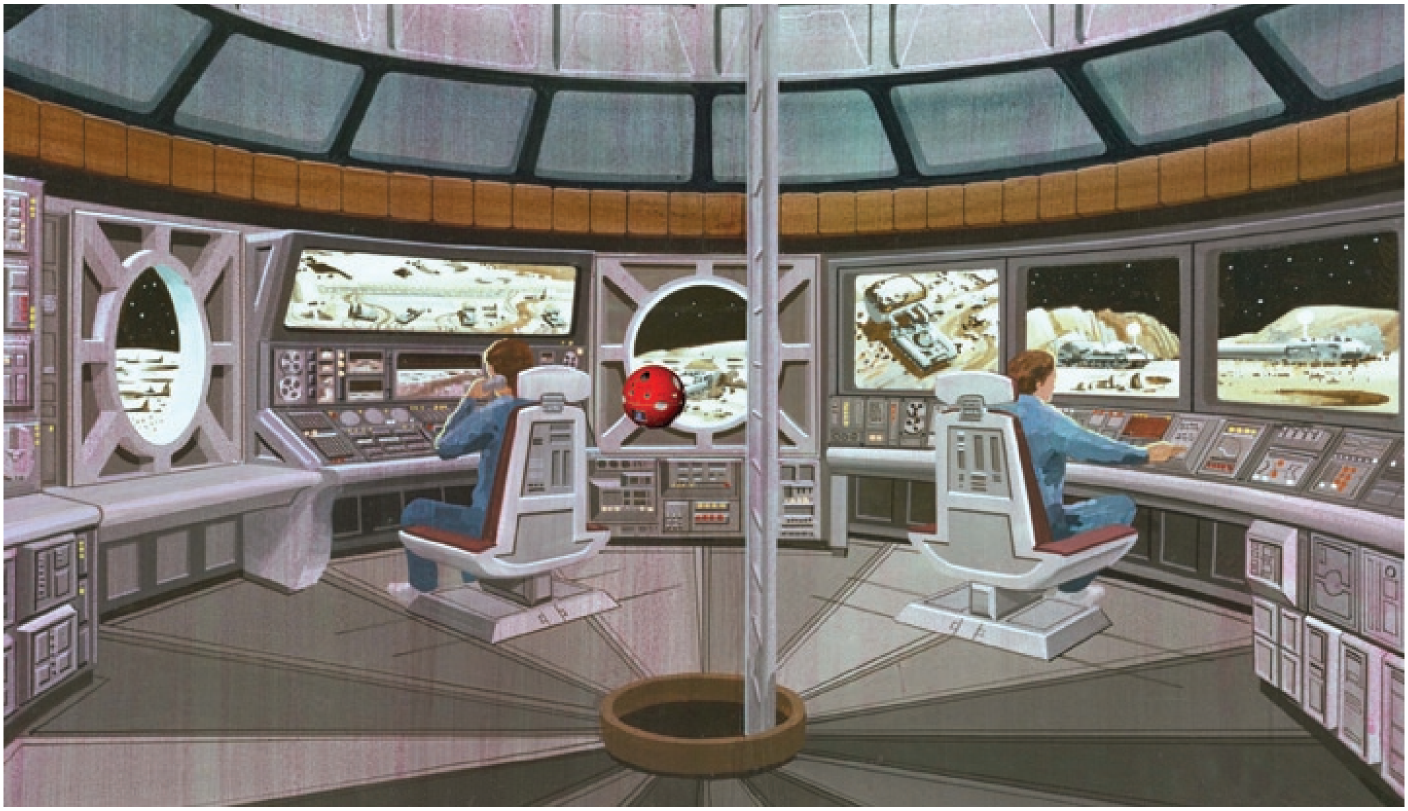


Lunar Colony Interior
Artist Concept

Abstract of Lesson

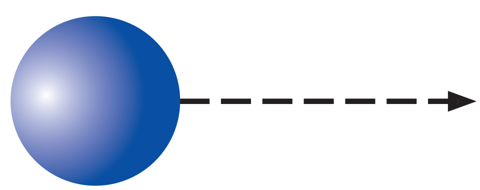
Students use the inquiry process to explore the effect of an object's mass on its motion. They build and operate a CD Glider to simulate motion in a frictionless environment and predict the motion of the Personal Satellite Assistant (PSA) with varying mass onboard the test environment of the International Space Station (ISS).

