PROJECT KIT

Ages 8+

GEEK & CO. SCIENCE!

WIND RACER

THAMES & KOSMOS

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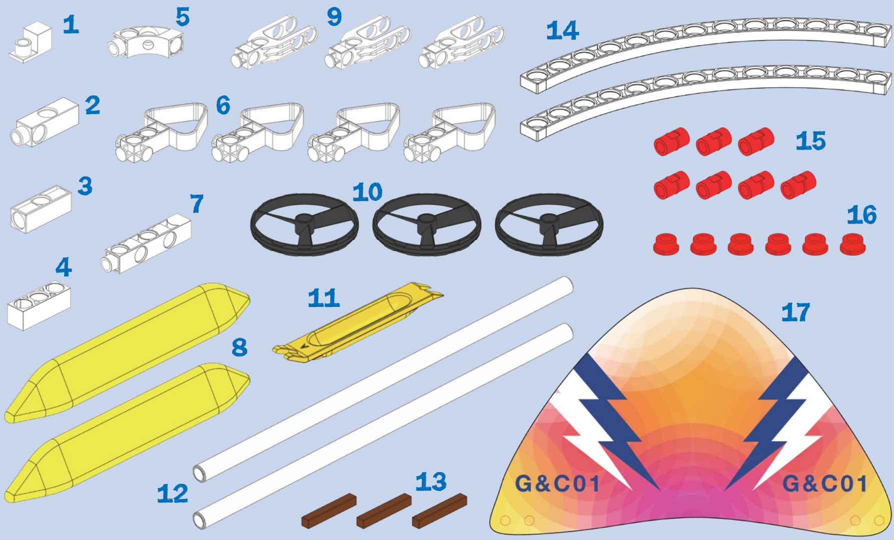
Safety information

WARNING.
Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled.
Keep the packaging and instructions as they contain important information.
A parent or other adult should supervise all outdoor experiments and all experiments with water in the bathtub, basin, or kiddie pool. Don't use electric fans or any other electric devices anywhere near the water.
Do not throw the models toward other people or animals. Make sure people and animals are well out of the potential flight path of the glider.
Be careful when inserting the wooden dowels into the plastic components.
If you put too much force on them, they can warp, splinter, or break. Do not injure yourself!

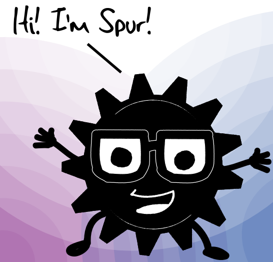
KIT CONTENTS



1 | 90-degree converter - Z (1)
2 | 3-hole dual rod (1)
3 | 3-hole cross rod (1)
4 | 3-hole rod (1)
5 | Curved rod (1)
6 | Pontoon holders (4)
7 | 5-hole dual rod (1)
8 | Pontoons (2)
9 | Forked rods (3)
10 | Wheels/propellers (3)
11 | Part separator tool (1)
12 | Clear tubes, 210 mm (2)
13 | Bamboo dowels, 20 mm (3)
14 | Curved flat rods (2)
15 | Anchor pins (7)
16 | Bearing pins (6)
17 | Sail (1)

YOU WILL ALSO NEED: *A windy place to test your models, an electric fan for indoor experiments, a bathtub or basin of water for sailboat experiments*

Hey Super Sailors!



Ready to build some cool sail cars and sailboats? With this kit, you can construct five vehicles powered by the wind and a wind direction indicator. Then investigate the physics behind how they work. Learn how sails function like wings to capture the forces of the wind and generate lift. Spur the Geeker will be your guide!

PART 1

SAILING ACROSS THE LAND

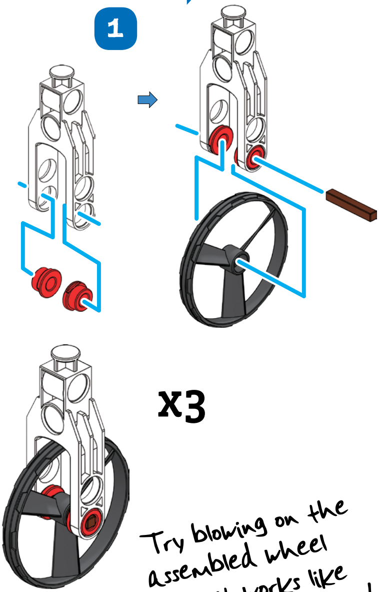
Assembling the sail car

Here's how:

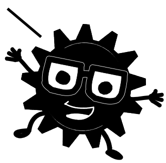
1. Assemble three wheel units by inserting the bearing pins into the forked rod, aligning the center to the wheel between them, and then sliding the bamboo dowel through them to hold the wheel.

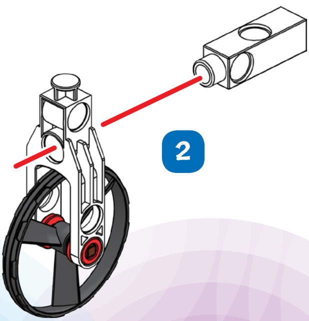
2. Insert one 3-hole dual rod into one of the wheel units.

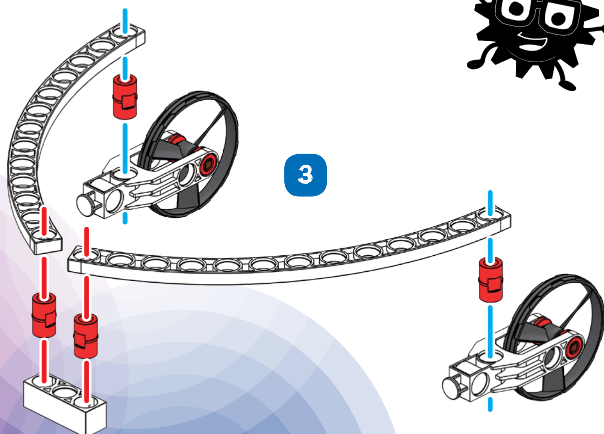
3. Assemble the chassis of the car with two curved flat rods, a 3-hole rod, two wheel units, and four anchor pins.



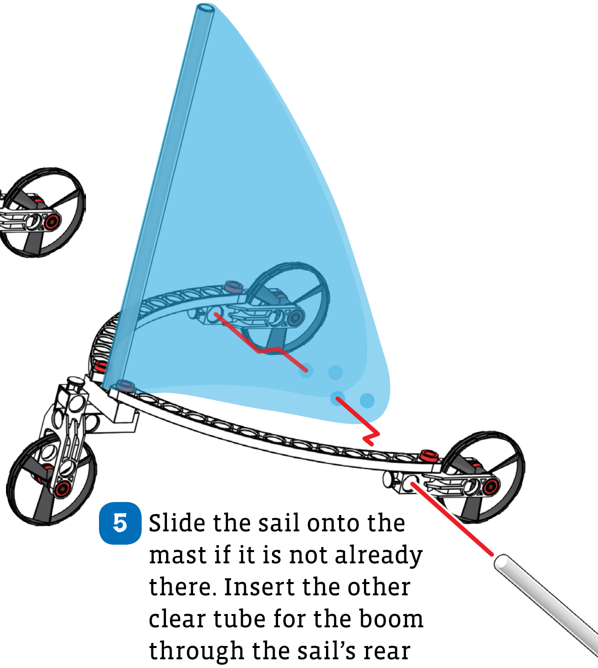
Try blowing on the assembled wheel unit... it works like a turbine and spins!



