Rocket STEM

Challenge problems and activities

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1. CHALLENGE PROBLEMS AND ACTIVITIES

This section contains challenge problems and activities. Challenge problems allow students to immerse themselves in the learning process to create solutions. Challenge problems are open-ended in that a number of possible solutions can be created. Activities describe specific exercises that teachers can provide to students. The activities allow students to experience more guidance than the challenge problems, through smaller, more defined exercises. As such, the activities are appropriate for students who are at more of a beginner level, and help prepare students for completing the challenge problems. The activities included in this guide are unique, but many other rocket activities exist, some of which are included in the Supporting Resources.

The challenge problems and activities included in this Teacher's guide are stand-alone activities, but complement one another. Therefore, the unit can be customized to include any number of challenge problems and activities that suit the instructional objectives or time constraints. The challenge problems and activities may leverage materials from the Kit.

1.1. CHALLENGE PROBLEMS

1.1.1. CHALLENGE PROBLEM #1: DESIGN THE ULTIMATE ROCKET

Utilize a commercial off-the-shelf water bottle rocket simulator to design and adjust conditions of a water bottle rocket to achieve maximum height. Use a simulator such as Rocket Modeler III to optimize rocket design and launch parameters. Solutions to this challenge will include a technical report of the data determined in the simulator and construction of a physical rocket based on those results. Compare actual flight results to those obtained in the simulator.

1.1.2. CHALLENGE PROBLEM #2: DETERMINE OPTIMAL FUEL LEVEL

Design and conduct an experiment to determine the optimal amount of water needed to propel the rocket to its maximum height. Use physical rockets and methods of height measurement. Solutions to this problem will include a properly designed experiment limiting variability, data analysis, and a technical report of the experiment. This challenge can be extended to compare experimental values against those obtained in a water bottle rocket simulator.

1.1.3. CHALLENGE PROBLEM #3: HIT THE TARGET

Adjust rocket design or launch parameters to hit a target. Design and conduct experiments to collect data so that rockets or launch parameters can be adjusted to hit a target (e.g., specific altitude, specific hang time, etc.). Solutions to this problem will include conducting many trials to collect data, and generating flight graphs and algorithms. This challenge could be extended to use the data to create a functional rocket simulator.

1.1.4. CHALLENGE PROBLEM #4: PRINT 3D PARTS OR MOLDS

Create customized parts or a nose cone mold for a water bottle rocket. Use 3D modeling software such as Autodesk Inventor or SketchUp, and a 3D printer. Solutions to this problem will involve creating a 3D part file and a printed component for a water bottle rocket that would serve a specialized function or improve rocket flight.

1.1.5. CHALLENGE PROBLEM #5: DECREASE DRAG-1

Utilize a commercial off-the-shelf wind tunnel simulator to optimize the aerodynamics of a water bottle rocket. Use tools such as Autodesk Flow Design, SketchUp, and a physical rocket. Solutions to this problem will include modeling the water bottle rocket, determining drag coefficient, and making a rocket of the optimized design. An additional challenge would be to compare drag coefficients obtained in the simulation against a student-built wind tunnel.

1.1.6. CHALLENGE PROBLEM #6: DECREASE DRAG-2

Design and build a wind tunnel to analyze aerodynamics of a water bottle rocket. Solutions to this problem could include modeling the wind tunnel with CAD software, determining drag coefficient, and building the wind tunnel. Wind tunnels should be calibrated using an object with a known drag coefficient. An additional challenge would be to comparing drag coefficients obtained in the wind tunnel against a wind tunnel simulator.

1.2. ACTIVITIES

1.2.1. ACTIVITY #1: NASA GUIDES TO ROCKETS

Investigate variables which affect rocket flight using Rocket Modeler III. Use NASA Beginner’s Guide to Rockets and All About Water Rockets, which are comprehensive sites that allow exploration of cross-cutting principles of rocketry with respect to math, science, and even history, and examine how water bottle rockets model those principles.

1.2.2. ACTIVITY #2: PRE-BUILT ROCKETS

Use pre-built rockets to quickly test fuel (water) amounts, nose cone shape, fin size, launch pressure, body length, etc. Design experiments, make hypotheses, and test these variables. Ten pre-cast nose cones sleeves (five conical and five spherical) and ten pre-made fin sleeves (five small and five large) are included in the kit to accommodate lessons with time constraints or to more directly focus on scientific method and experimental design. The sleeves can slide onto an intact 2L bottle making an instant rocket.

1.2.3. ACTIVITY #3: ROCKET MODELING AND SIMULATION

Students can complete these activities to gain experience in modeling and simulation.

1.2.3.1. ROCKET MODELER III SIMULATION

Investigate and determine optimal values for variables such as nose-cone length and mass, fin shape, size, number and placement, and pressure and fuel amounts for 2L bottle rockets using Rocket Modeler III simulator.

Note: This should occur before rocket construction.

1.2.3.2. CAD AND WIND TUNNEL SIMULATORS

Model rockets using CAD software. This will require not only designing rockets, but being cognizant of measurements and scale. After modeling, determine the drag coefficient and aerodynamics of the rocket in a wind tunnel simulator. This modeling and simulation piece parallels the scientific method as it allows students to design, test, redesign, and retest variables easily.

1.2.4. ACTIVITY #4: ROCKET CONSTRUCTION

Cast nose cones and cut out and attach fins to the bottles. Teachers can implement several additional activities or challenges at this stage.

Note: This activity is applicable if the student is not using the pre-made nose cone or fin sleeves.

1.2.4.1. NOSE CONE MOLDS

Design molds with a CAD program or by using everyday materials, such as a traffic cone. If a 3D printer is available, print molds or other rocket parts.

Note: Conical and spherical nose cone molds are included in the kit.

1.2.4.2. DETERMINE NOSE CONE VOLUME

Determine the volume of the nose cone mold or the nose cones themselves by using either volumetric measurements or calculations. This step is imperative when determining how much FlexFoam-iT!® to use.

Note: This activity can occur regardless of whether students cast their own nose cones.

1.2.4.3. DETERMINE EXPANSION COEFFICIENT OF FLEXFOAM-IT!

Design and write a protocol to determine the expansion coefficient. This challenge can be extended to determine what factors affect foam formation. This is also a good opportunity to discuss materials science and engineering.

The nose cones are cast from a polyurethane foam product called FlexFoam-iT!. It comes in two parts, which, when mixed together, chemically react and expand to produce mid-density foam. The expansion coefficient, the amount by which the foam expands from its original volume, is important when considering how much to use to cast the nose cones.

1.2.5. ACTIVITY #5: TEST THE ROCKETS

Before launching, determine the center of gravity (cg) and center of pressure (cp) of your rocket. For stable flight, the center of gravity needs to be above the center of pressure, relative to the direction of flight. After ensuring the cg is above cp, students should do a swing test to ensure rocket stability.

Build a wind tunnel, or use a pre-made tunnel, to calculate the drag coefficient of the rockets. Based on the results, students should modify their designs or make hypotheses about the rocket flights among the student groups.

1.2.6. ACTIVITY #6: LAUNCH ANALYSIS

Calculate rocket height by several different methods: altimeter, inclinometer, or by free-fall time. Principles of data collection, such as multiple observations or sources of error, could be discussed at this point. Recording the launch in front of a ticker (graduated marker) will allow students to calculate launch data such as velocity and acceleration.