College of ENGINEERING

VILLANOVA UNIVERSITY

Underwater Robotics Curriculum

Grade Levels: 6 – 9

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Lesson 1: Engineering Is Everywhere

Teacher Reference

Objective:

To introduce students to the many different fields within engineering.

PowerPoint Guide:

Slides 1-5: The purpose of the PowerPoint is to show students that engineers are just like us and we interact daily with devices, structures, electronics and lots more things that have been created and developed by engineers. There are many different fields within the engineering discipline. Some of the most common are civil, mechanical, electrical, chemical and computer.

Slides 6-7: Mechanical engineers utilize mathematics and physics to design moving devices. Manufacturing, analyzing, building and revising previous mechanical designs all encompass the role of a mechanical engineer.

Slide 8: Chemical engineers apply chemistry, physics, biology and mathematics to design new ways of storing, transporting and creating chemicals.

Slides 9-10: Civil engineers deal with physical structures such as bridges, buildings and roads. They also examine the environmental factors affecting our world.

Slides 11-12: Electrical engineers apply the principles of circuits, programming and electronics to study electricity. Electrical engineers are responsible for all different forms of telecommunications, computing, signal process and much more.

Slide 13: Robotics engineering is a new field that combines elements from computer, electrical, mechanical and materials engineering to create devices that can operate without human interaction.

Slide 14: Computer engineers work on computer architecture and microprocessor design, computer networking, computer security, artificial intelligence, digital system design, software development, parallel processing, and digital signal processing.

Slide 15: Engineers are needed in society now more then ever to compete in the global marketplace.

Optional Activity: Engineering Research

- Divide the students into groups.
- Each group is given one type of engineering (mechanical, civil, chemical and electrical).
- The goal is to examine in more detail each of the disciplines by researching on the computer or in a library.
- The student worksheet asks five questions to guide their research.
- Have each of the student groups give a presentation on their findings.

Relevant Websites:

Many engineering disciplines have societies that support their work. These websites can help students explore the different opportunities available in engineering.

American Institute of Chemical Engineers: www.aiche.org

American Society of Civil Engineers: www.asce.org

American Society of Mechanical Engineers: www.asme.org

Institute of Electrical and Electronics Engineers: www.ieee.org

Society of Manufacturing Engineers: www.sme.org

National Science Standards:

- Science as Inquiry
  - 12ASI2.1
  - 12AS12.2
- Science and Technology
  - 12EST2.1
  - 12EST2.2
  - 12EST2.3
- History and Nature of Science
  - 12GHNS1.1
  - 12GHNS3.3

Lesson 1: Engineering is Everywhere

Student Worksheet – Civil Engineering

What is civil engineering?

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Research and describe one structure that you think was created by a civil engineer?

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Civil engineering is the foundation of society. Explain how civil engineers helped build the first villages, towns and cities.

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Find a famous civil engineer. What have they designed?

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What would you design if you were a civil engineer?

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Lesson 1: Engineering Is Everywhere

Student Worksheet – Chemical Engineering

What is chemical engineering?

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Research and describe something that you think was designed by a chemical engineer?

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Chemical engineers help develop new ways of distributing medicine. Find a pharmaceutical company that hires chemical engineers and describe what they produce.

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Find a famous chemical engineer. What have they designed?

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What would you design if you were a chemical engineer?

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Lesson 1: Engineering Is Everywhere

Student Worksheet – Electrical Engineering

What is electrical engineering?

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Research and describe one device that you think was created by an electrical engineer?

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Electrical engineers were extremely important in the development of the first computer. Can you explain what part of the computer electrical engineers might have helped design?

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Find a famous electrical engineering. What have they designed?

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What would you design if you were an electrical engineer?

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Lesson 1: Engineering Is Everywhere

Student Worksheet – Mechanical Engineering

What is mechanical engineering?

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Research and describe one object that you think was created by a mechanical engineer?

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Mechanical engineering is very old. Can you find any examples of ancient mechanical engineering designs?

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Find a famous mechanical engineer. What have they designed?

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What would you design if you were a mechanical engineer?

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Engineering is Everywhere
Lesson 1
VILLANOVA


Engineering is Everywhere!!!
Everything you look at was influenced by an engineer
VILLANOVA


Who are Engineers???
VILLANOVA

"Scientists investigate that which already is; engineers create that which has never been."

-Albert Einstein

Engineering Disciplines

Civil

Computer

Mechanical

Electrical

Chemical

Environmental

Bio Medical

Robotics

Mechanical Engineering

Planes, Trains, Automobiles

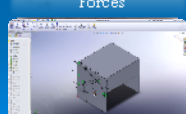
And So Much More

Machine Components

Forces

Energy

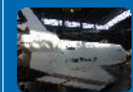
Materials

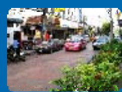


Design

Motion

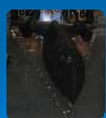
Were do Mechanical Engineers Work?


Aerospace


Automotive

Power

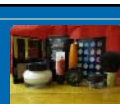

Construction


Military


Manufacturing

Everywhere…..

Chemical Engineering



- Pharmaceutical
  - What is the best way to package and deliver a drug for ensuring 100% accuracy
- Biomedical
  - How do surgical implants interact with the human body
- Cosmetics
  - How can different materials or elements be combined to create new colors, flavors or thicknesses.
- Food Processing
  - How is food safely packaged so that it remains at the same consistency and temperature

Civil / Environmental Engineering

- Physical Structures
  - Bridges
  - Buildings
  - Dams
  - Roads
  - Canals
- Environmental Factors
  - Geotechnical
  - Water Resources
  - Materials

Example: Bridges

There are three major types of bridges:

-The Arch Bridge
-The Girder or Beam Bridge
-The Suspension Bridge

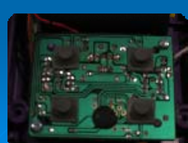
Arch Bridge

Suspension Bridge

Beam or "Girder" Bridge

Electrical Engineering

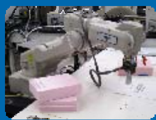
- Study and Application of electricity, electronics, and electromagnetism
- Power, digital and analog electronics, artificial intelligence, control systems, signal processing, telecommunications, and optoelectronics



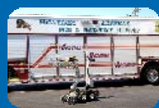
Example: Solar Cells

- Device that converts solar light (photons) into electricity (flow of electrons)
- Photovoltaic Cell – includes both solar and nonsolar sources of light

Robotics Engineering



Industrial Robots: Used in many manufacturing uses such as car assembly



Hazard Relief

Underwater Robots: For uses such as exploration of marine life

Space Exploration

Computer Engineering

- Computer Architecture and Microprocessor Design
- Computer Networking
- Computer Security
- Artificial Intelligence
- Digital System Design
- Software Development
- Parallel Processing
- Digital Signal Processing

Why Study Engineering

"In China today, Bill Gates is Britney Spears. In America today, Britney Spears is Britney Spears-and that is our problem. ... The World is Flat"

-Thomas Friedman

- Engineers are needed now more then ever!!!!

Lesson 2: Engineering Design Process

Teacher Reference

Objective:

To introduce students to the concept of engineering design.

PowerPoint Guide:

Slides 1-2: The engineering design process is used by all disciplines of engineers to thoroughly examine a problem, propose a solution, design the device and test the result.

Slide 3: The first step is to identify a need in society. This could take many forms. It could involve creating something new or improving something that already exists

Slide 4: The next step is to research. Is your proposed idea something feasible? Does your idea already exist?

Slide 5: Brainstorming is an extremely important step in the process. Depending on the problem this could be a lengthy process involving many different types of engineers. It is important to write down and think of as many solutions as possible so that your options are wide open. The end of the brainstorming process involves narrowing done all the ideas to a feasible solution.

Slide 6: Once you have identified the best solution it is time to plan and define exactly what that solution entails. Use diagrams, graphs, charts and lists to describe what must be included in the solution. Analyze the tradeoffs, strengths and weaknesses of the design.

Slide 7: After the design is thoroughly planned and analyzed it is time to actually construct. Most engineers will use computer aided drawings or designs to build their product.

Slide 8: An engineer’s work is never complete. The test and revision phase is a constant process. This is most evident if you look at the countless number of upgrades to computer programs, cell phone, I-pods and televisions.

Optional Activity:

Revise an Existing Design

- Divide the students into groups.
- Each group should pick a simple mechanical or electrical device that they believe should be improved (examples: toasters, hair dryers, alarm clocks, watches)
- The students will use each step in the engineering design process to help design a revision of the device.
- The student worksheet asks questions to help with the process.
- Have each of the students try to sell their new and improved product to the class.

Relevant Websites:

- A website created by the American Society for Engineering Educators that is specifically directed at K-12 students: http://www.egfi-k12.org/
- A website developed by the Society of Women Engineers specifically for females interested in entering engineering: http://aspire.swe.org/
- This website explains different careers in marine technology: www.oceancareers.com

National Science Standards:

- Science and Technology
  - 12EST1.1
  - 12EST1.2
  - 12EST1.3
  - 12EST1.4
  - I2EST1.5
  - I2EST2.2
  - I2EST2.3

Lesson 2: Engineering Design Process

Student Worksheet – Revising an Existing Design

What device is your team going to improve? ____

What is the main purpose of the device?

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Why does the device need to be improved?

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Are there any cost or material constraints that should be considered when improving this device?

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Brainstorm: write your ideas and make sketches of possible ways to improve the device?

What is the best possible improvement that can be made to this device and why?

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Describe how you would sell your new and improved product to the public?

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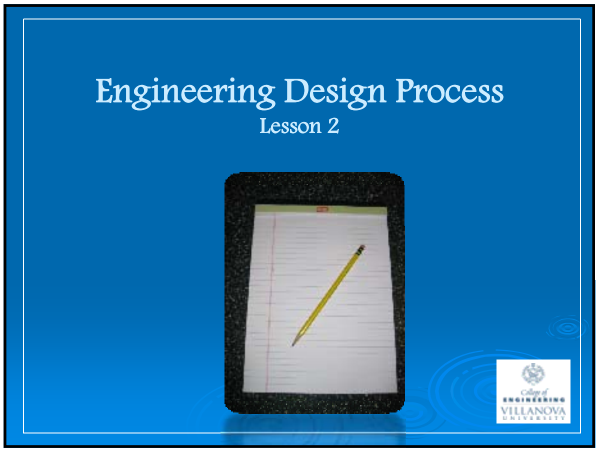
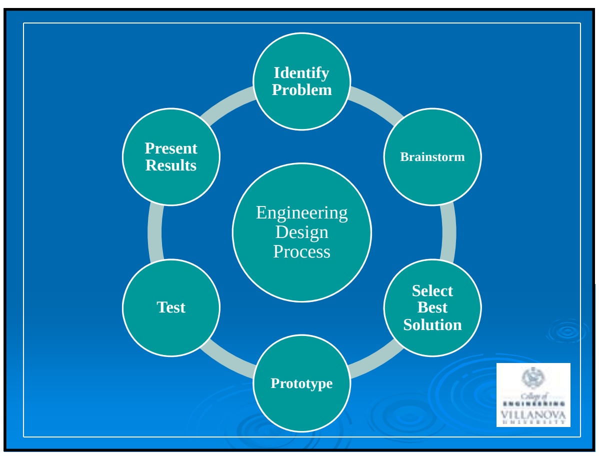

Engineering Design Process
Lesson 2
VILLANOVA


Identify Problem
Brainstorm
Select Best Solution
Prototype
Test
Present Results
Engineering Design Process
VILLANOVA


Ask- Identifying a Need
Ideas given to you
What is needed in society?
Improving technology
VILLANOVA

Research- Identifying a Need

- What must be done?
  - Is it possible?
  - Is it currently available?




Think: Define the Problem

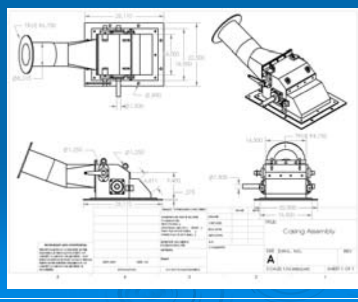
- How can this be solved?
- What resources are available?
- Brainstorming
- Narrow down to a certain idea


Prepare: Defining the solution

- Diagrams:
  - Important figures, equations, graphs
- Lists
  - What supplies do I need?
  - What is the cost?
- Analyze
  - Tradeoffs
  - Strengths and Weaknesses

Construct: Building the Product

- Follow your design specifications



Test, Test, Test, Test

Test, Revise, Test, Revise, Test, Revise,
Test, Revise, Test, Revise, Test, Revise,
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Test, Revise, Test, Revise, Test, Revise,
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Test, Revise, Test, Revise, Test, Revise

Lesson 3: Engineering Project Management

Teacher Reference

Objective:

To introduce students to the "soft skills" necessary to become successful engineers.

PowerPoint Guide:

The PowerPoint provides a large amount of information that can be edited and tailored to the specific needs of your students. The topics are meant to start students thinking about how to complete projects successfully.

Optional Activity:

Written Communication and Teamwork

1. Separate the students into groups of two
2. Pick two different locations in the building that are easily identifiable (bathroom, drinking fountain, etc.)
3. Have one student from the group write directions for the other student on how to reach that specific location.
4. Have the other student follow the directions exactly.
5. Did they make it to the location???
6. Repeat the activity for the other location.

Typically what occurs in this activity is that the students miss certain important steps in the process such as walking up a step or turning slightly right. This brief example helps show the importance of accurate written communication and teamwork.

National Science Standards:

- Science and Technology
  - I2EST1.5

Engineering Project Management
Lesson 3

Successful Engineers

- Successful engineers know more then theory
  - Scheduling
  - Time management
  - Written Communication
  - Teamwork
  - Presentation

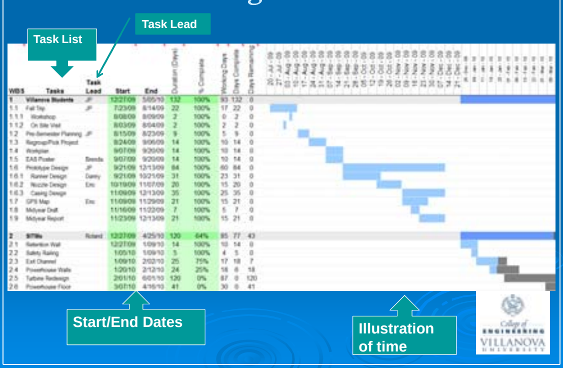
Why is it important to be a well rounded engineer?

- **Different situations require different skills**
  - Situation 1: You have a brilliant new idea but you need to sell the idea to your boss before you can start designing.
    - Written communication, presentation, teamwork
  - Situation 2: You are chosen as the project manager for a new landing gear system
    - Time management, teamwork, presentation, written communication, scheduling
  - Situation 3: You just invented a cell phone with the longest battery life on the market with similar fetchers to other top phones. Time to start your own company.
    - Time management, teamwork, presentation, written communication, scheduling, entrepreneurship.

Scheduling

- Prior to starting any new project it is important to determine a schedule
- Things to keep in mind
  - Some tasks can be done at the same time
  - Certain tasks must be accomplished before others can begin
  - The times should be realistic
- A simple way to schedule:
  - Step 1: Determine all the tasks necessary to complete your goal
  - Step 2: Put the tasks into an order of what must be done first, second, third etc…
  - Step 3: Assign start and end times to each task
  - Step 4: Assign engineers to different tasks

Scheduling- Gantt Charts



Time Management

- Once a the schedule is finished it is important to manage time properly so the task can be completed by the due date.
- Tips and Tricks for staying on time:
  - Prioritize your efforts based on the schedule
  - If possible work on the most difficult task first
  - Create daily lists of what must be accomplished
  - Budget your time so that no task is rushed
  - Monitor your behavior so you are not wasting time on non work related issues

Written Communication

- Engineers keep track of their work in many ways
  - Notebooks
  - Computer Programs
  - Portfolios
- It is extremely important to keep detailed records of everything so that people know how your work was created.

Engineering Notebooks

- Include all the details of a specific project
  - Drawings, Sketches, equations, charts
  - Notes from project meetings
  - Descriptions of different parts of the design
  - Timeline of your efforts

- It is important to sign and date any entries in the notebook
- A notebook is the proof of the work you have accomplished

Teamwork

- When cars were first invented they were made up mainly of mechanical components
- Now cars run on electric and mechanical devices as well as utilizing new types of fuel.
- Due to the change in how products are developed, engineers need to be able to work with people who have different skill sets.
- It is important to understand what each person can contribute to the project.

Presentation Skills

- Easy ways to present your findings:
  - Power Point
  - Posters
  - Lectures
- Presentation Tips
  - Speak load and clear
  - Do not read off of note cards or the computer
  - Utilize visual aids in your presentation
  - Avoid stalling words such as "um"
  - Try to minimize unnecessary body movements
  - Only present useful information.
    - It is not necessary to present all your data, charts, analysis, just present what exactly you found
  - Creativity always helps

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Lesson 4: Tool Shop Safety

Teacher Reference

Objective:

To help students learn the proper way to stay safe in a tool shop.

PowerPoint Guide:

In order to successfully construct an underwater robot many important safety considerations must be followed. The building process involves the use of power tools, hand tools and soldering equipment. Both students and instructors must understand how to use the equipment and dress in a way that protects your body from harm. This lesson will give a pictorial overview on the right and wrong way to operate and behave around tools.

Optional Activity: Safety Quiz

The quiz asks basic questions related to the content covered in the presentation.

Relevant Websites:

Soldering can be a difficult skill for beginners to learn. The following link helps step through the soldering process. http://www.instructables.com/id/How-to-solder/

Lesson 4: Tool Shop Safety

Student Quiz

Why is it important to wear safety goggles when working with power tools?

____

____

Why should you clamp the PVC before cutting or drilling?

____

____

What could happen if too many people are crowded around a table?

