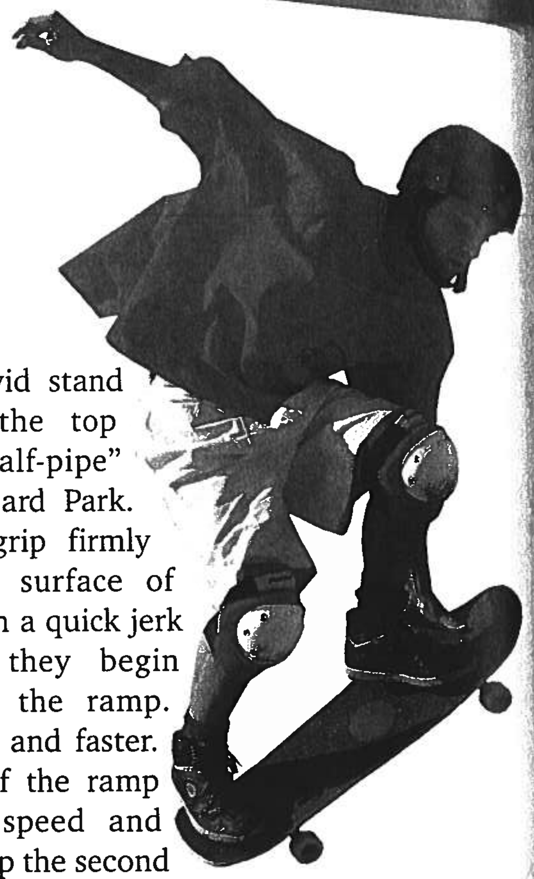
CHAPTER 10

Flight



OBJECTIVES

- describe the forces that oppose motion.
- identify and discuss the forces that allow an airplane to fly.
- identify and discuss the processes used to control flight in an airplane.

KEY TERMS

aerodynamics
aerospace
ailerons
airfoil
Bernoulli effect
drag
fluid friction
force
gravity
inertia

Sarah and David stand motionless on the top edge of the "half-pipe" ramp at Skateboard Park. Their sneakers grip firmly onto the rough surface of their boards. With a quick jerk of their legs, they begin the drop down the ramp. They glide faster and faster. At the bottom of the ramp they're at top speed and begin the climb up the second side of the ramp. They reach the top of the ramp and, with a final burst of energy, they become airborne. For a few seconds, David and Sarah are flying, but in the blink of an eye they return to the ramp and the process begins again. Each time Sarah and David reach the top of the ramp they become airborne—but only for a very short time.

Why are David and Sarah's flights so short? When airborne, why don't they continue to soar like a bird or plane?

Aerospace (air-oh-SPACE) is the study of how things fly. By studying aerospace technology, we can find out the answers to these and other questions about flight.

FORCES

Things move only when a force is applied to them. A **force** is a push or pull that transfers energy to an object. Force can set an object in motion, stop its motion, or change its speed and direction.

On a windy day, you can feel the force of moving air push against your body. The force of a magnet can pull paper clips towards it. The force of gravity pulled David and Sarah down the ramp. Fig. 10-1.

Birds, airplanes, rockets, and all things that fly need to apply force so they can become airborne.

Objects that are very heavy need a greater force to make them move. When heavy objects are moving, it takes a greater force to stop them or change their direction. An object will remain still or will continue to move in the same straight line unless an outside force acts on it. This property of matter is called **inertia** (i-NURR-shuh). It was inertia that pushed David and Sarah up the second side of the ramp. All things that fly rely on inertia to keep moving.

> **FASCINATING FACTS**
>
> **In 1992, school children in Virginia built a paper airplane with a wingspan of 30 feet, 6 inches. They launched it from a 10-foot-high platform. The plane flew more than 100 feet.**

Newton's Three Laws

Isaac Newton was an English scientist. He lived over four hundred years ago. He proposed three laws of motion. These three laws have helped scientists understand the forces that affect an object.

Newton's *first law of motion* states that a body will remain at rest unless a force acts on it.

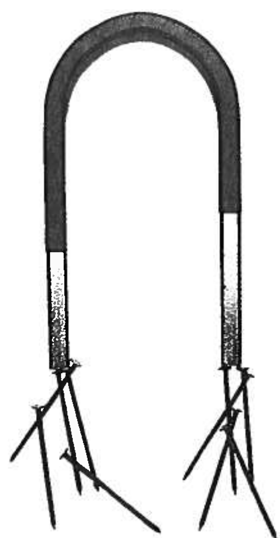


Fig. 10-1 **Forces transfer energy in different ways. What force is pulling down on the skydiver? What force is pulling up on the nails?**

Newton's *second law of motion* states that the change of motion is proportional to the force acting on the body.

Newton's *third law of motion* states that for every action there is an equal and opposite reaction.

Each of these laws of motion applies to Sarah and David and their skateboard runs. As you read this chapter, see if you can discover the answer to the following questions:

- What forces caused Sarah and David to begin to move on their skateboards?
- What forces caused them to slow down?

Forces That Oppose Motion

Certain forces oppose or act against objects in motion.

Friction is the force that brings moving objects to rest. Friction occurs when objects come in contact with each other. Friction acts in an opposite direction to motion, causing objects to slow down and then stop. Fig. 10-2.

As soon as David and Sarah began to move up the second side of the ramp they started to lose inertia or energy. They began to slow down and lose motion. The force of friction was working against them.

Gravity is a force that pulls objects towards the center of the Earth. It was gravity that gave Sarah and David the force needed to accelerate down the ramp. The force of gravity also pulled on them as they rose up the second side of the ramp. The pulling force of gravity increases as the mass of an object increases. Gravity is one reason why Sarah's and David's flights

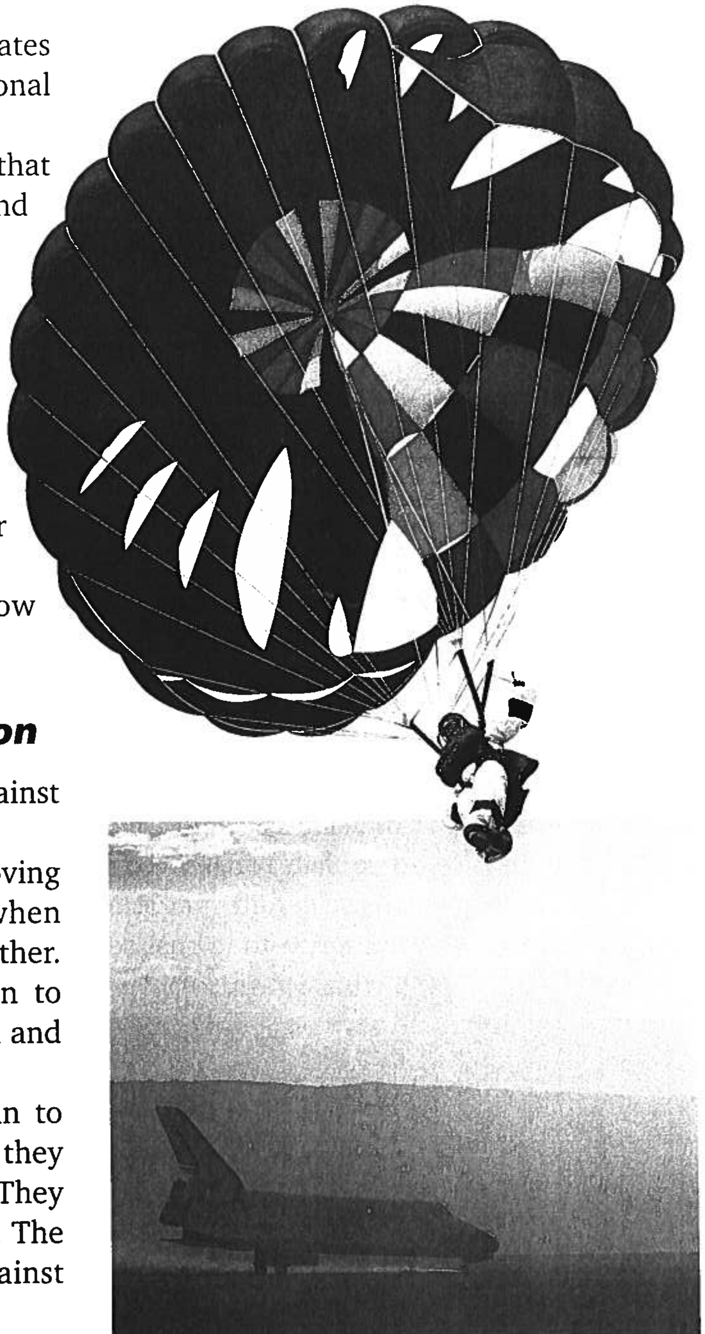


Fig. 10-2 Friction is a force that opposes the motion of the object. There are different kinds of friction. The landing space shuttle shows rolling friction. Resistance occurs between the wheel and the ramp. Why does it take so long for a parachute to drift to the ground? Air resistance, a fluid friction, slows the fall of the parachute.

