Zip Line Rescue

Program Type: Classroom Program	**Audience Type:** Grades 3–8

Description: Students will design and build a zip line carrier that will move an injured or stranded person safely and quickly out of danger.

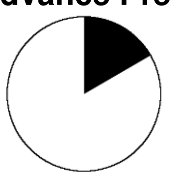
LEARNING OBJECTIVES

For Next Generation Science Standards alignment, see end of outline.

- Students will design a zip line carrier using the engineering design process, including creating, testing, and re-designing a prototype.
- Students will explore varying environmental constraints that affect the zip line carrier, including the presence of a person, adverse weather, and the need to make multiple trips.

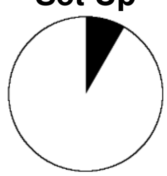
TIME REQUIRED

Advance Prep



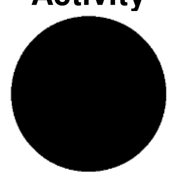
10 minutes

Set Up



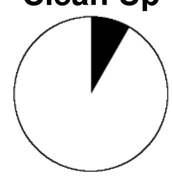
5 minutes

Activity



60-100 minutes

Clean Up



5 minutes

SITE REQUIREMENTS

- A separate space (approximately 6’×4’) for each group to set up a zip line.
- Each space needs to be near a wall, bookcase or chair capable of holding a clamp, with a table or open floor for students to design and build.
- *(Optional)* Access to a whiteboard and projector/document camera.

PROGRAM FORMAT

Segment	Format	Time
Introduction	Large group discussion	10 min
Design, Test, Improve	Group activity	40 min
Wrap-Up	Large group discussion	10 min

Levels

This activity is leveled to accommodate different class lengths and abilities of participants. Each level is an extension of the previous one and increases the complexity of the design challenge. The additions for materials and delivery are shown in each section. Instructors should choose the challenge level that is appropriate for their students and the length of the activity.

Level 1: Basic activity (good for younger participants and shorter classes).
Level 2: Introduces a bad weather element to the activity (additional 10–15 minutes).
Level 3: Additional challenge of using the carrier multiple times and creating a system to bring the carrier to the top of the zip line (additional 15-25 minutes).

SUPPLIES

Permanent Supplies		
Level 1 Supplies	**Amount**	**Notes**
Scissors	1/group	
Kite string or fishing line	6 ft./group	
Gallon jug	1/group	fill with water or sand
2” spring clamp (or larger)	1/group	Anything that attaches firmly but can be easily moved
Small human play figures	1/group	Ex: Playmobil® or Lego®
Meter stick or measuring tape	1	
Zip line rescue photos	2	*(Optional)* See *Appendix.*
Additional Level 2 Supplies	**Amount**	**Notes**
Fan	1	Can be 1/group if supplies are not limited
Spray Bottle	1	Can be 1/group if supplies are not limited
Additional Level 3 Supplies	**Amount**	**Notes**
Kite string, fishing line, or yarn	12 ft./group	
Stopwatch	1/group	
Additional human figurines	2/group	

The items below are suggestions for zip line carrier building materials. These can be added or removed as needed.

Suggested Supplies	Amount
Paper clips	12/group
Wooden craft sticks	12/group
Rubber bands	12/group
Binder clips	12/group
Drinking straws	12/group
Yarn	4 ft./group
Pennies or metal washers	4/group
Tack board (cereal boxes)	4/group
Pipe cleaners	8/group
Wooden skewers	8/group
Aluminum foil	6”×8” sheet/group
Brass brads	4/group
Craft foam sheets	1/group

ADVANCE PREPARATION

- Cut kite string into 6-ft. sections.
- Fill the gallon jugs with sand or water.
- Tie one end of the kite string to the neck or handle of the bottle and the other end to the clamp.
- *(Optional)* Print or create a slideshow of photos showing various zip line rescues (see Appendix for two examples).

Additional Level 3 Prep:

- Cut 12-ft. sections of string or yarn.

SET UP

- Divide the building materials (pipe cleaners, paper clips, foam, etc.) into equal piles for each group.
- Tie one end of each kite string to a clamp and the other end to the weighted bottle. Use the clamp to attach the string to a stable surface higher than the end of the string attached to the bottle.If the weighted bottle is on a table then the clamp can be attached to a bookshelf or windowsill. Alternatively, if the weighted bottle is on the floor then the clamp can be attached to a table or chair. Keep in mind the smaller the angle, the more of a challenge this activity will be.
- Set the weighted bottle on the floor or table so the string is taut.
- If possible, place the zip line set up over a table or other object to prevent anyone from tripping or walking into the thin, hard-to-see line.
- Place a small human play figure on each clamp.

