Size the Solar System

Lesson Plan (Metric System)

A Lesson Plan / Teachers Guide to complement the Size the Solar System IOS app

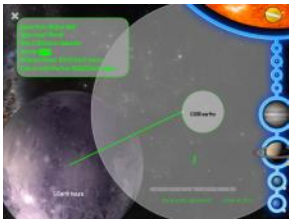
Version 1.0M Feb2015

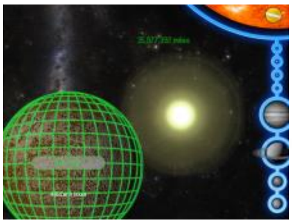
Contents

Size the Solar System App

Size the Solar System is an IOS (Apple) interactive app which models the Solar System out of everyday objects.

- Over 450 fascinating space facts.
- Using the 'missions' button users are prompted to think about questions relating to each planet (answers are then given).
- Three model scales, from classroom sized to city sized.
- High Definition video animations of each planet.
- What the Sun would look like from each planet.
- Teaches relative sizes of planets, and distances between them.
- Teaches appreciation of the vastness of space and the Solar System, and how amazing our space exploration achievements are.
- Metric or US measurements.



Available on the Apple AppStore
www.appstore.com/SizeTheSolarSystem

Note on Number Formats

The digit group separators used are spaces to accommodate both English speaking countries and the European method.
e.g. 5 000 000 = 5,000,000 = 5.000.000
However a decimal point will be indicated using the English method
e.g. 0.005 = 0,005

Time Required

One or two 45 minute lessons. Notes on more in-depth learning which could extend the number of lessons are included at the end of each section.

Equipment Needed

Digital Callipers (see page 7)
Measuring tape
Items for model (see page 14)
Calculators, ideally with a 16+ digit display (due to the very large numbers involved)

Learning Objectives

The learning objective is primarily one of maths – measurement and scaling, and comparing size and distance. However there will also be learning about space, planets, space exploration, so this could form the basis of a science lesson. Students will learn spacial awareness, appreciating distances, particularly up to units of the kilometre. Many students may not have considered this magnitude of distance before.

Introduction

The lesson will use the **Size the Solar System** IOS app to introduce students to the Solar System and to gain an understanding of just how enormous it is. We are quite used to seeing close up colour photos of all of the main planets, mainly photographed by the Voyager missions in the late 1970s and 1980s. A reasonably priced telescope will show you the rings around Saturn or Jupiter's stripes with quite good detail. With no reference points between us and them, it's difficult to judge the distances involved. It's very easy to forget just how far away and unreachable these objects are. Students will find objects to represent the relative sizes of the planets and the Sun, and build a scale model of the Solar System to appreciate how much space there is between them.

Some quick tips on navigating the app

- If you want to quickly skip through the intro video just tap anywhere on the screen.
- If you want to quickly skip the Solar System definition screen tap on the screen to the left hand side of the planets.
- Once you have completed the app journey once you can return directly to a planet by dragging the spaceship as instructed.

The app helps build three different scale models. The model scales are…

Earth is the size of a grain of salt	1 : 139 200 000 000*
Earth is the size of a sugar sprinkle	1 : 5 000 000 000
Earth is the size of a m&m	1 : 1 000 000 000

*This may seem an odd scale but it allowed the Sun to be exactly 1cm in size and the inner planets to be the size of salt grains… a small but consistent object. Also the software development environment won't allow map annotations (the orbits, which resize with the map) to be added at a scale much less than this.

Pre-lesson understanding

Students should have an understanding of the units of measurement, they should appreciate that object sizes and distances can be measured in a fraction of a millimetre, centimetres, metres up to a multiple of a kilometre, and have an understanding of the relationship between them.

Students should understand what the Solar System is, and not confuse that with the galaxy. They need to have an appreciation of the size of the Earth. They should understand that objects look smaller the further away they are. What they see isn't always what it seems, and the Sun looks relatively small (the same size as the moon) only because it is a very long way away. Explain it is in fact very big, and one lesson objective is to understand how vast everything in the Solar System is.

Students should know that the Sun is a star. Often because it appears different to the other stars we see people misunderstand that it is in fact the same.