/ere so short. Gravity pulled them back own towards the ramp. It opposed their iertia.

Gravity and friction also pull and slow own airplanes, kites, and rockets. They /ill slow down any object traveling ırough the air.

·orces and Flight

Birds, planes, rockets, and kites fly ecause they generate forces that are reater than opposing forces such as ravity and friction. Fig. 10-3. Sarah and)avid's flights were short because the orces they generated were quickly vercome by friction and gravity.

.ift

Lift is an upward force used to overcome ravity. The shape of the wings on airplanes and even birds provides the lifting force needed to fly. (This shape is discussed later in this chapter.) When the force of lift is greater than the weight of the plane, the plane will rise into the air.

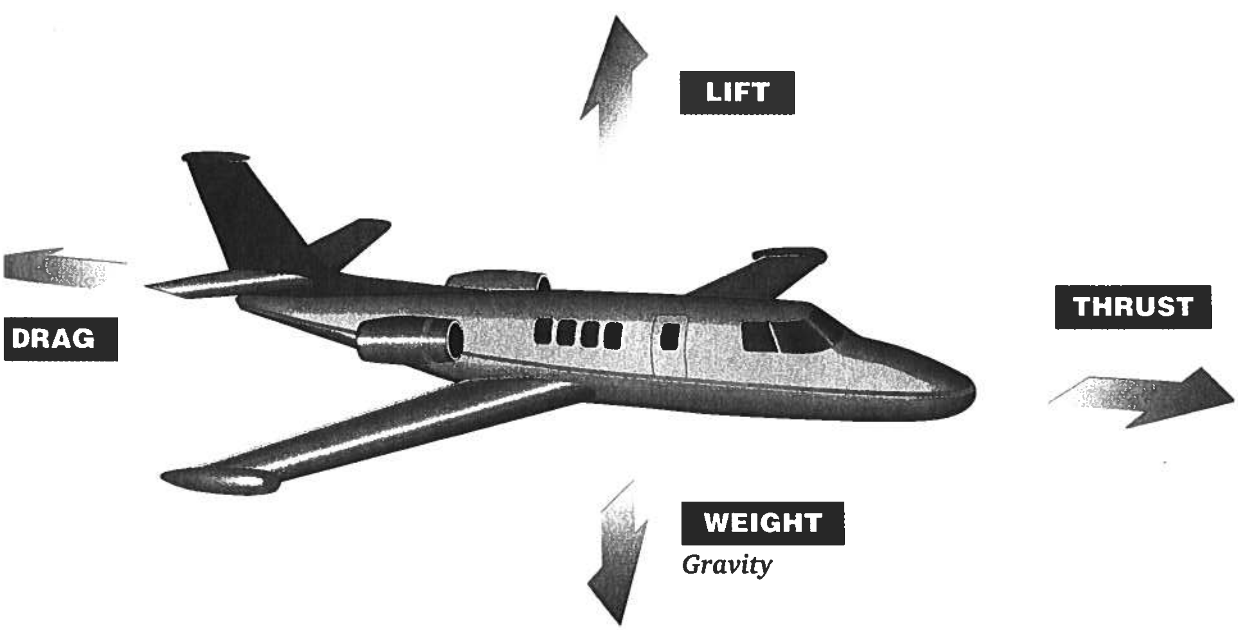
Thrust

Planes also need a forward force to fly. This forward force is called *thrust*. Thrust helps to provide lift and overcome friction.

What kind of force would Sarah and David have to generate to soar like birds from the top of the ramp?

AERODYNAMICS

A key factor in achieving flight is speed. We have learned that friction is a force that slows down and eventually stops an object in motion.



▸**Fig. 10-3** **The combined action of these four forces enables an aircraft to take off, fly, and land. /hich of these four forces are opposing forces?**

Linking to MATHEMATICS

Force, Mass, and Acceleration. There is a relationship between how fast an object is moving, its mass (amount of matter), and the force needed to move it. The mathematical formula that shows this relationship is:

force = mass x acceleration

As mass or acceleration increases, force also increases. Here's an example of how the formula works. If the acceleration of an airplane traveling down a runway is 2 m/sec/sec (2 meters per second per second) and the aircraft's mass is 1500 kilograms, the force needed to move that aircraft at that speed would be 3000 N.

Fluid friction is the cause of the resistance an object meets as it moves through the air. The force of fluid friction is created when particles of air contact the moving object.

Drag is the force of fluid friction on moving objects. Fig. 10-4.

Drag can be reduced by making air move more smoothly over the surface of an object.

