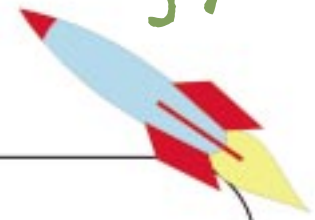
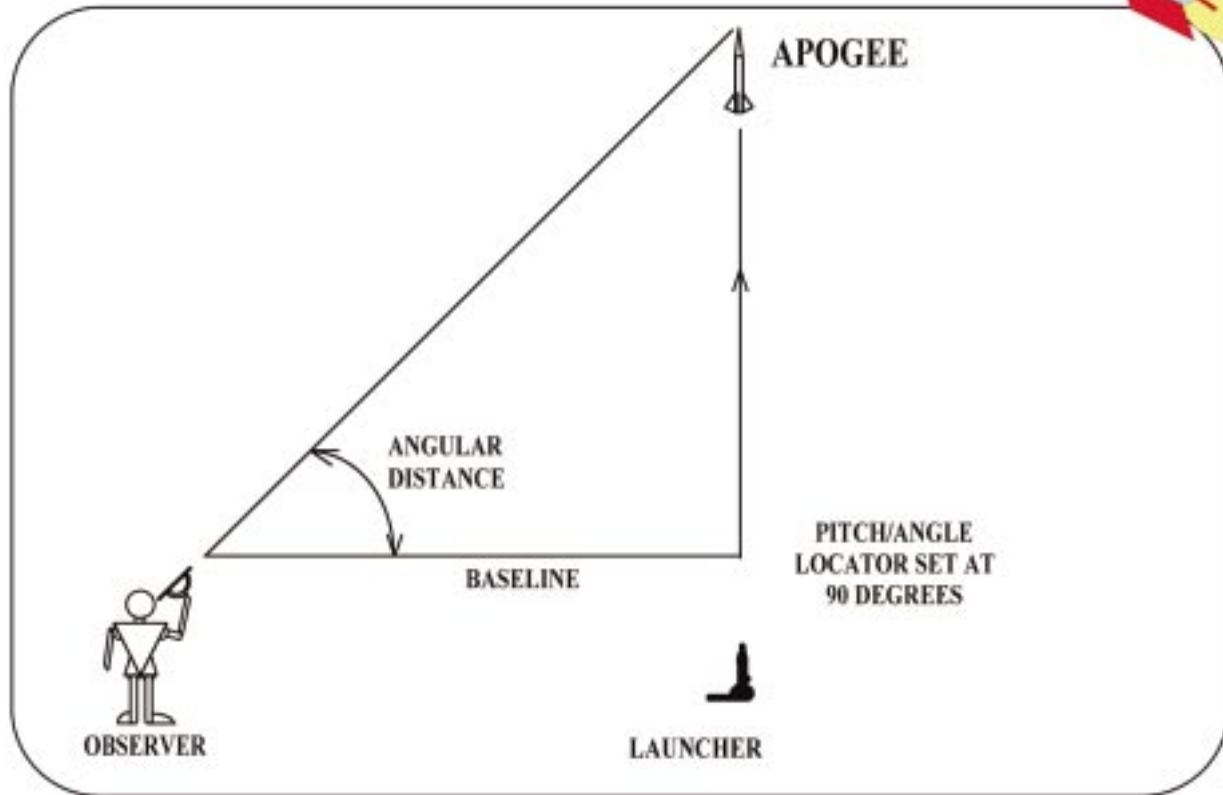


Cheapo Aerospace Technology



ALTITUDE MEASUREMENT



Altitude Measurement Procedures

1. Have students build a model rocket or establish several objects for them to measure.
2. Have students build an altitude tracker.
3. Establish a 30-meter baseline for measuring the object's altitude.
4. Have students sight the model's tip through the homemade altitude tracker.
5. Launch the model at a 90° angle.
6. Have students measure the model's angular distance as its nose reaches the highest point (apogee) in vertical flight.
7. Subtract the apogee measurement taken by the students from 90° .
8. Adjust for the difference in elevation from students to launch pad. Measure the difference in the students' angular distance of observation minus 90° .
9. Consult the trigonometry table to determine the tangent of the model's flight.
10. Multiply the established constant baseline by the tangent obtained from the table of tangents. The result will be the estimate of the apogee achieved.

Cheapo Aerospace Technology

Model Rocketry Safety

Any pursuit of model rocketry with your students should also include an overview of the model rocket safety code. The code detailed below was adapted from the NAR and is available at www.nar.org/NAmrsc.html.

