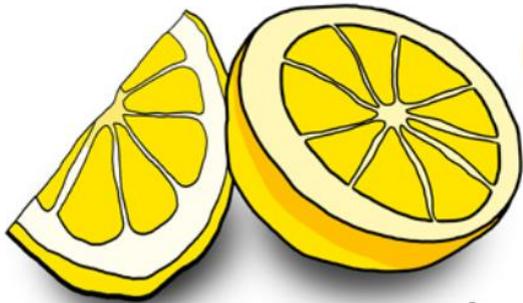
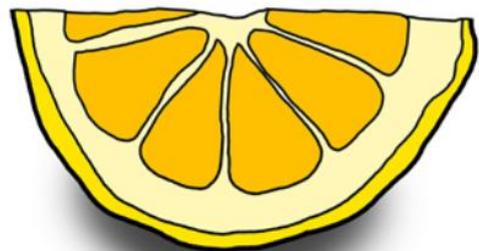
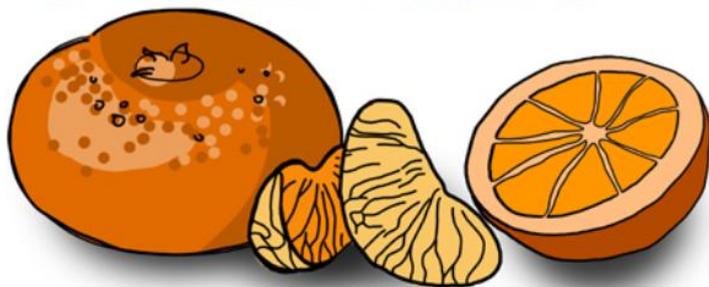


CITRUS SCIENCE



experiments using

ORANGES and LEMONS



			David Featonby Rute Oliveira

Imprint

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Introduction

This booklet presents a collection of ideas and activities using citrus fruits such as oranges, lemons and limes. The experiments cover a wide range of topics in physics, chemistry, mathematics and biology, suitable for different age groups and levels of learning. While some activities are more appropriate for older students, there is something here for everyone to explore and enjoy.

We encourage you to adapt these experiments, extend them into new areas, or create your own citrus-based investigations. If possible, please share your experiences and photographs with us via the Science on Stage office in Germany. We look forward to compiling and publishing a future appendix with even more citrus experiments.

It is believed that the Portuguese introduced the fruit to Europe from China in the sixteenth century, and then took it to the American continent, where today the largest orange plantations in the world are located.

For this reason, nowadays oranges are called Portuguese in some countries. In Romanian orange it is called "portocálâ", the Bulgarians and Turks call them "portukal" and the Greeks "portukáli". Following the map, in Persian, spoken in Iran, Afghanistan and countries such as Armenia, Georgia or Iraq, but also in Arabic, the word "Portugal" means "orange"!

A special thank you to:

David Featonby (UK, Science on Stage Europe)

Rute Oliveira (Portugal, Science on Stage Portugal)

Safety Notice

This booklet contains activities in which some require the handling of sharp objects, such as knives, hot surfaces, and chemical substances that should only be handled by an adult. Care should always be taken when using these materials to avoid accidents.

By carrying out any of the activities described, you accept full responsibility for your own safety and for the safety of others. The authors and publishers of this booklet cannot be held liable for any accidents, injuries, or damages that may result from attempting these activities.

1. Oranges in Space!

Using oranges to illustrate various phenomena in the solar system

1.1 Day and night and Seasons

An orange serves as an excellent model of the Earth for explaining day and night and the seasons. With a fixed light source representing the Sun, it becomes easy to show how rotation produces day and night and how the tilt of the Earth is responsible for seasonal changes.

Materials

- An orange
- A permanent marker (to draw the Equator and poles)
- A torch

Step by step

1. Draw a horizontal line around the middle for the Equator. Mark an "X" on the top half to represent your current location.
2. Place the torch on a table and turn it on.
3. With the orange a few cm apart, hold it with an inclination that represents the inclination of the Earth's axis of rotation.
4. Observe how the "X" moves from the light (day) into the shadow (night) (figure 1).
5. To represent the sequence of the seasons, simply move the orange one, in an elliptical trajectory around the lantern and observe how different hemispheres receive more direct light at different points in the orbit.

The Science Behind

Since an orange is approximately spherical, it serves as a model for planet Earth. With the orange we can explain the succession of days and nights by pointing a fixed torch at the orange, rotating it in a west-east direction, and observing that half is illuminated (day) and the other half is in darkness (night). By marking two dots on the orange (figure 1) and turning in a west-east direction, we can demonstrate that in different cities it dawns or the sun sets at different times.

1. Oranges in Space!

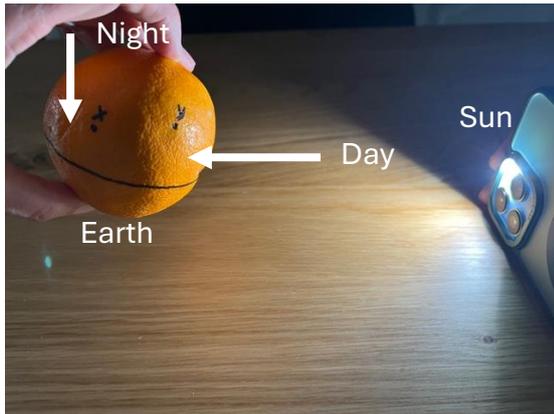


Figure 1: Distribution of solar illumination on Earth, highlighting the regions of day and night.

Figure 2: The sun rises first at point Y and only then at point X.

The Earth's axis of rotation is approximately 23.5° . This tilt and the movement of translation around the Sun are responsible for the succession of the seasons of the year. As the Earth orbits the Sun, the tilt causes different parts of the planet to receive varying intensities of sunlight throughout the year, creating the differences characteristic of the four seasons of the year (figure 3 - 5).



Figure 3: June Solstice.



Figure 4: March Equinox.



Figure 5: December Solstice.

1. Oranges in Space!

1.2 The earth is not flat

Eratosthenes, more than 2,000 years ago, proved that the Earth was round and was able to calculate its perimeter. In this activity, the orange will be planet Earth, and the two sticks will be the famous columns of Alexandria and Siena.

Materials

- 1 orange
- 2 sticks
- 1 light source (represents the Sun)
- Acetate pen

This activity should be carried out in a darkened room to more easily visualize the shadows.

Step by step

1. Place two toothpicks, a few cm apart, stuck on a flat surface, as shown in figure 1.
2. Point the flashlight from above. Observe the shadows (figure 1).
3. Draw on orange, with an acetate pen, a line representing the Equator.
4. Skewer both toothpicks in orange, one in the "Equator" and the other in a place closer to one of the poles.
5. Point the flashlight, fixed in a position, simulating the sun's rays (figure 2).

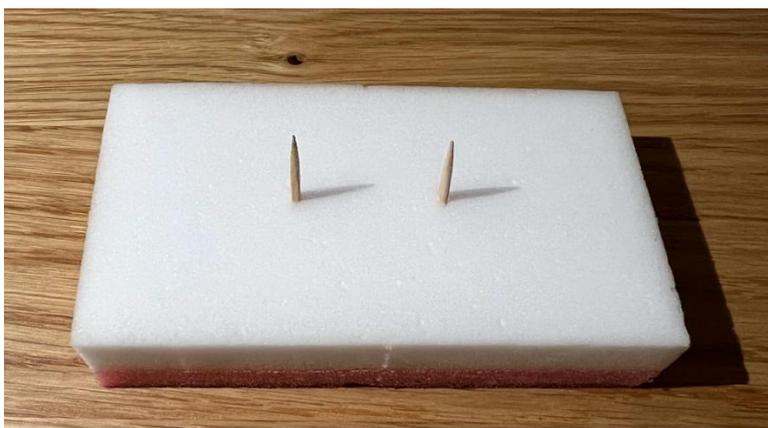


Figure 1: On a flat surface, the shadows of two sticks have the same length.

1. Oranges in Space!

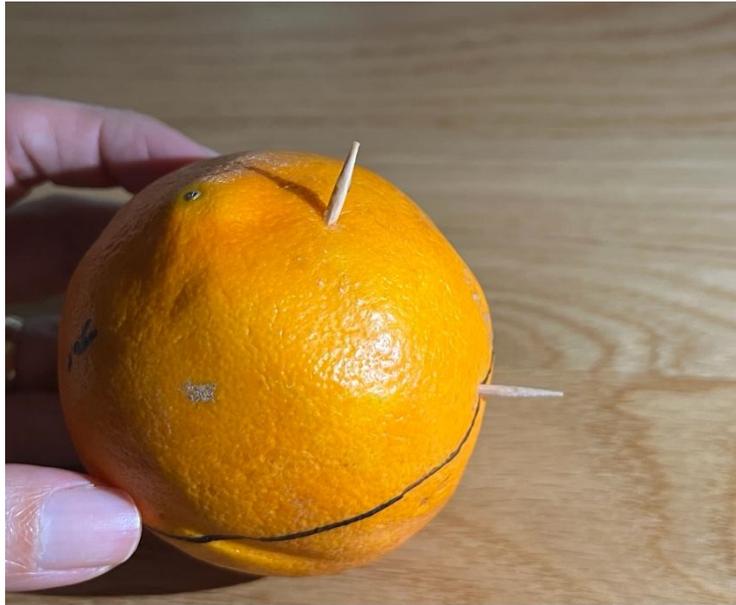


Figure 2: On a curved surface, the shadows of two sticks are different.

