Science In Flight

Celebrating the Centennial of Powered Flight

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Dear Educator

The United States Air Force is proud to present you with the Centennial of Flight themed Educational package "Education in Flight". These supplements are designed to provide you with a re-usable set of lesson plans, test, quizzes and posters that will help to enhance your curriculum. The Centennial of Flight year has been dedicated to celebrating the accomplishment of Wilbur and Orville Wright culminating on the official anniversary of their achievement in Kitty Hawk, N.C. on December 17th 2003. We hope that these themed plans can be incorporated in your lessons for this fall and used to encourage children to explore the many opportunities aviation has to offer.

Sincerely

JAMES J. SHEPHERD
Lieutenant Colonel, USAF
Director, Air Force Centennial of Flight Office

Outline of Plans

This text is designed for reading aloud, discussion, presentation on overhead projectors, and/or photocopying for distribution to students. An answer key for all of the questions that are used in assignments/assessments is included at the end of this text.

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Density and Weight

Density describes how much matter is contained within a given volume of space. Mathematically, density is mass (usually measured in grams) divided by volume (usually measured in cubic centimeters for gases or solids, and milliliters for liquids). The written formula is $D = {}^{m}/_{v}$. Thus, density usually is measured in grams per cubic centimeter (g/cm^3).

Calculation activity – Density

1. Calculate the density of an object with a mass of 603 grams and a volume of 18 cubic centimeters.
2. What is the mass of a 12-ml object with a density of 4.5 g/cm^3?
3. Calculate the volume of a substance with a mass of 60 grams and a density of 15 g/cm^3.
4. 2 L of substance has a mass of 3.5 kg. Find its density. (Hint: 1 L = 1000 ml, and 1 kg = 1000 g.)

The ***weight*** force of an object or substance is determined by its density, its total volume, and the local effect of gravity or some other acceleration. Therefore, weight can depend on location; an object weighs six times as much on the surface of Earth than the same object weighs on Earth's moon because gravity is six times stronger on Earth than on the moon. Density doesn't change just because an object is moved.

Mathematically, weight is mass (measured in kilograms) multiplied by the acceleration of the object (measured in meters per second per second, or m/sec^2). The written formula is $w = m \bullet a$. Thus, the metric system measures weight in newtons ($1\ N = 1\ kg \times 1\ m/sec^2$). Near the surface of Earth, the downward acceleration due to gravity is approximately 9.8 m/sec^2. Therefore, the weight of a 1 kg object on Earth is 9.8 N.

Calculation activity – Weight

1. Calculate the weight of a 50 kg object on Earth.
2. What is the weight of a 276 kg object on Earth?
3. How much would the object from question 2 weigh on the moon?
4. A substance has a density of 4.0 g/cm^3. How much does 5 L of the substance weigh on the surface of Earth?

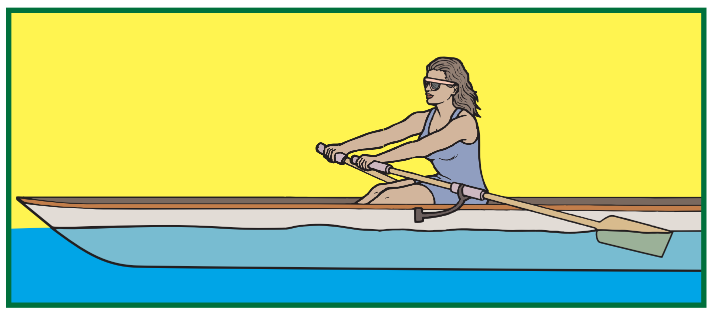
Buoyancy

Pure water has a density of 1.00 g/cm^3. In other words, one cubic centimeter of pure water consists of exactly one gram of matter. The density of oak wood is approximately 0.89 g/cm^3, and the density of steel is approximately 7.81 g/cm^3. Thus, one cubic centimeter of oak wood is less massive than the same volume of water or lead, and one cubic centimeter of steel is much more massive than the same volume of water or oak wood.

You probably have seen a piece of wood or a wooden canoe floating on top of water. A chunk of steel usually sinks in water, though. On the other hand, many ships that float on top of water are made of steel. How is this possible?

The tendency of an object to float on any fluid – liquid or gas – is called ***buoyancy***. (From the same root word, note that a *buoy* is a device that floats on top of water as a marker for boats and for swimmers.)

When Wilbur and Orville Wright made their pioneering flight on December 17, 1903, they already had a practical, experienced knowledge of the concepts of density and buoyancy. A wooden canoe and a steel ship both have buoyancy in water, but a chunk of steel doesn't. A hydrogen-filled or helium-filled zeppelin and a hot-air balloon both have buoyancy in air, but a basketball doesn't.



Archimedes' principle is illustrated by a canoe resting partially above and partially below the surface of the water.

Greek inventor/mathematician Archimedes determined long ago that the weight of the fluid displaced by an object is equal to the buoyant force pushing upward on the object. For example, if a cork is dropped into a glass of water, the cork will float, but some of the cork will lie beneath the original surface level of the water. To determine the buoyant force that is pushing upward on the cork, simply weigh the water that is moved out of the way by the floating cork. The weight force of the water is equal to the buoyant force on the cork.

An object floats – or is said to have buoyancy – in a fluid when the buoyant force pushing upward on the object is greater than the force of gravity pulling downward on the object.

Many people think that the weight of an object determines whether the object can float in a given fluid. However, remember that icebergs and steel ships can weigh hundreds of tons or more. The following activity demonstrates that density rather than weight determines buoyancy.

Lab – Buoyancy and Relative Density

Materials needed:

1. Large (1000 ml) beaker
2. Small (400 ml) beaker
3. Stirring rod or spoon
4. 3 cm piece of balsa wood
5. Polyethylene plastic pen cap or marker cap
6. Small steel bolt
7. 200 ml distilled water
8. Food coloring (dark red or blue)
9. 200 ml ethyl alcohol
10. 200 ml vegetable oil (of a distinguishable color from the alcohol)
11. 200 ml corn syrup

Procedure:

1. Carefully place the steel bolt, the polyethylene pen cap, and the piece of balsa wood into the large beaker.
2. Pour the water into the small beaker. Stir in five drops of food coloring.
3. Slowly pour the colored water into the large beaker, and observe.
4. ***Tilt the beaker*** and, one at a time, ***slowly*** pour the corn syrup, then the vegetable oil, and then the ethyl alcohol ***down the side*** into the large beaker. Observe after each pour.