Materials. Do not use metallic parts for building rockets. Use only such lightweight materials as balsa, plastic, and cardboard.

Motors. Use only commercially certified and constructed model rocket motors. Do not tamper with or modify these motors. Use model rocket motors only in accordance with the manufacturer's recommended purposes.

Ignition system. Launch rockets only with an electrical ignition system and igniter. The launch system's design should include a safety interlock wired in series with the launch switch. The system should also use launch switches that return to the off position after releasing the rocket.

Misfires. If a model rocket fails to ignite, the safety interlock for the launch system should be disconnected from the battery. You must wait at least 60 seconds after the launch attempt before approaching the rocket to make any repairs or adjustments.

Launch safety. Use a countdown before every launch. To ensure all spectators' safety, establish a safety area of at least 30 feet away from the launch pad. Ensure that all spectators are paying attention from this safe distance.

Do not launch an untested rocket if you have any doubts about safety or its stability. Check all rockets for stability before a launch and warn all spectators of every launch.

Launcher. Launch all rockets from a rod, tower, or rail pointed within 30° of the vertical to ensure that the rockets fly straight or nearly straight up. Use a blast deflector to prevent ground fires.

To prevent eye injuries, set the end of the launch rod above eye level or cap it when the rod is not in use. All spectators and participants should wear approved safety glasses or goggles during every launch attempt.

Size. Model rockets should not weigh more than 1,500 grams, or 53 ounces. Rockets should not contain more than 125 grams, or 4.4 ounces, of propellant.

Rockets should not have more than 320 Newton seconds, or 71.9 pound seconds, of total impulse. Rockets that weigh more than one pound, or 453 grams, or that use more than 4 ounces, or 113 grams, of

propellant will not be launched until all FAA regulations have been investigated and complied with.

Flight safety. Never launch rockets at targets, clouds, or aircraft. Never use explosives, inflammable payloads, or weapons in a model rocket.

Launch site. All rockets must be launched outdoors, in an open area, and in safe weather. Abort all launch attempts when wind speeds exceed 20 miles per hour.

Abort all launch attempts when ignition sources, such as dry grass, are close to the launch pad. Make every effort to prevent the risk of ground fires at the launch site.

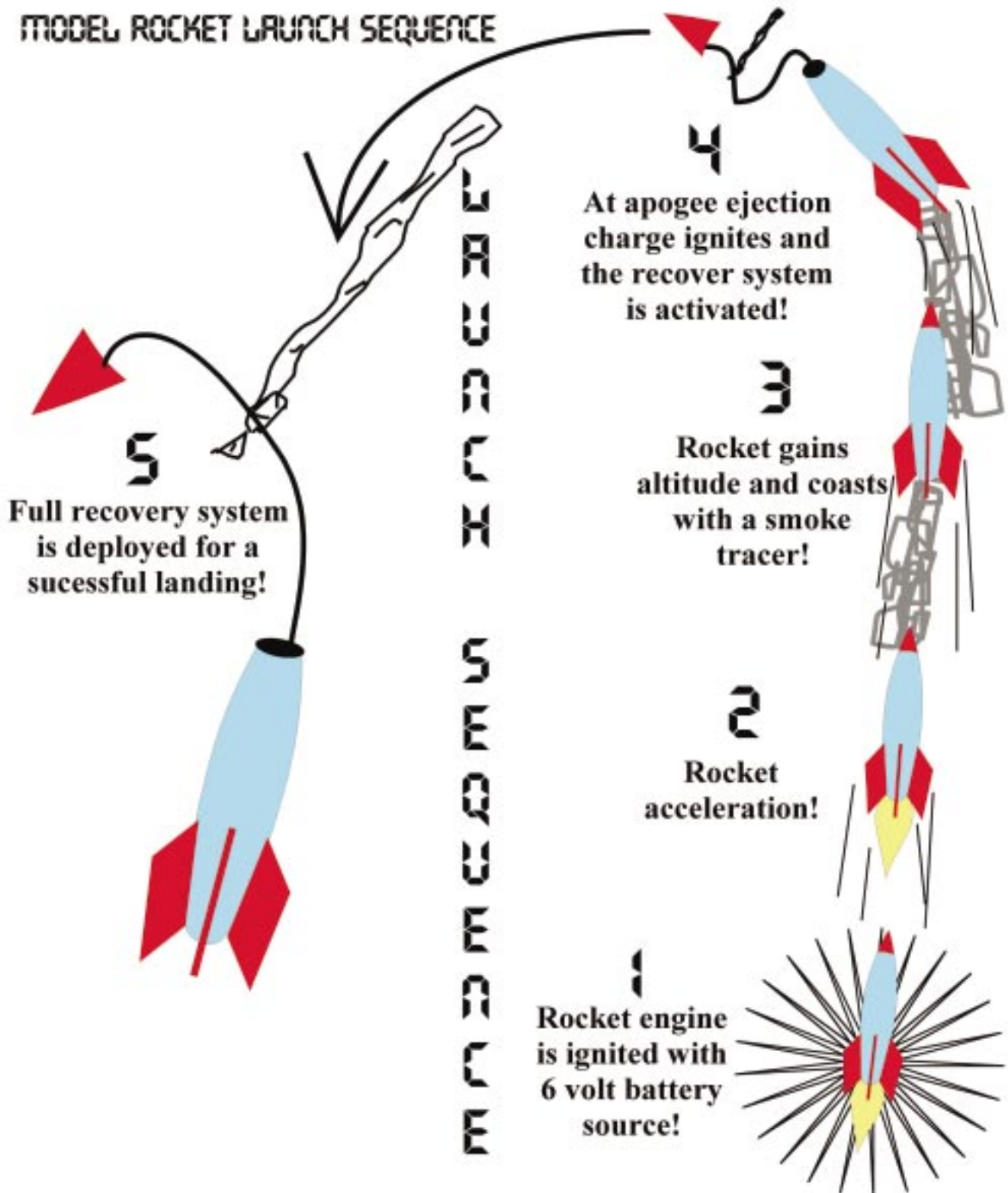
Always obtain permission to collect rockets that land on nearby properties. Always obtain permission in advance to use a location as a launch site from the property owner and the surrounding property owners.

