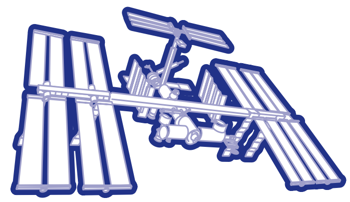
Education Product	
Teachers	Grades K-12

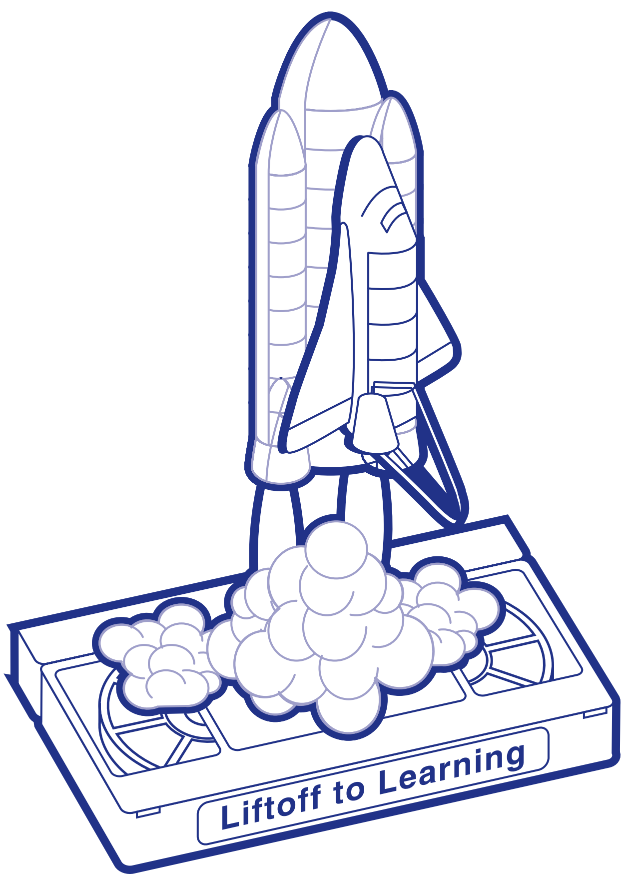
National Aeronautics and
Space Administration

Liftoff to Learning



Toys In Space II

A Videotape for Physical Science and Science and Technology



Video Resource Guide

EV-1997-07-012-HQ

Video Synopsis

Title: *Toys In Space II*

Length: 37:49

Subjects: Toys in microgravity

Description:
This program demonstrates the actions of a variety of children's toys in microgravity for classroom comparison with the actions of similar toys on Earth.

Science Standards:

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 and Technology
-Understanding about science and technology
-Abilities of technological design

Science Process Skills:

Observing
Communicating
Measuring
Collecting Data
Inferring
Predicting
Hypothesizing
Interpreting Data
Controlling Variables
Defining Operationally
Investigating

Background

Motion toys are effective tools for helping children learn science and mathematics. Scientific and mathematical principles make these toys work. For example, wind-up toys convert stored potential energy in their springs into kinetic energy as the springs unwind. Gravity often plays an important role in the actions of toys, but how would the same toys function in an environment where the effects of gravity are not felt? The Space Shuttle provides such a setting so students can discover the answer to this question.

A Space Shuttle orbiting around Earth is in a state of free-fall which eliminates the local effects of gravity, making objects inside appear to float. NASA refers to this environment as *microgravity*. Videotapes of toys in microgravity enable students to see subtle actions that gravity masks on the surface of Earth.

Dr. Carolyn Sumners of the Houston Museum of Natural Science, Houston, Texas, recognized the appeal of using toys in space. She assembled a small group of toys and placed them onboard Space Shuttle mission 51-D that flew in April of 1985. During the flight, crew members unstowed the toys and experimented with them. Their experiments were videotaped and have been used as an effective teaching tool in thousands of schools.

Because of this success, a second group of toys was flown on the STS-54 mission in January 1993. Dr. Sumners, working with a multi-grade and subject area educational advisory group, selected the toys from hundreds of possibilities. This videotape is the record of the actions of those toys in microgravity.

Teaching Strategy

The Toys In Space II flight was conceived as an experiment in which the Shuttle crew members and the student viewers of the videotape would be co-investigators. Students begin the experiment by investigating how selected toys function on Earth.

To gain the greatest benefit from this videotape, students should then develop a set of experimental questions about how these toys will function in microgravity. For example, can a basketball be thrown into a basket in space? Will a wind-up toy submarine swim in air? Will a Jacob's ladder flip? Through their own experiments, students develop hypotheses to answer their questions.

Students test their hypotheses by watching the videotape to see what actually happened in space. While not all student questions will be addressed by the orbital experiments, enough information can be gained from watching the videotape to accept, refine, or develop new hypotheses and explanations for what was observed.

Many of the toys chosen for the flight are readily available from toy stores. However, other toys, such as the comeback can, paper maple seed, paper boomerang, and the Jacob's ladder can be made by the students. Construction procedures are included in the toy section of this guide.

One set of toys can adequately allow all students in the class to experience examining the toys and forming hypotheses if the teacher keeps the following strategies in mind:

- Students can be organized into cooperative study groups that specialize on one or more toy and report to the rest of the class.
- Each student can specialize in a particular toy and report to the rest of the class.
- Each student can experiment with every available toy and engage in class discussions on how the toys will operate in space.

The following is a list of the toys used by the STS-54 crew:

<u>Available at Toy Stores</u>

- Flipping mouse
- Spring jumper (wind-up frog)
- Swimming frog (wind-up)
- Swimming angel fish (wind-up)
- Swimming submarine (wind-up)
- Flapping bird (trade name: Tim Bird)
- Balloon helicopter (trade name: Whistling Balloon Helicopter)
- Gyroscope (trade name: Gravitron)
- Rattleback (trade name: Space Pet)
- Klacker balls (various trade names)
- Racquetballs and pool balls
- Velcro balls and target (various trade names)
- Horseshoes and post (plastic or rubber shoes)
- Basketball and hoop (foam rubber ball, hoop with suction cups)
- Metal Coiled Spring (trade Name: Slinky)
- Police car and track (trade name: Darda)
- Magnetic marbles (trade name)
- Magnetic rings (see plans)

<u>Toys that can be made</u>

- Maple seed
- Jacob's ladder
- Paper boomerang
- Come-back can
- Ball and cup

<u>Toy Kits</u>

Most of the toys can be purchased from several vendors who have collected many of the toys from one or both Shuttle flights into packages. Three vendors are listed below:

Delta Education, Inc.
P.O. Box 950
Hudson, New Hampshire 03051
603-889-8899

Museum Products
84 Route 27
Mystic, CT 06355
800-395-5400

NASA CORE
(Central Operation of Resources for Educators)
Lorain County JVS
15181 St. Rt. 58 South
Oberlin, Ohio 44074
Phone: 440-774-1051 x249 or 293
FAX: 440-774-2144
E-mail: nasaco@leeca.esu.k12.oh.us

Videotape Design

This videotape is intended to be shown in segments to the students. The introduction is a greeting from the STS-54 crew, a description of their flight and an invitation to the students to participate in the experiment as co-investigators. The videotape does not demonstrate why objects appear to float on the Space Shuttle when it is in orbit. That topic is left to the teacher.