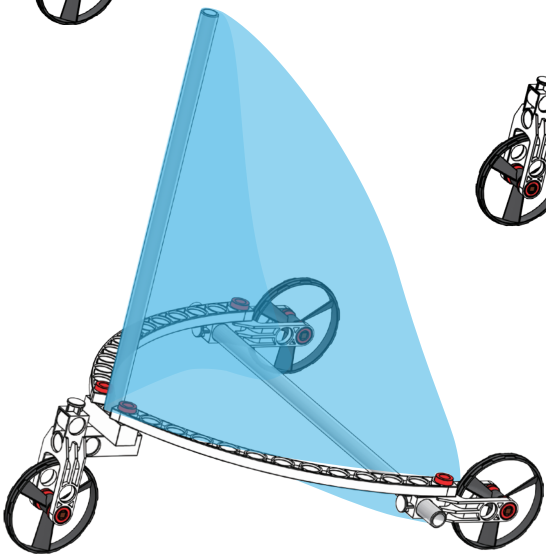




4 Insert the clear tube for the mast through the 3-hole rod and into the third wheel unit. (The tube may be already inserted into the sail.)



5 Slide the sail onto the mast if it is not already there. Insert the other clear tube for the boom through the sail's rear holes and then into the two rear wheel units.



6 The sail car is done! Follow the instructions below to test it.

Testing the sail car

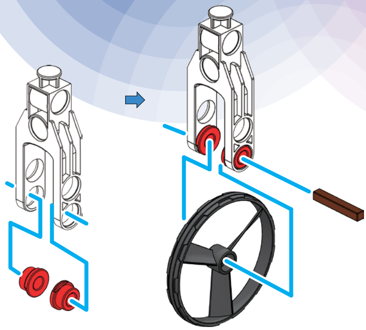
You can test your sail car outside on a breezy day or inside with the more controlled airflow from an electric fan. Position the car facing away from the direction from which the wind is blowing and let it go. The moving particles in the air will hit the surface of the sail. The particles push on the sail, **accelerating** (increasing the speed of) the sail and the car attached to it. The car moves! At the same time, the sail pushes back on the air particles, **decelerating** (decreasing the speed of) the air particles. But because there is so much wind, this doesn't stop the wind!

This is called **downwind sailing**. The physics of upwind sailing is described on page 11.

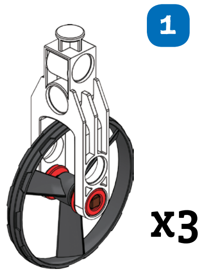
Assembling the wind catcher car

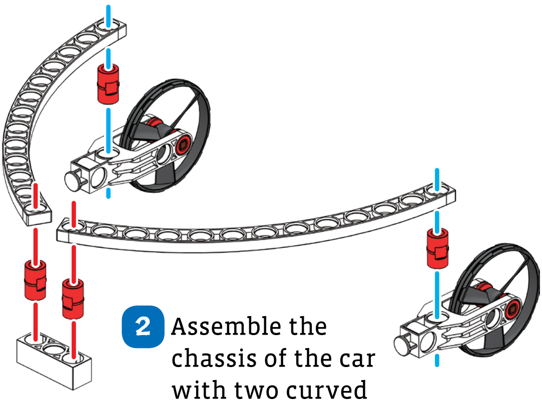
This car works like a windsock to capture a lot of the wind's force.

Here's how:

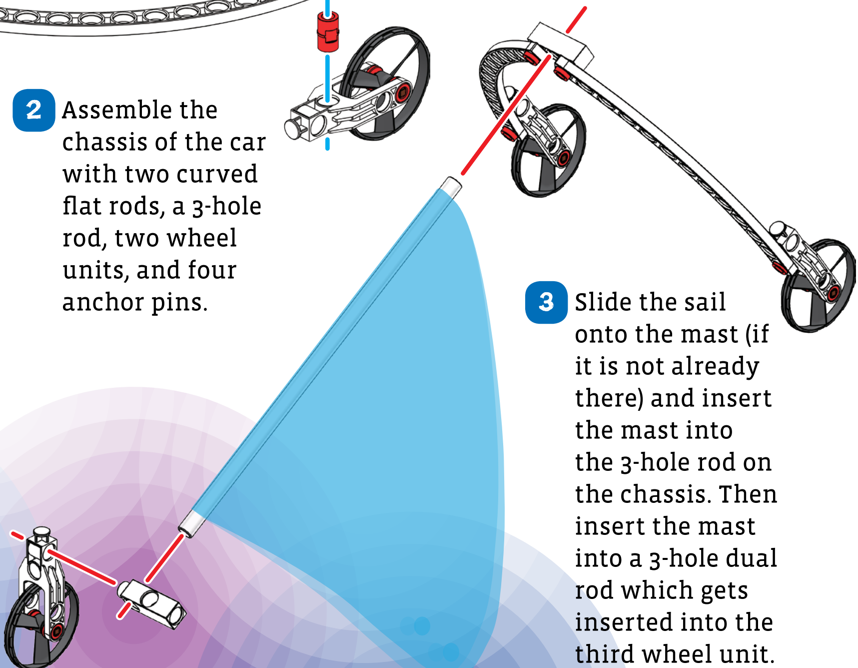


1 Assemble three wheel units by inserting the bearing pins into the forked rod, aligning the center to the wheel between them, and then sliding the bamboo dowel through them to hold the wheel.

