the dependent variable (time) on the y-axis. If they enter their data in a spreadsheet, they can very easily produce a scatter plot similar to the one shown in the answers. To add a trend line, they should go Chart/Add Trendline. Alternatively, they could create a line graph.

Discuss the shape of the graph and why it has that shape, especially in the context of question **2**. The shape should approximate to a straight line. In other words, there is a linear relationship between amount of water and boiling time. This should not be surprising. Every cup of water requires exactly the same amount of energy to take it from tap temperature to boiling. So 2 cups require twice the energy of 1 cup. Interestingly, the graph in the answers shows that the first cup took a little longer than the other cups (the trend line does not go through [0,0]) to reach boiling point. The likely reason is that the metal jug absorbed some of the energy that would otherwise have gone into the water.

As with any statistical investigation, reinforce the elements of the statistical enquiry cycle: problem, plan, data, analysis, conclusion. Prompt the students to think about why they are asked to start each time with cold water (controlled trials).

For **Activity Three**, caution the students not to underestimate their energy use. And, as with any activity involving estimation, remind them that an estimate is different from a guess. The table provided includes a range of appliances for both summer and winter, and not all the items will apply to all students. The figures given are approximate only but are sufficient for the students to use for their estimates.

For information on fridge energy use, see
http://oee.nrcan.gc.ca/residential/business/manufacturers/search/refrigerator-search.cfm.

According to the Energy Efficiency and Conservation Authority (EECA.govt.nz), New Zealand households consumed 63 500 terajoules of energy in 2007, which averages to about 40 million kJ or 11 000 kWh per household per year. A typical student's consumption is therefore likely to be in the order of 30–40 kWh per week. See www.physics.otago.ac.nz/eman/hew/ehome/energyuse.html for more detailed information.

Points of Entry: Science

Activity One is designed to encourage the students to discuss the units of **electrical energy** and what they actually mean in everyday language and contexts. The class could find out what the school power bill was for the previous month and how the school usage in summer compares with that in winter. The students could interview the principal about power saving ideas in the school. They could then design a power-saving campaign and monitor the school's power usage over a month. Some electricity suppliers produce usage graphs for the previous 3 months. Such graphs are a further potentially useful source of data.

Activity Two raises an important experimental issue: how can you judge exactly when the water starts boiling – especially when the lid is on the jug (as it must be). Make sure that the students agree what will signal when the water reaches boiling point and it's time to stop the timer. A good signal is the automatic cut-off switch on the kettle. When the light or switch trips, stop the timer. However, if the jug being used doesn't have a prompt or sensitive cut off (that is, continues boiling even after the water reaches boiling point), you could do a class experiment to establish the boiling point. Depending on the jug, the students are likely to find that sound is their best clue. In many jugs, as the water nears boiling point, the noise quietens and turns to a low growl and the splashing of bubbling water can be heard.

Ask the students to think about what happens when a liquid boils. *Is this a physical or chemical change?* The students should understand that each liquid has its own particular boiling point and that when it boils, it changes from a liquid to a gaseous state. To do this, the molecules need to gain energy, which is provided in the form of heat. Scientists view temperature as a measure of the average internal energy of a system. It takes more energy to boil a saucepan of water than a cup of water.

Possible misconceptions that you may want to clarify with your students:

- All electrical appliances use the same amount of power.
- Silver jugs heat up faster than plastic ones because they are made of metal, which is a better conductor.
- Water boils when the jug clicks off (some automatic cut-off switches are not sensitive, and the water may continue boiling after it has reached boiling point).

Given that warm or hot water in a jug boils more rapidly than cold, you could ask your students to think about whether it is a good idea to fill the jug from the hot tap. (It isn't. In most homes, hot water has to travel some distance from the cylinder or the on-demand unit. 3 m of standard 20 mm diameter water pipe contains nearly 1 L of water. So, if the source of the water is 6 m from the kitchen, you have to fill the pipe with nearly 2 L of hot water before any reaches you at the tap. So, to boil 1 L from the hot tap, you had to heat 3 L in the tank. But you still need to use further energy to heat the hot water in the jug to boiling point – for possibly 1 cup of boiling water!

Activity Three invites students to look at energy use in the home. Find out what they already know: *Do you know how much your family spends on electricity?* Parents or caregivers may be able to show them a recent power account. Ask *Do you have any idea which of your activities contribute most to household electricity use?* Electrical energy is versatile, clean, efficient, and can be moved from place to place with relative ease, but on the whole, we are incredibly wasteful of it as a resource. Encourage your students to investigate this issue in more detail. They have a lot of information at their fingertips at home. Almost all electrical appliances have the power consumption (in watts or **kilowatts**) marked on them, and anyone can read the electricity meters on the switchboard. You could challenge the students to investigate or monitor some aspect of their household power usage for a period of time and then report back to the class as a whole.

