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Space Shuttle Science

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This curriculum unit is designed to use the Space Shuttle as a "vehicle" to teach middle school children basic concepts in science. The introduction of scientific concepts follows the logical progression of a typical Shuttle mission from lift-off to landing.

Following the above format, this curriculum begins with a brief overview of America's Space Transportation System. All rockets rely on either solid or liquid fuels to generate the necessary thrust to achieve earth orbit. The Shuttle is unusual in that it uses both solid and liquid fuels for propulsion at lift-off. This arrangement makes it instructive to discuss with students the history of rocket propulsion systems as they progressed from the black powder of Chinese "fireworks" to the gigantic liquid fueled rockets in use today.

The typical Shuttle mission lasts seven days. Of this time period, only about ten minutes is required to achieve orbit, approximately thirty minutes is needed to de-orbit and execute a landing. The majority of the mission time is spend on-orbit.

While on-orbit the Shuttle provides a work platform like no place on earth. The experiments carried out to date, suggest enormous potential for scientific and applications research. The absence of gravity, the vibrationless platform and the hard vacuum of space maes possible the manufacture of ceramic, optical, electronic, metallurgical and pharmaceutical products of a quality and purity that simply cannot be achieved on earth.

The orbiter' s cavernous cargo bay area permits the transportation of large payloads both into and back from earth orbit. This unique capability allows the Shuttle to deploy large satellite systems directly into space. Equally important, the Remote Manipulator System (RMS) or robotic arm has proved extremely useful in capturing and retrieving malfunctioning satellites. In the near future, the Shuttle will be used to bring up the huge Rubble telescope and the component parts of the Space Station. The Rubble telescope, orbiting outside the obscuring effects of the earth's atmosphere will allow us to see to the very edge of our universe. This new tool will bring about changes in astronomy as revolutionary as those first discovered by Galileo, when he first used a telescope to peer into the night sky.

The Space Station will provide a permanently manned platform to look not only outwards to the stars but also downwards on our home. One unexpected result of space exploration has been our visual discovery of the earth. Philosophically, the space experience has expanded our awareness to new dimensions. Michael Collins, in his book, *Carrying the Fire: An Astronaut's Journey, wrote that "on* the way the moon we discovered the

Earth". The wider perspective from space, has practical as well as philosophical value. Meteorologists are now able to observe global weather patterns, conservationists monitor earth's resources worldwide. Furthermore, advancements made in space technology result in spin-offs that benefit us on earth. Finally, along with these tangible benefits, many intangible ancillary benefits result such as the impetus given education, the fostering of national pride and the enhancement of cooperation among nations.

In space the basic needs for survival, so often taken for granted on earth, are indeed a matter of life and death. Breathable air, potable water and nutritious food, shelter from the vacuum and radiation of space, suitable clothing, clear communications with ground control and management of waste are all basic requirements for life.

The primary purpose of this unit is to focus student attention on the micro-environment of the Space Shuttle with its attendant systems of life support, and to then lead students to perceive the wider view of how the planet Earth can be viewed as a space ship with a "crew" that must face and solve the very same problems.

This unit is designed to cover a period of approximately four weeks. Activities suggested may be carried out in a variety of ways. Individual and group work, class discussions, "brainstorming"; and gathering data or information as the result of experimentation and through teacher led discussion.

INTRODUCTION

The Space Shuttle is the prime element of America's Space Transportation System. Whereas earlier rockets had an effective life of only minutes, and all spacecraft were used just once, the Shuttle is our first reusable spacecraft. This capability has markedly expanded our ability to operate routinely in space.

The introduction of this new generation of space vehicle in 1981 caused a wave of excitement and interest to sweep across America. As adults we had grown up with the space program. Most of us ca vividly remember NASA proudly introducing the original seven Mercury astronauts in the early sixties. We would all watch in awe as Neil Armstrong became the first human to step onto the moon. The magnificent accomplishments of the first decade in space, however, was followed by a period of dormancy and the initial excitement of space exploration became part of our national history. Students attending school in the next decades would not be privileged to share the intimacy we shared with our heavenly heroes.

The maiden flight of the Space Shuttle Columbia changed this. Students in the classroom literally had new heroes to look up to. Unfortunately, the initial enthusiasm sparked by the first Shuttle launch did not last. Shuttle launches became so predictably routine, that by the time of the Challenger mission 51-L, none of the major networks elected to even cover the lift-off live. The growing lack of interest, however, was not shared by teachers and students for this particular launch. For the first time in the history of our space program, a private citizen, a teacher, would be onboard. Christa McAullife, a social studies teacher from Concord, New Hampshire, would "fly" for all of us on her quest "to reach for the stars".

Tragically, seventy-three seconds into the flight, our Nation's dream turned into a nightmare. The awesome complexity and dangers of placing humans into orbit was painfully painted in a grotesque scene across the clear blue Florida sky.

Only hours after this terrible tragedy a ninety-two year old grandmother called into a radio talk show. She reminded us all that the "'Challenger"' was gone but not the *challenge* . In a totally unexpected and unforseen way the Challenger accident created a demand from the public to learn more about Christa, the Space Shuttle program, the mission and its brave crew.