Please refer to the section of this guide on microgravity (page 4) for help explaining and demonstrating microgravity. The videotape concludes with a farewell by the STS-54 crew.

The introduction of the tape is followed with toy demonstrations. The toys are demonstrated in the following order, with the segments separated from each other by titles and music:

- "Rat Stuff"
- Spring jumper
- Swimming angel fish
- Flapping bird
- Maple seed
- Paper boomerang
- Balloon helicopter
- Gravitron gyroscope
- Rattleback
- Klacker balls
- Racquetballs and pool balls
- Ball and cup
- Velcro balls and target
- Horseshoes and post
- Basketball and hoop
- Jacob's ladder
- Coiled metal spring
- Magnetic rings
- Magnetic marbles
- Come-back can
- Police car and track

Because individual videotape machines have variations in their counters, specific numbers for each toy segment have not been provided. However, while previewing the tape, the number can be recorded in the space to the right of each segment listed above.

> **Note** - Additional information on each of the toys tested in the Toys in Space II flight begins on page 7 of this guide. Suggested activities, brief descriptions of what happened during the flight, and science and mathematics links also follow. The science/math links provide lists of relevant terms, principles, and equations. Additional information about these links begins on page 19.

Microgravity

Many people misunderstand why astronauts appear to float in space. A common misconception is that there is no gravity in space. Another common idea is that the gravity from Earth and the Moon each pull on the astronauts from the opposite direction and cancel out.

The real reason astronauts appear to float is that they are in a state of free-fall around Earth. To help your students understand microgravity, show them the videotape *Space Basics* or use the *Microgravity - A Teacher's Guide With Activities*. For more information about these NASA educational products, refer to the

References and Resources List on page 24.

Understanding why astronauts appear to float in space first requires an understanding of how the astronauts and their space vehicle stay in orbit. Rather than orbiting Earth because there is no gravity in space, the astronauts and the Space Shuttle orbit Earth because there is gravity.

More than 300 years ago the English scientist 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 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 firing cannonballs parallel to the ground. As each cannonball was fired, it was acted upon by two forces. One force propelled the cannonball straight forward 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.

STS-54 mission commander John Casper experiments with magnetic rings.

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 is called 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 321-kilometer-high orbit, the Shuttle must travel at a speed of about 27,750 kilometers per hour to circle Earth. At this speed and altitude, the curvature of the Shuttle's falling path will exactly match the curvature of Earth.

Knowing that gravity is responsible for keeping satellites in orbit leads us to the question, why do astronauts appear to float in space? The answer is simple: the Space Shuttle orbiter falls in a circular path about Earth and so does everything in it. The orbiter, astronauts, and the contents of the orbiter (food, tools, cameras, etc.) all fall together so they seem to float in relation to each other. Imagine if the cables supporting a high elevator would break, causing the car and its passengers to fall to the ground. Discounting the effects of air friction on the elevator, the car and its passengers all fall together at the same rate, so the passengers seem to float.

The floating effect of Space Shuttles and astronauts in orbit has been called by many names such as *free-fall*, *weightlessness*, *zero-G* (zero-gravity), or *microgravity*. Weightlessness and zero-G are incorrect terms that imply that gravity goes away in space. The term free-fall best describes what causes the floating effect. Space scientists prefer to use the technical term microgravity because it includes the very small (micro) accelerations that are still

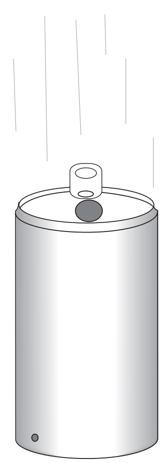
Mission specialist Susan Helms tries to understand the strange behavior of the Jacob's ladder.

Other Toys In Space Videotapes.
The original *Toys In Space* (1985 flight) videotape is available from NASA Educator Resource Centers. The live lesson (Physics of Toys) that was conducted during the STS-54 mission is also available.

experienced in orbit regardless of the objects falling.

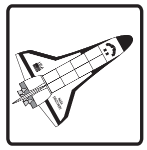
Classroom Microgravity Demonstration

To demonstrate microgravity in free-fall, poke a small hole near the bottom of an empty soft drink can. Cover the hole with your thumb and fill the can with water. While holding the can over a catch basin on the floor, remove your thumb and observe the water stream. Reseal the hole and refill the can. This time drop the can into the basin and watch to see if the water streams out of the hole. What happens? Why? (Recycle the can after you are finished with it.)

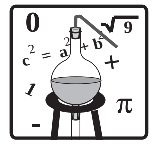


Toys in Space II Experiments

Suggested Activities

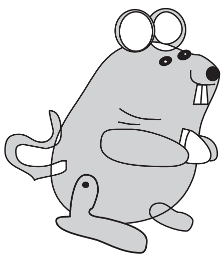


STS-54 Data

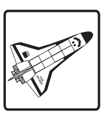


Science/Math Link

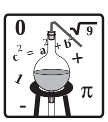
Rat Stuff - Susan Helms



Wind up the toy and let it jump out of your hand. How high did it jump?

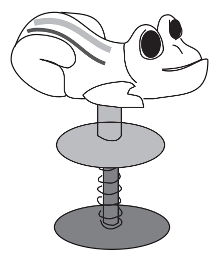


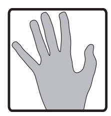
Rat Stuff flipped successfully out of Astronaut Helms' hand but did not return. When Rat Stuff was taped to a notebook, his kicking feet had no effect on the heavier book. Rat Stuff also flew on the Shuttle in 1985. Compare the actions of Rat Stuff in the two videotapes. In the 1985 flight, Rat Stuff was held with a small amount of velcro. No velcro was used in the 1993 flight.



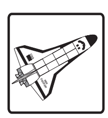
Newton's First and Third Laws of Motion (What was the shape of the mouse's trajectory away from Helms' hand?)

Spring Jumper - John Casper

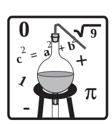




See what happens when you compress the Spring Jumper and release it on different surfaces. Push your Spring Jumper together and set the jumper on a hard flat level table, on a soft flat carpeted floor, on a very soft level pillow, and on your hand. When the spring releases, the jumper presses down on the surface below it. Which surface pushes back harder on the jumper? Which surface absorbs more of the jumper's push? Does the jumper always go the same direction? If not, can you explain why it changes direction?