The science behind it

If the Earth were flat, the Sun would illuminate all points in the same way and so two identical and vertical objects, under the same light would have identical shadows at the same time.

The variation in the length of the shadows in different places of the orange at the same time is a physical proof of the earth's curvature.

1.3 Orientation through the Sun (shadow size)

This hands-on demonstration provides a clear and intuitive way to discuss how the Sun's apparent path can be used for basic orientation.

Materials

- One lemon
- A torch
- A flat table

Step by step

1. Place the lemon in the centre of a table to represent the Earth.
2. Position the torch at one side of the lemon to represent the Sun at sunrise.
3. Observe the illuminated side of the lemon and the shadow formed on the opposite side.
4. Slowly move the torch around the lemon in a circular path, keeping the same distance.
5. Observe how the illuminated area and the shadow change position.
6. Explain that the direction from which the light comes represents east at sunrise, south at midday and west at sunset (for the Northern Hemisphere).
7. Explain that, in this model, the shadow points west at sunrise, north at midday and east at sunset (Northern Hemisphere).

The science behind it

When the torch is directed towards the lemon, it becomes easy to observe how the position of the Sun in the sky changes throughout the day. The Sun appears to rise in the east, reach its highest position at midday and set in the west. This hands-on demonstration provides a clear and intuitive way to discuss how the Sun's apparent path can be used for basic orientation.

1. Oranges in Space!



Figure 1: At sunrise in the Northern Hemisphere, the Sun is in the East and the shadow indicates the West.

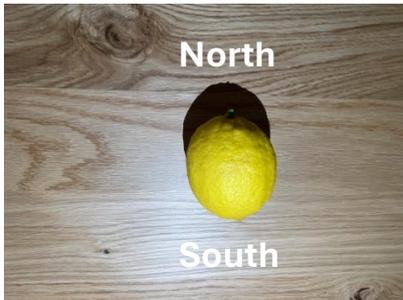


Figure 2: At solar noon, in the Northern Hemisphere, the Sun is in the South and the shadow indicates the cardinal point North.



Figure 3: At sunset, in the Northern Hemisphere, the Sun is to the West and the shadow indicates the cardinal point East.

Teacher's note: Emphasise to learners that this is the *apparent movement of the Sun*. In reality, it is the Earth that rotates, but from our point of view it appears as if the Sun is moving across the sky.

1.4 Sizing the Moon – Estimating its apparent size

Materials

One lemon seed (pip) and a ruler.

Step by step

1. Go outside on a clear night when the Moon is visible.
2. Hold the lemon seed at arm's length in front of one eye.
3. Close the other eye and slowly move the seed until it just completely covers the Moon.
4. Measure the diameter of the seed using a ruler and your arm's length.
5. Record your measurement and compare it with your predictions.

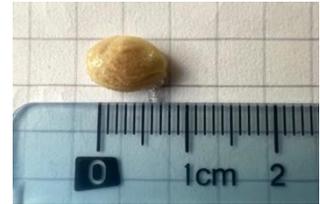


Figure 1: Measuring the lemon seed to estimate the apparent diameter of the Moon.

The science behind it

We know that the Moon is very far away from Earth (about 380,000 km), yet it appears quite small in the sky. One simple way to estimate its apparent size is to hold an object at arm's length and see what just covers the Moon completely.

Although a lemon is far too large for this purpose, much smaller objects work well. For example, the seed (pip) of a lemon held at arm's length can just cover the Moon.

The Moon has a diameter of about 3,500 km and is roughly 380,000 km away. Using these values, we can calculate its apparent size. At a distance of about 0.55–0.75 m from the eye (arm's length), the object needed to cover the Moon is only about 5–7 mm in diameter.

$$\frac{380000 \text{ km}}{3500 \text{ km}} = \frac{\text{arm's length}}{\text{lemon seed size}}$$

1. Oranges in Space!



Figure 2: The Moon and a lemon seed shown side by side to compare their apparent size in the sky.



Figure 3: A lemon seed held at arm's length can just cover the Moon, showing how small it appears from Earth.

Extension: The phases of the Moon can be demonstrated using a large orange in a darkened room. Cover half of the orange with black tape or a black sock (figure 1-4) and observe it as the orange is slowly rotated.

This demonstration is most effective in a completely dark room, where the changing illuminated portion of the orange can be seen clearly.

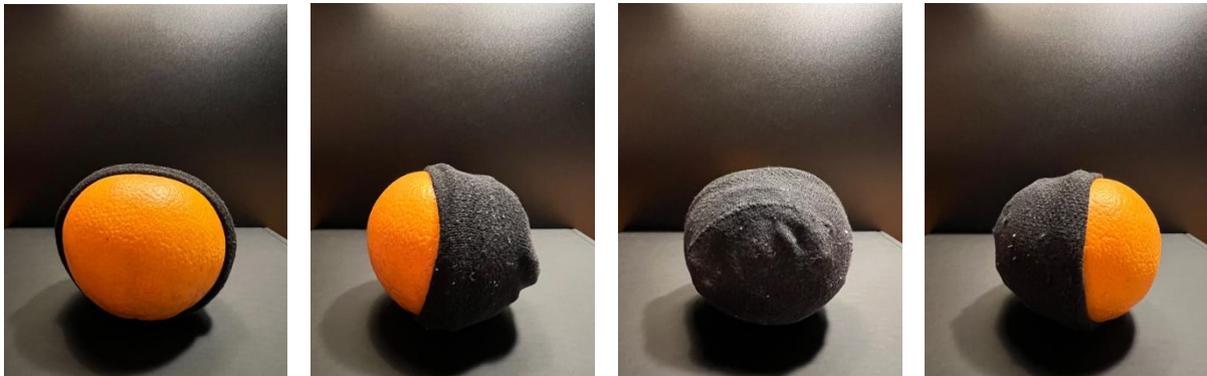


Figure 1: Full Moon.

Figure 2: Last Quarter.

Figure 3: New Moon.

Figure 4: First Quarter.

Note: The previous images show the sequence of the Moon phases as seen from the Northern Hemisphere. It may be interesting to discuss with the children whether the Moon looks the same at the Equator or in the Southern Hemisphere.

Video showing the sequence of the phases of the moon using an orange:

https://youtu.be/DzK1X_o8EY4?si=ZgfPccQ3BR3L8hpW

Instead of using an orange, a fluorescent ball covered with black tape or a sock can also be used to demonstrate the phases of the Moon. In the dark, the glowing effect makes

1. Oranges in Space!

the observation more spectacular and helps students clearly see the illuminated and shadowed parts.

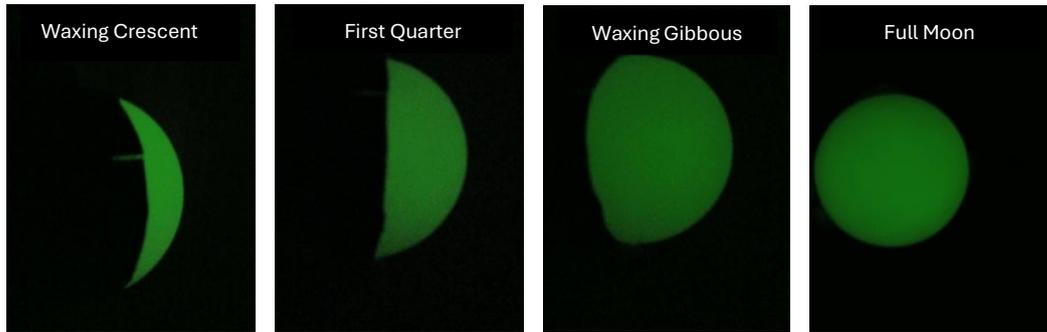


Figure 5 – 8: Demonstrating the phases of the Moon using a fluorescent ball in a dark environment.

2. Mass, Volume and Density

Making basic measurements

2.1 Measuring the Mass and Volume

Oranges are a very useful item to use as an introduction to measurement, being available in different sizes and also near spherical in shape. They can be used in a variety of ways...use your imagination.

Part I - Measuring the mass



Figure 1: Two oranges of different sizes.

Question: Can you predict how the masses of the two oranges will compare?

Step by step

Simply measure the diameters of two different oranges (preferably with one having twice the diameter of the other, as this makes the calculations easier) and weigh each one on a standard balance.

If the diameters are in the ratio 1:2, the larger orange will have a mass eight times greater than the smaller one.

Scientific explanation

The mass of an orange depends on its volume. Volume depends on the cube of the diameter. This means that an orange twice the diameter of another has eight times the volume and, if both have similar density, about eight times the mass.

Can we assume oranges have the same density?

Part II – Measuring the Volume of an Orange

The only way to obtain an exact measurement of volume is by using the displacement method, since fruit is not a perfect sphere. Oranges are close to being perfect spheres, whereas lemons certainly are not. Some suggested methods are given here, but others are also possible and useful for comparison and for discussing sources of error. Encourage student initiative!