Data: Complete the following table.

Object/Substance	Density (in g/cm^3)	Location (1 = top, 7 = bottom)
Corn syrup	1.38	
Ethyl alcohol	0.79	
Vegetable oil	0.82	
Water	1.00	
Steel	7.81	
Balsa wood	0.12	
Polyethylene plastic	0.92	

Analyses:

1. List the following objects and substances in the order that they came to rest, starting at the top of the large beaker and ending at the bottom of the large beaker: steel bolt, pen cap, balsa wood, water, alcohol, oil, and corn syrup.
2. How is your answer to question 1 related to the densities in the table above?
3. What do you know now about the density of air (a fluid)? Be specific.

Conclusion:

Explain how density of fluids (and solid objects placed into fluids) affects buoyancy.

Extensions:

1. Frozen water floats on top of liquid water. Explain how density of water changes when water undergoes the physical change of freezing or melting.
2. The density of steel is greater than the density of water. How do you think that a steel ship is able to float?

Overall Density

Very few objects or substances are evenly composed of one material throughout. Instead, most objects and substances vary in their compositions. In order to determine whether such an object or substance is buoyant in a given fluid, one must consider its ***overall density*** – the ratio of the total amount of matter to the total volume in which the matter is contained. When the Wright brothers first flew their plane in 1903, hot-air balloonists and pilots of hydrogen-filled zeppelins already knew the importance of overall density.

Mini-Lab 1A – Freshwater versus saltwater

Materials needed:

1. Large (2 L) transparent pitcher or beaker
2. Small glass or plastic container with sealable lid
3. Water
4. 500 ml salt
5. Stirring rod or spoon

Procedure:

1. Fill the pitcher almost completely with water.
2. Place the small container, with its lid on tight, into the pitcher. Observe.
3. Open the small container. Pour in a small amount of water. Tighten the lid onto the small container. Place the small container into the pitcher. Observe. Repeat, adding more water to the small container each time until the small container sinks slowly through the water in the pitcher.
4. Remove the small container from the pitcher. Stir 500 ml of salt into the water in the pitcher until the salt is dissolved.
5. Place the small container into the pitcher. Observe.

Mini-Lab 1B – Aluminum chunks versus aluminum boats

Materials needed:

1. Wide bowl
2. Water
3. 10 small metal paper clips
4. Two 5 cm x 5 cm sheets of aluminum foil
5. 500 ml salt
6. Stirring rod or spoon

Procedure:

1. Fill the bowl almost completely with water.
2. Tightly ball one foil square around five of the paper clips. Carefully place the balled chunk onto the water in the bowl. Observe.
3. Make a boat using the other foil square by folding the edges upward 1 cm, making sure to leave no holes nor open seams. Place the other five paper clips onto the boat. Carefully place the boat onto the water in the bowl. Observe.
4. Carefully push the boat under the surface of the water. Observe.

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Quiz – Density, Weight, and Buoyancy

1. What is the density of an object with a volume of 12 cm^3 and a mass of 102 g? Show your calculations. Give correct units in your answer.

2. Complete each sentence by circling the correct term in bold print:

a. The mass of an object on Earth is (***less than, greater than, equal to***) the mass that the same object would have on the moon.

b. The weight of an object on Earth is (***less than, greater than, equal to***) the weight that the same object would have on the moon.

3. If a floating object displaces 15 N of water, what is the buoyant force acting on the object? Explain how you know.

4. Circle the substances listed below that will float on top of pure water:

a. Balsa wood (0.12 g/cm^3)
b. Ethyl alcohol (0.79 g/cm^3)
c. Neoprene® rubber (1.23 g/cm^3)
d. Corn oil (0.84 g/cm^3)
e. Corn syrup (1.38 g/cm^3)
f. Sulfur (2.07 g/cm^3)

5. Steel is more dense than water. So how does a steel ship float on water?

Fluid Pressure and Bernoulli's Principle

A force exerted on a surface is pressure. Swiss scientist Daniel Bernoulli observed in the 1700s that as the speed of any fluid – liquid or gas – increases, the pressure in that fluid decreases. This concept, generally known as ***Bernoulli's principle***, was instrumental in the successful flights of the Wright brothers at Kitty Hawk, North Carolina in 1903.

Mini-lab 2A – A paper illustration of Bernoulli's principle

Materials needed:

1. Drinking straw
2. Paper without holes
3. Flat table or floor
4. Four thick textbooks of the same thickness

Procedure:

1. Stack two textbooks neatly on a flat tabletop (or on the floor). Neatly stack two other textbooks parallel to the first stack, approximately five inches away from the first stack.

2. Lay one piece of paper across the space between the stacks so that the paper makes a bridge from the top of one stack to the top of the other stack. Move the stacks closer together if needed to keep the paper from falling to the tabletop.

3. Hold a drinking straw with one end in your mouth and the other end pointed to the area below the paper, as parallel to the tabletop as possible.

4. Blow as hard as possible through the straw. Observe the paper as you blow.

Mini-lab 2B – Bernoulli under a funnel

Materials needed:

1. Ping pong ball
2. Flat table or floor
3. Transparent funnel large enough to lie face-down over top of ping pong ball with little extra room

Procedure:

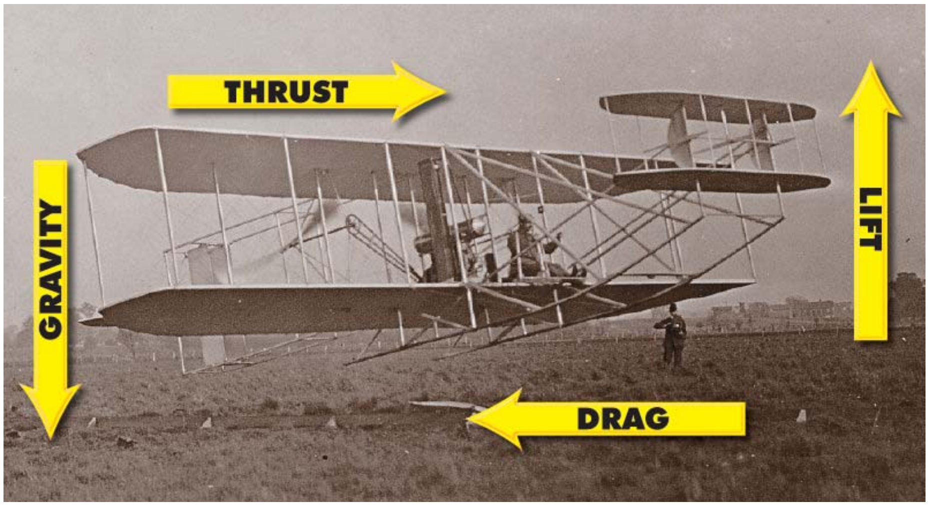
1. Place a ping pong ball on a flat tabletop (or on the floor).

