1. Title: Relative Sizes and Distance in the Solar System: Introducing Powers of Ten

Here we're going to learn how big the Sun is relative to the different types of planet in our Solar System and the huge distances that separate the different types of object one from another. These ideas can be among some of the most difficult concepts for children to understand (and for us to teach). But if we can explain them well, then the children will have a good basic understanding of their place in space and also some key tools that will help them better to understand many other areas of the curriculum especially the areas of science, technology, engineering and mathematics (STEM).

Early on in KS1* we can show children that the tree close by us in the school grounds is very big, we can stand under it, look up at it and try to draw it. Next have them look at a tree very far away if possible, ask them how they would describe it and get them to draw it. They may see it as smaller. Try to explain that the tree far away may be just as big but it just looks small because it is far away. If it were possible to stand beside this tree later they would understand this. Perhaps they have been in a very high building (housing/hospital) and looked down to see cars and people that seem to be very small below.

Again from a very young age children seem to be aware of the Sun and Moon in the sky. They may have songs or poems that the Sun comes out in the day and the Moon comes out at night as they go to bed. The Sun frequently appears in the birthday cards they draw for family members and in their paintings. As children get older they may observe that the Moon is still up during the day. We can use a Moon phase resource to explain the changing appearance and visibility of the Moon.

Ask the children which do they think looks bigger in the sky, the Moon or the Sun? Use observation, prediction and have a discussion. Do this when the Moon is full or near full and tell them to look for the Moon over the next few nights at bedtime, you can look up the Moon phases on www.heavens-above.com

Think: Get children to look at the Sun and Moon and compare their relative sizes.

H&S: warn the children **never** to look directly at the Sun and **never, ever** through binoculars or a telescope, as permanent eye damage would result.

Actually, the Sun's diameter is 400 times bigger than the Moon's diameter but by coincidence the Sun is 400 times further away and this makes them seem almost the same size in the sky! This coincidence allows a total eclipse of the Sun to happen when the Earth, Moon and Sun are all lined up correctly, with the Moon coming between Earth and the Sun.

As children get older, in KS2 for example, we can start to build scale some models to help them understand the size and distances in the Solar System.

** UK Primary schools have Foundation (P1 & P2), Key Stage 1 (P3, P4) and KS2 (P5, P6 & P7)*

Let's build some models!

1.1 Activity 1: Relative Sizes in the Solar System

Choose a small beachball or football to represent the Sun, around 24 cm across.

Think: Ask the children how big they think the Earth and other planets are, compared to the beachball; which planet lies closest to the Sun in space and so on.

Now give them the answer (refer to Table): the gas giants, Jupiter and Saturn, are about 2 cm across, and the terrestrial planets about 2mm across, and Uranus and Neptune in between. See Table for more exact figures. Now make them!

In this activity we are going to get the children to make scale **size** models of the Sun and planets to get some idea of their relative sizes. We could give them a table of information to read but they tend to get more of an impact and a wow factor when they finally put all the planets together in a row!

- You will need modelling clay
- 30cm rulers
- Planet name labels – supplied at end of this document
- ball - 24cm approx (1 to 3 needed)

Using the table below ask individuals to make a planet each – you could have up to 3 sets in the class. They need to measure the diameter across each sphere as accurately as possible and remember which planet they are making, perhaps hand them a planet label each at the start. You could put a rough colour code on the card e.g. Earth: green and blue, Neptune: bright blue, Saturn: beige/gold colours. (Make the approximate sizes in brackets for simplicity.)

The third column in grey is merely to show the scale distances these spheres would need to be placed apart if they were laid out on the ground on the *same scale as the planet sizes*.