As teachers we can take advantage of this tremendous interest and use it to transform a devastating tragedy into an opportunity to inform and inspire our students. The space program is spectacular. It has a cast of thousands, impressive sets, heroes and drama. We can and should use it to help make our curriculum more exciting for today's student.

GOALS AND OBJECTIVES

The primary goals and objectives of this unit are the following:

To use the Space Shuttle as a "'vehicle"' to teach basic science.

To use the excitement of the United States Space program as a catalyst to ignite the imaginations of our youth in the area of space science.

To familiarize students with the nomenclature, operation and purpose of America's Space Transportation system.

To provide teachers with relevant, current curriculum materials which can be infused into their science curriculums.

To emphasize the importance of science and technology as a base for modern and future society.

To improve student achievement in mathematics by integrating math activities into the science curriculum.

ROCKET PROPULSION SYSTEMS

The history of space flight is full of dreams, heroism, triumphs and tragedy. Long before man would actually travel in space he journeyed there in his mind. A Greek myth tells of Icarus flying too close to the Sun, melting his waxen wings. Persian legends speak of flying magic carpets and bird-drawn flying chariots. In more modern times, the American authors Jules Verne and his younger contemporary, H. G. Wells wrote fantastic science fiction stories that would become fact only a century later.

One of Jules Verne's most prophetic writings, From the *Earth to the Moon* , was first published in 1865. His books owed their popularity to their peculiar combination of fantastic detail and plausible scientific explanation. His most grievous error was his choice of a propulsion system. In his book, the space travelers are carried aloft in a velvet upholstered aluminum capsule shot from a giant cannon buried in the earth in Florida. This type propulsion system works in the circus, but surely would be fatal for moon voyagers!

The important contribution that writers like Jules Verne and others made to space flight, was that they sowed seeds in the form of ideas that would be harvested by a new breed of more practical dreamers. Two young impressionable readers of Verne's works were the Russian schoolmaster, Konstantin Tsiolkovsky and a shy American physics professor, Dr. Robert H. Goddard. Together, in widely separated parts of the world, these great visionaries began to seriously explore the feasibility of using rocket power to overcome the chains of gravity that had held man on the earth for all of recorded history.

Ardous Huxley once said that "'there is no more powerful force than an idea whose time has come."' The time had come for one of the most important ideas in human history. The rocket, more specifically the liquid fueled rocket, could provide mankind with the means to escape from the planet Earth-to begin the exploration of the universe. The Russian Tsiolkovsky was content to work in the abstract, but Goddard, the more practical of the two, wanted to put his theories into practice, much to the displeasure of his Massachusetts neighbors.

The work of the early space pioneers built on the genius of others. Sir Isaac Newton is quoted as having said, "'that if he had seen further than others, it was because he was standing upon the shoulders of giants that had come before him". Now Tsiolkovsky and Goddard would stand upon Newton's shoulders and look far, far into the future. By the time Goddard and Tsiolkovsky began their rocket experiments, nearly two decades had elapsed since Sir Isaac Newton had published his classic work *Philosophiae Naturalis Principia Mathematicia* , or "'Mathematical Principles of Natural Philosophy"'. One of the main ideas discussed in this work was Newton's Third Law of Motion. This law states: To every action there is always opposed an equal reaction; or, the mutual actions of two bodies upon each other are always equal but opposite in direction. It should be noted that at the time Newton stated this law, he had guns in mind, not rockets, but the principle remains the same. This law, although simple and direct, is often misunderstood by both students and adults alike. A common misconception is that a rocket pushes against air molecules. The fallacy of this idea becomes apparent when the learner is reminded of the fact that no air molecules exist in outer space. In fact, Robert Goddard conducted experiments in a vacuum chamber that proved that reaction engines like the rocket are actually more efficient in the vacuum of space. I believe that children learn best through direct evidence. In keeping with this philosophy there are many ways to have children investigate the law of action-reaction. Several examples of this principle can be drawn from their everyday experience. What happens when they jump off a skateboard? When you dive off a raft, which way does the raft tend to move? Several experiments with simple reaction engines are included in the sample lesson plans.

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM

The survival of the crew of the Space Shuttle depends upon the successful establishment of a closed ecological system that maintains a habitable environment. Shuttle astronauts are fortunate to enjoy a relatively high standard of living as a result of the knowledge gained from the earlier flights of the Mercury, Gemini, Apollo and Skylab spacecraft. The Space Shuttle Environmental Control and Life Support System provides a comfortable, shirt-sleeve environment for the crew as well as a conditioned thermal environment for the electrical components on-board.