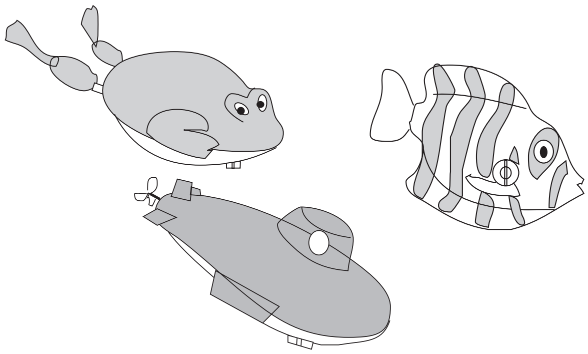


When the spring was released by the suction cup, the jumper jumped out of Commander Casper's hand. The jumper traveled in a straight line -- faster than the mouse. It could be deployed with its stand or its head touching Astronaut Casper's hand.



Newton's First and Third Laws of Motion

Swimming Frog, Fish, and Submarine - Susan Helms and John Casper



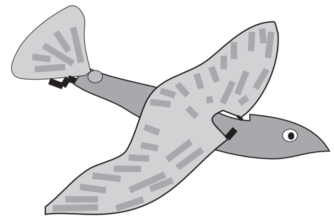
Test the swimming actions of each toy in a tub of water and in the air by suspending it with a string and observing its actions. Which toy works the best? How much air is pushed back by the submarine's propeller? Enlarge the blades by taping paper to them and observe the air flow again. Does the propeller's rotation speed change?

The frog did a poor job of swimming in air. The fish swam better than the frog, and its swimming was greatly improved when its tail fin was enlarged. The submarine swam the best and was even faster when its propeller blades were enlarged. When the propeller turned in one direction, the submarine turned in the other direction, which is the Conservation of Angular Momentum.

Newton's Third Law of Motion

Conservation of Angular Momentum (submarine)

Flapping Bird - John Casper



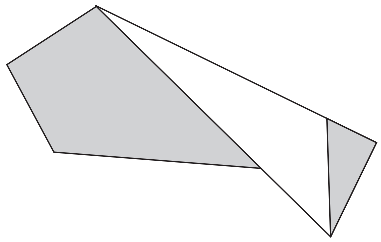
Wind up the bird between 25-50 turns. Hold onto the bird and release the wing. Watch how the bird's wings move and how they push the air. Imagine the bird flying without any force to hold it down. Throw the bird forward without winding up the rubber band. Notice how it soars. Which flying technique will work best in space?

When the rubber band inside the bird was wound up and the bird released, the bird's flapping wings caused it to do flip after flip after flip around the cabin. When the bird was not wound up, it would soar like a paper airplane. During the orbital tests of the bird, the rear of the bird's wing came lose from its body. To most accurately compare Earth and space tests of this toy, leave the rear of the bird's wing unattached.

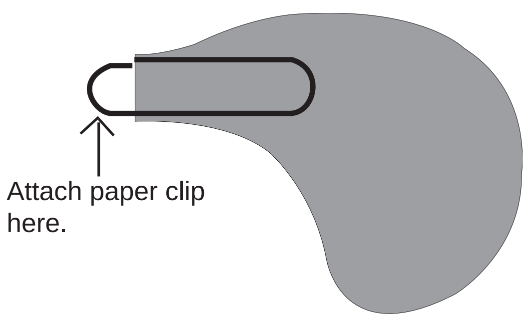
Newton's Third Law of Motion

Bernoulli's Principle

Maple Seed - John Casper



If you have access to actual maple seeds, collect enough for every student to experiment with one. If not, construct a simple "maple seed" from paper and a paper clip. Transfer the pattern below to a piece of paper and add a paper clip where indicated. You may have to adjust the position of the paper clip to get the "seed" to spin or use a smaller paper clip. Experiment with other seed shapes.

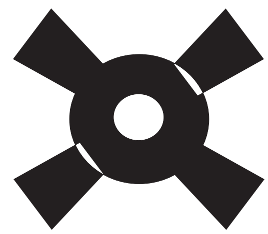


Raise the maple seed as high as you can above the floor. Drop it and observe what happens. Hold the maple seed by the wing and throw it across the room. What happens? Hold the seed by the heavy end and again throw it. What happens?
Note: The paper maple seed flown on STS-54 was patterned after an origami design. It is a difficult design for children to reproduce and the plans above have been substituted.

The paper maple seed works just like a real single-blade maple seed on Earth. In space, when the seed was thrown fast, it traveled like an arrow, seed first, without twisting. When the seed was thrown slowly, it would spin around, slowly circling like the real maple seed does as it floats to the ground on Earth.

