**Vertical Wind Tunnel
Design Challenge**

**Outcomes:**

1. Children will improve their creativity and engineering skills through practical application (i.e. imagine, plan, create, test, and improve).
2. Children will use critical thinking and problem solving skills to meet challenges.

**Design Challenge:**

1. Design and build an aircraft that can stay in the vertical airstream for at least 5 seconds.
2. Design and build an aircraft that can hit the ceiling or fly above a specific height in the vertical airstream.

**Design Requirements:**

1. Use at least three different materials in your design.
2. Make at least one change to your design after your first test flight.

**Supplies:**

All supplies should be low cost and readily accessible. Some supplies are linked to examples. What other supplies could you use in this design challenge?

* [Floor fan](https://www.amazon.com/B-Air-FIRTANA-20-Multi-Purpose-Velocity/dp/B01M0X1SOY/ref%3Dsr_1_4?ie=UTF8&qid=1525358182&sr=8-4&keywords=floor+fan)
* [Cardboard craft rolls](https://www.amazon.com/Colorations-ARTROLL-Sturdy-Recycled-Craft/dp/B005E9MGYU/ref%3Dsr_1_3?ie=UTF8&qid=1525709350&sr=8-3&keywords=cardboard+tubes#feature-bullets-btf)
* Glue (e.g. glue sticks, wood glue, etc.)
* 110v power source
* Stopwatch or smartphone with stopwatch capability
* Colored markers
* Kite string or yarn
* Safety scissors
* Hole punch
* Masking tape or clear adhesive tape
* Balloons (variety of round or elongated balloons)
* [3 oz. paper/plastic cups](https://www.amazon.com/Dixie-Bath-Coordinating-Designs-Count/dp/B0025WEF1Q/ref%3Dsr_1_4_s_it?s=hpc&ie=UTF8&qid=1525380486&sr=1-4&keywords=dixie%2Bcups&th=1)
* [8.5” x 11” cardstock](https://www.amazon.com/dp/B006P1ER8O/?coliid=I95ORKIPNKCPH&colid=3VGOHFV2P1Z12&psc=0&ref_=lv_ov_lig_dp_it)
* 8.5” x 11” copier paper
* [9” x 10.75” aluminum foil sheets](https://www.amazon.com/dp/B01LGHIRDW/?coliid=IY3ZBAAVKI6ME&colid=3VGOHFV2P1Z12&psc=0&ref_=lv_ov_lig_dp_it)
* [9” x 12” construction paper](https://www.amazon.com/dp/B0013CDJTS/?coliid=I77UH9YSBJFR9&colid=3VGOHFV2P1Z12&psc=1&ref_=lv_ov_lig_dp_it)
* [15” x 20” Tissue paper](https://www.amazon.com/dp/B00N1E776W/?coliid=I8VBAGGE9CHZI&colid=3VGOHFV2P1Z12&psc=0&ref_=lv_ov_lig_dp_it)
* Newsprint
* [6” Paper plates](https://www.amazon.com/Perfect-Stix-Paper-Plate-6-200ct/dp/B01DVPU1QS/ref%3Dsr_1_15?ie=UTF8&qid=1525386780&sr=8-15&keywords=6%22+paper+plates)
* Coffee filters
* [Cupcake liners](https://www.amazon.com/Direct-Standard-Cupcake-Baking-Liners/dp/B00IZGY4DA/ref%3Dsr_1_9?s=kitchen&ie=UTF8&qid=1525386843&sr=1-9&keywords=cupcake+liner)
* [12” chenille stems](https://www.amazon.com/dp/B000CD2DVY/?coliid=I3JQ1EXG33E6VR&colid=3VGOHFV2P1Z12&psc=1&ref_=lv_ov_lig_dp_it)
* [4.5” or 6” craft sticks](https://www.amazon.com/dp/B0033F7YQW/?coliid=I19UR2Q4930SZA&colid=3VGOHFV2P1Z12&psc=1&ref_=lv_ov_lig_dp_it)
* Bendable or straight straws

**Background:**

Children are given a basic challenge and asked to develop a solution to it. A variety of materials are available for their use.