As the name implies, the Life Support System ensures the survivability of the crew in the near-vacuum of space. If for any reason the cabin should depressurize suddenly, the results would be devastating. The astronauts blood would literally boil and turn to a gas. In order to avoid such a calamity, the cabin atmosphere is constantly monitored electronically. If this instrumentation detects the slightest drop in air pressure, from 6.66 kg. (14.7 lbs.) to 6.62 kg. (14.61 lbs.), an electronic "'smart box"' is alerted. This "'smart box"' checks all three oxygen sensors in the spacecraft. If two out of three sensors agree about the oxygen level, the majority opinion rules. If the sensors indicate a loss of cabin pressure additional oxygen and nitrogen is immediately introduced and an alarm is sounded.

Other serious hazards to life also exist. All spacecraft must be shielded against radiation. This shielding consists of special metal alloys that are resistant to cosmic radiation and atomic nuclei which constantly bombard the Shuttle. On earth we are also constantly bombarded by this radiation, however the amount we receive is basically harmless due to the shielding effect of the earth's atmosphere. Additionally, heat shields in the form of specially manufactured tiles protect the crew not only from the dangers of radiation, but also from the tremendous heat generated as a result of friction with air molecules on entry into the atmosphere during landing.

There are many experiments and demonstrations that can help to demonstrate some of the principles and concepts involved in the section of the curriculum on Life Support Systems. These experiments range from a simple demonstration of forcing a hard boiled egg into a milk bottle, to show the effects of air pressure in a dramatic fashion, to constructing a cloud chamber to visibly demonstrate gamma rays. Students can also be instructed to establish balanced aquariums as models of a closed life support system.

A basic life support system includes not only a breathable atmosphere, but other basic requirements of life such as food, water, shelter and the management of waste products. Each of these necessities of life will now be discussed in detail.

A. AIR

Air pressure inside the cabin of the Shuttle is maintained at 1,033 grams per square centimeter (14.71 lbs.), the same as that on earth at sea level. As a safety measure the system is redundant. The system consists of two separate oxygen systems, two nitrogen and one emergency oxygen system. Cabin atmosphere closely approximates that of earth. The Shuttle's atmosphere consists of a mixture of 20 percent oxygen and 80 percent nitrogen. A study of the composition of earth's atmosphere would be appropriate at this point.

Astronauts breathe this mixed gas atmosphere during the mission, however there are three times when they do not. All astronauts breathe pure 100 percent oxygen at lift-off, landing, and while on extra-vehicular activities. The astronauts wear helmets or a space suit which delivers the pure oxygen to help keep them more alert during these critical phases of the space flight.

In addition to providing a breathable atmosphere, the Orbiter,s Environmental Control System circulates the cabin air through filters of granular lithium hydroxide and activated charcoal that remove excess carbon dioxide and odors. A fine mesh screen catches debris, such as lint, hair and crumbs. A build up of the carbon dioxide level would cause discomfort for the crew at low levels, and in large amounts would displace the oxygen required for human respiration.

The humidity of the cabin atmosphere is also regulated at a relative humidity of between 35 and 55 percent. If the humidity level is too high the astronauts would be uncomfortable and their efficiency would be reduced. Humidity control is important when you consider that an astronaut doing strenuous physical work can give off up to two pounds of water per hour in the form of perspiration. Temperature can be regulated between 16 and 32 degrees Celcius (61 and 90 degrees Fahrenheit).

An investigation into the Shuttle's atmosphere suggests many corresponding terrestrial topics to explore. A natural avenue to investigate is the composition and layers of earth's atmosphere. Mathematical computations of the force of earth's atmosphere on the surface of a one gallon metal can be calculated. A dramatic demonstration of the weight of the air pressing on a one gallon metal can follows. To remove part of the air (the oxygen) from the can, light a slip of paper on fire and drop into the can, or a small quantity of water can be placed in the can and boiled to produce steam. The top of the can is then quickly screwed on and the can placed into ice water. The can is crushed by air pressure in a most spectacular fashion.

After completing a series of investigations into the physical science of the earth's atmosphere, the biology of human respiration can be studied. Circle graphs can be constructed to show the relative amounts of oxygen and carbon dioxide in inhaled and exhaled air. Directions for constructing a simple apparatus for testing for the presence of carbon dioxide using limewater is included in the sample lesson plans unit. Limewater, a clear colorless liquid, changes to a milky white color in the presence of carbon dioxide. In this experiment students exhale through the limewater solution. The resulting change in the solution indicates a positive test for carbon dioxide. It is instructive to produce oxygen by combining peroxide and chlorox at this point and to demonstrate how oxygen is detected using a glowing splint. A tangential study of weather could be introduced along with this section on the earth's atmosphere.

B. *WATER*

Students may be surprised to learn that no water is brought onboard the Shuttle. All water is supplied as a byproduct from the three fuel cells that generate electrical power for the spacecraft. These fuel cells produce electrical energy through the chemical reaction of hydrogen and oxygen. As part of this chemical reaction drinkable water is produced at the rate of 3.2 kilograms (7 lbs.) per hour. This supply is sufficient to supply not only water used for drinking, but also for the water necessary for re-hydration of foods and beverages, and for personal hygiene. Water is not recycled. If the water supply generated exceeds demand, it is routed to storage tanks. Excess water is automatically dumped overboard. As crew size and distances traveled increase, it is unlikely that such a precious resource as water will not be recycled. A study of earth's natural water or hydrologic cycle is a good model to investigate in this discussion of valuable resources that must be conserved. The chemical symbol H20 becomes meaningful to the middle school student if an electrolysis apparatus is available to break water into its component parts. Students can compare the volumes of the gases collected, (twice as much gas on one side as the other) and then test each gas using a glowing splint test.

