

3 Solar System Overview

The solar system is a big place. It's so big that it's a little hard to imagine. Nothing we come into contact with really prepares us to imagine just how big the solar system is. But we can try to get an idea of its size by scaling things down to size.

3.1 Solar System Recipe

When you (or your parents) cook, sometimes the recipe will say that it makes enough for, say 4 people. But what if you don't have 4 people in your family? What if you are having friends over for a party and expect to have 12 people? That's easy, you scale up the recipe: you need three times as much, so you multiply all the ingredient amounts by three to make enough for 12.

What if it worked the other way? What if you found a recipe for 1,000 cookies but you only want to make 100? That's easy too, you scale down by dividing the recipe amounts by 10. Then your recipe for 1,000 becomes a recipe for 100.

We want to make a solar system model that will fit in the hallway. The school hallway is about 50 meters long, so the first thing we have to do is decide how many planets we want to fit into the hall. Do we want to stop with Earth so our model has only the sun at one end, then Mercury, Venus, and Earth? Do we want to include only the eight major planets? Do we want to include Pluto?

3.2 Scaling Down

So how much do we have to scale down the solar system to fit it in the hall? First let's calculate how much we have to shrink things just to fit the inner planets: Mercury, Venus, Earth, and Mars.

Let's try to fit the eight major planets and Pluto into the hall. Mars is about 230 million kilometers from the Sun. That's a big

number, but just how big? If you could find a rope that would reach all the way around the Earth (at the equator), it would have to be about 20,000 kilometers. You would need over 11,000 of those ropes to reach from the Sun to Mars! And if instead of rope, you were to buy cheap cotton string it would cost you about one billion dollars to reach that far!

Okay, so Mars is a long way from the Sun. How much do we have to scale it down to fit in the hall? First, we measured the distance to Mars in kilometers, but the distance in the hall in meters. But that's easy to fix, right? 1 kilometer equals 1,000 meters, so we have 230 billion meters from the Sun to Mars. That's 230,000,000,000 meters (a lot of zeros, but we have to keep track of them).

You might be thinking about now that you want to include Pluto because it's always been considered a planet and it seems a shame to exclude it. That's fine, in the model we're going to build, I include Pluto. Keep in mind, that with the way that astronomers now classify Pluto as a dwarf planet, that we could also include Ceres (formerly classified as an asteroid), Haumea, Makemake, and Eris. The last three are similar to Pluto and even further from the sun. Eris is even bigger than Pluto. But if we include all those, we'll have to shrink things down even more; Pluto is only about 2/3 as far from the sun as Eris.

Just like our cookie recipe, we are trying to find the number we use to divide by to arrive at our final size.

$$230,000,000,000 \text{ meters} \div \boxed{} = 50 \text{ meters}$$

So what goes in the box? 4,600,000,000. That's a big scale-down factor. But remember, this is just to fit Mars in the hall and we want to fit all of the planets including Pluto. If we keep this scale, then Pluto will end up being 1,300 meters away, about the distance from 68th Street to 86th Street. Clearly, we have to scale down some more.

Planet	Real Distance (meters)	Hallway Distance (meters)
Mercury	58,000,000,000	
Venus	108,000,000,000	
Earth	150,000,000,000	
Mars	228,000,000,000	
Jupiter	778,000,000,000	
Saturn	1,429,000,000,000	
Neptune	2,871,000,000,000	
Uranus	4,504,000,000,000	
Pluto	5,914,000,000,000	

Table 1: To scale Pluto to fit in the hall (50 meters), I had to divide the real distance by $\boxed{}$. Fill in the table with the scaled distances for the rest of the planets so we can make our hallway model.

Complete Table 1 for our hallway model. If you have a calculator, you can use it; this isn't a math test, so we're not quizzing you on arithmetic, we just want to find the right way to build our model. It's also okay if you use a rounded number since we just want to get close.