Aerodynamics (air-oh-dy-NAM-iks) deals with the forces of air on an object

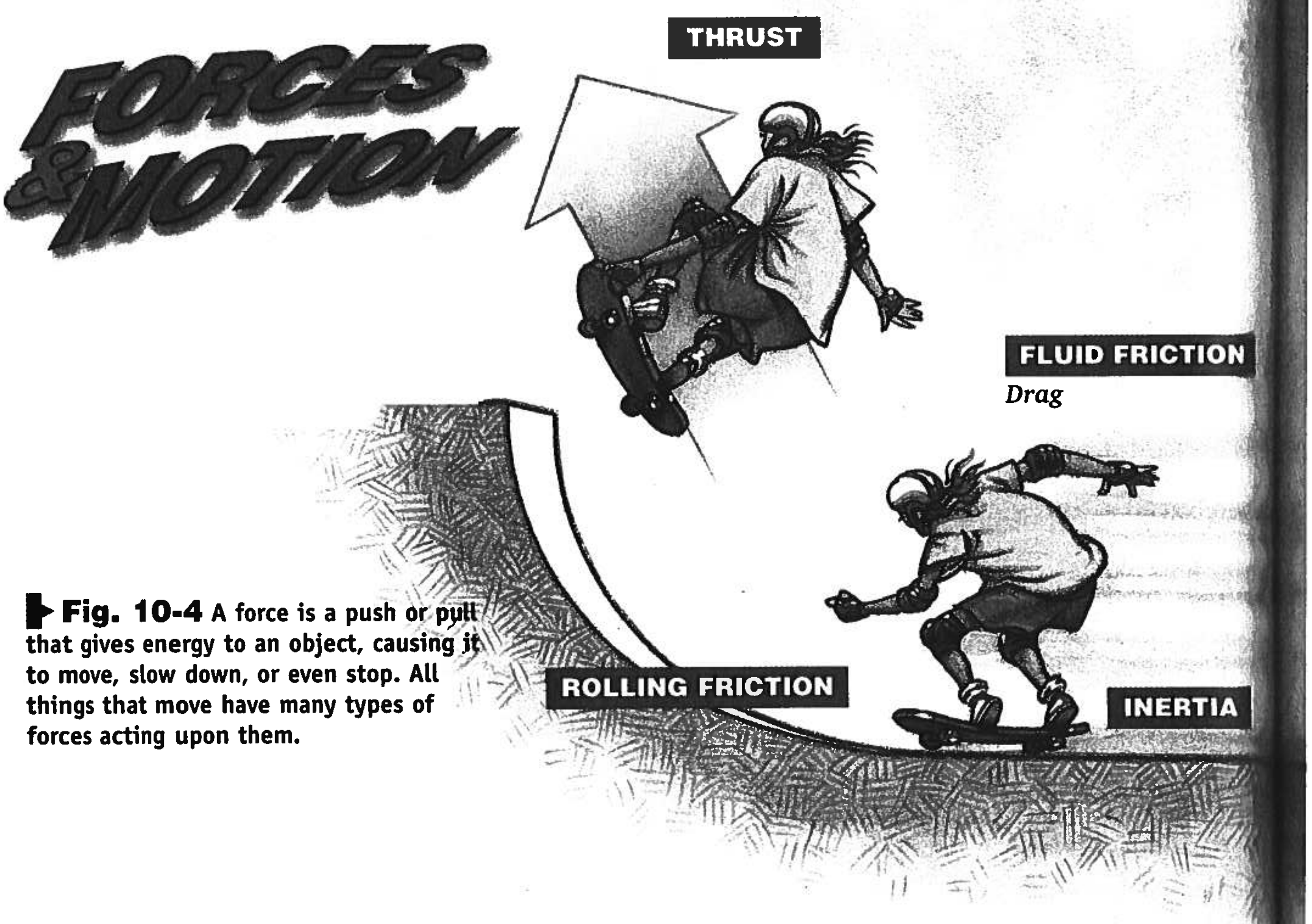


Fig. 10-4 **A force is a push or pull that gives energy to an object, causing it to move, slow down, or even stop. All things that move have many types of forces acting upon them.**

moving through it. One goal of aerodynamics is to design objects so that fluid friction is reduced as the objects move through the air. Cars, boats, and even the helmets worn by skateboarders have aerodynamic designs that reduce fluid friction. Aircraft and rockets are designed with pointed noses and rounded, smooth surfaces for the same reasons.

AIRPLANES

The wings of an airplane are used to create lift. Each wing is shaped like a

> **FASCINATING FACTS**
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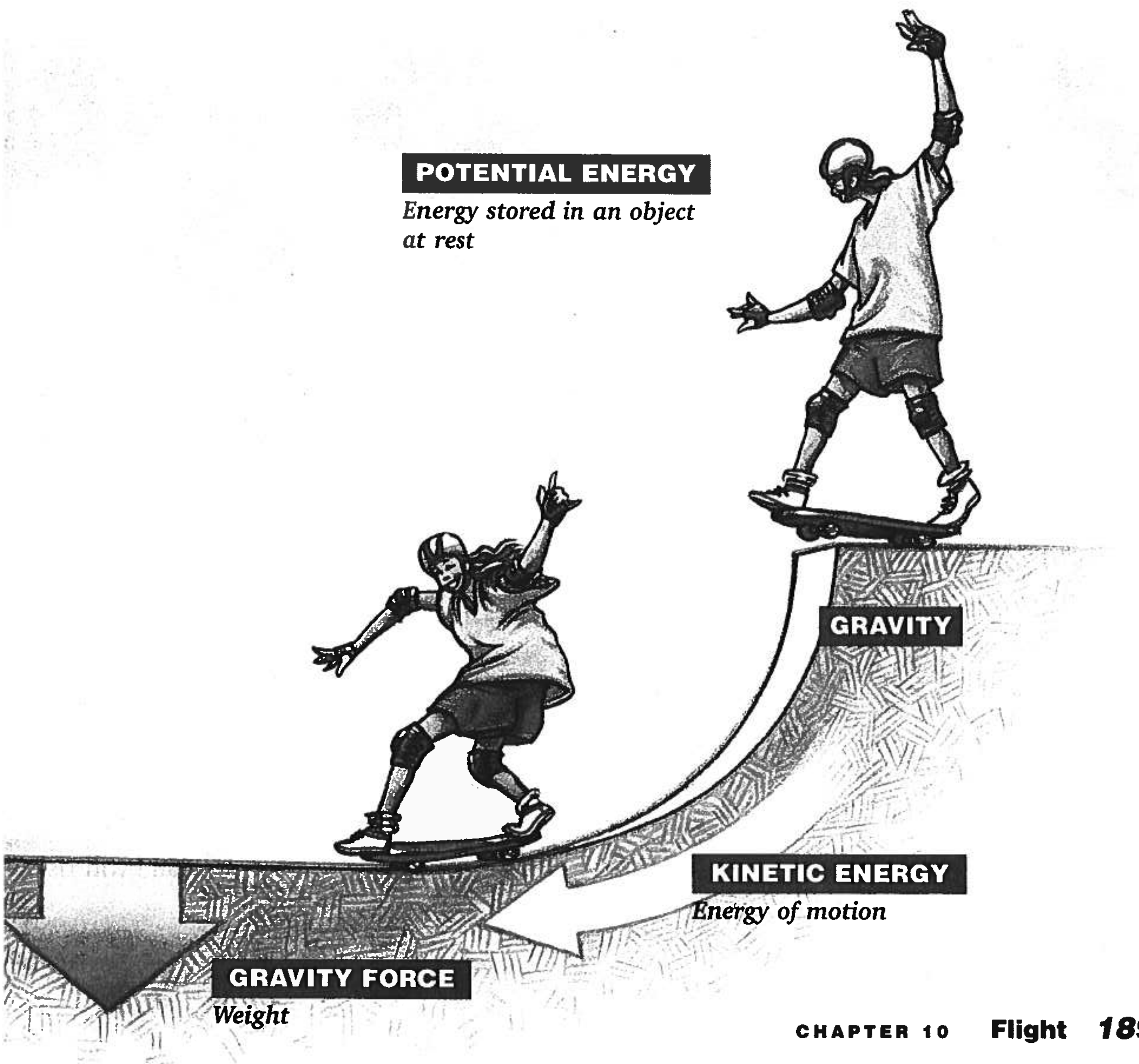
> The United States government discovered stealth technology by accident in the 1950s. They made a spy plane from wood and plastic instead of metal. The wood and plastic absorbed radar waves instead of reflecting them. When they realized the advantages, stealth technology was born.



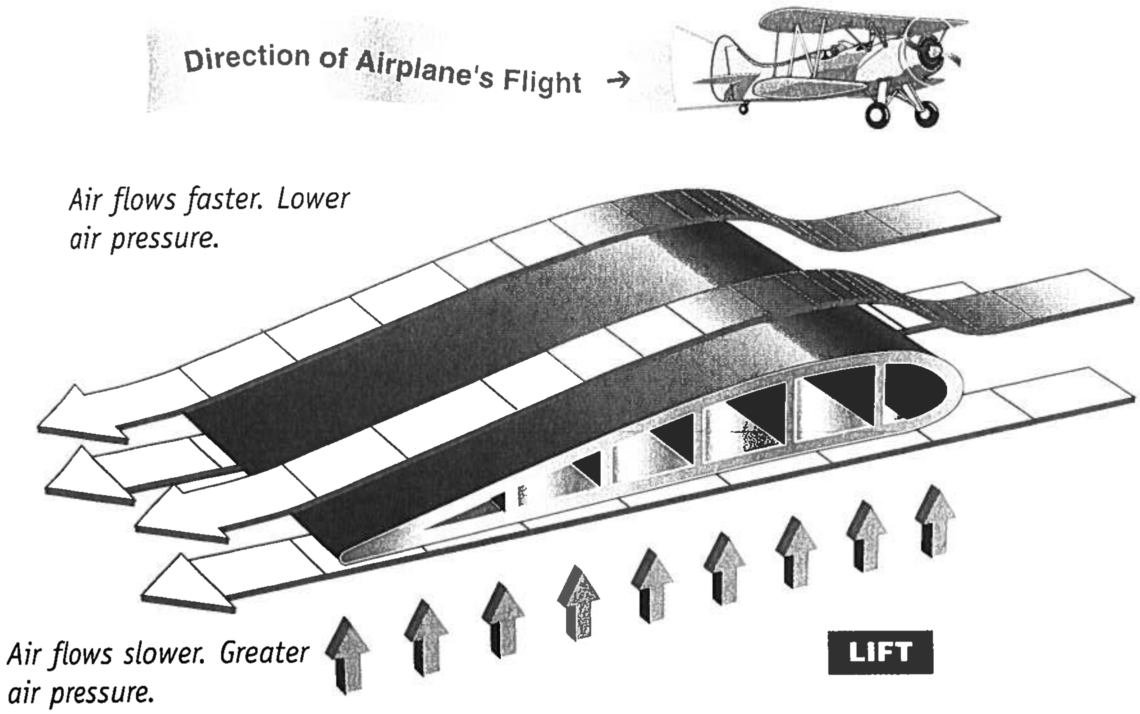


Fig. 10-5 A wing is an airfoil. As the wing moves through the air, the air divides to pass around the wing. Air passing above the wing moves faster than air passing below the wing. Fast-moving air has lower pressure. This difference in air pressure forces the wing upward. This force is called lift.

