MASS IN SPACE

Words	**Stage Directions**
Have you ever looked up and wondered how scientist know how big these tiny looking objects are? Well you are about to find out.	**S1: Have a picture of the night sky and circle one star**
Planets and other celestial bodies are usually described in terms of their mass. Mass is a measurement of the amount of material that an object contains.	**S2: One planet with dots inside and another planet of a different size with dots inside**
On Earth, you can use a gravitational balance to determine the mass in kilograms (and many have done this in science when using a triple beam balance).	**S3: Picture of a triple balance on earth**
But what about space?	**S3: Question marks outside Earth**
Astronomers use the gravitational interaction between planets to calculate the mass of celestial bodies like planets.	**S4: Two planets and draw arrows pointing away from each meeting in the middle**
Isaac Newton first described the force of gravity between the Earth and other objects with an equation that he found from	**S5: Picture of Isaac Newton**
observing the acceleration of the moon compared to that of an object on Earth, deeming both to be caused by the force of gravity.	**S5: Add moon and then an apple**
Then, he applied this formula to objects not on Earth. Now called Newton's Law of Universal Gravitation,	**S5: write "Newton's Law of Universal Gravitation"**
this relationship describes the force of gravity acting between two objects as directly proportional to the mass of both objects and inversely proportional to the square of the distance that separates the centers of the objects.	**S6: Under Law write "F" and "proportional (mass1*mass2)/d^2"**

What in the world does that mean?	**S6: draw question marks**
"Directly proportional to the mass"	**S7: draw "F proportional mass"**
means that the force of gravity increases as the mass of either of the objects increases.	**S7: draw up arrow by F and up arrow by mass**
If the mass of one of the objects doubles, then the force of gravity between the objects doubles.	**S7: under draw "2F proportional 2mass"**
The force of gravity would triple if one mass triples,	**S7: under draw "3F proportional 3mass"**
and quadruple if one mass quadruples,	**S7: under draw "4F proportional 4mass"**
and so on and so forth.	**S7: under draw vertical dots**
"Inversely proportional to the distance squared"	**S7: NEW COLUMN draw "F proportional 1/d^2"**
means that as the distance increases the force of gravity between the two objects decreases.	**S7: draw down arrow by F and up arrow by d**
For example, if the distance between the centers of the two objects doubled, the force of gravity would be one-fourth (or the inverse of 2^2) of the original force.	**S7: under write "1/4F proportional to 1/(2d)^2"**
If the distance tripled then the force of gravity would be one-ninth (or the inverse of 3^2) of the original force. And so on and so forth	**S7: under write "1/9F proportional to 1/(3d)^2" and then vertical dots**
This law is extremely powerful because it is true for any two objects. Planets? Yep.	**S8: Two planets and then a check mark**
People sitting next to each other? Check.	**S8: two people and then a check mark**
Even the force of gravity between two apples on a tree can be calculated with this.	**S8: two apples and then a check mark**

But the relationship described is still just a proportion, it can't give us exact measurements. So what do we do?	**S9: Have proportion and underline proportional symbol**
Multiply by a constant of proportionality! YAY!	**S9: write "(G)" by the proportional**
In this case, the constant of proportionality is called the universal gravitational constant	**S9 -to the right: write "G" and write underneath "universal gravitational constant"**
and it was determined in a series of experiments by Henry Cavendish in the 18th Century after Newton's death.	**S9-P1: picture of Henry Cavendish**
He determined that the universal gravitational constant is 6.673 x 10^(-11) Newtons times (meters^2)/kilograms^2).	**S9 -to the right: by "G" write "= 6.673*10^(-11) N*m^2/kg^2"**
Then, scientists use the Law of Universal Gravitation to determine the mass of the Earth	**S9 -center: picture of Earth**
by comparing the Earth at its center	**S9 -center: dot at center of Earth**
to the Earth at the edge of its crust.	**S9 -center: dot at edge of Earth**
This means that the distance is the radius of the Earth.	**S9 -center: line between two dots and label r**
Let's look at the Law of Universal Gravitation when we are comparing the Earth to itself and substitute in all the values we currently know.	
The original equation is F (for the force of gravity) is equal to G (the universal gravitational constant) times mass one times mass two all divided by d (the distance between the center of the objects) squared.	**S9: write "F=G*m1*m2/d^2" in center**
We know that G is 6.67*10^(-11) Newtons*meters^2/kilograms^2.	**S9: write "F=6.67*10^(-11)N*m^2/kg^2"**
The mass of the Earth is constant, so we know that mass 1 equals mass 2	**S9-to the left: write "m1 = m2"**
so we can substitute (m1)^2 in for mass1*mass2.	**S9: write "(m1)^2"**

We can also substitute 6.371*10^6 m for the distance since that's the radius of the Earth.	**S9: write "/(6.371*10^6 m)^2"**
But we still can't solve for the mass because we don't know what the Force is. Or do we?	**S9: circle F then erase**
We know that the Force (F) is also equal to mass*acceleration.	**S9-to the left: write "F=mass*acceleration"**
So we can substitute mass1*a (acceleration) for F.	**S9: rewrite equation as "m1*a= right side"**
We also know that the acceleration of any object on Earth is 9.8 meters per second square, so we put this in for a.	**S9: rewrite equation with a = "9.8 m/s^2"**
Now the only unknown is the mass! Let's take a second and solve this for mass and determine what the units are using some easy algebra.	
	S9: solve the equation.
We have found that the mass of the earth is about 5.963*10^(24) kilograms	**S9: circle the answer.**
It is approximate because all of our measurements are approximations. If you want to know how accurate we are, NASA says	**S10: NASA**
that the earth is 5.972*10^(24) kilograms.	**S10: draw an arrow write "5.972*10^(24)"**
Now that we have the mass of the Earth	**S11-P1: picture of the Earth**
we can find the mass of the Sun.	**S11-P2: picture of the Sun next to the Earth**
Then with the Sun we can find the mass of any planet in our solar system.	**S11-P3: picture of the Planets next to the Sun**
This same equation can find the mass of our solar system itself,	**S11-P4: picture of our solar system**
or the mass of our galaxy.	**S11-P5: picture of our galaxy**
Or the mass of any galaxy.	**S11-P6: picture of multiple galaxies**
That's one powerful equation.	**S11: write general equation underneath picture of galaxies**