Introduction

Students explore the relationship between force, mass, and acceleration. They discover that mass affects the motion of different sized Personal Satellite Assistant (PSA) prototypes, and determine why the smaller PSA is preferred.

Main Concept

For any given force, mass affects the speed and direction of an object in microgravity.



M Major Concepts

- The more massive an object is, the less effect a given force will have.
- A more massive object can be more dangerous when it is in motion, because it can cause more damage when it hits something.
- A greater force requires more power. Therefore, an object of less mass requires less power to move it. Likewise, a more massive object requires more power to move it.
- Engineers often must give up one characteristic of their technology in order to gain another feature or characteristic that they determine is more important. This is called a trade-off.

Prerequisite Concepts	Links To Lessons Or Resources That Address Concepts
• Objects move differently on Earth than they do in space because of the effects of gravity and friction. • Objects move in many different ways, such as straight, zigzag, round and round, back and forth, fast and slow. (2061: 4F (K-2) #1) • The way to change how something is moving is to give it a push or a pull. (2061: 4F (K-2) #2)	Forces and Motion, PSA Lesson 1: Identifying Forces on Earth and in Space http://whyfiles.larc.nasa.gov/text/kids/D_Lab/activities/expressions_motion.html http://whyfiles.larc.nasa.gov/text/educators/activities/2002_2003/inclass/sticky_friction.html http://spaceplace.nasa.gov/en/kids/ds1_mgr.shtml Non-atmospheric Flight 5 – 8 Grade Reading http://quest.nasa.gov/aero/planetary/nonatmosphere/nonatmos5-8read.html ISS: A Home in Microgravity http://quest.nasa.gov/projects/space/iss2001/index.html
Objectives	**Education Standards/Benchmarks**
1. Students will design an experiment to determine how mass affects the motion of an object in a frictionless environment. 2. Students will write a letter to NASA recommending a more massive or less massive PSA with an explanation of their reasoning, including how mass affects forces on an object. 3. Students will explain how forces and motion apply to sports and games.	Meets: ISTE 3, 5 Partially Meets: NSES: B (5-8) #2.2, #2.3 2061: 4F (3-5) #1

Additional Links and Resources	
Astronauts outside and inside Skylab, America's first space station	http://spaceflight.nasa.gov/gallery/video/skylab/skylab2/mpg/skylab2_mission1.mpg
Showering in Skylab	http://grin.hq.nasa.gov/IMAGES/SMALL/GPN-2000-001710.jpg
Dentist appointment in Skylab	http://images.jsc.nasa.gov/luceneweb/fullimage.jsp?photoId=SL2-02-157
Weightlifting in Skylab	http://grin.hq.nasa.gov/IMAGES/SMALL/GPN-2000-001946.jpg
APOLLO 8: It's Christmas in zero gravity...	http://lisar.larc.nasa.gov/UTILS/info.cgi?id=LV-1998-00027
APOLLO 11: Buzz Aldrin in Lunar Module "Eagle"	http://www.hq.nasa.gov/alsj/a11/BuzzInEagle.mov
APOLLO 11: Landing the Eagle	http://lisar.larc.nasa.gov/UTILS/info.cgi?id=LV-1998-00035
APOLLO 11: "One Small Step..."	http://lisar.larc.nasa.gov/UTILS/info.cgi?id=LV-1999-00001
APOLLO 12: "Pete" Conrad collects samples	http://lisar.larc.nasa.gov/UTILS/info.cgi?id=LV-1998-00038
APOLLO 15 Galileo's Gravity Experiment	http://lisar.larc.nasa.gov/UTILS/info.cgi?id=LV-1998-00046
APOLLO 16: One for the Album	http://lisar.larc.nasa.gov/UTILS/info.cgi?id=LV-1998-00048
APOLLO 17: Skipping on the moon	http://lisar.larc.nasa.gov/UTILS/info.cgi?id=LV-1998-00053

S Suggested Timeline

Prior to this lesson, build several CD Gliders (directions provided at the back of this lesson). Depending on time constraints, these gliders can either be used for the experiment by the students, or will serve as examples if students are building the gliders themselves.

