COLLECTIVE LEARNING IN THE PHYSICS CLASSROOM

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Resources can be found at www.edudesign.com.au

COLLECTIVE LEARNING

The history of science is a history of our collective learning.

Elshaikh, E.M (n.d) Standing on the shoulders of invisible giants, Khan Academy, www.khanacademy.org, [date accessed 7th Dec 2023]

OUTLINE

Collective learning: classrooms reflecting science practice

Example of practice U1AOS3: Transducer assignment

Example of practice U2AOS1: Mousetrap car investigation

Example of practice U2AOS3: Practical investigation


"IF I HAVE SEEN FURTHER, IT IS BY STANDING ON THE SHOULDERS OF GIANTS", ISSAC NEWTON

COLLECTIVE LEARNING

"Collective learning is the ability to share information so efficiently that the ideas of individuals can be stored within the collective memory of communities and can accumulate through generations."

Anderson, R (2016), Berkshire Encyclopedia of Sustainability

CLASSROOM PRACTICE

Build classroom connections and a collective learning culture

- Do your students know each other?
- Do your students understand the value of shared learning?
- Have you taught students how to work together?

CLASSROOM PRACTICE

Build classroom connections and a collective learning culture

- Do your students know each other?
- Do your students understand the value of shared learning?
- Have you taught students how to work in a collective?

Functioning in Groups

erve groups, note where and when any group member is engaged
up member's initials in the appropriate box. You might also want t
ace. Note: The bottom row are unproductive behaviors that somet

res, ing	**Seeking information or opinions**—requesting facts, preferences, suggestions and ideas.	**Giving information or opinions**—providing facts, data, information from research or experience.	**Ques** from chall other the ta
g ideas) or	**Connecting**—drawing connections between contributions from different people and linking up ideas that seem unconnected.	**Recording**—helping to track the groups ideas and conversation in some concrete way.	**Sum** contri while inform

CLASSROOM PRACTICE

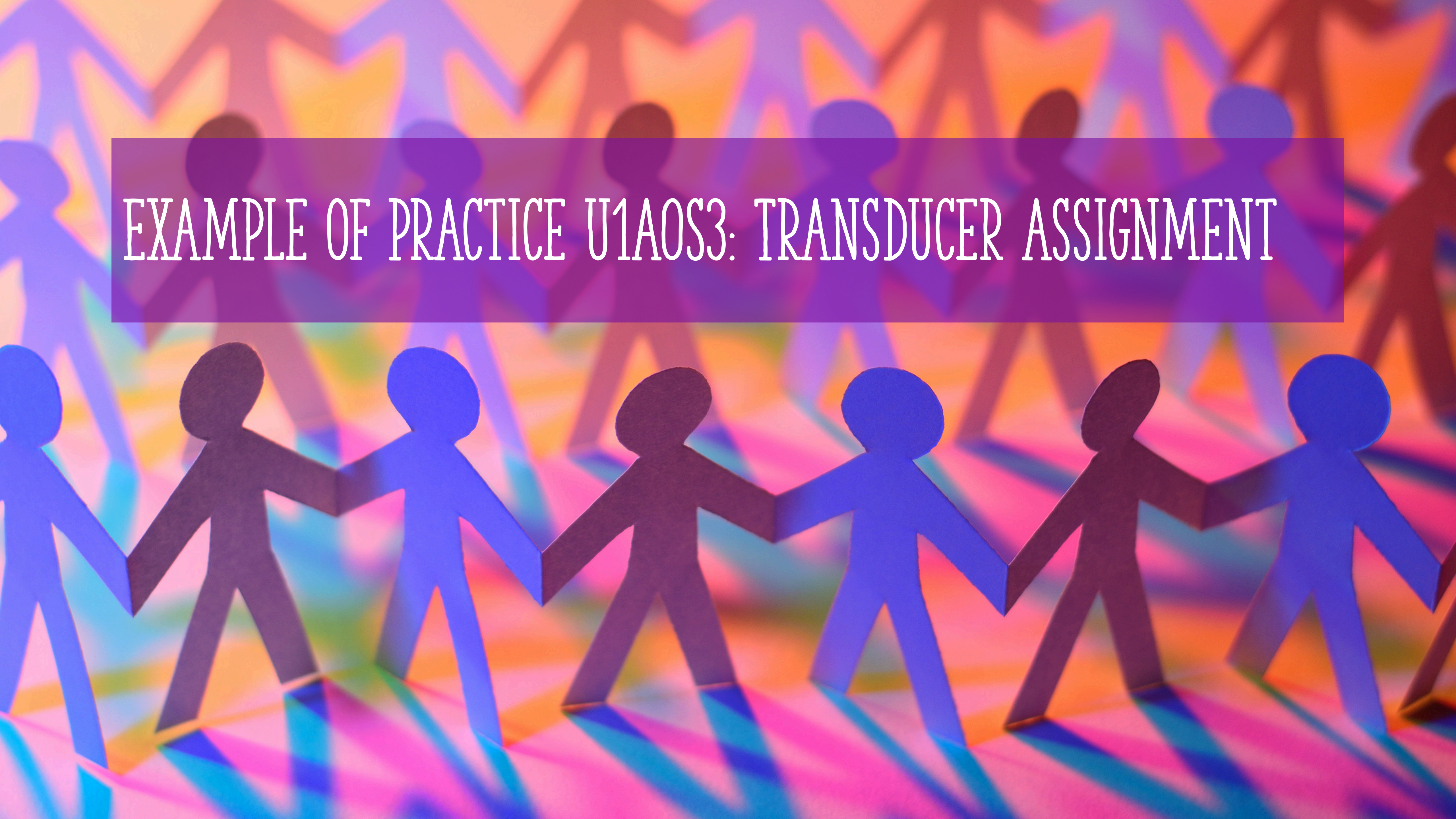
Promote student voice and expertise

- Delay answers. Hint: Deliberately tackle new questions in class
- Design class projects where you have limited knowledge e.g., Options projects
- Ask specific students to search for information and share
- Do not repeat student answers, but rather ask them to share their answers for others to write down
- Teach each student in the class a different skill and ask them to help others

CLASSROOM PRACTICE

Awesome resource: Cultures of thinking in action, Collective learning, https://www.cultures-of-thinking.org/6-collective-learning, [date accessed 12th Dec 2023]

EXAMPLE OF PRACTICE U1AOS3: TRANSDUCER ASSIGNMENT



TRANSDUCER TASK OUTLINE

In this task you will investigate how a transducer can be used in appliances.

- In Part A, you will build a voltage divider for a light dependent resistor (LDR) and determine the change in resistance with varying light intensity.
- In Part B, you will build a circuit for an ‘appliance’, as represented by an LED light, which will be turned on and off by a transducer; either a LDR, potentiometer or a thermistor. During the project you will determine whether the transducer is Ohmic or non-Ohmic.
- In Part C you will explain how a transducer works within an appliance and investigate the power consumption, energy use, running costs of an appliance and describe how safety devices in the home reduce the risk of electrocution or household fires.
- The final aspect of the SAC will be completed under test conditions, where you will be required to apply your understanding to a scenario where you will be required to select the most appropriate appliance and safety device.

TRANSDUCER TIMELINE

- The task can be shortened by students completing lesson 2, 5 and 6 at home.
- The final part of the task is completed under test conditions where students have to apply their understanding to a new context.

Timeline

Lesson	Task	Description	Checkpoints
1	Part A: Conduct voltage divider experiment	• Conduct experiment • Complete voltage divider calculations	Checkpoint 1 - Assessed Checkpoint 2 - Assessed
2	Part A: Evaluate errors	• Estimate effect of errors on data	Checkpoint 3 - Assessed
3	Part B: Plan transducer experiment	• Draw and label circuit diagram of your selected transducer. • Determine resistance of sections of the circuit and explains circuit can be used to control an appliance	Checkpoint 4 – Assessed Checkpoint 5 - Assessed
4	Part B: Conduct transducer experiment	• Collect current and voltage data for high and low transducer resistance • Graph data and determine whether transducer is Ohmic or non-Ohmic.	Checkpoint 6 – Assessed Checkpoint 7 - Assessed
5	Part C: Complete transducers in home appliance task	• Explain how your selected transducer is used in an appliance • Identify the power consumption of the appliance and calculate the energy consumption in kWh and the running cost per year. • Explain how safety devices can be used to reduce the risk of electrocution or household fires	Checkpoint 8- Indirectly assessed Checkpoint 9 – Indirectly assessed Checkpoint 10 – indirectly assessed
6	Part D: Problem solving task – preparation for SAC	• Application of understanding to new context	Checkpoint 11 – indirectly assessed
7	Problem solving task – completed under test conditions	• Application of understanding to new context	Checkpoint 12 - Assessed

TRANSDUCER RUBRIC

Assessment Rubric

estimates effect of errors on the quality of data	explains why appliance turns on when transducer has a high resistance		applies understanding of transducer function in appliance				
identifies systematic and/or random errors	compares total resistance of different parts of circuit for high and low resistance	identifies transducer as ohmic or non-ohmic and determines transducer resistance from *V/I* ratio	describes how transducer functions		tailors energy saving strategies for a specific context	accurately calculates running cost per annum	links findings to electric shocks in homes and danger thresholds
calculates theoretical output voltage of voltage divider	explains purpose of components, including why ammeter is in series and voltmeter is parallel	constructs current-voltage graphs for low and high resistance and explains significance of gradient	identifies purpose of transducer in appliance	compares energy use of appliances in the home	devises energy saving strategies	mostly completes required unit conversions	categorises effectiveness of safety devices
identifies relationship between transducer resistance and the output voltage	completes circuit diagram and annotates conventional and electrical current	represents current and voltage data in results table	defines transducer	explains power consumption (W) and energy use (kWh)	explains running cost per annum	mostly identifies correct formulas	describes how safety devices operate
Connects variables, data and errors	**Analyses circuit**	**Analyses data**	**Applies understanding**	**Compares energy use**	**Designs energy efficiency strategies**	**Calculations**	**Identifies safety devices**
Voltage divider experiment	**Transducer experiment**		**Transducers in the home** Completed under test conditions				
Checkpoint 1 - 3	**Checkpoint 4 - 7**		**Checkpoint 8- 12**				

