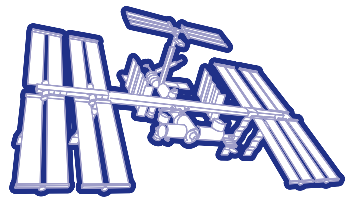
Educational Product	
Educators	Grades 5-8

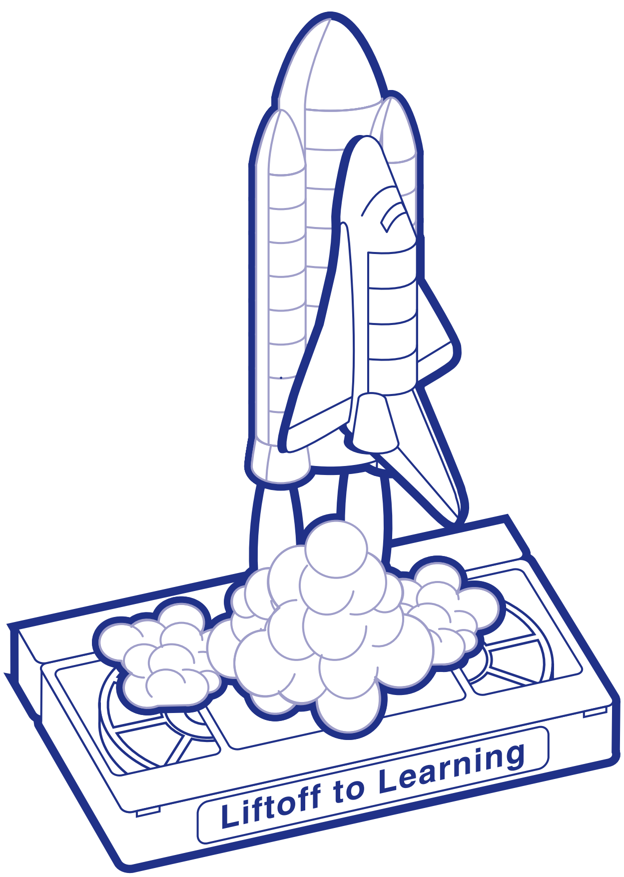
National Aeronautics and
Space Administration

Liftoff to Learning



Space Basics

A Videotape for Physical Science



Video Resource Guide

EV-1997-07-010-HQ

Video Synopsis

Title: Space Basics

Length: 20:55

Subjects: The science and technology of orbits and microgravity.

Description:
The *Space Basics* program tries to answer four basic questions about spaceflight. How do spacecraft travel into space? How do spacecraft remain in orbit? Why do astronauts float in space? How do spacecraft return to Earth?

Science Standards:
Science as Inquiry
Physical Science
- Position and motion of objects
- Properties of objects and materials

Unifying Concepts and Processes
-Change, constancy, and measurement
- Evidence, models, and exploration

Science Process Skills:
Observing
Measuring
Making Models
Defining Operationally
Investigating

Mathematics Standards:
Geometry
Measurement

Background

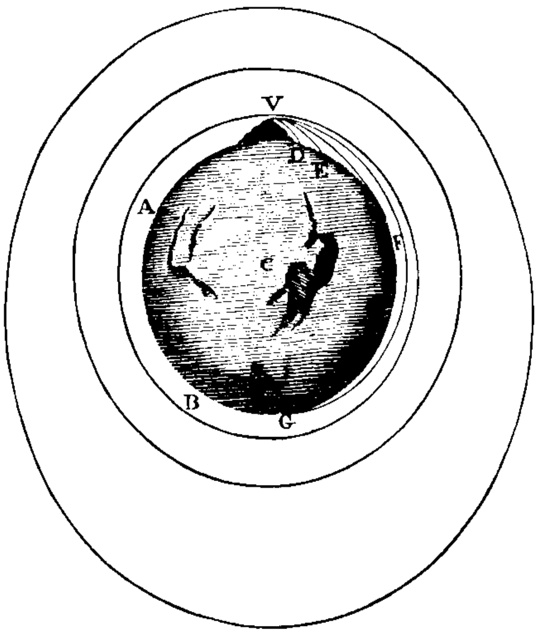
Orbits and Microgravity

Although words like *satellite* and *orbit* are fairly common terms in modern English, many people have little understanding of the scientific concepts that make it possible for satellites to orbit the Earth. When asked what keeps a satellite up, both children and adults typically answer that satellites are beyond the pull of Earth's gravity. If this were so, then why do satellites keep circling Earth? What keeps them from shooting off into deep space?