Estimated time for lesson: 90 –120 minutes

Materials and Equipment

- Chart paper
- 2 sealed plastic containers, one full of air and the other filled with water (1-liter plastic bottles work well) OR
- A ping pong ball and a golf ball, or a water balloon and an air balloon
- A pile of sand or flour (for the demonstration)
- Copies of the Student Handout, one per student or group of students
- Copies of "Directions for Building and Using the CD Gliders," one per group
- 1 straw per student
- 2 meter sticks per group
- 1 CD per group of 3-4 students
- Tape for each group
- Hot glue gun, instant glue, or modeling glue for each group
- 1 water bottle top with valve per group
- Balloons (long or round) for each group
- 1 3x5 index card per group
- 1 small square of transparency film (1 to 2 square inches)
- 1 balloon pump per group (optional)
- Tables that are flat, smooth, and clean
- Small flat objects such as coins, paper clips, or extra CDs to add mass to the CD Glider
- Pictures of the different PSA prototypes (see http://psa.arc.nasa.gov/hist.shtml)
- Pictures and videos of the International Space Station (images can be found at the following Web sites):
  - NASA Human Space Flight Space Station Gallery http://spaceflight.nasa.gov/gallery/images/station/
  - Kennedy Space Center ISS Payload Processing Directorate http://www-ss.ksc.nasa.gov/
  - NASA Human Space Flight International Space Station http://spaceflight.nasa.gov/station/
- Computer with Internet connection (see table, next page) to link to http://psa.arc.nasa.gov/

S System Requirements to Run PSA Web Site Activities

Platform	Browser
Windows 95 Windows 98 Windows Me	Internet Explorer 4.0 or later (Internet Explorer 5.0 or later is recommended), Netscape Navigator 4 or later, Netscape 7.0 or later (Netscape 6 is not recommended) JavaScript enabled
Windows NT Windows 2000 Windows XP or later	Internet Explorer 4.0 or later, Netscape Navigator 4 or later, Netscape 7.0 or later, with standard install defaults (Netscape 6 is not recommended) JavaScript enabled
Macintosh: 8.6 thru 9.2	Netscape 4.5 or later (Netscape Communicator 4.7 or Netscape 7.0 are recommended), Netscape 7.0 or later, (Netscape 6 is not recommended) Microsoft Internet Explorer 5.0 or later JavaScript enabled
Macintosh OS X 10.1 or later	Netscape 7.0 or later (Netscape 6 is not recommended), Microsoft Internet Explorer 5.1 or later JavaScript enabled
Browser plug-ins	Flash Player 6 or higher QuickTime Player 6 or higher RealPlayer 8 or higher, or RealOne Player (for Mac OS X)

P Preparation

- Gather the materials for the lesson (e.g., glue guns, CDs, bottle tops, balloons, index cards, transparency squares, balloon pump, meter sticks).
- Make copies of the Student Handout and the directions for the CD Glider.
- Post pictures of the International Space Station (ISS) and different Personal Satellite Assistant (PSA) prototypes.
- Set up the computer with Internet link to http://psa.arc.nasa.gov/.
- Prepare the chart paper with the major concepts of the lesson to post at the end of the lesson.

LESSON Engage

1. Review how objects move.

- ☐ Question: How do objects at rest begin to move?
- ■ *Answer: They need a force (a push or a pull) to get moving.*

- ☐ Question: How can you make an object move?
- ■ *Answer: We could apply a force to an object to make it move.*

- ☐ Question: How can you change the speed or direction of an object?
- ■ *Answer: You can apply a greater force to it, apply a force in another direction, or block its path.*

- ☐ Question: What effect does gravity have on objects in motion?
- ■ *Answer: Gravity pulls objects down and gives them weight. Gravity pulls objects down in constant contact with the surface of the Earth, resulting in rubbing or friction.*

- ☐ Question: How do frictional forces affect movement?
- ■ *Answer: Friction causes objects to slow down and stop.*

- ☐ Question: What affect does microgravity have on objects in motion?
- ■ *Answer: Microgravity is a nearly frictionless environment that causes objects in motion to move at a nearly constant rate until a new force is applied, and makes them appear weightless.*

If the first PSA forces and motion lesson was not completed, give students some background on this robot concept. Tell students that NASA is developing a wide variety of robots to support human exploration of space. One possible concept that NASA has been exploring is a spherical robot that can move around in microgravity or in reduced gravity environments as it provides long-term support for humans. This prototyped robot is called Personal Satellite Assistant, or PSA, and could be used on a wide variety of spacecraft or even on Mars. In developing this robot, NASA would test it in a number of environments, including the International Space Station (ISS).