Materials

Fruits; large beaker or jug measuring cylinder; water; wooden skewer or spoon (to hold the orange under water); thread and ruler.

Method 1 – Water displacement with a marked container



Figure 2: Determining the volume by water displacement

1. Fill a measuring jug or beaker with water and note the initial water level.
2. Gently lower the orange into the water until it is fully immersed (lower the orange if necessarily with a thin wooden skewer into the container), see figure 2.
3. Note the new water level.
4. Calculate the volume of the orange as the difference between the two readings.

Method 2 – Water displacement with an unmarked jug (overflow method)



Figure 3 - Filling the jug to the brim with water.



Figure 4 - Collecting the overflow water to measure the orange's volume.

1. Fill a jug completely with water until it just reaches the lip.
2. Slowly lower the orange into the jug and collect the overflow water in a container.
3. Transfer the overflow water into a measuring cylinder.
4. The volume of collected water equals the volume of the orange.

(This method follows the same principle as a displacement or Eureka can)

Method 3 – Using thread and geometry (approximation)

This method assumes the orange is a perfect sphere.

1. Wrap a thread around the widest part of the orange to measure its circumference (figure 4).
2. Mark or cut the thread at the point where it completes one turn (figure 5).
3. Measure the length of the thread with a ruler. This is the circumference C .
4. Calculate the radius using the formula: $C = 2\pi r \Rightarrow r = \frac{C}{2\pi}$.
5. Calculate the volume using the sphere formula: $V = \frac{4}{3}\pi r^3$

2. Mass, Volume and Density



Figure 4: Wrap the orange with a thread.

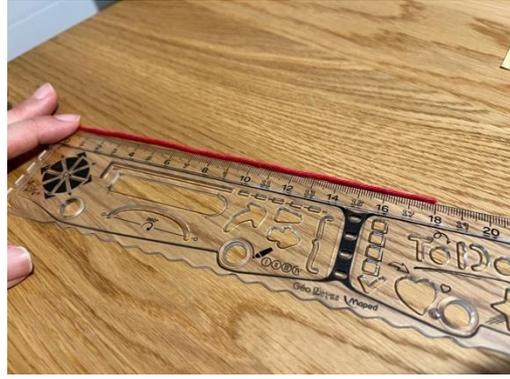


Figure 5: Measure the length of the thread.

Discussion

Which method gives the most reliable result?

Why is the thread method less accurate?

Extension:

How does the density of an orange compare with that of other citrus fruits, and also with non-citrus fruits, pears, apples, strawberries?

2.2 Floating and sinking – Peeled and unpeeled orange

Some objects float while others sink depending on their density. In this experiment, we will observe how the peel affects the flotation of the orange.

Materials

“Easy peel” oranges (although any oranges will do)

A lemon and a lime

1 container with water

Step by step

1. Pour water into a container wide enough to hold an orange inside.
2. Place an unpeeled orange in water and watch it.
3. Peel the orange and place it peeled in the container with water and observe.

Note that the unpeeled orange weighs more than the peeled orange.

The science behind it

The average density of a whole, unpeeled orange is slightly less than 1.0 g/cm^3 , so it floats with about seven-eighths of its volume submerged.

When the peel is removed, the average density becomes greater than 1.0 g/cm^3 , and the orange sinks to the bottom. Thus, once peeled, the orange — despite being lighter — will no longer float.



Figure 1: Unpeeled orange (floating) vs. peeled orange (sinking).

This phenomenon introduces the concept of density. Density is not about how much an object weighs (its mass); rather, it is about how much mass is packed into a particular volume.

2. Mass, Volume and Density

The combined skin and pith of an orange have a relative density which is considerably less than 1. So, this covering of the fruit decreases the overall relative density of a whole orange to <1 (less than water). The weight of the orange without skin is reduced, because there is no skin and pith, but its density is increased. The fruit itself is denser than water, so it sinks. Whether an object floats or sinks depends on whether it is more or less dense than the liquid it is in, not just on its total weight.



Figures 2 and 3 - Photos of orange unpeeled and peeled. The unpeeled orange weighs more.

Extension

Similar experiments can be conducted using a lemon and a lime, both with and without the skin. Unpeeled, a lime sinks, a lemon floats. If these fruits are cut open you will see that the skin of a lemon is much thicker, so the lemon floats due to the low-density skin, its overall relative density being <1 . A lime has a very thin skin. The thin skin of the lime does not have enough buoyancy to float the lime. The relative density of the lime is > 1 . These facts can all be checked using mass and volume measurements described previously.



Figure 4: Lemon Floating Lime sinking.



Figure 5: Lemon has thicker skin.

2. Mass, Volume and Density

Extra: Size versus Mass

When comparing the mass of oranges, we can assume that the average density of oranges is about the same for different oranges, that means that to mass will be proportional to the orange volumes.

It is interesting therefore to compare masses on a balance. Place the large orange on one side of the balance, with the smaller oranges on the other side, one by one, how many small oranges are required to balance with the large orange.

How does this compare with an estimate using the radius of each of the oranges? (Volume and mass are proportional to the radius cubed).



Figure 1: Balance with large orange.



Figure 2: Large orange balancing small oranges.
(6 oranges in left balance)



Figure 3: One small and one large orange, note diameters.

3. Chemistry of Oranges

The simple chemistry of oranges

3.1 Vitamin C Identification

Citrus fruits are a rich source of vitamin C, which is why a freshly squeezed orange juice at breakfast is a great way to start the day. In this activity, we will explore how to determine the vitamin C content of different fruits using two different experimental methods.

Method I

Materials

A container with water, iodine tincture solution and a citrus fruit (orange, lemon, clementine).

Step by step

1. Prepare an iodine solution by adding a few drops of iodine tincture to the water until it reaches a brownish colour as shown in figure 1.
2. Add the citrus juice until the solution becomes colourless.
3. To compare the amount of vitamin C in different citrus fruits, simply count how many drops of juice are needed to change the colour of the solution. The higher the number of vitamin C, the more drops of juice must be added.



Figure 1 – Iodine solution.



Figure 2 – Add the fruit juice.

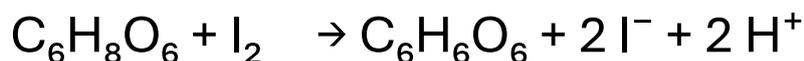


Figure 3 – Colour of the solution after adding the fruit juice.

The science behind it

Iodine tincture is a brownish-coloured solution that lightens when vitamin C ($C_6H_8O_6$) is added to it. The colour disappears because vitamin C reduces iodine (I_2) to iodide (I^-).

The overall (simplified) reaction is:



dehydroascorbic acid (oxidized form)

Method II

Materials

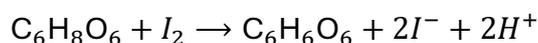
Citrus fruits to test	2 Plastic flakes
Balance	1 effervescent tablet of Vit C (1 g of Vit C)
1 L measuring cup	Cornstarch
1 tbsp (15 ml)	Hot water
1 tsp (5 ml)	Iodine tincture

Step by step

1. Prepare a cornstarch solution by adding 1 tablespoon of cornstarch to a glass of warm water, mix and let cool.
2. Prepare the calibration solution by measuring 1 L of water and add 1 effervescent tablet of vitamin C (1g/L solution).
3. Add 100 mL of water to a glass and add 10 mL (2 tsp) of vitamin C solution.
4. Add 5 mL (1 tsp) of starch solution to the previous beaker and the calibration solution is ready.
5. Add tincture of iodine drop by drop and against as many as are needed so that the solution is a consistent very dark blue colour.
6. We can thus calculate the mass of vitamin C present in the solution for each drop of iodine solution added.
7. In this way we can now determine the amount of Vitamin C in citrus juice, such as orange, lemon, clementine.

The science behind it

Vitamin C (i.e. ascorbic acid) is a $C_6H_8O_6$ reducing agent and Iodine (I_2) is an oxidizing agent. When adding an iodine solution to the juice of a citrus fruit, ascorbic acid reacts with iodine according to the following reaction:



That is, vitamin C is oxidized and iodine is reduced to iodide. Starch is used as an indicator because it forms a blue complex with free iodine. If there is vitamin C, all iodine is consumed and the blue colour does not appear. When the vitamin C runs out, the iodine remains and the solution turns blue, indicating the end point.



Extra Investigation

Compare the amount of vitamin C in oranges, lemons, and limes. Try to perform a fair test where the only variable is the type of fruit.

(Warning! - Iodine is poisonous so do not ingest or allow it to come in contact with eyes or skin).

3.2 Citric acid and baking soda

When citric acid reacts with baking soda, carbon dioxide gas is produced and the mixture becomes colder. This experiment shows how a chemical reaction can cause a noticeable drop in temperature and introduces the idea of endothermic reactions using simple household materials.

Materials

Baking soda and Lemon juice, 1 cup, 1 tbsp, 1 tsp and 1 thermometer.



Figure 1: Necessary material.