SECTION 1 : Major Concepts

Introduction

The Solar System formed with the Sun at its centre, and everything in the Solar System revolves around the Sun. By and large the Solar System is made up of the same stuff throughout. Each of the planets is different in some way, according to where they formed and their histories since they formed.

Objectives

Students will:

- Learn that there are 8 main planets in the Solar System.
- Learn some basic facts about each planet, such as its appearance, its size, its volume and its distance from the Sun.
- Find objects to represent the relative sizes of the planets and the Sun.
- Build a scaled down model of the Solar System which will help comprehend the sizes of the planets and the distances between them.

Learned Concepts

Maths

- That measurement can be done using various tools.
- The units of measurement are universal, and agreed upon by everyone.
- Scaling down of an objects size involves converting a larger scale of measurement into a smaller scale of measures. Proportions are kept the same.
- Why we might wish to round a very large number.
- Approximation.

Science

- The eight planets move around the Sun in their orbits.
- The orbits of most planets are nearly circular.
- Due to their ever increasing orbital radii the planets have an ever increasing distance to travel to make one journey around the Sun.
- The sizes of the planets greatly vary.
- There are not only planets in the Solar System, there are also asteroids, comets and man-made objects.

Science Review

Firstly find out how much the students already know about the Solar System.

EXERCISE: In groups or individually have them write down the names of, or draw the planets in their correct order from the Sun. Ask students to draw their relative size to each other, and although you are setting them up to fail ask them to draw the distances from each other to scale (drawing the distances to scale will not be possible).

Between them the students will probably come up with the Sun, the planets, and probably the moon. Some may have drawn the planets in round orbits around the Sun. Talk about the differences between a planet and a star. Ask for a show of hands of who thinks the Sun is a star. Some may not recognise this fact. Talk about the differences between the Sun and the other stars. You could use a famous star like Polaris (the North Star), or Betelgeuse (Orion's right hand). The main learning point is that they are essentially the same, but one is so much closer to us that it looks a lot bigger and brighter, much like a car's headlights when they are far away or close to us.

Myth Buster – Many will think that the Sun creates its energy (heat and light) by 'burning'. Burning is a chemical reaction where energy is released by one chemical substance changing to another with the help of an oxidant, usually the oxygen in air, i.e. wood to charcoal, smoke and ash. Students probably know that fires will burn themselves out when they run out of fuel, and also that fire needs oxygen. This can cause confusion in a couple of ways – *why doesn't the Sun run out of fuel and how can it burn in space where there is no oxygen*? Now is a good time to touch on the concept of nuclear fusion – that energy can be released by other means, namely hydrogen atoms bonding to create helium.

For the inquisitive, each second more than four million metric tonnes (4.4 million US tons) of matter are converted into energy within the Sun's core. In 4.5 billion years it has exhausted less than half of its fuel.

Talk about the orbits, that each planet moves in an ellipse around the Sun. Discuss what an ellipse is, and that the planets will be slightly closer* to the Sun at certain points in their orbits.

Myth Buster – Many will think that summer is when we are closer to the Sun, and Winter is when we are further away. In reality this doesn't make very much of a difference, as *the orbits of all but Mercury are approximately circular. The main cause of the temperature change on Earth is its 23.4 degree tilt. The hemisphere experiencing winter is tilted away from the Sun, which appears low in the sky and needs to pass through a lot more atmosphere to reach us, so it's less warming.

This is also a good time to talk about what planets and the Sun are made of. Largely the whole Solar System is made from the same stuff… this matter was left in space by previously exploded stars. The only place that heavy elements like carbon, oxygen and metals can form is in a supernova explosion or a star decaying into a planetary nebula. So the whole system formed from the same matter. The top ten elements by abundance are:

Hydrogen
Helium
Oxygen
Carbon
Nitrogen
Neon
Silicon
Magnesium
Iron
Sulphur

Explain that the Sun and the planets formed at the same time.

The app includes an amazing picture of a proto-planetary disc. This object is 450 light years away and would form into a star system of sun and planets. This is how our Solar System would have started life.

To find the image go through the initial stages of the app until you 'start your journey' at The Sun. Press the info button ⓘ and then in the info pane press the first Show Me button.