2. Place a funnel, face-down, centered over the top of the ball, flat on the tabletop.

3. Blow as hard as possible through the small hole in the funnel. Observe the ping-pong ball as you blow.

The Basics of Airplane Flight

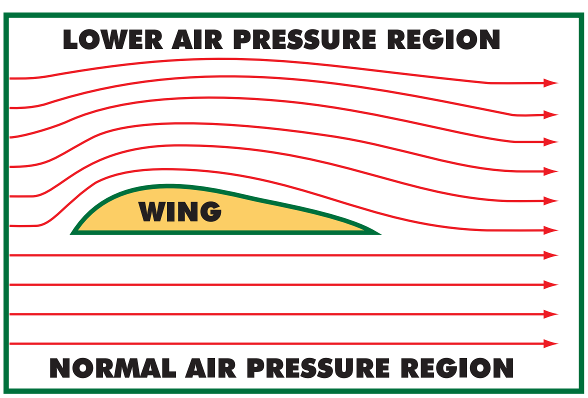
Four forces work together to determine whether an airplane rises or falls through the air: thrust, drag, lift, and gravity.



Thrust is the force that pushes or pulls a plane forward through the air. Propellers, jet engines, and all sorts of other outside sources – even catapults! – can provide thrust. Without enough thrust, air won't move past the plane quickly enough to create lift. A tailwind behind a plane increases thrust by using air to push the plane forward.

Drag is the force that resists forward motion and acts against thrust. Drag is created primarily by friction between the plane and the atmosphere. If the force of drag is too great, then a plane will move slower and will lose lift. A headwind increases drag by increasing the amount of air that collides with the plane from the front.

Gravity is the attractive force exerted by all objects in the universe. Earth has a great deal more mass than a plane, and so Earth's gravity pulls the plane strongly downward.

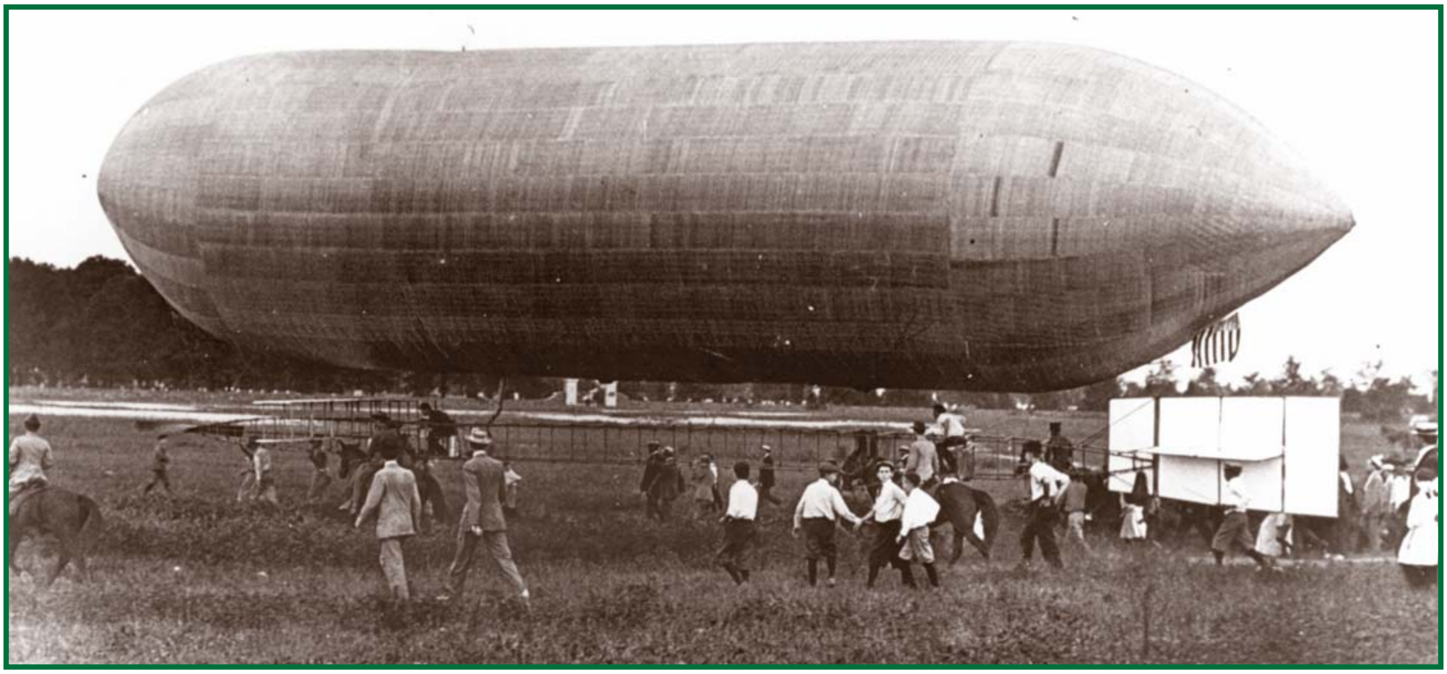


Scientists study different shapes of airfoils to address the speed and the directional control of airplanes.

When the force of ***lift*** is greater than the force of gravity, a plane rises. When the force of lift is less than the force of gravity, a plane falls. Lift is accomplished using Bernoulli's principle. A plane's wing – called an ***airfoil*** – is curved more severely on the top than on the bottom. Therefore, air passing around the wing must travel faster to cover the greater distance over the top of the airfoil than across the bottom. This results in lower air (fluid) pressure above the wing, and the wing is pulled upward (lifted) to fill the pressure gap.

What *Isn't* Flight?