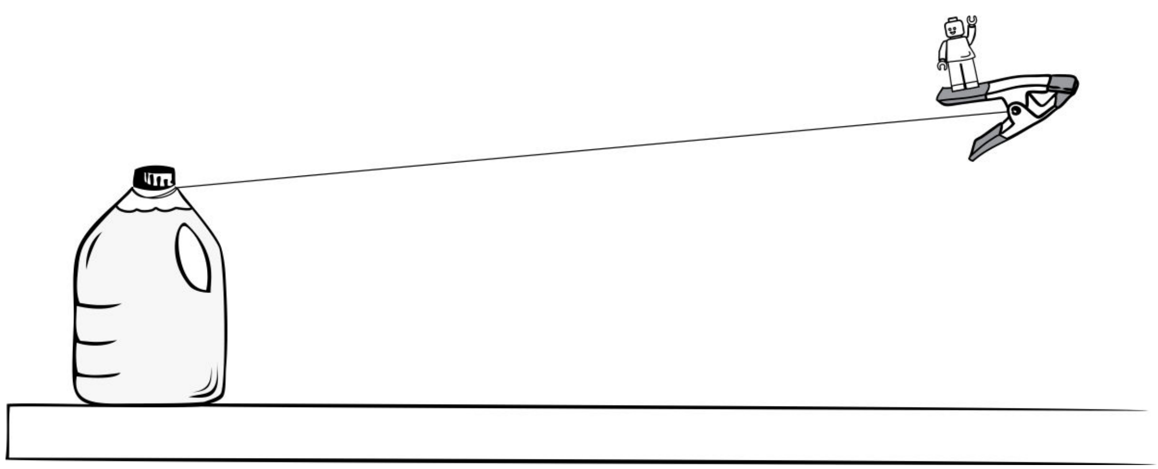


Figure 1: Zip line apparatus using a weighted gallon jug, fishing line, and a clamp. Adding the small human play figure emphasizes the altruistic nature of engineering.

<u>SAFETY WARNING</u>
If using the floor or an open space for this activity, keep in mind that the fishing line is difficult to see and can be a **tripping hazard**. You may wish to use cones or tape to mark these hazard zones.

Additional Set-up Levels 2 & 3:

- Fill spray bottle with water.
- Set up a station with a fan pointing at the zip line. This is where each group can bring their carrier for weather testing.

INTRODUCTION

10 minutes

Let students speculate before offering answers to any questions. The answers given are provided primarily for the instructor's benefit.

Suggested script is shaded. Important points or questions are in **bold**. Possible answers are shown in *italics*.

We are going to be designing, building, and testing an exciting new way to help people in trouble. There are times when people are hurt or stranded in places where it can be hard to get them to safety, like high up on a mountain, in a tram or gondola, or on the far side of a flooded river.

Show photos and diagrams illustrating these situations.

What are some ideas you have for how to get these people to safety?
Helicopters, climbers, parachutes…

One way rescue workers help people in hard to reach places is by using zip lines.

Have any of you heard of zip lines before? Have any of you used a zip line? How do they work?

Zip lines are often used for recreation—that is, for fun! However, they can also be helpful in emergency situations to get people to safety when there are no roads or easy path to take. Today, you will design a zip line attachment system to help a person who is stranded get to saftey.

LEVEL 1 INTRODUCTION

Your challenge today will be to create a carrier that will slide smoothly down the zip line. Your rig must be able to clip on and off the line easily and slide all the way to the bottom of the zip line without anyone controlling it. It is up to you to think creatively and come up with a great design. Once you have a working design, continue to work on the rigs so they can safely carry a person in trouble down the line.

Show zip line set-up, and model person. If desired, show an example of a carrier that doesn't work well and discuss what the problems are with it (doesn't move smoothly, gets stuck halfway down, is hard to get on and off of the zip line, etc).

LEVEL 2 and LEVEL 3

You may run into additional challenges as you create your design. Be prepared to make changes to your carrier as your rescue conditions change.

GROUP ACTIVITY

Design, Test, Improve

40 minutes

Divide students into groups of 3-4. Each group should sit around a space for working (either at a table, grouped desks, or on the floor). Hand out the materials to each group.

What are some factors that will affect if, or how quickly, the rig slides?
How steep the line is will affect how quickly it slides. How heavy the rig is will affect if it slides at all.

Move the bottle forward to make the line slack, showing how the carrier gets stuck.

