gravity DISCOVERY CENTRE

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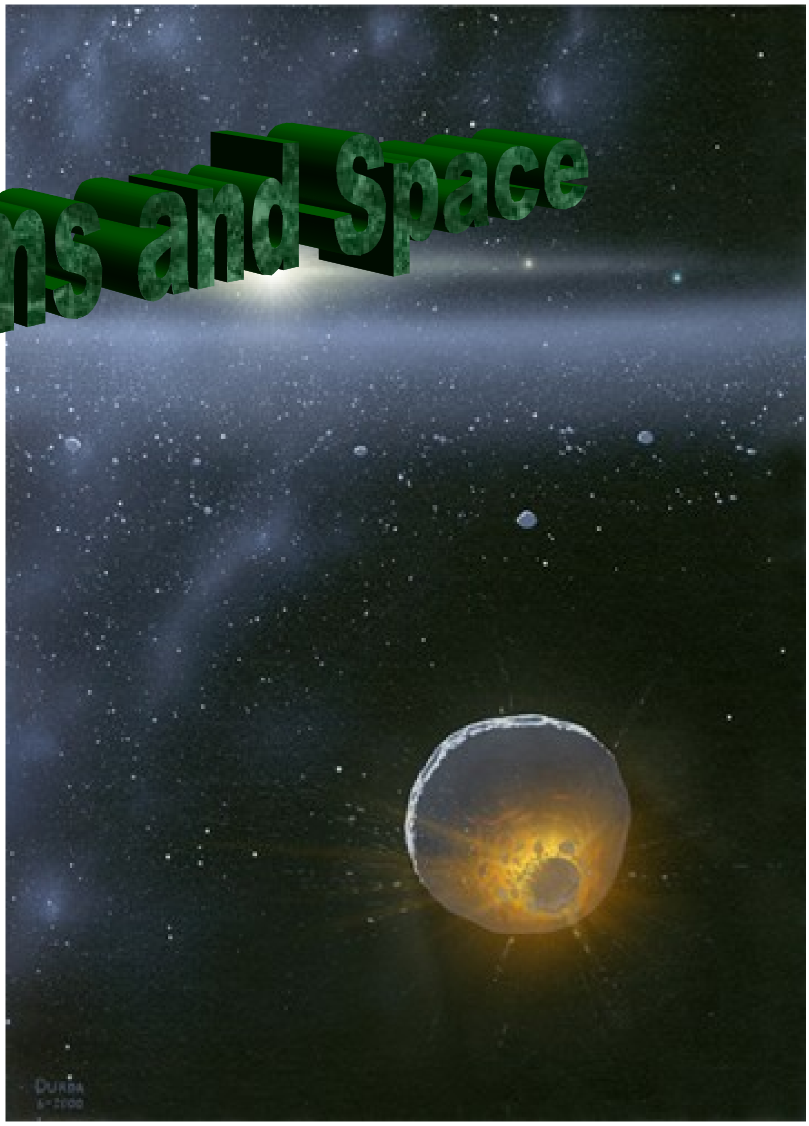
Module covers Working Scientifically and The Earth and Beyond strands. Suitable at Yr 8 – 10 Levels 3 – 5.

Vacuums and Space



When your students engage themselves in the activities in this module they will be tackling some of the bigger questions about ‘Life, The Universe & Everything’.

The learning doesn’t stop at the centre; your students will have fun investigating the effects of vacuum on their bodies while at school.

As a teacher you will appreciate the background information, answer sheet and levelling rubrics that you are given.

gravity DISCOVERY CENTRE

TEACHER USE

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These sheets are for teachers to provide them with background information that they may pass on to their students before, during or after their visit to the Gravity Discovery Centre.

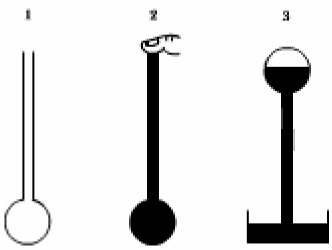
"Nothing is real." - The Beatles, "Strawberry Fields Forever".

