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Lesson 5.1: How Do We Launch Artificial Satellites?

Objectives:

- Students will learn Newton's Three Laws of Motion and the Universal Law of Gravity.
- Students will demonstrate an understanding that some form of propulsion is needed to lift a satellite out of Earth's gravity into orbit.
- Students will know that rockets are the means for transporting satellites and people into space.
- Students will explore various propulsion techniques and compare their efficiencies by doing activities.

Estimated Lesson Time:

Two or more classes (2+ hours)

Classroom strategies:

Two people critical for the development of spaceflight are Isaac Newton (who described the laws of motion) and Robert Goddard (who developed modern rockets). Begin with teacher-directed questions on how a satellite could be placed in its orbit. Use a short video to reinforce the concepts. Point out staging by Space Shuttle launches (the solid rocket motors are ejected first, followed by the main external engine - liquid propelled). Ask why rockets are launched straight up and then "pushed sideways" (to minimize atmospheric friction). Review Newton's Laws and gravity. Have students place Newton and Goddard on the timeline.

Science Background Information:

Isaac Newton, English physicist and mathematician, was the culminating figure of the scientific revolution of the 17th century. In optics, his discovery of the composition of white light integrated the phenomena of colors into the science of light and laid the foundation for modern physical optics. In mechanics, his three laws of motion, the basic principles of modern physics, resulted in the formulation of the law of universal gravitation. In mathematics, he was the original discoverer of the infinitesimal calculus. Newton's *Philosophiae Naturalis Principia Mathematica* (Mathematical Principles of Natural Philosophy), 1687,

was one of the most important single works in the history of modern science.

Newton's Three Laws of Motion are: (1) an object in motion tends to stay in motion and an object at rest tends to stay at rest unless acted upon by an external force; (2) force is equal to mass times acceleration; (3) every action has an equal and opposite reaction. Newton's Universal Law of Gravity states that any body with matter will attract any other body through the force of gravity which acts through space. Gravity is stronger when the two bodies are close and decreases as the inverse square of the distance between them. Earth's gravity tugs on objects and attracts them to its center. Therefore, you need to give an object some energy away from the Earth to overcome the downward force of gravity to put them in orbit. Satellites do not launch themselves - rockets do and that is what provides the upward force to lift the satellite to high altitudes. There are different types of rocket motors and launching techniques. Some rocket motors (engines) are made of liquid propellants (fuel) and oxidizer (the chemical that contains oxygen), others are made of solid material, yet a third type of rockets use a combination of solid and liquid fuel. Rocket exhaust is directed appropriately so they can lift the satellite to the desired orbit using Newton's Third Law - *to every action, there is an equal and opposite reaction.*

Robert Goddard is considered to be the father of modern rocketry. You can read all about him at

http://pao.gsfc.nasa.gov/gsfcservice/gallery/fact_sheets/general/goddard/goddard.htm.

To get to the desired orbit, rockets must overcome the Earth's gravity. If a rocket moves faster than 11.5 km/sec (called the escape velocity), it will leave the Earth's gravity forever. The space shuttle and all Low Earth Orbiting (LEO) satellites move at a speed of approximately 8 km/sec (5 miles per second). Rockets can be launched from different platforms. Most are launched from the ground - launch pad. Some are launched from ships or submarines (launch tubes). People have also used balloon and airplane based launches (TERRIERS and many other small satellites use airplane based launchers called Pegasus). For maximum fuel efficiency, rockets are staged, i.e., two or more rocket engines are used in tandem. As each stage burns out, the used up fuel container is discarded (usually it falls back to the Earth)

Vocabulary:

1. Launch -
2. Launch pad -
3. Launch tube -
4. Rocket -
5. Propulsion -
6. Force -
7. Gravity -
8. Inertia -
9. Acceleration -
10. Velocity -
11. Speed -

12. Escape velocity -
13. Oxidizer -

Materials and Equipment:

String or fishing line, straws, balloons of different sizes and shapes, water, distilled water, carbonated water, antacid tablet (powdered and tablets), paper clips or washer, translucent film canister, sports squeeze bottle, construction paper, model train track and model train car, tape, papers, scissors and clothespin.

Advance Preparation:

Gather appropriate materials.

Activities:

Add to timeline Sir Isaac Newton's birthdate (December 25, 1642) and flight of first liquid-fueled rocket by Robert Goddard (March 16, 1926).

Several activities are suggested below. Use one or more in the class to investigate the principles of propulsion and aerodynamics.

Balloon rocket race. Attach several individual strings (or fishing lines) from the ceiling (or across the room), these will guide the balloon rockets. Attach one soda straw to each balloon and thread the string through the straw. Inflate the balloons and ask the students to hold it shut by hand (or clothespin). Start the race; note the height attained and/or time each.

Investigate the effects of the following on the performance of the rocket: 1) reusing the balloon (does a newer balloon move faster or slower than a used one? Which one goes higher? why?), 2) the shape of the balloons (longer, rounder, bigger, other), 3) number of balloons, 4) weight (attach paper clip weights) and 5) the slope of the string

Antacid tablet rocket. In liquid fueled rocket, the fuel and oxidizers are kept separate until lift-off, when they are mixed and lit. In our experiment, we will use antacid tablets and water to produce rocket exhaust. Put water in a sports squeeze bottle and drop in a tablet. Attach the bottle to a model train car. Make sure that the top is closed. Start the engine by opening the pull-top (spout?). The experiment can also be performed using a plastic film canister (the translucent kind that does not have a wrap-around rim on its lid). The air pressure will pop-off the top of the lid.

Investigate the effects of the following on the performance of the rocket: 1) water temperature, 2) amount of water and number of tablets, 3) powdered vs. tablet, 4) tap water vs. distilled water vs. carbonated water, and 5) mass of paper clip payload and/or the container.

Construction paper rocket. Use the provided instructions to build a rocket out of construction paper. A balloon or antacid tablet rocket can be used in this investigation. Design the rocket so paper clip payloads

can be added to investigate the effects of mass.

Investigate the effects of the following on the performance of the rocket:
1) size, 2) shape, 3) shape of the nose cone, 4) material, 5) payload mass
and 6) number of fins.

Extension activities:

Staging (Real world rockets are staged - i.e., after one engine lifts the satellite partway, its shell is ejected to lower mass and a second engine is fired). Ask the students to design a two-stage balloon rocket.

Use a balloon or antacid tablet rocket to run a model train car around a track. Note the dependence of speed and distance on the size, shape and number of rocket motors.

Model rockets (subject to local rules)

Homework Assignment:

In their journals, have the students explain how Newton's Laws applied in their activities. How would you make your rocket more efficient? Why was the balloon forced along the string?

References:

Rockets: A Teacher's Guide with Activities in Science, Mathematics and Technology, NASA Publication (available free of cost from NASA ...)

Blueprint For Space, (Smithsonian Institute Press)

Connections:

Math: Graph all results.

History: What was going on during Isaac Newton's time? (For example, the plague was raging in Europe); Robert Goddard's connection to Massachusetts.

Literature: War of the Worlds (H. G. Wells) - this story from the late 1800's influenced Robert Goddard as a teenager. Suggest journal writings about which activity was their favorite and why.

Music: Rocket Man (Elton John)

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