Students can investigate further on age-appropriate websites such as:
www.sustainability.govt.nz
www.energywise.govt.nz
www.wcl.govt.nz/teens/eco_news.html
http://tonto.eia.doe.gov/kids/index.cfm
www.eere.energy.gov/kids
www.epa.gov/students

Station cards

Station 1: Rubbing Hands

Press your hands together. Rub one palm vigorously against the other.

a. What happens to your hands?

b. What happens to the energy in your muscles?

Station 2: Beating Water

a. i. Fill a plastic bowl with tap water and use a thermometer to measure the temperature of the water.

ii. Using an egg beater, take turns to beat the water as hard as you can for about 1 minute each and then immediately measure the temperature of the water.

b. i. What happens to the temperature of the water?

ii. What happens to the energy you used to beat the water?

Station 3: Rolling a Can

Gently push the can so that it rolls away from you.

a. How did the can move?

b. i. What happens to the rubber band inside the can as the can rolls forward?

ii. What happens to the energy in the rubber band after the can reaches the farthest point away from you?

Station 4: Bending a Paper Clip

Pick up a paper clip and feel how cool it is. Open the clip and bend it back and forth several times (try not to break it).

What happens to the temperature of the paper clip where you bend it?

Station 5: Lifting a Weight

Lift the weight at this station.

a. What happens to the energy of the weight when you lift it?

b. What would happen to your energy if you were to keep lifting the weight as many times as you can?

Station 6: Playing a Guitar

Gillian is experimenting with different ways of playing her guitar.

Using the instrument at this station, determine what will happen to the sound of Gillian's guitar if she strums more energetically.

Station 1: Rubbing Hands

The thermal energy needed to heat a cup of tea by 1°C is approximately 1 000 joules (J). When you press your palms together firmly and rub them back and forth, the work you do against the force of friction is about 0.8 J per rub (1 movement up and down). How many times will you need to rub your hands to make enough heat to warm your cup of tea by 1°?

Answer: ....

Station 2: Beating Water

The thermal energy needed to heat a 1 litre (1 kg) bowl of water by 1°C is approximately equal to the work of lifting the litre of water a distance of 400 m. If the egg beater lifts the water about 8 cm every turn, how many turns do you need to heat the water by 5°?

Answer: ....

Station 3: Rolling a Can

Each twist of the rubber band inside the can stores energy. If the rubber band twists $\frac{2}{3}$ of a full turn for every 10 cm the can travels, how far will the can roll back when the rubber band is twisted 6 full turns?

Answer: ....

Station 4: Bending a Paper Clip

The energy you use to bend the paper clip is equal to the weight of your arms multiplied by the height you lift them. 1 joule is about 1 kg x 10 cm. If your arms weigh about 10 kg and you lift them 1 cm each time you bend the clip, estimate how many joules of energy you put into the paper clip.

Answer: ....

Station 5: Lifting a Weight

When you lift a weight, its energy increases by its weight multiplied by the height you lift it. 1 joule is about 1 kg x 10 cm. How many joules of energy do you put into the weight?

Answer: ....

Station 6: Playing a Guitar

Gillian is playing an electric guitar. The louder she sets the volume on the amplifier, the greater the distance the membrane in the speaker moves and the greater the energy the speaker has to draw from the batteries or wall outlet.

Complete the pattern of volume settings and energy use for Gillian's guitar amplifier:

Volume setting	Low	2	3	4	5	6	7	8	9	Max
Energy used per hour in joules		3.4 J	3.8 J	4.2 J						6.6 J

How much energy does Gillian's amplifier use at the lowest setting?

Answer: ....

Copymaster: Pages 2–3: Playing with Energy

Example of energy	Type of energy (potential or kinetic)
Petrol	
A stretched rubber band	
A battery	
2 billiard balls colliding	
An apple falling from the tree	
A flying rubber band	
A child riding a bicycle	
A vibrating bass drum	
Air blowing out of a hairdryer	
Hot springs	

Copymaster: Pages 2–3: Playing with Energy

Energy game cards

1. **Wind** The wind is blowing at 300 metres per minute. **Move forward 1 space for each metre per second of wind speed.**	**2.** **Tornado** The energy in a small tornado can be equivalent to as much as 10 000 kilowatt-hours. A typical household uses 28 kilowatt-hours of energy a day. **Move forward the number of years it would take a typical household to consume as much energy as a tornado.**	**3.** **Rain** Rain is falling at 180 millimetres an hour. **Move forward the number of millimetres per minute.**

4.

Running

Keisha can run 5 kilometres in 30 minutes.

Move forward 1 space for each kilometre she runs in 12 minutes.

5.