Newton's Second and Third Laws of Motion

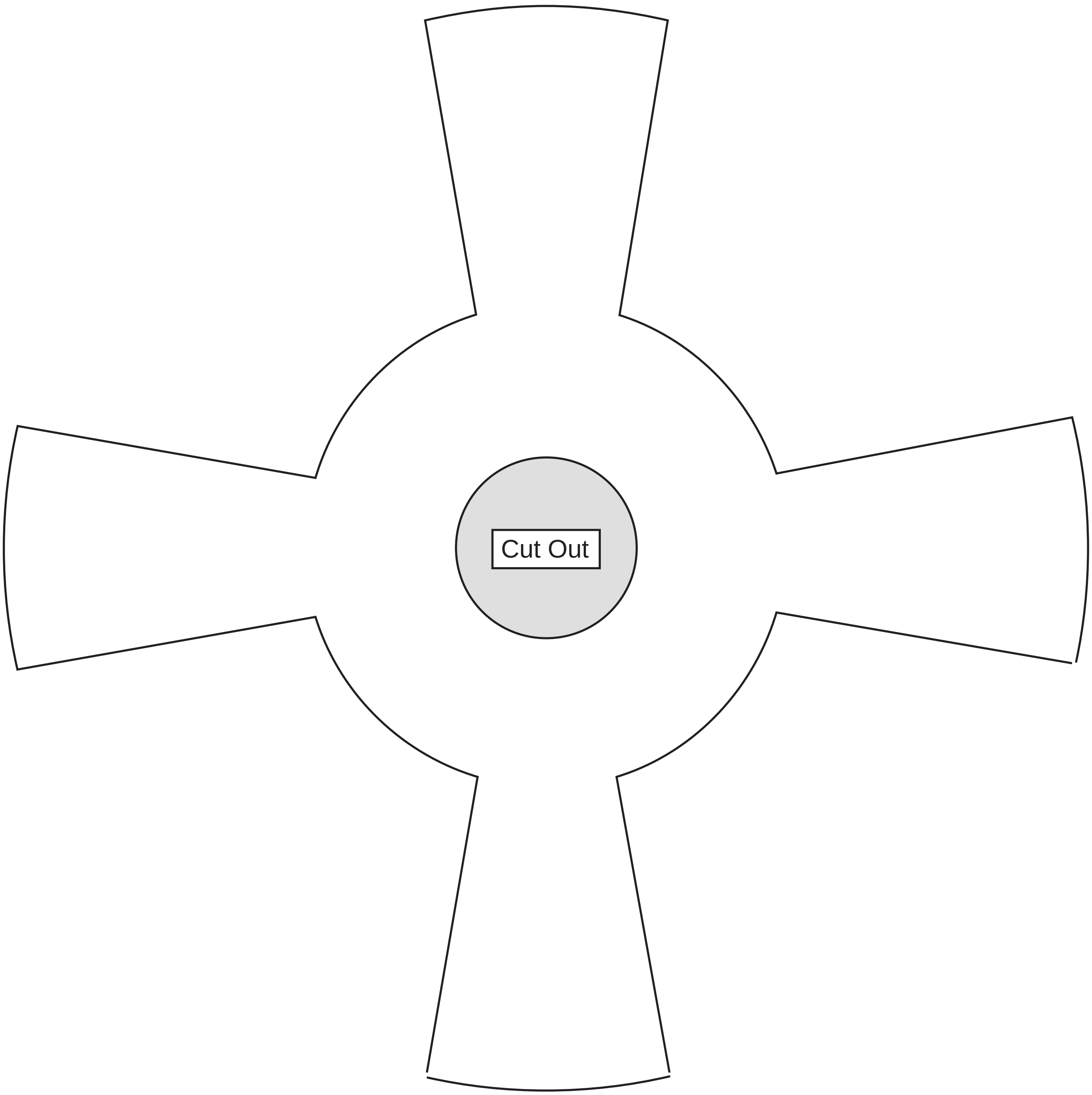
Paper Boomerang - John Casper



Use the pattern on the next page to cut out paper boomerangs from heavy stock paper, such as used in file folders. Hold the boomerang by one wing and toss it through the air. Spin the boomerang as you release it. Try to catch it. What happens when the wings are slightly bent?

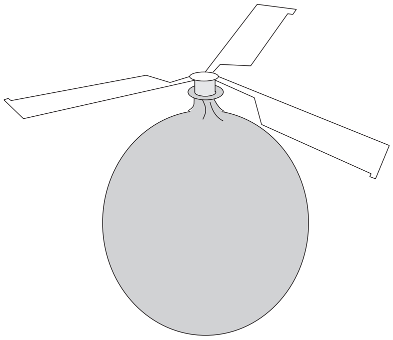
When thrown slowly with a vertical release, the 4-bladed cardstock boomerang traveled in a straight line while spinning. (At the end of the throw, the boomerang's flight was affected by air flow from an air conditioner duct.) Commander Casper was able to make the boomerang curve by throwing it horizontally; however it always crashed into a wall before returning. The boomerang needs a larger area in space for an effective demonstration.

Newton's Second and Third Laws of Motion

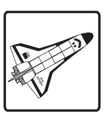


Paper Boomerang

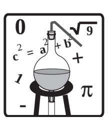
Balloon Helicopter - Don McMonagle



Blow up the balloon and attach it to the helicopter blades. Hold onto the neck of the balloon and release the air. Feel how the air travels through the wings. Predict what will happen when the helicopter is released. Blow up the balloon and attach it to the helicopter blades. Toss the helicopter upward as you release the balloon. What makes the wings turn? What makes the helicopter rise? Also estimate the distance from where you released the helicopter to the ceiling and calculate the helicopter speed as it rises.

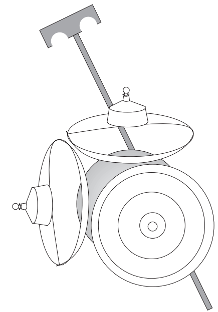


In space the helicopter climbed faster than it does on Earth and crashed into the ceiling of the cabin. The balloon separated from the helicopter and the blades continued to spin for a while.



Newton's Third Law of Motion

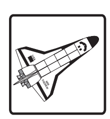
Gravitron Gyroscopes - Don McMonagle



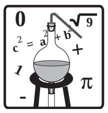
The gravitron is an enclosed gyroscope. Gyroscope axles that can be wrapped with string can also be used. A wiffle ball with holes drilled in it permitted up to three Gravitrons to be joined together for some of the experiments. Some of the space experiments involved a string.

Hold the spinning gravitron in your hand. Move your hand toward you, and then away from you while keeping the gravitron upright. Start the gravitron spinning again and tilt your hand to the left and to the right. How does the gravitron react to each motion? Place the spinning gravitron with the tall end down on a table. Watch what happens as the gravitron slows down. Can you think of another spinning object that wobbles like this? Tie a string on one end of a gravitron. Start the gravitron spinning using the pull cord. Then swing the gravitron around in circles. How does the gravitron orient its axis? What would happen if you did not spin the Gravitron first?

A spinning gravitron moved through the cabin without wobbling. When a spinning gravitron

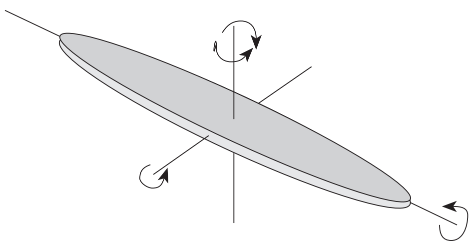


drifted into a non-spinning gravitron, the non-spinning gravitron tumbled, but the spinning gravitron did not. When two gravitrons spinning in the same direction were attached to a ball, the ball began to wobble and the gravitrons flew off. When the same gravitrons were spun in opposite directions, their spinning canceled each other out. Three spinning gravitrons attached to the ball caused the ball to spin around an axis that was the combination of all three gravitron axes. When a spinning gravitron was swung at the end of a string, it aligned its axis at right angles to the string so it would not have to change the orientation of its axis as it swung around in circles.

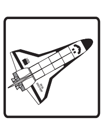


Conservation of Angular Momentum

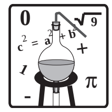
Rattleback - Don McMonagle



Set the rattleback on a flat, smooth surface with the curved side down. Push on one tip. What happens to the rattleback? Does it turn clockwise or counterclockwise? Push down on the other tip and see how it spins. Set your rattleback on a flat smooth surface and spin it counterclockwise. How many turns does it make before stopping? Now spin the rattleback in a clockwise direction. How many turns does it make before stopping? How does it behave just before it stops? What happens after it stops? If spinning the rattleback clockwise causes it to rock, can you explain why it changes direction of spin? Would these changes happen in space?

