HEAD HEART HANDS HEALTH

Construction & Flight of Model Rockets

UNIT 2 4-H MANUAL

COLORADO STATE UNIVERSITY
EXTENSION

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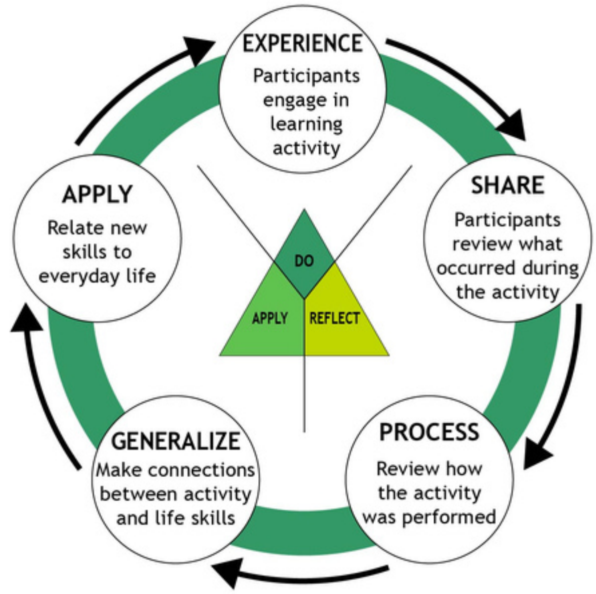
Experiential Learning Process



The 4-H program utilizes a process where adult leaders ask open-ended questions that challenge youth to think. Through this inquiry, youth can propose hypotheses and determine their own solutions. The Experiential Learning Model developed by Pfieffer and Jones (1985) and modified by 4-H includes five specific steps that can be summarized into three main processes: Do, Reflect, and Apply.

The Experiential Learning Model encourages discovery with minimal guidance from others. A situation, project or activity is undertaken for individual thought and problem solving. Minimum outside assistance is provided, but support is offered to the individual by questioning at each stage. The youth participating in an activity reflect on what they did and then assess how what they learned can be applied to a life situation. Below are questions that might help during each stage of learning.

1) Experience (Doing)
Questions: What sources of information are available? What is possible? What do you expect to see? How is it working? What else might you try?

2) Share (Reflecting on what occurred)
Questions: What was your goal for this project/activity when you began? What happened? What were the results? What was most difficult? How do you know? What did you learn? What surprised you? How did you share this project/activity with others?

3) Process (Reflecting on what's important)
Questions: What problems seemed to reoccur? How did you solve them? What similar experiences have you had? How was the experience like or unlike experiences others had? Would you do anything differently? What did you learn about making decisions? What suggestions would you have for someone else who wanted to do a similar project/activity? What life skills were you developing through your project? Why are life skills important? What new questions do you have about yourself, others, and future goals?

4) Generalize (So what?)
Questions: What did you learn about yourself or about the activity? What key points have you learned? How did you decide what to do? What else could you have done? How does this relate to something else in life? Where have you faced similar challenges in your life? Where might this situation occur in the future? Why is it important to have plenty of information before making decisions? What did you learn about your own skill in communicating with others?

5) Apply (Now what?)
Questions: How does this project/activity relate to your everyday life? Why is this project/activity important to you? Where else can this skill be used? How will you use this in the future? What will you do differently after this experience? How can I make an impact? What will I create next? In what ways do people help each other learn new things? What are qualities you think are important in a leader? If someone helped or mentored you in this project, what would you tell them you learned and what difference it has made in your life? How would you express your appreciation?

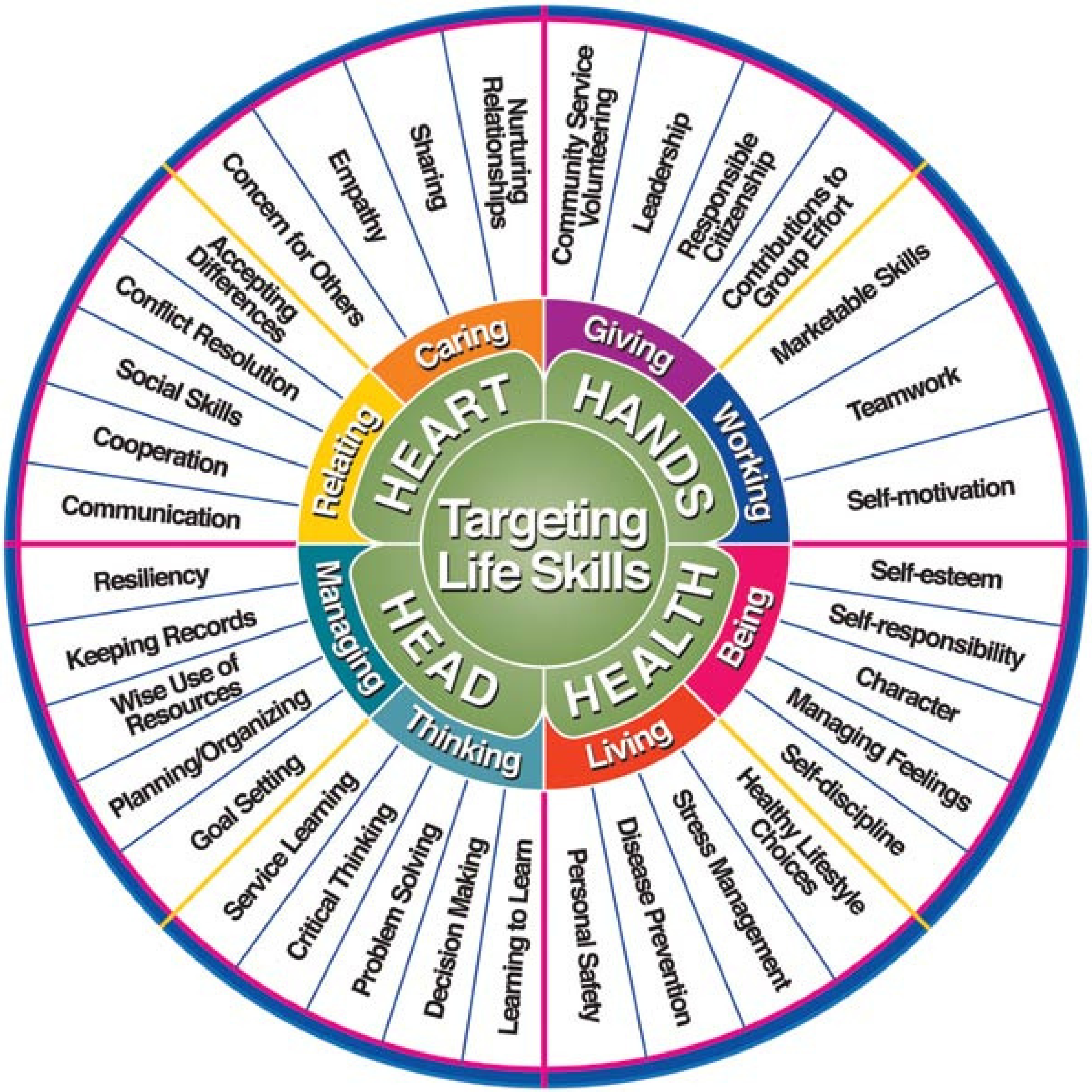


Image: Hendricks, P. (1998) "Developing Youth Curriculum Using the Targeting Life Skills Model" http://www.extension.iastate.edu/4H/skls.eval.htm

Targeting Life Skills

A skill is a learned ability. Life skills are those abilities that assist individuals to lead successful, productive, and satisfying lives. In 4-H, we use the Targeting Life Skills Model to help youth become competent and prepared for adulthood. The Targeting Life Skills Model categories are based on the four H's from the 4-H clover (Head, Heart, Hands, and Health). Under each of these main categories, there are four categories and eight subcategories listing specific skills youth learn in 4-H. The main goal in 4-H positive youth development is to provide developmentally appropriate opportunities for youth to experience life skills and to be able to use them throughout a lifetime. By understanding the importance of the 4-H framework and its structure, 4-H members, parents, professionals, and leaders will know the expectations and will be able to effectively use 4-H delivery methods to help youth learn these life skills.

4-H Thriving Model

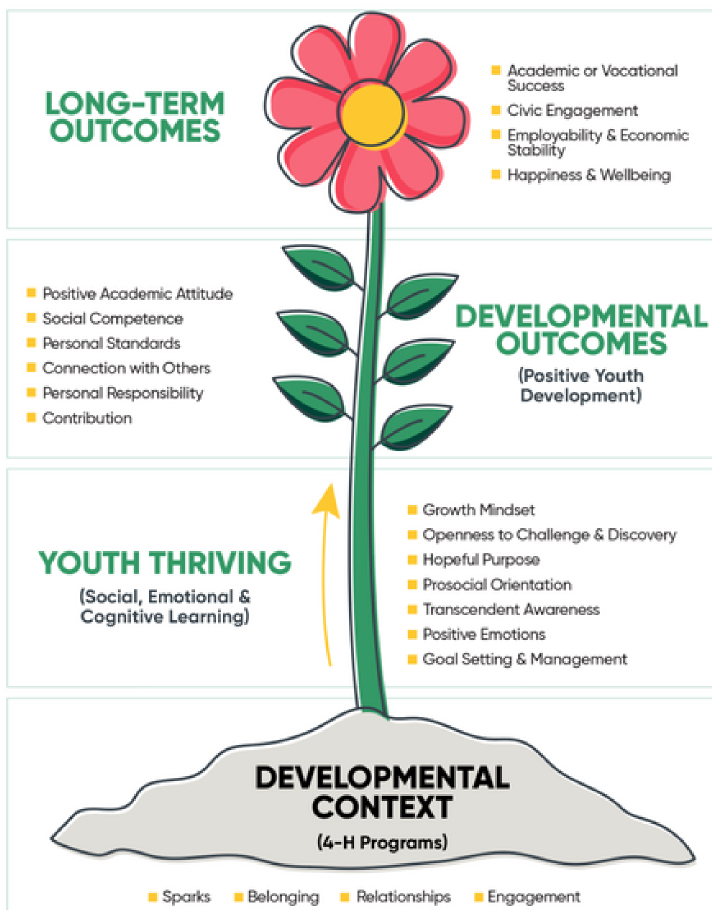
The 4-H Program Leaders' Working Group developed the 4-H Thriving Model to advance and support the accomplishment of the 4-H Youth Development 2025 National Strategic Plan. They describe the 4-H Thriving Model as follows:

The 4-H Thriving Model illustrates the process of positive youth development in 4-H programs by connecting high quality program settings to the promotion of youth thriving.

High quality 4-H program settings provide youth a place to belong, matter and explore their personal spark. High quality settings foster developmental relationships with youth, relationships that express care, challenge growth, and share power. These components help ensure that 4-H programs provide a nourishing developmental context – a place where youth can belong and grow.

High quality 4-H programs contribute to Positive Youth Development (PYD) through the intentional promotion of social, emotional, cognitive, and behavioral habits of mind. In the 4-H Thriving Model, this process of PYD is described by seven indicators of thriving: Openness to challenge and discover, growth mindset, hopeful purpose, pro-social orientation, transcendent awareness, positive emotionality, and self-regulation through goal setting and management.

Youth who experience high quality developmental settings in 4-H with an emphasis on these key social-emotional skills achieve key positive youth development outcomes, including academic motivation and success, social competence, high personal standards, connection with others, personal responsibility, and contribution to others through leadership and civic engagement.



Youth who achieve positive developmental outcomes are more likely to also achieve long-term outcomes marked by vocational or academic success, civic engagement, employability and economic stability and happiness and well-being. Learn more at https://helping-youth-thrive.extension.org/.

Additional information and activities are in the accompanying Model Rocketry Leader Guide.

Introduction

Unit 2 of Model Rocketry picks up after Introduction to Model Rocketry Unit 1 and discusses more of the techniques and science of Model Rocketry. It is always a good idea to review the Unit 1 manual if you don't recall a term or remember a principle. This manual assumes you have read and understand the principles in the Introduction to Model Rocketry Unit 1 manual.

Chapter 1: The Science of Model Rocketry

What makes a rocket launch into the air? How can you predict the flight of a rocket? The science of physics, developed after centuries of observations, predictions, and experiments, helps explain rocket science and was instrumental to its development. To understand the science of rocketry, it is important to first understand the concept of a force.

What is a Force?

Force is an action that tends to maintain or alter the movement of an object. Forces you might be familiar with are push and pull forces that are used to put an object into motion. Both the forces can be differentiated by the direction of motion of the object. These forces are easily observed and felt, but some are more difficult to observe. A pull force tends to move an object towards the person applying the force, while a push force moves the object away from the person. For example, most doors make use of push and pull forces for their operation. When you apply pull force, the door moves towards you. On the other hand, when you apply push force, the door moves away from you. When forces are balanced, they cancel each other out. If someone on one side of the door is pushing the door with the same amount of force as another person on the other side of the door, the door will not move. If the force becomes unbalanced, then the door will move.

Rocketry is all about the relationship between different kinds of forces. You will learn about gravity, thrust, lift, drag, and more in this and following units. All these concepts share the basic understanding of force and follow the Three Laws of Motion.

Abbreviations

In this book, similar to other scientific texts, you will find abbreviations are often used. Abbreviations (abv.) may appear inside of parentheses after the unit or word, similar to how you might weigh yourself in pounds (lbs.) or measure your height in inches (in.), or they may follow a measurement without parentheses.

THREE LAWS OF MOTION

Sir Isaac Newton explains the concept of force with the Three Laws of Motion. Newton's laws of motion are so important that when force is measured we call the units newtons (N). We discuss model rocket motors in how much force they produce in newtons or how much force over time in newton seconds (N · s or N s). The Three Laws of Motion explain how everything moves on earth and in space and are crucial to understanding how a rocket performs.

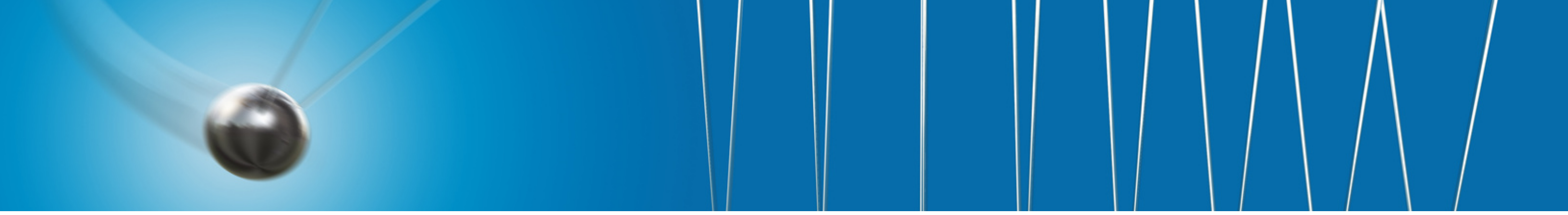
Galileo Galilei, Italian Astronomer, Physicist and Engineer

Image: SCALA/Art Resource, New York

The Law of Inertia

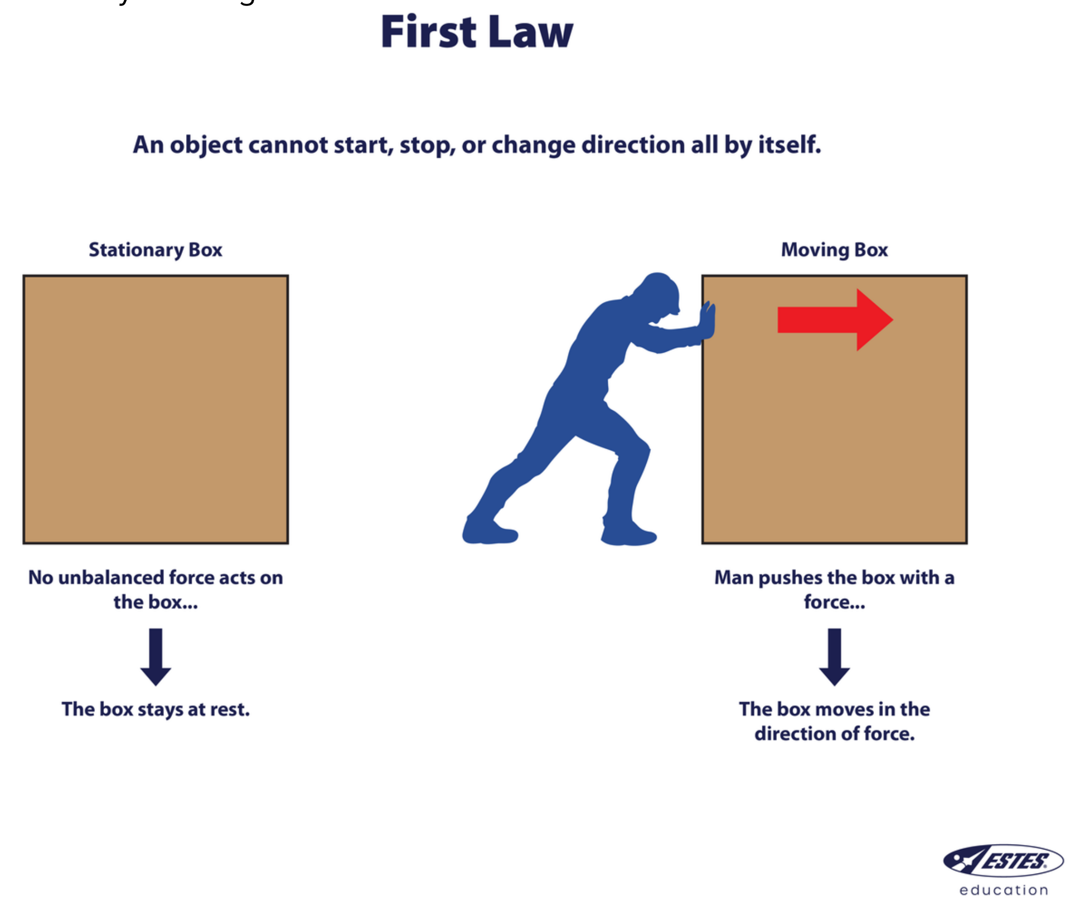
Before discussing Sir Isaac Newton's three laws of motion, let's discuss Galileo Galilei. You might recognize the name as an early astronomer and inventor of the telescope, but he also discovered other important scientific principles. Galileo first described inertia after noticing that objects that are still tend to stay still and objects, like a rolling ball, tend to continue to roll until something stops them. Galileo performed experiments by rolling balls down ramps, across flat surfaces, and threw them around a room. He discovered that falling objects fall increasingly faster because gravity is pulling them to the ground.

However, he noticed that objects rolling along a flat surface kept the same speed. Galileo called this concept inertia. Inertia is defined as the tendency to do nothing or remain unchanged and was the principle Newton explained in Newton's laws of motion. Inertia describes why a spacecraft keeps moving forever in space at the same speed unless it uses its engine to speed up or slow down or until it bumps into something.



First Law of Motion: The Law of Inertia

Newton's first law builds on Galileo's discovery of inertia and states that an object at rest remains at rest, and an object in motion remains in motion at constant speed and in a straight line unless acted on by an unbalanced force. This explains why things move or don't move. The nature of all objects can be described by saying that objects tend to "keep on doing what they're doing."



The idea of a balanced and unbalanced force can be demonstrated with a box like in the image above sitting on your table or desk. If you set this box on a table and observe it, you will notice it does not move. That is because the forces acting on the box are balanced - or equal. If you were to give the box a shove, it will likely slide across the table and you shoving the box would be an unbalanced force. You could also lift part of the table up and the box will slide down without you having to touch it. That is because the force of gravity pulling down is greater than the force of the table pushing up making that force unbalanced.