Tell students that NASA is trying to decide on the ideal size or mass of PSA and that they will be offering their advice. First, they are going to discuss how the mass of an object affects its motion. If necessary, review the difference between mass and weight.

2. Do the following demonstrations to introduce mass and motion.

Show students two sealed plastic containers, one full of air and the other filled with water. Have students hold both containers to get a sense of the difference in mass between the two.

> ***Note:*** *This can be done with other objects as an alternative, such as a water balloon and an air balloon or a ping-pong ball and a golf ball. However, to help overcome the misconception that more massive means larger size, try to use two objects of the same size but with different mass.*

☐ Question: What is the difference between these two containers?
■ *Answer: One is heavier than the other.*

> ***Note:*** *If students say that one is empty, ask them if there is really nothing in the bottle. Guide them to conclude that one is full of air, while the other is full of water.*

☐ Question: What causes one to be heavier?
■ *Answer: It has water in it, while the other only has air.*

Tell students that the container with water has more mass, so it is more massive. Encourage them to use this term as they go through the activities in the lesson.

☐ Question: Which container would you rather have fall on your head? Why?
■ *Answer: The one full of air would be preferable, because it has less mass and wouldn't hurt as much.*

☐ Question: Which container will require a greater force to move?
■ *Answer: The container full of water will require a greater force, because it is much more massive.*

To demonstrate this concept, select one student volunteer from the class. Have the students stand outside in a clear open space with nothing breakable nearby and all students behind the thrower. Instruct the student to throw the container with air across the open space. Then, ask the student to throw the container full of water. Ask the volunteer which container required a greater force to throw. Multiple students can carry out this activity if necessary.

Alternatively, you can have students do a pinky test to determine which container is easier to move using the same force. Have students place one pinky on each container and apply an equal force to each bottle to determine which one is easier to move.

☐ Question: Why was it more difficult to throw or move the full container?
■ *Answer: The full container had more mass, so it required greater force to move.*

- ☐ Question: If we were in microgravity, would it still be easier to move the container full of air than the container full of water?
- ■ *Answer: Yes, because it is the mass of an object — not its weight — that determines how easy it is to move.*

Do a similar demonstration, in which students drop a full container into a pile of sand or flour and compare it to an empty container dropped from the same height.

- ☐ Question: What is the difference between the impact of the more massive container and the less massive container?
- ■ *Answer: The more massive container made a larger impact than the less massive container.*

- ☐ Question: So what does this mean about more massive objects when they are moving?
- ■ *Answer: They can be more dangerous or destructive when they hit something.*

3. Introduce the scientific question and purpose of the lesson as follows.

Tell students that they will be thinking about mass while coming up with solutions to a challenge NASA needs help with:

NASA engineers are trying to decide on the ideal size for the PSA. They need your help in identifying the advantages and disadvantages of different sizes. Make a recommendation on whether to build a fully packed 30.5 cm (12-inch) diameter PSA or a fully packed 20 cm (8-inch) diameter PSA.

Tell students that the scientific question they will be exploring in answering this question is: How does mass affect the speed and motion of an object in microgravity?

Ask students to hypothesize how mass affects the motion of objects. Allow students to discuss their ideas about this, but don't give them the answer.

Explore

1. Have students conduct the Station 1, 2, and 3 activities.

Arrange students into groups of three or four, and divide the groups among three stations. Distribute the Student Handout sheets. Also distribute the Instructions for Building a CD Glider if students will be constructing the gliders themselves.

STATION #1: COMPARING CD GLIDERS OF DIFFERENT MASSES

Preparation:

- Provide each student with a CD Glider or provide them with supplies (CDs, balloons, glue, water bottle tops) and have them construct one for each group.
- Distribute coins, extra CDs, or other small, flat objects. Pass out chart paper and straws.

☐ Question: If you make the CD Glider more massive, how do you think its motion will change?

Tell students to record their hypotheses on their worksheets.

Ask students to design an experiment to test their hypotheses. Students may use any of the materials provided to them in order to determine whether or not their hypotheses are correct.

