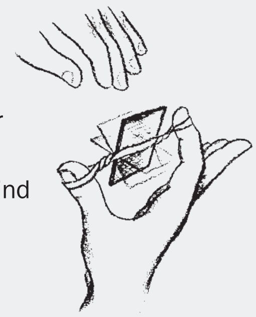
PADDLE POWER

The Challenge
Build a boat that paddles itself using a rubber band as its power source.

In this challenge, kids (1) follow the design process to make a boat out of cups; (2) design and build working paddles; (3) use rubber bands to store and release energy; and (4) figure out ways to attach their paddles to their boats.



1. **Introduce the challenge** (5 minutes)
Begin by looping a rubber band over your thumb and index finger. Slide a 1 x 2-inch piece of chipboard through the rubber band and wind it up. Let go so the chipboard spins. Begin by telling kids the challenge. Tell them that they'll be using this kind of rubber-band-powered paddle to drive a boat across a container of water. Then get them thinking about storing and releasing energy. Ask:

   - Where was the energy stored that made the paddle spin? (*In the rubber band*)
   - Tell kids that the term for stored energy is **potential energy**. Ask, "How can you increase a rubber band's potential energy?" (*Wind it up more.*)
   - How can you tell when potential energy stored in the rubber band is being used? (*Something moves.*)
   - Tell kids the term for motion energy is **kinetic energy**. Ask, "What are some examples of kinetic energy that occur when a paddleboat moves through the water?" (*The rubber band unwinds; the paddle spins; the boat moves; waves spread out*)

2. **Brainstorm and design** (10 minutes)
Show kids the materials and ask, "How can you use these materials to make a boat that paddles itself through the water using a rubber band as its power source?" After discussing their ideas, have them sketch their designs on a piece of paper or in their design notebooks.

3. **Build, test, evaluate, and redesign** (35 minutes)
Distribute the challenge sheet and have kids begin building. If any of the following issues come up, ask kids questions to get them thinking about how they might solve their problems.

   - Kids are all doing the exact same design. *Suggest different boat designs, such as: (1) Seal a cup by putting tape over the opening and floating it on its side; (2) Cut a cup in half lengthwise and tape the halves together to form an open boat; (3) Tape several cups together to make a raft; and (4) Use the chipboard for the boat's bottom and sides.*
   - Water leaks into the cup. *Seal openings with duct tape.*
   - The paddles are hard to attach to the cup. *(1) Tape straws or wooden skewers along the sides of a cup (or poke them through the sides and bottom) so they stick out far enough to loop a rubber band over them. (2) Build a frame out of straws or wooden skewers and mount it between two cups. Attach the rubber band and paddle to this frame.*

SHOW KIDS THE RELATED TV EPISODE

Photo: Parrish Kennington

In Paddle Power, kids figure out how to power a boat through the water. Show them the Aquatic Robotics episode in which *Design Squad* teams attempt to build a radio-controlled underwater robot. Get it online at pbs.org/designsquad.


Photo: Lauren Feinberg

A paddleboat moves when the rubber band's stored (***potential***) energy is converted into motion (***kinetic***) energy and spins the paddle.


Photo: Lauren Feinberg

Testing in a large container of water lets the boats paddle a good distance before hitting a side.

- The chipboard paddle warps when it gets wet. *Protect it by wrapping it in duct tape.*
- The paddle hits the frame that holds it. *Reposition the rubber band; widen or lengthen the frame; make the paddle smaller.*
- The frame holding the rubber band bends when the rubber band is wound tight. *Make sure the frame is securely taped to the cup. See if adding a crosspiece can help stiffen the frame. Also, move the rubber band toward the cup. The closer it is to the cup, the harder it will be to bend the frame. Finally, use wooden skewers. They're stronger than straws.*
- The boat tips and does not let the paddle hit the water properly. *Add weight to the boat to control its position. Tape a washer or two to the bottom of the hull. Weight used to keep a boat upright is called* ***ballast****.*