____

____

Name two important rules to follow when using a soldering iron?

____

____

Circle the correct answer to the following:

Is it ok to wear sandals in the tool shop? Yes No

Should long hair be up or down in the tool shop? Up Down

Tool Shop Safety

Lesson 4

The Do’s and Don'ts

Do’s and Don’ts for Clothing

Safety Glasses

Hair Tied Up

Gloves

Closed Toe Shoes

Do

Hair Loose or Down

Loose Fitting Clothes

Open Toed Shoes

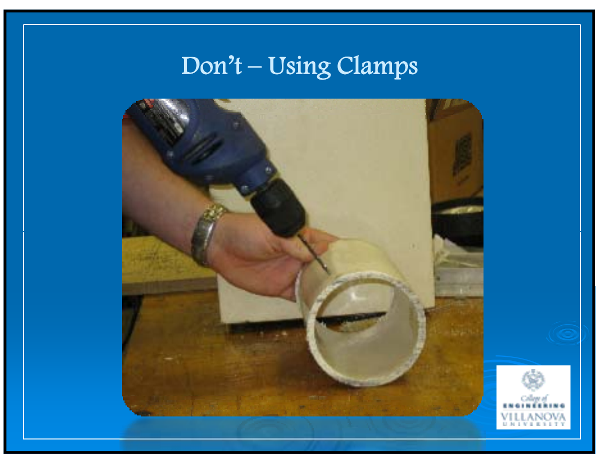
Don’t

CLOTHING- What is the difference

- Always wear goggles when using tools.
- Wear close toed shoes incase you drop anything.
- Clothing should not be baggy so it doesn’t get caught in anything.
- Long hair needs to be tied back and out of the way.
- Gloves should be worn when using adhesives, glues or anything corrosive.
- Aprons can be worn to protect your clothing.


Do-Using Clamps: Drilling


Do-Using Clamps: Cutting


Don’t – Using Clamps

Do~ Soldering Iron

Don't~ Soldering Iron

Do~ Using the Equipment

Don’t- Using the Equipment

Lesson 5: Forces

Introduction

Lesson Outline

The theory section of this lesson contains an array of demonstrations, thought provoking questions and mathematical equations to work through as a class. The best way to utilize the lesson is to show the slides and stop at critical points to add additional interactive experiences.

Learning Objectives

- Understand the different types of forces
- Learn to solve simple force equations
- Understand how forces are present in our lives everyday

National Science Standards

- Physical Science
  - 12BPS4.1
  - 12BPS4.2

Alignment with Sea Perch Construction

- This lesson is best taught in the early stages of construction.

Interesting Websites

- An interactive exercise that explains Newton's Laws of Motion: http://science.discovery.com/interactives/literacy/newton/newton.html
- Scuba diver safety, a lesson in pressure: http://adventure.howstuffworks.com/outdoor-activities/water-sports/question101.htm

Lesson 5: Forces

Theory

Forces Introduction:

When a force is exerted on an object, the object exerts a force back which is equal but in the opposite direction. For example the weight of your body is pushing down on the floor and since you are not moving up or down, the floor must be pushing up with a force equal to the force exerted by your body. When you sit on a chair, the force from your body is transferred to the legs of the chair (if you keep your feet off of the floor). If you are sitting in the middle of the seat of a four legged chair, each leg will be holding one-fourth of your weight plus part of the weight of the chair. The floor under that chair leg is pushing up with a force equal to the force the chair leg is pushing down. Those forces are then transferred to the walls or columns of the building and eventually down into the foundation of the building.

Newton's Laws:

Newton's laws govern 90% of everything we see in nature, from the motion of the earth and bicycles to the blood flow in our bodies! We won't discuss Newton's Law I as it is a special case of Law II.

Law II: $F = ma$

Force is the "cause" of motion; acceleration is the "effect". Newton's Law II is hence a statement of cause and effect. If *F* is in Newton's, *m* is in kg, and *a* is in meters/second^2.

Consider your bicycle moving forward. The above equation says that if you don't apply any force, the acceleration is zero. That does not mean that it is not moving, just that the velocity is constant. Which means you should be able to coast without doing anything. Obviously, that is not true, and the bike will keep slowing down if you don't keep pedaling.

Law III: For every action there is an equal and opposite reaction.

It is very important to remember this if you decide to push another person! Especially if that person's mass is bigger than yours.

Another example is a horse and cart. A horse pulls a cart with a force; the cart pulls the horse in the opposite direction with an equal force! So the two forces cancel each other out, and the cart cannot move!

Common Forces:

- **Friction** – always opposes the motion and exists when an object is in motion. In a fluid medium, the friction is viscous and increases if you speed up. So, the faster you go, the higher the friction.
- **Gravity** – exists always. Even a balloon that is floating has gravity acting on it. This force is always proportional to the mass (that is what we call "weight").
- **Normal force** – when an object is resting on a table (or bottom of the pool), there is a force applied by the table on the object.
- **Tension** – the force you would see in a string, cable or rope when it is attached to a weight. The tension usually acts along the string; it always pulls and never pushes.
- **Buoyancy** – This is an upward force that exists in any fluid medium, but is more important in a dense fluid such as water.
- **Thrust** – this is a force that typically pushes a vehicle (aircraft, boat, etc.) forward. The common sources of thrust are motors, propellers and engines.

Classroom Demonstration 1: Rolling Chair

Setup: Bring two wheeled chairs to the front of the classroom. Choose two students to help with the activity. Have one student sit in the wheeled chair and push off the wall. Next, have both students sit in chairs and push off each other.

Discussion: The student and chair will both move back away from the wall. This is caused by the wall pushing back with the same force that the student used when pushing on the wall. You can also have a contest to see who can get the wall to push them the farthest.

This however is not really a fair competition because the stronger students will tend to go further. Also, heavier students will have more rolling friction on the floor and will therefore lose more of their motion than the lighter students.

Classroom Demonstration 2: Balloon

Setup: Blow up a balloon and let it go across the classroom

Discussion: The force of the air pushing out the opening of the balloon pushes the balloon in the opposite direction.

Discussion Questions and Answers:

1. Which direction is the air shooting out the opening?
2. Which direction does the balloon fly?
3. If the balloon does not have as much air in it, does it fly as fast or as far?
4. What causes the air to come out of the balloon? Answer: The elastic forces caused by stretching the balloon when you forced air into it, exert forces on the air inside of the balloon forcing the air out of the balloon until the elastic forces are all gone from the now un-stretched balloon.
5. What makes some balloons float up? Answer: The helium in the balloon makes the balloon lighter than air. The buoyant forces on the balloon act in an upward direction. We will talk more about buoyancy in the future.
6. How do people keep their Helium balloons from floating away? Many people either hold the balloon or tie it to a chair. This is the same as applying a force downward onto the balloon.

Torque:

Torque is a function of a force that causes rotational motion. It is determined simply by multiplying force by the moment arm. For example, when you open a door, you are applying a torque; the further away your hand is from the hinge, the larger the torque, and the easier it is to open the door.

Statics:

When something is not moving the forces acting on it must add to zero. When this occurs the object is in static equilibrium. Statics is a field of engineering where objects are studied which have no outside forces acting on them. When all the forces add up to zero the object is considered to be in equilibrium

Thought Exercise:

If you wanted to make sure something did not go up-or-down or side-to-side, what could you do? There are many different options depending on the particular situation but in all cases the forces acting in every direction must add up to zero. So if something is moving in one direction it has or had unequal forces acting on it. To make it stay still you must add an equal force in the opposite direction.

Pressure:

Pressure is the force exerted by something divided by the area over which that force is exerted.

$$Pressure = \frac{Force}{Area}$$

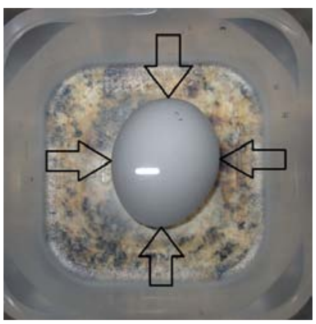
For example if one person pushed with a force of ten pounds on an area of five square inches, the pressure would be 10 pounds divided by five square inches.

$$Pressure = \frac{Force}{Area} = \frac{10\ pounds}{5\ square\ inches} = 2\ pounds\ per\ square\ inch = 2\ psi$$

If ten people each push on their own five square inch area with a force of 1 pound then the total force would still be ten pounds but the area would be much greater and therefore the pressure would be less.

$$Pressure = \frac{Force}{Area} = \frac{10\ pounds}{50\ square\ inches} = 0.2\ pounds\ per\ square\ inch = 0.2\ psi$$

Fluids exert pressure equally in all directions normal (perpendicular) to the object on which the pressure is exerted.



Thought Exercise:

Would you rather an elephant stepped on you or a small woman putting all of her weight on one of the heels of her high heels?

A large elephant weighs 15,000 pounds. Assume the total area of the elephant's four feet is 450 square inches. (pressure = 15,000/450 = 33.3 psi) A small woman weighs 150 pounds. The area of an average "high heel" is .2 square inches. (pressure = 150/.2 = 750 psi)

The pressure is actually greater when the women steps on your foot.

Atmospheric Pressure:

It may not seem obvious but everyday the atmosphere exerts pressure on each of us. This is because air is a fluid. The weight of the air in the atmosphere reacts with everything and everyone by applying a pressure. Higher altitudes have less air above them than lower elevations, therefore the pressure is lower and the air is less dense.

Thought Exercise:

Why do baseballs travel further in the mile high Colorado Rockies Stadium? The atmospheric pressure at sea level (14.7psi) is considerably greater then at the tops of mountains (as low as 4.9psi).

Can you determine the weight of air (atmosphere) pushing on a square foot of the earth's surface at sea level?

14.7 pounds / square inch * 144 square inches = 2116.8 pounds

Atmospheric pressure also affects our bodies. The air we breathe is atmospheric. Lungs have to overcome the differential pressure when breathing above ground and underwater. Scuba Divers have to worry about this every time they dive. Since the pressure is greater underwater if the diver tries to ascend too quickly high pressure bubbles in the body will burst in a lower pressure environment.

Thought Experiment:

If a balloon could float all the way up into space, what would probably happen?

The balloon would keep expanding so the pressure inside the balloon would continue to be the same as the pressure outside the balloon which keeps decreasing the higher that you go. Eventually the elastic in the balloon would stretch too much and break.

Lesson 5: Forces

Glossary

- **Acceleration:** an increase in rate of change; increasing velocity

- **Equilibrium:** stable situation in which forces cancel each other out

- **Friction:** the resistance encountered when an object is moved in contact with another; one of several forces resisting the motion of an object

- **Force:** strength or energy exerted or brought to bear; cause of motion or change

- **Mass:** the property of a body that is a measure of its inertia and that is commonly taken as a measure of the amount of material it contains and causes it to have weight in a gravitational field

- **Tension:** the act or action of stretching or the condition or degree of being stretched to stiffness; the force opposing gravity or drag when pulling an object with something such as a wire

- **Thrust:** the force produced by a propeller or by a jet or rocket engine that drives a vehicle forward

- **Torque:** a force that produces or tends to produce rotation or torsion; a turning or twisting force

Forces
Lesson 5

Forces Explained

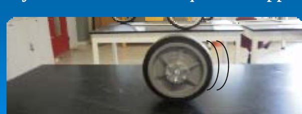
- When a force is exerted on an object, the object exerts a force back

Newton's Laws

Law I- An object in motion tends to remain in motion unless acted on by an outside force. An object at rest tends to stay at rest unless acted on by an outside force.

Law II- Force is equal to mass times acceleration

Law III- For every action there is an equal and opposite reaction



Common Forces: Friction

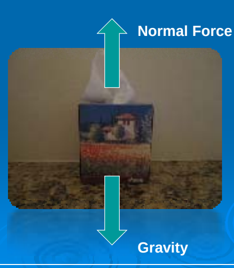
- Will always oppose the motion
- Exists when an object is in motion
- In a fluid the friction increases when you speed up

Common Forces: Gravity

- Always exists
- Weight is the force proportional to the mass of an object
- Even floating balloons are affected by gravity

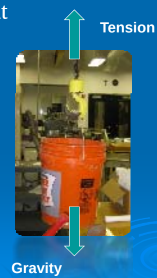
Common Forces: Normal Force

- If an object is resting on a table (force of gravity), the table is exerting a force up on the object (normal force).



Common Forces: Tension

- Seen in a string, cable or rope when it is attached to a weight
- Acts along the string
- Always pulls
- Never pushes

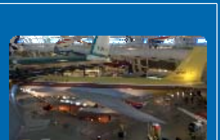


Common Forces: Buoyancy

- Upward force exists in any fluid medium
- Most important in denser fluids like water

Thrust

- Force that typically pushes a vehicle



- Commonly seen in airplanes and boats
- Sources are often propellers or engines

Torque

- Function of a force that causes rotational motion

  Torque = Force x Moment Arm

- Door Example:

  - You apply a torque when you open the door
  - The further away from the hinge the greater the torque

Statics

- When something is not moving the sum of the forces acting on the object must equal zero.
- The object is in static equilibrium.
- The field of statics is extremely important for civil engineers.

2 Normal Forces – Gravity = 0

Pressure

- Force exerted by something divided by the area over which the force is exerted.

$$Pressure = \frac{Force}{Area}$$

Atmospheric Pressure

- The atmosphere exerts pressure on each of us everyday
  - Because… Air is a fluid
- Higher altitudes have less air above them
  - Therefore…the pressure is lower at higher elevations

Lesson 6: Hydrostatics

Introduction

Lesson Outline

- Student Worksheet- Hydrostatics
  - Pre-Lesson Questions
- Theory-Hydrostatics
  - Hydrostatics, PowerPoint
- Student Worksheet- Hydrostatics
  - Post-Lesson Questions
- Activity- Hydrostatics
- Glossary- Hydrostatics

Learning Objectives

- Understand the concept of hydrostatics
- Learn different equations to solve for hydrostatic pressure and forces
- Understand the importance of buoyancy for underwater ROVs

National Science Standards

- Science as Inquiry
  - 12ASI1.2
  - 12ASI1.3
- Physical Science
  - 12BPS4.2
- History and Nature of Science
  - 12GHNS1.1

Alignment with Sea Perch Construction

- This lesson is best taught in the early stages of construction. However, it is necessary to have a completed ROV for the buoyancy activity. It may be best to teach the lesson in the beginning of construction and save the activity for after the ROV is built.

Lesson 6: Hydrostatics

Theory

Overview of Fluids:

Fluids can be liquids or gasses and typically take the shape of their container. Two terms are used to understand how a fluid behaves, compressible and incompressible.

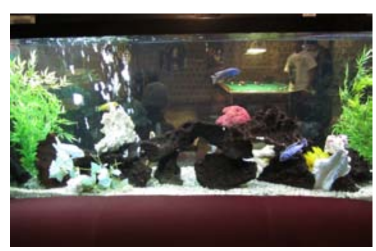
A compressible fluid is relatively easy to understand. Gasses are compressible and will both take the shape of their container and expand to fill a container. Where as water, which is an incompressible fluid, will never expand to fit a larger container. The volume of an incompressible fluid will never change, however when a compressible fluid expands; it is increasing its volume.

Thought Experiment: Compressible

What happens when you boil water in a teapot? Does the water stay in the teapot after it is boiled or does something happen to some of the water? When water boils some of it changes from a liquid to a gas. While the liquid (water) stays in the container, the gas (steam) expands to fill the entire room.

Thought Experiment: Incompressible

What happens when you pour water from a cup into a square cake tin? The water changes shape from the round cup to the square tin. Water is a liquid and will almost always take the shape of the container it is placed in.



Overview of Hydrostatics:

The term hydrostatics refers to how a fluid behaves at rest. There are three very important concepts to understand when discussing hydrostatics.

1. Density

Density is the mass of a fluid (or really anything) divided by the volume it occupies.

$$Density = \frac{Mass}{Volume}$$

An easy way to understand density is to think of three different fluids: air, water and maple syrup. If the all three fluids were in identical containers at the same temperature the density would be greatest for the thick maple syrup.

2. Specific Weight

Specific Weight refers to the weight of a fluid per unit volume. It is found by multiplying the density of the fluid by the acceleration due to gravity.

$$Specific\ Weight = Density * Gravity$$

3. Hydrostatic pressure

Hydrostatic pressure is the static pressure exerted by a liquid. This occurs when the fluid is not moving and no objects in the fluid are moving. The hydrostatic pressure increases the deeper you are in the liquid.

$$Hydrostatic\ Pressure = Specific\ Weight * Depth$$

Classroom Demonstration 1: Balloon in Atmosphere and Underwater

Setup: Place two marks with a permanent marker on either side of a balloon. Fill a large plastic container with water. Blow up the balloon so it is small enough to fit underwater in the plastic container. Ask a student to help you measure the diameter of the balloon. Using a string measure the balloon diameter by wrapping the string exactly around the balloon on the marks. Measure the string and record the results. Repeat the procedure when the balloon is underwater. Record the results.

4. Pressure Underwater:

The difference in pressure at different depths in a liquid can be calculated by multiplying the difference in elevation in the liquid times the unit weight of the liquid.

$$\begin{aligned} \textit{Difference in Pressure} &= \textit{pressure } 2 - \textit{pressure } 1 \\ &= \textit{unit weight} * (\textit{depth}2 - \textit{depth}1) \end{aligned}$$

5. Hydrostatic Force:

Hydrostatic force is the force that a liquid exerts on a body that is either fully or partially in the liquid or is adjacent to the liquid. Hydrostatic force is just the hydrostatic pressure multiplied by the area on which that pressure is acting.

$$\textit{Hydrostatic Force} = \textit{Specific Weight} * \textit{Depth} * \textit{Area}$$

6. Buoyancy:

Buoyancy is the force exerted upward on a body that is fully or partially submerged in a liquid. Archimedes first discovered the concept in 212BC when he was rumored to have question the displacement of water in his bathtub after he entered the tub. He determined that “any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object.”

$$\textit{Buoyant Force} = \textit{Weight of the Fluid Displaced by the Object}$$

The center of buoyancy is the center of gravity of the displaced liquid. (e.g. the center of gravity of the part of your vehicle that is submerged.)

