UNDERSTANDING THE GRAVITY OF THE SITUATION

INSTRUCTIONS

Overview:

In this lesson, students will use Newton's law of universal gravitation to see how mass and distance affect the gravitational attraction between two objects.

Objectives:

The student will:

- calculate the effect of mass on gravitational attraction;
- calculate the effect of distance on gravitational attraction; and
- use comparative mass and distance to calculate the gravitational attraction on other planets.

Targeted Alaska Grade Level Expectations:

Science

[9] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[9] SB4.2 The student demonstrates an understanding of motions, forces, their characteristics, relationships, and effects by recognizing that the gravitational attraction between objects is proportional to their masses and decreasing with their distance.

Materials:

- Calculator (1 per student)
- TEACHER INFORMATION SHEET: "Understanding the Gravity of the Situation"
- STUDENT WORKSHEET: "Understanding the Gravity of the Situation"

Whole Picture:

Sir Issac Newton is known for recognizing the force of gravity caused a falling apple to accelerate toward earth. Equally important is the universality of gravity. He stated that all objects exert a gravitational influence on all other object in the universe. The force of gravity between two objects is directly proportional to the mass of the objects and inversely proportional to the square of the distance between the centers of two objects. It can be summarized by:

$$F_{grav} \sim \frac{m_1 \times m_2}{d^2}$$

Where:

F_{grav} is the force of gravity between two objects

$\sim$ mean "proportional to'

m_1 is the mass of object one

m_2 is the mass of object two

d is that distance from the center of the objects

Activity Procedure:

1. Ask students to watch as you let a dollar bill drop from your fingertips. Let the dollar hit the floor.
2. Ask students what force was acting on the dollar bill. Ask students if they think the dollar would drop faster or slower on the moon if the difference in the affects of air resistance were neglected. What about dropping it on Jupiter? Ask students what factors affect the force of gravity.

3. Explain Sir Issac Newton's contribution to our understanding of gravity, the importance of the universal nature of gravity, how mass and distance effect gravitational attraction and how it can be expressed symbolically as:

$$F_{grav} \quad \frac{m_1 \times m_2}{d^2}$$

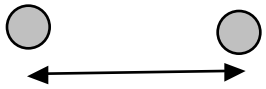
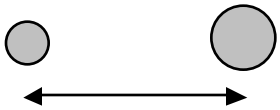
4. Guide students through solving the effects of mass and distance on the force of gravity.
5. Guide student through solving the change in weight on other planets. The mass and radius have been rounded and may vary from the values listed on other sources.

Answers:

STUDENT WORKSHEET: "Understanding the Gravity of the Situation"

Part 1

1.

Effects of mass on the force of gravity	Solution	F_{grav}
		1 F
		2 F
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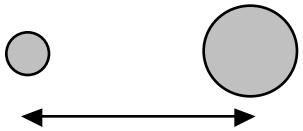
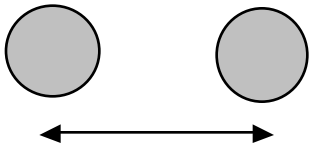
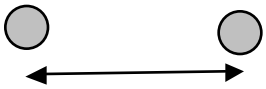
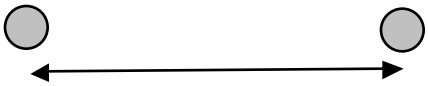
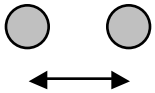
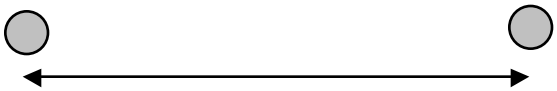
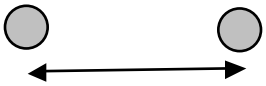
		3F
		9F

2.

Effects of distance on the force of gravity	Solution	F_{grav}
		1 F
		$1/4^{th}$ F
		4 F
		$1/9^{th}$ F

3.

Effects of mass and distance on the force of gravity	Solution	F_{grav}
		1 F
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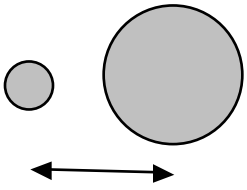
		12 F

Part 2

Planet	Mass compared to Earth	Radius compared to Earth	Solution	Weight Change	Weight of a 600 newton person on Planet	Weight of a 135 pound person on Planet
Jupiter	318	11		2.62 x	600N x 2.62 = 1572 N	135lbs. x 2.62 = 354 lbs.
Saturn	95.2	9		1.17	600N x 1.17 = 702 N	135lbs. x 1.17 158 lbs.
Venus	.82	.96		.89	600N x .89 = 534 N	135lbs. x .89 = 120 lbs.
Mars	.11	.53		.39	600N x .39 = 234 N	135lbs. x .39 = 53 lbs.
Mercury	.055	.383		.375	600N x .375 = 225 N	135lbs. x .375 = 51 lbs.

Short Answer

1. b. 10 times Earth's radius

2. No, even though the monkey is higher in the tree it has not doubled it's distance from the center of Earth.

3. Yes, because of their large mass and close distance they could be attracted to one another.

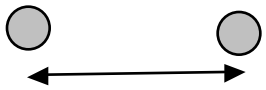
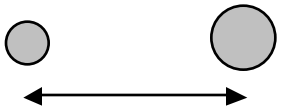
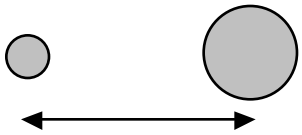
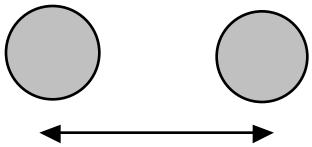
4. Gravitational attraction will decrease as the distance between the two objects increases. Even though it would be difficult to measure the person would weigh less because of the increased distance from the center of Earth.