TRANSDUCER BOOKLET

- Checkpoints help students to self-direct their own learning
- Each checkpoint connects to rubric
- Checkpoints highlight what is assessed

Part A: The effect of resistance on the output voltage in a circuit with voltage divider and a light dependent resistor

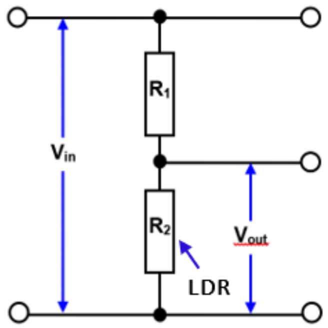
☐ **CHECKPOINT 1: Identifies the relationship between resistance and output voltage ASSESSED**

Introduction

Voltage dividers can be used to scale down a high voltage to a low voltage in an electrical circuit. When combined with a variable resistor, the voltage divider can also be used to switch on and off appliances.
In this circuit, a voltage divider is paired with a light dependent resistor (LDR) by which the resistance of the LDR changes with the amount of light intensity. A LDR is a transducer which converts light energy into electrical energy and is used in circuits where the appliance is switched on and off by differences in the light intensity such as a light sensor switch.

Aim

To determine the effect of resistance on the output voltage in a voltage divider and how the resistance of the LDR changes with changing light intensity.



Materials

- LDR
- 10 kΩ resistor
- connecting wires
- multimeter
- power supply
- lamp

Procedure

1. Use the multimeter to measure the resistance of the LDR in the dark, under the classroom fluorescent lights and under a lamp. Record your results in Table 1.
2. Set up the circuit shown in the diagram above where R_1 is a 10 kΩ resistor and R_2 is the LDR. Set the power supply to 6 V.
3. With the LDR wired in the circuit, cover the LDR so it is in the dark and use a multimeter to record the V_{out}. For this same circuit, place the LDR under the classroom fluorescent lights and record the V_{out}. Finally place the LDR under a lamp and record the V_{out}. Insert your data into Table 1.

Table 1. The change in resistance and voltage for a LDR under different light intensities.

	Resistance of LDR (Ω)	Experimental V_{out} of LDR	Theoretical V_{out} of LDR
Dark			
Fluorescent lights			

TRANSDUCER BOOKLET

- Assessment task covers a broad range of key knowledge descriptors
- Emphasis on students explaining their understanding

Part B: Transducer experiment

☐ **CHECKPOINT 4, 5: Complete circuit diagram and explain purpose of components. Calculate total resistance of sections of circuit. ASSESSED**

Introduction

In this experiment you will build a circuit for an appliance which will be turned on an off by a transducer. The appliance will be represented by an LED.
You will select **ONE** of the following transducers to use in your electrical circuit
1. Thermistor
2. LDR
3. Potentiometer

Planning and design of transducer circuit

1. Complete the diagram of the electrical circuit for your selected transducer. You will need to use the correct symbol for the transducer.
2. **On your diagram, show the direction of conventional current and electrical current.** Explain the difference between these two representations of current flow.
3. Include annotations on your circuit of the function of the following components: **LED, resistor, NPN transistor.**
4. In this experiment you will measure the current flow, and the voltage output of the transducer. Draw the ammeter and voltmeter on the circuit diagram and explain why the **ammeter needs to be in series and the voltmeter needs to be parallel.**
5. Measure the resistance of the transducer at the highest and lowest resistance. For example, what is the resistance of the thermistor when it is in cold conditions and what is the resistance in hot conditions?

   Use a lamp to change the resistance of the LDR and an ice pack and a heat pack to change the resistance of the thermistor.

Level	Resistance (Ω)
Low	
High	

6. Calculate the total resistance of the 330 Ω resistor and the NPN transistor and compare this with the total resistance of the 100 KΩ resistor and the transducer when it is set low resistance and the total resistance of the 100 KΩ resistor and the transducer when set at high resistance.

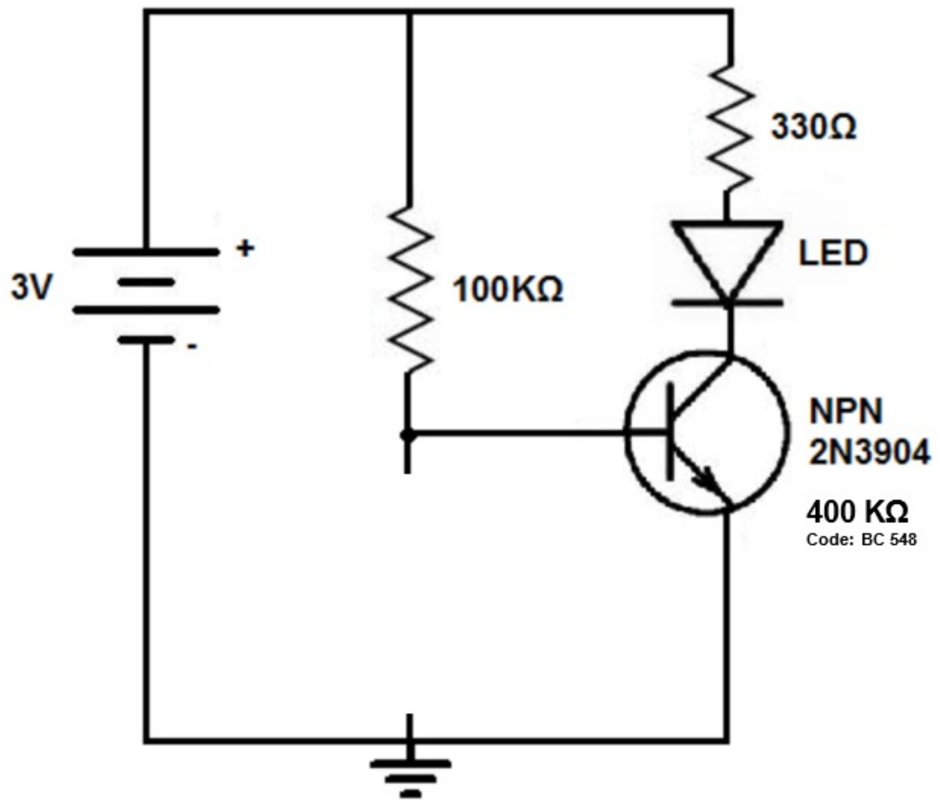
	Total resistance (Ω)
330 Ω resistor and the NPN transistor	

TRANSDUCER BOOKLET

- Assessment task covers a broad range of key knowledge descriptors
- Emphasis on students explaining their understanding

Annotate the circuit diagram below with:

- ☐ the correct symbol for your selected transducer.
- ☐ the direction of conventional and electrical current. Explain the difference between these two representations of current flow.
- ☐ a description of the function of the following components; LED, resistor, NPN transistor.
- ☐ an ammeter and voltmeter and explain why the ammeter is in series and the voltmeter is parallel.



TRANSDUCER BOOKLET

- Assessment task covers a broad range of key knowledge descriptors
- Emphasis on students explaining their understanding

Table 2 Design a results table for the current and voltage data for input voltages of 4, 6, 8, 10 and 12 V when the transducer is set to **high** resistance.

Graph Checklist

	Is a suitable graph for the data
	Includes a title
	Axes are labelled
	Units are included
	Appropriate scale is used
	Voltage is on the x axis

Graph

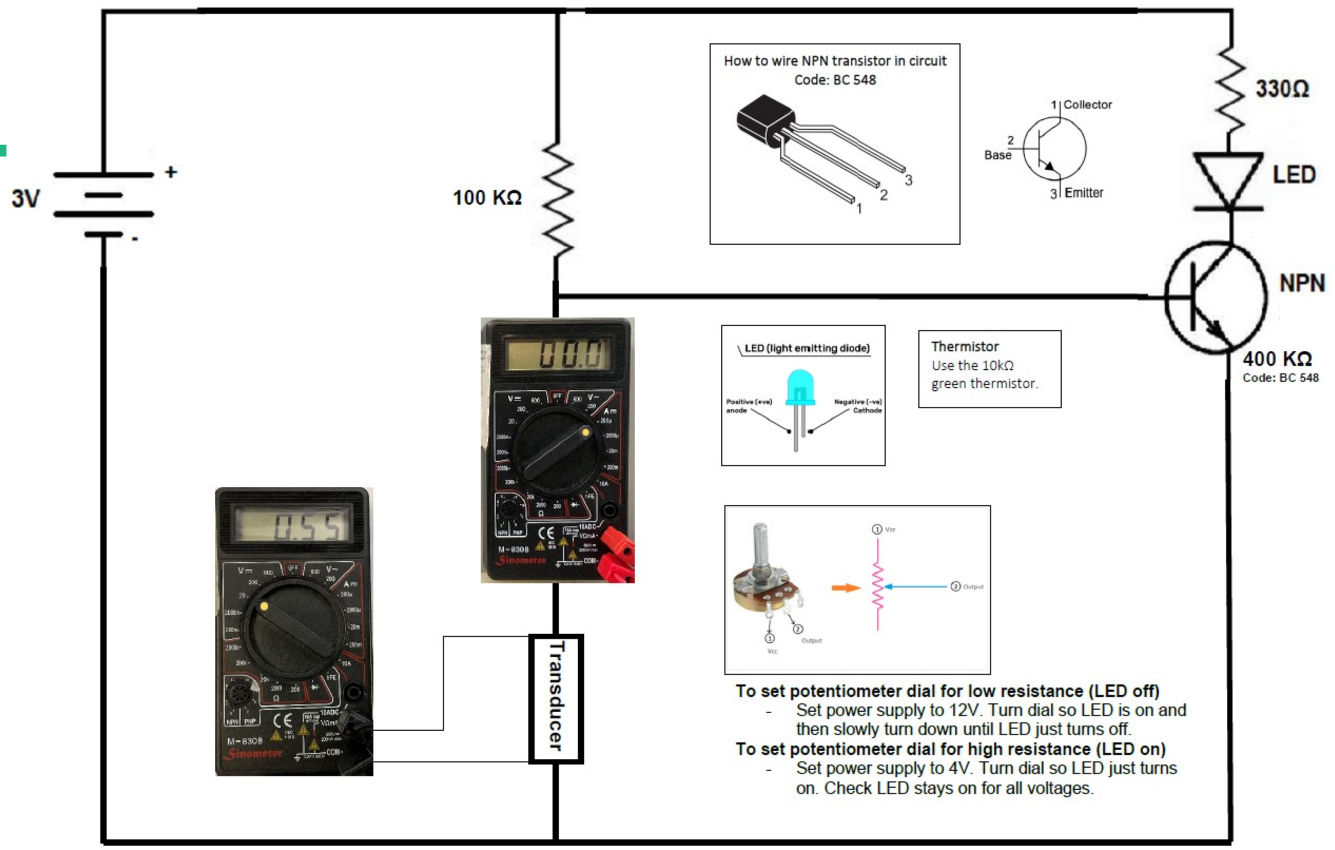
Explain the significance of the gradient of the line.

