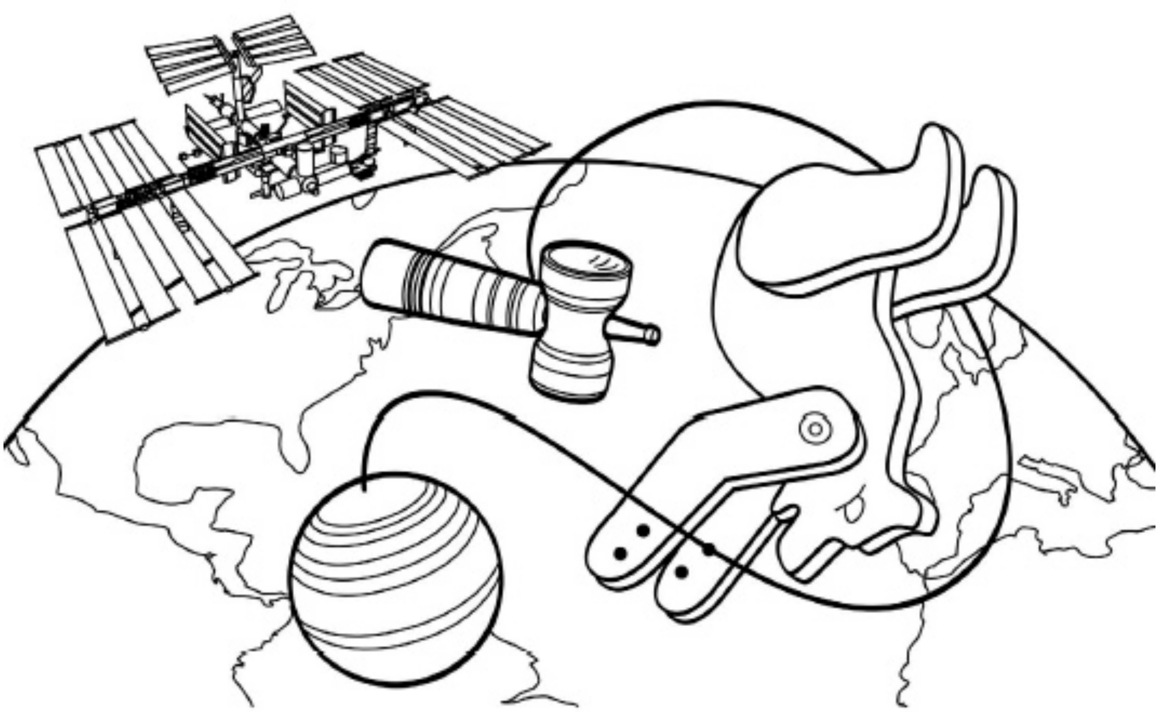
National Aeronautics and
Space Administration

Educational Product	
Educators & Students	Grades 5-8

TOYS in SPACE

Toys in Space Investigation: Science from the Station



Toys in Space Investigation: Science from the Station

Target Audience: 5-8

Focus Question:
In this investigation students play the role of scientists and engineers in examining the physics of popular toys and games in the classroom and try to answer the question: Will this toy work in microgravity?

Description:
The Toys in Space Investigation attempts to accomplish three things:

1. Use the fun concept of Toys in Space to serve as a physics primer by investigating forces and motion as they are applied to toys and games familiar to students; and then learning if these toys and games will function in a microgravity environment.
2. Let students participate in a NASA science investigation that allows them to be the investigators.
3. Expose students to Science, Technology, Engineering, and Mathematics (STEM) careers by letting them play the role of scientists, technicians, and engineers during the investigation.

Educational Objectives:
Science: To demonstrate the behaviors of toys in microgravity, thereby allowing students to determine how gravity affects the motions of familiar toys.
Engineering: To modify the way a toy is used so that it does function in microgravity, thereby illustrating the methods NASA uses in adapting tools to function on orbit.
Mathematics: To quantify, graph, and analyze the behaviors of toys in microgravity.
Social Studies: To investigate the origin of toys and decide which toys and sports activities might someday be used by a people living in space.