Submerged objects are stable (do not overturn) when the center of gravity of the object is directly below the center of buoyancy of the object.

For a floating object to be stable (not flip over), the center of gravity of the object must be directly below the center of buoyancy of the object. The object may become unstable when the center of gravity moves out of vertical alignment with center of buoyancy.

Classroom Demonstration 2: Buoyancy

Setup: Push a helium balloon around the classroom. Then demonstrate instability using the helium balloon by rotating an attached string 90 degrees upward.

Discussion:

1. Why doesn't the helium balloon fall to the ground? Answer: It is buoyant because the balloon displaces more air @14.7 psi than the balloon and its' contents weigh.

2. What happens each time the balloon moves back and forth? Answer: The balloon moves because the forces acting on it are unbalanced.

3. What force or forces in what direction/ directions would be needed to get the balloon to stay in the same place? Answer: Assuming there is no wind, a force applied in the downward direction would be necessary.

4. How could you make the balloon neutrally buoyant? Answer: You could add weight.

5. Why is the balloon unstable when it is rotated? Answer: The center of gravity is not directly below the center of buoyancy.

Lesson 6: Hydrostatics

Activity: Buoyancy of Underwater Robot

Materials:

Item	Quantity	Purchase Location Suggestion
Completed Underwater Robot	1	
Weights	1	Fishing weights work best
Metal Hangers	3	

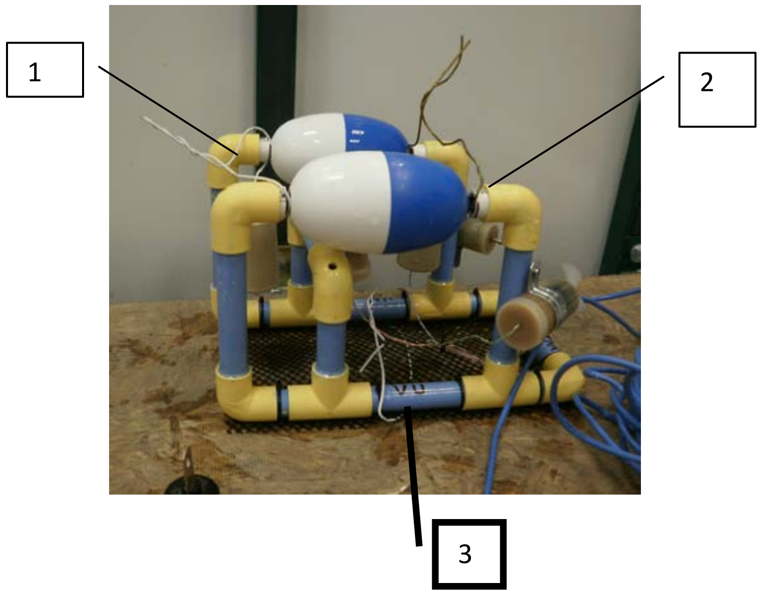
Background:

The purpose of this activity is to determine how much ballast must be added to your underwater ROV to make it neutrally buoyant. Ballast refers to the weight used to help keep an object buoyant. Making an object neutrally buoyant means the object will both not sink and not rise without the help of thrust. This is extremely important since your ROV needs to be capable of maneuvering horizontally and vertically at any depth.

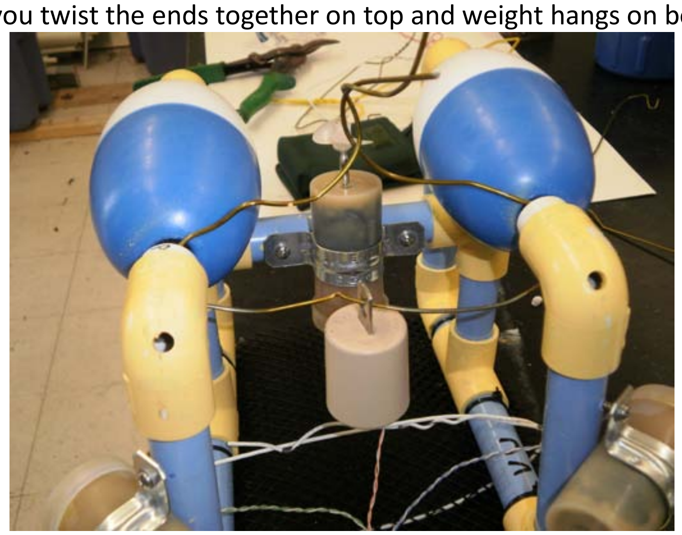
Procedure:

Setup:

1. Attach the three metal hangers in the spots shown in the picture
   a. You may have to cut the hangers so there is not too much excess
   b. Be careful of wires and the sharp ends



2. Attach so that you twist the ends together on top and weight hangs on bottom



Testing:

1. Attach a weight to the lowest point on the ROV
2. Place the ROV in water tank
3. Push the top of your ROV off center

Does the ROV self right?

4. Attach a weight to the highest point of your floating ROV (a combination of spots on the two top hangers)
5. Place ROV in water tank
6. Push the top of the ROV off center

Does the ROV self right?

You might find out that the boat flips instead of returning to a naturally buoyant position.

7. Determine how much ballast must be added to make the robot neutrally buoyant.

Lesson 6: Hydrostatics

Student Worksheet

Pre-Lesson Questions

1. Give three examples of objects that float.

____

____

2. What actually makes an object float?

____

____

____

3. Why do people's ears hurt when they swim near the bottom of a pool?

____

____

____

Post-Lesson Questions

1. What are two examples of a compressible fluid?

____

____

2. What are two examples of an incompressible fluid?

____

____

3. What fluids interact with your underwater robot?

____

____

____

Lesson 6: Hydrostatics

Glossary

- **Ballast:** a heavy substance placed in such way as to improve stability and control

- **Buoyancy:** the tendency of a body to float or to rise when submerged in a fluid; the power of a fluid to exert an upward force on a body placed in it

- **Density:** the mass of a substance per unit volume; the distribution of a quantity (as mass, electricity, or energy) per unit usually of space

- **Elevation:** the height above the level of the sea

- **Fluid:** having particles that easily move and change their relative position without a separation of the mass and that easily yield to pressure; capable of flowing

- **Gas:** a fluid, such as air, that has neither independent shape nor volume but tends to expand indefinitely

- **Hydrostatics:** a branch of physics that deals with the characteristics of fluids at rest and especially with the pressure in a fluid or exerted by a fluid on an immersed body

- **Liquid:** the state in which a substance exhibits a characteristic readiness to flow with little or no tendency to disperse and relatively high incompressibility

- **Specific Weight:** weight per unit volume of the material

- **Volume:** the amount of space occupied by a three-dimensional object as measured in cubic units

Hydrostatics

Lesson 6

Fluids are Everywhere

- Liquids or Gasses
- Air is a fluid!!!
- Typically take the shape of their container

Fluids: Important Terms

Compressible Fluid: Gasses

- Take shape of container
- Expand to fill container
- Can increase its volume

Incompressible Fluid: Water

- Never expands to fit container
- Volume never changes

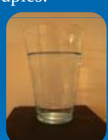
Hydrostatics

- The study of how a fluid behaves at rest.

Hydrostatics- Important Terms

- Density
  - Mass of a fluid divided by the volume it occupies.

$$Density = \frac{Mass}{Volume}$$



- Which fluid do you think has a higher density at the same temperature?

Hydrostatics- Important Terms

- Specific Weight
  - Weight of a fluid per unit volume
  - Found by multiplying density of fluid by the acceleration due to gravity

$$Specific\ Weight = Density \times Gravity$$

Hydrostatics- Important Terms

- Hydrostatic Pressure
  - Static pressure exerted by a liquid
  - Occurs when the fluid is not moving and no object in the fluid is moving
  - Increases at deeper depths

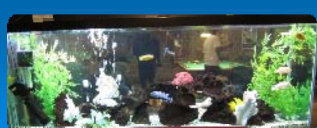
Hydrostatic Pressure = Specific Weight x Depth

Finding the Pressure Underwater

- Calculated by multiplying difference in elevation in the liquid times the unit weight of the liquid

Difference in Pressure = pressure 2 – pressure 1

= unit weight x (depth 2- depth 1)



Hydrostatic Force

- Force that liquid exerts on body either fully or partially in the liquid or adjacent to liquid
- Formal: the hydrostatic pressure multiplied by the area on which the pressure is acting

Hydrostatic Force = Specific Weight x Depth x Area

Buoyancy

- Force exerted upward on a body that is fully or partially submerged in a liquid
- Discovered by Archimedes in 212BC

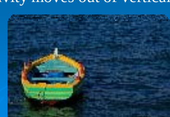
Archimedes Principle

"Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object."

Buoyancy

Buoyant Force = Weight of the Fluid Displaced by the Object

- Center of buoyancy is the center of gravity of the displaced liquid
- How do you stop a submerged object from overturning?
- Ho do you keep a floating object from not flipping over?
  - When the center of gravity of the object is directly below the center of buoyancy of the object.
- Instability of objects occur when?
  - The center of gravity moves out of vertical alignment with center of buoyancy.



Lesson 7: Fluid Dynamics, Thrust

Introduction

Lesson Outline

- Theory-Fluid Dynamics, Thrust
- Fluid Dynamics, Thrust PowerPoint
- Activity- Fluid Dynamics, Thrust
- Student Worksheet-Fluid Dynamics, Thrust
- Glossary- Fluid Dynamics, Thrust

Learning Objectives

- Understand the term fluid dynamics and what constitutes a fluid
- Determine the different forces acting on an underwater ROV
- Understand the relationship between thrust and drag

National Science Standards

- Science as Inquiry
  - 12ASI1.1
- Physical Science- Motions and Forces:
  - 12BPS4.2

Alignment with Sea Perch Construction

- After the Sea Perch is constructed this lesson can be used to explain how and why it moves in water.

Interesting Websites

- A website that has information about marine technology including pictures of other ROVs: www.marinetech.org

Lesson 7: Fluid Dynamics, Thrust

Theory

Background Information:

Fluids are everywhere – you cannot avoid them! You are in a fluid right now: air. The seaperch is also in a fluid: water. These fluids are often in motion – when you are in a strong breeze, the air is moving around you, pushing you one way or another. The interaction between moving fluids and solid objects is called **fluid dynamics**. Sometimes the fluid is still, and you are moving through the fluid; this is also fluid dynamics. The key point is that fluid dynamics come into play whenever the fluid is moving relative to you.

Thought Experiment:

If you roll down the window in a moving car, you feel a breeze since you are moving fast relative to the air around the car. This is the same effect as sitting in a parked car with a strong breeze flowing around you. Either way, there's fluid dynamics going on.

It's important to know what makes the seaperch move around in the water. In general, what makes the seaperch move in any direction is called **force**. Forces are seen everywhere in nature: drop a book on the floor and the force that makes it fall is called **gravity**. If you throw a baseball you are applying a force onto the ball to make it move. The seaperch uses two different types of force that affect how it moves: thrust and drag. **Thrust** is a force that makes the seaperch move forward, while **drag** is a force that prevents it from moving faster once it is in motion. Drag is an interesting force. The amount of drag on the seaperch depends on how fast it goes. In fact, there is zero drag force when the seaperch isn't moving at all!

Thought Experiment:

Consider you want to ride a bike on a level street (not the side of a hill). Before you start to pedal, there are zero thrust and drag forces on the bike. When you start to pedal the bike, you are applying a thrust to the bike to make it go faster (the rate at which you increase your speed is called **acceleration**). As the bike starts to move faster, you feel a breeze – this breeze is the drag force. Notice that the breeze gets stronger the faster you go, which makes it harder to pedal. Eventually, you can't go any faster no matter how hard you try pedaling, which means that you've reached the **terminal velocity** of the bike.

Mathematically, you and your bike have **mass** or the amount of matter in an object. When a force is applied, you accelerate. When two different forces are applied on you, your acceleration is the difference between them.

You can write it out like this:

$$ma = F_{thrust} - F_{drag}$$

Where m is mass, a is acceleration, F_{thrust} is thrust force, and F_{drag} is drag force.

At the terminal velocity:

$$F_{thrust} = F_{drag}$$

Therefore the acceleration is zero (you aren't speeding up anymore). Basically when you pedal you're bike you're doing what seaperch is doing. In pedaling you are moving a **vehicle** (your bike) through a fluid (air). The Seaperch is a vehicle that also moves through a fluid (water). In riding your bike, you are providing a thrust by pedaling; the seaperch has thrust that comes from its propellers. The drag you experience on a bike is due to the air, the drag the seaperch feels is from the water.

This lesson focuses on thrust. There are lots of different ways to generate thrust but here we focus on thrust generated by a **propeller**. You have probably seen propellers before, like in a fan or an airplane. The idea is that as the propeller rotates, it does one of two things:

1. It pushes the fluid away from the vehicle. This is done in a submarine like the seaperch.

2. It pulls fluid towards the vehicle. This is done in most airplanes.

Classroom Demonstration 1: Box Fan

Setup: Place a typical box fan on the floor within 1 foot of a wall. Plug in and turn on the fan. Turn to the highest speed. The box fan should tip over in the direction away from the wall.

Discussion: What you have essentially done is turned the box fan into a vehicle – the force of the fluid from the box fan pushes off the wall, causing a thrust in the box fan. This forward force makes the fan tip over. Seaperch does the same thing in water: the rotating propeller pushes the water away from it, causing it to move forward.

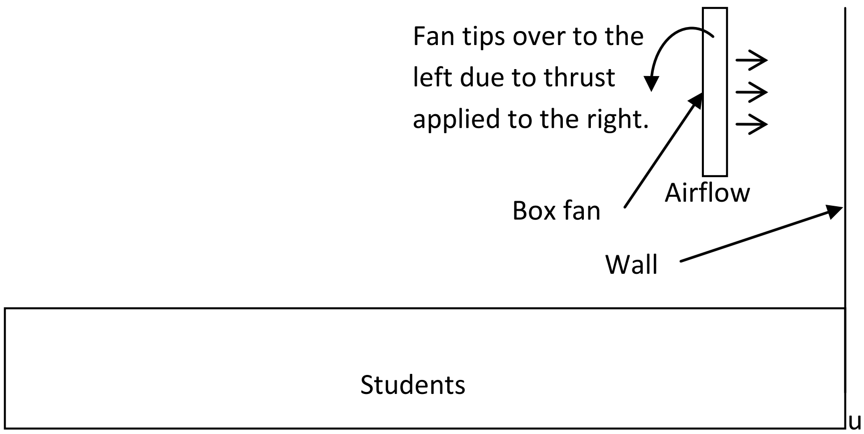


Figure 1: Thrust demonstration using a box fan.

Classroom Demonstration 2: Seaperch on a String

Setup: Tie one end of a three-foot string to the Seaperch. Hold the other end to suspend the Seaperch in air. Turn on the propellers, and notice that the Seaperch does not move.

Discussion: One key difference between the fan and the seaperch propeller is the fluid it's pushing. The fan pushes air while the seaperch propeller pushes water. Water has about 1000 times the **density** of air, which provides the seaperch more thrust than in air. To understand density better, think about a gallon of milk. If water has 1000 times the density of air, then a gallon of water is 1000 times heavier than a gallon of air. If you think about it, a gallon of unopened milk (full of milk which is very similar to water) weighs a lot more than an empty milk carton (the carton is now full of air). It turns out that pushing a fluid with higher density results in more thrust force. This means that although the seaperch doesn't move in air, the thrust force in water is 1000 times stronger, allowing the seaperch to move around in the water. If we were all underwater, and the demonstration was redone, then you would see the seaperch move forward.

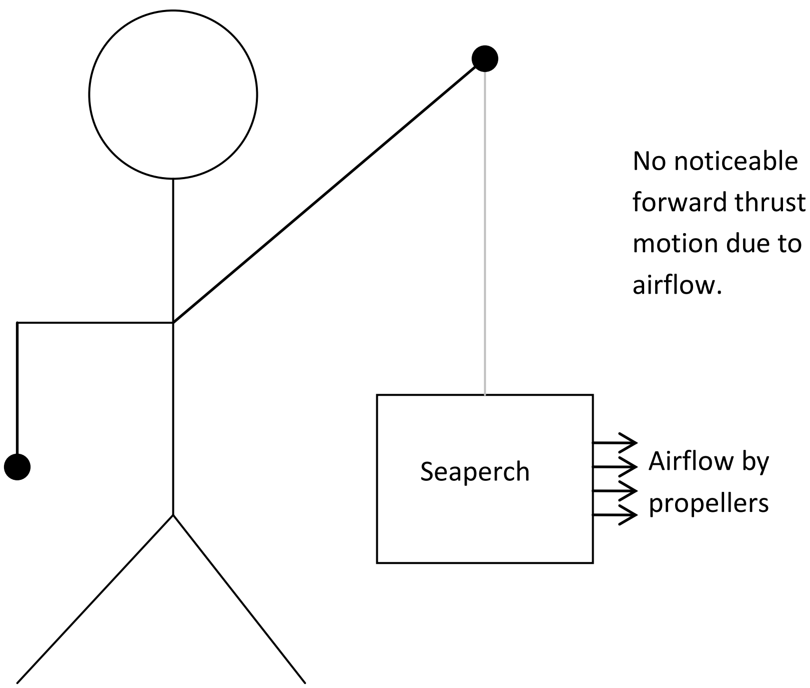


Figure 2: Demonstration showing the influence of density on thrust.

