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Kaboom... Up, Up, and Away

Kaboom ……………….Up Up and Away

(Estes Educator Series)

(Science & Model Series, Modified)

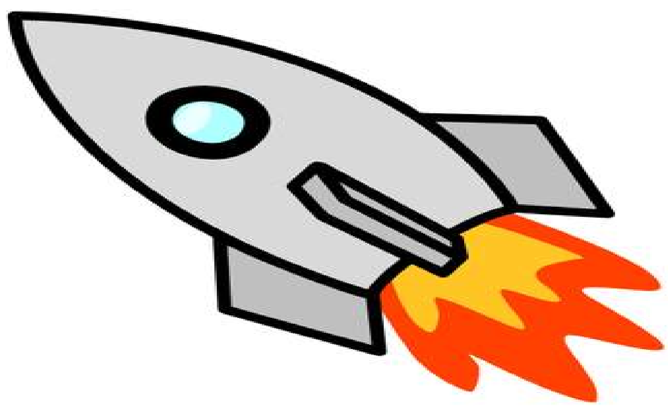

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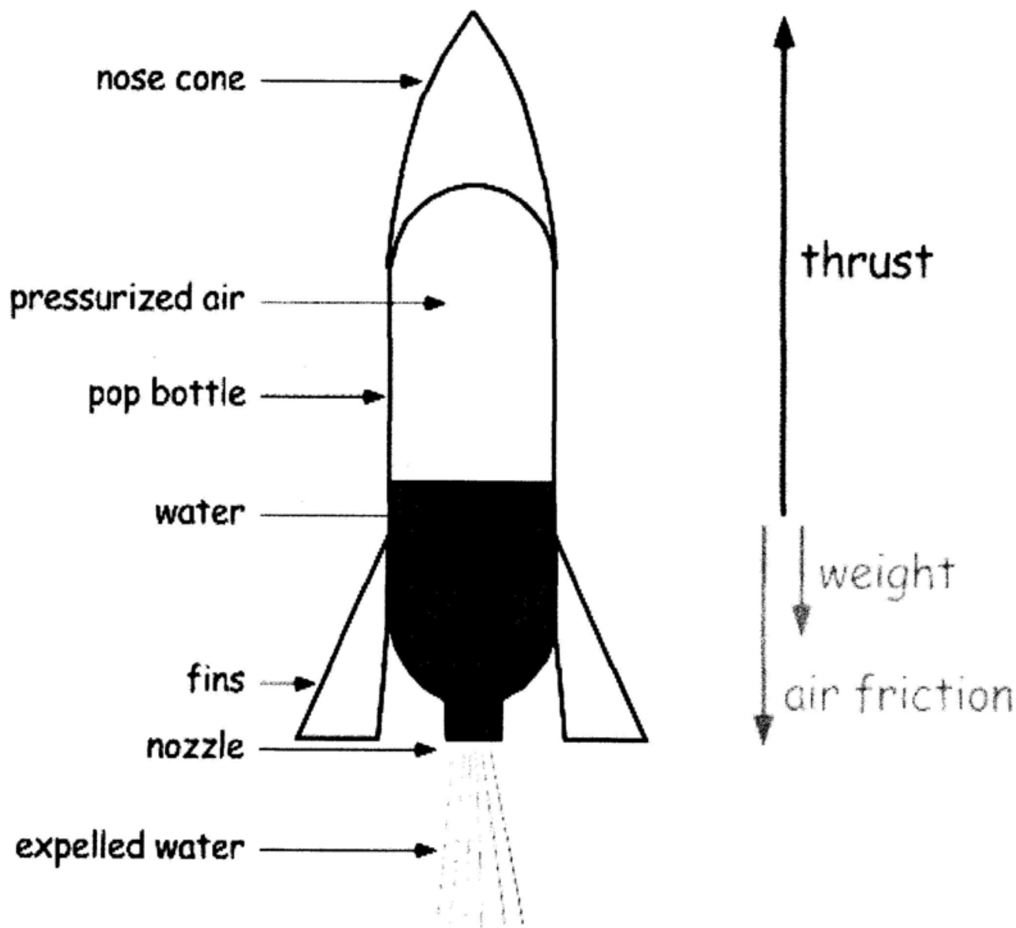
Table of Contents

Water Bottle Rocket



Overview/Introduction

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, and the study of motion or aerospace education.

