Water Rocket Design Project

This document is provided for use by members of INTAD.

Asbjorn Pettersson and David Christiansen researched the information contained herein.

Both teachers have found that students are actively engaged in learning, enjoy using the design process, must use higher order thinking skills, and enhance their research skills throughout this project.

Any teacher implementing this project will require a LAUNCHER. These can be very simple devices. Some information is included in this document.

With thanks to Stephen Reed (email: streed@email.kyrene.k12.az.us) for the concept and project brief. Other sites and graphics are referenced to their respective URL's.

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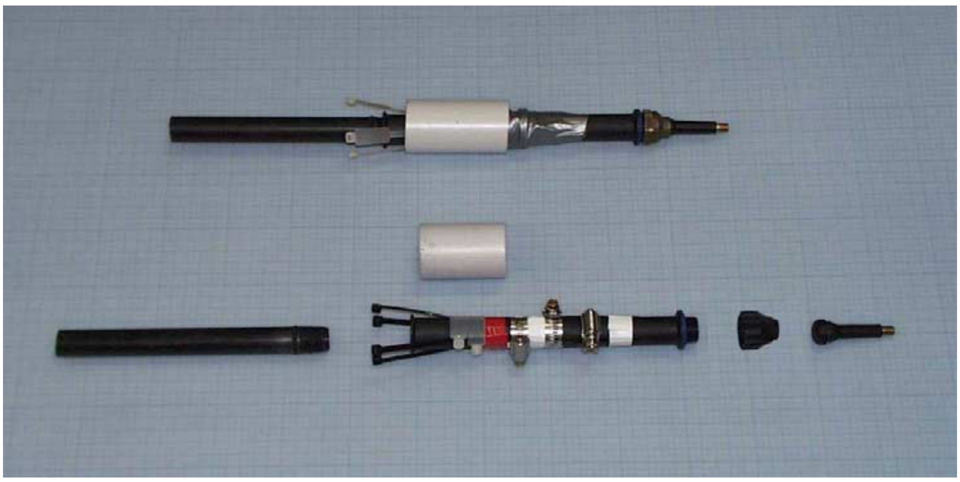
Topic: Transportation Technologies

One of the main areas of technology study in the new standards proposed by the International Technology Education Association is Transportation technologies. *Ref: ITEA (2000) Standards for technological literacy.*

People view transportation as one of life's basic needs. The transportation system is a complex network of interconnected components that operate on land, on water, in the air, and in space. Although travelling into space has been realised, it has not yet become a fully integrated part of the larger transportation system. *Ref: ITEA (2000) Standards for technological literacy, p. 175.*

Photograph Reference: http://www.h2orocket.com/

A version of a "Cable tie launcher" (see page 6)
Reference: http://redrival.com/rockets/launcher.htm



Background Information (Reference: InfoPlease.com)

http://www.infoplease.com/

Development of Rockets

The invention of the rocket is generally ascribed to the Chinese, who as early as A.D. 1000 stuffed gunpowder into sections of bamboo tubing to make military weapons of considerable effectiveness. The 13th-cent. English monk Roger Bacon introduced to Europe an improved form of gunpowder, which enabled rockets to become incendiary projectiles with a relatively long range. Rockets subsequently became a common if unreliable weapon. Major progress in design resulted from the work of William Congreve, an English artillery expert, who built a 9kg rocket capable of travelling up to 3 km. In the late 19th cent., the Austrian physicist Ernst Mach gave serious theoretical consideration to supersonic speeds and predicted the shock wave that causes sonic boom.

The astronautical use of rockets was cogently argued in the beginning of the 20th cent. by the Russian Konstantin E. Tsiolkovsky, who is sometimes called the “father of astronautics.” He pointed out that a rocket can operate in a vacuum and suggested that multistage liquid-fuel rockets could escape the earth's gravitation. The greatest name in American rocketry is Robert H. Goddard, whose pamphlet *A Method for Reaching Extreme Altitudes* anticipated nearly all modern developments. Goddard launched the first liquid-fuel rocket in 1926 and demonstrated that rockets could be used to carry scientific apparatus into the upper atmosphere. His work found its most receptive audience in Germany. During World War II, a German team under Wernher von Braun developed the V-2 rocket, which was the first long-range guided missile. The V-2 had a range greater than 322 km and reached velocities of 5,600 km per hr.