"Nothin' ain't worth nothin', but it's free." - Kris Kristofferson, "Me and Bobby McGee".

"I see nobody on the road," said Alice. "I only wish *I* had such eyes," the King remarked in a fretful tone, "to be able to see Nobody! And at that distance too!" – Lewis Carroll, "Alice in Wonderland"

Alice may have seen nobody during her adventures through the looking glass, but Al Jolson tells us that we **"ain't seen nothing yet."** Certainly artists have been investigating nothingness throughout history. There has been **"Much Ado About Nothing"** in other areas of human thought as well. This is especially so in philosophy and the sciences.

What is empty space? On first read this seems an easy question. There's nothing to it! 2300 years ago Aristotle announced, **"Nature abhors a vacuum."** And for a long time after the belief was that it was not possible to have a complete vacuum. There were many arguments, religious and philosophical, over the centuries, as to why a vacuum was not permitted in God's universe.



In 1643 Evangelista Torricelli (who had been one of Galileo's students) conducted a simple experiment that produced a region of space where all matter seemed to have been removed. Previous to this, thought experiments were used to refute the possibility of the existence of vacuums. The experimental method that is currently used in science was not employed. What Torricelli did was construct a simple mercury barometer. (*An empty glass tube, 1 ,was filled with mercury and sealed with a thumb, 2. It was then inverted with the sealed end placed into a mercury bath, and the thumb removed. The mercury fell down the tube, leaving a space above the mercury.*) Was this the vacuum that scientists and philosophers had been telling us was impossible? There does seem to be no matter present.

It would appear that Aristotle was wrong, not only does nature not abhor a vacuum; it allows us to create only very simply. Or does it? Light travels through this 'vacuum'. We can see what is on the other side of the barometer. Heat will also radiate or travel through this region. If it were to truly be a vacuum there should be nothing in it, not even this electromagnetic radiation.

Late in the 19th century it was realised that this, so called, vacuum still contained heat or thermal radiation. If this container with the vacuum was perfectly insulated so that no heat could get in or out, and then cooled to zero Kelvin, then all thermal radiation would have been removed.

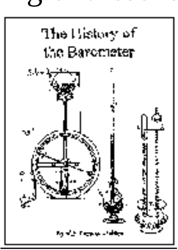
Now we should expect that along with no matter being present, there will also be no energy. We would now expect to have a complete vacuum. Surprisingly, this is not the case. Both experiments and theory show that this vacuum still contains measurable energy. This energy is called the zero-point energy (ZPE), since it is present at zero Kelvin.

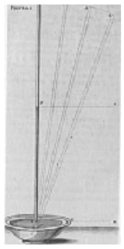
ZPE can explain observations such as why helium will not freeze due to lowering its temperature alone (unless pressure is applied ZPE fluctuations prevent helium's atoms from getting close enough to allow solidification), or why there are limits to the amount of amplification for signals in electronic circuits (ZPE fluctuations cause random 'noise').

These fluctuations are not obvious at everyday levels but become significant when observations at the atomic level are made. The magnitude of ZPE is not insignificant, however. (When looking at energy density the unit 'erg' is used. An erg is define as the work done when a mass of 1 g undergoes an acceleration of 1 cm s^{-2} over a distance of 1 cm. Think of 10^7 ergs per second being equivalent to 1 watt.) Estimates assigned to the energy density of the ZPE range from 10^{44} ergs per cubic centimetre up to infinity! In actual practise it appears the upper limit for this value may be 10^{114} ergs cm^{-3}.(This limit is imposed by the Planck length.) To put this value into perspective our sun radiates energy at the rate of approximately 3.8 x 10^{20} W, and in our galaxy there are in excess of 100 billion stars. If we make the assumption that all these stars radiate at approximately the same rate as our sun, then the amount of energy expended by our entire galaxy of stars shining for 1 million years is roughly equivalent to the energy locked up in one cubic centimetre of 'vacuum'!! When Freddy Mercury sang **"Nothing really matters"** in the song "Bohemian Rhapsody" was he singing about the vacuum of space?

