AC 2011-1632: EXCHANGE SEA PERCH/MATE SCIENCE LEARNING MODULES

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Exchange – Sea Perch/MATE Science Learning Modules

Introduction

The SeaPerch and MATE programs focus on increasing engineering interest in 7th through 12th grade students. This is achieved through the design and development of an underwater remotely operated vehicle (ROV). While the programs are great successes, they lack an in-depth curriculum to support teachers who are supervising SeaPerch and MATE groups. To address this need, we have developed a curriculum covering ROV-related subjects such as motors, electricity, force, and fluid mechanics. The material is targeted at middle and high school students with or without physics backgrounds.

To enable SeaPearch and MATE teachers and advisors to teach the scientific and technological concepts related to underwater ROVs, thus improving the technical education of the students involved, training modules for middle and high school teachers were developed. These modules give teachers and advisors the information they need to successfully present to their students the necessary scientific and engineering concepts. Note that this curriculum in not plans explaining how to build and underwater ROV, but rather, modules that relate hands-on learning activities to pertinent scientific and engineering concepts.

Development Process

The first step in the curriculum development was to identify the scientific and engineering concepts that needed to be taught or reinforced. To do this, a committee consisting of faculty members, working with educators familiar with the needs and capabilities of middle and high school students and teachers, developed a list of topics. This list included topics such as force, pressure, density, buoyancy, statics, electricity, project management, engineering design, and system control. In addition, how these concepts related to the National Science Standards was determined.

Next, university faculty with expertise in each of these areas determined how these concepts should be presented. Following the faculty guidance, modules aimed at presenting the concepts to teachers and PowerPoint slideshows aimed at presenting the concepts to their students were developed. This development was carried by the faculty experts with the help of engineering graduate students. All demonstrations and experiments were built, tested, and modified by graduate students and staff members of the College of Engineering under the supervision of the faculty members.

Lists of all materials needed for teachers to successfully present these lessons were also developed and included with the plans. In cases where the teachers may not be familiar with how to obtain the materials, a way to procure them was included. Finally, student worksheets and glossaries of terms were developed for each module.
**Description**

Ten modules have been developed to help middle and high school students and teachers better understand the science and engineering concepts related to underwater robotics. The included concepts are:

1. Engineering is Everywhere
2. Engineering Design Process
3. Engineering Project Management
4. Tool Safety
5. Forces
6. Hydrostatics
7. Fluid Dynamics, Thrust
8. Fluid Dynamics, Drag
9. Motors
10. Circuits and Wiring

Many of the demonstrations and projects are related to the construction of an underwater ROV. However these modules are not intended to be instructions about how to build an underwater ROV. Their purpose is to improve STEM education in middle and possibly high schools.

A copy of *Module Seven - Fluid Dynamics, Thrust* is included in the appendix. The complete curriculum, including all above modules, can be viewed at the following Villanova University website:

[http://www72.homepage.villanova.edu/aaron.wemhoff/URC/index.html](http://www72.homepage.villanova.edu/aaron.wemhoff/URC/index.html)

The modules have six components. Each component is described below.

**Introduction**

This contains a Lesson Outline, learning objectives, how these objectives and concepts relate to the National Science Standards, how they align with underwater robot construction, and interesting websites related to these concepts.

**Glossary of Terms**

A list and explanation of technical terms related to this module is included here.

**Theory**

This is intended to be used by the teacher. It explains background information about the scientific and engineering concepts related to the module; suggests how they can be taught; describes demonstrations; and has “thought experiments” to be presented to the students.
Slideshow presentation
A graphical and textual presentation in Microsoft PowerPoint format intended to be used by the teacher in presenting concepts to the students is included here.

Activities
Activities reinforcing the concepts being presented are described in detail. Step-by-step instructions are given. Lists of required materials with possible places to acquire the materials are presented.

Student Worksheets
Included here are worksheets to be filled out by students. The worksheets have questions to be answered, tables to be filled out, graphs to be drawn, and other related activities.

Testing
Thus far, preliminary assessment of the curriculum has been carried out by teachers and advisors working with groups of students on Sea Perch or MATE in the Philadelphia School System. They used the first draft of some of the modules during the Spring of 2010. Their suggestions, mostly related to pictures, have been incorporated into this version of the plans. They are currently using the latest version of the plans and will provide formal feedback at the end of this academic year. Anecdotally, the curriculum has been well received.

In addition, during the Spring of 2011 Villanova engineering students working with middle and high school students and, again, some teachers in the Philadelphia School System used the modules. Modifications to the modules will again be made based on the input from these two groups.

Currently, the testing of this curriculum is ongoing.

Acknowledgments

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Electronic copies of all of the modules are available, free of charge, to any teacher who wants them. The files are accessible and can be easily downloaded from the following Villanova University website:

Appendix
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

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
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:

\[ ma = F_{\text{thrust}} - F_{\text{drag}} \]

Where \( m \) is mass, \( a \) is acceleration, \( F_{\text{thrust}} \) is thrust force, and \( F_{\text{drag}} \) is drag force.

At the terminal velocity:

\[ F_{\text{thrust}} = F_{\text{drag}} \]

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**

**Set up:** 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.

![Diagram of Box Fan](image)

**Figure 1:** Thrust demonstration using a box fan.

**Classroom Demonstration 2: Seaperch on a String**

**Set Up:** 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 all of 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:

<table>
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<tr>
<th>Item</th>
<th>Quantity</th>
<th>Purchase Location Suggestion</th>
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<tbody>
<tr>
<td>Balsa Wood Rubber Band</td>
<td>1</td>
<td><a href="http://www.Guillow.com">www.Guillow.com</a></td>
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<tr>
<td>Airplanes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper Clips</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Permanent Marker</td>
<td>1</td>
<td></td>
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<tr>
<td>Fishing wire</td>
<td>10ft</td>
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<tr>
<td>Electrical Tape</td>
<td>1</td>
<td>Sea Perch Kit</td>
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<tr>
<td>Tape Measure</td>
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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 but 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 than the ending side?

Data Collection- Thrust Test

Instructions:

- Place your airplane at the 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 it 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.

<table>
<thead>
<tr>
<th>Number of Winds</th>
<th>Distance Traveled (inches)</th>
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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.
Distance Traveled in.

Number of Winds

y-axis

x-axis