MARYLAND ENGINEERING CHALLENGES™

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American Institute of Chemical Engineers, Maryland Section
and
The Baltimore Museum of Industry

A Middle School Challenge

THE HOVERCRAFT CHALLENGE

This is our first year compiling the parts and providing our own kit and set of instructions. Please don't hesitate to communicate with us if you find some typos or if something doesn't make sense. Please be sure to read through the instructions beginning to end before you do anything!

Introduction

Disclaimer: This Hovercraft kit is a derivation of the current Kelvin Electronics which is available for purchase through this company. AIChE and the BMI decided to put together their own kit based on the original Kelvin Hovercraft dating back to the very early years of the Hovercraft Challenge. We did this because Kelvin had been changing the challenge kit in a number of ways and as the changes occurred, we were seeing less and less success among the teams that had entered this engineering challenge. The Hovercraft kit being made available by the BMI is only available for purchase to the coaches for registered teams who plan to participate in the Hovercraft Challenge. The purchase price reflects the cost for the BMI to purchase the parts and put together the kits.

There are numerous principles and concepts in science, technology, and math that apply to the Hovercraft.

- Newton's Laws of Motion
- Power Transfer
- Weight Distribution
- Lift
- Proportion
- Acceleration
- Aerostatics
- Energy Conversion
- Gravity
- Thrust
- Balance
- Electrical Circuits
- Aerodynamics
- Air Pressure
- Friction
- Measurements
- Speed

The Hovercraft is a transportation vehicle that can be used on land, water, ice, or swamps. While it is classified as an air cushion vehicle" or ACV, it is sometimes referred as a "ground effect machine." A Hovercraft can range in size from a small, single person craft to a large, passenger ferry used to cross large bodies of water. Speeds up to 60 mph are not uncommon, while some Hovercraft can travel well over 100 mph.

General Information

While actual Hovercrafts are designed to be operated on land and water, the Hovercraft model you are going to build will only operate on a dry, smooth surface. The Motors and battery and the wiring are not protected from contact with water. Therefore, trying to operate the Hovercraft on water is likely to result in a short-out of the electrical circuit. Please do not try to operate the Hovercraft on water!

Safety Suggestions

- Always wear eye protection when using tools and machines, including the hot glue gun and soldering iron
- Use care When handling all sharp tools and materials
- Handle the glue gun and soldering iron carefully. The hot tips and molten glue or solder can cause serious burns!
- Remember, do not use on or over water. Damage to the Motors can easily occur

Construction Suggestions

- Be careful when making measurements. Remember: measure TWICE, cut ONCE!
- Use *low temperature* hot glue on Styrofoam. High temp glue will melt the Styrofoam. However, when gluing materials together that are not Styrofoam or other materials that may melt, it is recommended that *high temperature* hot glue be used.
- Make sure the Hovercraft is balanced when it is lifted above the floor surface. When it is out-of-balance it will lean or drag, causing poor performance, typically causing the Hovercraft to move in circles or spin.
- Permanent marking pens may be used to decorate and write on your finished Hovercraft, but be careful. The permanent marking pen can react with the Styrofoam if it is left pressed against the Styrofoam for more than a moment.
- Be sure the wiring between Motor and battery is correct. You want the hull propellor to lift the hull so if air is blowing up through the hole in the hull, the polarity of the wiring is reversed. Likewise for the thrust Motor, make sure the propeller is blowing towards the back not the front of the Hovercraft.
- These instructions provide you the steps to create an in-series electrical circuit. An in-parallel electrical circuit will give you more power but use up the battery faster. *If you choose to use an in-parallel circuit, you must research the two types of circuits, explain the difference between them and explain why you chose the in-parallel circuit. This must all be included in your report.* A diagram of an in-parallel circuit has been provided, but no details on how to put it together and use in the Hovercraft. That's your challenge!

MAIN COMPONENTS IN THE HOVERCRAFT KIT

	1.5-volt Motor for thrust 1	Used with Styrofoam clamshell
	3-volt Motor for lift 1	Used with Styrofoam tray
	Kelvin 3-blade Propeller 2	One each used with the Motors for lift & thrust
	Rocker Switch SPST 1	Installed in clamshell and used to turn on and off the electric circuit

9-volt Battery holder clip
1

Used to hold battery on top of clamshell

9-volt battery connector
1

Styrofoam tray
1

Serves as the hull of the Hovercraft

Styrofoam clamshell
1

Top or bottom will serve as the cabin on top of the Hovercraft's hull

MISC. COMPONENTS IN THE HOVERCRAFT KIT

Push Quick Wire Connector (double quick-connect Connector)
2

Tool to connect wires during construction and attempts to get Hovercraft operating properly