Standards:

Florida's Next Generation Standards

Elementary Level Grades 3-5

Big Idea 13, Standard 6:

A. It takes energy to change the motion of objects.

B. Energy change is understood in terms of forces--pushes or pulls.

C. Some forces act through physical contact, while others act at a distance. (SC.1.P.13)

1. Investigate the effect of applying various pushes and pulls on different objects. (SC.2.P.13.1)

2. Demonstrate that magnets can be used to make some things move without touching them. (SC.2.P.13.2)

3. Recognize that objects are pulled toward the ground unless something holds them up. (SC.2.P.13.3)

4. Demonstrate that the greater the force (push or pull) applied to an object, the greater the change in motion of the object. (SC.2.P.13.4)

Standard 7:

A. Energy is involved in all physical processes and is a unifying concept in many areas of science.

B. Energy exists in many forms and has the ability to do work or cause a change. (SC.3.P.10)

Physical Science, Middle Grades 6- 8th Grade

Big Idea 13, Standard 12: Motion

A. Motion can be measured and described qualitatively and quantitatively. Net forces create a change in motion. When objects travel at speeds comparable to the speed of light, Einstein's special theory of relativity applies.

B. Momentum is conserved under well-defined conditions. A change in momentum occurs when a net force is applied to an object over a time interval.

C. The Law of Universal Gravitation states that gravitational forces act on all objects irrespective of their size and position.

D. Gases consist of great numbers of molecules moving in all directions. The behavior of gases can be modeled by the kinetic molecular theory.

E. Chemical reaction rates change with conditions under which they occur. Chemical equilibrium is a dynamic state in which forward and reverse processes occur at the same rates.

(SC.912.P.12)

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 a 2 liter bottle rocket.

- Describe how water bottle 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.

- 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.

Lesson 1

Learning about Motion and Flight with a Model or bottle 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 rocket.
- Begin the construction of a rocket by assembling pressure chamber.
- 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. Almost any 1 or 2 liter bottle will work; however, some bottles have a mouth or opening (nozzle) that is too small to accommodate the launch tube. The launch tube is a regular 1/2 inch piece of PVC tubing. The tube should slide snugly into the nozzle of the bottle forming a nearly air tight seal. We have found that the majority of Coke™ related 2 liter bottles and Sam's Choice 1 liter water bottle will work while a majority of Pepsi™ related bottles will not. This is not to say that the smaller nozzle bottles are worthless, rather they should be used for other components of the rocket like the nose cones.

#1 MAIN BODY/PRESSURE CHAMBER

The main part of your rocket is the body or PRESSURE CHAMBER. Peel the label off your bottle and try to clean the glue residue the best that you can. Do NOT use a knife or other object to scrape the label off. Scrape marks can weaken the plastic. Also, do not use hot water the plastic may shrink and weaken the bottle. Some people have tried to use chemical solvents to remove the glue residue on the bottle. This might alter the walls of the bottle and make them too brittle or soft. Therefore we don't recommend it.

#2 AFTER CLEANING

When launching, the pressure inside the bottle will cause the walls to expand. This expansion leads to a loss of energy and will make the rocket fly to a lower altitude. To solve this problem take some or duct tape, strapping tape, or packing tape and pre-wrap three bands around the pressure chamber. You don't want the tape to be too bulky and watch for wrinkles. This will strengthen the walls of the bottle without adding too much mass and launch altitude will increase overall. The gas escapes at a high speed. This produces thrust.

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

Propellant: water 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.

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

Strategy:

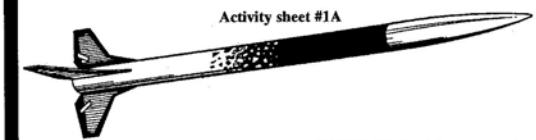
Each student should have a small shoe box or other similar shape and size box to store the parts and instructions. If notches are cut in each side of the shoebox, the rocket can rest in them as the rocket is assembled. Each student should have a manilla envelope or folder for the activity and record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

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. Label the appropriate parts.
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.
C. 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.

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.

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

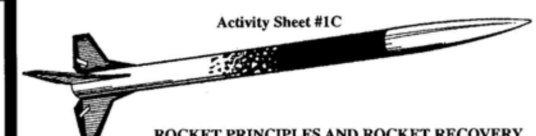
1. Action/Reaction
2. Aerodynamic Stability
3. Balance point
4. Fins
5. Launch Rod
6. Launch Lug
7. Velocity
8. Shock Cord

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

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. 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.