Thought Experiment:

You can also demonstrate this by having the students stand up and do a “swimming” motion with their arms. They aren’t moving since the density of air is so small compared to water. If they were in water, they’d be moving all around the room!

Lesson 7: Fluid Dynamics, Thrust

Activity: Rubber Band Powered Airplanes

Materials:

Item	Quantity	Purchase Location Suggestion
Balsa Wood Rubber Band Airplanes	1	www.Guillow.com - Any rubber band powered airplane model
Paper Clips	2	
Permanent Marker	1	
Fishing wire	10ft	
Electrical Tape	1	Sea Perch Kit
Tape Measure	1	

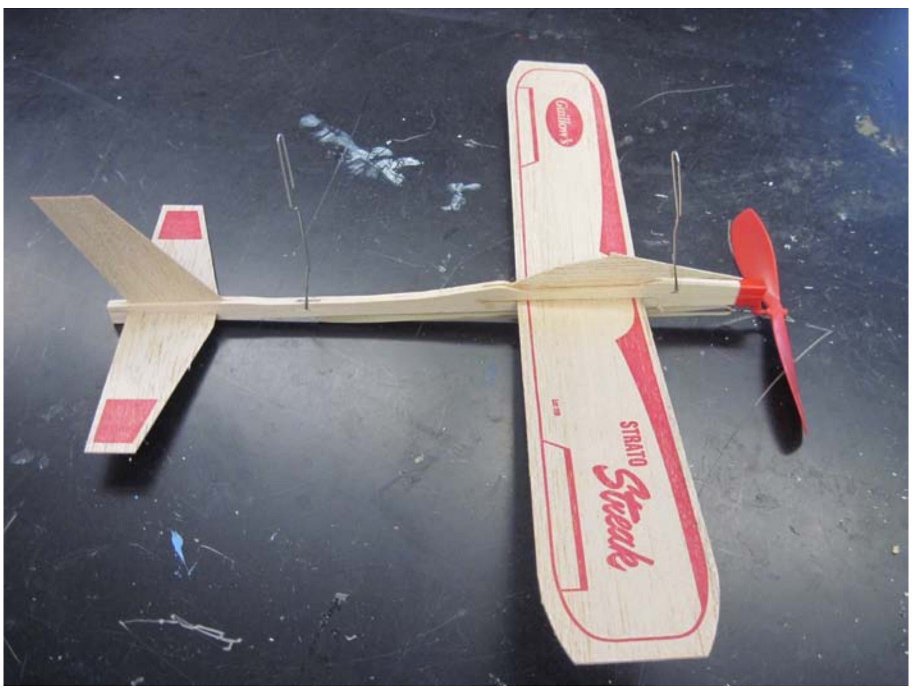
Background:

Rubber band powered airplanes allow you to change the amount of thrust simply by winding the band. In this activity students will explore how changes in thrust affect the airplanes performance.

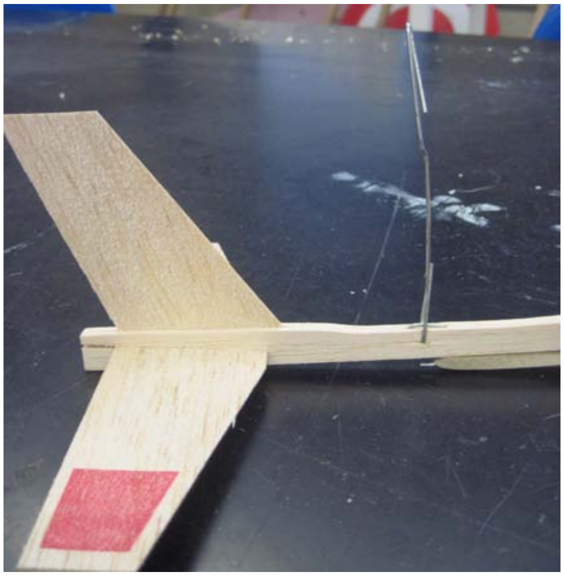
Procedure:

1. Have students answer and discuss the pre-activity questions in the Student Worksheet- Fluid Dynamics Thrust.
2. Assemble the airplane according to package instructions.

3. Straighten out two large paper clips. Insert one end of the paper clips carefully through the balsa wood frame of the plane as shown in the picture. It is extremely important to do this with care since the balsa wood snaps easily.



4. Make sure the paperclips are standing higher then the tail of the plane.



5. Place two chairs directly across from each other about 10ft apart. Attach the fishing wire in a straight line to the two chairs. It is important that the string is level.

6. The airplane should now hang loosely from the fishing wire.

7. Test the airplane to make sure it glides smoothly across the wire.

8. Adjust the paperclips so that the airplane hangs perfectly horizontal

9. It may be necessary to use electrical tape to ensure the paperclips stay in place.

10. The assembly is now complete.

11. Use a tape measure to record how far the plan travels across the wire.

12. The students can now complete the data analysis section in the Student Worksheet- Fluid Dynamics Thrust.

13. After the worksheet is complete have students discuss any trends that appear in their graph.

Lesson 7: Fluid Dynamics, Thrust

Student Worksheet

Pre-Activity Questions

Answer the following questions before beginning the activity.

1. What parts of the airplane produce thrust?

____

____

____

2. How can you increase the airplanes thrust?

____

____

____

3. Why is it important that the airplane hangs level on the line?

____

____

____

4. How will the plane behave differently if the wire is higher on the starting side then the ending side?

____

____

____

Data Collection- Thrust Test

Instructions:

- Place your airplane at the on end of the wire.
- Find the minimum number of winds required to make the airplane move.
- Start by winding the plane a certain number of times. Launch the plane and record the number of winds and the distance the plane traveled in the table.
- Try adjusting the winds to find the minimum winds required to make the airplane move. Record each trial in the data table.
- Now determine the number of winds required to reach the end of the wire. Record all trials in the data table.

Number of Winds	Distance Traveled (inches)

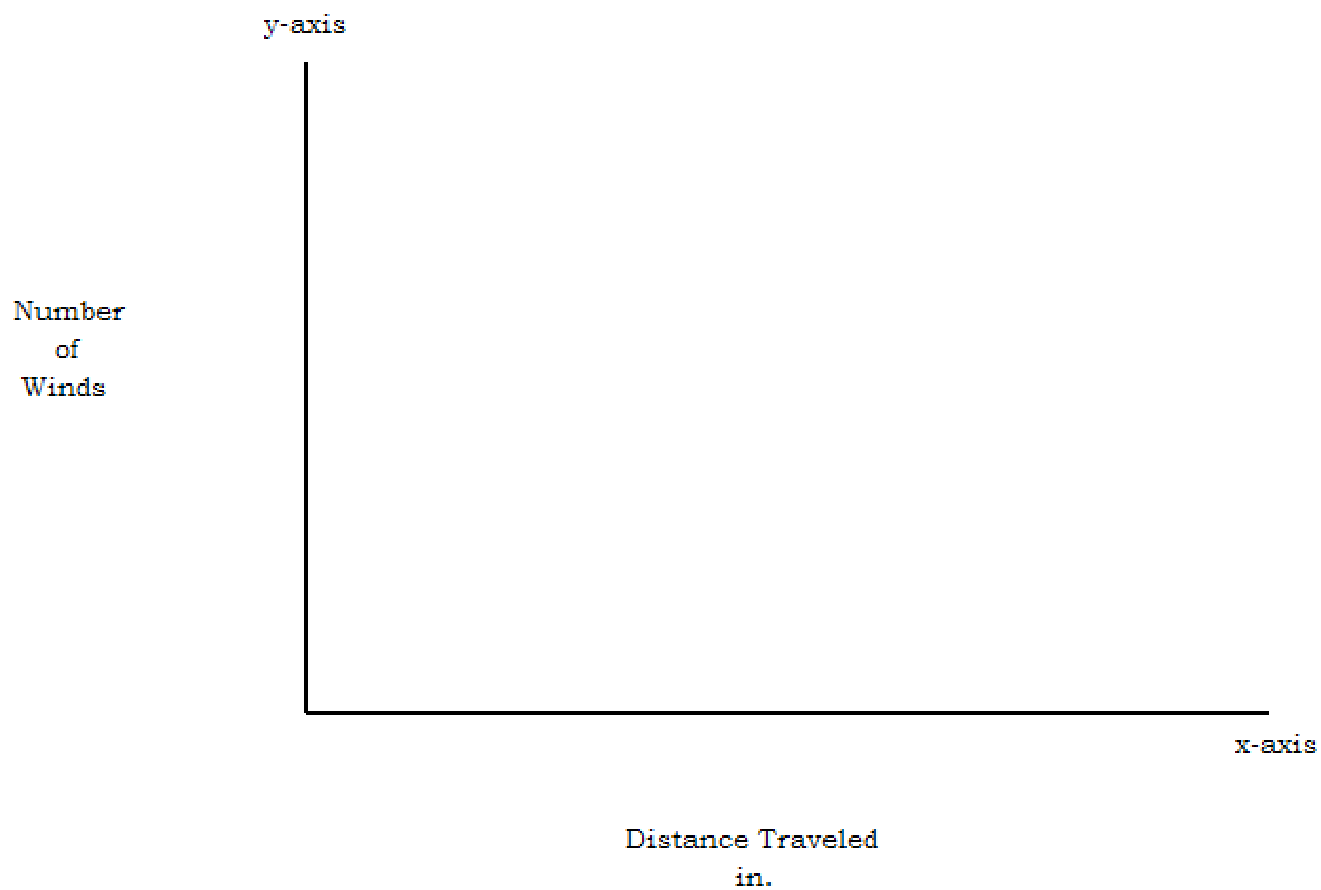
Questions

How many winds did it take to reach the end of the wire? _____

What is the minimum number of winds required to move the airplane? _____

Data Analysis Instructions

- Your goal is to graph the results of your test and determine if any trends appear.
- Based on your results determine an appropriate scale for the x axis and y axis.
  - For example: number of winds could go in increments of 5 (5, 10, 15…) and the distance traveled could go in increments of 2 in. (2 in, 4 in, 6 in)
  - Plot your data from the thrust test on the graph.



Lesson 7: Fluid Dynamics, Thrust

Glossary

- **Acceleration:** an increase in rate of change; increasing velocity
- **Density:** the mass of a substance per unit volume; the distribution of a quantity (as mass, electricity, or energy) per unit usually of space
- **Drag:** something that slows down motion, action, or advancement
- **Dynamics:** a branch of mechanics that deals with forces and their relation primarily to motion but sometimes also to the equilibrium of bodies
- **Force:** strength or energy exerted or brought to bear; cause of motion or change
- **Mass:** the property of a body that is a measure of its inertia and that is commonly taken as a measure of the amount of material it contains and causes it to have weight in a gravitational field
- **Propeller:** a device that consists of a central hub with radiating blades placed and twisted so that each forms part of a helical surface and that is used to propel a vehicle
- **Terminal Velocity:** the speed at which drag matches the pull of gravity resulting in a constant fall rate
- **Thrust:** the force produced by a propeller or by a jet or rocket engine that drives a vehicle forward

Fluid Dynamics: Thrust

Lesson 7

What is Fluid Dynamics?

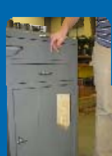
- Fluid dynamics helps engineers and scientists make sense of :
  - how fluid moves
  - how fluids affect moving objects
- Velocity is how fast something moves

Many things behave like a fluid
- Air
- Gas
- Liquid
- Electricity
- Traffic

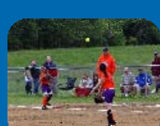
- Fluids are hard to contain since they take many shapes based on their environment

Forces: What Makes the Sea Perch Move???

- Forces are everywhere:



Force of Gravity



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Person Applied Force to Ball

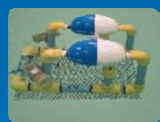
Magnetic Force

Forces and Sea Perch Movement

- Two main forces affect the movement of the Sea Perch.
  - Thrust: force that allows Sea Perch to move forward
  - Drag: force that prevents Sea Perch from moving faster once in motion

Large Picture of Sea Perch moving through hula hoop toward object

Thrust



Drag

Thrust vs. Drag

Thrust = Drag = 0

Pedaling is a way of applying thrust

The breeze in your hair is drag

- The rate at which you increase your speed on the bike is acceleration.
- However, the faster you go the stronger the breeze
  - This makes the bike harder to pedal
- Eventually you can't go any faster no matter how hard you pedal
  - Now you have reached terminal velocity

Thrust vs. Drag: Mathematically

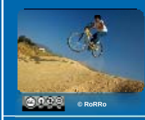
- When a force is applied to a mass you accelerate:

$$ma = F_{Thrust} - F_{Drag}$$

- m is mass: the amount of matter in an object
- a is acceleration: the rate at which you increase your vel
- F thrust: the force of thrust
- F drag: the force of drag

- What happens when you reach terminal velocity?
  - F thrust = F drag and a = 0

How is a Bike Similar to the Sea Perch?

Vehicle	Thrust	Drag
	Caused by peddling	Caused by air
	Caused by propellers	Caused by water

Propellers Cause Thrust

- What happens when a propeller rotates:

1. It pushes fluid away from the vehicle

2. It pulls fluid towards the vehicle

How Does Fluid Density Affect Propellers?

Propeller pushes water

Fan pushes air

- Water has about 1000 times the density of air
- A gallon of water is 1000 times heavier than a gallon of air
- Pushing fluid with greater density requires more thrust
- Thrust force in water is then 1000 times greater than the thrust force in air

Lesson 8: Fluid Dynamics, Drag

Introduction

Lesson Outline

- Student Worksheet- Fluid Dynamics, Drag
  - Pre-Lesson Questions
- Theory-Fluid Dynamics, Drag
  - Fluid Dynamics, Drag PowerPoint
- Activity- Fluid Dynamics, Drag
- Student Worksheet-Fluid Dynamics, Drag
  - Activity
- Glossary- Fluid Dynamics, Drag

Learning Objectives

- Understand the difference between thrust and drag
- Understand how density and weight affects drag

National Science Standards

- Science as Inquiry
  - 12ASI1.1
- Physical Science- Motions and Forces:
  - 12BPS4.2

Alignment with Sea Perch Construction

- After the Sea Perch is constructed this lesson can be used to explain how and why it moves in water.

Lesson 8: Fluid Dynamics, Drag

Theory

Concept 1: Thrust vs. Drag

In Lesson 7, two different **forces** are discussed that affect the motion of the seaperch. These forces are the **thrust**, which moves the seaperch forward in the water; and **drag**, which acts against the forward motion of the seaperch. The drag force increases as the seaperch moves faster through the water and the fastest the seaperch can go is the **terminal velocity**, where the thrust and drag are equal. This module focuses on the drag force and what can be done to reduce its magnitude.

Drag force is an important concept in fluid dynamics. Basically, there are two ways to increase the terminal velocity of the Seaperch:

1) Increase the thrust

2) Reduce the drag.

Increasing the thrust is difficult as you are limited by the size of the motors and the propeller type used on the seaperch propellers.

Drag force, on the other hand, can have a significant impact on the motion of the seaperch. If the drag force is reduced on the seaperch, then the terminal velocity will increase. The following demonstration will show how this works.

Classroom Demonstration 1: Paper and Air Drag

Setup: Take out two identical pieces of paper. Ball up one piece of paper. Hold both the flat sheet and the balled up sheet out in front of you. Drop both at exactly the same time.

Discussion: The balled-up sheet of paper hits the ground a lot sooner. The reason for this is that the air provides more drag on the flat sheet of paper than the balled-up one. Therefore, the terminal velocity of the balled-up sheet of paper is higher than the flat sheet of paper.

Classroom Demonstration 2: Riding a Bike

Setup: Have a student come to the front of the class and have him/her pretend that they are riding their bike down a hill, and that they want to go fast.

Discussion: The student instinctively will lower their head down to where the handlebars would be. What they are naturally doing is reducing their drag so their terminal velocity is faster!

Concept 2: Weight and Thrust

It is important to also recognize the significance of mass when it comes to the first demonstration. The **weight** of the sheet of paper is a force that pulls it down toward the earth (also called **gravity**). In a sense, the weight acts the same way as thrust. Consider the balled-up piece of paper: when the paper is initially let go, there is zero drag on it, but its weight acts to **accelerate** the paper downward, increasing its speed and therefore the drag. Soon the paper reaches the terminal velocity as the drag upward on the paper equals the weight downward.

The main difference between weight and thrust is that you can increase the weight force by simply adding mass, but you can't increase the thrust so easily.

Classroom Demonstration 3: Paper Ball with a Rock

Setup: Take out a third piece of paper and wrap it around a rock while balling it up. Now drop the two balled-up pieces of paper at the same time – the one with the rock hits the ground first.

Discussion: This is because the weight of the one with larger mass (the paper ball with the rock inside) is stronger, meaning that the terminal velocity of that paper ball is larger.

Concept 2: Weight and Thrust

The thrust exhibited by the propellers on the seaperch acts differently than weight. If you add more **mass** to the Seaperch, then the acceleration of the Seaperch is smaller, meaning that it takes longer for it to reach its terminal velocity (note, however, that the terminal velocity doesn't change).

Thought Experiment:

Imagine you are pulling your friend through the snow on a sled. You are providing the thrust by tugging on the rope so you can get the sled to reach the desired velocity (normal walking speed). It's a lot harder to pull the sled up to your normal walking speed when your friend is in it compared to when he/she is not. However, you will eventually get to the walking speed; it just takes longer.

Classroom Demonstration 4: Density of Water vs. Air

Setup: Blow up one balloon with air, fill up a different balloon with water, making sure that the sizes of the two blown-up balloons are approximately the same. Do not tie off the opening of the balloons but pinch them shut with your thumb and finger. Place a paperclip in a Tupperware tray on the table. Place the opening of the balloon filled with air near the paperclip, release the opening of the balloon, and see if you can get the paperclip to move using the air from the balloon. Then do the same thing with the balloon filled with water.