Penguins are called "flightless birds." However, a penguin can control its overall density by holding or releasing air from its lungs, thus affecting its depth in water. The penguin uses muscles for thrust and fins for direction. So do you think that penguins can fly?



Balloons have limited control over direction and overall density.

Is *control of overall density* required? Dirigibles and hot air balloons fly by floating, as helium and hot air both are less dense than the air in most of Earth's atmosphere. The overall densities in complex versions of these vessels might be controlled using such devices as sandbags or by releasing some of the lighter-than-air gas, but toy balloons don't have such control mechanisms. You've probably seen a helium-filled balloon begin to fall after several days of pushing upward against its tether or against the ceiling. Why does this occur? (Small leaks in the balloon slowly release helium over time. When the overall density of the balloon along with the gas that it contains is less than the density of the surrounding air, the balloon falls through the air.)

Is movement through air required? If so, then do spaceships fly? They travel through airless space. If not, then why don't we just call swimming "water-flying"?

Is control over direction required? If so, then do helium-filled balloons fly? A balloon's direction is determined by surrounding winds. If not, then do simple algae fly in water?

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Worksheet – Bernoulli's Principle and Airplane Flight

1. State Bernoulli's principle.

2. An undertow is created in the ocean when a fast-moving current of water runs parallel to the shore several feet below the surface. Explain how an undertow can be dangerous to people swimming in the area above the undertow current.

3. Explain how Bernoulli's principle can be used to create lift for an airplane.

4. What is the primary source of drag on a flying airplane?

5. When does an airplane climb through the air? When does it descend?

6. On the back of this page, write a detailed paragraph explaining whether you think penguins really are flightless birds and why.

Parts of an Airplane

The Wrights' famous plane, *Flyer*, was a reinforced glider with an engine. Modern airplanes, on the other hand, are sophisticated machines with thousands of moving parts.

The ***propellers***, the ***jet engines***, or the ***rocket engines*** provide thrust for the plane. The ***wings*** are shaped like airfoils to create lift using Bernoulli's principle.

The ***elevators*** are hinged, horizontal surfaces attached to the back of the tail of the plane. Elevators control the plane's movement upward or downward. When the elevators are raised, the tail is forced downward, the wings are forced upward, and the plane climbs.

The ***ailerons*** are hinged, horizontal surfaces attached to the back, outer edges of the wings of the plane. The ailerons are used to turn the plane. As one aileron rises, the opposite aileron lowers, raising one wing and lowering the other. When the aileron on the left wing is lowered, the left wing rises, and the plane tilts (or banks) to the right.

The ***rudder*** is a hinged, vertical surface attached to the tail of the plane that assists the plane in entering and recovering from turns by swinging the tail to the left or right.

Mini-Lab 3 – Paper airplane designs

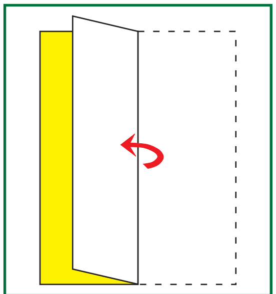
Materials needed:

1. Crisp paper without holes
2. Scissors

Procedure:

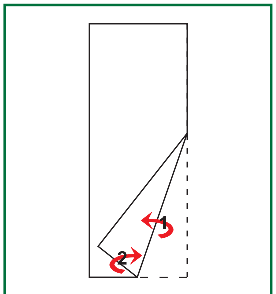
1. Fold a long paper airplane. Launch the airplane. Observe its flight.
2. Use the scissors to cut flaps at the tail end of the plane. Fold one flap upward and one flap downward. Launch the airplane. Observe its flight.
3. Fold both flaps upward. Launch the airplane. Observe its flight.
4. Fold both flaps downward. Launch the airplane. Observe its flight.
5. Repeat the above steps using a short paper airplane. Repeat the above steps with other modifications to the airplanes.

How To Fold An F-117 Stealth Fighter



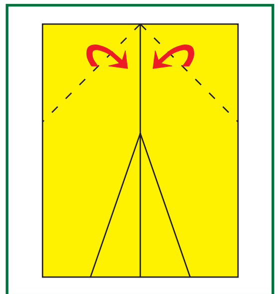
STEP 1

Start with an 8.5” x 11” piece of paper. Lay it flat on a table and then fold the paper exactly in half along its long edge. Make sure all folds are sharp, crisp, and precise.



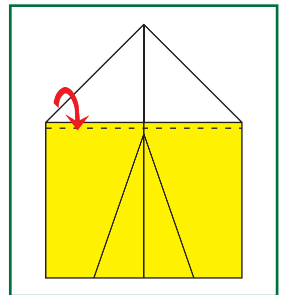
STEP 2

1. Make a crease for the **tail** by folding about a 2” wide flap from the new edge of the page (up to nearly half the page length — see above). 2. Open it back flat.



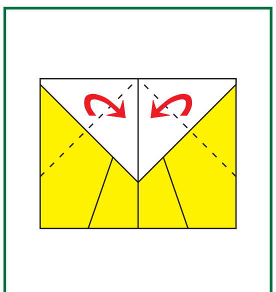
STEP 3

Unfold the paper and lay it flat on the table. The creases for the **tail** should be at the bottom. Fold the upper right and left corners of the page down along the center line of the paper. They should be even.



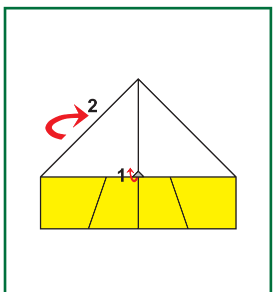
STEP 4

Fold the top, or **nose**, of the page down about ½” below the new folds from **STEP 3** — see above. When folding, make sure the tip of the **nose** stays centered on the center line of the page.



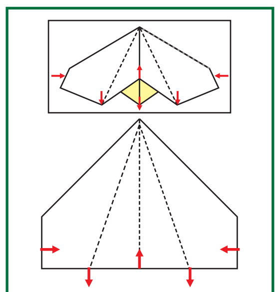
STEP 5

Now fold the new right and left corners down along the center line in the same way as in **STEP 3**.



