Western Engineering

Outreach

Tetrahedral Flight

Grade 6-8

Meet Today's ENG HERO!

Greg Kopp - Professor and Associate Dean with Western Engineering

Dr. Kopp's expertise and research projects relate to mitigating damage to structures during extreme wind storms such as tornadoes and hurricanes. Details include model-scale wind tunnel and full-scale component test methods, field surveys of damage caused by tornadoes, building aerodynamics, wind effects on building component and cladding systems, tornado and thunderstorm winds, wind loads on solar arrays, the role of turbulence on wind loads, wind-borne debris and turbulent shear flows. To learn more about Dr. Kopp visit: https://www.eng.uwo.ca/civil/faculty/kopp_g/index.html

Learning Goal:

- Understanding the concept of lift and the interactions between forces involved in flight
- Curriculum connections: Grade 6- Flight, Grade 8- Fluids

Materials Needed:

- Straws (12 or 48)
- Scissors
- Thread
- Tape
- Tissue Paper or Plastic food wrap
- One pipe cleaner
- Hair dryer or fan

Engineering and Science Connections:

Have you ever thought about how it is that we make things that weight hundreds of tons fly through the sky? Humans have only had powered, heavier than air, flight since 1903 CE. Less than sixty years later, the first person went to outer space in 1961 CE. How were we able to go all that way in such short time? One of the important parts of the story is the knowledge we learned about how forces work. Today we will learn about some of the fundamental balancing acts that need to take place for us to achieve flight.

Aerodynamics

The science behind things that fly is all rooted in *aerodynamics*. What is aerodynamics?
The study of the properties of moving air (the "aero" part) and the interaction between the air and solid bodies moving through it (the "dynamics" part).
Aerodynamics is a smaller branch of physics that comes from a much larger area of study called *Fluid dynamics*. Fluid dynamics studies all fluids, including both liquids and gasses.

Before we can start talking about flying, we need to remember what we know about *forces*. What is a force?

- **Force:** A *push, pull, or other factor that can make an object change velocity.*

Velocity is the combination of an object's speed and its direction, so anything that changes either one of those things is a force.

What are some common examples of forces?

- Gravity
- Thrust
- Drag
- Lift
- Magnetism
- Buoyancy
- Push
- Friction

But from the forces we know about, which ones are important if we want to learn how to fly?

Gravity:

Starting with gravity, it's pretty clear that our **weight** pulls all of us down and is what keeps us firmly on the surface. So that will definitely be important for us to find a force that can counteract gravity. With balloons, that force is

generated by the same force that causes submarines to work and boats to float: Buoyancy. Buoyancy is due to displacing a volume of fluid, but it's not very easy to use buoyant forces to keep you in the air because air is not very dense. This is why balloons, blimps, zeppelins, and other airships all need to be so huge.

Lift:

But those devices all need to be lighter than air in order to get off the ground, how do birds, kites, and airplanes get off the ground? These heavier than air things rely on a different force which acts opposite to gravity: **lift.**

Thrust:

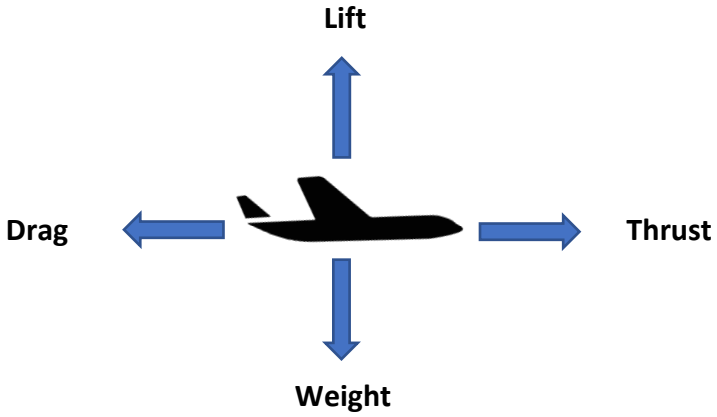
But for a plane to go anywhere we need it to go forward! So we need a force which either pushes or pulls the plane forward. This is called **Thrust**. Thrust is what makes the plane go forward through the air.

Drag:

As anything moves through the air, it hits the air faster and harder as it moves faster, the air slows the plane down, this force is called **Drag.**

So the four primary forces that we need to balance in order for us to learn how to fly are:

- **Weight** is the force of gravity on a mass. It acts in a downward direction-toward the center of the Earth.
- **Lift** is the force that acts opposite the direction of gravity. Lift can be created by a number of things, but is partly created by differences in air pressure and a redirection of air flow fields (see recommended video)
- **Thrust** is the force that propels a flying machine in the direction of motion. Engines make thrust.
- **Drag** is the force that acts opposite to the direction of motion. Drag is caused by friction, differences in air pressure, and turbulence.



What out of the four forces above, what two forces must be greater during takeoff?
Lift and thrust
What forces must be greater during landing?
Weight and drag

What is the difference between *flying* and *gliding*?
The main difference between an airplane and a glider is its power source. A flyer has an internal power source to propel it forward and to generate lift, a glider does not. Instead of being powered internally, gliders get an initial velocity by relying on an external force to generate their thrust. In the case of a hang glider, the person operating the glider usually runs along the side of a cliff or a hill. Gliders often use air currents to help them get additional thrust or lift while still in the air.