Linking to SCIENCE

Bernoulli Effect. The Bernoulli (burr-NEW-lee) effect states that a fast-moving fluid exerts less pressure than a slow-moving fluid. This effect helps airplanes to fly. Because of the airplane wing's shape, air moves faster over the top of the wing than under it. The difference in pressure helps create lift.

Try this activity to see the Bernoulli effect in action. Hold an 8 1/2" x 11" sheet of note paper by its two 8 1/2" ends. The 11" sides will curve downward. Blow across the top of the paper. Observe how the farther side of the paper rises. The fast-moving air above the paper created an area of lower pressure, lifting the sheet.

wedge. It is round in the front, thickest in the middle, and narrow at the rear. A shape such as this is designed to speed up the air passing over the top surface. Such a shape is known as an **airfoil**. The speed of moving air particles affects the amount of pressure that particles place on an object.

Pressure is a force. Airplane wings reduce the air pressure above the wing, allowing the stronger pressure below the wing to lift the aircraft. Fig. 10-5.

An airplane's engine provides the thrust that moves the airfoil through the air. When the force of lift is greater than the weight of the aircraft, the airplane will rise.

Explore

Design and Build an Airfoil

State the Problem

To design and test a model wing section that demonstrates lift when air is moved past it.

Develop Alternative Solutions

Gather diagrams and pictures of various airfoil designs. Take specific note of each shape.

Select the Best Solution

Using graph paper, draw a pattern for an airfoil design you think will provide a great deal of lift.

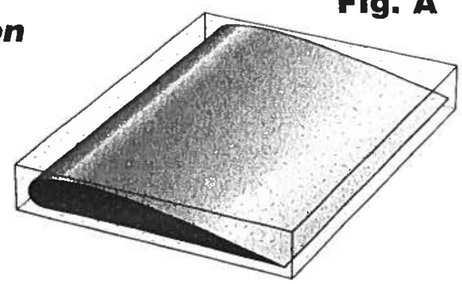


Fig. A

Implement the Solution

1. Trace this pattern onto a Styrofoam® block. Remove material from the block until it takes the shape of your design. See Fig. A.
2. Mount the airfoil model as shown in Fig. B., using wire. Use a block of wood for the base as shown.
3. Set a blow dryer at cool temperature and high speed. Use it to force air past the front edge of the airfoil as shown in Fig. C.

Collect Materials and Equipment
pen high-density Styrofoam® blocks, 3" wide, 3/4" thick, and 4" long coat hanger wire block of wood (for a base) graph paper wet/dry abrasive paper files end-cutting pliers blow dryer hand drill and twist drills

Fig. B

Evaluate the Solution

1. Did the airfoil lift? If not, what corrections do you have to make?
2. Experiment with a few additional designs. How does shape affect lift?
3. Sketch the most successful airfoil designs. Study your drawings to see what these designs had in common.

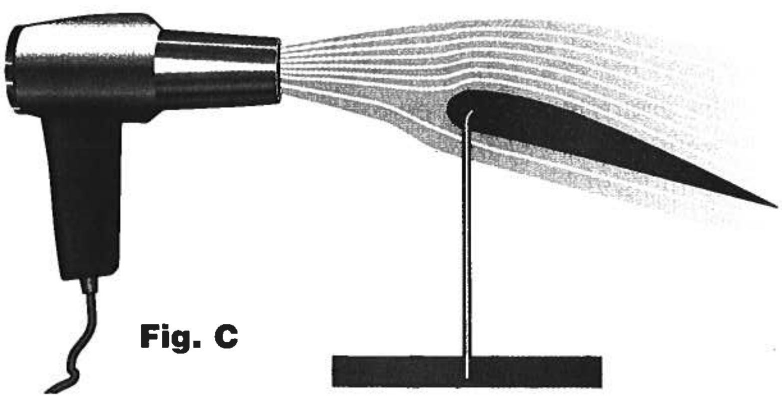


Fig. C

Propellers

Propellers are spinning airfoils. They create low pressure areas in front of the propeller so that high pressure areas behind the aircraft can push it through the sky. The propeller helps to move the wings through the air so they can create lift.

Controlling Airplanes

Pilots control the position of an airplane by adjusting flaps located on the wings and tail section of the aircraft. The flaps act like rudders on a boat. They deflect air and create drag. The increased drag causes the plane to turn.

Wing flaps called **ailerons** (AY-luh-rons) change the shape of the wing, increasing and decreasing the amount of lift the wing creates. Flaps at the front and rear edges of the wing create drag to slow the aircraft's speed during landing and aid in turns. Fig. 10-6.

The rudder, located on the tail section of the airplane, is used to turn the aircraft. Flaps on the tail, called elevators, are used to help the aircraft climb and dive in the air.

Explore

Design and Build a Rocket

State the Problem

To produce a model rocket that will reach the highest possible altitude. The rocket will be powered by the gases produced when water and Alka Seltzer® tablets are combined.

Develop Alternative Solutions

Gather pictures of various rocket and fin designs. Note difference between shapes.

Select the Best Solution

Develop a design for a rocket that you think will be able to attain the greatest altitude. Sketch the design on graph paper.

Implement the Solution

1. The plastic film canister will become the rocket engine. Produce a body tube by wrapping the notebook paper around the film canister.
2. Develop a nose cone.
3. Fasten the nose cone to the top of the body tube.
4. Develop a pattern for the fins. Cut the fins from the notebook paper.

Collect Materials and Equipment

- plastic 35-mm film canister. (The canister must have an *internal sealing* lid. These are usually translucent canisters. A canister with an external lid — a lid that *wraps around the canister rim* — will not work.)
- cellophane tape
- sheet of notebook paper
- two Alka Seltzer® tablets
- water
- graph paper
- pencil
- ruler
- scissors
- bucket

