SAE STEM@Home™: Up, Up in the Air

EDUCATOR GUIDE

Resources from A World In Motion®
What Is a Glider?

A glider is a unique type of aircraft because it has no engine. Gliders are pulled into the air by powered aircraft and then released when they have reached a certain height. Gliders can stay aloft for many hours—the world record for a single-person glider flight is 56 hours, though glider flight duration records are no longer recognized because it is dangerous.

Making a Glider

Glider Supplies

If your child hasn’t had a chance to play with a Glider, you can make one at home! You’ll need the following materials:

• Thin Styrofoam sheets (meats and vegetables from the supermarket often come in Styrofoam trays). You will need pieces that have the following dimensions:
  - Wings: 36 cm x 6 cm (approximately 14” x 2.5”)
  - Stabilizer: 6 cm x 12 cm (2.5” x 5”)
  - Rudder: 6 cm x 7 cm (2.5” x 2.75”)
• 3/8” x 3/8” balsa or basswood stick (45 cm/18”)
• Small piece of balsa
• Rubber bands
• Modeling clay
• Glue (preferably a low-heat hot glue gun)

To assemble the glider, cut the Styrofoam wing, stabilizer, and stabilizer assembly. Use a pen to score the rudder 1 cm from the edge and bend the Styrofoam. Glue the stabilizer assembly perpendicularly to the stabilizer in the center—do not glue the 1 cm moveable rudder to the stabilizer.
Use the rubber bands to attach the wing and stabilizer to the fuselage. To mount the wing using a rubber band, place a rubber band around the fuselage. Place the wing on the fuselage next to the rubber band. Stretch the rubber band over the wing and hook it under the fuselage.

Attach the stabilizer using the same method. Then, make a small ball of modeling clay and attach it to the nose of the glider.

Launch the glider by hooking a rubber band to the launch hook on the fuselage. Hold the glider by the rear of the fuselage, stretch the rubber band to the desired length, and gently release the glider.

You and your child can modify the glider design to see what modifications make the glider fly best. You can change the following:

- The amount of clay on the nose
- The position of the wings
- The position of the stabilizer
- The angle of the rudder
- The shape of the wings
- The size of the wings
- The shape of the stabilizer
- The size of the stabilizer
STEM CONNECTION
How Does the Glider Work?

The phenomena involved in flight are complex. Objects near the earth are subject to forces at all times. To understand how a glider flies, we must understand the forces that act on it. There are four forces that affect flight: lift, weight (or gravity), thrust, and drag. The relative strength of these and other forces determines the speed and direction of moving objects.

Weight

*Weight* is the measurement of the effect of the force of gravity on an object. The effect of gravity is to pull objects towards the earth. The force we measure as weight can be represented diagrammatically by an arrow. The length of the arrow indicates the strength, or magnitude, of the weight of an object. The longer the arrow, the greater the weight. The direction in which the force acts is represented by the direction of the arrow.

As Isaac Newton’s Third Law of Motion states, when an object is at rest, the forces acting on it must be equal and opposite. For instance, when a baseball is resting on a table, the weight, or force of gravity, acting downward on the ball must be opposed by an opposite and equal force upward from the table.

It seems counter-intuitive to think of a table as exerting a force, but that is, in fact, what causes the ball not to move. The ball does not move upward or downward because the upward and downward forces acting on it are equal and opposite. This state of equal and opposite forces is called equilibrium. If the object is not moving, it is in static equilibrium. Every stationary object is in a state of static equilibrium.
Now, if the ball rolls off the table, it begins to fall because the force of its weight is no longer opposed by the upward force exerted by the table.

As it falls, it moves faster and faster. This increasing rate of motion is called acceleration. If the ball fell from a great height, it would accelerate to a great speed. An object that is subjected to unbalanced forces (such as one unopposed force) accelerates in the direction of the greater force.

**Understanding Lift**

Unlike a projectile, a glider in flight creates an upward force that helps keep it in the air and opposes the downward force of gravity. This force is called lift.

When a glider travels at a constant speed without turning, the forces of lift and weight are in balance. It is in a state of dynamic equilibrium. If the lift force is less than the weight of the glider, it will accelerate downward. If the lift force is greater than the weight of the glider, it will accelerate upward. (The amount of lift depends on several factors that will be discussed in more detail below.)

**Drag**

Drag acts on an object as it falls and as it moves forward or backward through the air.
Drag on a Falling Object

A falling object displaces air molecules, pushing them out of its path. This displacement is a type of friction called air resistance or drag. This force acts in the opposite direction in which the object is traveling. In the example of the falling ball, the ball is dropping straight down, and the opposing force of drag is represented by an upward arrow.

The longer the ball falls, the more it accelerates and the faster it travels. The faster it travels, the faster it has to push aside the air it displaces, increasing the drag acting against it. So, the drag increases as the ball falls. The weight force, however, does not change. As the ball falls, the increasing drag force slows its rate of acceleration. If the ball reaches a great enough speed, the drag force will equal the weight force.

