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Science and Model Rockets

A Curriculum for Grades 5-8

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INTRODUCTION

This curriculum guide is designed to meet the needs of the teacher who has had experience teaching rocketry to students as well as the teacher who is a beginner in teaching rocketry.

Rocketry is an excellent means for teaching a number of scientific concepts such as aerodynamics, center of gravity, point of balance, apogee, drag and thrust. It is also great for the teaching of math using problem solving, calculating formulas, geometry and determining altitude and speed.

Graphing is another skill which can be used in rocketry.

In learning to construct rockets, the student must follow directions, read a diagram and work carefully and precisely.

This guide is intended to make it as easy as possible to understand rockets and to teach about rockets. The objectives for each lesson are stated, along with a list of the vocabulary to be emphasized, the materials needed and what to do during each lesson. The background for the teacher is designed to give the necessary information to present the lesson and to help the teacher develop understanding of the concepts.

This guide is directed to teachers of fifth, sixth, seventh and eighth grades whose students have had little or no experience with rockets. The math may be challenging for some fifth, sixth or seventh graders. If that is the case, the math does not need to be done independently. The teacher may choose to guide the students through all activities and problems.

This curriculum provides an introduction to an enhancement of the study of space, space exploration, the study of motion or aerospace education.

GOALS

- Bring science to life through the experience of building and flying a model rocket.
- Integrate rocketry with science and math.

STUDENT OUTCOMES

The student will be able to:

- Describe and demonstrate proper safety procedures when launching a rocket.
- Identify each part of a rocket and describe its function.
- Construct an E2X Series or Beta Series rocket.
- Describe how an E2X Series or Beta Series rocket works from launch through acceleration, coasting, apogee and landing.
- Describe how fins provide aerodynamic stability to the flying rocket.
- Construct and demonstrate the use of an altitude measuring device.
- Describe rocket recovery systems and determine which type is best for the rocket being constructed.
- Demonstrate proper safety procedures based on the Model Rocketry Safety Code when launching a rocket.
- Describe Newton's three Laws of Motion and how they relate to model rocketry.

CONCEPTS TO BE DEVELOPED

- How a rocket is constructed.
- How the parts of a rocket function.
- How a rocket works.
- How math is related to rocketry, specifically formulas for determining altitude and speed.
- How science and rocketry are connected, specifically Newton's three Laws of Motion.

SCIENCE PROCESS SKILLS

- Observing
- Reading and following a diagram
- Predicting
- Describing
- Identifying
- Evaluating
- Problem Solving

GENERAL BACKGROUND FOR THE TEACHER

There are four basic forces operating on objects in flight such as a rocket. They are *gravity, thrust, drag* and *lift*.

Gravity is the force that pulls all objects toward the center of the earth. The amount of this force is proportional to the mass of the object.

Thrust is the force that propels the flying object.

Drag is the force acting on an object moving through a fluid. Since air and water are fluids, drag is the resistance that the object encounters as it moves through the fluid.

Lift is the force that is directed opposite to the force of gravity produced by the shape and position of a body moving through a fluid. An object moving in a vacuum produces no lift. Lift is generated by an object moving through a fluid if the object's shape causes appropriate reactions as the object moves through a fluid.

Newton's three Laws of Motion are concepts essential to understanding rocket flight. The laws will be an integral part of the lessons in this unit. The laws are as follows: 1. A body at rest will remain at rest, the body in motion will continue in motion with a constant speed in a straight line as long as no unbalanced force acts upon it. This law is often referred to as the law of inertia.

2. If an unbalanced force acts on a body, the body will be accelerated; the magnitude of the acceleration is proportional to the magnitude of the unbalanced force, and the direction of the acceleration is in the direction of the unbalanced force.

3. Whenever one body exerts a force on another body, the second body exerts a force equal in magnitude and opposite in direction of the first body. This law relates to the principle of action-reaction.

UNIT PLAN

Lesson 1 (One Day)

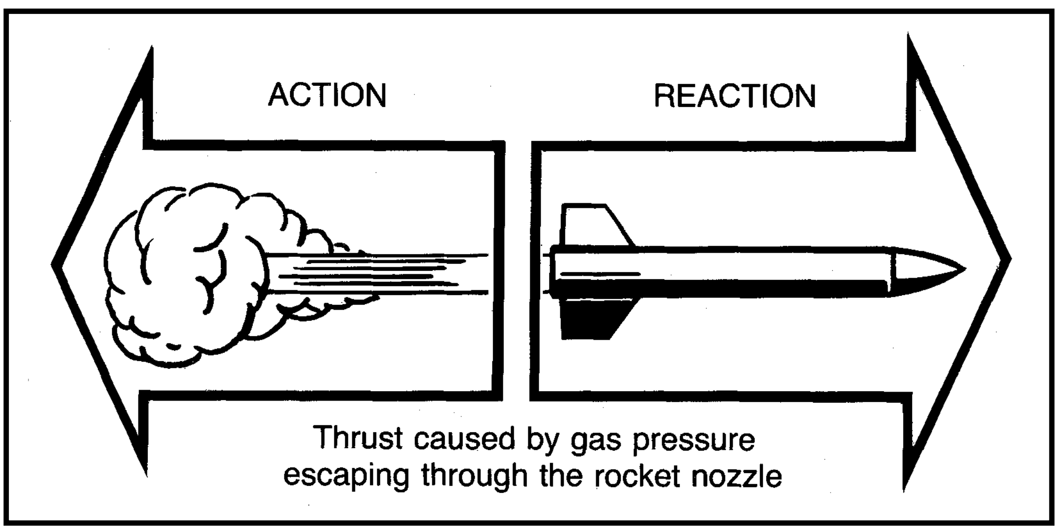
Learning About Motion and Flight With a Model Rocket

Objective of the Lesson:
The student will be able to:

- Identify and trace the basic path of a rocket from launch to recovery.
- Describe how Newton's Third Law of Motion relates to launching a model rocket.
- Begin the construction of a rocket by assembling the engine mount.
- Recognize and define vocabulary.

BACKGROUND FOR THE TEACHER

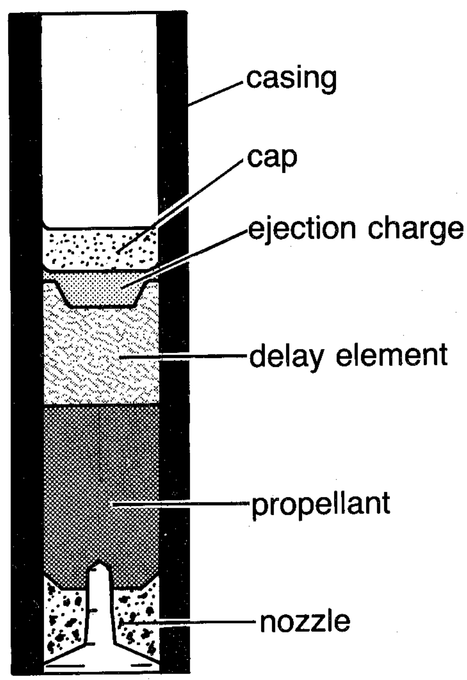
Thrust is the upward force that makes the rocket accelerate upward. This is a demonstration of Newton's Third Law of Motion : "For every action there is an equal and opposite reaction." The action is the gas escaping through the nozzle. The reaction is the rocket accelerating upward. The rocket will continue to accelerate until all of the propellant in the rocket engine is used up.



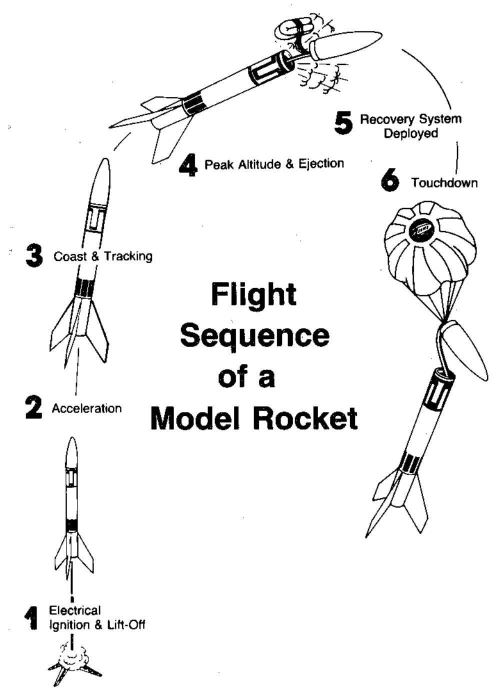
The casing of a model rocket engine houses the propellant. At the base of the engine is the nozzle, a heat-resistant, rigid material. The igniter in the rocket engine nozzle is heated by an electric current supplied by a battery-powered launch controller. The hot igniter ignites the solid rocket propellant inside the engine which produces gas while it is being consumed. This gas causes pressure inside the rocket engine, which must escape through the nozzle. The gas escapes at a high speed. This produces thrust.

Above the propellant is the smoke-tracking and delay element. Once the propellant is used up, the engine's time delay is activated. The engine's time delay produces a visible smoke trail used in tracking, but no thrust. The fast moving rocket now begins to decelerate (slow down) as it coasts upward toward apogee (peak altitude). The rocket slows down due to the pull of gravity and drag. Drag is the force that resists the forward motion of an object through the air.

When the rocket has slowed enough, it will stop going up and begin to arc over and head downward. This high point is the apogee. At this point the engine's time delay is used up and the ejection charge is activated. The ejection charge is above the delay element. It produces hot gases that expand and blow away the cap at the top of the engine. The ejection charge generates a large volume of gas that expands forward and pushes the parachute out of the top of the rocket. The parachute now opens and provides a slow, gentle and safe landing. The rocket can now be prepared to launch again!



Rocket Engine



VOCABULARY

Accelerate: Speed up.
Gravity: The force that pulls all objects to the center of the Earth.
Apogee: The peak altitude a rocket reaches when it is farthest from the surface of the earth.
Igniter: An electrical device that ignites the combustion of the propellant in a model rocket engine.
Decelerate: Slow down.
Launch: The lift off of a model rocket following the ignition of the engine.
Delay Element: Ignites after the propellant burns out and is an aid in tracking the rocket and in providing a time delay during which the rocket coasts to apogee.

VOCABULARY (Continued)

Propellant: A mixture of fuel and an oxidizer which is the source of motive energy in a rocket.

Drag: The force that resists the forward motion of an object as it moves through the air.

Recovery System: The device in a model rocket whose purpose is to return the rocket to the ground safely by creating excess drag or by creating lift.

Ejection Charge: Ignited by the delay element and produces expanding gases which activate or eject a recovery device.

Thrust: The force that makes the rocket accelerate upward as the propellant is burning.

STRATEGY

Materials Needed for Each Student: An Estes E2X Series or Beta Series rocket, the appropriate glue* (*Caution—-Plastic model cement should be used only in a well-ventilated area*) and a pencil. In addition, the teacher should have constructed one model rocket in order to understand the assembly and to serve as a demonstration model.

Each student should have a small shoe box or other similar shape and size box to store the model parts and instructions. If notches are cut in each side of the shoe box, the rocket can rest in them as the rocket is assembled and as glue is drying. Each student should have a manilla envelope or folder for the activity and record keeping sheets that will be accumulated during this unit.

**Requirements for types of glue are listed on the E2X or Beta kit instructions.*

MOTIVATION:

Show the students the rocket you have constructed. **(It is essential that the teacher construct the specific rocket before beginning this unit.)** Ask: What is this object? How does it work? (Allow the students to discuss how rockets are used in space specifically and other ideas they may have, such as rockets used to launch missiles and for launching fireworks.)

A. Using a blank overhead transparency, begin to put the outline of the events of a model rocket launch in order as the students contribute ideas. Begin with the launch and end with the recovery. Then display the overhead transparency (1: Flight Sequence of a Model Rocket). Use both transparencies to demonstrate the areas that need clarification. Label the appropriate parts of the engine as you describe the flight sequence.

B. Distribute a copy of the assembly instructions to each student. Ask the students to look at the assembly instructions and to highlight the parts necessary to construct the engine mount assembly. Distribute and identify the necessary parts for the students' engine mount assembly, a pencil and the appropriate glue. It may be necessary to go over each step of the directions for Section 1 with younger students before they follow the directions on their own.

C. The students should follow Step 1 in the E2X directions with the exception of building the parachute. When the students have completed assembly and gluing the engine mount, the assemblies should be put aside to dry for about ten minutes. Students can be given Student Activity Sheet #1, Rockets in Motion vocabulary study. The teacher may prefer to have students work in pairs or in threes to complete this sheet.

D. When the engine mounts are totally dry, the students should follow the instructions and glue the mounts into the rocket body tube

**Make certain the students glue the assemblies in the rocket body tube so that the engine hook hangs down toward the bottom of the rocket.*

When the students have finished this step, the body tube with the installed engine mount should be laid flat as it dries.

Closure:

Review with the students the concepts of thrust, launch, apogee, delay element, ejection charge, drag and recovery by asking them to read the definitions from their vocabulary sheet.

Extension:

A. The computer program <u>In Search of Space: Introduction to Model Rocketry</u>™, Estes Industries, is helpful to students in understanding the flight sequence of a rocket and in reinforcing the vocabulary. Students may want to use this program to complete their vocabulary sheet, using A, B and C from the menu.

B. The word search puzzle "Rockets in Motion" (Extension Activities) may be used in connection with the vocabulary sheet.

Solution to "Rockets in Motion" Wordsearch Puzzle

U	U	D	F	F	R	P	D	R	A	G	P	P	W	F	P	G	T	B	G	A
O	R	K	E	V	D	R	A	I	F	B	L	N	M	U	M	P	G	L	H	W
C	D	V	W	S	Z	O	C	G	Q	O	G	B	I	D	D	H	W	J	T	T
Z	E	O	V	Q	V	P	C	N	G	G	G	H	D	O	W	M	Y	S	P	H
F	W	T	V	N	R	E	E	I	M	J	W	W	R	P	O	P	M	E	L	R
S	M	H	O	S	M	L	L	T	R	A	C	K	I	N	G	M	I	Y	X	U
A	P	O	G	E	E	L	E	E	J	E	C	T	I	O	N	T	R	C	Y	S
D	E	L	A	Y	J	A	R	R	E	C	O	V	E	R	Y	C	D	V	I	T
C	O	Z	I	O	J	N	A	K	M	E	R	X	S	G	R	A	V	I	T	Y
B	C	W	I	I	Q	T	T	K	J	W	O	N	O	Z	Z	L	E	Q	W	H
L	I	F	T	O	F	F	E	L	A	U	N	C	H	R	A	I	C	N	E	O
D	E	C	E	L	E	R	A	T	E	R	I	M	P	C	O	A	S	T	O	F

ACCELERATE
APOGEE
COAST
DECELERATE
DELAY
DRAG
EJECTION
GRAVITY
IGNITER
LAUNCH
LIFT OFF
NOZZLE
PROPELLANT
RECOVERY
THRUST
TRACKING

Evaluation

The teacher will need to walk around and check as students are assembling the engine mounts. Some students may have difficulty with following the directions. Encourage the students to problem solve on their own, but since they will need a well-built rocket, they need to follow directions carefully. Going over the vocabulary words in class enables the teacher to determine which concepts are understood and which ones still need work.