Step by step

1. Squeeze the lemon juice and place a tablespoon of the juice in a glass (figure 1).
2. Place the thermometer in the cup and measure the temperature of the solution (figure 2).
3. Add 1 teaspoon of baking soda and observe the release of the gas (figure 3).
4. Register the final temperature (figure 4).



Figure 2: Initial temperature (20 °C).



Figure 3: Citric acid reacts with sodium bicarbonate, releasing CO_2 .



Figure 4: Initial temperature (15 °C), showing the decrease in temperature.

The science behind it

Baking soda, widely used in cooking, reacts with acidic ingredients, such as lemon juice or yogurt, releasing carbon dioxide which creates bubbles that make the doughs fluffy and light.

The citric acid, $C_6H_8O_7$, in lemon juice reacts with baking soda, $NaHCO_3$, to produce carbon dioxide, CO_2 , sodium citrate, $Na_3C_6H_5O_7$ and water, H_2O . This is an acid-base reaction, being endothermic*. That is why the temperature during the chemical reaction decreases.

** An endothermic reaction is a chemical reaction that absorbs heat from its surroundings. As a result, the temperature of the mixture drops, and it feels cold to the touch.*

3.3 pH of several citrus fruits

When talking about acids and bases, lemon juice is often used as a familiar example of an acid. When we compare a lemon and an orange, we usually say without hesitation that the lemon is more acidic than the orange. But is this really true?

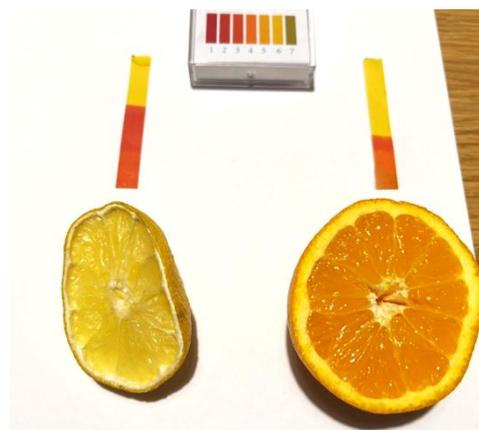
Materials

Lemons and oranges, pH indicator.

Step by step

1. Squeeze a little juice from each citrus fruit into separate cups.
2. Dip pH paper into each sample.
3. Match the colour to the pH scale and record the value.

Figure 1: pH indicator paper showing the acidity of lemon and orange juice.



The science behind it

Citrus fruits contain citric acid, which makes them acidic. The pH scale is used to measure how acidic or basic a substance is. Indicator paper changes colour depending on the pH of the liquid it touches. By comparing the colour of the paper with a pH chart, we can estimate how acidic each fruit juice.



Figure 2: Detailed view of the pH of lemon juice using the indicator colour chart (pH = 3).



Figure 3: Detailed view of the pH of orange juice using the indicator colour chart (pH = 5).

Extension: Investigate whether the ripeness of the fruit affects its pH. Explore how diluting the juice with water changes its pH.

4. Oranges in Water

Floating and sinking

4.1 Weighing an object in water experiment (Archimedes Principle)

We often talk about forces but don't appreciate how invisible they really are.... we see the effects of the force but not the force itself. So, in this fairly simple experiment, we make the forces "visible" using the kitchen scale on which the beaker rests. Just how will this force be affected in the different scenarios described.

Materials

Kitchen scale

Transparent container with water

Oranges

Skewer rod

String

Step by step

1. Place the glass of water on the scale and place the orange next to it (outside the glass) on the scale and record the value m_1 (figure 1).
2. Place the orange inside the glass with water. Records the new value that the scale shows m_2 (figure 2).
3. Push the orange gently below the surface of the water with a skewer rod, so that the orange total volume is immersed (figure 3).
4. Records the new value that the scale shows.

4. Oranges in Water

The science behind it

Often younger children will think that the floating orange system will weigh less, that is because they hear (as I sneakily repeated) that things weigh less in water. The truth is that they don't, things weigh the same, but the water supports part or all their weight. You can justify the "same" answer in terms of the extra upthrust/downthrust or note that the increase in depth of the water when the orange goes in, is equivalent to the weight of the orange.



Figure 1: Mass of a glass of water with an orange placed next to it.



Figure 2: Mass of a glass of water with the orange floating inside.

The mass m_1 is equal to m_2 . The scale measures the downward force that the whole set (glass + water + orange) exerts on it. This force is the total weight of the things placed on top. When the orange is out of the water, the orange pushes the scale plate with its own weight, and the scale registers the weight of the glass + water and the orange.

When the orange is placed in the water and floats the water pushes the orange upwards (this force is called upthrust) but the orange, in turn, pushes the water downwards with exactly the same force (Newton's Third Law). This downward force is transmitted to the base of the cup and therefore to the scale. Even if the orange is not directly resting on the plate, the scale continues to "feel" the weight of the orange through the water. Therefore, the final value is the same.

What happens to the reading when the orange is pushed gently below the surface of the water, so that the orange's total volume is immersed? (Figure 3).

If the orange is pushed under the surface, this additional force is balanced by the upthrust from the water. Hence the total downward force is once more weight of water and beaker plus weight of orange.

4. Oranges in Water



Figure 3 - Orange submerged, extra upthrust due to top of orange being under water.

Extension

1. Students should draw the forces acting in all cases, being clear which forces act on the beaker, and which on the orange.

2. More advanced students should be able to estimate the density of the orange by recording the amount of orange below the surface when it floats, assuming that the orange is a sphere. Mark the line between the orange in air and in water. Noting the depth of this line together with R the radius of the orange enables you to calculate the volume of the whole orange, and the volume of the orange below the surface, and hence the density of the orange.

(How does this compare with other methods for calculating density?)

4.2 Orange peel with a hole, floats or not?

Another set of experiments on floating and sinking using an orange. Using half an orange provides extra challenges as to how the half orange floats (or sinks) compared with a whole orange and gives us the opportunity to look at the stability of some floating arrangements.

Materials

Half orange skin, container with water, small tin can (e.g. tuna fish tin) and knife or scissors (adult supervision required).

Step by step

Part A – Half orange

1. Note that a whole orange will float with a small fraction of the orange above the surface (figure 1).
2. Cut the orange in half (with adult supervision) and place it on the surface of the water. Will it float curved side down (as a boat shape) or with the cut side down in the water?
3. Note that the half orange with the curved side down is unstable (figure 2) and that the orange will readily flip over so that the cut side is down (figure 3).



Figure 1: A whole orange floating on water.



Figure 2: Half an orange floating on the surface.



Figure 3: An orange floating in an inverted position.

Part B – Floating the orange peel

1. Cut an orange in half and remove all the fruit, leaving only the peel.
2. Place the half peel on the surface of the water in different orientations.
3. Observe whether it floats or sinks.
4. **Now begin adding water to the upturned peel. Will you be able to add sufficient water to sink the peel? (No because it is the average density that is still less than that of the water because of the peel).**

4. Oranges in Water



Figure 4: Half orange peel.



Figure 5: Half an orange peel floating in water

Part C – Orange peel with a hole

1. Cut a small hole (about 1–2 cm in diameter) in the orange peel (figure 6).
2. Place the peel in the water again and observe what happens (figure 7).
3. Allow water to enter the peel and note whether it floats or sinks.
4. Compare the behaviour with that of a boat that has a hole in it.



Figure 6: Half orange with hole.



Figure 7: Orange with hole floating.

Part D – Tin can experiment

1. Place the empty tin can gently on the water surface and observe whether it floats.
2. Make a small hole in the can (adult supervision required).
3. Place the can in the water again and observe what happens.
4. Watch as water slowly enters the can and record when it begins to sink.

4. Oranges in Water



Fig. 8: Can with hole.



Fi. 9: Surface tension prevents water entering the can, so it floats.



Fig. 10: Can filling with water, but not sufficient to sink it.



Fig. 11: Full can of water, beginning to sink.

Observations to Discuss

- Does the orange-peel float with or without a hole?
- Does the tin can behave in the same way?
- What happens as water enters the can?

The science behind it

The average density of the half orange is still less than that of the water and therefore it will float.

Placed gently into the water it is possible for the half orange to float either way up with the same proportion of orange above the surface, however with the flat cut surface above the surface the half orange is in unstable equilibrium and will readily upturn to float stably.

The heaviest part of the orange (flat surface) moves to be lowest for stability.

The orange peel floats because its average density is lower than that of water. Even when water enters through a hole, the overall density of the peel remains less than the density of water, so it continues to float. You can't sink the skin even if filled to the brim with water as the average density remains less than 1 g/cm^3 because of the skin. Upside down the half orange skin is less stable as it may trap some air.

4. Oranges in Water

Some students may think the orange peel acts like a boat and should sink when filled with water. However, unlike most boats, the orange peel is made of material that is naturally less dense than water.

When a hole is made in the tin can, it is expected to sink, just like a boat with a hole in its hull. Water enters the can and, because metal is denser than water, the average density of the can increases, and it sinks. However, in this experiment it can be observed that, after making a hole and placing the can on the water, it may still float for a short time. This happens because surface tension can temporarily prevent water from entering through the hole. Once the water breaks through the surface tension and fills the can, the can will eventually sink.

