

Teacher Notes- “99.86%- Measuring Our Sun’s Mass”

Our sun, with a mass that consumes 99.86% of *everything* in our solar system, is beyond enormous. But how do you actually grasp that? Simple- you draw a box. But not just any box. One whose size represents .14% of the total area of a piece of paper.

It takes a 9-step mathematical journey to get to the end, but anyone can do the steps. The activity concludes with a tie-in to gravity.

1. Measure the length of your paper	__mm
2. Measure the width of your paper	__mm
3. Line 1 x line 2 = total area	__mm ²
4. Measure the diameter of a hole	__mm
5. πr^2 to get area of circle	__mm ²
6. x 3 (3 holes)	__mm ²
7. Line 3 - line 6	__mm ²
8. Line 7 X .0014	__mm ²
9. $\sqrt{\quad}$ of line 8	* __mm
*draw a box with sides this long near the middle hole of your paper	

Materials per student:

- 1-clean sheet of lined notebook paper
- 1-12-inch ruler
- 1-calculator

And...

- 1 Marble
- PowerPoint-99.86%-Measuring Our Sun's Mass (located in *Resources* folder)

Beforehand:

1. Find the section in your textbook that deals with the sun. Anything will do, but if it mentions how massive it is then select that passage. Doing a short reading from your text sets a more academic tone to the lesson.
2. If you're using the PowerPoint, insert a picture from the internet*¹ of the solar system on slide #1 (for copyright reasons, none were included). When you find one you like, right-click on it and “Copy”, come back to the PowerPoint and right-click then “Paste” it in. Drag a corner out to enlarge it. Then right-click the picture → *Order* → *Send to Back* to put the words over the front of the picture
3. Go through the 9 mathematical steps yourself. That will give you a much better feel for what's going on, and will help you explain things better. You need confidence as you teach this lesson.
4. Print PowerPoint slide #5 for students who are slow writers or are absent.
5. Just before your first class comes in, remind yourself to keep things simple and focused. Don't stray too far- there's not much extra time, nor can students keep track of endless bits of excess information anyway.

Procedure:

1. As class starts, take care of some Preliminaries:
 - a.) Have students take out a clean sheet of lined notebook paper (unless they're using the handout in the *Resources* folder) and open their books to the page you'll be reading from.
 - b.) Begin the PowerPoint, showing the solar system picture on slide #1 that you inserted.

2. Give an introduction:

“True or false class- our sun is big (*trick question – “big” is a relative term. It depends on what you’re comparing it to. Compared to us- earth- it’s big. But to other things, no.*)^{*2}

My goal is for everyone is to leave class today thinking, ‘My goodness, the sun is big!’. We’re going to use a 9-step mathematical process to calculate exactly how massive our sun is.

Don’t worry about the mathematics. Students of all abilities have done this. All you have to do is listen and do what each step says. All the hard work has already been done for you. You just plug in your numbers when you’re told to.”^{*3}

3. Read aloud the section from the textbook about the sun.
4. Clarify and focus the activity:

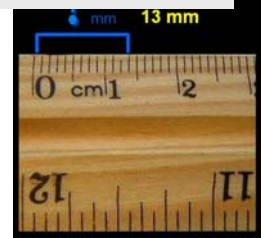
“What we just read says that our sun is the most massive thing in our solar system. Did you catch how massive the sun is? (99.86% of the mass in our solar system alone belongs to the sun).

We’re not talking today about the size of our solar system.^{*4} The topic is *mass*. Mass is every-thing...all the “stuff” that is in the solar system. Every proton, neutron, and electron everywhere.”

5. What is a solar system anyway? Surprisingly, many students don’t understand that we’re just talking about one star and all the objects that revolve around it:

“Let’s make sure we all understand what a “solar system” is. Who knows? (one host star and everything that revolves around it).

Which leads me to the picture you see on the screen behind me. When we talk about our solar system, or any solar system for that matter^{*5}, we’re referring to a host star and everything that revolves, or orbits, around it. I have a list of 7 main kinds of things that our solar system is made of. Let’s see how many you can think of. (star/sun, planets, their moons, comets, asteroids, dwarf planets, dust)”




6. Now go through the quick refresher slides on measuring with millimeters. We have to use millimeters today because the little box we'll draw later is so small that its sides will be measured using that unit. To make sure students understand how to measure in cm and mm, ask them how many total millimeters you would have if you were at 5 marks past 9 cm point (95 mm), or 8 marks past 23 cm (238mm). Now you're ready to move on.
7. As directed by the PowerPoint, have students number from 1-9 on their papers, consecutively.
8. Go through the 9 steps (shown below in the table, and on the PowerPoint). Have students record their answers by each number:

