What's the Matter? Part IV

In the last several e-mails, we've continually defined **mass** and **weight** as:

- **Mass** is a measure of resistance to change in motion.
- **Weight** is the force of attraction between an object and the Earth.

Last week, however, we left you with several questions:

What happens if we travel to another celestial body?

- *Does the definition of **weight** change?*
- *Does the **weight** of an object on another celestial body change compared to its weight on Earth?*
- *Does the **mass** of an object on another celestial body change compared to its mass on Earth?*

In the last few weeks, we've been comparing the **mass** and **weight** of two cylinders; let's pack them and a spring scale and take virtual trips to other celestial bodies to answer the above questions…

How does weight compare on different celestial bodies?

- If we were able to take our spring scale and cylinders to the moon and Jupiter we would find their **weights** had changed:

	Weight (in Newtons)	
	Smaller Cylinder	**Larger Cylinder**
Earth	1.96 N	4.9 N
Moon	.33 N	.82 N
Jupiter	4.96 N	12.39 N

The cylinders **weigh** less on the moon and more on Jupiter than they do on Earth. On the moon, objects weigh about 1/6 as much as they weigh on Earth. On Jupiter, objects weigh 2.529 times as much as they weigh on Earth.*

How do we explain the weight change?

There is an attractive force between objects such as the cylinders and the celestial body that the objects are on. There are forces of attraction between massive bodies such as the Earth, the moon, and Jupiter on all *matter* on their surfaces. That attractive force is **weight**. The **weight** of our cylinders on Earth is a measure of the force of attraction between the cylinder and the Earth.

When we move the cylinders to the moon, the attractive force between the moon and the cylinders is measured by how much the spring scale is stretched. Because the moon is less massive than the Earth, the spring scale is stretched less, so we say that the **weight** of each cylinder on the moon is less than its **weight** on Earth.

When we move the cylinders to Jupiter, the attractive force between Jupiter and the cylinders is measured by how much the spring scale is stretched. Because Jupiter is more massive than Earth or the moon, the spring scale is stretched more, so we say that the **weight** of each cylinder is more than its **weight** on the moon or on Earth.

How does mass compare on different celestial bodies?

You recall that in a recent e-mail you observed that the force required to *just set* the larger cylinder in motion in a horizontal direction was more than the force required to *just set* the smaller cylinder in motion. We concluded that the larger cylinder has a greater **mass** than the smaller cylinder. To arrive at this conclusion, we traveled the following path:

- To change the motion of the cylinders, we needed to exert forces on them.
- Because the larger cylinder took more force to change its motion, it had a greater resistance to changing its motion.
- Thus, the larger cylinder has the greater **mass**.

In this previous demonstration, we only *compared* the masses of the two cylinders; we did not *measure* their masses. So how can we figure out whether or not the **masses** of the cylinders change on different celestial bodies?

Let's do a thought exploration……

As we defined it, *mass is a measure of an object's resistance to change in motion*. What causes that resistance? It's the substance of the object itself; how much "stuff" or *matter* is contained in it. No matter where we travel: to the ocean, to a mountaintop, to the moon, or to Jupiter, the amount of "stuff" in an object doesn't change. If we think of our cylinders, it's going to require the same amount of force to *just set* each cylinder in motion whether we're in the CRSEP office or in the Bay of Tranquility. We still have to push or pull the same amount of matter.

How do we explain the consistency of mass?

Because *mass is defined as resistance to change in motion* and because an object's resistance to change in motion does not change with its location (its distance from the Earth's surface or the celestial body on which it is located), its mass does not change.

It seems pretty simple, for our understanding at the moment:

- ***Mass*** is a measure of resistance to change in motion.
- ***Weight*** is the force of attraction between an object and the celestial body it is on.

So what have we learned?

	Weight (in Newtons)		**Mass (in kilograms)**	
	Smaller Cylinder	Larger Cylinder	Smaller Cylinder	Larger Cylinder
Earth	1.96 N	4.9 N	.20 kg	.50 kg
Moon	.33 N	.82 N	.20 kg	.50 kg
Jupiter	4.96 N	12.39 N	.20 kg	.50 kg

Readings for **mass** on Earth came from using a double pan balance to compare each cylinder with gram masses. Readings for the moon and Jupiter were inferred from our knowledge of **mass** (measure the mass of resistance to change in motion).

- The **masses** of the cylinders are not changed when they go to the moon and Jupiter. It takes the same force to change each cylinder's motion (for example, from at rest to in motion in a horizontal direction) on the moon, Jupiter, and Earth.

- The **weights** of the cylinders change when they are transported to the moon and Jupiter.

But wait a minute- I have seen video of astronauts on the moon. If their masses did not change, why are they able to jump so high?

Think about the forces on the astronaut as his motion changes from at rest (standing on the moon's surface) to moving upward. Start with thinking about what you do to your body to set it in motion in an upward direction. We'll look at this in next week's email.

* You might want to check out these websites for more information on comparing weights among different celestial bodies.

- http://mac.usgs.gov/visitors/html/quiz/moon.html
- http://btc.montana.edu/ceres/html/weight.html