Period 4 Activity Sheet Solutions: Gravity, Mass and Weight

4.1 Where Does the Force of Gravity Appear to Act on An Object?

a) **Distributed forces:** Your instructor will show you how to lift a heavy metal rod using strips of paper.

1) Is it possible to lift the rod with a single strip of paper? **_No, the paper strip breaks._**

2) If 4 strips of paper are distributed along the rod so that each exerts an upward force of 5 lbs, what is the combined force of the strips?

4 strips x 5 lbs/strip = 20 lbs. The net force is the sum of the applied forces acting in the same direction.

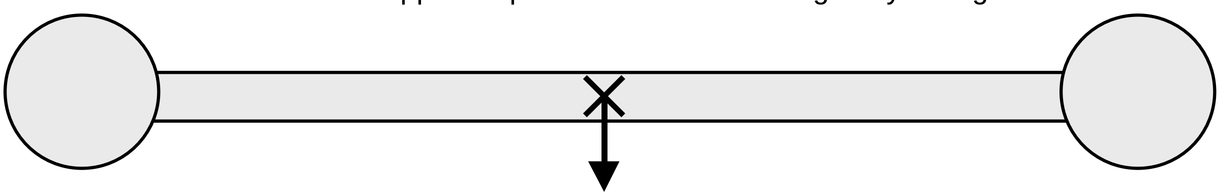
Explain why can you lift the rod using several strips at the same time.

When 4 strips are used, each strip must support only ¼ of the weight of the rod.

b) **Center of mass and center of gravity:**

1) If you were to lift the rod with 4 paper strips placed at one point along the rod, where must you place the strips? **__at the center of the rod__**

2) Draw an "X" on the diagram to show the center of mass of the rod. Draw an arrow to show the apparent position of the force of gravity acting on the rod.



4.2 How Can You Find the Center of Mass of an Object?

a) Stack one wooden block on top of a second block. Slide the top block so that it is not directly over the bottom block.

1) How far can the top block overhang the bottom block before it falls?

It falls when more than ½ of its length overhangs the bottom block.

2) How does the distance the top block can overhang relate to its center of mass?

Assuming each block has a uniform density, the center of mass of the block is at its geometric center. To balance, the center of mass of the top block must be supported by the bottom block.

b) Use the gravity set to find the center of mass of the irregularly shaped brown board. Before you begin, attach a piece of paper to the board with tape. Draw a diagram showing the center of mass and how you found it.

Attach the hook and the pointer to one corner of the board. Hold up the board by the hook, letting the pointer hang down. Draw a line along the pointer on the paper. Attach the hook to a hole in another corner of the board. Draw the line along the pointer. The center of

mass of the board is the point where the two lines intersect. If you repeat this process, subsequent lines should also pass through this point.

c) Adapt the method you used in part b) to find the center of mass of a C clamp. (Hint: pieces of string are useful.) Explain what you did. Draw a diagram showing the center of mass of the C clamp.

Hang the C clamp from a string, with one long end of the string hanging down. Mark with tape the points where the string supports the object and where it touches the bottom of the object. Move the string to another location and mark the points where the string supports the object and where it touches the bottom. The center of mass is the point of intersection of the line connecting the first set of marks and the line connecting the second set.

4.3 What Is the Acceleration of Gravity?

Your instructor will discuss the gravitational force and the acceleration of gravity.

a) Drop two balls from the same height at the same time. The larger, heavier ball is golf ball size and the smaller, lighter ball is marble size. Predict which ball will reach the floor first. Then drop the balls to check your prediction.

Prediction:____ Answer: _Both balls reach the floor at the same time._

b) Watch the video of a feather and a penny falling in a vacuum jar. Do the objects accelerate as they fall? If so, what causes them to accelerate?

The downward force of gravity accelerates the penny and the feather.

c) A penny and a feather fall for 4 seconds inside of a very tall vacuum tube. Calculate the penny's velocity after it has fallen for 4 seconds. **The force of gravity causes objects to accelerate at the rate of 9.8 m/sec^2.**

$$\frac{9.8\ \text{m}}{\text{sec}^{\not 2}} \times 4\ \not{\text{sec}} = 39\ \text{m/sec}$$

d) What is the feather's velocity after it has fallen for 4 seconds? __**39 m/sec** __

e) If we neglect the slowing effect of air resistance, we can determine what the velocity of falling objects depends upon.

1) Does the rate of an object's fall depend upon its size (volume)? _**No**_

2) Does it depend upon how much matter the object contains (its mass)? _**No** _

3) Does it depend upon the shape of the object? _**No**_

4) Does it depend upon how long it falls? _**Yes**_

f) Suppose that a soccer ball and a bowling ball are dropped from a 4th story window at the same time.

1) Neglecting the effect of air resistance, which ball will reach the ground first? **_They reach the ground at the same time.__**

2) How does the acceleration of the bowling ball compare to the acceleration of the soccer ball? **__If the soccer and bowling balls hit the ground at the same time, their velocities must be the same. Therefore, their accelerations are also the same.__**

3) Is the amount of gravitational force acting on the soccer ball the same as the amount of gravitational force acting on the bowling ball? **_No_**
(Hint: consider ***F* = *M a***) Explain your answer.

According to Newton's second law, *F* = *M a*, force is proportional to mass. Since the mass of the bowling ball is greater than the mass of the soccer ball, the gravitational force acting on the bowling ball is greater than the force acting on the soccer ball.

g) Now the bowling ball is dropped from a 4th story window, but the soccer ball is dropped from an 8th story window.