Explain that the disc of matter clumped together, a process called accretion, to form planets with the Sun at its centre. Students may wonder, if they all came from the same soup of stuff, why are the planets so different, especially the inner planets and the outer planets?

The planets are made of different parts of the soup due to the different temperatures the further from the Sun you go. Silicon, metals, carbon reach their solid state nearest the Sun, and other elements, which we usually think of as gases reach their solid state further away. This is also the reason why the gas giants are bigger, there was simply more hydrogen and helium in the initial soup to draw from, and less silicon, carbon and metals to form the inner planets.

The disc of matter also gave the Solar System its initial anti-clockwise spin, which explains how most of the objects in it spin or orbit.

Taking the learning further:

NASA have outlined an activity where students can learn more about accretion. Students play the role of proto-planetary dust, and have to tag each other to bond together. http://discovery.nasa.gov/education/pdfs/Active%20Accretion_Discovery_508.pdf

Maths Review

Students should be familiar with measuring distances and sizes. In order for the smallest model to fit inside a school corridor, sports hall or playground the objects needed to be really small, and students may not be so familiar with measuring to a fraction of a millimetre. A good tool to get hold of is a Digital Calliper, as shown below. The price of these is now very cheap, and the accuracy is good enough for the job.

For modelling the planets the smallest sizes that we need to measure are…

Earth is the size of a grain of salt	0.03 millimetres
Earth is the size of a sugar sprinkle	0.9 millimetres
Earth is the size of a m&m	4.8 millimetres

For modelling the Solar System the largest distances that we need to measure are…

Earth is the size of a grain of salt	32.3 metres
Earth is the size of a sugar sprinkle	900.6 metres
Earth is the size of a m&m	4 503 metres*

*It is obviously not feasible to measure this distance using conventional measuring tools, which is why the app was conceived. It does the measuring for you and displays the planet orbits on a localised map.

EXERCISE: Students should be asked to consider what method of measurement should be used in each case.

The very small could be measured with a ruler, but more accurately with the callipers. The medium distances could be measured with a tape measure, or if available a laser measuring device. The distances of over a kilometre could be measured using a map.

What are standard measurements and why do we use them?

Standards are agreed measures that are used by everyone. Some measurements such as a foot originated literally as measurements of the body. An inch was the width or three barley corns! Even a thousand years ago it was recognised that measures needed to be standardised. Once this was done manufacturing of parts could be done in two places, and when people paid for a particular length of something they knew what they would be getting.

International standards are now based upon exact scientific measurements of known fixed properties e.g. "The metre is the length of the path travelled by light in vacuum during a time interval of 1 ⁄ 299792458 of a second.", and the foot and inch are derived from this. A yard is defined as 0.9144 metres. There are 12 inches in a foot and 36 inches in a yard.

In the app the map view is only shown for the 'the Earth is the size of a m&m' scale. This is because the technology has a minimum scale where it will display the overlay orbit graphics. When using the other scales students may struggle to conceptualise the larger distances. We recommend using some familiar distances from your local neighbourhood. There are some great free web tools out there.

Distance	Familiar distance
1 kilometre	Use a web tool to find a landmark that is 1km from your current location. For example… http://www.acscdg.com/ can be used to draw a 1km radius circle on a Googlemap.
100 kilometres	Use a web tool to find some suitable cities near you, for example… http://www.distancefromto.net/ http://www.freemaptools.com/how-far-is-it-between.htm [these tools are not provided by app patch]
1000 kilometres	Use web tool. Some examples are London to Monaco The height of France New York to Indianapolis Seattle to Sacramento

EXERCISE: Students are tasked with finding a landmark that is a particular distance away.

Taking the learning further:

To better the understanding of the distances is useful if the students can have a line of sight to some landmark 1km away and then walk to that.

SECTION 2 : Sizing the Solar System

The main objective of the lesson is to gather scale models of the Sun and planets, and then build a scale model of the Solar System. It's time to introduce scaling.

On launch the app intro video introduces the relative scale of things. Firstly considering how big a city is, then a whole country, and then the Earth. The app uses a comparison of the Earth's size when looking at the size of other planets and the Sun, so that needs to be understood first.

EXERCISE: Play the app intro to the class and ask them to estimate a size in kilometres for each object (city, country, Earth).

