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FOR EXCELLENCE IN MIAMI-DADE PUBLIC SCHOOLS

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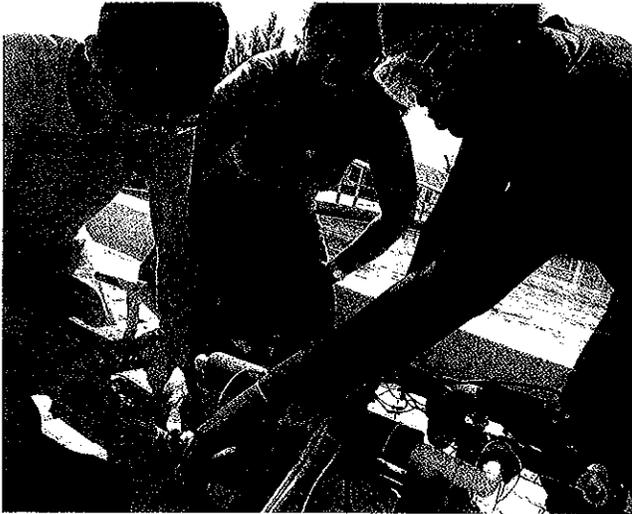
Designing Underwater Vehicles

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Designing Underwater Vehicles

Originally a Teacher Mini-Grant



Student teams are presented with an open-ended design problem which is based on a real-working underwater situation that involves designing and building a remotely-operated vehicle (ROV). Possible simulations for ROV-designs include navigating through Hawaii's Loihi Seamount (underwater volcano) or inspecting the Deepwater Horizon oil spill, both of which are relevant examples of commercial ROV use.

To begin, the teams make sketches and calculations outlining the structure and propulsion system. After fabricating the ROVs using PVC pipe and parts from a kit, teams test for neutral buoyancy in a pool. Once buoyant, teams perfect and modify their ROVs to improve control and maneuverability. Finally, a timed dive competition is held with points gained for completing mission objectives. Each team submits technical reports that include background research, schematics of their control boxes, drawings of their ROVs and an analysis of their ROVs' performance.

Engineering is not the product but the process. What better way to learn than to progress from a general problem to a designed, tested and constructed solution?

Students

This project was designed and implemented in a mixed level second and third year engineering classroom with students in grades 10th - 12th. It can be modified for use with sixth - ninth grades in physical science classrooms.

Staff

Melissa Fernandez teaches Engineering Technology, Information Technology and AP Computer Science and coaches the Mecha Makos, MAST Academy's engineering and robotics competition team. She holds a M.S.Ed. in Education Technology from Barry University and is currently pursuing a Ph.D. in Computing Technology.

Materials & Resources

All project materials are available from hardware and a marine/outdoor outfitter. ROV-in-a-Bucket kits are recommended for novices at www.marinetech.org (Web site lists on-line suppliers of materials to build ROVs). If a pool is not available, smaller ROVs can be built using a bathtub/child's pool to test the designs.

Books and Web sites: *Build your own Underwater Robot and Other Wet Projects* by Harry Bohm & Vickie Jensen; immersionlearning.org (interactive build-a-ROV); www.marinetech.org/rov_competition/resources.php (ROV competitions).

Standards

Sunshine State Standards
Standards for Technology Literacy:
STL.1.J; STL.2.BB;
STL.5.I; STL.8.H;
STL.8.I; STL.8.J;
STL.9.J; STL.10.J;
STL.11.P; STL.11.Q;
STL.11.R; STL.12.M;
STL.16.N

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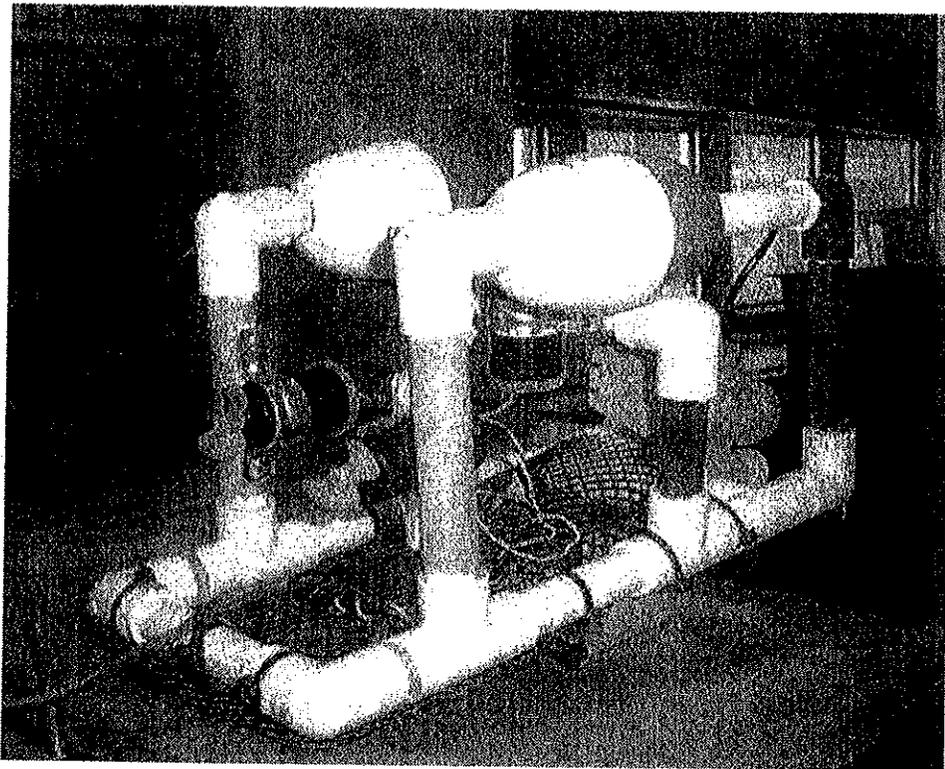
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MIT SEA GRANT

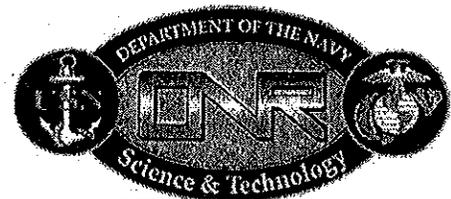
presents

Sea Perch: *Integrating Ocean Exploration into the Classroom*




Sea Grant

Massachusetts Institute of Technology



MITSG 09-3

 MIT SEA GRANT

February 2009

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1.0 Project Overview



MIT SEA GRANT

MIT Sea Grant's Sea Perch project introduces pre-college students to the wonders of underwater robotics. Part of the Office of Naval Research's initiative, "Recruiting the Next Generation of Naval Architects," this program teaches students how to build an underwater robot (called a Sea Perch), how to build a propulsion system, how to develop a controller, and how to investigate weight and buoyancy. This endeavor is one of many exciting new projects funded by the Office of Naval Research as part of its National Naval Responsibility Initiative. The initiative focuses on bringing academia, government and industry to work together to ensure that the talent needed to design the Navy's next generation of ships and submarines will be there when needed.



The Sea Perch project is based upon the book *Build Your Own Under Water Robot and Other Wet Projects* by Harry Bohm and Vickie Jensen. Our program goes beyond the design, hosting training workshops for teachers, mentors and potential trainers on how to build the remotely operated vehicles (ROVs) constructed of PVC pipe. With a marine engineering theme, this project teaches basic skills in ship and submarine design and encourages students to explore naval architecture and marine and ocean engineering concepts. The Sea Perch project can easily be turned into a multidisciplinary venture. For instance, by incorporating novels that focus on ocean exploration, focusing on ship and submarine technology throughout history, adding environmental sensors for data collection and studying the math and physics involved in ocean exploration, teachers can develop extensive, in-depth programs for their classes.

Our project website is our main source of materials for the Sea Perch project. Please visit the site for PDF versions of the manuals, experiments, activities and additional online resources at: <http://seaperch.mit.edu>

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2.0 National Standards Met Through the Sea Perch Project

National Science Standards Matrix for Sea Perch Project

Activity	Grade Level	National Science Content Standard							
		U	A	B	C	D	E	F	G
Building the Frame	9-12	X	X				X		
- measurement - design - buoyancy									
Building the Motors	9-12	X	X	X			X		
- motor movement - vectors - soldering - water proofing									
Building the Control Box	9-12	X	X	X			X		
- circuits and switches - reading wiring diagrams - ergonomic design									
Experiments/Field Use									
Buoyancy Activity	9-12	X	X	X			X		
Student Design Modification	9-12	X	X				X		
Measurement of Depth	9-12	X	X				X		
Biological Sampling	9-12	X	X		X		X	X	X
Exploring the Sites and Sounds of Underwater	9-12		X		X		X	X	X
Making a Circuit	9-12	X	X	X			X		
Attenuation of Light	9-12		X	X			X	X	X

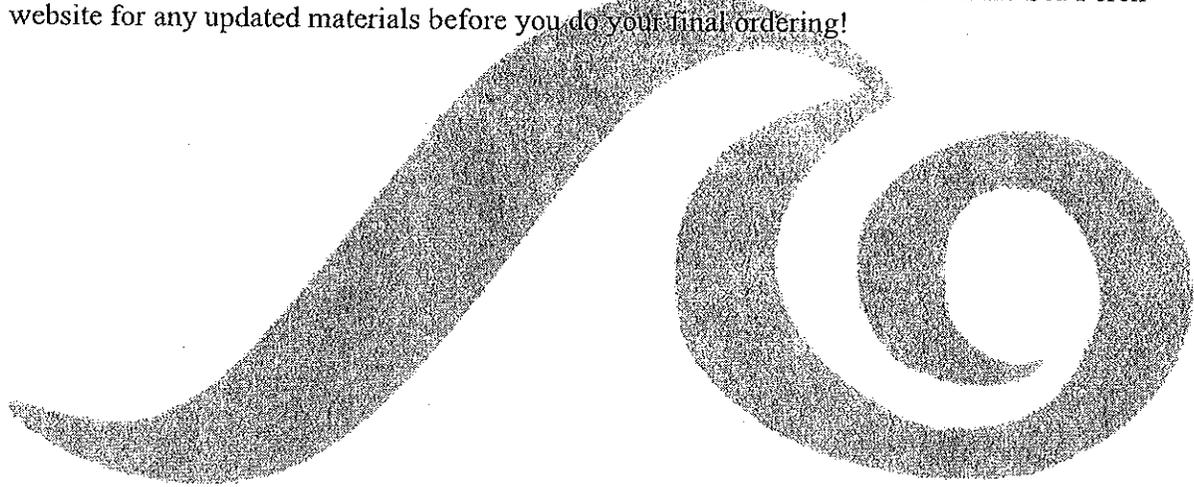
KEY: Content Standards:	
U = Unifying Concepts and Processes	D = Earth and Space Science
A = Science as Inquiry	E = Science and Technology
B = Physical Science	F = Science in Personal and Social Perspectives
C = Life Science	G = History and Nature of Science

3.0 Preparing to Build

This section contains all the information you will need to prepare for building a Sea Perch. Everything from a parts and tools list to pre-lessons that will help the students grasp the theory and concepts behind constructing an underwater vehicle are discussed.

3.1 Parts and Tools List

The following pages contain a list of all the parts and tools you need to assemble a Sea Perch. We have identified vendors that carry each product and have made notes on bulk purchases or alternative sources for materials. There are many vendors that carry the same materials. If your organization has an agreement with a company that carries these parts, by all means, order the parts from that vendor if it is more convenient. Please be sure to double check the Sea Perch website for any updated materials before you do your final ordering!



Sea Perch ROV

Parts and Tools Lists

These lists have been compiled in order to assist you in building the Sea Perch in your classroom and in ordering the necessary parts and tools. Please consult the construction manual and reference your Sea Perch training to verify what you will need.

The suggested vendors have been selected for convenience, price, and/or ease of use. Many of the items may be available at lower cost from other sources, or may be already available at your school (especially tools). Many items come in bulk, or are only available in quantities or packages larger than that needed for a single Sea Perch kit. In these cases, the cost per kit is calculated as a fraction of the minimum order quantity and price. When ordering for multiple kits, verify the quantity needed to order with the quantity needed for each kit and the minimum order quantity. Do not rely solely on the quantity column for the number to order. Many vendors have significant quantity discounts available, and some may have educational discounts.

<u>Key</u>	
Qty.	Quantity - number of items needed for 1 kit, or length needed for items such as wire.
Size	Size or amount of item required, or unit of measure.
Item	Description of item.
Suggested Vendor	Suggested source for purchase of items.
Cat.No.	Catalog Number of item in suggested vendor's catalog
Minimum Package Quantity	Minimum amount available from vendor in a single order - may be more or less than needed for 1 kit
Per Package Cost	Cost of minimum order.
Order Quantity (# Pack.)	Number of packages of minimum order size needed for 1 kit.
Minimum Order Cost	Cost of quantity needed to order (minimum order)
Per Kit Cost	Cost of material needed for 1 kit (ignoring minimum orders)
Notes	Additional information, including quantity discounts and alternative sources

These lists were last updated in August 2007. All items were available from the suggested vendors at that time, but availability may change.

We strongly suggest ordering some extra film cans (sample vials), fuses, and hookup wire, as these items often need replacing.