> ***Note:*** *Be sure to discuss with students the importance of having everything exactly the same in both the control and variable in their experiment, except for the item that is being tested. This includes applying the same force to each CD Glider, which will be difficult to do but is something they should strive for. One way to do this is to have them flick the CD Gliders, by placing their index finger behind their thumb, and then flick the index finger out from the thumb. Another way is to use straws to blow the CD Gliders. By blowing the gliders, they will really experience that the more massive CD Gliders are more difficult to move. Also, it helps to have the same student applying the force each time.*

> Optional Extension: Because the application of the force is such an important variable, you might challenge students to design a flicker that will always apply the same force to the CDs.

Have students set up their experiments and record the materials and procedures on their worksheets.

Each student should prepare a CD Glider to test his or her hypothesis, or use a previously made CD Glider.

Explain that the CD Glider will ride on a thin cushion of air (from the balloon) in a similar way that an air hockey puck glides across the table with little friction.

> ***CAUTION:*** *Make sure that students who inflate the balloons are not allergic to latex. If they are allergic, use a balloon pump.*

Tell students to note any differences and record the motion with drawings, words, or tables in the way they think is appropriate.

Have the students compare the most massive CD Glider to the least massive one, and record the motion. Ask students to keep adding mass to their most massive gliders until they barely float. Have students compare the motion of the barely floating gliders versus the least massive gliders. In order to measure the difference in motion, students may want to construct a track by taping down two meter sticks a little more than one CD-width apart.

Tell students to note any differences and record the motion with drawings, words, or tables in the way they think is appropriate.

STATION #2: VIDEO CLIPS ON FORCES AND MOTION

1. Instruct students to watch the forces and motion video clips.

Show the following online video clips. In their Student Handout, ask students to take notes of what they see and to pay attention to how rockets of different masses take off.

Apollo 11 liftoff
http://heasarc.gsfc.nasa.gov/Videos/historical/saturn5.mov

Space Shuttle liftoff
http://spaceflight.nasa.gov/gallery/video/shuttle/sts-upgrades/mpg/up_srbign.mpg
http://spaceflight.nasa.gov/gallery/video/shuttle/sts-97/real28/sts97launch_28.rm
http://spaceflight.nasa.gov/gallery/video/shuttle/sts-92/real28/sts92launch_28.rm

Mars Explorer liftoff
http://realserver1.jpl.nasa.gov:8080/ramgen/070703-MER-B-Launch.rm

STATION #3: COMPARING PSAs OF DIFFERENT MASSES

1. Have students compare PSAs of different masses.

> *Note: In observing the use of these activities in classrooms, we observed that students found the two-dimensional activities to be challenging. While the boys appeared to be intrigued, the girls appeared to be intimidated. We suggest discussing with students the value of experimenting and learning from mistakes and enforcing a safe environment that doesn't punish failures but asks what can be learned from them. Provide encouragement for girls and encourage them to discuss with a partner what is working and not working and why or why not. Assure them that because things move differently in microgravity than what we are used to on Earth, NASA scientists are also surprised by how things behave in this environment.*

Go to the "Activities" section of the PSA Education Web site http://psa.arc.nasa.gov/

Have students click "Activities" to go to http://psa.arc.nasa.gov/acti.shtml and observe how the PSA will move in the test environment of the ISS. Ask students to complete the following Forces and Motion activities:

1. *Introductory video* (if this is their first introduction to the PSA)
2. *Experiment 2: How does a PSA with more mass move differently than a PSA with less mass?*
3. *Your Mission: video file* (introduces the purpose of the mission activities)
4. *Your Mission:* Have students compare the first Missions on the Web site ("Part 1" and "Part 2") with the last two Missions on the site ("Part 3" and "Part 4"). Students may play either the Easy or Hard versions of these missions.
5. *Key Ideas:* Encourage students to review the descriptions and video clips in this section once they have done Experiment 2 to better understand how mass affects motion. In particular, they may want to review the last section.

In their Student Handout, ask students to compare how easy or hard it is to move PSAs of different masses and to consider how mass might constrain the design of a PSA.

Explain

1. Discuss observations and conclusions from the CD Glider experiment.

Have students share their findings and describe the results of their glider comparisons.