For info the Earth is 12 756 km (7 926 miles) in diameter at the equator. The other object sizes will depend on where you are.

Ask the students why would we want to scale a measurement or distance?

- It's easier to comprehend.
- It's easier to document. A smaller drawing is more portable.
- The accuracy of the drawing or model is maintained.
- Proportions are maintained.
- Maps are essentially a scaled down drawing of our surroundings.
- In certain situations it allows us to take a bigger view of something. For example if building a new freeway between two cities planning it on a map is easier than doing so on the ground.
- Only the detail required is shown. There should be agreement to what is the smallest detail that should be included. For example if we were drawing a map of the world we wouldn't want to draw individual buildings on it.
- Scaling in everyday life
    - Cooking twice/half as many cookies as the recipe will make.
    - Building a lego model. We want the proportions to look right.
    - Buying fruit by weight. A price is given per kg but you need to work out the price for the weight of fruit you have.
    - A model railway
    - An architect's model.

Applying Scaling

The easiest way to think about scaling distances is to replace a large unit for a smaller one, so for example a metre becomes a centimetre. We are transforming one measurement into another.

EXERCISE: Draw a scaled model of the classroom, with the dimensions of the room, and size of desks and chairs scaled down in this way. This is made easier using grid paper that already has a centimetre grid on it.

If converting metres to centimetres we would say that we are scaling by using 1 centimetre for each 100 centimetres , so the scale is 1/100th or 1 cm / 100 cm. This is typically written as a ratio 1 : 100. Note that when working out the ratio it's important not to mix the units up. We can't say 1cm / 1m, both sides of the ratio have to be using the same unit.

If something is drawn 'to scale' the ratio is 1 : 1. The more that something is scaled, the bigger the ratio, so 1 : 10 000 is scaled down less than 1 : 100 000 000.

Showing the students a couple of maps of the same region drawn at different scales will demonstrate the differences that different ratios might make.

Scaling therefore doesn't have to be just 1 bigger unit equalling 1 smaller unit. It can be any fraction of any unit. When scaling the Solar System a very large scaling is required, as the units involved are hundreds of millions of kilometres. In order for our model to be classroom or school-yard sized, the optimum unit to scale to is the millimetre.

For our exercise we will use the following scales

	Scale Ratio	Using…	…for every
Earth is the size of a grain of salt	1 : 139 200 000 000	1 mm	139 200 km
Earth is the size of a sugar sprinkle	1 : 5 000 000 000	1 mm	5 000 km
Earth is the size of a m&m	1 : 1 000 000 000	1 mm	1 000 km

Note that the scale ratio MUST use the same unit on each side, so the 5 000 km is stated in terms of millimetres 5 000 x 1 000 (metres in a km) x 1 000 (millimetres in a metre) = 5 000 000 000

Applying rounding

As the scales of space are so enormous it is typical to round up the distances to the nearest 1 000. This is like the map of the world mentioned above. We are not interested in measuring the size of a planet to the nearest millimetre, as that would be very difficult, possibly changing all the time and does one millimetre carry any meaning, when we are comparing more than one massive object? We usually agree to the smallest level of detail to be used throughout. Sometimes we might even just use a number of 'significant digits', that is only looking at the numbers that carry meaning.

When talking about massive distances in space we go even further to using 1 AU, an Astronomical Unit, the average distance between the Sun and the Earth (about 150 million km, or 93 million miles), and then 1 Light Year, the distance that light travels in a year (9.4 trillion km or 5.8 trillion miles).

MAJOR EXCERCISE: Sizing the planets

Students are given the diameters of the planets and have to determine the scaled down diameters for a given ratio.

So to scale down a size or distance we must divide by the number after the colon in the ratio (called the ‘consequent’) and then multiply by the first number, if not 1 (called the ‘antecedent’).

Due to the large numbers involved in the calculations calculators should be used, preferably with a 16+ digit display, so that the full number can be entered and displayed. Calculators with smaller displays will tend to truncate the number using the iterated exponential notation e.g. 100 000 000 e+25. This is beyond the scope of the intended age group and will cause confusion! (If your calculators can’t do this, the Microsoft Windows calculator can do 16 digits).

These are the answers they should achieve. A blank worksheet is provided as Appendix A. The digit group separators used are spaces to accommodate both English speaking countries and European methods.

