Jet Propulsion

LESSON THEME
To build a model to demonstrate how thrust is created in a jet engine.

OBJECTIVES
Students will:
- Investigate how thrust is created in a jet engine
- Design a model jet engine
- Construct a model jet engine from materials provided
- Observe how their model jet engine operates

NASA SUMMER OF INNOVATION

UNIT
Physical Science - Aeronautics

GRADE LEVELS
4^{th} – 6^{th}

CONNECTION TO CURRICULUM
Science, Mathematics, and Technology

TEACHER PREPARATION TIME
2 hours

LESSON TIME NEEDED
2 hours *Complexity : Advanced*

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NATIONAL STANDARDS

National Science Education Standards (NSTA)
Science as Inquiry
- Understanding of scientific concepts
- An appreciation of 'how we know' what we know in science
- Understanding of the nature of science
- Skills necessary to become independent inquirers about the natural world
- The dispositions to use the skills, abilities, and attitudes associated with science

Physical Science Standards
- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

Science and Technology Standards
- Abilities of technological design
- Understanding about science and technology

History and Nature of Science Standards
- Science as a human endeavor

Common Core State Standards for Mathematics (NCTM)
Operations and Algebraic Thinking
- Use the four operations with whole numbers to solve problems
- Generate and analyze patterns

Operations and Algebraic Thinking
- Analyze patterns and relationships
- Write and interpret numerical expressions
- Analyze patterns and relationships

ISTE NETS Performance Indicators for Students (ISTE)
Creativity and Innovation
- create original works as a means of personal or group expression
- use models and simulations to explore complex systems and issues

Communication and Collaboration
- contribute to project teams to produce original works or solve problems

Research and Information Fluency

- plan strategies to guide inquiry
- process data and report results

Critical Thinking, Problem Solving, and Decision Making

- identify and define authentic problems and significant questions for investigation
- plan and manage activities to develop a solution or complete a project
- collect and analyze data to identify solutions and/or make informed decisions

Technology Operations and Concepts

- understand and use technology systems
- select and use applications effectively and productively
- troubleshoot systems and applications

MANAGEMENT

Student data sheet, Part 1 is out of date and needs to state the scientific method. Each station can have a separate data sheet with a student data table listing independent variables and the dependent variable and contain a table for data collection. Then have students compute the range, mean, and median distances of each jet engine test. Graph for plotting averaged numerical data and make a picture representation (line graph).

Stations need the following:

- Intake Station has one fan. Include instructions on how to build a simple anemometer device used to measure wind speed in m/s units
- Compression Station has one and two fans. Fan speed is an independent variable (low, medium, and high). Include instructions on how to build a simple anemometer device used to measure wind speed in m/s units
- Combustion Station can have different size balloons. Measure the circumference of each inflated balloon and calculate expansion of air (volume).

MATERIALS

Part 1

Intake Station

- Small desk fan
- One sheet of paper
- Intake Station Directions

Compression Station

- Butcher paper
- Two desk fans that are the same size
- Twenty 6-inch lengths of string
- Twenty 5-by-7-inch index cards
- Tape
- Two markers
- Compression Station Directions

Combustion Station

- Flask, medium size
- Balloon
- Can of Sterno, Matches, or lighter
- Tongs
- Combustion Station Directions

Part 2

- One cardboard paper towel core per student
- One flexible straw per student
- One 12-by-12-inch sheet of aluminum foil per student
- Four paper circles 1-1/2 inches in diameter per student
- One small (1-inch) paper clip per student
- One 3-oz. paper cup per student
- One pair of scissors per student
- Tape
- Glue (not glue sticks)
- One copy of the Student Work Sheet Part 2 for each student

CONTENT RESEARCH

Key Concepts:

- Parts of a Jet Engine (Jet engines come in a variety of shapes and sized with the specifics usually dictated by the speed of the aircraft.)
    - **Engine** - The part of the aircraft that provides the power for takeoff and landing and sustains flight
    - **Air Intake (Intake)** - Front section of a jet engine that brings a free stream air into the engine.
    - **Compressor** - The compressor is made with many rotary blades attached to a shaft. The blades spin at high speed and compress or squeeze the air before it enters the combustion section.
    - **Fuel line (Burner or Combustion Section)** – The compressed air is then sprayed with fuel and an electric spark lights the mixture and the burning gases expand.
    - **Turbine** - The gases produced in the combustion chamber move through the turbine and spin its blades. The turbines are linked by a shaft to turn the blades in the compressor.
    - **Nozzle(s) -** The rear section of a jet engine tailpipe through which the exhaust gases escape.