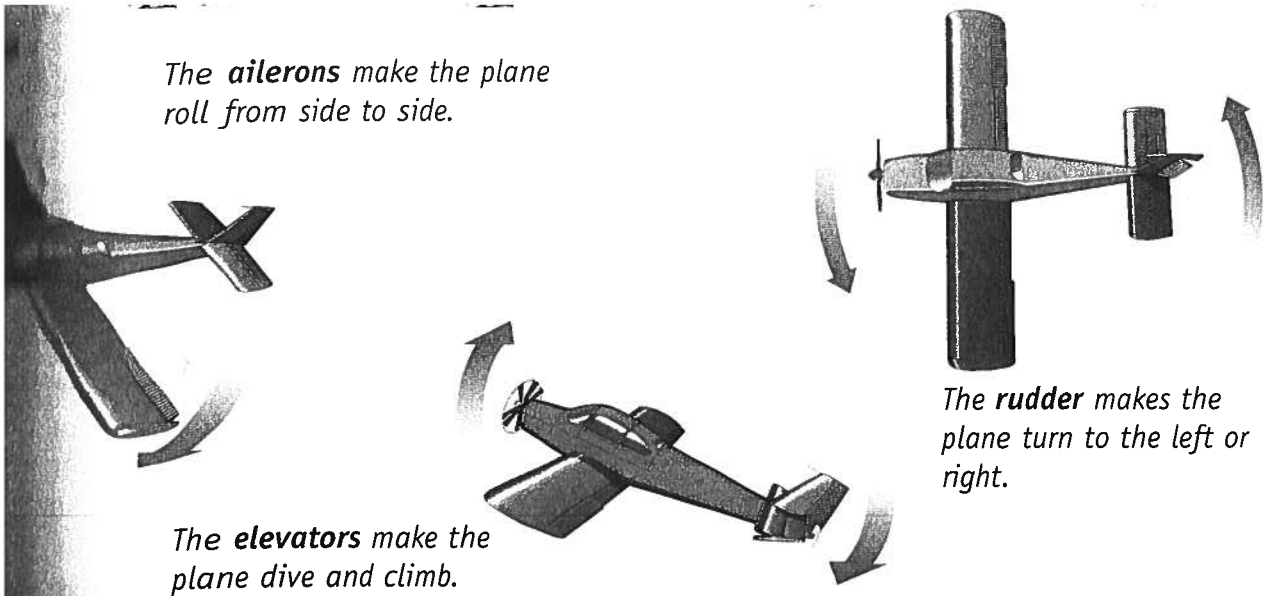
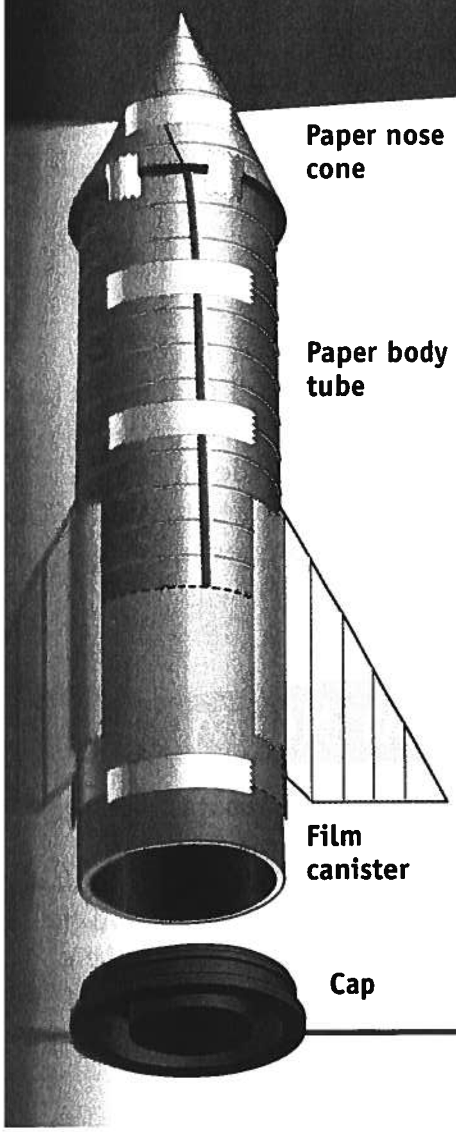


Fig. 10-6 Notice how the parts of an airplane create forces that affect flight.



5. Fasten the fins to the rocket.
6. Turn the rocket over. Place about 1/4" of water in the canister. Drop one-quarter of a tablet of Alka Seltzer® into the canister. Quickly cap the canister. Place the rocket in the bucket for launching. Be sure to stand back. Keep classmates away. **NOTE:** All students should be wearing safety glasses.
7. Make note of the height achieved by the rocket.
8. Experiment with the body tube length, mass, and fin size. Test again for the greatest altitude.
9. Conduct four more test flights with your design. Refine the design if needed. Test again. Record the heights reached by each flight.

Evaluate the Solution

1. What effect did the mass of the body tube, fins and nose cone have on the height reached by the rocket?
2. What effect did fin size, shape, and area have on the trajectory of the rocket?
3. Which of Newton's three laws explains why the rocket lifts off?

Linking to COMMUNICATION

Baggage Tags. Baggage tags from Chicago's O'Hare International Airport read ORD. If the airport is named O'Hare, why doesn't the baggage tag read OHA? The reason is that the enormous O'Hare airport was once a very small airfield called Orchard Field. O'Hare is not alone in having a baggage tag abbreviation that does not match its present name.

Using a map, locate the five airports closest to you. Then find out what initials each airport uses on its baggage tags. If the initials do not match the airport's name, find out what the initials do stand for. Your research may require you to communicate face to face, by telephone, by fax, by letter or postcard, or by e-mail.

Present the results of your research to the class. In your written or oral presentation, mention the ways you obtained the information. Comment on the effectiveness of each method.

▲

HELICOPTERS

How is a helicopter different from an airplane? Helicopters can move in any direction. They can even hover, or float, in midair. The rotors, or blades, of the helicopter control its motion. Rotors are shaped like propellers. They are also airfoils, which provide the lift and thrust the aircraft needs.

Controlling Helicopters

Helicopters can have two to eight rotor blades. The flight of the helicopter is controlled by changing the angle, or *pitch*, of the blade. The front edge of the rotor blade can be raised or lowered to vary the amount of lift the blade creates.

As the pitch increases, lift increases and the helicopter moves vertically. When a helicopter hovers, the rotors are pitched so that they produce only enough lift to match the weight of the aircraft. Fig. 10-7.

A helicopter moves forward when the rotor blades are moved forward. The combined pitch and forward position splits the force of lift into a raising force and a thrusting force.

A helicopter that has experienced engine failure can sometimes descend safely. Such a helicopter can *autorotate* to a rough landing. How does autorotation help break the fall of a helicopter?

JET PLANES

Jet planes streak across the sky every day. Have you ever noticed that they have no propeller? How is thrust provided? How do their wings provide lift?

Jet planes use a different process to generate thrust. Jet planes use reaction

FASCINATING FACTS

A sheep, a duck, and a rooster were the first living creatures to travel by air. They were sent up in a hot air balloon in the 1700s to see if the ascent would harm them. They were fine on landing.