Recovery system. Use a suitable recovery system, such as streamer or parachute, so that the rocket returns safely and undamaged and can be flown again. Use only flame-resistant or fireproof recovery system wadding with your rocket.

Recovery safety. Never attempt to recover rockets from power lines, tall trees, or other dangerous places.

Cheapo Aerospace Technology

MODEL ROCKET LAUNCH SEQUENCE



Cheapo Aerospace Technology



HOW TO FIND THE CENTER OF GRAVITY

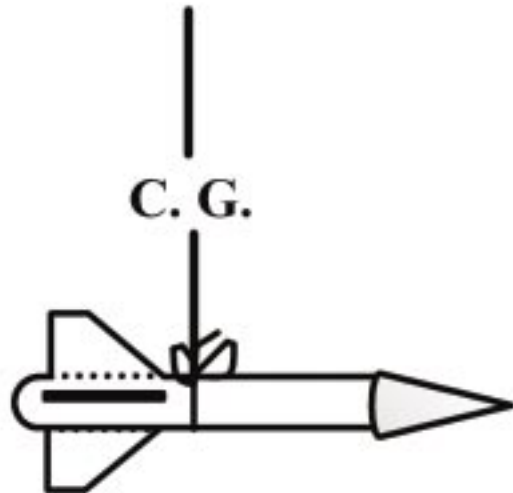


Figure 6

HOW TO BALANCE A MODEL ROCKET!

PRE-FLIGHT TESTING

A properly balanced model is important in order to insure a successful flight and recovery! All model rockets should be inspected and tested prior to flight!

All parts should be attached well. Loose parts should be repaired, replaced, or strengthened! Otherwise you may experience one of the following problems!

CATO: A catastrophic such as the motor exploding!

SHRED: Engine shreds through the rocket!

ZIPPER: The tube is pulled through like a zipper.

COOK: The parachute cooks/melts!

PIGGY BACK: Rocket drags the launch pad into the air!

SEPARATION: Rocket breaks into pieces in flight!

LAND SHARK: The rocket comes at you!

SWING TESTING A MODEL

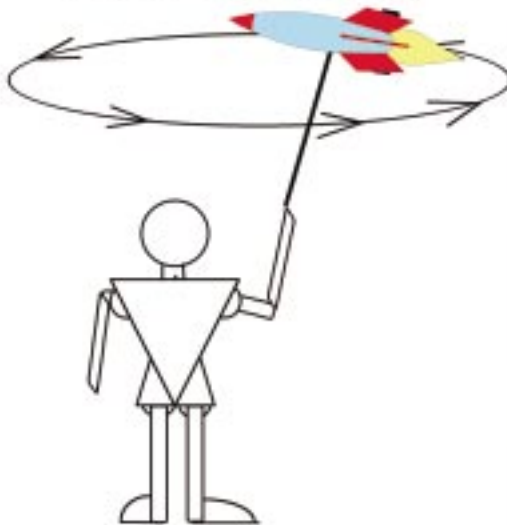


Figure 7

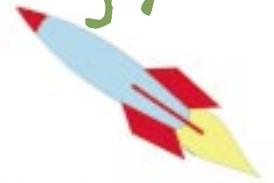
After you are certain that the airframe is built correctly you must next perform a swing test! The first thing you will need to do is obtain a 4' long piece of string (for small models). The next step is for you to attach the engine, parachute etc. In other words the model must be completely assembled!