Determine resistance from the ratio of V/I
High resistance:

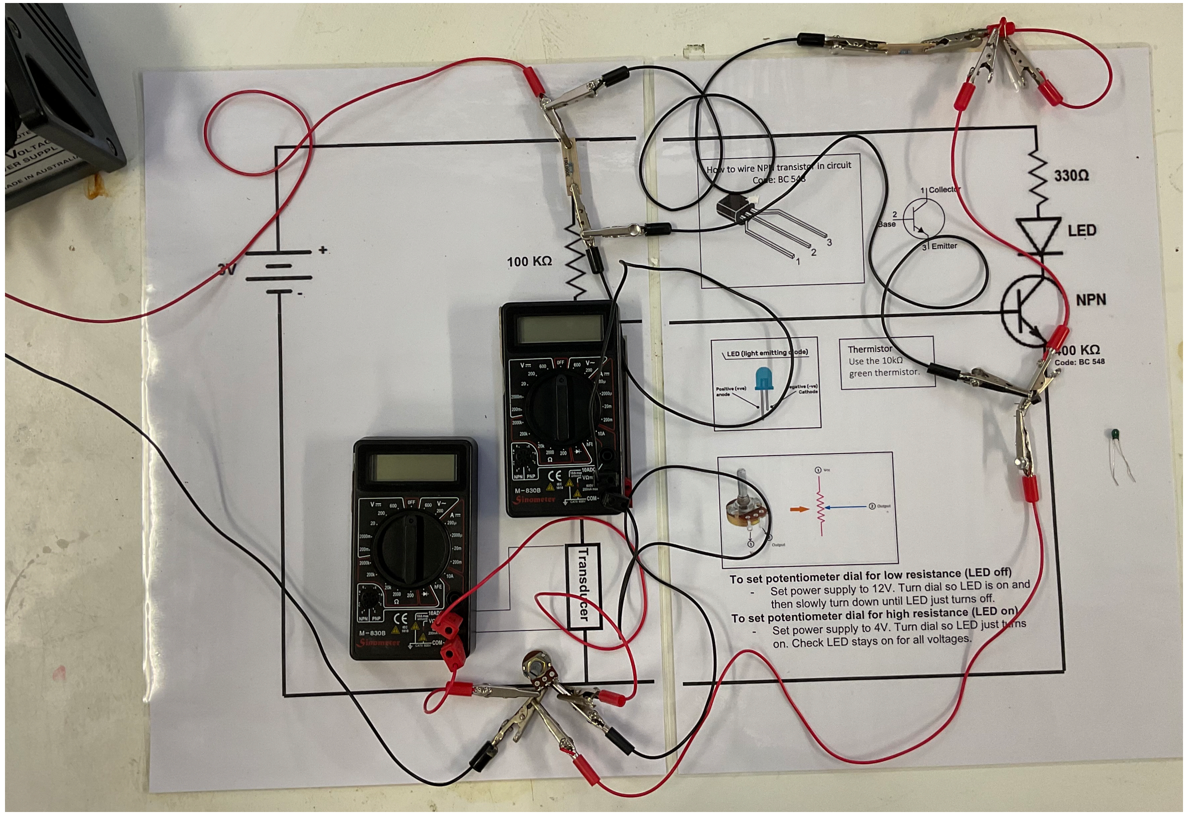
Low resistance:

TRANSDUCER EXPERIMENT

- Challenging circuit for students
- Print out circuit diagram over two A3 pages (laminate)
- Students wire their circuit on top of diagram using blue tac to hold wiring in place
- Make up shorter electrical wires to simplify wiring



TRANSDUCER SET UP



TRANSDUCER: PART C

- Appliances in the home

Part C: Transducers in home appliances

CHECKPOINT 8-12: Apply understanding to transducers in home appliances and discuss safety devices in the home - INDIRECTLY ASSESSED

1. Select an appliance where the transducer is used and explain how it is important in the operation of the appliance.

applies understanding of transducer function in appliance
describes how transducer functions
identifies purpose of transducer in appliance
defines transducer
Applies understanding

2. Model ____________________ Identify the power consumption (Watts) of the appliance and explain what the 'power consumption' means.

3. Calculate how much energy the appliance would use during one year of operation in the home.
   a. Estimate how many hours per week the appliance operates.
   b. How many hours per year?
   c. Calculate energy in kWh per annum.

compares energy use of appliances in the home
explains power consumption (W) and energy use (kWh)
Compares energy use

   d. Explain energy used in kWh per annum.
   e. Is this appliance a high energy device compared to other appliances in the home? Explain your answer.

TRANSDUCER : PART C

- Appliances in the home
- Explain how safety devices operate

4. Calculate the running cost of the appliance per year if the consumer is charged at rate of 21.70 c/kWh

tailors energy saving strategies for a specific context
devises energy saving strategies
explains running cost per annum
Designs energy efficiency strategies

a. Explain what running cost per annum means.

b. Describe how families could reduce the running costs of using this appliance.

accurately calculates running cost per annum
mostly completes required unit conversions
mostly identifies correct formulas
Calculations

5. Explain how the safety devices used in the home reduce the risk of electrocution or household fires.

a. Provide definitions for the following safety devices and explain how they operate. Order the devices as most effective (1) to least effective (4).

Safety device - Definition	Description of how they operate
Earth wire	
Fuse	

links findings to electric shocks in homes and danger thresholds
categorises effectiveness of safety devices
describes how safety devices operate
Identifies safety devices

TRANSDUCER : PART D

In this task you will apply your understanding to a new context by:

- selecting **ONE** household scenario and **ONE** appliance.
- Identifying the power consumption of the appliance and explaining the purpose of the relevant transducer.
- discussing suitable energy saving strategies for the household and the most suitable safety devices that should be installed in their home.

Part D: Problem solving task

☐ **CHECKPOINT 8-12: Apply understanding to a specific scenario - INDIRECTLY ASSESSED**

In this task you will apply your understanding to a new context by:

- selecting **ONE** household scenario and **ONE** appliance.
- Identifying the power consumption of the appliance and explaining the purpose of the relevant transducer.
- discussing suitable energy saving strategies for the household and the most suitable safety devices that should be installed in their home.

Household scenarios – **Tick** which house scenario you have selected

Name	Description of people	Description of home
☐ Johnson household	Four persons in the home with two adults and two children. The children are both less than 5 years old. The children are cared for by one parent while the other is at work so there are always at least three people in the house. They have family over on the weekend for large gatherings.	Four bedroom home with two living rooms. The living room has cathedral ceilings. They have two bathrooms and a powder room. The home has single glazed windows with no insulation in the walls and minimal insulation in the ceiling.
☐ Arora household	Five persons in the home with two adults and three teenagers with the youngest being 13 and the oldest 17. The teenagers go to school, play sport and have part time jobs so they are often not at home. As the parents both work full time jobs, the home is only full after 7:00 pm in the evening and on weekends. On the weekends they will have family and friends over for large gatherings.	Four bedroom home with a study and two living rooms. They have two bathrooms. The home has single glazed windows with no insulation in the walls and minimal insulation in the ceiling.
☐ The Lim household	Four persons in the home with two adults and two children in primary school. The children play sport and have music lessons after school. Both parents work full time so the family returns home by 6:00 pm during the week. On the weekends they will travel to their family's holiday home on the coast.	Five bedroom home with study, two living rooms and a games room. The home has four bathrooms. The home has single glazed windows with no insulation in the walls and minimal insulation in the ceiling.
☐ Mathieson household	Three persons in the home with two adults and one child in primary school. The child is in an outdoors group and plays sport after school. Both parents work remotely so someone is always in the home. On the weekends they work in the small vegetable garden and do revegetation work in the adjoining grasslands.	Three bedroom home with one living area and a small nook for a study. The home has one bathroom and a powder room. The home is a Passive house design where thermal comfort is achieved with minimal heating and cooling. The windows are tripled glazed, and both the walls and ceiling have maximum insulation.

Appliances – Tick which appliance you have selected

Transducer	Appliance	Appliance power requirements
☐ Light dependent resistor	Burglar alarm where light sensor is used to detect movement	230V A.C and 0.94 A
☐ Potentiometer	Oven where potentiometer is used as the	230V A.C and 25 A

TRANSDUCER: SAC TEST

Sample of student answer

5. There is a risk of electric shock and fires in the home, mostly due to inappropriate use of electrical devices or faulty appliances. Overloading power boards can occur by plugging in too many appliances, or electrocution can occur by small children putting metal objects into power outlets. Appliances and devices that use lithium powered batteries can also cause electrical fires.