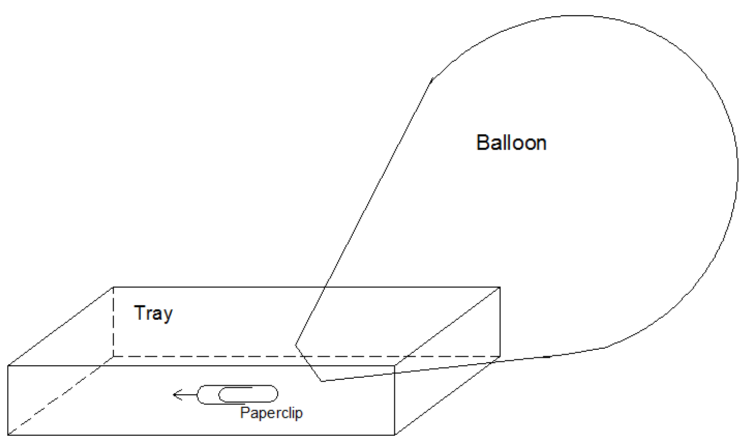


Figure 1. Demonstration to show the effect of density on drag force.

Discussion: You will see that the balloon filled with water has a much higher **density** than the balloon filled with air. In the Fluid Dynamics I Module, we discussed that thrust by a propeller increased with the density of the fluid it was operating in. The same applies to drag. The water has a much higher density than air, so the drag created by the water hitting the paperclip produced a much larger force than the air.

Lesson 8: Fluid Dynamics, Drag

Activity: Propeller In Water and Effect of Shape on Drag

Materials:

Activity # 1		
Item	**Quantity**	**Purchase Location Suggestion**
Balsa Wood Rubber Band Airplanes	1 per group	www.Guillow.com - Any rubber band powered airplane model
Round Plastic Containers	1	- At least 8in in diameter and 9 in deep
Activity # 2		
Item	**Quantity**	**Purchase Location Suggestion**
Computer Paper	4-6 sheets per group	
Stopwatch	1 per group	

Activity # 1 – Effect of Density on Drag

Background:

In this activity students will be observing a change in propeller speed in different mediums. The students will try to predict what will occur.

Procedure:

1. Attach the propeller to the front of the balsa wood frame
2. Connect the rubber band to the frame
3. Fill the container with water
4. Students should test the plane in both the water and in air with the same number of winds of the propeller.

Activity # 2 – Effect of Shape Geometry on Drag

Background:

In this activity students will be observing a change in the terminal velocity of a piece of paper based on the shape the paper. The students will try to predict and come up with the most efficient shape.

Procedure:

1. Have the students come up with and fold at least 4 different shapes out of paper
2. Drop the different shapes from a fairly high point (always drop from the same spot) and time the fall with a stopwatch.

Lesson 8: Fluid Dynamics, Drag

Student Worksheet

Pre-Lesson Questions

Answer the following questions to prepare for your introduction to drag.

1. Why do we need to worry about drag when we already have tried to improve thrust?

____

____

____

2. Why are race cars more curved looking than buses?

____

____

____

3. Why do you think it's hard to walk against a strong wind?

____

____

____

Activity # 1 Hypothesis

What do you think will happen to the speed of the propeller when it is placed in water?

____

____

____

Post - Activity # 1 Questions

Did the propeller act differently in the air verses in the water?

____

____

____

How do you think the propeller would behave if it was dipped in a tub of molasses?

____

____

____

Activity # 2 – Hypothesis

What type of shape do you think will minimize the drag the best?

____

____

____

Post - Activity # 2 – Questions

In the table draw or write the shape being tested and record the time it takes to reach the ground.

1.	2.
Time:	Time:
3.	4.
Time:	Time:

5.	6.
Time:	Time:

Which shape had the shortest time? Which shape had the longest time?

____

____

____

Was your prediction correct? If not why do you think you were incorrect?

____

____

____

Lesson 8: Fluid Dynamics, Drag

Glossary

- **Acceleration:** an increase in rate of change; increasing velocity

- **Density:** the mass of a substance per unit volume; the distribution of a quantity (as mass, electricity, or energy) per unit usually of space

- **Drag:** something that slows down motion, action, or advancement

- **Dynamics:** a branch of mechanics that deals with forces and their relation primarily to motion but sometimes also to the equilibrium of bodies

- **Force:** strength or energy exerted or brought to bear; cause of motion or change

- **Gravity:** the gravitational attraction of the mass of the earth, the moon, or a planet for bodies at or near its surface; a fundamental physical force that is responsible for interactions which occur because of mass between particles, between aggregations of matter (as stars and planets), and between particles (as photons) and aggregations of matter, that is 10-39 times the strength of the strong force, and that extends over infinite distances but is dominant over macroscopic distances especially between aggregations of matter

- **Mass:** the property of a body that is a measure of its inertia and that is commonly taken as a measure of the amount of material it contains and causes it to have weight in a gravitational field

- **Terminal Velocity:** the speed at which drag matches the pull of gravity resulting in a constant fall rate

- **Thrust:** the force produced by a propeller or by a jet or rocket engine that drives a vehicle forward

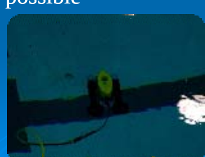
- **Weight:** the force with which a body is attracted toward the earth or a celestial body by gravitation and which is equal to the produce of the mass and the local gravitational acceleration

Fluid Dynamics: Drag

Lesson 8

Thrust vs. Drag: Review

- Thrust: moves the Sea Perch forward
- Drag: acts against the forward motion
- Terminal Velocity: occurs when Thrust = Drag
- When the Sea Perch reaches terminal velocity it is going as fast as possible



How Do You Increase Terminal Velocity?

1. Find a way to increase thrust
2. Find a way to reduce drag

- 3 Motors and 3 Propellers
  - Limit ability to increase thrust
  - Any modifications result in a very small change in overall performance

ANSWER: Reduce Drag

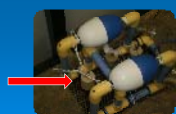
Mass: How it affects Terminal Velocity

- As weight goes up it makes forward acceleration more difficult
- Takes longer to reach terminal velocity
- Terminal velocity does not change

More Difficult to Reach Walking Speed

Easier to Reach Walking Speed

Adding Weight to Sea Perch



How Do Engineers Examine Drag?

- Bulk Drag Test: overall measure of drag on Sea Perch
- Detailed Drag Test: examines spots along Sea Perch that influence drag most

Streamlines over cars

- Streamlines: trails of bubbles (water) or smoke (air) that indicate the amount of drag over an object
  - Should be smooth and sleek
  - Severely distorted lines indicate large amounts of drag

Lesson 9: Motors

Introduction

Lesson Outline

- Theory-Motors
  - Motors Pre-Lesson Discussion
    - Motors Power Point Slides 1-5
  - Concept 1: Converting Electricity to Mechanical Motion
    - Motors PowerPoint Slides 5-10
- Activity 1- Motors
- Theory- Motors
  - Concept 2: Inside a Motor
    - Motors PowerPoint Slides 10-13
- Activity 2- Motors
- Glossary

Learning Objectives

- Develop an understanding of magnetic fields
- Understand how electricity can be converted to mechanical motion
- Explain the basic components of a motors

National Science Standards

- Physical Science- Motions and Forces:
  - 12BPS4.3
  - 12BPS4.4
  - 12BPS4.5

Alignment with Sea Perch Construction

- Motors are introduced in Build Unit 1

Interesting Websites

History of Motors: http://www.solarbotics.net/starting/200111_dcmotor/200111_dcmotor.html

Lesson 9: Motors

Theory

Motors Pre-Lesson Class Discussion

Thought Exercise:

What is a motor? –

A motor is any device that converts any type of energy to mechanical motion. This is a very broad definition that takes any energy (electrical, chemical, heat, etc) and turns it into motion.

The motors that we most commonly deal with are electric motors. An electric motor is an electromechanical (implies electrical and mechanical) device that converts electricity into mechanical motion (most commonly rotational motion, but there are linear motors too.)

What are motors used for? – Compile a list of objects that use motors – it is very easy to find more than 20, just look around the classroom. For example: computers (hard drives, disk drives, fans), DVD players, VCRs, Air conditioners, etc.

The purpose of this discussion is to determine the student's knowledge of motors.

Concept 1: Converting Electricity to Mechanical Motion

This concept provides an introduction to the basics behind what make motors work, specifically, the idea that a force is felt on an electrical current flowing through a conductor (e.g. copper wire) in a magnetic field.

Concept 1.1 – Magnets

Magnets are named for a region in Asia Minor known as Magnesia where rocks were found that attracted each other. One of the earlier uses of magnets was in China in the early 11th century in compasses – the needle is a magnet that points towards the North Pole.

Magnets attract certain metals (iron, nickel, cobalt). This magnetic effect comes from a special alignment of the atomic structure of the material.

All magnets have two poles, a north pole and a south pole – note: it is impossible to have a singular magnetic pole, they always come in pairs. North poles attract south poles and repel north poles. Conversely south poles attract north poles and repel south poles.

Magnets are a necessary component in motors. The magnetic field *B* goes from north to south (see figure 1). The way to test a magnetic field is to place a compass near a magnet, and the needle will align itself with the magnet field, with the north needle pointing toward the south pole (remember south poles attract north poles).

Concept 1.2 – Mechanical motion from electricity

Hans Christian Oersted discovered the relationship between mechanical force, magnetism, and electricity through a series of experiments in the early 1800's. This was followed up by work from Maxwell, Faraday, and Lorentz (whom a more generalized form of the relationship between motion and electricity is named after).

When a wire that is conducting current is placed in a magnetic field, a force is induced on the conductor (this is the basis for the electric motor).

The force is given by the equation:

$$F = iL \times B$$

where *F* is force, *B* is the magnetic field strength and *L* is the length of the conductor and *i* is the current. The *x* denotes the cross product, which is a vector operator. This is visualized in figure 1 below.

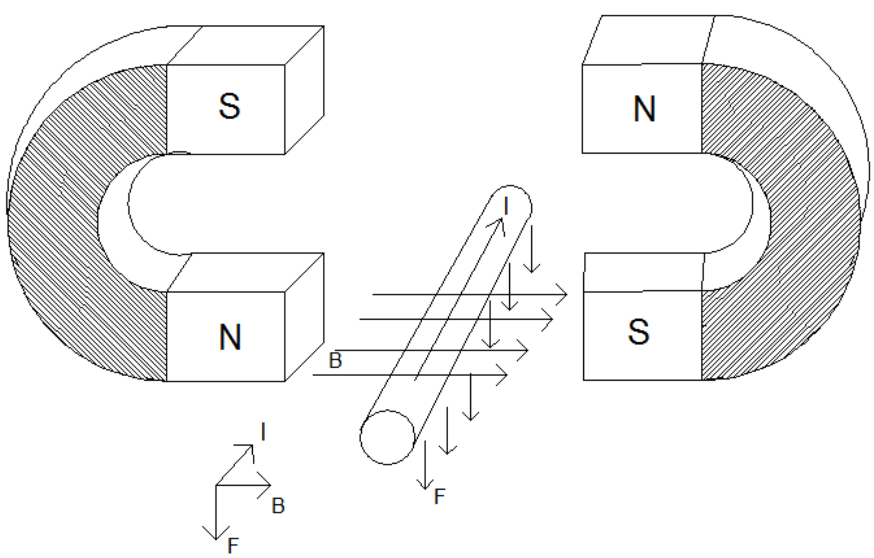


Figure 1: A schematic diagram of a current carrying wire in a magnetic field.

The cross product x – The cross product *x* takes two vectors *B* and *iL* and produces a third vector *F* that has magnitude $BiL\sin(\theta)$, where θ is the angle between the two vectors. For our purposes, we will consider only vectors that are at right angles to each other so that the size of the force is $F = iLB$. Note that vectors are defined as having both a magnitude and direction.

The right hand rule – In order to find the direction of the force on the wire *F*, we use the right hand rule. To do this, we point our hand with an open palm (like you are shaking someone's hand) in the direction of the first vector in the cross product *iL* (shown as just i in figure 1.) Then you close your fingers in the direction of the second vector *B*. The direction your thumb is pointing is the direction of the resulting *F*. Try this with figure 1.

Summary

Electricity can be turned in to mechanical force by placing a current carrying wire in a magnetic field. This yields a force:

$$F = iL \times B$$

which has magnitude *iLB* (provided the forces are at right angles) and direction from the right hand rule. The take away message is that an increase in current *i*, length *L*, or magnetic field force *B* will result in a larger force *F*. These are the variable we can change as design engineering – note, they are not entirely independent, i.e. *L* and *i* are related.

Concept 2: Inside a Motor

Concept 2.1 – Conducting loops in magnetic fields

The force on a current *i* in a magnetic field can be turned into a torque (like a force, but causes rotation instead of linear motion) by running current through a loop of wire in a magnetic field, as in Figure 2.

The current runs around the loop, so the current is in one direction on one side of the loop and in the other direction on the other side. This creates a pair of forces (*F* in figure 2) in different direction. This causes a torque around the center axis of the loop (shown as a dotted line).

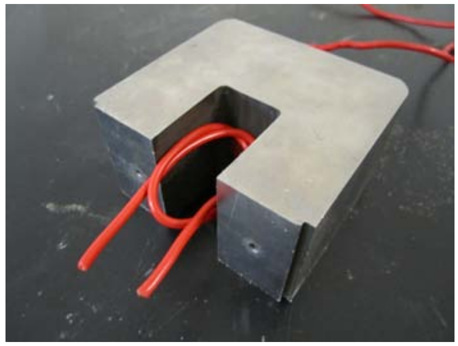


Figure 2: Schematic diagram of a coil of wire conduction current in a magnetic field

Problem with the above set up – Without any changes, the coil will move, but it won't spin (like a motor should.) As shown in figure 3, the forces on the coil will just cause the coil to align with the magnets.

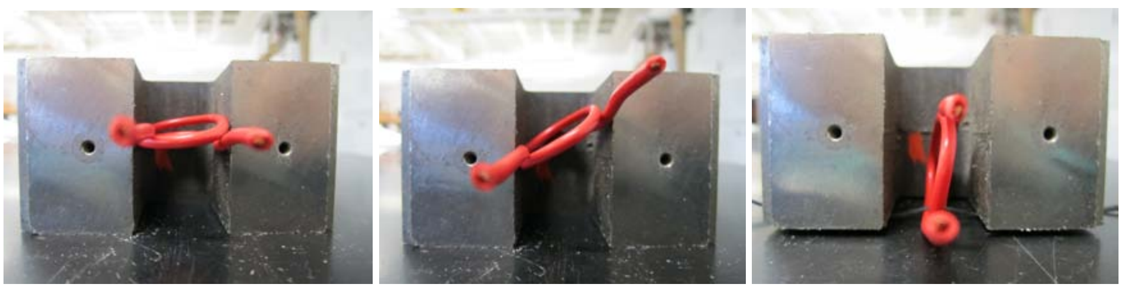


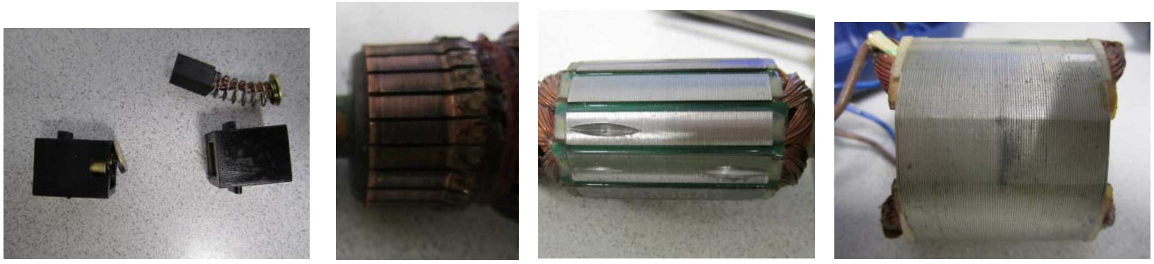
Figure 3: Schematic diagram showing the difficulty with a coil in a magnetic field.

Thought Exercise:

What can we do to make the coil spin?- Have the students try to determine different ways to make the motor spin knowing how the force is generated from the magnetic field.

Concept 2.2 – How does a motor work?

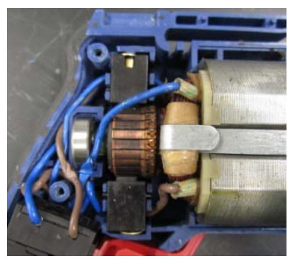
There are a few different ways to make the coil spin, but the most common is to add physical components to make the current change direction – remember, this will change the direction of the force (see right hand rule above). These components are shown schematically in figure 4.



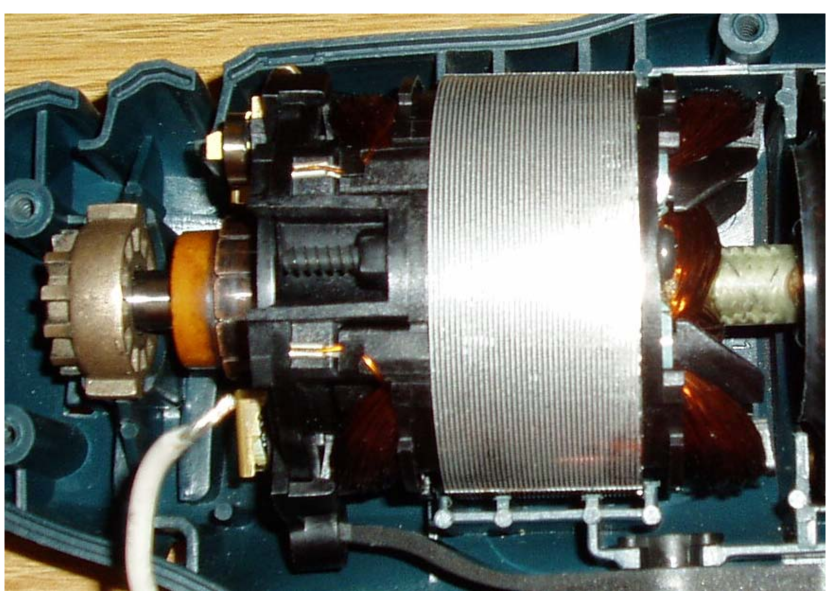
Brushes Commutator Coil Magnet

Figure 4: Internal parts of a motor

In order to switch the direction of the current, the electrical connection is switched using brushes and a commutator. The commutator is attached to the coil so it spins when the coil spins. The brushes are attached to the power source and do not move. As the commutator spins, the brushes automatically change the connection direction, thus switching the current direction.