The stability of floating objects can be researched and there are many examples, one to discuss is the sinking of the VASA galleon in Stockholm Harbour (figure 1), which was unstable when launched. The craft was designed to be a certain height, but the king insisted of there being extra levels (extra height) to the vessel. Furthermore, when the ship was launched in Stockholm harbour all the proposed ballast was not in place, and therefore the galleon was "Top Heavy" and therefore unstable, toppling over and sinking after a few hundred metres on the water. The half orange is stable when the heaviest part is down below making it stable in that position.



Figure 1: VASA galleon in Stockholm Harbour.

5. More Chemistry

5.1 Antioxidant action

When fruit is cut, it quickly turns brown due to oxidation. Lemon juice contains vitamin C, which slows down this process. This activity explores how citrus juice can protect fruit from browning and demonstrates the role of antioxidants in everyday food.

Materials

1 apple
1 knife
Natural lemon juice
Chronometer

Step by step

1. Cut 2 identical thin slices of apple and leave one slice in the air and the other soaked in lemon juice.
2. Observe over time if the slices darken.

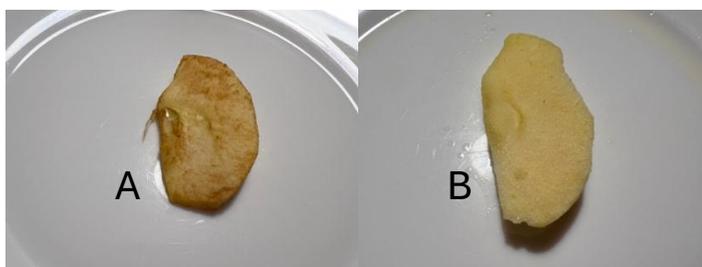
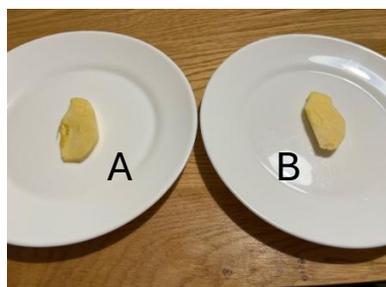


Figure1: Sample A (control) exposed to air and Sample B in open air, and Sample B treated with lemon juice to inhibit treated with lemon juice (citric acid).

The science behind it

Apples contain enzymes called Polyphenol Oxidase. When you cut the fruit, you damage the cells, exposing these enzymes to oxygen. This chemical reaction creates melanin (the same pigment that colours our skin and hair), which gives the apple its brown colour. When an apple is cut or bruised, its cellular structure is damaged. This rupture allows components that are normally separated within the cell to mix. Specifically, enzymes called Polyphenol Oxidase, located in the chloroplasts, come into contact with phenolic compounds stored in the cell's vacuoles. In the presence of atmospheric oxygen O_2 , the Polyphenol Oxidase enzyme acts as a catalyst. It oxidizes the phenols into molecules called quinones. These quinones then polymerize (link together) to form melanin, the dark brown pigment we see on the surface of the fruit.

From an evolutionary perspective, this is a defence mechanism. The brown layer creates a barrier that is toxic to bacteria and fungi, helping to protect the damaged fruit from infection.

Adding lemon juice introduces citric acid, which denatures the enzyme. This change in shape makes the enzyme inactive.

5.2 Chemical balance of a fizzy drink and add a slice of lemon

Fizzy drinks contain dissolved carbon dioxide, which creates bubbles. Adding lemon juice introduces citric acid and can change the chemical balance of the drink. In this experiment, we will observe what happens when a slice of lemon is added to a fizzy drink.

Materials

A carbonated drink and a slice of lemon.

Step by step

Add just a slice of lemon inside a transparent glass with a fizzy drink and observe.



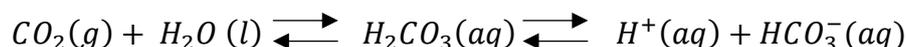
Figure 1: Lemon slice in a fizzy drink showing the release of carbon dioxide bubbles.

The science behind it

When a slice of lemon is added to a fizzy drink, the drink begins to fizz more vigorously and releases bubbles more quickly.

This happens mainly because the surface of the lemon provides nucleation sites where dissolved carbon dioxide (CO_2) can escape more easily from the liquid. In addition, the lemon juice contains citric acid, which slightly changes the chemical balance of the drink and can speed up the release of CO_2 .

In a fizzy drink, carbon dioxide is in chemical equilibrium:



When citric acid (from lemon juice) is added, the pH of the drink decreases (it becomes more acidic). This change disturbs the existing chemical equilibrium. According to Le Châtelier's Principle, the system responds by shifting the equilibrium to release more carbon dioxide as gas.

As some sparkling waters contain sodium bicarbonate, especially those of natural mineral origin, where it occurs naturally, or artificially carbonated, in which minerals can be added for flavor and stability, it is found that in this type of water there is a greater release of gas because there is also a chemical reaction between the sodium bicarbonate and the lemon acid with the release of the extra carbon dioxide resulting from this reaction.



6. Fractions and Oranges

Simple mathematical calculations with oranges

6.1 Fractions with orange segments

The natural division of an orange into segments offers a simple and appealing way to explore fractions. Counting and comparing segments helps to build an intuitive understanding of parts and the whole, making fraction concepts easier to grasp.

Materials

- An orange.

Step by step

1. Begin by showing the whole orange and asking the children what happens when it is opened.
2. Peel the orange and separate it into individual segments.
3. Invite the children to count how many segments make up the whole orange.
4. Ask the children to describe one segment using fraction language, for example “one out of eight” or “one eighth”.
5. Invite the children to select different numbers of segments.
6. Ask questions such as: How many segments are there? What fraction of the orange does this represent? Is this more or less than half?
7. Encourage children to compare groups of segments and to look for equivalent fractions, for example showing that four segments out of eight are the same as one half.
8. To conclude, ask the children to reassemble the orange and reflect on how all the parts combine to make the whole. Reinforce the idea that fractions describe equal parts of one object.



Figure 1-2: The orange as a whole unit and its segments as fractional parts.

6.2 Surface Area Calculation

Materials

One orange, one sheet of graph paper and one marker.

Step by step

1. Peel the orange.
2. Place the pieces of peel flat on a sheet of squared paper.
3. Gently press the peel so that it lies as flat as possible.
4. Count the number of full squares covered by the peel.
5. Estimate the partial squares by combining them to make whole squares.
6. Add the full and estimated squares together to find the total number of squares covered.
7. Multiply the total number of squares by the area of one square on the paper to obtain an estimate of the orange's surface area.

The science behind it



Figure 1: Estimating the orange's surface area with squared paper.

By removing the peel and laying it flat on squared paper, the surface area of an orange can be estimated by counting the number of squares covered. This activity encourages observation, estimation and the practical application of geometric ideas in an accessible way.

How does the measured surface area compare with the calculated surface area using your estimate of the orange's volume ($A = 4\pi r^2$)?

Use the measured volume to calculate the radius of the orange, and then use this radius to calculate the surface area.

Which method gives the more accurate result?

6.3 Calculation of the % of water after dehydration

Citrus fruits are typically 80–90% water. To calculate the percentage of water in a fruit by comparing its fresh mass with its mass after complete drying.

Materials

One orange or one lemon	Oven or sunny, well-ventilated outdoor space
Digital balance	Baking tray
Knife and chopping board (adult supervision required)	

Step by step

1. Wash and dry the fruit.
2. Weigh the whole fruit and record its mass as: Fresh mass (M_0).
3. Cut the fruit into thin slices. *Thin slices dry faster and more evenly.*
4. Arrange the slices on a tray without overlapping.
5. Drying the fruit. Choose one of the following methods:

Method A – Oven drying (fast)

- Place the tray in an oven at 70–90 °C.
- Leave the oven door slightly open to allow moisture to escape.
- Dry for 2–4 hours, turning the slices halfway through.

Method B – Sun drying (slow)

- Place the slices in a sunny and well-ventilated area.
- Leave to dry for 1–3 days, bringing them indoors at night.
- Drying is complete when the slices are fully hard and dry.
- The slices are ready when they are rigid and show no visible moisture.
- Weigh all the dried slices together and record the value as: Dry mass (M_s).

Calculate the mass of water lost: Water lost = $M_0 - M_s$

Calculate the percentage of water: Percentage of water = $\frac{M_0 - M_s}{M_0} \times 100$

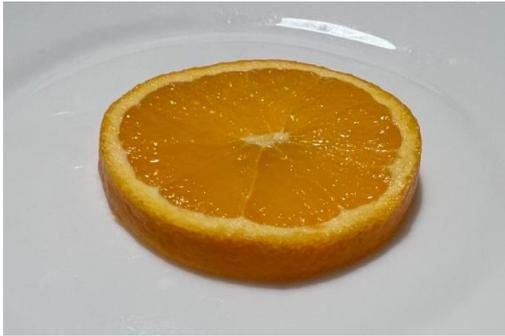


Figure 1: Cutting a fresh orange slice before drying.



Figure 2: Dried orange slice after complete dehydration.

The science behind it

Fresh fruit contains a large amount of water trapped inside its cells. When the fruit is heated or exposed to dry air, the water evaporates, while most of the solid components (such as sugars and fibres) remain.