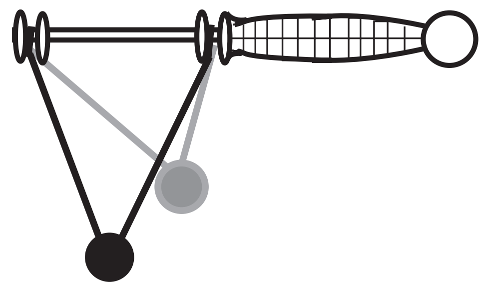


In space, a rattleback will spin in all directions equally well.

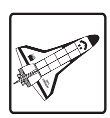


Conservation of Angular Momentum

Klacker Balls - Mario Runco



Hold the two balls horizontally on either side of the handle. Drop the balls at the same time. As they hit, move the handle upward. When they hit on top, move the handle downward. Do the klacker balls remain on the same side of the handle or do they change sides? Hold one ball above the handle and let the other one hang below. Release the top ball. As it swings down, it will hit the lower ball. With a small turn of the paddle, you can get the moving ball to circle the handle and hit the other ball. With a little practice this klacking motion will be easy.

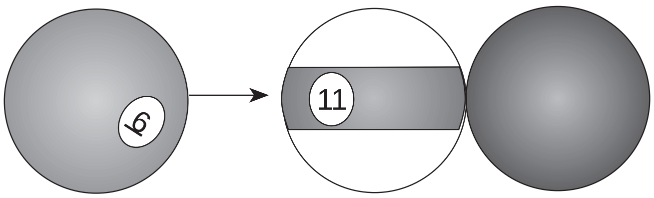


The klacker's motion where the balls hit on the top and bottom could be done in space. The circular motion where you hit the ball at the bottom of each circle could not be mastered in space. There was no force to hold the ball down at the bottom of the circle and it kept circling the handle with the other ball. When taped open, and spun by twisting each ball in the same direction, the klacker's balls and handle swung around the center of mass.

Conservation of Angular Momentum

Newton's Third Law of Motion

Racquetballs & Pool balls - Susan Helms



Pool balls can be purchased, but it is less expensive to borrow some from someone who has a pool table.

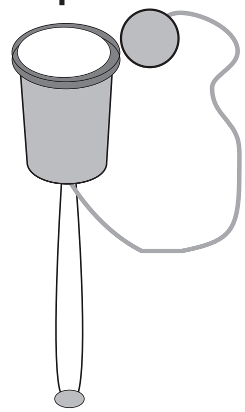
Roll the balls across a smooth surface and observe what happens when they collide. Is there a difference between balls of different mass or the same mass colliding with each other?

The astronauts carried two blue racquetballs and two standard pool balls. The pool balls had four times the mass of the racquetballs. When the racquetball hit the pool ball, it bounced backward much faster than the pool ball moved forward. When the pool ball hit the racquetball, it continued to move forward pushing the racquetball forward also.

Newton's Third Law of Motion

Collisions - Elastic and Inelastic

Ball and Cup - John Casper



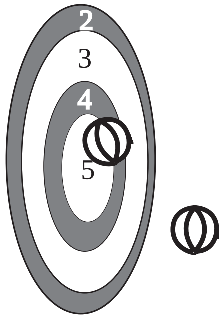
A ball and cup can be made from a stick, small paper cup, thumbtack, string and ball. Attach the cup to the end of the stick by pressing a thumbtack through the cup's bottom into the wood. Attach a small ball to one end of the string by "stitching" with an upholstery needle. Tie the other end of the string to the stick.

Hold the cup in one hand. Use a scooping motion to swing the ball upward. Try to catch the ball in the cup. What keeps the ball in the cup after it is caught?

Although several attempts were made to capture the ball in the cup, the ball would always bounce away. The ball also could not be thrown into the floating cup.

Newton's First and Third Laws of Motion

Velcro Balls & Target - Susan Helms

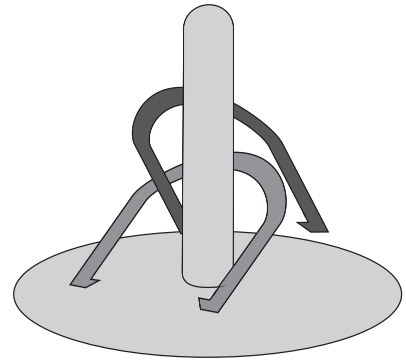


Place the target on the wall. Stand two meters away. Throw the balls overhanded and then underhanded at the target. Which method works better? Which method would work in space? Place the target on the floor. Stand on a chair directly above it. Drop the balls toward the target. Is it easier to hit the target this way? Hang the target from one string in the center of the room. Throw the balls toward the target from a distance of two meters. What happens to the target when you hit the center? What happens to the target when you hit the edge? What happens when you hit the target with a faster ball?

Astronaut Helms threw the ball as she would on Earth and it hit far above the target. The ball traveled in a straight line instead of falling downward as it does on Earth. When she pushed the ball, it traveled straight toward the target. When she gave the ball a top spin, the ball appeared to drop slightly as it moved toward the target. When she hit the floating target along the edge, she caused it to tumble. When she hit it in the middle, it merely moved away with the ball attached.

Newton's First and Third Laws of Motion

Horseshoes and Post - Susan Helms



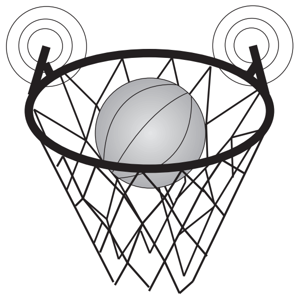
Try to make ringers. What happens if you hit the post too hard? What do you think will happen in space?

To make a ringer, Susan Helms had to catch the hook at the end of the horseshoe around the post. When this was done correctly, the horseshoe spun around the post for up to 5 minutes. Other ringer attempts resulted in the horseshoe bouncing off the target. When the horseshoe hit a floating post near the base, it caused the target to move away with the horseshoe. When the horseshoe hit near the top of the post, it caused the target to tumble.

Newton's First and Third Laws of Motion

Conservation of Angular Momentum

Basketball and Hoop - Greg Harbaugh



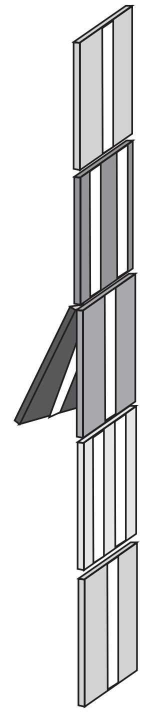
Using the suction cups, secure the hoop to a wall. Practice throwing the ball until you make a basket. Where do you aim when you throw the ball? Would this technique work in space? Bounce the ball through the basket. You may bounce the ball off the floor, ceiling, or any wall. Which bounce might also work in space?