Sea Perch

Master List - Parts for 1 vehicle

Qty.	Size	Item	Suggested Vendor	Cat. No.	Minimum Package Quantity	Per Package Cost	Order Quantity (# Pack.)	Minimum Order Cost	Per Kit Cost	Notes	
Vehicle Frame											
1	14 in	3/8" ABS H-Column	Pliastruct	H-12	1	\$ 1.45	1	\$ 1.45	\$ 1.45	Quantity discount: 4 for \$5.55	
1	5 ft	1/2" Sch. 40 PVC Pipe	McMaster-Carr	48925K91	1	\$ 1.97	1	\$ 1.97	\$ 1.97		
10	each	PVC elbows, 1/2" Sch. 40	McMaster-Carr	4880K21	1	\$ 0.34	10	\$ 3.10	\$ 3.10		
4	each	PVC Tees, 1/2" Sch. 40	McMaster-Carr	4880K41	1	\$ 0.38	4	\$ 1.52	\$ 1.52		
1	12"x8"	Polyethylene Mesh (sold 36" wide, per foot)	McMaster-Carr	9314133	1	\$ 1.05	1	\$ 1.05	\$ 1.05		
3	each	Conduit straps (motor mounts)	McMaster-Carr	9429136	60	\$ 5.00	1	\$ 5.00	\$ 3.00		
6	each	#6 x 1/2" stainless steel sheet metal screws	McMaster-Carr	92485A148	100	\$ 7.36	1	\$ 7.36	\$ 0.44		
6	each	#6 stainless steel flat washers	McMaster-Carr	90107A007	100	\$ 4.08	1	\$ 4.08	\$ 0.24		
2	each	Football floats 3"x5"	Aquatic Ecosystems	NF7	1	\$ 1.80	2	\$ 3.60	\$ 3.60	24+ @ \$1.60/ea. Or use large fishing sinkers	
4	each	1 oz. and/or 2 oz. large steel nuts (ballast weight)									
Thrustor Assembly											
3	each	Plastic Sample Vial, 50ml (or use free film cans!)	US Plastics	81037	1	\$ 1.57	3	\$ 4.71	\$ 4.71	Quantity Discount available	
6	each	Brass Hex Nuts, 4-40	McMaster-Carr	95130A110	100	\$ 3.13	1	\$ 3.13	\$ 0.19		
3	each	Threaded Coupler, 4-40, 0.095" (Propeller Shaft)	Tower Hobbies	GPW03832	2	\$ 2.78	2	\$ 2.78	\$ 2.09		
3	each	1/8" plastic propeller, 0.19, 0.35	Tower Hobbies	DJMB1860	1	\$ 3.45	3	\$ 3.45	\$ 3.45		
3	each	Motors 12 volt	Jameco	232021	1	\$ 2.25	3	\$ 6.75	\$ 6.75	100+ @ \$1.79/ea.	
40	ft. long	Cat5 cable, 4 twisted pair, stranded (by the foot)	Jameco	201582	25	\$ 9.45	2	\$ 18.90	\$ 15.12	Quantity discounts available	
Control Box											
1	each	Plastic box 4.9"x2.5"x1.5"	Jameco	18913	1	\$ 3.63	1	\$ 3.63	\$ 3.69	10+ @ \$3.32/ea.	
2	each	DPDT center off toggle switches	Jameco	21922	1	\$ 1.55	2	\$ 3.10	\$ 3.10	Quantity Discount available	
2	each	SPDT mom. push button switches	Jameco	121304	1	\$ 3.59	2	\$ 7.18	\$ 7.18	Quantity Discount available	
2	each	Alligator clips	Jameco	256525	2	\$ 0.50	1	\$ 0.50	\$ 0.50	Quantity Discount available	
1	each	Insulator for alligator clip - Red	Jameco	248972	2	\$ 0.51	1	\$ 0.51	\$ 0.26	Quantity Discount available	
1	each	Insulator for alligator clip - Black	Jameco	248962	2	\$ 0.51	1	\$ 0.51	\$ 0.26	Quantity Discount available	
1	each	Fuseholder, in-line, 1.25"x.25" fuse	Jameco	151918	1	\$ 1.19	1	\$ 1.19	\$ 1.19	Quantity Discount available	
1	each	Fuse, 10A, slow-blow	McMaster-Carr	7085K15	5	\$ 6.44	1	\$ 6.44	\$ 1.29	Quantity Discount available	
6	ft. long	#18AWG speaker wire, 6 foot length	McMaster-Carr	70405K34	1	\$ 0.18	6	\$ 1.08	\$ 1.08	250+ @ \$.09/ft.	
Expendable Supplies											
0.5	ring	Wax Toilet Bowl Ring (1/2 ring for each vehicle)	McMaster-Carr	2793K31	1	\$ 1.40	1	\$ 1.40	\$ 0.70	@ HomeDepot: 8 rings for \$3.35	
1	each	Epoxy packet & mixing stick	McMaster-Carr	7483A34	10	\$ 2.04	1	\$ 12.04	\$ 1.20		
2	ft. long	#24 stranded hookup wire, red (sold by 100' roll)	McMaster-Carr	7587K921	100	\$ 6.83	1	\$ 6.83	\$ 0.14		
2	ft. long	#24 stranded hookup wire, black (sold by 100' roll)	McMaster-Carr	7587K922	100	\$ 6.83	1	\$ 6.83	\$ 0.14		
15	6 in.	6" cable ties (aka: zip-ties or tie-wraps), black	McMaster-Carr	7130K42	100	\$ 4.14	1	\$ 4.14	\$ 0.62		
3	inches	Butyl Rubber Tape aka, "Monkey Dung" (16 yd. roll)	McMaster-Carr	7638SA15	576	\$ 18.25	1	\$ 18.25	\$ 0.10		
1	roll	Electrical tape	Jameco	285587	1	\$ 0.99	1	\$ 0.99	\$ 0.99	higher quality tape also available	
1	roll	Solder, 60/40 rosin core (contains lead)	Jameco	170457	1	\$ 1.39	1	\$ 1.39	\$ 1.39		
1	bottle	Rubbing Alcohol									
1	roll	Paper Towels									
		Newsprint, cardboard or droplets to protect waxing table, wall & floor									
Total for ROV									\$ 144.92	\$ 69.79	per kit, w/o battery or charger

Sea Perch

Battery & Charger			
1	12v. Battery, Sealed Lead Acid (SLA), 12 volt, 7 AH	batterymart.com	\$ 14.95
1	Charger - 12v, 500mA Automatic SLA Charger	batterymart.com	\$ 15.95
1	Cord for Charger	batterymart.com	\$ 1.95
Total for Battery and Charger			\$ 32.85

Individual Tools (suggested for each Sea Perch kit)			
1	PVC Pipe Tubing Cutter (RATCHEI Style)	4657	\$ 17.88
1	Screwdriver, flat, medium	5682A18	\$ 4.46
1	Screwdriver, Phillips, small	5682A27	\$ 3.32
1	Scissors	3608A14	\$ 11.51
1	Slip joint pliers (and/or needle-nose pliers)	5624A8	\$ 8.12
1	Diagonal cutter pliers (wire cutters)	3621A11	\$ 5.81
1	Wire strippers (for 26-16 AWG Stranded wire)	7294K58	\$ 9.91
1	Safety Glasses (Eye Protection)	54185T601	\$ 2.30
1	Plastic Tote, parts and/or tool container (optional)	4387T51	\$ 4.34
1	Soldering Iron	224611	\$ 7.95
1	Soldering Iron Tip, conical	36329	\$ 4.95
1	Sharpie (marker)	226018	\$ 0.95
1	Ruler		
1	Pen		
1	Pencil		
1	Pad of paper (lab notebook)		
1	Paint set, enamel, regular colors (optional)	LXHH93	\$ 7.89
1	Paint brush set (optional)	LXB838	\$ 3.39

Shared Tools (shared by multiple Sea Perch kits)			
1	Drill bit, 1/4"	2901A124	\$ 2.16
1	Drill bit, 3/32"	2901A113	\$ 1.06
1	Twisted Pair Cable Stripper (for tether sheath)	4333K26	\$ 23.28
1	Hand drill, variable speed - corded or cordless	various	\$ 29.99
1	Electric Skillet (by Presto)	65987	\$ 29.99
1	Metal cup or beaker for melting wax		
1	Digital Multimeter for debugging (optional)	220812	\$ 9.65
1	Desoldering Pump, aka, "solder sucker" (optional)	19166	\$ 4.95
1	Bench vise, 4" (optional)	5310A42	\$ 49.16
1	Thru-hole potting holder parts: wood, fine nails, wood glue (optional)		
Total for a complete set of Tools			\$ 243.02

also @ Jameco # 264057, \$18.15 ea.
 also @ McMaster # 7448K67, \$38.33
 (cord not needed with McMaster Charge above)

also available at McMaster #8336A13, for \$44.37

For over prescription glasses, use #62755T9, \$5.02 ea.
 Many options available, for +/- \$

Quantity Discount available, 12+
 Quantity Discount available, 12+
 @ Jameco: #230447, \$18.89
 Many types available: \$30-\$200
 Any Hot plate and pan will do
 cups with handles suggested
 Or use solder wick, Jameco # 41081, \$1.75 ea.
 cheaper @ HomeDepot, etc.

Sea Perch

Web Addresses of Vendors

Ace Hardware www.acehardwareoutlet.com
Allied Electronics www.alliedelec.com
Aquatic Ecosystems www.aquaticeco.com
BatteryMart.com www.batterymart.com
Home Depot www.homedepot.com
Jameco www.jameco.com
McMaster-Carr www.mcmaster.com
Plastruct www.plastruct.com
The Plumbing Store www.PlumbingStore.com
Seats www.sears.com
Tower Hobbies www.towerhobbies.com
US Plastics www.usplastic.com

Old Suppliers (no longer used in this list, but still useful as backup)
Radio Shack www.radioshack.com
Small Parts Inc. www.smallparts.com
Newark Electronics www.newark.com
Contact East www.contacteast.com
DataComm Warehouse www.warehouse.com
Go Fishin www.gofishin.com
IWP www.rubbermaidproducts.com

Optional Accessories for the Sea Perch

Alternative switches

Some educators have been successfully using larger toggle switches to replace both the toggle and pushbutton switches. They are cheaper and easier to hookup because of their screw terminals. They are available from:
Part# 270013 \$1.75 ea. (\$1.45 ea. for >10)
<http://www.kevin.com>

Cheaper Tether Cables

Ethernet cable is available in bulk from various vendors. Searching online will yield cheaper sources, as prices fluctuate. Be sure to get Cat5 or Cat5e cable with 4 twisted pairs, and STRANDED wires!

Sensors

Hobo Data Loggers <http://www.iscienceproject.com/> K-12 teachers can sign them out for free!
Underwater cameras <http://www.resunited4u.com/> part# GM-300CX-10 \$179
Resources Unltd <http://spycorder.com/waterproof.htm> Model # SLC-131 \$150
Security labs www.polarisusa.com
Polaris www.matco.com
Matco

Tank for testing ROV (allows for testing during adverse weather)

Aquatic Eco Systems <http://www.aquaticeco.com/> QTS02, \$352, Portable Tank, 450 gallons - 30 inches high, 6ft diameter

3.2 Safety

❖ General Safety Guidelines

- Always conduct yourself in a responsible manner.
- Follow all written and verbal instructions carefully. If you do not understand something, ask the instructor before proceeding.
- Never work alone. No student may work in the laboratory without an instructor present.
- When first entering the laboratory, do not touch any equipment or materials until you are instructed to do so.
- Do not eat, drink, or chew gum in the laboratory. Do not use laboratory glassware as containers for food or beverages.
- Be prepared for your laboratory. Read procedures thoroughly before entering the laboratory.
- Never fool around in the laboratory. Practical jokes and pranks are dangerous and prohibited.
- Clean up after yourself. Work areas should be kept clean and tidy at all times. All materials not needed for the laboratory should be kept in the classroom area.
- Know the locations and operating procedures of all safety equipment, including the first aid kit, eyewash station, safety shower, fire extinguisher, and fire blanket. Know where the fire alarm and the exits are located.
- Be alert and proceed with caution at all times in the laboratory. Notify the instructor immediately of any unsafe conditions you observe.
- Labels and equipment instructions must be read carefully before use. Set up and use the prescribed apparatus as directed in the laboratory instructions or by your instructor.
- Experiments must be personally monitored at all times. You will be assigned a laboratory station at which to work. Do not wander around the room, distract other students, or interfere with the laboratory experiments of others.
- Know what to do if there is a fire drill during a laboratory period: containers must be closed, gas valves turned off, fume hoods turned off, and any electrical equipment turned off.
- When using knives and other sharp instruments, always carry with tips and points pointing down and away. Always cut away from your body. Never try to catch falling sharp instruments. Grasp sharp instruments only by the handles.
- If you have a medical condition (e.g. allergies, injuries, etc.) check with your physician prior to working in lab.

❖ Clothing

- Any time chemicals, heat or glassware are used, students must wear laboratory goggles. There are no exceptions to this rule.
- Contact lenses should not be worn in the laboratory unless you have permission from your instructor.
- Dress properly during a laboratory activity. Long hair, dangling jewelry, and loose or baggy clothing are a hazard in the laboratory. Long hair must be tied back, and dangling jewelry and loose or baggy clothing must be secured. Shoes must completely cover the foot. No sandals are allowed.

❖ Accidents and Injuries

- Report any accident (spill, breakage, etc.) or injury (cut, burn, etc.) to the instructor immediately, no matter how trivial it may appear.
- If you or your lab partner are hurt, immediately get the attention of the instructor.

❖ Handling Glassware and Equipment

- Never handle broken glass with your bare hands. Use a brush and dustpan to clean up broken glass. Place broken or waste glassware in the designated glass disposal container.
- When removing an electrical plug from its socket, grasp the plug, not the electrical cord. Hands must be completely dry before touching an electrical switch, plug or outlet.
- Report damaged electrical equipment immediately. Look for things such as frayed cords, exposed wires, and loose connections. Do not use damaged electrical equipment.
- If you do not understand how to use a piece of equipment, ask the instructor for help.
- When using a drill, make sure the piece you are drilling into is well secured in a vise.

❖ Working with Electronics

- Exercise extreme caution when using a soldering iron. Take care that hair, clothing, and hands are a safe distance from the tip at all times. Do not touch the tip to any substance unless specifically instructed to do so.
- Never leave a soldering iron on and unattended. Always make sure that the iron is on its holder and turned off when it is not in use.
- Do not place the soldering iron directly on the laboratory desk. Always put it in its stand.
- Wires stay hot for a few minutes after being heated. Do not touch the wire close to where the connection was made until it is cool.
- Always make sure there is no power connected to the piece of electrical equipment you are soldering.
- Never touch the electrical connections when there is power connected to it. When testing connections with your hands, make sure power is turned off. Only use one hand to test the connections in case there is any power in the system.
- Be sure to not allow Butyl tape to touch any electrical connections – it will burn out your wires.

3.3 Pre-lesson: Buoyancy

This section focuses on the concepts that go along with the frame construction. Buoyancy is the main concepts to be understood before you construct the frame of a Sea Perch.