4 Discuss what happened (10 minutes)
Have kids talk about their designs and how they solved any problems that came up. Emphasize the key themes in this challenge—potential and kinetic energy—by asking questions such as:

- What are some examples of potential and kinetic energy in your paddleboat? (*An example of potential energy is the wound rubber band. Examples of kinetic energy include the things that moved, like the paddle, rubber band, boat, and water.*)
- How can you store a lot of energy in your boat? (*Wind up the rubber band tighter, or use more than one rubber band.*)
- What was the hardest problem to solve when building your boat? (*Answers will vary, but perfecting the paddles and attaching them to the cup is often quite challenging.*)

FOR EVENTS

- Draw kids into your area by asking, "How quickly can you get a boat to power itself through the water?"
- It's hard to make boats that float well with cups smaller than 8 ounces. If you want to give kids more design options, offer them two different-sized cups, such as 8- and 12-ounce cups.
- Test boats in large containers. Kiddie pools, underbed storage containers, or wallpaper trays offer kids longer, more satisfying travel times for their boats. In addition, even when a boat doesn't go straight, it can still go reasonably far before hitting a side.
- To avoid overcrowding, provide one kiddie pool per 20 participants expected, one underbed storage container per 10 kids expected, or one wallpaper tray per 4 kids expected. Since kids won't all be testing at once, these numbers will provide plenty of open water for testing.
- Large containers filled with water are heavy and awkward. Put the container where you want it on the floor of the testing area. Then use a bucket to fill and empty it.
- Have towels on hand to mop up spills.

To determine how many materials you'll need for different-sized events, for information on obtaining large quantities of materials, and for other general event tips, see page 7.

PADDLE POWER

DESIGN SQUAD as built on TV
pbs.org/designsquad

YOUR CHALLENGE

Design and build a boat that paddles itself across a container of water using a rubber band as its power source.

BRAINSTORM & DESIGN

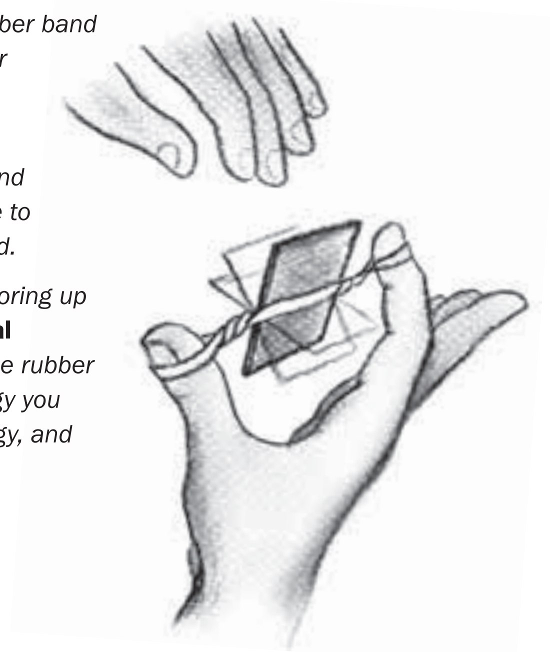
Look at your materials and think about the questions below. Then sketch your ideas on a piece of paper or in your design notebook.

1. How can you use these materials to make a boat that floats well?
2. How will you attach a rubber band and paddle to your boat?
3. How big a paddle do you need so that it reaches the water and drives the boat?
4. How will you make sure your boat doesn't sink, tip, or roll over?