NOTES

Activity sheet #1A

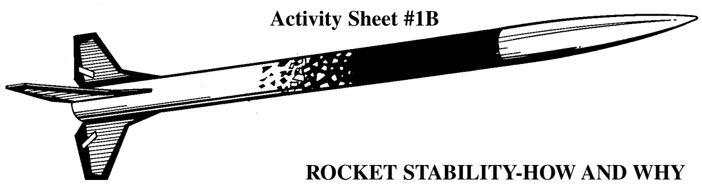
WORDS FOR ROCKETEERS

Directions: As you learn these words during each session about rockets, you can fill in the definition. If you need more information, you can also use a dictionary.

ROCKETS IN MOTION

1. Accelerate
2. Apogee
3. Decelerate
4. Delay element
5. Drag
6. Ejection charge
7. Gravity
8. Igniter
9. Launch
10. Propellant
11. Recovery system
12. Thrust

Activity Sheet #1B



ROCKET STABILITY-HOW AND WHY

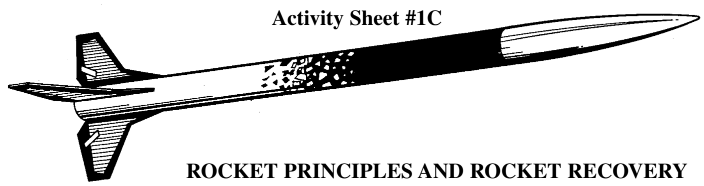
1. Action/Reaction
2. Aerodynamic Stability
3. Balance point
4. Fins
5. Launch Rod
6. Launch Lug
7. Velocity
8. Shock Cord

HISTORY GUESS

Who were the first people to develop rockets?

When were the first rockets developed?

Activity Sheet #1C



ROCKET PRINCIPLES AND ROCKET RECOVERY

1. Acceleration
2. Featherweight Recovery
3. Force
4. Glide Recovery
5. Helicopter Recovery
6. Mass
7. Motion
8. Parachute Recovery
9. Recovery Wadding
10. Rest
11. Shroud Line
12. Streamer Recovery
13. Tumble Recovery

Lesson 2 (One Day)

Rocket Stability - How and Why

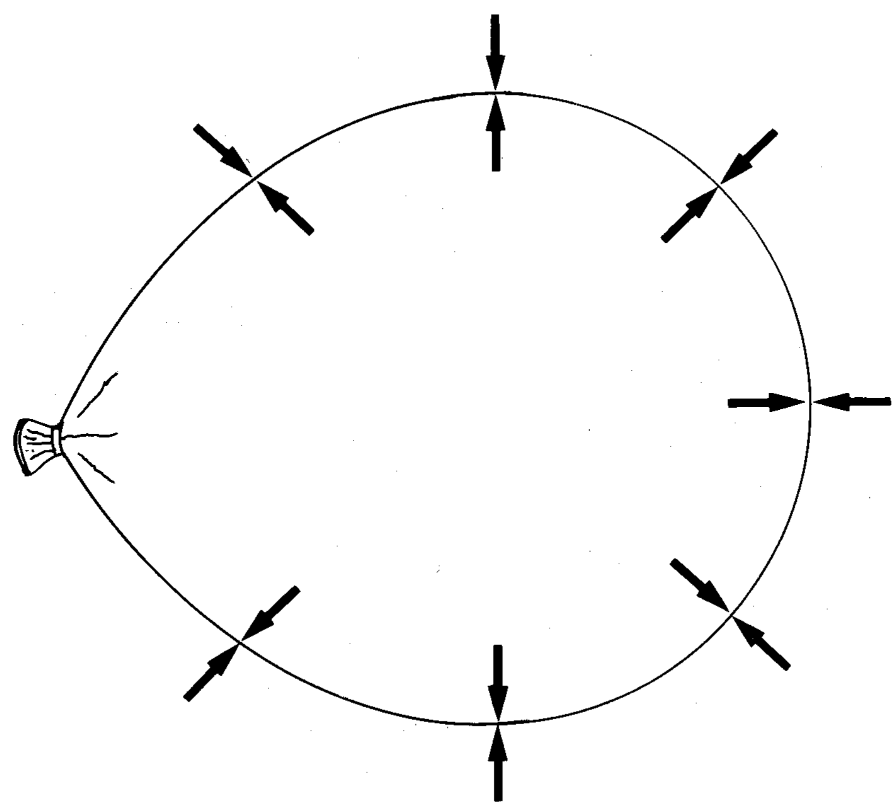
Objectives of the Lesson:

The student will be able to:

- Recognize the application of Newton's Third Law of Motion to rocket stability, the law of action and reaction.
- Describe the necessity of fins on a rocket for aerodynamic stability.
- Follow directions to add fins to a rocket correctly.

BACKGROUND FOR THE TEACHER

Newton's third Law of Motion states that whenever one body exerts a force on another, the second body exerts a force equal in magnitude and opposite in direction on the first body. An effective model of this law is an inflated rubber balloon. The pressure on the outside of the balloon is equal to the pressure on the inside.



Forces on an Inflated Balloon

When air is allowed to escape from the balloon, the balloon will fly about erratically. The unbalanced force on the inside front end of the balloon as on a rocket engine, pushes the balloon around the room or pushes a rocket through space. The action of the gas escaping from the balloon causes a reaction, moving the balloon forward.

Fins make a rocket fly straight. A rocket without fins will tumble around its balance point when flying through the air like a balloon that is inflated and then let go. The balloon will fly erratically because it is uncontrolled. With fins a rocket has more surface area behind the balance point than in front. The balance point is also known as the "center of gravity".

When the rocket is flying through the air, the air has more surface area to push against behind the balance point than in front because of the greater surface area provided by the fins. Therefore, the rocket tends to stabilize itself. The rocket will rotate until the nose is pointing forward in the air and the fins are pointing backward.

Fins only work to provide stability when the rocket is flying fast through the air and the rocket has left the launch rod on the launch pad. The students will glue a launch lug, which resembles a straw, on their rockets. The launch lug will slide along the launch rod. The launch rod guides the rocket as it is accelerating. When the rocket leaves the end of the launch rod, it is moving fast enough for the fins to take over the guidance of the rocket.

VOCABULARY

Action/Reaction: Newton's Third Law of Motion.

Fins: Provide guidance for the model rocket.

Aerodynamic Stability: Tendency of a rocket to maintain a straight course along the axis of its thrust.

Launch Lug: Slipped over the launch rod and guides the rocket in a stable path until the rocket has reached a speed at which the fins stabilize it.

Velocity: Rate of motion in a given direction measured in terms of distance moved per unit of time.

STRATEGY

Materials Needed: Pencil, instructions, body tube, launch lug(s), fins or fin unit and the appropriate glue for each student. The teacher should also have available an uninflated balloon and a completed model rocket. If possible, the teacher should show the video tape, Ignite the Imagination™, Estes Industries, or a similar video showing how model rockets are put together, the functions of the parts of a rocket and how much fun model rocketry can be.

Motivation:

If possible, show the video tape, Ignite The Imagination™ Estes Industries. Use Activity Sheet 2 to accompany the video. Before the students watch the video, ask them to fill in the first and second columns. As they watch the video, they can write some new information in the third column. Allow some students to share what new information they learned from the video. The students should put these sheets in their folders.

Show the students an uninflated balloon. Ask them what will happen to the balloon when it is inflated and then released. Allow the students to describe what they think will happen and to tell why.

Blow up the balloon and hold it so the air is trapped inside. Ask them to tell why they think the balloon stays inflated. Draw the diagram showing the pressures both inside and outside the balloon (Background for the Teacher) . Now let the balloon go. The students will observe that it flies erratically without control. If time permits and students are interested, distribute a balloon to each student. Allow them to inflate it and test its surface to feel the tension on the balloon's wall as the compressed air keeps the balloon inflated. Then allow them to release the balloon and observe its flight. Students can also let the balloon push against their open palms. They can feel the balloon push against their hands as the air escapes the nozzle.

Ask the students, "Is this how rockets move through space?" Let them discuss why not.

Allow the students to describe how they think the rocket should move. Show them the model rocket you made or a picture of a model rocket. Also refer back to the video they just watched. Ask, "What on this rocket do you think causes the rocket to move straight?" (Allow the students to guess which part does make the rocket move straight and ask them to support their guess.) The teacher should demonstrate how the fins provide guidance for the rocket. The basic principle is that the center of gravity must be ahead of the center of pressure for the rocket to be stable. The **center of gravity** is the point at which the mass of the rocket is balanced because the weight forward from this point is equal to the weight to the rear of this point. Refer to the balloon demonstration to show how fins provide the guidance the balloon did not have. The **center of pressure** is the point on the rocket at which half of the aerodynamic surface is located forward and half to the rear.

A. Using either the model rocket or a diagram of the rocket, explain how the fins stabilize the rocket. (Background For The Teacher)

B. Distribute each student's kit, making certain that there are fins, a rocket body, the engine mount assembly and launch lugs. Go over the assembly instructions with the students. Emphasize that it is important that the fins be glued correctly and carefully to provide stability.

C. If the rockets have individual fins (Beta Series rockets), demonstrate the correct way the fins go on by holding up the already completed rocket or a student's body tube and one fin. Walk around the room to check that each student can demonstrate the correct way to glue fins by holding one fin and their body tube.

If the rockets have a complete fin unit (E2X Series rockets), make certain it is all the way on and straight. Check each student's fins to make certain they are on correctly before they dry. The fins must dry before moving the rockets. Rockets may be stored in the notches in the shoeboxes on a shelf or a counter.

The smoother the joint, the less the drag. By eliminating sharp angles and smoothing the flow of air over the joint, drag is reduced. Fin attachment is stronger, but glue adds weight.

D. Students should follow the kit assembly directions to put the launch lugs on their rockets. Explain that the launch lug enables their rocket to slide on the launch rod on the launch pad as it is being launched. As you demonstrate using your own rocket, explain that the purpose of the launch lug is to guide the rocket straight on the launch rod until the rocket is going fast enough for the fins to guide it straight through the air.

E. Distribute students' folders and give them time to complete the vocabulary study for "Rocket Stability - How and Why".

Closure:

Spend the last few minutes of class going over the definitions to ensure that students have a good understanding of the concepts.

Extension:

Pose the challenge questions, "Who were the first known people to develop any kind of rocket and when was it?" Allow the students to guess today and record their guesses on the bottom of their vocabulary sheet. They will have until the next class period to find out the answer and bring it to class. Give some kind of recognition (Certificate in Appendix D) to those who guessed correctly and those who brought in the facts.

Evaluation:

Observe the students' responses on Activity Sheets 1 and 2 to determine what concepts they are grasping and which ones need continued emphasis.

Student Activity Sheet #2

WHAT I ALWAYS WANTED TO KNOW ABOUT ROCKETS

What I know about rockets	Questions I have about rockets that may be answered in this video	Important things I learned in this video

NOTES

Lesson 3 (Two Days)

How Can I Figure Out How High My Rocket Can Fly?

Objectives of the Lesson:

The student will be able to:

- Continue assembling individual rockets by adding shock cords and shock cord mounts to the rocket.
- Describe how a shock cord will help absorb shock from the ejection charge.
- Construct an altitude measuring device.
- Demonstrate how an altitude measuring device is used and how the height of common objects can be determined.
- Demonstrate how the altitude of a rocket's apogee is calculated.

BACKGROUND FOR THE TEACHER

This lesson will help students learn to determine the altitude their rockets reach by using a one station tracking system, an altitude tracking device and the mathematical formula, Height = Baseline x Tangent of Angular Distance. Using a one station tracking system consists of accurately measuring the distance between the launch pad and the tracking station, measuring carefully the angular distance risen by the rocket through the calculation of the formula. For example, the distance from the launch pad to the tracking station (the spot where an individual with an altitude measuring device stands) is 500 feet. The angular distance (90˚ - 60˚ = 30˚) is 30˚. Using the table of tangents, found at the end of this lesson, the tangent of the angular distance of 30˚ is .5774. Height = 500 feet x .5774, Height = 287.2 feet.

If necessary, the students will be reinforcing the fins on their rockets, by using the appropriate glue to fill in any points that are not secure (Beta Series rocket). There are two reasons for this. One is to ensure that the fins will stay on. The other is to smooth any rough surfaces to reduce drag. Adding too much glue increases weight.

As you know, drag is the force that resists the forward motion of an object through the air. Any disturbance in the air flow increases drag. To reduce drag, engineers design streamlined airplanes and rockets. The fuselage or body of an airplane or rocket has a rounded nose and long, slim, tapered tail. Well-streamlined airplanes and rockets are aerodynamically "clean".

VOCABULARY

Altitude of Apogee: Determined by the formula, Height = Baseline x Tangent of Angular Distance.
Shock Cord: Elastic cord used to attach the recovery system (parachute or streamer) to a model rocket's fuselage.

VOCABULARY (Continued)

Angular Distance: Distance found by subtracting the reading taken (angle marked) of the rocket at apogee from 90˚.

Tangent of Angle: Found by using a table of tangents.

Altitude Measuring Device: Designed to measure the angular distance of a rocket at apogee from 90˚.

Baseline: Distance between the launching point and the tracker with an altitude measuring device.

STRATEGY

Materials Needed: Shock cord, shock cord mount, assembly instructions, scissors, plastic cement, glue, Activity Sheet # 3, a protractor, a large diameter plastic soda straw, 20 cm length of string and a small eraser for each student.

A. Distribute the shock cord and mount, the instructions for assembling the rocket, scissors and the appropriate glue to each student.

B. Review the directions in the assembly instructions.

Emphasize the importance of having the shock cord mount glued down well. If it rips out, the parachute and nose cone could be lost.

C. Explain that the shock cord mount has a top and a bottom. The shock cord mount is put on so that the bottom of the wall mount is first glued in, leaving the shock cord hanging outside the tube. Walk around the room to make sure everyone has done it correctly.

D. The mounts need to be allowed to dry. While the mounts dry, students can construct an altitude measuring device, be introduced on how to use it and to determine altitude of apogee by using a mathematical formula.