Part1

1. Effects of mass on the force of gravity

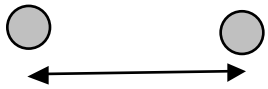
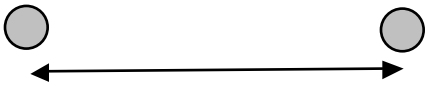
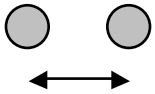
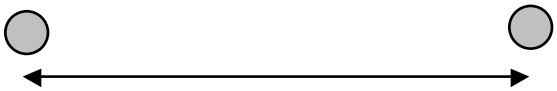
   Gravitational force is directly related to the mass of the objects. The greater the mass an object has the greater the gravitational attraction it will have on another object. If the mass of one object is doubled, then the gravitational attraction between the two objects is also doubled. Use the formula below to find the effect of mass on the gravitational force.

$$F_{grav} \quad \frac{m_1 \times m_2}{d^2}$$

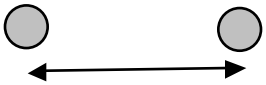
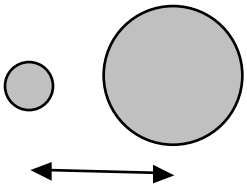
Effects of mass on the force of gravity	Solution	F_{grav}
		
		
		
		
		

2. Effect of Distance on the Force of Gravity

Gravitational force is inversely proportional to the square of the distance between two objects. If the distance between two objects is doubled, then the gravitational attraction is reduced by 1/4th. If the distance were to decrease by half, then the gravitational attraction would increase four times.

Effects of distance on the force of gravity	Solution	F_{grav}
		
		
		
		

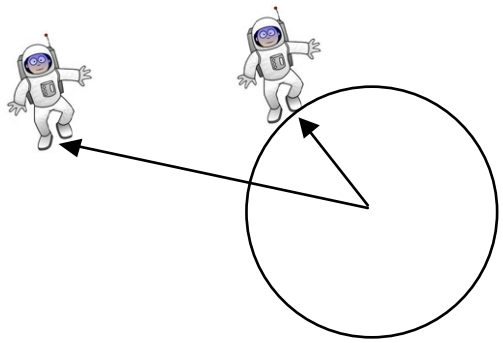
3. Effect of Mass and Distance on the Force of Gravity

Effects of mass and distance on the force of gravity	Solution	F_{grav}
		
		
		

Part2

Weight on other planets

Weight is a measure of the force of gravity acting on an object. The SI (metric system) unit of force is a newton. In the U.S. pounds are used. One pound is equal to 4.45 newtons. When you stand on a scale the gravitational force acting on you is a result of your mass and the mass of the object (Earth) that you are standing on along with the distance you are away from the center of Earth. If you increase your distance away from the center of the Earth your weight would decrease. A 600-newton (134.8 pound) person at sea level would weigh 598 newtons (134.4 pounds) when standing on Mt Everest. For every 1000M of altitude above sea level the gravitational force exerted by earth decreases by .031 percent. An astronaut that weighs 1000 newtons (225 pounds) at the surface of the Earth would weigh 1/4th that or 250 newtons (56 pounds) if the astronaut's distance from the center of the Earth were doubled. If the astronaut were to increase the distance by 5 earth radii they would weigh 1/25th of their weight on Earth.



Jupiter has a mass 318 times greater than Earth. If Jupiter were the same size as Earth a person would weigh 318 times more on Jupiter than on Earth. However, it is important to remember that the distance from the center of the mass also has an effect on gravitational attraction. The radius of Jupiter is 11 times greater than Earth. Using the formula below we have $(1 \times 318) / 11^2 = 2.6x$ greater.

$$F_{grav} \quad \frac{m_1 \times m_2}{d^2}$$

If a person weighed 600 newtons (135 pounds) on Earth calculate how much they would weigh on each of the planets listed in the table below.

1.

Planet	Mass compared to earth	Radius compared to earth	Solution	Weight Change	Weight of a 600 newton person on Planet	Weight of a 135 pound person on Planet
Jupiter	318	11		2.62 x	600N x 2.62 = 1572 N	135lbs. x 2.62 = 354 lbs.
Saturn	95.2	9				
Venus	.82	.96				
Mars	.11	.53				
Mercury	.05	.27				

Short Answer:

1. If an astronaut weighs 1000 newtons (225 pounds) at the surface of the earth how far away would the astronaut need to be from earth to weigh only 10 newtons (2.25 pounds)?
   a. 100 times earth's radius b. 10 times earth's radius c. 2 times earth radius

2. A monkey weighing 100 newtons is sitting in a tree 3 meters above the ground. If the monkey climbs up the tree so it is sitting 6 meters above the ground would it have 1/4th the weight that it did on the lower branches? Explain your answer.

   _____

   _____

3. If two large supertankers came very close to one another and stopped would it be possible for them to be pulled together by gravitational attraction? Explain your answer.

   _____

   _____

4. Explain why a person in an airplane flying 5 kilometers above the surface of Earth would weigh less than they would at sea level.

   _____

   _____