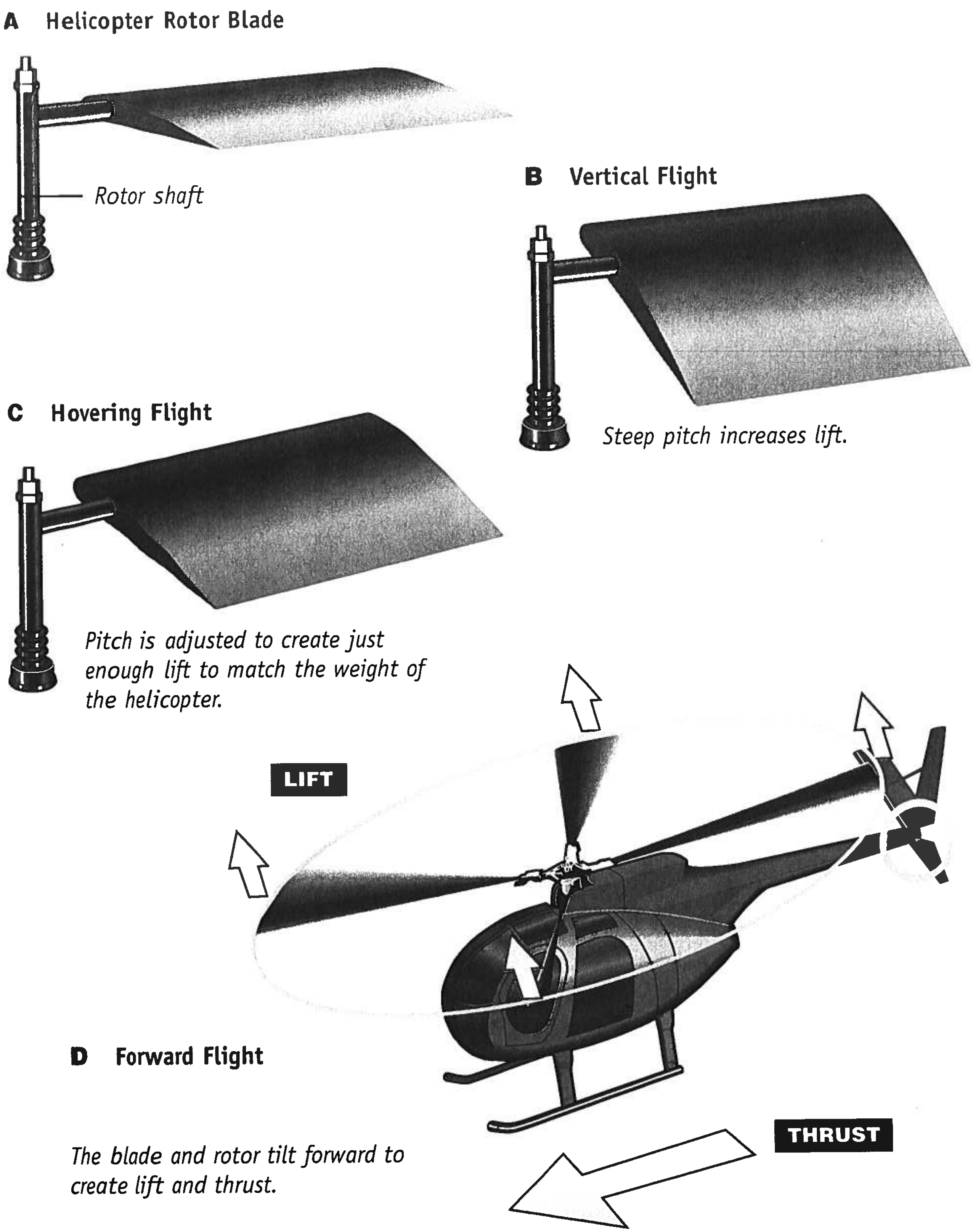


Fig. 10-7 How the position of a helicopter rotor blade affects helicopter flight.

engines to provide the force needed to move the wings through the air. Reaction engines work on the principle of action / reaction, which is Newton's third law of motion.

Newton's third law states that for every action there is an equal and opposite reaction. This means that forces come in pairs. Every force must have an equal and opposite force.

Imagine this. You're sitting on a swing. Your feet dangle below you, not touching the ground. You are absolutely motionless. You hold a red brick in each hand. All at once you thrust the bricks forward with all your strength. Which way does the swing move? The swing moves backwards. The force of the bricks moving forward is the action. The opposite, or reaction, force propels the swing backwards.

Have you ever seen firefighters handling a fire hose at a fire scene? If you have seen this, you have probably noticed that several firefighters may be holding the hose itself. Another firefighter may be holding the nozzle of the hose to aim the stream of water on the fire.

The hose is under pressure from the water rushing into it. To compensate for this pressure, the firefighters must keep a very tight grip on the hose. As shown in

Fig. 10-8 **Forces come in pairs. Every force must have an equal and opposite force. Notice the reaction of these firefighters to the thrust of the water within the hose.**

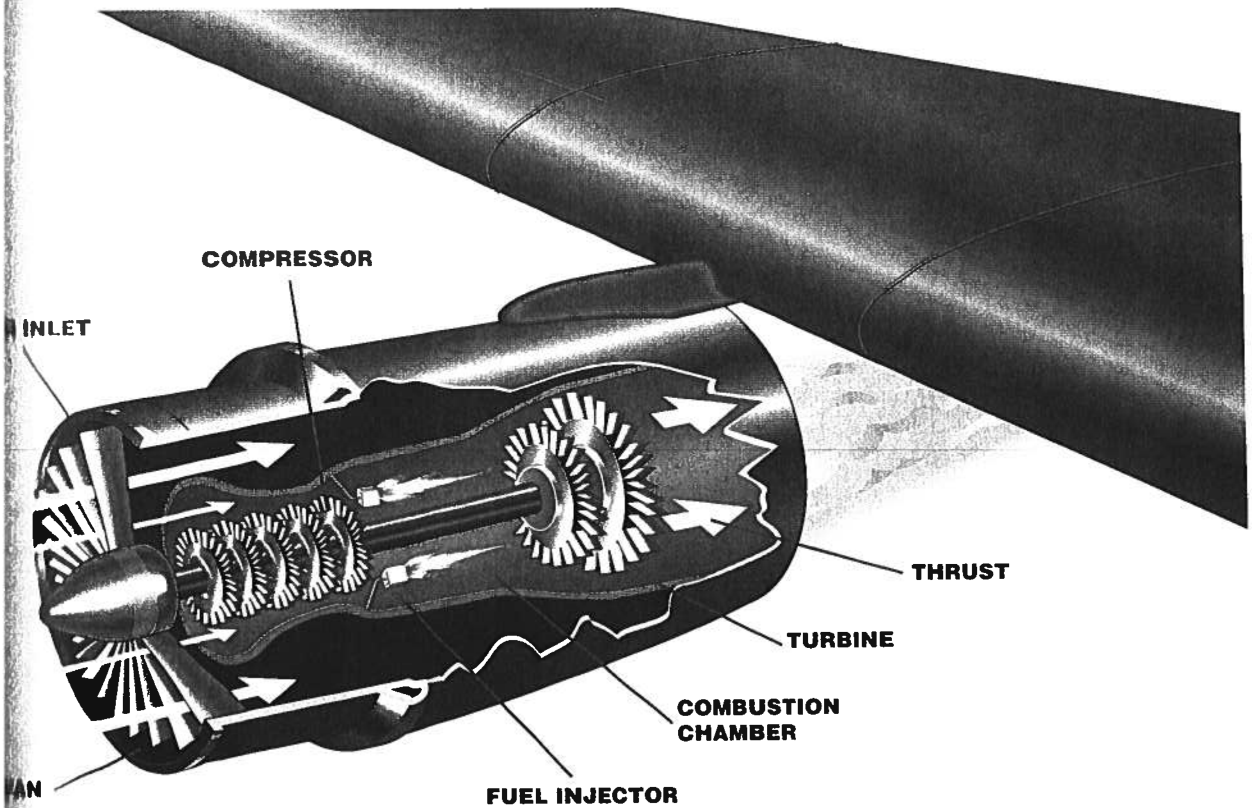


Fig. 10-9 The jet engine shows the forces of action and reaction. When air enters the front of a jet engine, it is compressed and squeezed in the combustion chamber of the engine. The jet moves forward in reaction to the gases rushing out the back of its engine.

Fig. 10-8, the firefighters are struggling to keep the stream of water on target.

Jet engines suck air into the front of the engine. Then they compress it, heat it, and eject it from the back at a very high speed. The air streaming out the back is the action force. The aircraft moving forward is the reaction force. The reaction force moves the wings through the air, creating lift. Fig. 10-9.

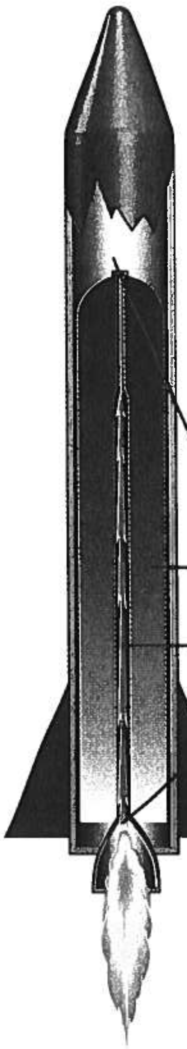
Aircraft powered by jet engines are more powerful and efficient than propeller-driven aircraft.

Fascinating Facts

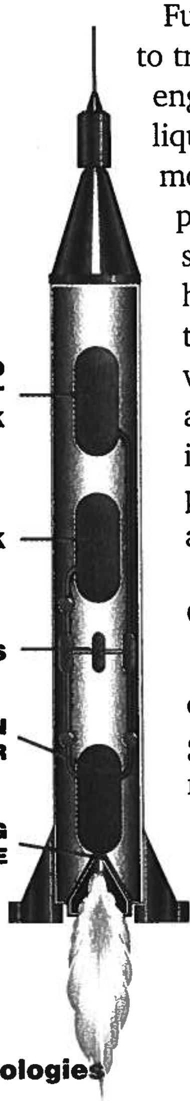
North American Aviation built the X-15 to be the fastest plane in history. In 1962, it entered space. On October 3, 1967, the X-15 reached 4,534 mph, flying faster than any other plane. The temperature on the plane surface was 3,000 degrees Fahrenheit, blistering the outside of the plane. Luckily, all the fuel had been exhausted, preventing a major explosion.