When you've designed your carrier, go ahead and test it on your zip line. Each person in your group should have a chance to try it out and make any improvements. Call me over to your group when you've successfully tested your rig so you can show me how it works.

If groups are having problems getting a rig to slide, remind them about friction between the rig and the line. Which of their materials might have less friction? How might they incorporate those materials into their design?

LEVEL 2 ADDITIONS

A storm just rolled in! You will need to design a zip line carrier that can work in strong winds and rain. How will you keep the person you are rescuing dry and safe?

Show fan and squirt bottle at the weather testing station. Turn on the fan with medium airflow pointed at the zip line and use the squirt bottle to simulate rain. Test each group's carrier again.

How can you protect your passenger from the rain and the wind? Is it safe even in the high wind conditions?

If their carrier is unstable in the wind and flips, or gets stuck and doesn't travel all the way down the zip line, suggest adding weight or lowering the center of mass.

LEVEL 3 ADDITIONS

There are more people that need to be rescued! You will need to redesign the rig so that it can be used again and again, and so that people can be loaded and unloaded quickly. You will have to figure out a way to pull your carrier back to the top of the zip line without touching it.

In addition to the wind and rain (use level 2 additions), groups must also be able to demonstrate that their rig can carry a person down the zip line more than once without being pushed by hand up the line. Groups should use the extra string to create a system that can be controlled from one end of the zip line to raise the rig back up for another passenger.

To encourage carriers that emphasize easy entrance and exit for the passenger, you can challenge groups to safely rescue as many people as they can in a set amount of time (e.g., 3 minutes).

WRAP-UP

10 minutes

Ask for student observations. There is no correct answer. Let students guide the discussion and present their hypotheses before discussing explanations.

What designs worked best for your rigs? What were some troubles you had? How did you work through those troubles?

Save time at the end for each student group to share their carrier with their classmates and demonstrate its features.

CLEAN UP

10 minutes

- Collect and disassemble the zip line set-ups and carriers.
- Place any unused materials back in their storage containers.

OPTIONAL EXTENSIONS

- Challenge students to see how quickly their rig goes down the line. Can they get it to complete the trip in fewer than 3 seconds?
- Challenge them to slow the rig down. Can they get it to take more than 5 seconds to make the trip?
- Can they complete the challenge with a less steep line? Try lowering the high end to only a few inches above the low end.
- Can they get their rig to carry other objects (ping-pong balls, pennies, etc.) down the line?
- Challenge students to modify their design to fit a variety of different needs, such as a carrier for recreation, for someone who can't stand up, for someone who is afraid of heights, or for a young child or a pet.

BACKGROUND INFORMATION

A zip line is a long cable suspended between two high points, along which people or cargo can slide, often using a pulley. Zip lines have been engineered for all different kinds of uses, including:

- **Ancient transportation** – Before the advent of modern roads and bridges, people living in mountainous areas utilized ziplines to cross steep valley and rivers.
- **Biological research** – Scientists studying the forest canopy often use zip lines to efficiently travel from tree to tree.
- **Recreation** – Today, tourists can explore the forest canopy and other aerial environments all over the world via zip line. Zip lines also satisfy thrill-seekers at theme parks and challenge courses.
- **Emergency situations** – Zip lines have been used to safely transport people down from a broken chairlift, out of a burning building, across a flooded river, and out of other dangerous situations. NASA has even piloted a zip line system to evacuate astronauts from the Starliner crew capsule before launch, in the event that something go awry during the launch sequence.

For photos of ziplines in action, see Appendix.

For a short article on the history of zipline use, see:
Fagaly, Steve. "Zipping Through History: The Origins of the Zipline." Oahu, Zipline, 2016, https://oahuzipline.com/zipping-through-history-the-origins-of-the-zipline/.

GLOSSARY

Zip line	An inclined cable or rope with a suspended harness, pulley, or handle, down which a person slides.
Rig	An apparatus, device or piece of equipment designed for a particular purpose.
Friction	The resistance that one surface or object encounters when moving over another.
Balance	An even distribution of weight enabling something to remain steady.
Weight	An item's relative mass or the quantity of matter contained by it, in a given measurement, as determined by a downward force.
Center of gravity	The point at which the weight of a body is concentrated; if supported at this point, the body would remain balanced.