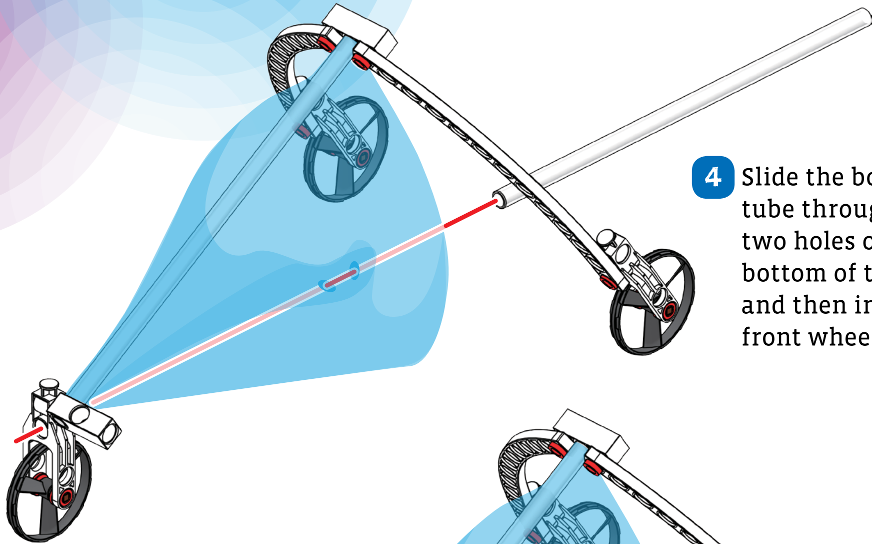




2 Assemble the chassis of the car with two curved flat rods, a 3-hole rod, two wheel units, and four anchor pins.

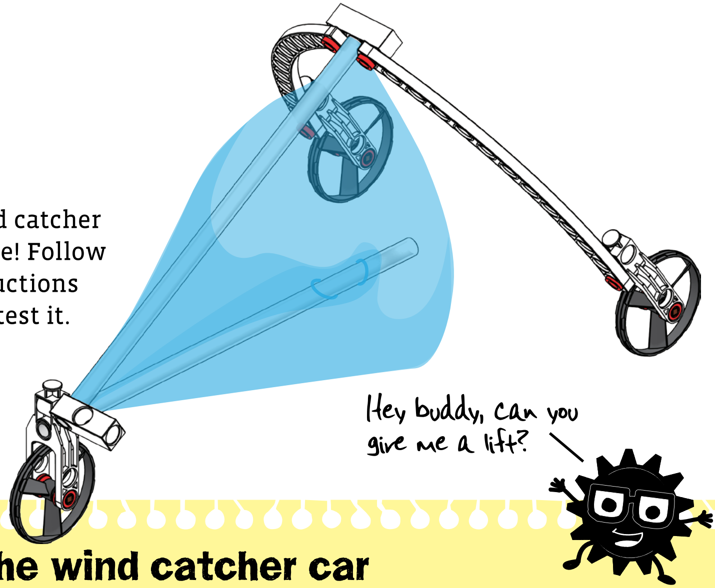


3 Slide the sail onto the mast (if it is not already there) and insert the mast into the 3-hole rod on the chassis. Then insert the mast into a 3-hole dual rod which gets inserted into the third wheel unit.



4 Slide the boom tube through the two holes on the bottom of the sail and then into the front wheel unit.

5 Your wind catcher car is done! Follow the instructions below to test it.



Testing the wind catcher car

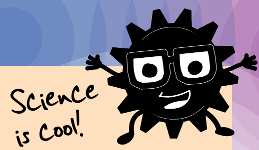
As with the sail car, you can test your wind catcher car outside on a breezy day or inside with the more controlled airflow from an electric fan. Position the car facing away from the direction from which the wind is blowing and let it go.

The moving particles in the air will enter the wind catcher cone, hit the inner surface of the cone, and push the car forward. This car has more **wind resistance**, also called **drag**, than the first car because the particles of air cannot simply slip around the sail. They enter the cone and bounce around until they are pushed out by more incoming air particles.

How does the performance of the wind catcher car compare to that of the first sail car? You may notice it is faster but less stable. The cone can create a lot of **turbulence**, a chaotic, irregular flow of air, disrupting the car's motion.

GEEK OUT!

THE PHYSICS OF THE SAIL CAR

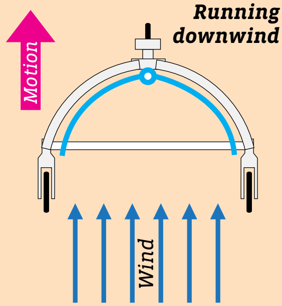


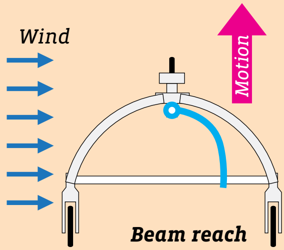
Sail cars and sailboats use the wind to create forward motion in similar ways. While the sailboat needs its keel to channel the forces into a forward motion, the sail car needs its wheels. Sails work in three ways: If the wind is coming from behind, the wind can simply push the sail and the vehicle forward. This is called **running downwind**.

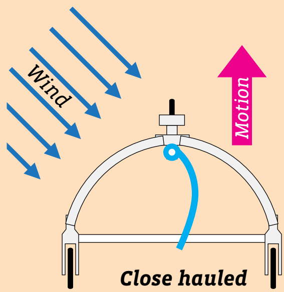
If the wind is coming from the side, the sail redirects the wind toward the back, which accelerates the wind backward and the vehicle forward. The resulting force has a strong sideways component, but the keel or wheels counteract that, keeping the vehicle moving forward. This is called a **beam reach**.

If the wind is coming more from the front, then the sail must be brought in tightly. Now the sail works like a wing, generating a lift force perpendicular to the sail as the wind flows over the two sides at different speeds. Here again the keel counteracts the sideways force, leaving the forward component of the force to move the vehicle forward. This is called **close hauled**.

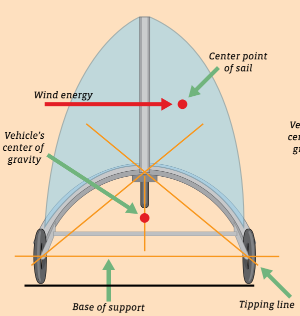
The models in this kit work best running downwind, and it is difficult to get them to work well otherwise. But experiment with them and you might be surprised by what you can do!



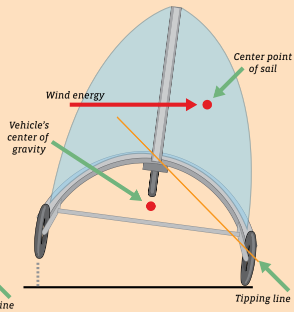




STABLE EQUILIBRIUM



UNSTABLE EQUILIBRIUM



Stability

The wheels and a low center of gravity keep the sail car stable so that it doesn't tip over. If the wind is so strong that it pushes the center of gravity over the tipping line, then the car will tip over.

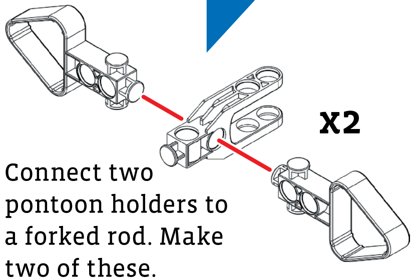
PART 2

SAILING ON THE WATER

Assembling the sail catamaran

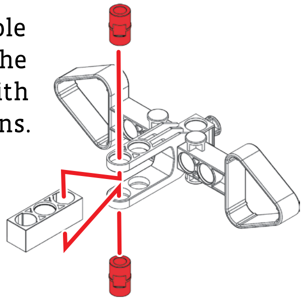
Let's build a sailboat with two hulls called a catamaran!