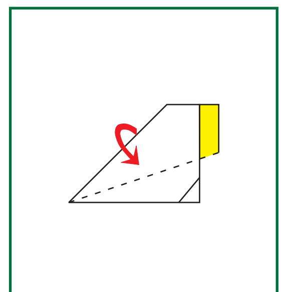
STEP 6

1. Fold the small exposed triangle flap up so the point at its tip meets the center line crease. This will help hold the body together.
2. Flip the plane over so the folded flaps are underneath and the **nose** is pointing up.



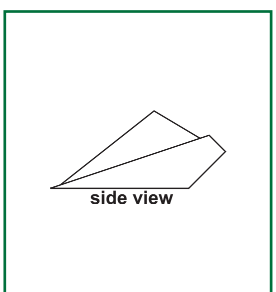
STEP 7

This step is tricky. While pushing the top **tail** section up and the bottom down, fold the plane in half along the center line. When folded correctly, the **tail** section will be hidden between the **wing flaps**.



STEP 8

Rotate the plane so it appears as above. Fold each **wing** down so their outer edges are even with the bottom edge of the plane. The tail should be the only remaining flap sticking up from the middle.



STEP 9

You can now open up the wing flaps and adjust them so they are even. Angle them down slightly for more stability. You are now ready to take a test flight with your new ***F-117 Stealth Fighter***.

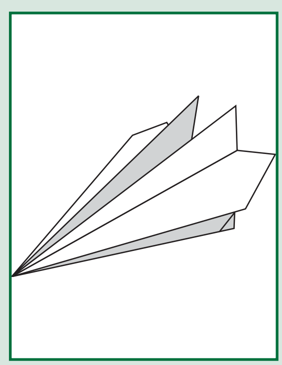
TIPS

Here are some hints for making your *F-117 Stealth Fighter* really soar:

1. Throw the plane with a level or slightly nose-up push throw.

2. Try placing a small paper clip on the bottom nose of the plane for greater distance.

3. Cut the top tail of the plane down the center and bend each tail flap slightly outward to form two stabilizers.



Bird Flight

Like the airplane that first carried Orville Wright in 1903, birds have several components that make flying easier. They have long, sturdy bones that are lightweight and either porous or hollow, decreasing overall density. Their wings are shaped like airfoils, curved more severely on the top than on the bottom. Their feathers are durable, movable, and smooth, helping to reduce drag. Birds' muscles allow twisting movement of the wings to create thrust, but some birds take advantage of other thrust devices, as well.

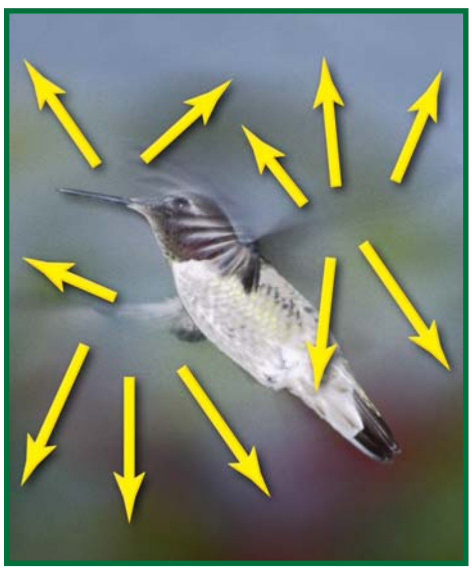
Gliding

Birds like hawks and vultures have large wings that are designed to capture great quantities of air from below. Large birds of prey often climb through the atmosphere by soaring in an upward spiral upon streams of warm air called *thermals*. Pelicans also glide by taking advantage of air rising above waves at the surface of the ocean.

Similarly, hang-gliders are aircraft that gain lift from updrafts in the surrounding air.

Flapping

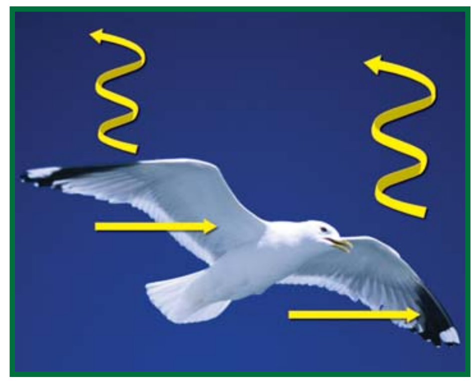
Smaller songbirds – like robins and orioles – have powerful muscles in and around their wings to generate thrust by flapping. Hummingbirds' muscles can twist their short wings in almost any direction and can flap their wings more than 100 times per second!



This provides superb control over thrust and direction but requires enormous amounts of energy, which is why hummingbirds consume sugary flower nectar. Like these small birds, most airplanes must use constant thrust from propellers, jets, or other devices to maintain lift.

Combining methods

Seagulls are designed for both gliding and flapping.



Their long, slender wings capture moving air above the water and the beach on windy days. When no wind is available, though, their strong flight muscles flap their wings to provide thrust from within their bodies.

Like gulls, toy kites receive some thrust from muscle movement, but they can also stay aloft by soaring in the wind.

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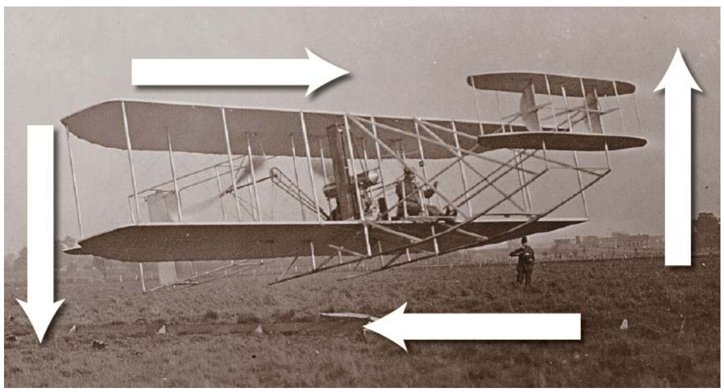
Quiz – Fluid Pressure and Flight

1. According to Bernoulli's principle, as a fluid moves faster, what happens?

2. Complete the sentence by circling each correct term in bold print: An airplane rises through the air when the force of (***thrust, drag, gravity, lift***) is greater than the force of (***thrust, drag, gravity, lift***).

3. On the diagram below, label the four main forces that affect an airplane's ability to fly:



4. Contrast how gulls climb through the air on a windless day and how gulls rise over beach dunes without moving their wings much in a breeze.

