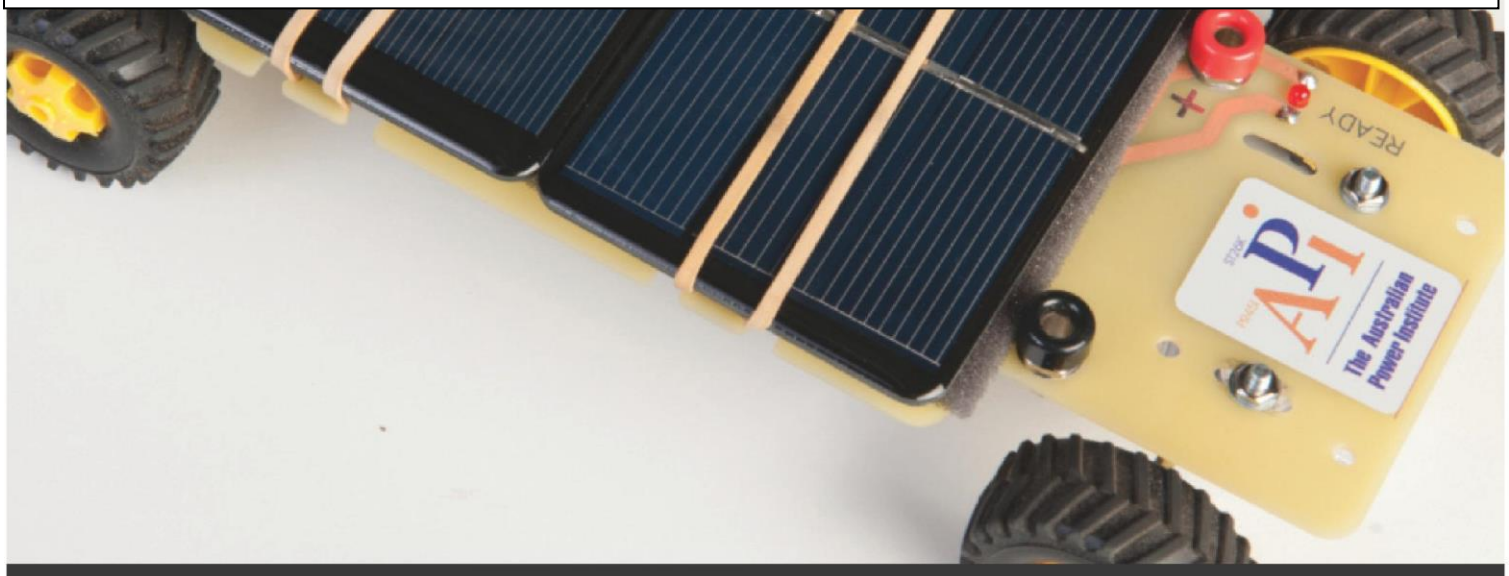
STUDENT BOOKLET

ATSE STELR PROJECT

SOLAR CARS

MATHEMATICS OF GEARS



NAME

CLASS

Become a power engineer and power our world!

BRAIN TEASER

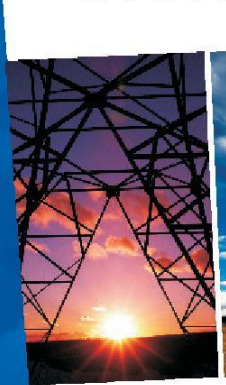
A) At midday, there is approximately 1kilowatt (1kW) per square metre of solar energy reaching the tropical latitudes. If solar panels were 20% efficient at converting solar energy to electricity, how many panels, each 2 metre long and 1metre wide, do we need to supply the average household load of 2kW?

B) How many solar panels would you need to supply a 1000 megawatt (1000 MW) aluminium smelter at midday under the same conditions, 1 MW being 1000 kilowatts.

Is this a practical solution?
What are the alternatives given that we still need to make aluminuim 24/7? Continuing with coal fired generation and closing the aluminium smelter are only two of them.
This indicates the kind of challenges you'll encounter as a power engineer!