For the household scenario that you have selected, list the safety devices required for their home. Describe how the devices operate and state which devices are most effective. Also explain which factors have the greatest influence on the severity of injuries people experience from electric shocks in the home.

correct formulas
Calculations

links findings to electric shocks in homes and danger thresholds
categorises effectiveness of safety devices
describes how safety devices operate
Identifies safety devices

1-3
most- least effective

2. Circuit Breaker.

A circuit breaker is able to work because, when the left metallic strip heats up more than the right metallic strip, the bimetallic strip begins to bend. When the strip bends too far, the circuit breaker trips the circuit. Because the Yadav household has 4 bedrooms, 2 living rooms, 2 bathrooms and a powder rooms, it is likely that the powerboards could overload. The circuit board will eventually be able to trip the circuit. However, because it takes 10 seconds to trip, and the fact that the danger threshold of coming into contact (for 0.1 seconds) with 0.364 amps can result in severe burns, ventricular fibrillation, and defibrillating, lack of breath and fatality, it will not be effective in preventing electrocution.

links findings to electric shocks in homes and danger thresholds
categorises effectiveness of safety devices
describes how safety devices operate
gives definition of devices
Identifies safety devices

7

TRANSDUCER: TEACHER NOTES

- Expected current and voltage values for different transducers

Teacher notes

Data obtained for each transducer at high and low resistance

LDR

Light conditions (Lamp shining on LDR); LED (appliance) turns off

Voltage in (V)	**4**	**6**	**8**	**10**	**12**
I (µA)	43.5	61.2	81.1	100.5	121.1
V(V)	0.03	0.04	0.05	0.07	0.08

Dark conditions (Finger over LDR); LED (appliance) turns on

Voltage in (V)	**4**	**6**	**8**	**10**	**12**
I (µA)	1.5	1.6	1.7	1.8	1.9
V(V)	0.66	0.69	0.71	0.72	0.73

Thermistor

Green thermistor, 10 kΩ, NTC order number RN3440; Thermistor simulates conditions for heater.
Cold conditions (Cold rice pack from freezer); LED (appliance) turns on

Voltage in (V)	**4**	**6**	**8**	**10**	**12**
I (µA)	24.3	26.6.	28.1	29.0	29.6
V(V)	0.52	0.58	0.61	0.64	0.65

Hot conditions (Rice pack; heated in microwave with 250 mL beaker of water for 1-2 min); LED (appliance) turns off

Voltage in (V)	**4**	**6**	**8**	**10**	**12**
I (µA)	43.2	60.5	80.3	100.1	119.5
V(V)	0.11	0.16	0.20	0.25	0.29

Potentiometer

To set dial for low resistance; Turn on power supply to 12 V. Turn dial so LED turns off. This will supply just enough resistance so that the voltage values are measurable.
Low resistance; LED (appliance) turns off

Voltage in (V)	**4**	**6**	**8**	**10**	**12**
I (µA)	43.6	61.2	81.0	101.0	120.8
V(V)	0.08	0.12	0.16	0.20	0.24

To set dial for high resistance; Turn on power supply to 4 V. Turn dial so LED turns on. This will supply high enough resistance so the LED light will remain on for all voltages.
High resistance; LED (appliance) turns on

Voltage in (V)	**4**	**6**	**8**	**10**	**12**
I (µA)	22.1	24.1	25.5	26.3	26.9
V(V)	0.54	0.59	0.62	0.64	0.66

EXAMPLE OF PRACTICE U2AOS1: MOUSETRAP CAR INVESTIGATION

MOUSETRAP CAR: TASK OUTLINE

- Your objective is to use your understanding of force, energy and motion design and build a mouse trap car that will travel the greatest distance.
- There are two awards:
  - The car that that travels greatest distance
  - The team that makes the most improvement in the baseline data of the car
- You will be work in pairs and will be allocated a basic mousetrap car. You will need to determine the baseline data for this car and then use your understanding of the mechanical advantage, energy and torque to improve the design.
- The baseline data will be collected over several lessons after which the car will be redesigned and new measurements taken. You will then complete an analysis of your data and write a conclusion under test conditions.

Project Timeline

Lesson 1	Data collection 1: Pulling distance and mechanical advantage
Lesson 2	Complete analysis of pulling distance and mechanical advantage data
Lesson 3	Data collection 2: Determine the static and kinetic friction force
Lesson 4	Complete analysis of static and kinetic friction force data
Lesson 5	Data collection 3: Determine the torque and potential energy of the spring
Lesson 6	Design one improvement that you will make to car and justify with theory
Lesson 7	Modification Day – make improvements to car
Lesson 8	Testing Day
Lesson 9	Competition
Lesson 10	Assessment under test conditions

Lessons 2, 4 and 6 can be completed by students for homework

Marking Criteria: 14 marks allocated

		explains how modifications improve quality of results in terms of accuracy and precision	discusses implications of key findings *"How do your findings affect the design and maintenance of cars?"*
explains how observations can be explained by theories	explains how variables are connected	justifies effect of modifications using theory	makes recommendations which overcome the limitations
reasons for observations	identifies how different variable are connected	explains how modifications improve design	identifies limitations of key findings
records observations	lists results of variables	identifies modifications	summarises key findings
makes observations	**reports results**	**modifies method**	**makes conclusions**

MOUSETRAP CAR:DATA COLLECTION 1

- Students strengthen understanding of how to interpret formulae

Determine pulling distance, mechanical advantage, and total distance

Purpose

To determine the pulling distance, mechanical advantage and distance travelled by Mouse trap car.

Equipment

- Ruler or digital callipers
- Measuring tape or meter ruler

1. Determine theoretical pulling distance

The pulling distance of a mousetrap car is a measurement of how far the car will be under the pulling force of the mouse trap spring. In this activity, you will calculate how far your mousetrap car should be pulled (theoretical pulling distance) and then compare this to the actual pulling distance.

IMPORTANT FACTS

The distance that a Mouse trap car is being pulled under the force of the mouse trap's spring is directly proportional to the size of the drive wheels, the drive axle, and the length of the lever arm.

The travel distance is inversely proportional to the size of the drive axle.

Measure the length of string that is normally pulled from the drive axle and record in meters.

This is usually twice the lever arm length. Important: If there is more string than is pulled from the drive axle, then make sure to measure only the amount of string that is pulled from the drive axle to the mouse trap.

Calculate the theoretical pulling distance

The theoretical pulling distance is calculated from the number of turns that the drive wheel(s) make multiplied by the circumference of the drive wheel. The number of turns that a drive wheel makes depends on the length of string that can be pulled from the drive axle divided by the circumference of the drive axle.

Pulling Distance = Turns * π d_{wheel}

Explanation of Formula: pulling distance (distance) is defined as the number of turns of the drive wheel (Turns) multiplied by the circumference of the drive wheel (π dwheel)

To calculate the number of turns:

Turns = String Length / $\pi d_{drive\ axle}$

Explanation of Formula: the number of turns of the drive wheel (Turns) is defined as the length of string (string length) pulled from the drive axle divided by the circumference of the drive axle (πddrive axle)

Table 1. The number of turns and the theoretical pulling distance

Turns = String Length / $\pi d_{drive\ axle}$	
Theoretical Pulling Distance = Turns * π d_{wheel}	

MOUSETRAP CAR:DATA COLLECTION 1

- Students strengthen understanding of how to interpret formulae
- Make comparisons between theoretical and experimental data
- Analyse the quality of the data

2. Determine Mechanical Advantage and experimental pulling distance

Mechanical advantage

1. Use a digital calliper to measure and calculate the average diameter of the drive axle.
   a. Measure the drive axle without string on it and then measure it with the string wound-up on the axle. The string needs to be wound evenly and not clumped.
   b. Calculate the average by adding the two measurements together and then dividing by two.
2. Use a ruler to measure the diameter of the drive wheel and record the diameter in meters.
3. Calculate the mechanical advantage from the following formula and record in Table 2.

Mechanical advantage =	$d_{drive\ wheel} / d_{drive\ axle}$

Divide the drive wheel diameter ($d_{drive\ wheel}$) by the drive axle diameter ($d_{drive\ axle}$).

Experimental pulling distance

1. Place the Mouse trap car at a start line, release the car, and then follow the car marking the exact point on the ground where the Mouse trap stops pulling string from the drive axle.
2. This point is not the total travel distance, but the point where the Mouse trap's spring is no longer pulling the string from the drive axle. Measure from the start line to the end of the pulling distance.

Table 2. Mechanical advantage, theoretical and experimental pulling distance

Av diameter of drive axle (m)	Diameter of drive wheel (m)	Mechanical Advantage	Theoretical pulling distance (m)	Experimental pulling distance (m)

3. Measure total distance

Measure the total distance travelled by the car 3 times. Calculate the average and insert into Table 3. Use the provided excel spreadsheet to determine the 95% confidence interval of the data.

Table 3. Three replicates of the total distance (s) travelled by the car.

	Replicate 1	Replicate 2	Replicate 3	Average	95% confidence interval
Distance (m)					
Time (s)					
Average speed ($m.s^{-1}$)					

Questions

1. What could cause the differences between the theoretical pulling distance and the experimental pulling distance? Consider the possible energy transformations (e.g. transformation to heat energy due to friction.)

2. Identify the connections between mechanical advantage, pulling distance and total distance. For example, what effect does mechanical advantage have on the pulling distance?

MOUSETRAP CAR:DATA COLLECTION 2

- Plot data and obtain data from line of best fit
- Students can use predesigned excel spreadsheet to simplify process

Calculate the Normal force

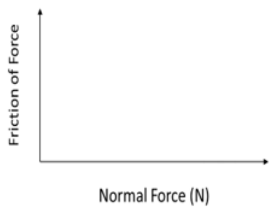
Indirectly determine the Normal force (upwards contact force) by calculating the weight force of the Mouse trap car + masses where $Fg = m\ g$ (Assume g = 10 N kg^{-1} down). The normal force will be equal and opposite to the weight force.