Planet	Size of sphere (approximate in brackets)	Distance of body from Sun <u>to same scale</u> in <u>metres</u>
Sun	Ball at 23.28cm (24 **cm** approx.)	0
Mercury	0.08 cm (1mm)	9.68m
Venus	0.20 cm (2mm)	18.08m
Earth	0.21 cm (2.5mm)	25m
Mars	0.11 cm (1.5mm)	38.10m
Ceres	0.02 cm (0.25 mm)	69.16m
Jupiter	2.34 cm	130.08m
Saturn	1.95 cm	238.43m
Uranus	0.85 cm	479.78m
Neptune	0.82 cm	751.73m
Pluto	0.04 cm (0.5mm)	987.05m
		(Nearest star Proxima Centauri would be 6644.75 **km or 4.2LY** away on this scale!)

Think: For our model Sun (diameter c.23-24cm), Mercury and Mars are around 1mm across, Earth and Venus are around 2mm across, Jupiter and Saturn are around 2cm across and Uranus and Neptune are intermediate in size at around 8mm across.

Think: Can you see any pattern (the planets come in pairs; the terrestrial planets are all much smaller than the gas giants (and in particular are around 10 times smaller than Jupiter and Saturn) which in turn are around 10 times smaller than the Sun etc.)

Having made your planets, now lay them out in the correct order and where you think they should go in relative distance to the Sun. (The third column of the Table gives the correct results, but we haven't quite got there yet.)

1.2 Activity 2: Distances in the Solar System

In this activity we will construct a scale model of the **distances** between the Sun and planets and we will not worry too much about their relative sizes for now.

- You will need modelling clay
- 10m of string
- scissors
- 1m rule/tape measure
- Planet name labels – supplied at end of this document - Moon not needed here
- ball

The ball will represent the Sun. Make the other nine objects so there are five very small, two about ten times larger than these, and two in between these sizes - these are all very approximate.

Now use the Table below to mould your modelling clay to the string at the correct distances, using a tape measure to measure the correct relative distances in metres from the Sun.

Planet	Distance from Sun (cm) (Rounded)
Sun	0
Mercury	9.68cm (10)
Venus	18.08cm (18)
Earth	25cm (25)
Mars	38.10cm (38)
Jupiter	130.08cm (130)
Saturn	238.43cm (238)
Uranus	479.78cm (480)
Neptune	751.73cm (752)
Pluto	987.05cm (987)

Get the children to hold up the model as they stretch their new Solar System along the classroom and pretend to be the Sun, Earth, Jupiter etc. Talk about what they notice (grouping/gaps?) and display their new model along the side of the classroom.

Think: What lies between the orbit of Mars and Jupiter?

Think: On this model, how big do you think the Sun should be?

Think: How big does the Sun (or Moon, as they are both the same) look from the Earth. (NB H&S re Sun!) If Earth is 25cm from the Sun (about a foot rule), get children to estimate the size of the ball that would represent the Sun for it to subtend the same angle as the real Sun does from the real Earth.

Answer: Sun should be a couple of centimetres across, i.e. 100 times smaller than the beachball/football we first thought of.

Think: Select a ball of about this size to demonstrate the fact. Now replace this ball with the one you first thought of.
Think: How far away should the Earth now be placed? (Answer: 25 metres, i.e. 100 times farther away. And the same for all the other planets).

Extension Activity. (Can be done in the playground or sports field.)

We now get someone to hold the football for the Sun, and another to go 25 metres away with his/her "Earth" (the ball about 2mm across), and another to go 130 metres away with his/her "Jupiter" (the ball about 2cm across). This gives them a feel for the real size of the Solar System.

To Orbital Period: The time it takes one planet to make a complete orbit around the Sun. Divide the children into four groups, two "timers" and two "runners". Get the timers to time how long it takes each of the other groups to run from the Sun and back to the Earth six times. Now get them to time how long it takes each of the runners to run from the Sun and back to Jupiter six times (i.e. to and from three times.) The Jupiter ones will get tired, so their average speed should be much less than that of the Earth runners, simulating Kepler's third law! Collect all your results...

Now to get back to our playground model:
The Edgeworth-Kuiper Belt (EKB) extends from roughly Pluto's distance to 25 times Pluto's distance from the Sun, i.e. from roughly **1 kilometre to 25 kilometres away**. This would be a vast distance on our model where Pluto is already 987 meters away.