NEXT GENERATION SCIENCE STANDARDS

	Practices
✓	Asking questions and defining problems
✓	Developing and using models
✓	Planning and carrying out investigations
	Analyzing and interpreting data
	Using mathematics and computational thinking
✓	Constructing explanations and designing solutions
	Engaging in argument from evidence
	Obtaining, evaluating, and communicating information

	Crosscutting Concepts
	Patterns
✓	Cause and effect
	Scale, proportion, and quantity
	Systems and system models
	Energy and matter
✓	Structure and function
	Stability and change

	Disciplinary Core Idea	3	4	5	MS
	Physical Science				
PS1	Matter and Its Interaction	n/a	n/a		✓
PS2	Motion and Stability: Forces and Interactions	✓	n/a	✓	✓
PS3	Energy	n/a	✓		✓
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a	
	Life Science				

LS1	From molecules to organisms: Structures and processes				
LS2	Ecosystems: Interactions, Energy, and Dynamics		n/a		
LS3	Heredity: Inheritance and Variation of Traits		n/a	n/a	
LS4	Biological Evolution: Unity and Diversity		n/a	n/a	
Earth & Space Science					
ESS1	Earth's Place in the Universe	n/a			
ESS2	Earth's Systems				
ESS3	Earth and Human Activity				
Engineering, Technology, and Applications of Science					
ETS1	Engineering Design	✓	✓	✓	✓

<u>DCI Grade Band Endpoints</u>

3-5 ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (By the end of Grade 5)

3-5 ETS1.B: Developing Possible Solutions

- Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (By the end of Grade 5)
- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (By the end of Grade 5)
- Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (By the end of Grade 5)

3-5 ETS1.C: Optimizing the Design Solution

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (By the end of Grade 5)

MS ETS1.A: Defining and Delimiting Engineering Problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (By the end of Grade 8)

MS ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (By the end of Grade 8)
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (By the end of Grade 8)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (By the end of Grade 8)
- Models of all kinds are important for testing solutions. (By the end of Grade 8)

MS ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (By the end of Grade 8)
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (By the end of Grade 8)

3 PS2.A: Forces and Motion

- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object’s speed or direction of motion. (By the end of Grade 5)
- The patterns of an object’s motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (By the end of Grade 5)

MS PS2.A: Forces and Motion

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (By the end of Grade 8)

<u>Performance Expectations</u>

3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5-ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
3-5-ETS1-3	Plan and carry out fair tests in which variables are controlled and failure

	points are considered to identify aspects of a model or prototype that can be improved.
MS-ETS1-1	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
3-PS2-1	Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.
3-PS2-2	Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.
4-PS3-1	Use evidence to construct an explanation relating the speed of an object to the energy of that object.
MS-PS2-2	Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
MS-PS3-2	Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

Zip Line Rescue
Appendix

Test of a space shuttle zip line escape system for NASA astronauts. ***Credit: NASA. (Image from: https://www.space.com/36344-zip-line-emergency-escape-system-astronauts.html).***

Rescue dog crossing a river on a zip line to help in the search and rescue of victims of a landslide in China. Credit: Reuters. (Image: http://metro.co.uk/2017/06/25/rescue-dog-takes-zip line-to-help-victims-of-devastating-landslide-in-china-6733520).

FACILITATION GUIDE

Zip Line Rescue

Description: Students will design and build a zip line carrier that will move an injured or stranded person safely and quickly out of danger.

Promoting collaboration and organization

- Each student in a team can design his or her own zip line carrier on paper, labeling each material used. Then, the team can collaborate and come up with a design that combines ideas from all of its members.
- Encourage students to work on and improve different parts of the zip line carrier: attachment to the line, a seat belt, the material of the carrier, etc.
- Suggest that students take turns launching the carrier from the top.
- Suggest that students use drawings or demos to communicate their ideas more clearly.
- As a class, try to create the ultimate carrier by incorporating different ideas from each group.

Encouraging iteration

- There will be many rounds of trial and error—facilitate the engineering design process of improvement and re-testing. Some good questions to ask may include:
    - Does the carrier get all the way to the bottom of the zip line? What could you change to make it go all the way?
    - Does your carrier seem comfortable? Can the person see? What if he or she is afraid of heights?
    - How is the person strapped in? Is it easy to get in and out? Does your person fall out?
    - Would your design work if the person was injured?
    - Can you control which way the person goes down? Head first? Sideways?
    - What other sorts of difficulties might you have? How could you adapt your zip line to overcome them?
    - Does the landing seem like it would be gentle for the passenger?

Helping those who are stuck

- Do a test run with the group and discuss specific points where the rig is not working. Ask specific questions about how they could change the weight, size, center of mass, and the point of contact between the zip line and the carrier.
- Show photos of zip line rescue equipment and ask students what they notice about the designs.
- Invite students to go and observe the designs of other groups.

Real-world applications

- NASA has created a zip line that would help astronauts escape a space shuttle from the launch pad.