Results

Mass car =	Normal force (N)	Static friction force (N)	Kinetic friction force (N)
Mass car + 0.5 kg =			
Mass car + 1.0 kg =			
Mass car + 2.0 kg =			

Calculate the static and kinetic coefficient of friction

1. Plot on the same axes a graph of static force of friction and the kinetic force of friction against the normal contact force (N). **What trends can you identify?**



2. The coefficient of friction can be determined by using: μ = Ff/N which in turn can be determined from the gradient of the line. Insert the coefficient of friction for static and kinetic force of friction into the table.

	Coefficient of friction (μ)	Which materials (Table 1) have similar values?
Static friction		
Kinetic friction		

Questions

1. List 3 ways that you could you reduce the μ(static) or μ(kinetic) of the Mouse trap car.

Measuring the coefficient of static and kinetic friction

Background

Friction is a force that resists motion when two objects are in contact. Every surface of an object has microscopic peaks and valleys which catch on one another when two objects are moving past each other. While chemical bonding and electrical interactions also contribute to friction, this explanation is sufficient for this project.

The level of friction that different materials exhibit is measured by the coefficient of friction.

The formula to calculate the coefficient of friction is $\mu = F_f / N$

- μ is the coefficient of friction
- F_f is the force of friction
- N is the normal force.

Normal force

The force at which one surface is being pushed into another. If a rock with a weight of 50 Newtons is lying on the ground, then the normal force is 50 Newtons of force. Increasing normal force and μ will increase the friction force.

Static and kinetic friction

If you attempt to slide two objects past each other and there is no motion then the force of friction is greater than the applied force. This resistance is called **static friction**.

If you then apply more force and the object "breaks free" and slides, the force required to overcome friction and keep the object sliding is called **kinetic friction**. The kinetic friction is always less than the static friction.

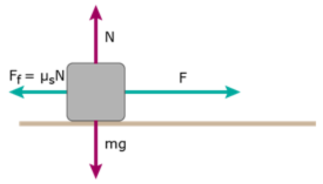
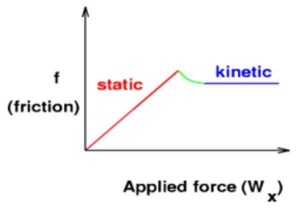


Table 1. Some common coefficients of static and kinetic friction values.

Steel	μ(static)= 0.74	μ (kinetic) = 0.57
Glass on glass	μ (static)= 0.94	μ (kinetic) = 0.40
Ice on ice	μ (static)= 0.10	μ (kinetic) = 0.03



Materials

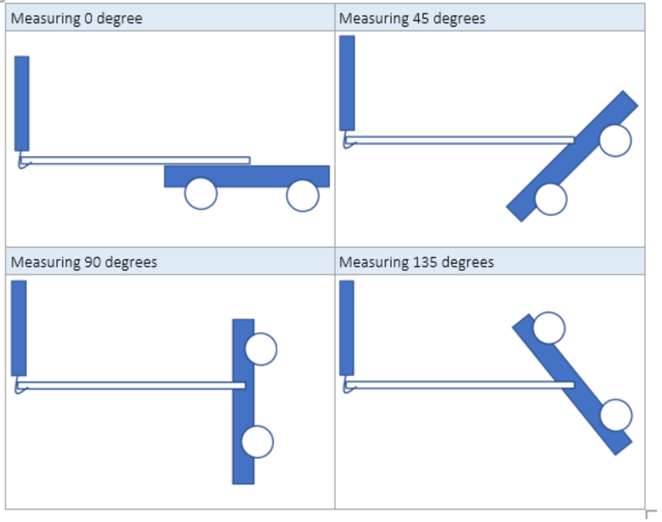
- 1 x Mousetrap car
- 1 × force sensors (need wireless sensors + Vernier graphical app)
- 1 × 0.5kg mass
- 1 × 1.0kg mass (or two 0.50kg masses)
- 1 × 2.0 kg mass
- 2 x mass balances for the class

Procedure

1. Find the mass of the Mouse trap car. **IMPORTANT: Find the mass of the car first without any added masses. Measuring the car and the mass will overload the electronic balance.**
2. Set up the apparatus as in the diagram below, starting with 0.5 kg on the Mouse trap car. Ensure you orientate the force meter so that it is horizontal. Zero the force meter.
3. Select a smooth section of bench top and gently increase the force on the Mouse trap car by pulling the force meter.
4. Record the maximum force just before the car begins to move. This is the force required to overcome static friction and equal to the static force of friction.
5. Then record the force needed to keep the car moving at a steady a speed. This force is equal to the kinetic

MOUSETRAP CAR:DATA COLLECTION 3

- Students measure torque at multiple angles to determine the spring constant from the graph.
- It is very important students keep the lever at 90º to the spring balance and change the angle of the lever with car.



Measuring torque and spring constant

Introduction

A Mouse trap car is powered by the energy stored in the spring where the spring is connected by a lever and string to the axle of the car. As the lever is released, the tension that was built up in the spring is released, and the car sets into motion. A Mouse trap car will travel further when more potential energy is stored in the spring. The amount of energy stored in the spring can measured with a **spring constant**. A car which has a higher spring constant will be able to store more potential energy.

The spring constant (k) can be calculated by measuring the torque using the following formulae:

Calculating torque

$\tau = r_{\perp} F_{\perp}$

Where $r_{\perp}$ is the length of the lever and $F_{\perp}$ is the force applied to the lever at 90º.

Calculating spring constant (k_1)

The spring constant (k_1) can be determined from the equation that connects torque (τ) and the angle of rotation (θ) as measured in radians.

$\tau = k_1\theta$, $k_1 = \tau/\theta$

Rearranging the equation shows that k_1 can be determined from the gradient when torque (τ) is plotted against the angle of rotation (θ) as measured in radians.

Materials

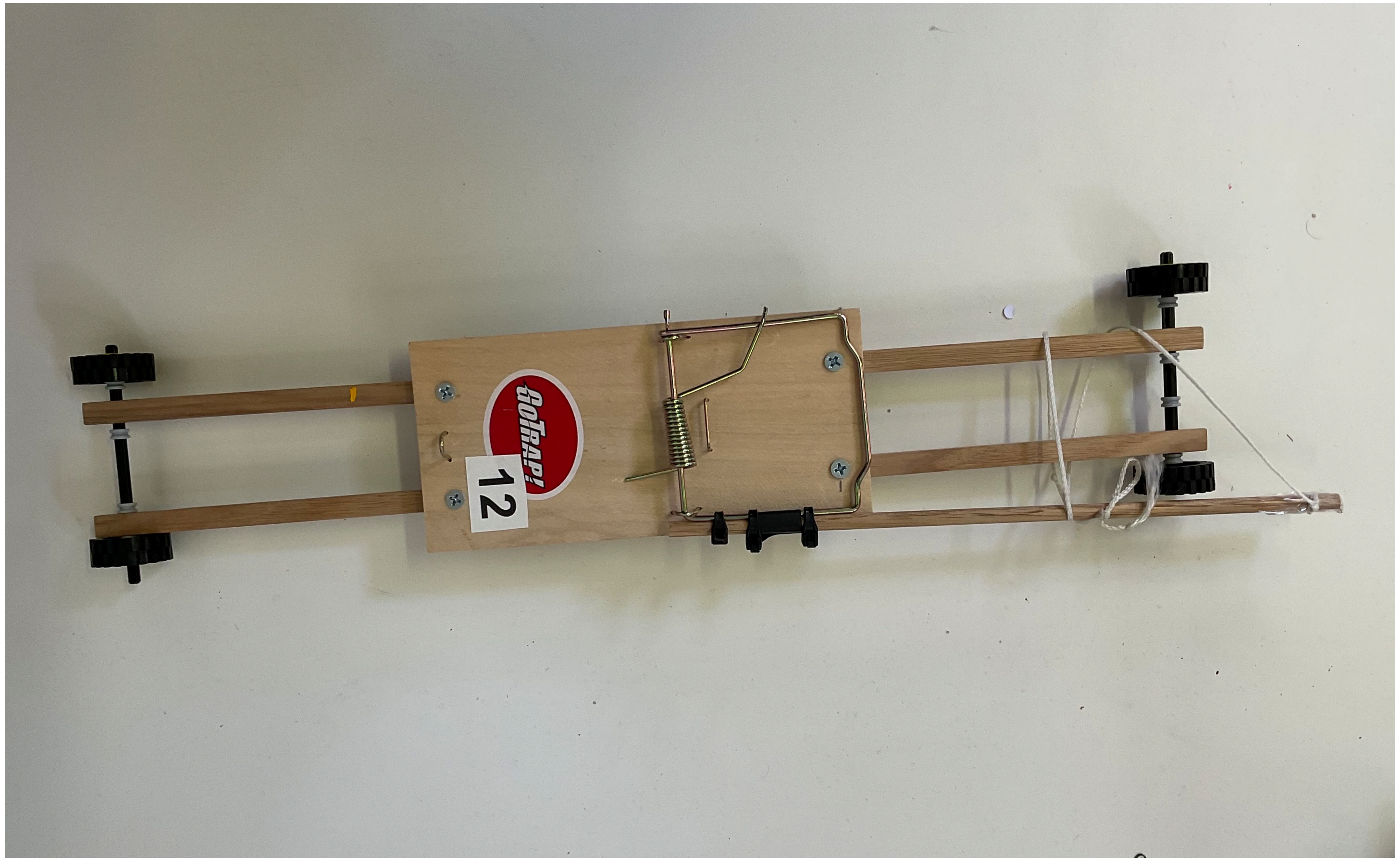
- Mouse trap Car
- Force Sensor capable of measuring 2.5 N.
- ruler