Amplifying the rotation effect – Just like before, the torque increases as the number of wires in the coil increases. In addition, there are typically multiple motor coils, oriented in different directions, connected to different commutator connections. This helps keep the torque on the coil constant.



Lesson 9: Motors

Activity #1: Building An Electromechanical Actuator

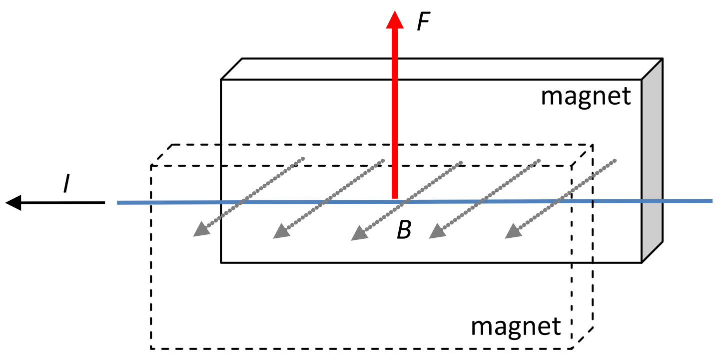
Materials:

Item	Quantity	Purchase Location Suggestion
Copper Wire	6ft	Radio Shack: 45-Ft. UL-Recognized Hookup Wire (18AWG) Model: 278-1223 | Catalog #: 278-1223
Magnets	2	Radio Shack: High-Energy Ceramic Magnet Model: 64-1877 | Catalog #: 64-1877
Rubber Bands	5	
Digital Multimeter	1	Radio Shack
Textbooks	5	
Battery Pack-6V	1	
Alligator Test Clips	4	Sea Perch Kit
Simpson Strong Tie	1	Home Depot
Electrical Tape	1 Roll	Sea Perch Kit
Soda Bottle	20oz	
PVC Pipe- ¾ in.	3-9in 2-1ft	
PVC-Elbows ¾ in.	2	
PVC- Tee ¾ in.	2	

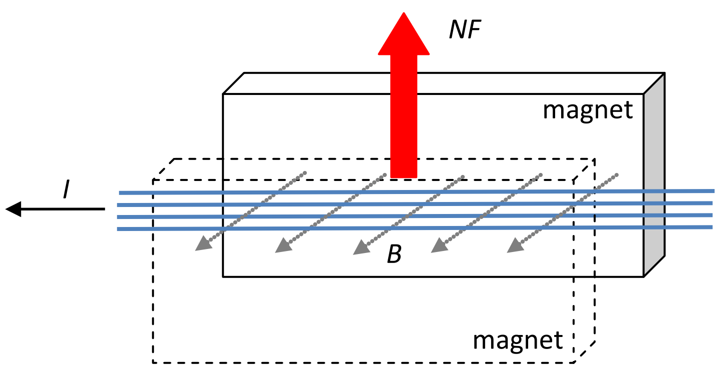
Background:

It is important to first understand the concept that if a current is run through a wire in a magnetic field, a force is felt on the wire. This equation is $F = iL \times B$.

Design Question: How can we amplify this force? – This force is relatively small. To amplify this, we will use multiple lengths of wire running through the magnetic field (shown in figure 1) giving the amplified force, $NF = NiL \times B$, where N is the number of wires – this is N times the original force. The force can also be amplified by designing a structure sensitive to this force (i.e. a flexible beam or a very soft spring.)



(a)



(b)

Figure 1: Illustration showing the force induced on a wire with current running through it for (a) one wire and (b) multiple (N) wires – the force

Design question – How can multiple lengths of wire be put in a magnetic field and still have the current flowing in the same direction? Two possible configurations are shown in figure 2.

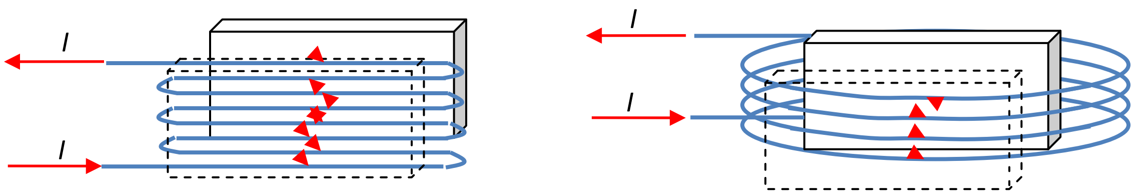
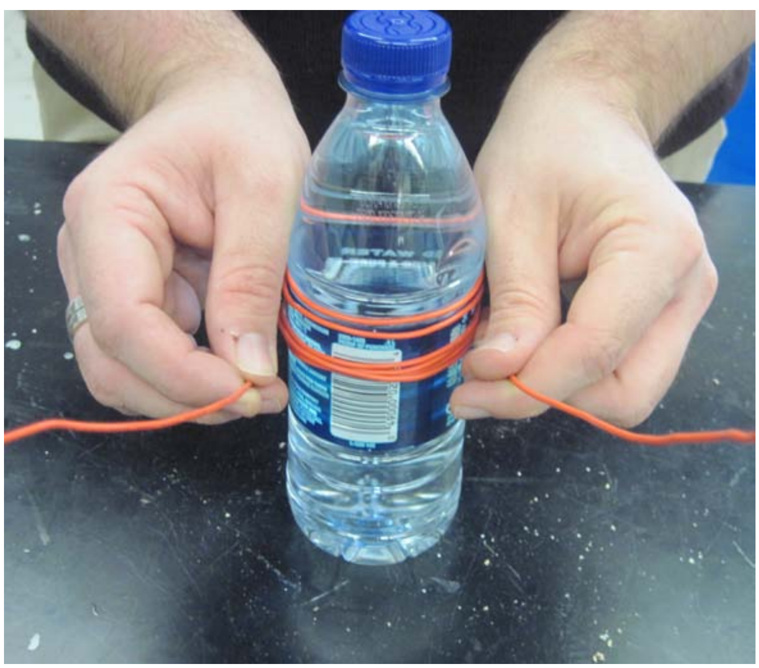


Figure 2: Two possible wire configurations. The current direction is shown as a red arrow.

Procedure:

1. Coil

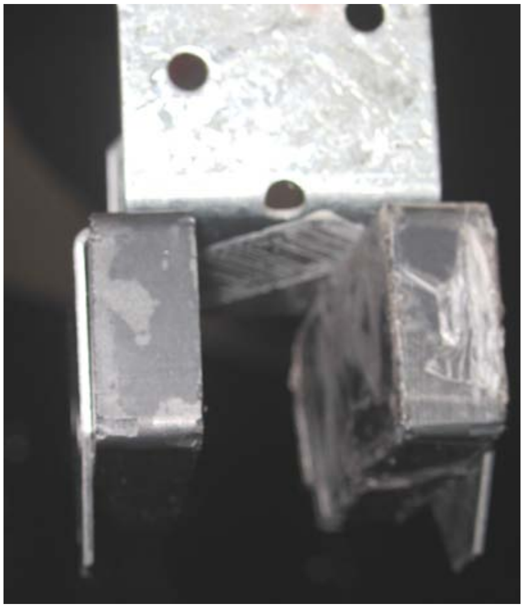
- Wrap the copper wire around a soda bottle multiple times. The more times you wrap the coil (N) the stronger the force.

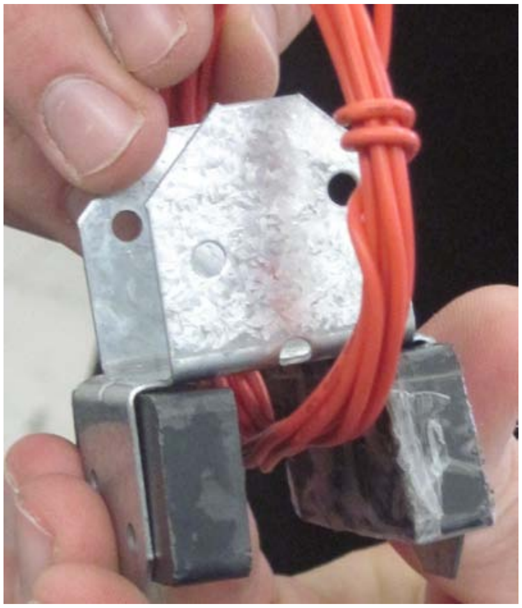


- Tie off the coil so that that it will not unwind but be sure to leave at least two feet of wire on each end.

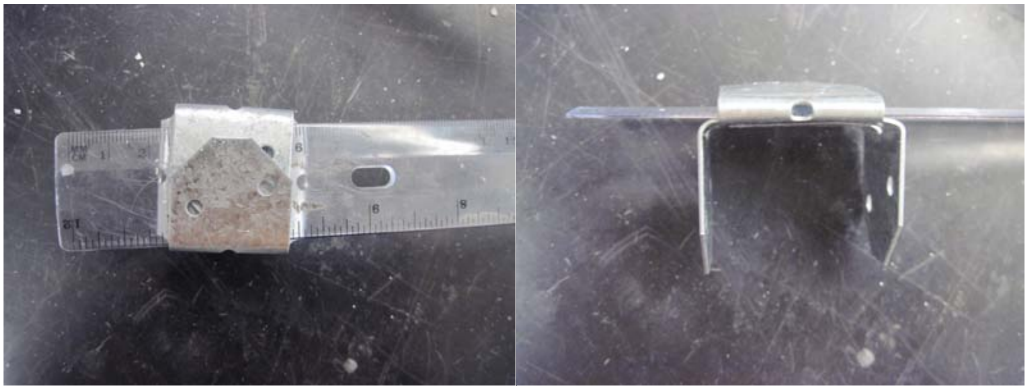
2. Magnet Assembly

- The magnets need to be mounted so they are attracting each other.
- They must also be far enough away so the coil will fit between them.
- Using the Simpson Strong Tie place two magnets on either side.



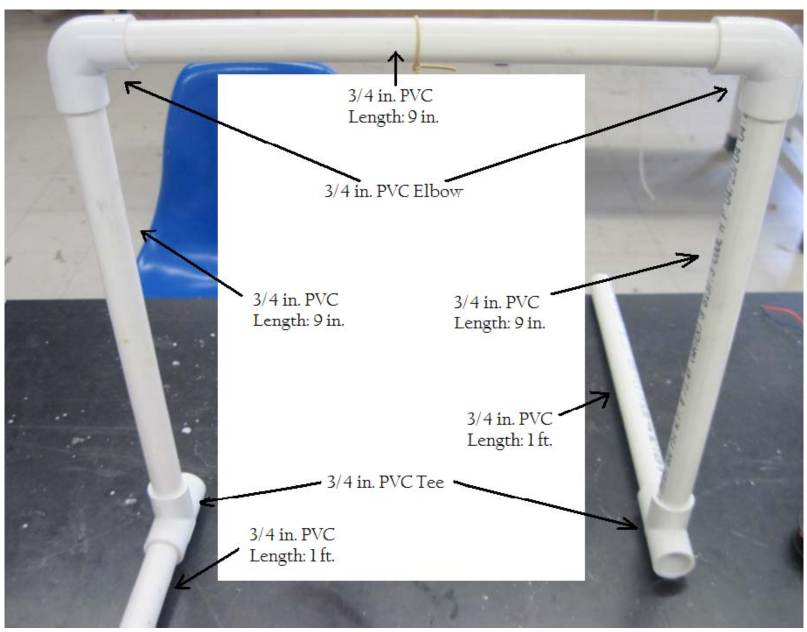


- Attach a stiff ruler to the strong tie
- Bend the top portion of the strong tie down to create a small opening for the ruler to slide through.



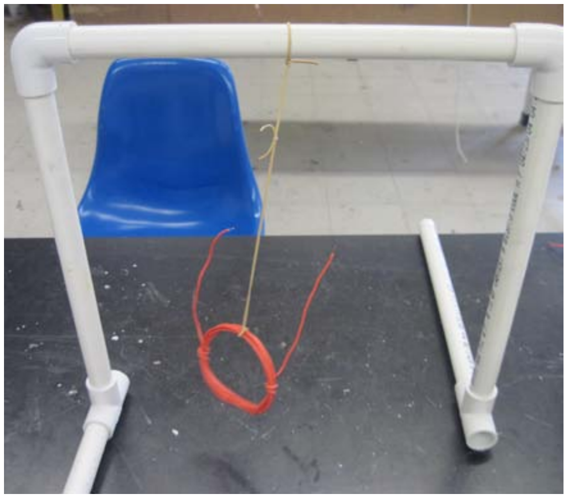
3. Support Structure

- A simple support structure can be built out of PVC.
- Build the structure according to the picture and measurements.

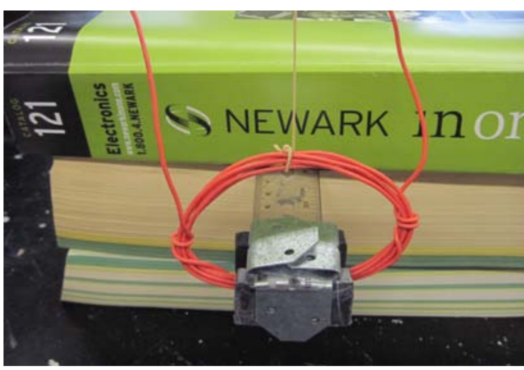


4. Actuator

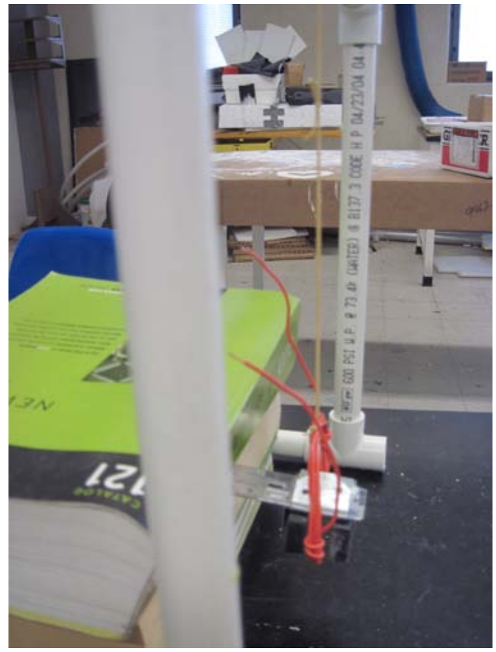
- It is now time to build the actuator using the support structure, magnet holder and coil.
- Cut and tie together two large rubber bands. Attach one end to the middle of the support structure and the other end to the wire loop. The wire loop should hang at least 4 inches off the table.



- Collect 3-4 large textbooks and place them in a stack next to the support structure
- Slide the ruler below the highest book in the stack.



- Loop the two feet of wire over the top of the support structure.
- Attach an alligator clip to each side of the wire
- Connect the alligator clips to the battery pack
- Watch the coil move up and down



Variations:

- Flip the ruler so the magnets are facing up. How does the coil behave differently?
- Vary the number of winds in the coil. How high does the coil jump?

Lesson 9: Motors

Activity #2: Building a Simple Motor

Materials:

Item	Quantity	Purchase Location Suggestion
Battery	1	Sea Perch Kit
Drinking Straw	1	
Erasers	2	
Film Canister	1	
Insulated Copper Wire	1	Radio Shack: 315-Ft. Magnet Wire Set Model: 278-1345 Catalog #: 278-1345
Magnets	2	Radio Shack: High-Energy Ceramic Magnet Model: 64-1877 | Catalog #: 64-1877
Multimeter	1	
Paper Clips- Metal, Large	6	
Rubber Bands	10	

Background:

This is designed as a multi group project where each group constructs a subsystem for the motor. The subsystems are as follows:

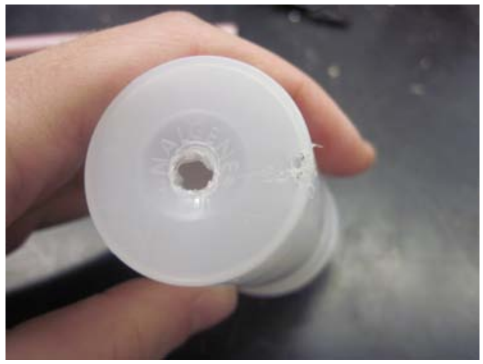
A) Rotor - motor coil
B) Bearings, commutator, and battery hook-ups
C) Stator - magnet holder

The details of the construction of each of these subsections are given in the procedure.