Object	Diameter at equator in km	Diameter at equator in mm (km x 1 000 000)	1 : 1 000 000 000 in mm	1 : 5 000 000 000 in mm	1 : 139 200 000 000 in mm
The Sun	1 392 000	1 392 000 000 000	1392.0	278.40	10.00
Mercury	4 879	4 879 000 000	4.9	0.98	0.03
Venus	12 104	12 104 000 000	12.1	2.42	0.08
Earth	12 756	12 756 000 000	12.8	2.55	0.09
Mars	6 794	6 794 000 000	6.8	1.36	0.04
Jupiter	142 984	142 984 000 000	143.0	28.60	1.02
Saturn	120 536	120 536 000 000	120.5	24.11	0.86
Uranus	51 118	51 118 000 000	51.1	10.22	0.36
Neptune	49 528	49 528 000 000	49.5	9.91	0.35

At this point the scaled down dimensions which have been calculated could be produced in modelling clay, however it is more interesting to find everyday objects which could represent the items, with the added benefit that the objects and their relative sizes stick in the mind.

In the app we tried to choose objects that are consistently the same size. Obviously the size of a corn kernel is going to vary somewhat, as are any of the other naturally occurring items. 100% accuracy isn't necessarily the objective here, so long as the proportions to each other are relative.

For the 'Earth is the size of a grain of salt' model (scale 1 : 139 200 000 000) the app uses a grain of salt for all of the inner planets (Mercury, Venus, Earth, Mars). Looking at the actual measurements above it should be noted that Mercury and Mars will require a smaller grain size than the Earth and Venus. We found that table salt grains were consistently in this range, so students should be tasked with finding bigger and smaller grains.

Students could be tasked with finding appropriate objects from a selection offered. The list below shows the objects that are used in the app, as well as some possible alternatives. For the very small objects (salt, sugar grains), it is advisable to present them on black card and provide a tool to separate them such as a cocktail stick or tooth pick.

Object	1 : 1 000 000 000 in mm		1 : 5 000 000 000 in mm		1 : 139 200 000 000 in mm	
The Sun	1392.0	Golfing Umbrella, Weather Balloon.	278.40	Soccer Ball, Watermelon	10.00	Lego head
Mercury	4.9	Black Pepper Corn, Dried Sweetcorn kernel	0.98	Brown Sugar Crystal	0.03	Small Table Salt Grain, Width of Human Hair, Grain of Sand
Venus	12.1	Cheerio, Glass Marble	2.42	Candy Sprinkle, Sesame Seed	0.08	Table Salt Grain, Grain of Sand
Earth	12.8	m&m, Skittle Candy, Small Blueberry	2.55	Candy Sprinkle, Sesame Seed	0.09	Table Salt Grain, Grain of Sand
Mars	6.8	Sweetcorn kernel, Pea, Coffee bean	1.36	Pin head	0.04	Small Table Salt Grain, Width of Human Hair, Grain of Sand
Jupiter	143.0	Galia Melon, Large Grapefruit	28.60	Walnut	1.02	Pin head
Saturn	120.5	Toilet Roll, CD disc	24.11	Hazelnut (Cobnut, Filbert nut)	0.86	Brown Sugar Crystal
Uranus	51.1	Lime	10.22	Cheerio	0.36	White Sugar Crystal
Neptune	49.5	Kiwi Fruit	9.91	Lego head	0.35	White Sugar Crystal

MAJOR EXCERCISE: Walking the Solar System

As a purely classroom based exercise the 'Earth is the size of a m&m' will allow students to visualise the Solar System using the app, based on their locality. The map automatically uses the device's location as the Sun's location in the model, and draws the orbits of the planets as you work through the app.

More interaction can be gained by using the other sized models. The 'Earth is the size of a grain of salt' model is an excellent option if the activity is going to be indoors, or another small space. Most schools will have an area that is 32.3 metres long, either in a corridor, sports hall or playground.

The 'Earth is the size of a sugar sprinkle' model requires 901 metres, and so could be done on a school sports field or along a sidewalk.

