

THEORIES OF RELATIVITY

Primary Module – Years 4 – 7

Learning Area – Science

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BACKGROUND INFORMATION

These sheets may be used for teachers to provide information prior to the visit to the GDC. Students may want to access these sheets before, during or after their visit.

Einstein's Theory of Relativity is based on Newton's laws of mechanics and Maxwell's electromagnetic theory and the concepts of space and time. If we want to describe the Universe as we know it in its most basic terms we could say that it consists of a handful of properties. We are so familiar with these properties that we take them for granted. But under special relativity they behave in unexpected ways.

The fundamental properties of the Universe are:

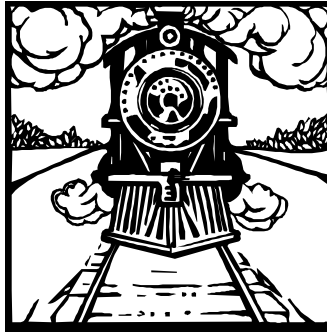
- Space
- Time
- Matter
- Motion
- Mass
- Energy and
- Light

The principle concept underlying the foundations of the Newtonian theory is that 'space' and 'time' are absolute, that is they exist independent of each other and any other physical phenomena. Space and time are considered to be continuous, invariable and not affected by the motions of material bodies. Space is considered to be endless and of the same composition throughout while time is also considered to be endless without relation to anything external.

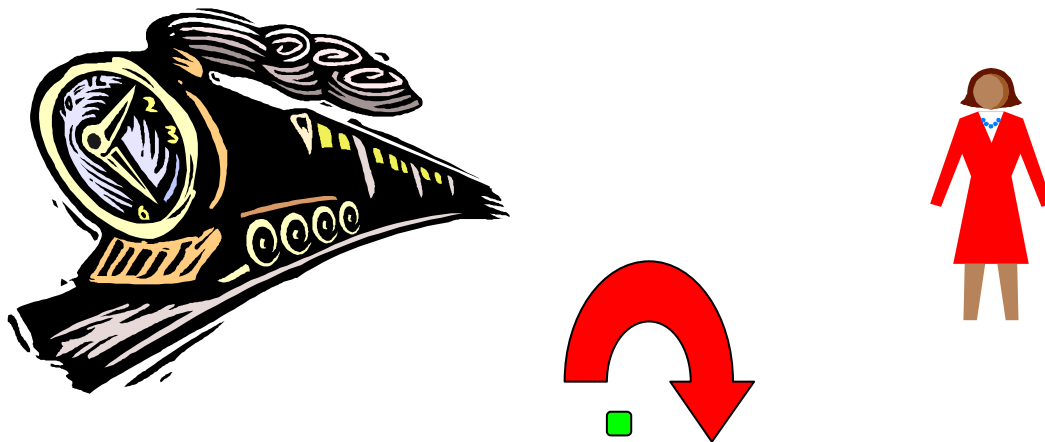
Einstein's theories however, are based on his conclusion that time and space are not constant but vary in accordance with the motions of the bodies being considered.

To illustrate the relativity of objects and events Einstein used the example of a person riding in a railway carriage:

A person travelling at a constant speed drops a stone out of the window. Assuming there is no air friction the person sees the stone fall to the ground in a straight line, as the stone's forward motion is continued at the same speed as that of the travellers as it falls to the ground.



However a pedestrian sitting on the embankment watching the train go by sees the stone falling to the earth in a parabolic curve, rather than in a straight line. This is because the stone has a forward velocity relative to the stationary pedestrian.



So which is the ‘real’ path traversed by the stone – the straight line or the parabola? Einstein answered this question by saying that the stone traversing in a straight line is relative to a ‘system of coordinates’ attached to the train but the stone traversing in a parabola is relative to the coordinates attached to where the pedestrian is standing.

It is easy to see that time is also relative and not absolute. Einstein explored whether two or more events that occur simultaneously in one coordinate system also occurs simultaneously in another. As an example, Einstein considered the case of lightning striking at the same time two different points on a railroad track, A and B. The question is whether the two events, lightning striking point A and lightning striking point B, which are simultaneous for a person on the ground with respect to the embankment, are also simultaneous when viewed from the railway car.