1) How does the acceleration of the bowling ball compare to the acceleration of the soccer ball? **__Their accelerations are the same.__**

2) Which ball reaches the ground traveling at a faster velocity? **_soccer ball _**
Why?

Neglecting air resistance, both balls accelerate at the same rate. Their velocities increase by 9.8 m/s for every second of fall. Therefore, the ball that falls for a longer time period has the greater velocity. Since the soccer ball falls from a greater height, it falls for a longer time and has a greater velocity.

4.4 What Is the Acceleration of Gravity (g)?

a) To denote the acceleration of falling objects, we use the more specific symbol ***g*** instead of the more general symbol ***a*** for acceleration.

The value of ***g*** is different for each planet or moon. Near the Earth, ***g*** = 9.8 m/s^2 or 32 ft/s^2.

Write the equation for the gravitational force acting on a rock falling toward the Earth. (Hint: this is a form of Newton's second law.)

Substitute *g* for *a* and M_{rock} for *M* in *F* = *M a*: $F = M_{rock}\ g$

b) We can also express the gravitational force acting on the falling rock as

$$F = \frac{G\ M_{rock}\ M_{Earth}}{D^2}$$

where $\boldsymbol{D}$ is the radius of the planet, $\boldsymbol{M_{Earth}}$ is the mass of the Earth, and **G** is the universal gravitational constant = 6.67×10^{-11} N m^2/kg^2

Set these two equations equal to each other and solve for ***g.***

$$M_{rock}\ g = \frac{G\ M_{rock}\ M_{Earth}}{D^2}, \quad g = \frac{G\ \cancel{M_{rock}}\ M_{Earth}}{\cancel{M_{rock}}\ D^2}, \quad g = \frac{G\ M_{Earth}}{D^2}$$

c) Using your result from part b), explain why the rate at which an object falls is independent of the mass of the object.

g **is the acceleration of gravity, the rate at which an object falls. In the equation for *g*, the term for the mass of the falling object, $\boldsymbol{M_{rock}}$, has cancelled.**

d) Using your equation from part b), calculate the value of ***g*** on the surface of the Earth. The mass of the Earth = 5.98×10^{24} kg and the radius of the Earth = 6.37×10^6 m

$$g = \frac{G\ M_{Earth}}{D^2} = \frac{(6.67 \times 10^{-11}\ N\ m^2/kg^2)\ \times (5.98 \times 10^{24}\ kg)}{(6.37 \times 10^6\ m)^2} =$$

$$\frac{(6.67 \times 10^{-11}\ N\ \cancel{m^2}/kg^{\cancel{2}})\ \times (5.98 \times 10^{24}\ \cancel{kg})}{4.06 \times 10^{13}\ \cancel{m^2}} = 9.82\ N/kg = 9.82\ m/s^2$$

4.5 What is the Difference between Mass and Weight?

a) Hang a 1 kg mass from a ring stand. Calculate the amount of gravitational force acting down on the mass.

$$F = M g = 1\ kg \times 9.8\ m/s^2 = 9.8\ kg\ m/s^2 = 9.8\ N$$

b) Since the mass is not falling, what amount of force must be exerted up on the mass by the ring stand to hold it up? **_9.8 N_**

c) In the metric system, weight is measured in units of newtons (N). Hang the 1 kg mass from the blue spring scale. What is the weight of the 1 kg mass as measured by the scale? **_9.8 N _**

d) Explain how force, weight, and mass are related.

The weight of an object is equal to the force of gravity acting down on the object. Weight = force = *M g*

Mass is a measure of the amount of matter an object contains. Mass is intrinsic to an object, so that an object has the same mass anywhere in the universe. Weight is the measure of the gravitational force on an object. Weight = Mass x g

e) Indicate with a check mark in the table whether the quantities are measures of mass or of weight.

Quantity	Measure of Mass?	Measure of Weight?
10 kilograms	X	
10 pounds		X
10 newtons		X
10 milligrams	X	

f) Calculations with mass and weight.

1) What is the mass of an 80 kg person on the surface of the Earth? **_80 kg_**

2) What is the weight of an 80 kg person on the surface of the Earth?

Weight = force = Mg = 80 kg x 9.8 m/s^2 = 784 kg m/s^2 = 784 N

3) What is the mass of an 80 kg person on the surface of the Moon? **_ 80 kg_**

4) What is the value of ***g*** on the Moon? The mass of the Moon = 7.36×10^{22} kg and the radius of the Moon = 1.74×10^{6} m

$$g = \frac{G\,M_{Moon}}{D^2} = \frac{(6.67 \times 10^{-11}\ N\ m^2/kg^2) \times (7.36 \times 10^{22}\ kg)}{(1.74 \times 10^{6}\ m)^2} =$$

$$\frac{(6.67 \times 10^{-11}\ N\ \cancel{m^2}/kg^{\cancel{2}}) \times (7.36 \times 10^{22}\ \cancel{kg})}{3.03 \times 10^{12}\ \cancel{m^2}} = 1.62\ N/kg = 1.62\ m/s^2$$

5) What is the weight of an 80 kg person on the surface of the Moon?

On the Moon, *g* = 1.62 m/s^2. Therefore, on the moon

Weight = force = Mg = 80 kg x 1.62 m/s^2 = 130 kg m/s^2 = 130 N

The weight of an object on the surface of the Moon, where *g* = 1.62 m/s^2, is less than its weight on the surface of the Earth where g = 9.8 m/s^2 . Therefore, an 80 kg person weighs 784 N on Earth, but 130 N on the Moon.

g) Group Discussion Question: Which requires more force to lift off – a rocket traveling from the Earth to the Moon or a rocket traveling from the Moon to the Earth? Why?