Next you need to tie the string onto the model and find where it will balance. This location is known as the center of gravity. Usually the C.G. should be off center and toward the tail of the rocket.

Now you will need to mark this location upon your rocket. Also make certain that the string will not slide off of your rocket's airframe. Tape can be used to help it stay in position on small models. Now you must swing the rocket over your head. Whirl the model and observe if it moves front first or tail first.

If the model flies tail first add weight to the nose and then swing test it again. Repeat this process until the model flies nose first when it is tested. Your model is now ready to launch!

Cheapo Aerospace Technology



FLIGHT FORCES AND SIMPLE ORBITAL MECHANICS

The forces that affect the flight of a rocket are thrust, gravity, weight, and aerodynamics. These forces will affect the performance of a rocket in many ways. In practice applications it can be stated that a larger engine will allow a rocket to reach higher altitude and speed. Yet this concept is actually dependent upon the amount of weight of the rocket airframe, aerodynamics and the rocket's payload in relationship to the amount of thrust that it can produce. Furthermore, the gravitational pull upon the space craft such as the difference from launching from Earth versus the moon will affect the ultimate performance as well!

A SIMPLE WAY TO EXPLAIN ORBITAL MECHANICS CAN BE DESCRIBED IN ILLUSTRATION FIGURE 5.

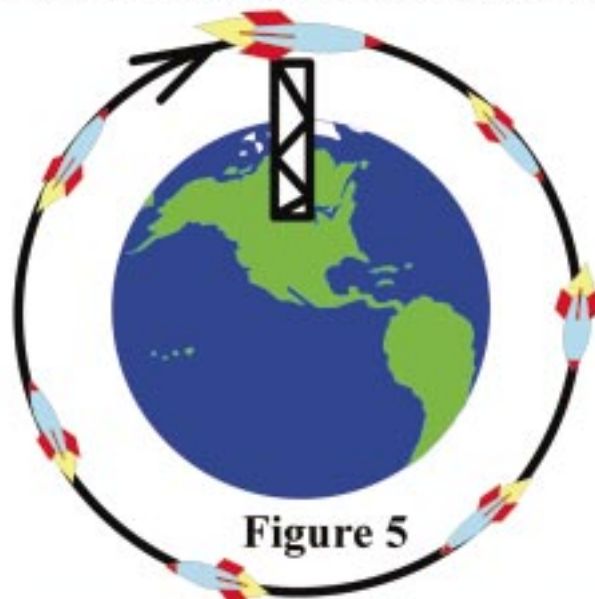


Figure 5

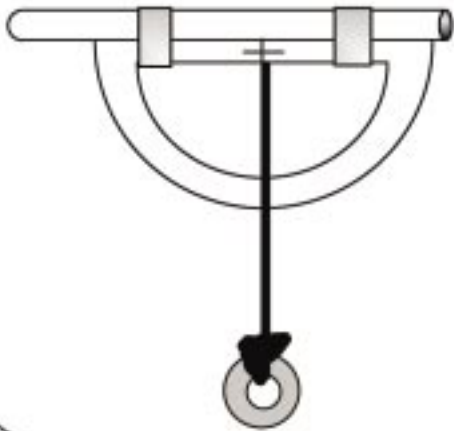
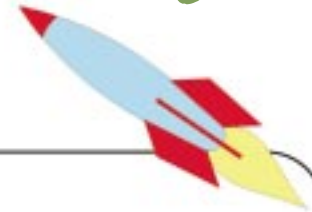
We could build a tall garage into space and stand on top of it from my back yard in Muncie, Indiana. We could then launch your model from it! We would do this so that we could create a simple example of how to make spacecraft travel around the Earth!

When the rocket circles the earth it would be pulled upon by Earth's gravity. If we could control where the rocket circles in relationship to the amount of gravity that is exerted upon it we could establish what is known as an "orbit". In other words the rocket would fall around the Earth! The rocket would continue to do this until it "falls" out of orbit. If the rocket were to use it's engines to push away from the Earth we could go out and investigate a planet, moon, or star. If we were to use the engines to push us back toward the Earth's atmosphere we could go back home and start construction on my REALLY BIG GARAGE!