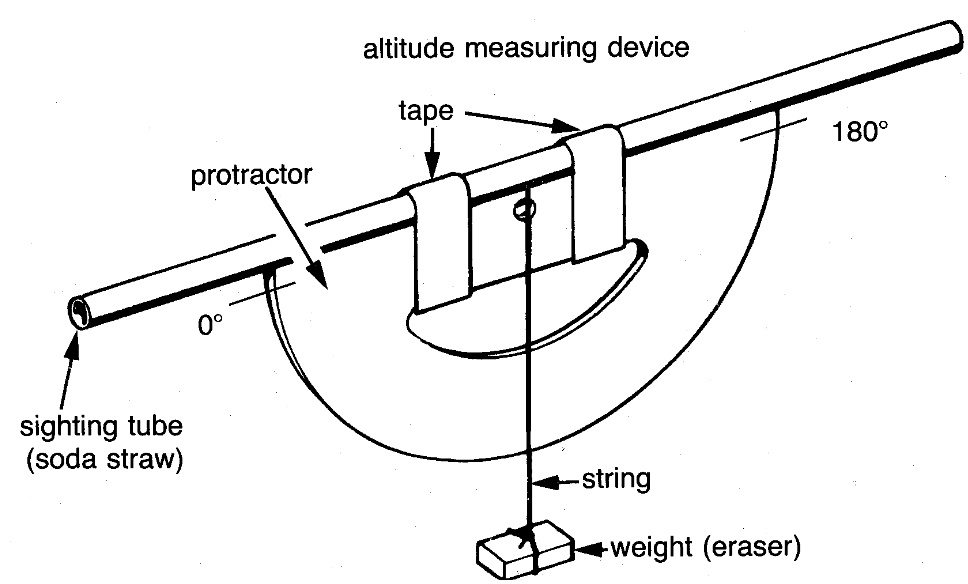
Motivation: Ask the students to think about a rocket launch. Review with them the concepts of apogee, drag, acceleration and deceleration by asking them to describe each idea. Then ask them to think about interesting facts or statistics that they could discover about their own rockets when they are launched. When their ideas have been discussed, emphasize that they can determine the altitude at which their rocket reaches apogee and the average speed of their rocket.

Ask the students how they think scientists and engineers determine distances in space, such as to the moon or to Mars.

Discuss the importance of the performance of their rockets and the amount of fuel they will need to ensure that the rocket reaches its destination.

Then give each student a large soda straw. Demonstrate how to use it like a small telescope by holding it up to one eye. Demonstrate the use of the altitude measuring device by using one already assembled by the teacher.

E. Provide each student with the directions for making an altitude tracking device, using a straw, a protractor, string and an eraser. (Activity Sheet #3 which will include the formula for determining altitude using a table of tangents.) Provide each student with a copy of a table of tangents.
Students could be allowed to work in groups of two or three on this project.

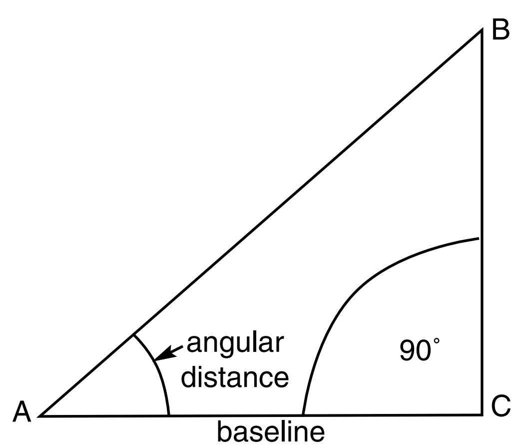


F. Allow the students to follow the directions for completing the altitude measuring device. When most students have completed the device, ask "How do you think this device could work to determine altitude?" Accept all guesses. Demonstrate the use of the altitude measuring device by using the straw as a sighting tube. Demonstrate how this would be used to track the rocket and to hold the string at that location the instant it reaches apogee.

The string should point to an angle on the protractor, i.e. 60˚. Present and explain the mathematical formula for determining the height of the rocket at apogee.

Height = Tangent of angular distance x Baseline

G. On the board, draw a diagram like the one in the figure.



Describe the location of the launch pad, C, the tracking station, A and the rocket at apogee, B. AC is the baseline. Angle A is the angular distance. Angular distance is found by using the altitude tracking device to find a point on the protractor just as the rocket reaches apogee. Remind the students that the sum of the angles of a triangle equals 180˚. Since the angle at C on the diagram is a right angle, because the rocket is launched straight up, angular distance then is determined by subtracting the number on the protractor from 90˚. This number will be the angular distance. Demonstrate to the students how to find the tangent of the angular distance on a table of tangents. Explain that the students want to determine the height of the line, CB, or the height of apogee of the rocket by using the formula Height = Tangent of angular distance x Baseline.

H. Guide the students through using the formula giving by giving the number of 500 feet for the baseline and write that on the diagram on the board. The degrees found on the protractor at the tracking station is 60˚. Since angular distance is found by subtracting that number from 90˚ (write that at angle C), what is the angular distance found at the tracking station? 30˚. Write that at angle A. Ask, "Do we have enough information to fill in the formula?" No, we need to use the table of tangents to find the tangent of the angular distance of 30˚. Using the table of tangents, that number is found to be .5774.
The students should write the formula as follows:

Height = .5774 x 500 ft.
Height = 288.7 feet

I. Allow students to work through the formula using at least two more examples with everyone working together.

J. Allow students to work through the problems on the activity sheet independently and then check them together in class. Students could continue to work in groups of two or three on these problems.

Closure:

Discuss and compare the students answers on the activity sheet.

Extension:

Ask the students to estimate the height of the flagpole, a tree and the school's basketball backboard. Record their estimates on a sheet of paper. After tomorrow's activity, practicing the use of the altitude measuring device, recognize those who had the nearest estimates (Certificate in Appendix D). Older students can calculate the percentage of error using this formula:

$$\% \text{ of error} = \frac{\text{error}}{\text{actual}} \times 100$$

Error = The difference between the estimate and the actual.

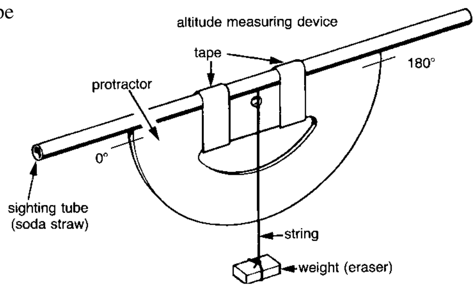
Evaluation:

Observe which students are having difficulty using the formula and give them the support they need to determine altitude, since this is an important part of the statistical record for model rocketry.

Activity Sheet # 3A
Lesson
DETERMING ALTITUDE
Making your own altitude measuring device

You will need the following things:

- A large soda straw
- A 20 cm length of string
- A protractor
- A weight (an eraser)
- Tape



You will be constructing a device that looks like the on in the diagram. Tape the straw across the top of the protractor as shown. The straw will act as a sighting tube. Secure the string to the protractor, by slipping it under the straw and around. Tie it to itself and tape it to the back of the protractor. Tie the eraser at the opposite end of the string, so that it can act as a weight. The way an altitude tracking device is used is this:
Hold the straw up to your eye. You will focus on the rocket as it is being launched. Move the device up as the rocket ascends. When you see the parachute on your rocket pop out, you will know your rocket has reached apogee: At this instant, hold the string with your finger exactly where it is on the protractor. Read the number on your protractor and record it on a pad of paper. That number will help you determine how high your rocket went. Try the procedure several times now so that you can get the feel of it before the rocket launch. Your teacher has selected some objects, such as a flagpole, on which to practice measuring altitude. Stand at the place he or she has marked for each object. Hold the straw up to your eye. Move the other end of the device up until you can see the top of the object. At that point, hold your finger on the string against the protractor. Record the angle. Your teacher will give you the baseline measurement. Use the formula and the table of tangents to determine the height or altitude of each object.

Activity Sheet #3b

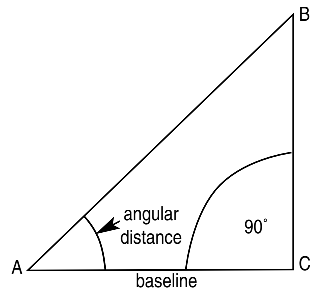


TABLE OF TANGENTS

Angle	Tan.	Angle	Tan.	Angle	Tan.	Angle	Tan.
1°	0.02	21	0.38	41	0.87	61	1.80
2	0.03	22	0.40	42	0.90	62	1.88
3	0.05	23	0.42	43	0.93	63	1.96
4	0.07	24	0.45	44	0.97	64	2.05
5	0.09	25	0.47	45	1.00	65	2.14
6	0.11	26	0.49	46	1.04	66	2.25
7	0.12	27	0.51	47	1.07	67	2.36
8	0.14	28	0.53	48	1.11	68	2.48
9	0.16	29	0.55	49	1.15	69	2.61
10	0.18	30	0.58	50	1.19	70	2.75
11	0.19	31	0.60	51	1.23	71	2.90
12	0.21	32	0.62	52	1.28	72	3.08
13	0.23	33	0.65	53	1.33	73	3.27
14	0.25	34	0.67	54	1.38	74	3.49
15	0.27	35	0.70	55	1.43	75	3.73
16	0.29	36	0.73	56	1.48	76	4.01
17	0.31	37	0.75	57	1.54	77	4.33
18	0.32	38	0.78	58	1.60	78	4.70
19	0.34	39	0.81	59	1.66	79	5.14
20	0.36	40	0.84	60	1.73	80	5.67

The rocket is being launched at C. You are standing at A, with your altitude tracking device. You are trying to determine the angle at A by tracking your rocket as it travels from C to B. B is apogee and that is where you need to note where the string is on the protractor. **Remember that you have to subtract that number from 90˚ in order to get the angular distance.**
The sum of the angles of a triangle is 180˚. The angle at C is a right angle and is 90˚.
Now that your teacher has taught you the formula for determining altitude, try some of these problems with a partner.

Height = Tangent of angular distance x Baseline

Angular distance=25˚
Tangent of angular distance = ? (You will need your table of tangents
Baseline = 150 feet
Height = _______

Angular distance = 40˚
Tangent of angular distance =
Baseline = 300 feet
Height = ______
Make up problems for your partner to solve. Make sure you know the right answer!

Activity Sheet #3C

HOW HIGH IS THAT FLAGPOLE

Flagpole
Angular distance =
Tangent of angular distance =
Baseline =
Height =

Tall tree
Angular distance =
Tangent of angular distance =
Baseline =
Height =

Basketball backboard
Angular distance =
Tangent of angular =
Baseline =
Height =
Make up problems for your partner to solve. **Make sure you know the right answer!**

HOW High is That Thing, Anyway?

Objectives of the Lesson:

The student will be able to:

- Use an altitude measuring device to determine the angular distance to the top of an object.
- Use the data of angular distance, baseline and the tangent of an angle to determine the heights of objects.

STRATEGY

Materials Needed: Individual altitude measuring devices, Activity Sheet #3, a pencil. The teacher should have selected some objects to measure, such as the flagpole or a tall tree. The baseline from the objects to the spot where the tracker will stand should be measured and marked ahead of time.

Motivation: Review the students' estimates of the height of various objects around the playground. Review the use of the altitude measuring device by demonstrating its use and then letting the students try it out in the classroom.

A. Distribute the students' folders with Activity Sheet #3. Review the problems done in the previous lesson. Review the formula and remind the students of the information they will need to get and record outdoors: the angular distance and the baseline.

B. Allow the students to work in groups of two or three. Point out the objects to be measured, where the tracking stations are and the length of each baseline.

C. When all students have had an opportunity to use their altitude tracking device, bring them in to calculate their problems.

D. Let each group report their answers. There may be disagreement. Angles, baseline distances, tangents and calculations will need to be rechecked until there is reasonable agreement.

E. Look at the list of estimates with the students. Determine which ones were nearest to the correct answer.

Closure and Evaluation:

Ask the students to discuss what was the most challenging part of this activity and why? Observe which concepts and skills need continued emphasis.

Extension:

Challenge question: What was the big event in 1957 that challenged the United States to become more focused on rockets?

NOTES

Lesson 4 (Two Days)

Rocket Principles and Rocket Recovery

Objectives of the Lesson:

The student will be able to:

- Describe the relationship of Newton's three Laws of Motion to the launch and flight sequence of a model rocket.
- Recognize and identify the recovery systems including feather-weight recovery, tumble recovery, streamer recovery, parachute recovery, helicopter recovery and glide recovery.
- Build a parachute recovery system.

BACKGROUND FOR THE TEACHER

Newton's Three Laws of Motion

1. Objects at rest will stay at rest, and objects in motion will stay in motion in a straight line unless acted upon by an unbalanced force.

To understand this law it is necessary to understand the terms *rest, motion* and *unbalanced force.*

Rest and motion can be thought of as opposite. Rest is the state of an object when it is not changing position in relation to its surroundings. Rest cannot be defined as a total absence of motion because it could not exist in nature. All matter in the universe is moving all the time, but in the first law of motion, motion means changing position in relation to surroundings.

When an object is at rest, the forces acting upon it are balanced. In order for an object to move, the forces acting upon it must become unbalanced.

A model rocket is at rest when it is on the launch pad. The forces acting upon it are balanced. In order for an object to move, the forces acting upon it must become unbalanced. The force of gravity is pulling the rocket downward and the rocket launch pad is pushing against it holding it up. When the propellant in the engine is ignited, that provides an unbalanced force. The rocket is then set in motion and will stay in a straight line until other unbalanced forces act upon it.

2. Force is equal to mass times acceleration.

This is really a mathematical equation, $f = ma$. Force in the equation can be thought of as the **thrust** of the rocket. Mass in the equation is the amount of rocket fuel being burned and converted into gas that expands and then escapes from the rocket (Background for the Teacher, Lesson 1). Acceleration is the rate at which the gas escapes. The gas inside the rocket does not really move. The gas inside the engine picks up speed or **velocity** as it leaves the engine. The greater the mass of rocket fuel burned and the faster the gas produced can escape the engine, the greater the thrust of the rocket.

3. For every action there is always an opposite and equal reaction.

A rocket can lift off from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas and the gas pushes on the rocket. With rockets, the action is the expelling of gas out of the engine. The reaction is the movement of the rocket in the opposite direction. To enable a rocket to lift off from the launch pad, the action or thrust from the engine must be greater than the weight of the rocket.