Most high school teachers and students ignore this feature of the 'vacuum of space'. We talk about the physical vacuum having properties that are uniform throughout the cosmos. It appears smooth and featureless. However at the size of atoms it has been described as a seething sea of activity. In this realm of the very small, in fact at the Planck length (1.616 x 10^{-33} cm) we see the vacuum as being not smooth, but granular in structure. The vacuum seems to be not made of 'nothing', but even gives rise to short-lived particle/antiparticle pairs that flip in and out of existence incredibly quickly.

Your students will be probably be more concerned with questions such as "If I'm in the vacuum of space, without protection, will I explode?", or the classic problem of "Why does a feather fall slower than a hammer when dropped on Earth? But the same pair of objects, when dropped on the moon fall at the same rate?" The activities that your students will undertake will give them an understanding of these issues.





gravity DISCOVERY CENTRE

AT SCHOOL USE

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These sheets describe an activity to be undertaken by students at school, either before or after their visit to the Gravity Discovery Centre.

You've watched the movie Total Recall and saw peoples eyes bulge when exposed to the thin atmosphere of Mars. Your science teacher explains that this occurs due to the difference in gas pressure between the Martian atmosphere and the insides of our bodies. She says that without protection our bodies would squirt blood through our skin and eventually explode if we were exposed to a vacuum. You make a note to self – 'Always wear a space suit when in a vacuum.'

You don't think of this again until your parents ask you to light your barbeque. 'Hold on,' you think 'there is a very high pressure inside the gas bottle compared to the atmosphere outside. It's not exploding, or squirting gas through the metal. Why should our bodies be any different?' Could it be possible that your science teacher was wrong? Surely not. Just to be sure you decide to investigate the matter further.

Your research should involve, at least the following:

- just what is a vacuum?
- what sort of pressure exists inside our bodies. And how 'tough' are our skin and other organs?
- what sorts of effects on our body could be realistically expected by short and long exposure to a vacuum?

Once you have gathered your information you decide to share it with those that need to know; moviemakers, NASA engineers etc.

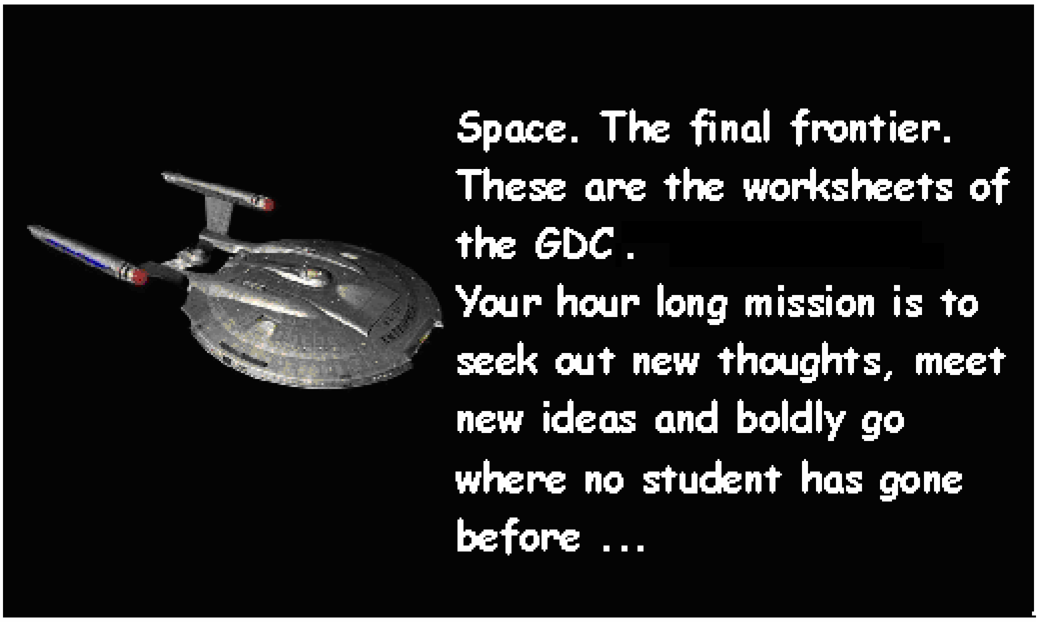
Present your findings in one of the following ways:

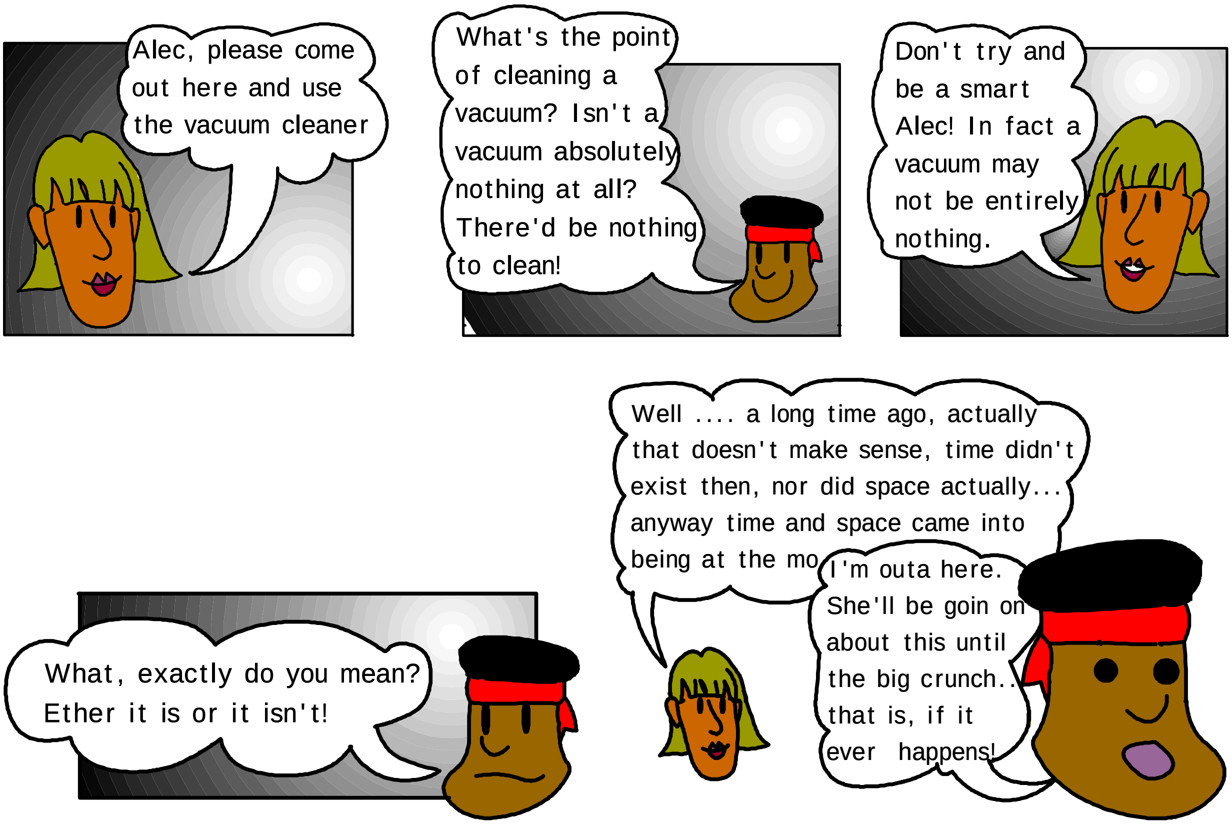
- A warning label to go on the air lock doors of all future spacecraft that NASA constructs. Try to think of symbols similar to other types of warning labels that would convey the information to the readers. As well as the symbol you will need to provide information about the effects of different lengths of exposure.
- A letter written to a movie scriptwriter to give them the correct scientific information so that their future movies are more accurate.
- A scene from a science fiction movie where one of the characters is set adrift from their vessel without a space suit.
- A chapter in an astronaut training manual that informs them of the reality of exposure to a vacuum. Graphic diagrams should help you convey your message.
- A presentation to your science class so that your classmates **and teacher** get the facts about exposure to vacuum.