To dive or not to dive

This activity is being used with permission from KiddoScience. It has been adapted from its original form. <http://www.kiddoscience.co.za/teacherprimary/buoyancy.html>

Time Requirement:

- 1 class period

National Science Content Standards Addressed:

Unifying Concepts and Processes

- Evidence, models, and explanation
- Constancy, change, and measurement

Content Standard A – Science as Inquiry

- Understanding about scientific inquiry
- Abilities necessary to do scientific inquiry

Content Standard B – Physical Science

- Motions and forces

Content Standard E – Science and Technology

- Abilities of technological design
- Understanding about science and technology

Introduction

Who are scientists? They are people whose minds never stop running-not even in the bath tub.

One famous scientist was Archimedes, a Greek physicist, mathematician and inventor who was called the "father of the experimental science." Archimedes lived most of his life in Syracuse, a city in Sicily, which is an island in Italy. According to the story, the king of Syracuse asked Archimedes to tell him if his new crown was pure gold. Archimedes thought of a way to test the crown. When he stepped into a full bathtub, the bathtub overflowed. He realized that his body had displaced a certain amount of water that is when, according to the story, he ran out naked calling *Eureka*-I have found it!

He realized that if the crown were pure gold it would displace the same amount of water as a chunk of pure gold weighing the same as the crown. He conducted a test and found that the crown was not pure gold. The crown-maker who claimed the crown was pure gold had cheated the king. This discovery led to the discovery of buoyancy.

Buoyancy is the tendency of an object that is immersed in a fluid to rise. Archimedes discovered that when an object is placed in water (or any other fluid) it displaces (pushes aside) a certain amount of water. The upward force from that displaced water is equal to the weight of the displaced water. Whether this force is strong enough to make an object float/ rise depends on the density (mass per volume) of the object.

Some objects, such as submarines, can adjust their density. A submarine becomes more or less dense –allowing submerging or rising – by taking water into its tanks or forcing them out, using compressed air.

Ideas for illustrating those concepts:

- Raise the following question: why is it that an iron ball placed in water will sink and a boat made out of iron can float? The difference is the density. The boat has more volume per mass than the iron ball. To experiment: give each learner plasticine, let them roll it into a ball and place it into water, it will sink. Let them try and change the shape of it until it floats (into a similar shape of a boat)
more on sink and float
- Place oil in a jar. What will happen when you add water? The oil will float.
more on sink and float in liquids

An important application: how do we put out a fire caused by burning oil? Is it by pouring water? NO because the burning oil will float above the water. (We would use an old blanket or sand)

Technology: how does a submarine work?

A submarine is a ship that operates underwater. Submarines are used mostly as a weapon of war. Others are built for peaceful uses such as sunken treasure hunt and ocean research.

Most submarines are shaped like a cigar with tapered ends and an almost round body. At the front and the back end are placed the diving planes, which control the ships up and down movements.

A tall structure called a coning tower rises above the top of the submarine and it contains the control and navigation centre. (It includes the periscope, a kind of telescope that is used for observing the surface when the ship is submerged.) A submarine operates on the surface just like any other ship. When it goes under water, sea water is allowed to enter and fill tanks called ballast tanks. They are placed around the living space. To make the submarine surface, the lower valves open and compressed air from inside the submarine forces the water out of the tanks. To make the submarine dive the valves open to allow air to escape from the top of the tanks.

Project- Make your own submarine

This project illustrates the theme, needed available materials, and how each learner can make it or you can use it as a model in the classroom.

All you need:

- “Submarines” -medicine dropper or plastic drinking straws, a paper clip, and some modeling clay
- Transparent container filled with water
- 2L plastic bottle filled with water

Procedure

Fill the container with water and place the medicine dropper in the glass. Get some water inside the dropper by squeezing the rubber bulb while the end is in the water. You want to get the dropper to just barely float upright in the water. Once you've done this, place the dropper in the soda bottle and screw on the cap tightly. Don't allow much air to be between the top of the bottle and the cap. Gently squeeze the bottle. As you squeeze, the diver will dive (sink) to the bottom of the bottle. If you stop squeezing, the diver floats back to the top.

If you can't find a medicine dropper, you can duplicate the same effect by bending a plastic drinking straw in half and securing it with a paper clip. Put a small amount of modeling clay on the bottom end of the straw and, as with the medicine dropper, get it to barely float on the surface of the water in the water glass. Now think of some other 'submarines' to make and try...

What's going on?

This experiment demonstrates the property of **buoyancy**. An object is buoyant in water due to the amount of water it displaces or "pushes aside". If the weight of water that is displaced by an object in water exceeds the weight of the object, then the object will float. As you apply pressure to the bottle, you apply pressure to the air bubble in the dropper, thus reducing its size. As the bubble gets smaller, the dropper becomes less buoyant and begins to sink. Release the pressure on the bottle and the dropper begins to rise back to the top.

Fish keep themselves from either sinking or floating to the surface by using muscles to squeeze or relax a small sac (with a small air bubble inside) in their bodies. By squeezing the sac, fish will make themselves sink. By relaxing their muscles, the fish makes the sac get bigger. The fish then displaces more water and will begin to rise to the surface. Scientists use this same principle to control the buoyancy of a submarine. By pumping water in and out of tanks stored in the submarine, a submarine can be made to rise and sink.

Create a show

Call your submarine by a name and tell the learners that if they greet your "Friend" an amazing thing will happen. As they greet it press the bottle with your hands and the submarine will sink. As you stop pressing it will go up and float. It is a good opportunity to repeat vocabulary such as: sink, float, buoyancy as well as reminding the learners that it is not magic but has got a scientific explanation.

Determination of Mass, Volume, and Ballast of a Sea Perch ROV

Submitted by Robert Valtos NSWC Philadelphia

Overview:

This lab will result in students demonstrating knowledge of mass measurements, volume measurements of an irregularly shaped object, and ballast determination for a Sea Perch ROV. This lesson is to help the students understand the principals behind why a ROV needs to be ballasted and how to determine how much ballast is needed. It will also show them how to determine the volume of an irregularly shaped object.

Grades: 7th – 12th

Time: One 45-minute period.

Objective:

The students will:

- Determine the mass of an object
- Determine the volume of an irregularly shaped object
- Calculate the density of an irregularly shaped object

Skills Attained:

- Develop a method to determine the density of a Sea Perch ROV
- Determine how much ballast a Sea Perch ROV needs
- Develop an understanding of the ballast buoyancy relationship

National Science Content Standards Addressed:

- Unifying Concepts and Processes
- Science as an Inquiry
- Physical Science
- Science and Technology for grades 9-12

Lesson:

Buoyancy is an upward force exerted on an object by the fluid it is surrounded by. How buoyant an object is, is determined by the weight of fluid an object displaces. To determine how buoyant an object is you need to know the density of the fluid it will be surrounded by. With this information and the known volume of the object, you can determine the buoyant force exerted on the object. This is the force that an ROV would have to supply to submerge itself. A ROV needs to be slightly buoyant so that it will return to the surface if it loses power, but if it is too buoyant, it will take more energy to submerge it or it may not submerge at all. To adjust the buoyancy of a ROV weight known as ballast needs to be added. To calculate the ballast needed to make your ROV neutrally buoyant you need to know the density of the fluid your ROV is submerged in, the density of the ballast weights, as well as the volume and weight of the ROV. Remember that the densities of your weights must be greater than the density of your fluid otherwise they just add more buoyant force to the craft. This is why you use lead or

steel instead of foam, because lead and steel are denser than water and foam is less dense than water.

Materials:

- Pool float found in Sea Perch kit
- String to attach weights, also known as ballast, to the float
- Scale that weighs in fractions of an ounce
- One pound coffee can, or uniform cylindrical object that will hold water and that the float will fit into
- Electrical tape
- Measuring tape or ruler accurate to 1/16 of an inch
- Weights (ballast) Washers and lead sinkers work well. Washers are a little easier to calculate the volume for. Lead sinkers are irregularly shaped and you need to figure out the volume of the weight.

Procedure:

1. Weigh the pool float and write the weight down.
2. Measure your coffee can diameter and write it down
3. Place ruler or measuring tape into coffee can and tape it to the side with electrical tape
4. Fill coffee can half way up with water
5. Make sure that the ruler is at least partially submerged and write down the height of water
6. Place pool float into coffee can and submerge. You will have to push the float below the water, take care not to submerge your finger too as this will affect your volume calculation. Write down the height of water with the float submerged.
7. Subtract the first measurement from the last measurement and use this as your height to calculate the volume of water displaced.

Remember: Volume for a cylinder is

$$V = \pi r^2 H$$

This is the volume of your pool float

8. Calculate the density of the float by dividing the weight of the float by the volume of the float
9. Determine the density of the ballast you are going to use.
10. Start adding ballast to the float until it just submerges.
11. Weigh the ballast and see how much it took to make the float neutrally buoyant.

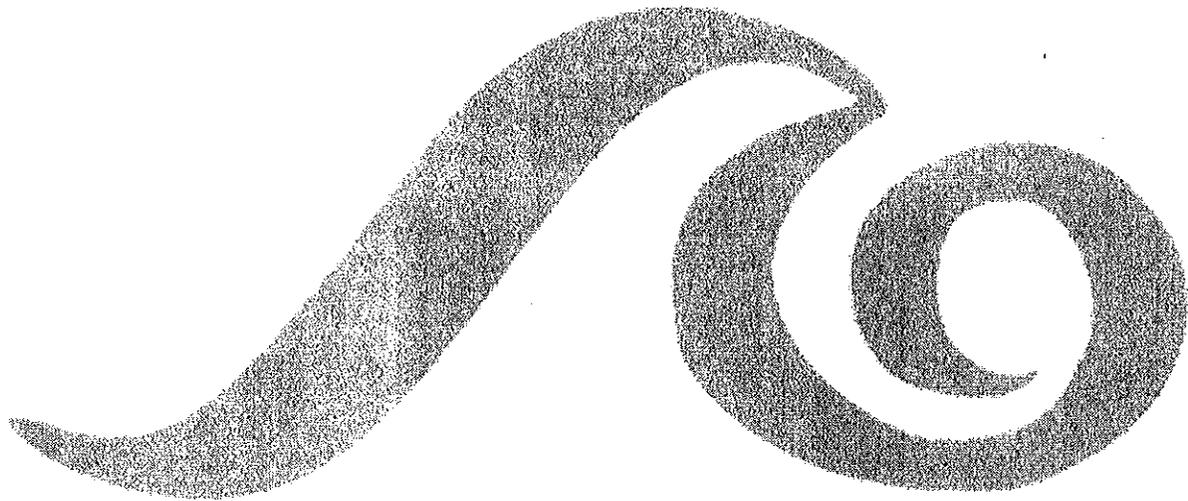
Assessment:

- Calculate the density of a 4 inch piece of PVC plastic used in the Sea Perch frame. Will it float?
- What happens if you place tape over the ends of the 4 inch PVC piece so water can't flood the inside?
- Using the principals of what you just learned, devise an experiment to determine the displacement of a Sea Perch using a 5 gallon bucket.
- Determine how much ballast you need for your Sea Perch frame.

Mass of Ballast = (Density of Water*Volume of ROV)-Mass of ROV
1- (Density of Water/Density of Ballast)

References:

<http://en.wikipedia.org/wiki/Buoyancy>



Building A Simple Submarine

Submitted by Robert Valtos NSWC Philadelphia

Overview:

This lab will result in students understanding the principles of how a submarine controls its buoyancy.

Grades: 7th – 12th

Time: One 45-minute period.

Objective:

The students will:

- Construct a model of a submarine's ballast system

Skills Attained:

- Develop an understanding of an active ballast system
- Develop skills to devise an active ballast system for a Sea Perch ROV

National Science Content Standards Addressed:

- Unifying Concepts and Processes
- Science as an Inquiry
- Physical Science
- Science and Technology for grades 9-12

Lesson:

A submarine controls its ballast by allowing water to fill ballast tanks located around the ship. To make a submarine submerge, vent valves at the top of the ballast tanks open allowing air to escape and water to fill the tanks through holes in the bottom. To make a submarine surface, the vent valves are shut and high pressure air is released into the tanks forcing the water out through the holes in the bottom.

Materials:

- 24 inches of flexible tubing with a 3/8 inch outside diameter
- 16 oz. plastic soda or water bottle with cap.
- Approximately 8 oz. of ballast weight
- Electrical tape
- 3/8 inch drill bit and drill
- 5 gallon bucket filled with water

Procedure:

1. Drill a 3/8 inch hole in the bottle cap and the bottom of the bottle.
2. Tape the ballast weight to the bottom of the bottle.
3. Place the flexible tubing in the hole in the cap and insert it about 1 inch.
4. Tape the tubing in place.
5. Screw the cap onto the top of the bottle.

6. Place the bottle in the 5 gallon bucket and make sure your thumb is over the other end of the tubing.
7. Now remove your thumb and watch as the bottle fills with water. You should feel air rushing out of the tubing.
8. When the bottle has sunk to the bottom, blow into the tubing and watch the bottle come back to the surface.

Assessment:

- What did you observe happen?
- Why do you have to place your thumb over the end of the plastic tubing to keep the bottle afloat?
- How would you be able to put an active ballast system on you ROV?
- What would be the advantages and disadvantages to an active ballast system?

References:

Build Your Own Underwater Robot and Other Wet Projects

By Harry Bohm and Vickie Jensen

Published by Westcoast Words, Vancouver, B.C., Canada

ISBN 0-9681610-0-6

<http://www.westcoastwords.com>

3.4 Pre-lesson: How Motors Work

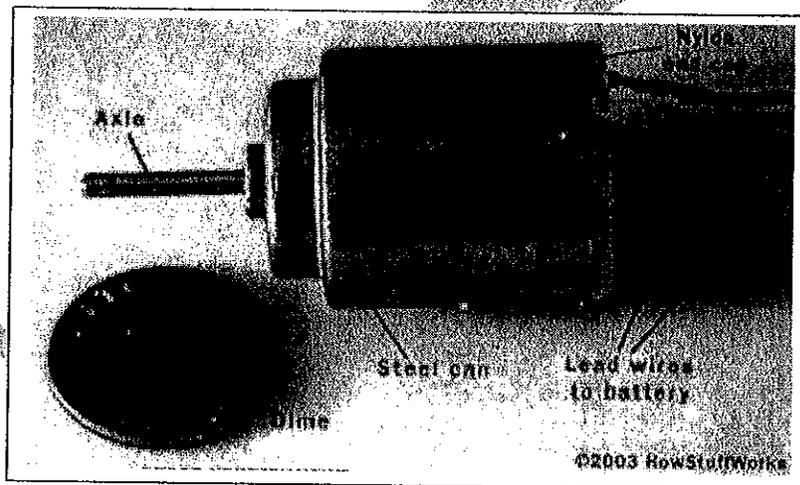
This section focuses on constructing the thrusters and the concepts that go along with the thruster assembly. Understanding how motors and propellers work will assist students in the construction process.