Recovery Systems - Six Main Types

The purpose of all recovery systems is to bring the rocket safely back to earth by creating enough drag or lift to resist the force of gravity. Given Newton's First Law of Motion, the ejection charge is an unbalanced force that stops the motion of the rocket from continuing in a straight line in addition to the force of gravity. Without a recovery system, the ejection charge would cause the rocket to fall to Earth rapidly reacting to the force of gravity.

1. Featherweight Recovery

The model is very light, usually under 1/4 oz. without the engine and flutters to the ground after the engine ejects from it. The spent engine also flutters unless a streamer is attached to it to further slow it down. The rocket is light in relation to its size. A featherweight rocket can encounter a thermal or heated rising air which produces **lift** during recovery. The rising air slows the rocket's descent due to gravity, making its return slower. These models have to be very well constructed to survive this type of recovery.

2. Tumble Recovery

The force of the engine's ejection charge pushes the engine backwards and this moves the center of gravity (center of balance) of the rocket back. The center of gravity is now behind the center of pressure, the point about which all of the aerodynamic forces appear to be centered. The aerodynamic forces in operation during recovery do not realign the rocket as it falls so that the nose of the rocket precedes the tail. The rocket is now unstable and tumbles end over end. The tumbling motion of the rocket produces extremely high drag on the rocket so it falls slowly. This method of recovery is rarely used on models that are not simple in design and sturdy in construction because the rate of descent is usually higher than with a parachute or streamer recovery.

3. Streamer Recovery

A streamer is usually attached to the nose of the rocket and ejected by the engine's ejection charge to whip around in the air, creating substantial drag with which to slow the rocket's descent. The effectiveness of the streamer in slowing the descent of the model rocket is chiefly determined by the streamer's surface area and its roughness. The larger the streamer, the slower is the descent of the rocket. Streamers are useful for returning rockets with a minimum of drift. The size of the streamer needed primarily depends upon the weight of the rocket being returned. Parachutes and streamers can be easily interchanged, depending upon needs and wind conditions. However, streamers do not produce enough drag for heavier rockets. Streamers are packed by rolling them into a compact roll or into two compact rolls.

4. Parachute Recovery

The parachute is usually attached to the nose of the rocket and is ejected from the rocket body by the engine's ejection charge, like the streamer. It fills with air and creates tremendous drag to slow the rocket's descent and allow it to float gently back to earth. Between the parachute packed in the body tube and the engine is a layer of flameproof recovery wadding. If there is not enough wadding, gases from the ejection charge can pass through or around the wadding layer and either burn holes in the parachute or melt the parachute into a lump.

5. Helicopter Recovery

An example: vanes on the rocket are activated by the engine's ejection charge. The air hits these vanes and is deflected causing the side of the rocket to rotate away in the opposite direction. The deflection is the **action** and the rocket rotating in the opposite direction is the **reaction**. The rotation produces drag and slows the descent.

6. Glide Recovery

The rocket is launched and the engine's ejection charge causes it to convert into a glider. The wings of the glider generate **lift** as it flies through the air. The glider glides through the air, descending slowly. During glide recovery, the rocket moves forward as it descends. The horizontal motion decreases the rate of fall. Most model rockets that use the glide recovery system are shaped much like airplanes. They move forward along their longitudinal axis as they descend and sink at the same time they move forward. As with the featherweight recovery system, a glider can encounter an area of heated, rising air called a thermal which slows the rate of descent, but it can also carry the glider away from sight.

VOCABULARY

Acceleration: The rate of *change* in the speed of an object.

Motion: Moving, change of position in relation to surroundings.

Featherweight Recovery: Rocket recovery system which involves a very light model which flutters to the ground.

Parachute Recovery: Rocket recovery system in which a parachute is attached to the nose of the rocket and is ejected from the rocket by the engine's ejection charge.

Force: Causes acceleration of a body which can cause movement.

Recovery Wadding: Flame resistant tissues that are packed between the model rocket engine and the streamer or parachute to protect the recovery device from hot gases of the ejection charge.

Glide Recovery: Rocket recovery system in which the engine's ejection charge causes it to convert into a glider and which creates *lift* as it flies through the air.

VOCABULARY (Continued)

Rest: Not moving, without motion.

Helicopter Recovery: Rocket recovery system in which vanes on the rocket are activated by the engine's ejection charge and air hits these vanes and is deflected causing the side of the rocket to rotate away in the opposite direction.

Shroud Line: String or cord used to attach a parachute to a shock cord or nose cone.

Mass: Amount of matter an object contains. On Earth, this is measured as weight which is the amount of the force of gravity acting on the mass.

Streamer Recovery: Rocket recovery system in which a streamer is attached to the nose of the rocket and ejected by the engine's ejection charge to whip around in the air.

Tumble Recovery: Rocket recovery system in which the force of the engine's ejection charge pushes the engine backwards. This moves the balance point of the rocket to the rear causing the rocket to be unstable so that it tumbles end over end.

Unbalanced Force: Causes an object at rest to move or an object in motion to slow or stop.

STRATEGY

First Day

Material Needed: Tennis balls, one for each small group of students.

Motivation: Ask if anyone found out the significant rocket event of 1957 (Sputnik was launched by the Soviet Union). Ask the students how long they think rocket-powered devices have been in use? (They may know from the question about history.) Ask them how long the scientific basis for the understanding how rockets work has been known? (Since about 1687 with the work of Sir Isaac Newton.) Newton stated three important scientific principles that govern motion of all objects whether on earth or in space. Because of these principles, rocket scientists have been able to construct the modern giant rockets of today.

A. Use overhead transparencies to project each law of motion. Give each small group of students a tennis ball or other small ball.

Project Law #1 on overhead projector - Discuss with the students what they think it means. Ask them to place the tennis ball in the middle of the group and to leave it at rest. Discuss what would cause it to stay at rest and what would put it into motion. Discuss what balanced forces are holding it at rest (The force of gravity and the floor or the table). What unbalanced force would put it in motion? Rolling it, tossing it up.

Ask a student from each group to carefully toss the ball in the air. What unbalanced force caused the ball to leave the student's hand? What caused the ball to change from a state of motion? As the ball leaves the student's hand, it is going fast? What two forces are acting on the ball to slow it down as it rises? (Gravity and drag).

Project Law #2 on the overhead - Ask a student from each group to drop the ball on the ground. Discuss with the students that the ball falls because of the unbalanced force of gravity acting on it. The ball is **accelerating** as it falls and begins to gain momentum. The **mass** stays the same but the **velocity** or speed of the ball changes.

At the same time, the air the ball is passing through resists the movement of the ball through it. This resistance is called **drag**.

Project Law #3 - Remind the students of the balloon demonstration. Review with them the action and reaction. Ask the student to roll the tennis ball against a wall or a barrier. What happens when the ball hits the barrier? If it is rolling fast enough it rolls away from the barrier. Discuss what happens when a ball is pitched to a batter. The ball is traveling through air being acted upon by the forces of gravity and drag. When it hits the bat, it begins traveling through the air in another direction.

B. Project Newton's Laws of Motion, Putting Them Together with Model Rocketry. Discuss each law as it relates to a rocket flight sequence. Lead the students to make the connections between the performance of the tennis ball and the performance of a rocket.

Closure:

Allow the students to work on their vocabulary sheets, "Rocket Principles and Rocket Recovery", with a partner or small group. The teacher should walk around and give assistance as needed. Some of the concepts involved will be challenging for some of the students.

Evaluation:

Observe the involvement and participation of the students in the small group tennis ball activity. Observe the students' responses to the vocabulary study and clarify concepts as needed.

Extension:

Challenge the students to design a demonstration of one of the laws of motion to present to the class.

NOTES

Second Day

Materials Needed: Shroud lines, parachutes, set of tape discs, scissors, recovery wadding and nose cone for each student. One can of talcum powder for the class. A model rocket to demonstrate the effects of the types of recovery systems and examples of streamers and parachutes.

Motivation: Ask the students to guess what a recovery system for rockets might be. Ask the students why a recovery system is important and what would happen to rockets without one. Allow them to describe some ideas they might have for designing a recovery system.

A. Describe each type of recovery system (Background for the Teacher). As you name each type, write it on the board and ask students to think about how it might work and make a prediction. As you complete the description of each type, reinforce the student who was closest to the correct description. The teacher should use a model rocket to demonstrate how the rocket behaves during recovery with each system.

B. When you have completed the description of all six types, ask the students to consider which one they think would work best with the rocket they are constructing and to support their opinion with facts about how it is constructed.

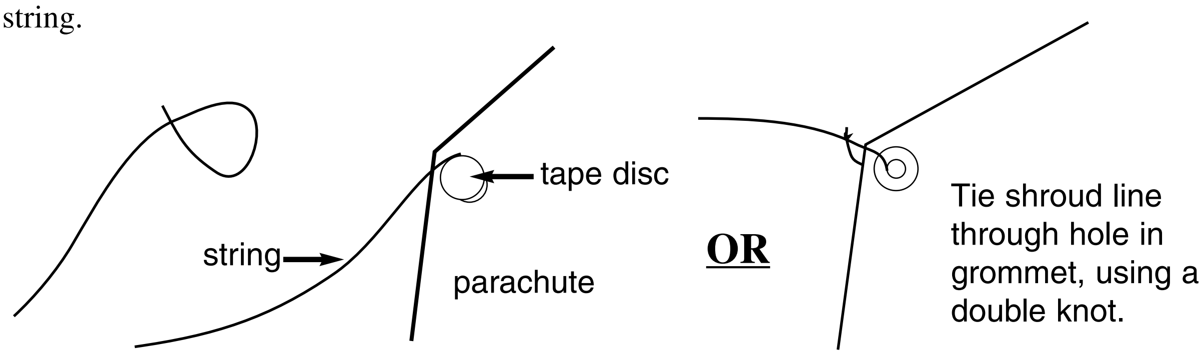
C. One recovery system that is good for this type of rocket is the parachute recovery system. That is what students will be constructing. Distribute the shroud line, the bundled thread with tape on it, to each student. The shroud line should be opened very carefully so it will not tangle. Cut the shroud line into three *equal* pieces.

D. Distribute a parachute canopy and a set of tape discs to each student. Each student should cut out the parachute, if not pre-cut already. Check to see that each student has a parachute, tape discs and three shroud lines.

E. Help the students determine that they have a hexagonal parachute and three shroud lines with two ends each. Ask them how they think the shroud lines will be attached to the parachute. Emphasize that the top of the parachute is the side to which the discs will be stuck.

F. *If the tape discs have no holes in the center,* students should pick up a shroud line and follow the teacher's demonstration.

Make a little balloon shape on one end of the shroud line by curving the end of the string.



Stick one of the tape discs to the balloon shape with some of the “balloon” sticking above. This will help prevent the shroud lines from pulling away from the completed parachute. Students should attach the tape discs with the shroud line attached to the first corner of the parachute canopy on the circle, pressing firmly. They should take the other end of the same shroud line, repeat the steps of forming the balloon and attaching the tape disc, and then attach that end to the next corner of the parachute. If the tape discs (grommets) have holes in the center, instruct the students to attach a grommet to each corner of their parachute. If holes are pre-cut in the parachute corners, grommets should be put over the holes. If the holes are not pre-cut in the corners, students will need to make holes in their parachutes. They should push a pencil gently through the center of the grommet. The ends of the shroud lines are attached to the parachute by tying them through the grommets. Use double knots.

The process should be repeated with each shroud line until all three shroud lines are connected to all six corners of the parachute. (Note: Some Estes Bulk Pack rocket kits may come with parachutes preassembled).

G. Pick up the parachute from the middle of the top side. Slide one hand down over it and pull the parachute and shroud lines together. At the bottom of the gathered shroud lines, tie a knot. Explain that the reason for doing this is that it leaves the shroud lines long from the knot up to the parachute and each of the lines will be of equal length.

H. The students should test their parachutes by holding onto the knot only and pulling the chute through the air to see how well it opens.

I. Distribute three squares of recovery wadding to each student. Explain that this material is treated with a fire retardant chemical. It will protect the parachute from melting from the intense heat caused by the engine’s ejection charge. It is necessary to use fresh wadding every time a rocket is launched because it floats away from the rocket and is lost. The wadding is biodegradable so it is easy on the environment. The student should loosely crumple the wadding and push it down the top of the body tube with a pencil. The wadding should be pushed all the way down until it touches the top of the engine mount assembly.

J. It is desirable for each student’s parachute to be sprinkled with a little talcum powder in order for the parachute to open easily, since nothing sticks to talcum powder. The teacher may want to go outside to do this. The students should line up and the teacher can sprinkle a little powder on each student’s parachute. Dump out any excess on the ground if outdoors.

K. Distribute the nose cones. The teacher may need to clean the flash from the eyelets. Tie the end of the shock cord onto the nose cone with a double knot. Be careful not to use too much of the shock cord when tying knots. Being careful not to tangle the shroud lines with the shock cord, tie the parachute onto the nose cone by passing the knotted end of the shroud lines through the eyelet and tie a double knot. Keep the shroud lines long. This completes the assembly of the rocket.

L. To pack the parachute, the teacher should demonstrate how to fold and pack it so it will easily eject and open. Use the following method:

Fold the parachute by pulling it gently into a spike shape.

Fold in half and then roll up in the other direction, not too tightly. **Loosely wrap** the shroud lines around the folded parachute like the stripes on a barber pole.

M. Put the folded parachute into the body tube first, followed by the shock cord and then plug in the nose cone. Nothing should be sticking out or jamming the nose cone.

Closure:

Review the recovery systems with the students and discuss the appropriateness of parachute recovery for their rockets

NOTES

Lesson 5 (One Day)

Launching Rockets Safely - A Necessity !

Objectives of the Lesson:

The student will be able to:

- Demonstrate proper safety procedures based on the Model Rocketry Safety Code.
- Check rocket for stability.
- Install the engine and igniters in the rocket.

BACKGROUND FOR THE TEACHER

NAR MODEL ROCKETRY SAFETY CODE

1. Materials - My model rocket will be made of lightweight materials such as paper, wood, rubber, and plastic suitable for the power used and the performance of my model rocket. I will not use any metal for the nose cone, body, or fins of a model rocket.

2. Engines/Motors - I will use only commercially-made NAR certified model rocket engines in the manner recommended by the manufacturer. I will not alter the model rocket engine, its parts, or its ingredients in any way.

3. Recovery - I will always use a recovery system in my model rocket that will return it safely to the ground so it may be flown again. I will use only flame resistant recovery wadding if required.

4. Weight and Power Limits - My model rocket will weigh no more the 1500 grams (53 ounces) at liftoff, and its rocket engines will produce no more than 320 newton-seconds (4.45 newtons equal 1.0 pound) of total impulse. My model rocket will weigh no more than the engine manufacturer's recommended maximum liftoff weight for the engines used, or I will use engines recommended by the manufacturer for my model rocket.