After the war, rocket research in the United States and the Soviet Union intensified, leading to the development first of intercontinental ballistic missiles and then of modern spacecraft. Important U.S. rockets included the Redstone, Jupiter, Atlas, Titan, Agena, Centaur, and Saturn carriers. Saturn V, the largest rocket ever assembled, developed 3.4 million kg of thrust. A three-stage rocket, it stood 91 m high exclusive of payload, and with the Apollo delivered a payload of 44 tons to the moon. Today payloads are put into orbit by the space shuttle; the Atlas-Centaur, which can put an 3,600 kg payload into geosynchronous orbit; and the Ariane 44L, which has launched a double satellite totalling 3,900 kg.

Rockets in Space

Although studies from earth using optical and radio telescopes had accumulated much data on the nature of celestial bodies, it was not until after World War II that the development of powerful rockets made direct space exploration a technological possibility. The first artificial satellite, Sputnik I, was launched by the USSR on Oct. 4, 1957, and spurred the dormant U.S. program into action, leading to an international competition popularly known as the “space race.” Explorer I, the first American satellite, was launched on Jan. 31, 1958. Although earth-orbiting satellites have by far accounted for the great majority of launches in the space program, even more information on the moon, other planets, and the sun has been acquired by unmanned space probes.

Lunar Probes

In the decade following Sputnik I, the United States and the USSR between them launched about 50 unmanned space probes to explore the moon. The first probes were intended either to pass very close to the moon (flyby) or to crash into it (hard landing). Later probes made soft landings with instruments intact and finally achieved stable orbits around the moon. Each of these four objectives required increasingly greater rocket power and more precise maneuvering; successive launches in the Soviet Luna series were the first to accomplish each objective. Luna 2 made a hard lunar landing in Sept., 1959, and Luna 3 took pictures of the moon's far side as the probe flew by in Nov., 1959. Luna 9 soft-landed in Feb., 1966, and Luna 10 orbited the moon in April, 1966; both sent back many television pictures to earth. Early American successes generally lagged behind Soviet accomplishments by several months, but provided more detailed scientific information.

The U.S. program did not bear fruit until 1964, when Rangers 7, 8, and 9 transmitted thousands of pictures, many taken at altitudes less than 1.6 km just before impact and showing craters only a few feet in diameter. Two years later, the Surveyor series began a program of unmanned soft landings on the moon. Surveyor 1 touched down in June, 1966; in addition to television cameras, it carried instruments to measure soil strength and composition. The Surveyor program established that the moon's surface was solid enough to support a manned spacecraft.

In August, 1966, the United States successfully launched the first Lunar Orbiter, which took pictures of both sides of the moon as well as the first pictures of the earth from the moon's vicinity. The Orbiter's primary mission was to locate suitable landing sites for Apollo, the manned-spacecraft program, but in the process it also discovered the lunar mascons, regions of large concentration of mass on the moon's surface. Between May, 1966, and Nov., 1968, the United States launched seven Surveyors and five Lunar Orbiters. The USSR launched four Lunas; it is believed that the Soviets intended a fifth Luna to make a soft landing, take rock samples, and return them to earth, but the mission, launched 33 days before Apollo 11, failed.

Two-Litre Bottle Rocket

Stephen S. Reed Reference: http://www.kyrene.k12.az.us/itech/kmsitech/2litrock.htm

Introduction:

Using human muscle power, animal power, and the wind, people have been building transportation systems since ancient times. These transportation systems can be classified as land, air, water, space, and nonvehicle transportation. Nonvehicle transportation systems include things like elevators, escalators, pipelines, and conveyor belts. Transportation has enabled people to explore the world. They have gone everywhere, from deep under the sea to the cold polar-regions to the upper reaches of the atmosphere.

Now we have begun to explore space. In space, far from the pull of gravity of planets, objects have no weight. This is known as weightlessness or zero gravity. Sputnik I was launched by the Soviets in October 1957 and was the first spacecraft to go into orbit around the earth. In April 1961, Soviet astronaut Yuri Gagarin became the first person to travel in space. The National Aeronautics and Space Administration (NASA) is constantly trying to develop a system which will deliver a payload into orbit.

The world's mightiest rockets work on exactly the same principle as a balloon that zooms around when you release it. The balloon and rocket are pushed forward by a rush of gas escaping backward. This thrust is what pushes the rocket forward. The safe return of the delivery system is also an important part of their mission.

This activity will allow you to take on the role of an engineer for NASA. You will design, build, and launch a compressed air rocket that will fly as straight as possible and return its payload safely back to Earth.

Problem:

Design, build, and launch a compressed air rocket made from a plastic two-litre bottle. The rocket should fly as straight as possible and return its payload (a raw egg) to Earth safely.