Gel-Filled Connectors for wires
4

Used to make final connections with wires in lieu of soldering wires together

OTHER COMPONENTS IN THE HOVERCRAFT KIT

- Stranded Copper Wire, 24 AWG, 12 inches each, Black & Red — Used to connect Motors in the electric circuit, you will need to cut them in half
- Wooden Dowel Rod, 12 inches by 1/8 inch diameter — Use to construct rudder
- Wood Craft stick with holes — Use to attach 3-volt Motor on hull
- Wood Craft stick, solid & smaller — Use to attach 1.5 volt Motor to cabin
- Straw, approx. 7.5 in. long & very narrow diameter — Use to construct rudder fitted over wooden dowel

OPTIONAL ADD-ONS

0.5 in. dia Poly Foam Caulk Saver (Frost King @ Home Depot)

Use to glue or tape (double-stick) around bottom edge of hull to increase space height below hull

Plastic bag or plastic sheeting (maybe trash bag)	View YouTube videos for an idea: https://www.youtube.com/watch?v=5_jzMWa2V_w https://www.youtube.com/watch?v=g4lGQ2ltU08	Glue or tape to bottom of hull to create an air cushion… You will need to design and adapt the plastic bag for the BMI Hovercraft using the videos for inspiration

TOOLS / SUPPLIES YOU WILL NEED

Ruler	Pencils / Pens	Scissors
X-Acto knife	Low-temp hot glue gun	High-temp hot glue gun
Hot glue sticks	Soldering iron	Solder (lead based)
Needle nose pliers	Markers (permanent)	9-volt batteries
Butt Connectors T-tap[1]	Heat shrink tubes & heater[2]	

1. *Suggested if participants are going to try to set up an In-Parallel circuit. Search Amazon for UG K5 IDC Butt Connector T-tap (the link was too long) and scroll down until you see green connectors. $8 for 100 pieces. "3-port" connectors will also work.*
2. *A high-temperature hair dryer can work as the heater, although it will take longer. Use needle pliers to hold the encased connection to prevent burning your fingers. Only use heat shrink tubes where you have connected two wires and soldered them. This should not be necessary as you have been supplied with extra connectors for the wires.*

NOTE: *ALWAYS USE LOW-TEMP GLUE ON STYROFOAM*. HIGH-TEMP GLUE MAKES A STRONGER BOND BETWEEN CRAFT STICKS AND MOTORS, but low-temp glue will work.

MOTOR POLARITY

Both Motors with Propellers, Battery Connector & 9-volt Battery

Even if the motors are marked to tell you which node is positive, you should check the polarity of the nodes on the motors before getting started.

1. Strip about ½ inch of the jacket off each wire on the Battery Connector.
2. Push RED wire end through the hole of one node on the Motor, bending the bare wire in half and wrapping the bare wire gently around the node.
3. Repeat with the BLACK wire on the other node.
4. Attach the propeller to the shaft of the Motor.
5. With one team member holding the Motor so the fan is perpendicular to the ground and a strip of paper in front of the fan about 6 inches from the fan, have another team member connect the Battery to the Battery Connector. If the strip of paper DOES NOT blow away from the propeller, switch the wires on the nodes. Verify that the paper strip blows away from the propeller. Mark the Motor on the side which has the RED wire with a plus sign to indicate it is the positive side of the Motor. Carefully remove the wires.
6. Repeat with the other Motor. Carefully remove the wires and propellers when you have completed the task.

THE CABIN

Hole in Cabin	• 2.75 inch diameter, centered on top of clamshell (cut the clamshell in half at the "hinge" and trim excess around the edges). Cut out the circle with X-Acto knife.
Hull Battery Holder Craft Stick 1.5-volt Motor	• Glue the smaller craft stick across the hole, bisecting it. • Glue the Battery Holder onto the craft stick centered over the hole in the cabin. • Glue the 1.5-volt Motor to the end of the Craft Stick stretches past the edge of the Cabin, flat side down so nodes are on top[3].
Switch Battery Connector	• Choose a location to put the Switch in the Cabin, front, left or right side. Given how participants hold the Hovercraft when it is time to cross the Bay, it might be best to put it on one side or the other, instead of the front of the Cabin. • Measure the length and width of the lower part of the Switch. Draw a rectangle on the side of the Cabin using the measurements of the Switch body and cut out the rectangle with X-Acto knife. You want the Switch to fit snugly in the hole. Eventually, you will affix it with glue. • Connect the RED wire of the Battery Connector to one of the nodes on the switch.[4]
Motor, 1.5 volt Red wire Battery Connector	Connect Wires to the Thrust Motor: • Cut the RED wire in half. Take one of the halves, strip about ½ inch of the jacket from one end and attach it to the positive node[5] of the Motor, twisting tightly. • Connect the BLACK wire of the Battery Connector to the negative node of the Thrust Motor.