Procedure

1. Measure the length of the lever in meters and record in Table 1.
2. Orientate the car so that the angle between the force sensor and the lever is 90º. The force sensor must also be kept in the vertical orientation to get the best measurement.
3. Use the force sensor to measure the force at 0 degrees. Repeat for 45º, 90º and 135º.
4. Calculate the torque for each angle of rotation by using $\tau = r_{\perp} F_{\perp}$
5. Draw a graph of the angle of rotation (θ) on the x-axis and the torque (τ) on the y-axis.
6. Determine the gradient of the line. This is equivalent to the spring constant of the mouse trap car.Results

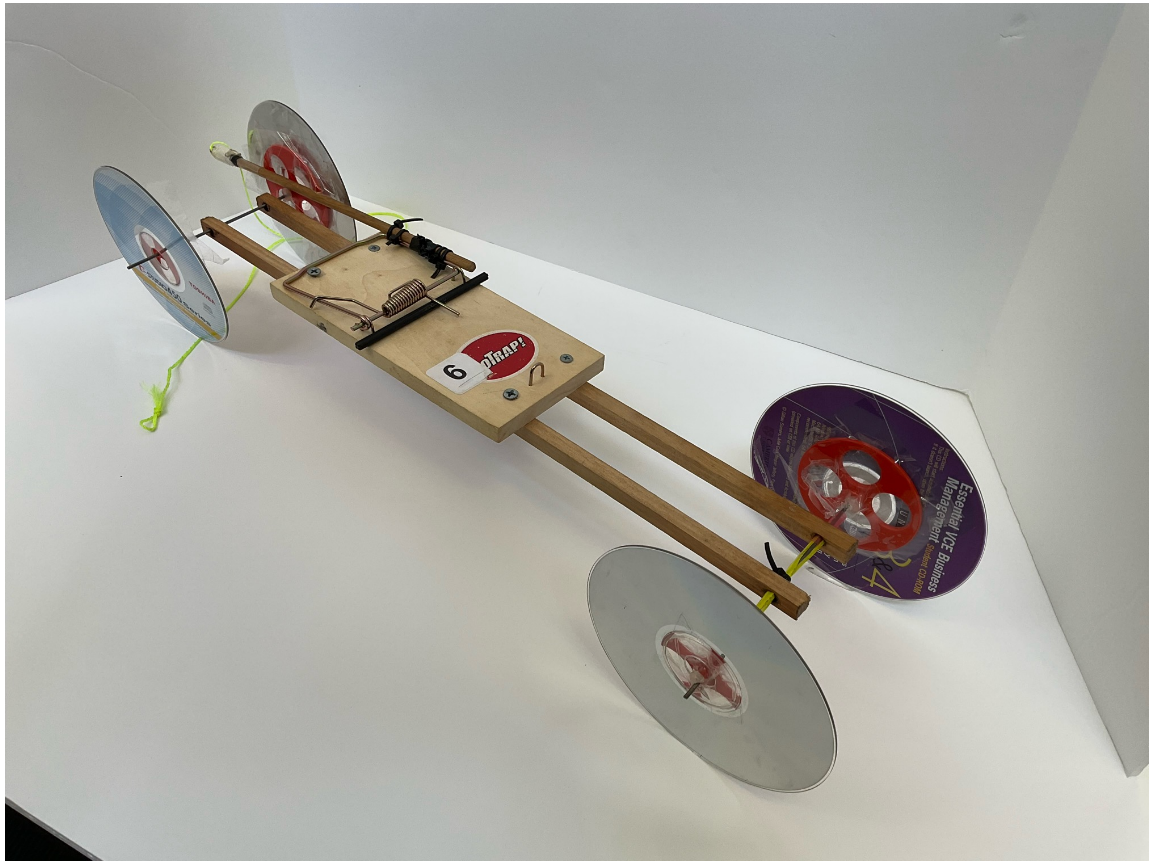
Angle of rotation (degrees)	Angle of rotation (radians)	Length of lever (m) $r_{\perp}$	Force (N) $F_{\perp}$	Torque (Nm) $\tau = r_{\perp} F_{\perp}$	Spring constant
0	0				
45	$\frac{\pi}{4} = 0.7854$				
90	$\frac{\pi}{2} = 1.571$				
135	$\frac{3\pi}{4} = 2.356$				

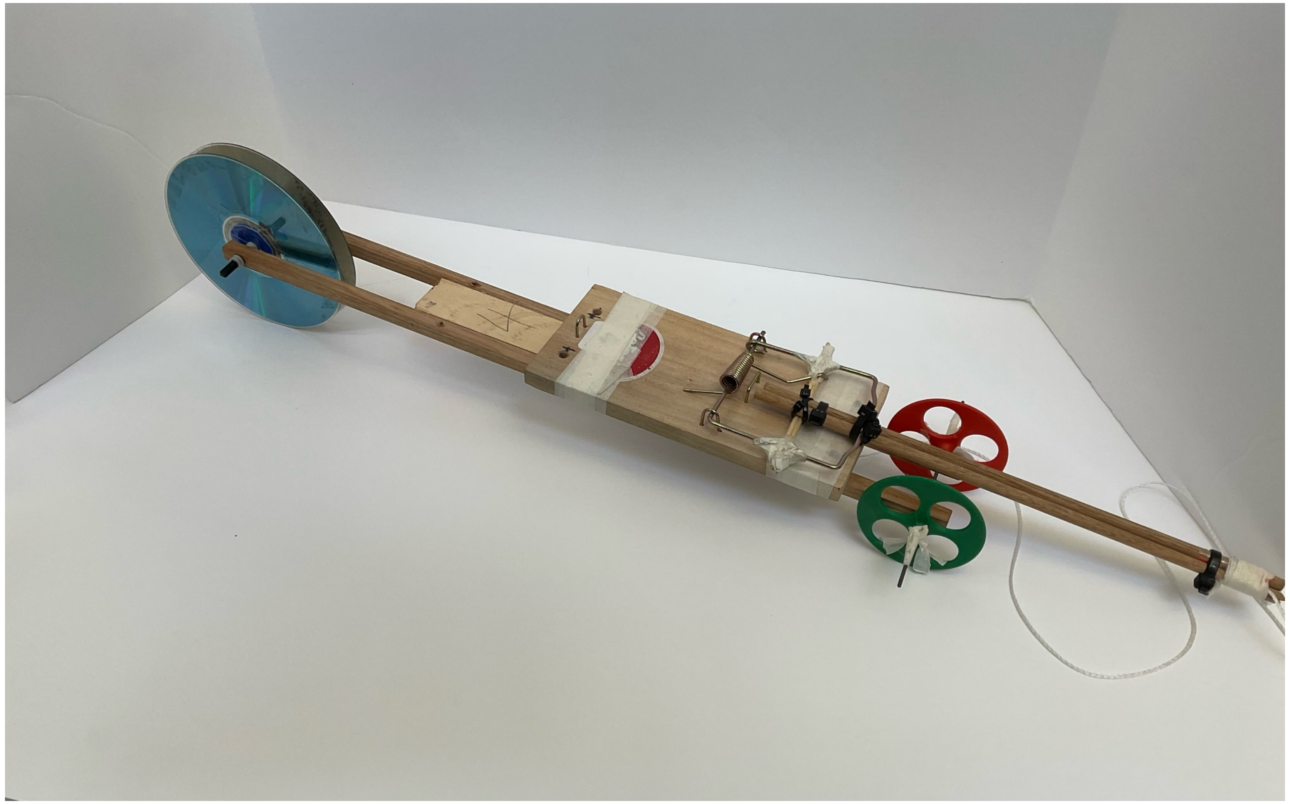
MOUSETRAP CAR: EXP SET UP



MATERIALS READY TO GO

MOUSETRAP CAR: EXP SET UP- MODIFICATIONS





MOUSETRAP CAR: MODIFICATIONS

- Students summarise their key findings from the experiment by listing the base car data and suggesting modifications they could use to improve their car.
- They also predict the effect of the modification on the data

Modifications

Predict the effect of modifications on the base car data

	Base car data	Description of modification and predicted effect on data
Mass (kg)		
Mechanical Advantage		
Pulling Distance (m)		
Total distance (m)		
Average speed ($m.s^{-1}$)		
Static coefficient of friction		
Kinetic coefficient of friction		
Spring Constant		

MOUSETRAP CAR: REFERENCE SHEET

- Students prepare for the SAC test by completing a reference sheet which summarises their key findings

Sample of student reference sheet

Physics concept / measurement being targeted and definition of this concept	Modification(s) made that affects this measurement	How modification affects change in measurement
Mechanical Advantage: The ratio of the force produced by the machine to the force applied to it Original: 6.24 Modified: 24.95	**Increasing the diameter of the drive wheel by using CDs as wheels instead of smaller LEGO wheels** **Using a skinnier axle**	Mechanical advantage increased due to the larger diameter of the wheel. This is because the large diameter of the drive wheel will increase the pulling distance which in turn means the car will be under power for a greater time. Pulling distance = turns x pi x diameter drive wheel Mechanical advantage increases because the number of turns of string will increase as the drive axle diameter is smaller which will result in a greater pulling distance. Turns = string length/ pi x diameter of drive axle