C. *FOOD*

Weight and volume are the primary design criteria for any object launched into space from earth. The Space Shuttle has the capability of delivering a total payload weight of 29,500 kilograms (65,000 lbs..). This relatively large payload capability is due in part to deliberate weight reduction design of all hardware and equipment. One area where weight reduction may not at first appear significant is in the food supply for the astronauts. All savings on weight at lift-off translate directly into fuel economy which results in increased payload capability. The actual total weight allowed for food is limited to 3.4 pounds per astronaut per day. One pound of this figure represents the weight of packaging. The total weight of the food supply for a typical seven day mission may not seem to be of much consequence, however, the significance becomes clearer when we compute the weight and volume required for future missions that will last up to thirty days or more.

Having discussed the above information with your students, challenge them to "'brainstorm"' ways in which weight reduction of the food supply could be accomplished. Try to elicit the response that weight reduction could be achieved by removing some or all of the water from some of the food items prior to launch, and then the food could be rehydrated in space. At this point it is helpful to have on hand freeze dried instant coffee as a familiar example of the type of process used to prepare food for space flight. Freeze dried ice cream can be purchased which provides children with a more exciting and tasty sample of astronaut food. Health food stores are also a source of common low moisture foods such as dried peaches, pears, apricots and beef jerky. After discussing the process of preparing foods for space flight and tasting both foods and re-hydratable beverages such as Tang and instant tea, explain some of the other techniques used in food preparation such as thermostabilizing, irradiating and removing some, but not all, the moisture from food items.

In the earlier Mercury missions astronauts had to squeeze their food out of toothpaste-like tubes. Unable to see or smell the food, there was little interest in eating. Today, astronauts aboard the Shuttle enjoy a menu of over seventy food items and twenty beverages. This is a wider selection than most restaurants offer:

Astronauts may eat from a standard menu or they may substitute food items to accommodate their own taste. All personal preference items are checked by a NASA dietician to insure that the foods selected supply the astronaut with the Recommended Dietary Allowances (RDA) of vitamins and minerals. The daily menu is designed to provide about 3,000 kilocalories per day for each astronaut.

This discussion of food, a favorite topic of middle school children, presents an opportune time to introduce lessons on digestion, the four basic food groups, vitamins and minerals kid caloric intake. Once these topics are explored, challenge your students to create a personal preference menu for a typical seven day mission aboard the Shuttle. This is an opportunity for students to see the practical application of mathematical skills in computing total caloric intake, RDA requirements, food grouping and, if possible, actual weight. Once students gain practice in this activity, they can assemble actual meals to take on a field trip or schoolyard adventure.

CLOTHING

Symbolically, the space suit epitomizes space flight. When we see a picture of a human or “‘alien”’ space being, we expect to see him or her appropriately dressed. The early Mercury astronauts dressed the part. They wore silver metallic suits, gloves, boots and fishbowl helmets. They dressed not for style, however, but for safety. The astronauts’ space suit was in effect a “‘personal backup spacecraft”’ that they wore. It was their extra protection from the hostile, airless environment of space. In an emergency this spacesuit would supply oxygen to breathe, provide an envelope of atmospheric pressure and reflect the unfiltered rays of the harsh sun. Comfort and mobility was limited and waste management limited to a urine collection device.

Today, astronauts need only wear space suits during extravehicular activities. At all other times, they wear attractive cobalt blue flight suits, consisting of soft cotton pants, a navy blue cotton knit short-sleeved shirt and a lined zipper jacket. These items come in standard sizes and are selected “‘off the rack”’ at NASA’s Johnson Space Center. All clothing, except underwear, is the same for both sexes. As a safety feature, the cotton material used to manufacture the flight suit is treated with a chemical soak to make it fireproof.

Flight suits are designed to fit loosely for comfort, without being so loose that they might accidently catch on a critical switch or control. Expansion pleats are built into the back and shoulders of the jacket and the waist size can be changed with Velcro straps. These built in adjustments are necessary because astronauts gain between two and five centimeters in height in the weightlessness of space. The apparent absence of gravity in space allows the cartilage disk between the vertebrae in the spine to expand increasing height.

The jackets and pants contain over a dozen pockets in which specific items are stored. These pockets contain such items as pressurized ball-point pens, a flashlight, data books, sunglasses, a pocket knife and surgical scissors. Velcro strips or zippers keep these small items from floating out of the pockets while in space.