In both cases the box will stop on its own. Why? The first law of motion says, "an object in motion remains in motion," so why does the box not continue off the table forever when you shove it?

Friction - A Type of Force

An object in motion will continue moving in a straight line at a constant speed until an unbalanced force acts on it. For example, if you kick a soccer ball, it will keep rolling. However, you know that the soccer ball will eventually stop rolling, and Newton's first law explains why. The force from the friction of the grass and the air acts on the soccer ball, slowing it down until the soccer ball eventually stops. In rocketry, Newton's first law says that a rocket will move in a straight line at the same speed until other forces change the flight path of the rocket. In space, there is almost no friction, so a rocket will continue forever until gravity of a nearby object changes its flight path.

When you watch the movement of a puck on an air hockey table, you are observing a system with almost no friction, similar to outer space. The puck keeps moving in a straight line until it bumps into the side of the table, hits the goal, or until a player hits the puck. What causes friction? Tiny grooves and ridges on the surface of objects cause friction. Many times, you cannot even see these grooves and bumps. However, the grooves and ridges snag on each other, slowing down the object. The larger the grooves and ridges, the easier it is to snag and slow down the object. This is why the box in the diagram on the previous page slows down. The ridges and grooves of the box and table slow and stop the box.

Drag - A Type of Friction

Drag is a type of friction that occurs when objects move through water or air. Drag slows down runners, swimmers, and race cars. That is why many swimmers in the Olympics wear specially designed swimsuits to make the grooves and ridges in the swim suit fabric smaller, or in other words, to minimize the drag of a swimmer in the water. These specially designed swim suits can make a person swim a fraction of a second faster, enough to help that person win a race. Drag is also why race cars have a more streamlined shape than a van or a bus. Drag can increase or decrease depending on how fast an object is moving.

Drag also affects model rockets. If the surface of your model rocket is not smooth, your rocket will not accelerate as much and will not soar as high as predicted with a certain rocket engine. Therefore, it is recommended you sand and airfoil your rocket fins. When you participate in an advanced model rocketry project, you will have the opportunity to design your own rocket. In that project, you may want to design a streamlined rocket to minimize drag.

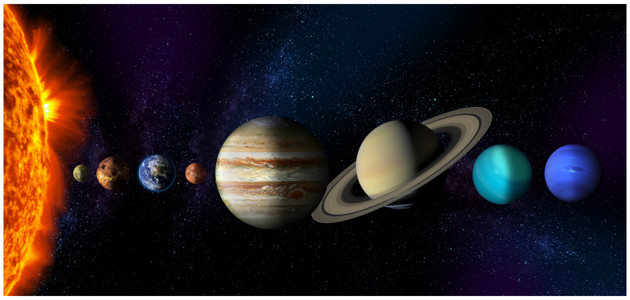
Gravity - A Type of Force

We experience gravity all the time in our everyday lives. If you have ever dropped something heavy on your toe or had something fragile fall to the floor and break, you know that gravity is always there; but have you ever wondered what it is? Gravity is a phenomenon where an object with mass is attracted to another object with more mass. Everything that has mass also has gravity. Objects with more mass have more gravity. Gravity also gets weaker with distance. So, the closer objects are to each other, the stronger their gravitational pull is. The Earth is very large and has a lot of mass which causes objects, like us, to be pulled down toward it.

Airfoil

An airfoil is a streamlined body, like the cross-sectional shape of an airplane wing, that generates more lift than drag when in motion relative to the surrounding air. Airfoils are highly-efficient lifting shapes like in wings and propeller blades. Each wing of a boomerang is an airfoil section. Model rockets use airfoil through the shape of the nose cone and fins. Rounding leading and trailing fin edges provides a faster lift (motion) to the rocket.

Different planets in our solar system are different sizes and have different amounts of mass. This means the force of gravity is different. If you weigh 100 pounds (lbs.) on Earth and travel to the Moon, which is a lot smaller than Earth, and weigh yourself on the scale, you would weigh only 17 lbs. From there if you traveled to a smaller planet, like Mars, your scale would read 38 lbs. You have the same amount of mass, but because the planet has less mass there is less gravity forcing down on you. After you leave Mars and travel to Jupiter, a really big planet, you would be 253 lbs. That’s a lot of gravity!



Second Law of Motion: The Law of Acceleration

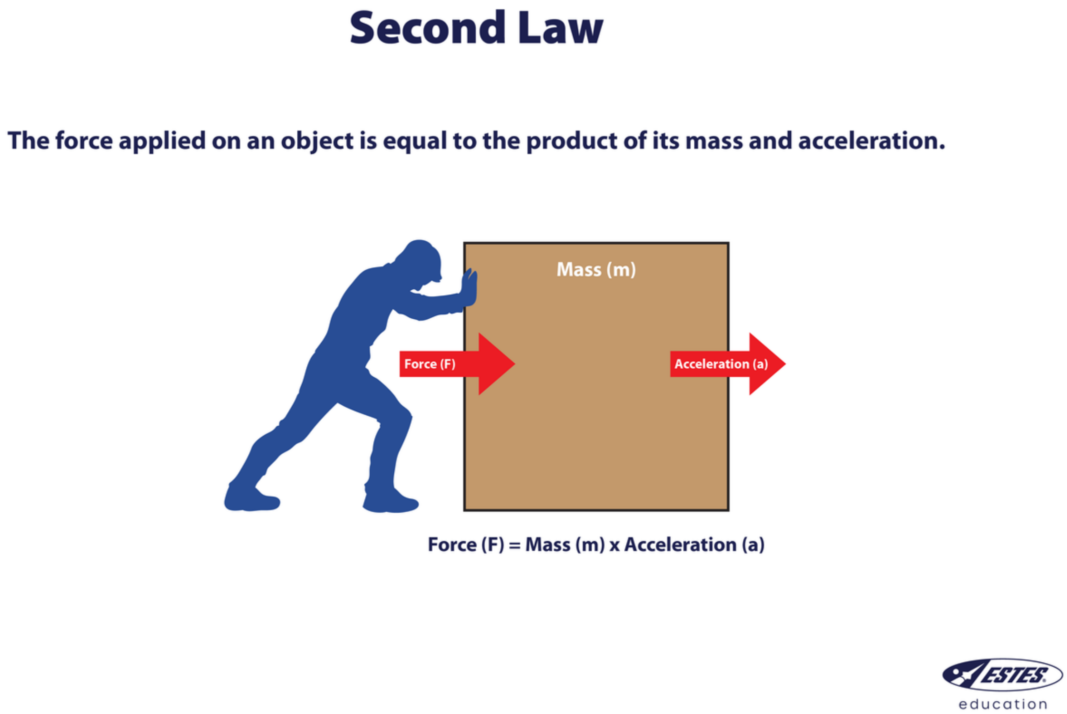
Newton's second law describes what happens when a force acts on something. If the force acts on an object that is not moving (at rest) and the force is big enough, then the object will start moving (accelerating) in the direction of the force. If the object is moving, then the force can make the object move faster (accelerate), slow it down (decelerate), or change its direction.

Newton expressed these ideas in a simple mathematical equation:

F = ma

meaning Force (f) = mass (m) multiplied by (x) acceleration (a).

According to his equation, if the object keeps the same mass, the bigger the force that is applied, the larger the acceleration will be. Therefore, the more powerful the rocket engine that you use to launch your rocket, the greater the acceleration of your model rocket will be.



However, Newton's equation also says that if the force stays the same, an object that has less mass will accelerate or decelerate faster than an object with more mass. What does this mean? For example, if you are racing on a bicycle, it is easier to go faster on a lighter weight bicycle than on a heavier one. Similarly, this law explains why it takes longer for a freight train to come to a stop than a car or a person on a bicycle; a freight train loaded down with coal is a much heavier object with much more mass.

Mass and Weight

You have probably noticed that we have used the words mass and weight. Many people use the terms weight and mass interchangeably, but they are actually different. Mass is how much matter is in an object. The mass of an object will be the same no matter where it is measured. You can think of weight as an object's mass multiplied by the force of gravity. If you recall in the previous discussion on gravity, if you weigh 100 pounds on Earth, your weight on the Moon, Mars, and Jupiter would be different, but your mass on all of them would be the same.

This is important because we can use mass to calculate how an object will move anywhere in the Universe. If you go back and look at Newton's equation, it uses mass instead of weight. The equation says that the force necessary to move an object is the same on the Earth, the Moon, Jupiter, or in outer space. However, the energy required to move the object will vary because the weight is dependent on the gravity of the planet, while the mass stays the same.

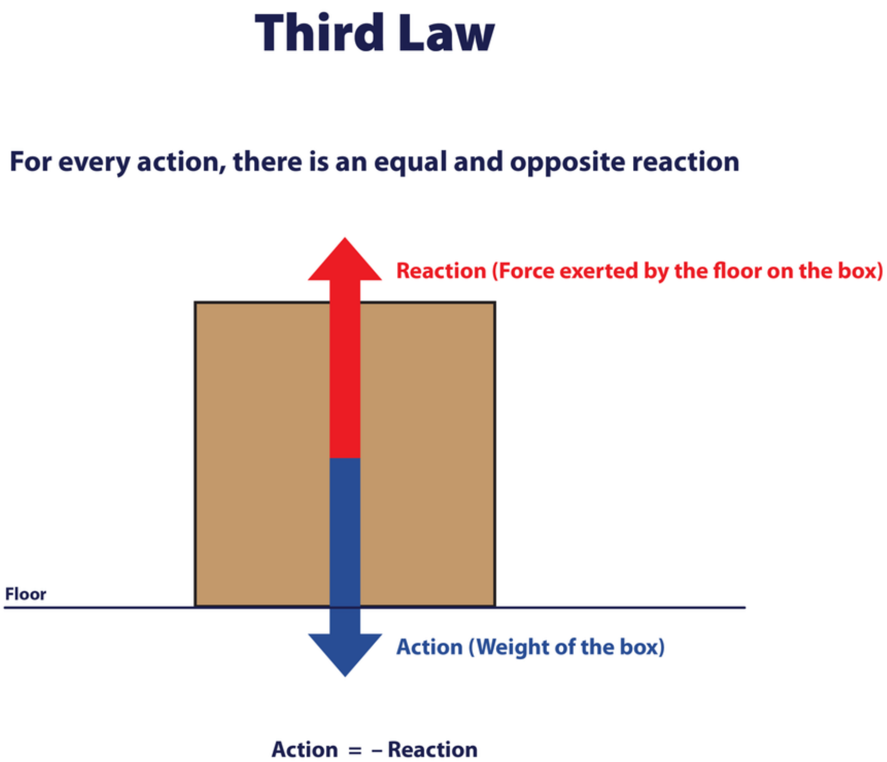
Acceleration and Speed

There is also a difference between acceleration and speed. Speed is how fast you are traveling. Acceleration describes any change in speed or direction, whether positive or negative. A decrease in speed is called deceleration. Let us say that you are running at the pace of nine miles per hour. (This is your speed.) After a while, you get tired and start to slow down. Then as you are reaching the finish line, you see that your competitor is just in front of you, so you speed up (accelerate) to catch them. By accelerating or increasing your speed, you cross the finish line before your opponent and win the race! Thus, speed is how fast you are traveling and acceleration, either positive or negative, describes any change in your speed.

Third Law of Motion: Law of Reaction

Newton's third law states that for every action, there is an equal and opposite reaction. This law explains why a rocket launches into space. When the rocket motor pushes gasses outward from the rocket toward the ground (the action in Newton's law), the gas pushes back on the rocket (the reaction in Newton's law), pushing the rocket upward, and liftoff occurs. This is called the thrust of the rocket motor.

ACTIVITY GUIDE: Complete the Rocket Balloons activity in the Activity Guide at the end of this unit. The activity includes more ways to explore and experiment with Newton's third law of motion.



ESTES education

Do you know who Sir Isaac Newton is? He was born in 1643 and discovered the three laws of motion.

When we discussed what a force was, we talked about how there are some forces you can observe and feel and some that you can not. We also discussed the concept of balanced and unbalanced forces. You can apply that knowledge and think of the third law of motion whenever you see or feel a force (action) and try to think of what the opposite (reaction) force is.

Take a car, for example, the car accelerates because the ground pushes forward on the drive wheels in reaction to the drive wheels pushing backward on the ground. What happens when the ground doesn't push forward? You are probably familiar with a car losing traction due to being on ice or loose gravel, but there is always an equal and opposite reaction and you can see the action and reaction of the wheels pushing backward when tires spin on gravel roads and throw rocks backward.

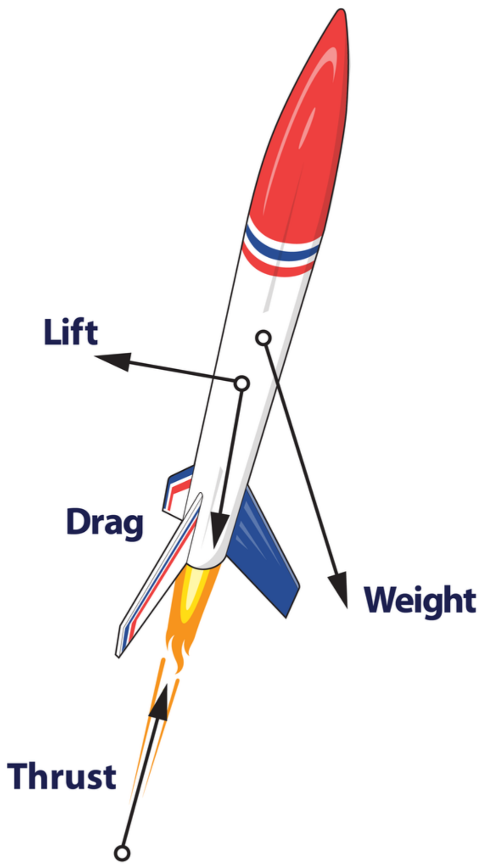
This also explains how airplanes and helicopters work. As an airplane's wings, or a helicopter's rotors move through the air, they force (action) air down and the reaction is the airplane and the helicopter going up (reaction). This type of mechanical force is called lift and can also apply to rockets. Lift in model rocketry is an aerodynamic force applied to the rocket that can stabilize and control the direction of flight. Lift will be covered more in future units.

Newton's Laws in Model Rocketry

Newton's laws can all be demonstrated in a model rocket launch. Gravity, thrust, lift, and drag are forces that are all involved from ignition to recovery.

When a model rocket is on a launch pad, the force of gravity is balanced with the force of the pad (Newton's first law of motion). When the rocket motor is ignited, it creates hot gasses that exit the nozzle of the engine. The resulting thrust is greater than the force of gravity, and propels the rocket into the sky (Newton's third law of motion), also resulting in the rocket lifting off the pad. As the hot gasses exit the nozzle, the rocket moves in the opposite direction upward through air and space.

As the thrust of the motor accelerates the rocket upwards, other forces are also in play. Gravity still works to pull the rocket back to earth. Drag slows down the rocket, especially if the design is not smooth or streamlined. If the rocket has too much drag, it will not accelerate as anticipated. The acceleration of a model rocket depends upon the mass of the rocket and the force of the rocket engine (Newton's second law). A model rocket with less mass will have a greater acceleration than a rocket with more mass using the same type of rocket engine. Therefore, the acceleration of a model rocket depends upon the mass of the rocket and the force of the rocket engine. If you are attempting to launch a model rocket with more mass, you will need to use a more powerful engine to overcome the force of gravity.



ESTES education

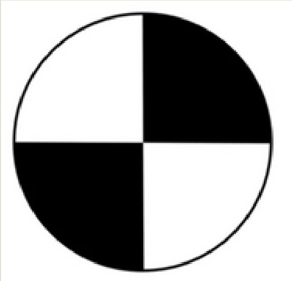
ACTIVITY GUIDE: Complete the Drawing Forces activities in the Activity Guide at the end of this manual.

Chapter 2: Rocket Stability—Understanding Stability

The ideal model rocket flight is in a straight line up into the sky. Stability in rocketry means a rocket has a straight and predictable flight path. If you've ever tried to walk across a balance beam, you know that your ability to be stable against other forces is the difference between walking across the beam and falling off. Optimal flight performance rockets are designed with safety in mind. A rocket that is unstable can fly out of control and become dangerous to people and property near the launch site; that is why it is important to understand what makes a rocket stable. There are two main terms important to rocket stability: Center of Gravity and Center of Pressure.

Center of Gravity (CG)

The center of gravity is the balance point of an object, also expressed as the point where all the mass appears to be located. The center of gravity is the point where the weight is even on all sides. If, for any reason, a force is applied to a stable flying rocket that causes it to rotate, the rotation will always be around its center of gravity. CG is represented by this symbol:



Center of Pressure (CP)

As a model rocket flies through the air, the aerodynamic force of lift acts on all parts of the rocket. Lift in rocketry keeps the rocket flight straight. In the same way that the weight of all the rocket components acts through the center of gravity, the lift aerodynamic force acts through a single point called the center of pressure. CP is represented by this symbol:

Rocket Stability

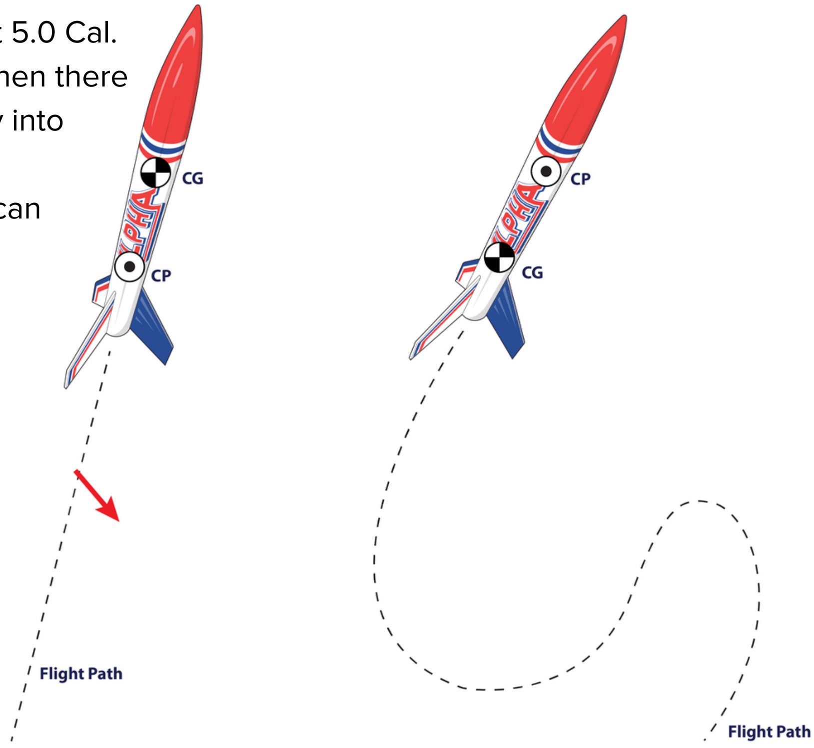
Once you know the location of your rocket's Center of Gravity and Center of Pressure, you can calculate how stable the rocket will be. For a rocket to be considered stable, the Center of Gravity needs to be above the Center of Pressure (see graphic below).

A rule of thumb for a stable flight is that the Center of Gravity (CG) should be at least 1.5 to 2 times the diameter of the body tube above the Center of Pressure (CP). It is common in model rocketry to call the diameter of your rocket's body tube a Caliber (Cal). A rocket with the CG 1.5 Cal above the CP has a stability of 1.5 Cal.

For example, if you are building a larger model rocket that has a 3-inch diameter body tube, and you calculate the Center of Pressure and measure the Center of Gravity to be 6 inches above the Center of Pressure, your Stability is 2.0 Cal.

A rocket can become over-stable past 5.0 Cal. Over-stable only becomes an issue when there is wind as it will cause the rocket to fly into the wind. This phenomenon is called "weathercocking." All stable rockets can weathercock, especially during the coasting phase of flight, but a high Caliber of stability will make this more evident.