MOUSETRAP CAR: SAC TEST

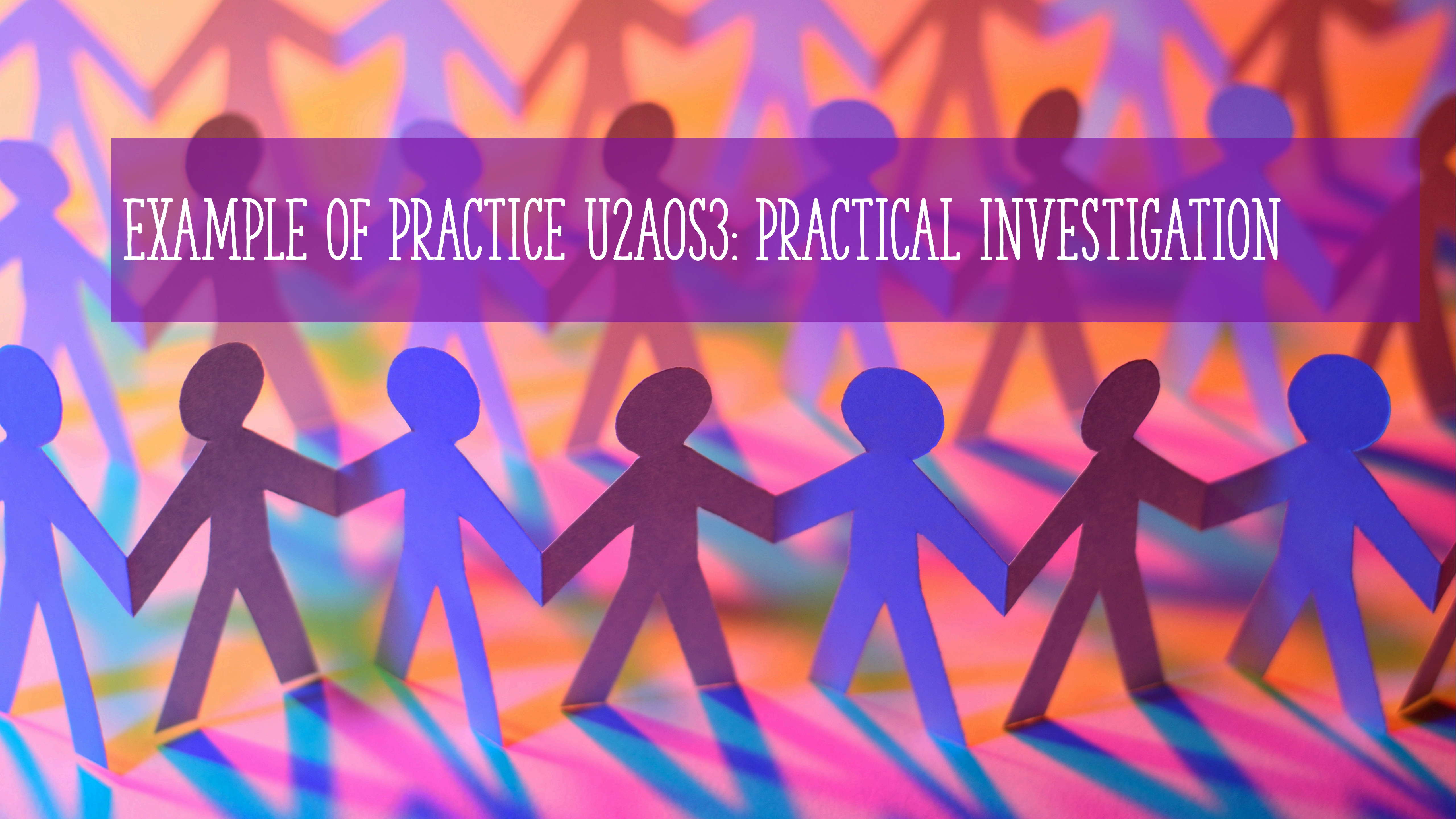
Students justified their card design in the SAC test

Kinetic ~~Static~~ **coefficient of friction** **Base car value:** 0.069 μ **Mod car value:** 0.0219 μ	One Modification that affects this measurement: adding straw between axle and wooden base. Justification of modification: When a plastic straw is added over the axle when it crosses the holes in the base, this would allow the car to move forward without exerting as much force. This is due to the fact that, with there being less microscopic bumps for the axle to get slowed down by, adding a smooth straw creates a film between the two surfaces, reducing friction, and allowing the axle to spin with less energy. ✓ (Shield, 2018) Increased validity because the car could data close to the theoretical pulling distance value.	Observation of the experimental effects of modification: Kinetic coefficient of friction decreased due to the friction force between the axle and base being decreased, compared to using no form of lubrication, the use of a smooth surface in between is much more effective at decreasing kinetic friction ✓

Mousetrap Car Design Justification

Concept – respond to any 4 THAT YOU HAVE CHANGED	Predicted effect of ONE modification on the measurement, **justify with theory** (use in-text citations)	**Observations** **Explain** your observations of the effect of the modification
Mechanical Advantage **Base car value:** __________	One Modification that affects this measurement: Justification of modification:	Observation of the experimental effects of the modification:
(m)	One Modification that affects this measurement: Justification of modification:	Observation of theoretical vs experimental testing of pulling distance: Observation of the experimental effects of modification:

EXAMPLE OF PRACTICE U2AOS3: PRACTICAL INVESTIGATION



Unit 2 AOS3 Practical Investigation 2023

Scope of Assessment

Unit 2 Outcome 3

In this area of study you will design and conduct a practical investigation related to knowledge and skills developed in Area of Study 1 and/or Area of Study 2.

Task Outline

The investigation requires you to develop a question, plan a course of action that attempts to answer the question, undertake an investigation to collect the appropriate primary qualitative and/or quantitative data, organise and interpret the data, and reach a conclusion in response to the question. You need to design and undertakes an investigation involving two independent variables one of which should be a continuous variable. You will need to use a logbook for recording, authentication and assessment purposes.

The task is divided into three phases:

- Planning the experiment
- Conducting the experiment
- Communicating your findings on a poster

Task 1: Planning and Design - Rubric 1

Your background research, investigation design and introduction will be assessed prior to you conducting your experiment.

Task 2: Results and Findings - Rubric 2

The presentation of your results and discussion of your findings will be assessed at the end of the investigation.

Topic Areas

There are four research topics to choose from. You will complete an individual research task within a research group. In your research group you will be able to support each other. However, you will have individual research questions.

1. Crumple zones
2. Safety barriers
3. Ski jump safety
4. Protective air bags

PRACTICAL INVESTIGATION: OUTLINE

PRACTICAL INVESTIGATION: TIMELINE

Timeline

Lesson	Content	Checkpoints
1	Topic Selection Background questions	Checkpoint 1 Checkpoint 2 - Assessed
2	Research question, aim and variables	Checkpoint 3 - Assessed
3	Introduction plan and hypothesis	Checkpoint 4 - Assessed
4	Materials and procedure Risk assessment Design results table	Checkpoint 5 Checkpoint 6 - Assessed Checkpoint 7
5	Conduct experiment - Experimental log	Checkpoint 8
6	Conduct experiment - Experimental log	Checkpoint 8
	Rubric 1 Due	
6	Conduct experiment - Experimental log	Checkpoint 8
7	Conduct experiment - Experimental log	Checkpoint 8
8	Analyse data and draw graphs	Checkpoint 9 - Assessed
9	Discussion and Conclusion Plan	Checkpoint 10 - Assessed
10	Discussion and Conclusion Plan	Checkpoint 10 - Assessed
	Rubric 2 Due	

Assessment Rubric 1

elaborates on ideas				applies ideas to new contexts
supports ideas with evidence	justifies predictions using known theory	distinguishes between variables in prediction		uses evidence to support ideas
uses scientific ideas	makes predictions based on theory	identifies all variables	uses a risk assessment that follows requirements	explains ideas
lists facts	guesses outcomes	distinguishes between factors to control, measure and change	records risks and controls	identifies aims
analyses ideas	**makes predictions**	**identifies factors**	**identifies risks and controls**	**forms ideas**
Planning				**Introduction**

PRACTICAL INVESTIGATION: PLANNING RUBRIC

PRACTICAL INVESTIGATION: DISCUSSION RUBRIC

Assessment Rubric 2

		makes generalisations based on key findings		makes recommendations to overcome limitations	communicates scientifically
uses graphs that includes statistical analysis	evaluates quality of data	uses theory to link or reconcile key findings including outliers	assesses effect of errors on quality of data	identifies limitations of key findings	uses graphics to convey ideas
uses graphs that follows the set conventions	summarises data	explains key findings using theories	explains effect of errors on experimental design	explains implications of key findings	Includes scientific conventions
includes graphs and/or tables	lists data	matches key findings with theory	identifies errors	summarises key findings	uses required poster format
represents data	**reports data**	**analyses results**	**evaluates method**	**makes conclusions**	**presents ideas**
Graph	**Discussion and conclusion**				**Poster**

PRACTICAL INVESTIGATION: TOPIC SELECTION

1.Topic selection

CHECKPOINT 1: Complete the task summary and topic selection table

Instructions

1. Read through the topics and evaluate what interests you personally about each of the topics.
2. Indicate your preference for each topic where 1 represents the topic that interests you most.

Topics	Interesting aspects/facts?	Preference (1-4)
Crumple Zones Crumple zones were first introduced into passenger cars in 1952. The main purpose of the crumple zone is to absorb the kinetic energy from the crash to reduce the amount of force being distributed to the occupants of the car.		
Safety barriers The design of safety barriers is important in preventing severe injuries when cars run off the road. The main aim of safety barriers is to slow down the impact time of cars during collisions.		
Ski jump safety When a skier falls they transform gravitational potential energy into kinetic energy. Therefore, if they fall from greater heights they will generate more kinetic energy and will have a higher final velocity. It is important that a skier comes to a stop slowly otherwise they will experience a large deceleration which in turn can cause an injury.		
Protective air bags Air bags were first installed in a passenger car in 1980. They have contributed to a reduction in fatalities in car collisions with estimates that along with seat belts they reduce the risk of death in frontal clashes by almost 60%.		

PRACTICAL INVESTIGATION: TOPIC SELECTION

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2.Background questions

Instructions

1. Insert the topic and names of the students who are in your research team.
2. Answer the background questions in the area below.
3. Record the details of your sources so that you can access them again.
4. Refer to the rubric for how you will be assessed. It is important to include relevant scientific ideas.