- ☐ Question: How does the motion of the CD Glider with no added mass compare with the motion of the gliders with extra mass?
- ■ *Answer: The gliders with extra mass moved more slowly and less readily than the original CD Glider.*

2. Discuss observations and conclusions from video clip observations.

- ☐ Question: What differences did you notice between the launches?
- ■ *Answer: Answers vary, but should include an observation of the different sizes or masses of rockets and different speeds of lift off.*

Show JPL video clip Blowing in the Wind on Mars
http://www.jpl.nasa.gov/technology/features/tumbleweed.html

(Direct link to video is:
http://realserver1.jpl.nasa.gov:8080/ramgen/Video-Tumbleweed-010810.rm?mode=compact)

3. Discuss observations and conclusions from the online PSA experiment.

- ☐ Question: How does a more massive PSA move in comparison with a less massive PSA?
- ■ *Answer: For a same amount of force, a more massive PSA moves more slowly.*

- ☐ Question: So, if you want a large PSA to move at the same speed as a small PSA, what do you have to do?
- ■ *Answer: You have to apply more force to the larger PSA.*

- ☐ Question: Was the big or small PSA easier to move around ISS?
- ■ *Answer: The small PSA was easier to move.*

- ☐ Question: Why might it be useful or necessary have a PSA with more mass?
- ■ *Answer: A more massive PSA is likely to have more features that will allow it to carry out more tasks.*

- ☐ Question: What are some of the drawbacks of having a PSA with more mass?
- ■ *Answer: A PSA with more mass requires more power to move it. It also can cause more damage when it runs into things. (To bring out the second conclusion, remind students how the impact of the full container compared to the empty container when they were dropped in the sand or flour).*

☐ Question: What does this mean for NASA engineers designing the real PSA?
■ *Answer: NASA engineers must carefully consider the advantages and disadvantages of added mass. More massive robots are more difficult to move and to stop from moving. So, they will require more power than a light robot.*

Tell students that when engineers have to give up something to gain something else, that is called a trade-off. Discuss other examples of trade-offs, such as saving money for cheaper parts that may not be as small or strong, or giving up good gas mileage to have a larger vehicle.

Have students write a letter to NASA with their recommended solution to the NASA challenge introduced at the beginning. They should include a description of the PSA's motion and how mass will be affected:

NASA engineers are trying to decide on the ideal size of the PSA. They need your help in identifying the advantages and disadvantages of different sizes. Make a recommendation on whether or not to build a fully packed 30.5 cm (12-inch) diameter PSA or a fully packed 20 cm (8-inch) diameter PSA.

Extend

1. Discuss familiar instances when force and mass are important and how these examples may be different in microgravity.

Have students consider other objects with similar size and shape, but varying masses, such as sports balls, cars, and bicycles.

☐ Question: What games or sports rely on differences in mass or force? Explain how each uses a difference in mass or force.
■ *Answer: Answers may include tug of war, crack the whip, marbles, football, etc.*

Make a list of all the students' ideas on the board. Ask students to pick two of the games or sports listed and write a description of how the games/sports would be different in microgravity. These descriptions should include descriptions of how motion and forces would be different in microgravity and how mass would affect motion in microgravity. Have students make a list of how the sports would be similar and different in microgravity, and ask students to assess whether or not changes would need to be made to the game/sport for it to be possible to play.

Evaluate

1. As a class, create an assessment rubric for this activity.

Suggested criteria for the rubric include:

- Reasonable assessment of how mass affects the motion of the CD Glider.
- Reasonable assessment of how mass affects rocket launches.
- Reasonable assessment of how mass affects the motion of the PSA onboard the International Space Station.
- Clear reasoning of the advantages and disadvantages of increasing the mass of the PSA.
- Clear oral reasoning as to how different sports on Earth would change in a microgravity environment.
- Clear written presentation of results.
- Clear oral presentation of results.
- Clear explanation of constraints taken into consideration.

Use the rubric to assess students' recommendations to NASA on the PSA's size to make sure they've mastered the major concepts. Also assess students' ability to apply the main concepts to a game or sport.

Consider using chart paper to post the main concepts of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the "conceptual flow" and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Student Handout

STATION #1: COMPARING CD GLIDERS OF DIFFERENT MASSES

1. HYPOTHESIS: If you make a CD Glider more massive, how do you think its motion will change?

2. Design an experiment to determine how the motion of a glider will change as it becomes more massive. You may use any of the materials provided in class. In the space below, list what MATERIALS you will use in your experiment and provide a step-by-step PROCEDURE.