You can increase the stability by lowering the Center of Pressure (by moving the CP closer to the rear of the rocket) or by raising the Center of Gravity (by moving the CG closer to the nose cone of the rocket). To lower the center of pressure, you can increase the surface area of the fin by making it bigger or adding more fins. Often an easier solution to increase stability is to raise the Center of Gravity by adding weight to the nose cone.

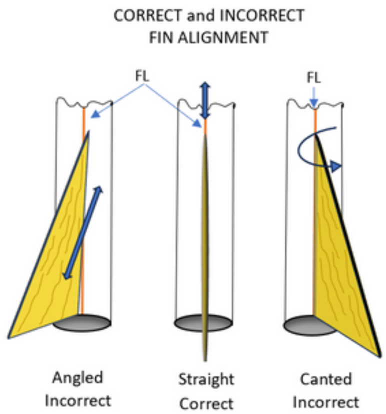


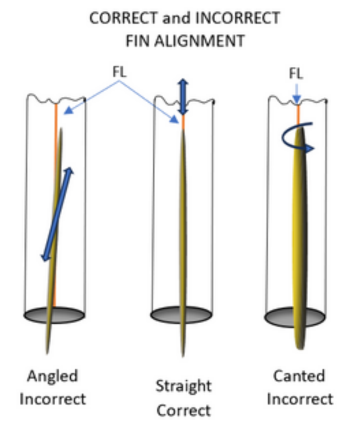
For stable flight, center of gravity must be above center of pressure. To improve stability, add weight to the nose, or increase fin area.

Other Factors that Impact Stability

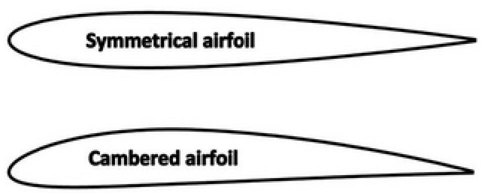
Numerous factors can cause a model rocket flight path to become unstable in flight. A few of those factors are listed below. These are considerations as you build your model rocket.

CROOKED OR CANTED FINS: If you have fins on your rocket that are not perfectly straight, they have the potential to cause unexpected lift forces to be generated.





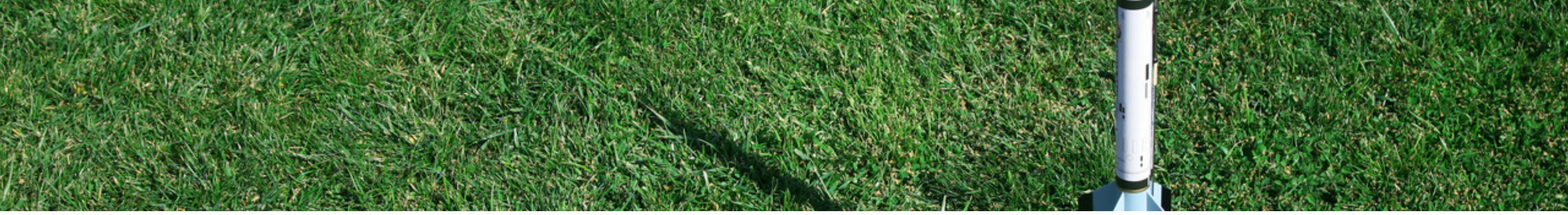
FINS WITH DIFFERING AIRFOILS: If each fin on your rocket has a different airfoil, this would have the same effect as crooked or canted fins. It generates non-uniform lift forces. The best airfoil on all the fins would be the teardrop shape (symmetrical); but if it is not uniform on both sides, you have what is called a “cambered” airfoil. This type of airfoil is similar to those on the wing of an airplane, whose purpose is specifically to generate lift.



FORWARD FINS (ALSO KNOWN AS "CANARD" FINS): These are any fins placed on the model in front of the Center of Gravity (CG). They are always destabilizing if they generate lift. Therefore, it is critically important that they be made as small as possible and that they are “perfectly straight” on the model. If they are not, the model is probably going to be unstable.

ASYMMETRICAL FIN ARRANGEMENTS: The word asymmetrical means “not” symmetrical; in other words, fins that are not placed or spaced equal distances around the tube. It would also include having some fins on the rocket being bigger than others are. In either case, the lift force on one side of the rocket can be bigger than on the other side. Fins should generally be placed in a symmetrical manner, unless a kit instructs otherwise. Manufactured stock kits are tested for proper flight stability.

FINS THAT POP OFF DURING FLIGHT: When this happens, the result is that the lift forces around the rocket are not uniform. This makes the rocket do loops, and it is easy to figure out after the flight if you are fortunate to find the parts afterward.



Other Factors that Impact Stability - Continued

LOOSE FINS: Even if the fins do not pop off during flight, the reason we do not tolerate loose fins on the rocket is that they can vibrate back and forth. This disrupts the airflow on one side of the model and can cause it to go unstable. So never tape a fin onto a rocket or permit someone else to do so.

LOOSE NOSE CONES THAT ARE CANTED IN THE TUBE: This is similar to having a loose, missing, or crooked fin. A canted nose cone can generate more lift forces on one side of the rocket than the other can.

LAUNCH ROD INTERFERENCE: This is similar to the one above. The rocket hangs up on the rod for just a moment, decreasing its speed. When it lets go of the rod after hanging up, it likely will not be traveling fast enough to be stable when leaving the launch rod.

GETTING ENTANGLED IN THE IGNITER CLIPS: This would prevent the rocket from lifting off smoothly. Anything that slows the rocket while it is on the rod may be a detriment to the stability of the flight.

LOOSE LAUNCH LUG: The sudden force of pressure applied to a loose launch lug after the motor is ignited can cause the launch lug to snap off. The rocket will respond by twisting, causing it to turn horizontal before even leaving the distance of the launch rod.

CONSTRICTED LAUNCH LUG: Launch lugs that are not completely straight in line with the body tube or have decals placed in front or behind it are factors that can cause the launch lug to bind against the launch rod. The results can cause the rocket to decrease in speed prior to leaving the pad, hang up on the rod and not leave the pad, or cause the flight to become unstable.

ACTIVITY GUIDE: Complete the Rocket Stability activity in the Activity Guide at the end of this manual.

Chapter 3: Supplies, Tools, and Construction Techniques

Now that you know about the science behind model rocket flights, it is your turn to build a model rocket! All great rockets require the best tools and supplies. Explore this section to learn about recommended materials, tools, and basic building techniques to build your rockets.

Recommended Supplies

APPLICATORS (toothpicks, hobby sticks, etc.): Use for performing application tasks such as applying glues, epoxy, fillers, decals, etc.

CARDBOARD BOX (oversized): Use as a paint booth for your rocket.

CLOTH (tack cloth, microfiber cloth, or lint-free towels): Removes residue from parts of the rocket during the sanding and painting processes.

CONTAINERS: Small disposable cups or plastic containers with lids are helpful to mix wood filler with water to form a workable paste or when working with glues.

GLUE FOR CARDBOARD AND WOOD: Use to glue wood fins, paper shock cord mounts, shock cord knots, motor mounts, and for filets (a thin line of glue along fins and launch lugs). It is recommended to use water-based glue, such as yellow carpenter’s wood glue. You may purchase wood glue at most hobby stores and home improvement stores. Glues come in many container sizes. One brand of wood glue comes in a small “pen-shaped” container with a small nozzle end, and it is easy to refill.

GLUE FOR PLASTIC ONTO CARDBOARD: Use to glue plastic fin units to the rocket’s cardboard body tube. Suggested glues include: E6000, epoxy or a general-purpose adhesive. Check the label on the glue to see if it is compatible for plastic and cardboard. NOTE: Adult supervision is required for most of these glues, as well as proper ventilation.

HOBBY KNIFE: A soft grip hobby knife with a protective blade cap and extra blades. Use to remove flashing on nose cones or other plastic parts and the inner mold from the nose cone eyelet. A hobby knife can also be used to slice through the tabs of wood fins when removing them from their wood sheets (preventing tears in the fins).

PAINTER'S TAPE: For masking off areas of the rocket you do not want to paint.

Recommended Supplies - Continued

RULER: Use for measuring where the launch lug(s), the motor mount and other parts of the rocket may fit together. A small 6-inch or 12-inch hard plastic or metal ruler is recommended.

SAFETY GOGGLES: May be used when painting to protect the eyes from paint dust or overspray.

SANDPAPER (280-, 320-, 400-, 600-grit, micro-fine): Lower grit sandpapers (280- and lower) are recommended on harder wood fins like plywood or composite fins or for smoothing dried wood glue. These are used to remove material when you add air foiling to the fins. Medium grits (320- up to 600-grit) can be used on softer woods like balsa or basswood, wood filler material, and primer coats. Higher grit sandpaper is great for sanding plastic edges, smoothing out the seam lines of a plastic nose cone, and for sanding final top coat paint.

SANDING BLOCK: Use to sand the flat sides of fins.

SCARF OR FACE MASK: Safety prevention tool to keep from breathing in sanding particles or fumes from glues and paint.

SCISSORS: For cutting out patterns, decals, and shock cord mounts, shroud lines, etc., as needed.

SEALER/FINISHING CLEAR COATS: Use to secure decals and for providing a nice flat, matt, or glossy finish to your rocket (an optional technique).

SPRAY PAINT GRIP (plastic): A plastic spray gun, which uses a trigger device, that can be attached directly to the spray paint can, making it easier to hold, control, and guide the flow of paint. Easily found at hardware stores.

SPRAY PAINTS FOR TOP COATS: Use to add color to your rocket. Mixing different brands of paint for your primer, top and finishing coats could cause what is known as an “orange-peel” or a bubbling reaction to the paint. Until you know for certain what works well together, it is recommended that you use the same brand name for all the various stages of coats of paint. If you choose to paint your rocket in bright colors to help with sighting your rocket, like yellow, red, orange, and pink, a first coat of white paint is recommended.

SPRAY PRIMER (sandable): Use a sandable primer prior to spraying on any top coats! Gray, white, or rust sandable primer is acceptable.

Recommended Supplies - Continued

WOOD FILLER (water-based): Fills in the grove lines on the rocket's body tube and grain lines on wood fins. Look for fillers that are water cleanup, have no chemical odors, and are easy to sand and paint. Recommended examples include Elmer's Carpenter's or ProBond Wood Fillers or Zar's Latex Wood Patch. Note that small tubs of filler may be easier to use than tubes, which can be difficult to squeeze, especially for younger 4-H members.

Optional Build Equipment and Supplies

ACETONE: Use for CA (e.g. Super Glue©) removal from exposed skin. NOTE: Adult supervision required.

AIRBRUSHES: If you are skilled in using airbrushes, they can be an excellent tool when painting a rocket.

NITRILE GLOVES: Use to protect your hands from glues, chemicals and paints, keeps the oils of your hands from transferring to your rocket causing some paints to not adhere well to the rockets, etc.

CYANOACRYLATE (CA) GLUE (e.g. Super Glue©): Use for reinforcing the inside ends of body tubes (an optional technique). Note: Adult supervision is required.

ELASTIC BINDING CORD (1/16", 1/8," or 1/2"): An alternative to using the rubber-band shock cord. The rubber band shock cords tend to become dried out and brittle, breaking after a few flights.

GLUE APPLICATION TIPS: Small tips that can be connected to plastic cement tubes to provide a thin line of glue.

HOBBY SYRINGE OR EYEDROPPER: Use to apply two or three drops of water at a time to wood fillers.

MODELING PLASTIC PUTTY: Fills in dips, seam lines, and scratches on external plastic parts.

PAINT DRAPES OR NEWSPAPERS: Use to line and protect the floor and cabinetry when painting. It can also be used to cover large sections of the rocket you do not want to get painted.

Optional Build Equipment and Supplies - Continued

PAINT SUPPORTS OR STANDS: A means to prop the rocket nose cone and/or rocket for painting. See suggestions given under “Painting Techniques.”

PAPER TOWELS OR SOFT WHITE CLOTH: Use for quick cleanups.

RIGHT-ANGLE METAL BAR: Use to assist in drawing straight lines along the body tubes. NOTE: Door frames or any right-angle object can be used for this technique. Another option is using Estes Ultimate Tube Marking Guide.

TRANSFER OR DECAL PAPER: May be used to create your own decals.

TWEEZERS: Particularly useful for attaching small parts onto the rocket or placing decals.

Balsa and Basswood Model Rocket Construction Techniques

Each model rocket kit is unique in its design and construction. The following section describes some basic techniques and methods that many rocketeers use in building and finishing model rockets that may not be included in your kit instructions. Using any or all of the following techniques and methods should assist you in building a sturdy and stable rocket with a nice appearance that will be easy to see in the sky, as well as alternative recovery methods for wind variables. Begin with reading your kit instructions completely prior to starting any work. Check to see if there are any techniques or methods listed below that may apply to your specific kit's assembly. Include them as a supplement or alternative method to your kit's instructions and build.

NOTE: Your model rocket kit may or may not require some of the following construction techniques. Read each section to see if it would apply to your kit build. If it does not, then proceed to the next section.

SAFETY TIP: Hold and guide your knife blade away from your body. Use a scraping method rather than a cutting method to remove the flashing. Remember to replace the safety cap when you are done with the hobby knife.

ACTIVITY GUIDE: Complete the Cost of Building Supplies activity in the Activity Guide at the end of this manual.

Preparation of All Plastic Parts

REMOVING PLASTIC FLASHING: Flashing is leftover plastic from the molding process. With a sharp blade (hobby knife), trim all excess flashing off each part.
Pro Tip: Be sure to not scrape off any tabs or pegs used to connect pieces together. Use the back of the blade to scrape off excess material and avoid cutting into the part.

WASH OFF CHEMICALS: During the molding process, chemical agents are used to coat the molds so the plastic parts will not adhere to the molds themselves when formed. When the plastic parts are removed from the molds, an unseen residue of those chemicals can transfer to those parts, making it difficult for paints to adhere to them. Use warm water with a couple drops of dishwashing detergent to wash off any residue chemicals (also referred to as “film”) from any exterior plastic parts, including the nose cone.

Gluing Plastic Parts

SAFETY TIP: Always work in a well ventilated area when working with any type of chemical-based compound or glue.

TEST FIT (OR DRY FIT) PARTS PRIOR TO GLUING: Make sure you are working with the correct parts and that they fit together snuggly prior to gluing. If you find parts that do not fit properly, you can sand wood and plastics or add strips of tape.

APPLICATION OF GLUE: Use applicator tips, toothpicks, etc., something that will allow you to apply a thin line of glue. Do not use your fingers!

SAFETY TIP: Use protective gloves to keep the glue off your hands, especially when working with any type of plastic cement.

APPLY GLUE SPARINGLY: Use glue sparingly and work quickly. Plastic cement heats up the plastic, effectively softening it (melting it), so both pieces join together to form one piece.
Pro Tip: It is recommended to not use CA (e.g. Super Glue©) or any type of quick repair glue for general construction. Sometimes, kit instructions will recommend a type of glue to use. Tester’s Plastic Cement generally works well for most plastic modeling construction.

Nose Cone Techniques

If your rocket kit comes with a plastic nose cone, be sure to follow the steps stated in the above section about removing the flashing and washing off the nose cone. Balsa nose cones require sanding and filling in of the wood grain to make it smooth creating less drag. A sleek, smooth nose cone will enable your rocket to fly straighter

and faster into the air. Also, with less drag on your rocket, your rocket will soar higher into the sky. (Refer to Newton's Three Laws of Motion, the Law of Inertia, starting on page 6.)

PLASTIC NOSE CONES - FILLING IN DIPS, GROOVES, AND SCRATCHES ON THE NOSE CONE: You can use modeling plastic putty to fill in any dips, grooves, or scratches you may find on your nose cone, particularly along the mold seam lines. Once the putty has hardened, start with 400-grit sandpaper to smooth the filler down even with the body of the nose cone.
Pro Tip: Check with your local hobby stores or do an Internet search for plastic putty.

SAFETY TIP: Many types of plastic putty used for model craft have toxic and flammable vapors. Be sure to follow the product's instructions for use and storage and use only in a well-ventilated area.

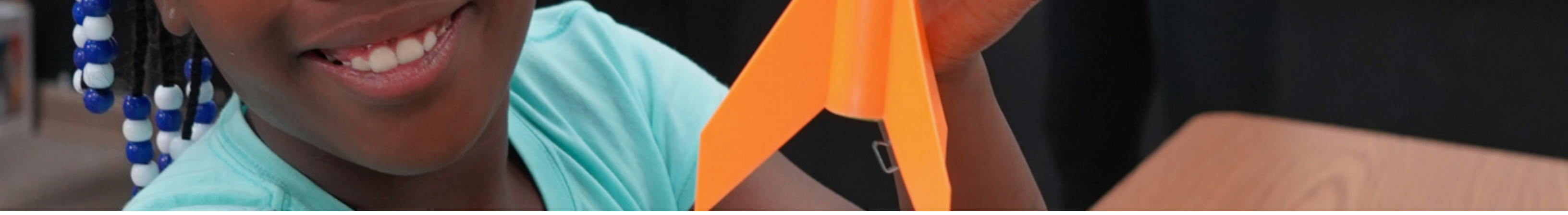
BALSA NOSE CONES - FILLING IN WOOD GRAIN, GROOVES, AND SCRATCHES ON THE NOSE CONE: Use either a wood filler paste or a balsa sealer to fill in the grain and any gouges or scratches the balsa nose cone may have.

SAFETY TIP: Proper ventilation is required when working with any chemical fillers and sealers.

WATER-BASED WOOD FILLER: Put a small amount of wood filler into a small container and mix in just enough water to make it into a toothpaste-like consistency. Too much water could cause the balsa nose cone to lose its pre-formed shape. Thinly coat the entire nose cone and allow it to dry.
Pro Tips: Use an eyedropper or plastic syringe to apply two or three drops of water at a time. Use a stiff wire to twist through the eyelet or eye screw prior to applying the filler. Allow the nose cone to hang upside down after the application somewhere it can get an even airflow to dry.

SANDING AND FILLING: After your nose cone is dry, starting with heavier grit sandpaper and going to lighter grits, lightly sand the nose cone.
Repeat sanding and filling until you achieve a nice smooth finish.
Pro Tip: Remember! Do not sand too far down on the "lip" of the nose cone.

SAFETY TIP: Wear a face mask if you are sensitive to dust particles.



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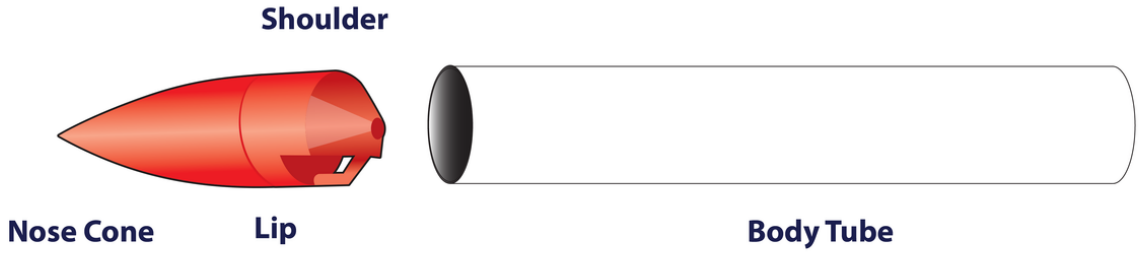
TEST FIT NOSE CONE: Test the fit of the nose cone "shoulder" into the rocket's body tube. The lip of the nose cone should match the outside edge of the body tube. See the illustration below. The nose cone should fit snug enough that when you tip the rocket upside down, the nose cone will not fall out, but not so tight that it is difficult to pull out.
Pro Tip: If the nose cone easily falls out, take a small piece of masking tape and attach it to one side of the nose cone's shoulder. Retest fit the nose cone to the body tube. If the nose cone still falls out when the rocket is tipped upside down, add a little more masking tape to the nose cone's shoulder until it fits properly.