CHECKPOINT 2: Answer the background questions - **ASSESSED Rubric 1**

Crumple Zones

1. When were crumple zones introduced in vehicles and why?
2. Which aspect of a crumple zone makes the vehicle safer in a collision?
3. What types of materials are used in crumple zone and how do materials increase the time of impact?
4. How does increasing the collision time lead to fewer injuries in impact collisions?

Safety barriers

1. When were safety barriers introduced in vehicles and why?
2. Which aspect of a safety barrier makes vehicle collisions safer?
3. What types of materials are used in safety barriers and how do these materials increase the time of impact?
4. How does increasing the collision time lead to fewer injuries in impact collisions?

Ski jump safety

1. What is ski jump safety and why is it important?
2. Which aspect of ski jump protection makes the participant safer?
3. What types of materials are used in ski jump and how do these materials increase the time of impact?
4. How does increasing the collision time lead to fewer injuries in impact collisions?

Protective air barriers

1. When were protective air bags introduced in vehicles and why?
2. Which aspect of a protective air bag makes the vehicle safer in a collision?
3. What types of materials are used in air bags and how does using these materials increase the time of impact?
4. How does increasing the collision time lead to fewer injuries in impact collisions?

PRACTICAL INVESTIGATION: PLANNING

3. Research Question, Variables and Aim

Instructions

1. Write your research question in the space provided. Remember to make it specific.
2. Identify your variables by completing the table.
3. Include the units for your dependent variable.
4. List as many controlled variables as possible to ensure it will be a fair test.
5. Write the aim of your practical investigation, taking note of the aim checklist.

CHECKPOINT 3: Identify your research question, variables and aim - **ASSESSED Rubric 1**

Research Question

A research question is used to guide all parts of the investigation. It is important that your research question is not too broad or too generalised. For example, "What is the effect of the mass of the person on the force of impact on the person at the lowest point of a bungy jump?"

Research Question Checklist

Includes the variable(s) that will be changed.	
States what will be effected	

Variables

Identify the independent, dependent and controlled variables. Use the table below as a guide.

Independent Variable (what will you be changing?)	**Dependent variable** (what change will you be measuring? Include units)	**Controlled variables** (What will you keep constant? – You will need at least 5 controlled variables)

Aim

The aim states the purpose of the experiment. In the aim, you need to explain what will be done, and how it will be measured. The sentence should also start with a verb, such as "to investigate, to measure, to verify, to determine, to compare or to calculate."

Aim Checklist

States what will be done	
States how it will measured	
Uses a verb to begin sentence	

PRACTICAL INVESTIGATION: INTRODUCTION

4.Introduction Plan and Hypothesis

Instructions

1. Use the information from your background and variables research to complete your introduction plan below by:
   a. describing the problem and the importance of your investigation
   b. explaining what scientists already know about the topic
   c. identifying the current gaps in scientific knowledge or understanding that need to be addressed
   d. stating your research question
   e. stating your hypothesis with a justification for your prediction. This is usually written using the 'If… then… because' sentence structure.

Complete the plan as a series of dot points.

*Note down your in-text citations with your 'facts' so that they can be easily incorporated into your introduction.

CHECKPOINT 4: Plan the introduction and design the hypothesis - **ASSESSED Rubric 1**

Describe the problem
What is already known
Gaps in knowledge
Research question or aim
Hypothesis
If _________ then __________because____

PRACTICAL INVESTIGATION: RISK ASSESSMENT

6. Risk Assessment

Instructions

1. List any equipment or process that you plan to use that may create a hazard.
2. Identify the hazard and describe the required safety precautions.

CHECKPOINT 6: Consider and rate risks - ASSESSED Rubric 1

Hazard Assessment

Whenever conducting an experiment, it is important to identify the hazards and then state what precautions will be taken to prevent injury. This section must be completed before the experiment is conducted.

Equipment or Process	Hazard	Safety Precaution

PRACTICAL INVESTIGATION: RESULTS TABLES

7. Results Table

Instructions

1. Design the results table
   a. Write a descriptive title
   b. Label your independent and dependent variables
   c. Including your units
2. Record your data directly into your results table as you are completing your experiment

You need to include a MINIMUM of 3 replicates

Table Checklist

Includes a descriptive title and three replicates	
Units are included	
The independent variable is in the left column	

CHECKPOINT 7: Design and complete your results table including statistical analysis.

Table of Results

Title:	

Dependent Variable (unit):			
Independent Variable:	**Replicate 1**	**Replicate 2**	**Replicate 3**

PRACTICAL INVESTIGATION: OBSERVATIONS

8. Experimental Log

Instructions

1. Record your experimental observations.

CHECKPOINT 8: Record the progress of your experimental work. Collect observations and notes.

Experimental Session - Date:

Observations and notes

Experimental Session - Date:

Observations and notes

Experimental Session - Date:

Observations and notes

PRACTICAL INVESTIGATION: GRAPHS

9. Graph

Instructions

1. Use the instructions below to create an electronic graph of your results using Excel.
2. Insert your graph in the space provided.

CHECKPOINT 9: Create an electronic graph of your results - **ASSESSED Rubric 2**

The choice of graph needs to be suitable for the data that is collected. Generally, line graphs are used for continuous data, while bar graphs are used for data for separate categories.

Graphs need to include a title that describes the data, labels on the axes with units and an appropriate scale. The independent variable should be on the x axis. The graph needs to be drawn electronically.

Graph Checklist

	Is a suitable graph for the data
	Includes a title and axes are labelled
	Units are included and appropriate scale
	The independent variable is on the x axis
	95% CI included

Use the provided excel spreadsheet to generate your graph

PRACTICAL INVESTIGATION: DISCUSSION PLAN

Discussion Planning Document (print to A3)

1. Aim

2. Summarises data

Evaluates quality of summarised data

3. Key finding (related to aim)

Theory to explain key finding

4. Key finding (related to aim)

Theory to explain key finding

5. Link key findings and/or unusual results

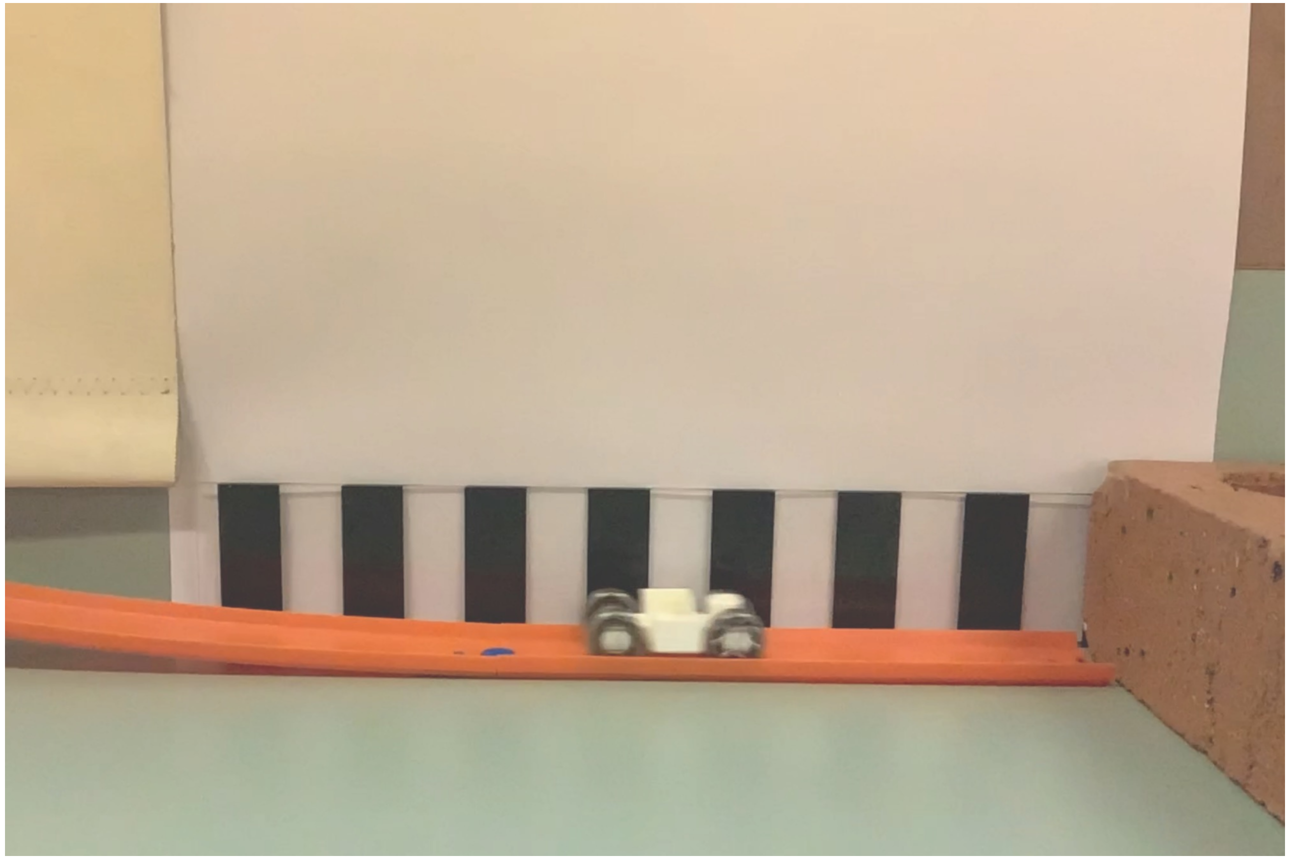
6. Makes generalisations based on key findings

7. Error and effect on quality of data

8. Conclusion — summarises key findings, explains implications, identifies limitations, and makes recommendations

PRACTICAL INVESTIGATION: EXP SET UP

PRACTICAL INVESTIGATION: EXP SET UP



COLLECTIVE LEARNING IN THE PHYSICS CLASSROOM

Dr Adele Hudson — Gilson College

Lisa Mililli — Aitken College

Jill Forward — Aitken College

Resources can be found at www.edudesign.com.au