Here's how:

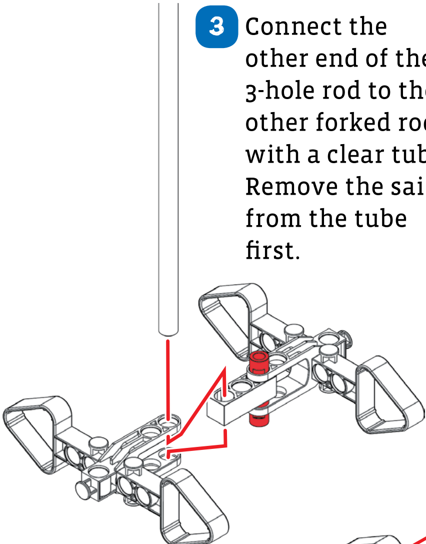


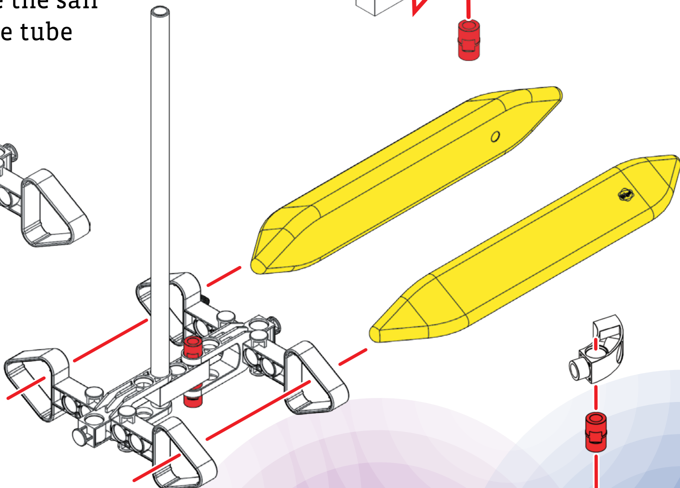
1 Connect two pontoon holders to a forked rod. Make two of these.

2 Connect a 3-hole rod to one of the forked rods with two anchor pins.



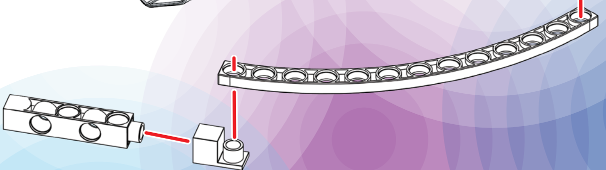
3 Connect the other end of the 3-hole rod to the other forked rod with a clear tube. Remove the sail from the tube first.

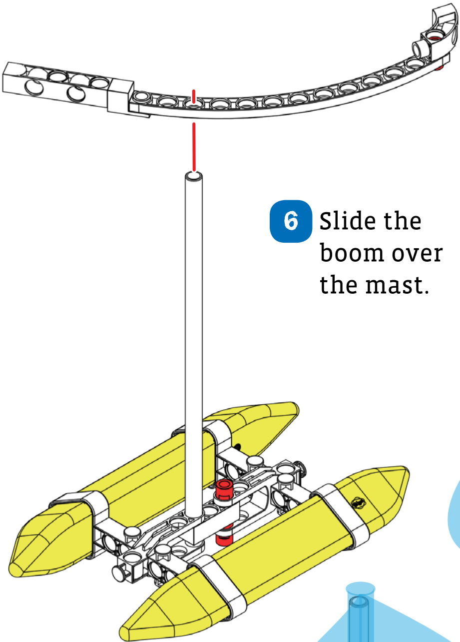




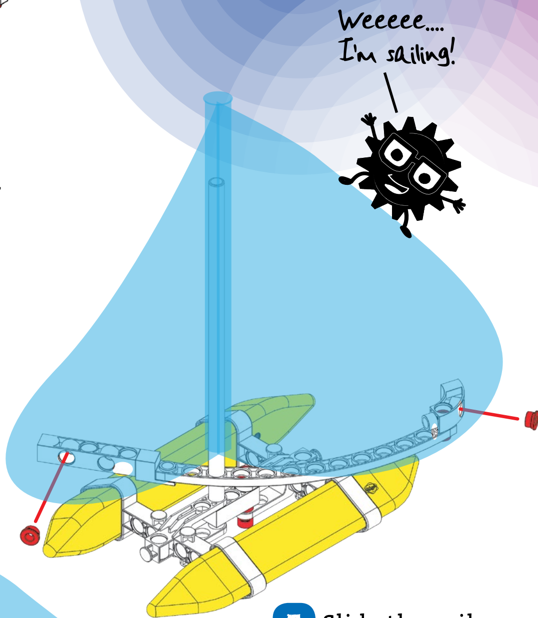
4 Slide the two pontoons into the pontoon holders.

5 Assemble the boom as shown here.

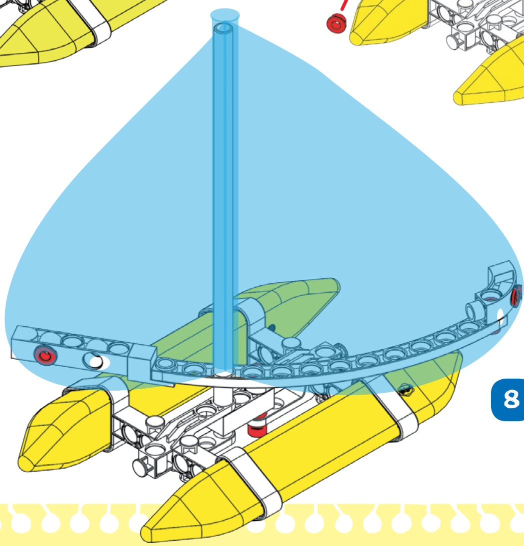




6 Slide the boom over the mast.



7 Slide the sail over the mast. Attach the bottom with two bearing pins



8 Done! Follow the instructions below to sail your boat.

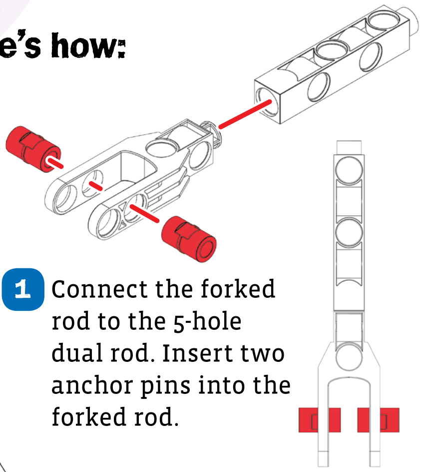
Testing the sail catamaran

You can test your catamaran in a bathtub, large basin, or a kiddie pool. Make sure you have an adult helping you. Don't use electric fans or any other electric devices anywhere near the water.

Your sailboat will sail in the direction the wind is blowing toward. This is called the **leeward** direction. The direction the wind is coming from is called the **windward** direction. The air particles push on the sail, causing a reaction force which pushes the sailboat in the opposite direction.

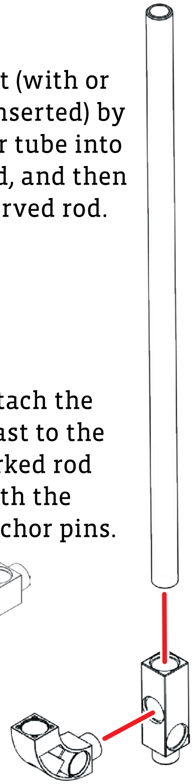
Assembling the sailing dinghy

Here's how:

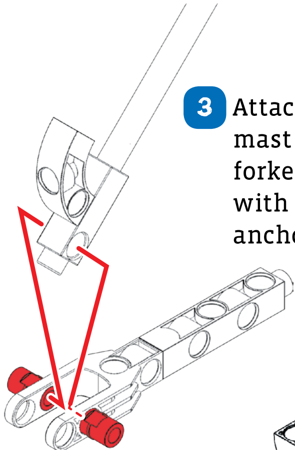


1 Connect the forked rod to the 5-hole dual rod. Insert two anchor pins into the forked rod.

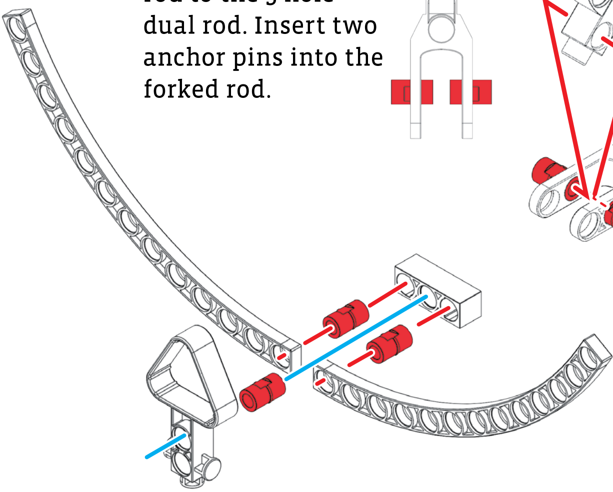
2 Assemble the mast (with or without the sail inserted) by inserting the clear tube into the 3-hole dual rod, and then connecting the curved rod.



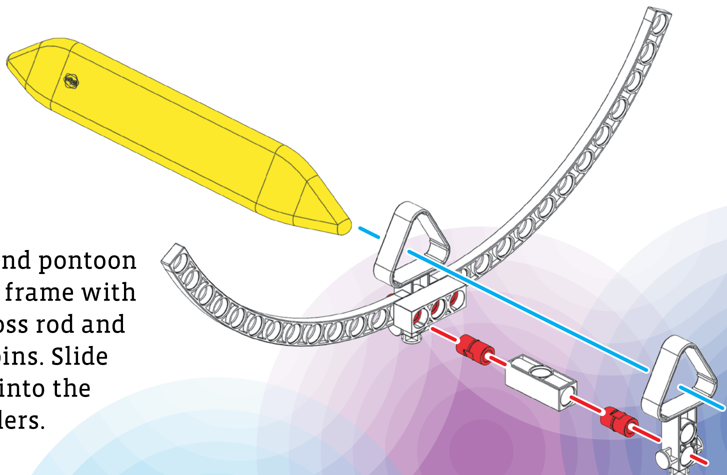
3 Attach the mast to the forked rod with the anchor pins.

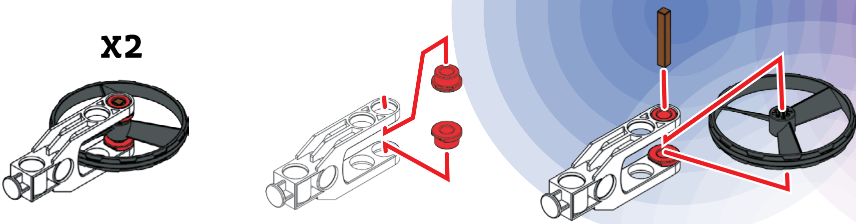


4 Attach the two curved flat rods to the 3-hole rod and a pontoon holder with three anchor pins.

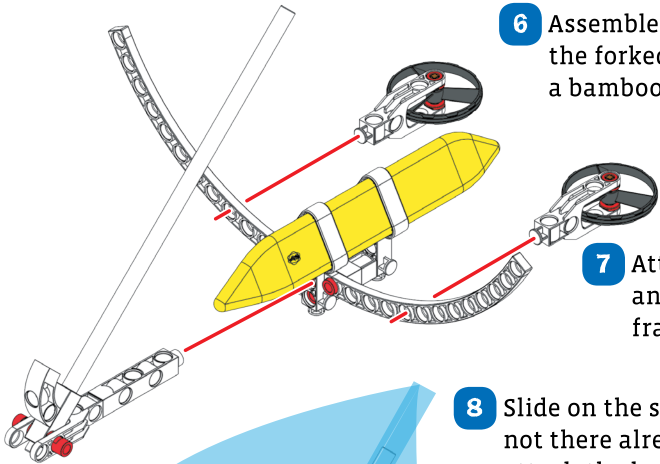


5 Attach a second pontoon holder to the frame with the 3-hole cross rod and two anchor pins. Slide the pontoon into the pontoon holders.



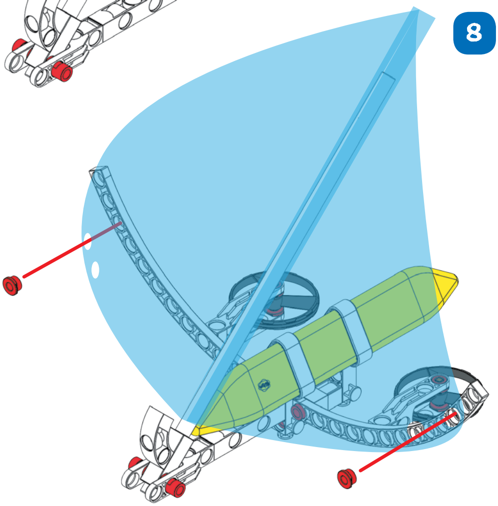


6 Assemble two wheel units with the forked rod, two bearing pins, a bamboo dowel, and a wheel.

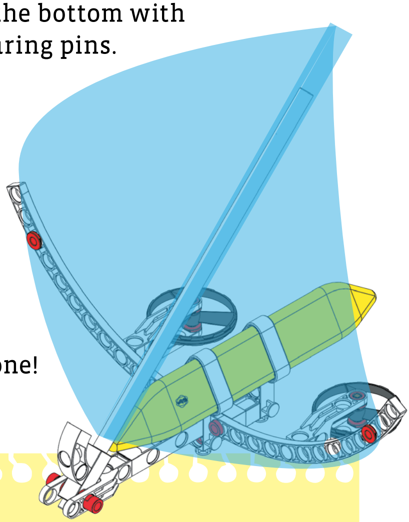


7 Attach the mast holder and the wheel units to the frame.

8 Slide on the sail if it is not there already and attach the bottom with two bearing pins.



9 Done!



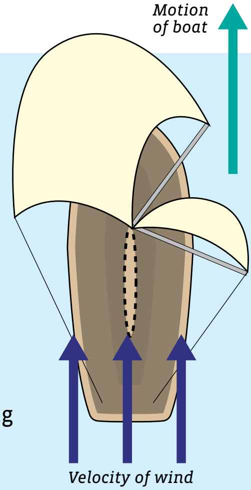
Testing the sailing dinghy

You can test your dinghy in a bathtub, large basin, or a kiddie pool. Make sure you have an adult helping you. Don't use electric fans or any other electric devices anywhere near the water.

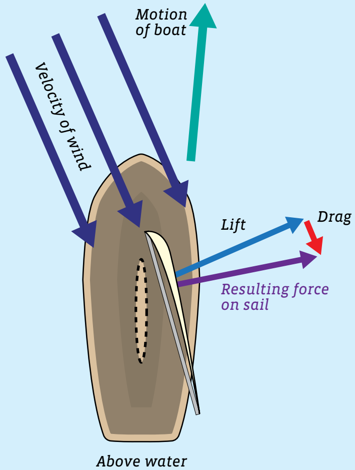
The dinghy sits lower in the water than the catamaran because it has only one pontoon to give it **buoyancy** and lift it up. You may also notice it is less stable, so you must adjust the sail to keep it balanced.