Electricity impacts everyone's life. Although it is invisible, it is something real and essential. Think about life with limited or no electricity - it would be near impossible to live like we do today. By choosing power engineering as your career choice today, you can make sure we have electricity for tomorrow. You will also have the opportunity to champion change and help the electricity industry control greenhouse gases and develop sustainable energy solutions to help us maintain our lifestyle.

Power engineering offers opportunities to work across Australia and the world, and it can reward you with good pay, a good lifestyle and a great career. Even better, the industry offers scholarships, bursaries and work experience to assist you in your studies, and graduate programs that provide jobs straight out of university. If you enjoy teamwork, practical problem solving, maths and science, you may have what it takes!



For more information about power engineering and relevant universities, visit www.api.edu.au and www.powerengineering.org.au

The Australian Power Institute

Answers to brain teasers: a) 5 panels b) 2.5 million panels

www.api.edu.au

INVESTIGATION INTO HOW GEARS WORK

INTRODUCTION

You may know that gears on a bike make it easier to pedal uphill or faster to go along the flat, but how do they actually make a difference?

In this investigation we look at how to calculate gear ratios and what differences they make to driving a car (or riding a bike)

EQUIPMENT

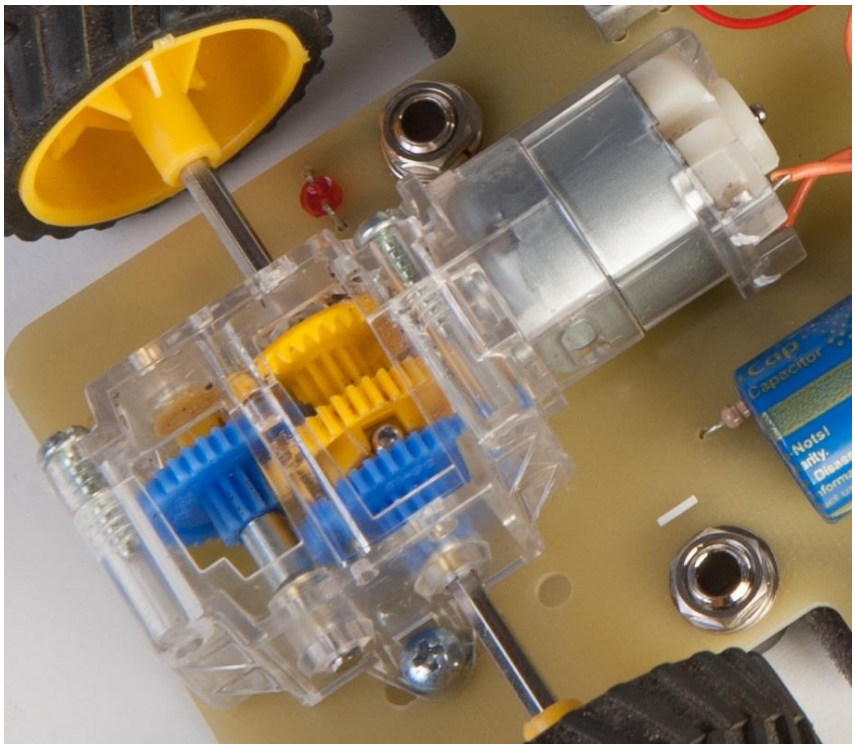
STELR solar car kit

Screwdriver

INQUIRY QUESTION

What are the most efficient gear combinations to make my solar car:

a. Go faster,
b. Go up a steeper hill, or
c. Pull with more power?



VOCABULARY

Gear,

Drive gear,

Driven gear,

Gear train,

Idler gear,

Compound gear,

Crown gear,

Torque

BACKGROUND INFORMATION

Gears

Gears are examples of **wheel and axle machines**.

Gears have evenly spaced teeth called cogs.