How Electric Motors Work

*This article is being used with permission from HowStuffWorks.
<http://electronics.howstuffworks.com/motor.htm/printable>*

by Marshall Brain

Electric motors are everywhere! In your house, almost every mechanical movement that you see around you is caused by an AC (alternating current) or DC (direct current) electric motor.

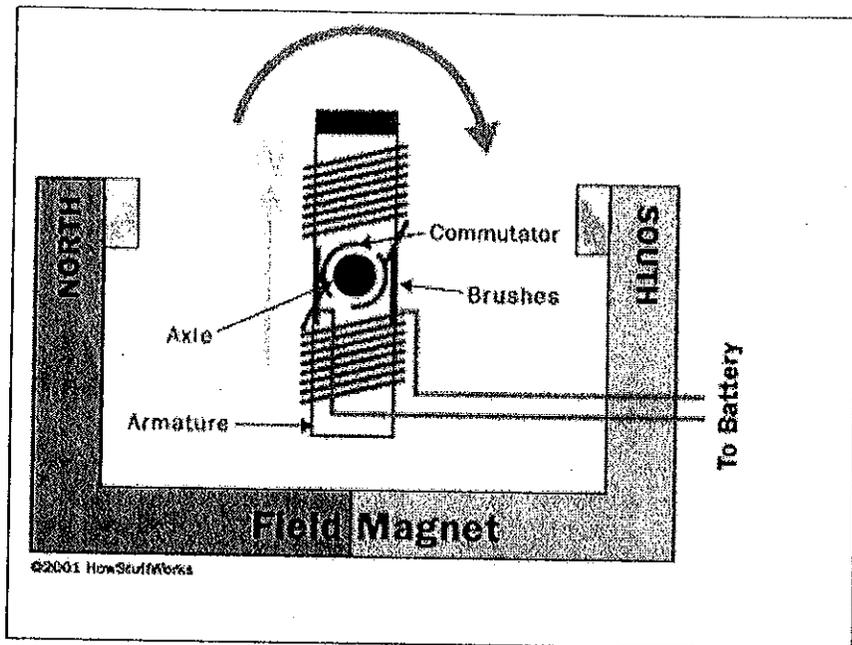


By understanding how a motor works you can learn a lot about magnets, electromagnets and electricity in general. In this article, you will learn what makes electric motors tick.

Inside an Electric Motor

Let's start by looking at the overall plan of a simple two-pole DC electric motor. A simple motor has six parts, as shown in the diagram below:

- Armature or rotor
- Commutator
- Brushes
- Axle
- Field magnet
- DC power supply of some sort



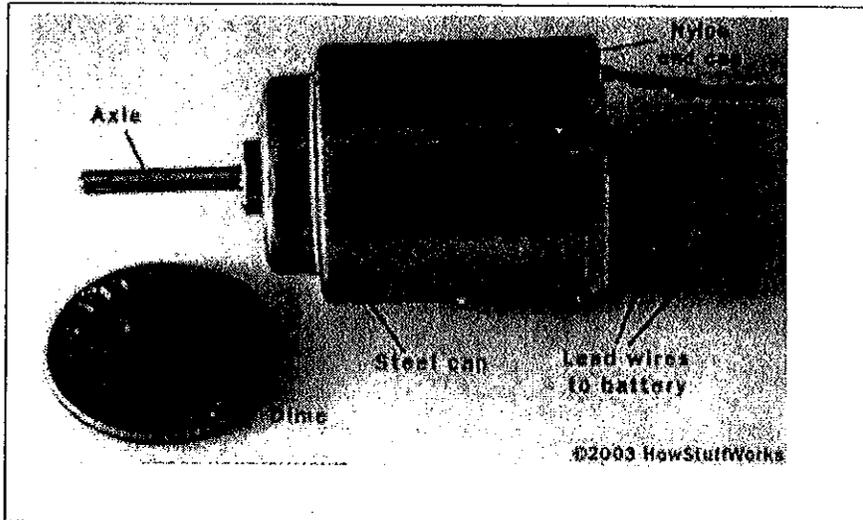
Parts of an electric motor

An electric motor is all about magnets and magnetism: A motor uses magnets to create motion. If you have ever played with magnets you know about the fundamental law of all magnets: Opposites attract and likes repel. So if you have two bar magnets with their ends marked "north" and "south," then the north end of one magnet will attract the south end of the other. On the other hand, the north end of one magnet will repel the north end of the other (and similarly, south will repel south). Inside an electric motor, these attracting and repelling forces create rotational motion.

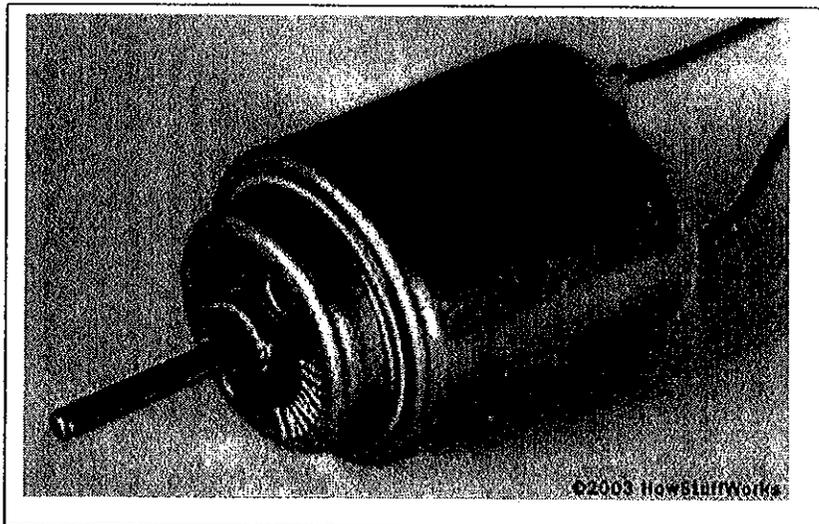
In the above diagram, you can see two magnets in the motor: The armature (or rotor) is an electromagnet, while the field magnet is a permanent magnet (the field magnet could be an electromagnet as well, but in most small motors it isn't in order to save power).

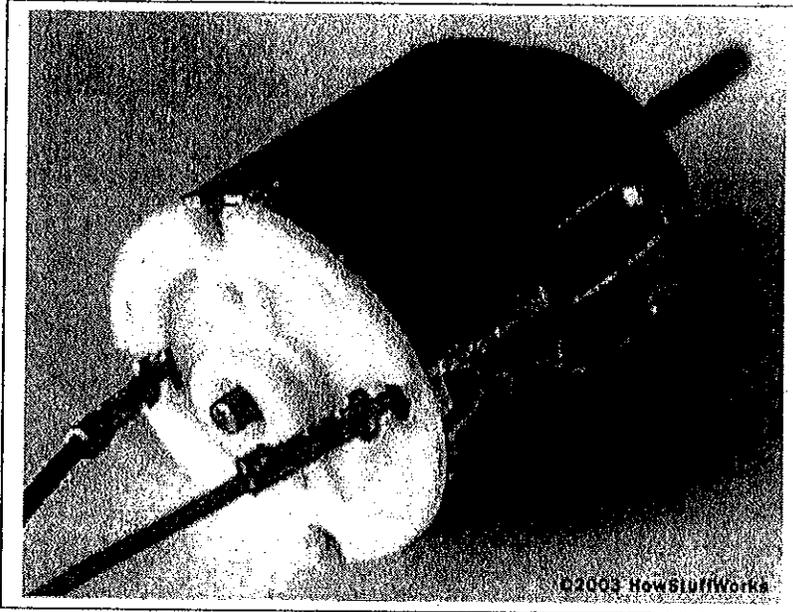
Toy Motor

The motor being dissected here is a simple electric motor that you would typically find in a toy:

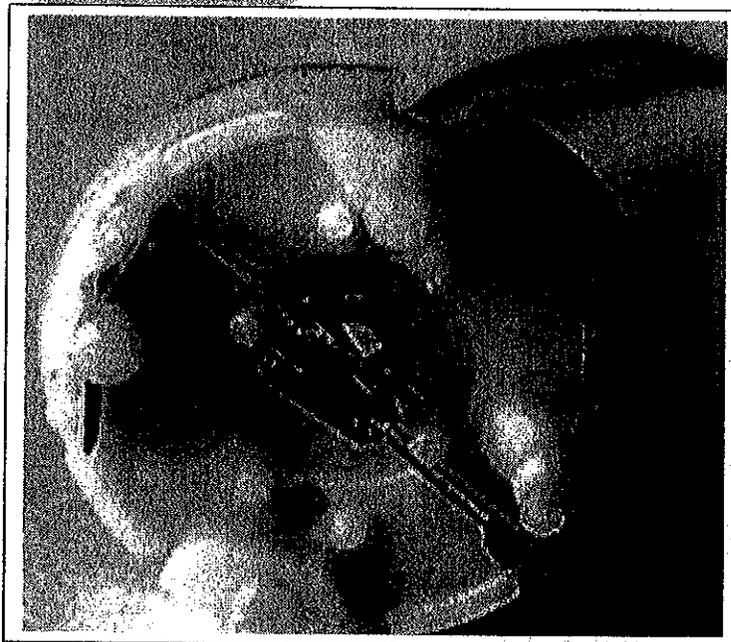


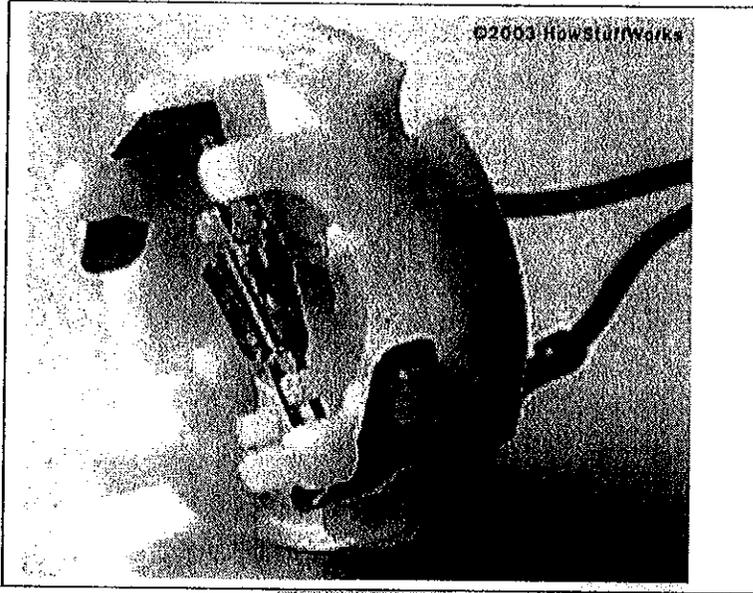
You can see that this is a small motor, about as big around as a dime. From the outside you can see the steel can that forms the body of the motor, an axle, a nylon end cap and two battery leads. If you hook the battery leads of the motor up to a flashlight battery, the axle will spin. If you reverse the leads, it will spin in the opposite direction. Here are two other views of the same motor. (Note the two slots in the side of the steel can in the second shot -- their purpose will become more evident in a moment.)





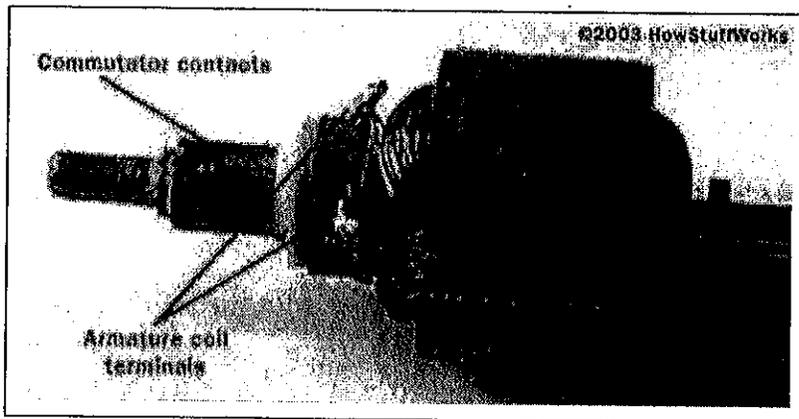
The nylon end cap is held in place by two tabs that are part of the steel can. By bending the tabs back, you can free the end cap and remove it. Inside the end cap are the motor's brushes. These brushes transfer power from the battery to the commutator as the motor spins.



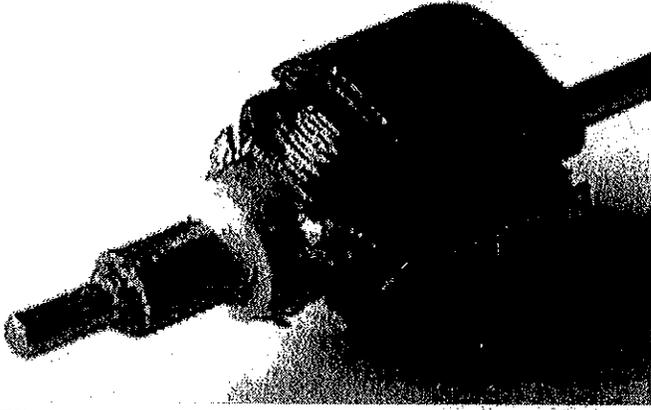


More Parts

The axle holds the armature and the commutator. The armature is a set of electromagnets, in this case three. The armature in this motor is a set of thin metal plates stacked together, with thin copper wire coiled around each of the three poles of the armature. The two ends of each wire (one wire for each pole) are soldered onto a terminal, and then each of the three terminals is wired to one plate of the commutator. The figures below make it easy to see the armature, terminals and commutator:



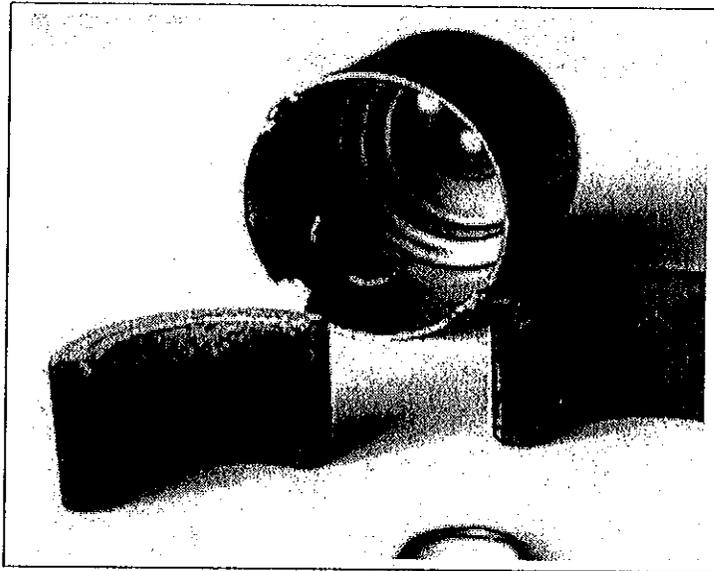
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The final piece of any DC electric motor is the field magnet. The field magnet in this motor is formed by the can itself plus two curved permanent magnets.