5. Stability - I will check the stability of my model rocket before its first flight, except when launching a model rocket of already proven stability.

6. Payloads - Except for insects, my model rocket will never carry live animals or a payload that is intended to be flammable, explosive, or harmful.

7. Launch Site - I will launch my model rocket outdoors in a cleared area, free of tall trees, power lines, buildings, and dry brush and grass. My launch site will be at least as large as that recommended in the following table.

LAUNCH SITE DIMENSIONS

Installed Total Impulse (newton-seconds)	Equivalent Engine Type	Minimum Site Dimensions (feet)	(meters)
0.00-1.25	1/4 A1/2 A	50	15
1.26-2.50	A	100	30
2.51-5.00	B	200	60
5.01-10.00	C	400	120
10.01-20.00	D	500	150
20.01-40.00	E	1000	300
40.01-80.00	F	1000	300
80.01-160.00	G	1000	300
160.01-320.00	2G's	1500	450

8. Launcher - I will launch my model rocket from a stable launch device that provides rigid guidance until the model rocket has reached a speed adequate to ensure a safe flight path. To prevent accidental eye injury, I will always place the launcher so the end of the rod is above eye level or I will cap the end of the rod when approaching it. I will cap or disassemble my launch rod when not in use, and I will never store it in an upright position. My launcher will have a jet deflector device to prevent the engine exhaust from hitting the ground directly. I will always clear the area around my launch device of brown grass, dry woods, or other easy-to-burn materials.

9. Ignition System - The system I use to launch my model rocket will be remotely controlled and electrically operated. It will contain a launching switch that will return to "off" when released. The system will contain a removable safety interlock in series with the launch switch. All persons will remain at least 15 feet (5 meters) from the model rocket when I am igniting model rocket engines totalling 30 newton-seconds or less of total impulse and at least 30 feet (9 meters) from the model rocket when I am igniting model rocket engines totalling more than 30 newton-seconds of total impulse. I will use only electrical igniters recommended by the engine manufacturer that will ignite model rocket engine(s) within one second of actuation of the launching switch.

10. Launch Safety - I will ensure that people in the launch area are aware of the pending model rocket launch and can see the model rocket's liftoff before I begin my audible five-second countdown. I will not launch a model rocket using it as a weapon. If my model rocket suffers a misfire, I will not allow anyone to approach it or the launcher until I have made certain that the safety interlock has been removed or that the battery has been disconnected from the ignition system. I will wait one minute after a misfire before allowing anyone to approach the launcher.

11. Flying Conditions - I will launch my model rocket only when the wind is less than 20 miles (30 kilometers) an hour. I will not launch my model rocket so it flies into clouds, near aircraft in flight, or in a manner that is hazardous to people or property.

12. Pre-Launch Test - When conducting research activities with unproven model rocket designs or methods I will, when possible, determine the reliability of my model rocket by pre-launch tests. I will conduct the launching of an unproven design in complete isolation from persons not participating in the actual launching.

13. Launch Angle - My launch device will be pointed within 30 degrees of vertical. I will never use model rocket engines to propel any device horizontally.

14. Recovery Hazards - If a model rocket becomes entangled in a power line or other dangerous place, I will not attempt to retrieve it.

This is the official Model Rocketry Safety Code of the National Association of Rocketry and the Model Rocket Manufacturers Association.

STRATEGY

Materials Needed: Rocket launch controller and launch pad; an example of the engine being used to launch the rockets; Activity Sheet #4 and copies of the NAR Safety Code for each student; an engine igniter and plug (if available) for each student with instructions for installing the igniter and installing the engine into the mount; plus a decal sheet for each student.

Motivation: Ask the students to think of some situations in their lives where they have to follow safety rules or put themselves at risk. Allow the students to tell some of these situations.

Ask the students, "What reasons can you think of that safety around rockets is so important that the NAR has developed a safety code for model rocketry?" Allow the students to contribute reasons.

Ask the students "What are some ideas for rules that might be included in the model Rocket Safety Code?" Let the students give their ideas. Record them on paper.

A. Distribute decal sheets to each student. Students should follow instruction #7 on the assembly instructions for placement of the decals.

B. Distribute copies of the safety code to each student. Distribute copies of Activity Sheet #4 (contains evaluation questions related to each part of the safety code) to each student.

C. The students should, in groups of three or four, read each item of the safety code and answer the questions related to it on the Activity Sheet. When most groups have finished, a total group discussion could involve the responses of each group on the Activity Sheet. Students can be allowed to correct their activity sheets if necessary. To make sure each student knows and understands the safety code, give each student a written test on it. Each student should pass with a score of 98% or above to become an official "Launch Control Officer" and be able to launch their rocket.

D. Distribute engines and the instructions included with engines for the proper installation of igniters. Each student should carefully insert an igniter into an engine and secure it with an igniter plug. Demonstrate to the students how to slide the engine into the engine mount. The igniter end should stick out the bottom and the engine hook should be latched over the end of the engine to prevent it from ejecting.

The rockets are ready to launch.

Activity Sheet #4C

NAR MODEL ROCKETRY SAFETY CODE

1. Materials- Does the method we have constructed meet the code according the materials used to construct it?____

List the materials used in your model rocket.

____
____

2. Engines/Motors- Your teacher will show you the engines that will be used. Do they meet the Safety Code standards?

____

3. Recovery- Describe the recovery system you will be using.
____
____

Will this recovery system meet the Safety Code?

____

4. Weight and Power Limits- Use a small postage scale to weigh your rocket. What is your rocket's weight?____________________. You can also look on the package that contained your kit to determine the weight. Does the weight of your rocket meet the code?____

5. Stability- Did you follow the directions carefully for attaching the fins?___________ If the fins are attached properly at the end of the rocket, then the balance point of the rocket should be correct. Since you built the rocket from a kit, it should be stable.

6. Payloads- Describe the likely consequences of a flammable, explosive or harmful payload.______________________
____
____

7. Launch Site- Does the launch site your teacher has designed meet the Safety Code standards?__________ What size engine will you be using?______________ Find it on the chart of launch site dimensions. Is the launch site large enough for that engine?______________________________

8. Launcher-Your teacher should have the launch device that will be used for your launch. Take a look at it. Describe how an accidental eye injury could occur.

____
____

Why do we need to be careful to prevent the engine exhaust from hitting the ground directly?

____
____

Why is it important to consider the danger of fire?

____
____

Activity Sheet #4D

9. Ignition System- Your teacher will be in charge of the ignition system for this launch. Observe how it works. Why is it important for all persons to stand a specific distance from the launcher?
____
____
____

10. Launch Safety- What are the possible consequences of failing to warn people of the pending launch?
____

What are possible consequences of launching the rocket as a weapon?____
____

11. Flying Conditions- Think of each adverse condition. Describe why each one could be dangerous when launching a rocket.
High winds of over 20 miles an hour___________________
____

Near buildings______________________________________
____

Near power lines____________________________________
____

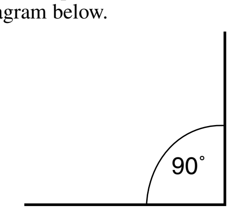
Near tall trees ______________________________________
____

On a crowded playground____________________________
____

12. Pre-Launch Test- The rocket you will be launching for this launch is a proven design, built from a kit. However, if you build rockets on your own, describe why pre-launch tests are essential. ______________________________________
____

What are things you would test? _______________________
____
____

13. Launch Angle- Use a protractor and draw an angle of 30˚ from vertical on diagram below.



This shows you the limit of the angle that a rocket should be launched.

14. Recovery Hazards- What is the danger of recovering a rocket from a power line?____________________________
____
____

NOTES

Lesson 6: (Two Days)

Launching a Rocket - Seeing is Believing

Objectives of the Lesson:

The student will be able to:

- Participate appropriately in the launching of each student's rocket.
- Demonstrate proper safety procedures during a launch.
- Record flight data on a class chart and on an individual chart.
- Demonstrate ability to track the rocket, measure the angular distance and mathematically determine the height of apogee for the rocket.
- Calculate the average speed of the rocket ascending and the rocket descending.

BACKGROUND FOR THE TEACHER

The launch area should be large enough, clear of people and clear of any easy to burn materials. On the day of the launch, the wind speed should not be more than 20 mph. Early morning or early evening when there is little wind is usually the best time of day to launch.

The launch pad and the launch cable should be anchored down by bricks or something similar.

The safety cap should be on the launch rod *at all times* except during launch.

The *teacher* should be in possession of the safety key at all times.

STRATEGY

Materials Needed: A completed model rocket for each student, an altitude measuring device for each student, Activity Sheet #7 for each student, two stopwatches, the launcher and the launch controller.

Motivation: Review with the students the need for safety and following procedures.

Review the launch data sheets.

A. The launch pad should be set up by the teacher. Measure off a 100 foot baseline from the launch pad for the tracking station. Mark the end of the baseline with a cone or flag.

B. Demonstrate where each student must stand during the launch, a minimum of 15 feet away from the launch pad while launching.

C. Each student should have his/her rocket and his/her altitude measuring device, as well as a pencil and the Individual Launch Data Sheet. Review with the group how to use the altitude measuring device - sighting, following the rocket, holding the string promptly at apogee against the protractor and recording the number on the protractor. The parachute will pop out at apogee.

D. *The safety key must <u>never</u> be in the launch controller while the rocket is being loaded onto the launch pad and the micro-clips are being attached.* When it is each student's time for launch, the student gives the rocket to the teacher or another student. That person slides the rocket onto the launch rod and hooks up the launch system's micro-clips. That student should go out to the tracking station. After everyone is 15 feet or more away from the rocket, insert the safety key. All the students do the countdown, 5...4...3...2...1...0. The teacher or student then presses the launch button on the controller. Be sure to remove the safety key immediately after launch.

E. The students should look at the rocket through the straw and allow the weighted string to swing freely. Lift the altitude measuring device to follow the rocket until it reaches apogee, when the parachute pops out. The students should "lock" in the reading by by holding the string with their finger against the protractor the instant the parachute pops out. Write down the number where the string rests. The teacher may select one or two student recovery teams to recover rockets after a certain number of rockets have landed or the students may recover their own rockets.

F. Two other teachers, or a student timing team should record the time of each flight to apogee and again to landing, using a stopwatch. Make certain each student records his/her angle of distance, the baseline distance, the time to apogee and the time to recovery on both the class chart and his/her individual chart (Activity Sheet #6 and #7). It will help to have a student in charge of the Group Launch Data Sheet (#6).

G. Before going in, be certain all students' Activity Sheet #7 are collected. Distribute participant certificates to all rocket launchers. (Appendix D)

<u>NOTES</u>

Activity Sheet #6

Launch Data - Group

Student Name	Baseline	Angular Distance	Time at Launch (seconds)	Time at Apogee (seconds)	Time at Landing (seconds)	Altitude at Apogee	Average Speed Ascending	Average Speed Descending

Activity Sheet #7

Launch Data - Individual

Baseline	Angular Distance	Time at Launch (T_o) (seconds)	Time at Apogee (T_A) (seconds)	Time at Landing (T_L) (seconds)

Student Name____

STRATEGY

Materials Needed: Individual student folders, Activity Sheets #3, #5 and #7 and a table of tangents for each student.

A transparency of completed Activity Sheet #6.

Motivation: Before beginning calculations ask for several volunteers to estimate the highest altitude reached by a rocket during yesterday's launch. Record the estimates on a piece of paper. Repeat the procedure with estimates of highest average speed ascending per second and lowest average speed descending per second.

Ask the students to give ideas about variables that would have an effect on the average speed of descent, such as wind or the type of recovery system.

A. Distribute individual student folders, Activity Sheet #5 and completed Activity Sheet #7.

B. Display the overhead transparency for the Group Launch Data. Make certain that all students have their individual sheets filled in. The teacher will give them the measurement of the baseline. The column for Time at Launch will be 0.

C. Using the formula for determining altitude, guide the students through the process, if needed. When each student has an altitude, record that beside their name on the Group Launch Data Sheet. From this data, determine which five rockets achieved the highest altitude. Also determine which estimates were nearest to the highest altitudes. (If desired, give certificates to closest estimates and for the highest altitudes achieved by the rockets.)

D. Guide the students through Activity Sheet #5. Using the formulas, guide the students through the process of determining the average speeds of their rockets, ascending and their rockets descending. Record the average speeds for each student on the Group Launch Data. From this data, determine which five rockets had the highest speed ascending and the lowest speed descending. Also determine which estimates were nearest the actual data. (Give certificates for best estimates, highest speeds ascending, and lowest speeds descending.)

Closure:

Display the overhead transparency, “Newton’s Laws of Motion, Putting Them Together With Model Rocketry”. Review each point with the students and tie it to their experience with the launch.

Allow the students to discuss why their rockets did not continue going on into space. What unbalanced forces continued to act on their rockets after the launch?

Distribute the giant wordsearch puzzle, “All About Rockets”, (Appendix C). The students should highlight or circle rocket part words in red, rocket flight sequence words in blue, laws of motion words and principles in green and recovery system words in orange.

Evaluation:

Collect the students’ folders and assess their work, particularly the responses to the vocabulary words and their individual launch data charts.

Ask the students to write three new and important things they learned from studying about and launching model rockets.

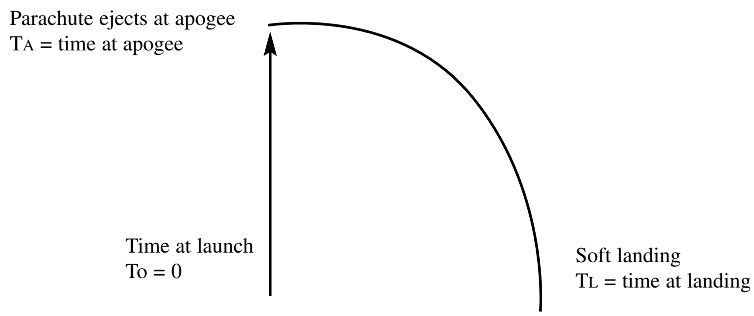
Use the wordsearch puzzle as an assessment of their understanding of the concepts.

NOTES

Activity Sheet #5

DETERMINING AVERAGE SPEED

How Fast Did It Fly?



We can calculate the “launch at apogee” average speed and the “apogee to landing” average speed.

The formula is Average Speed = Distance traveled ÷ Time of travel. Distance traveled on the diagram is the distance between T_O and T_A (launch to apogee).