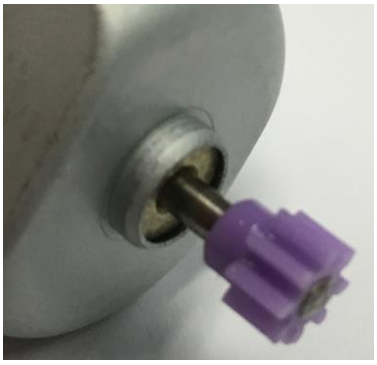
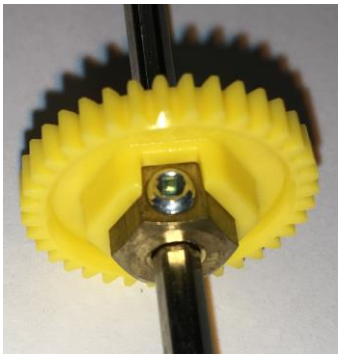
A **cog** is a tooth on the rim of a wheel or gear.

The cogs on gears fit into each other so that when one gear turns, it causes the other gear to turn.

If two gears are connected, when one gear turns clockwise, it will cause the next gear to turn anticlockwise.

Drive and driven gears

The *drive gear*, or input gear, takes the energy from the motor and transfers it to the *driven gear*, or output gear, to make the axle spin.

		
Drive gear or input gear (attached to motor).	Driven gear or output gear (attached to axle).	Compound gear A compund gear has two (or more) gears fixed together.

Example

The STELR wind turbine has two gears as shown in this photo.

The top gear has 30 teeth. The bottom gear has 12 teeth.

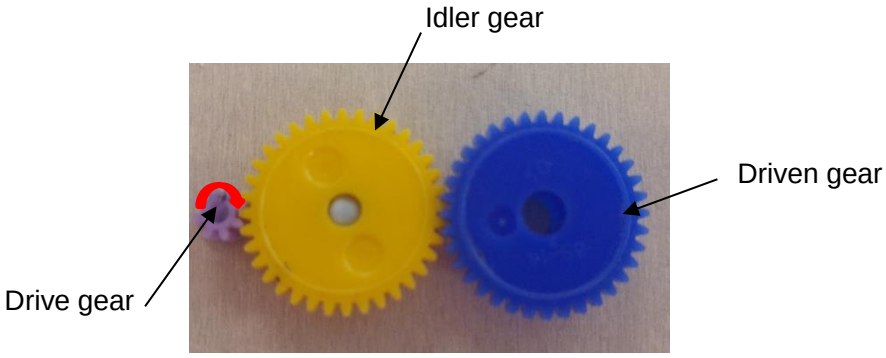
If the top gear rotates once, 30 teeth will pass through the point of contact. The bottom gear will have to rotate 2.5 times so that 30 teeth also pass through the point of contact.

If the top gear rotates in a clockwise direction, the bottom gear will rotate in the anticlockwise direction.

Idler gears

A system of gears working together are known as a *gear train*. In a simple gear train the gears between the drive gear and driven gear are *idler gears*. These do not contribute to the gear ratio (no matter what their size), but change direction of rotation or extend the distance between the drive and the driven gear.

In the diagram below, the arrow, , shows the direction of rotation for the drive gear.



For each gear, write down the direction of rotation (clockwise or anticlockwise).

Drive gear: Clockwise

Idler Gear: _____

Driven gear: _____

Gear ratios

To calculate the gear ratio, divide the number of teeth on the driven gear by the number of teeth on the drive gear. Using the gears with your solar car, or the picture above, first count the number of teeth on each gear, and then calculate the gear ratio.

$$\text{Gear ratio} = \frac{\text{\# teeth on driven gear}}{\text{\# teeth on drive gear}}$$

$$= \frac{32}{8}$$

$$= \frac{4}{1}$$

Or 4:1

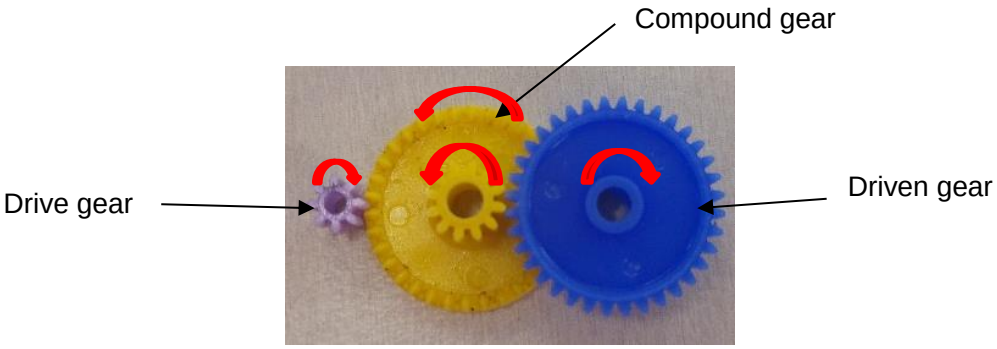
The drive gear turns 4 times to make the driven gear turn once.

