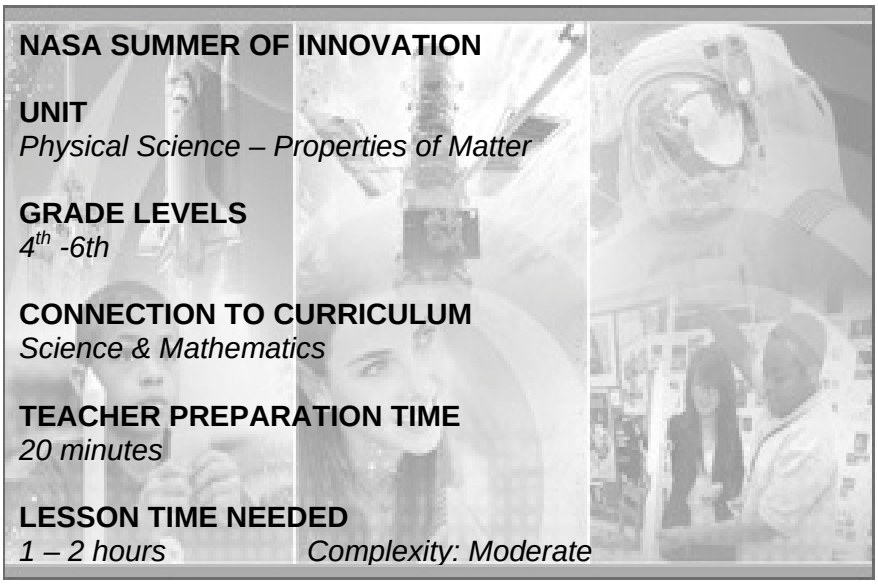
COMPOSITE MATERIALS

LESSON DESCRIPTION
Students explore the properties of composite materials through a series of four demonstrations.

OBJECTIVES
Students will:
- Examine several samples of carbon fiber materials.
- Measure at least one sample and determine its volume.
- Calculate a sample's density.



NASA SUMMER OF INNOVATION

UNIT
Physical Science – Properties of Matter

GRADE LEVELS
4th -6th

CONNECTION TO CURRICULUM
Science & Mathematics

TEACHER PREPARATION TIME
20 minutes

LESSON TIME NEEDED
1 – 2 hours *Complexity: Moderate*

NATIONAL STANDARDS

National Science Education Standards (NSTA)
Physical Science
- Properties and changes in properties of matter
- Properties and motions of objects

Science as Inquiry
- Understanding the nature of science

Science and Technology Standards
- Understanding Science and Technology

Common Core State Standards for Mathematics (NCTM)
Measurement and Data
- Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition

MANAGEMENT
Start with the Nitinol demonstration. Show the students a sample of Nitinol that is in the shape of the word "ICE". Nitinol is an alloy of nickel and titanium that has a very unusual property. Then deform the sample by gently stretching it so that the word "ICE" is no longer discernable. Then immerse the sample into warm water so that the original shape returns.

Some safety precautions to take include not allowing students to push on the scale and handling the scale carefully. Any force heavier than the capacity of the scale can damage its delicate apparatus. Make sure the hot water is really hot and the ice water really cold. Also, do not attempt to cut any of the carbon fiber materials.

CONTENT RESEARCH

There has been an interesting trend in the use of materials in the aviation industry since the beginning of the Wright Flyer in 1903. The original Wright Flyer was constructed from wood (spruce, ash) and muslin (fabric). The all-new revolutionary Boeing 787 is light years away from that early model. About half, or 50%, of the empty weight of this new aircraft is constructed from **composite** materials.

Composites are engineered materials made from two or more materials with significantly different physical or chemical properties. These materials have been around for 3500 years. Mention is made in Exodus in reference to the construction of brick from mud and straw. A typical composite today is made from carbon fibers combined with a resin or plastic. Advanced composite design offers two significant advantages in aircraft design: greater strength and less weight.