Step	Answer	Comment
1. Measure the length of your paper	Ave: 265 mm Range: ~250 – 280 mm, (depending on the brand/kind of paper)	<p>“Lay the ruler long-ways down your paper. To get millimeters, take the last centimeter number you see and multiply it by 10, then add to it the extra marks past the centimeter number.” (call on 2-3 students and talk through theirs as examples)</p> <p><i>(Measure a piece of your own paper along with your students- you'll describe what to do better and be able to show them what you mean.)</i></p> <p>“Each piece of paper is slightly different, so don't worry if your neighbor has a different number”</p>
2. Measure the width of your paper	Ave: 202 mm Range: ~190-220 mm	<p>Same method as in step 1, except now across the paper.</p> <p>Before proceeding to step 3, ask how many square feet a room that's 10 feet by 12 feet would be (120 feet²). Ask how they got that (by multiplying length x width). Bingo- let's do that for step 3.</p>
3. Step 1 x Step 2 = total area *6	Ave: 53,530 mm ² Range: ~48,000- 60,000 mm ²	<p>“Students, when you see the large number, don't panic. Since we're using a very small unit- millimeters- this number will be large. Just try to be mechanical and emotionless.”</p> <p>Leading up to step 4 ask (with a hint that you're up to something), “So...that's exactly how much <i>total</i> paper is in this space (referring to the area the paper takes up)? I don't know if I agree.” (You're about to break the news that they have to subtract out the space the holes take up.)</p>
4. Measure the diameter of a hole	Ave: 8 mm Range: 5-9 mm	Careful- this step goes so fast that some students forget to write their diameter down, causing some to put answers on the wrong line.
5. πr^2 to get area of circle	Ave: 50.2 mm ² Range: 19.6 – 63.4 mm ²	<p>Remember that radius is half of the diameter.</p> <p>Square the radius first, then x 3.14. Do 2-3 student examples out loud. If the hole is 7mm</p>

		across, the radius is then 3.5mm. $3.5 \times 3.5 = 12.25$. Times 3.14 = 38.465mm^2 . That is how much space that little hole takes up.
6. $\times 3$ (3 holes)*7	Ave: 150.8 mm^2 Range: $58.8 - 190.2 \text{ mm}^2$	You could be mean and put out some hole punches at the beginning of class and let them, if they choose to, punch extra holes in their paper without telling them why. Your risk-takers can't help but do it!
7. Line 3 – line 6	Ave: $53,379.3 \text{ mm}^2$ Range: $\sim 48,000-60,000 \text{ mm}^2$	Subtract out the area of the holes from the total original area. This is exactly how much space the paper takes up. In this activity it also represents the total mass of everything in our solar system.
8. Line 7 $\times .0014$	Ave: 74.7 mm^2 Range: $\sim 67-84 \text{ mm}^2$	The sun contains 99.86% of all mass in our solar system. That leaves .14% for everything else. When you multiply line 7 by .0014 (the decimal equivalent of .14%) you're left with the amount of paper (or solar system) of everything besides the sun.
9. $\sqrt{\text{of line 8}}$ *8	Ave: 8.6 mm Range: 7.9-9.2 mm	<i>This is it!</i> What we've worked so hard to get. Draw a box that's 8.6mm on each side near the middle hole (so small you might lose him!).

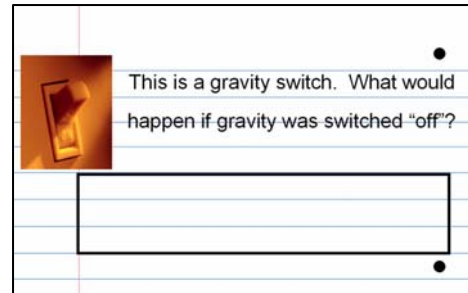
9. Before rushing into the statements for students to copy, pause to take a breath. This is an important moment you've been building up to. Wonder out loud how important this box must be if we went through so much trouble to make it.
10. Now move into the statements that explain the box:

	<ul style="list-style-type: none"> •The area this sheet of paper takes up represents all the mass in our solar system •The sun's mass is all but this square •In this square is the combined mass of the planets, their moons, and everything else •Jupiter and Saturn take up 90% of this box!

11. Go slow enough that the thoughts have time to settle, and students have time to react and ask questions. They should be struggling with what all this means because it is a difficult concept.
12. Following those statements, the lesson moves into gravity. This is not essential to cover, but it is a natural extension of mass. You may find it a better fit the next day, especially if you're pressed for time. Have them copy the gravity statements*9, then

go through the examples on the next slide (all of which are building up to the homework assignment), and then move onto to the homework slide.

13. For homework, have them draw a box 3 lines tall on the back side (as shown), where they will write their answer to the homework question. This box gives the assignment a “special feel”, and a space that feels small, which will help them get right to the point. The question was written open-ended so students can respond any way they like.



14. Begin class tomorrow by reviewing what the little 8.6mm box meant. It needs another day to soak in.

Accessories: Other sub-topics you can add for more length and depth.