Shuttle astronauts must wear special protective clothing during the liftoff and re-entry into the earth's atmosphere. A pair of antigravity trousers are worn over the underwear during atmosphere entry. These pants have bladders inside the fabric that inflate creating pressure on the lower part of the astronaut's body. This pressure counteracts the tendency of blood to pool in the lower extremities, averting grayout, or even a blackout during this critical part of spaceflight. Astronauts also wear special communications headgear and protective helmets. This headgear provides communications and is hooked to a separate supply of air for emergency conditions.

WASTE MANAGEMENT SYSTEMS

In the early flights of the Mercury spacecraft, the management of human waste was achieved primarily through proper pre-flight diet. This was a suitable arrangement for short duration flights, but as the flight time in space was extended, the need for a reliable, sanitary and efficient system of waste management became a necessity.

Today, a sophisticated system collects and processes biowaste from both male and female crew members aboard the Space Shuttle. In addition to urine and feces, Shuttle systems remove or store exhaled carbon dioxide, perspiration, waste water, garbage and food packaging materials.

The Waste Collection System (WCS) or toilet aboard the Space Shuttle is surprisingly earth-like. The most visible difference is the addition of a waist belt and foot restraints required to keep the user "'in place"' during use. A second major difference from an earth system is that the Shuttle's toilet utilizes an air suction in the place of gravity to carry waste away from the user. The fecal matter and sanitary tissue are shredded by high speed tines and thrown off to the sides of a cylindrical storage tank. After operation, the storage tank is opened to the vacuum of space which dries the waste. Some of the waste may be used for post-flight analyses. In the past, such analyses have enabled doctors to determine which minerals are lost excessively in space, which helps to increase our understanding of bodily functions. Urine is collected with the user either standing or sitting on the commode. A contoured body cup provides a good seal with the female crewmember's body. Liquid wastes are stored in a waste water storage tank. A filtering system removed bacteria, dirt and odors.

Located in the mid-deck area of the Shuttle is a personal hygiene station. Health is an important factor in a successful Space Shuttle mission. To guard their health, the astronauts must keep clean. Earlier experiments aboard Skylab demonstrated the difficulties associated with astronauts taking showers. In the weightlessness of space, water drops would fl oat around in the cabin. Shuttle astronauts do not take showers, they take sponge baths to keep clean. Water and soapsuds stick to the skin in space, so a dual washcloth arrangement works best. One washcloth is used for washing and a second for rinsing. In the forward mid-deck cabin area each astronaut has a personal hygiene kit. These kits provide each crewmember with articles for dental hygiene, haircare, nailcare and shaving devices.

The management of trash is accomplished by routine stowage and daily collection of wet and dry trash. The bulk of this trash consists of expended wipes, tissue and used food containers. To facilitate clean up a liquid biocidal cleanser is used. This cleanser is sprayed onto surfaces such as the Waste Collection System, the dining area and on the floors and walls when required. Disposable plastic gloves are worn while using this biocidal cleaner and general purpose dry wipes are used to wipe us the sprayed area. Sanitation is very important within the confines of the Shuttle cabin. Studies show that some nicrobes increase their population at a dramatic rate in the weightless environment of the Shuttle's cabin. If these microbes were not controlled, it is possible that an illness could spread to everyone on board. A vacuum cleaner is provided for general housekeeping duties.

LESSON PLAN

Topic

Decomposition of water by electrolysis

Rationale

The Space Shuttle's cabin atmosphere is generated from the release of oxygen and nitrogen gas which is stored in a liquid state in tanks located in the fuselage of the spacecraft. There is a sufficient supply to meet the needs of the crew for seven day missions. Future missions will be much longer, lasting up to thirty days in duration. The Space Station will be a permanently manned station. The Space Shuttle and the Space Shuttle will both require extended supplies to support their crews for their say in space. The supply of oxygen will be especially critical. Electrolysis of water to produce oxygen and hydrogen is one option being investigated as a source for replenishment of the oxygen supply.

Objective

To demonstrate to students how water can be broken down into its component gases of hydrogen and oxygen by electrolysis.

Materials Required:

Hoffman of similar apparatus

water

weak acid (vinegar)

six volt dry cell or power supply

wood splints

test tubes

bell wire

safety goggles

figure available in print form

Procedure

Set up the Hoffman or Brownlee apparatus as shown in the diagram. Fill the apparatus with water. Add a small amount of vinegar to the water. Connect a six volt dry cell or power supply to the electrodes of the apparatus. The electric current passing through the water will cause bubbles of gas to begin to form at each electrode. These bubbles of gas will rise up and displace water in the vertical collection tubes. Direct students to observe this process carefully. This experiment will take some time to complete. It is best to start this activity at the beginning of the class period so that there will be enough time for the process to occur. Students should observe that the gases are not of equal volume. In fact that one gas collected (Hydrogen) has twice the volume of the other (Oxygen). Challenge the students to explain this phenomena.

CAUTION: The next part of this experiment should be performed with caution. Safety goggles must be worn at all times and extreme care exercised while testing for Hydrogen. Hydrogen gas is highly combustible. Only a small quantity of gas should be tested.