When the opposing forces of weight and drag are equal, the ball will no longer accelerate, but will fall at a steady speed called terminal velocity. This is a state of equilibrium similar to the state of a ball resting on a table. However, in this case, because the ball is moving, it is called a state of dynamic equilibrium. An object moving at a steady speed in one direction is in a state of dynamic equilibrium.

Drag in Flight

The friction caused by an object pushing air molecules aside as it moves through the air is also called drag. Drag is affected by the speed, size, and shape of an object. The faster an object moves, and the bigger it is, the greater the drag. Vehicles that are designed to move as fast as possible through air have streamlined shapes that slip through the air, disturbing it as little as possible, to minimize drag.
Like all objects moving in an air flow, wings produce drag as they push air aside. In fact, wings produce lift by pushing air aside in a particular way. A flat wing produces lift by deflecting air downward via its positive angle of attack. A cambered wing produces additional lift by deflecting air first over the curved top surface of the wing and then downward. This deflection of air has the unavoidable side effect of creating drag, which slows the aircraft. The challenge of wing design is to design a wing that produces the amount of lift appropriate for an aircraft’s specified speed and weight, while producing the least amount of drag.

**Thrust**

Thrust is the force that moves aircraft through the air. In the case of the glider, thrust is produced by the muscles of the arm when the glider is thrown or by the rubber band if launched. In a powered aircraft, thrust is generated by the engines of the aircraft.

Once a glider is in flight, it does not generate thrust. The glider must generate lift to counteract the force of gravity. To generate lift, a glider must move through the air, generating drag. Because there is no continued thrust to balance out drag, the glider slows down until it can no longer generate enough lift to overcome gravity and it must land.

**More About Newton’s Laws**

**Newton’s First Law**

Newton's First Law states that an object in motion will continue to move in the same direction and speed unless forces act on it. This can be counterintuitive because moving objects always stop on Earth. For example, when you kick a ball, it eventually rolls to a stop, no matter how strong the kick is. On Earth the forces acting on your ball to make it stop are friction and gravity. *Friction* is the resistance of motion when one object rubs against another. Friction is also generated by air in the form of air resistance which is why an object flying through the air eventually stops. Gravity is the force that pulls objects together. The more mass an object has, the more gravity it has. The closeness of objects also factors into gravity in that the closer you are, the more the gravitational force.

**Newton’s Second Law**

Newton's Second Law states that force equals mass times acceleration.

- *Force* is a push or pull on an object.
- *Mass* is the amount of matter or substance that makes up an object. People sometimes think of mass as weight, but it is slightly different as weight is affected by gravity. Mass stays the same no matter what the gravity is, while your weight might be 45 pounds on Earth and only 7.4 pounds on the moon!
- *Acceleration* is the measurement of change in an object’s velocity (speed).
The second law means that the greater the mass of an object, the more force it will take to accelerate the object. This also means that the harder you kick a ball the farther it will go.

**Newton’s Third Law**

Newton’s Third Law states “For every action there is an equal and opposite reaction.”

We describe these actions as forces. Even sitting on a chair brings Newton’s Third Law into play. When you sit down on the chair, you exert force on the chair and the chair exerts force on you—equal and opposite reactions. Forces are found in pairs. If the pair of forces is equal in opposite directions (such as the example with the chair), nothing will move. However, if one force is greater than the other objects will move.
ACTIVITIES
1. Observing Flight
In this activity, children observe birds in flight (both in the real world and on video) to learn more about the science of flight.

**Observing Bird Flight**
**Materials**
- Notebook
- Pencil

2. What Is Air?
In this activity, children investigate air to prove that air is actually matter.

**Proving That the Air Is There**
**Materials**
- 2 latex balloons (same size and shape)
- Yardstick or meter stick or long, straight piece of wood
- String
- Pin

3. Learning About Lift
In this activity, children explore the force that allows objects like birds or planes to fly: lift.

**The Bernoulli Principle**
**Materials**
- 2 empty soda cans
- A straight drinking straw
- A ruler

4. Exploring Gravity
In this activity, children investigate the force of gravity by making a hole in the side of the cup and testing what happens when the cup is filled with water and comparing it to what happens when the cup is dropped.

**Water Fall**
**Materials**
- Paper cup
- Water
- Bucket or basin
- Pencil
- Optional: smartphone or digital camera that can record video

Some people have an allergy to latex. Latex allergies are relatively rare (between 1 and 6 percent of the population suffers from latex allergies). Read about latex allergies on the Complete Guide to Latex Allergy page of the Allergy & Asthma Network.
5. Investigating Thrust
In this activity, children build device similar to a Hero’s engine—a steam-powered machine called an aeolipile that was invented by Heron or Hero of Alexandria (10 AD – 70 AD) who was a Greek engineer and mathematician.