GENERAL USE

Notes and Recording

These sheets are for students to record their results in various activities, and to use to draw graphs if needed.





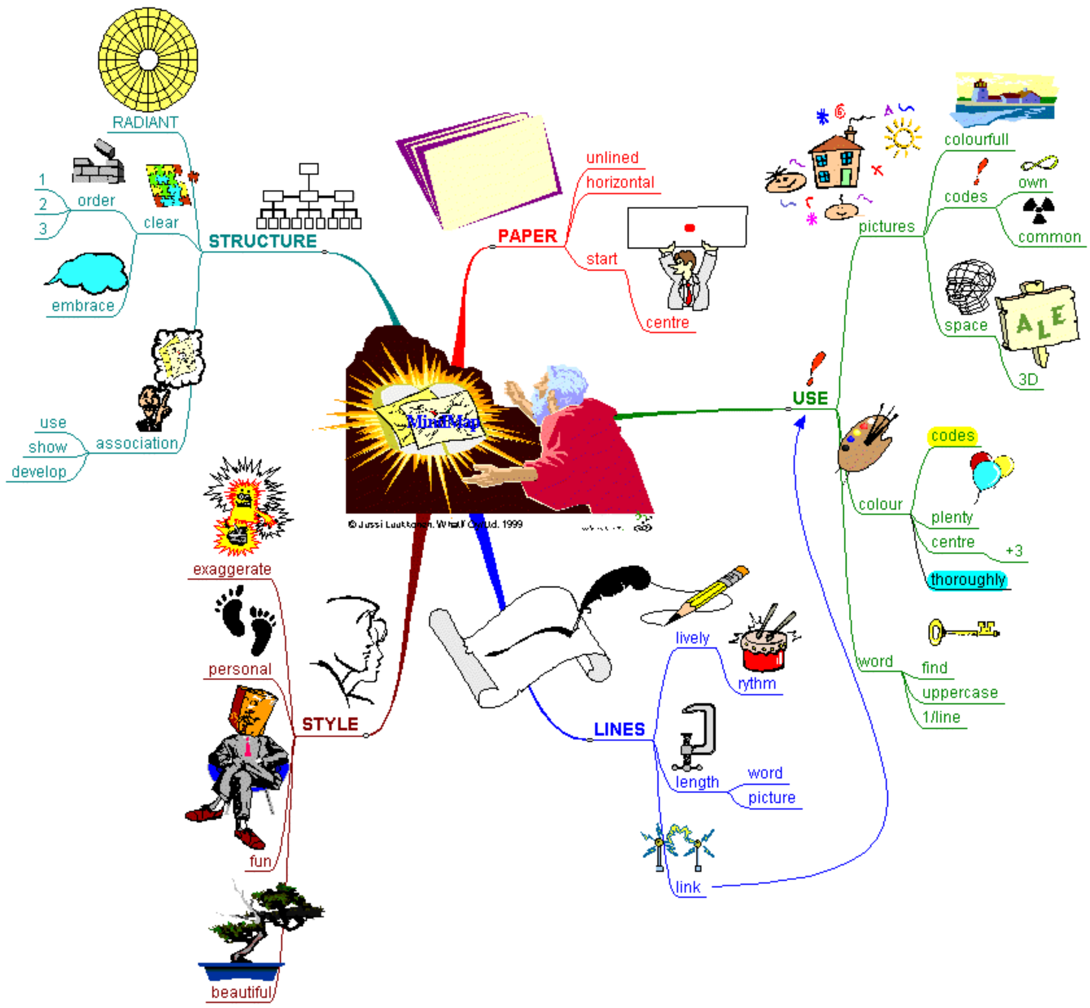
Map your mind.

Just what was that previous comic about? What is a vacuum? In fact what is space? In your group make a mind map of your knowledge of the subject.

What is a mind map? Think of it as mapping the ideas, thoughts, feelings, symbols, shapes etc in your brain, or in this case the brains of your group! Be creative with it. Use colour and drawings – anything that will help you.