You have learned how to determine the altitude or the distance traveled by using your altitude tracking device and using the mathematical formula Height = Tangent of angular distance x baseline. Use the following example data:

T_O = 0 seconds

T_A = 3.2 seconds (this would be determined by someone with a stopwatch starting at launch and stopping at apogee).

T_L = 4.1 seconds (this is determined by someone with a stopwatch starting at apogee and stopping at landing).

Altitude = 288.7 feet

Plug those figures into the following formula:

Average Speed ascending = Altitude ÷ T_A - T_O

288.7 feet ÷ 3.2 seconds - 0 = 90.21 feet per second

If you would like to know the miles per hour you can multiply your answer by 0.682.

90.21 feet per second x 0.682 = 61.52 miles per hour.

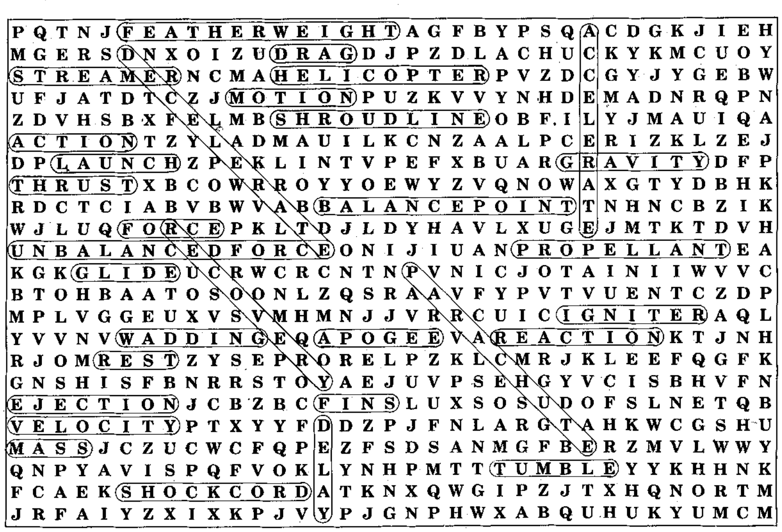
When you want to know the average speed descending, from apogee to landing, use this formula:

Altitude ÷ T_L - T_A

288.7 feet divided by 4.1 - 0 seconds = 70.41 feet per second (T_A in this formula = 0) because the stopwatch was restarted at apogee.

Multiply your answer by 0.682 (70.41 feet per second x 0.682 = 48.02 miles per hour).

ALL ABOUT ROCKETS PUZZLE SOLUTION



ACCELERATE
APOGEE
DECELERATE
DELAY
DRAG
EJECTION
GRAVITY
IGNITER
LAUNCH
PROPELLANT
UNBALANCED FORCE
THRUST
ACTION
REACTION
BALANCE POINT
FINS
VELOCITY
SHOCK CORD
FEATHERWEIGHT
FORCE
GLIDE
HELICOPTER
MASS
MOTION
PARACHUTE
WADDING
REST
SHROUD LINE
STREAMER
TUMBLE
RECOVERY

UNIT EXTENSION

Science:

Interested students can be encouraged to present a demonstration illustrating Newton's Laws of Motion. Class time should be set aside for the demonstrations.

Math:

Since students have had experience with calculating a rocket's altitude at apogee, they could predict the altitude of a rocket before another launch. Since they have had experience with calculating altitude, their predictions will probably be more accurate. One variable could be a different power engine or a different recovery system, such as a streamer or a different sized parachute.

Graphing:

The students could construct graphs which show the average speed for the group for each launch. They could also graph the altitudes of their individual rockets at each launch or for each person in their group for each launch.

History:

For those students interested in biographies and history, Robert Goddard, Werner Van Braun or Sir Isaac Newton would make subjects for an interesting bulletin board for which students could collect information and pictures. NASA would make a good focus for a bulletin board or center created by students for another grade level classroom.

Language Arts:

Students interested in receiving information from NASA or from the U.S. Space Foundation can visit their web sites at the following addresses:

NASA Spacelink
http://spacelink.nasa.gov

U.S. Space Foundation
www.spacefoundation.org

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Cannon, Robert L. The Laws of Motion and Model Rocketry, Estes Industries, 1979

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Smith, Harry T. and Warden, Henry J., Industrial Arts Teachers Manual for Model Rocketry, Estes Industries, 1980

Model Rocketry Study Guide, TR-8, Estes Industries, 1985 EST 2841

Rockets, A Teaching Guide for an Elementary Science Unit on Rocketry, NASA, 1991, PED-112

ACTIVITY SHEETS

Activity Sheet # 1A **Name**________________________

WORDS FOR ROCKETEERS

Directions: As you learn these words during each session about rockets, you can fill in the definition. If you need more information, you can also use a dictionary.

ROCKETS IN MOTION

1. ACCELERATE

2. APOGEE

3. DECELERATE

4. DELAY ELEMENT

5. DRAG

6. EJECTION CHARGE

7. GRAVITY

8. IGNITER

9. LAUNCH

10. PROPELLANT

11. RECOVERY SYSTEM

12. THRUST

Activity Sheet # 1B **Name**________________________

ROCKET STABILITY - HOW AND WHY

1.ACTION/REACTION

2.AERODYNAMIC STABILITY

3.BALANCE POINT

4. FINS

5. LAUNCH ROD

6. LAUNCH LUG

7. VELOCITY

8. SHOCK CORD

HISTORY GUESS

Who were the first people to develop rockets?

When were the first rockets developed?

Activity Sheet # 1C **Name**________________________

ROCKET PRINCIPLES AND ROCKET RECOVERY

1. ACCELERATION

2. FEATHERWEIGHT RECOVERY

3. FORCE

4. GLIDE RECOVERY

5. HELICOPTER RECOVERY

6. MASS

7. MOTION

8. PARACHUTE RECOVERY

9. RECOVERY WADDING

10. REST

11. SHROUD LINE

12. STREAMER RECOVERY

13. TUMBLE RECOVERY

14. UNBALANCED FORCE

Activity Sheet #2

Name___________________________

WHAT I ALWAYS WANTED TO KNOW ABOUT ROCKETS

What I know about rockets	Questions I have about rockets that may be answered in this video	Important things I learned in this video

Activity Sheet #3A **Name________________________**

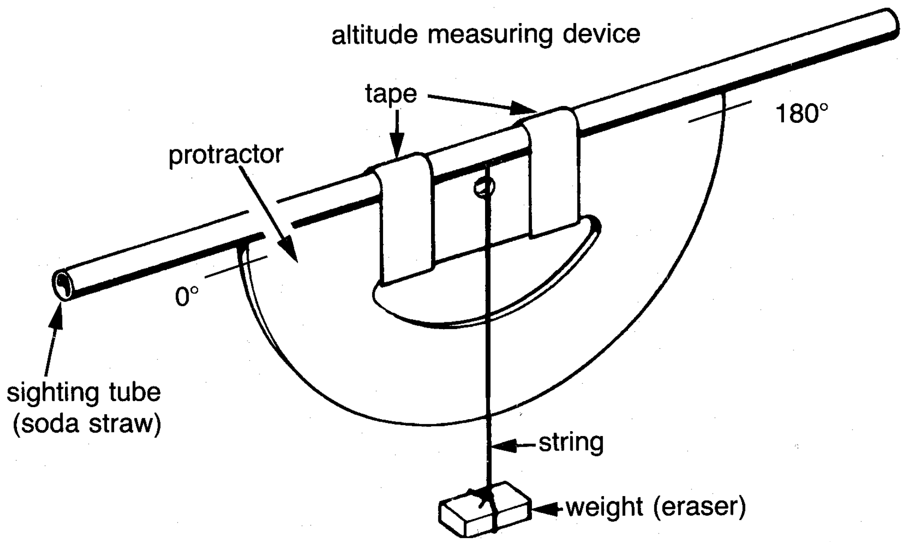
Lesson

DETERMINING ALTITUDE

Making Your Own Altitude Measuring Device

You will need the following things:

- A large diameter soda straw
- A 20 cm length of string
- A protractor
- A weight (an eraser)
- Tape



You will be constructing a device that looks like the one in the diagram.

Tape the straw across the top of the protractor as shown. The straw will act as a sighting tube. Secure the string to the protractor, by slipping it under the straw and around. Tie it to itself and tape it to the back of the protractor. Tie the eraser at the opposite end of the string, so that it can act as a weight.

The way an altitude tracking device is used is this:

Hold the straw up to your eye. You will focus on the rocket as it is being launched. Move the device up as the rocket ascends. When you see the parachute on the rocket pop out, you will know your rocket has reached apogee. At that instant, hold the string with your finger exactly where it is on the protractor. Read the number on your protractor and record it on a pad of paper. That number will help you determine how high your rocket went.

Try the procedure several times so that you can get the feel of it before the rocket launch. Your teacher has selected some objects, such as a flagpole, on which to practice measuring altitude.

Stand at the place she or he has marked for each object. Hold the straw up to your eye. Move the other end of the device up until you can see the top of the object. At that point, hold your finger on the string against the protractor. Record the angle.

Your teacher will give you the baseline measurement. Use the formula and the table of tangents to determine the height or altitude of each object.

Activity Sheet #3B Name________________________

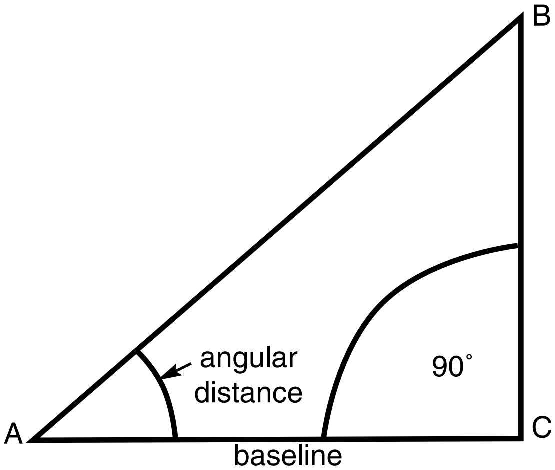


TABLE OF TANGENTS

Angle	Tan.	Angle	Tan.	Angle	Tan.	Angle	Tan.
1°	0.02	21	0.38	41	0.87	61	1.80
2	0.03	22	0.40	42	0.90	62	1.88
3	0.05	23	0.42	43	0.93	63	1.96
4	0.07	24	0.45	44	0.97	64	2.05
5	0.09	25	0.47	45	1.00	65	2.14
6	0.11	26	0.49	46	1.04	66	2.25
7	0.12	27	0.51	47	1.07	67	2.36
8	0.14	28	0.53	48	1.11	68	2.48
9	0.16	29	0.55	49	1.15	69	2.61
10	0.18	30	0.58	50	1.19	70	2.75
11	0.19	31	0.60	51	1.23	71	2.90
12	0.21	32	0.62	52	1.28	72	3.08
13	0.23	33	0.65	53	1.33	73	3.27
14	0.25	34	0.67	54	1.38	74	3.49
15	0.27	35	0.70	55	1.43	75	3.73
16	0.29	36	0.73	56	1.48	76	4.01
17	0.31	37	0.75	57	1.54	77	4.33
18	0.32	38	0.78	58	1.60	78	4.70
19	0.34	39	0.81	59	1.66	79	5.14
20	0.36	40	0.84	60	1.73	80	5.67

The rocket is being launched at C. You are standing at A, with your altitude tracking device. You are trying to determine the angle at A by tracking your rocket as it travels from C to B. B is apogee and that is where you need to note where the string is on the protractor. **Remember that you have to subtract that number from 90˚ in order to get the angular distance.**

The sum of the angles of a triangle is 180˚. The angle at C is a right angle and is 90˚.

Now that your teacher has taught you the formula for determining altitude, try some of these problems with a partner.

Height = Tangent of angular distance x baseline

Angular distance = 25˚
Tangent of angular = ? (You will need your table of tangents)
Baseline = 150 feet
Height = ————-

Angular distance = 40o
Tangent of angular distance =
Baseline = 300 feet
Height = ————-

Make up problems for your partner to solve. **Make sure you know the right answer!**

 Name_________________________

HOW HIGH IS THAT FLAGPOLE?

Flagpole
Height estimate =
Angular distance =
Tangent of angular distance =
Baseline =
Height =

Tall tree
Height estimate =
Angular distance =
Tangent of angular distance =
Baseline =
Height =

Basketball backboard
Height estimate =
Angular distance =
Tangent of angular distance =
Baseline =
Height =

Make problems for your partner to solve. **Make sure you know the right answer!**

Activity Sheet #4A Name________________________

NAR MODEL ROCKETRY SAFETY CODE.

1. Materials - My model rocket will be made of lightweight materials such as paper, wood, rubber, and plastic suitable for the power used and the performance of my model rocket. I will not use any metal for the nose cone, body, or fins of a model rocket.

2. Engines/Motors - I will use only commercially-made NAR certified model rocket engines in the manner recommended by the manufacturer. I will not alter the model rocket engine, its parts, or its ingredients in any way.

3. Recovery - I will always use a recovery system in my model rocket that will return it safely to the ground so it may be flown again. I will use only flame resistant recovery wadding if required.

4. Weight and Power Limits - My model rocket will weigh no more than 1500 grams (53 ounces) at liftoff, and its rocket engines will produce no more than 320 newton-seconds (4.45 newtons equal 1.0 pound) of total impulse. My model rocket will weigh no more than the engine manufacturer's recommended maximum liftoff weight for the engines used, or I will use engines recommended by the manufacturer for my model rocket.

5. Stability - I will check the stability of my model rocket before its first flight, except when launching a model rocket of already proven stability.

6. Payloads - Except for insects, my model rocket will never carry live animals or a payload that is intended to be flammable, explosive, or harmful.

7. Launch Site - I will launch my model rocket outdoors in a cleared area, free of tall trees, power lines, buildings, and dry brush and grass. My launch site will be at least as large as that recommended in the following table.

LAUNCH SITE DIMENSIONS

Installed Total Impulse (newton-seconds)	Equivalent Engine Type	Minimum Site Dimensions (feet)	(meters)
0.00-1.25	1/4A & 1/2 A	50	15
1.26-2.50	A	100	30
2.51-5.00	B	200	60
5.01-10.00	C	400	120
10.01-20.00	D	500	150
20.01-40.00	E	1000	300
40.01-80.00	F	1000	300
80.01-160.00	G	1000	300
160.01-320.00	2GS	1500	450

8. Launcher - I will launch my model rocket from a stable launch device that provides rigid guidance until the model rocket has reached a speed adequate to ensure a safe flight path. To prevent accidental eye injury, I will always place the launcher so the end of the rod is above eye level or I will cap the end of the rod when approaching it. I will cap or disassemble my launch rod when not in use, and I will never store it in an upright position. My launcher will have a jet deflector device to prevent the engine exhaust from hitting the ground directly. I will always clear the area around my launch device of brown grass, dry weeds, or other easy-to-burn materials.