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

Strategy:

Fins are the guidance system for your rocket. Without them a rocket would tumble end over end. Fins can give your rocket life and beauty. Fins can portray aggressive power or aerodynamic grace. However, fins tend to be the single greatest downfall of many young rocket builders. With the incredible speeds and acceleration generated at launch, many fins get ripped off the rocket body within a fraction of a second.

MOTIVATION: *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. Fins should be firm; if they flop around they are useless.

Fins should be adequately secured; duct tape works well. I do not use glue because it does not expand with the pressure chamber and may cause it to become brittle.

The best fins are made of rigid cardboard or styrofoam board.

The size of the fin does matter! The best rockets fly well with long and narrow fins.

Materials: (remember lightweight but sturdy)

Duct Tape or Clear packing tape

Cardboard (cheap, plentiful, soggy when wet)

Chipboard (cereal boxes)

Foam core (a little tougher but more $, some water damage)

Sturdi-board (like plastic cardboard, great stuff, $$, no water damage)

Styrofoam sheets* (cheap, low mass, fragile on impact)

*Requires PL Premium Construction adhesive to attach

How many fins do I need?

To ensure stability and safety, the minimum number of fins on a rocket is three (3). Many people choose a 3 or 4 fin design. There is no maximum number of fins you may have but keep in mind that the more fins you have the more drag you will create and drag slows a rocket down.

B. Constructing fins

1. Be creative and cut out 3 or 4 identical fins. You can use any shape except "forward swept" fins.

2. Lay the fin on a flat surface.

3. Use a paper clip bent at 90 degrees and taped it to the fin or an index card taped onto the side of the fin. Be sure to leave a one-inch tab on the index card. You will later bend this tab out 90 degrees to make an attachable area for the rocket.

4. Repeat the same for the other side of the fin.

Closure:

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

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

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.

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.

Stratgey:

Students will need Activity Sheet # 3, a protractor, a large diameter plastic soda straw, 20 cm length of string and a small eraser for each student.

1. 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.
2. 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
3. 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.
4. 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

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

- 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 student's answers on the activity sheet.

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 rocketry.

Lesson 3 ……part 2

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.

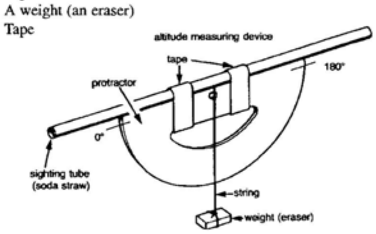
C. When all students have had an opportunity to use their altitude tracking device, bring them in to calculate their problems.
D. Let each group report their answers. There may be disagreement. Angles, baseline distances, tangents and calculations will need to be rechecked until there is reasonable agreement.
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.

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

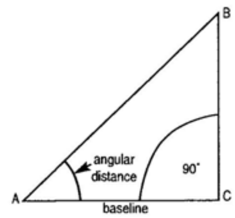


TABLE OF TANGENTS

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!**

Lesson 4

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.

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

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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.

Lesson 5

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 procedures at all times.

Bottle Rocket Lab

Physics Concepts: Newton's 1st

Law - Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it. This we recognize as Galileo's concept of inertia, and this is often termed simply the "Law of Inertia."

Newton's 2nd

Law – If an unbalanced (net) force acts on an object, that object will accelerate (or decelerate) in the direction of the force.

Newton's 3rd Law – For every action force, there is an equal and opposite reaction force.

A body at rest is considered to have zero speed (a constant speed). So any force that causes a body to move is an unbalanced force. Also, any force, such as friction, or gravity, that causes a body to low down or speed up, is an unbalanced force. This law can be shown by the following formula.

F=ma

• F is the unbalanced force (vector)

• m is the object's mass (scalar)

• a is the acceleration that the force causes (vector)

Force and acceleration are both vector quantities. In this law the direction of the force vector is the same as the direction of the acceleration vector. Vector and Scalar Quantities: An understanding of vectors is essential for understanding of physics and Newton's Second Law. A vector is a quantity that has two aspects. It has a size, or magnitude, and a direction. In contrast, there are quantities called scalars that have only size. If a quantity has only a size, it is called a scalar. Mass, distance, speed, time and temperature are examples of scalars. If a quantity has a size and a direction, it is a vector quantity.