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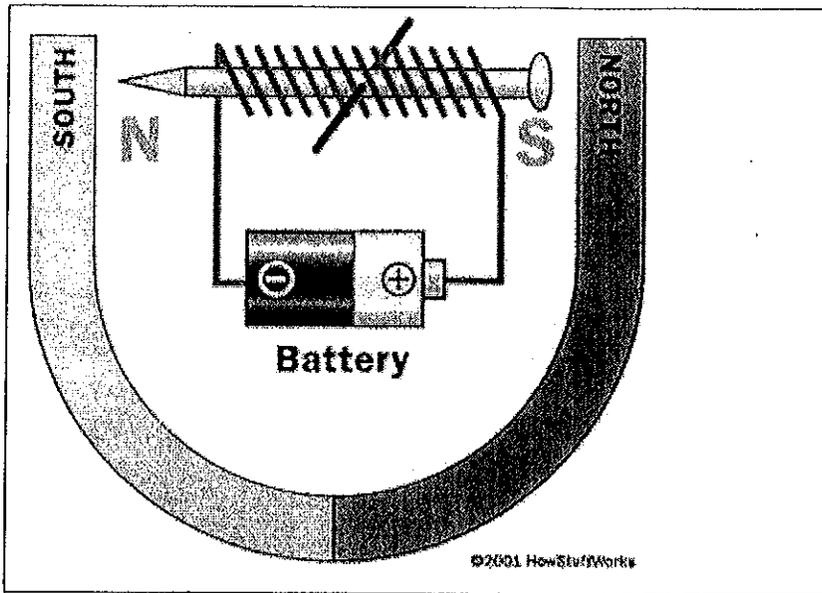
One end of each magnet rests against a slot cut into the can, and then the retaining clip presses against the other ends of both magnets.

Electromagnets and Motors

To understand how an electric motor works, you will need to understand how the electromagnet works. (See How Electromagnets Work for complete details.)

An electromagnet is the basis of an electric motor. You can understand how things work in the motor by imagining the following scenario. Say that you created a simple electromagnet by wrapping 100 loops of wire around a nail and connecting it to a battery. The nail would become a magnet and have a north and south pole while the battery is connected.

Now say that you take your nail electromagnet, run an axle through the middle of it and suspend it in the middle of a horseshoe magnet as shown in the figure below. If you were to attach a battery to the electromagnet so that the north end of the nail appeared as shown, the basic law of magnetism tells you what would happen: The north end of the electromagnet would be repelled from the north end of the horseshoe magnet and attracted to the south end of the horseshoe magnet. The south end of the electromagnet would be repelled in a similar way. The nail would move about half a turn and then stop in the position shown.



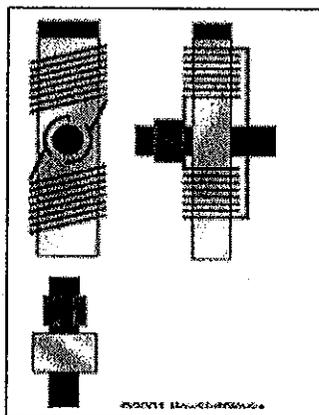
Electromagnet in a horseshoe magnet

You can see that this half-turn of motion is simply due to the way magnets naturally attract and repel one another. The key to an electric motor is to then go one step further so that, at the moment that this half-turn of motion is completed, the field of the electromagnet flips. The flip causes the electromagnet to complete another half-turn of motion. You flip the magnetic field just by changing the direction of the electrons flowing in the wire (you do that by flipping the battery over). If the field of the electromagnet were flipped at precisely the right moment at the end of each half-turn of motion, the electric motor would spin freely.

Armature, Commutator and Brushes

Armature

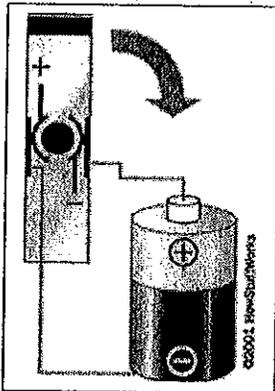
Consider the image on the previous page. The armature takes the place of the nail in an electric motor. The armature is an electromagnet made by coiling thin wire around two or more poles of a metal core.



The armature has an axle, and the commutator is attached to the axle. In the diagram to the right, you can see three different views of the same armature: front, side and end-on. In the end-on view, the winding is eliminated to make the commutator more obvious. You can see that the commutator is simply a pair of plates attached to the axle. These plates provide the two connections for the coil of the electromagnet.

Brushes and commutator

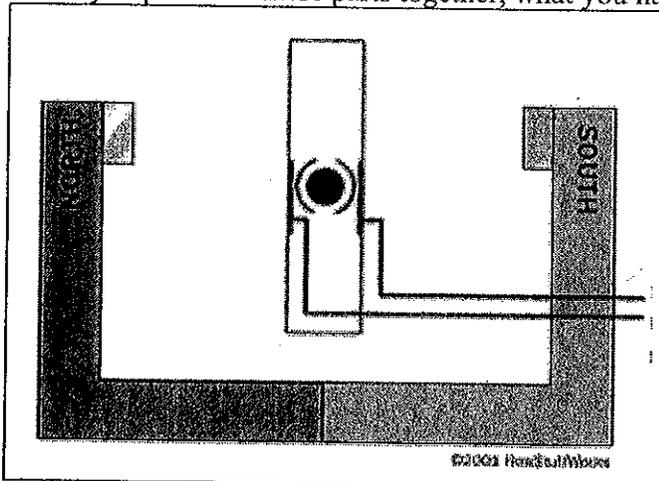
The "flipping the electric field" part of an electric motor is accomplished by two parts: the commutator and the brushes.



The diagram at the right shows how the commutator and brushes work together to let current flow to the electromagnet, and also to flip the direction that the electrons are flowing at just the right moment. The contacts of the commutator are attached to the axle of the electromagnet, so they spin with the magnet. The brushes are just two pieces of springy metal or carbon that make contact with the contacts of the commutator.

Putting It All Together

When you put all of these parts together, what you have is a complete electric motor:



Armature

In this figure, the armature winding has been left out so that it is easier to see the commutator in action. The key thing to notice is that as the armature passes through the horizontal position, the poles of the electromagnet flip. Because of the flip, the north pole of the electromagnet is always above the axle so it can repel the field magnet's north pole and attract the field magnet's south pole.

If you ever have the chance to take apart a small electric motor, you will find that it contains the same pieces described above: two small permanent magnets, a commutator, two brushes, and an electromagnet made by winding wire around a piece of metal. Almost always, however, the rotor will have three poles rather than the two poles as shown in this article. There are two good reasons for a motor to have three poles:

It causes the motor to have better dynamics. In a two-pole motor, if the electromagnet is at the balance point, perfectly horizontal between the two poles of the field magnet when the motor starts, you can imagine the armature getting "stuck" there. That never happens in a three-pole motor.

Each time the commutator hits the point where it flips the field in a two-pole motor, the commutator shorts out the battery (directly connects the positive and negative terminals) for a moment. This shorting wastes energy and drains the battery needlessly. A three-pole motor solves this problem as well.

It is possible to have any number of poles, depending on the size of the motor and the specific application it is being used in.

Motors Everywhere!

Look around your house and you will find that it is filled with electric motors. Here's an interesting experiment for you to try: Walk through your house and count all the motors you find.

Starting in the kitchen, there are motors in:

The fan over the stove and in the microwave oven

The dispose-all under the sink

The blender

The can opener

The refrigerator - Two or three in fact: one for the compressor, one for the fan inside the refrigerator, as well as one in the icemaker

The mixer

The tape player in the answering machine

Probably even the clock on the oven

In the utility room, there is an electric motor in:

The washer

The dryer

The electric screwdriver

The vacuum cleaner and the Dustbuster mini-vac

The electric saw

The electric drill

The furnace blower

Even in the bathroom, there's a motor in:

The fan

The hair dryer

The electric razor

Your car is loaded with electric motors:

Power windows (a motor in each window)

Power seats (up to seven motors per seat)

Fans for the heater and the radiator

Windshield wipers

The starter motor

Electric radio antennas

Plus, there are motors in all sorts of other places:

Several in the VCR

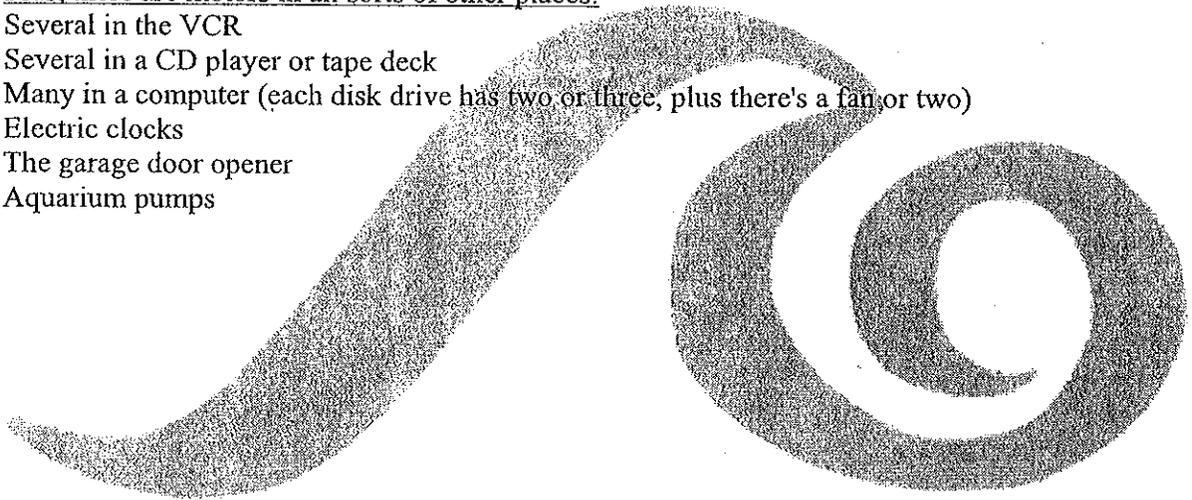
Several in a CD player or tape deck

Many in a computer (each disk drive has two or three, plus there's a fan, or two)

Electric clocks

The garage door opener

Aquarium pumps



3.5 How Propellers Work

*This article is being used with permission from Mercury Marine.
http://www.mercurymarine.com/chapter_3_-_how_propellers_work*

The "Push/Pull" Concept

To understand this concept, let us freeze a propeller just at the point where one of the blades is projecting directly out of the page (Figure 3-1). This is a right-hand rotation propeller, whose projecting blade is rotating from top to bottom and moving from left to right. As the blade rotates or moves downward, it pushes water down and back as is done by your hand when swimming. At the same time, water must rush in behind the blade to fill the space left by the downward moving blade. This results in a pressure differential between the two sides of the blade: a positive pressure, or pushing effect, on the underside and a negative pressure, or pulling effect, on the topside. This action, of course, occurs on all the blades around the full circle of rotation as the engine rotates the propeller. So the propeller is both pushing and being pulled through the water.

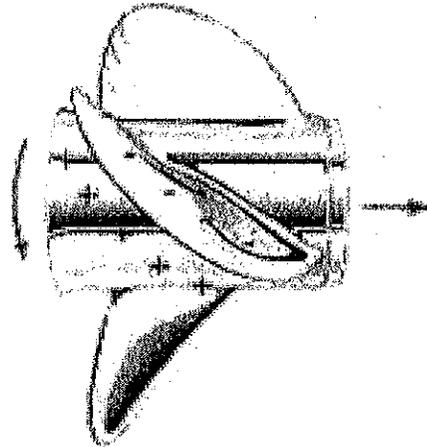


Figure 3-1
"Push-pull" concept

Thrust/Momentum

These pressures cause water to be drawn into the propeller from in front and accelerated out the back, just as a household fan pulls air in from behind it and blows it out toward you (Figure 3-2 below).

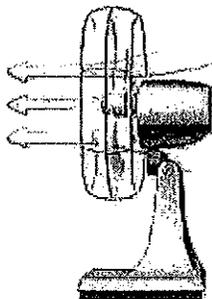


Figure 3-2
Airflow through a fan is similar to waterflow through a propeller.