GEEK OUT!

THE PHYSICS OF THE SAILING



Let's get a little more in depth on how sails work. A boat's **keel** — the large flat structure on the bottom of the boat that runs parallel to the direction of motion, so it easily glides through the water forward and backward, but resists movement from side to side — is critical to the boat's forward motion through the water. When the boat is running downwind, the wind simply pushes on the sail and pushes the boat forward through the water.



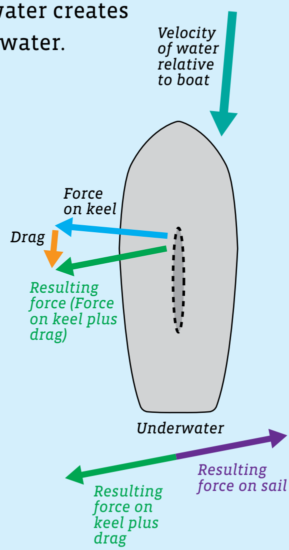
But when the boat is sailing into the wind, the forward motion of the boat relies on the counteracting forces on the sail and on the keel. The velocity of the wind (relative to the boat) on the sail generates a **lift** force (see page 16) which is perpendicular to the wind. The lift combined with the **drag** force, which is parallel to the wind, create a **resultant force** on the sail.

At the same time, underwater, the **velocity of the water** (relative to the boat) creates a **lift** force on the keel, which acts like an underwater wing. The force on the keel combined with a **drag** force from the keel and the water creates a **resultant force** underwater.

When this resultant force is equal and opposite to the resultant force on the sail, the boat will not accelerate or decelerate — it will stay traveling at the same velocity. If one of the forces changes, the boat will either accelerate or decelerate accordingly.

When the boat is moving fast with the wind coming at an angle from the front, the velocity of the wind relative to the boat is actually much faster than the velocity of the wind relative to the water. This is called **apparent wind**, and it is why traveling into the wind is faster than running downwind.

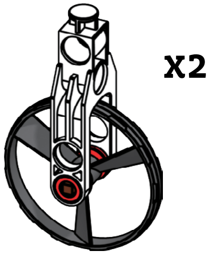
The boat can never travel directly into the wind, so in order to keep moving upwind, sailboats must **tack**, or quickly move the bow to the other side.

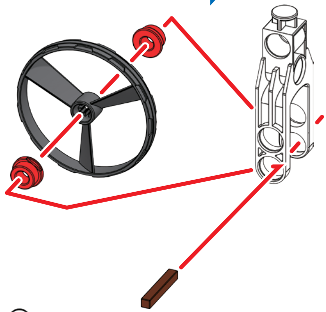


PART 3 CAPTURING THE WIND

Assembling the wind direction indicator

Use this device to test the direction of the wind.

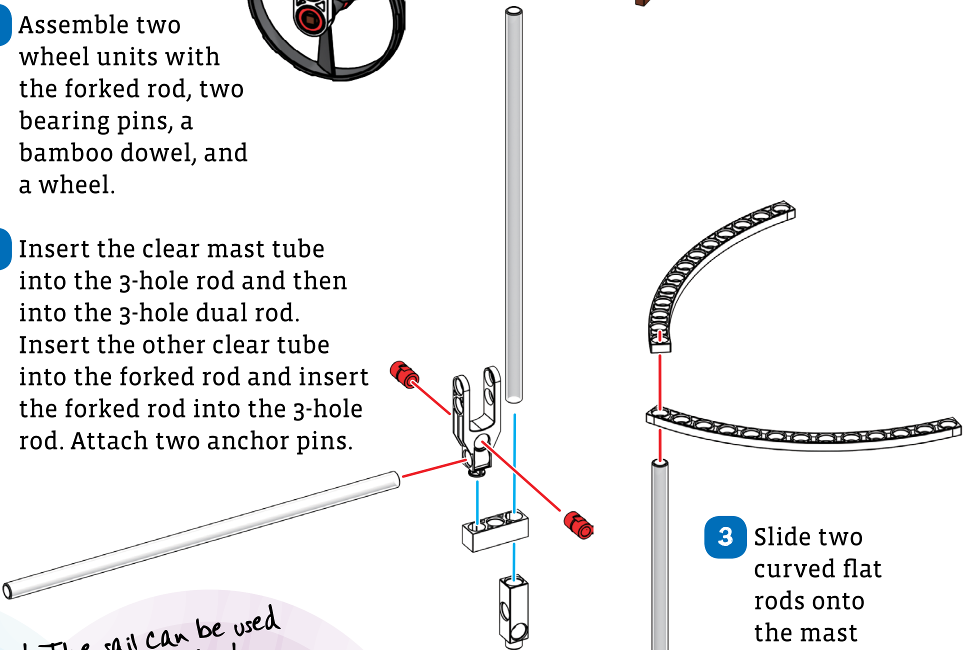




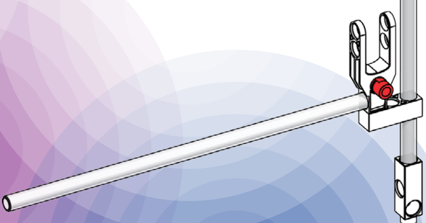
Here's how:

1. Assemble two wheel units with the forked rod, two bearing pins, a bamboo dowel, and a wheel.

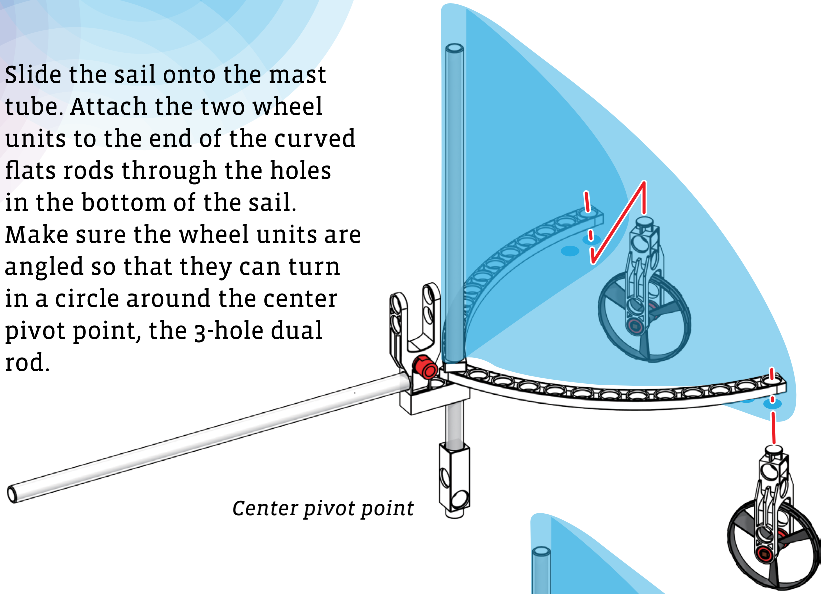
2. Insert the clear mast tube into the 3-hole rod and then into the 3-hole dual rod. Insert the other clear tube into the forked rod and insert the forked rod into the 3-hole rod. Attach two anchor pins.