By comparing the mass before and after drying, it is possible to determine how much water was originally present in the fruit. This method illustrates the concept of dehydration and shows that water makes up a significant proportion of citrus fruits.

7. Oranges in a box

Surprising figures and an illusion with oranges

7.1 How many oranges to make a box of juice?

When we buy products at the supermarket, we never quite know what is really inside them. Orange juice is a good example. How many real oranges are needed to make a small box of juice?

Materials

- A selection of orange juice boxes and bottles (real ones or research images)
- One small orange juice box (200 ml)



Figure 1: Orange juice box and bottle.

Step by step

1. Question: How many oranges are needed to produce one small 200 ml box of pure orange juice?
2. Students look for information on the juice box label or research online.
 - ⚠ Important warning: Many “orange drinks” are not pure orange juice and may be made from concentrate or contain only a small percentage of real juice.
3. Compare answers from different brands and sources.

The Science Behind

The number of oranges depends on the size of the oranges (small vs large) and their juiciness. Typically 2 to 4 medium-sized oranges are needed to make about 240 ml of juice. This can become an excellent research project, comparing different orange sizes, different brands and juice made fresh vs packaged juice.

7.2 The orange box illusion

This activity explores how our senses can be fooled. Even when two objects have the same mass, they can feel heavier or lighter depending on how that mass is distributed.

Materials

Three identical small orange drink boxes (200 ml), two empty and one full.



Figure 1: Lifting 3 boxes together.



Figure 2: Lifting only the top (heavy) box.

Step by step

The boxes are placed as a tower as shown with the full box on the top and then lifted holding the lower two boxes as in figure 1. They are placed back on the table and then the top box only (the full one) is lifted by itself and the student asked which feels the heaviest.

Amazingly it is the single boxes which appears to weigh more!!

Of course it doesn't as can be verified with a balance, the three boxes are heavier by the weight of the two empty boxes.

The Science Behind

The "weight illusion" is an example of a sensual illusion, not unlike an optical illusion. It occurs because the mass is distributed over 3 boxes initially, but then just over one. Even with your eyes closed the single full box seems to be heavier than all three!

Extension

The concentration of mass explains why a small steel ball, may seem heavier than a larger hollow ball with the same mass, and why, when moving larger items (e.g. furniture) it is critical where on the item you hold it.

8. Oranges, Inertia and Free Fall

Investigating Newton's Laws using oranges

8.1 Inertia and Forces

Without a resultant force a body will stay in its position if at rest or continue to move in a straight line (Newton's 1st law). This investigates the former statement.

Materials

Oranges, beakers, placemat, tubes (smarty sweets or similar).

Step by step

Arrange the apparatus as shown in the figure 1, ensuring that the tubes are directly above the beakers below the placement and the placemat has its greatest friction facing down.

The idea is to sharply knock the placemat horizontally so that the tubes and mat move out of the way so that the orange falls vertically down into the lower beaker (figure 2).



Figure 1: The set up.



Figure 2: The result.

The science behind it

This is a simple task that all ages can complete successfully often to their amazement!!!

When the placemat is struck sideways the slippery lower face easily slides off the lower beakers, whilst the rougher upper surface has sufficient friction to move the bottom of the tubes (the tubes have a low mass). This leaves the orange on the top of the tube, and there is no horizontal force on the orange, so

8. Oranges, Inertia and Free Fall

with the tube removed the only force on the orange is the force of gravity acting vertically down. The orange falls vertically into the beaker below.

(The key is to strike the placemat confidently, if a student hesitates then the challenge is likely to fail)

Extensions

Whilst this is a good demonstration using oranges it can be adapted at different times of the year.

Replace the oranges with ...

- i) chocolate eggs as Easter approaches.
- ii) raw eggs for some excitement into beakers containing water (so eggs don't break!).
- iii) small toys suitable for any time of the year, e.g. Christmas.



Figure 3: Other options.

8.2 Oranges and free fall

The aim of these experiments is to understand free fall using oranges which have different sizes, different volumes and masses but the same density.

We often compare a heavy object with e.g. a feather where air resistance in a fall is significant from the start. This time we shall compare over short and long drops, objects which have the same density.

Materials

Two oranges, one large and one small.

Step by step

Two oranges with different sizes, (but the same density) are dropped together from the same height (measured to the lowest part of each orange), see figure 2. The oranges should land on a surface that makes a clear sound as it is reached.

The experiments can be repeated from increasing heights to see if there is any difference.



Figure 1: Large and small orange, twice the diameter, 8x the weight.



Figure 2: About to drop oranges over a short distance.

The science behind it

Stage 1 – Initial fall

At the start of the fall, over short distances (less than a few metres) air resistance is very small compared with the force of gravity. Both oranges accelerate at the same rate and fall together, just as Galileo predicted. This is what most pupils will be able to see.

8. Oranges, Inertia and Free Fall

Stage 2 – The smaller orange moves ahead

As their speed increases, air resistance becomes more significant. The smaller orange experiences less air resistance, at any speed, because it has a smaller surface area facing the air. For a short time, this allows the smaller orange to move slightly ahead of the larger one, as seen in the photographs.

Stage 3 – The larger orange eventually overtakes

With greater height and longer falling time, the larger orange reaches a higher terminal velocity because its weight increases faster than its air resistance. If the drop were long enough, the larger orange would eventually overtake the smaller one.

(This final stage is not observed in our experiment because the drop height is not sufficient.)

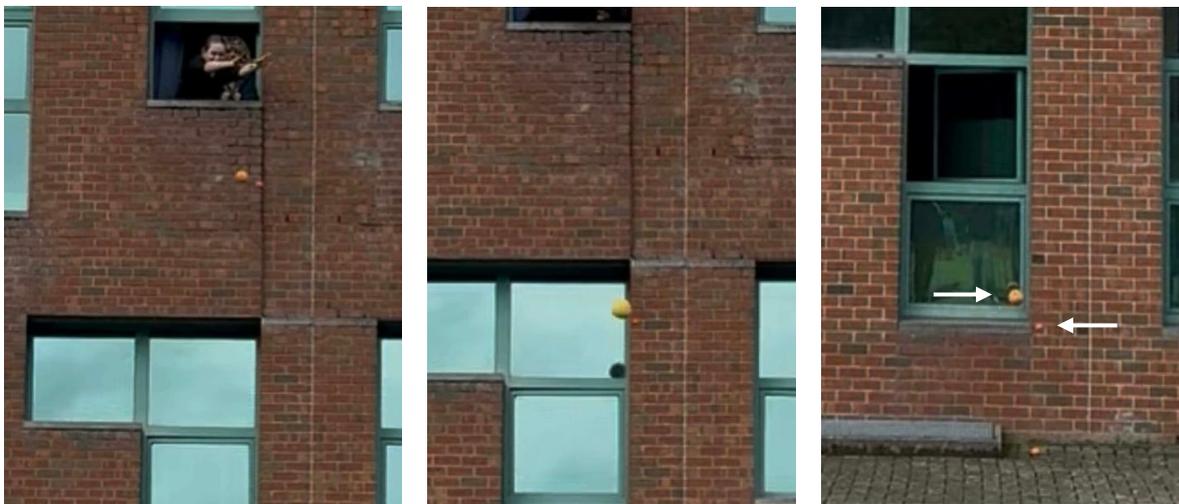


Figure 3: Experiment: Two oranges of different sizes dropped from a height greater than 7 m.

Advanced students: You can use the equation for the volume of a sphere, equations of motion and Stokes law to calculate the positions of the oranges at different stages by integrating, given the viscosity of air.

8.3 Free fall roll

How is the speed of descent, rolling down an incline, affected by the size of the oranges?

Materials

Two fairly round oranges* one large and one small or an orange and a melon.

A table or medium sized board, say 2 m long, that can be tilted.

* Oranges need to be round and well balanced as they need to roll in a straight line fairly freely.



Figure 1: Two oranges (same density).

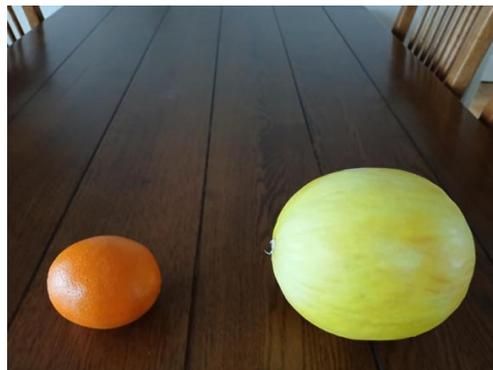


Figure 2: Orange and Melon.

Step by step

Hold the oranges side by side at the top of the incline and release them simultaneously, observing their descent, ensuring both roll off immediately rather than slipping.

The experiment can be repeated using a large melon (figure 2), however this introduces an additional variable, as the density of the melon is not the same as that of oranges.

As a second experiment attach the oranges to small carts that will roll down the incline without friction being significant (figure 3). How will the descent of the oranges compare now?

