



Whatever Floats Your Boat



Cardboard Boat Engineering



The Challenge

Design and build a human-powered boat made of cardboard which is capable of completing at least one trip around a short course. No footprints left behind; everything must be removed from the lake.

Construction Rules

- The entire boat must be built of corrugated cardboard only.
 - No pre-treated cardboard allowed. No sona tubes. No waxed or 'treated' cardboard.
- Tape and glue may be used to construct boat. Glue cardboard together and use tape to secure seams.
 - No caulking compounds or two-part/mixed adhesives.
 - No wrapping boat in any material, for example tape, plastic, or fiberglass.
- The boat must have sides so that the crew sits in the boat throughout the race. The crew must paddle the boat. Propelling the boat through the water by any other means than a paddle is prohibited. No paddlewheels. No wind power.
- The crew compartment CANNOT be fully enclosed. The area where the paddlers sit must be open so as NOT to interfere with escape. No covered crew areas.
- Waterproof the boat with latex paint, varnish, or polyurethane (one-part poly only). Due to toxicity levels, no two-part substances are allowed.
- Decorations are permissible if they do not affect the structural strength or buoyancy of the boat.
- You may only use materials list below as "Permissible." You may NOT use any other materials to contribute to the structural rigidity of the boat or improve the boat's buoyancy. Upon inspection, if you are found to be in violation of any of the "Construction Rules," your boat will be disqualified and prohibited from racing. If this occurs, you will forfeit your entry fee. No refunds will be given for cheating.

PERMISSIBLE ITEMS
Use: <ul style="list-style-type: none"> Corrugated cardboard <ul style="list-style-type: none"> Standard cardboard boxes can be found at grocery or appliance stores Cardboard "blocks" <ul style="list-style-type: none"> Can be found at furniture stores Cardboard tubes <ul style="list-style-type: none"> Can be found at flooring stores Fastening materials <ul style="list-style-type: none"> Duct or masking tape Wood glue or Liquid Nails Latex paint, varnish, 1-Part Poly

PROHIBITED ITEMS
Do NOT Use: <ul style="list-style-type: none"> Treated or coated, pasteboard, or chipboard cardboard Wood, staples, clamps, or screws Styrofoam or foam core boards Plastic, plastic wrap, or tarps Metal, metal foil, or metal paint Fiberglass or any resins of any sort Silicon, epoxies, or caulking compounds Wax or tar 2-Part treatments, 2-Part paints, 2-part adhesives

Cardboard Boat Basics

Planning:

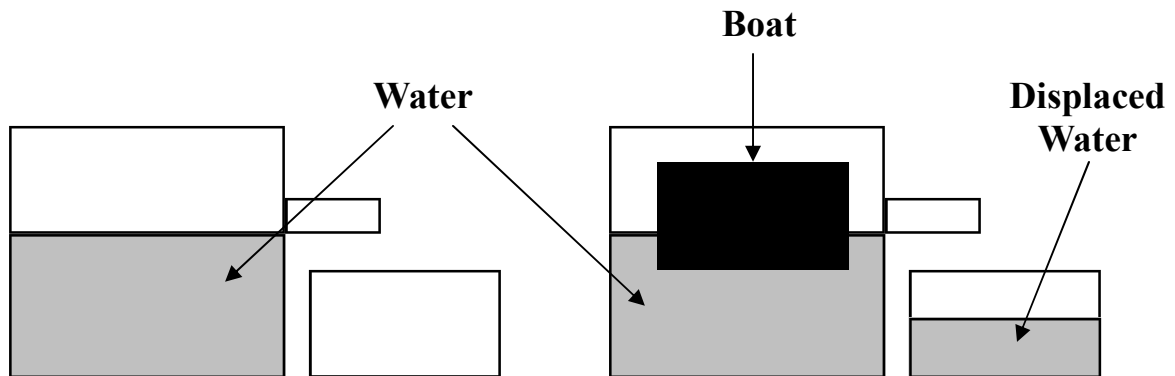
How big does my boat need to be?

How much will the boat sink?

Are you designing your boat for fun or for speed?

Once you determine the size of the crew (up to 8 people in a boat), you need to decide whether your boat will be built for performance (speed) or for pleasure (fun and creative). After that, you might want to do some physics...

Displacement



Formulas:

$$\text{Area (A)} = \text{Length (L)} \times \text{Width (W)}$$

$$\text{Volume (V)} = \text{Length (L)} \times \text{Width (W)} \times \text{Height (H)}$$

$$\text{Water Displacement (ft}^3\text{)} = \frac{\text{Total weight of loaded boat (lbs)}}{\text{Weight of water (lbs/ft}^3\text{)}}$$

$$\text{Depth boat sinks (ft)} = \frac{\text{Water displaced (ft}^3\text{)}}{\text{Area of boat (ft}^2\text{)}}$$

$$\text{Weight of water} = 62.4 \text{ lbs/cubic-foot}$$

Example: A boat is 10 feet (L) by 3 feet (W) and has 1 foot high walls

$$V = 10' \times 3' \times 1' = 30 \text{ ft}^3$$

The boat's volume is 30 cubic feet.