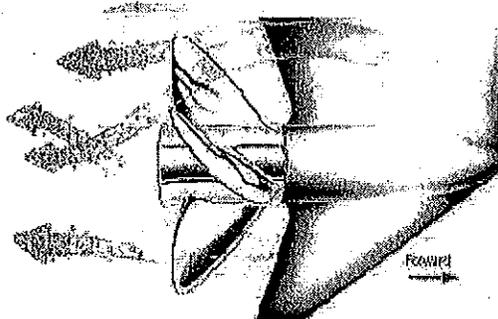
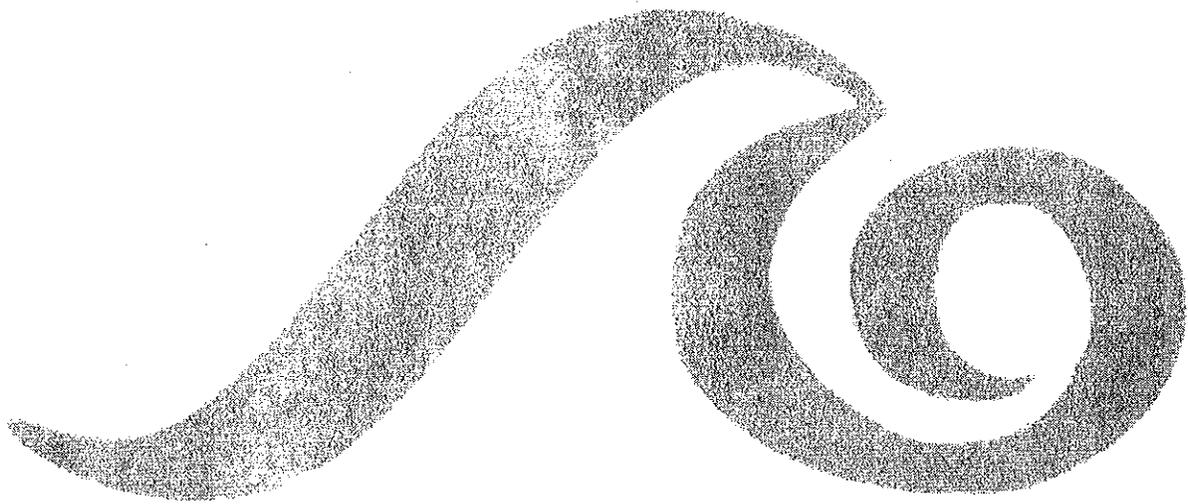


Figure 3-3
Thrust development

The marine propeller draws or pulls water in from its front end through an imaginary cylinder a little larger than the propeller diameter (Figure 3-3). The front end of the propeller is the end that faces the boat. As the propeller spins, water accelerates through it, creating a jet stream of higher-velocity water behind the propeller. This exiting water jet is smaller in diameter than the actual diameter of the propeller.

This water jet action of pulling water in and pushing it out at a higher velocity adds momentum to the water. This change in momentum or acceleration of the water results in a force which we can call thrust.



3.6 Pre-Lesson: Circuits

This section focuses on concepts that are important to know when you will build the control box for the Sea Perch. Circuits and design of control box for ease of use are the two main concepts in this section.

Make-a-Circuit

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For original PDF, please see:

<http://www.raft.net/resources/ideas/Make%20a%20Circuit.pdf>

Time Requirement:

- 1 class period

National Science Content Standards Addressed:

Unifying Concepts and Processes

- Systems, order, and organization
- Constancy, change, and measurement

Content Standard A – Science as Inquiry

- Understanding about scientific inquiry
- Abilities necessary to do scientific inquiry

Content Standard B – Physical Science

- Interactions of energy and matter
- Motions and forces

Content Standard E – Science and Technology

- Abilities of technological design
- Understanding about science and technology

Topics

Electricity, Circuits (series & parallel), Diagrams

This activity is a useful way for students to gain additional practice creating circuit diagrams after studying series and parallel circuits and predicting voltage in a circuit. An excellent tool for review!!

Materials List

- Rubber steel sheet
- Full-page labels
- Flexible magnet sheet, light color such as gray
- Matte board or other stiff material, 5: x 6 ½ +"
- Adhesive to attach rubber steel to matte board
- Access to a paper cutter and/or scissors
- Small bags (for storage pieces)
- Optional: access to a laminator
- Copy of the circuit pieces template (page 2 of PDF)

These materials will greatly aid students in designing basic electrical circuits. Open (off) and closed (on) circuits can be modeled with the lit and unlit symbols.

Assembly

The full-page labels (from page 2 of PDF could be laminated before mounting, if desired.)

1. Trim the sheet of symbols on the outer thick lines to create a 10" x 8" section.
2. Peel part of the backing and align the 10" side of the trimmed page of adhesive symbols with the 10" side of the colored magnet sheet. Peel backing and apply.
3. Cut off the excess magnet sheet. Cut apart so as to make 4 sections with matching sets of symbols.
4. Take a symbol section, cut apart the symbols, and put all the pieces in a separate bag. Repeat with the other 3 sections, creating 4 bags of symbols.
5. Cut the 4 rectangles apart to make 4" x 5 ½" sections. Peel the backing, align and apply to 5: x 6: rubber steel sections, in the upper left corner. The extra space on the bottom and right side can hold symbols that are not being used.
6. Cut matte board into sections of 5: x 6 ½" or longer.
7. Adhere each rubber steel section to the matte board or other stiff surface.

To Do and Notice

Have the students create different types of circuits using the symbols and rectangles.

- 2 bulbs in series, 2 bulbs in parallel
- 2 bulbs in parallel that in turn are in series with a third bulb
- 2 bulbs in series that in turn are in parallel with a third bulb
- 2 batteries in series, 2 bulbs in series; 2 batteries in series, 2 bulbs in parallel
- 2 batteries in parallel, 2 bulbs in series; 2 batteries in parallel, 2 bulbs in parallel

If this activity precedes work with an actual circuit, have students predict the relative brightness of the bulbs in the different circuits. What will happen when one bulb burns out in a series circuit or in a parallel circuit? Build the circuits and see! After students build the circuits the symbols can be used for reinforcement or testing.

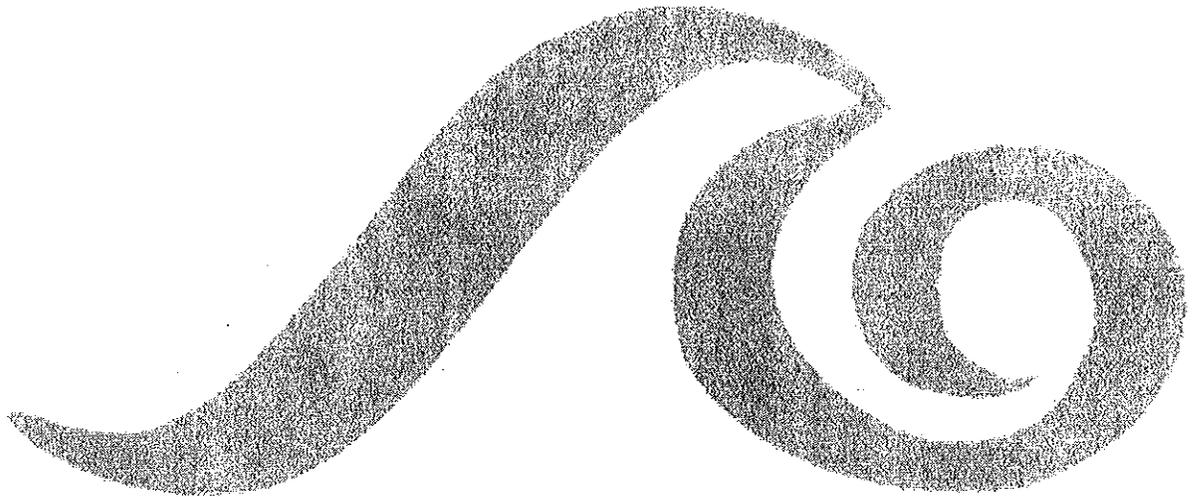
The Science Behind the Activity

A closed circuit requires a continuous path of conducting materials going from one contact of a battery (or other power sources) to the other contact. An open circuit will have a break or gap in the circuit. A closeable gap is a switch, which can open or close the circuit as desired by the

user. In a series circuit a burned out bulb creates a gap in the continuous path and stops the flow of electrons in the circuit. A burned out bulb in a parallel circuit will not break the flow of electrons in the other part(s) of the circuit.

Taking it Further

The symbols for the 3 way switch can be used to model more advanced circuits such as light in the hall and that is controlled by 2 switches.



4.0 Constructing a Sea Perch

4.1 Helpful Hints

Sea Perch Helpful Hints

- Inventory tools and materials on site/at school before ordering.
- Purchase supplies and tools needed at least 4 weeks before construction. * Be sure you check for the most updated parts and tools list from the Sea Perch website (seaperch.mit.edu)*
- Pre-assemble Sea Perch kits and tool kits before building begins. (See checklist on parts list)
- Review Sea Perch manual before building. * Be sure you check for the most updated building instructions from the Sea Perch website (seaperch.mit.edu)*
- Workspace should be in a well ventilated area with electrical outlets. Water will be needed for soldering and for clean up.
- Review safety procedures with students before each section. Be sure students wear safety glasses throughout building process.
- Have student's inventory kits before construction begins and allow them to ask questions about parts/tools.
- Keep paper towels handy for clean up.
- Visit website (<http://seaperch.mit.edu>) for video clips on building steps, curriculum connections and resources.

MIT SEA GRANT

Sea Perch *Construction Manual*

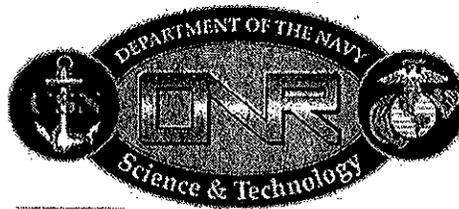
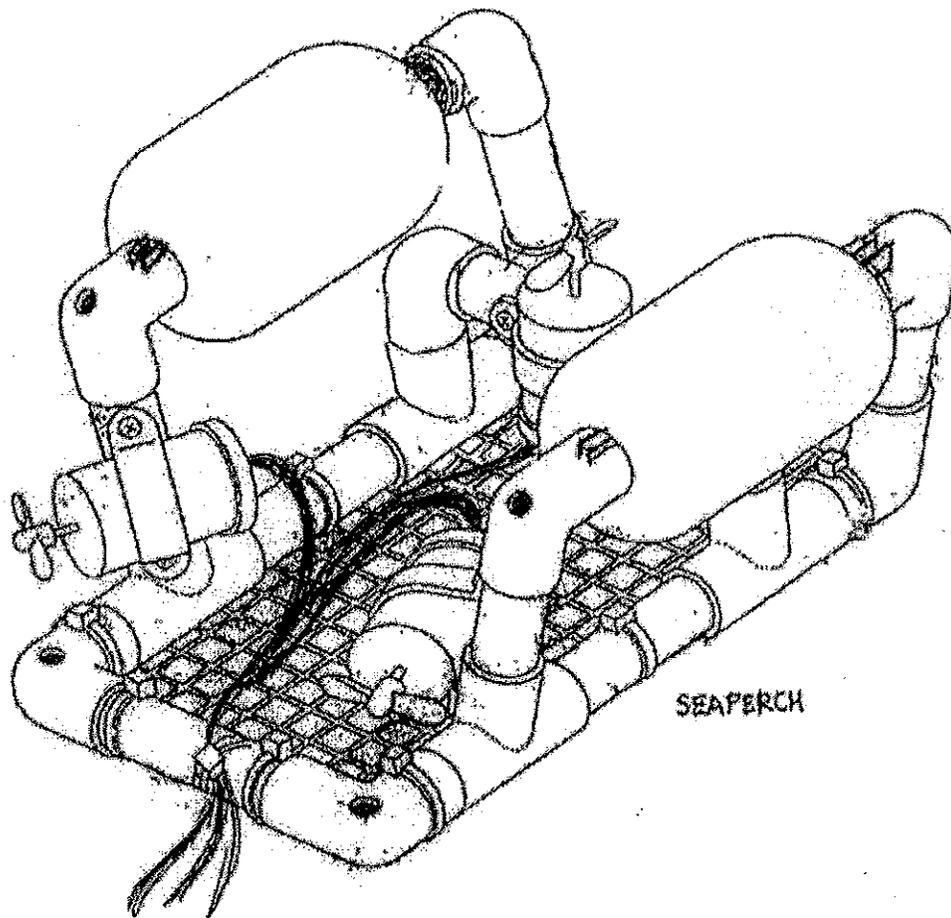


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4.2 Vehicle Assembly 1: Frame

This section contains Unit 1: Assembly of Subsystem 1, The Vehicle Frame.

The main learning concepts to the frame construction are:

- Buoyancy
- Measurement (standard and metric)
- Design

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SAFETY REMINDERS

EACH STUDENT, EVERY TIME!

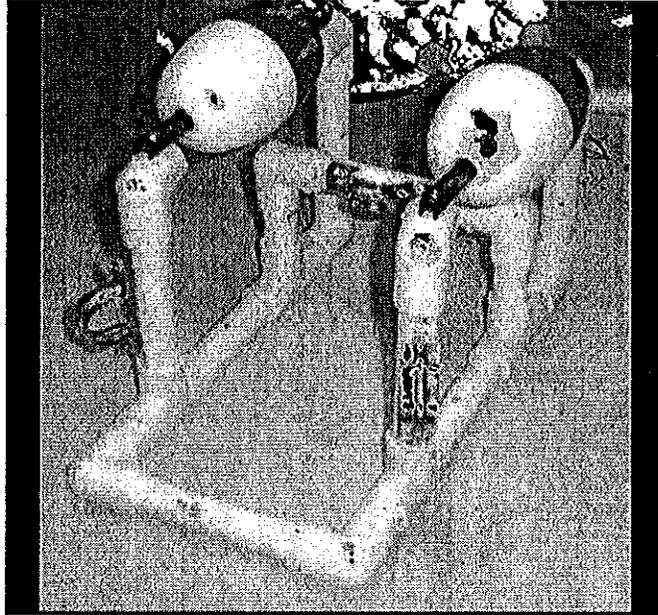
- Make sure the work space is well ventilated and well lit
- Each student must wear
 - Safety goggles
 - Close-toed shoes
 - Aprons
- Each student must have adequate space while soldering
- Make students put soldering irons in holders while asking questions, inspecting work, taking instruction and helping others
- Students **MUST USE A VISE/CLAMP WHEN SOLDERING AND DRILLING!**
- Hold solder in solder case to avoid touching lead-based solder and to avoid putting fingers too close to hot iron

It is a very good idea to practice skills such as drilling and soldering BEFORE using them on your vehicle!