Astronaut Harbaugh could not arc the ball into the basket or make a banked shot off the backboard. He could not get high enough above the basket to bounce the ball in. To make a basket, Astronaut Harbaugh had to bounce the ball off of the ceiling. Slam dunks were easy and usually included several 360°s before pushing the ball through the hoop. The 360°s were possible in the layout and tuck positions.

Newton's First and Third Laws of Motion

Collisions-Inelastic

Jacob's Ladder - Susan Helms



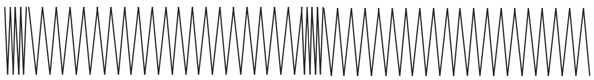
Jacob's ladders can be made with small rectangles of soft wood, ribbon, and staples. It is best to obtain a commercially-made Jacob's ladder to use as a pattern.

Let the Jacob's ladder "fall" normally. Notice the location of the ribbons when the blocks flip. Why do the blocks flip? Will they flip in space? Hold the Jacob's ladder in a horizontal position with your hands on the end blocks. Pull the end blocks apart with tension. Fold the end blocks up or down to make changes in the ladder. Then pull the end blocks apart several times. Does the same thing happen each time? What might happen when this is done in space?

When the blocks were pushed together, they rebounded and moved apart. Then they came back together like an accordion. When the blocks were pulled apart, one block would either stick up or down. On the next pull, another block might stick out from the row of blocks.

Universal Law of Gravitation

Coiled Metal Spring - Mario Runco

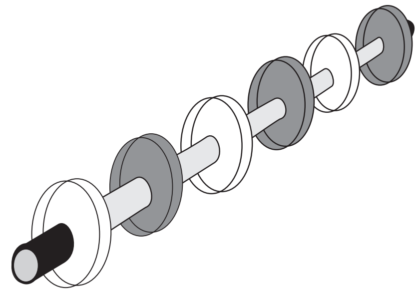


Stretch out your coiled spring between your hands. Then move one hand back and forth, pushing in and pulling out on the coiled spring. Watch the compression waves travel along the spring. Stretch the spring between your hands. Move one hand to the left and right. Then watch as this wave motion travels along the spring. Notice what happens when the wave reaches the end of the coiled spring. Repeat the first activity at a rate where places in the coiled spring seem to stand still. These are called standing waves and the still places are called nodes.

In the experiments conducted with the coiled spring in space, the spring functioned very much like it does on Earth.

Wave Motion

Magnetic Rings - John Casper



Slip 3 to 6 ring magnets on a pencil so that they repel each other. Wrap the ends of the pencil with tape so that the magnets cannot fall off. What happens if you push all the magnets together?

Six magnetic rings were placed on a one-foot-long plastic rod. The ends were taped to keep the rings from escaping. These rings have poles on the top and bottom. They were arranged so that like poles were facing and the rings pushed away from each other. When the rings were pushed together on one end of the rod and released, they returned to their original position and vibrated for a moment. When Commander Casper caused the rod to spin quickly like a majorette's baton, the rings moved to the ends of the rod.

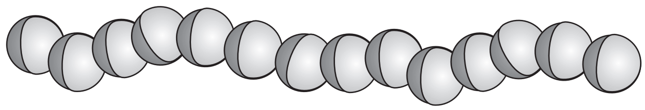
Magnetism

Newton's Second Law of Motion

Centripetal Acceleration

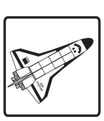
Circular Motion

Magnetic Marbles - Greg Harbaugh

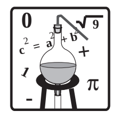


Inside each marble is a small cylindrical magnet. Therefore, each marble has a north and a south pole. Put a dot on one end of a marble. Add a second marble. Put a dot on the pole of the second marble that is NOT touching the pole of the first marble. Continue until all of the poles of your marbles are marked. (The magnetic marbles used in space were modified slightly to achieve the yellow/blue patterns. Solid color marbles were split open and halves were matched in the right color combinations.)

Divide your marbles into two chains of four. Move the chains toward each other on a smooth table. How close do they come before the marbles jump together? Holding one marble, pick up another marble and then another. Repeat until your chain of marbles breaks. The weight of the marble chain minus one marble is a measure of the force between the top two marbles on the chain. On a smooth flat surface, roll two marbles toward each other slowly. Try this experiment several times to see if you can get the marbles to spin around each other.



The magnetic marbles in space were yellow on the north end and blue on the south end. When two marbles were held close together with opposite sides facing each other, they came together and joined with a spinning motion. When like sides were facing, the marbles flew apart. When one marble was floated into two, it joined the others and they began spinning around the middle marble. When a marble was moved quickly past another marble, it caused the other marble to spin. When two chains of four marbles moved toward each other, they joined into a single chain that oscillated back and forth. When a long chain of marbles was swung around in a circle, the chain broke at the innermost marble. When left floating in the cabin, the individual magnetic marbles aligned themselves with Earth's magnetic field.

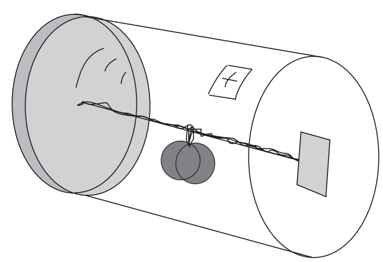


Magnetism

Newton's Second Law of Motion

Centripetal Acceleration

Come-Back Can - Don McMonagle



A come-back can can be made from a clear plastic food storage container (1 qt.). Drill a hole in the center of the lid and in the center of the bottom. Attach a paper clip to one end of a rubber band and insert the other end through the hole in the bottom of the jar. Next attach two one-ounce fishing sinkers to the center of the rubber band so that they will hang down as shown in the diagram. Stretch the rubber band and insert the other end through the hole in the lid. Attach a second paper clip. The paper clips prevent the rubber band from slipping back through the hole. Fix both paper clips with tape so that they will not shift when the rubber band is wound. Screw the lid of the jar in place and roll the can along a table top. If the weights are hung properly, they will cause the rubber band to wind up as it rolls. When the can stops rolling, the stored energy in the rubber band will cause the can to roll back to its starting position. How would you wind up the rubber band if you could not place the can on a table top?