To determine this, Einstein said let us assume that rays of light are emitted at the same moment at both A and B at the time the lightning strikes these points. An observer on the track at the midpoint M between A and B would observe the rays of light from A and B caused by the lightning at the same instant, and would conclude that the lightning struck A and B simultaneously.

Now, let us assume that the points A' and B' on the train exactly correspond to points A and B on the embankment at the instant the lightning strikes these points. Let us also assume that an observer is positioned at the midpoint M' between A' and B'. Since the train is travelling at a velocity v relative to the embankment, the light from point B will reach the observer at M' on the train sooner than the light from point A. Therefore, the observer on the train would conclude that the lightning flash of B took place earlier than that of A. However, if the train were stationary and not in motion relative to the embankment at the moment the lightning struck, then the light rays from A & B would have reached the observer at the same instant and the person would have concluded the lightning flashes were simultaneous.

Accordingly, Einstein came to the conclusion that time depends on how you are moving. Previously, as already mentioned, it had been assumed in physics that a statement of time had an absolute significance, that time is independent of any motion of the reference-body.

We also know that gravity makes things fall down, it is the gravitational field of the earth that is responsible for elevated objects falling to the ground. The action of the earth on objects occurs indirectly. The earth attracts objects to it not because the earth acts directly on objects through the intermediate space, but because there exists something physically real in the space around the earth, that we call the *gravitational field*. It is the gravitational field that acts on objects, so that they are pulled towards the earth.

The theory of gravitation derived by Einstein called the General Theory of Relativity, according to Einstein, effectively explains astronomical observations which cannot be explained by Newton's law of motion of classical mechanics. According to Newton's theory, a planet moves around the sun in an ellipse, which would permanently maintain its position with respect to the fixed stars, providing the motion of the fixed stars themselves and the action of other planets can be neglected. If the observed motion of the planets are corrected for these influences, and if Newton's theory is correct, the orbit of the planet obtained should be an ellipse, which is fixed with reference to space.

However, the orbit of Mercury is not stationary in space, but it rotates slowly in the plane of the orbit and in the direction of its orbital motion. This effect cannot be explained by Newton's Laws only. Einstein was able to explain this. He found that the ellipse of every planet around the sun must necessarily rotate in the manner indicated above, but that for all planets, with the exception of Mercury, this rotation is too small to be detected with the delicacy of observation possible at that time. In the case of Mercury it was determined to amount to about 43 seconds of arc per century, which has been verified through observation.

The General Theory of Relativity indicates that the properties of space are not independent of matter, but are determined by it; that it is the distribution of matter in space, which determines the shape of the universe. According to the Theory, if matter is distributed uniformly, the universe would necessarily be spherical (or elliptical). To the extent that the distribution of matter is not uniform, the actual universe will deviate from a perfect sphere in individual parts, but will be generally spherical in form, and will necessarily be finite, according to the Theory.

(Adapted from: <http://science.howstuffworks.com/relativity3.htm>)



TEACHER AND/OR STUDENT USE

These sheets are for teachers and students to assist in the levelling of student work completed during the Relativity module

Overarching Learning Outcomes

There are opportunities 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 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 5** Students describe and reason about patterns, structures and relationships in order to understand, interpret, justify and make predictions.

Progress Maps– Science**Investigating Scientifically****Planning:**

Students plan investigations to test ideas about the natural and technological world.

	Level	Pointers	Demonstrated
IS 2.1	The student identifies, given a focus question in a familiar context, some of the variables to be considered	<ul style="list-style-type: none"> • Contributes to brainstorming • Recognise focus variable 	
IS 3.1	The student plans for investigations, showing some awareness of the need for fair testing; and makes simple predications based on personal experience	<ul style="list-style-type: none"> • Identify constant in investigation • Plan to conduct investigation the same way 	
IS 4.1	The student identifies the variables to be changed, the variable to be measured and at least one variable to be controlled and plans for observations to be made	<ul style="list-style-type: none"> • Plan specifying two main variables • Plan to keep one variable constant 	

Conducting:

Students collect and record a variety of information relevant to their investigations

		Pointers	Demonstrated
IS 2.2	The student observes, classifies, describes and makes simple non standard measurements and limited records of data	<ul style="list-style-type: none"> • Uses simple non standard measurements • Uses words, pictures or numbers to record observations 	
IS 3.2	The student uses simple equipment in a consistent manner and records data in simple tables, diagrams	<ul style="list-style-type: none"> • Consistently uses equipment • Uses standard units in measurement • Chooses appropriate forms of presentation 	
IS 4.2	The student takes care with data collection so that data are accurate; uses repeated trials and uses independent variables that are usually continuous	<ul style="list-style-type: none"> • Uses equipment appropriately and consistently • Measures accurately 	