If the boat's volume is 30 cubic feet, then it will displace 30 cubic feet of water.

$$\text{Water displacement} = 30 \text{ ft}^3 \times 62.4 \text{ lbs/ft}^3 = 1872 \text{ lbs}$$

1,872 lbs is the total weight that the boat can support (including its own weight) before completely submerging under water. This equates to 156 lbs per inch of wall height (because the walls are 1 ft). Plan accordingly and double check your math!

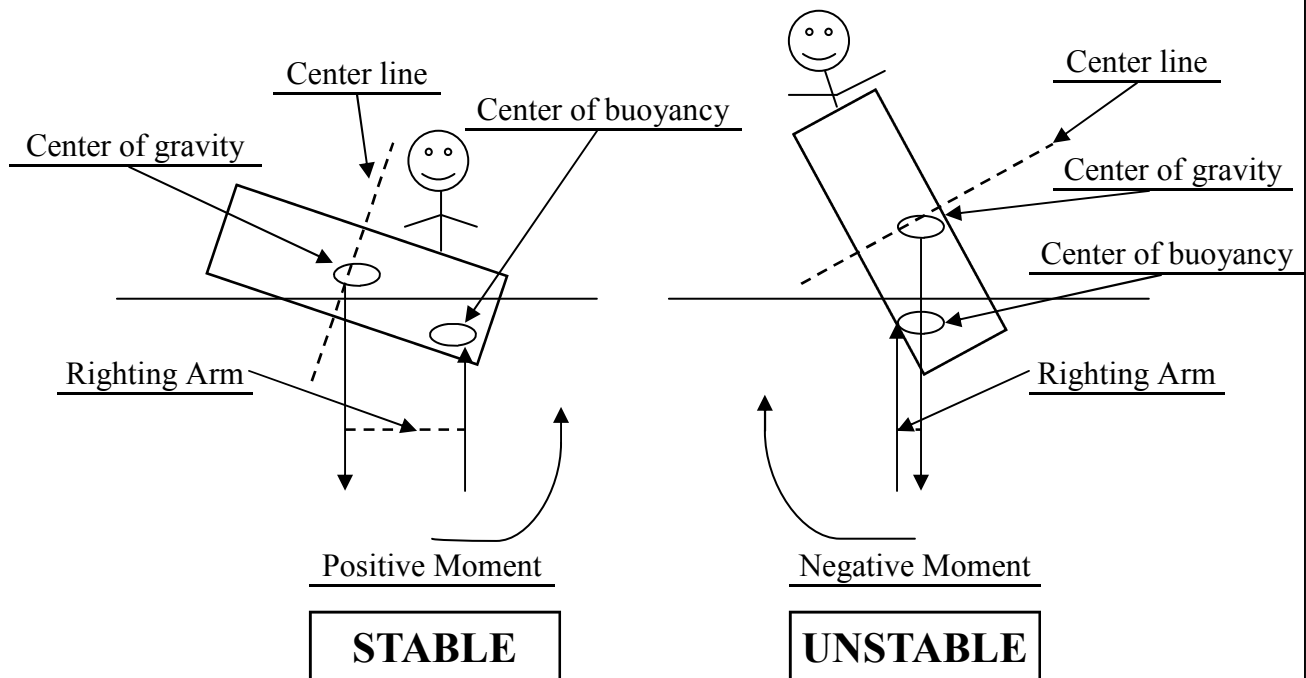
Cardboard Boat Basics

Design Tips:

Carefully consider the size of the boat. You must be able to construct the boat, transport it to the race location - Ti Beach, and you must be able to carry it from the parking lot to the waterfront.

- The boat should be big enough to hold the crew and support the weight. When determining the height of the walls, you must remember that the race takes place on Lake George... There will be waves. Be sure not to leave your walls too short to the point where waves will flood your boat.
- Remember the boat must have sides. No flat raft or surfboard style designs are allowed.
- 1' x 1' x 3' box will float 187 lbs. If your boat is big enough to hold you, in all probability it is big enough to float with you in it.
- Wider is better... Think about the boat's center of gravity versus the center of buoyancy. Wider is better, but be sure you are still able to paddle.

Let's look at the 1' x 1' x 3' box...
Horizontally vs. Vertically:



Wider is better...

- Decorations and costumes are encouraged. Use your imagination!
- No materials left behind! Everything must be removed from the lake and the beach.

Cardboard Boat Basics

Design Tips (cont'd):

Do not underestimate the importance of planning and preparation. Set your design goals and sketch out your design. Estimate material needs and plan how to use your materials. Plan out what construction techniques to utilize [See “Construction Techniques”].