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

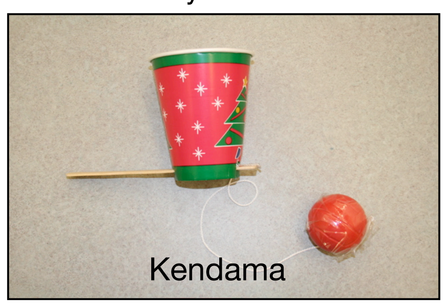
- Hypothesizing
- Interpreting Data
- Controlling Variables
- Defining Operationally
- Investigating

Sequence of Events

Pre-conference Activities:
Classroom Investigation

- As part of the DLN Toys in Space module, students investigate four toys in the classroom and complete a Student Investigation Sheet for each of the toys
- The four toys that will be investigated are:
    - Jump Rope
    - Soccer
    - Paper Boomerang
    - Kendama

- Engineering a Boomerang and Kendama- Most schools have a soccer ball and jump rope, but usually do not have a boomerang or a kendama. This module allows for the students to build a boomerang and design and engineer a kendama. Use the below to help with the constuction:
    - Boomerang- using card stock paper, print the template at the end of this document (also on the support website) onto the card stock paper and have the students cut it out. Teacher note: have students try throwing the boomerang several different ways; each time recording information about thrust, spin, and direction. Also, toys stores often carry several “in door” boomerang that can also be used
    - Kendama- this toy can be build using the following supplies: plastic cup, string, tape, ping-pong balls, and a craft stick (optional). Describing the toy to the students (instead of showing them what it looks like) often produced many different “ball and cup” toys.



- Break classroom into four sets of teams (one team per toy). With larger groups it may be necessary to have more than one team per toy. Have each team investigate and complete the Student Investigation Sheet together, or they may break-up the assignments so everyone gets to participate.
    - Lead Scientist Presenter- Coordinates with team investigation findings and presents back to NASA for videoconference.
    - Lead Scientist Recorder- Coordinates with team so that all questions are answered shares findings with Lead Scientist Presenter.
    - Engineer- Builds or modifies experiment being tested and helps to explain how toy / game is supposed to function and origin of toy.
    - Astronaut Technician- Conducts experiments on Earth for rest of team to observe.

- Complete Student Investigation Sheet and gather any other physical demonstrations you would like to share with NASA (digital photos, on-camera example, etc…)

Videoconference Activities:
Connect with NASA for results

Post-conference Activities:
Have students build on what they've learned by designing, building, and testing a toy that would work on the Moon or Mars. Students then develop a marketing campaign for the toy using: print, electronic media, or by presenting to the class.

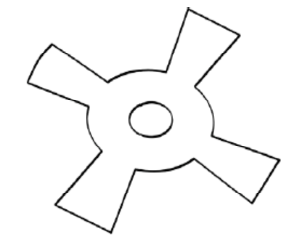
NASA Lithograph on the Moon:
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Earths_Moon_Lithograph.html

NASA Lithograph on the Moon:
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Mars_Lithograph.html

Setting up the *Toys Investigation*

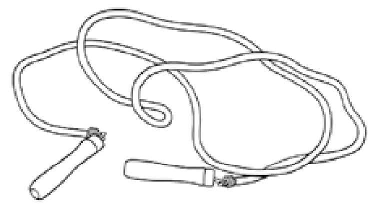
Paper Boomerang

Students should first make their own boomerangs from the attached pattern copied onto cardstock paper. The four blades must curve slightly upward, like the curve in a plate. Holding the boomerang vertically, students should throw it and release it with a vertical spin. When thrown correctly, the boomerang tilts from vertical to horizontal, which brings the boomerang back to the thrower. The more curved the blades, the more quickly the boomerang returns. Students need to experiment with the boomerang to discover the effects of how fast the boomerang is spinning and how much the blades are curved. Talking points could include: gravity, angular momentum, winged flight, air resistance, origin of toy, and why it was invented.