Processing Data:

Students translate and analyse information to find patterns and draw conclusions to extend their understanding

		Pointers	Demonstrated
IS 2.3	The student makes comparisons between objects and events observed	<ul style="list-style-type: none"> • Compares events • Compares places 	
IS 3.3	The student displays numerical data as tables or bar graphs, and identifies patterns in data and summarises the data	<ul style="list-style-type: none"> • Uses tables to organise data • Identifies patterns • Draws bar graphs to show patterns in data • Does not explain patterns in data 	
IS 4.3	The student calculates averages from repeated trails, plots data as line graphs where appropriate and makes conclusions which explain data	<ul style="list-style-type: none"> • Calculates averages • Collects data over a period of time • Summarises data and attempts to explain patterns 	

Evaluating:

The student reflects on an investigation, evaluates the process and generates ideas.

	Level	Pointers	Demonstrated
IS 2.4	The student comments on what happened and can say if what happened was expected	<ul style="list-style-type: none">• Comments on what happened• Can say whether what happened was expected• Can say whether the outcome was different to the prediction	
IS 3.4	The student identifies difficulties experienced in doing the investigation	<ul style="list-style-type: none">• Can say it was difficult to make exact measurements• Identifies external factors that influence the results	
IS 4.4	The student, makes general suggestions for improving the investigation	<ul style="list-style-type: none">• Suggests the need for better equipment• Establishes the need for more exact measurement• Establishes the need for repeat testing	

TEACHER USE

The following activities will assist students in gaining some understanding of the concepts of Relativity.

Task 1: All About Albert Einstein

- a) Students research Albert Einstein and prepare an oral presentation to be presented to their peers during their visit to the GDC.
- b) Format for presentation could be as follows:
- Who was he? Where was he born? Family, early life, early education
 - Tertiary education, teenage and young adulthood
 - Discoveries
 - Impact on us and our lives through Einstein's discoveries
 - Applications to daily life of Einstein's theories
 - References
- c) Students can present this orally in any suitable format, supported by posters, pictures, power points, slides etc.
- d) Teacher assessment could be based on: Content, Language Structures, Independence and Participation

Area	1	2	3	4
Content	Very basic content	Simple description and explanation	Detailed description and explanations included	In depth research evident and reflective comment
Language Structures	Single word responses or incomplete sentences	Simple sentences, stereotyped sentence pattern and repetition of words, non specific vocab.	More complex sentence structure with range of connectors, specific vocab. used to refer to Einstein	Sentences linked to create 'text like' effect,
Independence	Sharing totally prompted	Needs frequent prompts or closed prompts used, e.g. <i>What did Einstein discover?</i>	Needs some prompts or open prompts e.g. <i>Can you explain more?</i>	Shares research independently
Participation	Avoids turn or has refusal behaviour	Has turn at teacher request but has non verbal signs of discomfort	Bids for turn, has appropriate non-verbal behaviours	Approaches sharing with confidence and enjoyment, high level of interaction with audience

STUDENT USE

The following sheets are for students to us, for recording purposes during their visit to the GDC

Einstein, it is fairly well known, was no genius at school. His best work was done, not as a professor but as a clerk in a patent office in Bern, Switzerland.

It was in his spare time in 1905 that he created the Special Theory of Relativity which led to a famous equation, $E=mc^2$ and his explanation of the photoelectric effect – light energy from the Sun being transformed into electrical energy. This is how a solar panel works.

Activity 1.