— Hull Designs —



Box



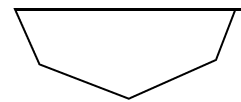
Elliptical



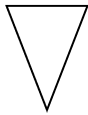
Oblong



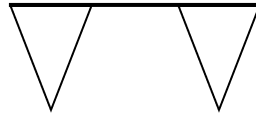
Hexagonal



Shallow V-Shape



Deep V-Shape



Deep V Pontoons



Pontoon Design
Must have sides



Raft Design
Must have sides

For cardboard boat building, flatter-bottomed hulls perform better than v-shaped. They are much more stable and tend not to roll as much, thus providing the crew with a smoother ride and allowing them to focus on paddling as opposed to balance.

— Flat-Bottomed Hull Designs —



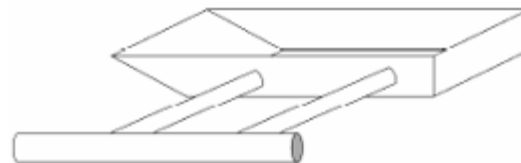
Simple
Box



V-Shaped
Box



Slanted
Box



Outrigger
Design

Go crazy and have fun with your design, but...
Choose your hull carefully!

Cardboard Boat Basics

Design Tips (cont'd):

A few more tips before we get to the techniques.

- Rudders help keep you straight but may make maneuvering more difficult. Not to mention rudders add a certain level of complexity to your design and building the boat is already challenging enough.
- Longer boats go straighter and tend to go faster, but they are harder to turn. Shorter boats (under 10ft) are difficult to keep straight.
 - Ideal length: 8-12 ft (for solo rider/two-person)
 - Ideal length for team boats depends on size of team. Be sure that each crew member has enough room to paddle and remember your physics!
- Best width for solo rider can vary from 18 inches to 30 inches depending on size of person. For two people side by side, allow for at least 48 inches.
- Kneeling is a “power” position, but sitting is more comfortable.

Construction Tips:

Adhere to these guidelines during construction and you should have smooth sailing.

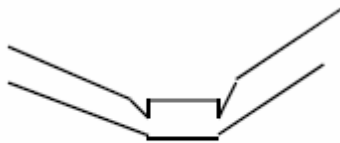
- Cover edges of cardboard. Any uncovered edge acts like a siphon and you will surely founder.
- Cardboard tubes (not sona tubes or other treated tubes) make great frames [See “Construction Techniques” for cutting, bending, and joining tubes].
- Be sure to use at least 2 layers of cardboard to reinforce the hull. Be sure to overlap the seams, so that the stress points are supported.
- Reinforce the area where the crew sits, kneels, or stands.
- When positioning where the crew will sit, kneel, or stand, be sure to keep the majority of the weight toward the back of the boat. Doing so will keep the nose of the boat up out of the water. If water comes over the bow, you’re pretty much sunk!
 - Design the bow of the boat carefully, especially the nose of the boat.
- Any bends or folds in the cardboard could weaken the boat. Be sure to use larger, unfolded sections of cardboard for the hull and other areas of importance.
- Use carpenter’s glues. Wood glue or liquid nails work well.
 - Please note that hot-glue may not hold in hot, sunny weather.
- Waterproof your vessel by painting the boat with (1-part substances only) paint, varnish, or polyurethane.
- Use duct tape, masking tape, or reinforce paper tape to seal non-painted seams. Duct tape shrinks when painted and will not hold effectively. Clear tape melts when painted.
 - Duct tape can be covered by masking tape and then painted.

Cardboard Boat Basics

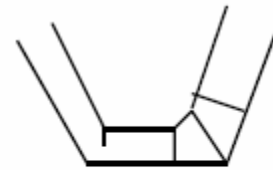
Construction Techniques:

To control the damage from bending and folding the cardboard, make shallow cuts to limit the affect on the cardboard's strength. Frame the angles with v-shaped cuts to permit bending. Make multiple cuts for sharper angles.

— Framing Angles —



V-Shaped Cuts

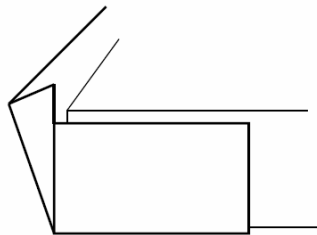


Multiple Cuts
for Sharper Angles

To strengthen corners, fold overlapped cardboard around corners and glue. Then be sure to tape the seams.

— Reinforce Corners —

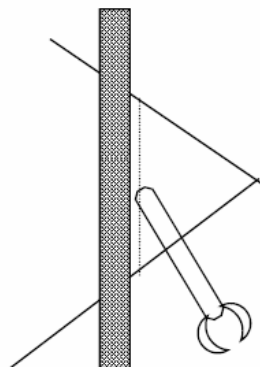
Fold & Overlap
Cardboard
Around Corners



To make clean, crisp folds, use a straight edge and a smooth object - no sharp edges or points - to crease a line before folding.

— Straight Folds —

Crease/Score a Line
for a Nice, Neat Fold



Construction Techniques (cont'd):