The science and engineering of materials now occupies its own separate category. The design and manufacturing of aircraft draw heavily on the knowledge and information available in this field. An unusual metal alloy called **Nitinol** has found its way into the space and aeronautics industry. Discovered by the Naval Ordinance Laboratory in 1962-63, it is a mixture of nickel and titanium, hence the name from: Nickel, Titanium and the Naval Ordinance Laboratory. This alloy is in the category of **Shape Memory Alloys**, or SMA's. A shape memory alloy (SMA, also known as a smart metal, memory alloy, or muscle wire) is an alloy that "remembers" its shape and can be returned to that shape after being deformed, by applying heat to the alloy. Shape memory alloys have numerous applications in the medical and aerospace industries.

Muscle Wire is a brand name of a shape memory alloy. It possesses a unique quality. At room temperature it is easily stretched by a small force. If an electric current is applied, the wire heats and changes to a much harder form that returns to the unstretched shape. When the wire shortens in length, a usable amount of force occurs.

Shape memory alloys have been pioneered and incorporated in the aeronautics industry. One of the earliest applications was in the construction of the F-14. SMA couplings were used in the hydraulic pipe connections.

Materials used in the Boeing 787 Dreamliner

1. Composites - 50%
2. Aluminum - 20%
3. Titanium - 15%
4. Steel - 10%
5. Other - 5%

MATERIALS

- Vernier calipers
- Balance
- Calculator
- Worksheet copies
- Composites:
  - Carbon fiber samples (7)
  - Carbon fiber strip
  - Spruce strip
- Worksheets
- Nitinol:
  - Memory Metal pink book
  - Nitinol sample (inside front cover of book; shaped to form the word "ICE")
  - 300 ml. of hot water
- Density Cube Set
  - 6 metal cubes
  - Blue sheet with graph of "% Zinc vs Density of ZnAl Sample"
- Density Paradox Set
  - Two plastic cylinders with metal hooks
  - Yellow instruction sheet
  - Large glass of very hot water
  - Large glass of ice water (with the ice cubes removed)

A LIST OF KEY CONCEPTS

- The **density** of a solid is determined by its **mass** and **volume**.
- Properties of materials influence how they are used in aircraft.
- Composites are engineered materials made from two or more materials with significantly different physical or chemical properties.
- Shape memory alloys remember their shapes.
- Material science is important in the design and construction of aircraft.

MISCONCEPTIONS

- Objects float in water because they are lighter than water.
- Objects sink in water because they are heavier than water.
- Mass/volume/weight/heaviness/size/density may be perceived as equivalent.
- Wood floats and metal sinks.
- All objects containing air float.
- Liquids of high viscosity are also liquids with high density.
- An object that appears to be on top of the solution is not floating but is held up by the solutions "skin."
- Objects that are completely submerged but freely suspended, such as fish or submarines, are not buoyant.

LESSON ACTIVITIES

Students explore the properties of composite materials through a series of four demonstrations. http://www.aeronautics.nasa.gov/mib.htm.

ADDITIONAL RESOURCES

These short videos from NASA eClips titled *Real World: Self Healing Materials, Real World: Lessons in Heavy Metal* and *NASA 360: Composite Materials* support the concepts in this lesson. They can be downloaded from www.nasa.gov/education/nasaeclips

DISCUSSION QUESTIONS

Ask students to name some of the materials used in the 1903 Wright Flyer, which may include some of the following: wood (spruce), cloth or fabric (muslin), iron (engine), steel wire. Pine was used in early experiments. Pine did not do well in hard landings, so spruce was chosen. Wood had been used for thousands of years and the properties were well known. Ask “What are some of the characteristics that engineers must consider when choosing a particular material for any given part of a modern airplane?” *Possible answers: strength, elasticity, weight or density, cost, supply, hardness and resistance to corrosion.*

Ask students to name some materials that were developed in recent times. *Answers may include: plastics, composites, synthetic rubber, fiber glass (a type of composite), foams and alloys (two or more metals in a matrix).*

ASSESSMENT ACTIVITIES

In order to determine whether or not students are achieving the learning goals for the activity, the activity write up provides a worksheet titled “Determining the Density of Material Samples.”

ENRICHMENT

- Visit a sporting goods or bicycle store. Ask if they have any merchandise made from carbon fiber materials.

- Visit an eyeglass business. Ask to see some flexible eyeglass frames. Flexon is one brand name.

- Make up your own version of “Float and Sink” game. Look around for some objects which are not easily identified as either a floater or sinker. Play the game with friends and family.