MEASURING ROCKET IMPULSE

INTRODUCTION

In this lesson students will compare experimental data with the manufacturer's specifications for impulse of a model rocket engine.

LEARNING OUTCOMES

Upon completion of this lesson plan, students will be able to:

- Derive the impulse equation from Newton's Second Law
- Graph impulse data from experimental launches and compare to engine manufacturer specifications.
- Compare impulse data for several classes of rocket engines (optional)

CURRICULUM ALIGNMENT

NORTH CAROLINA ESSENTIAL STANDARDS: HIGH SCHOOL PHYSICS

Phy.1.2 Analyze systems of forces and their interaction with matter

Phy.1.2.3 Explain forces using Newton's Laws of Motion as well as the universal law of gravitation.

Phy.1.3 Analyze the motion of objects based on the principles of conservation of momentum, conservation of energy and impulse.

Phy.1.3.2 Analyze the motion of objects based on the relationship between momentum and impulse.

CRITICAL VOCABULARY

Momentum: a vector quantity proportional to the product of mass and velocity, p=mv

Impulse: change in momentum

Unbalanced Force: a force that causes acceleration

Thrust: the propulsive force of a jet or rocket engine

CLASSROOM TIME

1.5 to 3 hours for rocket construction and 4 to 5 hours for classroom activities

MATERIALS NEEDED

Students can work individually or in groups of 2-4 depending on budget constraints.

Per Group/Student

- One model rocket*
- One spark timer
- Spark timer tape (15 meters/rocket)
- Masking tape (15 meters/rocket)
- Graph paper and/or graphing software (like Excel)
- Brightly colored spay paint (optional)

Per Class

- Launch pad and launch controller with batteries (http://www.estesrockets.com/rockets/accessories/launch-systems)
- 2 wire coat hangers (to fix the launch pad to the ground)
- Access to an electrical outlet (with extension cords) and a large open field.

*For first time rocket builders, I suggest using a low level skill classroom bulk pack kit sold at most hobby stores and made by Estes Rockets: http://www.estesrockets.com/rockets/educator
For teachers and/or students with rocket building experience, higher level skill kits can be ordered from a model rocket supplier such as Apogee
http://www.apogeerockets.com/Rocket_Kits?zenid=lmt4dvkd79oia2eed4hf742ol3
And for those wishing to push the envelope, individual parts can be ordered
http://www.apogeerockets.com/Building_Supplies

Another consideration when choosing a rocket is recovery rate. Smaller engines will increase recovery rate, particularly if a very large field is not convenient to an electrical outlet.

TECHNOLOGY RESOURCES

- Spark Timer from Fisher Scientific (S434172)
- Spark Timer Tape from Fisher Scientific (S434175)
- Computer with Microsoft Excel
- Printer
- Video recorder and/or camera (optional)

PRE-ACTIVITIES

1. Students should already have covered Newton's Laws of Motion and should be familiar with the Critical Vocabulary.
2. (Optional) Students can build simple model rockets and use them to study the concepts of average velocity, displacement, and acceleration. Students can use collected data to calculate average velocity of a rocket in flight.
3. Students should be familiar with the operation of a spark timer.
4. Have students read about Momentum and Impulse from "The Physics Classroom" at http://www.physicsclassroom.com/class/momentum/u4l1a.cfm and http://www.physicsclassroom.com/class/momentum/Lesson-1/Momentum-and-Impulse-Connection before beginning the lesson.

ACTIVITIES

1. Have the students assemble a model rocket. Be sure to choose a rocket that matches your student's skill level. Allow about 90 minutes to build the rocket and additional time if the rockets are to be painted. Colorful spray paint is helpful for rocket recovery.
2. Immediately before flight, record the total mass of the rocket system.
3. Modify the spark timer tape to increase strength - the tape will break off prematurely if it is not reinforced.
    a. Take a 15 meters of spark timer tape and place 15 meters of masking tape on the back (dull) side of the spark timer tape, running the entire length. Only the top (shiny) side of the tape will make spark marks.
    b. Cut and trim the tape to fit in the spark timer. The opening in the spark timer is sufficient to fit this thicker tape piece.
    c. Thread the tape with the top-side facing the spark timer marker.
4. Use masking tape to connect the threaded spark timer tape to one fin on the rocket. The tape should be running along the slanted edge of the rocket fin.
5. Align the rocket and tape to the spark timer to reduce interference from friction, which can be substantial. Remind students that the act of taking measurements always alters the experiment but we need to minimize effects whenever possible.
6. Plug in the spark timer and fix it to the ground. A bent coat hanger or two works well. Set the spark timer to 60 Hz.
7. Have students step back behind the launch controller for safety purposes and launch the rocket.
8. Recover the rocket and remove the tape.
9. Measure all intervals on the tape.
10. Have the students create a spreadsheet for computing velocity and impulse values.
    Since the timer was set to 60 HZ or 60 cycles per second, each interval has a constant time of $1/60^{th}$ of a second. Velocities can be calculated at each interval, dx/dt, by dividing the distance between marks by $1/60^{th}$ of a second.
11. The change in momentum (Impulse) can be calculated by multiplying the change in velocity by the pre-launch mass of the rocket.
12. Compare the measured impulse with the value provided by the manufacturer.
    For Estes rockets you can use this chart: http://www.spaar.org/Downloads/Library/EstesEngineSpecs.pdf
13. If students/groups used different types of rockets, compare the measured impulse for the different types of rockets.

ASSESSMENT

Have students compare their experimental impulse values with the manufacturer's specifications. Account for all discrepancies - both observed and potential sources of error.

Complete a formal laboratory report describing the experimental procedure, data, analysis, conclusion and sources of error.

COMMUNITY ENGAGEMENT

The American Association of Physics Teachers (AAPT) is an extremely valuable resource for students to present their original research using rocketry. Local University professors can be approached to provide mentorship and resources not normally accessible to K-12 students. Consider having students present their research at local, regional and even national AAPT meetings. More information on AAPT resources can be found at http://aapt.org/Resources/pre-college.cfm

Team America Rocketry Challenge is another source for mentors to assist with custom rocket builds, guest speakers and lesson plan resources. More information, including a video on how to build a model rocket, can be found at http://rocketcontest.org/resources.cfm

WEBSITES AND RESOURCES

Resources from Team America Rocketry Challenge including everything from building rockets, Newton's Laws and Aerodynamics
http://rocketcontest.org/pdf/stem_model_rocketry_curriculum_sarradet.pdf

NASA's Adventures in Rocket Science Educator's Guide
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Adventures_in_Rocket_Science.html

Estes Educator's Guide
http://www2.estesrockets.com/cgi-bin/wedu001P.pgm?p=educator

National Association of Rocketry
http://www.nar.org/teacher.html

AUTHOR INFO

Kathleen Melious teaches Aviation Fundamentals, Honors Physics and AP Physics at T W Andrews High School in High Point, NC. She has 12 years experience teaching High School science and 5 years teaching Middle School science and algebra. Kathleen holds a BS in Biomedical Engineering from the New York Institute of Technology and a MS in Biomedical Engineering from Rutgers University/UMDNJ.

ACKNOWLEDGEMENT

Lesson developed through the Flight Fellowships: STEM in Aerospace Science and Aeronautics, a program of the Kenan Fellows Program and the North Carolina Science, Mathematics and Technology Education Center.

Funding provided for the Flight Fellowships by NASA K-12 Cooperative Agreement #NNX10AU89A.

KENAN FELLOWS PROGRAM

SMT

North Carolina Science, Mathematics, and Technology Education Center