Oral presentation

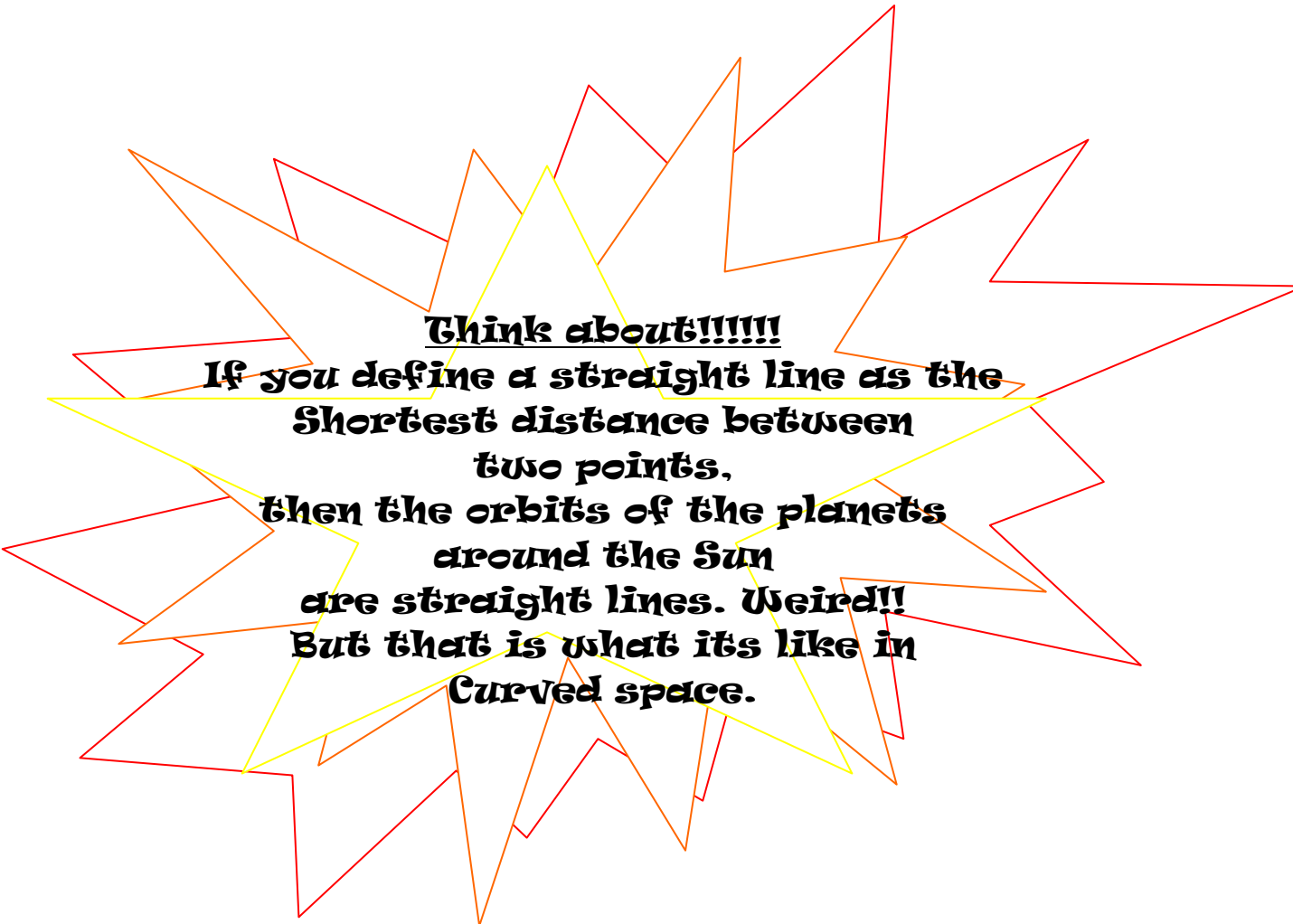
Activity 2: Curved Space:

Einstein proposed that the Earth distorts and curves space around it. The curved space then makes things move.

Einstein said that space was elastic, but still very stiff a little like a very tight trampoline or a large rubber sheet stretched taut. He believed that the planets and the Sun deformed the fabric of space. Gravity is just the curvature of space. Because space is like a trampoline it can also have waves rippling across it. These are called gravity waves. Making detectors for these waves, scientists think they will be able to listen to the sounds of stars exploding (super nova explosions) and black holes colliding far away in the universe.