Think: What places do you know that are that far away (shops, cinemas, towns). You may be able to use Google maps and see that Armagh to Dungannon is about a 21km distance. If your Sun model was in Armagh the EKB would extend from Pluto's orbit to further away than Dungannon!

Even further away, the Oort cloud extends from 25 times Pluto's distance from Sun (or 1000 times Earth's distance if that makes it easier to explain to 200,000 times Earth's distance) **i.e. on the model from 25km to 5000km away.**

Think: What places do you know that far away (more distant towns, to distant countries (USA, Russia, South Africa), introducing Geography and world knowledge. Through EU-UNAWE we can collaborate with schools in some countries this far away.

Finally, on this model how far are the nearest few stars: Proxima Centaur at around 7,000 km, i.e. roughly as far as the other side of the Earth (e.g. Australia, New Zealand)... which means we need a world-size space to explain the Solar System on a scale model in which the Sun is a small football.

Introducing the Astronomical Unit

We can tell the children all about the vast distances but getting them to think relatively may be more helpful. For example, it is 150,000,000 km (150 million km) from the Sun to Earth, what if we used this distance to compare the distance of other bodies? Well, we do and this special distance is called 1 Astronomical Unit or **AU**.

From this we can say Mars is a distance of 1.52 AU from the Sun, Jupiter 5.20 AU. Neptune is a distance of 30 AU from the Sun (30 times the Sun-Earth distance unit) and so on.

From just beyond Neptune's orbit, from approximately 40AU to approximately 60 AU is the Edgeworth–Kuiper belt.

Even more distant, the Oort cloud is located at approximately 1,000 – 200,000 AU. The outer limit of the Oort cloud defines the boundary of the Solar System and the region of the Sun's gravitational dominance.

Advanced work: Introducing Powers of ten

We will know from our Maths about units, tens, hundreds, thousands, tens of thousands, hundreds of thousands, millions etc. Sometimes in astronomy we need to deal with very large numbers and in websites etc. you will see a notation like 7×10^9 km. The tiny superscript 9 would indicate as in the simple table below a multiplication of a billion. 7,000,000,000. In the UK a billion is one thousand million.

Name	Power	Number	Example
One	0	1	
Ten	1	10	
Hundred	2	100	
Thousand	3	1,000	$1\text{x}10^3$
Million	6	1,000,000	$1\text{x}10^6$
Billion	9	1,000,000,000	$1\text{x}10^9$
Trillion	12	1,000,000,000,000	$1\text{x}10^{12}$
Quadrillion	15	1,000,000,000,000,000	$1\text{x}10^{15}$
Quintillion	18	1,000,000,000,000,000,000	$1\text{x}10^{18}$

A simple example would be notation for the Astronomical Unit (AU)

1AU = 150,000,000 km = **150×10^6 km**

Let's finish with a really simple scale and see if you can see a pattern in the relative sizes:

If the Sun were represented by a sphere 23-24 cm diameter:

Then make the 4 innermost planets very small: Mercury 1mm, Venus 2mm, and Earth 2.4mm and
Mars 1.5mm
Jupiter 2.4 **cm**
Saturn 2**cm**
Uranus and Neptune 1**cm** each
Tiny Pluto 0.5mm

The Bottom Line

If we can see and only remember from this exercise that (approximately):

1 the 4 innermost planets are 1/100th the size of the Sun;
2 the two biggest planets Jupiter and Saturn are approximately 1/10th the size of the Sun
3 the 4 innermost planets are 1/10th the size of the 2 big planets.

Also
Earth's distance from the Sun is approximately 100 solar diameters. So in this model 100x24cm = 24m = 1AU therefore our Sun and Earth would have to be 24 metres apart for this model!

For children fascinated by space flight;
as of August 2011, at 118 AU, *Voyager 1* is the farthest human-made object from the Sun. It is currently travelling at about 3½ AU/yr.

Labels for models

Sun	**Mercury**	**Venus**	**Earth**
Mars	**Ceres**	**Jupiter**	**Saturn**
Uranus	**Neptune**	**Pluto**	**Moon**