Materials:

Tools/Equipment: - plastic two-litre bottle - hot glue gun - glue - scissors - tape - band saw/jig saw - string - disc sander/spindle sander - plastic trash bags - air compressor - wood/metal/plastic - launch pad - cardboard/styrofoam - hot wire styrofoam cutter - raw egg

Concepts:

1. The problem solving process involves seven steps:
   A. Define (write) the problem.
   B. Set goal(s).
   C. Research.
   D. Develop (sketch) alternative solutions. (Minimum of 3)
   E. Select the "best" solution and explain why you chose this one.
   F. Implement (build) the solution.
   G. Test and adjust.
2. Transportation is moving people and/or goods from one place to another.
3. Transportation systems can be classified as land, air, water, space, and nonvehicle transportation. 4. NASA stands for National Aeronautics and Space Administration.

5. The four basic parts of any transportation system are: guidance; propulsion; payload; and control. 6. Newton's Third Law of Motion says, "For every action there is an equal, but opposite reaction." 7. The six recovery systems of a rocket include: parachute; streamer; tumble; featherweight; glide; and helicopter recovery.
8. Aerodynamics is the study of how things are affected by the flow of air around them.

Specifications:

(i) The result must be a space transportation vehicle capable of carrying a payload (the egg).
(ii) The vehicle must include guidance, propulsion, payload, and recovery systems.
(iii) The bottom bottle that serves as the engine for the rocket cannot be cut, punctured, or damaged in any way or the rocket will not hold the air pressure.
(iv) The fins can't extend any lower than where the bottle begins to narrow into the neck. Otherwise they will interfere with the launch pad.
(v) The rocket must launch as one complete unit, but may come down as separate pieces.
(vi) On launch day, the rocket will be launched once and it will be judged on how straight it flies. When the rocket is recovered, the payload will be inspected for damage.

Evaluation:

1. The evaluation will rate the following:
Rocket design
- creativity 15 pts
- workmanship 15 pts

Rocket performance
- flight path (straightness of flight) 15 pts
- payload survival (egg's condition) 15 pts
- problem solving log sheet (steps 1-7) 40 pts

Total possible points = 100
2. In addition, winners of each of the following will receive additional points:
- Most creative (as voted by the class) 10 pts
- Best built (as voted by the class) 10 pts
- Best overall flight (as voted by the class) 10 pts


Photograph Reference: (above)
http://www.kyrene.k12.az.us/itech/amsitech/activities/2litrock/samples.htm

Rocket Named "Rudolph" (photo on right) Photograph Reference: http://www.geocities.com/CapeCanaveral/Lab/5403/myrockets.html

Water Rockets: Launchers

When launching, the priority is safety. Two popular launcher mechanisms are the "cable-tie" launcher and the garden hose fitting launcher.

Asbjorn has used an adaptation of the "cable-tie launcher" (see http://www.smoke.com.au/~ic/cable-tie.html). The tap-connector launcher is an even easier design to implement. Also, follow the online links on the next page to find many safe launcher designs.

The Australian site: http://www.netspace.net.au/~bradcalv/wrbook.htm has this to say about the garden hose connector launcher:

Quick connecting plastic household hose fittings may be used, acting both as a release mechanism and a nozzle. In Japan a commercially produced fitting is available, one end fits a PET bottle neck, the other a hose fitting, a similar nozzle can be home-made from a bottle cap and a part from a garden hose fitting. This release method enables the launch time to be controlled, but does not allow for an open mouth rocket, ie. the nozzle is restricted to the diameter of the hose fitting. A restricted nozzle produces more modest thrust but for a longer duration than an open mouth rocket.

And the "rubber stopper": (the simplest launcher?)

A rubber stopper, with a ball inflation needle passing through, is placed in a bottle and air pumped into the bottle. At a certain pressure the stopper is forced out and the water inside the bottle is able to escape. The main weakness of this launching method is that the exact time of release cannot be determined and it is less efficient and does not provide the directional guidance of a launching tube.

Two sites with detailed explanations are:
Australian Water Rocket Site "Rocket Roos": very good **cable-tie launcher** explanation and photographs.
http://www.geocities.com/rocketroos/launchers.htm
and
Water Rocket Index: **hose connector launcher**
http://ourworld.compuserve.com/homepages/pagrosse/h2orocketlauncherquickrel.htm

This Australian site includes directions and an animation fully explaining the process of making a garden **hose connector launcher**:
http://www.alphalink.com.au/~brucej/launch.htm

Ref: http://www.osa.com.au/

Water Rockets: World Wide Web Resources

Water-rockets.com (about 90,000 people have visited this website):

http://www.water-rockets.com/main.shtml

AT THIS SITE: Safety First; NEW Java-based Water-Rocket Simulation!