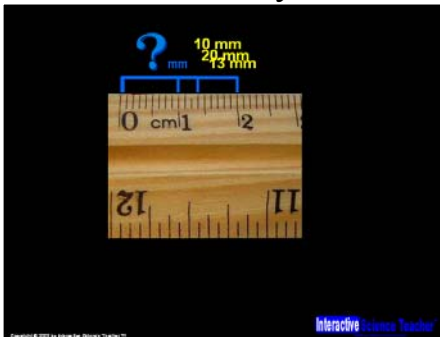
- *¹ http://en.wikipedia.org/wiki/Solar_system & <http://www.rense.com/general72/size.htm>
- *²”Ok, so let’s say the sun was as big as this classroom. How big would earth be then? (*take some answers, but then hold up the marble-it would be about that big!*). When we say the earth is 100 times smaller than the sun, we’re saying it would take 100 marbles side-by-side to go across this room. There are things bigger than our sun. The sun is a small/medium star compared to other stars. But that’s good for us- that makes it more stable, and burn its fuel slower. It should last about 5 billion more years.”
- *³ “Before we begin, I’d like to know how you see things right now. Look at your blank sheet of paper. Let’s say that it represents every *thing* in our solar system. Now, I’d like you to draw a faint line across your paper, anywhere you like. Everything above that line represents the sun’s mass. Everything below is the combined mass of everything else. You can draw the faint line at any point you want, but wherever you draw it shows me how massive you believe the sun is, compared with everything else.”
- *⁴ Some astronomers believe our solar system could be up to 2 light years across. Translated- there are objects 1 light year (about 6 trillion miles) away from the sun responding to it. Like what? Comets. This is where the Oort Cloud is, the origin of long-period comets.
- *⁵ Already, hundreds of extra-solar planets (planets outside of our solar system, orbiting other stars) have been discovered. The first came in 1995 when a Jupiter-sized planet was found orbiting its host star, Peg-51, at a very close distance. The planet itself has never been seen. It was detected by observing the wobble of Peg-51 (so-named because it’s in the constellation Pegasus). The number of extra-solar planets will only grow, since there are

so many stars, and the way planets form appears to be a very routine process that likely means that *every* star has its own set of planets.

- *⁶Keep their minds active by asking how to do the next step before revealing the formula or process. Like on line 3- “How would we get the total area of the paper?”, or “Who knows the formula for the area of a circle?”
- *⁷For extra fun, put out some hole punches at the beginning of class and allow them to punch as many holes as they like in their paper, but don’t tell them yet why. You can also tease students who tore out a sheet of spiral paper, that have all those jagged teeth hanging off. What a nightmare to calculate their area!
- *⁸For students who don’t end up with a number in the ballpark, allow them to use the value 8.6 mm without having to go back through and find what went wrong. Let’s just say a miracle happened, leaving their numbers suddenly corrected.
- *⁹When on gravity statement 2 (“it causes bodies to revolve around each other”) a helpful thought is “Let’s say that when I snapped my fingers the sun disappeared. What would happen to earth? Would we still keep going in a circular orbit?”

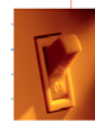
Come back and visit InteractiveScienceTeacher.com to upgrade this lesson with:

PowerPoint- lead your students through the lesson click-by-click



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**draw a box with sides this long near the middle hole of your paper*



This is a gravity switch. What would happen if gravity was switched "off"?

Optional Student Handout

99.86%- Measuring Our Sun's Mass

1. Measure the length of your paper _____mm
2. Measure the width of your paper _____mm
3. Line 1 x line 2 = total area _____mm²
4. Measure the diameter of a hole _____mm
5. m² to get area of circle _____mm²
6. x 3 (3 holes) _____mm²
7. Line 3 - line 6 _____mm²
8. Line 7 X .0014 _____mm²
9. √ of line 8 * _____mm

QuickNotes

Teacher Quick Notes- "99.86%"

Materials:

- 1-clean sheet of lined notebook paper
- 1-12-inch ruler
- 1-calculator
- Colored pencils (optional)

- 1 Marble
- PowerPoint-99.86%-Measuring Our Sun's Mass

Procedure:

1. Have students take out a sheet of paper and open their books to the reading page. Begin PowerPoint.
2. Read the section from the textbook about the sun.
3. Introduce the lesson, and make sure, before beginning, that everyone knows what we mean by "solar system". Ask what the 7 main parts of it are.
4. Practice using millimeters, as directed by the PowerPoint.
5. Have students number from 1-9 on their papers.
6. Go through the 9 step mathematical process. Have students record their answers by each number.
7. After step 9, draw a little box (about 8.6 mm X 8.6 mm), and color it.
8. Ask if anyone knows why we went through all the trouble of making it.
9. Have students copy the statements describing the box.
10. Cover the gravity section.
11. Assign homework-the gravity switch.