MATERIALS

PROCEDURE

3. In the space below, provide the results of your experiment. Be sure to provide pictures, graphs, numbers, and tables to decide if your hypothesis was correct.

STATION #2: VIDEO CLIPS ABOUT FORCES AND MOTION

1. In the video clips, what differences did you notice between the launches of less massive rockets compared with more massive rockets?

2. What would cause this?

STATION #3: COMPARING PSAs OF DIFFERENT MASSES

1. How does adding more mass to the PSA affect its motion?

2. How might this change the design of the PSA?

3. What are some advantages to having a more massive PSA?

4. What are some disadvantages to having a more massive PSA?

Teacher Handout (Answer Key)

Instructions on how to build a CD Glider are provided at the end of this lesson.

STATION #1: COMPARING CD GLIDERS OF DIFFERENT MASSES

As mass is added to the CD Glider, it will become more and more difficult to move. It will travel shorter distances, and eventually will not be able to lift itself off the ground.

STATION #2: VIDEO CLIPS ABOUT FORCES AND MOTION

Rockets with more mass appeared to take off slower and need more fuel in order to lift off. This is because it takes more force to move more massive objects.

STATION #3: COMPARING PSA'S OF DIFFERENT MASSES

Adding more mass to the PSA will slow it down substantially. It will also make it more difficult to start and stop and will be more harmful if it runs into someone or something. For NASA engineers, the ability to initiate and cease motion is a crucial design consideration that places limits on the size of the PSA, as well as its ability to carry instrumentation. Of course, a more massive PSA will probably be more resistant to breakage than a less massive PSA. Plus, a more massive PSA is more likely to carry useful equipment.

Sample Scoring Tool

4

Calculations are correct and clearly presented.
The CD Glider experiment is reasonable and is likely to prove or disprove the student's hypothesis.
Appropriate data are collected from the experiment to prove or disprove the student's hypothesis.
Reasoning is logical and clear explanations are provided for the advantages and disadvantages of having a more massive PSA.
Oral and written presentations are clear.

3

Most calculations are correct and attempts are made to present clearly.
The CD Glider experiment demonstrates a reasonable thought process and may prove or disprove the student's hypothesis.
Appropriate data are collected from the experiment to prove or disprove the student's hypothesis.
Attempts are made to reason logically and clear explanations are provided for the advantages and disadvantages of having a more massive PSA.
Attempts are made to provide clear oral and written presentations.

2

Some calculations are correct and attempts moderately clear.
The CD Glider experiment demonstrates a reasonable thought process and may prove or disprove the student's hypothesis.
Data collected from the experiment do not prove or disprove the student's hypothesis.
Explanations demonstrate limited logical bases for assessing the advantages and disadvantages of having a more massive PSA.
Oral and written presentation skills need improvement.

1

Few calculations are correct and attempts are unclear.
The CD Glider experiment does not prove or disprove the student's hypothesis.
Data collected from the experiment do not prove or disprove the student's hypothesis.
Explanations do not demonstrate adequate knowledge of the lesson content.
Oral and written presentations do not effectively express results or reasoning.

Instructions for Building and Using a CD Glider

Have you ever wondered what to do with all those free CDs you get in the mail? Wonder no more—you're going to learn how to simulate being in space!

If you've played air hockey, you know that the puck rides on a thin cushion of air just above the table, allowing it to travel with virtually no friction. We're going to use the same effect to make a CD glide across a table.

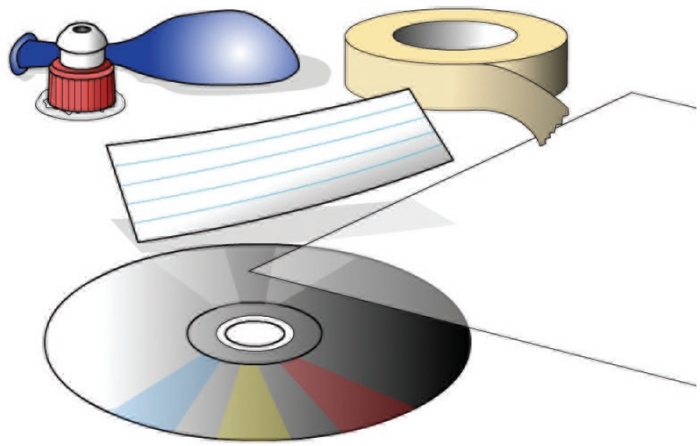
Materials

- Hot glue gun, instant glue or modeling glue
- 1 water bottle top with a valve—you can get these at the grocery store (sports bottles). Try to get one with a large valve stem; they control airflow better.
- 1 CD, without any nicks or scratches
- Balloons, either round or long
- 1 balloon pump per group (optional)
- 1 3x5 index card per group
- 1 small square of transparency film (1 to 2 square inches)
- Tape