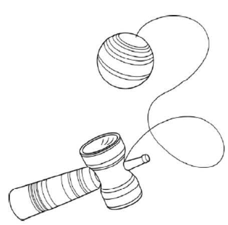
Jump Rope

The jump rope is a good toy for students trying to predict what will happen in microgravity. Students know that jumping doesn't work in space, so they must design another way to use the jump rope. Ask students to explain why the jump rope will not work in space and to describe how a crewmember might swing the rope to get exercise in space. Talking points could include: why people jump rope, gravity, centripetal force, and conservation of angular momentum.



Kendama

Although this toy is available in stores, **students can also make their own** version with two cups taped on either side of one end of a wide craft stick and a superball or ping pong ball on a string attached to the craft stick. The size of the cups and the ball determines how hard it is to catch the ball in the cup. The challenge on Earth and in space is to get the ball into the cup. Talking points could include: gravity, volume, measurement, action-reaction, friction, and origin of toy.



Soccer

Have students watch a soccer game on video tape or describe what happens when they play soccer. Talking points could include origin of toy, gravity, airflow, drag, spin, trajectory, Newton’s Laws.

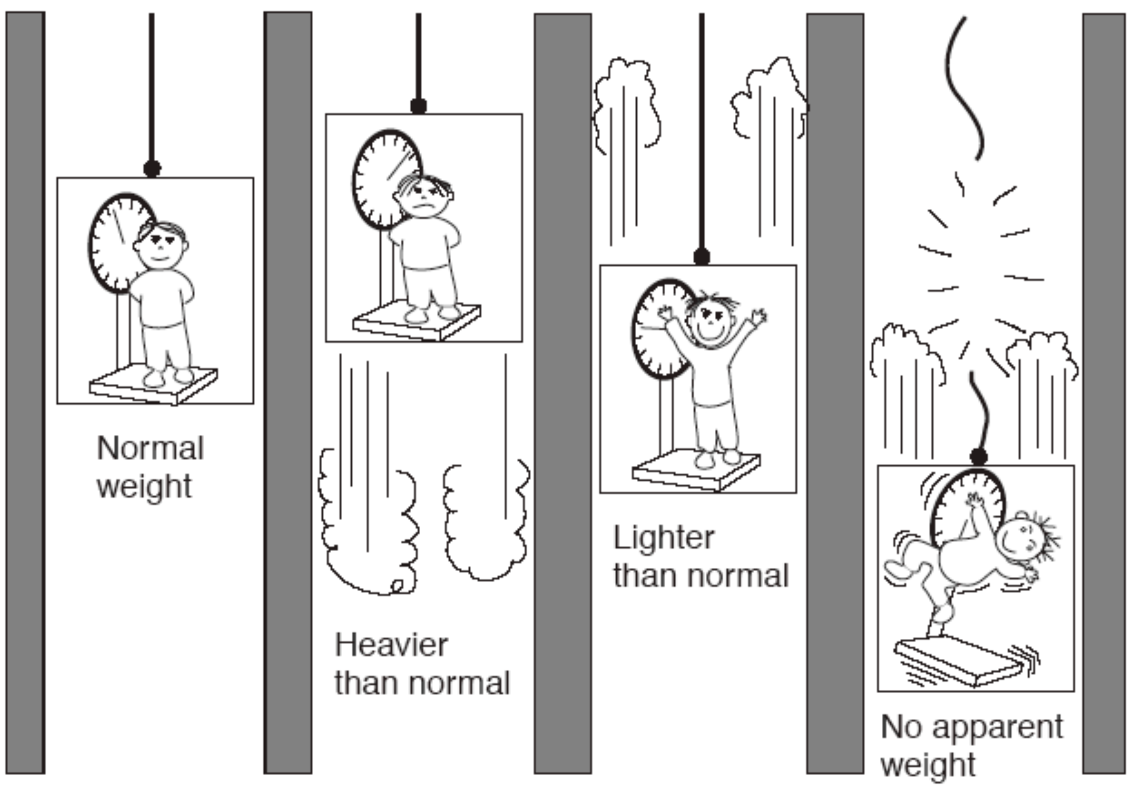
Microgravity

Gravity is an attractive force that all objects have for one another. It doesn't matter whether the object is a planet, a cannonball, a feather, or a person. Each exerts a gravitational force on all other objects around it.