There is no one correct solution or design. Children are encouraged to be creative. Adults should limit factual statements to a minimum and focus on ask questions to make children think, promote discussion, or seed ideas.

Adults should help when children are ready to test their designs by making sure the vertical wind tunnel (i.e. floor fan) is running, pointing directly up, and helping place their design in the air stream if necessary. Questions should be asked of children who succeed and children who fail. For successful flights, adults should elicit what was successful and what steps the children took to become successful. For failed flights, adults should ask what the children’s plans are to improve. If the children plan to start from scratch, what was successful or what features were successful about a particular design, etc.? Adults should not make suggestions as to what could be changed or how something could be changed, although they may lead children towards this point through questions.

**Glossary:**

* Aeronautical – Relating to the science or practice of building or flying an aircraft.
* Aircraft – A machine capable of flight.
* Airstream – A current of air.
* Analyze – Examine carefully to identify causes, key factors, and possible results.
* Asymmetric – Not identical on both sides of a central line.
* Challenge – A task that requires a good amount of mental or physical effort in order to be completed or done successfully.
* Collaboration – Two or more people working together to create or achieve something.
* Data – Facts or statistics collected for analysis.
* Design – To create, fashion, execute, or construct according to a plan.
* Drag – The force that acts opposite to the direction of motion. Drag is caused by friction and differences in air pressure.
* Engineer – A person who uses mathematics and science to solve a problem.
* Engineering Design Process – A method made up of a series of steps that engineers use to solve problems. The steps include:
	+ Ask – Identify a problem or challenge.
	+ Imagine – Develop a possible solution or solutions.
	+ Plan – Select a solution.
	+ Create – Build a prototype.
	+ Test – Test and evaluate a prototype.
	+ Improve – Redesign prototype as needed.
* Failure – The lack of success. An opportunity to learn.
* Flow – The movement of fluids (e.g. liquids, gases, etc.) in one direction.
* Gravity – The force that attracts objects towards one another, especially the force that makes things fall towards the ground.
* Iteration – The repetition of a process, or redesign, with the aim of approaching a desired goal or result.
* Lift – The force that acts at a right angle to the direction of motion through the air. Lift is created by differences in air pressure.
* Materials – Physical substances that things can be made from or built from.
* Problem – A question raised for inquiry or solution.
* Process – A series of actions or steps taken in order to achieve a particular goal.
* Prototype – A model from which other forms or procedures are developed.
* Self-orient – To naturally adjust with relation to surroundings or circumstances.
* Solution – An answer to a problem or the action or process of solving a problem.
* Stability – The ability of an object to maintain equilibrium or return to its original position after displacement.
* Symmetric – Made up of exactly similar parts facing each other or around an axis.
* Weight – The force that gravity exerts on an object, equal to the mass of an object times the acceleration of gravity. It acts in a downward direction.
* Wind tunnel – Large tubes with air moving inside. Wind tunnels are used to copy and test the actions of an object in flight.

**Setup:**

1. Create a flow straightener that is at least 20” x 20”. The cardboard craft rolls should be glued together, using glue, until you have an area that is at least 20” wide x 20” tall. If you use the craft rolls suggested, which are 1.75” in diameter, you should have a square area about 12 rolls wide by 12 rolls tall. Let the glue on the flow straightener dry before securing it to the front of the fan. The flow straightener will help straighten the swirling air coming from the fan. All wind tunnels use flow straighteners for this purpose.
2. Secure the 20” x 20” honeycomb material to the front of the fan (i.e. the outtake side) with tape or string. If using string, make sure string/wire do not interfere with the movement of the fan blades.
3. Tilt fan into a position parallel to the floor or table. When you turn the fan on, the airstream should be flowing straight up.
4. Test fan speed to determine appropriate airstream strength for heavier designs. Turn fan setting to appropriate speed.
5. Make sure to put out enough supplies, so children can make multiple iterations.

