Zip Line Racers

Lesson Type: Construction/Challenge
Target: Elementary School/High School
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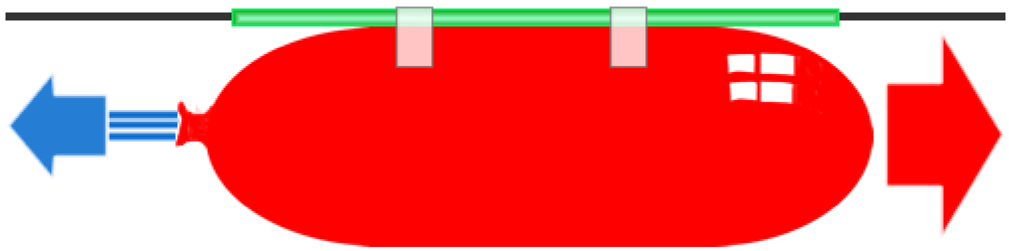
Challenge: Build a racer that can use a balloon's air propulsion to travel across a string or wire.



Materials

- Balloons (various types, 2-3 per group)
- Drinking straws (2-3 per group)
- Clothes pins (for holding balloon shut, 1 per group)
- Paper clips (3-4 per group)
- Buttons (2-3 per group)
- Masking tape (1 roll per group)
- Fishing line (or some other string. It does not have to be very strong. 1 roll per site)
- Paper (construction and/or printer)
- Plastic cups (1 per group)
- Cardboard
- Sharpie/highlighter (for HS only)

Key Concepts

- A major part of the design process is prototyping. Make sure your mentees test their device along the way.
- By blowing up the balloon, you store potential energy in the form of air pressure. This is released to power the racer.
- Creative, free experimentation with materials.

Agenda

Setup (5 min) - Before lesson begins

Tie two lines across the room parallel to each other with 2-4 feet of space between them. It is up to you if you want the line to be parallel to the ground or slanted (and whether they have to go up or downhill). You want them spaced close enough so that it feels like two parallel racetracks, but far enough that the kids' racers don't bump into each other.

Introduction (10 min) - Explain the challenge, then break off into groups of 3-5 mentees.

Build balloon zip line racers to either go the **farthest** or the **fastest**. The racers must adhere to the following criteria (you can adjust for your site):

- Be powered by balloon(s).

- Be able to attach and detach from the line without untying the line.
- Be able to travel along the line on its own, without assistance.
- Be able to carry a sharpie/highlighter (HS only)

Choose to either have them build the fastest or the farthest if you think that just a single racer will occupy them for the entire teaching period. If not, then have two build-compete sections, one to build the fastest and another to build the farthest-traveling racer.

Build and Test (30 min) - Assist the kids who are working in groups.

Allow infinite material access.

Allow them to use the lines to test their racers throughout the build period if desired.

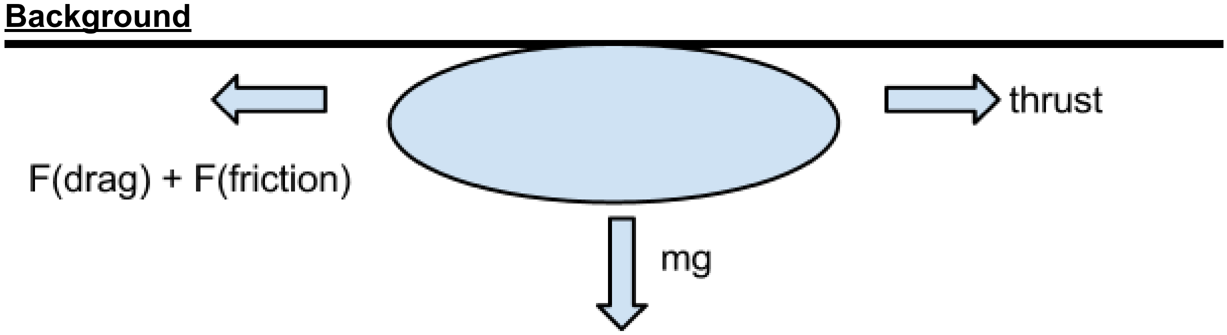
Compete (15 min) - Have the racers compete in pairs, against each other.

When finished, allow the kids to take their racers home.

Hints/Things to Try

- The materials are deliberately very "ambiguous" since there are many different ways to use them to approach this challenge.
- There are two major ways to attach the racer to the line:
    1. Straw cut along its length.
    2. Paperclips holding the balloon below it.
- Which method for attaching the racer has the least friction?
- There is a balance between weight and power. Having two balloons may provide better propulsion, but would also increase friction due to greater weight and air resistance.
- The more aerodynamic the balloon, the better. Hot dog-shaped balloons thus work better than round ones.
- Does the extra propulsion from more balloons outweigh the added drag?
- Would placing a plastic cup at the nose of the racer help?
- Cut the straw along its length to turn it from an O shape to a C that can slip on and off the line.
- Not all balloons are the same shape. Select one to suit your needs.
- You can use a rubber band to restrict air flow or to "squeeze" the balloon to force air out faster.
- Make your racer as symmetrical and balanced as possible so it doesn't tip or spiral out of control. Keep in mind that the weight distribution of your racer will change as air leaves the balloon.

Background



Constructing a force diagram, we have thrust propelling the racer forward. Pointing downward, we have the force of gravity, mg.

And resisting thrust, we have the friction from drag (air resistance) and kinetic friction.

The equation for drag is given as $F_D = \frac{1}{2}\rho v^2 C_D A,$ where:

? is the density of the fluid, in this case air.

v is the object's speed.

C_d is the drag coefficient

A is the cross-sectional area of the object. As you can see, the greater the cross-sectional area, the greater the drag as a result. Also important is the fact that the faster the object moves, the greater the air friction it experiences. Thus, to maximize distance, there is a certain optimal speed at which the racer can move without having too great air resistance.

Kinetic friction's equation is given as $F_f = \mu_k N = \mu_k mg$, where:

μ_k is the coefficient of kinetic friction, which is related to the properties of the two materials making contact and their area of contact.

N is the normal force, which in this case is equal to the force of gravity, mg. As you can see, the heavier the racer, the greater the frictional force. In addition, the way that the racer is attached to the line can affect the friction.

References

http://www.sciencebob.com/experiments/balloonrocket.php

http://www.reachoutmichigan.org/funexperiments/quick/alaska/balloon.html