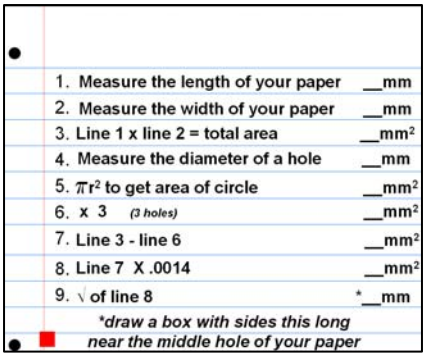
Teacher Notes- "99.86%- Measuring Our Sun's Mass"

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.

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 a 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. To put the words back over the front of the picture, right-click the picture → Order → Send to Back.

3. Go through the 9 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 notes 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 and to open their books to the page you'll be reading from (unless they're using the handout in the *Resources* folder).
   b.) Begin the PowerPoint, showing the solar system picture on slide #1 that you inserted.

2. Give a general 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 mathematical 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 the section from the textbook about the sun aloud.

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."

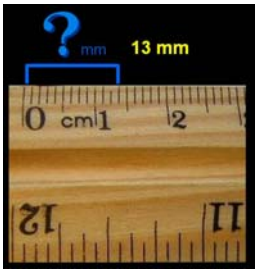
5. What is a solar system anyway? Surprisingly, many students don't understand that we're just talking about one star and all the objects that revolve around it:

   "Let's make sure we all understand what a "solar system" is. Some of us know, but some of us aren't sure. 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're using millimeters today because the little box we'll draw later is so small that its sides will be measured using that unit. Before leaving that slide, ask them how many mm 5 marks past 9 cm would equal (95 mm), and 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.

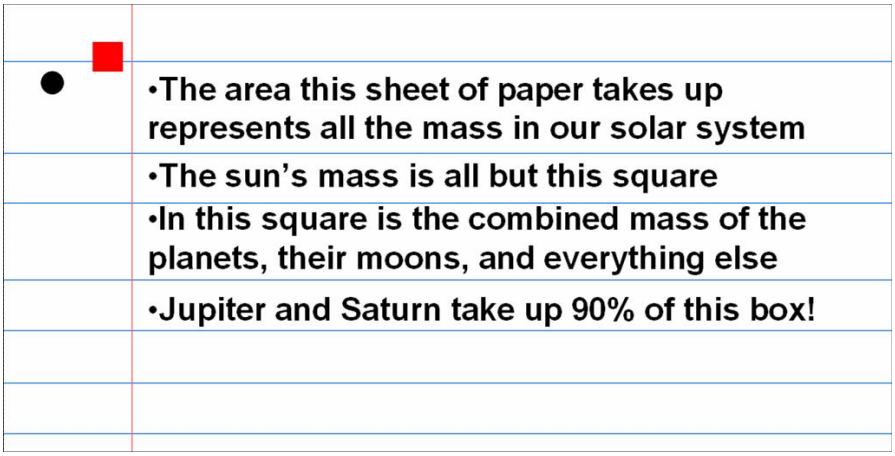
8. Go through the 9 steps. Have students record their answers by each number:

Step	Answer	Comment
1. Measure the length of your paper	Ave: 265 mm Range: ~250 – 280 mm, (depending on the brand/kind of paper)	"Lay the ruler long-ways down your paper. 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) *(Do this along with your students- you'll describe what to do better and be able to show them what you mean.)* "Each piece of paper is slightly different, so don't worry if your neighbor has a different number"
2. Measure the width of your paper	Ave: 202 mm Range: ~190-220 mm	Same method as in step 1, except now across the paper. Before proceeding to step 3, ask how many square feet a room that's 10 feet by 12 feet would be (120 $feet^2$). Ask how they got that (by multiplying length x width). Bingo- let's do that for step 3.
3. Step 1 x Step 2 = total area*[6]	Ave: 53,530 mm^2 Range: ~48,000- 60,000 mm^2	"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 be mechanical and emotionless." Leading up to step 4 ask (with a hint that you're up to something), "So…that's exactly how much *total* 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.)
4. Measure the diameter of a hole	Ave: 8 mm Range: 5-9 mm	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	Remember that radius is half of the diameter.

		Square the radius first, then x 3.14. Do 2-3 student examples out loud. If the hole is 7mm across, the radius is then 3.5mm. 3.5 x 3.5 = 12.25. Times 3.14 = 38.465mm^2. That is how much space that little hole takes up.
6. x 3 (3 holes)*[7]	Ave: 150.8 mm^2 Range: 58.8 – 190.2 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 mm^2 Range: ~48,000-60,000 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 x .0014	Ave: 74.7 mm^2 Range: ~67-84 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. √ of line 8*[8]	Ave: 8.6 mm Range: 7.9-9.2 mm	This is it! What we've worked so hard to get. Draw a box that's 8.6mm on each side near the middle hole (he's so small you'll lose him).

9. Before rushing into the statements for students to copy, stop, 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:

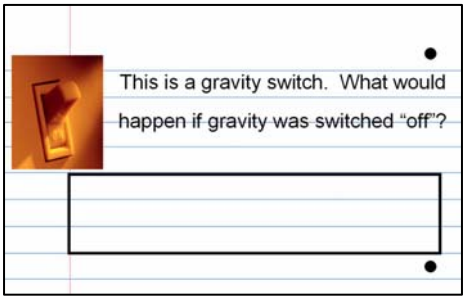


11. Go slow enough that the thoughts have time to settle, and students have time to react and ask questions. They should be struggling with what all this means because it is a difficult concept.

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, 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 this 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. But you're right- 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 it's fuel slower than bigger stars. It should last about 5 billion more years."

- *[3] "Before we begin, I want to see how you see things right now. Look at your blank sheet of paper. Let's say that represents every *thing* in our solar system. I'd like you to draw a faint line somewhere across your paper. Everything above the 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- with the sun at the center, there are objects 1 light year (about 6 trillion miles) away 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 (other 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.

- *[6]Keep 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?". "Who knows the formula for the area of a circle?"

- *[7]For extra fun, put out some hole punches at the beginning of class and tell them to punch as many holes as they like in their paper, but don't tell them 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!

- *[8]For 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.

- *[9]When 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?"

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 _____mm^2
4. Measure the diameter of a hole _____mm
5. $\pi r2$ 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. √ of line 8 *_____mm

*Quick*Notes

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.