I Do the Shimmy When I Fly Through the Air Part One

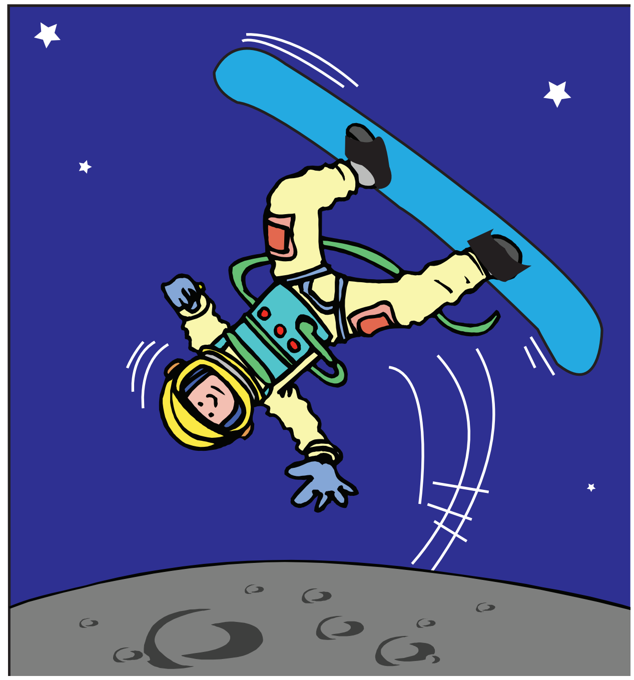
Pre-game Talk Show

How do they do that? If you watched the snowboarders run the half-pipe during the Winter Olympics, you probably want to know. The killer aerials performed on the half-pipe are amazing. (Oops! Just said something twice: "killer" = amazing, "aerial" = a cool trick in the air.) Like every sport, snowboarders have their own slang to describe everything from their gear to their aerials to their crashes ("yard sale" is a snowboarder's gear, hats and/or gloves that end up scattered on the slope).

When you listen to TV commentators describing the performances, you hear lots of oohs and aahs and remarks about artistry in the air. True, there is artistry, but the real secret of snowboarding is science!

Snowboarding has a lot in common with other sports. In fact, snowboards were inspired by skateboards, surfboards, and skis. These three sports depend upon reducing friction (science). Like skis, snowboards ride the low-friction snowy slopes. Like surfing, snowboards are made of a single board, but snowboards are attached to the feet with ski bindings. Like skateboarders, snowboarders can perform killer aerials (nollies, doublechuks, fakies, rocket airs, McTwists, tame dogs, misty flips, etc.) using a U-shaped snow structure called a half-pipe similar to that found in a skateboard park.

Catching some serious air, this snowboarder has gained enough momentum to perform some killer tricks!

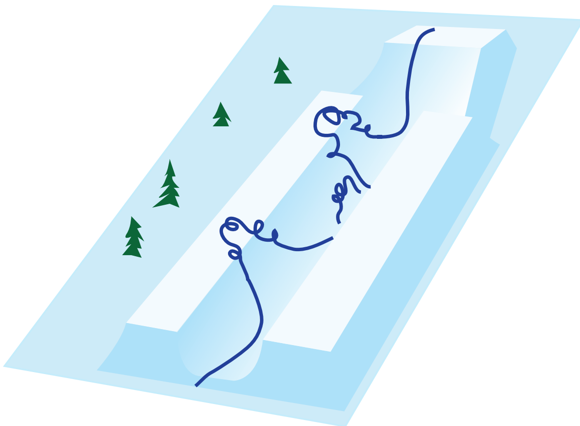


A half-pipe is a wide U-shape channel with steep sides that stretches between 100 and 150 meters down a steep hill. Above the half-pipe is a small snow ledge or platform where the snowboarder sets up and creeps to the edge. Just below the platform is a drop-in ramp (steep slope) that aims and accelerates the snowboarder toward the half-pipe.

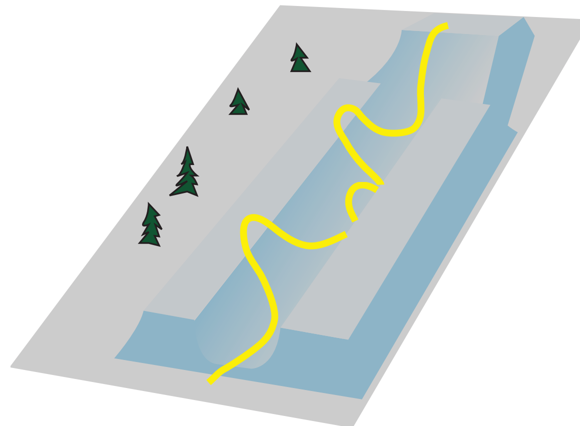
A snowboarder leaps down the ramp and shoots into the half-pipe. The energy to do so comes from gravity. Gravity causes the snowboarder to accelerate (go faster and faster). At the right moment, when enough speed has built up, the snowboarder leans to one side or another, cuts into the snow with the board edge and blasts up the half-pipe side.