Australian Rocket Enthusiast Clifford Heath's Page

http://www.osa.com.au/~cjh/rockets/

Plenty of information about PET bottles and changing their shape; Melbourne Area Rocket Society (MARS), with photos; simulation program to get the most of your rocket by providing graphs and important data (eg. apogee, total flight time); parachute release information; and a **detailed list of links to other sites.**

Water Rocket Annex. Our Motto: "Really, it is rocket science..."

http://www.geocities.com/CapeCanaveral/Lab/5403/

- Intro
- Rocket Theory
- Launchers
- Pumps
- Rocket Construction
- Recovery Systems
- Staging
- Miscellany
- Links and references
- The Water Rocket Mailing List

Ref: Water Rocket Annex

Australian Ian Clark's Water Rocket Launcher Diagram:

http://www.smoke.com.au/~ic/cable-tie.html

Copied/adapted by rocket enthusiasts all over the world.

The Water Rocket Garage

http://www.geocities.com/CapeCanaveral/Lab/5402/

What's New?

- New Launcher plan (2/99)
- New and improved Explicit Simulation provides a fast spreadsheet to optimise just about any parameter on a single stage rocket. (11/98)
- The Millenium VIII rips through the 1000 ft (barrier!
- Improved Staging Mechanism design (3/98)
- Added Deployment Timer page(2/98)

The Water Rocket Index

http://ourworld.compuserve.com/homepages/pagrosse/h2oRocketIndex.htm

If its not here or is noted as a hyperlink from this site - it may not exist! Very detailed.

Water Rockets: Science Net - Project based physical science.

http://library.thinkquest.org/50109/projects/wrockets.html

A water rocket project implemented as a THINKQUEST (an online learning tool). At the site are several QuickTime(TM) movies to explain topics such as: launch safety; nosecone preparation; launch preparation; water rocket overview.

Compressed Air Rocket Research Links

http://www.kyrene.k12.az.us/itech/amsitech/activities/2litrock/2litlink.htm

Links page collated by Stephen S. Reed, author of the Two-Litre Bottle Rocket Project.

Editor's Note: This list of sites should get you started. The information and links to be found here will keep even the most avid rocket enthusiast busy for some time. As the web is so dynamic, the URL's for the links noted above may change at any time. They were current as at 20.5.00.

Water Rockets: Frequently Asked Questions (**(c) 2000 P.A.Grosse**)

http://ourworld.compuserve.com/homepages/pagrosse/h2orfaq.htm

How powerful is a water rocket compared to a pyro rocket?
The power of a rocket is, for convenience's sake measured in terms of the force the engine gives, multiplied by the time, which is known as the Impulse. The result of this is an answer in Newton Seconds but to make life easier, the impulse for various motors is put into bands. There are ¼A and ½A, A, B, C and so on, doubling the impulse with each letter. The rocket motors that you can buy in the shops for a pyro rocket are usually A, B or C. *A standard 2 litre water rocket gives an impulse rating of E, or 8 times more powerful than a B rating.*

How much does it cost to build a water rocket compared to a pyro rocket?
Pyro rocket kits in the UK, based on a C motor and having a thin plastic chute for recovery, can cost £10 - £20. A two litre water rocket, made from two or three pop bottles (costing 15p each in winter or 25p each in summer) and a chute made from a bin liner and some cord will cost around £1 to make.

How much does it cost to launch a water rocket compared to a pyro rocket?
A pyro rocket uses a motor with each launch and these cost around £1.50 each. A water rocket uses around 600mls water and some compressed air so unless you are using expensive mineral water the price of launching a water rocket is negligible. In fact, you can build a water rocket for less than the price of a pyro rocket motor.

Is water rocketry safe?
If you follow the same types of safety rules that apply to pyro rockets, it is as safe. One thing that you can't do with a water rocket (with cold water in it) though is burn yourself on the fuel.

How does a water rocket work?
You put some water (roughly 33% of the capacity of the rocket) into the water rocket, place it on the launcher, fix it in place and then pressurise the gas above the water in the rocket by pumping air into it. When you release the rocket, the force caused by the nozzle accelerating the water out of the rocket provides enough lift to make the rocket go up into the air.

Note: "Pyro rockets" are available from hobby shops and toy stores and come with a launcher, rocket, and usually, a parachute. They require a new solid fuel rocket engine and igniter for each launch.

"Flying Model Rocket" ToysRus website
Reference: http://www34.toysrus.com/product_images/e4/4777601813e.jpg

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