Earthquake

Each whole number on the Richter scale represents an earthquake that is 10 times more powerful than the preceding one. That is, a 2.0 earthquake is 10 times more powerful than a 1.0 earthquake.

Move forward the number on the Richter scale that is 100 times more powerful than a 2.0 earthquake.

6.

Kumar can cycle 24 kilometres in an hour.

Move forward the number of kilometres he rides in 10 minutes.

7.

Travelling by car

From Levin to Hamilton is 420 kilometres.

Move forward 1 space for each hour it takes to reach Hamilton at an average speed of 70 kilometres per hour.

8.

Sefo can kick a soccer ball 33 metres.

Move forward the number of kicks it will take him to kick the ball the length of a 100 metre soccer field.

9.

A shout

Sound travels at 0.34 kilometres per second.

Move forward 1 space for each kilometre that sound travels in 9 seconds.

10.

A ski-lift carries 7 200 people every hour.

Move forward the number of people it carries each second.

11.

PENALTY

Energy drain! Your cellphone has a dead battery.

Lose 2 potential energy tokens.

12.

PENALTY

You forgot to eat lunch!

Lose all your potential energy tokens.

13.

You catch a big wave.

Surf ahead 5.

14.

Wind

A 19 kilometre per hour wind is about 10 knots.

Move forward at the speed in knots of a 9.5 kilometre per hour wind.

15.

Tornado

The winds in a tornado can blow at speeds of greater than 180 kilometres per hour, but the tornado itself may move forward at only 30 kilometres per hour.

Move forward the number of minutes it would take this tornado to travel 2 kilometres.

16.

Helen burns 500 kilojoules in 10 minutes of skateboarding.

Move forward 1 space for each minute she needs to burn 300 kilojoules.

17.

Rain

MetService predicts 16 millimetres of rain between 8 a.m. and noon.

Move forward 1 space for each millimetre that falls in an average hour.

18.

Jogging

Dina burns 250 kilojoules in 5 minutes of jogging.

Move forward 1 space for each minute she needs to burn 150 kilojoules.

19.

Earthquake

Each whole number on the Richter scale represents an earthquake that is 10 times more powerful than the preceding one. That is, a 6.0 earthquake is 100 times more powerful than a 4.0 earthquake.

Move forward the number on the Richter scale that is 1 000 times more powerful than a 1.0 earthquake.

20.

A half-full kettle boils in 90 seconds.

Move forward the number of minutes a one-third full kettle takes to boil.

21.

Kumar burns 500 kilojoules in 10 minutes of cycling.

Move 1 square for each minute he needs to burn 100 kilojoules.

22. Travelling by car

From Christchurch to Kaikoura is 180 kilometres.

Move forward 1 space for each hour it takes to reach Kaikoura at an average speed of 60 kilometres per hour.

23. Rolling ball

A ball rolling downhill travels 2 metres the first second, 4 metres the next, 6 metres the next, and so on,

Move 1 space for each second it takes to travel 30 metres.

24.

Sefo burns 1 kilojoule per second playing soccer.

Move forward 1 square for each minute he needs to burn 300 kilojoules.

25.

A skier is travelling downhill at 30 kilometres per hour.

Move forward 1 square for each kilometre he travels in 8 minutes.

26. PENALTY

Too much friction!

You're stuck on this square.

27. BONUS

You get a new skateboard.

Skate ahead 4 spaces.

28. BONUS

You catch a tail wind.

Move ahead 3 spaces.

29. PENALTY

Your rubber band snaps!

Lose 1 potential energy token.

30. BONUS

You remember to charge your cellphone.

Gain 3 potential energy tokens.

Copymaster: Pages 4–5: Measuring Potential

Pendulum Swings				
Weight	**Height of bob at start**			
	Height 1: ____	Height 2: ____	Height 3: ____	Height 4: ____
Number of weights (washers)	Distance the block moved			

Energy Values				
Weight	**Height of bob at start**			
	Height 1: ____	Height 2: ____	Height 3: ____	Height 4: ____
Number of weights (washers)	Energy value: weight x height			

Copymaster: Pages 6–7: Bungy Jump Energy

Bungy Trials				
Weight (number of marbles)	Stretch (difference in height)			
	Trial 1	Trial 2	Trial 3	Average
2				

Copymaster: Pages 8–9: Food Energy

	Suggested daily energy intake (in kJ) by level of physical activity (www.mydailyintake.net/di_calculator.php)			
Age	**Boys**		**Girls**	
	Not active	Very active	Not active	Very active
9	6 800	9 700	6 400	9 100
10	7 300	10 400	6 700	9 500
11	7 700	11 000	7 000	10 000
12	8 200	11 600	7 400	10 600
13	8 700	12 400	7 800	11 100

