Lesson Plan: Rockets: Kinematics or Energy?

Grade Level: 11-12

Subject Area: Physics

Time Required: Preparation: 1 hour
Activity: 3 - 4 hours

National Standards Correlation:

Science (grades 9-12)
- Science as Inquiry Standard: Abilities necessary to do scientific inquiry.
- History and Nature of Science Standard: Nature of scientific knowledge.
- Unifying Concepts and Processes Standard: Evidence, models, and explanation.
- Unifying Concepts and Processes Standard: Change, constancy, and measurement.

Math (grades 9-12)
- Number and Operations Standard: Compute fluently and make reasonable estimates.
- Algebra Standard: Use mathematical models to represent and understand quantitative relationships.
- Measurement Standard: Apply appropriate techniques, tools, and formulas to determine measurements.
- Representation Standard: Create and use representations to organize, record, and communicate mathematical ideas.

Summary: In this lesson, students will work in cooperative teams to build model rockets. They will then launch the rockets and measure the initial velocity of the rocket and determine the maximum height of the rocket. They will then predict the maximum based on the initial velocity. They will also calculate the initial velocity based on the maximum height. A comparison of the results using the two methods can then be made.

Objectives: Student will:
- Work in small groups to construct model rockets
- Measure and record initial velocity and maximum height of launched rocket
- Calculate initial velocity from height data and maximum height from velocity data using kinematics and conservation of energy
- Compare the two methods for inaccuracy
- Determine the reason for the discrepancy between the results
- Explain why both methods give a high prediction, i.e., why does the kinematic method and conservation of energy method give higher maximum heights and larger initial velocities than actually measured

Background: The purpose of this lab is for students to compare two methods of studying motion, i.e., kinematics and conservation of energy.

Starting with one of the four basic kinematic equations, students can determine the initial velocity of their rocket using the maximum height of the rocket after it is launched. That is, beginning with \( v_f^2 = v_i^2 + 2gh \) where
vf is the rocket's final velocity
vi is the rocket's initial velocity
g is the acceleration due to gravity, assumed to be 9.8 m/s² and
h is the maximum height of the rocket

and considering that the velocity, vf, of the rocket at its maximum height is zero, students can perform simple algebra to obtain the equation for initial velocity:

\[ v_i = \sqrt{2gh} \]

Rearranging the same equation will also allow the students to perform the reverse prediction that is determining the rocket's maximum height from its initial velocity, which is:

\[ h = \frac{v_i^2}{2g} \]

Applying conservation of energy, students should get identical results. If one neglects air resistance, mechanical energy is conserved and the students can begin with the conservation of energy equation, that is,

\[ U_i + K_i = U_f + K_f \]

where
- \( U_i \) is the initial gravitational potential energy
- \( K_i \) is the initial kinetic energy
- \( U_f \) is the final gravitational potential energy
- \( K_f \) is the final kinetic energy

and using the defining equations for gravitational potential energy and kinetic energy, that is

\[ U = mgh \]

where
- \( m \) is the rocket's mass
- \( g \) is the acceleration due to gravity, assumed to be 9.8 m/s² and
- \( h \) is the maximum height of the rocket

where \( v \) is the rocket's velocity

\[ K = \frac{1}{2}mv^2 \]

the student's should be able to rearrange the equations to determine the same equations they got using kinematic methods.

**Materials:**

You will need:
- Model rocket kits (Estes Alpha preferred)
- Tacking glue
- Exacto knives
- Engine kits (including engines, igniter plugs, rocket igniters and recovery wadding)
- 2 altitude finders
- Launcher with safety key
- Launch pad
• Electronic motion detector (e.g., TI CBL, Vernier motion detector, etc.)
• Student handout (follows)

Procedure:

A. Model Construction (Days 1-2)
1. Students should follow the directions specific to the model rocket purchased to construct a rocket. Depending on the level of the student you may want to walk them through the steps or you may choose to have them follow them. In either case, it is helpful if you have a model constructed for students to observe.

2. You will probably want to stop construction on the first day after students have attached the fins. This will allow them to dry in the proper position, before students handle the rockets further.

B. Rocket Launch (Day 3)
1. Divide students into three groups: those who will launch rockets, those who will recover rockets, and those who will measure the rocket altitude and initial velocity. The groups can then rotate.

2. SAFETY: You cannot emphasize enough to your students that no one enter the launch area unless you direct them to do so. If anyone breaks the safety rules, END THE ACTIVITY.

3. Explain to students how to use the altitude finder. Once at the launch area, set up two points 25 m from the launch pad. Have students at each of the two points measure the angle to the maximum height. For consistency, you may want to have the same student repeat all measurements from each point.

4. Have someone else from the observation team, using the motion detector to measure the rocket's initial velocity.

5. Launch the rockets according to the directions of your launch system. It is safer if your launcher has a safety key, to always keep it on your person. This is particularly important, if a rocket fails to launch you need to check the ignition wires.

6. After all of the rockets have launched from the first group, rotate groups. Continue rotating groups until everyone has launched their rocket.

C. Data Analysis (Day 4 or at home)
Have students complete the handout attached which requires them to calculate maximum height and initial velocity. This can be assigned as homework the night after the rocket launch.

D. Wrap-up (Day 4 or 5)
1. Discuss the "rightness" of using the two different methods. This is an important opportunity for students to see that there is more than one right way to solve a problem.

2. Discuss the possible sources of error. Neglecting air resistance should be the most obvious answer. Errors in maximum height measurement due to different heights of the observer and different distance to the launch pad can also be discussed.

3. Refer back to Newton's Third Law and discuss how a rocket works. Many students have the misconception that rockets must push off the air to lift. The obvious question to address this is "How did the lunar module ascent stages rise of the moon's surface when there is no atmosphere?" Another way to address is to blow up a balloon and without
tying it let it go. It’s pretty easy for students to see that the balloon rushes forward because air rushes out.

**Assessment/Evaluation:**

Students should be evaluated on their accuracy in deriving the equations, calculating maximum height and initial velocity, and discussing the sources of error.

**Extensions/Variations:**

1. If budget will not allow teams to build rockets, the lab could be done as a demonstration with a single rocket.

2. Students could view the movie *October Sky* or preferably read the book the movie was based upon, i.e., *Rocket Boys* by Homer Hickam, Jr. This book describes the attempt of a group of young boys who idolized Werner von Braun to build their own rockets during the Sputnik era.

**Resources/References:**