BUILD, TEST, EVALUATE & REDESIGN

Use the materials to build your paddleboat. Then test it by winding it up, putting it in the container of water, and releasing it. When you test, your design may not work as planned. The saying, "If at first you don't succeed, try, try again," is at the heart of the design process. Testing a design and then revising it based on what you've learned is a key to success. Study the problems and then redesign. For example, if your paddleboat:

- tips—*Add some weight to the bottom of the boat to help keep it upright.*
- has a warped paddle—*Think of some ways to waterproof the paddle.*
- has a paddle that hits the frame holding it—*See if moving the rubber band makes a difference. Also consider changing the size of the frame or the paddle.*
- has parts that bend when the rubber band is wound tight—*Make sure parts are taped on securely. Also, see if moving the rubber band makes a difference. The closer it is to the boat, the harder it will be to bend things. Finally, find ways to add support to any parts that bend.*
- doesn't make it across the container—*Experiment with ways of storing up more energy. Your boat moves by changing stored energy (***potential energy***) into motion energy (***kinetic energy***). The more you wind the rubber band (or the more rubber bands you use), the more potential energy you store. When you let go, this potential energy turns into kinetic energy, and the boat moves.*



MATERIALS (per person)

- chipboard (8 ½ x 11 sheet)
- wide container partially filled with water (e.g., kiddie pool, bathtub, underbed storage container, wallpaper tray)
- duct tape
- 2 paper cups (8 ounce or larger)
- 5 rubber bands
- scissors
- towels (paper or cloth)
- 4 straws
- washers (1-inch or larger)
- 4 wooden skewers

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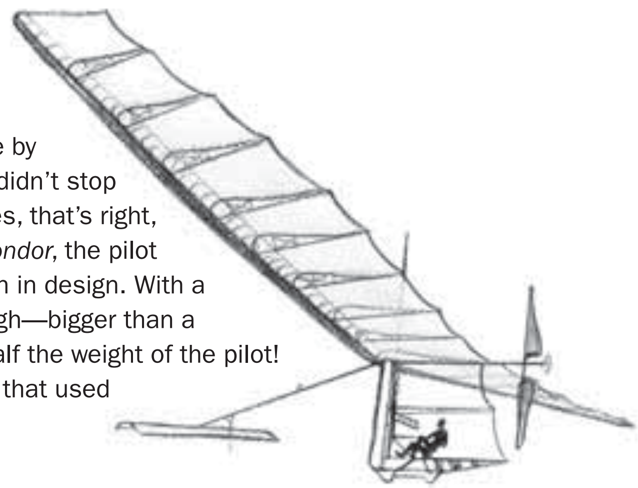
TAKE IT TO THE NEXT LEVEL

- Watch your fingers! Add an on-off switch so you can start and stop the paddle.
- Ready. Set. Go! Experiment with the paddle, the rubber band, or the boat's shape to increase its speed. Then race other paddleboats.
- Tugboat time! Carry or tow a Ping-Pong ball from one side of the container to the other.

MAKE IT ONLINE

Is that a bird or a plane?
Build an airplane that flies by flapping its wings out of wood, wire, tissue paper, rubber bands, and glue. See how on Make Magazine's project page at makezine.com/designsquad.

ENGINEERING IN ACTION



Engineer Paul MacCready was always intrigued by the way birds soared through the air. As an adult, he brought his passion to life by building gliders that won contests and set records. His success didn't stop with gliders—he built the world's first human-powered aircraft. Yes, that's right, *human* powered! In one of MacCready's planes, the *Gossamer Condor*, the pilot pedaled a modified bike to spin a propeller. It was a breakthrough in design. With a wingspan of 96 feet, the *Condor* was 30 feet long and 18 feet high—bigger than a tractor-trailer truck. And it weighed only 70 pounds—less than half the weight of the pilot! MacCready made his planes light and strong with clever designs that used materials in new ways. His motto was "do more with less."

Look at the materials below. MacCready used all but one to build the Condor. Guess which one wasn't a part of his incredible flying machine?

A. Mylar® plastic (like in silver balloons)
B. Aluminum tubes
C. Bicycle parts
D. Cardboard
E. Titanium panels
F. Piano wire
G. Clear household tape
H. Styrofoam®

(Answer: E. Titanium panels. Even though titanium is a lightweight metal, it's still a lot heavier than Mylar®.)

Mylar is a registered trademark of DuPont Teijin Films. Styrofoam is a registered trademark of Dow Chemical Company.

Watch the DESIGN SQUAD Aquatic Robotics episode on PBS or online at pbs.org/designsquad.

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