3. *Note: There are vents on one of the flat sides, the side that will be glued to the craft stick. Apply glue carefully so the vents are not blocked. The glue will keep the Motor from being flat against craft stick so they will not be blocked.*
4. *Suggestion: To check that you have enough wire on the Battery Connector, put the Battery in the Battery Holder, Snap the Battery Connector onto the Batter, check to see if the Red wire will reach the Switch with some slack, and check to see if the Black wire will reach the Thrust Motor's negative node with some slack.*
5. *Put about ¼ inch of the bare wire strands through the hole in the node, bend the bare wire in half and twist, not tight.*

THE HULL

Hole in Hull	• 3.5 inch diameter, offset the center point of the Hull by ¼" toward the bow[5] (front) of the Hull. Cut out the circle with X-Acto knife.
Motor, 3-volt Lift Motor	• Center the large Craft Stick (with holes) across the hole lengthwise and glue it to the Hull.

- Glue Motor to craft stack with shaft through center hole.

Quick-Connect Connector

Black Wire

Red Wire

Cabin

Gel-filled Connector

- Cut the BLACK wire in half. Take one of the halves, strip about ½ inch of the jacket from one end and attach it to one node of the Lift Motor (to be connected to the Thrust motor).
- Attach the remaining half of the RED wire to the other node on the Lift Motor (also stripped of ½ inch of the jacket) (to be connected to the Switch).
- Center the Cabin over the Lift Motor on the Hull. Make markings where the Cabin sits on the Lift Motor's Craft Stick on front and back of Cabin. Use these markings to create a notch so the Cabin will fit over the Craft stick and flush against the top of the Hull.
- Set the Cabin on top of the Hull fitted over the Lift Motor's Craft Stick and mark the Cabin's four corners on the Hull.

NOW, complete the Wiring Circuit…

- Take the RED wire that is connected to the Lift Motor, determine how much is needed to reach the Switch, add about an inch, strip ½ inch jacket from the end of the wire, then attach it to the unused node on the Switch.
- Cut the white double-quick Connector in half. Use one quick-connector to connect the Lift Motor's BLACK wire to the Thrust Motor's RED wire.
- Attach a propeller to the Lift Motor's shaft, rest the Cabin on the Hull, connect the Battery Connector to the Battery and place Battery in its holder. Use the Switch to open the circuit and check that the Hovercraft is levitating.
- When you are satisfied the propeller is levitating the Hull, use the switch to turn it off, remove the propeller, remove the battery from the holder, disconnect the battery connecter from the battery, then solder the wires to the Motors and Switch.[6]
- Shorten the Black and Red wires between the two motors, then connect them permanently with a gel-filled connector (orange cap).[7]
- Place the Cabin on the Hull and line up the four corners with the markings you made earlier. Glue the Cabin to the Hull.

6. *Decide which end of the Hull will be the BOW and notate information on bottom side.*
7. *Search the internet for videos which explain the techniques of soldering.*
8. *You will lose points if your Hovercraft has quick-connectors when the Judges evaluate your work product.*

Finish the Hovercraft

Your Hovercraft will need a Steering System, otherwise known as a Rudder. This is where you need to do some research and get creative. Kelvin Electronics has some suggestions for Rudder designs and the BMI will provide you with a copy of their suggestions upon request. Or, you may search the internet and see what you can find that might be feasible for the Hovercraft you have built. Or, you can do both consider the Kelven designs and search the internet. Below is some information and a couple of links to get you started.

You might try adding a plastic bag to the bottom of the Hovercraft, something that a real Hovercraft would actually have (rubber) to protect the fans and engines from water. You could add foam weather stripping around the perimeter of the Hull to increase the height (and therefore the volume) of the cavity below the top deck.

Add a Rudder/Steering System

Styrofoam meat trays (cleaned and sanitized)

(for Kelvin design)

Use to create the rudder

Large (>= 16 oz) Styrofoam or Plastic drinking cup (cleaned)

(for Kelvin design)

Use as a cowl over the rudder as part of the steering system

Rudder ideas (https://www.instructables.com/How-to-make-a-RC-Hovercraft/) can you create a similar Steering System seen in this instructable?