UNIT 1

ASSEMBLY OF SUBSYSTEM ONE

THE VEHICLE FRAME



FOR THIS UNIT YOU WILL NEED:

Tools	Materials
Ruler	5 ft. (1.5 meters) of 1/2" PVC pipe
Marker	10 1/2" PVC elbows
PVC pipe cutter or saw	4 1/2" PVC T's
Phillips Screwdriver	15" Plastruct H-beam
Drill	2 Football Floats
1/4" drill bit	3 Motor Mounts
3/32" drill bit	6 #6 x 1/2" Screws
Vise or clamp	6 #6 washers
	Netting
	Tie Wraps (zip ties)
Time: Unit one requires approximately 2 hours to complete:	
1 class period to cut the PVC pipe and drill the holes	
1 class period to assemble the frame, and attach the payload netting and motor mounts.	

STEP 1

PURPOSE: Cut the frame parts

MATERIALS:

5' (1.5m) of 1/2" PVC pipe

TOOLS:

Ruler
Marker
PVC Pipe cutter
(or saw)

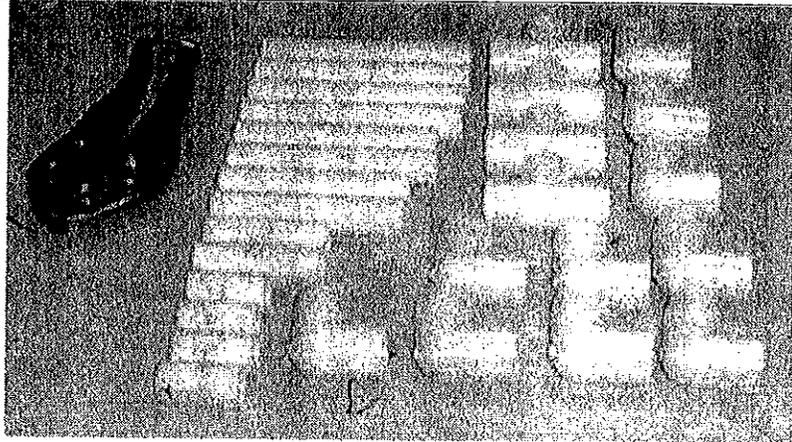


Figure 1:
PVC pipe cutter, Cut sections of PVC pipe, Elbows and T's

PROCEDURE:

1. From a straight end of the pipe measure and cut:

Two pieces – 2 1/2" or 6.4 cm long

Two pieces – 4" or 10.2 cm long

Two pieces – 4 1/2" or 11.4 cm long

Four pieces – 1 1/2" or 3.8 cm long

Four pieces – 5" or 12.7 cm long

Four pieces – 3/4" – set aside for use in the next step

Try to cut straight, so that the ends of each piece are square with the sides, but don't worry if it's not perfect.

2. You may want to write the length on each piece to keep track.

Pipe Cutting Tips

PVC pipe can be cut in many ways, each of which has its own concerns:

Ratchet Style Pipe Cutters are the easiest and safest option. To open the cutter, pull the handles FAR apart. Then click them closed through the pipe by pumping the handles together and apart.

Non-ratchet Pipe Cutters are a cheaper alternative, but more difficult to use. Place the pipe in the cutter, push down LIGHTLY, and turn the cutter around the pipe slowly, applying light pressure, until it cuts through all the way.

Hack Saws and other saws can cut through PVC, but are the most labor intensive option.

Band Saws are large pieces of shop equipment, and can be very dangerous. Make sure to get your teacher's permission and supervision before using one.

STEP 2

PURPOSE: Create drain holes in vehicle frame

MATERIALS:

10 1/2" PVC elbows

TOOLS:

Hand drill or
drill press

1/4" drill bit

Vise or clamp

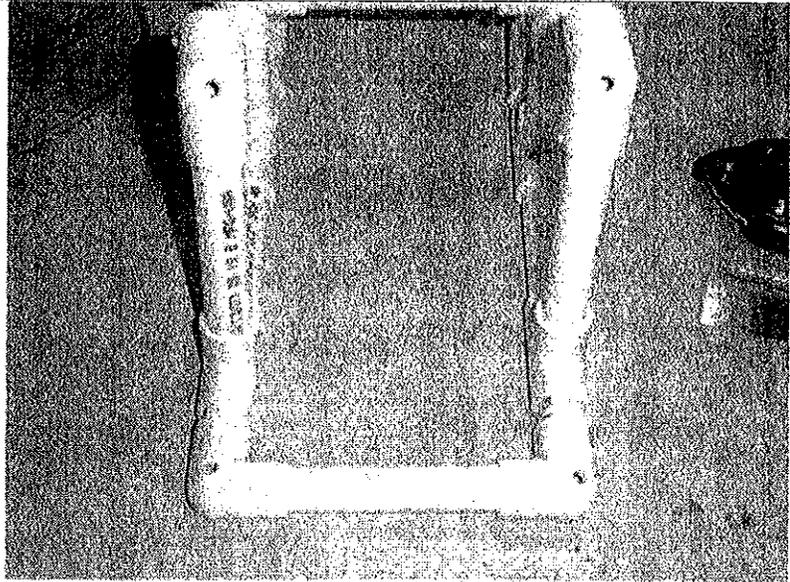


Figure 2: Drain holes drilled with 1/4" drill bit

PROCEDURE:

1. Secure a PVC elbow in the vise or clamp.
2. Place the 1/4" drill bit in the drill (or drill press), and drill a hole in the outer corner of the elbow.
3. Repeat for each of the ten PVC elbows.

These holes are meant to let water fill the frame when you put your SeaPerch in the water and for the water to drain out when you take the SeaPerch out.

Drill Safety:

Drills can be dangerous pieces of equipment, but are very useful if operated properly. Always get your teacher's permission and supervision before using a drill or other power tool. Always wear safety glasses when using a drill or other power tool.

It is good practice to secure the object you are drilling in a vise or clamp before drilling. This keeps it steady, prevents it from spinning and hurting your hand if the drill should bind, and keeps your fingers away from the drill bit while drilling.

If you do not have a vise or clamp available, push the elbow onto one end of a long (5" or more) piece of PVC pipe, and hold the pipe while drilling the hole. **DO NOT** drill the elbow while holding it in your hand!

If you do not have a vise or clamp available, push the elbow onto the end of a long (5” or more) piece of PVC pipe, and hold the pipe while drilling the hole. DO NOT drill the elbow while holding it in your hand!

STEP 3

PURPOSE: Assemble the vehicle frame

MATERIALS:

Cut pieces of pipe
from step 1

10 1/2" PVC elbows
with holes drilled from
step 2

4 1/2" PVC T's

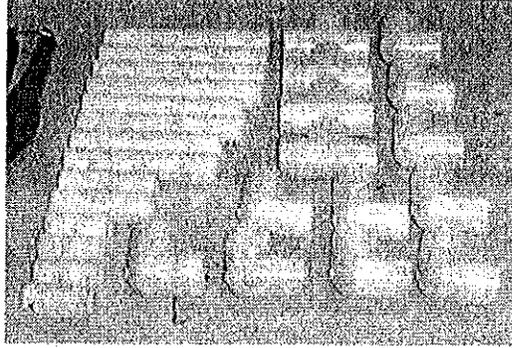


Figure 3: PVC Frame Parts

PROCEDURE:

Assemble the frame using all the PVC parts as shown in Figure 4 below.

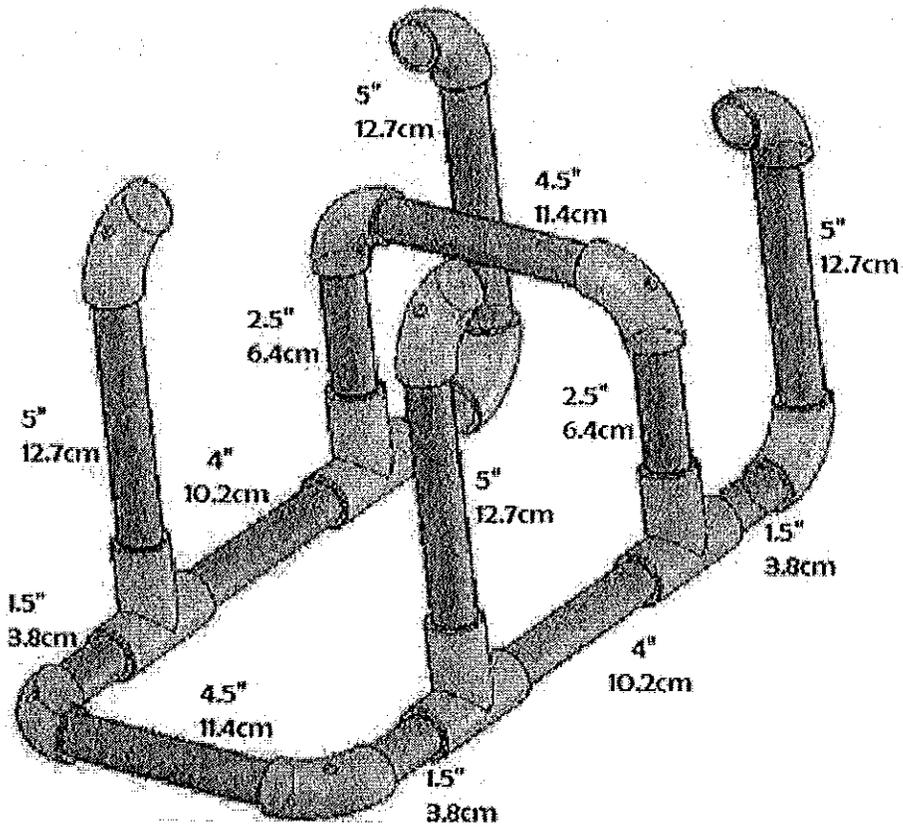


Figure 4: Frame Assembly

STEP 4

PURPOSE: Assemble the float supports and tighten the frame

MATERIALS:

Assembled frame
15" Plastruct H-beam
2 Football Floats
PVC pipe scraps

TOOLS:

PVC Pipe Cutter

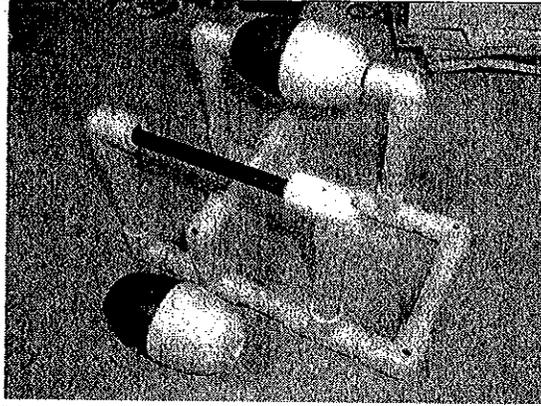
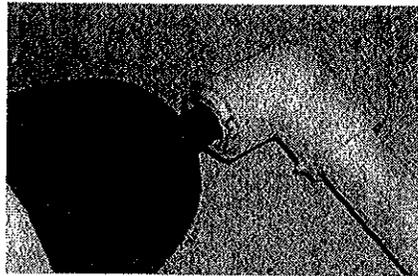
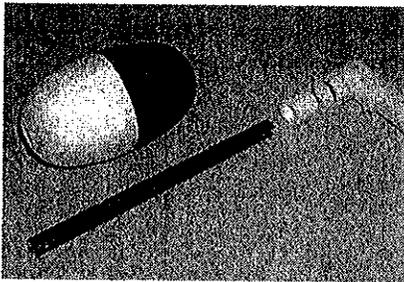


Figure 5: H-beam Assembly for floats

PROCEDURE:

1. Cut the 15" Plastruct H-beam into two 7 1/2" pieces.
2. Cut Four 3/4" (2cm) pieces of PVC pipe from your scraps.
3. Insert one of the 3/4" (2cm) PVC pipe pieces into the open end of each of the four PVC angles on the top of your vehicle.
4. Insert an H-beam through each of your floats and between each pair of PVC angles.
5. Push all parts of your vehicle frame together **HARD**, so that H-beams cannot fall out of the PVC angles.



Figures 6: Assembly of H-beam float supports.

TIP: If you place the vehicle on your work bench and push down hard from all sides, you can squeeze all the frame sections together tightly. Unless you are building a larger frame, or have PVC that remains loose, it is not necessary to glue or screw the joints.

STEP 5

PURPOSE: Attach the motor mounts to the frame

MATERIALS:

Vehicle frame
3 Motor Mounts
6 #6 x 1/2" Screws
6 #6 washers
Washers

TOOLS:

Marker
Phillips Screwdriver
Drill
3/32" drill bit

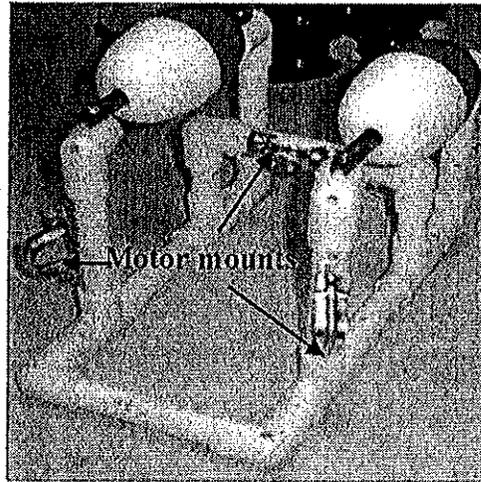


Figure 7: Motor mount placement

PROCEDURE:

1. Hold motor mounts against frame in locations shown in Figure 7. It's more important to center them between the joints on the pipe than to get the right angle around the pipe.
2. With a marker or pencil, mark vehicle frame through the holes in motor mounts.
3. Using the 3/32" drill bit, drill holes through the marks on the frame.
4. Place washers over the outside of the holes in the motor mounts, and place a screw through each washer and motor mount hole into hole in vehicle frame. If the heads on your screws are large enough that they don't pass through the holes in the motor mounts, then the washers are optional.
5. Using the screwdriver, **LOOSELY** attach the motor mounts to the frame. **DO NOT over-tighten and strip the holes in the PVC!!** You will be removing the motor mounts later anyway to get the motors under them.

Motor angle tips:

For now, don't worry about what angle your motors mounts are attached at. Since we do not glue the joints in the PVC we can adjust the angle later by simply turning the pipe in its joints using a pair of pliers. For now, it's easier to drill and attach the motor mounts on the back (outside) of the frame... we'll turn them in later.

Think about how the angle of the motors affects the performance of the ROV. What angles will get you the best forward and backward thrust? What angles will get you the best turning ability? What is the best compromise for your mission needs?