A glowing splint is used to test the gases collected. Using an inverted test tube draw off a small quantity of the gas to be tested. Light the wood splint with a match. Blow out both the match and the wood splint. Place the glowing wood splint into the test tube containing the gas to be tested. If the splint burst back into flame, oxygen is present. If an explosive pop is heard, the presence of Hydrogen is indicated.

LESSON PLAN

Topic

Human respiration

Rationale

In any closed environmental system, whether aboard a spacecraft or on the planet earth, humans require an atmosphere with an oxygen content sufficient to support life. The atmosphere of the Space Shuttle closely approximates that of earth, both in regards to its air pressure and oxygen content. As a result of human respiration carbon dioxide (CO_2) is exhaled into the atmosphere. One earth this gas is absorbed by green plants and does not accumulate in dangerous levels. Since there are no plants aboard the Space Shuttle to absorb carbon dioxide, chemical means are employed. Canisters of granular lithium hydroxide are used to absorb carbon dioxide from the cabin atmosphere.

Objective

After instruction the student will be able to construct and use the apparatus described to test for the presence of the gas carbon dioxide (C02).

Materials Required

small mouth bottle or flask

two hole stopper

25 ml flint glass tubing

calcium hydroxide

test tubes

straws

water

figure available in print form

Procedure

Construct the apparatus pictured in the diagram. This apparatus is designed to be used by the teacher for demonstration purposes. If supplies are adequate, students should construct similar apparatus for desk top use. It is most effective to have the students work in pairs for this activity. If the resources are not available to construct the type apparatus pictured, students can simply use a test tube filled with limewater and then exhale into it using an ordinary drinking straw.

Distribute student activity sheets to the class and discuss the process of human respiration. Focus attention to the exchange of gases that occurs as a result of this process. One way to raise awareness to the differences between inhaled and exhaled gases is to provide students with circle graphs that they can color with crayons or colored pencils. Using different colors for carbon dioxide and oxygen will help students visualize the changes in the gases.

To use the breathing apparatus, place tube A between your lips, draw outside air from tube B in through limewater by inhaling on tube A. Continue this process for a one-minute time period. Direct the students to observe any changes that may occur in the appearance of the limewater solution. (Inhaled air has a negligible amount of CO_2, so there will be no noticeable change in the appearance of the limewater solution.) Now exhale into tube B for a period of one minute. As exhaled air containing CO_2 passes through the limewater solution students should observe a noticeable change in the appearance of the limewater. A milky color indicates the presence of the gas carbon dioxide (CO_2).

Background Information:

The primary function of the human respiratory system is to deliver oxygen to the bloodstream. Oxygen is carried via the bloodstream to all the cells of the body, where it is used to produce heat and energy. In the process of using oxygen, carbon dioxide is produced which the respiratory system disposes of through the lungs during exhaling. This exchange of oxygen for carbon dioxide within the lungs is called *RESPIRATION* .

Note: To prepare limewater solution add powdered calcium hydroxide to a beaker of water. Stir constantly and continue to add the powdered lime (calcium hydroxide) until the lime can no longer be dissolved into the water and falls to the bottom of the beaker. Filter this solution through filter paper and it is ready for use.

figure available in print form

LESSON PLAN

Topic

Hero’s engine

Rationale

Strange as it may seem, the action-reaction engine widely used today in both aviation and spacecraft had its genesis in a toy that served no practical purpose other than entertainment. This activity reproduces at a very modest cost, the famous toy invented by Hero over 2000 years ago.

Objective

To demonstrate the principle of action-reaction using common laboratory equipment.

Materials Required

250 ml Pyrex boiling or erlenmeyer flask

30 ml flint glass tubing

rubber two hole stopper

ball-bearing fishing swivel

heat source (bunsen burner)

water

figure available in print form

Procedure

Obtain a 250ml boiling or erlenmeyer flask. Select a two hole stopper that will fit into the top of the flask. Using flint glass tubing and a bunsen burner or propane torch, fashion the two jet arms pictured in the diagram. The outside ends of the arms should be formed so that they form nozzles that will restrict the flow of the escaping steam. If they are fashioned correctly they should resemble the end of an eye dropper. A pattern to make a strap that will support the device so that it can be hung from a wire or string, is provided in the appendix of this unit. This strap can be made from a tin can or piece of scrap metal. A strap could also be fashioned from coat hanger wire.

CAUTION: When attaching this supporting strap, it ia very important that the strap does not block the stopper from lifting upwards if the steam pressure becomes so great that the flask ia in danger of bursting. The fact that the rubber stopper can pop up if the steam pressure becomes to great is an important safety feature, that must not be interfered with. Next, attach a ball-bearing fishing swivel to the top of the strap. This swivel will allow the fl ask to spin freely. Suspend the device from an overhead support. Place a small quantity of water (25-50 ml) into the flask. Insert the stopper with the two jet arms into the flask. Press the stopper in, but do not force it in to tightly. Use a bunsen burner, alcohol lamp or propane torch under the glass flask. Heat the water under a moderate flame until the water begins to boil. The steam generated from the boiling water will escape out the two jet nozzles. The action of this escaping steam will cause the model to rotate rapidly in the opposite direction due to the reaction force generated, demonstrating in a spectacular fashion Newton's Third Law of Motion.