**Tips:**

* Define what an engineer is and remind the children they will be acting like engineers during the design challenge.
* Describe the engineering design process and explain what each step of the process will look like during the design challenge.
* Describe the design challenge(s).
* Answer children’s logistical questions.
* Ask children content-related questions.
* Assist in testing designs.
* Encourage success and failure.
* Maintain a neat and safe design space.
* Make sure to check newspapers for controversial stories before you set them out. When in doubt, remove the sheet with the controversial story.
* Recycle, recycle, recycle!
* How do you teach children to be innovative? Simply leave them alone and let them experiment and play. Teaching children that there is only one right way to do something can stifle their creativity and pass along the concept that making mistakes is to be avoided. Making mistakes is essential to innovation.
* Try not to give children answers directly! Children should be encouraged to find answers on their own. If children have questions, follow up with questions of your own in an attempt to promote critical thinking. If children seem to be getting stuck, don’t let them sit there struggling and getting discouraged. Ask children directed questions to get them thinking along specific lines towards success. For example, if they can’t figure out why their aircraft won’t fly well in the wind tunnel, ask them if they think maybe a lighter/heavier aircraft (i.e. different materials) might improve its flight.
* For unsuccessful flights – encourage children to try again. Explain that most inventors/engineers don’t get things right the first time. The Wright Brothers built gliders to test before their first airplane and it took them years to get the gliders working to their satisfaction.
* For successful flights – depending on the flow of children in the room, children may be encouraged to improve upon their already successful designs (by using different materials for example), or thanked for participating and subtly encouraged to move out from the space to make room for others.
* For children focused on the aesthetics of a piece – Encourage them to design and build a aircraft that first meets the challenge, then to add decorative elements to it. When engineers build, their first designs are often not as nice looking as the final ones.
* Remember to be positive and encouraging during the design and testing process. Compliment spectacular or productive failures!
* Encourage children with particularly interesting or successful designs to leave their prototypes behind, or to take photographs, to help provide other children with ideas for their designs.

**Cautions:**

* Floor fans are fairly safe, but please make sure children keep their fingers, hands, jewelry, clothing, and hair away from the fan blade housing.
* Don’t allow children to drop anything into the fan housing.
* Fans often have both a strong intake and outtake. Objects placed near the intake may be pushed into the fan. Objects near the outtake may be blown away from the fan.
* Make sure the fan is sitting stable on a horizontal surface, so it won’t tip over.
* Make sure the cord is secured, so no one will trip over it.
* Don’t allow children to lean over into the vertical airstream. Dust particles could be blown into their eyes.

**Common Errors:**

***Challenge: Stable flight***

1. Instability - Objects that don’t self-orient tend to tumble and get pushed out of the airstream. It’s best to add elements to center “lift” and gravity.
* Ask: “How can you keep the aircraft from turning sideways and blowing out of the stream of air?”

***Challenge: High flight***

1. Excess weight – Objects that don’t rise off the top of the fan or far off the top of the fan.
* Ask: “What keeps objects down against the Earth? To overcome the force of gravity you have to take advantage of the airstream pushing up. How is the air pushing your aircraft up? What can you do to get the air to push your aircraft up higher?”
1. Instability - Objects that don’t self-orient tend to tumble and get pushed out of the airstream. It’s best to add elements to center “lift” and gravity.
* Ask: “How can you keep your aircraft from turning sideways and blowing out of the stream of air?”

**Focused Discussion Points:**

* How do the materials you used in your design affect its flight?
* How do you think stability affected the flight of your design? Staying in the airstream or getting to a particular height?
* Can you name any factors that go into making stable flight?
* Which materials are heaviest or lightest? Stiffest or most flexible?
* Which features are most important? Are they different for each challenge? Is your design streamlined, lightweight, or stable?
* How did changes to your design affect the way your aircraft flew?
* How is this similar to what engineers do?