Satellites actually remain in orbit about Earth because of gravity. More than 300 years ago the scientific foundations for satellites were laid when Isaac Newton discovered the Universal Law of Gravitation. He reasoned that the pull of Earth that causes an apple to fall to the ground also extends out into space to pull on the Moon as well. Newton expanded on this discovery and hypothesized how an artificial satellite could be made to orbit Earth. He envisioned a very tall mountain extending above Earth's atmosphere so that friction with the air would not be a factor. He then imagined a cannon at the top of that mountain that fired cannonballs parallel to the ground. As each cannonball was fired, it was acted upon by two forces. One force propelled the cannonball straight outward and the second force, gravity, pulled the cannonball down towards Earth. The two forces combined to bend the path of the cannonball into an arc ending at Earth's surface.

Newton demonstrated how additional cannonballs would travel farther from the mountain if the cannon were loaded with more gunpowder each time it was fired. Eventually, a cannonball was fired so fast, in Newton's imagination, that it fell entirely around Earth and came back to its starting point. This became an orbit of Earth.

Without gravity to bend the cannonball's path, the cannonball would not orbit Earth and would instead shoot straight out into space. The same condition applies to Space Shuttles. The Space Shuttle is launched high above Earth and aimed so that it travels parallel to the ground. If it climbs to a 200-mile-high orbit, the Shuttle must travel at a speed of about 17,240 miles per hour to circle Earth. At this speed and altitude, the curvature of the Shuttle's falling path will



Isaac Newton's *System of the World*

exactly match the curvature of Earth.

Knowing that gravity is responsible for keeping satellites in orbit leads us to the next question. Why do astronauts float in space? The answer is simple. The Space Shuttle orbiter falls in a circular path about Earth. Because the orbiter, astronauts, and all the contents of the orbiter (food, tools, cameras, etc.) are falling together, they seem to float in relation to each other. This is comparable to the imaginary situation that would take place if the cables supporting a very high elevator would break, causing the car and its passengers to fall to the ground. (In such an example, we have to discount the effects of air friction on the falling car.) Since the motion of the falling car and the passengers are relative to each other, the people inside seem to float.

One of the common questions children and adult visitors to the NASA Johnson Space Center in Houston, Texas ask is, "Where is the room where a button is pushed and gravity goes away so that astronauts float?" No such room exists because gravity can never be made to go away. The misconception comes from the television pictures that NASA takes of astronauts training in a special aircraft. The aircraft is flown to about 40,000 feet above sea level and then put into a steep dive. The pilot attempts to exactly match the speed of a falling object. Inside the cargo section of the airplane, astronauts and researchers float about and perform brief experiments and training activities before the pilot pulls the airplane out of the dive. Indeed, for approximately 30 seconds during each dive, the airplane acts like the Space Shuttle in orbit or like the imaginary elevator car.

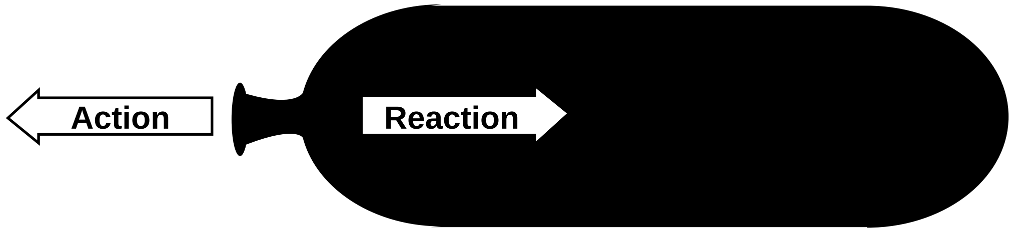
The floating effect of Space Shuttles and astronauts in orbit is called by many names. It is referred to as *free-fall*, *weightlessness*, *zero-G* (zero-gravity), or *microgravity*. Space researchers prefer to use the term *microgravity* because it better represents the actual conditions of Earth orbit. Thus, even though free-fall simulates the absence of gravity, very small (micro) gravitational forces are still detectable.