For another explanation on how to calculate gear ratios go to

http://www.wikihow.com/Determine-Gear-Ratio

Compound gears

In a gear train with compound gears, like in the solar car, the gear ratio does change.
The benefits of compound gear trains are you can change the speed of the gears and as the gears overlap, the gear trains takes up less space.



To calculate the gear ratio of a compound gear, multiply the gear ratios of each stage of the gear train.

Stage 1 drive gear (purple in the photo) and outer ring of the compound gear (yellow)

$$\text{Gear ratio} = \frac{\#\text{ teeth on outside compound gear}}{\#\text{ teeth on drive gear}}$$

$$= \frac{34}{8}$$

Stage 2 inner ring of compound gear (yellow) and driven gear (blue)

$$\text{Gear ratio} = \frac{\#\text{ teeth on driven gear}}{\#\text{ teeth on inside compound gear}}$$

$$\frac{36}{12}$$

The final ratio is found by multiplying the two stage ratios together:

$$\text{Final ratio} = \frac{\#\text{ teeth on outside compound gear}}{\#\text{ teeth on drive gear}} \times \frac{\#\text{ teeth on driven gear}}{\#\text{ teeth on inside compound gear}}$$

$$= \frac{34}{8} \times \frac{36}{12}$$

$$= \frac{17}{4} \times \frac{3}{1}$$

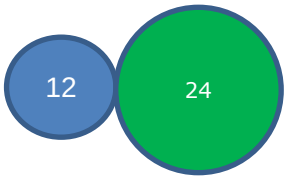
$$= \frac{51}{4}$$

Or 12.75:1 (The drive gear turns 12.75 times to make the driven gear turn once.)

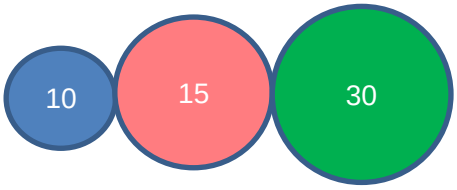
CALCULATE GEAR RATIOS

Work out the gear ratios of these gears: (numbers inside the circles are the numbers of teeth on each gear) Blue=drive gear, green=driven gear, pink=idler gear, yellow=compound gear

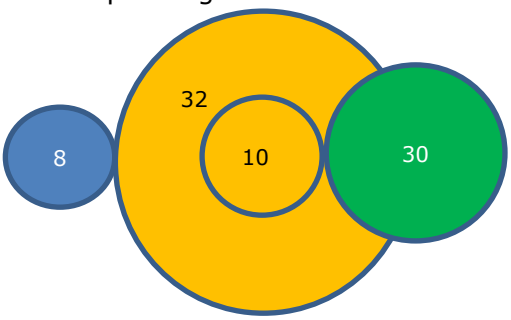
1: Simple meshed gear



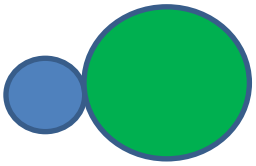
2: Simple gear train with idler gear



3: Compound gear train



4: Choose the correct words to make these statements true for these gear trains.



When the drive gear is smaller than the driven gear:

The drive gear will turn MORE/LESS times than the driven gear.

The drive gear will turn FASTER/SLOWER than the driven gear.

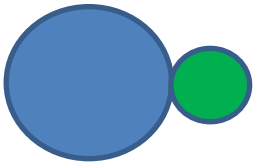
The driven gear produces MORE/LESS torque.

5: When the drive gear is larger than the driven gear:

The drive gear will turn MORE/LESS times than the driven gear.

The drive gear will turn FASTER/SLOWER than the driven gear.