ESTES education

Body Tube Preparation

The main body tube of the rocket, the one where all the parts fit onto or into, is the "airframe" of the rocket. Some rockets have more than one body tube to create either a longer or a wider airframe or to serve as accessory parts to the rocket. Model rocket body tubes are made up of several layers of paper/cardboard material and rolled to create a tube. Many have narrow or large "roll" grooves in them. These grooves will cause drag on your rocket and paint will not hide the grooves. To eliminate the additional drag on your rocket and to give your rocket a sleeker look, you will need to fill in the grooves. Follow the steps below to prep your body tube(s).

FILL IN GROOVES: Put a small amount of wood filler into a small container and mix in just enough water to make it into a toothpaste-like consistency. Too much water can cause the cardboard to swell, so use sparingly.

ProTip: Use an eyedropper or hobby syringe to apply two or three drops of water at a time.

With a small applicator (toothpick, hobby stir stick, or even your finger), pat the wood filler into the grooves along the body tube. Try to keep it mostly in just the groves, for whatever excess is on the body tube will need to be sanded away later. Let it dry completely.

Sand the wood filler smooth and even with the body tube. Start with 320-grit, wipe off body tube residue, and repeat the steps with 400- and then 600-grit sandpaper.
Pro Tip: Use a tack cloth, a microfiber cloth, or a dust-free towel to wipe off residue.

REMOVE GLOSSY COATING: Even if your rocket's body tube does not need to have any groves filled in, you may still want to paint it. Some body tubes have a glossy coating to them, which could be removed prior to painting, making it easier for the primer paint to adhere to the body tube. Use 400- to 600-grit sandpaper to sand lightly away the glossy coating and to smooth out any bumps in the body tube.
Pro Tip: If you sand down too much on the body tube, you can cause the cardboard to fuzz, which makes it hard to paint.

STRENGTHEN THE TOP END OF THE BODY TUBE (OPTIONAL): The end of the body tube from where the recovery system deploys tends to start unraveling or breaking down after a few flights. Strengthening the inside edge of the tube with a little CA (e.g. Super Glue©) helps to keep the end from deteriorating too fast.

SAFETY TIP: Be sure to have adult supervision whenever using CA and to always read the warning labels. Work in a well-ventilated area and have acetone nearby in case fingers get stuck. Nail polish remover has acetone in it and works well to remove CA.

Depending on which end of the rocket the recovery system is deployed—front or rear ejection—paint on a thin layer of CA inside the tube, from the top edge to about ¾" down. Let it dry.

Take a small piece of 320- or 400-grit sandpaper and lightly sand smooth.

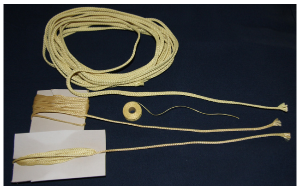
Re-test the fit of your nose cone to the body tube. If necessary, remove either excess masking tape or lightly sand the shoulder of the nose cone to obtain a smooth, but snug fit. Remember: the nose cone should come out easily when tugged, but not fall out when tipped upside down.

About Shock Cords

Shock cords serve two main purposes for the rocket. First, they are used to connect the nose cone to the rocket’s body tube. Second, shock cords absorb the shock of force produced by the ejection charge of the rocket motor. The “force” is the result of the hot gasses created and released by the ejection charge.

Most Skill Level 1 and 2 rocket kits contain a shock cord made out of rubber band type material. Two other common types of shock cords for model rockets are elastic band material, commonly used in sewing projects, and Kevlar cord. Inspect rubber band shock cords before launching, because they can dry out, become brittle, and separate during flight. Elastic band shock cords, the type used for sewing, will generally last longer than the rubber band shock cords. However, these too will become charred from the hot gasses and burn through or break over time. Kevlar cord is a flame resistant material, but it has no elastic material in it. Being flame and heat resistant, though, Kevlar shock cords will last longer than the other materials.

Shock cord length is also important. Shock cords need to be long enough to keep the nose cone from bouncing back into the rocket, which could cause damage. The “bounce back” is referred to as “recoil.” When you stretch a rubber band and release it, it recoils back to its original shape. Since the Kevlar cord is not elastic, it needs to be long enough to absorb the shock of force applied to it, as well as long enough to keep the nose cone from damaging the rocket. A general rule to follow is to make your shock cord at least three times as long as your rocket, especially if you are using Kevlar.

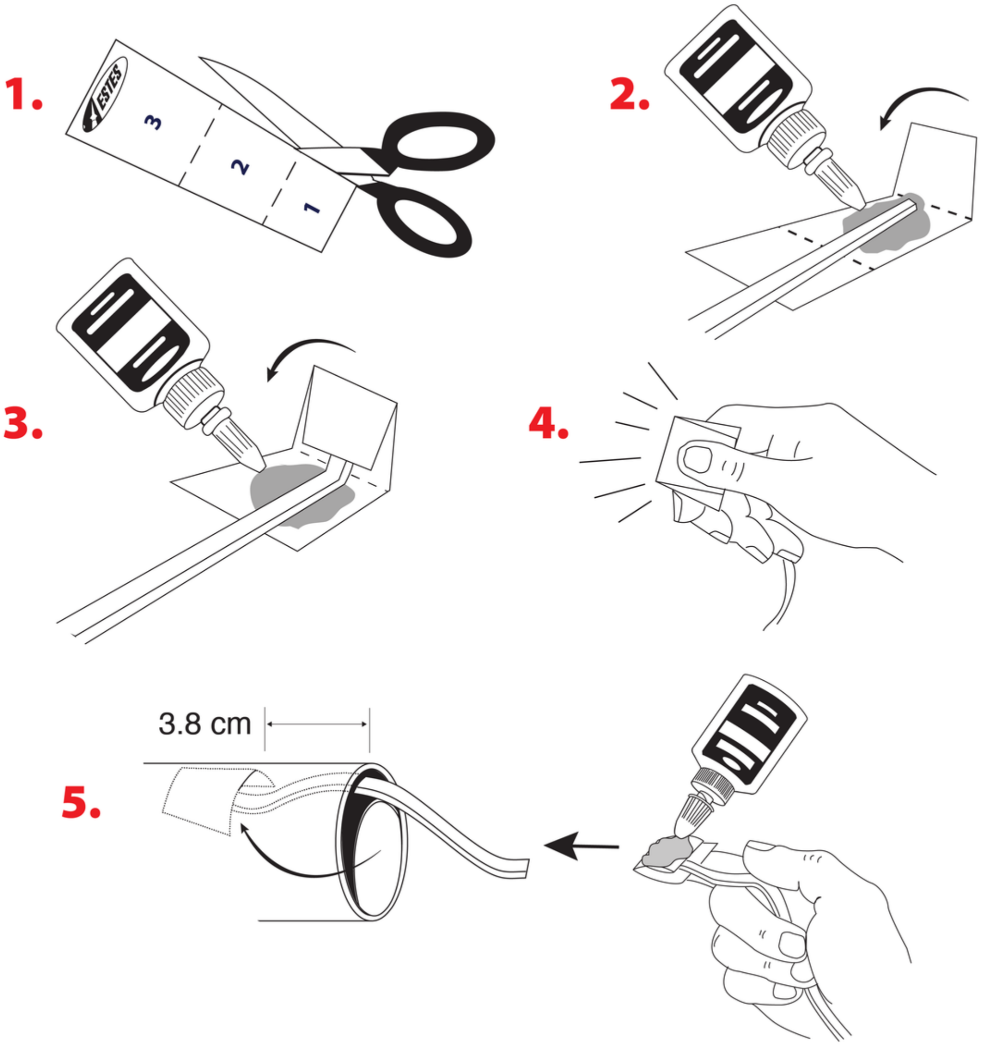


Methods of Attaching the Shock Cord

There are three primary methods to secure the shock cord to a rocket. Read your kit instructions on how to connect the shock cord to your rocket and how to build your motor mount (also see “Motor Mount Assembly” on page 29). Consider where you would like to place your shock cord to your rocket. You can always follow your kit instructions, or try one of these three methods:

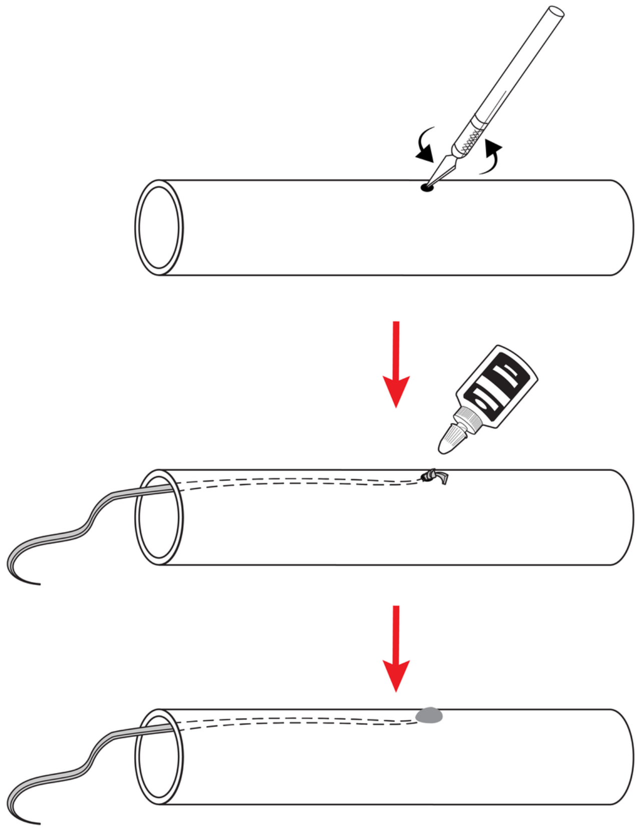
PAPER SHOCK CORD MOUNT METHOD: Use this method with a rubber band or flat elastic shock cords only. Cut out the shock cord mount from the kit instructions or use the template shown on the next page to make your own. Follow your kit instructions on how to glue the shock cord to the shock cord mount.

It is important that the shock cord is coming out at the top of the folds at a slight angle on the shock cord mount after all the folds are completed. Refer to the picture shown below.



While the glue is still wet, curve the shock cord mount around your finger with the smooth side next to your finger. Place glue to completely cover the folded side of the shock cord mount and insert into the body tube. The top of the shock cord should be below the shoulder length of the nose cone, approximately 1 1/2" from the top of the tube. Press the shock cord mount against the interior of the body tube, making it as smooth as possible. Remove any excess glue from inside the tube. Bumps in the shock cord mount or rough dried glue on the inside of the tube could cause the parachute or streamer recovery system to snag and not deploy properly.

THROUGH-THE-WALL METHOD: This method is best used with rubber band or flat elastic shock cords. Some kits use the through-the-wall method and use a small plastic cover to place over the knot.



Cut a small slit in the body tube near the center of the tube. Line the slit up with where a fin will be placed. This prevents the shock cord from getting in the way of the launch lug and launch rod.

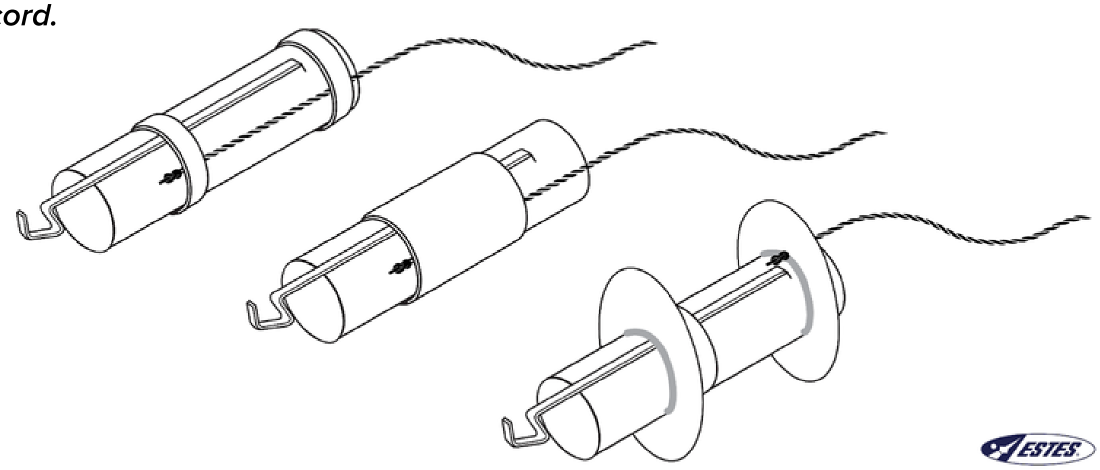
Slip one end of the shock cord through the slit, pulling it through the body tube about half way. Then secure the outside end of the shock cord with a double knot. Finish pulling the shock cord through the tube until the knot rests on top of the body tube. Add a drop or two of white glue to the knot to secure it. Let it dry.

Take some wood putty or filler and mold a small mound over the knot and onto the body tube. Round and smooth the mound towards the rear of the body tube to allow the airflow to glide over the mound, creating less drag on the rocket. Let it dry.

ONTO THE MOTOR MOUNT ASSEMBLY METHOD: This method works best with Kevlar shock cords. Read your kit instructions on how to build your motor mount assembly completely through prior to adding the shock cord. If you decide to connect your shock cord

to the motor mount assembly, and your kit requires you to build a motor mount, follow the steps below. There are several ways to connect the shock cord to a motor mount. The image below shows different ways you could choose to connect the cord to the motor assembly. To do that, secure the end of the shock cord with a tight double knot. Tie the shock cord around the motor casing on the far side of the centering ring to give added security. (Examples are pictured below.)

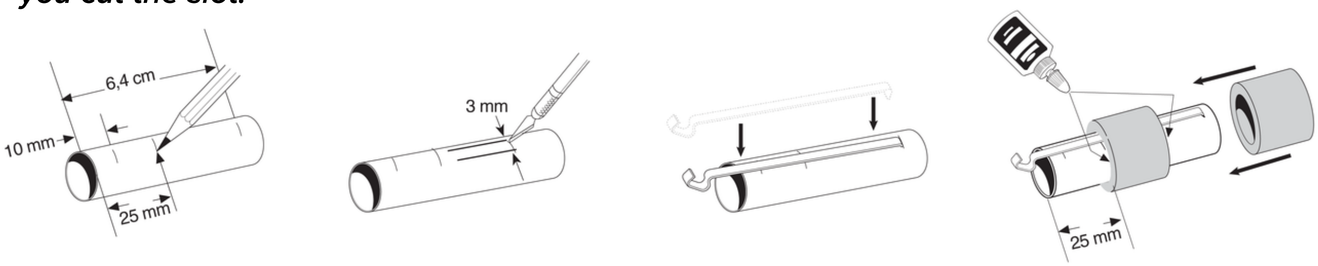
Pro Tip: File or cut a small groove inside the centering ring for the shock cord to rest into. This makes it easier for the centering ring to slide over the motor tube, motor hook and shock cord.



Motor Mount Assembly

BUILDING THE MOTOR MOUNT ASSEMBLY: Make a mark where the centering ring(s) go and where the motor hook inserts into the motor tube. Most kit instructions will have you cut a 1/8 inch wide slot about 1/4 inch from the top of the motor tube.

Pro Tip: Slightly pinch the motor tube end with your thumb and forefinger as you "gently" press down with the tip of the hobby knife. This will help you to avoid crushing the tube as you cut the slot.



1. 2. 3. 4.

Motor Mount Assembly - Continued

SAFETY TIP: Be careful when applying pressure with the hobby knife. Less pressure will help avoid slips and possibly cutting your hand.

- Secure the motor hook in place (in a straight line down the tube) with a piece of cellophane tape. This will help to prevent it from shifting or sliding out of position while you are placing on your centering ring(s). Always test fit parts prior to gluing.

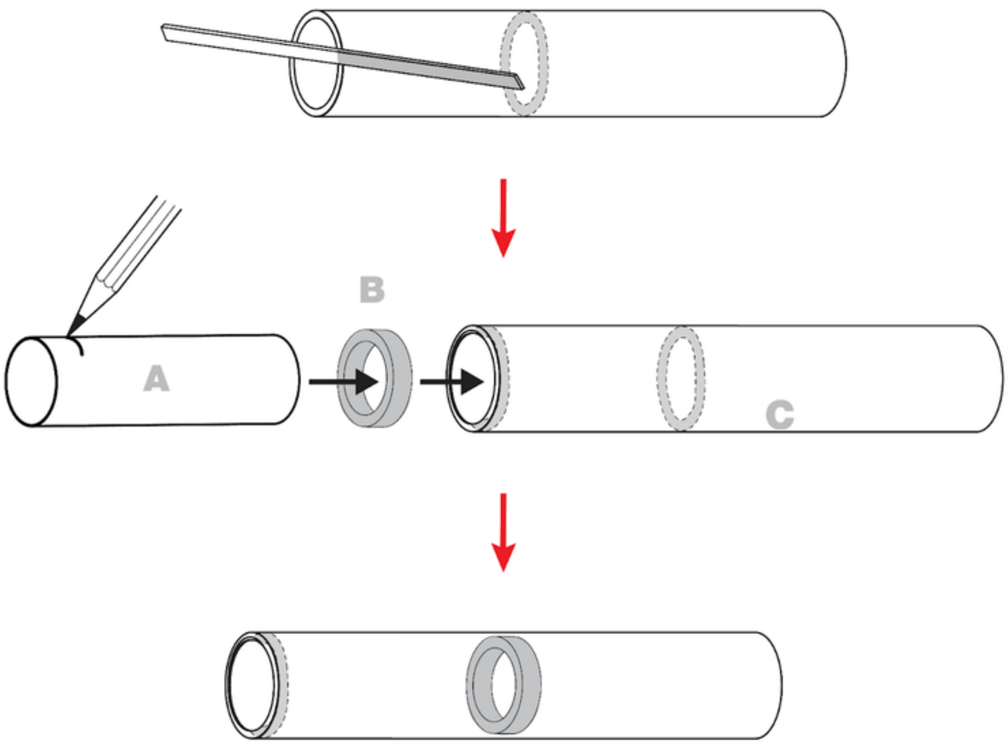
- Apply enough glue to the motor tube about ½ inch from the centering ring line to allow you to slide and position the centering ring into the proper place. Wipe off the excess glue from the end of the centering ring with your finger. Leave some glue on the joint. Let it dry.
  Pro Tip: Note that too little glue will tend to 'freeze' the centering ring before it is properly placed. Allow enough glue for the centering ring to glide down the motor tube.

- Apply another line of glue on the other end of the centering ring. Stand on end and let dry. Glue applied to a joint is called a "fillet". Fillets are used to strengthen parts together.
  Pro Tip: Wipe off any excess glue that may be on top of the centering ring(s) as it will interfere when you put the motor mount assembly into the body tube.

SECURING THE THRUST RING: If your rocket kit comes with a thrust ring (sometimes referred to as an engine block), follow your kit instructions in the placement of the thrust ring. It may either go directly into the rocket's body tube, or it may be placed into the motor tube.

Refer to the diagram on the next page. Some basic steps to follow when gluing the thrust ring into the motor tube or body tube are as follows:

- Make a mark on a motor (preferably a spent motor) about ¼" from the nozzle end.
- Mark an applicator stick about ¼ "shorter than the size of the motor.
- Apply glue to the marked end of the applicator stick.
- Insert the applicator stick into the body tube (or motor tube, per your kit instructions) up to the line you marked.
- Apply the glue to the inside of the body tube (or motor tube). Be sure to spread glue all the way around the inside of the tube.
- Place the thrust ring into the tube.
- Using the pre-marked motor, push the thrust ring up into the body tube (or motor tube).
- Continue to push up to the line marking on the motor. Quickly remove the motor.