In the classroom, prior to any interactive adventures, students should scale down the distances between the planets. They then need to convert those millimetre distances into something more appropriate for the measurement tool that they selected in the earlier exercise (see p7). Typically this is going to be metres and centimetres.

These are the answers they should achieve. A blank worksheet is provided as Appendix B. The digit group separators used are spaces to accommodate both English speaking countries and European methods.

Span	Distance in km	Distance in mm (km x 1 000 000)	1 : 1 000 000 000 in mm	1 : 5 000 000 000 in mm	1 : 139 200 000 000 in mm
The Sun to Mercury	57 900 000	57 900 000 000 000	57 900	11 580	416
Mercury to Venus	50 300 000	50 300 000 000 000	50 300	10 060	361
Venus to Earth	41 400 000	41 400 000 000 000	41 400	8 280	297
Earth to Mars	78 300 000	78 300 000 000 000	78 300	15 660	563
Mars to Jupiter	550 700 000	550 700 000 000 000	550 700	110 140	3 956
Jupiter to Saturn	654 900 000	654 900 000 000 000	654 900	130 980	4 705
Saturn to Uranus	1 439 000 000	1 439 000 000 000 000	1 439 000	287 800	10 338
Uranus to Neptune	1 622 600 000	1 622 600 000 000 000	1 622 600	324 520	11 657

The distances should be measured out and a marker or student left with the chosen everyday object. The next span distance should be measured from the previous planet until all the planets are included in the model. Students will quickly get a sense of scale of the Solar System.

For the inquisitive, we have used measuring equipment to measure our distances, but what do astronomers use to measure the distance to the planets? With modern technology we can measure the distance directly and extremely accurately using radar. A beam of radiation is aimed at the planet and the time it takes to receive the echo is measured using an atomic clock. Because the speed of light is known exactly the distance to the planet is half the time (the signal travels there and back) divided by the speed of light.

Taking the learning further:

In our model the planets will all be in a straight line. This is typically only likely to happen, every 1500 years. If you have the space and the time the scaled orbits could be measured onto string and students walk around a central point (the Sun) with the string taught. Asking the 'planet' students to all walk as fast as they can around their orbits will demonstrate the different distances each planet must travel, and why they take much more time to orbit the Sun. The inner planets are likely to make several orbits for one orbit of Neptune.

Asteroid Alert! Asteroid Alert!

Myth Buster –Building the model is a great way to visualise the amount of space between the planets. This is a great opportunity to dispel one of the biggest myths of the Solar System, the nature of the Asteroid Belt. When modelling the space between Mars and Jupiter you should mention the Asteroid Belt and that this position in the solar system should probably have another planet in it.

Unfortunately for that planet Jupiter got really big, and its gravity pulled a lot of the larger planetesimals out of the orbit. They either crashed into Jupiter, one of the other outer planets, or were ejected from the Solar System altogether. The objects that were left were too small and dispersed to form a planet. The myth, spread by many science fiction movies is that the asteroids are densely packed, jostling for position and frequently hitting one another.

In reality the Asteroid belt is about 1 AU wide (about 150 million km) and 1 AU high, and filling the entire orbit circumference. An estimated 1.5 million asteroids in the main asteroid belt are larger than 1 km. With a total volume of 8 trillion, trillion cubic km, that would be about 5.5 million, trillion cubic km per asteroid. Taking the cube root of this gives a typical separation of 1.75 million km, or about 8 times the distance from the Earth to the Moon. In reality, if you were stood on one, you probably wouldn't ever see another asteroid.

In our model the asteroids would be these distances apart, and too small to see. For the large models have students stand this far apart to be typical asteroids.

	Asteroid Separation
Earth is the size of a grain of salt	12.57 mm
Earth is the size of a sugar sprinkle	350 mm
Earth is the size of a m&m	1 750 mm

Taking the learning further: Space Travel

This entire section could extend the learning.

Students will begin to understand the distances between the objects in the Solar System. To further put this into perspective the app estimates the time it will take for a spacecraft to travel between planets.

This is actually a very difficult question to answer, because if you have enough fuel, you can accelerate to some pretty fantastic speeds in the frictionless environment of space. The New Horizons probe is currently travelling at 49 500 km per hour (31 000 miles per hour).