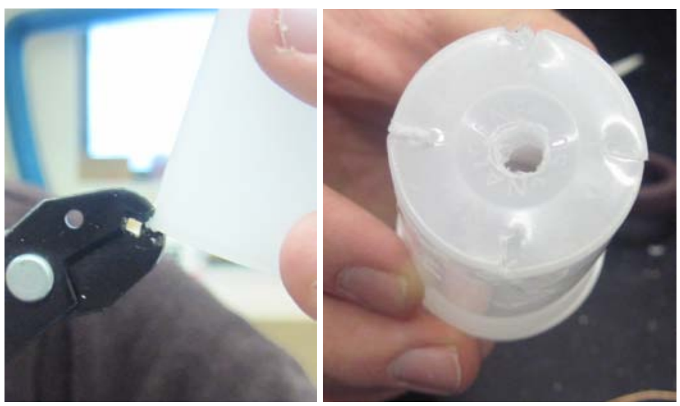
Procedure:

A) Building the Rotor (Motor Coil)

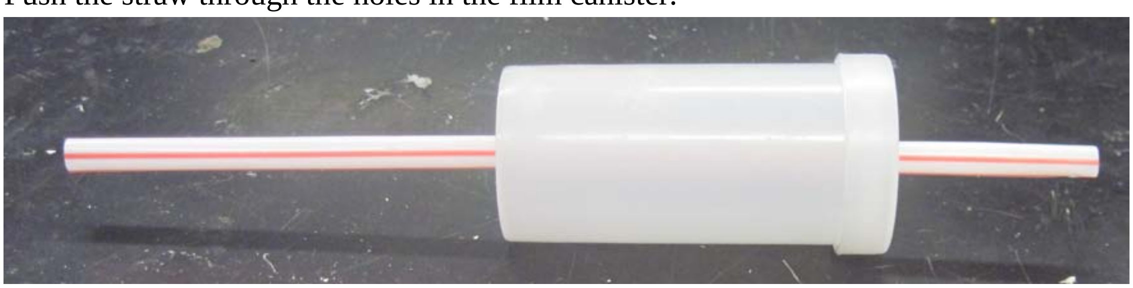
1) Take the film canister and put a hole in either end that has a diameter just smaller that the diameter of the straw. (Use ¼ in drill bit and widen if necessary)



2) Put four notches in the top and bottom of the film canister with the wire strippers – the notches should be 90 degrees apart. Make sure the notches are clear of plastic debris.

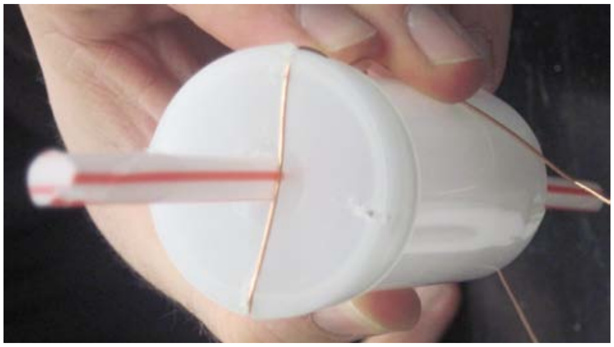


3) Push the straw through the holes in the film canister.

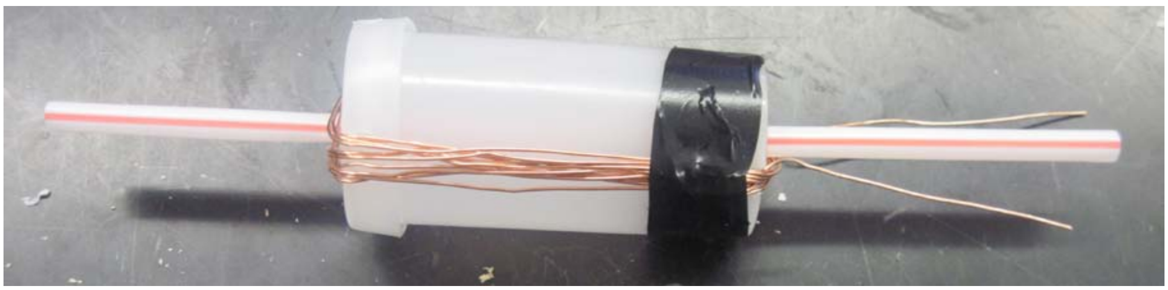


4) Strip 2 inches of insulation from one end of the wire. Make sure to sand off the plastic coating if using coated wire. You can check for a connection by attaching the multimeter to each end of the wire strip and making sure there is resistance.

5) Wrap the wire around the canister using opposite notches – the number of wraps will determine the torque on the motor. You will need at least 10 wraps.

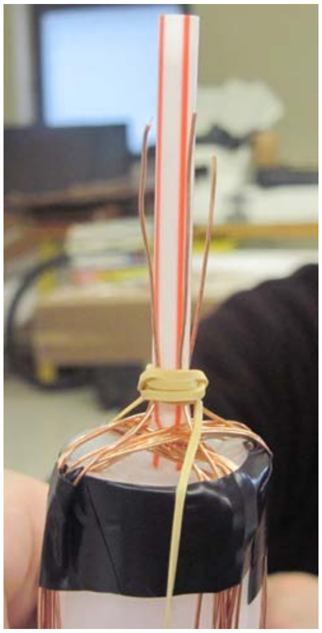


6) When you have enough wraps, cut the wire about 2 inches longer than you need. Strip the last inch of shielding off the end of the wire. Tape the ends down near the notches with electrical tape.

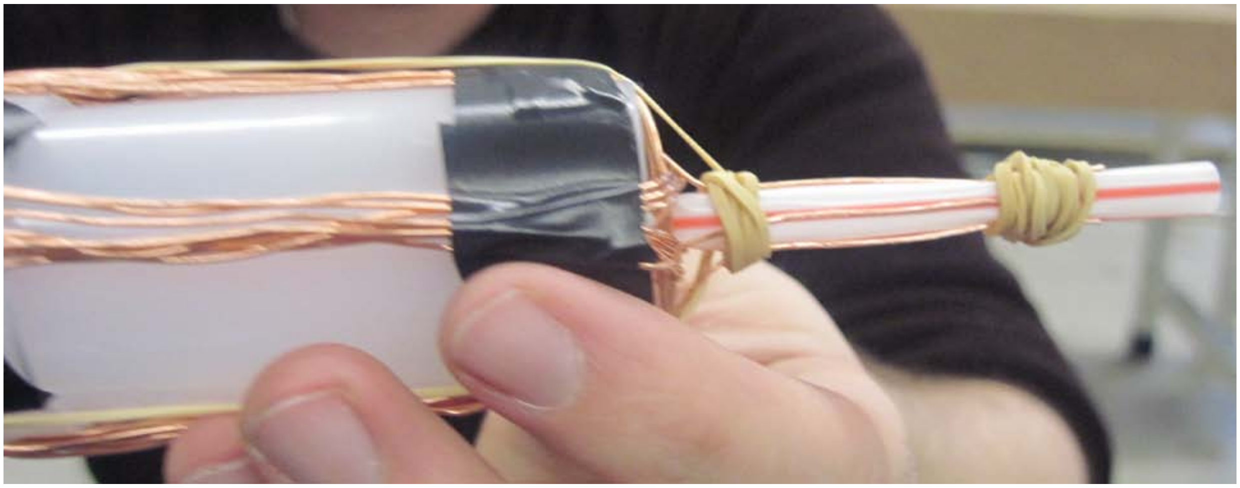


7) Repeat steps 4-6 for the other set of notches.

8) Use a rubber band to hold the exposed wire to the straw. The wires should line up with their respective coils.
9) Trim off the ends of the coils so that there is a ½ inch clearance from the end of the straw.



10) Use another rubber band to secure the end of the wires to the straw

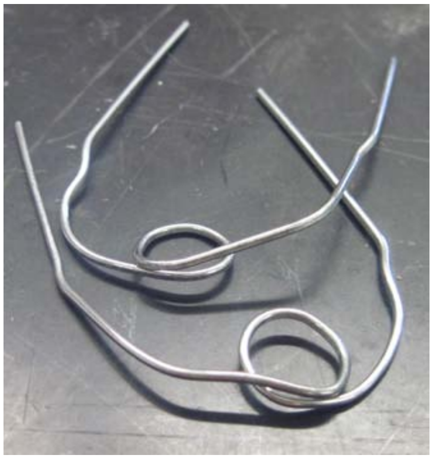


11) Test the wires to determine which strips are connected to one another. You can use the multimeter to check for the resistance.

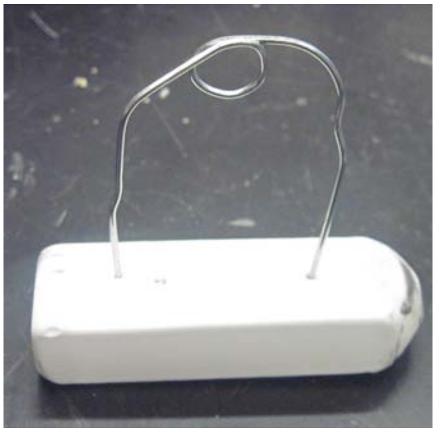
B) Building the bearings, commutator, and battery hook ups.

1) Take the paper clips and stretch them out so they are straight.

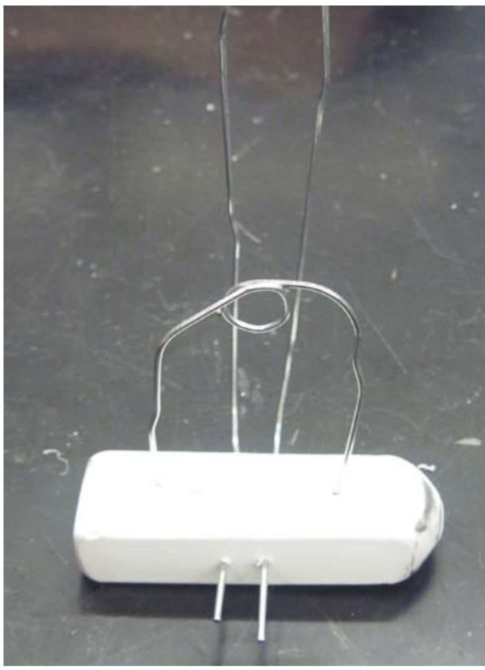
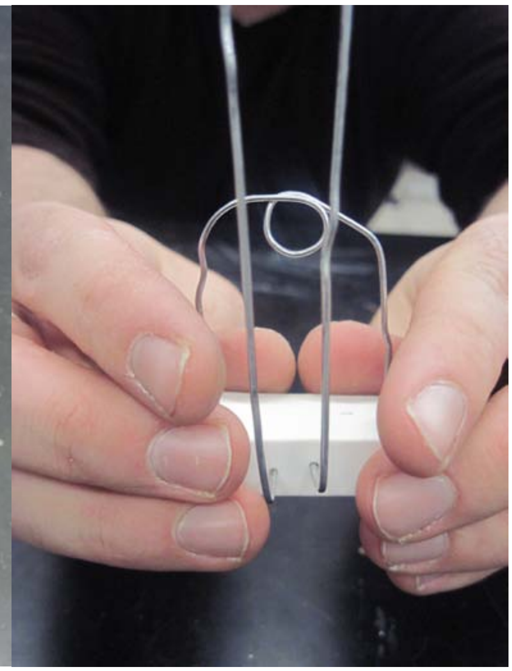
2) Bend two paper clips to form the bearings (supports) for the motor. Feel free to use your imagination in the design. The two paper clips should be identical.



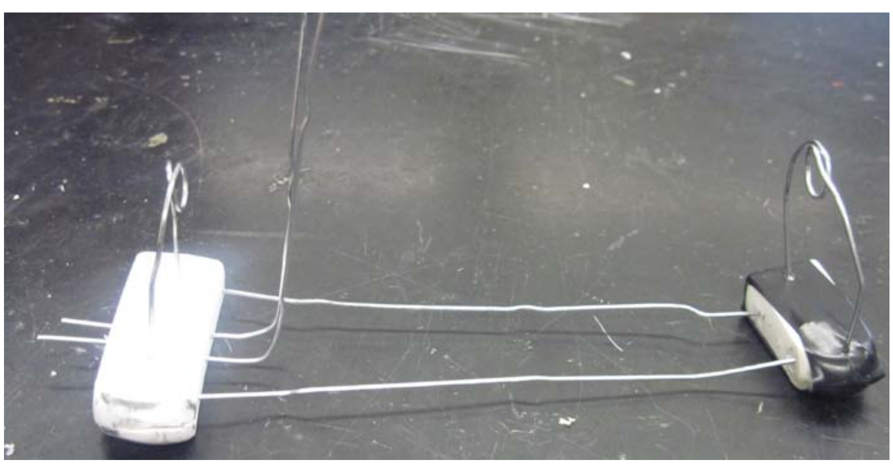
3) Push the ends of the paper clip bearings into the erasers.



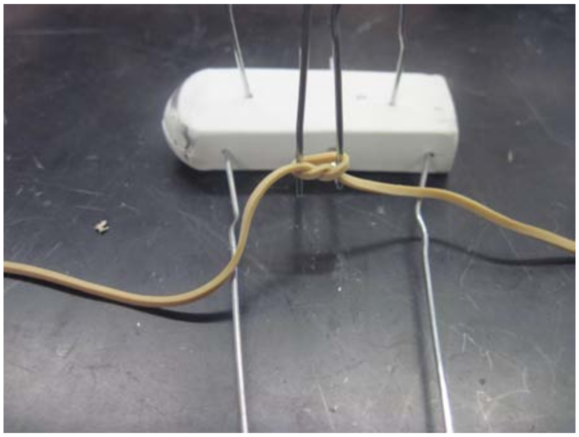
4) The last two paper clips will be the battery hookups and commutator. Bend the two paper clips to form an “L.” The lower part of the “L” should be about 1.5 times the width of the erasers.
5) Push both “L” paper clips through the same eraser so that the long part of the “L” sticks up next to the bearing. There should be a small a separation between the two paper clips a little larger than the diameter of the straw. The paper clips should go all the way through the eraser, so there is exposed metal poking through the other side of the eraser.

6) Use two other paper clips to attach the sides of the two erasers – the distance between the two erasers should be less than the length of the straw.



7) Finally, take a rubber band, cut it, and tie it around the two paper clips – you will adjust how tight the rubber band is when the rotor is added.



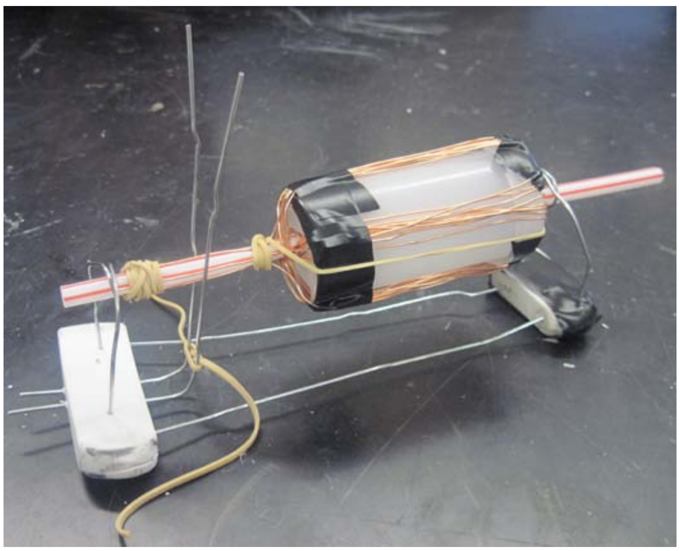
C) Building the Stator (Magnet Holder)

Depending on the magnet holder you are using, this may or may not be needed. You can hold the magnets or design

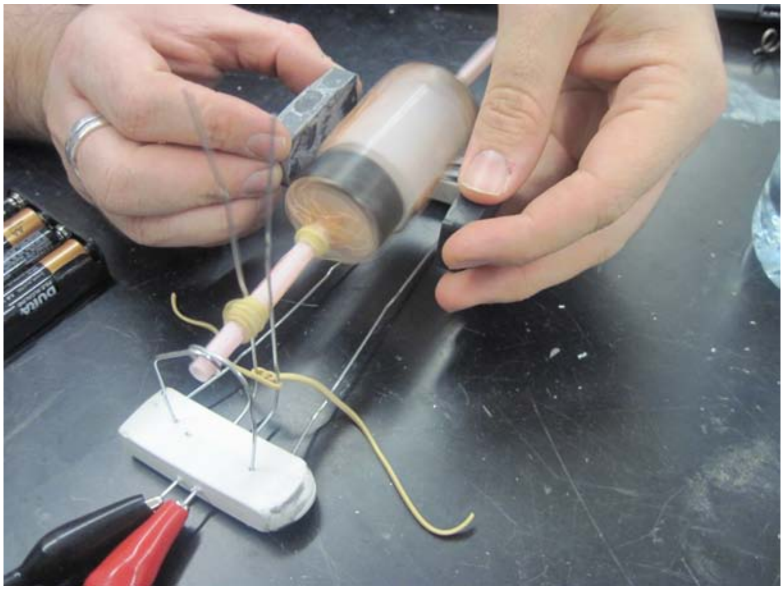
1) The goal is to design a structure to hold the magnets.
2) The magnets need to be held on either side of the rotor, perpendicular to the ground.

Motor Assembly

1) Insert the rotor through the holes in the paperclips
2) Tighten the rubber band until the straightened paperclips make contact with the shaft of the rotor.



3) Test by spinning the shaft to make sure it is not sticking at any point
4) Attach alligator clips to either end of two pieces of wire. Connect one end of the wires to the battery pack terminals and the other end to the terminals on the side of the motor.
5) Place the stator around the rotor.
6) The motor should spin!!!



