Teacher Guide: Weight and Mass

Learning Objectives

Students will…

- Define mass as the amount of matter in an object.
- Define weight as the force of gravity on an object.
- Use a balance to measure mass.
- Use a spring scale to measure weight.
- Discover that the weight of an object changes when it is moved to another planet.
- Discover that the mass of an object is constant no matter where it is located.

Vocabulary

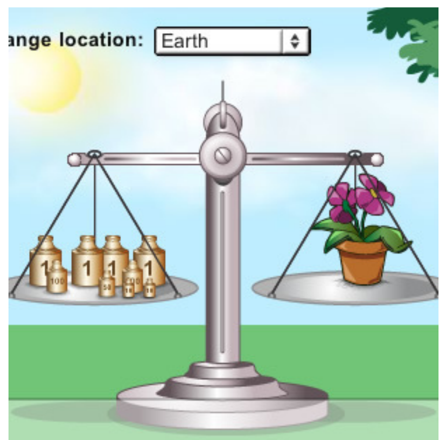
balance, force, gravity, mass, newton, spring scale, weight

Lesson Overview

On the *Weight and Mass* Gizmo™, students use a balance to measure mass in kilograms and a spring scale to measure weight in newtons or pounds. This can be done on Earth, the Moon, Mars, or Jupiter.

The Student Exploration sheet contains two activities and an extension:

- Activity A – Students measure the weight of three objects on different planets.
- Activity B – Students measure the mass of the same three objects on different planets.
- Extension – Students calculate the ratios between mass and weight on different planets.



Finding the mass of a flowerpot

Suggested Lesson Sequence

1. **Pre-Gizmo activity** (10 – 20 minutes)
   Demonstrate how a spring scale and a balance work. First, show students that a spring scale measures the strength of a force. This force could come from adding weight with a hanging object or by pulling directly on the scale. Next, show how adding a mass to one side of a balance causes that side to be pulled down. When an equal mass is added to the other side, the balance is balanced, i.e., the forces are equal. Note that a balance does not directly measure the mass of an object. Instead, it allows one to compare the weights of objects. In the same location, objects with equal weight have equal mass.

2. **Prior to using the Gizmo** (10 – 15 minutes)
   Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations.

3. **Gizmo activities** (15 – 20 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:
   - Spring scales measure force. Why do you use a spring scale to measure weight?
   - Why does mass stay the same on each planet, but weight changes?
   - Why is the measurement shown by the spring scale affected by the location, but the measurement on the balance is not?
   - How can a spring scale be used to compare the gravity on different planets?

5. **Follow-up activity: Losing weight** (10 – 20 minutes)
You can simulate the effect of lower gravity by submerging objects in water. The buoyant force of the water will push objects up, lessening the effect of gravity. To do this you will need an aquarium filled with water, a balance that can get wet, and a spring scale.

   Tie a rock or a similar object to a spring scale and record its weight. The object should be something that sinks in water. Next, dip the object in the water so that it is under the surface but above the bottom. Record its weight again. (Note: spring scales are often marked in units of mass such as grams. Don't worry about the units here.)

   Now use the balance to measure the mass of the object in the air, and again under water. You and your students will see that while the weight measured on the spring scale changes, the mass recorded on the balance is the same in both locations.

   While this activity simulates conditions on a small planet, there is of course a difference. On a small planet, there is less gravity pulling the object down so it simply weighs less. Under water, the object has the same weight (i.e. gravity is just as strong as before), but the water pushing up on the object cancels out some of its weight. Thus the net force pulling the object down is reduced.

Scientific Background
In everyday usage, we rarely distinguish between weight and mass. If a man says "I weigh 150 pounds" he is probably talking about his mass. If a woman says "I felt weightless when I was swimming" she is probably talking about her weight. This does not cause many problems in our day-to-day lives, but is a major issue for scientists. To successfully make any kind of calculation in physics or engineering, it is vital to distinguish between mass and weight.

An object's **mass** is the amount of matter it contains. An object's mass does not depend on its location. If you move a bowling ball from Earth to the Moon, it will still contain the same amount of matter. The metric units for mass include the kilogram (kg) and the gram (g).

Unlike mass, **weight** is a force. Weight is the force of gravity pulling on an object. The weight of an object (w) is equal to the product of its mass (m) and the gravitational acceleration (g) at that spot, $w = mg$. The unit of weight in the metric system is the same as the unit of force—the newton (N). An object's weight can be changed either by altering its mass or by moving it to a location with stronger gravity (like Jupiter) or weaker gravity (like the Moon or Mars).

In 1676, Robert Hooke discovered that the length a spring is stretched is proportional to the applied force. Because weight is a type of force, it can be measured on a spring scale. Examples of spring scales include bathroom scales and produce scales. If you use a spring scale to weigh a piece of fruit on Earth and on the Moon, it will correctly show that the fruit has less weight on the Moon than on Earth. The force of gravity pulling the fruit down is much weaker on the Moon.

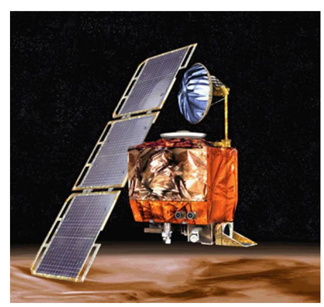
A balance measures mass by comparing the weights of two objects. An object placed on the pan of a balance exerts a downward force equal to its weight. An object of equal weight placed on the other pan will balance the pans. Because the pans are in the same gravitational field, the equal weights of the two objects imply their equal masses. If two objects have equal mass on Earth, they will have equal mass on the Moon, Mars, Jupiter, or anywhere else.

Current Events Connection: Unit Confusion

A dizzying variety of units have been used to describe the mass or weight of objects: pounds, ounces, tons, stones, grains, drams, carats, pennyweights, scruples, talents, shekels, newtons, kilograms—the list goes on and on. Until fairly recently, little or no distinction was made between units of mass and units of weight.

To avoid confusion, scientists use System Internationale (SI) units. This system, also known as the metric system, is convenient to use because it is easy to convert from one unit to another. There are 100 centimeters in a meter, and 1000 meters in a kilometer. Compare this to 12 inches in a foot and 5,280 feet in a mile!

The United States is one of the few countries in the world that has not adopted the metric system for everyday use. Occasionally this leads to serious problems. Perhaps the most notorious case of unit confusion occurred in 1999. NASA scientists were collaborating with engineers from Lockheed Martin to control the flight of the Mars Climate Orbiter. While the NASA group calculated forces in newtons, the engineers assumed that the numbers were given in units of pounds-force. The resulting miscalculation sent the $25 million probe hurtling into the Martian atmosphere at a steep angle, where it burned up.



Mars Climate Orbiter
(Courtesy of NASA)

Selected Web Resources

Your weight on other worlds: http://www.exploratorium.edu/ronh/weight/
Weight on other planets: http://www.teachervision.fen.com/planets/lesson-plan/353.html
Make a balance: http://www.raft.net/ideas/Measuring%20Mass.pdf
Measuring matter: http://www.dmturner.org/Teacher/Library/4thText/MatPart2.html
Types of force: http://www.physicsclassroom.com/Class/newtlaws/U2L2b.html
Weight and mass: http://ourworld.compuserve.com/homepages/Gene_Nygaard/weight.htm
Metric units in the US: http://www.unc.edu/~rowlett/units/usmetric.html
Mars probe: http://www.space.com/missionlaunches/launches/orbiter_errorupd_093099.htm