Grades 3–5, 6–8

20–60 minutes

ZIP LINE CHALLENGE

DESIGN CHALLENGE

Build a device that can transport a ping-pong ball from the top of a zip line to the bottom in 4 seconds or less.

SUPPLIES AND EQUIPMENT

Per whole group

- ☐ 1 spool of fishing line
- ☐ Several pairs of scissors
- ☐ Several hole punches
- ☐ Several stopwatches
- ☐ Several rolls of masking tape
- ☐ 100 paper clips

Per person or team

- ☐ 1 ping-pong ball
- ☐ 4 flat, 1" steel washers
- ☐ 4 index cards
- ☐ 4 wooden skewers
- ☐ 4 paper cups, 3 oz. size
- ☐ 4 straws

Use the metal washers to add weight to your zip line. That will keep it balanced and provide extra mass.
Credit: Bill Shribman for WGBH Educational Foundation

GETTING READY

Cut about 4 feet of fishing line to make a zip line. Attach one end of the line to a wall or chair and the other end to an object about 2 feet lower. Make as many zip lines as you want or have space for.

INTRODUCTION

Ask participants to describe a zip line. Ask questions to get them thinking:

- What forces are involved in an object moving down a zip line? (Friction, gravity, etc.)
- How are zip lines used today? (Tourism, biological surveys.)
- What else could they be used for?

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INTRODUCTION (CONTINUED)

Children in the small village of Los Pinos, Colombia, don't have a school of their own. Instead, they ride a zip line half a mile across a canyon to attend school in a neighboring town.

When designing zip lines, engineers must consider speed, the difference in height between starting and ending points, and the safety needs of a rider. Making zip-lining safe is of critical importance.

INSTRUCTIONS

Introduce the design challenge and provide instructions to the participants: build a device that will transport a ping-pong ball down a zip line from start to finish in 4 seconds or less. Provide the following guidance:

- Design, build, and test the device.
- Make adjustments to the weight, center of mass, and friction of the device as needed. Participants may need help assessing what needs to be changed. Ask questions like "What can you do to make your zip line faster?" or "Which materials can help your zip line slide quickly?"
- Try different prototypes until the conditions of the design challenge are met.

Evaluate the success of each design.

- ☐ Did the designed device carry the ball to the end of the line?
- ☐ Did the ball reach the end of the zip line in 4 seconds or less?

A student uses a zip line to explore the forest canopy. Credit: National Park Service.

ACTIVITY VARIATIONS

Raise the stakes by transporting eggs instead of ping-pong balls. Design a way to slow the egg so that it doesn't crack at the end of the ride.

Make several identical long zip lines and have a race.

Design a zip line that can drop the ball onto a target at the end of the ride.

Try a zip line that is two or three times as long, but keep the 4-second time limit.

TROUBLESHOOTING

- If the zip line is too slow, try reducing the friction between the carrier and the line. Also, make sure there is enough of a vertical drop.
- If the ball falls out of the designed carrier, consider building a larger contraption.
- Moving the center of mass by placing metal washers at different locations can impact the zip line.

RELEVANT TERMINOLOGY

Acceleration: The process of moving faster or happening more quickly. As the ping-pong ball moves down the zip line, it accelerates, or goes faster.

Force: A push or pull on an object. Gravity is a force that pulls us toward the center of the Earth.

Friction: The force that slows objects down when they are rubbing against each other. Some things make lots of friction, like brakes on a tire, and some make very little friction, like skates on ice.

Gravity: A force of attraction that occurs between all objects. We experience it as the constant force that pulls objects toward the center of the Earth.

Mass: The amount of matter in an object. The more the mass, the heavier the object.

Slope: The direction and steepness of a line. Slope is measured by the vertical drop divided by the horizontal distance covered by the line.

Speed: The distance traveled over a period of time. If something is accelerating, it is moving at a faster speed.

Weight: The force of gravity on an object. The more something weighs, the stronger the force of gravity.

