



Mass vs. Weight

Introduction

This series of activities is based on video education demonstrations presented by Crew Members Robert Thirsk, Koichi Wakata, and Nicole Stott during the 2009 Expedition 20 mission on the International Space Station

Objectives

- To demonstrate the difference between *Mass* and *Weight* by integrating classroom activities with video filmed by astronauts in the microgravity environment on the International Space Station (ISS)
- To explore careers in space exploration
- To explore the international partnerships involved in the International Space Station development, construction and operations

Activity Descriptions

Careers in Space

Students will be introduced to the three ISS astronauts who are featured in the *Mass vs. Weight* video clips. Students will learn about their backgrounds, experiences, interests, and careers. This information will guide them to understand the importance of these factors in why the astronauts chose their career. Students will discuss their own backgrounds, experiences and interests and explore space exploration careers that interest them.

Stretching Mass

Students measure the amount of force gravity exerts on objects of different mass by suspending them on rubber bands then measuring the distance the rubber bands stretch. Students will collect and discuss their data and compare it to video results of a similar experiment done on the International Space Station.

Air Powered Mass

Student teams build a **mass car** and measure the movement of the car with varying amounts of mass as a given force is applied. A blast of air from an air pump will accelerate the car across rollers. During a set of experiments, students will vary the mass being carried by the mass car and measure how far the car rolls each time in response to the air blast. Once the experiments are completed, students will graph, discuss their data and compare to video results of a similar experiment performed on the ISS.

MASS VS WEIGHT

Accelerating Mass

Students explore Newton's Second Law of Motion by attaching an empty (air-inflated) foil drink pouch to a spring release tape measure, and measure the time it takes the pouch to travel one meter as the tape is automatically retracted. The same process will be repeated using a full (fluid-filled) pouch. Which drink pouch will accelerate the fastest - the full one with the greater mass or the empty one with the lesser mass? Once this experiment is completed, students will discuss their data and compare it to the video results of a similar experiment done on the International Space Station

Design Your Own International Space Station Experiment

Students design their own International Space Station experiment. They outline their objective and what they hope to accomplish with it. They explain their experiment design, how it works, and what materials they will need for it to be successful. They will also develop questions they would want other students to answer after those students would observe the experiment if it was performed in the microgravity environment of space.

International Space Station Partners

This activity will be a component of the *Mass vs. Weight* companion worksheet, *Learning in Space: The Journey of Exploration Continues* (EW-2010-09-00010-SSC). Students use geography skills to learn about the sixteen countries of the ISS partnership. The students first identify and color the flags of the partner nations and then locate those countries on a political map. Finally, students use lines of latitude to determine which of these countries the ISS will fly over as it orbits Earth and why this may be important to each nation.

Background

We often confuse the terms **mass** and **weight** and use them interchangeably even though they have very different meanings. (Refer to the definitions that follow for the explanation of these terms.) We can measure weight here on Earth, but not in the microgravity environment on the International Space Station. Mass plays a critical role in the activities and experiments performed by the astronauts. Mass does not change whether it is measured on Earth or the ISS. Weight can change depending upon the gravitational pull such as on the Moon where weight is reduced to one-sixth that of on Earth.

Each activity in the *Mass vs. Weight* series demonstrates the difference between mass and weight by comparing results with video clips filmed by astronauts performing similar activities onboard the ISS. Students perform the activities in the classroom, record, analyze, and interpret their data. Following data analysis, they observe video of astronauts performing similar demonstrations on the ISS. The activities focus on Newton's Second Law of Motion.

$$\text{Force} = \text{mass} \times \text{acceleration}$$
$$(F=ma)$$

This law can be paraphrased and explained simply as, *the more mass an object has, the more force needed to move it.*

To understand and present the activities in the classroom, a few terms are defined:

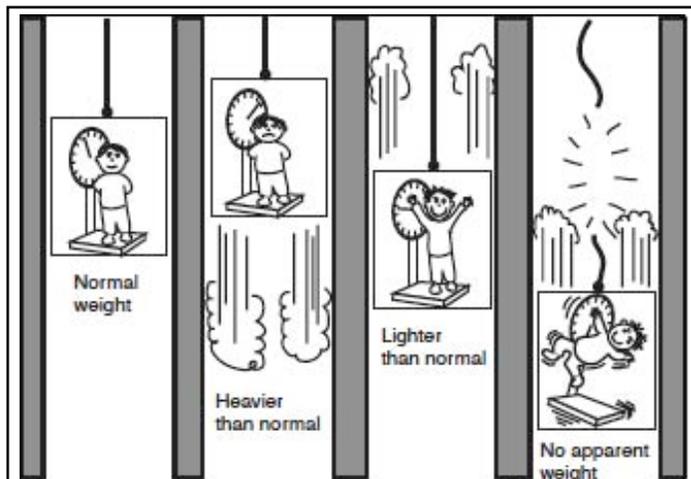
Gravity is a force that governs motion throughout the universe. It holds us to the ground, keeps the Moon in orbit around the Earth, and the Earth in orbit around the Sun. Contrary to what most students think, gravity is also the force that enables spacecraft to orbit Earth. Gravity is best described as the force of attraction between any two masses. Gravity is most apparent when one mass is very large, like Earth. The acceleration of an object toward the ground caused by gravity, near the surface of the Earth, is called **normal gravity**, or **1g**. It is equal to 9.8 m/sec². If you drop an apple on Earth, it accelerates toward Earth at 9.8 m/sec². If an astronaut on the Space Station drops an apple, it falls

too; but does not look like it is falling. That is because they are all falling together: the apple, the astronaut, and the ISS.

Mass is the amount of matter in an object. It can also be defined as the property of a body that causes it to have weight in a gravitational field. It is important to understand that the mass of an object is not dependent on gravity. Bodies with greater mass are accelerated less by the same force.

Microgravity literally means very little gravity. Another way to think of *micro-* is in measurement systems, such as the metric system, where *micro-* means one millionth or 1×10^{-6} g. Scientists do not use the term microgravity to accurately represent millionths of 1 g. The microgravity environment, expressed by the symbol μg , is defined as an environment where some of the effects of gravity are reduced compared to what we experience at Earth's surface. It can also be described as the apparent weightlessness that is felt in freefall, as on a ride at an amusement park or on the ISS when it orbits around the Earth. Objects in a state of free-fall, or orbit, are said to be weightless because a weight scale would not register any weight due to the object being measured, the scale and the ISS are all falling together and at the same rate.

Weight is the vertical force exerted by a mass as a result of gravity. Weight can also be defined as the strength of the gravitational pull on the object; that is, how heavy it is. Weight is dependent on gravity. Using more physics and mathematics terms, weight is defined as the force with which a body is attracted to Earth or another celestial body, equal to the product of the object's mass and the acceleration of gravity: $\text{gravity} = \text{mass} \times \text{acceleration due to gravity}$, which is constant (Earth = 9.8 m/sec^2).



Acceleration and weight

The person in the stationary elevator car experiences normal weight. In the car immediately to the right, apparent weight increases slightly because of the upward acceleration. Apparent weight decreases slightly in the next car because of the downward acceleration. No weight is measured in the last car on the right because of free fall. This is microgravity.

Standards

The standards addressed in the *Mass vs. Weight* activities are listed below. See each activity for specific standards addressed in that activity:

National Science Education Standards (NSTA)

Unifying Concept and Processes

- Evidence, models, and explanation
- Change, constancy, and measurement

Science as Inquiry

- Abilities necessary to do scientific inquiry

Physical Science

- Motions and Forces

History and Nature of Science

- Science as a human endeavor

Principles and Standards for School Mathematics (NCTM)

Number and Operations

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Understand meanings of operations and how they relate to one another
- Compute fluently and make reasonable estimates

Measurement

- Understand measurable attributes of objects and the units, systems, and process of measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

Data Analysis and Probability

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
- Develop and evaluate inferences and predictions that are based on data
- Understand and apply basic concepts of probability

Process Standards

- Problem Solving
- Communication
- Connections
- Representation

National Geography Standards (NGGE)

The World in Spatial Terms

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective
- How to use mental maps to organize information about people, places, and environments in a spatial context
- How to analyze the spatial organization of people, places, and environments on Earth's surface

Places and Regions

- How culture and experience influence people's perceptions of places and regions

The Uses of Geography

- How to apply geography to interpret the present and plan for the future

***Mass vs. Weight* Home
education.ssc.nasa.gov/massvsweight.asp**

International Space Station (ISS) Basics

(excerpt from NASA Fact Sheet FS-2009-01-002-JSC)

Clearly visible with the naked eye in the night sky, the expansive International Space Station is a working laboratory orbiting 240 statute miles (386.24 kilometers) above the Earth traveling at 17,500 miles per hour (32,410 kilometers per hour) and is home to an international crew.