Action-Reaction

Rockets are able to travel into space because of the action-reaction principle described by Isaac Newton in his third law of motion. In modern terms, the law is stated:

> *For every action, there is an equal and opposite reaction.*

In other words, for an object (person, automobile, rocket) to move in one direction, the object must push in the opposite direction. In walking, for example, when a person pushes (exerts a force) rearward on



Balloon rocket demonstrates Action/Reaction principle

the ground with foot and leg muscles, the person's body moves in the opposite direction. To travel to space, the Space Shuttle exerts a downward force with the exhaust of its rocket engines (action) and moves upward in the opposite direction (reaction). The force of the downward push and the upward force on the Shuttle are equal.

To return from space, the Space Shuttle orbiter also takes advantage of the action-reaction principle. Remember, a spacecraft in orbit is traveling at the right velocity so that the curvature of the path in which it is falling matches the curvature of the Earth. If the spacecraft slows down slightly, the path it follows changes from a circular shape to a long arc ending at Earth's surface. To slow the orbiter, astronauts fire rocket engines in the direction the orbiter is moving to apply a braking force. Then, the long fall to Earth's surface begins.

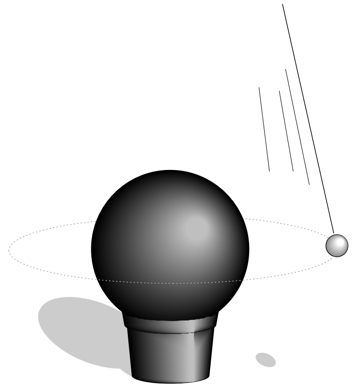
Terms

Altimeter - Device for measuring altitudes.
Apollo - Name of the NASA project to land astronauts on the Moon.
Barometric pressure - The weight of the atmosphere pressing at any point above Earth's surface.
External Tank - The large brown tank that holds the liquid propellants for the Space Shuttle's main engines.
Freedom 7 - The name of the Mercury spacecraft that Alan Shepard rode for his historic suborbital flight on May 5, 1961.
Gemini - Name of the NASA project that orbited teams of two astronauts above Earth.
Gravity - The attraction of all objects to one another due to their mass.
Jupiter C - The name of the rocket that launched the United States' first satellite, Explorer 1, on January 31, 1958.
Mercury - Name of the first NASA project that orbited astronauts above Earth.
Microgravity - An environment, produced by free-fall, that alters the local effects of gravity and makes objects seem weightless.
Orbit - The periodic path taken by a satellite (spacecraft, moon, or planet) as it revolves around another body.
Orbiter - The winged spacecraft portion of the Space Shuttle that orbits about Earth.
Propellant - The combination of fuel and oxidizer burned in rocket engines.
Relative humidity - A measure of the amount of moisture in the air compared with what it could hold at that temperature. (A relative humidity of 50% means that the air is holding 50% of the water it could hold at its current temperature.)
Robert H. Goddard - American rocket pioneer who invented the liquid-propellant rocket.
Satellite - A smaller body (spacecraft, moon, etc) revolving about a larger body.
Solid Rocket Boosters - The white, solid-propellant rockets attached to the side of the external tank of the Space Shuttle.
Space Shuttle - NASA's manned space vehicle consisting of an orbiter, external tank, and two solid rocket boosters.
Stack - The term for a complete rocket (all pieces joined together) on the launch pad.
Werner von Braun - German-American rocket pioneer and leader in the development of the Saturn V rocket.

Classroom Activities

The following hands-on activities can be used to demonstrate some of the concepts presented in this videotape.

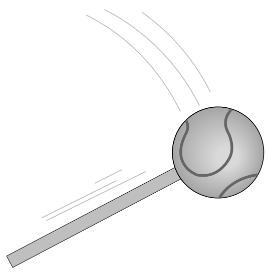
Satellite Orbit Model



Materials
Volleyball or basketball
Flower pot
String
Small ball
Note: A world globe with a stand can be substituted for the ball and flower pot.