The amount of force between two objects depends upon how much mass each contains and the distance between their centers of mass. For example, an apple hanging from a tree branch will have less gravitational force acting on it than when it has fallen to the ground. The reason for this is because the center of mass of an apple, when it is hanging from a tree branch, is farther from the center of mass of Earth than when lying on the ground.

Although gravity is a force that is always with us, its effects can be greatly reduced by the simple act of falling. NASA calls the condition produced by falling microgravity.

You can get an idea of how microgravity is created by looking at the diagram below. Imagine riding in an elevator to the top floor of a very tall building. At the top, the cables supporting the car break, causing the car and you to fall to the ground. (In this example,

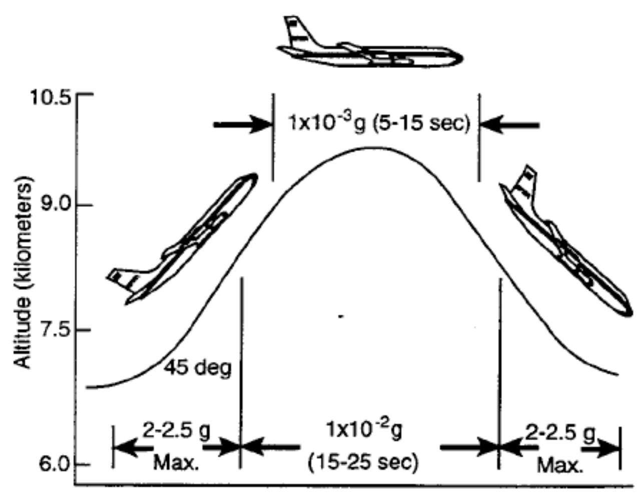


The person in the stationary elevator car experiences normal weight. In the car immediately to the right, weight increases slightly in the next car because of the downward acceleration. No weight is measured in the last car on the right because of freefall.

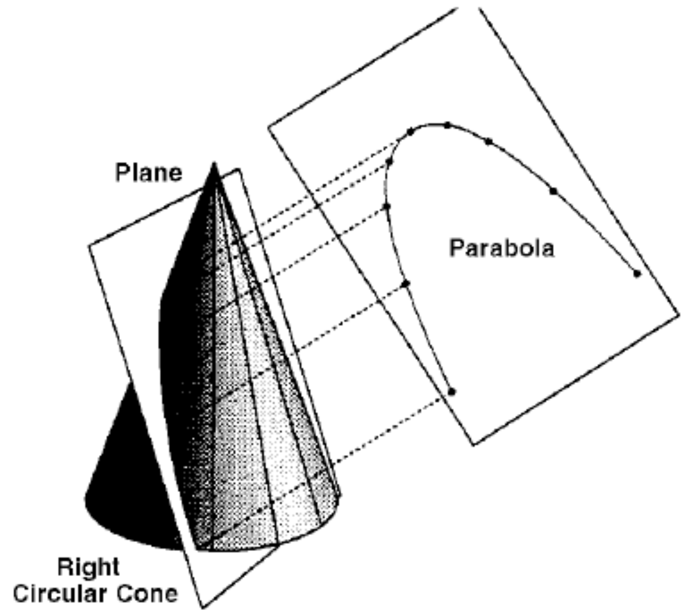
we discount the effects of air friction on the falling car.) Since you and the elevator car are falling together, you feel like you are floating inside the car. In other words, you and the elevator car are accelerating downward at the same rate due to gravity alone. If a scale were present, your weight would not register because the scale would be falling too. The ride is lots of fun until you get to the bottom.