These are some of the ways to pick up speed

- Very big initial boost when leaving the previous planet
- Gravity assisted slingshot around another planet. Usually the distance travelled is greater but a close fly-by of a planet will use its gravity to give the craft a boost.
- Continuous propulsion. The Ion engine on the Dawn spacecraft emits charged particles over a long period of time. Each gives an infinitesimal forward thrust, but when fired for long enough this slowly acts to accelerate the craft.

The downside of picking up speed is if we intend to visit the next planet we then have to slow down to a speed where the destination planet's gravity will capture us into an orbit. So whatever magnitude energy is applied to speed us up will also be required to slow us down, and this could be a lot of fuel. More fuel is more mass and more mass means more energy to escape the gravity of the planet we are leaving.

As all of the planets are continuously moving simply pointing in the right direction and blasting off won't work. By the time we reach the planet, it would have moved. So the shortest distance is an arc between the two orbits, and if calculated correctly the destination object will be in the same location as the craft when it arrives. The manoeuvre to achieve this shortest distance travel is called a 'Hoffman Transfer Orbit'.

Two inputs of energy are needed, one to escape the initial planet's gravity (the escape velocity) and one to transfer to the new orbit. The escape velocity is generally of higher magnitude than the transfer velocity, so the initial energy boost should suffice.

Also important for a Hoffman transfer is the location of the planets. The shortest distance assumes that the planets have optimal alignment. For the inner planets that alignment or 'launch window' may happen a couple of times a year, but for the outer planets this could be thousands of years. For simplicity we assume everything is optimal!

The app assumes the lowest energy transfer orbit, this is using a Hoffman Transfer Orbit route and maintaining the escape velocity required to leave the last object. An optimal alignment is assumed, although the app suggests we could visit one planet and then jet off to the next the launch window may require a very long wait!

SECTION 3: EVALUATE

The following questions can be used for a class discussion or for a more formal test or quiz.

Check for Understanding

1. What is a kilometre? What is something 1 kilometre from the school?
2. How does the apparent size of an object change when it is viewed from a long way away?
3. What is contained in the Solar System?
4. Name the 8 main planets and what order they orbit the Sun.
5. Is the Sun a star? Does it burn?
6. How do the Sun and planets interact? What shape are the orbits?
7. What is the Solar System made of and how did it form?
8. What do the two numbers in a scaling ratio mean? What units must both numbers be?
9. List the planets and Sun in order of their size. Biggest first.

Reflection

1. Does a planet's orbit create its seasons?
2. Why are some planets much bigger than others?
3. We have all used rulers to measure lengths, but what methods can be used to accurately measure something very small or very big?
4. Why do we need standardised measurements?
5. What is the best unit for measuring the Solar System?
6. What is the best unit for modelling the Solar System?
7. Why might we want to make a scale model?
8. Why might we want to round a number?
9. There is a lot of matter in the Solar System / There is a lot of space in the Solar System. Which of these statements do you support?
10. It would take a skilled pilot to fly through the Asteroid Belt, True or False, Explain why?
11. Why is it difficult to visit the other planets?

APPENDIX A – Worksheet 1

Calculate the diameter of the Solar System object in millimetres and then the scale down the measurements for our model.

Object	Diameter at equator in km	Diameter at equator in mm (km x 1 000 000)	1 : 1 000 000 000 in mm	1 : 5 000 000 000 in mm	1 : 139 200 000 000 in mm
The Sun	1 392 000				
Mercury	4 879				
Venus	12 104				
Earth	12 756				
Mars	6 794				
Jupiter	142 984				
Saturn	120 536				
Uranus	51 118				
Neptune	49 528				

APPENDIX B – Worksheet 2

Calculate the distance of the Solar System object from the Sun in millimetres and then the scale down the measurements for our model.

Span	Distance in km	Distance in mm (km x 1 000 000)	1 : 1 000 000 000 in mm	1 : 5 000 000 000 in mm	1 : 139 200 000 000 in mm
The Sun to Mercury	57 900 000				
Mercury to Venus	50 300 000				
Venus to Earth	41 400 000				
Earth to Mars	78 300 000				
Mars to Jupiter	550 700 000				
Jupiter to Saturn	654 900 000				
Saturn to Uranus	1 439 000 000				
Uranus to Neptune	1 622 600 000				