Activity Sheet #4B

9. Ignition System - The system I use to launch my model rocket will be remotely controlled and electrically operated. It will contain a launching switch that will return to "off" when released. The system will contain a removable safety interlock in series with the launch switch. All persons will remain at least 15 feet (5 meters) from the model rocket when I am igniting model engines totalling 30 newton-seconds or less of total impulse and at least 30 feet (9 meters) from the model rocket when I am igniting model rocket engines totalling more than 30 newton-seconds of total impulse. I will use only electrical igniters recommended by the engine manufacturer that will ignite model rocket engine(s) within one second of actuation of the launching switch.

10. Launch Safety - I will ensure that people in the launch area are aware of the pending model rocket launch and can see the model rocket's liftoff before I begin my audible five-second countdown. I will not launch a model rocket using it as a weapon. If my model rocket suffers a misfire, I will not allow anyone to approach it or the launcher until I have made certain that the safety interlock has been removed or that the battery has been disconnected from the ignition system. I will wait one minute after a misfire before allowing anyone to approach the launcher.

11. Flying Conditions - I will launch my model rocket only when the wind is less than 20 miles (30 kilometers) an hour. I will not launch my model rocket so it flies into clouds, near aircraft in flight, or in a manner that is hazardous to people or property.

12. Pre-Launch Test - When conducting research activities with unproven model rocket designs or methods I will, when possible, determine the reliability of my model rocket by pre-launch tests. I will conduct the launching of an unproven design in complete isolation from persons not participating in the actual launching.

13. Launch Angle - My launch device will be pointed within 30 degrees of vertical. I will never use model rocket engines to propel any device horizontally.

14. Recovery Hazards - If a model rocket becomes entangled in a power line or other dangerous place, I will not attempt to retrieve it.

This is the official Model Rocketry Safety Code of the National Association of Rocketry and the Model Rocket Manufacturers Association. (Effective 10-91)

NAR MODEL ROCKETRY SAFETY CODE

1. Materials - Does the model we have constructed meet the code according to the materials used to construct it?____________

List the materials used in your model rocket.______________________________

____

2. Engines/Motors - Your teacher will show you the engines that will be used. Do they meet the safety code standards?______________________________________

3. Recovery - Describe the recovery system you will be using.________________

____

Will this recovery system meet the safety code?_______________

4. Weight and Power Limits - Use a small postage scale to weigh your rocket. What is your rocket's weight?_______________________. You can also look on the package that contained your kit to determine the weight. Does the weight of your rocket meet the code?________________

5. Stability - Did you follow the directions carefully for attaching the fins?_______ If the fins are attached properly at the end of the rocket, then the balance point of the rocket should be correct. Since you built the rocket from a kit, it should be stable.

6. Payload - Describe the likely consequences of a flammable, explosive or harmful payload.____

____

7. Launch Site - Does the launch site your teacher has designated meet the Safety Code standards?____________

What size engine will you be using?______________ Find it on the chart of launch site dimensions. Is the launch site large enough for that engine?________________

8. Launcher - Your teacher should have the launch device that will be used for your launch. Take a look at it. Describe how an accidental eye injury could occur.

____

____

Why do we need to be careful to prevent the engine exhaust from hitting the ground directly?____

____

____

Why is it important to consider the danger of fire?___________________________

____

____

Activity Sheet #4D

9. Ignition System - Your teacher will be in charge of the ignition system for this launch. Observe how it works.
Why is it important for all persons to stand a specific distance from the launcher?
____
____

10. Launch Safety - What are possible consequences of failing to warn people of the pending launch?____
What are possible consequences of launching the rocket as a weapon?____________
____

11. Flying Conditions - Think of each adverse condition. Describe why each one could be dangerous when launching a rocket.
High winds of over 20 miles an hour_______________________________________
____
____

Near buildings____
____

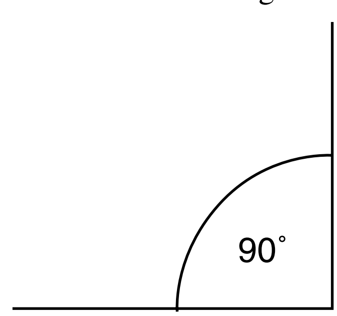
Near power lines____
____

Near tall trees____
____

On a crowded playground____
____

12. Pre-Launch Test - The rocket you will be launching for this launch is a proven design, built from a kit. However, if you build rockets on your own, describe why pre-launch tests are essential.____
____
What are things you would test?____
____

13. Launch Angle - Use a protractor and draw an angle of 30˚ from vertical on the diagram.



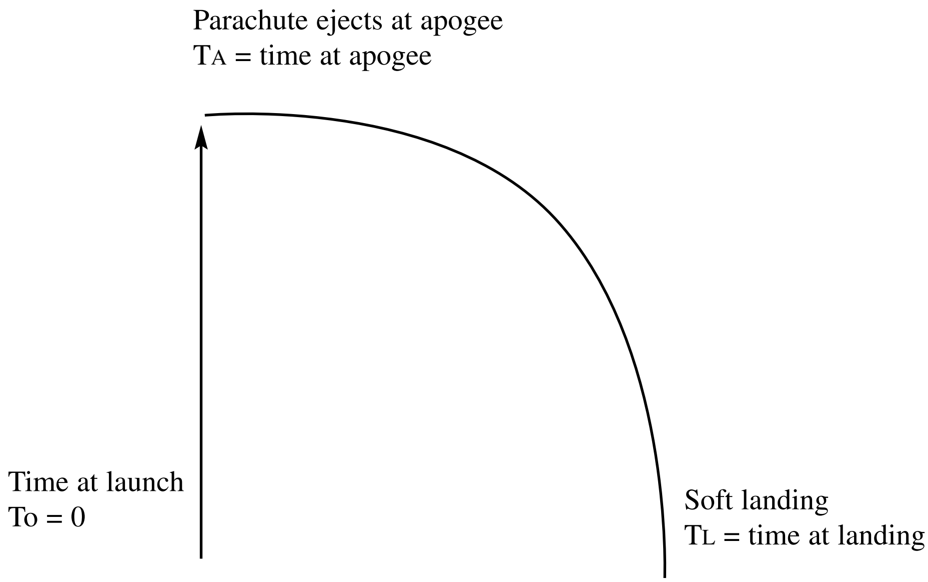
This shows you the limit of the angle that a rocket should be launched.

14. Recovery Hazards - What is the danger of recovering a rocket from a power line?____
____

Activity Sheet #5 Name_______________________

DETERMINING AVERAGE SPEED

How Fast Did It Fly?



We can calculate the "launch at apogee" average speed and the "apogee to landing" average speed.

The formula is Average Speed = Distance traveled ÷ Time of travel. Distance traveled on the diagram is the distance between T_o to T_A (launch to apogee).

You have learned how to determine the altitude or the distance traveled by using your altitude tracking device and using the mathematical formula:

Height = Tangent of angular distance x Baseline.

Use the following example data:

$T_o = 0$ seconds

$T_A = 3.2$ seconds (this would be determined by someone with a stopwatch starting at launch and stopping at apogee).

$T_L = 4.1$ seconds (this is determined by someone holding a stopwatch starting at apogee and stopping at landing).

Altitude = 288.7 feet

Plug those figures into the following formula:

Average Speed ascending = Altitude ÷ T_A-T_o

288.7 feet ÷ 3.2 seconds - 0 = 90.21 feet per second

If you would like to know miles per hour you can multiply your answer by 0.682.

90.21 feet per second x 0.682 = 61.52 miles per hour.

When you want to know the average speed descending, from apogee to landing, use this formula:

Altitude ÷ T_L - T_A

288.7 feet ÷ 4.1 - 0 seconds = 70.41 feet per second (T_A in this formula = 0) because the stopwatch was restarted at apogee.

Multiply your answer by 0.682 (70.41 feet per second x 0.682 = 48.02 miles per hour).

Name________________________

Launch Data - Group

Student Name	Baseline	Angular Distance	Time at Launch (seconds)	Time at Apogee (seconds)	Altitude at Apogee	Average Speed Ascending	Average Speed Descending

Activity Sheet # 7

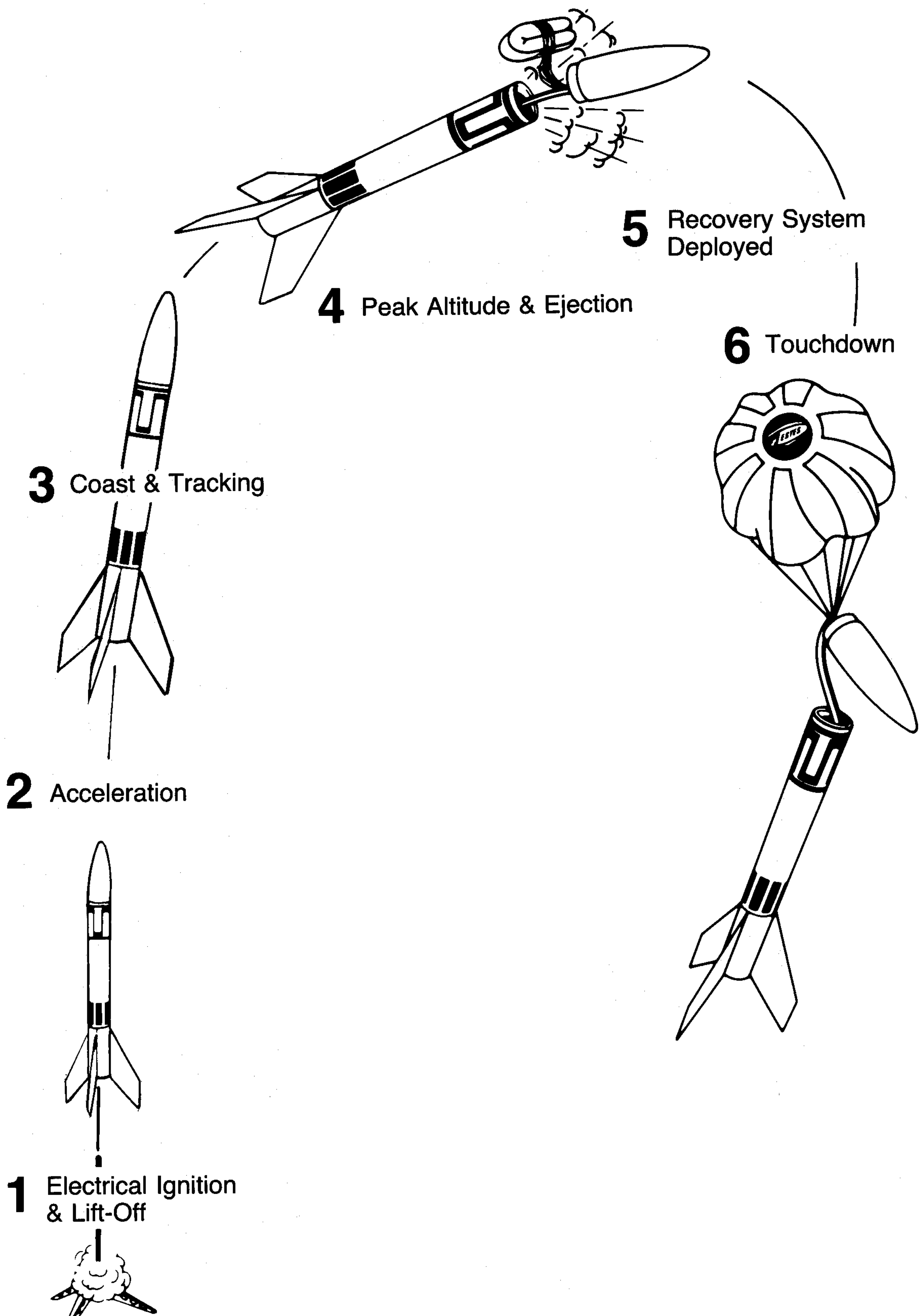
Launch Data - Individual

Baseline	Angular Distance	Time at Launch (To) (seconds)	Time at Apogee (Ta) (seconds)	Time at Landing (TL) (seconds)

Student Name______________________________

OVERHEAD TRANSPARENCIES

FLIGHT SEQUENCE OF A MODEL ROCKET



1. Newtons First Law of Motion

• Objects at rest will stay at rest, and objects in motion will stay in motion in a straight line unless acted upon by an unbalanced force.

- **REST**
- **MOTION**
- **UNBALANCED FORCE**

2.
Newtons Second Law of Motion

- **Force is equal to mass times acceleration.**

  - **MASS**
  - **ACCELERATION**
  - **FORCE**

3.
Newtons Third Law of Motion

- **For every action there is an opposite and equal reaction.**

- **ACTION**

- **REACTION**

Newtons Laws of Motion Putting Them Together with Model Rocketry

Law 1:
An unbalanced force must be exerted for a rocket to lift off from a launch pad.

Law 2:
The amount of thrust (force produced by a rocket engine) will be determined by the mass of rocket fuel that is burned and how fast the gas escapes the rocket.

Law 3:
The reaction, or motion, of the rocket is equal to and in an opposite direction from the action, or thrust, from the engine.