Background Information

In this activity, we construct a model of an ancient reaction engine that was first described in writings over 2000 years ago. This device was invented by Hero of Alexandria, a great mathematician and natural philosopher who lived somewhere around 100 or 150 B.C.. Hero seems to have invented a great number of machines and automata, however, he is best known for his creation of this reaction engine.

Its construction was quite simple. Water was poured into a spherical boiler. This boiler was placed over a fire. The boiler was free to rotate on two vertical axes. Steam generated within the boiler escaped through two nozzles that were positioned on opposite sides of the sphere. The force of the escaping steam jets caused the sphere to rotate rapidly in the opposite direction of the escaping jets.

Apparently this device was created by Hero solely for entertainment purposes and served no practical value. In 1750, the Hungarian physicist and mathematician Johann Andreas Von Segner developed a device based on reaction motion produced by escaping water jets. This device known today as The Segner Wheel is often found in physics classrooms.

LESSON PLAN

Topic

Micro-rocketry

Rationale

This simple desk top activity can easily be carried cut in the classroom. This exercise is an effective and practical way to investigate Newton's Third Law of Motion, without having to purchase expensive equipment or relying on fair weather required for launching model rockets.

Objective

To demonstrate in a safe and simple way Newton's Third Law of Motion.

Materials Required

shallow plate or dish

waxed stencil paper

dropper pipets

liquid dishwashing detergent

single hole puncher

scissors

pens or pencils

figure available in print form

Procedure

It is best to have students work in pairs for this activity. The design requirements for this project are very simple. The micro-rockets should be approximately one inch (2.54 cm.) in length. The front end should be pointed to form a nose cone, so that the "'rocket" will move easily over the water. The width of the rocket is determined by the number of combustion chambers. The rockets shown here vary from one-half inch to about one inch in width.

Using a hole puncher, punch a hole approximately one-half inch from the "'aft"' or rear end. This hole forms the "'combustion chamber"'. A narrow nozzle is cut from the aft end to the combustion chamber. The dimensions of this nozzle is not critical, however, its width should be no more than half the width of the combustion chamber, and it should taper outwards toward the aft end as it leaves the combustion chamber.

Students may elect to design their own micro-rockets or may wish to follow the examples shown here. The examples A, B, C and D pictured on the diagrams can be photocopied and printed directly onto stencil paper for student use.

After the students have constructed their microrockets, direct them to fill their plate or shallow dish with clean, fresh, cold tap water. Their rocket should be placed on top of the water at one edge of the dish, with the nose cone pointing toward the center of the dish. Using an eyedropper, place one drop of liquid detergent "'fuel"' into the combustion chamber. The micro-rocket will zoom across the water's surface. Challenge students to carry out several investigations using this simple example of action-reaction forces. Encourage students to make and then test their predictions as to the path or course that the micro-rockets A, B, C and D will follow. What will happen if equal amounts of detergent are placed into both combustion chambers of rocket A simultaneously? What will happen if only the right or left combustion chamber is fueled? What will be the likely path or course followed by rockets B, C and D?

Background Information

This simple and elementary experiment, which is

easily performed in the classroom,has real and meaningful lessons for the students involved. Newton's Third Law of Motion which states that for every action there is an opposite and equal reaction is visibly evident to the student. The action of the escaping liquid detergent out the aft nozzle causing the forward movement or reaction of the rocket across the surface of the water. Through these simple investigations students can be led to see the same forces at work on all rocket propulsion systems. In the case of the Space Shuttle, the experiments with the micro-rocket with two identical combustion chambers is very useful in having students make important understandings as to the critical importance of the two solid rocket boosters (SRB'S) generating identical thrust for stable controlled flight of the Shuttle.

It should be explained to students, if they do not ask, that one of the physical properties of a soapy liquid introduced into clean water is a tendency to spread out evenly over the entire surface of the water. This movement of the soapy liquid rearward out of the aft nozzle causes the forward thrust of the micro-rocket. Unfortunately, the soap film will,in time, spread over the entire surface of the water and the micro-rocket will cease to respond to fresh drops of “fuel”’. To obtain the best results instruct the students to change the water after each run.

BIBLIOGRAPHY FOR TEACHERS

Asimov, Isaac. *Our World in Space* . Life Time Inc., 1964

Collins, Michael. *Carrying the Fire; An Astronaut’s* Journey., 1974

Freeman, Michael. *Space Traveler’s Handbook* . New York: Sovereign Books, 1979

Goldman, Nathan C. *Space Commerce: Free Enterprise on the High Frontier* . Cambridge Mass. Ballinger Publishing Company, 1985

Jastrow, Robert. *Until the Sun Dies* . New York: W. W. Norton & Company Inc. 1977

Irwin, Jim. *To Rule the Night, The Discovery Voyage of* Astronaut Jim Irwin. Lippincott, 1973.