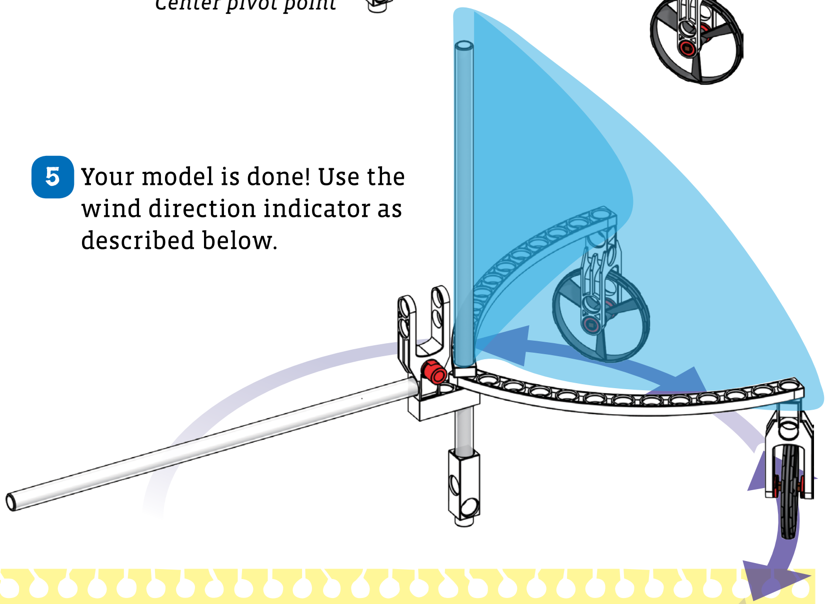
3. Slide two curved flat rods onto the mast tube.



4 Slide the sail onto the mast tube. Attach the two wheel units to the end of the curved flats rods through the holes in the bottom of the sail. Make sure the wheel units are angled so that they can turn in a circle around the center pivot point, the 3-hole dual rod.



5 Your model is done! Use the wind direction indicator as described below.



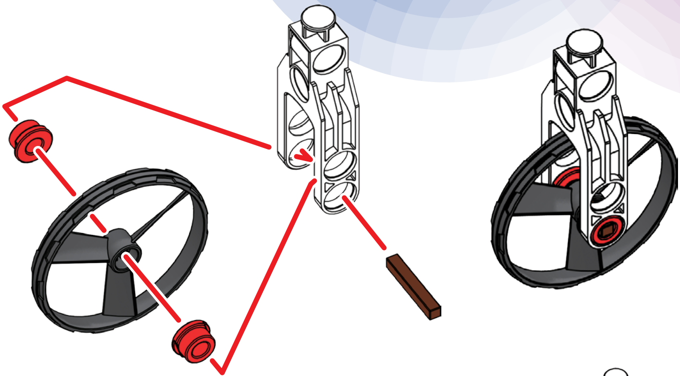
Testing the wind direction

To use your wind direction indicator, set it outside on a smooth, hard surface. Make sure the wheels are angled so that they can turn in a circle around the center pivot point. Let it go and watch how it spins around and points to the direction the wind is coming from.

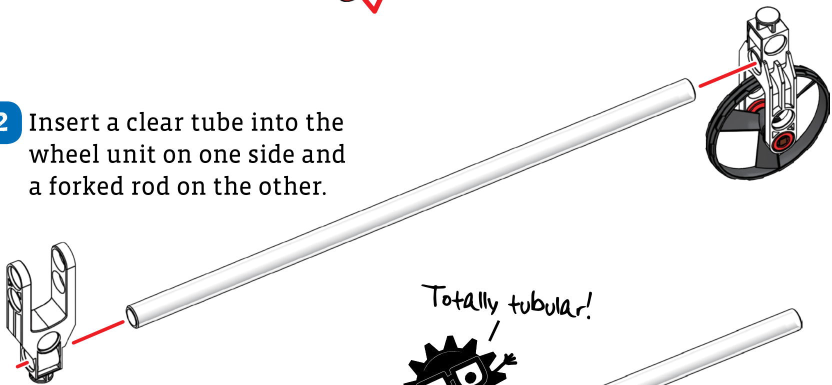
This model works just like a **wind vane**. Wind hits the sail and pushes it leeward. The model just rotates around the pivot point because the friction between the rod and the ground prevents the whole model from moving. When the sail moves leeward, the tube points windward!

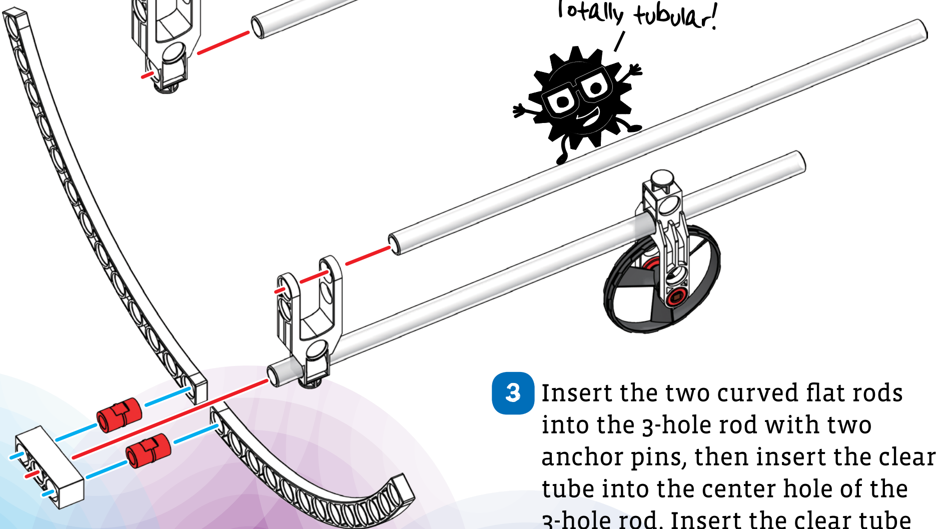
Assembling the mini glider

1 Assemble one wheel unit with the forked rod, two bearing pins, a bamboo dowel, and a wheel.



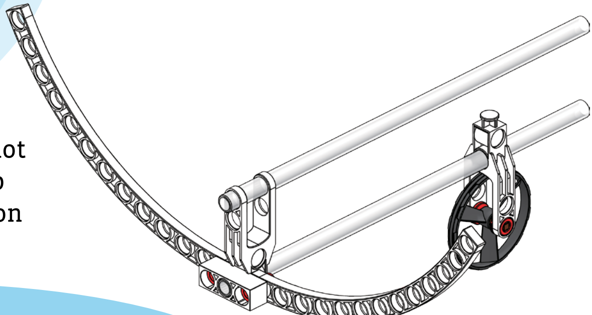
2 Insert a clear tube into the wheel unit on one side and a forked rod on the other.