5. For each description below, write the name of the corresponding airplane part.

a. Horizontal flaps attached to wings that are used for turning:

b. Components shaped like airfoils to provide lift:

c. Horizontal flaps attached to tail that control ascent and descent:

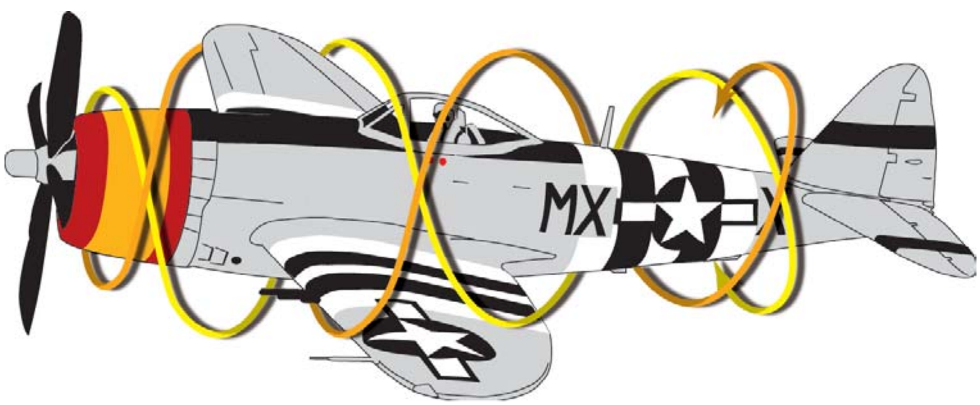
d. Vertical tail flap that assists with entering and recovering from turns:

e. Any one of three airplane thrust devices discussed in class:

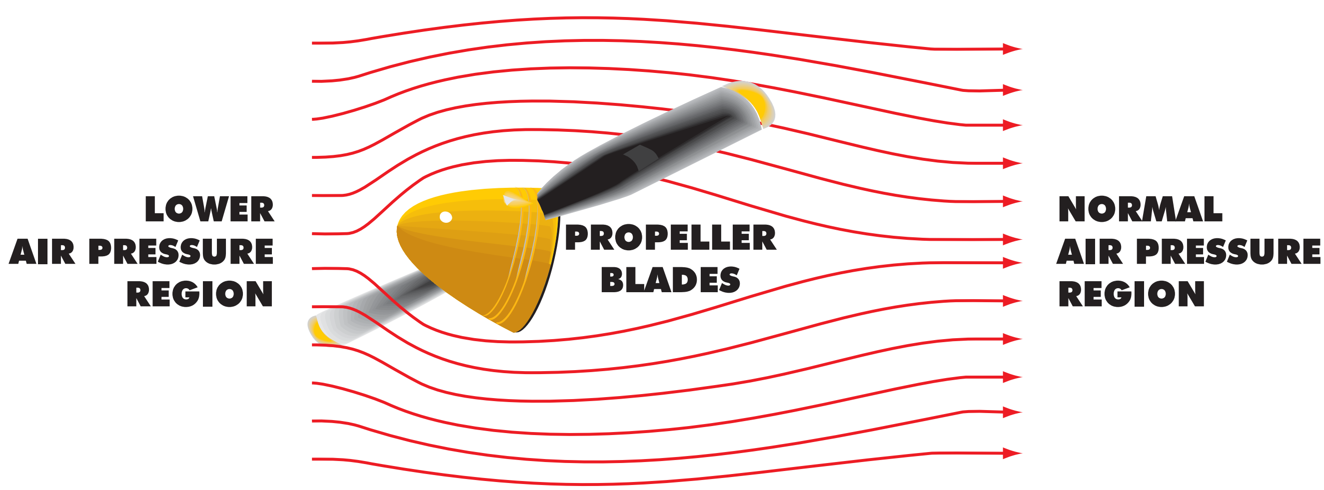
Propellers

The Wright brothers' 1903 *Flyer* had a pair of two-bladed ***propellers*** that were located behind the wings and turned by a small gasoline engine. Today, propeller planes use one, two, or four propellers with between two and six blades apiece, but the basic mechanics of the propeller haven't changed much.

Propellers also are called *airscrews* because they are designed to slice and pull forward through air in the same way that a metal screw cuts into solid matter.



Most propeller blades are shaped like airfoils, having a front surface that is more severely curved than the back surface. As the engine spins the propeller, air pressure in front of the blades decreases due to Bernoulli's principle. The result is that the blades and the air behind them are pulled forward to fill the pressure gap, thereby providing thrust for the plane attached to the propeller.

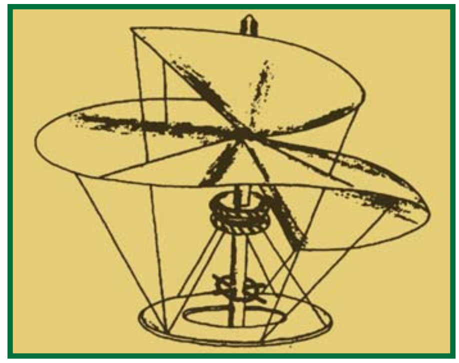


<u>*Write your responses to the following tasks on the back of this page:*</u>

On the internet find three facts about propellers that weren't discussed on this handout. Write those facts *and* the website(s) where you found them.

Write a paragraph *in your own words* explaining the basics of propellers.

Helicopters



The roots of the ***helicopter*** date back at least as far as the 15th century drawings of Italian artist and inventor Leonardo da Vinci, but no such device carried human travelers into the air until years after the Wright brothers' historic 1903 adventure in their winged *Flyer*. Today, helicopters can carry thousands of pounds of cargo, weaponry, and passengers over long distances with superb directional control, but the key mechanics of the helicopter haven't changed much since the designs of da Vinci.

A helicopter's rotor blades create lift by essentially screwing into the air much the same way that a metal screw slices and pulls forward into solid matter. Taking advantage of Bernoulli's principle, a lower pressure region is generated on one side of the blade, and the blade is pulled into that region. Thus, rotor blades on a helicopter perform the same basic function the wings on an airplane, but the primary advantage that a helicopter has over winged airplanes is maneuverability.