A CLOSER LOOK

Rockets



SOLID FUEL BOOSTERS (rocket engines) contain a solid propellant. A circular or star-shaped channel runs down the center of the fuel, forming the combustion chamber. The fuel burns along this channel. Solid fuel, once ignited, must burn completely.



LIQUID FUEL BOOSTERS (rocket engines) usually burn liquid hydrogen and liquid oxygen. These are fed from separate tanks into the combustion chamber. Liquid fuel engines can be turned on and off.

Rockets are the largest objects that fly. Like jets, rockets use the forces of action and reaction. Rockets move forward by pushing out powerful streams of hot gases. These gases are made by burning fuel.

Rockets are unique because they must work in outer space, where there is no oxygen. Rocket engines must carry oxygen with them.

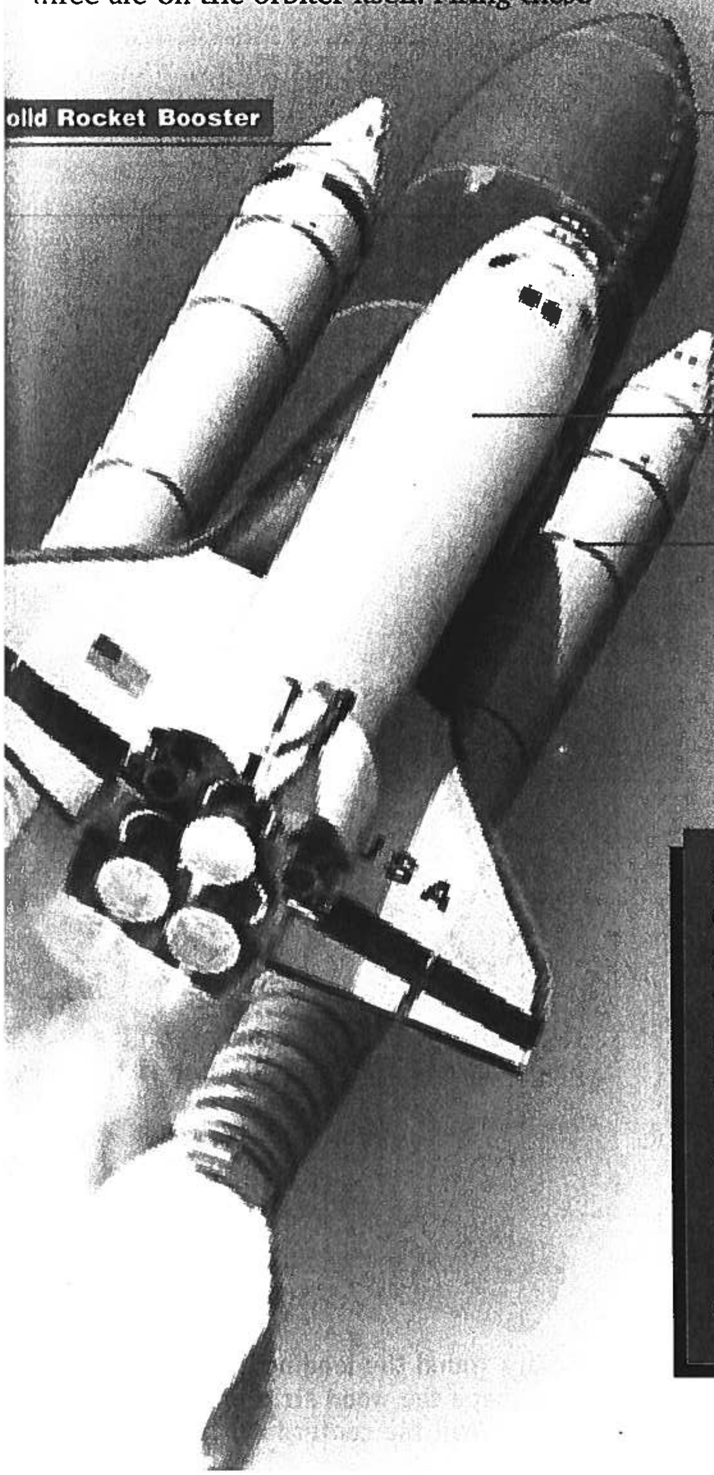
Future space missions will require rockets to travel longer distances. Nuclear rocket engines could replace liquid hydrogen/ liquid oxygen engines. Nuclear engines are more efficient and provide more thrust per pound of fuel. A nuclear reactor superheats liquid hydrogen. The hydrogen does not burn, but passes through the nozzle of the rocket at high velocity, creating thrust. Nuclear engines are not designed for launching rockets into space. They are designed as power plants for shuttle transports to the moon and beyond.

CONTROLLING ROCKETS

The nozzle at the base of the engine can swivel. It can direct the burst of hot gases in different directions. The rocket reacts by changing direction. The swivel of the nozzle is used to steer the rocket. The space shuttle orbiter is steered by small rocket engines.

SPACE SHUTTLE ORBITER

How does the space shuttle orbiter differ from an airplane? First, the shuttle has six powerful rocket engines. Three of these engines are detachable. The remaining three are on the orbiter itself. Firing these engines allows the shuttle to break out of its orbit and return to earth. To assist in reentry, the orbiter also uses two orbital maneuvering system engines.



External Tank

Provides fuel for orbiter's main engines. Separated from orbiter just before orbiter enters orbit. Reenters atmosphere and burns up.

Orbiter

Solid Rocket Booster

Provides thrust in liftoff. Separated from orbiter at height of 28 miles (45 km). Parachuted into ocean. Recovered by U.S. Navy ship. Reused.

SPECIFICATIONS

Operational life: 100 flights

Length: 123 ft (37 m)

Wingspan: 78 ft (24 m)

Frame material: mainly aluminum

Exterior covering: heat-reflecting tiles on underside

Crew: Flight crew of 3, plus 4 mission specialists

Weight: 114 tons (103 metric t)

Number of main engines: 3

Total thrust: 470,000 lbs (211,500 kg)

Apply What You've Learned

Design and Build a Propeller

State the Problem

Research, design, build, and test a model air propeller.

Develop Alternative Solutions

Gather diagrams and pictures of various air propeller designs. Take specific note of each shape.

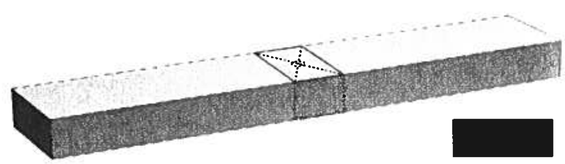
Select the Best Solution

Evaluate the various shapes. Select the shape that you think will be most effective.

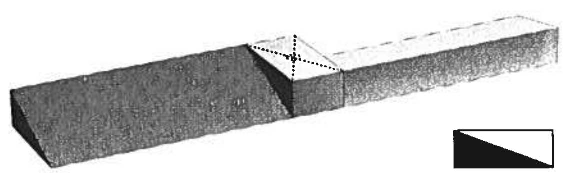
Collect Materials and Equipment
wood strip 1" wide, 1/4" thick, and 4" long
abrasive paper
wood support for motor
wood base for motor support
DC toy motor
files and other shaping tools
deflection gauge
safety motor mount
DC battery

Implement the Solution

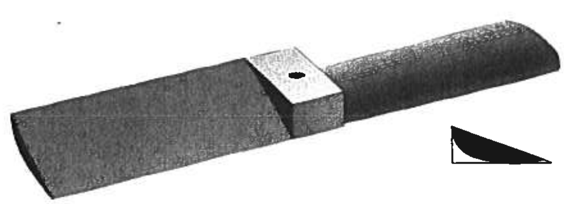
1. Shape the propeller. Fig A.
2. Construct the deflection gauge. Fig. B.
3. Mount the propeller to the motor stand. Connect the motor to the battery. Fig. C. Place the deflection gauge in front of the motor.
4. Test the effectiveness of the propeller. Measure the amount of air moved by the propeller. Do this by determining the angle the paper swings from vertical when the propeller is blowing air on it. Plot this amount on a graph. Label this entry "Prop 1."
5. Reverse the direction of the motor. How does this affect the output of the propeller?
6. Construct a different propeller. Do this by changing the shape and size of the airfoil. Test its effectiveness.
7. Measure the amount of air moved by the second propeller. Plot this amount on the graph. Label this entry "Prop 2."