GUIDANCE FOR YOUNGER CHILDREN

QUESTIONS TO ASK AFTER THE ACTIVITY

- What material(s) did you use to carry your ping-pong ball down the zip line?
- How high were the start and end points of your zip line? Why does this matter?
- Were you able to get your ping-pong ball from the top to the bottom of your zip line in 4 seconds on the first try? What changes did you make after the first test to increase the speed of the ball on the zip line?
- What factors affect the speed of the ping-pong ball?

ENGINEERING CONNECTIONS

Have you ever ridden on a zip line? Zip lines are usually made of a cable that is stretched between two trees or posts. The person riding it wears a harness that is attached to the cable with a pulley that rolls along the line. Zip lines were originally for people to travel in and through wild places such as forests or jungles. Over time, they have become a way for biologists to study the environment. They have also become huge tourist attractions for thrill seekers who want to “zip” through or above the trees. Zip lines are sloped so that the force of gravity pulls the rider down the cable. When designing zip lines, engineers must ensure the safety of riders by considering the weight that the line can support, the speed of the person “zipping” down the line, and the strength of the materials used for both the cable and the harness. Since most modern-day zip lines are designed for fun and excitement, engineers must also balance the need for safety with the desire for a fast, thrilling ride.

SCIENCE CONNECTIONS

Engineers must have a strong understanding of many scientific laws. To design the best solution to a problem, they must know how their design will function in the real world. To build a zip line that is safe for riders, engineers must make sure that it will not only hold a rider’s weight when that rider is on it, but also allow the rider to safely stop before reaching the end. For riders to stop at the end of the zip line, they need to use the force of friction, which is the same force that you use if you drag your feet to stop your bicycle. By pushing two surfaces together, like taking your feet off the pedals and dragging them on the ground, the force of friction increases. The brakes on the zip line also cause a friction force to grow bigger the harder you squeeze. This causes the zip line rider to slow down before the end of the cable. Science and engineering must be used hand-in-hand to make our world useful, safe, and fun.

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GUIDANCE FOR OLDER YOUTH AND ADULTS

QUESTIONS TO ASK AFTER THE ACTIVITY

- What materials did you use to attach your ping-pong ball to your zip line?
- What factors affect the movement of an object traveling down a zip line?
- What is the slope of your zip line? How does that affect the set-up?
- If your ping-pong ball was moving too slowly, what are some ways you could help to increase its speed?
- What do you think would happen if you used a golf ball instead of a ping-pong ball?

ENGINEERING CONNECTIONS

When engineers set out to build a zip line, they must first analyze the needs of the user. What are the weight requirements? How long will the zip line be? What is the maximum speed that the rider will be traveling while on the zip line, and how much force will it take to stop a person moving at that speed? In considering these questions, engineers must determine what materials should be used to design the zip line itself as well as the mechanism that carries the rider and eventually stops the rider at the end of the cable.

Understanding material science helps engineers determine what materials will best complete the job. Is it steel? Aluminum? String? Something else entirely? In considering a material for the cable, engineers must determine what material will be able to support the weight of the rider while allowing for some flexibility. Engineers also need to design a mechanism that can carry a rider smoothly down the zip line by minimizing friction, but that allows the rider to apply a frictional force at the bottom of the cable to stop before reaching the end.

SCIENCE CONNECTIONS

When a rider is on a zip line, the cable takes the shape of what is known as a *catenary curve*. This is the natural shape of a cable when supported at two ends where one end is lower than the other. When a person rides the zip line, that person's weight causes the curve to be stretched into two straight lines. These two lines produce two triangles, where the angles and lengths of the sides depend on the rider's weight, the tension in the cables, and the exact position of the rider on the zip line.

To calculate the maximum speed of an individual riding the zip line, we would need to use a combination of mathematical and science formulas including the Pythagorean Theorem and Newton's Second Law of Motion. Newton's Second Law states that the force of an object is equal to its mass times its acceleration. As soon as a rider steps off of the platform, we can see Newton's Laws of Motion in action as gravity takes over and the person accelerates down the cable. The rider will continue in motion along the zip line until a braking force is applied to stop the rider.

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