NASA uses several different strategies for conducting microgravity research. Each strategy serves a different purpose and produces a microgravity environment with different qualities. One of the simplest strategies is the use of drop towers. A drop tower is like a high-tech elevator shaft. A small experiment package is suspended from a latch at the top. The package contains the experiment, television or movie cameras, and a radio or wire to transmit data during the test. For some drop towers, when the test is ready, air from the shaft is pumped out so the package will fall more smoothly. The cameras, recording equipment, and data transmitter are turned on as a short countdown commences. When T minus zero is reached, the package is dropped.

NASA has several drop tower facilities including the 145 meter drop tower at the NASA Lewis Research Center in Cleveland, Ohio. The shaft is 6.1 meters in diameter and packages fall 132 meters down to a catch basin near the shaft's bottom. For 5.2 seconds, the experiment experiences a microgravity environment that is about equal to one one-hundred-thousandth (lx10-5) of the force of gravity experienced when the package is at rest. If a longer period of microgravity is needed, NASA uses a specially equipped jet airplane for the job. Most of the plane's seats have been removed and the wall, floor, and ceiling are covered with thick padding similar to tumbling mats.



For the first few seconds of the pull up, the experiments and experimenters onboard the airplane feel a gravity force of about two times normal. During the upper portion of the parabola, microgravity is produced that ranges from one onehundredth to one one-thousandth of a g. During the pull out, the gravity force again reaches about two times normal.

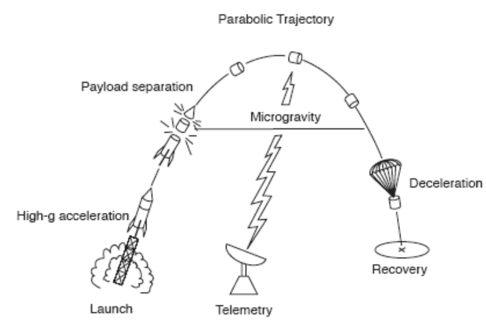


A parabola is the mathematical shape you get if you slice a cone in the way shown in the picture.

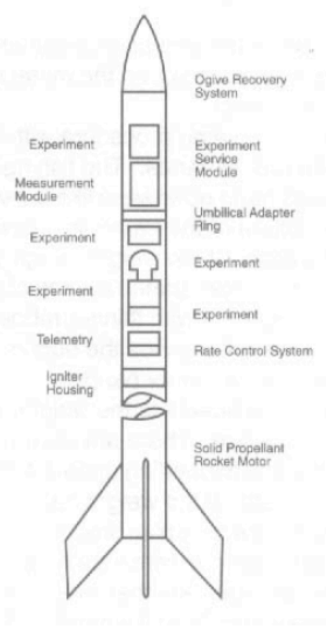
One of the advantages of using an airplane to do microgravity research is that experimenters can ride along with their experiments. A typical flight lasts 2 to 3 hours and carries experiments and crew members to a beginning altitude about 7 kilometers above sea level. The plane climbs rapidly at a 45-degree angle (pull up) and follows a path called a parabola. At about 10 kilometers high, the plane starts descending at a 45-degree angle back down to 7 kilometers where it levels out (pull out).

During the pull up and pull out segments, crew and experiments experience a force of between 2 g and 2.5 g. The microgravity experienced on the flight ranges between one one-hundredth and one one-thousandth of a g. On a typical flight, 40 parabolic trajectories are flown. The gut-wrenching sensations produced on the flight have earned the plane the nickname of “Vomit Comet.”