Curved Space Model

1. Describe what you see.



Think about!!!!
**If you define a straight line as the
Shortest distance between
two points,
then the orbits of the planets
around the Sun
are straight lines. Weird!!
But that is what its like in
Curved space.**

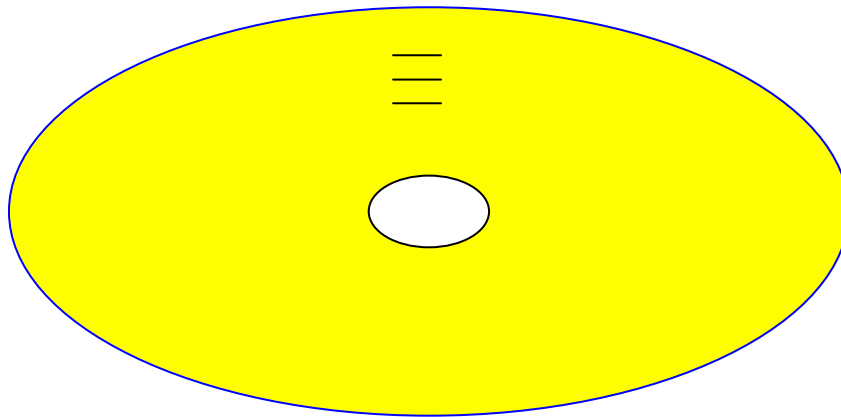
Activity 3

Black Hole Model

Light is also affected by the mass of an object. If a star larger than our Sun comes to the end of its life, it passes through a series of stages. As the hydrogen burns to form helium, the star will eventually 'burn out'. It then becomes a red giant, then a neutron star and then if the initial mass is large enough it becomes a black hole. The star collapses inside itself due to the force of gravity. Its size is minute compared to the original size of the star. This collapse results in an intense gravitational field around the star. This field is so great that light is prohibited from escaping from the star and so the name Black Hole resulted.

1. Predict the time taken for your ball to complete one orbit of the black hole at the outer most point. Use the work sheet supplied to record your prediction.

2. Look at the markings along the inside of the Black Hole model. You will observe that they are approximately 50cm. Apart. Predict what the time taken will be for the ball to complete a revolution if it is released at each of these markings.
3. Using the ball release it at each of the 50 cm. markings and record the time taken for the ball to complete one revolution. Look carefully at the diagram to assist you in completing this experiment correctly.



Task 2

1. Predict what will happen if you set the ball on a circular route around the Black Hole model. Record your prediction on your work sheet.
2. Set the ball rolling around the black hole model. Observe what happens and record it using the digital camera. Record your findings on the work sheet.

Pre Visit Activities

Information on Einstein:

a. Who was he? Where was he born? Family, early life, early education

Einstein was born on 14th March 1879 in Ulm, Wurttemberg, Germany and died on 18th April 1955 in Princeton, New Jersey, USA. Around 1886 Albert Einstein began his school career in Munich. He learnt to play the violin and was taught Judaism..

b. Tertiary education, teenage and young adulthood

He studied Mathematics, particularly calculus. In 1894 his family moved to Milan but Einstein remained in Munich. In 1895 he failed an entrance examination to enable him to study electrical engineering in Zurich so attended a secondary school there. He decided to become a teacher and succeeded with his plan, graduating in 1900 as a teacher of mathematics and physics. But at the beginning of 1901 he still had not landed a job. By mid 1901 he had a temporary job as a teacher. Another temporary position at a private school followed. From 1902 to 1909 he held the position in a patent factory, during which time he was promoted technical expert. In 1905 he earned a doctorate from the University of Zurich.

c. Discoveries

In 1905 Einstein wrote three papers:

1. examined the phenomena in w

- d. Impact on us and our lives through Einstein's discoveries
- e. Applications to daily life of Einstein's theories
- f. References

Student Worksheet**Investigation and Recording sheet for Going, going, gone!!**

Name: _____ Others in my Group _____

Task 1

1. What are you going to investigate?
2. Background knowledge: What previous knowledge do you have which might be useful?
3. Predictions: What predictions can you make about the orbits, which are relevant?
4. Linking prediction to theory: From what you know already, why do you think your prediction will happen?

10. You can use the table below to record your **prediction** or draw up a suitable table for showing what you have predicted

Distance (cm)	Time taken to complete one revolution (sec)
0	
50	
100	
150	
200	

Table for predictions

11. Use the table below to record the **actual time** taken when the ball is released at the set measurements or draw up your own table

Distance	Time taken to complete one revolution
0 cm.	
50 cm.	
100 cm.	
150 cm.	
200 cm.	