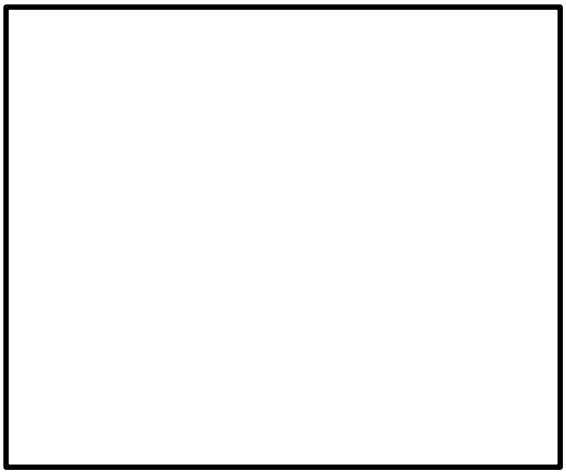
The driven gear produces MORE/LESS speed.



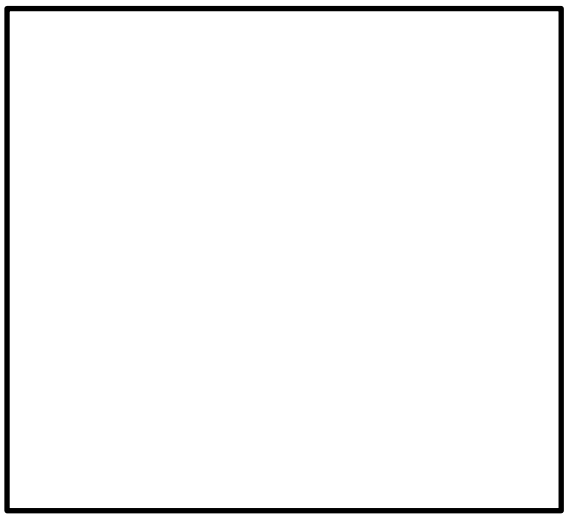
CREATE YOUR OWN GEAR TRAIN

For this part of the activity you may like to use the following applet from Geogebra:
https://ggbm.at/j6ajgbra

1: Create a gear diagram to show a gear to create torque. Calculate the gear ratio for your gear.



2: Create a gear diagram to show a gear to create speed. Calculate the gear ratio for your gear.



3: What do you notice about the gear ratio for speed compared to the gear ratio for torque?

THE STELR SOLAR CAR GEARBOX

This is the link to the STELR video about changing gears in your solar car.

https://www.youtube.com/watch?v=dcpdUAC5-5k&feature=youtu.be

In the solar car kit, there are four gears (cog wheels). The number of teeth on the outer and inner gears are printed on the gear body.

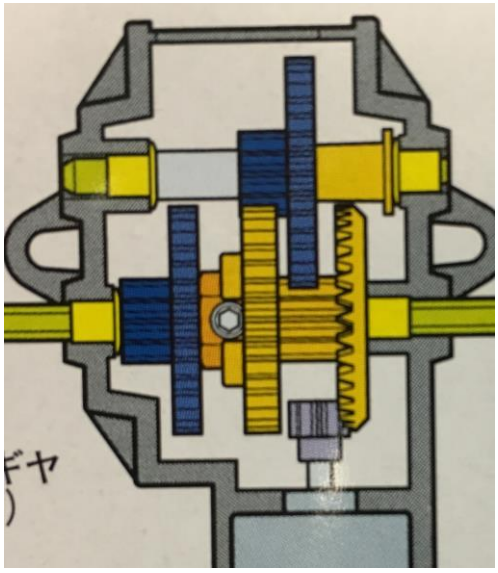
	
Drive gear (8T) Delivers the force of the motor to the next gear.	**Compound gear** (36T/12T) The compound gear can rotate freely on an axle.
	
Crown gear (34T/12T) The crown gear changes the direction of rotation by 90°. The crown gear can rotate freely on an axle.	**Driven gear** (36T) This is connected to the axle by fitting over a hex nut. It makes the axle rotate. It delivers the force to the axle. The turning effect of the force is called 'torque'.