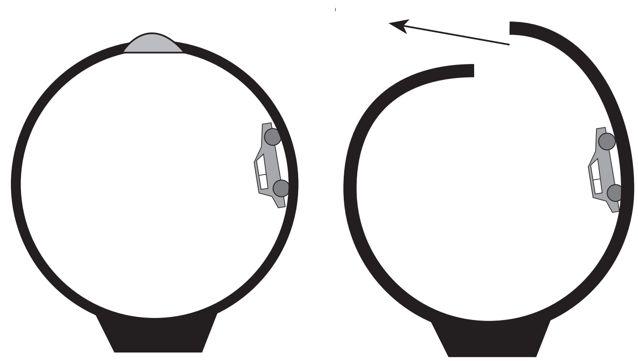
When the come-back can was released with a spinning motion, the can turned as did the weight in the center. When the weight was wound up inside the can and the can was released, the weight unwound inside the can while the can turned the other direction. When the weight inside the can was wound up and the can was placed against a locker, the can pushed off the locker and floated into the cabin.

Newton's Third Law of Motion

Universal Law of Gravitation

Conservation of Angular Momentum

Pull-Back Car and Track - Mario Runco



Give the car a push and measure how far it rolls on a smooth level floor. What affects the distance that your car travels? Would it roll on a wall in space? Roll the car’s wheels back and forth while pressing the car against a surface. Release the car and notice how the wheels push the car forward. What would happen when the car’s engine is wound up and the car is released in space? Place a wound-up car in a loop and watch it go around. How does its speed change as it moves around the loop? Where on the loop does it fall out? Would it fall out of the loop in space?

When the car was wound up and released in air, it began spinning in the opposite direction from the turning motor inside. When the car was wound up and released inside the track, it circled until its engine wound down. When the car was wound up and released inside the track and the track was released, the track turned round and round as the car circled inside.

Newton's Three Laws of Motion

Centripetal Acceleration

Universal Law of Gravitation

Glossary of Science Terms, Principles and Mathematical Equations

The following terms, scientific principles, and mathematical equations are useful in describing the actions of toys on Earth and in space. It is recommended that you refer to physical science or physics textbooks for detailed explanations of terms, principles, and equations with which you are unfamiliar.

Acceleration - This is the rate of change in velocity.

Action Force- This is a force exerted on an object.

Air Resistance - This is the force of the air pushing against a moving object.

Amplitude - This is the distance that a moving wave rises or falls above or below its rest position.

Angular Momentum - This is a property of spinning motion that must be conserved. Angular momentum is the product of an object's mass, the radius of its circular path, and its velocity.

The angular momentum of a spinning object is equal to its moment of inertia times its angular velocity. If the resultant external torque acting on a system is zero, the total angular momentum of the system is constant. The angular momentum is greater when the mass is farther from the rotation axis as in the spinning disk of a gyroscope. The direction of the angular momentum of a spinning object is along the axis of rotation in a direction defined by the right hand rule. When the curled fingers point in the direction of the rotation, the direction of the angular momentum is that of the outstretched thumb.

Bernoulli's Principle - In a flowing fluid, increases in its velocity are accompanied by a decrease in its pressure. Bernoulli's Principle applies to all fluids including liquids.

Buoyancy - This is an upward force exerted on an object in a liquid equal to the weight of the liquid which the object displaces. Microgravity is a neutral buoyancy condition.

Center of Mass - This is the point at which the entire mass of an object is centered.

Centrifugal Force - This is the <u>apparent</u> outward force exerted by an object moving in a circle. In reality, the object is simply trying to move in a straight line.

Mario Runco watches his police car leave the track after its forward motion became zero.

Centripetal Force - This is the inward force which causes an object to turn.

$$\text{Centripetal Force} = \frac{\text{mass x velocity}^2}{r}$$

Circular Motion - A force is required to change the direction of the velocity of an object which is moving in a circle. This inward force is called a **centripetal force**. Without an inward centripetal force, the object would move outward in straight line motion.

Collision: Elastic and Inelastic - For perfectly elastic collisions, the relative speed of recession after the collision equals the relative speed of approach before the collision. In a perfectly inelastic collision, there is no relative speed after the collision--the objects remain together. All other collisions lie between these two extremes.

Compression - This is a concentration of particles in a longitudinal wave.

Conservation of Energy - The amount of energy in a closed system remains constant over time.

Conservation of Momentum - The conservation of momentum is equivalent to Newton's third law of motion: for two objects subject only to their mutual interactions, the sum of the momenta of the objects remains constant in time.

Also note that momentum is a vector quantity and the momenta of objects must be added vectorally.

Crest -This is the high point in a wave.

Drag - Drag is the resistant force exerted by a fluid (such as the air) when an object moves through it. The drag force opposes the motion of the object.

Mission specialist Don McMonagle prepares to release three Gravitrons connected to a wiffle ball.

Elastic Potential Energy - This term is used to describe the energy stored in a stretched object (usually a spring).

Energy - This is a property of nature that is present in many forms. Energy that moves from one system to another under the action of forces is called work.

Force - This is a push or pull.

Free-fall - This is the condition of an object falling in a gravity field.

Frequency - This is the number of waves or pulses passing a point per unit time.

Friction - This is a force which opposes sliding motion.

When two bodies are in contact with each other, they exert forces on each other due to the interaction of the particles in one body with those of the other. The tangential component of the contact force exerted by one object on another is called a frictional force.

Mission specialist Susan Helms tries to make "ringers" with the horseshoes.

Law of Universal Gravitation - All particles exert a gravitational force of attraction upon each other. The magnitude of the force between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

$$Force = G\frac{m_1 m_2}{r^2}$$

(**Note:** G is a constant, r = distance between the center of masses for the two objects.)

G-Force - The ratio produced when the force felt by an object is divided by the weight of that object when motionless on Earth's surface.

Gravitational Potential Energy - This is the energy possessed by an object by virtue of its position relative to Earth or any large mass.

Gravity- The attraction of all objects to one another due to their mass.

Gyroscopic Stability - This term describes the resistance of a spinning object to any torque that would change the orientation of the object's spin axis.

Heat Energy - This is the energy associated with the vibration of atoms and molecules.

Inertia - This is the property by which an object tends to resist any change in its motion.

Kinetic Energy - This is the energy possessed by an object because of its motion.

Longitudinal Wave - A wave which vibrates back and forth in the direction of the wave's motion. (Also called a compression wave)

Magnetism - This is a property of certain objects in which there is an attraction to unlike poles of other objects. Its origin lies in the orientation of atoms within the object. The strength of the magnetic force varies inversely with the square of the distance between the magnets. The magnetic force drops off very quickly with distance.

Mass - This is the amount of matter an object contains.

Microgravity - An environment, produced by free-fall, that alters the local effects of gravity and makes objects seem weightless.