Table for actual results

12. Were your predictions close to the actual experiment times?

13. Is there a pattern to your results?

Task 2

1. What is the task you have been set?

2. Predictions: What predictions can you make which are relevant?

3. Linking prediction to theory: From what you already know, why do you think your prediction will happen?

4. Background knowledge: What previous knowledge do you have which might be useful?

5. What will I need?

6. What will I measure?

7. What is the best way to represent your results?

8. Analyse your data. What are your results telling you?

9. What happened?

10. Why did it happen?

11. What is your conclusion?

12. Did you have any questions that haven't been answered - jot them down below for discussion.

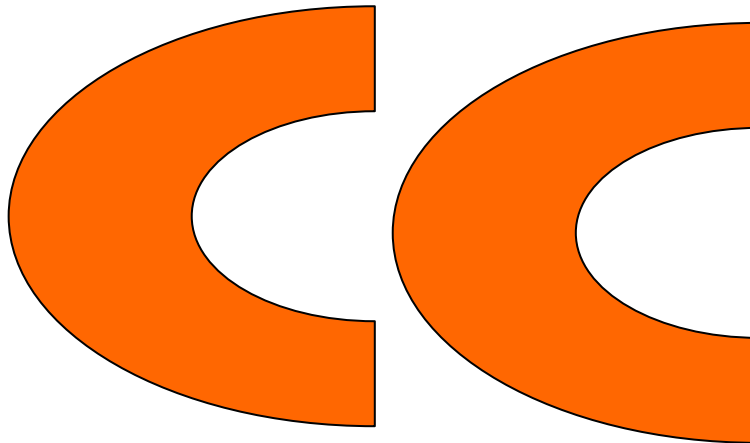
These activities will consolidate understandings and support students learning

1. Power point presentation

Using the images that you took digitally at the GDC put together a power point presentation demonstrating what you learnt about curved space, gravity waves and the relationship between space and time. Present this to your class.

2. Which is bigger?

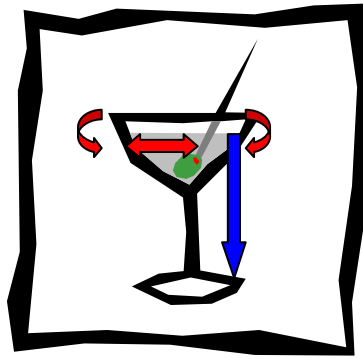
Students examine copies of shapes and determine if they are the same size and shape.



When you look at the two shapes you look at the edges, which are next to each other – the long edge of one shape next to the short edge of the other. This difference in length makes the shapes appear to be different sizes.

The shapes are exactly the same size and shape but our eyes can play tricks on us when we look at objects relative to another one.

Can you trust your judgement?



The question is, which is bigger, the distance around the rim of the glass or the height of the glass?

Students make a prediction.

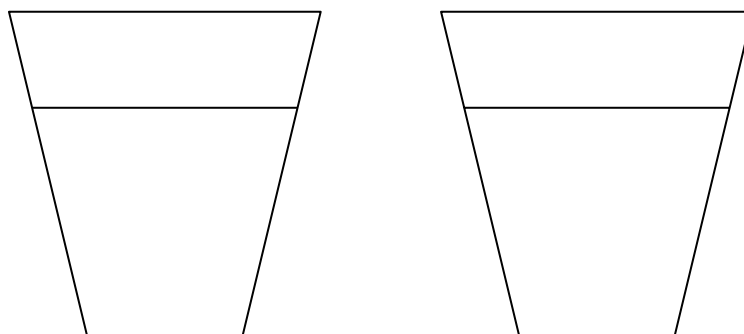
Most glasses are bigger around the rim, (the circumference), than their height, but they don't appear to be so. This is a good example of how our eyes can lead us to make bad guesses. It is because we can't trust our senses that measurement came to be.

Because the dimensions of the glass do not lie in the same plane it is difficult to determine the relative size of objects.

3. More to do.

Are you better at estimating distance than volume? For this activity you need two conical glasses and some water. Fill one glass to the brim and then pour half into the second glass. You will see that they immediately appear to be more than half full.

Get students to predict whether if you pour all the water from one glass into the other, the glass will overflow, and how much water will be left in the first glass when the other glass is full.



Remember that when you are asked to guess volume or length your eyes are not always trustworthy. It is always useful to measure relative to some of your own body measurements, hand span, finger length or length of your foot.