There's more…google: "rudder ideas for Hovercraft model"

In this photo, the "cowl" is square, so you would want another meat tray instead of a cup.

Rudder idea (https://Hovercraft-kits.com/products/molded-rudder) can you recreate something similar with Styrofoam tray and drinking cup?

Working with the Hovercraft

Start working with your Hovercraft to get it to run straight along the floor. You may find that you need to balance the Hovercraft because it is veering off from a straight path. You can use coins to do this to provide weight to change the balance of the Hovercraft. Experiment by taping a small coin to a corner and see what happens. If nothing seems to change, increase the size of the coin. You could also use washers. You will have to experiment with the various corners to see if one corner with a weight on it has an impact on the movement of the Hovercraft and to determine how much weight, if any, is needed.

Decorate your Hovercraft. The judges do evaluate the Hovercrafts for visual creativity.

See next two pages for wiring diagrams.

Diagram of the Completed In-Series Electrical Circuit

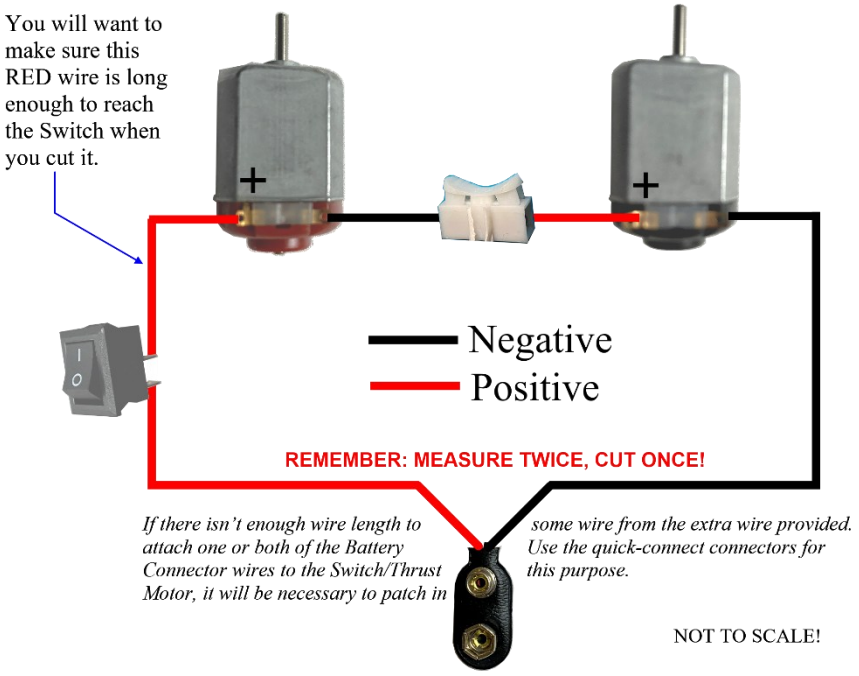
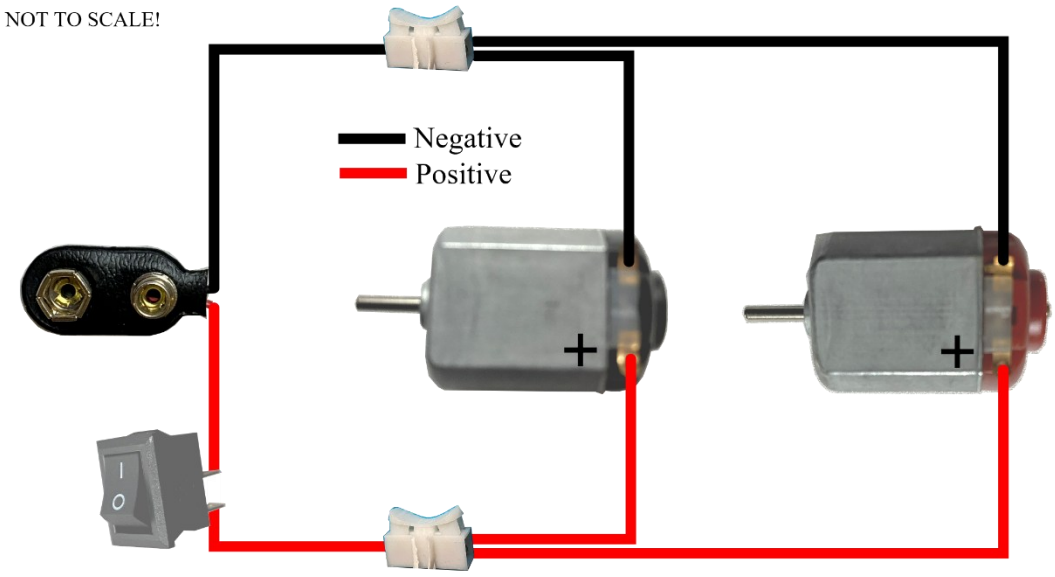


