Rocket Physics

Students will learn the basics of rocket physics by constructing an astrolabe and solving related equations.

LESSON PLAN

Learning Objectives:

The students will:

- Build their own simple astrolabes.
- Calculate theoretical values for the maximum velocity and height of the rocket.
- Measure the maximum height and approximate maximum velocity of the rocket.
- Calculate the energy lost to atmospheric drag.

`

Purpose:

Students will investigate the relationships between impulse, momentum, kinetic energy, potential energy, and aerodynamic drag. They will do this by launching a model rocket and observing its average mass, the average force on the rocket, the impulse delivered by the engine, its velocity at engine burnout, and its height at engine burnout.

Introduction:

Rockets, although not air-breathing vehicles like airplanes, abide by forces of flight and have different variables reacting to movement. Rockets require a vast amount of thrust and propulsion to overcome gravity and the atmosphere. Rockets receive thrust by firing hot exhaust gas outward, creating an equal and opposite reaction force that propels the rocket in the opposite direction. This causes the rocket to experience opposing forces from the gas particles within the air. Rockets are even more complex with navigation, gas, and engine components since they have to sustain vast amounts of force. To learn more about rockets and the science behind these complex systems, refer to the **Resources** section.

Grade Level: 9 - 12

Ohio Learning Standards/Science (2018)

Expectation of Learning

Nature of Science

Physical Science & Physics

PS.FM.1: Motion

PS.FM.2: Forces

PS.FM.3: Dynamics

P.M.3: Projectile motion

P.F.5: Air Resistance & drag

P.F.6: Forces in two dimensions

P.F.7: Momentum & conservation of momentum

Ohio Learning Standards/Mathematics (2017)

Numbers & Quantity Standards

N.Q.1: Use units to understand problems

(+) N.VM.1: Recognize vector quantities

(+) N.VM.3: Solve problems involving velocity

Algebra, Functions and Geometry

A.SSE.1: Interpret expressions in its context

A.CED.4: Rearrange formulas for quantities of interest

A.REI.1: Explain each step in solving an equation

(+) F.TF.3: Use special triangles to find sine, cosine, and tangent

G.SRT.7: Explain relationship between sine and cosine

(+) G.SRT.11: Understand Law of Sines & Cosines

Materials Required:

- Protractor, String, Drinking straw
- Cellophane tape
- Large washer or an eraser
- Model rocket, wadding, igniters
- Rocket motors, such as the B-4 or C-6
- Launch pad with igniter system
- Balance

Procedure:

A. Making the Astrolabe

Each student will attach the drinking straw to the flat side of the protractor with the adhesive tape. The string (about 50 cm.) is to be attached to the protractor as shown, and the mass is to be attached to the string. (See page 5)

B. Activity

1. Find the total mass of the rocket and motor before launch.

2. Take the rocket, launch equipment, and students to a field large enough to accommodate the rocket and motor performance.

3. Determine the direction of the wind (easiest method: drop a few blades of grass)

4. Place students (trackers) with astrolabes on opposite sides of the rocket at a distance of 50 meters from the launch pad. Make sure that the students and the launch pad are in line with the wind direction.

5. Place the safety key in the launcher, start a ten second countdown, and have a student launch the rocket. Have the trackers follow the rocket through their drinking straws, up to the point where the motor stops burning. At that point, have other students record the angles of elevation of the rocket by noting where the strings crosses the protractors. (Remember to subtract the angle on the protractor from 90 to get the correct angle of elevation.)

C. Analysis

1. Using the angles of elevation and the length of the line between the trackers (100m), students can calculate the height of the rocket at burnout using trigonometry. Please examine page 5, figure 2. It can be shown, through the use of the law of sines, that

$$h = \frac{(100 * sinA * sinB)}{\sin C}$$

2. Impulse is equal to force multiplied by the time over which the force acts, if the force is constant. The impulse of the motor is given on the motor and is available online. Net impulse, which is the impulse of the motor minus the impulse from the weight of the rocket

$$Net\ Impulse\ (NI) = (Imp - W * t)$$

is **equal** to the change in the momentum of the rocket,

.

$$m * (v_{final} - v_{initial})$$

The average mass can be calculated by taking the measured mass of the rocket and motor, and subtracting one-half of the mass of the fuel. The mass of the fuel can be found online. The weight of the rocket and motor is

$$\left(rocket\ (m) + motor(m)\right) - \left(\frac{fuel\ (m)}{2}\right)$$

As the initial velocity of the rocket is zero, the theoretical final velocity can be calculated easily:

$$v_{final} = \frac{NI}{m}$$

3. As the motor selected provides nearly uniform force, acceleration (a) should be fairly constant. In that case since we know the distance the object flew we can calculate final velocity:

$$v_{final} = v_{initial} + a\Delta t$$
$$\text{where } \Delta t = t_{final} - t_{initial}$$

Thus, the actual final velocity can be calculated and compared to the theoretical value.