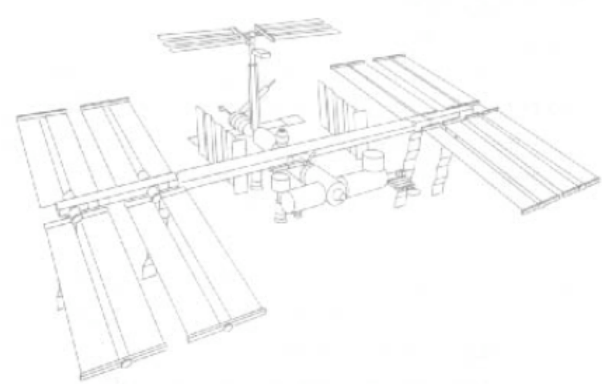
Small rockets provide a third technology for creating microgravity. A sounding rocket follows a parabolic path that reaches an altitude hundreds of kilometers above Earth before falling back. The experiments onboard experience several minutes of freefall. The microgravity environment produced is about equal to that produced onboard falling packages in drop towers. Although airplanes, drop facilities, and small rockets can be used to establish a microgravity environment, all of these laboratories share a common problem. After a few seconds or minutes of low-g, Earth gets in the way and the freefall stops. When longer term experiments (days, weeks, months, and years) are needed, it is necessary to travel into space and orbit Earth. We will learn more about this later.



Microgravity begins when the rocket arrives above Earth's atmosphere and the payload section is released. Microgravity ends when the payload falls back into the atmosphere and begins feeling atmospheric drag.



Typical design of a sounding rocket used for microgravity research.



The Toy Experiments were completed on the ISS by the Expedition 5 crew.

Investigator: ______________________

Hardware / Toy: ______________________

Student Investigation: Toys in Space

1. How does the toy or game work?

2. Observations, data, and results from toy performance on Earth (1-g) and what forces have an impact on your toys performance; and how does gravity impact the use of the toy or game?

3. Make a Prediction: Do you think the toy or game work in space on the International Space Station; and why or why not?

4. Would you change anything (hardware or how you play with the toys) to make the toys work in microgravity?

<u>Complete after seeing results with NASA</u>

5. What were the results of your toy in microgravity?

6. Is there anything you would change after seeing your results?

7. Based on what you learned from your experiment and the Expedition 5 experiments; Do you believe the results would be the same if the experiment were conducted on the Moon or Mars; and why?