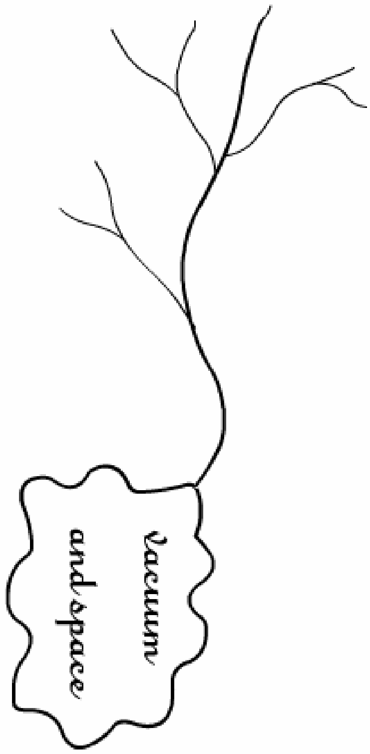
We use mind maps because they:

- give you an overview of a large subject.
- gather and hold large amounts of data for you.
- enable you to be very efficient.
- encourage problem solving by showing you new creative pathways.
- are enjoyable to look at, read over and remember.
- attract and hold your eye and brain.
- let you see the whole picture *and* the details at the same time.



http://www.mind-map.com/

There is the beginning of a skeleton of a mind map below, to get you started. There are two posters that may give you some ideas as well – '***History of Vacuum' and 'What is Space?'.***



Galileo concluded that all objects fall to Earth at the same rate, regardless of their mass. He explained the fact that the paper took longer to fall as being due to the air that it fell through. If there was no air he thought that the paper and ball would fall at the same rate. On the Apollo 15 mission to the moon astronauts Dave Scott and Jim Irwin did an experiment to see if Galileo was correct by dropping a hammer and a feather at the same time. You will now conduct an experiment to check if he was right.

Locate and workout how to use the vacuum tube.

Make a sketch of the Vacuum tube with notes about how it works. Include what you understand a vacuum to be.

1. Try the vacuum parachute. Record your observations in the space below. Can you explain your observations?

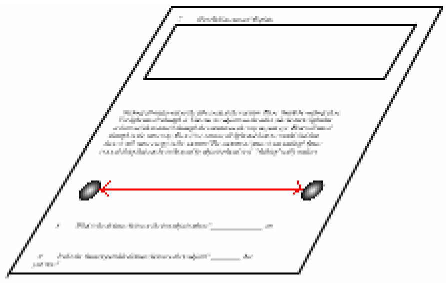
2. Was Galileo correct? Explain.

Sucking all matter out of the tube created the vacuum. There should be nothing there. Yet light travels through it. You can see objects on the other side because light that reflects off them travels through the vacuum on the way to your eye. Heat will travel through in the same way. Even if we remove all light and heat we would find that there is still some energy in the vacuum! The vacuum of space is not nothing! Space is a real thing that can be influenced by objects placed in it. ‘Nothing’ really matters.

Warp Factor

3. What is the distance between the two objects above? ________________ cm

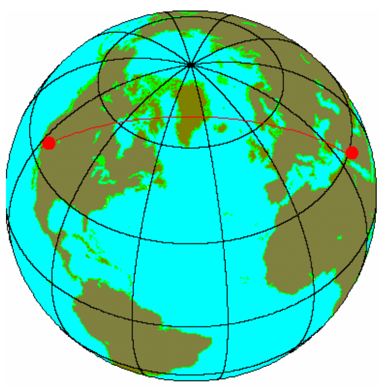
4. Is this the shortest possible distance between these objects? _________ Are you sure?

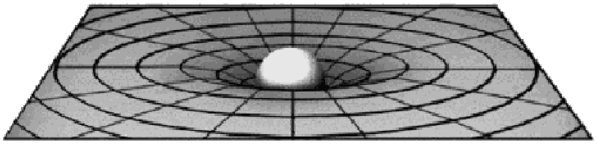


When the page is flat the shortest distance is the straight line that you measure between the objects. Can you make a shorter distance between the objects if you fold or warp the page? Do you have to change your answer for question 9?