Normal speed, normal torque

When you have the gear set up in 'medium speed' mode (the mode it is set up in originally) what is the gear ratio?

Hint: calculate the separate stages and multiply ratios together.

- Purple drive to yellow crown outside gears
- Yellow crown inside to blue outside gears
- Blue inside to yellow driven gears



1: How many times must the drive gear turn to make the driven gear (and the car wheels) turn once?

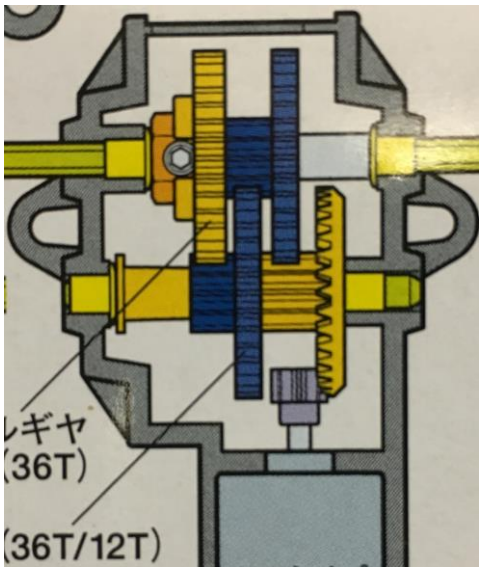
More torque, less speed

To make a car climb up a steep slope, or carry a heavy mode, you need to increase the **torque**.

This happens if it takes more turns of the drive gear to make the driven gear turn once.

1: From the work you did previously, would you expect the gear ratio when the gears are set up in 'torque' mode to be less or more?

2: Calculate the gear ratio when the gears are in 'torque' mode.



3: How many times must the drive gear turn to make the driven gear (and the car wheels) turn once?

Activity

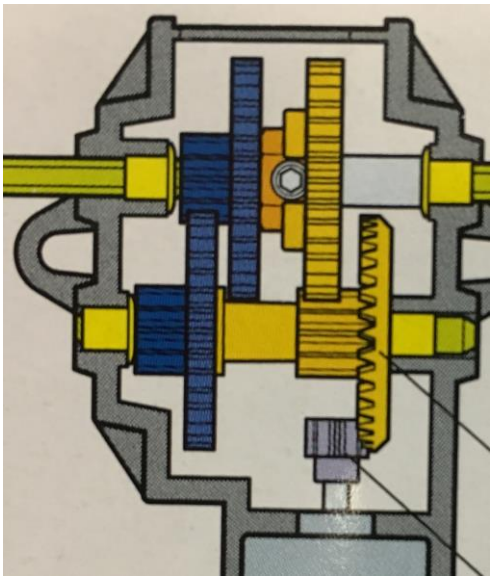
Build this gearbox and describe how it affects the performance of the car.

Use the capacitor to run the motor if necessary.

More speed, less torque

To make the car go faster, you need the drive gear to turn fewer times to make the driven gear (and the car wheels) to turn once. The wheels will spin faster, but the car will have less power. It might not move when going up a slope.

1: Calculate the gear ratio when the gears are in high speed mode. The blue gears in this case are only used as spacers. They do not contribute to the gear ratio.



2: How many times must the drive gear turn to make the driven gear (and the car wheels) turn once?

Activity

Build this gearbox and describe how it affects the performance of the car.

Use the capacitor to run the motor if necessary.

Summary

1: Which gear combination is best for the fastest car?

2: Which gear combination is best for a powerful car?