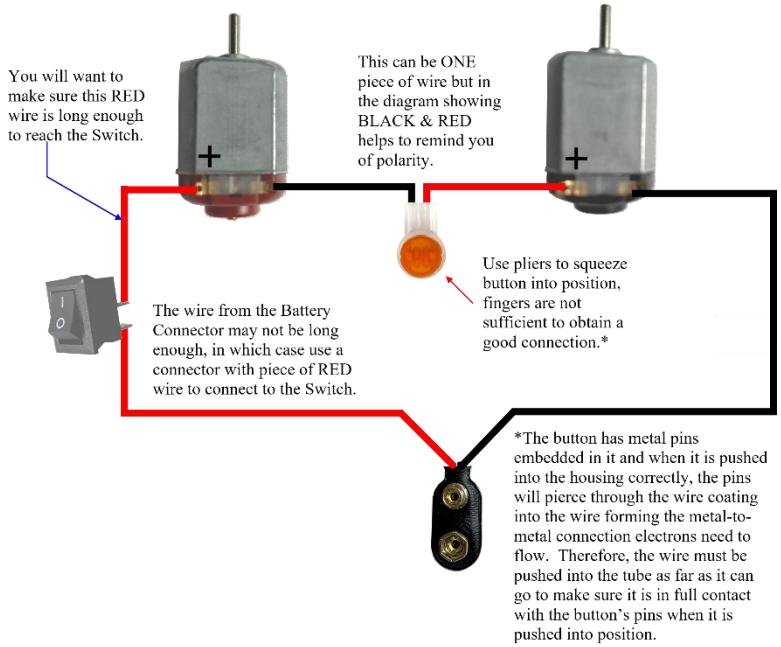
Diagram of the In-Parallel Electrical Circuit



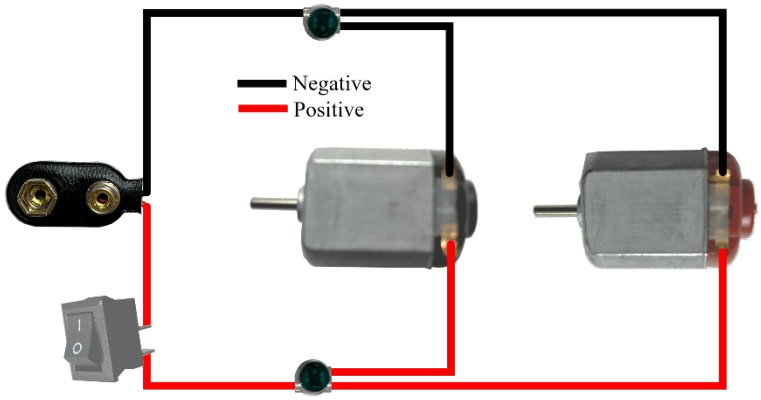
The electrical Circuit diagrams shown above use temporary connectors that make the circuit more efficient than just twisting wires together testing and perfecting the Hovercraft's

movements. When you are satisfied that everything is working correctly, you may replace the quick-connect connectors with the orange button connectors that have been provided for the in-series circuit. If you are going to go with the in-parallel circuit, you can twist the three wires together and solder them then cover them with a heat shrink sleeve. Or, you can purchase specially designed push-button connectors as described in the table listing additional tools and supplies you will need. No exposed wire connections, please! See diagrams on the next page showing connectors in use

In-Series Electrical Circuit with button connector



In-Parallel Electrical Circuit with button connectors



Wow, you've made it all the way to the end, hopefully by way of reading the instructions!! We'll close with a suggestion. Before you start cutting holes in Styrofoam, cutting wires, attaching wires, etc., we recommend that you step through the instructions using paper and red & black pens. Take a piece of paper, cut it in half. One of those halves will serve as the Hull. Take the other half and cut in half again. Take one of the resulting quarters, and cut a square from it. From the other quarter, cut two "craft sticks", one wider (representing the Hull craft stick) than the other. From the remaining paper, cut rectangles to represent the Battery Holder, the Switch (small rectangle), the Thrust Motor, and the Lift Motor. Now follow the Instructions for a "dry" run through. Use Red & Black markers to draw in the wires when directed to connect wires to something. Hopefully, this will aid you in following the Instructions while building your Hovercraft.