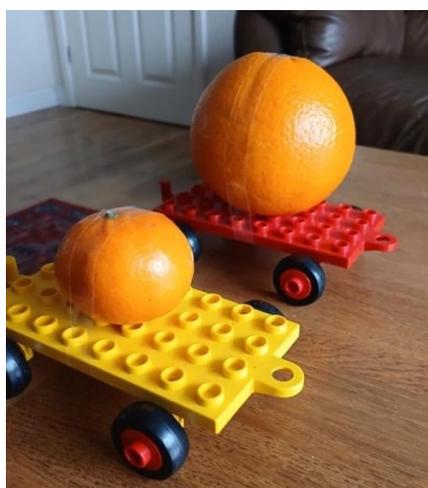


Figure 3: Using small carts to study the motion of oranges on an inclined surface with minimal friction.

The science behind it

The potential energy at the top of the slope is converted to kinetic energy of the oranges as they go down the slope. This can be translational kinetic energy or rotational. Translational Kinetic energy depends on the mass and velocity, whereas rotational energy depends on the speed of rotation and the moment of inertia about the rotating axis.

($I = \frac{2}{5} mr^2$) Thus the larger the orange the greater the energy that has to be transferred to rotational. But the small orange will still move down the slope and reach the bottom at the same time. By equating the potential energy to the kinetic energies, we find that the velocities of descents are the same.

When the orange does not rotate both oranges again reach the bottom of the slope simultaneously if sliding without significant friction. But if friction is significant the larger mass will have more friction and so may take longer to reach the bottom. There are plenty of investigations to investigate.

8.4 Inertia and an orange

A stationary body (orange) stays at rest unless an external resultant force acts upon it, for sufficient time, i.e. there is sufficient impulse.

Materials

A selection of oranges, wooden skewers, and a hammer.

Step by step

Push the skewer through the fruit so that the fruit is held halfway down (figure 1).



Figure 1: Skewer in Orange.



Figure 2: Orange has not moved but skewer has passed through.

Holding the skewer as shown give it a sharp tap with the hammer. What happens? Does the skewer with the orange pass through the holding hand? Does the orange stay still, whilst the skewer moves through it and the hand?

The science behind it

We say that the orange has “inertia”, that is it resists movement. The larger the orange the more likely it is to remain in its original position. There is insufficient force from the skewer to the orange to move the large orange and so the skewer slips through the orange (Figure 2) (i.e. the orange does not move).

8.5 Orange in the rotating bucket

(Circular motion and density)

An orange resting in a clear bucket is rotated in a vertical circle. Will the orange fall out?

Materials

A Perspex bucket (often found in seaside shops where collecting crabs is popular), oranges and water.

Step by step

1. Place the orange in the empty bucket and whirl the bucket in a vertical circle over your head. Note that the orange stays on the bottom of the bucket provided that you “whirl” fast enough (Students should draw force diagrams showing forces on the bucket and on the orange separately)
2. Repeat the whirling in a vertical circle experiment with the water in the bucket. Will the water stay in the bucket stay or fall out?
3. Next place the orange in the bucket half full of water (figure 1). Note that it floats with a small fraction of the orange above the surface. Consider the forces acting:

i) on the orange

ii) on the bucket.

Note what proportion of orange is below the surface?

4. Fill the bucket to about three-quarters with water and repeat the first experiment, allowing the orange to float on the surface.

Will the water stay in the bucket?

What happens to the orange?

...will it sink further down towards the base of the bucket?

...will it stay at the same level in the water?

...will it change position as it goes round?



Figure 1 to 4: Sequence of the circular movement of the bucket.

The science behind it

To remain on a circular path an orange must experience an accelerating force of the correct size, directed towards the centre of the circle (centripetal force), if not, the orange will continue in a straight line (Newtons 1st Law of Motion).

Extention

If you want to be really exciting, repeat the experiment using a small orange, floating on water in a beaker, the beaker stands freely resting on a flat frisbee, suspended on strings ...see figure 5.

Note: Make sure the beaker does not slip easily on the frisbee.

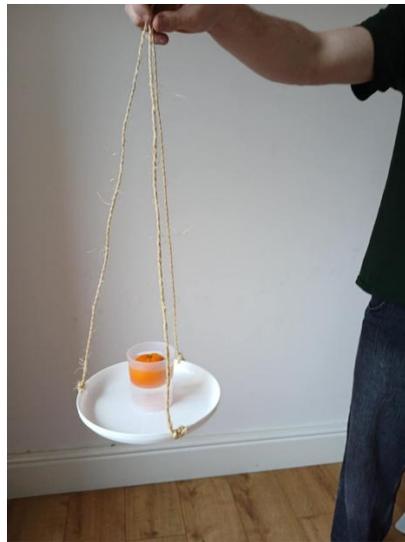


Figure 5: Showing the floating orange in the plastic beaker on the frisbee.

The frisbee is once more rotated vertically and the orange remains floating at the same depth in the water, and neither water nor orange comes out of the beaker, and of course, the beaker itself stays on the frisbee. It is a worthwhile exercise to identify which forces are acting on each of the separate parts (strings, frisbee, beaker, water, orange) of the system.

8.6 Oranges and money

Oranges can be used as simple masses to demonstrate Newton's First Law of Motion. By observing how an orange resists changes in motion, this activity links an important physics concept to familiar everyday objects.

Materials

“Paper” money and oranges.

Step by step

Place the note on a table and an orange on top (figure 1). Make sure the fruit is not wet.

The challenge is to remove the note without disturbing the orange.

If pulled slowly the orange will ride along on to off the note. The trick is to move the note very quickly making sure that you pull down on it, so you don't pull upwards on the orange. Move the note and orange to the edge of a table so that bringing your hand down on the note keeps it level with the table under the orange (figure 2). The result is shown in figure 3.



Figure 1: The set-up.



Figure 2: Ready to strike.



Figure 3: Result.

The science behind it

This is another example of ensuring that the impulse (Ft) felt by the orange is minimal. Keeping the orange dry reduces the force, and a sharp pull ensures that the time is minimised.

**This is often best achieved over the edge of a table and striking the note downwards below the orange so there is no upward force (by lifting).*

Extension

Think of other situations where you can remove something by fast movement without disturbing the rest.

E.g. 1. just pulling a skewer quickly out of an orange. If you move slowly, you pull the orange with you, but pulling quickly will remove it.

E.g. 2. The tablecloth trick...pulling the cloth away while leaving the tableware on the table.



Figure 4 - 5: The tablecloth trick.

Make sure that you just leave a small amount of cloth beyond the china before you start and that the cloth doesn't have a "hem"!! Pull quickly believing that you will achieve your aim and pull down on the cloth so that it doesn't lift the pots and china.

9. Uses of Chemistry

Simple chemical reactions with useful applications

9.1 Cleaning coins with lemon juice

Coins can become tarnished over time because of oxidation. Lemon juice can help clean the surface of the coin. In this experiment, we will observe how lemon juice affects oxidized coins.

Materials

Two tarnished coins; lemon juice and salt.

Step by step

1. Look for two tarnished coins (figure 1).
2. Add the juice of half a lemon to a cup and add a teaspoon of salt (figure 2).
3. Stir the solution until the salt dissolves completely.
4. Place the coin in the solution and let it soak for a few minutes (figure 3).
5. Observe that the coin begins to change colour and shine.
6. Remove the coin, wash it under running water and dry it thoroughly (figure 4).



Figure 1: 2 tarnished coins.



Figure 2: Solution of lemon juice and salt.



Figure 3: Add the coin to the solution.



Figure 4: Compare the 2 coins.

The science behind it

Redox reaction.

Copper, which is found in some coins, reacts with oxygen in the air over time, forming copper II oxide (CuO), which gives the coin a darker and more tarnished appearance.

Lemon juice, a citric acid solution, reacts with the copper oxides present on the surface of the coin, forming water-soluble copper salts. The acid solution removes the oxide layer, exposing the shiny metallic copper underneath.

The salt (sodium chloride) helps to solubilise these copper salts, accelerating the cleaning process. The sodium chloride provides chloride ions (Cl^-) that help to form soluble compounds with the oxidised copper. This helps to solubilise the copper salts, so they are more easily removed from the surface of the coin. Salt also increases the conductivity of the solution, which facilitates chemical reactions because it increases the number of charged particles (ions) in solution. Thus, the reactions between the acid in the lemon juice and the copper oxides happen faster.

After cleaning, the coin will be brighter and have the original colour of copper, as the oxides that made it opaque have been removed.

Extension

The experiment can also be extended by testing other substances such as cola, tomato sauce and mustard to remove the tarnished.

9.2 Secret message (lemon and heat)

Many of us remember doing this experiment when we were younger. Who hasn't tried writing a secret message with lemon juice?

Materials

- Lemon juice
- A brush
- A sheet of paper
- A heat source (hot plate, oven, flame, iron)

Step by step

Warning: This activity involves hot surfaces and requires adult supervision.

1. Squeeze the juice of one lemon.
2. Write or draw on a sheet of paper a "secret" message with lemon juice (figure 1).
3. Let it dry so that the message is imperceptible.
4. Hold the paper over a hot burner on a stove or "iron" your paper but don't use the steam setting (figure 2).



Figure 1: Write the message with the lemon juice and let it dry.