GLOSSARY

Term	Meaning

CHOOSE
MATHS

AN AMSI SCHOOLS PROJECT

DELIVERED BY AMSI Australian Mathematical Sciences Institute

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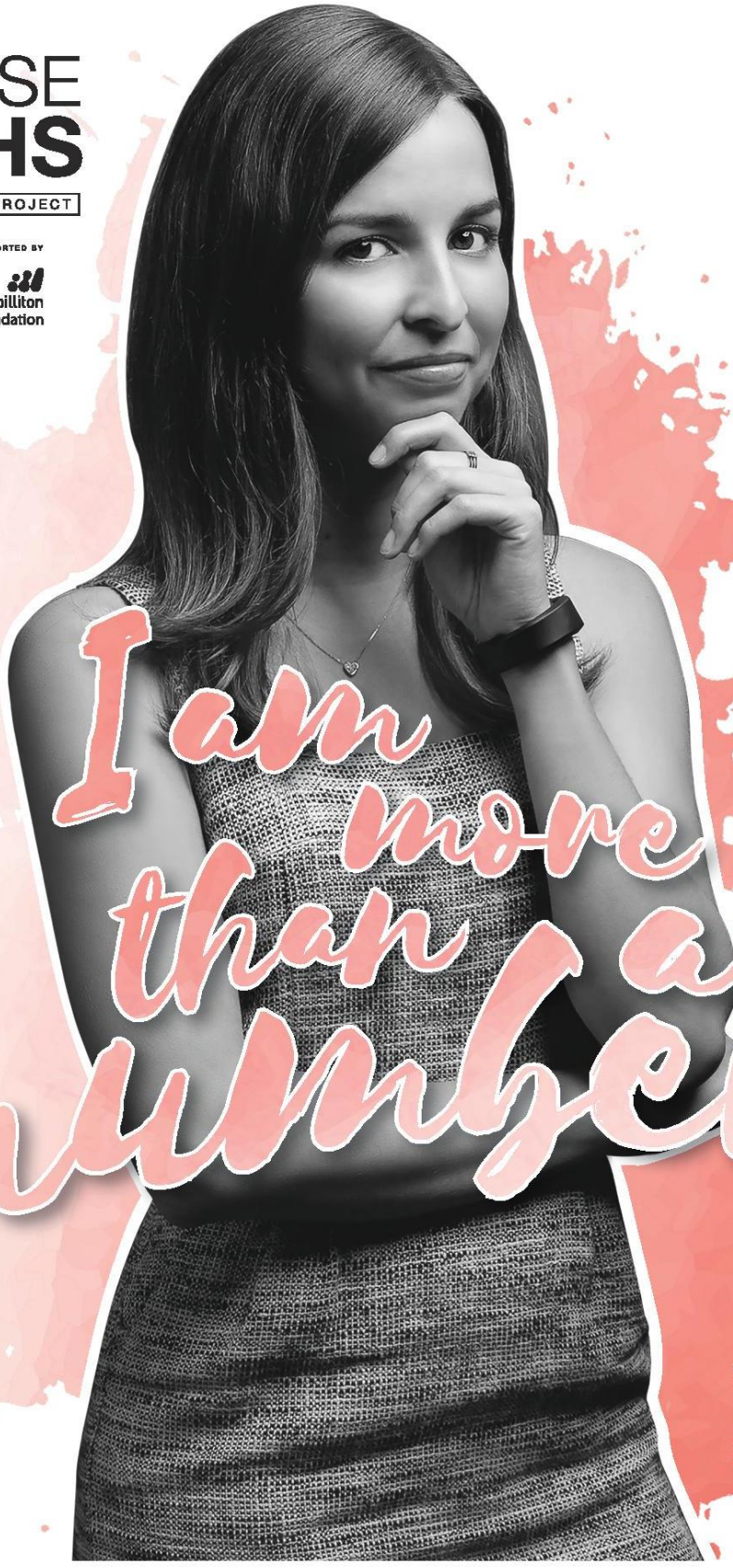

I am more than a number

Meet Karin Ditchfield

One of 12 CHOOSE**MATHS** Careers Awareness Ambassadors inspiring the next generation of mathematically capable professionals. Read her story at

CHOOSEMATHS.ORG.AU

AUSTRALIAN CURRICULUM OUTCOMES

Year 6
Mathematics

Add and subtract decimals, with and without digital technologies, and use estimation and rounding to check the reasonableness of answers (ACMNA128)

Multiply decimals by whole numbers and perform divisions by non-zero whole numbers where the results are terminating decimals, with and without digital technologies (ACMNA129)

Interpret and compare a range of data displays, including side-by-side column graphs for two categorical variables (ACMSP147)

Interpret secondary data presented in digital media and elsewhere (ACMSP148)

Science

Electrical circuits provide a means of transferring and transforming electricity (ACSSU097)