Another way to explain how an object orbits the earth is for you to take a ball and attach it to a string. As you whirl the ball and string over your head the ball will perform an orbital motion. Since you are the whirler you have now become the Earth! The faster the ball moves the more energy it will gain. If you were to release the ball and string it would move out and away from you. If you were to slow down the orbital motion eventually the ball (space craft) would crash back into you!

In space travel this same concept is used by space craft to reach far away planets. The spacecraft will approach a gravitational force such as the Moon. The space craft will then use the gravitational force of the object to increase its speed and "sling shot" itself around and toward another planet like Mars!

Cheapo Aerospace Technology

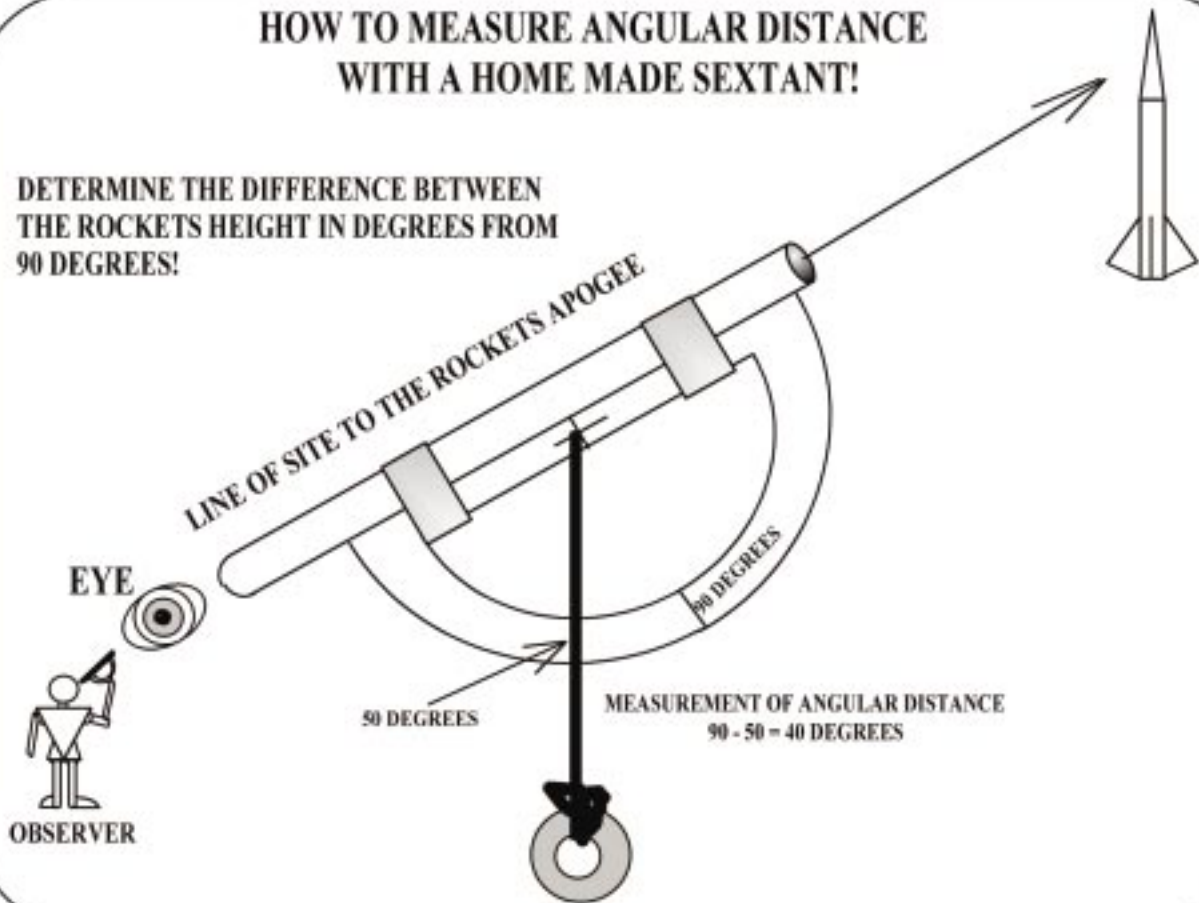


HOW TO MAKE A HOMEMADE SEXTANT!

Assemble a soda straw, tape, string, protractor, and weight such as a fender washer as shown.

