Gravity and Distance Help Sheet

Materials you will need:

- several sheets of paper
- pen or pencil
- ruler with centimeters
- calculator (optional)
- compass (optional)

The force of gravity gets weaker as 2 objects get farther apart. However, we must be careful to understand the scale of things so we know when a significant change has occurred. For example, consider the following questions:

> Does the force of gravity acting on an apple (i.e. its weight) change significantly as it falls 10 feet to the earth?
>
> Does the force of gravity acting on you change significantly as you climb to the top of Mt. Everest?
>
> When you are halfway to the moon, is there a force of gravity acting between you and the earth?

To help answer these questions, we will create a scale model of the earth-moon-sun system. The actual sizes and distances are shown in meters. To make a reasonable model, we will divide by 1,000,000 to get a scaled measurement in centimeters (this will make a 1:100 million scale model). The first one has been done for you: 6.37×10^6) / (1,000,000) = 6.37 cm.

Take out a piece of paper and draw a circle with a diameter of about 6.4 cm to represent the earth (which means it has a diameter of 12.8 cm). If you don't have a compass, do the best you can to draw the scaled earth.

measurement	actual	scaled
Earth radius	6.37×10^6 m	6.37 cm
moon radius	1.74×10^6 m	

Once you have determined the size of the scaled moon (r=1.74cm), go ahead and draw a circle on a separate piece of paper to represent the moon. Then divide the earth-moon distance by 1 million:

Earth-moon distance	3.84×10^8 m

This tells us how far apart to put our picture of the earth and picture of the moon. Note that 384 cm is the same as 3.84 m, which is a about 12 ½ feet. Go ahead and move your moon across the room (about 12 ½ feet away, if you can). Next, calculate how thick we should draw the atmosphere:

atmosphere	500,000 m

Right, dividing 500,000 by 1 million gives a value of 0.5. This tells us that we should draw the atmosphere 0.5 cm thick. Go ahead and draw this on your picture of the earth. You can see that even though there is air all around us, you do not have to go very far away from the earth's surface before air becomes a scarce commodity. Next, calculate how big we should draw Mt. Everest:

Mt. Everest	10,000 m

This is going to be a challenge. On your picture of the earth, draw a triangle to represent Mt. Everest that is 0.01 cm high. Your triangle should be about the same height as 1/10th the thickness of a penny. In other words, you should barely be able to see it on your drawing.

Although not necessary to answer the above questions, we can use this same process for the sun. For our scale model, we should draw a circle with a radius of 7 m (more than 40 feet in diameter) to represent the sun. We would also find that we need to place the sun about 1500 m (~0.9 miles) away from the earth!

sun radius	6.96×10^{8} m
Earth-sun distance	1.50×10^{11} m

Follow up

Now, let's go back to those questions:

Does the force of gravity acting on an apple (i.e. its weight) change significantly as it falls 10 feet to the earth?

Yes, the force of gravity is getting stronger as the apple gets closer to earth, but not significantly. The distance to consider is the distance between the center of the apple and the center of the earth. Try drawing in the apple at 10 feet above the earth's surface and then sitting right on the earth. It is impossible on our scaled drawing! That shows us that the apple is not changing its distance from the center of the earth enough to make a difference in the size of the force of gravity acting on it.

Does the force of gravity acting on you change significantly as you climb to the top of Mt. Everest?

Yes, the force of gravity is getting weaker as you get farther away from the center of the earth. However, similar to the last question, the distance to consider is the distance between the center of you and the center of the earth. Again, this distance is nearly the same whether you are at sea level or on the top of Mt. Everest.

When you are halfway to the moon, is there a force of gravity acting between you and the earth?

Well, yes, because there is a force of gravity acting between any two objects regardless of their mass or how far apart they are. However, realize that as soon as you went 1 earth radius away from the earth (6.4 cm from our scaled earth), you the force of gravity between you and the earth was cut by three-fourths. Then, when you went 2 more earth radii away from the earth (now 19.2 cm from our scaled earth), the force of gravity between you and the earth was reduced by another three-fourths. In other words, the force of gravity pulling you towards the earth is about 6% what it was when you were standing on earth, and you are not even one-tenth of the way the moon yet! At one-half the distance to the moon, the force of gravity acting on you would only be about 0.008% as big as when you are standing on the earth.