Energy from a variety of sources can be used to generate electricity (ACSSU219)

Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena (ACSHE098)

Scientific understandings, discoveries and inventions are used to solve problems that directly affect peoples' lives (ACSHE100)

Scientific knowledge is used to inform personal and community decisions (ACSHE220)

With guidance, pose questions to clarify practical problems or inform a scientific investigation, and predict what the findings of an investigation might be (ACSIS232)

With guidance, plan appropriate investigation methods to answer questions or solve problems (ACSIS103)

Decide which variable should be changed and measured in fair tests and accurately observe, measure and record data, using digital technologies as appropriate (ACSIS104)

Use equipment and materials safely, identifying potential risks (ACSIS105)

Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate (ACSIS107)

Compare data with predictions and use as evidence in developing explanations (ACSIS221)

Suggest improvements to the methods used to investigate a question or solve a problem (ACSIS108)

Communicate ideas, explanations and processes in a variety of ways, including multi-modal texts (ACSIS110)

YEAR 7

Mathematics

Multiply and divide fractions and decimals using efficient written strategies and digital technologies (ACMNA154)

Round decimals to a specified number of decimal places (ACMNA156)

Recognise and solve problems involving simple ratios (ACMNA173)

Construct sample spaces for single-step experiments with equally likely outcomes(ACMSP167)

Identify and investigate issues involving numerical data collected from primary and secondary sources (ACMSP169)

Science

Change to an object's motion is caused by unbalanced forces acting on the object (ACSSU117)

Science knowledge can develop through collaboration and connecting ideas across the disciplines of science (ACSHE223)

Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations (ACSHE120)

People use understanding and skills from across the disciplines of science in their occupations (ACSHE224)

Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124)

Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125)

In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (ACSIS126)

Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships, including using digital technologies as appropriate (ACSIS129)

Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions (ACSIS130)

Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the method (ACSIS131)

Use scientific knowledge and findings from investigations to evaluate claims (ACSIS132)

Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate (ACSIS133)

YEAR 8

Mathematics

Carry out the four operations with rational numbers and integers, using efficient mental and written strategies and appropriate digital technologies (ACMNA183)

Solve a range of problems involving rates and ratios, with and without digital technologies (ACMNA188)

Investigate techniques for collecting data, including census, sampling and observation (ACMSP284)

Explore the practicalities and implications of obtaining data through sampling using a variety of investigative processes (ACMSP206)

Science

Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems (ACSSU155)

Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world (ACSHE134)

Science knowledge can develop through collaboration and connecting ideas across the disciplines of science (ACSHE226)

Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations (ACSHE135)

People use understanding and skills from across the disciplines of science in their occupations (ACSHE227)

Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS139)

Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS140)

In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (ACSIS141)

Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships, including using digital technologies as appropriate (ACSIS144)

Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions (ACSIS145)

Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the method (ACSIS146)

Use scientific knowledge and findings from investigations to evaluate claims (ACSIS234)

Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate (ACSIS148)

YEAR 9

Mathematics

Solve problems involving direct proportion. Explore the relationship between graphs and equations corresponding to simple rate problems (ACMNA208)

Identify everyday questions and issues involving at least one numerical and at least one categorical variable, and collect data directly and from secondary sources (ACMSP228)

Science

Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community (ACSHE157)

People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions (ACSHE160)

Advances in science and emerging sciences and technologies can significantly affect people's lives, including generating new career opportunities (ACSHE161)

The values and needs of contemporary society can influence the focus of scientific research (ACSHE228)

Formulate questions or hypotheses that can be investigated scientifically (ACSIS164)

Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS165)

Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data (ACSIS166)

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS170)

Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS171)

Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS174)

THE SOUTHERN CROSS UNIVERSITY PROJECT

'INSPIRING SCIENCE AND MATHEMATICS EDUCATION'

IS PARTIALLY FUNDED BY THE AUSTRALIAN GOVERNMENT DEPARTMENT OF EDUCATION AND TRAINING THROUGH THE

AUSTRALIAN MATHS AND SCIENCE PARTNERSHIPS PROGRAM

Thank you from our partners

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Southern Cross University

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Stile