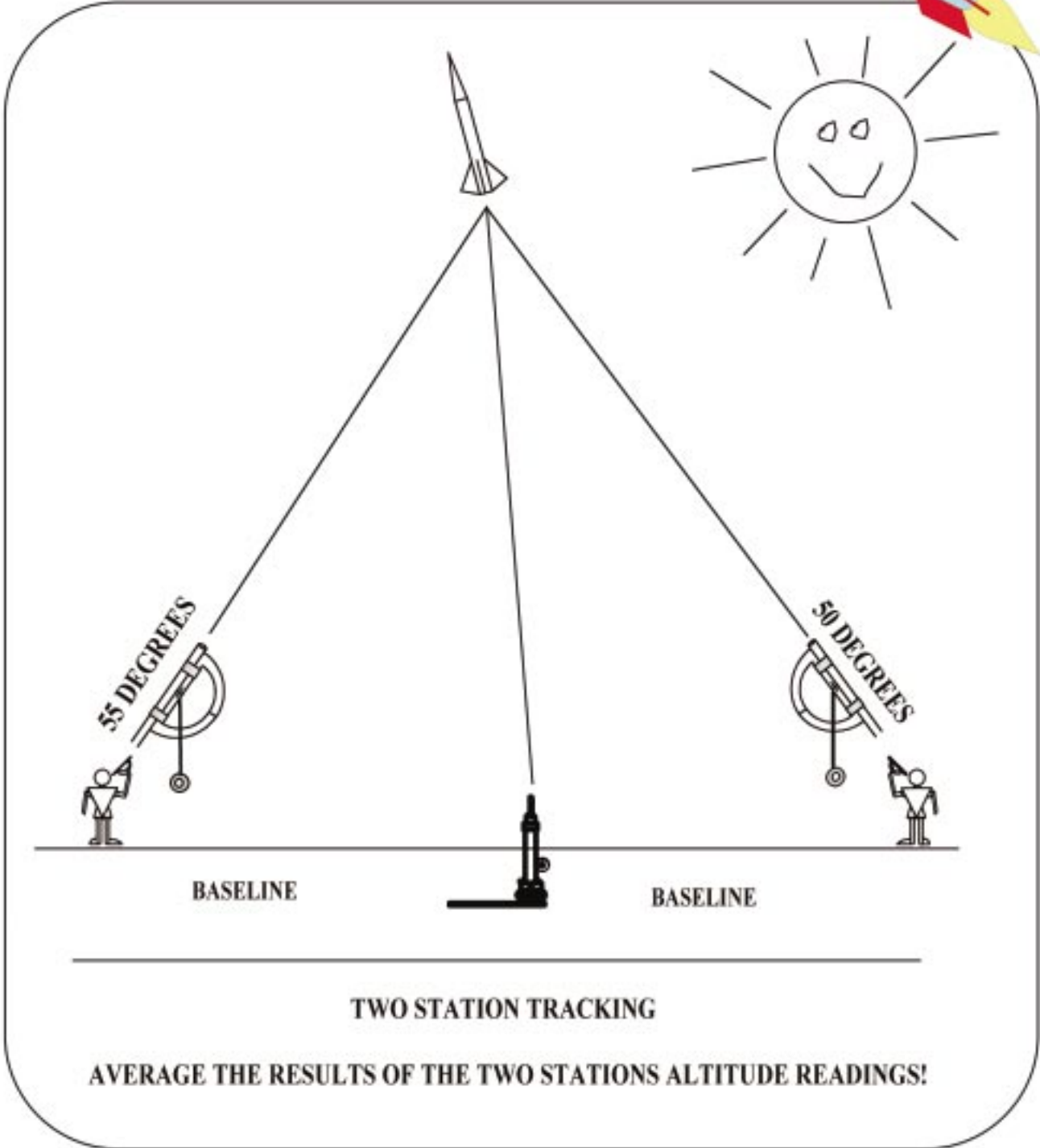
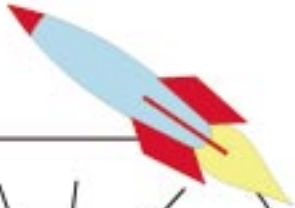
HOW TO MEASURE ANGULAR DISTANCE WITH A HOME MADE SEXTANT!

DETERMINE THE DIFFERENCE BETWEEN THE ROCKETS HEIGHT IN DEGREES FROM 90 DEGREES!