It is the most complex scientific and technological endeavor ever undertaken, involving support from five space agencies representing 16 nations. Once completed, this research outpost in space will include contributions from the U.S., Canada, Japan, Russia, Brazil, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

As a research outpost, the station is a test bed for future technologies and a research laboratory for new, advanced industrial materials, communications technology, medical research, and much more.

On-orbit assembly began in 1998 with the launch of Zarya, and once completed will provide crew members with more than 33,000 cubic feet (935 cubic meters) of habitable volume – almost equal to one and a half Boeing 747 jetliners – and will weigh 925,000 pounds (419,600 kilograms). It will measure 361 feet (110.03 meters) end to end, which is equivalent to a U.S. football field, including the end zones. The station's solar panels exceed the wingspan of a Boeing 777 jetliner and harness enough energy from the sun to provide electrical power to all station components and scientific experiments.

The station now includes the Russian-built Zarya Module and the Zvezda Service Module, which contain the station's living quarters and life-support systems; the U.S.-built Unity Connecting Module, providing docking ports for several station

components; the U.S.-built Destiny Laboratory, which expands the station's scientific capabilities with experiment compartments that allow nearly continuous scientific research and provide additional life-support and robotic capabilities; the U.S.-built Quest Airlock, a doorway to space that supports station-based spacewalks; the European-built Columbus Module with its capacity to support up to 10 interior experiment racks as well as four exterior payload platforms; the Japanese-built Kibo Experiment Module consisting of 23 experiment racks and a storage module; the Italian-built Harmony Node 2 that increases crew living and working space, provides a passageway between the U.S. Destiny Laboratory, the Japanese Experiment Module, and the European Columbus Module and also provides connecting ports for supply vehicles and the space shuttle; the Canadian-built Mobile Servicing System that consists of the Canadarm2, a new-generation robotic arm that gives the station a movable space crane, the Special Purpose Dexterous Manipulator, or Dextre, a smaller two-armed robot capable of handling the delicate assembly tasks currently handled by astronauts during spacewalks, and the Mobile Base System, a work platform that moves along rails covering the length of the space station and provides lateral mobility for the Canadarm2 as it traverses the main trusses; the Russian-built Pirs docking compartment, which adds additional spacewalking and docking capabilities to the station; and the Integrated Truss Structure, which is composed of multiple elements and forms the backbone of the station.

The station's first resident crew, Expedition 1, marked the beginning of a permanent international human presence in space, arriving at the station in a Russian Soyuz capsule in November 2000. Currently, station crews stay on orbit for six months at

a time. The International Space Station provides the first laboratory complex where gravity, a fundamental force on Earth, is virtually eliminated for extended periods. This ability to control the variable of gravity in experiments opens up unimaginable research possibilities.

The International Space Station is vital to human exploration. It's where we're learning how to combat the physiological effects of being in space for long periods. It's our test bed for technologies and our decision-making processes when things go as planned and when they don't. It's important to learn and test these things 240 statute miles (386.24 kilometers) up rather than encountering them 240,000 miles (386,242 kilometers) away while on the way to Mars or beyond.

The International Space Station, an unprecedented, state-of-the-art, orbiting laboratory complex, continues to expand the boundaries of space research. The unique capabilities of its laboratories will lead to discoveries that will benefit missions farther into outer space. These discoveries will also benefit people all over the world, now and for the future.

Completion of the International Space Station is one of the first steps toward NASA's newest exploration goals. Using the station to study human endurance in space and to test new technologies and techniques, NASA will prepare for the longer journeys to the moon, Mars, and beyond.

For more information about NASA, visit: www.nasa.gov