Moment of Inertia - The moment of inertia for a spinning body depends on the mass distribution relative to the axis of rotation. The moment of inertia equals the sum of the mass times the square of the distance from the axis of spin for each particle in the body. The moment of inertia is greater for spinning objects with their mass distributed farther from the axis of rotation. Gyroscopes and tops are designed on this principle.

Momentum - This is the product of an object's mass times its velocity. Momentum is a conserved quantity within a closed system.

$$Momentum = mass \times velocity$$

Newton's Laws of Motion - Sir Isaac Newton first formulated these three basic laws of motion:

Newton's First Law of Motion - An object continues in its initial state of rest or motion with uniform velocity unless acted on by an unbalanced external force. This is also called the **Law of Inertia** or the **Inertia Principle.**

Newton's Second Law of Motion - The acceleration of an object is inversely proportional to its mass and directly proportional to the resultant external force acting on it.

$$Force = mass \text{ x } acceleration$$

Newton's Second Law for Rotation - The torque of a spinning object is equal to the object's moment of inertia times its angular acceleration. The fact that a torque is required to change a spinning gyroscope's angular velocity is called **gyroscopic stability**.

Newton's Third Law of Motion - Forces always occur in pairs. If object A exerts a force on object B, an equal but opposite force is exerted by object B on object A. Application: objects move forward by pushing backward on a surface or on a fluid.

Node - This is a point in a standing wave where no motion occurs (zero amplitude).

Parabola - One possible path of an object falling freely in a gravity field. A tossed ball follows a parabolic arc.

Photon - This is a packet of radiant energy.

Potential Energy - This is the energy required to place an object in a position. This energy is stored in the object until the object moves. It is then converted into another form of energy, such as kinetic or thermal.

Precession -This is the wobbling of a spinning object.

Rarefaction - This is the part of a longitudinal wave where the density is lower than the surrounding medium.

Reaction Force - This is the force exerted by an object experiencing an action force. The reaction force is equal to the action force, but in the opposite direction.

Surface Tension - This is the strength of the boundary film at the surface of a liquid.

Speed - This is the rate of change of an object's position with time.

Mission specialist Greg Harbaugh slam dunks a basket.

Mission specialist Mario Runco tries the Klackers.

The frequency of a wave is the number of vibrations per unit time. The wavelength is the distance between two wave crests. The wave's speed of propagation is equal to the frequency times the wavelength.

Wavelength - This is the distance between two identical points in a wave (ie. from crest to crest).

Weight -This is the magnitude of a gravitational pull.

Toronal Wave - This is the wave caused by twisting a coiled spring.

Transverse Wave - This is the wave in which vibrations are to the left and right as the wave moves forward.

Trough - This is a wave valley.

Velocity - This is the speed and direction of an object's motion.

Wave Motion - In a longitudinal wave, the vibration of the medium is along the same direction as the motion of the wave. A longitudinal wave is also called a compression wave. In a transverse wave, the vibration of the medium is perpendicular to the motion of the wave. A vibration caused by twisting the coiled spring is called a torsional wave.

A standing wave has places where the wave appears to stand still. Locations where the waves interfere to produce no motion are called nodes.

Acknowledgments

Some of the text in this video resource guide was provided by Dr. Carolyn Sumners of the Houston Museum of Natural Sciences, Houston, Texas. Dr. Sumners, working with an educator advisory panel, selected the toys shown in this videotape and planned the experiments. She has published a book on the two Toys in Space experiments. Refer to the reference section of this guide for the book's title.

A technical review of physics concepts was provided by Dr. Tom Hudson Physics Department, University of Houston, Texas.

References

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Access these resources through the NASA Education Home Page:
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Crew Biographies

Commander: John H. Casper (COL, USAF) John Casper was born in Greenville, South Carolina, but calls Gainesville, Georgia, home. He earned a bachelor of science degree in engineering science from the U.S. Air Force Academy and a master of science degree in astronautics from Purdue University. He is also a graduate of the Air Force Air War College. He flew 229 combat missions during the Vietnam War. He has been a test pilot and served at USAF Headquarters at the Pentagon as an action officer for the Deputy Chief of Staff, Plans and Operations, and later as deputy chief of the Special Projects Office. Casper has logged over 6,000 flying hours in 50 different aircraft. He was named an astronaut in 1984 and flew as pilot aboard STS-36.

Pilot: Donald R. McMonagle (LTCOL, USAF) Donald McMonagle was born in Flint, Michigan. He earned a bachelor of science degree in astronautical engineering from the U.S. Air Force Academy and a master of science degree in mechanical engineering from California State University-Fresno. He served as an F-4 pilot at Kunsan Air Base, South Korea, before assignment to Holloman Air Force Base, New Mexico, where he flew F-15s. He was the operations officer and a project test pilot for a technology demonstration aircraft, the F-16, while stationed at Edwards Air Force Base, California. McMonagle has over 4,200 hours of flying time in several aircraft. He became an astronaut in 1987, and flew as a mission specialist aboard STS-39.

Mission Specialist: Gregory J. Harbaugh. Gregory Harbaugh was born in Cleveland, Ohio, but Willoughby, Ohio, is his hometown. He received a bachelor of science degree in aeronautical and astronautical engineering from Purdue University and a master of science degree in physical science from the University of Houston, Clear Lake. He has held engineering and technical management positions in various areas of Space Shuttle flight operations at NASA's Johnson Space Center. He also holds a commercial pilot's license and has logged over 1,000 hours flying time. Harbaugh was named an astronaut in 1987 and flew as a mission specialist aboard STS-39.

Mission Specialist: Mario Runco, Jr. (LCDR, USN) Mario Runco, Jr., was born in the Bronx, New York, but considers Yonkers, New York, his hometown. He earned a bachelor of science degree in meteorology and physical oceanography from the City College of New York and a master of science degree in meteorology from Rutgers University. He has worked as a research hydrologist for the U.S. Geological Survey and a as New Jersey State Trooper before entering the U.S. Navy. In the Navy he served as research meteorologist and later became the commanding officer of Oceanographic Unit Four embarked in USNS Chauvenet (T-AGS-29). Runco was selected as a NASA astronaut in 1987 and was a mission specialist on STS-44.

Mission Specialist: Susan J. Helms (MAJ, USAF) Susan Helms was born in Charlotte, North Carolina, but calls Portland, Oregon, her hometown. She earned a bachelor of science degree in aeronautical engineering from the U.S. Air Force Academy and a master of science degree in aeronautics/astronautics from Stanford University. While at Eglin Air Force Base, Florida, she was an F-16 weapons separation engineer and later lead engineer for F-15 weapons separation. She subsequently was assigned to the faculty of the USAF Academy where she held the position of assistant professor. She has flown in 30 different types of U.S. and Canadian aircraft. Helms was named an astronaut in 1990.

NASA Liftoff to Learning

Toys in Space II

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