Cheapo Aerospace Technology

TWO STATION ALTITUDE TRACKING



Cheapo Aerospace Technology

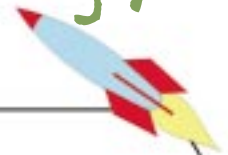
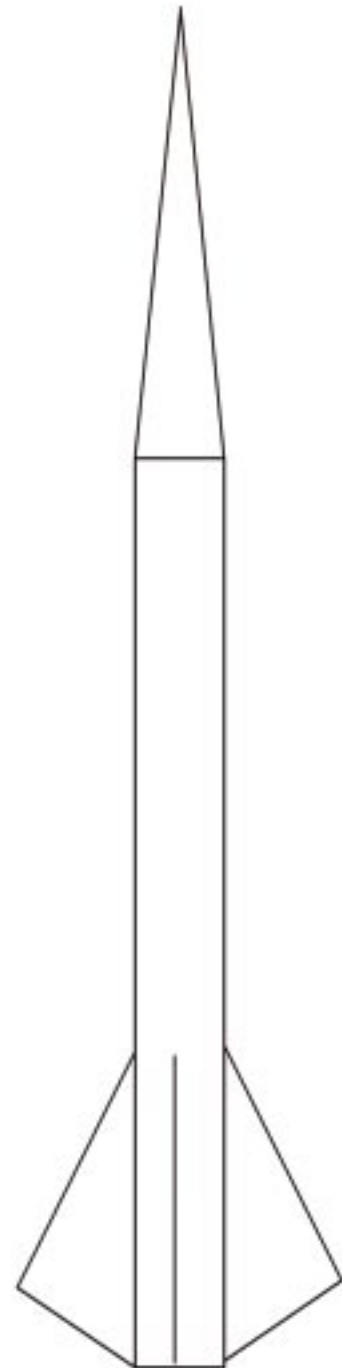


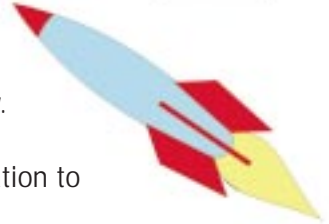
TABLE OF TANGENTS

Degree	Tangent	Degree	Tangent	Degree	Tangent
0	0.0000	31	0.6008	62	1.8807
1	0.0174	32	0.6248	63	1.9626
2	0.0349	33	0.6494	64	2.0603
3	0.0524	34	0.6745	65	2.1445
4	0.0699	35	0.7002	66	2.2460
5	0.0874	36	0.7265	67	2.3558
6	0.1051	37	0.7535	68	2.4750
7	0.1227	38	0.7812	69	2.6050
8	0.1405	39	0.8097	70	2.7474
9	0.1583	40	0.8390	71	2.9042
10	0.1763	41	0.8692	72	3.0776
11	0.1943	42	0.9004	73	3.2708
12	0.2125	43	0.9325	74	3.4874
13	0.2308	44	0.9656	75	3.7320
14	0.2493	45	1.0000	76	4.0107
15	0.2679	46	1.0355	77	4.3314
16	0.2867	47	1.0723	78	4.7046
17	0.3057	48	1.1106	79	5.1445
18	0.3249	49	1.1503	80	5.6712
19	0.3443	50	1.1917	81	6.3137
20	0.3639	51	1.2348	82	7.1153
21	0.3838	52	1.2799	83	8.1443
22	0.4040	53	1.3270	84	9.5143
23	0.4244	54	1.3763	85	11.4300
24	0.4452	55	1.4281	86	14.3006
25	0.4663	56	1.4825	87	19.0811
26	0.4877	57	1.5398	88	28.6362
27	0.5095	58	1.6003	89	57.2899
28	0.5317	59	1.6642	90	-----
29	0.5543	60	1.7320		
30	0.5773	61	1.8040		



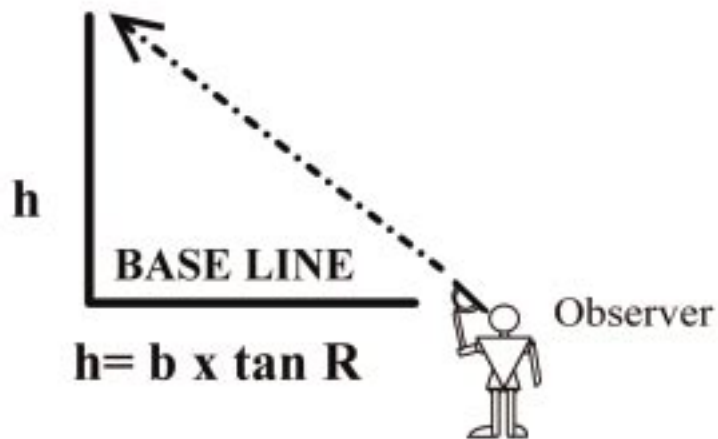
Cheapo Aerospace Technology

NAME _____
 DATE _____ HOUR _____



Instructions:

1. Find a tall object such as a tree or light pole and record it in the table below.
2. Make a sextant (see handout).
3. Measure the length in meters of one of your steps. You will use this information to "step off a distance."
4. Starting from the base of the object that you plan to measure, walk out at least 15-20 steps. Use your rate of steps to calculate the baseline and record the measurement below. The distance should be about 30 meters.
5. Hold the sextant as shown below. Sight the top of your object through the straw.
6. Read the measurement where the string crosses the angle mark on your protractor and record your data below.



<u>Object</u>	<u>Baseline (b)</u>	<u>Angle</u>	<u>90-angle=R</u>	<u>Height = b x tan R</u>
1. <u>Flag pole</u>	<u>30 m</u>	_____	_____	_____
2. _____	_____	_____	_____	_____
3. _____	_____	_____	_____	_____
4. _____	_____	_____	_____	_____
5. _____	_____	_____	_____	_____

Calculations:

1. Subtract the angle measurement from 90° to obtain the correct angle and record it above.
2. Find the tangent (tan) of the angle (R) in the tangent table and multiply this by the baseline (b). The result is the height of the object.

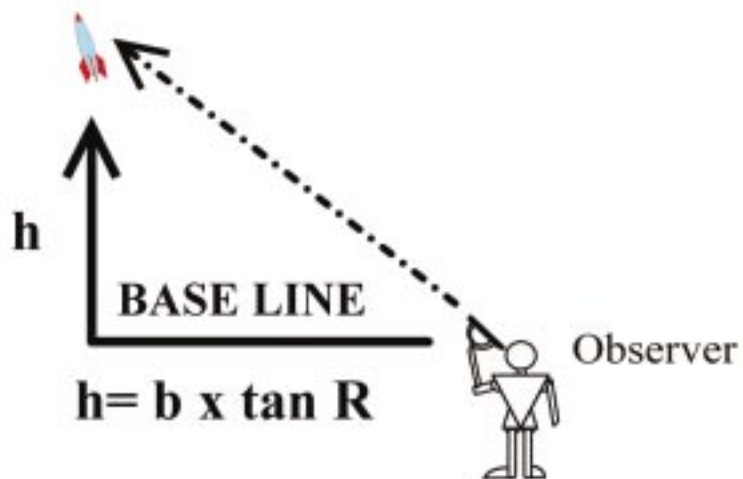
Cheapo Aerospace Technology

NAME _____
 DATE _____ HOUR _____



Instructions:

1. Measure the length in meters of one of your steps. You will use this information to "step off a distance."
2. Starting from the launch pad, walk out at least 20 steps (about 30 meters). Use your rate of steps to calculate the baseline and record the measurement below. All measurements should be from this location.
3. Hold the sextant as shown below. At apogee, sight the top of each rocket through the straw.
4. Read the measurement where the string crosses the angle mark on your protractor and record your data below.



<u>Object</u>	<u>Baseline (b)</u>	<u>Angle</u>	<u>90-angle=R</u>	<u>Height = b x tan R</u>
1. <u>Rocket #1</u>	_____	_____	_____	_____
2. <u>Rocket #2</u>	_____	_____	_____	_____
3. <u>Rocket #3</u>	_____	_____	_____	_____
4. <u>Rocket #4</u>	_____	_____	_____	_____
5. <u>Rocket #5</u>	_____	_____	_____	_____

Calculations:

1. Subtract the angle measurement from 90° to obtain the correct angle and record it above.
2. Find the tangent (tan) of the angle (R) in the tangent table and multiply this by the baseline (b). The result is the height of the object.

Cheapo Aerospace Technology

Vocabulary Development

acceleration	force	opposite side
adjacent side	feet per second	orbit
aerodynamics	geo-synchronous orbit	payload
air frame	gravity	pitch
altiscope	hypotenuse	propellant
altitude	kato	right angle
angular distance	launch lug	sextant
apogee	lift	shred
baseline	Newton's First Law of Motion	stability
body tube	Newton's Second Law of Motion	streamer
center of gravity	Newton's Third Law of Motion	table of tangents
control		tangent
drag		thrust
ejection		velocity
engine	nose cone	wadding
fins	nozzle	zipper