The snowboarder's momentum (the product of the snowboarder's mass times velocity) sends the snowboarder airborne. That's when the fun begins. The snowboarder executes a couple of great tricks - turns, twists, flips - and then drops down the half-pipe side, to gain momentum for shooting up the other side.

Each maneuver carries the snowboarder farther down the half-pipe. Then comes the final



Daytime snowboarder showing twists and turns of the aerial path.



Nighttime snowboarder run showing center of mass path.

aerial, with the most spectacular tricks ending in a great landing with only the board touching the snow (or so that is the plan). The more difficult the aerial and the better the landing, the more points the snowboarder gets.

As you might guess, there is still more science involved in snowboarding. Gravity provides the kinetic (motion) energy and momentum enables the air time, but where do the twists and turns come from?

First, think about the actual path the snowboarder follows down the half-pipe. If we could send a snowboarder down the slope in complete darkness except for a light bulb near the snowboarder's waist, something interesting would be seen. The light streak would be a very smooth line with turns and bumps but none of the circles or loops or jags we see when the lights are on. That's because all the tricks occur around the snowboarder's center of mass (also called center of gravity).

The center of mass is the average location of all of the mass in a body. Pick up a pencil and balance it horizontally on your finger. When the pencil is balanced, its center of mass will be directly above your finger. That's the only place in the pencil that will enable it to balance horizontally. Sharpen the pencil, and the center of mass will move towards the eraser end. Less mass on the pencil tip end moves the center of mass towards the other end.

The next activity will challenge you to locate the center of mass of an object with a very unusual shape. As you will see, there's always a way to find the "Center of All Things."

Center of All Things

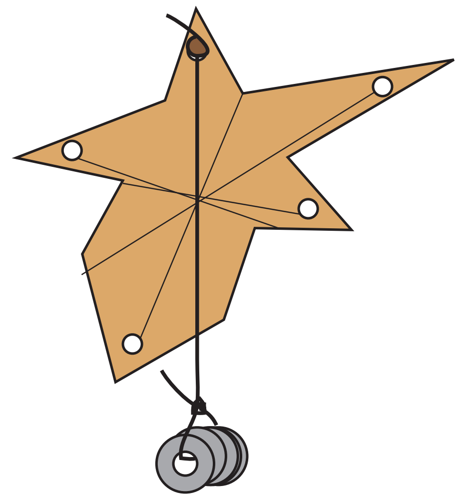
Objectives:
Students will;
- use gravity to locate the center of mass of irregular-shaped objects
- define the center of mass of an object as the average location of all of the mass contained in that object
- balance an object by supporting it under center of mass

Preparation:
Cut one cardboard shape for each team of two or three students. Follow the instructions in the procedures. Create plumb lines and bobs by tying 50-cm strings to the middle of the short sticks and tie five washers on the other end of the string.

Materials: (per team of students)
- Prepared cardboard “stars” (see procedure)
- Five metal washers (3/8 or 1/2 inch)
- Strings
- Short stick (10-cm-long piece of wooden skewer, small-diameter wood dowel, or straight drinking straws)
- Paper punch
- Student sheets

Management Tips:
Organize students into cooperative teams of two or three. Save class time by preparing plumb lines and bobs in advance. If time is available, have student teams create their own.

Procedure:
1. Cut out irregular shapes of corrugated cardboard, approximately 30-40 cm across. Use copy paper boxes or cardboard from other boxes, and make each piece look like a misshapen star. Make each star different.
2. Using the paper punch, punch one hole in the tip of each star point.



3. Tie five washers to the end of strings to make plumb lines. The washers serve as plumb bobs. (Plumb lines are strings with weights used in surveying and construction for creating a vertical line.) Tie a small loop at the other end of the string for suspending on the stick.
3. Provide teams with a star, plumb line with washer bob, and a short stick.
4. Demonstrate how to balance the star by inserting the stick through any of the holes and allowing it to hang. Gravity will cause the star to hang so that exactly half its mass hangs to one side of the stick and the other half to the other side. Suspend the bob from the stick and carefully draw a light pencil line on the cardboard along the string. Ask your students to predict what will happen if you move the stick to other holes and repeat the steps.
5. Have students follow the student sheet procedures.
6. Discuss what the student teams learned about center of mass.
7. Give students new stars and have them predict where the centers of mass are located. Then have the teams check their predictions with the plumb lines.