Directions

1. If you are using a glue gun, plug it in and let it warm up.
2. Twist off the top from the water bottle and put the bottle aside—you can drink the water while you work, if you want.
3. Cut transparency film into a circle that fits between the bottle top and the CD. Poke a hole in the middle of the film about the size of a pencil tip. This will allow the air in the balloon to release more slowly.
4. Turn the CD so that the label is facing up and the silvery side with no label is facing down.
5. Draw a line of glue around the edge of the transparency piece. Glue the transparency piece onto the label side of the CD, covering the CD hole. Make sure the transparency hole is in the middle of the CD hole. Don't use so much glue that it is dripping. Make sure the glue does not go though the CD hole to the other side of the CD. This will prevent the CD from gliding properly.
6. Draw a line of glue around the bottom of the bottle top: it should be a thick bead going all the way around. If you are using a glue gun, you will need to do this quickly; neatness does not matter, but don't use so much glue that it is dripping.
7. Before the glue begins to set, place the bottle top on top of the transparency piece over the center hole of the CD and press together. Don't worry about getting the bottle top exactly in the middle; as long as the CD hole is covered by the bottle top, you're OK. The bottle top should be attached to the label side of the CD.
8. After letting the glue set, draw another bead around the joint between the bottle top and the CD. Let all the glue dry.
9. Make a collar out of a 3x5 index card by cutting it in half lengthwise and rolling it so that the diameter roughly matches the bottle top nozzle and it has a height of 1 1/2 inches. This will provide support for the balloon so that it will not fall over as it deflates. Start by threading the balloon through the collar, then inflate, and finally twist the balloon closed and attach to the bottle top.

How to Use:

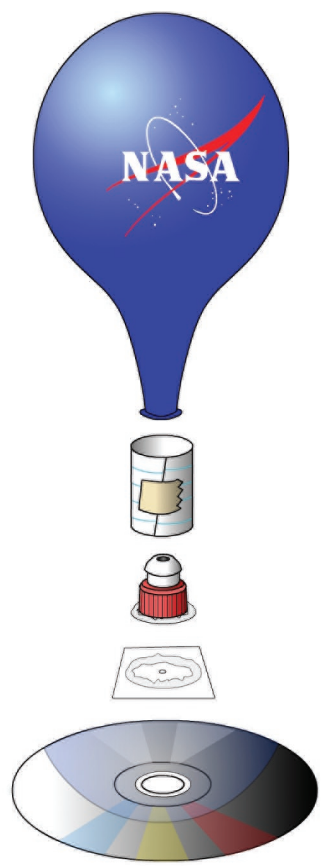


1. Make sure the valve of the bottle top is closed.
2. Inflate a balloon and twist the bottom, then pull the balloon over the valve. If your valve is shut, you can release the balloon without losing any air.

> ***Note:*** *To attach the inflated balloon, it might be helpful to have one person hold the balloon closed while another puts the balloon over the bottle top to prevent air from escaping.*

3. Carefully pull the valve up until you hear a hiss of air.
4. Place the CD Glider, silvery side down, on a flat, smooth surface
5. Work in pairs for glider "launch" so that one student holds the balloon in the ready position and releases the bottle top and the second student is responsible for blowing the CD with a straw.

Have fun!



Troubleshooting

- *The CD Glider drifts to one side all the time.*
  - Is the table level?
  - Does the joint between the CD and bottle top have any holes or gaps?
- *The CD Glider doesn't glide very far.*
  - Did you open the valve just enough to hear air hiss out?
  - Did you glue the bottle top on the silvery side with no printing?
  - Does the printed side have large scratches or cuts, or excess glue?
- *The balloon flops over and drags on the table.*
  - Try bracing it with tape or a paper cylinder. Be creative!