A pilot can control the tilt (or *pitch*) of the rotor blades to move a helicopter in almost any direction. Just as a toy kite gains lift by tilting through moving air, so does tilting a helicopter's rotor blades create lift for the aircraft. However, a helicopter can rise straight upward with great stability. Lesser pitch in the blades decreases lift, and gravity pulls the ship straight downward. By tilting the entire saucer created by the spinning of the rotor blades, a helicopter pilot can make the vehicle move forward, backward, or sideways, even while ascending or descending through the air.

The pitch of the smaller set of revolving blades near the tail of a helicopter is controlled by the pilot for use in turning or keeping the ship straight.

Write your responses to the following tasks on the back of this page:

On the internet find three facts about helicopters that weren't discussed on this handout. Write those facts *and* the website(s) where you found them.

Write a paragraph *in your own words* explaining the basics of helicopters.

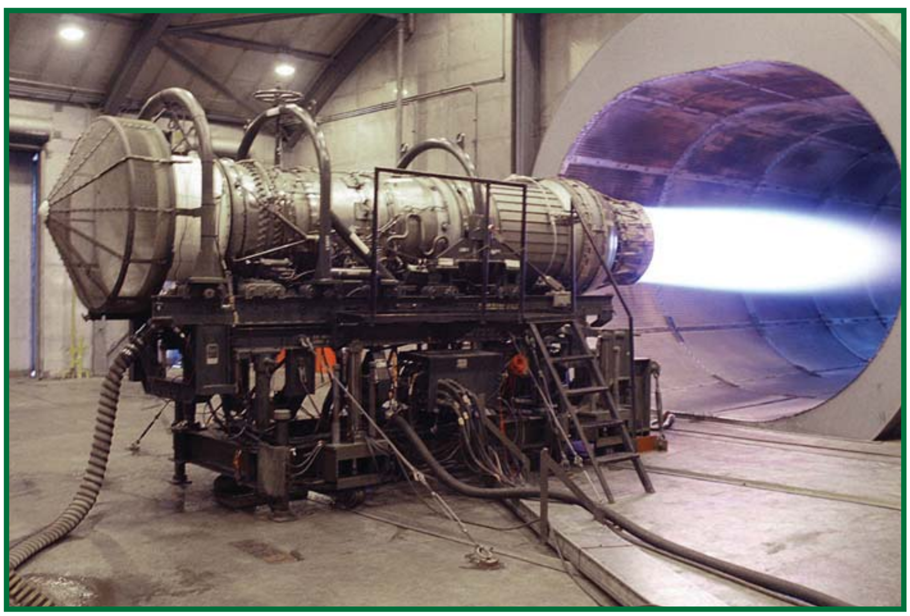
Jets

When Orville Wright flew solo for 37 meters (120 feet) in 12 seconds in 1903, the *Flyer* received its thrust from a pair of two-bladed propellers. Today, airplanes weighing several tons can carry many thousands of pounds of cargo and passengers across continents and oceans for hours at a time, largely thanks to the development of ***jets***.

If you release an open-nozzle balloon filled with compressed air, the air inside rapidly escapes through the nozzle, and the balloon travels through the air. The escape of compressed air is an *action*, and the movement of the balloon is a *reaction*. English mathematician and scientist Sir Isaac Newton described this event in his *Third Law of Motion* – every action has an equal and opposite reaction. Based on this principle, jet flight is like the propulsion of the balloon.

In all types of jets, air is drawn into a combustion chamber, compressed, mixed with injected fuel, and ignited by a spark. Rapidly-expanding gases created by the burning of the mixture rush out of the rear of the jet engine. This action generates the reaction of forward movement of the jet.

A *ramjet* has no moving parts. Air is compressed in a ramjet by the plane's forward movement, which means that a ramjet only can work when the plane is moving. Thus, a "mother ship" has to launch a ramjet plane into the air. A *pulsejet* is only slightly more sophisticated, having an inlet valve that controls the amount of air entering the engine.



A *turbojet* has a compressor that acts like a fan, compressing the air that is drawn into the engine and forcing it through tubes into the combustion chamber. As the hot gases blast out the back of the turbojet engine, they pass through a bladed turbine wheel. The turbine wheel turns the main shaft, which operates the front compressor, increasing efficiency.

Write your responses to the following tasks on the back of this page:

On the internet find three facts about jets that weren't discussed on this handout. Write those facts and the website(s) where you found them.

Write a paragraph *in your own words* explaining the basics of jets.

Rockets

When the Wright brothers launched their *Flyer* in 1903, most of the encounters that people had with ***rockets*** were in the form of gunpowder-propelled fireworks and weapons. Today, rocket engines drive supersonic planes, carry satellites into orbit around Earth, propel weaponry missiles, and launch human beings and their creations into outer space, but the basic mechanics of the rocket haven't changed much.

If you jump backward off a skateboard, it rolls forward with a force equal to that of your backward movement. Your jump is an *action*, and the roll of the board is a *reaction*. English mathematician and scientist Sir Isaac Newton described this event in his *Third Law of Motion* – every action has an equal and opposite reaction. Rocket flight is based on this principle.

Some rockets use solid fuels, often including black gunpowder and a substance that is principally rubber. Others use various liquid fuels – hydrogen peroxide, alcohol, gasoline, hydrogen, fluorine, or liquid oxygen.

Gases created by the burning of such propellants rush out of the thrust chamber of a rocket. This action generates the reaction of forward movement of the rocket. If the rocket produces enough thrust to reach an escape velocity of nearly 40000 kph (25000 mph), the rocket can overcome Earth's gravity and travel to outer space.

Satellites

When the Wright brothers launched their historic *Flyer* in 1903, the only ***satellite*** orbiting Earth was the moon. Today, hundreds of human-made satellites in the skies above Earth are used to detect events on or near the surface of the planet, to relay information around the globe, to conduct scientific experiments, to aid with navigation, and to look deep into outer space without the obstructions of Earth's lower atmosphere, but these satellites are governed by the same orbital principles as the moon.

An artificial satellite is launched into *orbit* approximately 500 km (300 miles) above Earth by a rocket that releases the satellite at an orbital velocity of at least 29000 kph (18000 mph). The satellite is directed in a path that is tangent to the curve of Earth's surface. According to Sir Isaac Newton's *First Law of Motion*, an object in motion will remain in motion unless acted upon by an outside force, and this suggests that the satellite should travel away from Earth into outer space. However, an outside force does act upon the satellite. *Centrifugal force* caused by Earth's gravity pulls the satellite into a curved orbit around the planet.