**Sample Interaction:**

***Challenge: Stable flight***

**Adult:** Today we’re going try our hand at being an aeronautical engineer. What is an engineer? An engineer is someone who uses math and science to solve problems. Much like engineers do on a daily basis, we’re going to try to solve a problem, or more accurately a design challenge. As an aeronautical engineer, your first challenge is to design a stable aircraft that can stay in the vertical airstream for at least five seconds. You can use as many materials as you want, but you must use at least three different materials in your design. Let me know if you have any questions, or when you’re ready to test your solution.

**Child:** *[Children work on designing solutions.]*

**Child:** *[Children approach the vertical wind tunnel with design.]*

**Adult:** Are you ready to test your design?

**Child:** Yes.

**Adult:** *[Assist children place their aircraft in the airstream if necessary. Using the stopwatch, time the amount of time how long their aircraft stays in the airstream from the moment released, until it passes over the lip of the vertical wind tunnel.]*

**Adult:** So how do you think you did?

**Child:** *[Response.]*

**Adult:** It looks like your aircraft stayed in the stream for 4 seconds and then left the air stream. What is something you are planning on changing about your design in order to improve your flight?

**Child:** I don’t know.

**Adult:** I noticed that your aircraft seemed to tumble end over end. Can you think of a way to make it more stable (i.e. keep the top of your design facing up and the bottom facing down)?

**Child:** Maybe I can add some fins.

**Adult:** That might work. Why don’t you go try it out, and then we can test it again when you finish?

**Child:** *[Children return with a modified design.]*

**Adult:** Ready to test again? So what did you change about your design and what did you think that would change about your flight?

**Child:** *[Tests their aircraft in the wind tunnel. They can test twice in order to make more concrete observations]*

**Adult:** So what did you notice about this flight that was different than your last flight? Did your changes help or hurt?

***Challenge: High flight***

**Adult:** Your second challenge is to design a high flying aircraft that can hit the ceiling. Again, you can use as many materials as you want, but you must use at least three different materials in your design. How high do you think you can get your prototype to fly? The goal is to hit the ceiling. Are you planning to use the same design that you tested for stability? If so, do you think you need to make any changes from one challenge to the other? Let me know when you’re ready to test.

**Child:** *[Children work on designing solutions.]*

**Child:** *[Approach the vertical wind tunnel with their design.]*

**Child:** Hi, I’m ready to go!

**Adult:** Awesome, let’s fire it up! [*Turn on wind tunnel and place aircraft in stream.]*

**Adult:** Great try! What happened?

**Child:** It’s a piece of junk! I’m horrible at this!

**Adult:** Hey, don’t worry about it. A lot of people who design something fail at their first try. Even the Wright Brothers failed so badly at making gliders they almost gave up on making an airplane! You just need to look at what went wrong and try again. So, what do you think kept it from going up all the way?

**Child:** It just didn’t go up.

**Adult:** Good observation! What can you do to make it go higher?

**Child:** I could add more balloons or increase the surface area of my aircraft some other way.

**Adult:** Good! Go try that and bring it back when you’re ready.

**Child:** *[Children redesign.]*

**Adult:** Back? Alright, let’s see what sort of problems we can find and fix this time. [*Test aircraft again.]*

**Child:** It’s still not working!

**Adult:** Well, it worked better than last time! What did you see?

**Child:** It went up a little, but then it just stayed there.

**Adult:** Now last time you added stuff to make it fly higher. What can you try this time to make it go even higher?

**Child:** I could take stuff off and decrease its weight.

**Adult:** That’s a great idea! Go try making it lighter and we’ll try again.

**Child:** *[Redesign, build, and retest their design.]*

**Child:** Alright, let’s try again.

**Adult:** Great attitude! Let’s fire it up! *[Retest aircraft.]*

**Child:** It hit the ceiling!

**Adult:** Great work! Give me a high five!