NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE™

Rockets: Kinematics or Energy?

Students will learn about kinematics and conservation of energy by constructing and testing model rockets.

LESSON PLAN

Learning Objectives:

The students will:

- 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
- 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

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Purpose:

Students will work in 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.

Introduction:

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:

v_f = rocket's final velocity
v_i = rocket's initial velocity
g = acceleration due to gravity, assumed to be 9.8 m/s2 and
h = maximum height of the rocket

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

Grade Level: 9 - 12

Ohio Learning Standards/Science (2018)
Expectation of Learning
Nature of Science

Physical Science
PS.FM.1: Motion
PS.FM.2: Forces
PS.FM.3: Dynamics

Physics
P.M.1: Motion graphs
P.M.3: Projectile motion
P.F.6: Forces in two dimensions
P.F.7: Momentum & conservation of momentum

Ohio Learning Standards/Mathematics (2017)
Numbers & Quantity Standards (-quantities & -vectors)
N.Q.1: Use units to understand problems
(+) N.VM.1: Recognize vector quantities
(+) N.VM.3: Solve problems involving velocity

Algebra
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

Materials Required:

- Model rocket kits
- Glue
- Motor kits (including motors, igniter plugs, igniters and recovery wadding)
- 2 altitude finders
- Launcher with safety key
- Launch pad
- Electronic motion detector
- Student handout (follows)

$$v_i = \sqrt{2gh}$$

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:

$$h = {v_i^2}/{2g}$$

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,

Ui + Ki = Uf + Kf

Ui = initial gravitational potential energy
Ki = initial kinetic energy
Uf ;= final gravitational potential energy and
Kf = final kinetic energy

Using the defining equations for gravitational potential energy and kinetic energy, that is U = mgh, where:

m = rocket's mass
g = acceleration due to gravity, assumed to be 9.8 m/s2 and
h = maximum height of the rocket
where v = rocket's velocity

$$K = \frac{1}{2}mv^2$$

The students should be able to rearrange the equations to determine the same equations they got using kinematic methods.

Procedure:

A. Model Construction (Days 1-2)

1. Students should follow the directions specific to an **"easy to build"** model 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 an "easy to build" model constructed for students to observe.
2. **NOTE:** If budget will not allow teams to build rockets, the lab could be done as a demonstration with a single rocket.

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.

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 correctness of using the two different methods. This is an important opportunity for students to see that there may be 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.

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:

Students could view the movie *October Sky* or read the book the movie was based upon, *Rocket Boys* by Homer Hickam, Jr. This book describes the attempt of a group of young boys to build their own rockets immediately following the launch of Sputnik I.

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/

Kinematic Equations

https://courses.lumenlearning.com/boundless-physics/chapter/problem-solving-for-basic-kinematics/#:~:text=There%20are%20four%20kinematic%20equations%20when%20the%20initial%20starting%20position,v%3Dv0%2Bat&text=d%3D12(v0,alternatively%20vaverage%3Ddt&text=d%3Dv0t%2B(at22)

https://www.physicsclassroom.com/class/1DKin/Lesson-6/Kinematic-Equations

Conservation of Energy

https://www.grc.nasa.gov/WWW/K-12/airplane/thermo1f.html

https://energyeducation.ca/encyclopedia/Law_of_conservation_of_energy