PUZZLES

ROCKETS IN MOTION

Name________________________

U	U	D	F	F	R	P	D	R	A	G	P	P	W	F	P	G	T	B	G	A
O	R	K	E	V	D	R	A	I	F	B	L	N	M	U	M	P	G	L	H	W
C	D	V	W	S	Z	O	C	G	Q	O	G	B	I	D	D	H	W	J	T	T
Z	E	O	V	Q	V	P	C	N	G	G	G	H	D	O	W	M	Y	S	P	H
F	W	T	V	N	R	E	E	I	M	J	W	W	R	P	O	P	M	E	L	R
S	M	H	O	S	M	L	L	T	R	A	C	K	I	N	G	M	I	Y	X	U
A	P	O	G	E	E	L	E	E	J	E	C	T	I	O	N	T	R	C	Y	S
D	E	L	A	Y	J	A	R	R	E	C	O	V	E	R	Y	C	D	V	I	T
C	O	Z	I	O	J	N	A	K	M	E	R	X	S	G	R	A	V	I	T	Y
B	C	W	I	I	Q	T	T	K	J	W	O	N	O	Z	Z	L	E	Q	W	H
L	I	F	T	O	F	F	E	L	A	U	N	C	H	R	A	I	C	N	E	O
D	E	C	E	L	E	R	A	T	E	R	I	M	P	C	O	A	S	T	O	F

ACCELERATE
APOGEE
COAST
DECELERATE
DELAY
DRAG
EJECTION
GRAVITY
IGNITER
LAUNCH
LIFT OFF
NOZZLE
PROPELLANT
RECOVERY
THRUST
TRACKING

ALL ABOUT ROCKETS

Name________________________

P	Q	T	N	J	F	E	A	T	H	E	R	W	E	I	G	H	T	A	G	F	B	Y	P	S	Q	A	C	D	G	K	J	I	E	H
M	G	E	R	S	D	N	X	O	I	Z	U	D	R	A	G	D	J	P	Z	D	L	A	C	H	U	C	K	Y	K	M	C	U	O	Y
S	T	R	E	A	M	E	R	N	C	M	A	H	E	L	I	C	O	P	T	E	R	P	V	Z	D	C	G	Y	J	Y	G	E	B	W
U	F	J	A	T	D	T	C	Z	J	M	O	T	I	O	N	P	U	Z	K	V	V	Y	N	H	D	E	M	A	D	N	R	Q	P	N
Z	D	V	H	S	B	X	F	E	L	M	B	S	H	R	O	U	D	L	I	N	E	O	B	F	I	L	Y	J	M	A	U	I	Q	A
A	C	T	I	O	N	T	Z	Y	L	A	D	M	A	U	I	L	K	C	N	Z	A	A	L	P	C	E	R	I	Z	K	L	Z	E	J
D	P	L	A	U	N	C	H	Z	P	E	K	L	I	N	T	V	P	E	F	X	B	U	A	R	G	R	A	V	I	T	Y	D	F	P
T	H	R	U	S	T	X	B	C	O	W	R	R	O	Y	Y	O	E	W	Y	Z	V	Q	N	O	W	A	X	G	T	Y	D	B	H	K
R	D	C	T	C	I	A	B	V	B	W	V	A	B	B	A	L	A	N	C	E	P	O	I	N	T	T	N	H	N	C	B	Z	I	K
W	J	L	U	Q	F	O	R	C	E	P	K	L	T	D	J	L	D	Y	H	A	V	L	X	U	G	E	J	M	T	K	T	D	V	H
U	N	B	A	L	A	N	C	E	D	F	O	R	C	E	O	N	I	J	I	U	A	N	P	R	O	P	E	L	L	A	N	T	E	A
K	G	K	G	L	I	D	E	U	C	R	W	C	R	C	N	T	N	P	V	N	I	C	J	O	T	A	I	N	I	I	W	V	V	C
B	T	O	H	B	A	A	T	O	S	O	O	N	L	Z	Q	S	R	A	A	V	F	Y	P	V	T	V	U	E	N	T	C	Z	D	P
M	P	L	V	G	G	E	U	X	V	S	V	M	H	M	N	J	J	V	R	R	C	U	I	C	I	G	N	I	T	E	R	A	Q	L
Y	V	V	N	V	W	A	D	D	I	N	G	E	Q	A	P	O	G	E	E	V	A	R	E	A	C	T	I	O	N	K	T	J	N	H
R	J	O	M	R	E	S	T	Z	Y	S	E	P	R	O	R	E	L	P	Z	K	L	C	M	R	J	K	L	E	E	F	Q	G	F	K
G	N	S	H	I	S	F	B	N	R	R	S	T	O	Y	A	E	J	U	V	P	S	E	H	G	Y	V	C	I	S	B	H	V	F	N
E	J	E	C	T	I	O	N	J	C	B	Z	B	C	F	I	N	S	L	U	X	S	O	S	U	D	O	F	S	L	N	E	T	Q	B
V	E	L	O	C	I	T	Y	P	T	X	Y	Y	F	D	D	Z	P	J	F	N	L	A	R	G	T	A	H	K	W	C	G	S	H	U
M	A	S	S	J	C	Z	U	C	W	C	F	Q	P	E	Z	F	S	D	S	A	N	M	G	F	B	E	R	Z	M	V	L	W	W	Y
Q	N	P	Y	A	V	I	S	P	Q	F	V	O	K	L	Y	N	H	P	M	T	T	T	U	M	B	L	E	Y	Y	K	H	H	N	K
F	C	A	E	K	S	H	O	C	K	C	O	R	D	A	T	K	N	X	Q	W	G	I	P	Z	J	T	X	H	Q	N	O	R	T	M
J	R	F	A	I	Y	Z	X	I	X	K	P	J	V	Y	P	J	G	N	P	H	W	X	A	B	Q	U	H	U	K	Y	U	M	C	M

ACCELERATE
APOGEE
DECELERATE
DELAY
DRAG
EJECTION
GRAVITY
IGNITER
LAUNCH
PROPELLANT
UNBALANCED FORCE

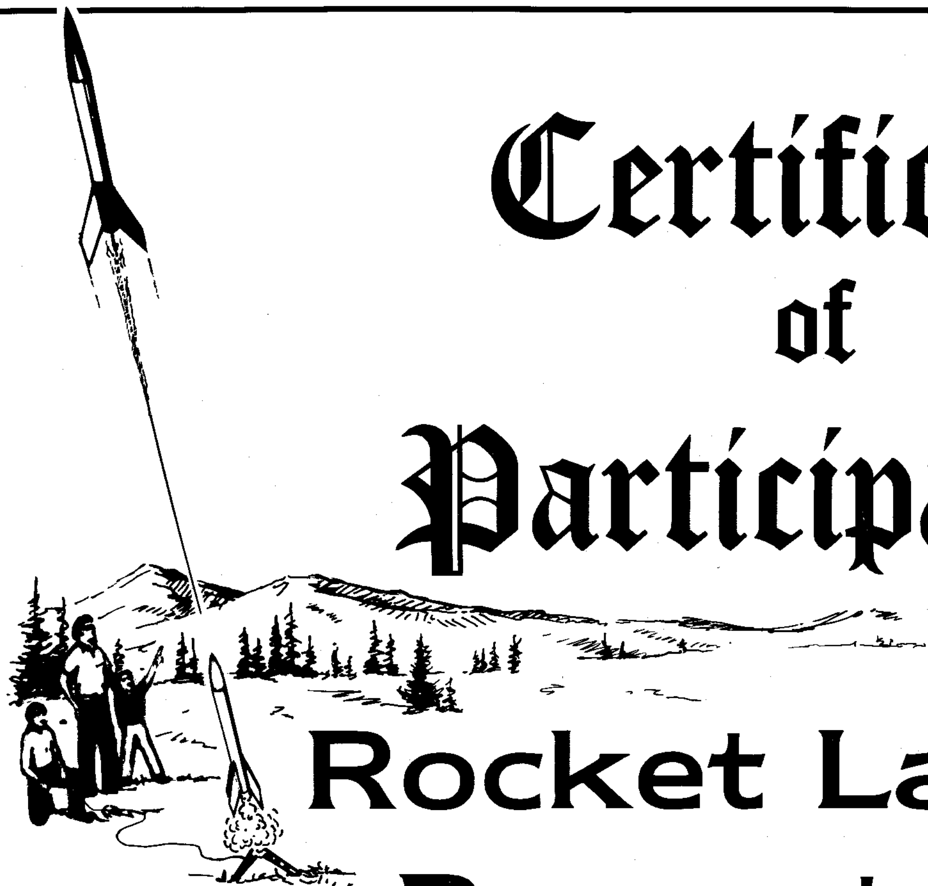
THRUST
ACTION
REACTION
BALANCE POINT
FINS
VELOCITY
SHOCK CORD
FEATHERWEIGHT
FORCE
GLIDE

HELICOPTER
MASS
MOTION
PARACHUTE
WADDING
REST
SHROUD LINE
STREAMER
TUMBLE
RECOVERY

Highlight or circle rocket part words in red, rocket flight sequence words in blue, laws of motion and principles in green and recovery system words in orange.

CERTIFICATES

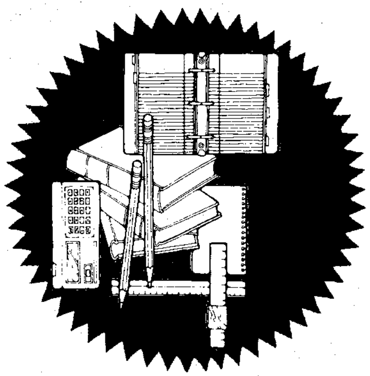
Certificate of Participation



Rocket Launch!

Presented to

____



Certificate
of
Mathematics Skills

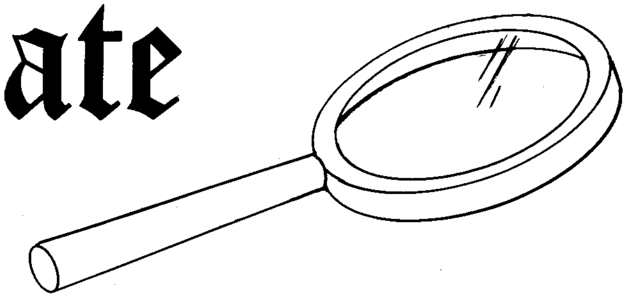
Good Guesser Award

Presented to

____

For Excellence
in Estimating

Certificate of Recognition



The "Get the Facts" Award

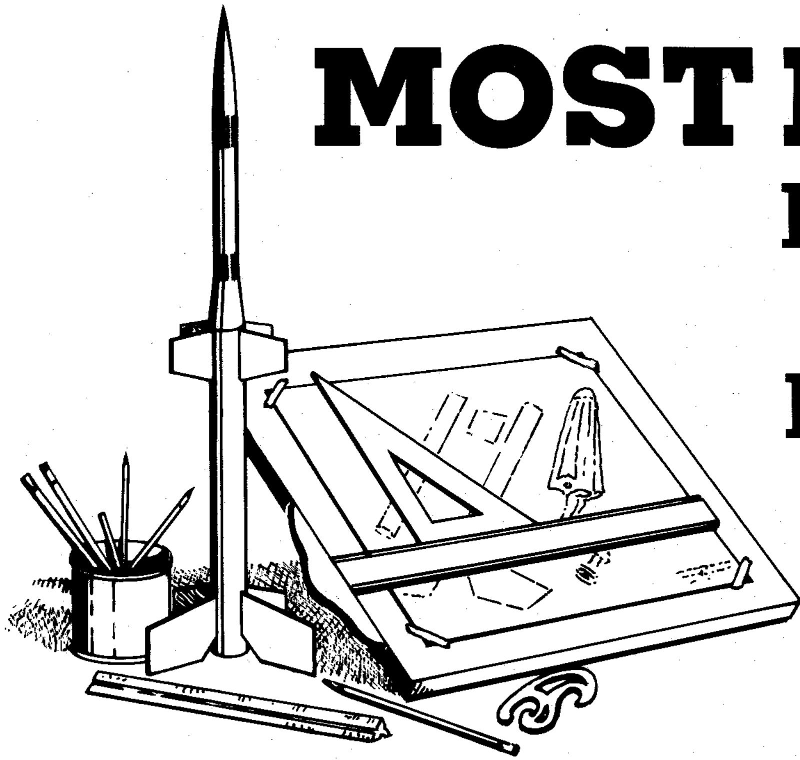
Presented to

____

ESTES

MOST LIKELY TO

BECOME AN EXPERT ROCKETEER



HIGH FLYING ROCKET AWARD

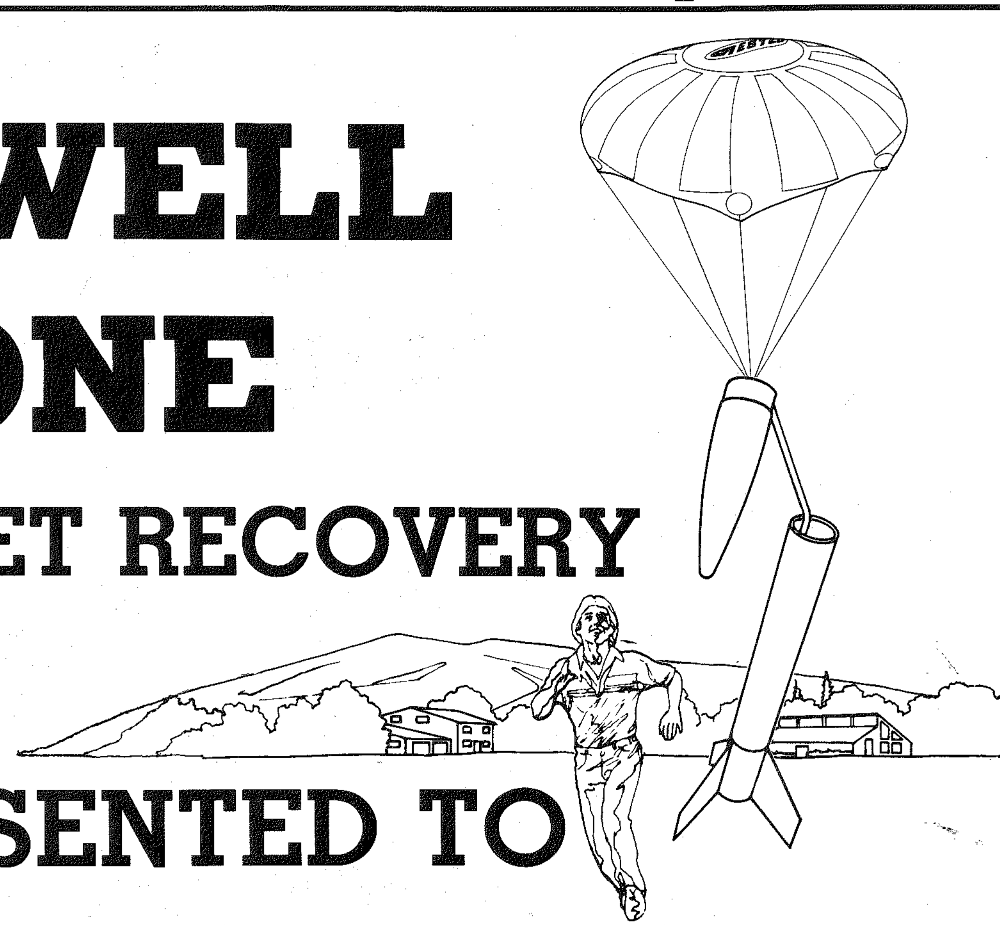
PRESENTED TO

____

ESTES

JOB WELL DONE

BEST ROCKET RECOVERY



PRESENTED TO

____

ESTES.

JOB WELL DONE

BEST ROCKET SPEED

ASCENDING

PRESENTED TO

____

JOB WELL DONE

BEST ROCKET SPEED

DESCENDING

PRESENTED TO

____

NOTES

ESTES INDUSTRIES
1295 H Street
Penrose, CO 81240