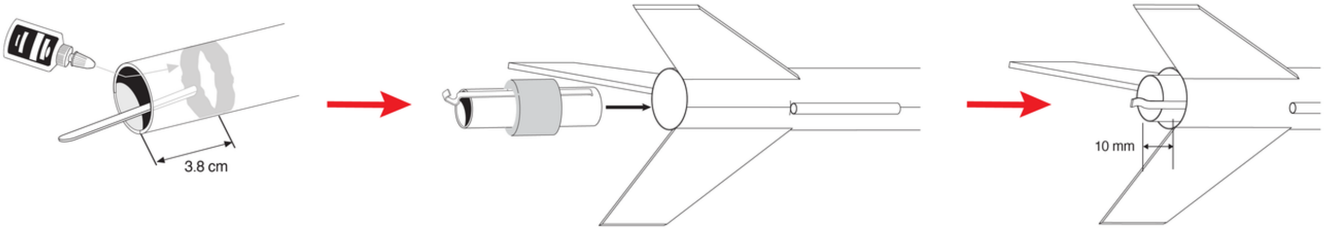


INSERTING THE MOTOR MOUNT INTO THE BODY TUBE: Again, read your kit instructions prior to inserting your motor mount (sometimes referred to as an engine mount) into the body tube of your rocket. Some kits will have you insert the motor mounts even with the bottom of the body tube. Others will have you leave about ¼" to ½" of the motor assembly to extend beyond the outside of the body tube.

The kit instructions should tell you how far down inside the body tube to apply the glue for the motor mount assembly. In general, you will apply glue into the body tube just short of where the centering ring will be placed. The glue will spread forward into the body tube as the motor assembly is pushed into the body tube. The general steps to securing the motor mount into the body tube are similar to the steps used in gluing the thrust ring into the body tube (or motor tube).

Motor Mount Assembly - Continued

- Mark an applicator stick to the depth indicated in your kit instructions.
- Apply glue to the same marked end of the applicator stick.
- Insert the applicator stick into the body tube up to the line you marked.
- Apply glue to the inside of the body tube. Be sure to spread glue all the way around the inside of the body tube.
  Pro Tip: This is a case where more glue is preferred to less glue. Too little glue could cause the motor mount to "freeze" in place before getting it all the way into the body tube. However, too much glue can cause excess glue to run down the inside of your body tube and onto the shock cord.
- In one quick motion, slide the motor mount into the body tube.
  Pro Tip: If you have already placed lines for your fins and launch lug onto your body tube, be sure to place the motor hook between two of those lines. Aligning the motor hook along one of the fin lines could make it impossible to put a motor into the motor mount. Aligning the motor hook along the launch lug can cause interference with the launch rod and cause a short in the electrical current.
- Once you have the motor mount into position, prop the body tube up with the motor mount end down to prevent excess glue from running down the inside of the body tube. Let it dry.
- Apply a glue fillet to the outside joint of the motor mount to the body tube. Stand the rocket on the nose cone end, and let it dry.



ESTES education

Couplers and Payload Sections

COUPLERS: Some model rocket kits include one or more couplers. Couplers are used to join two body tubes together to make a longer airframe. Sometimes, the body tubes are the same size in diameter, and sometimes they are not. Couplers are also called "transitions" when connecting two body tubes of different diameters. Couplers are made from balsa, plastic, or cardboard tubing. Couplers are sometimes glued on both ends, and sometimes just one end is glued.

PAYLOAD SECTIONS: Other model rocket kits may include a payload section. For most model rocket kits, the payload section is made from a clear plastic tube. Some common payloads are eggs, scientific experiments, and liquids. (Never put a living creature in a payload.) Payloads sections usually have just one end glued to the body tube.

RECOMMENDED GLUES FOR COUPLERS AND PAYLOAD SECTIONS: Use wood glue when gluing cardboard or balsa parts to a cardboard body tube. To glue a plastic coupler or payload section to a cardboard body tube, it is recommended to use an E6000, epoxy, or a general-purpose adhesive. Check the label on the glue to see if it is compatible for plastic and cardboard. NOTE: Adult supervision is required for most of these glues, as well as proper ventilation.

Learning About Fins

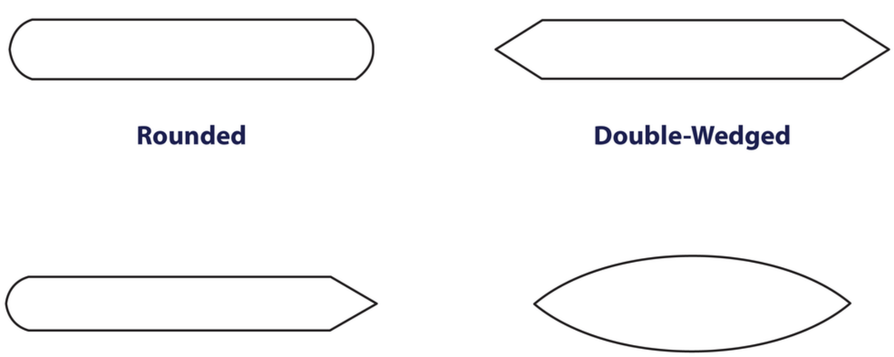
Fins come in all sizes and shapes. They are used to stabilize your rocket while in flight. The center of gravity (CG) and center of pressure (CP) are also determined by the size and placement of fins. Always place your fins as your rocket kit instructions tell you. Commercial rocket kits are tested for proper fin placement and size, so you know that the CG and the CP will be in the right places on the rocket.

Most fins have three or four edges to them. All edges have a name. The “root edge” is the edge that will be glued to the rocket’s body tube. Many rocket kits mark the root edge with a small hole. The “leading edge” is the edge that will lead into the sky. The “trailing edge” is the edge last to enter into the sky, and the “outboard edge” is the edge between the leading and trailing edges, also known as the “outside edge” or "outward edge".

In the graphic, notice that the wood grain is going in the same direction as the leading edge. This is very important. If the wood grain is going in any other direction, the airflow around the fin could simply snap the fin apart.

Balsa and basswood fins will come out of wood sheets with flat edges. Flat edges on fins will add additional drag to your rocket while in flight. To achieve better flight performance, you will want to "airfoil" your fins' edges (except the root edge of a fin). Some of the most common types of airfoil shapes are as shown.

Airfoil Shapes



Balsa and Basswood Fin Preparation

CUTTING, SHAPING, AND SAILING: When you open your rocket kit, your fins are probably still seated in a balsa or basswood sheet. Most fins are laser cut for easy removal. Before removing the fins from the sheet of balsa or basswood, sand the fins on both sides of the sheet. For initial sanding, start with 280- or 320-grit. To avoid creating “finger” grooves in the soft wood, we recommend using a sanding block.

Do not pop the fins out from the sheet. Instead use your hobby knife to cut through the tabs in the wood. Popping the fins out can cause the wood to snag, to tear away from your fin, which will require repairing. If necessary, use a metal or sturdy ruler to use as a guide. Stack fins together and as a single unit, sand the root edge flat. Sand all remaining edges to make the fins uniform in size and shape, and to remove any tab stubs.

Shape the leading and trailing edges round. If you have an outboard edge on your fin, you may either leave it flat or sand it round as well. Periodically stack the fins together to ensure uniformity in size and shape. Remove the dust from the fins using a microfiber or tack cloth. ***Pro Tip: Tack cloth uses a sticky wax substance to collect wood dust off the surface of the fins. Microfiber cloth has tiny loops of thread that collect the dust. Never rub these materials over the fins as one will leave wax on the surface and the other can catch tiny attached splinters snagging the wood. Instead, drape the cloth over the fins and slowly pull it across.***

USING FILLERS OR SEALERS AND MORE SANDING: The grain in the wood consists of lots of tiny pits which, again, causes drag on your rocket. To remove all appearances of wood grain, coat each fin with either wood filler or a balsa sealer (or any other sandable filler medium). The most popular techniques include water-based or chemical-based fillers. There are pros and cons to both. When using water-based mediums, you will need to coat both sides at the same time. Wood absorbing water and coating on one side at a time will cause the wood to curl or "warp." The advantage of chemical-based fillers is that they do not warp balsa wood fins. However, chemical-based fillers must be used with adequate ventilation, usually in an open garage or outside.

After treating the wood fins with a filler or sealer, the fins need to dry. If you used a water-based filler, the fins should have an even air-flow encircling the entire fin. A good and cheap method for a reusable prop is to purchase a pool noodle. Standing the fins up against a box can cause uneven airflow and possibly warp the fins. Plus, some of the filler could transfer from the fin to the box or implement used to prop the fin up with.

POOL NOODLE PROPS: Cut off several sections of the noodle (about twice as long as the root edge of your fin, or make a set for different sizes of fins). Split each section in half lengthwise. On the curved side of each noodle section, create another slit part way through the noodle material to about half again the size of the fin's root edge. The noodle prop will lay on its flat (cut) side and provide an even air-flow for your fins. One pool noodle can supply you with several fin props. It is recommended to have an adult cut the noodles for younger youth.

After applying the filler (water-based or chemical-based), slip the root edge into the noodle, just far enough to hold the fin up. Apply any extra filler where needed, making sure every part of the fin, both flat sides and all edges except the root edge, are covered. Let them dry and then sand starting with 320-grit paper. Stack the fins together to ensure uniformity in size and shape. Remove the excess dust with a microfiber or tack cloth, and repeat the process until the fins have a smooth finish, approximately two to four times.

SUGGESTED FILLER MEDIUMS (SANDABLE AND WATER BASED):
Elmer’s Carpenter’s Wood Filler—(thin wood filler with water to create a toothpaste-like texture)
Deluxe Materials Model Light Lightweight Filler
Deluxe Materials Sand'n'Seal
Hobbico Hobbylite Filler

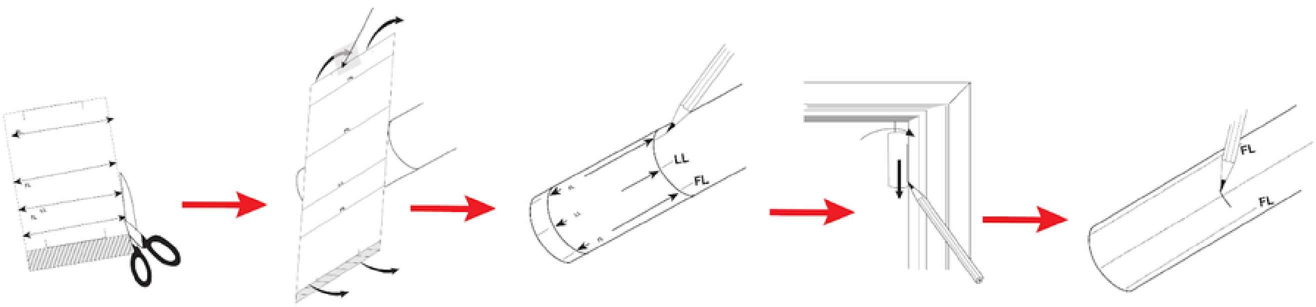
After the last filler layer has been applied and sanded with 320- or 360-grit paper, increase the sanding paper grit number to 400- to 600-grit, etc., using a tack cloth or microfiber cloth between each sanding. This will achieve an almost glass-like smoothness.

Marking the Body Tube for the Fins and Launch Lug

If you have not already done so, consider lightly sanding the body tube to remove the waxy coating. Removing the waxy coating will allow the glue and, later, the paint to adhere to the body tube.

Refer to your kit instructions and cut out the fin alignment guide. Slip the guide over the rocket's body tube on the end where the motor mount is located. The launch lug should be placed where it will not interfere with the fins of the rocket or the motor hook. Line up your guide and mark all lines as your kit instructs.

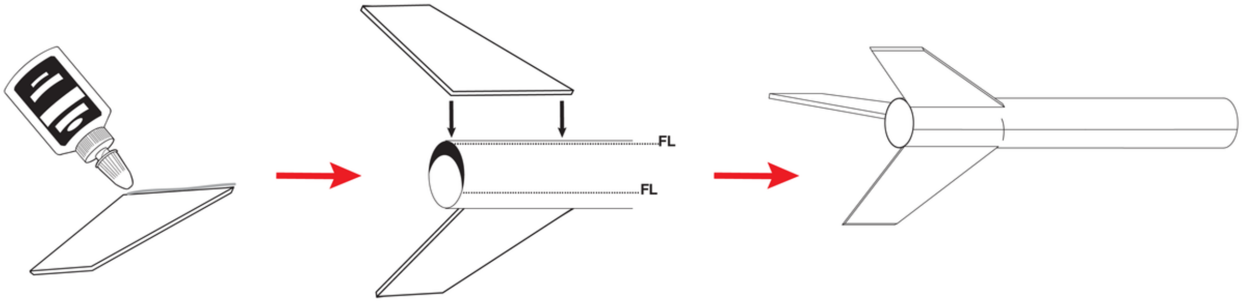
To mark straight lines along the body tube, you can use a door frame, a fin alignment tool, or a right-angle bar. Mark all lines from one end of the body tube to the other end. This will provide you an alignment to "sight" down when attaching your fins and launch lug(s) to ensure the fins and lugs are on straight. Read your kit instructions for the exact placement of the fins and launch lug(s) and make a little "x" mark on the lines you drew of where the top of each fin and launch lug will sit.



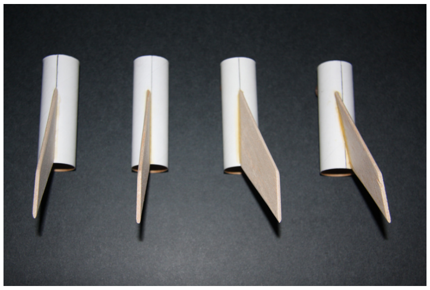
Attaching, Aligning and Filleting the Fins

ATTACHING THE FINS TO THE BODY TUBE: Have a location set up to rest your rocket prior to attaching your fins. Do not allow your rocket to rest on the fins while they are drying as the weight of the rocket may put the fins out of alignment.

Put a thin layer of glue on the fin line (only where the fin will be placed), and again, wipe most of it off; leave just enough glue to make the tube look shiny. Wait about one minute.



Apply a second thin layer of glue to the root edge of the fin, wipe most of it off, and then "walk" the fin onto the body tube, along the glued line.
Pro Tip: This is another case of too much glue is a bad thing. Allowing the glue to "set" on both the fin and the body tube, prior to attaching the pieces together, provides a tacky surface on each piece. This allows the fin to stay in place better. If you applied a line of glue to the fin and then immediately place the fin onto the body tube, you may find that it will tend to slide off or out of alignment.



ALIGNING ALL ANGLES OF THE FINS: Check the alignment of the fin by sighting down the body tube along the line you drew with your eye, holding it out at arm's length. The fins should be vertical to the body tube and straight along the fin line from the tip to the tip along the root edge. Adjust if necessary. Let it dry. Repeat the above two steps for all remaining fins and let dry. In the photo, the first fin is aligned correctly, the others are incorrect being off the line, canted, or crooked.

APPLY FILLETS: Apply a thin stream of glue (called a fillet) along both sides of each fin, along the joint with the body tube, and smooth out with your fingertip. Let it dry. Sometimes a second application of glue may be needed if bubbles form in the fillets. Fillets add strength to hold the fins onto the rocket.

Attaching, Aligning and Filleting the Launch Lug

CHECK PLACEMENT OF THE LAUNCH LUG: Small rockets generally use only one launch lug, but larger rockets may use longer launch lugs, two or even three launch lugs in vertical alignment with each other. Generally, one launch lug is placed near or at the CG (center of gravity). You may discover your instructions will have you place a lug centered between two fins about one inch above the fins, but it may also be placed along the edge of a fin.

If using two launch lugs, the second launch lug should be placed about one- to two-inches down from the top of the body tube. NOTE: It is recommended to follow your kit instructions as to the proper placement for your launch lug(s).

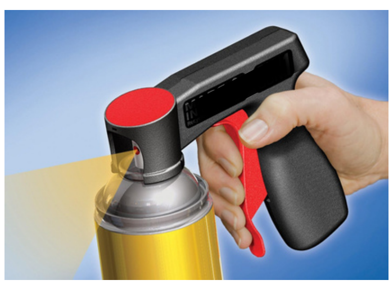
ALIGNMENT AND ATTACHMENT OF THE LAUNCH LUG: It is important to align the launch lug vertically along the rocket's body tube. If the launch lug is slanted any, it can bind against the launch rod on takeoff, which can cause the launch lug to tear off or partially tear off, causing the rocket to fly off in any direction.

Lightly sand one side of the launch lug along its entire length. As you did when attaching your fins to the body tube, apply a slight amount of glue to the body tube line where the launch lug will be placed, wipe off excess, and let sit for about one minute. Apply a second slight amount of glue to the launch lug (in the same spot where you sanded it) and attach to the body tube. If you apply too much glue, the launch lug will easily slip off or out of alignment. Raise the rocket to eye level and hold out at arm's length. Sight down the rocket's body tube and launch lug to ensure proper alignment. Let dry.

APPLY FILLETS: Apply fillets to both edges of the launch lug and smooth with your fingertip. Be sure the glue does not close up the launch lug holes. Again, do not use plastic cement for this procedure, as it does not adhere well to cardboard body tubes. Wood glue is best.

Painting Techniques

All painting takes time, two days or more depending on your paint's drying instructions and the number of colors you use. Plan ahead for your launch or judging events to ensure you have plenty of time to accomplish your painting. No matter how your rocket is painted, you want to produce a nice smooth surface, and avoid runs or splatters. Spray paints are recommended. A small plastic spray gun, which attaches to the top of spray paint cans, can easily be found in hardware or automotive stores and are easy to work with. If you have experience using airbrushes, those may also be used. Using small paint brushes to hand paint designs can cause excess paint buildup, causing additional weight and drag to your rocket.



Paint reveals all. If the grooves in the body tube or notches in the nose cone, etc., were not completely filled in and sanded smooth, they will appear through the paint. Never paint your rocket's nose cone while attached to the body tube. The paint will seal the nose cone into the rocket and you will have to cut it out, sand, and repaint.

Choosing a Color Scheme

Now that you have your rocket built, how should you paint it? Scale, semi-scale, or scale-like rockets should be painted and decaled according to the picture on the kit package. If your rocket is not a scale, semi-scale or scale-like rocket, then you are free to paint it in any color scheme you choose. If your rocket kit comes with decals, choose an appropriate color scheme that will coordinate well with your decals. Some colors of paint will blend in with the decals and the decals will become nearly invisible to the eye.

Consider what colors are best seen in the sky or on the ground, i.e., blue or cloudy skies, sandy soils with sparse vegetation or land with green or brown grasses. White and yellow colors show up well in blue skies, catching the light and making the rockets sparkle, but not in cloudy skies. Most dark colors do well in clear blue skies, but may be at a loss in trees or tall vegetation. Bright oranges, reds and pinks usually do very well in both scenarios. Lastly, the smaller the rocket, the harder it is to follow in the sky or be found on the ground. Bright top coats or parachutes, or both, are ideal for small rockets. If you want your rocket to be 'stealthy,' then camouflage colors with matt clear coats are what you are looking for.

Choosing a Brand of Paint

There are excellent brands of paint that are easily found in local hobby, hardware, and automotive stores. Some are relatively cheap and some can be quite expensive, and many come in different spray paint can sizes. What is important is that you choose one brand for all the coats of paints you will be using on your rocket, i.e., primer coat, top coat(s), and finishing coat(s). As stated on page 19, mixing different brands of paint for your primer, top and finishing coats could cause what is known as an “orange-peel” or a bubbling reaction to the paint. (If you have the means and time, it's always recommended to test the different types of coats on each other using pieces of balsa or cardboard tubing to see how they react to each other.) Lastly, always follow each can's application instructions!