First, lay out the strip of wood. Locate its center. Create a 3/4" center hub.



Then, cut or file away diagonals on the propeller, leaving the center hub flat.



Finally, round the leading edges. This will help shape the wood strip into an airfoil design. Drill the center hold for the motor shaft.

Fig. A **Shaping the propeller. The small drawings on the right show a cross section of the propeller. The shaded part shows the shaped propeller.**

8. Reverse the direction of the motor. How does this affect the output of the propeller?
9. Compare the output of the first propeller with the output of the second propeller.

Evaluate the Solution

1. How does changing the shape or size of the propeller affect its output?
2. Write a brief report (150-200 words) regarding this activity. Your report should contain no spelling errors. It should be written in complete sentences. In your report, be sure to mention the difference in the amount of air moved. Be sure also to mention what accounted for this difference. Discuss the effects of propeller design differences. Be sure to relate any differences in the amount of air moved to the Bernoulli effect.

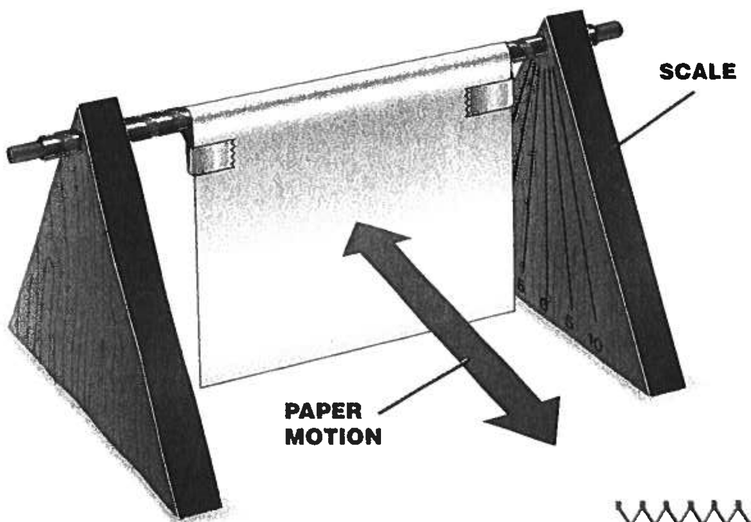


Fig. B Construct the deflection gauge by assembling a dowel rod, a drinking straw, and a sheet of 8 1/2" x 11" paper as shown. The greater the angle of the paper from vertical, the greater the force of the propeller.

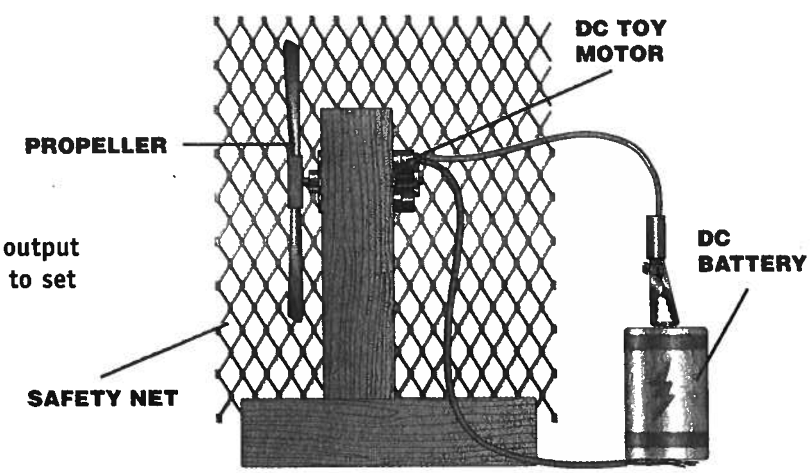


Fig. C Testing the output of the propeller. Be sure to set up the safety net.

CAREERS IN Aviation

RESERVATION ASSISTANT
Friendly, outgoing person to handle airline reservations in busy airport. Reservations experience preferred, but we will train appropriate candidate. Excellent benefits. Send resume to: Comet Aircraft Transport, Inc., 4560 Grainbelt Avenue, Oak Tree, MO 83932.

AIR FREIGHT COORDINATOR
Manufacturing company with growing international business requires someone to manage and track air shipments. Ideal candidate will have experience in air-freight operations. Must be able to work against tight deadlines. Must be able to work easily with others and quickly resolve problems. Send hand-written resume to Integral International Parts, P.O. Box 190, Little

CATERING COORDINATOR
Large regional airline requires person to manage in-flight meals. Responsibilities will include the purchase and inventory of in-flight meals and snacks. Must be willing to relocate to Chicago. Administrative experience in food service helpful. Send resume to InterAir, 2319 W. Smithville Road, Pontiac, IN 37321.

AIR TRAFFIC CONTROLLER
Prior experience at a medium-size airport a must. Ability to communicate clearly, pay attention to detail, and work calmly under pressure. Attractive wage and benefit package to right candidate. To schedule a confidential interview, call Todd Foster, (378) 672-9061.

AIRCRAFT MECHANIC
Graduation from a certified technical school required, plus 3 years on-the-job experience in repair of propeller-driven aircraft. Must be able to work under tight deadlines. Prior references essential. Send resume to: **Ace Aircraft, 2987 Rampart Drive, Topeka KS 45987. No phone calls, please.**

FLIGHT ATTENDANT
Major domestic airline has immediate openings for flight attendants. No experience needed. If you enjoy working with the public, like to travel, and are interested in an exciting career in aviation, this could be the job for you. Must be flexible and at ease with people. Must be willing to relocate. Selected candidates will receive free paid training at our company training institute. Call for an interview: (110) 345-9467. Ask for Anne Smith.

Linking to the WORKPLACE

You can explore a career in aviation through library research or a personal interview. Choose any of the careers highlighted above. Pretend that you have a career goal of obtaining employment in that job. Identify what you would have to do to obtain that job. Then draw up a list of the specific steps you would need to take. Share that list with the class in a brief report. Ask for class feedback on your plan.

Chapter 10 Review

SUMMARY

- Several forces affect an object in flight. These forces include friction and gravity, which oppose motion.
- Lift and thrust also affect an object in flight. They help the object overcome gravity.
- An airplane is able to fly because its wings are airfoils. Their shape reduces the air pressure above the wing. This allows stronger air pressure below the wing to lift the plane.
- An airplane is controlled by movable parts of the wing (ailerons) and tail (rudder).
- A helicopter is controlled by the angle or pitch of the blade. A helicopter rotor is also an airfoil.
- Rockets are powered by hot gases made by burning fuel. The fuel may be solid or liquid.

CHECK YOUR FACTS

1. Sarah's sneakers gripped the rough surface of her skateboard, keeping her from slipping off the board. What is the name of the force at work?
2. Describe two forces that oppose motion.
3. Name two forces that help an airplane overcome gravity.
4. Identify the parts of an aircraft that help control flight. Briefly describe how they work.
5. What force acting upon the wing flaps of an airplane causes the plane to turn or slow down?

CRITICAL THINKING

1. Would it be more difficult to stop a rolling bowling ball or a rolling tennis ball? Explain your answer.
2. Describe how thrust is used to create lift in an airplane.
3. Describe how an air propeller works. Does a water propeller work in the same way?
4. Make a sketch of an airfoil. Describe the forces that act on the airfoil as it moves through the air.
5. Early in this century, some inventors tried to fly by fastening birdlike wings to their arms. They then flapped their arms as hard as they could while running down a steep hill. Why didn't they fly?