Joels, Kerry M., Kennedy, Gregory P. The *Space Shuttle Operator’s Handbook* . New York: Ballantine Books, 1982

Nicolson, Iain. *The Road to the Stars* , William Morrow & Company, 1977

Oberg, James E. *Pioneering Space: Living on the Next* Frontier. New York: McGraw-Hill 1980.

O’neill, Gerard K. *The High Frontier* , William Morrow & Company 1977

SUGGESTED READINGS FOR STUDENTS

Bendick, Jeanne. *First Book of Space Travel* : Watts, 1969

Berwin, Clyde and William F. Coleman. *Animal Astronaut:* They Opened the Way to the Stars. Prentice Hall, 1975

Chappell, Carl L. *Virgil I. Grissom: Boy Astronaut* . BobbsMerrill 1971

Clifford N. Geary. *Exploring Earth and Space* . New York: McGraw-Hill, 1957-1967

Dwiggins, Don. *Spaceship Earth: A Space Look at Our Troubled Planet.* Golden Gate, 1970.

Hyde, Margaret Oldroyd. *Exploring Earth and Space* , New York. McGraw-Hill, 1970

Jacobs, Leland B. (ed.) *Poetry for Space Enthusiasts* . Garrad, 1971

May, Charles. *Women in Aeronautics* . Nelson, 1962

Pitcher, Caroline. *Build Your own Space Station* . New York: Frankiin Watts. 1983

Vogt, Gregory. *The Space Shuttle: Projects for Young Scientists.* Franklyn Watts, 1983.

Von Braun, Wernher and F. I. Ordway, III. History *of Rocketry and Space Travel* . New York: Crowell Collier Macmillan Library Services, 1974.

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GLOSSARY

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ablative material—a material, especially a coating material, designed to provide thermal protection to a body in a fluid stream through loss of mass.

abort—to end the mission short of its objective. An abort is usually caused by equipment failure or emergency.

airlock—a hermetically sealed chamber used for passage from one area to another; for example between the Orbiter and the outside space environment.

bungee—an elastic cord used to hold equipment in place; also used for exercise on the treadmill to increase the workload and hold you in place.

cryogenic—requiring or involving the use of very low temperatures.

deorbit—to leave orbit to return to Earth.

deploy—to release an object (usually a satellite) into orbit.

drogue parachute—a small parachute used specifically to pull a larger one out of stowage; a small parachute used to slow down a descending aircraft or spacecraft.

electrolysis—the process of separating an electrolyte into its elements by passing an electric current through it.

ET (External Tank)—the large propellant tank that supplies the Shuttle's main engines with fuel.

ET SEP (External Tank Separation)—the release of the External Tank from the Orbiter after the fuel is exhausted.

EVA (Extravehicular Activity)—work done outside the pressurized section of the spacecraft; a spacewalk.

filter—any device containing a porous material used to strain out impurities from a liquid or gas.

fuel cell—a device that mixes oxygen and hydrogen together in a controlled process to produce electricity and pure water.

geosynchronous orbit—a orbit in which a satellite revolves about the Earth at the same rate at which the Earth rotates on its axis. From the Earth, the satellite thus appears to be stationary over a point on the Earth.

gravity—the force that draws all bodies toward each other.

lithium hydroxide—a chemical compound (LiOH) used for removing carbon dioxide from the atmosphere of the Shuttle's cabin.

Mach—the term used to describe the speed of objects relative to the speed of sound.

MMU (Manned Maneuvering Unit)—a jet thruster backpack used by astronauts to move freely about in space.

microgravity—the term used to describe the apparent weightlessness and fractional g-forces produced in orbit. In orbit,you essentially fall around the Earth, producing a "'floating"' condition.

NASA—National Aeronautics and Space Administration; the United States agency which is the governing body for space exploration and policy.

nozzle—that part of a rocket thrust chamber assembly in which the combustion gases are accelerated to high velocity.

payload—useful cargo aboard a spacecraft

photovoltaic—solar cells which collect the energy of the sun and use it to drive electricity producing machines such as turbines

rocket engine—a reaction engine that contains both fuel and oxidizer so that it can be operated in the absence of air.

SRB (Solid Rocket Booster)—solid rocket motors attached to the sides of the External Tank, that provide thrust to boost the Shuttle into Earth orbit.

SRB SEP—the moment when the Solid Rocket Booster separate from the External Tank. The SRB's are no longer needed because their fuel is exhausted, they are recovered at sea.

STS (Space Transportation System)—a system consisting of the Space Shuttle Orbiter, External Tank and Solid Rocket Boosters, and associated payloads.

stinger—an attachment mounted on the Manned Maneuvering Unit to facilitate the capture and retrieval of satellites.

Teflon—trade name for synthetic fluorine containing resins used for molding articles and for coatings that prevent sticking.

umbilical—a line from a spacecraft that supplies oxygen to an astronaut; a cable used before takeoff to carry power to a rocket or spacecraft.

vacuum—a space devoid of matter

Velcro—trade name for hook and pile fastener, generally made of nylon and used to replace zippers or to attach objects or things.

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