**Thrust Power**

**Materials**
- 3-4 empty soft drink cans
- String
- Bucket or basin
- Nails or screws of various sizes
- Duct tape
- Water
- Thrust-powered Engine activity sheet

6. What A Drag!
In this activity, children explore how the shape on an object affects drag.

**Investigating Drag**

**Materials**
- Printouts of the pattern sheets
- Tape

7. Make an Ornithopter
In this activity, children build an ornithopter—a machine designed to fly by means of flapping wings. Building the ornithopter can be complicated, so it may take some time and experimentation—and some help from an adult.

**Build an Ornithopter**

**Materials**
- Wooden coffee stirrers, balsa wood strips, or popsicle sticks
- Paper clips
- Rubber bands
- Super glue
- Needle-nosed pliers
- Tissue paper
- Hot glue gun
- One of the following (the hole should be 1-1.5 mm in diameter):
  - Tube beads
  - Beads
  - Plastic tubing
  - Sip stirrer
SAMPLE SOLUTIONS
1. Observing Flight

Think About It!

1. What different types of flight did you observe when you watched birds outside or on the video? (This answer will vary depending on what birds were observed. Some possible answers include):
   - I saw birds that flapped very fast
   - I saw birds that barely flapped at all
   - I saw birds that went up and down as they flew
   - I saw birds that looked like they were falling

2. Why do you think different birds fly differently? (Children may recognize that different birds fly differently because they have different weights, different wing sizes and shapes, or different tails and bodies.)

3. If you had wings, how big do you think they would need to be to let you fly? Do you think you would be strong enough to flap those wings? (Children might think it would be possible for humans to fly if we had wings. However, birds are much lighter for their body size than humans because they have hollow bones. In fact, the average adult male human would need wings that were at least 6.7 meters (22 feet) wide to fly. That’s about 2/3 as long as a yellow school bus.)

2. What Is Air?

Think About It!

1. What other evidence can you think of that might prove that air is not nothing? (Children may have ideas for various ways to prove that air is not nothing. Simply blowing up a balloon or soccer ball might be sufficient. The only way that air could make a ball or balloon larger is if air takes up space. Children might also suggest blowing bubbles underwater or into a liquid also provides proof that air is not nothing. Search for “proving that air has volume” on the internet to find other ways to prove that the air is there.)

3. Learning About Lift

Think About It!

1. What did you expect would happen in your experiment with two soda cans and drinking straw? (Children likely did NOT expect the cans to move closer together.)

2. Why do you think that the two cans moved together? (In the soda can experiment, the air between the two cans was being blown away, lowering the air pressure the air pressure between the cans. The air pressure on the outsides of the cans remained the same, pushing the cans toward the area of lower pressure.)
4. Exploring Gravity

Think About It!

1. What happened when you dropped the cup filled with water? What do you think this experiment tells you about gravity?
   *When the cup was dropped, the water should have stopped pouring through the hole.*

2. Are you surprised about any of the things you learned about gravity? If so, what?
   *Children’s answers will vary.*

3. Do you think that gravity on Venus is more than or less than gravity on Earth? Why?
   *What would you need to know about Venus to say for sure?*
   *Children may think gravity is greater on Jupiter. If so, they would be right! Jupiter is a more massive planet than Earth, so it has greater gravitational pull.*

4. How much would you weight on other planets? Use the [Your Weight on Other Worlds](#) website to explore!
   *Have fun!*

5. Investigating Thrust

Think About It!

1. Can you imagine any way to use a Hero’s engine in real life?
   *A Hero’s engine could be used to power a toy vehicle or produce power like a turbine.*

2. How do airplanes produce thrust? How is a jet engine the same as or different from a propeller? (You may need to do some research to figure this out!)
   *An airplane generates forward thrust when air is pushed backwards. This can be accomplished by the spinning blades of a propeller, a rotating fan pushing air out from the back of a jet engine, or by expelling hot gases from a rocket engine. Jet engines are a bit like propellers as they have fan blades that are like propeller blades inside them. However, propellers are powered differently than jet engines.*
6. What a Drag!

Think About It!

1. Look at some pictures of old cars (HowStuffWorks has some nice pictures). How have cars changed over time? Do you think any of the design changes helped overcome drag? *Children will likely notice that cars have become more rounded and sleek over time.*

2. How do you think a parachute uses drag to slow things down? *A parachute catches the air, slowing down the fall of the object. A larger parachute creates more drag, slowing the falling object even further.*

7. Make an Ornithopter

Think About It!

The article [Scratch-Built Ornithopter: Here’s How I Flapped My Way To Flight](https://www.hackaday.com) from Hackaday might help you and your child to fine-tune your ornithopter.

1. Did your ornithopter fly? Why do you think it did/didn’t? *Answers will vary.*

2. What shape did you choose for the wings? Why? *Answers will vary.*

3. How long did your ornithopter fly? Can you think of any way to keep it flying longer? *Answers will vary.*
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