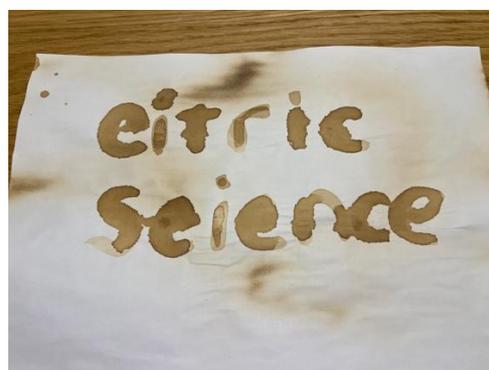


Figure 2: After heating in the oven for a few seconds.

The science behind it

Lemon juice, consisting essentially of water, sugars, citric acid and ascorbic acid, is practically colourless on the sheet of paper after it dries. In this way we will have an invisible "ink".

Writing with lemon juice creates a "secret message" through the process of oxidation and decomposition. Lemon juice is rich in citric acid and Vitamin C (ascorbic acid). When the paper is heated, these organic compounds undergo a chemical change.

The acid breaks down the cellulose in the paper, making the area where we painted with lemon juice more susceptible to heat. As the temperature rises, the carbon compounds in the juice react with the oxygen in the air. This causes the juice to oxidize and turn brown, a process like caramelization. The lemon juice caramelises before the paper catches fire.

9.3 Lemon Battery

With a few lemons we can demonstrate how chemical energy can be converted into electrical energy.

Materials

2 - 4 lemons, copper coins or copper strips, zinc nails or galvanised nails, connecting wires with crocodile clips, small LED. **(adult supervision required)**

Step by Step

1. Roll the lemons gently to get the juice moving inside.
2. With adult help, make two small cuts in each lemon.
3. Put one copper coin and one zinc nail into each lemon (do not let them touch).
4. Join the lemons together using wires.
5. Connect the ends to a small light or a meter.

The Science Behind It

Lemon juice contains citric acid, which acts as an electrolyte and allows electric charges to move. The zinc and copper act as electrodes. A chemical reaction occurs at the zinc electrode, releasing electrons. These electrons flow through the wire to the copper electrode, creating an electric current. Each lemon acts as a small battery (cell). When several lemons are connected together, the voltage increases, making it possible to power a small device such as an LED or to measure a voltage with a voltmeter.

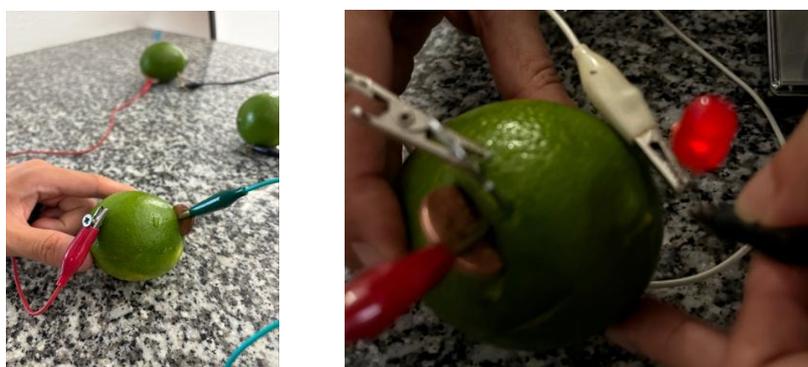


Figure 1 and 2: Lemon battery powering a red LED using a copper coin (+) and a zinc nail (-).

Extensions / Questions

Does using more lemons increase the voltage?

Does a lemon produce more electricity than an orange or a lime?

What happens if different metals are used?

Can you light a small clock or buzzer?

10. Limonene: Secret ingredient

Properties of limonene in orange/lemon skin with spectacular reactions demonstrated

10.1 Fireworks with orange peel

Orange peel contains limonene, a natural oil that is flammable and produces tiny sparks when sprayed near a flame. This simple and entertaining experiment can be carried out safely with adult supervision and is a fun way for families to explore chemistry together at the dinner table.

Materials

The peel of an orange or lemon; 1 candle; 1 lighter.

Step by step

1. Light a candle.
2. Peel an orange and reserve its peel.
3. Bring the orange peel close to the candle and squeeze it so that it directs the essential oil of the peel onto the candle flame.

<https://youtu.be/fM46mPZ8Q7Y?si=qNJHv-AKT0dlxDeW>

The science behind it

By squeezing orange peel towards the flame of a candle, it is possible to observe a brief increase in the size of the flame or a jet of sparks (figure 1 to 3).

The peel releases essential oils, limonene, that ignite when they come into contact with the flame, providing a safe and fascinating demonstration of flammable substances.

Limonene, 1-methyl-4-prop-1-en-2-yl-cyclohexene, is a hydrocarbon (composed only of carbon and hydrogen) and fuel with the molecular formula $C_{10}H_{16}$.

This activity can be used to start discussions about chemical reactions.



Figure 1 to 3: Squeezing lemon peel towards the flame of a candle.

10.2 Pop a balloon with the orange peel

In this activity, we use orange peel to pop a balloon and discover how chemicals found in everyday fruits can interact with common materials in surprising ways.

Materials

1 latex balloon and orange peel.

Step by step

1. Inflate a latex balloon.
2. Peel an orange and reserve its peel.
3. Bring the orange peel close to the balloon and squeeze it so that it directs the essential oil of the peel onto the balloon surface.

https://youtu.be/DOhC_O4AsP4?si=v9rWgk9J8TCFU2Hu

The science behind it

When droplets of oil from the peel touch the balloon, the latex weakens and the balloon may burst.

Limonene from citrus peels acts as a solvent.

When inflated, the balloon has a very thin layer of latex, and when a small amount is dissolved in the limonene, it produces a tiny perforation, the limonene expands the polypropylene molecules of the latex, through which the pressurized air will begin to escape, producing, in most cases, an explosion.

Sometimes it is necessary to give the limonene a little encouragement by gently rubbing but usually this is not the case.

A further excellent article can be found by Francesca Butturini and Javier J. Fernández in Science in School.



Figure 1: Bring the orange peel close to the balloon and squeeze it

11. Recipes

Cooking involves a great deal of science, from chemical reactions to changes in texture. Recipes that include citrus fruits provide an excellent opportunity to explore scientific ideas while preparing and enjoying everyday food.

11.1 Recipe: Fruit salad

Ingredients: Fruits of your choice (apple, banana, pear, grapes...) and juice of 1 orange or 1/2 lemon.

Preparation: Cut the fruit into pieces. Drizzle with the orange or lemon juice, mix and serve.

The science behind it

Orange or lemon juice can stop fruit from turning brown, they prevent oxidation in fruits.

11.2 Recipe: Ceviche

Ingredients: White fish cut into small cubes, lime or lemon juice, red onion, coriander, salt.

Preparation: Mix the fish with the lime/lemon juice, salt, onion and coriander. Leave to stand for 10–15 minutes, then serve.

The science behind it

Lemon juice can “cook” fish in ceviche. The acid in lemon juice denatures the proteins in the fish. This makes the fish firmer and opaque, similar to gentle cooking. Salt and acid also draw out moisture (osmosis), helping to firm the texture.

Safety

Acid changes the texture, but it does not kill all harmful bacteria or parasites the way heat does. Ceviche should therefore be made with very fresh, high-quality fish that is safe to eat raw.

11.3 Recipe: Merengue

Ingredients: 4 egg whites, 250 g sugar, a few drops of lemon juice.

Preparation: Whisk egg whites with lemon juice until foamy. Add sugar gradually and whisk to stiff peaks. Bake small spoonfuls at 140 °C for 75 min, then cool.

The science behind it

Acidity helps egg white proteins unfold and form stable peaks.

11.4 Recipe: Citrus Marinade

Ingredients: Juice of 1 lemon or 1 orange, 2 tablespoons olive oil, 2 cloves garlic minced, salt, pepper and rosemary.

Preparation: Mix everything and wrap the meat. Let the meat marinate for 30 minutes. And it's ready to grill.

The science behind it

Citrus breaks down muscle fibres at the surface, affecting texture.

11.5 Recipe: Chocolate Candied Orange Peel

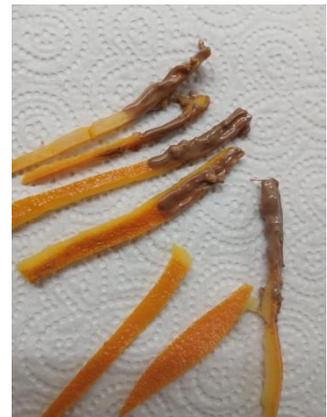
Ingredients: Orange, sugar and chocolate.

Preparation: Peel an orange and remove as much of the white pith as possible. Cut the peel into thin strips and boil them in a thick sugar syrup. Remove the strips and allow them to dry so that the syrup forms a sugary coating on the peel.

Melt some chocolate in a small container (for example, in a microwave). Dip the ends of the orange peel strips into the melted chocolate and set them aside until the chocolate cools and solidifies over the sugar coating.

The science behind it:

How many state changes can you identify?



Notes



This page is yours, a space to gather your experiences, reflections, and ideas.

Notes



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