Variations:

- Pull the magnets away from the device to vary the magnetic field. How does the motor behave differently?
- Switch the alligator clips on the battery terminals. Does the motor change directions? You can make the motor go different directions by changing the polarity of the battery
- Test the resistance at different points on the motor

Lesson 9: Motors

Glossary

- **Actuator:** mechanical device for moving or controlling a mechanism; a device to take an electrical signal and convert it to a physical action

- **Bearings:** A mechanical device that supports another part and/or reduces friction

- **Commutator:** a series of bars or segments so connected to armature coils of a generator or motor that rotation of the armature will in conjunction with fixed brushes result in unidirectional current output in the case of a generator and in the reversal of the current into the coils in the case of a motor

- **Coil:** a number of turns of wire wound around a core to create a magnetic field for an electromagnet or an induction coil

- **Current:** a flow of electric charge

- **Force:** strength or energy exerted or brought to bear; cause of motion or change

- **Magnetic Field:** the portion of space near a magnetic body or a current-carrying body in which the magnetic forces due to the body or current can be detected

- **Motor:** a rotating machine that transforms electrical energy into mechanical energy

- **Multimeter:** an instrument for measuring the properties of an electrical circuit, such as resistance, voltage, or current

- **Resistance:** the opposition offered by a body or substance to the passage through it of a steady electric current

- **Rotor:** the rotating armature of a motor or generator

- **Stator:** the fixed part of an AC motor, consisting of copper windings with steel laminations

- **Torque:** a force that produces or tends to produce rotation or torsion; a turning or twisting force

- **Vector:** a straight line segment whose length is magnitude and whose orientation in space is direction

Motors

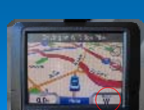
Lesson 9

Thinking About Motors

- What is a motor?
  - Device that converts energy into mechanical motion
- What are motors used for?
  - Hard drives, disk drives, fans, DVD players etc..
- How do motors work?

Magnets- Necessary Component of Motors

- History
  - Named for a region in Asia Minor called Magnesia
  - Magnesia was the first location magnetic rocks were found
- Earliest Uses- 11th Century China
  - Compass needles
  - Needle is made of a magnet that points towards the north pole



How Magnets Work

- Magnets Attract
  - Metals: iron, nickel cobalt
- Why?
  - Alignment of atomic structure of material

Magnetic Poles

- Magnets have two poles
  - North pole- attracts south pole, repels north
  - South pole- attracts north pole, repels south
- Easy way to determine north vs. south pole
  - Hold a compass next to a magnet
  - The compass needle will point to the south pole

Mechanical Motion from Electricity

- Hans Christian Oersted
  - Discovered relationship in 1800's between:
    - Mechanical Force
    - Magnetism
    - Electricity
  - Followed up by Maxwell, Farady and Lorentz

Mechanical Motion from Electricity

- Basis for Electric Motor
  - A wire conducting current will experience a force when it is placed in a magnetic field

$$F = iL \times B$$

  - F (Force)
  - i (Current)
  - L (Length of Conductor)
  - x (Cross Product)
  - B (Magnetic Field Strength)

Mechanical Motion from Electricity

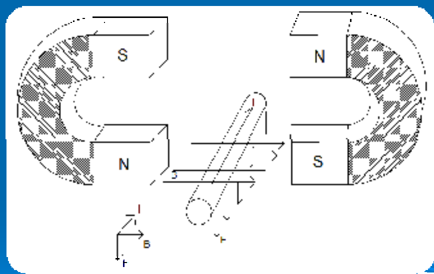
- Vectors
  - Vectors represent a quantity with a size and direction
- According to the formula:
  - The force is a cross product of the vectors B and iL
  - Cross Product: takes two vectors B and iL and produces a third: BiLsin(Θ)
  - We will only consider vectors at right angles: F= iLB

Mechanical Motion from Electricity

Right Hand Rule

- Used to find the direction of the force on the wire
- Point hand with open palm in direction of first vector in the cross product (iL)
- Close fingers in the direction of second vector (B)
- Your thumb is now pointing in direction of F

Practice the Right Hand Rule!!!



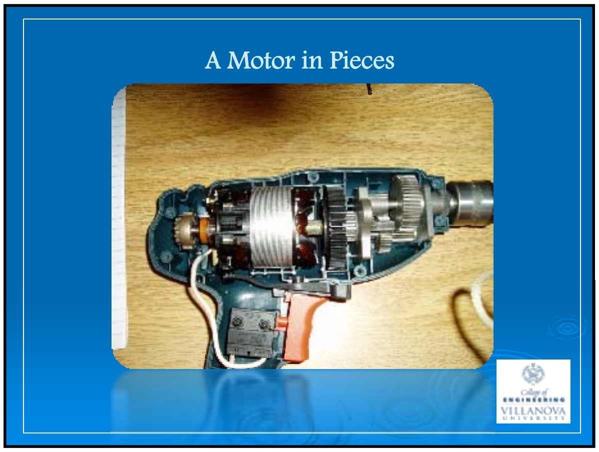
Inside a Motor

- Force on current (i) in a magnetic field can be turned into torque
  - Simple: run current through a loop of wire in a magnetic field
  - Current switches direction based on what side of the loop it is on
  - Results in a pair of forces which cause torque
  - The loop will align with the magnets but will not spin

How Does a Motor Spin?

- Add physical components to make current change direction
  - Brushes: attached to power source, do not move
  - Commutator: attached to the coil , spins with coil
- When commutator spins , brushes change direction which results in current switching direction
- The torque will increase with more coils




A Motor in Pieces
VILLANOVA

Lesson 10: Circuits and Wiring

Introduction

Lesson Outline

- Theory-Circuits and Wiring
  - Basic Electrical Concepts
    - Circuits and Wiring PowerPoint Slides 1-6
- Experiments- Circuits and Wiring
  - Experiment 1
- Theory-Circuits and Wiring
  - Concept 1: Understanding Circuit Diagrams
    - Circuits and Wiring PowerPoint Slides 7-10
- Experiments- Circuits and Wiring
  - Experiment 2
- Theory-Circuits and Wiring
  - Concept 2: Motor Circuits
    - Circuits and Wiring PowerPoint Slides 11-12
- Experiments- Circuits and Wiring
  - Experiment 3
  - Experiment 3
- Glossary

Learning Objectives

- Understand the foundations of electricity
- Be able to construct basic circuit diagrams
- Understand how motors can be affected by different circuit constructions

National Science Standards

- Science as Inquiry
  - 12ASI1.2
  - 12ASI1.3
- Physical Science- Motions and Forces:
  - 12BPS4.3
  - 12BPS4.4
  - 12BPS4.5

Alignment with Sea Perch Construction

- Circuits and Wiring is introduced in Build Unit 3

Interesting Websites

Different circuit symbols used by engineers:

http://library.thinkquest.org/10784/circuit_symbols.html

Lesson 10: Circuits and Wiring

Theory

Basic Electrical Concepts

Voltage, Current, and Resistance

There are three main electrical quantities that are very important in circuits.

> **Voltage** (*V*, measured in volts): A difference in electrical potential that is used to drive electrons around circuits.
>
> **Current** (*i*, measured in Amperes or Amps): The measure of electron flow around a circuit.
>
> **Resistance** (*R*, measured in Ohms): This is how difficult it is for an electron to flow through a material. It measures how a material *resists* the movement of electrons.

The three electrical quantities above are related using Ohm's law:

$$V = i*R$$

Current flowing through circuits

Current can only flow if it has a path to a lower voltage. When a path exists, this is called a closed circuit, when a path doesn't exist; this is called an open circuit. This is important when designing and constructing circuits (for example running a motor.) If the circuit is open, no current will flow, so the motor won't spin. It is also possible to use this concept to your advantage by putting buttons or switches in a circuit to allow the operator to open and close the circuit.

How do batteries work?

Batteries are an important component in any electrical (or electro-mechanical) system. They supply a portable source of voltage and current. Simply put, batteries are a container with chemicals inside that produce electrons. These electrons are then drawn to an electrode inside the battery. When a circuit is connected between the plus (+) and minus (-) ends of the battery, electrons flow from – to +. Note that the amount of electrons depends on Ohm's law.

Concept 1- Understanding Circuit Diagrams

The goal of this section is to introduce the students to the basic concepts necessary in understanding, designing, and drawing circuits for the seaperch vehicle.

Concept 1.1 – Circuit symbols

There are many different circuit symbols that are used for drawing diagrams. For the purposes of this lesson, we are going to focus on the symbols that are used in the seaperch instructions (plus a few others) – see table 1.

Concept 1.2 – Circuit diagrams

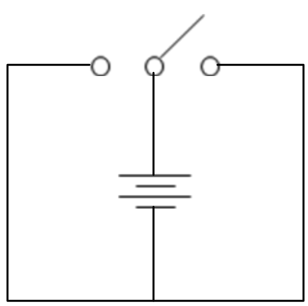
Circuit diagrams are very important for designing circuits. They allow the designer to visualize many different ideas without actually constructing the circuit. For example, wouldn't it have been easier to draw different circuit ideas for the light bulb-wire-battery exercise? In addition to circuit diagrams being used to visualize ideas, they also serve as:

a) records for circuits that have been designed

b) tools for analysis

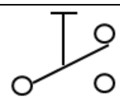
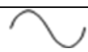
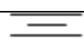
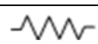
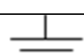
When drawing/reading a circuit diagram, remember what a circuit is– it is a path for electrons. Consider some of the elements in Table 1.

Switches and Buttons



In the switch circuit to the left, the switch changes the path of the electrons from one side of the circuit to the other. This allows things like motors to be turned on or off (if you put a motor on one of the circuit paths). Buttons perform very similar operations. How would the circuit above change if there was a button instead?

Table 1 – Important Circuit Symbols

Name	Symbol	Notes
Button		Buttons are used to either a) open/close a circuit allowing current to flow or b) switch between two different circuits. Note that there is a normal position (either up or down) that the button will return to with no user input. (A button with two connections is shown).
Switch		Similar to a button, but there is no normal state -- the switch stays where the user puts it. (A two way switch is shown).
Fuse		This device is used to limit the current in a circuit. If the current gets to large, the fuse breaks causing an open circuit.
Motor		Motors are thoroughly discussed in the motor portion of the curriculum.
Battery		Supply a portable source of voltage and current.
Resistor		Resistors are elements that have a fixed resistance. They can be used to limit current using Ohm's law.
Ground		This is a point of zero voltage in a circuit. It is often used when analyzing circuits. This is where current wants to go.

LECTURE TOPIC 2 – MOTOR CIRCUITS

Concept 2- Motor Circuits

This section will introduce students to the concepts required to wire the motor for forward, backward, and variable motion.

Concept 2.1 – Running motors forward and backward

The direction a motor spins is dependent on current direction (remember that the direction of the force in the motor depends on the current direction.) The current direction in a motor can be changed by swapping the battery terminals connected to the motor (remember that electrons flow from the negative battery terminal to the positive terminal. Given this information we can design circuits that can switch the way the battery is connected to the motor.

Concept 2.2 – Changing the motor speed

The speed of the motor is also related to the current being applied to the motor – more current leads to more force, which in turn leads to a faster motion. There are a number of ways to vary the current flowing into the motor. One way is to vary the voltage (remember that Ohm's law say voltage is related current) – this can be achieved by using a variable voltage source. Another way is to change the resistance of the motor (remember that Ohm's law says that less resistance means more current) – this can be achieved by adding a fixed resistance in line with the motor.

Lesson 10: Circuits and Wiring

Activities

Experiment 1- Lighting a light bulb with one wire and a battery

Supplies:

Battery: One D-Cell

Wire: One six inch piece of wire.

Light bulb: Flashlight light bulb

Theory: How light bulbs work

Light bulbs work when current runs through the small wire inside the glass (filament). The current makes the filament glow. The light bulb is set up so each end of the filament is connected to a different part of the screw-end of the light bulb. Specifically, one end is connected to the bottom of the screw and the other is connected to the side.

Exercise:

The goal of this exercise is to make the light bulb turn on by completing the wire-battery-bulb circuit. There are four possible configurations that the students should find.

Experiment 2- Drawing Circuits

Exercise:

Draw circuit diagrams for each of the light bulb configurations developed in Experiment 1.

Design and build a circuit that incorporates a button to turn the light on and off.

Experiment 3- Making the motor switch directions

Materials:

This experiment can be done entirely with objects from the sea perch kit.

Exercise:

It is desirable to operate the motors both backwards and forwards. Design a circuit that will allow this to be accomplished by just pressing one or more buttons or flipping one or more switches.

Solutions:

There are a number of different circuit designs that will accomplish this (e.g. see Figure 26 in the Sea Perch Construction Manual). The important thing is that the students are allowed to design and test their own circuits.

Experiment 4- Changing the motor speed

Materials:

This experiment can be done almost entirely using objects from the Sea Perch kit. The only added objects will be a variable resistor (potentiometer, rheostat) and a multimeter.

Setup:

The potentiometer is wired in series with the motor, allowing the motor resistance (and therefore the current) to be varied.

Activity:

Students can measure how the voltage and current applied to the motor change as the resistance is varied. If possible, the students can also see how the speed of the motor changes with increase in voltage or current.

Lesson 10: Circuits and Wiring

Glossary

- **Amperes:** the practical meter-kilogram-second unit of electric current that is equivalent to a flow of one coulomb per second or to the steady current produced by one volt applied across a resistance of one ohm

- **Closed Circuit:** a complete electrical circuit with no gaps in the wiring which current flows or a signal circulates

- **Current:** a flow of electric charge

- **Electron:** an elementary particle consisting of a charge of negative electricity equal to about 1.602×10^{-19} coulomb and having a mass when at rest of about 9.109×10^{-31} kilogram or about 1⁄1836 that of a proton

- **Filament:** a tenuous conductor (as of carbon or metal) made incandescent by the passage of an electric current; specifically: a cathode in the form of a metal wire in an electron tube

- **Ground:** an object that makes an electrical connection to the earth in order to discharge electricity in the case of failure

- **Multimeter:** an instrument for measuring the properties of an electrical circuit, such as resistance, voltage, or current

- **Ohms:** the practical meter-kilogram-second unit of electric resistance equal to the resistance of a circuit in which a potential difference of one volt produces a current of one ampere

- **Open Circuit:** an electrical circuit with a break in the wiring, either from a switch/button or a disconnected wire, which current does not flow due to the break

- **Parallel (circuit):** a closed circuit in which the current divides into two or more paths before recombining to complete the circuit; circuit in which the identical voltage is presented to all components, with current dividing among the components according to the resistances or the impedances of the components

- **Potentiometer:** an instrument for measuring electromotive forces; also can be used to vary the voltage

- **Resistance:** the opposition offered by a body or substance to the passage through it of a steady electric current

- **Resistor:** a device that has electrical resistance and that is used in an electric circuit for protection, operation, or current control

- **Rheostat:** a resistor for regulating a current by means of variable resistances

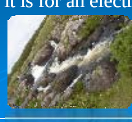
- **Series (circuit):** Any electric circuit having all elements joined in a sequence such that the same current flows through them all

Circuits and Wiring

Lesson 10

Important Electrical Concepts

- Voltage, Current and Resistance
  - Voltage (V)- measured in volts
    - Difference in electrical potential is used to drive electrons around circuits
  - Current (i)- measured in Amps
    - The measure of electron flow around a circuit
  - Resistance (R)- measured in Ohms
    - How difficult it is for an electron to flow though a material.



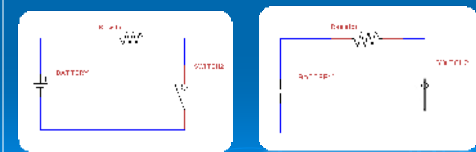
How are the three concepts related? Ohm's Law

$$V = i \times R$$

- Voltage is equal to the current times the resistance.
- If any two quantities are known you can solve for the missing quantity.

Current Flowing Through Circuits

- Current only flows if it has a path towards lower voltage
- Closed Circuit: when a path exists
- Open Circuit: when a path does not exist



Open Circuit   Closed Circuit

Using Open and Closed Circuits

- Buttons and switches
  - Used to open and close a circuit
- If a circuit involves a motor a button can be used to stop the motor from spinning.

Batteries

- Supply a portable power source or voltage
- How do batteries work?
  - Batteries are filled with chemicals that produce electrons
  - The electrons are drawn to an electrode inside
  - You can connect a circuit to the plus (+) and minus (-) ends
  - Electrons will flow from – to +

Circuit Diagrams: The Symbols

- Many different symbols are used:

Name	Symbol	Notes
Button		Buttons are used to either a) open/close a circuit allowing current to flow or b) switch between two different circuits. Note that there is a normal position (either up or down) that the button will return to with no user input. (A button with two connections is shown).
Switch		Similar to a button, but there is no normal state -- the switch stays where the user puts it. (A two way switch is shown).
Fuse		This device is used to limit the current in a circuit. If the current gets to large, the fuse breaks causing an open circuit.

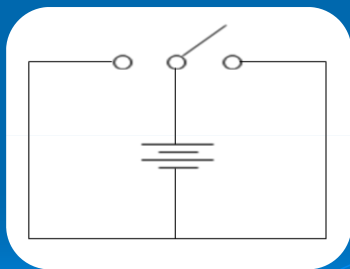
Circuit Diagrams: The Symbols

Motor		Motors are thoroughly discussed in the motor portion of the curriculum.
Battery		Supply a portable source of voltage and current.
Resistor		Resistors are elements that have a fixed resistance. They can be used to limit current using Ohm's law.
Ground		This is a point of zero voltage in a circuit. It is often used when analyzing circuits. This is where current wants to go.

Circuit Diagrams

- Importance
  - Visualize circuit without actually constructing
  - Record circuits that have been designed
  - Tool for analyzing the circuit
- Remember!
  - A circuit is a path for electrons

Can you identify the elements in the circuit?



Battery

Switch

Motor Circuits

- Switching direction of motor
  - Depends on current direction
  - Easily changed by swapping battery terminals connected to motor
  - It is easy to create a circuit that switches the direction of the motor

Motor Circuits

- Motor Speed
  - Related to current applied to the motor

    More Current = More Force = Faster Speed

  - How do you vary the current
    - Remember: Ohm's law relationship between voltage, current and resistance
    - Use variable voltage source
    - Change resistance of motor

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