Instructions
To illustrate what an orbit looks like, attach the string to the small ball and hang it from the ceiling. The ball should hang just below the middle point of the volleyball (the equator on a world globe). In this model, the small ball is a satellite and the larger ball is Earth. Try to make the satellite orbit about Earth. Begin with the satellite resting next to Earth. Which direction should the satellite be pushed to make it orbit? What would happen to the orbiting satellite if the string were cut?

Ball and Ribbon

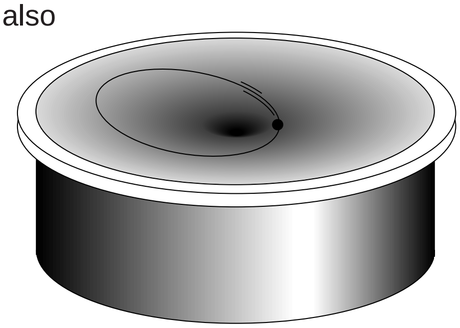


Materials
Tennis Ball
Knife
Cloth ribbon (1 m)

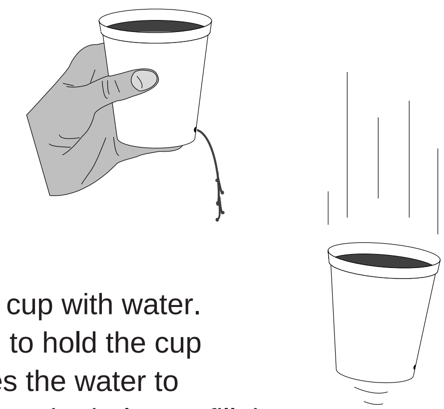
Instructions
To show what would happen to a satellite if gravity did not hold it, make a slit in the side of the tennis ball. Tie a knot in one end of the ribbon, and stuff the knot through the slit. Hold the ribbon in one hand and twirl the ball in a horizontal circle. What will happen if you release the ribbon? Will the ball fly straight away from you? (The ribbon makes it easier to see the path the ball travels.) Compare this activity to the demonstration of the apple and the string in the video tape.

Museum Gravity Well

Take your class to a hands-on science museum. Many of these museums have gravity well exhibits that permit experiments with orbits. Small versions of gravity wells are also available at some toy and novelty stores. Use small marbles or coins to represent orbiting objects and roll them around the well. Observe the relative speeds of rolling objects that are far from the center with those close to it.



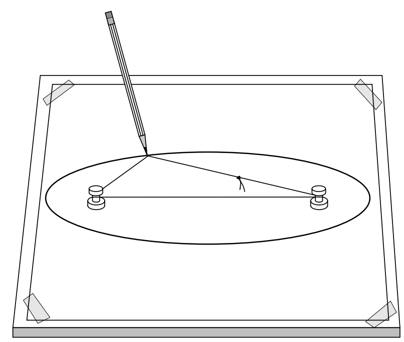
Falling Coffee Cup



Materials
Styrofoam coffee cup
Sharp pencil
Catch basin or bucket
Water

Instructions
Demonstrate the principle of weightlessness by filling the coffee cup with water. With a pencil, punch a hole near the bottom of the cup. Be sure to hold the cup over the catch basin as you do this. Observe how gravity causes the water to pour through the hole and into the basin. Next, place a finger over the hole. Refill the cup with water. What do you think will happen if you drop it? Drop the cup from a height of several feet into the catch basin or bucket. Does the water pour from the hole as the cup falls? Why or why not?

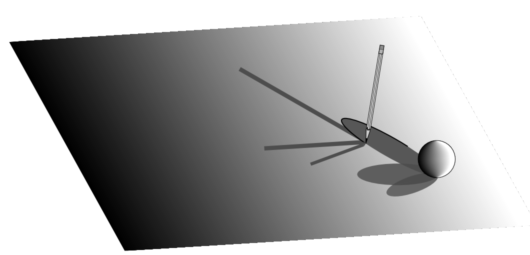
Drawing Ellipses I



Materials:
2 push pins
Square of cardboard
Sheet of paper
String
Pencil

Instructions:
Investigate the shape of orbits by drawing ellipses. Set up the materials as shown above, with the pencil inside the loop. Hold the string taut while drawing a line completely around the push pins. What will happen to the figure if the pins are brought closer together? What will happen to the figure if the pins are moved farther apart? Look up Kepler's Laws in any astronomy text book or encyclopedia. The laws describe the orbits of planets as ellipses. The same laws apply to the orbits of spacecraft around Earth.