Copymaster: Pages 10–11: Energy Density

Water Content and Energy Density							
A	B	C	D	E	F	G	H
Food	Original mass (g)	Energy density in kJ/g (not dehydrated)	Energy (kJ)	Normal water content (% by mass)	Dry mass (g)	Mass saved (g)	Energy density (kJ/g, dehydrated)
Apples	450	1.5		85			
Bananas	610	3.4		76			
Beef	540	9		54			
Carrots	420	0.8		88			
Peas	450	2		89			
Rice	280	5.2		10			
Dried fruit and nuts	150	7.5		0			
Total							

Copymaster: Pages 12–13: Wind Chill

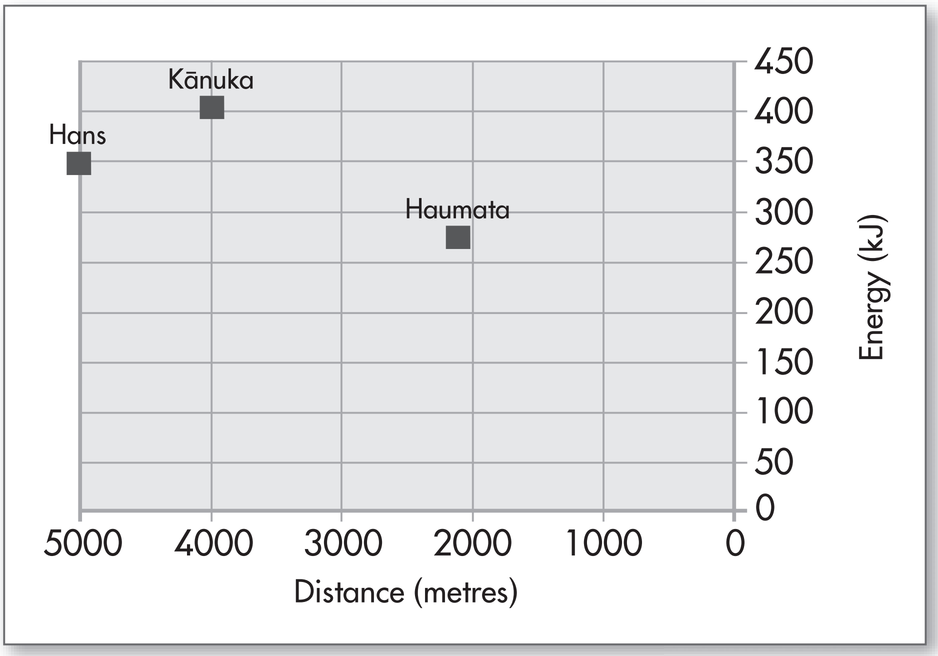
Wind Chill Experiment					
"Wind"	Water temperature (C°)				
	1 min	2 min	3 min	4 min	5 min
No fan					
Low					
Medium					
High					

Wind Chill Experiment					
"Wind"	Water temperature (C°)				
	1 min	2 min	3 min	4 min	5 min
No fan					
Low					
Medium					
High					

Wind Chill Experiment		
"Wind"	Water temperature (C°)	
	Loss over 5 min (°C)	Energy transferred from water to air (J)
No fan		
Low		
Medium		
High		

Wind Chill Experiment		
"Wind"	Water temperature (C°)	
	Loss over 5 min (°C)	Energy transferred from water to air (J)
No fan		
Low		
Medium		
High		

Copymaster: Pages 14–15: Tramping against Gravity



Copymaster: Pages 16–17: Hypothermia

Clothing type	2 ice cubes, starting mass (g)	2 ice cubes, final mass (g)	Mass lost (g)	Energy transferred (J)	Clothing mass (g)	Insulating effect (J) [energy from bare hands minus energy for this type], for question 2	Energy savings by mass (insulating effect ÷ clothing mass)
Bare hand							
Thick glove							
Aluminium foil "survival blanket"							
Plastic and paper layers							

Copymaster: Pages 22–24: Using Electricity

Appliance	Wattage	Hours per week	Energy (kWh)
100 W light bulb	100		
Air conditioner	1 050		
Ceiling fan	70		
Clock radio	4		
Compact fluorescent light bulb – 60W equivalent	18		
Computer (including monitor & printer)	200		
Dishwasher	1 300		
Electric blanket	60		
Electric oven	5 000		
Fan (portable)	115		
Hairdryer	1 200		
Kettle	1 500		
Microwave oven	1 000		
Fridge or freezer	50 (average)		
Hot-water heater	5 500		
Stereo	30		
Television (regular)	110		
Television (large screen, high definition)	300		
Toaster	1 250		
Vacuum cleaner	800		
Washing machine	500		
Clothes dryer	3 500		
Heater	1 500		
Your total			