Misconceptions:
A jet engine is an air breathing engine. It will not operate in the vacuum of space. A rocket engine is not an air breathing engine. A rocket carries oxygen into space by burning fuel through combustion (or burning). Liquid Propulsion Rocket engine has a fuel tank and oxygen tank (oxidizer). Solid Propulsion Rocket engine has solid propellant that is a mixture of fuel and oxidizer.

LESSON ACTIVITIES
Have students complete data sheets that apply the Scientific Method. At each station students should:

- Describe the experiment (Research Question)
- Predict what will happen before doing the experiment (Hypothesis)
- Conduct the experiment (Experiment)
- Record your observations (Data Collection)

Option: The Teacher demonstration of an operational jet engine can be done using inexpensive, locally obtained, recycled materials.
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Extreme.Guide.html

ADDITIONAL RESOURCES
The Beginner's Guide to Aeronautics Homepage
http://www.grc.nasa.gov/WWW/K-12/airplane/index.html

Airplane Parts – turbine engines
http://www.grc.nasa.gov/WWW/K-12/airplane/turbine.html

Beginners Guide to Propulsion
http://www.grc.nasa.gov/WWW/K-12/airplane/bgp.html

Fact sheets, Interactive jet engine Simulator
http://www.grc.nasa.gov/WWW/K-12/airplane/ngnsim.html

The Courage to Soar Educator Guide
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/The_Courage_to_Soar.html

Aeronautics Educator Guide
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Aeronautics.html

- Air Engine activity

DISCUSSION QUESTIONS

- What did you observe at station 1 with the paper and the fan? Did this match your prediction? *The paper that is held in front is blown away from the fan. The paper held in the back is sucked in towards the fan.*
- What was your prediction for what would happen if the air had been moving into the front fan instead of being still? What actually happened? *The air speed increases when the air behind the fan is blown into the fan rather than being still.*
- What happened to the balloon at station 3? Why do you think this happened? What would happen if the air was enclosed in a tube that didn't expand instead of inside a balloon? *The balloon inflated because the air inside was heated. Heated air expands. If this had taken place in a tube, the air would have been forced out the end of the tube.*
- All these stations demonstrate the processes that take place inside the various parts of a jet engine. In what order do you think they take place? Why? *The proper order of the stations is intake, compression, and combustion. There is an additional step of using a turbine to move the air out of the engine. This was not demonstrated. According to one NASA engineer, a shorthand way to remember the steps is "suck, squeeze, burn, and blow."*
- Describe the function of each part of the jet engine and state the scientific concepts that occur.
    - ***Air inlet (also intake) -*** *The air intake brings ambient or outside air into the engine. The compression section moves the air through a series of fans that compress, or squeeze, the air*

causing it to increase in speed. The combustion section heats the air by burning fuel. This causes the air to expand very rapidly and significantly increases its speed again. Finally, the turbine forces the heated, expanding air out the back of the engine, creating thrust.

- o ***Compressor*** *- The compression section moves the air through a series of fans that compress, or squeeze, the air causing it to increase in speed.*
- o ***Fuel line*** *- The combustion section has fuel lines that supplies fuel that is sprayed into the airstream. The air is mixed with fuel and then ignited. The burning fuel heats the air producing hot expanding gases.*
- o ***Turbine*** *- The turbine forces the heated, expanding air out the back of the engine, creating thrust.*
- o ***Jet nozzle -*** *The jet nozzle is the exhaust duct of the jet engine. This is the jet engine part which actually produces the thrust.*

ASSESSMENT ACTIVITIES

- Conduct a class discussion where students share their findings about how a jet engine works.
- Assess the Jet Propulsion Work Sheet that describes the function of each part of the jet engine.
- Using their jet engine model, take a blank sheet of paper and draw a jet engine cross section and then describe the function of each part.

ENRICHMENT

How a jet engine works website
http://www.grc.nasa.gov/WWW/K-12/UEET/StudentSite/engines.html#enginework
This website contains:

- How a jet engine works video
- History of the jet engine
- Parts of a jet engine
- Types of jet engines