4. Kinetic energy is computed as follows:

$$KE = \frac{1}{2} * mv^2$$

Compute the theoretical and actual values of the kinetic energy of the rocket at motor burnout, and use them to calculate the energy lost due to atmospheric drag.

Assessment/Evaluation:

Students should write lab reports indicating the purpose of the experiment, the procedures, the data obtained, and the conclusions drawn. They should determine the percent difference between theoretical values and experimental values of maximum velocity and kinetic energy.

Extension:

Given the kinetic energy of the rocket at burnout, what is the maximum height that the rocket should reach (if the parachute didn't pop too early)? What effect would aerodynamic drag have on this calculation?

Resources:

Rocket Science

https://www.nasa.gov/audience/foreducators/diypodcast/rocket-science-index-diy.html#:~:text=Thrust%20works%20the%20opposite%20of,bodies%20moving%20through%20the%20air.&text=Drag%20is%20the%20aerodynamic%20force,upward%20movement%20of%20the%20rocket.

https://www.grc.nasa.gov/www/k-12/rocket/TRCRocket/rocket_principles.html

https://www.nationalgeographic.com/science/space/reference/rockets-and-rocket-launches-explained/

https://www.explainthatstuff.com/spacerockets.html

Astrolabe

https://www.ifa.hawaii.edu/tops/astl-hist.html#:~:text=An%20astrolabe%20is%20a%20two,most%20used%2C%20multipurpose%20astronomical%20instrument.

https://www.smithsonianmag.com/innovation/astrolabe-original-smartphone-180961981/

Kinematic Equations

https://www.khanacademy.org/science/physics/one-dimensional-motion/kinematic-formulas/a/what-are-the-kinematic-formulas

https://www2.chem.wisc.edu/deptfiles/genchem/netorial/modules/thermodynamics/energy/energy2.htm#:~:text=Kinetic%20energy%20is%20directly%20proportional,meters%20squared%20per%20second%20squared.

http://www.ux1.eiu.edu/~cfadd/1350/09Mom/Rock.html#:~:text=Rockets%20provide%20a%20wonderful%20example%20of%20Momentum%20Conservation.&text=A%20rocket%20does%20much%20the,rocket%20fuel%20is%20burned%20continuously.

Model rocket motors

https://www.nar.org/standards-and-testing-committee/nar-certified-motors/

https://www.nar.org/standards-and-testing-committee/

https://www.grc.nasa.gov/WWW/K-12/rocket/rktenglab.html

Astrolabe

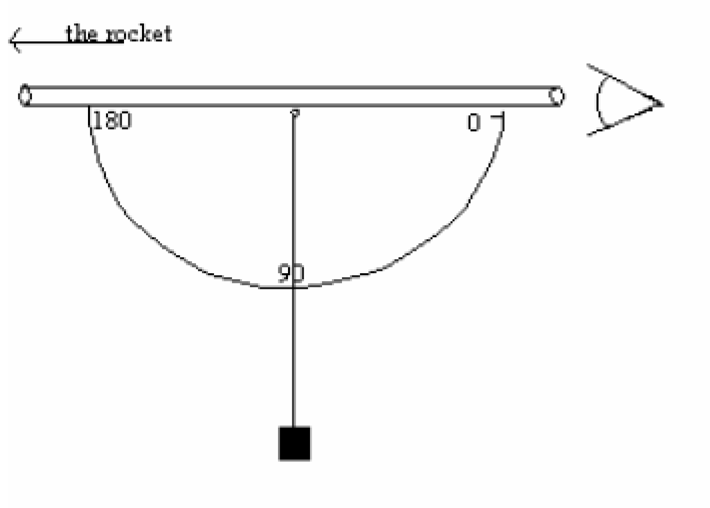

Figure 1

Rocket Flight Path

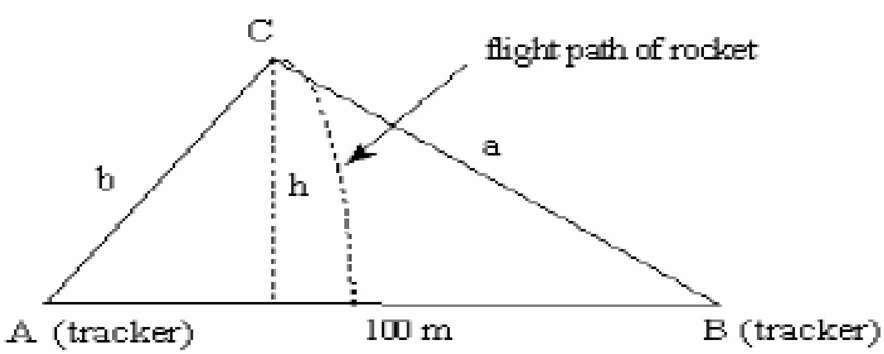

Figure 2