Write your responses to the following tasks on the back of this page:

On the internet find three facts each about rockets and satellites that weren't discussed on this handout.

Write those facts and the website(s) where you found them.

Write a paragraph *in your own words* explaining the basics of rockets.

Name ________________________________ Date __________ Class period _____

Test – The Science of Flight

1. An object with a density 20 g/cm^3 has a total volume of 400 cm^3. Calculate *both* the mass of the object and the weight of the object on Earth. Show your calculations. Use correct units.

2. An object rests just below the surface of a pool of water. How could you make the object float without changing or attaching anything to the object?

3. Fluid A has a density of 1.35 g/cm^3. Fluid B has a density of 2.11 g/cm^3. If both fluids are poured into a beaker and they don't undergo a chemical reaction, what will happen to them? Explain how you know.

4. An object placed into a tub displaces 4 N of water while floating. What is the buoyant force acting on the object? Explain how you know.

5. Steel is more dense than water. So how does a steel ship float on water?

6. Explain how thrust, drag, gravity, and lift affect airplane flight.

7. Write Bernoulli's principle. Explain how it is used in airplane flight.

8. List three components of an airplane that help to control the direction of flight. Briefly explain how each listed component is used.

9. A hawk spirals upward into the sky without moving its wings much. A sparrow moves its parts much more when flying. Explain the differences in these two types of bird flight.

10. In three complete sentences, write three interesting facts that you learned about the science of propellers, helicopters, rockets, jets, or satellites.

Answers to assigned/tested questions

Calculation activity – Density

1. 603 g / 18 cm^3 = 33.5 g/cm^3
2. (12 cm^3) (4.5 g/cm^3) = 54 g
3. (60 g) / (15 g/cm^3) = 4 g/cm^3
4. 3500 g / 2000 cm^3 = 1.75 g/cm^3

Calculation activity – Weight

1. (50 kg) (9.8 m/sec^2) = 490 N
2. (276 kg) (9.8 m/sec^2) = 2704.8 N
3. 2704.8 N / 6 = 450.8 N
4. Mass = (5000 cm^3) (4 g/cm^3) = 20000 g = 20 kg
   Weight = (20 kg) (9.8 m/sec^2) = 196 N

Lab – Buoyancy and relative density

Data: 6, 2, 3, 5, 7, 1, 4

Analyses:

1. Balsa wood, ethyl alcohol, oil, pen cap, water, corn syrup, steel bolt.
2. Same order.
3. Air floated on top the other substances, so its density must be less than 0.12 g/cm^3.

Conclusion: Denser substances sink in less dense fluids. Less dense substances float in denser fluids.

Extensions:

1. Solid, frozen water is less dense than liquid water.
2. The overall density of the entire object (ship with contained air) is less than the density of water because water is denser than air, so the ship floats.

Quiz – Density, weight, and buoyancy

1. 102 g / 12 cm^3 = 8.5 g/cm^3
2. a. equal to b. greater than
3. 15 N. Archimedes' principle states that the weight of the fluid displaced by an object is equal to the buoyant force acting on that object.
4. Substances a, b, and d will float in pure water.
5. The overall density of the entire object (ship with contained air) is less than the density of water because water is denser than air, so the ship floats.

Worksheet – Bernoulli's principle and airplane flight

1. As a fluid moves faster, its pressure decreases.
2. The lower pressure in the undertow current will be filled by pulling nearby objects, including swimmers, into the current.
3. An airplane's wings are shaped like airfoils, more severely curved on the top than on the bottom. As the plane is pushed or pulled through the air by thrust devices, air moves faster over the tops of the wings than across their bottoms, making a region of lower pressure above the wings. The wings (and the attached airplane) are pulled upward into the lower pressure region. When the force of such lift exceeds the downward force of gravity, the plane climbs.
4. friction between the plane and passing air
5. Plane climbs when lift exceeds gravity; descends when gravity exceeds lift.
6. Answers will vary. See page 9.

Quiz – Fluid pressure and flight

1. The pressure in the fluid decreases.
2. lift, gravity
3. Forward thrust, backward drag, upward lift, and downward gravity.
4. Gulls use their long, airfoil-shaped wings to glide on windy air rising over dunes. Away from wind, gulls use their strong muscles to twist and flap their wings to create thrust and lift.
5. a. ailerons b. wings c. elevators d. rudder
   e. propellers, jet engines, or rocket engines

Detailed studies

1. Answers will vary. See Centennial of Flight website, www.centennialofflight.com.
2. Answers will vary. See pages 14 – 18 and website.

Unit test

1. Mass = (400 cm^3) (20 g/cm^3) = 8000 g = 8 kg
   Weight = (8 kg) (9.8 m/sec^2) = 78.4 N
2. Increase the density of the fluid in the pool (by adding salt to the water, for example).
3. Fluid A will float on top of Fluid B. Less dense substances (like A) float atop denser fluids (like B).
4. 4 N. Archimedes' principle states that the weight of the fluid displaced by an object is equal to the buoyant force acting on that object.
5. The overall density of the entire object (ship with contained air) is less than the density of water because water is denser than air, so the ship floats.
6. Thrust moves a plane forward through the air. Drag created by friction with the air slows forward motion. When lift (created by pressure differences above and below the wings) exceeds gravity, the plane climbs.
7. As a fluid moves faster, its pressure decreases. An airplane's wings are shaped like airfoils, more severely curved on the top than on the bottom. As the plane is pushed or pulled through the air by thrust devices, air moves faster over the tops of the wings than across their bottoms, making a region of lower pressure above the wings. The wings (and the attached airplane) are pulled upward into the lower pressure region. When such lift exceeds the downward force of gravity, the plane climbs.
8. Propellers, jet engines, and rocket engines create forward thrust. Airfoil-shaped wings provide lift. Hinged, horizontal surfaces attached to the tail are called elevators and turn the plane upward and downward. Hinged, horizontal surfaces attached to the backs of the wings are called ailerons and turn the plane left and right. A hinged, vertical surface attached to the tail is called the rudder and helps control entry into and recovery from left/right turns.
9. The hawk uses its long, airfoil-shaped wings to glide on rising columns of warm air (thermals). The sparrow uses its strong muscles to twist and flap its wings to create thrust and lift.
10. Answers will vary. See detailed studies above.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