If you placed a small heavy object in the middle of your sheet of paper it would probably bend or distort the sheet. A mass placed in space will also distort or warp the space around it.

Sometimes the straightest line that you can travel is curved! If the space that you are travelling through is curved you would think that the line that you travelled was straight. In fact you would be following the curve of space. Seems difficult to imagine, but we do it everyday. Imagine you were to travel the shortest path between two points on the Earth’s surface. You would take a straight path between the two points, wouldn’t you? In fact you wouldn’t. You would walk a curved path, since the surface of the Earth is curved. It would just seem to be straight to you because you think that you are travelling across a flat surface.





You will see a model of curved space in the theatre. It is meant to represent the ‘shape’ of space around a massive object. Try to roll a ball across the surface so that it follows a straight path.

5. Try rolling it across various parts of the surface and record your observations.

6. How can you relate you observations with the solar system?

Look back at the mind map that you made at the start of this activity. You may now have some different or new ideas to add to it. In your group make appropriate alterations to your mind map.

TEACHER AND/OR STUDENT USE

Rubric

These sheets are for teachers and students to assist in the levelling of student work completed while doing the 'Vacuum and Space' module.

Overarching Learning Outcomes

There are opportunities within the activities in this package for students to demonstrate the following outcomes:

OLO 1

Students use language to understand, develop and communicate ideas and information and interact with others.

OLO 2

Students select, integrate and apply numerical and spatial concepts and techniques.

OLO 3

Students recognise when and what information is needed, locate and obtain it from a range of sources and evaluate, use and share it with others.

OLO 4

Students select, use and adapt technologies.

OLO 5

Students describe and reason about patterns, structures and relationships in order to understand, interpret, justify and make predictions.

OLO 7

Students understand and appreciate the physical, biological and technological world and have the knowledge and skills to make decisions in relation to it.

OLO 10

Students participate in creative activity of their own and understand and engage with the artistic, cultural and intellectual work of others.

OLO 12

Students are self-motivated and confident in their approach to learning and are able to work individually and collaboratively.

The activity would assist you in the levelling of your students in the Investigating Scientifically strand, specifically the Conducting and Processing Data sub-strands.

The following pointers could be used to determine the level at which your students have performed the activity.

CONDUCTING
'Students conduct and collect a variety of information relevant to their investigations.'

Level		**Pointer/s**	**Demonstrated**
IS 1.2	The student carries out activities involving a small number of steps; and observes and describes.	• 'plays around' with the vacuum parachute	
IS 2.2	The student observes, classifies, describes and makes simple non-standard measurements and limited records of data; and uses independent variables that are usually discrete.	• makes observations of the rate of fall in and out of a vacuum	
IS 3.2	The student uses simple equipment in a consistent manner; and records data in simple tables, diagrams or observations.	• takes numerical measurements of the fall of the vacuum parachute	
IS 4.2	The student takes care with data collection so that data are accurate; uses repeated trials or replicates; and uses independent variables that are usually continuous.	• performs repeat trials of the vacuum parachute and records results in a table	

PROCESSING DATA
'Students translate and analyse information to find patterns and draw conclusions to extend their understanding.'

Level		Pointer/s	Demonstrated
IS 1.3	The student shares observations.	• no written record, but can describe what was done and seen. Q 1,2,6	
IS 2.3	The student makes comparisons between objects or events observed.	• can say if their results and Galileo's ideas are similar or different Q 1,2,6	
IS 3.3	The student displays numerical data as tables or bar graphs, and identifies patterns in data and summarises the data.	• uses a table for results for Q 1,2,6	
IS 4.3	The student calculates averages from repeated trials or replicates; plots data as line graphs where appropriate; and makes conclusions that summarise and explain patterns in the data.	• can give an explanation for results Q 1,2,6	
IS 5.3	The student makes conclusions that are consistent with the data and explains patterns in the data in terms of scientific knowledge.	• can explain results using scientific knowledge and past experience Q 1,2,6	

This sheet could be reproduced and provided to your students before they conduct the activity, or used by you to assess their performance, once the activity has been completed.