How do kites work then?

Everything you've just learned about how things fly tells you what you need to figure out how kites work.
Ask yourself these questions:

- If the wind is pushing against the kite, creating drag and lift, where does the thrust for the kite come from?
- How does the shape of the kite effect the way the wind flows around it?

Video Recommendation:

https://youtu.be/PF22LM8AbII

Activity:

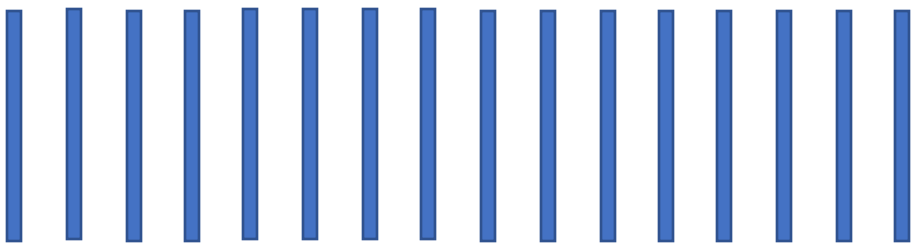
Identify the Needs and Constraints:

Whenever we design something, we have specific things that we need to do. These things limit our options. Our constraints today are the following:

- Needs to be able to fly in the wind.
- Each tetrahedron MUST have 4 equally sized triangles as sides
- Each tetrahedron must be covered on two sides by either tissue paper or plastic wrap.
- Tetrahedrons may only be connected at the corners, not along the edges or the faces.

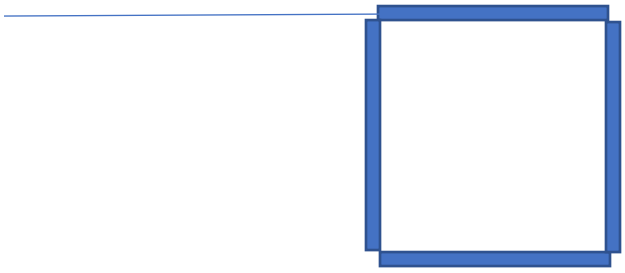
How do we make a tetrahedron?

- Start by cutting the bending parts off all the straws. All the straws should be the same length.

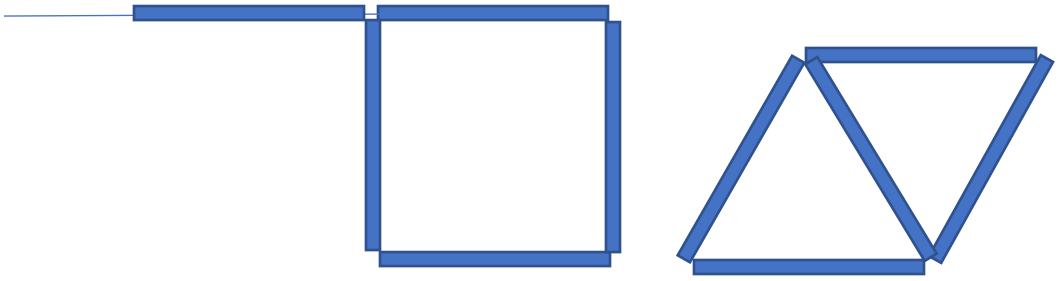


- Next, place four straws on the thread in a line. Use the pipe cleaner as a needle to pull the string through the straws.

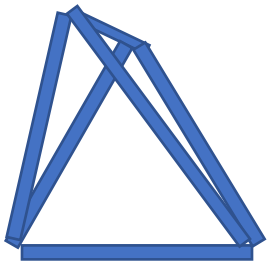
- Now tie the two ends of the thread together to form a square, leave roughly 1 ½ straw-lengths of string left.



- Pass a new straw onto the string between two corners of the square, forcing it into two triangles.



- Now, take one more piece of thread through another straw and connect the two farthest points on the triangles by tying the ends of the strings together.



- Now take your tetrahedron and place it on top of either a piece of thin tissue paper or plastic food wrap. Tape your lightweight material to two of the sides.
- Repeat the above steps three more times and connect the four tetrahedrons together by their corners so that their two covered sides all face the same direction.
- Tie a flight string to the outer edge of the big tetrahedron that is between the two covered sides on

Now we're ready to fly the kite!
If doing this activity indoors, set up your fan in front of the kite and see if you can get it to fly!

If the kite doesn't work on the fan, have students think about what redesign would be needed for how the tetrahedron cells are connected, or if something might need to be added.

What Did You Learn?

- What are the four main forces that need to be balanced for something to fly?
- How did the shape of the kite affect its ability to glide?
- What is the difference between something that is flying and something that is gliding?

Future Learning

- Turn this kite activity into a design challenge! In order to do this, go through the steps for making the first tetrahedron, but try out different ways to connect all the tetrahedrons together to figure out which way works best. Make a prediction: what will happen to the design if you connect the flight string to a different place on the kit? What about if we change which faces in the smaller tetrahedra are covered? Which design did you like the best and why?

Share your creations!

We would love to see what you made. Email as at discover@uwo.ca or tag us on social media.

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Thanks for discovering with us!