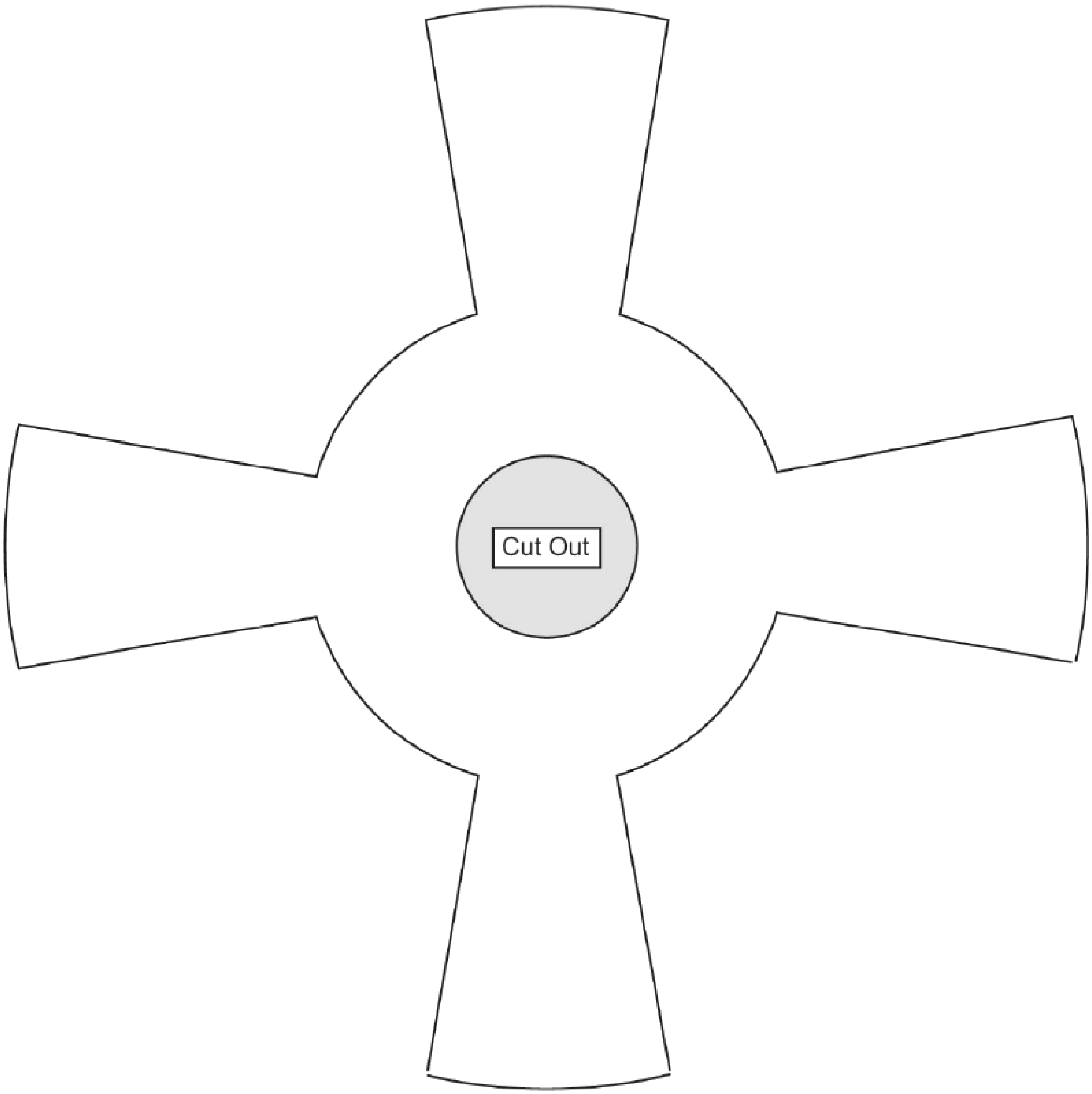
Investigator: ______________________

Design Modification:

Hardware / Toy: ______________________

Modification Description:

Paper Boomerang
Use Cardstock Paper



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 – The rate of change in velocity. Action Force – A force exerted on an object.

Air Resistance – The force of the air pushing against a moving object.

Amplitude – The distance that a moving wave rises or falls above or below its rest position.

Angular Momentum – 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 of the right hand point in the direction of the rotation, the direction of the angular momentum is that of the outstretched thumb.

Center of Mass – The point at which the entire mass of an object is centered.

Centrifugal Force – The apparent outward force exerted by an object moving in a circle. In reality, the object is simply trying to move in a straight line.

Centripetal Force – The inward force which causes an object to turn.

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.

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 quantity and the momenta of objects must be added vectorally.

Energy – 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 – A push or pull.

Free-fall – The condition of an object falling in a gravity field.

Friction – 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.

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 – 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.

Inertia – The property by which an object tends to resist any change in its motion.

Kinetic Energy – The energy possessed by an object because of its motion.

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.

Mass – 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 – The product of an object's mass times its velocity. Momentum is a conserved quantity within a closed system.

Momentum = mass x 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 x acceleration

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.

Potential Energy – 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.

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

Speed – The rate of change of an object's position with time.

Velocity – The speed and direction of an object's motion.

Weight – The magnitude of a gravitational pull.