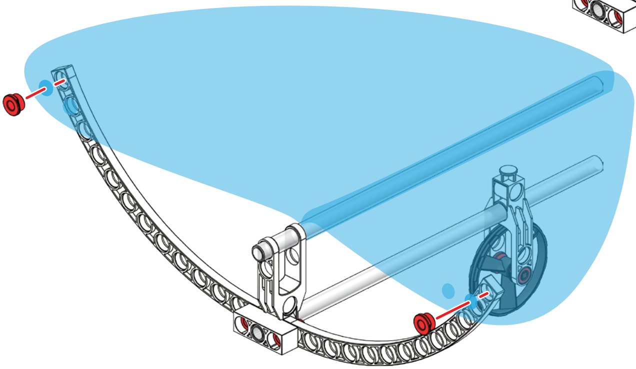




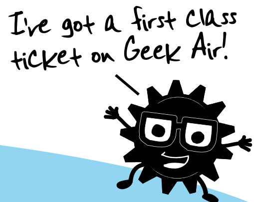
3 Insert the two curved flat rods into the 3-hole rod with two anchor pins, then insert the clear tube into the center hole of the 3-hole rod. Insert the clear tube (with or without the sail) into the forked rod.

4 If the sail is not yet on the top tube, slide it on now.

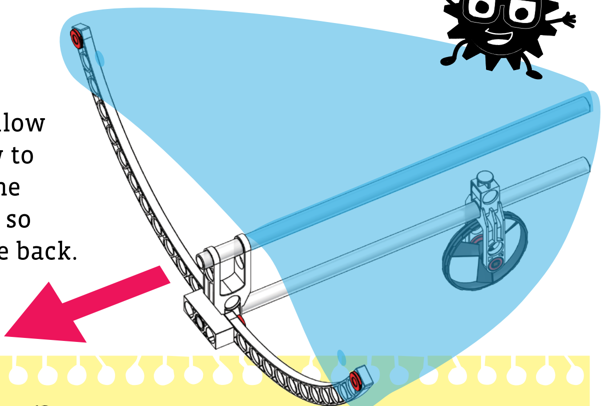




5 Secure the sail to the ends of the curved flat rods with two bearing pins.



6 Your glider is done! Follow the instructions below to throw it. Throw it in the direction of the arrow, so that the wheel is in the back.



Testing the mini glider

To use your glider, bring it to an open area that is not very windy, preferably with a soft floor or ground, such grass or carpeting. Gently toss the glider with the wheel in the back and the front angled slightly upward. Don't throw it with a lot of force; release it gently. Can you get it to sail softly down toward the ground? It is challenging to get it to glide, but try your best. The glider slowly falls down toward Earth because wind from its forward motion hits the bottom of the sail and pushes it upward slightly. It isn't enough force to keep it in the air for a long time, but it is enough to demonstrate the concept. Can you make it better?

GEEK OUT!

HOW ARE SAILS LIKE WINGS?

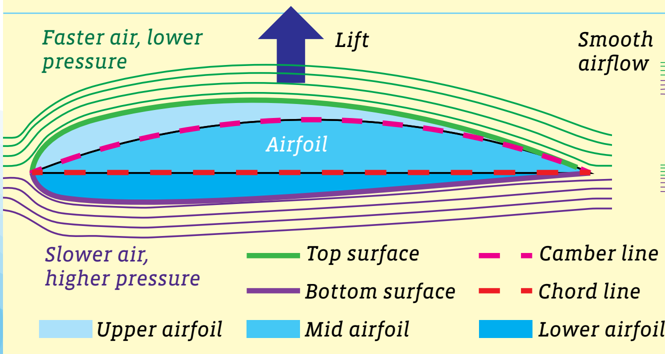
Hint: They both have a curved surface...

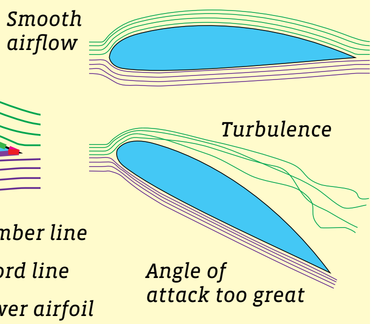
Sails and keels work just like the wings of a plane, but sideways. The sail produces a sideways "lift" perpendicular to the direction of the wind. The keel produces a sideways "lift" in the water to counteract the force on the sail.

Wings need **cambers**, or curved top surfaces, to produce lift. The bottom surface is either flat or less curved. This shape is called an **airfoil**. In the case of the sail, it must have a concave inner surface along which the airflow is shorter than the airflow along the convex curve of the outer surface.

The air flowing over the curved top surface of a wing has to travel farther than the air flowing under the surface. After all, the shortest distance between two points is a straight line. The same number of air molecules flowing over a greater distance results in faster moving air and thus a lower air pressure above the wing. **Bernoulli's principle** states that air pressure decreases as its speed increases. Because the air pressure is higher under the wing, it pushes the wing upward. The low pressure above can't push as hard downward as the higher pressure below can push upward.

Wings and sails also create lift in another way. As the wing moves through the air, its lower surface hits air particles, which push back on it, generating additional upward force. The greater the **angle of attack**, or the angle of the wing relative to the air flow, the greater the lift. But only to a point, because if the wing's angle is too great, turbulence forms at the back of the wing. This turbulence disrupts the smooth flow of air, and the wing cannot generate any lift without a smooth airflow.





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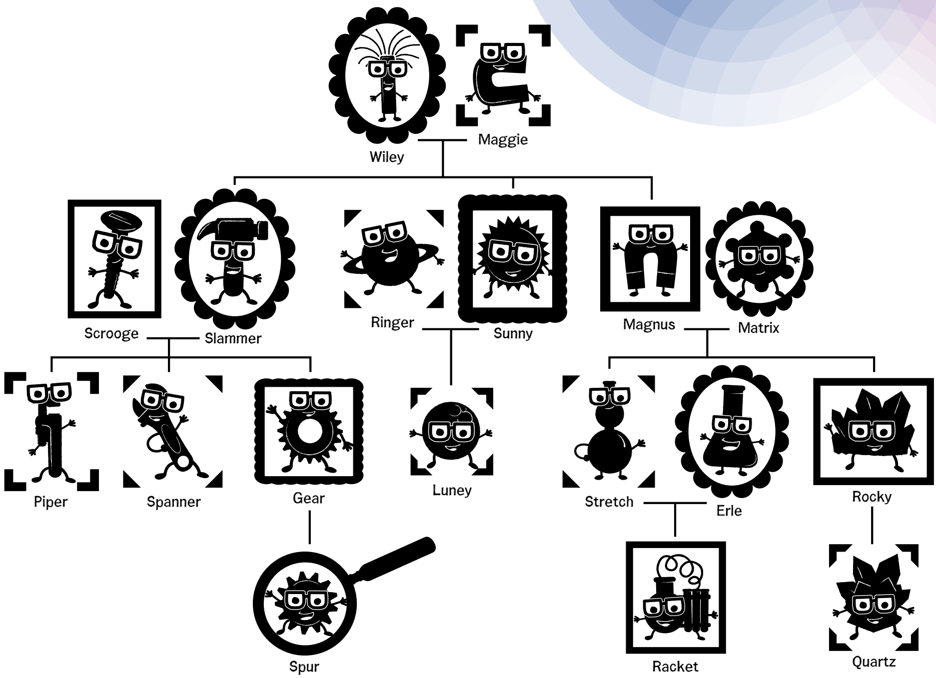
MEET THE GEEKERS!



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