Drawing Ellipses II



Materials:
Spot lamp
Ball
Sheet of paper
Pencil

Instructions:
As an alternative to the first ellipse investigation, make ellipses by casting a shadow from a ball on a flat surface. Alter the shape of the shadow by moving the spot lamp. How are ellipses and circles related?

References

NASA On-line Resources for Educators provide current educational information and instructional resource materials to teachers, faculty, and students. A wide range of information is available, including science, mathematics, engineering, and technology education lesson plans, historical information related to the aeronautics and space program, current status reports on NASA projects, news releases, information on NASA educational programs, useful software and graphics files. Educators and students can also use NASA resources as learning tools to explore the Internet, access information about educational grants, interact with other schools, and participate in on-line interactive projects, communicating with NASA scientists, engineers, and other team members to experience the excitement of real NASA projects.

Access these resources through the NASA Education Home Page:
http://education.nasa.gov

Other web sites of interest:

http://www.jsc.nasa.gov
http://shuttle.nasa.gov

The following books will provide additional information.

Allen, J.P. with Martin, M., Entering Space, An Astronaut's Odyssey, Stewart, Tabori & Chang, 1984.

Joels, K. M. & Kennedy, G. P., The Space Shuttle Operator's Manual, Ballantine Books, 1982.

Ride, S., Okie, S., To Space & Back, Lothrop, Lee & Shepard Books, 1986.

STS-41 Crew Biographies

Commander: Richard N. Richards (Capt., USN). Richard Richards was born in Key West, FL but, considers St. Louis, MO, his home. He earned a bachelor of science degree in chemical engineering from the University of Missouri in 1969 and a master of science degree in aeronautical systems from the University of West Florida in 1970. Richards became a naval aviator in 1970 and a NASA astronaut in 1980. Richards flew previously on the STS-28 mission.

Pilot: Robert D. Cabana (Lt. Col., USMC). Robert Cabana was born in Minneapolis, MN. He received a bachelor of science degree in mathematics from the Naval Academy in 1971. He became an aviator upon graduation and a NASA astronaut in 1986. The STS-41 mission was his first Space Shuttle flight.

Mission Specialist: Thomas D. Akers (Maj., USAF). Thomas Akers was born in St. Louis, MO, but considers Eminence, MO his home. After receiving his bachelor and master of science degrees in applied mathematics from the University of Missouri-Rolla in 1975, he served as a high school principal in Eminence. Akers joined the U.S. Air Force in 1979 and was selected as a NASA astronaut in 1987. The STS-41 mission was his first Space Shuttle flight.

Mission Specialist: Bruce E. Melnick (Cmdr., USCG). Bruce Melnick was born in New York, NY, but considers Clearwater, FL his home. He received a bachelor of science degree in engineering from the Coast Guard Academy in 1972 and a master of science degree in aeronautical systems from the University of West Florida in 1975. Melnick became an astronaut in 1987. The STS-41 mission was his first Space Shuttle flight.

Mission Specialist: William M. Shepherd (Capt., USN). William Shepherd was born in Oak Ridge, TN, and received a bachelor of science degree in aerospace engineering from the Naval Academy in 1971 and degrees of ocean engineer and master of science in mechanical engineering from the Massachusetts Institute of Technology in 1978. Shepherd became an astronaut in1984. Shepard flew previously on the ST-27 mission.

NASA Liftoff to Learning
Space Basics

EDUCATOR REPLY CARD
Video Resource Guide

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Please take a moment to respond to the statements and questions below. You can submit your response through the Internet or by mail. Send your reply to the following Internet address:

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   College/University - ______ Undergraduate ______ Graduate

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4. I expect to apply what I learned in this video and video resource guide.
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