Create an Appropriate Environment in Which to Paint

If you ever had experience working with spray paints, you know that much of the paint spreads out into the air like dust particles. These dust-like particles are the "overspray" of the paint. They can land on surfaces far away from where you are painting. Select a safe area in which to paint, either in a well ventilated shop or garage, or outdoors out of the wind. Make sure there are no drafts in the direction of your work area that can blow dirt onto your rocket.

- Wear old clothes that you can afford to get paint stains on.
- Spread out plastic sheets, paint drapes or newspapers to cover the surrounding floor area and cabinetry.
- Use an oversized box with one side cut out as a paint box. It is recommended to cover the box with brown or white paper. As your paper becomes covered with paint residue, you can replace it with new paper, allowing you to use your box repeatedly.

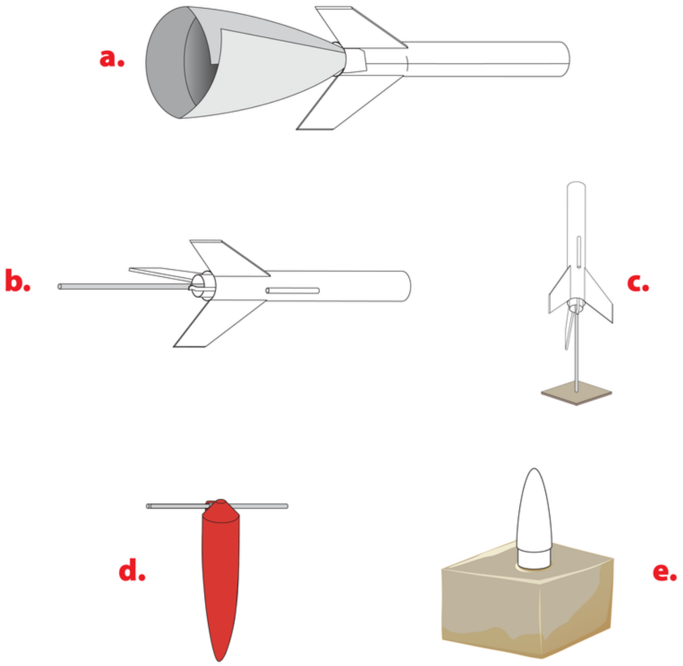
Methods to Hold the Rocket for Painting

Prior to any painting, give your rocket a last-minute cursory check for any nicks, dips, or bumps that may need to be removed or filled in. Remove all dust particles from the rocket. And lastly, fill in all tube openings with crumpled paper to prevent paint running into the body tube or launch lug.

Roll up heavy paper into a cone and insert into the motor mount or the top of the body tube. (See example a. on the next page.)
Pro Tip: Avoid getting paint inside the launch lug by inserting a small wad of tissue lightly covered with Vaseline just inside each end of the lug. Keep in place until the entire rocket is finished. Afterwards remove with tweezers and clean the Vaseline out using a swab or Q-Tip.

Use an extra body tube with a coupler or a dowel rod and insert into the motor mount of your rocket. (See example b. on the next page.) Use a stand to hold the rocket while painting. (See example c. on the next page.) Holding the rocket horizontally is the preferred method to hold the rocket when painting as it helps to avoid paint "runs" down the side of the rocket.

SAFETY TIP: If you are sensitive to paint fumes, consider wearing a facemask while you paint. Safety goggles and gloves are also recommended to avoid getting paint in your eyes, on your glasses, or on your hands.



Prior to painting the nose cone, use painter's tape (preferred) or masking tape to cover the shoulder area of the nose cone. Place the tape right up against the upper lip of the shoulder. if the nose cone has an eyelet attached to its base, run it through a coat hanger wire or other stiff wire, which you can then lay across the top of the box and rotate as you paint. (See example d.)

You can also brace the nose cone into a foam block or cut a small opening in the top of a box and sit the shoulder of the nose cone through the opening. (See example e.)
Pro Tip. Remember to leave space between the top of the box and the lip of the nose cone, so the paint can be smoothly applied clear to the lip's edge.

Primer

Select a "sandable" primer. Primer and topcoat paints should be the same brand name to avoid any "crazing" damage (dissolving, cracking, or bubbling of paint). Lightly spray in a continual motion parallel to the rocket, about 8 to 10 inches away from the rocket. Be sure to cover all parts of the rocket, but do not paint the inside of the body tube. Do not forget to paint all the fin edges, including the trailing and outboard edges. Allow to dry completely. Lightly sand the entire rocket. Remove paint dust with a cloth (micro-cloth, tack cloth, or other lint-free cloth).

Pro Tip: Remember to 'drag' or 'lightly' brush the cloth over the rocket to avoid getting sticky wax or catching on the rocket.

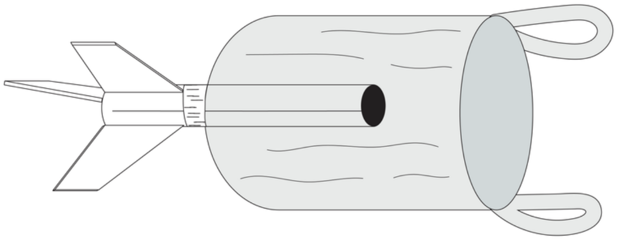
Repeat the painting process with light coats of primer, sanding in between, until all blemishes are gone. Usually two to three coats of primer will do. Spray one last light coat of primer, and let the rocket dry for 24 hours. Read the paint instructions before applying repeated coats.

To primer the nose cone, follow the same steps as above. NOTE: Usually you can use the same primer for plastic nose cones, but there are sandable primers specifically made for plastic, as well. Be sure to read the instructions on the primer can.
Pro Tip: Remember to mask off the shoulder of the nose cone. If paint gets onto the shoulder, sand it off. Having paint on the shoulder of the nose cone may cause it to stick to or fit too snugly to the body tube. Sun and heat can also cause paint to become sticky.

Masking

Masking is a method of shielding parts of the rocket you do not want to paint or wish to paint a different color from the rest of the rocket. Regular masking tape, often a tan or beige color, usually does not seal well and is not recommended. Instead, an alternative would be to purchase a paint masking tape, often blue, that will give you sharp paint lines. Most home hardware stores carry several brands of tape that will work well. When working with masking tapes, be sure to rub the tape down to form a good seal against the body tube or fins and to whatever material you use to shield the rest of your rocket.
Pro Tip: Plastic automotive masking tape is excellent for multicolor painting and is easy to peel off. It is a much more expensive product, though.

Use plastic bags, white, or brown paper bags to shield the rest of the rocket. Never use newspaper to shield your rocket as the newsprint can rub off onto your hands and onto your rocket.
Pro Tip: Plastic grocery sacks or small plastic trash bags make excellent shielding material. Create a small hole in the bottom of the sack, large enough to place your rocket through. Secure the bottom end with the masking tape to the area you want to shield. Drape the rest of the sack over your hand and arm while you are holding the rocket.



Allow your rocket to partially dry prior to removing the tape. If you allow the paint to dry completely, it may chip the paint when you remove the tape, and if the paint is too wet, the paint may drip or run when the tape is removed. Partially dry paint will show fingerprints if you touch it with your fingers, so it takes practice to find just the right amount of dryness.

Applying Top Coat Paint

As noted before, if your model rocket is considered a scale, scale-like, or semi-scale model, then you can paint your rocket according to the scale (kit package photo). Otherwise, you may choose your own colors. If you decide to paint a bright color—yellow, red, orange—do a light undercoat of white paint first. Allow to dry completely before applying the bright color.

Take your time when painting. Do not rush the job. In order to avoid runs, applying several light coats of paint is better than one heavy layer of paint. Again, be sure to read the instructions on the can on how to apply multiple layers. Different paint brands have very different rules for painting. Let the paint dry completely. Once completely dry, remove the tape and shield.

Multicolor Painting

The first color applied must be "hardened" (dry for one to two days) prior to applying an additional color to your rocket. Again, for fine and crisp lines use masking tape appropriate for paint masking and some type of shielding to mask off areas not to be painted.

Apply all additional paint colors the same as your first top coat color, allowing the paint to dry and harden completely between each color.

Finishing Techniques, If Needed

Confirm that the paint is "hardened" before applying decals. It is recommended to wait 36 to 48 hours before applying decals to a painted rocket.

Scale, scale-like, or semi-scale rockets should have all decals applied according to their respective kit photos. Otherwise, you may follow the kit package photo, or decide where to apply the decals yourself. The following are methods of applying different types of decals.

Water Decals

If you painted your rocket with a dull coat finish, paint the rocket with a clear gloss coat before applying water decals. The decals will stick better and will not form a fog under them. Make sure the clear coat is completely dry prior to applying the water decals.

Soak the decals in warm water, about 30- to 60-seconds, to soften the glue on the backing paper. Once softened, slide the decal onto the surface of the rocket and position it into place. Blot excess water off with a soft cloth or a paper towel. Do not rub, as it may cause the decal to tear. Starting from the center and pressing outward, work bubbles out to the edge of the decal. Let it dry.

To return your rocket to a nice dull finish after applying your decals and after the decals have completely dried, spray paint a test sample decal with clear dull coat paint. If successful, and no crazing occurs, spray the entire rocket.

Pressure-Sensitive Decals

Many rocket kits come with adhesive backed decals (pressure-sensitive). Some need to be cut out, while others can be peeled off the backing sheet. Check to see where the decal is to go before you remove it from its protective backing sheet. For scale models, apply the decals as depicted on your kit photo.

Carefully cut close to the edges of one decal, or peel off one decal. Line the decal up by sight before placing it onto the rocket. Carefully place the center of the decal into place. Smooth the decal from the center out, carefully working out any air bubbles. If you are unable to get all the air bubbles out, use a hobby knife to cut a small slit and work out the bubbles. Repeat the process for all your decals.

For placement of large pressure-sensitive decals, draw a line with a pencil along one edge of the decal onto the rocket prior to removing the backing. Gently peel the backing from that edge of the decal only, line up with the pencil marking, and gradually peel and smooth the rest of the decal on.
Pro Tip: Soak the decal without its backing in one drop of dishwashing detergent to one bowl of water for about 10 seconds. This will help in the placement of the decal. Be sure to remove all access water.

Make Your Own Decals

Transfer paper for homemade decals is available at most hobby stores or you can purchase decal paper for laser or inkjet printers at most home office stores. Create your own decals and apply the same methods used for pressure-sensitive decals.

Using Finishing Clear Coats

Some modelers use this optional technique on their rockets. When painting scale models of military missile rockets, many of the rockets are painted with camouflage colors. Adding a dull clear coat over the camouflage provides a more realistic look to the rocket. When using any type of finishing coat, remember to stay with the same brand name of paint that you use for both your primer and top coats to avoid any crazing (bubbling or peeling).

Apply light coats of the clear coat, allowing each to dry completely before applying any additional coats. Usually, though, one coat will be sufficient. Let dry completely before handling.

ACTIVITY GUIDE: Complete the Air Pressure Straw Rockets activity in the Activity Guide at the end of this manual.

Model Rocketry Activity Guide

Now that you have read through the manual, it is time to put your knowledge to the test! Make sure that you show all of your work and bring any extra materials with you to your interview so that the judge can see what you have learned! The following pages include the activities that are referenced in the Construction & Flight of Model Rockets Unit 2 Manual.

Complete a minimum of four activities. You do not need to complete the activities in order. If you are repeating this unit, do different activities than you did previously.

List of Activities:

Rocket Balloons	Pages 48-51
Drawing Forces	Pages 52-55
Rocket Stability	Pages 56-61
Cost of Building Supplies	Pages 62-67
Air Pressure Straw Rockets - How Does Rocket Design Impact Flight?	Pages 68-73

ROCKET BALLOONS

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: CRITICAL THINKING, LEARNING TO LEARN
TIME NEEDED: 10-15 MINUTES
SPACE: AT LEAST 10 FEET OF OPEN SPACE
SUGGESTED GROUP SIZE: TWO OR MORE

LEARNER OUTCOMES:

Participants will identify how Newton’s Third Law of Motion applies to the balloon moving on the string and apply that knowledge to model rocketry.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

3-PS2-1 Motion and Stability: Forces and Interactions
Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2 Motion and Stability: Forces and Interactions
Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion.

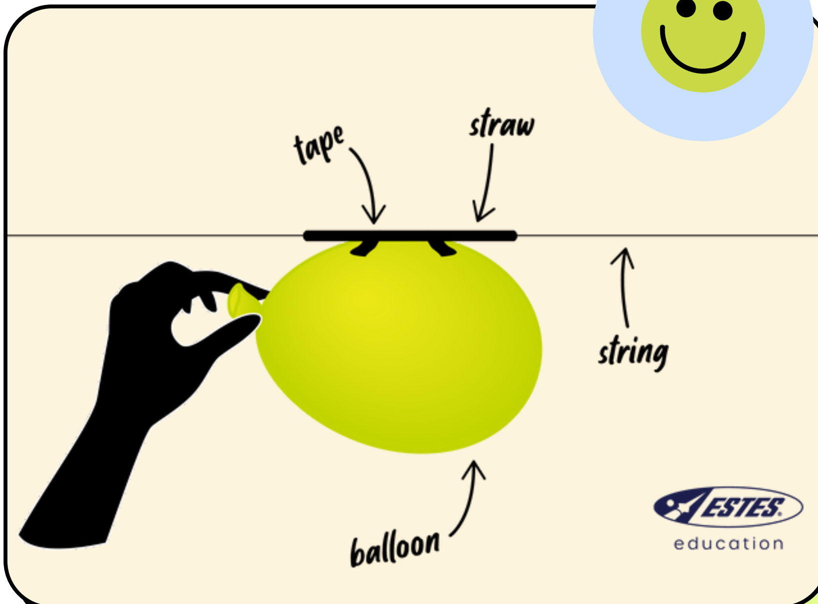
TAGS: MODEL, ROCKET, MODEL ROCKETRY, SCIENCE, PHYSICS, NEWTON

LESSON PREPARATION

MATERIALS LIST

- BALLOONS
- DRINKING STRAW
- SMOOTH STRING OR FISHING LINE (AT LEAST 10 FEET)
- TAPE (EXAMPLE: MASKING TAPE)
- TAPE MEASURE
- SMALL WEIGHTS (COINS, PAPER CLIPS, ETC.)

Introduction: Understanding how the balloon is able to move across the string will help participants understand how model rockets lift off of the launch pad.



BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH "THIRD LAW OF MOTION: LAW OF REACTION" IN THE CONSTRUCTION AND FLIGHT OF MODEL ROCKETS UNIT 2 MANUAL.

Before the Activity (steps facilitator must take prior to the activity)

If it has been a while since they have read "Third Law of Motion: Law of Reaction," review this section with the participants. Answer any questions that they may have about the laws of motion.

Let's Do It! (steps to conduct the activity)

- Thread the string through the drinking straw. If you are doing this in a group with multiple participants, have a helper hold each end of the string, pulling the string taut. If you do not have multiple helpers, tie or tape one end of the string to a stationary object, and then you hold the other end taut. The straw should be close to one end of the string.
- Blow up the balloon. (Do not tie the opening.)
- Have another helper carefully tape the balloon to the drinking straw. The straw should be taped in the middle of the balloon (this will help with stability). The opening of the balloon should be facing the end of the string that the balloon is closest to.
- Release the balloon, and measure the distance it travels.
- Attach weights to the bottom of the balloon using a bag or a cup, and try this again. Make note of any changes.

ROCKET BALLOONS: TALK IT OVER

OPENING QUESTION:

- What is Newton's Third Law of Motion?

SHARE:

With the group or individual, discuss what happened to the balloon. Have them explain why the balloon moved across the string and how this displays Newton's Third Law of Motion.

REFLECT:

Discuss how this activity relates to launching model rockets and where they can see Newton's Third Law of Motion when launching model rockets.

GENERALIZE:

What parts of the balloon acted similar to parts of a model rocket when it launches? What did we learn from this activity that can help us understand the model rocket flight process?

TERMS:

- NEWTON'S THIRD LAW OF MOTION - for every action (force) there is an equal and opposite reaction (force)
- THRUST - a push or pull
- DRAG - a force that tends to slow the movement of an object through liquid or gas
- GRAVITY - a force that pulls everything down toward the center of the earth

APPLY:

Why would understanding Newton's Third Law of Motion help someone become a better rocket scientist? What are some other ways you have seen Newton's third law in action?

Success Indicator:
Explain Newton's Third Law of Motion.

Learn More:
Did you know that an apple never actually fell on Isaac Newton's head? Many people talk about a scenario where an apple fell on his head causing him to think about why the apple fell in the first place. In reality, he did witness an apple falling leading to his Theory of Gravity, but it never hit him in the head!

Reference for Activity:
4-H Basic Model Rocketry Manual Units 1 & 2, 1/2012, CSU Extension

ROCKET BALLOONS HANDOUT

DIRECTIONS

Record information from releasing the balloon on the chart below.
Attach weights to the bottom of the balloon using a bag or a cup, and try releasing the balloon again. Make note of any changes.

	Distance Traveled	Other Observations
No added weight		
A little added weight		
Lots of added weight		

VARIATION:

Participants should experiment with this activity. They can use different types of balloons, blow them up to various capacities, and adjust where the balloon is taped to the straw. Participants can also tape a small paper cup to add weights (paperclips or pennies). Students can investigate how many pennies they can carry across the space. If you add weights, discuss how this demonstrates Newton's second law of motion.

DRAWING FORCES

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: LEARNING TO LEARN, CRITICAL THINKING
TIME NEEDED: 20-30 MINUTES
SPACE: TABLE
SUGGESTED GROUP SIZE: ANY

LEARNER OUTCOMES:

Participants will understand which forces are acting on a model rocket when it is on the launch pad, accelerating, and decelerating.

NGSS Crosscutting Concepts

Cause and Effect: Cause and effect relationships are routinely identified.

Systems and System Models: A system can be described in terms of its components and their interactions.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

CCSS.ELA-LITERACY.W.3-5.2.D
Use precise language and domain-specific vocabulary to inform about or explain the topic

CCSS.ELA-LITERACY.L.4.6
Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases, including those that signal precise actions, emotions, or states of being (e.g., quizzed, whined, stammered) and that are basic to a particular topic (e.g., wildlife, conservation, and endangered when discussing animal preservation)

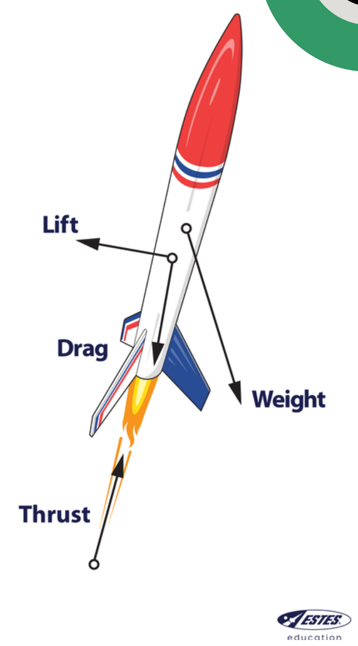
TAGS: MODEL, ROCKET, MODEL ROCKETRY, SCIENCE, PHYSICS, DRAWING

LESSON PREPARATION

MATERIALS LIST

- PAPER
- WRITING UTENSILS

Introduction: To understand the science of rocketry, it is important to first understand the concept of a force. In this activity, youth will identify the forces acting on a model rocket when it is sitting on the launch pad, accelerating, and decelerating.



Before the Activity

If it has been a while since they have read "The Science of Model Rocketry," review this section with the participants. Answer any questions that they may have about forces.

BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH "THE SCIENCE OF MODEL ROCKETRY" SECTION IN THE CONSTRUCTION AND FLIGHT OF MODEL ROCKETS UNIT 2 MANUAL.

Let's Do It!

Group:

- Start by drawing a picture of a model rocket on a launch pad, when accelerating, and decelerating (if it is a small group, this can be done on a piece of paper. If it is a larger group, you may be able to use a white board, poster paper, etc.)
- Ask the group what forces are acting on the model rocket at each of these stages and label them on the picture.

Individually:

- Have each youth draw a picture of a model rocket on a launch pad, accelerating, and decelerating.
- Ask them to label each of the forces acting on the rocket at each of these stages and include arrows to show which direction the forces are acting on the rocket.

DRAWING FORCES: TALK IT OVER

OPENING QUESTIONS:

- What is a force?
- What is lift?
- What is drag?
- What is thrust?
- What is weight?

SHARE:

If participants did this individually, ask them to share their drawing and what forces they labeled. As a group, go through each of the forces and have them think about each stage the model rockets are in. If they missed any forces, have them label that force now.

REFLECT:

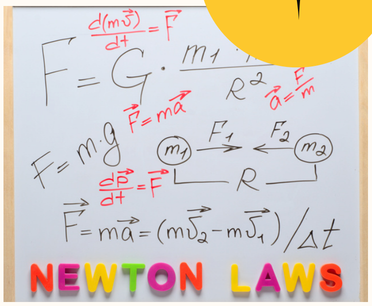
Discuss how this activity helps them have a better understanding of the flight process. You can discuss how these forces may be different for planes, birds, etc.

GENERALIZE:

Ask them to explain how the forces in the stage before affect the forces in the next stage. How do the parts of the rocket cause different forces to have an effect on the flight?

TERMS:

FORCE - an action that changes or maintains the motion of an object
GRAVITY - a phenomenon where an object with mass is attracted to another object with more mass
DRAG - force that tends to slow the movement of an object through liquid or gas
LIFT - a side force used to stabilize and control the direction of flight
WEIGHT - an object's mass multiplied by the force of gravity
THRUST - the force that causes an object to move



Success Indicator
Identify which forces are acting on a model rocket at each stage.

Acknowledgments and References
Estes Education

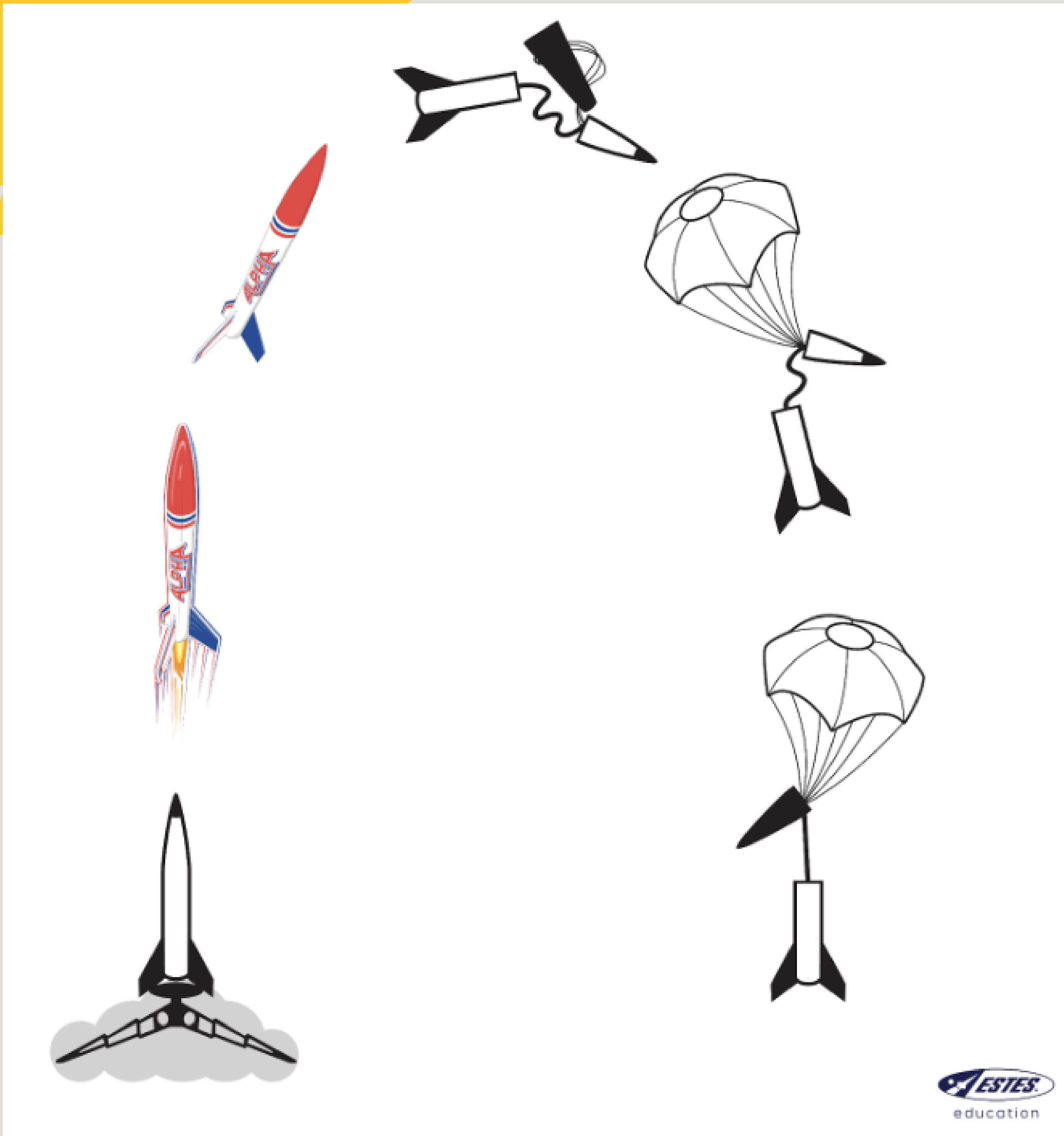
APPLY:

Ask how this activity helped participants understand cause and effect. Can they think of other experiences in everyday life that have a similar chain reaction?

VARIATION:

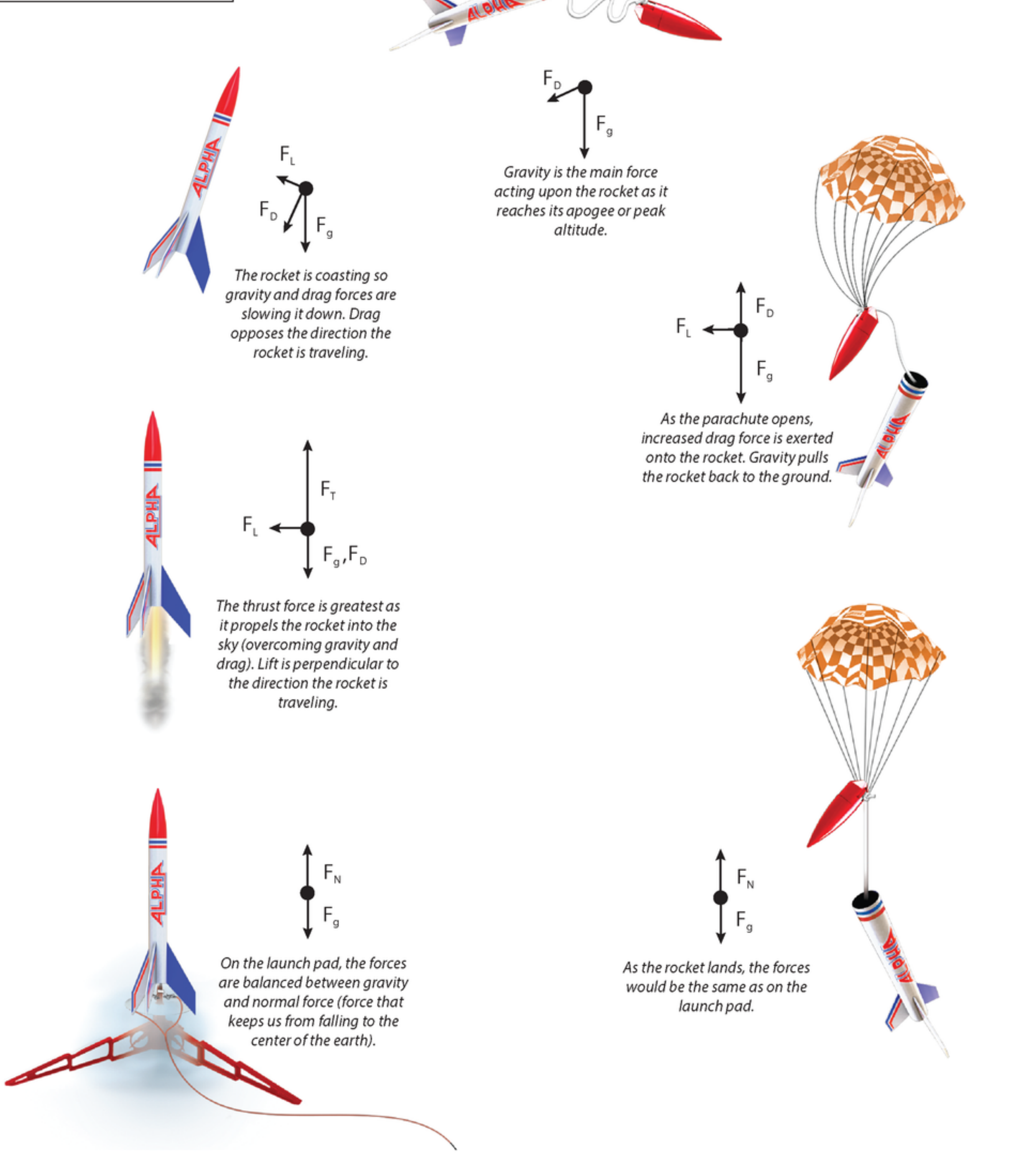
If need be, an unlabeled flight path (see handout on next page) can be printed ahead of time for younger participants or to save time. Participants could also build three dimensional models showing rockets at each stage and the forces acting upon it.

DRAWING FORCES HANDOUT



DRAWING FORCES HANDOUT ANSWER KEY

Key:
Drag Force F_D
Gravity/Weight Force F_g
Lift Force F_L
Normal Force F_N
Thrust Force F_T



ESTES education

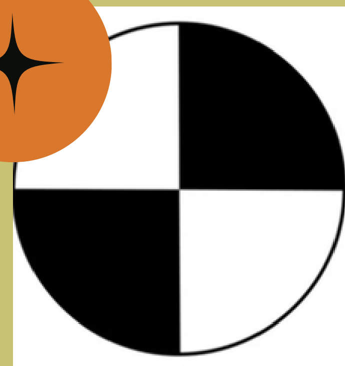
ROCKET STABILITY

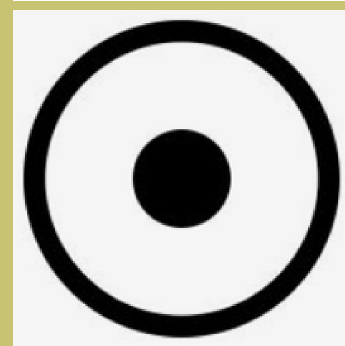
LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: CRITICAL THINKING, LEARNING TO LEARN
TIME NEEDED: 20-30 MINUTES
SPACE: A LARGE OUTDOOR AREA
SUGGESTED GROUP SIZE: ONE

LEARNER OUTCOMES:

Participants will identify where the center of gravity and center of pressure are on a model rocket. Then they will use that information to decide if their model rocket is stable.





EDUCATIONAL STANDARDS

3-5-ETS1-3 Engineering Design
Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

NGSS Crosscutting Concept:
Structure and Function: The way an object is shaped or structured determines many of its properties and functions.

3-PS2-1 Motion and Stability: Forces and Interactions
Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2 Motion and Stability: Forces and Interactions
Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

TAGS: MODEL, ROCKET, MODEL ROCKETRY, SCIENCE, PHYSICS, STABILITY

LESSON PREPARATION

MATERIALS LIST

- CONSTRUCTED MODEL ROCKET WITH MOTOR IN
- STRING (6-10 FEET OF DURABLE STRING)
- CARDBOARD
- PENCIL
- BOX CUTTER OR HOBBY KNIFE

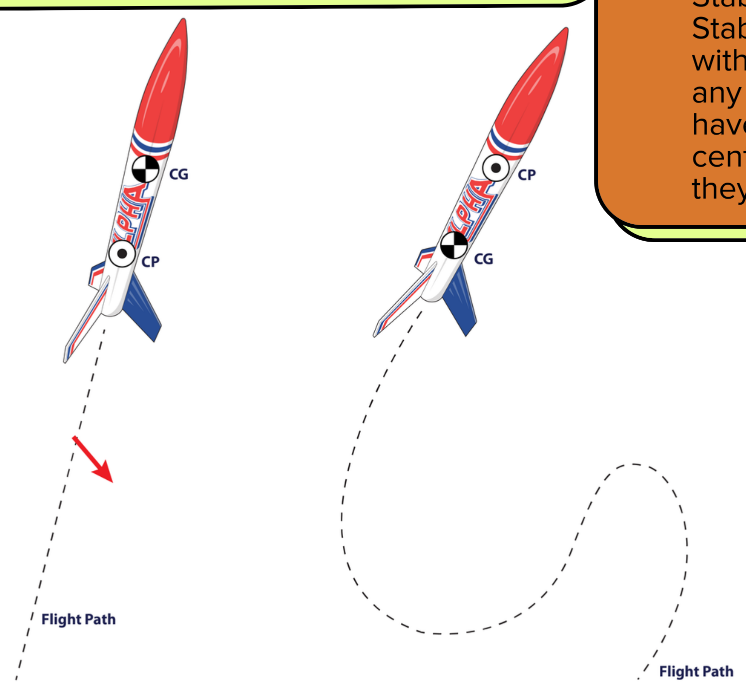
Introduction: Rockets are designed with safety in mind meaning that stability is important. Stability in rocketry means a rocket has a straight and predictable flight path. There are two main terms important to rocket stability: center of gravity and center of pressure. In this activity, youth will learn how to identify both the center of gravity and the center of pressure and determine if the rocket is stable or unstable.

BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH CHAPTER 2: ROCKET STABILITY—UNDERSTANDING STABILITY IN THE CONSTRUCTION AND FLIGHT OF MODEL ROCKETS UNIT 2 MANUAL.

Before the Activity

- If it has been a while since they have read Chapter 2 “Rocket Stability—Understanding Stability,” review this section with the participants. Answer any questions that they may have about center of gravity, center of pressure, or where they should align on the rocket.



For stable flight, center of gravity must be above center of pressure.
To improve stability, add weight to the nose, or increase fin area.

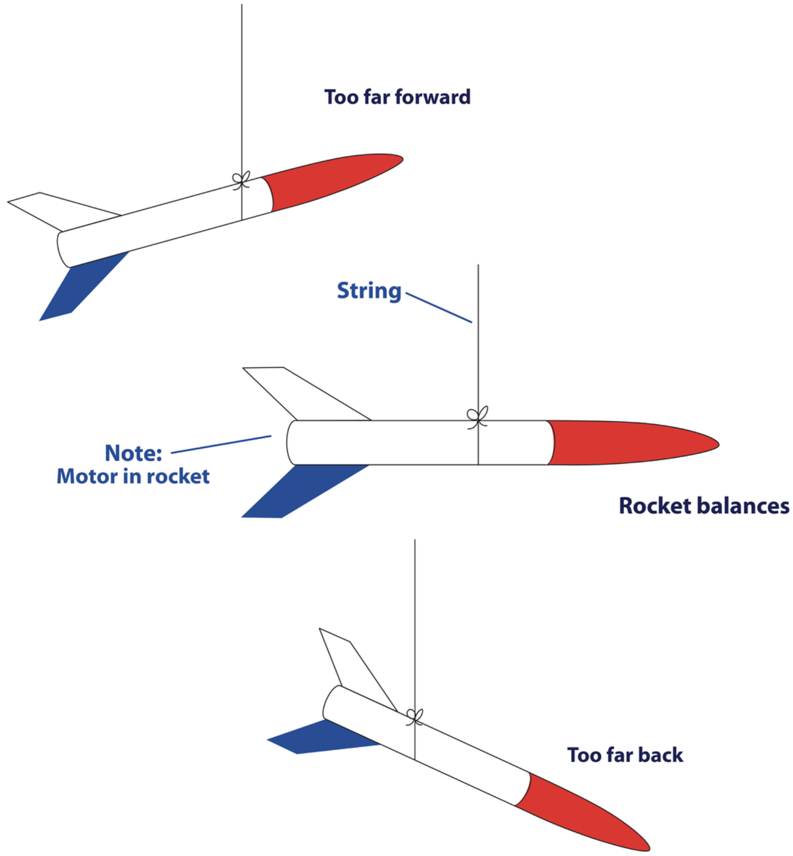
ESTES education

ROCKET STABILITY

Let's Do It!

Part 1: Finding the center of gravity

- Tie some string around the rocket. The string does not have to be very long. Just long enough that it will tie around your rocket and have enough room to dangle. Be sure to have an engine inside the rocket.
- Move the location of the string on the rocket until it stays horizontal on its own.
- Mark this location on the rocket using a writing utensil or a piece of tape. Use the letters "CG" to label this spot. We will need this location later.



VARIATIONS:

You could do this activity as a group. Ideally, each participant should check their own rockets, but the activity could be completed as a group first. If you have access to or can build a rocket with the center of gravity closer to or below the center of pressure than it should be, using a swing test or wind tunnel with this rocket could help participants get a better understanding.

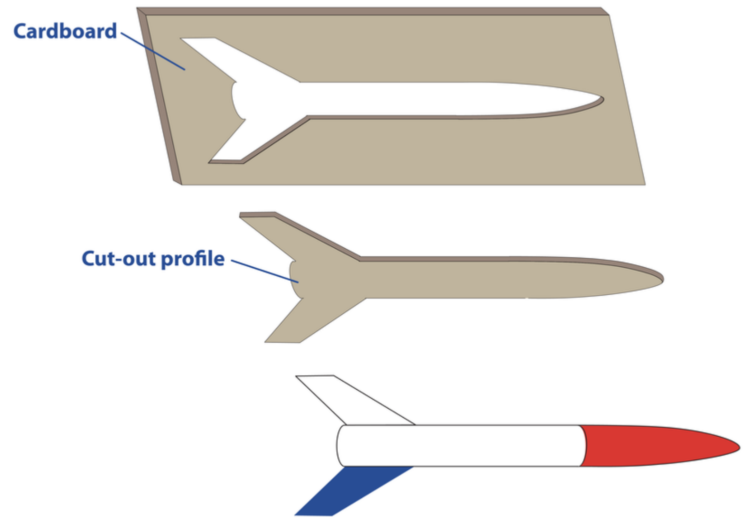
Another variation of this activity would be to add weight to the nose cone or with different sized engines to see how those changes in weight distribution can impact the stability of the rocket.