Force, acceleration, velocity, displacement, gravitational field, torque, and electric and magnetic fields are all vectors. The following excerpt is borrowed from the NASA website:

http://exploration.grc.nasa.gov/education/rocket/newton1r.html

It explains how Newton's three laws apply in rocket flight. Sir Isaac Newton first presented his three laws of motion in the "Principia Mathematica Philosophiae Naturalis" in 1686. His first law states that every object remains at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force. This is normally taken as the definition of inertia. The key point here is that if there is no net force acting on an object (if all the external forces cancel each other out) then the object maintains a constant velocity. If that velocity is zero, then the object remains at rest. If the velocity is not zero, then the object maintains that velocity and travels in a straight line. If a net external force is applied, the velocity changes because of the force. The liftoff of a rocket from the launch pad is a good example of this principle. Just prior to engine ignition, the velocity of the rocket is zero and the rocket is at rest. If the rocket is sitting on its fins, the weight of the rocket is balanced by the re-action of the earth to the weight as described by Newton's third law of motion. There is no net force on the object, and the rocket would remain at rest indefinitely. When the engine is ignited, the thrust of the engine creates an additional force opposed to the weight. As long as the thrust is less than the weight, the combination of the thrust and the re-action force through the fins balance the weight and there is no net external force. The rocket stays on the pad. When the thrust is equal to the weight, there is no longer any re-action force through the fins, but the net force on the rocket is still zero. When the thrust is greater than the weight, there is a net external force equal to the thrust minus the weight, and the rocket begins to rise. The velocity of the rocket increases from zero to some positive value under the acceleration produced by the net external force. As the rocket velocity increases, it encounters air resistance, or aerodynamic drag, which opposes the motion. Drag increases as the square of the velocity. The thrust of the rocket must be greater than the weight plus the drag for the rocket to continue accelerating. If the thrust becomes equal to the weight plus the drag, the rocket continues to climb at a fixed velocity, but it does not accelerate. This flight condition is often encountered by model rockets because of the low thrust and high drag of their design. Full scale rockets usually have sufficient excess thrust to continue accelerating. Drag eventually begins to decrease because drag depends on the air density and density decreases with increasing altitude.

Newton's 3rd law applies to bottle rockets in the same manner except that the fuel is not burned. A rocket gets its lift from the built up air pressure and the water pushing out of its tail. The force of these fluids is the action force. They force the rocket up in the opposite direction creating the reaction force. Directions for building the bottle rockets:

Materials:

- 2 liter soda bottles
- Construction paper
- Heavy paper
- Modeling clay
- Garbage bags
- Rulers
- String
- Duct tape
- Scissors
- Rulers
- Tag Board

Design Ideas:

- Fins:

o Fins should be firm

o Fins should be secure: duct tape works well

o The size of the fin matters. It works well to make a few patterns for students to model their fins from.

Check out Mr. Hayhurst's Quick and Easy Bottle Rocket site for some great patterns and ideas:

http://www.lnhs.org/hayhurst/rockets/

o Us the string to measure the diameter of the bottle and divide the length of the string by three. Make two marks on the string dividing it into three equal parts and use those marks to mark the bottle for accurate placement of the fins.

• Nose Cone:

o Tag board builds a firm secure nose cone

o The nose cone should have a higher mass to surface area ratio

o Modeling clay can be used to allow students to add mass to the nose cone.

o The nose cone must go through the air easier than the body of the rocket.

o If students choose to add a parachute…the nose coneneeds to be able to separate from the rocket body.

o After applying the nose cone and fins, a string should be tied around the middle of the rocket to see if the rocket hangs evenly. If it doesn't, then it has too much weight on one end or the other and should be balanced. You can also fly it overhead on the string to see if it is balanced in flight

. • Parachute: (optional)

o A garbage bag parachute will work

o Cut open the bag so that it can lay flat.

o Attach strings to the end of the bag

o Place bag inside the nose cone and attach the loose end

of the strings to the inside of the sleeve on the body of the rocket.

o Use a "z" fold to insert the parachute, do not wrap the strings around the parachute. (see Mr. Hayhurst's web site referenced above for a pattern)

Preliminary Questions to ask:

• What is a bottle rocket and what does it have to do with science?

• Why do bottle rockets fly?

• What is the expected outcome for these rockets?

• Why do we have to use water…or do we?

• Will it fly without water?

• If a little water works, will a lot of water work better?

Proceeding Questions to ask:

• Why did the rocket that was full of water barely take off?

o It was too heavy or massive. This can be explained with Newton's first law of motion.

• The rocket didn't have enough "oomph" (force) to make it take off. Why?

o There was not enough force for the relatively huge mass. The force from the pressurized water leaving the rocket must be greater than the force due to gravity (weight of rocket and water). More mass can cause less acceleration using the same force. This can be explained with Newton's second law of motion.