If you have a typical calculator, you're going to have a problem. Some of those

distances are too big to type in! But you can scale down by *almost* enough if you just divide by 100,000,000 (that's 100 billion). Then Pluto is 59.14 meters down the hall (that's 59 meters plus 14 centimeters). That's a little too far; Pluto is past the end of the hall into the gym, but the rest of the solar system will fit.

3.2.1 Are We There Yet?

Let's rewrite this table a little bit to try and understand what those distances mean in real life. We we were traveling by car, how long would it take to drive to each of the planets? We can calculate that answer using the values in Table 2. A car travels about 100 kilometers per hour (just over 60 miles per hour). We'll ignore details like, well, if you were driving to the Sun, where you you stop for gas, to use the bathroom, or get a snack. What about the roads? There are no roads in space. No, we're just interested in how long it takes to get there.

Planet	Real Distance (kilometers)	Car Travel Time (100 kph)	Commercial Jet Travel Time (500 kph)
Mercury	58,000,000		
Venus	108,000,000		
Earth	150,000,000		
Mars	228,000,000		
Jupiter	778,000,000		
Saturn	1,429,000,000		
Neptune	2,871,000,000		
Uranus	4,504,000,000		
Pluto	5,914,000,000		

Table 2: Fill in the table with the number of hours it would take to travel from the sun to each of the planets if you were driving and if you were traveling by commercial airline.

A car drives about 60 miles per hour which is very close to the same as 100 kilometers per hour (kph = kilometers per hour). Most commercial jets travel about 500 kph (300 mph). The two fastest airplanes ever made, SR-71 blackbird and the X-15, could travel at about 2,300 kph and 6,400 kph. But you could only fit one person inside!

3.3 Home Activities

3.3.1 Moon Phases

For most of this past week, the moon has been “in hiding” near the sun. But by Friday or Saturday night, you might be able to find a very thin crescent moon very close to the horizon just after sunset. Nearby will be a very bright “star.” That “star” is actually our nearest neighbor planet, Venus!

Continue the Moon phases chart. How has the time-of-day when you can find the moon been changing? How has its appearance been changing?

Solar System in my Notebook

Draw a small model of the orbits that fits on sheet of notebook paper using the values in Table 3. Note that the “Notebook Paper Distances” are in millimeters.

Planet	Real Distance (kilometers)	Notebook Paper Distance (millimeters)
Mercury	58,000,000	2
Venus	108,000,000	5
Earth	150,000,000	6
Mars	228,000,000	10
Jupiter	778,000,000	33
Saturn	1,429,000,000	60
Neptune	2,871,000,000	121
Uranus	4,504,000,000	190
Pluto	5,914,000,000	250

Table 3: The right-hand column shows the sizes of the orbits (distance from the sun to the planet) scaled to fit onto a sheet of 8½ x 11 paper.

3.4 Vocabulary

Planet

The official definition is a bit difficult to understand (even for professional astronomers!). There are two main parts. It has to be big enough that gravity turns it into something close to a sphere, and it has to be big enough that other object don't have much effect on its orbit.

Dwarf Planet

The official definition makes it sound like a dwarf planet is not really a planet, but professional astronomers are still not really in agreement over that part. Most seem to think that we should still consider them a kind of planet, but unlike the the major planets, either they are not quite big enough for gravity to squeeze them into a sphere or there are other planets nearby that have a big

effect on their orbit.

Orbit

An orbit is the path an object takes as it goes around the sun. All of the distances we put in the tables measure the size of the orbit. Most orbits are not circles but ovals (ellipses). But all of the orbits of the planets (not dwarf planets) are pretty close to being a circle. Pluto, and all of the dwarf planets, have orbits which are much more oval.

3.5 Resources

- <http://www.sr-71.org/> is an “online aircraft museum” with information on the SR-71. And, of course, you can go see the SR-71's cousin, the A-12 sitting on the deck of the Intrepid!
- <http://www.nineplanets.org/> has most of what you would ever like to know on the solar system. The distances in the tables were taken from that web site.
- <http://www.kidsastronomy.com/> is simply a fun web site complete with some astronomy songs. Our family especially enjoyed “Constellation Jig.”