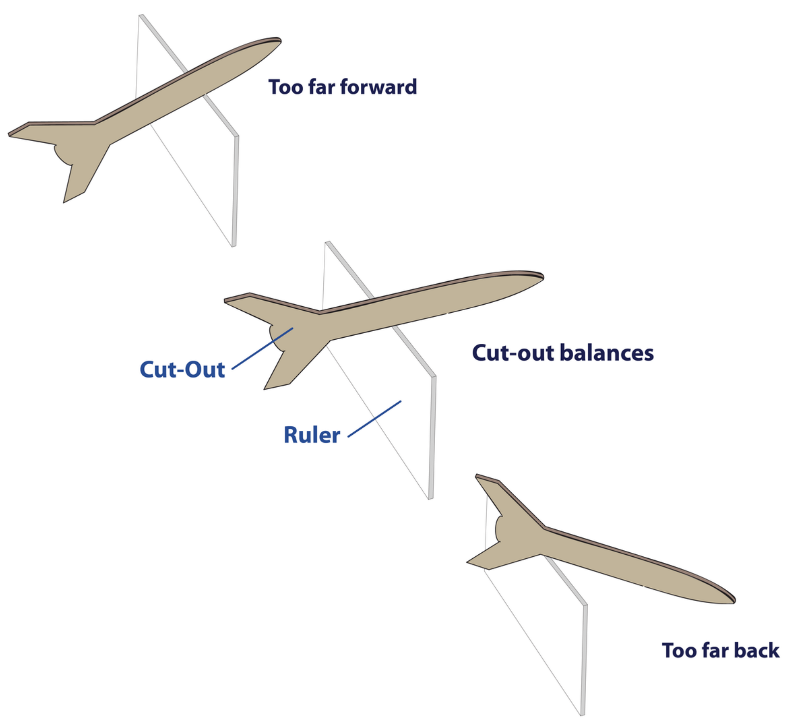
ROCKET STABILITY

Let’s Do It!

Part 2: Finding the center of pressure

- Cut out a profile of your rocket in cardboard. It does not have to be the same size, but it does need to be accurate in shape and scale
- Balance your cutout on the edge of a ruler.
- Mark where it balances on the rocket and use “CP” to label this spot.





ROCKET STABILITY

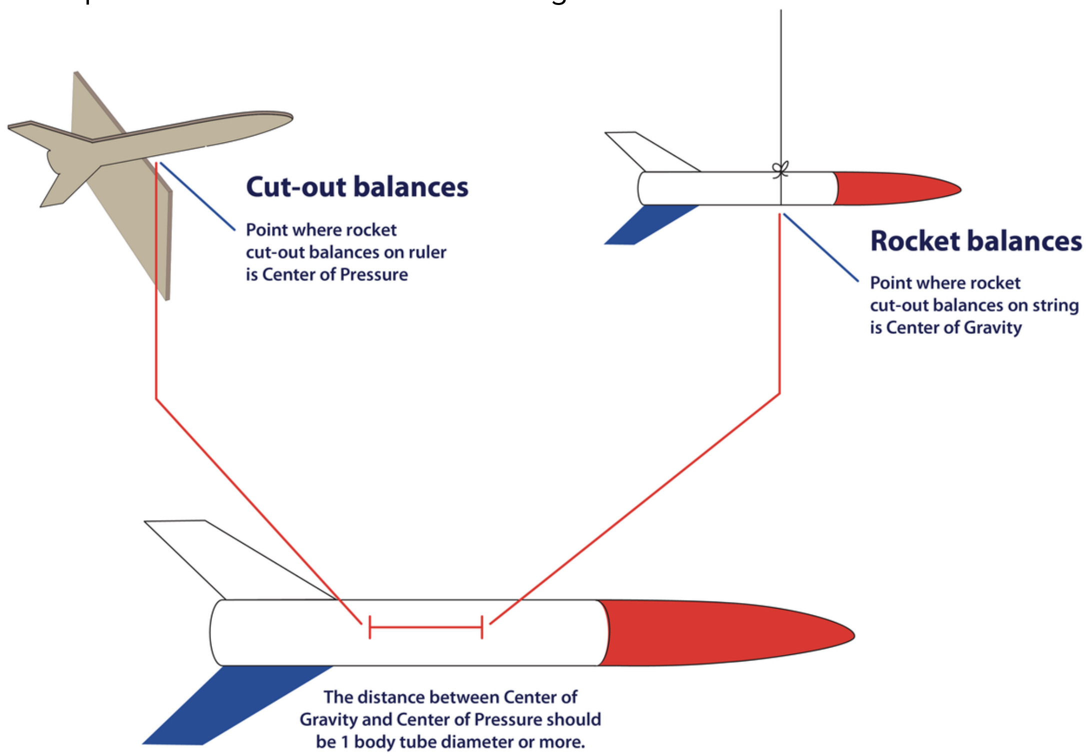
Let's Do It!

Part 3: Swing test

- Tie string around the body of the rocket at the CG point with a motor installed. Gently swing the rocket around your head like a lasso. Begin slowly with a short amount of string. Slowly release the rest of the string until you can grab the handle. Be sure to have plenty of space between you and your peers. If it flies straight without wavering, then it is stable. If it does not fly straight, then it is not stable.

Part 4: Is it stable?

- Determine how far apart the center of gravity and the center of pressure are from each other. Then determine whether or not the rocket is stable. Measure the diameter of your rocket, and then record what that value is times 1.5 and times 2. This is the range that the difference between the center of gravity and center of pressure should be for a stable flight.



ESTES education

ROCKET STABILITY: TALK IT OVER

OPENING QUESTIONS:

- What is the center of gravity?
- What is the center of pressure?
- Where should these align on a model rocket for it to have a stable flight?
- How can we ensure a stable flight path of a model rocket?

SHARE:

Ask the participants to describe how far apart the center of gravity and the center of pressure are. Ask them if they remember which of these measurements should be closest to the nose cone and how much distance there should be between the two. Based on these responses, ask them if this rocket is stable.

REFLECT:

Discuss how this activity relates to launching model rockets. If the center of gravity and center of pressure are not the correct distance apart, have youth discuss what they can do to fix the problem (ex. Adding putty to the nose cone.)

GENERALIZE:

Why is it important to know where the center of gravity and center of pressure are located on a model rocket. What would happen to the model rocket during flight if it is unstable?

TERMS:

- CENTER OF GRAVITY - The balance point of an object.
- CENTER OF PRESSURE - The point at which the aerodynamic forces on a rocket in flight are centered.
- STABILITY - When the center of gravity is above the center of pressure.

Did you know?

Learn more about stability with a free rocket simulator, Open Rocket. Try to build your own designs into something stable.
https://openrocket.info/

Acknowledgments and References

4-H Basic Model Rocketry Manual Units 1 & 2, 1/2012, CSU Extension, Estes Education

APPLY:

Did you learn more from reading about the center of gravity and center of pressure or from finding their locations on your model rocket? What did that teach you about how you learn best?

COST OF BUILDING SUPPLIES

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: LEARNING TO LEARN, CRITICAL THINKING
TIME NEEDED: 30 MINUTES
SPACE: TABLE
SUGGESTED GROUP SIZE: ANY

LEARNER OUTCOMES:

Participants will identify how to build a model rocket kit on a budget and understand profit and costs.

Success Indicators

Participants will design a model rocket kit on a budget.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

CCSS.2.MD.C.8. Solve word problems involving dollar bills, quarters, dimes, nickels, and pennies, using $ and ¢ symbols appropriately

CCSS.4.MD.A.2. Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale.

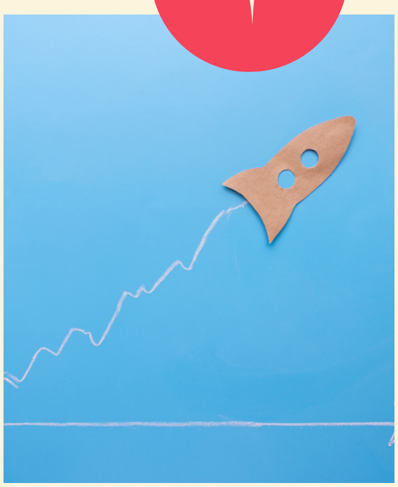
TAGS: MODEL, ROCKET, MODEL ROCKETRY, COST, SPENDING, BUSINESS, PROFIT

LESSON PREPARATION

MATERIALS LIST

- PAPER
- PENCILS
- CALCULATOR

Introduction: Every day we make decisions about where to spend our time and money. This activity will help youth think about budgeting, quality, and entrepreneurship as they design a model rocket kit.



BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH "CONSTRUCTION SUPPLIES AND TOOLS" IN THE MANUAL.

Before the Activity

- If participants have not read through "Construction Supplies and Tools," read through this section with them.

Let's Do It!

- Go through the opening questions with participants. Help them understand how and why businesses may price their items.
- Using the supply tables on the next three pages, ask participants to design a model rocket. (They do not have to focus on stability for this activity.) Give them a price limit that they have to keep their model rocket under.

VARIATIONS:

Depending on the age of the participants, leaders can determine different budgets that would make this activity easier or more difficult. You can also ask youth to identify how much they would have to sell their model rocket kits for in order to make a profit. Then discuss how the risks they identified might impact their selling price.

COST OF BUILDING SUPPLIES: TALK IT OVER

OPENING QUESTIONS:

- How do businesses decide the price of their products?
- What do profit and loss mean?
- Why is it important to think about what supplies you might use for items you plan to sell?

SHARE:

With the group or individually, discuss how youth decided what items to use for their model rocket kit. Ask what parts challenged them.

REFLECT:

Ask participants to identify risks that could apply to their “business” of selling these model rocket kits. If they are struggling to identify them, discuss how things like shipping costs, damage to parts during shipping, etc. could impact their profit.

GENERALIZE:

Ask youth if they think these risks could impact their profit.

TERMS:

- PROFIT - The difference between the money a business receives and the money the business spends in the same time period.
- LOSS - When you sell something for less than it cost.
- COST - The money that flows out of a business.
- RISK - Something that can go wrong.

APPLY:

Why might it be important for participants to understand the business side of this project? What other places can they use this information?

Did you know?

Did you know that Estes Rockets was started in Denver, Colorado, in 1958? They have stayed in Colorado since they started and are currently operating in Penrose, Colorado.

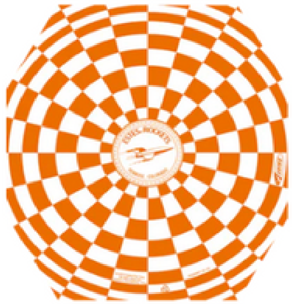
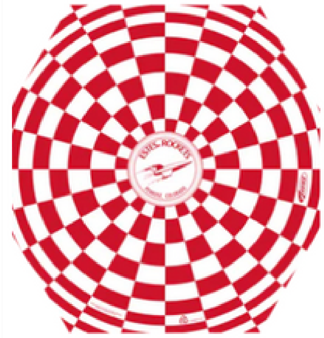
COST OF BUILDING SUPPLIES: SUPPLY TABLE

Nose Cones	 **NC-80K Nose Cone** $4.49	 **NC-80b Nose Cone (1 pk)** $4.99	 **Egg Capsule Nose Cone** $4.99

Body Tubes	 **Pro Series II™ 3" OD Slotted Body Tube** $10.99	 **Pro Series II™ 3" OD Body Tube** $6.99	 **BT-80 Body Tube** $9.99

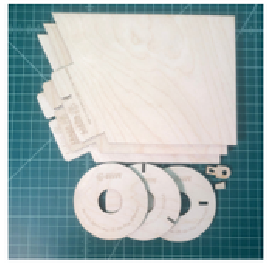
Motor Mount	 **D and E Engine Mount Kit** $11.99	 **Regular Engine Mount Kit** $7.99	

COST OF BUILDING SUPPLIES: SUPPLY TABLE

Parachute	 **12 Inch Printed Parachute** $4.99	 **18 Inch Printed Parachute** $5.99	 **24 Inch Printed Parachute** $6.99

Paint	 **White Acrylic Paint** $5.99	 **Spray Paint** $6.98	 **GLOSSCOTE Gloss Clear LACQUER** $5.99

COST OF BUILDING SUPPLIES: SUPPLY TABLE

Fins	 **Balsa Wood Sheet** $5.99	 **Mega Der Red Max Plywood Fin Upgrade Set of 3** $29.59	 **Balsa Wood Surface** $5.99
"Extras"	 **BT80 Tube Couplers** $2.94	 **Launch Lug Pack** $7.64	

AIR PRESSURE STRAW ROCKETS - HOW DOES ROCKET DESIGN IMPACT FLIGHT?

LESSON INFORMATION

SKILL LEVEL: BEGINNING (AGES 8-10)
LIFE SKILLS: LEARNING TO LEARN, CRITICAL THINKING
TIME NEEDED: 1.5 HOURS
SPACE: SMALL AREA OUTSIDE
SUGGESTED GROUP SIZE: 8-10

LEARNER OUTCOMES:

Participants will identify how all three of Newton's Laws of Motion affect the way a model rocket flies.

EDUCATIONAL STANDARDS

COMMON CORE STATE STANDARDS

3-PS2-1 Motion and Stability: Forces and Interactions
Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2 Motion and Stability: Forces and Interactions
Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

3-5-ETS1-3 Engineering Design
Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

LESSON PREPARATION

MATERIALS LIST

- PAPER DRINKING STRAWS (NO BENDS)
- SCOTCH TAPE
- SAMPLE STRAW ROCKET (PREPARED BY LEADER AHEAD OF TIME)
- MODELING CLAY
- CARD STOCK
- SCISSORS
- STRAW ROCKET LAUNCHER

Introduction: Launching the Air Pressure Straw Rockets will allow youth to experiment with rockets of different shapes and sizes without the expense and time of building model rockets. Through this activity, youth should be able to identify how each of Newton's Laws of Motion are present in the launching of model rockets.

TAGS: MODEL, ROCKET, MODEL ROCKETRY, SCIENCE, PHYSICS, AIR PRESSURE

NGSS Crosscutting Concepts

Structure and Function: The way an object is shaped or structured determines many of its properties and functions.

BACKGROUND INFO

PARTICIPANTS SHOULD HAVE READ THROUGH "THE SCIENCE OF MODEL ROCKETRY" SECTION IN THE CONSTRUCTION AND FLIGHT OF MODEL ROCKETS UNIT 2 MANUAL.

Before the Activity

- If it has been a while since they have read "The Science of Model Rockets" review this section with the participants. Answer any questions that they may have about the laws of motion.
- The leader should build a sample straw rocket for participants to refer to.

LESSON PREPARATION

Let's Do It!

- Show youth an example of an air pressure rocket and have them name the parts: body tube, fins, and nosecone. Launch the example the leader has built ahead of time. If time allows, each participant can build a control similar to the version the leader created.

- Discuss all the possible variables when building an air pressure rocket:
  - Size of fins
  - Location of fins
  - Fin material
  - Shape of fins
  - Size of body tube

- Let's build! Have the participants cut their straws (body tubes) to any length they wish. Next, have them take a small thumb-tip size of clay and "plug up" one end of the rocket, shaping it into a nose cone. Tell the participants to smooth the clay over the tip of the body tube just far enough to seal any air holes. Ask youth to build each rocket differently. That way they can see the impact these changes may have on the stability of the flight. If only one youth is participating, have them build multiple rockets.

- Have youth then cut three fins to attach to the other end of the rocket with tape.

- Gently load the straw onto the launching tube, making sure the youth do not jam it on, as this can cause clay to get into the tube and cause launch failure.

- You can either have youth launch for altitude or aim for a target by rotating the launching tube gently to an angle. For safety purposes, aim the rocket away from people and at an angle between 30 and 90 degrees.

- Before youth begin launching their own rocket, launch your sample rocket so that youth can see what a stable flight should look like.

- As each participant is ready to launch their rocket, have them compare it to the sample. Ask them how they think their rocket will fly compared to the control, and why they think the differences in rockets will lead to that change. When the youth are ready to launch the rocket, have them pull the rod up and just let it go. Do not allow them to slam it down, as it makes no difference in the rocket performance and only compresses the spring and damages the launcher.

- Have youth look at how each of their peers' rockets launched. Ask them to think about why some rockets had a more stable flight than others.

- Have youth draw the flight path of their straw rocket and then label the forces that were acting on it at each phase.

AIR PRESSURE STRAW ROCKETS: TALK IT OVER

OPENING QUESTIONS:

- What are Newton's Laws of Motion?
- How do you think different sized fins will affect the flight of straw rockets?
- How do you think different sized body tubes will affect the flight of a rocket?
- How do you think the parts of the straw rocket will impact its flight?

SHARE:

After each participant or group has launched their rocket, discuss with the group the differences in flight between each of the rockets. Discuss how each of Newton's Laws of Motion affected the flight of each rocket. Also discuss what part of each design may have caused a change in its flight. Fill out the comparison table.

REFLECT:

Discuss how this activity relates to launching model rockets and where they can see Newton's Laws of Motion when launching model rockets. If possible, look at photos or videos of model rockets and discuss how they think each rocket would fly based on what they learned.

GENERALIZE:

How did that activity help give you a closer look into how model rockets are launched?

APPLY:

How did experimenting with different parts of a model rocket help you become a better problem solver?

Learn More

Check out the Forces and Motion simulator: https://phet.colorado.edu/en/simulations/forces-and-motion-basics

References

4-H Basic Model Rocketry Manual Units 1 & 2, 1/2012, CSU Extension

AIR PRESSURE STRAW ROCKETS: TALK IT OVER

TERMS:

- NEWTON'S FIRST LAW OF MOTION - An object in motion stays in motion unless a force acts upon it
- FORCE - an action that changes or maintains the motion of an object
- LIFT - a force that directly opposes the weight of an aircraft and holds the aircraft in the air
- GRAVITY - a phenomenon where an object with mass is attracted to another object with more mass
- INERTIA - an object at rest will remain at rest unless acted upon by another force
- MASS - how much matter is in an object
- ACCELERATION - any change in speed or direction, whether positive or negative
- DECCELERATION - a decrease in speed
- NEWTON'S THIRD LAW OF MOTION - for every action, there is an equal and opposite reaction
- ACTION (in regard to the law) - a force that tends to maintain or alter the movement of an object
- REACTION (in regard to the law) - the opposite force of the action
- THRUST - the force that causes an object to move
- DRAG - force that tends to slow the movement of an object through liquid or gas.
- CONTROL - an element that remains unchanged or unaffected by variables
- VARIABLE - an element, feature, or factor that is liable to change

VARIATIONS:

If you are planning to do this experiment with one participant or a smaller group, try this experiment while changing one item at a time. Have participants start by building and launching a control rocket. Then change one thing at a time. For example, change the amount of force from the launcher. Have participants record the differences they notice.

Another method to launch a straw rocket is to buy two sets of straws, where one just fits inside the other snugly, but not tight. These work great as the participant uses their own air power, blowing off the top straw (rocket).

AIR PRESSURE STRAW ROCKETS HANDOUT

	Control	What changed	Observations
Size of fins			
Location of fins			
Fin material			
Shape of fins			
Force of launch			
Size of body tube			
Other:			
Other:			

Example Table:

	Control	What changed	Observations
Size of fins	1 inch tall	Made fins 2 inches tall	
	1 inch tall	Made fins ½ inch	
Location of Fins	½ inch from bottom	Fins at top of rocket	
	½ inch from bottom	Fins at bottom of rocket	
Fin Material	Cardstock	Light cardboard	
	Cardstock	Regular paper	
Shape of fins	Clipped delta	Rectangular	
	Clipped delta	Elliptical	
Force of launch			
Other:			

MY MODEL ROCKETRY NOTES

MY MODEL ROCKETRY NOTES

Colorado 4-H Mission

4-H empowers youth to reach their full potential by working and learning in partnership with caring adults.

Colorado 4-H Vision

A world in which youth and adults learn, grow and work together

4-H Pledge

I pledge…..
My head to clearer thinking,
My heart to greater loyalty,
My hands to larger service,
My health to better living
for my club, my community,
my country and my world.

Promesa 4-H

Prometo usar mi mente para pensar con más claridad,
mi corazón para ser más leal,
mis manos para ser más servicial,
mi salud para cuidarme más,
por mi club, mi comunidad, mi país y mi mundo.

4-H Motto

"To Make the Best Better."

COLORADO STATE UNIVERSITY
EXTENSION

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