Assessment:

Have students fill out their student sheets and review their entries.

Check to see if student teams have correctly determined the center of mass of the stars. Ask one member of each team to balance the star on a fingertip. The fingertip should go directly beneath the intersection of the lines. If drawn accurately, the star will balance.

Hold up various objects and ask them to speculate where the center of mass for each object is. (E.g., The center of mass of a hula hoop will be in the middle of the air space surrounded by the hoop. The center of mass of an object doesn't have to be inside the object itself. Show how the hula hoop rotates around its "air" center of mass by tossing it into the air while it is spinning.)

Discussion Questions:

Do you have a center of mass? Where is it?

When standing straight, your center of mass will be along a perpendicular line stretching from the head, straight through your body to the floor. Because of differences in distribution of fat and muscles, the center of mass for boys tends to be higher along the line than the center of mass for girls.

Why is center of mass important for astronauts?

During spacewalks, an astronaut needs to move. All movement will take place around the astronaut's center of mass. If using a propulsion device like Ed White's hand-held maneuvering unit (gas gun), the gas thrust has to be in direct line with the body's center of mass (Page 31). If not, the astronaut will spin out of control. Also, remember the astronaut is wearing a bulky spacesuit that has mass too. Modern spacewalking propulsive units are usually worn around backpacks. They have multiple gas nozzles and several fire at the same time to bracket the center of mass and enable precise maneuvers.

Extensions:

- Place a heavy book on a smooth tabletop. Using just one finger, push on the book binding to move it across the table. If the book moves in a straight line, you are pushing in line with the book's center of mass. If you are pushing away from the center of mass, the book will rotate.

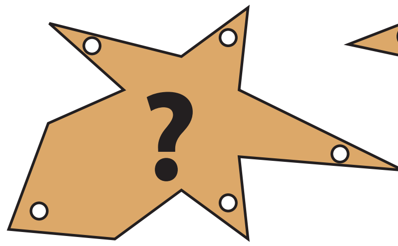
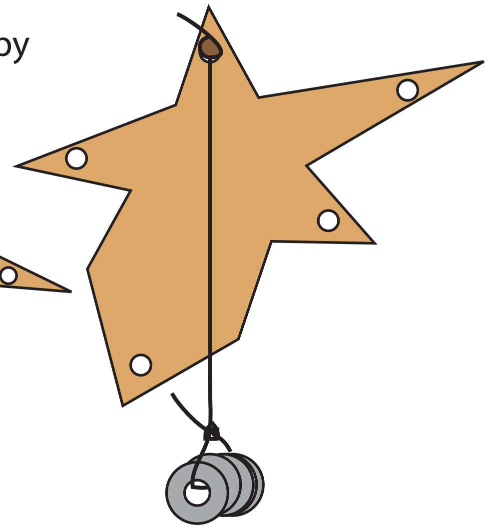
- Place a heavy object like a small barbell weight plate or a heavy book in a copy paper box to one side of the center. Close the box. Have students try to locate the center of mass of the box by pushing on it in different places. (Note: Even though most of the box is filled only with air, the entire box has a center of mass. The center will be near the weight.)

- Set up a boys-against-girls challenge. Place a folding chair sideways to the wall. Have a student stand facing the wall but positioned so that his or her feet are not under the chair. Tell the student to bend over at the waist and touch his or her forehead against the wall while keeping the back straight. Challenge the student to lift the chair and stand up without moving his or her feet. Be prepared to catch the boys! The center of mass for boys is higher than for girls. A boy's center of mass will extend over the chair, making it impossible for him to stand up without pulling away from the wall. A girl's center of mass in closer to her hips. Even when bent over, her center of mass is still over her feet, so she can lift the chair and stand.

Center of All Things

Name: ______________________

Where is the center of mass of the cardboard star provided by your teacher? How can you find out?

Instructions:

1. Gather the following materials:
   - Cardboard star
   - String with washers attached
   - Small stick
   - Pencil
2. Insert the stick through one of the holes in the star points. Let the star hang freely.
3. Hang the loop of the string on the stick so that the washers dangle below.
4. While keeping the star and string still, draw a straight pencil line across the star right next to the string.
5. Repeat steps 2 through 4 for the other star points. What happened to all the lines you drew?
6. Where do you think the center of mass for your star is located. Explain why you think it is in this location.
7. Write a definition for center of mass.
8. The star is flat. How would you determine the center of mass of an object that is three-dimensional (like a box, ball, or an astronaut)? Explain your idea. Use the back if you need more space for your answer.