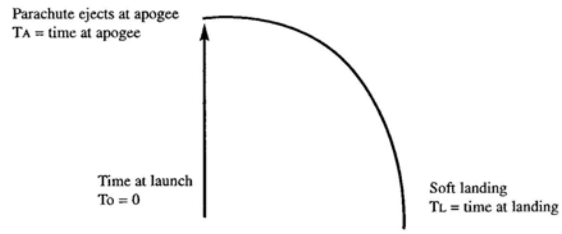
• Why did the water go one way and the rocket the other:

o There is an equal force in both directions. This can be explained by Newton's third law of motion.

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 To and TA (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.

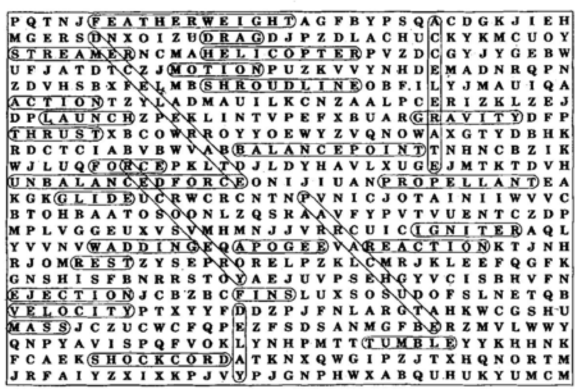
When you want to know the average speed descending, from apogee to landing, use this formula:

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

Day 2 (After Launch)

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.

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 word search puzzle, “All About Rockets”, (Appendix B). 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 word search puzzle as an assessment of their understanding of the concepts.

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____

Activity Sheets

EstesEducator.com is the site to find all worksheets within the curriculum guide for grades 5-8. The entire unit is called Science and Model Rockets. The curricular specifies for model rocketry, however, it can be modified and adjusted to satisfy water bottle rocket requirements. Fundamentals of rocketry, data collection and calculations are the worksheets found in this section. For more information: www.esteseducator.com

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 #3B **Name**________________________

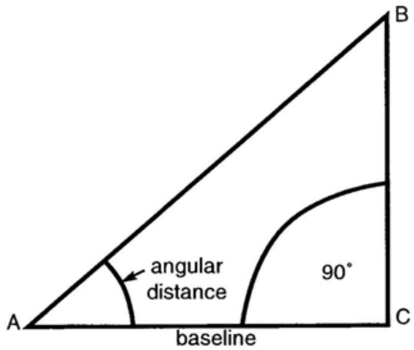


TABLE OF TANGENTS

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!**

Activity Sheet #3C **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 #3A

Name________________________

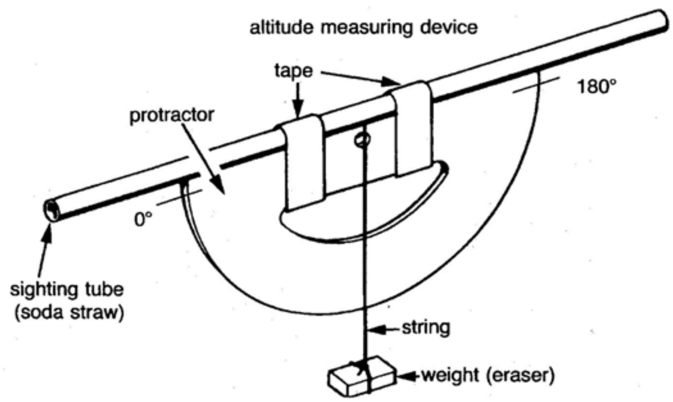
Lesson

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.

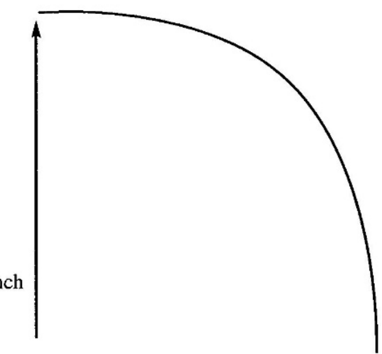
Stand at the place she or he has marked for each object. Hold the straw up to your eye. Move the other end of the device up until you can see the top of the object. At that point, hold your finger on the string against the protractor. Record the angle.

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 #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).

Activity Sheet #6 **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 (T_o) (seconds)	Time at Apogee (T_a) (seconds)	Time at Landing (T_L) (seconds)

Student Name______________________________

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____________________

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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
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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.

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