STEP 6

PURPOSE: Attach the payload netting

MATERIALS:

Netting
Tie wraps (zip ties)
Assembled Vehicle frame

TOOLS:

Scissors
Pliers

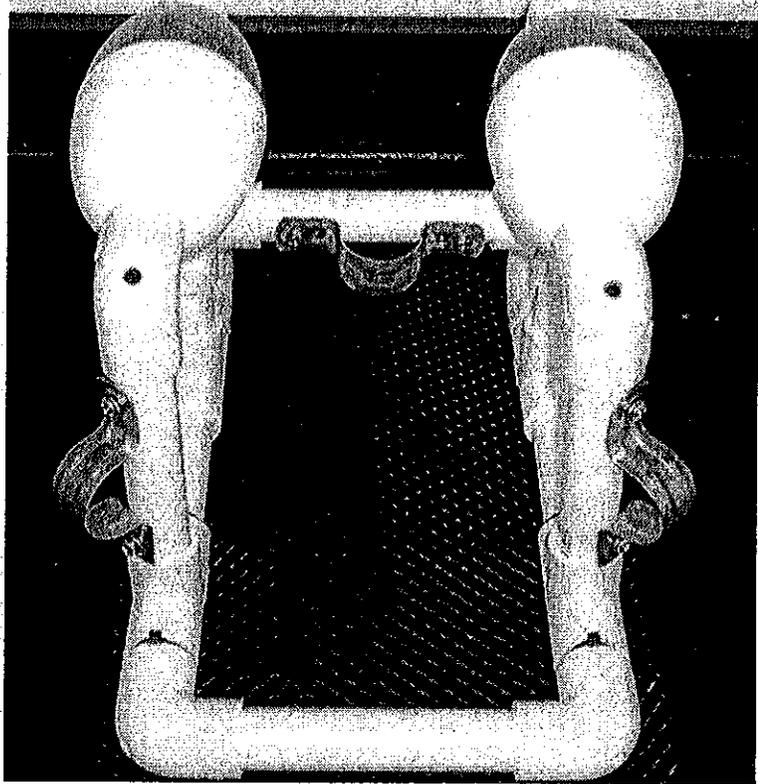


Figure 8: Net attached to frame

PROCEDURE:

1. If you wish to paint your vehicle's frame, do so before attaching netting, and make sure to use waterproof paint.
2. Place the netting underneath the vehicle frame and trim to size with scissors if necessary.
3. Attach the netting to the frame with about 6 to 8 tie wraps (aka. cable ties or zip ties). Pull them tight, using pliers if necessary.
4. Trim off the tie wrap ends with scissors.
5. You have now completed the vehicle frame of your SeaPerch ROV!

4.3 Vehicle Assembly 2: Thrusters

This section contains Unit 2: Assembly of Subsystem 2, Thrusters.
The main learning concepts to the frame construction are:

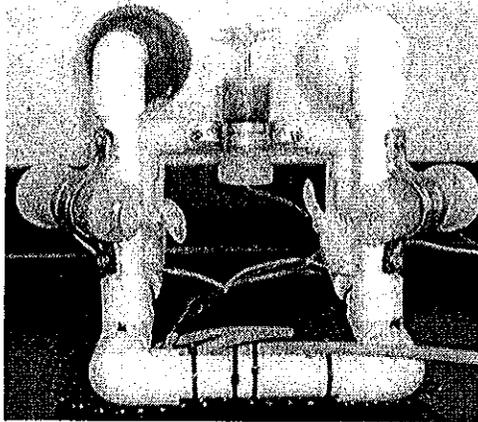
- Motor movement
- Vectors
- Soldering
- Waterproofing

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UNIT 2

ASSEMBLY OF SUBSYSTEM TWO: THE THRUSTER ASSEMBLY



FOR THIS TASK YOU WILL NEED:

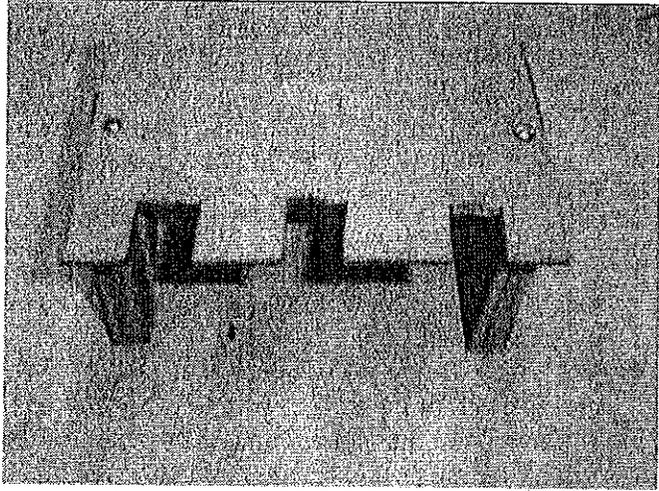
Tools	Materials
Assembled potting holder (see step 1) Drill Drill Bit: 3/32" Electric hot plate Metal cups or beakers for melting wax Lead sinkers Pliers Saw Marker Ruler Scissors Soldering Iron and solder Phillips Screwdriver Eye Protection	Tether wire 3 film cans with caps 3 12 volt DC motors 3 Propellers 3 Propeller Shafts 6 small brass nuts (#4-40) Epoxy and mixing stick Wax bowl ring Water Electrical tape Butyl Rubber tape #24 stranded hook up wire, Red #24 stranded hook up wire, Black 12 volt battery Paper towels Rubbing Alcohol Potting Holder, or wood and screws to make one.
<p>Time: Unit 2 requires about 3 hours to complete:</p> <ul style="list-style-type: none"> 1 class period to solder the tether wires to the motors 1 class period to pot (waterproof) the motors 1 class period to attach propellers, and A short amount of time to mount the motors on the frame after the epoxy has hardened 	

STEP 1

PURPOSE: Assemble the potting holder.

NOTE: The potting holder is no longer necessary with the new instructions (June 2008) for gluing the propeller on to the shaft. It is still useful, but can be substituted with a cardboard box or other raised surface with small holes in it to stand up the motors.

NOTE: The Potting Holder is used later in this unit, and will probably have ALREADY been assembled for you. If not, follow the procedure below:

<p>MATERIALS: 1 piece of thin plywood or stiff plastic 2 scrap pieces of wood 2 self tapping screws</p> <p>TOOLS: Saw Screwdriver Marker Ruler</p>	 <p>Figure 9: Assembled potting holder</p>
--	--

PROCEDURE:

1. Measure and Cut a 6" x 4" piece of thin (approx. 1/8") plywood or plastic.
2. Make three 1/2" wide 3/4" deep notches in the plywood/plastic.
***TIP:** Make three notches on two sides of the plywood/plastic to double the capacity of the potting holder
3. Measure and cut two 2 1/2" x 1 1/2" legs from the scrap wood.
4. Using screws, attach legs to the notched piece of wood.

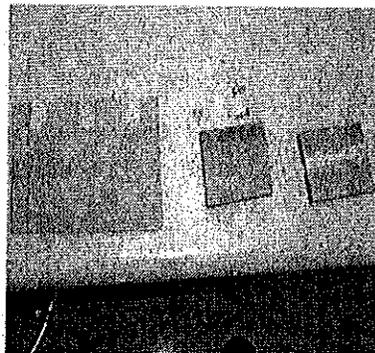


Figure 10: Potting holder materials

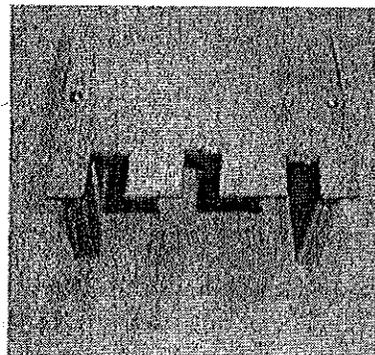


Figure 11: Assembled potting holder

STEP 2

PURPOSE: Test the motors and mark the polarity of the terminals.

MATERIALS:	3 motors	12-Volt Battery
	2 Alligator clips	2 pieces of wire, red and black
TOOLS:	Marker	

It is necessary to mark the polarity of the motor terminals, since we will not be able to see the polarity markings on the motor housing once we wrap it in electrical tape.

PROCEDURE:

1. Make a pair of test wires: (these are temporary, and will be disassembled for making your control box in unit 3)
 - a. Strip 1/4" (7mm) of insulation from both ends of the loose black wire, without cutting the copper threads inside. Connect the black wire to the black alligator clip by twisting or screwing it on. **(NO SOLDER)**.
 - b. Repeat with the loose red wire and the red alligator clip.
2. Look carefully to see if the terminals on your motors are pre-marked with polarity (+/-). If so, continue with #3, if not, skip to "Trouble Shooting" below.
3. Locate the negative (-) terminal on the motor, and mark the actual terminal with a black marker. Connect the exposed end of the black wire (-) to the negative (-) motor terminal.
4. Mark the positive (+) terminal with a red marker (if available). Connect the exposed end of the red (+) wire to the positive (+) motor terminal.
5. Holding on to the motor, connect the alligator clips to the corresponding (+/-) battery terminals and ensure the motor is in good working order. The shaft should spin rapidly counter-clockwise.
6. Repeat steps 3 through 5 with the other 2 motors. If any motor is not working, get a replacement. Motors should spin COUNTER CLOCKWISE.

TROUBLE SHOOTING: IF you cannot see polarity markings (+ and - signs) near the terminals of the motor, THEN follow this procedure to find the + and - motor terminals:

1. Put a small piece of tape on the motor shaft, so you can easily see it spin.
2. Connect the black wire to one terminal and the red wire to the other, and connect the alligator clips to the proper battery terminals (red on +, black on -)
3. Observe the rotation direction of the motor.
4. If the motor shaft turns *counter-clockwise*, then you have chosen the correct terminals: black wire on negative (-) and red wire on positive (+).
5. If the motor shaft turns *clockwise*, then the wires are reversed. Switch them around and make sure the motor turns counter-clockwise
6. Mark at least one motor terminal with the correct color(s): (-)=black, (+)=red

WARNING - TO AVOID ELECTRIC SHOCK AND SEVERE BURNS:

DO NOT touch exposed wires to the battery terminals.

DO NOT touch the battery terminals with or ANY metal object, especially tools!

STEP 3

PURPOSE: Seal the motors from the wax.

MATERIALS:

3 12 volt DC Motors
Electrical tape

TOOLS:

Scissors

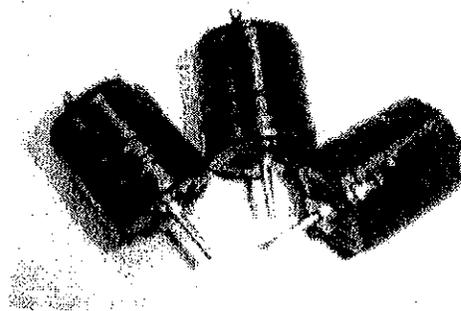


Figure 12: 12VDC Motors sealed with electrical tape

PROCEDURE:

1. Make sure the negative and/or positive terminals are marked on each motor so that you can tell them apart after covering the motor in tape. If not, go back to the previous step.
2. Completely wrap each motor with electrical tape to seal the holes. See the tips below before you begin!
3. Make sure **ALL** holes are sealed, and the motor is still thin enough to easily slide into the container (film can).

Motor wrapping tips:

The purpose of wrapping the motors is to keep the molten wax out of the motor when we waterproof it, so **EVERY** hole must be sealed, and folds in the tape where wax could pass through must be avoided. The care with which this is done will help determine how long your thrusters will last.

It may be easiest to cover the ends of the motor first with short pieces of tape, and then wrap longer pieces around the sides. But don't make it too thick by wrapping too much tape around the sides, since the motor still has to be thin enough to fit inside the thruster container (film can), while leaving some room for wax around it.

You can push the tape right over the motor terminals so that they punch right through the tape. It is best to avoid putting tape on the motor shaft, as this will reduce the efficiency and possibly stop the motor. Make sure **ALL** holes are sealed, and the motor is still thin enough to easily slide into the container.

STEP 4

PURPOSE: Drill holes in the thruster containers.

MATERIALS:

3 film cans with caps
1 12 volt DC motor
1 pair of test wires

TOOLS:

Drill
3/32" drill bit

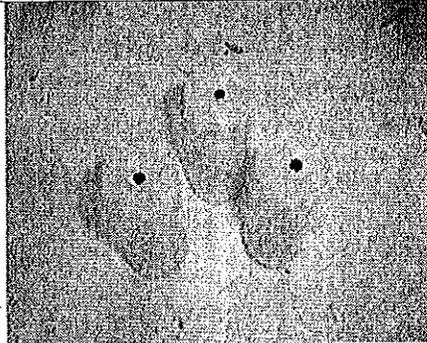


Figure 13: Drilled motor canisters (film cans)

PROCEDURE:

1. Using the 3/32" drill bit, drill a hole in the center of each film can cap. The holes in the caps are where the wires pass through, so high precision is not essential.
2. Now drill a hole in the bottom of each film can (see Figure 13). The holes in the cans are where the motor shafts pass through the cans, and form the shaft seals, so it is **VERY IMPORTANT** that these holes are drilled extremely carefully. First, pick any plastic lumps off of the center of the can with your fingernail or a screwdriver. Then carefully and slowly drill the hole straight into the very **CENTER** of the can. Pull the drill straight out to avoid enlarging the hole.
3. You can use one of your motors to polish the hole in the can to the perfect size. Hook the motor up to the battery using the test wires. With the motor spinning, carefully push the motor shaft into the hole you drilled, and hold it there for a few seconds, until the motor spins freely.
4. Check each can to make sure that the hole is drilled exactly in the center, and that a motor fits inside easily.

Drill Safety:

Always get your instructors permission and supervision before using a drill or other power tool. Always wear safety glasses when using a drill or other power tool. It is good practice to secure the object you are drilling in a vise or clamp before drilling. This keeps it steady, prevents it from spinning and hurting your hand if the drill should bind, and keeps your fingers away from the drill bit while drilling.

STEP 5

PURPOSE: Attach the tether wires to the motors.

MATERIALS:

3 motors sealed with tape
3 film cans and caps with
holes drilled in step 4
Tether wire
Solder

TOOLS:

Drill
3/32" drill bit
Soldering iron

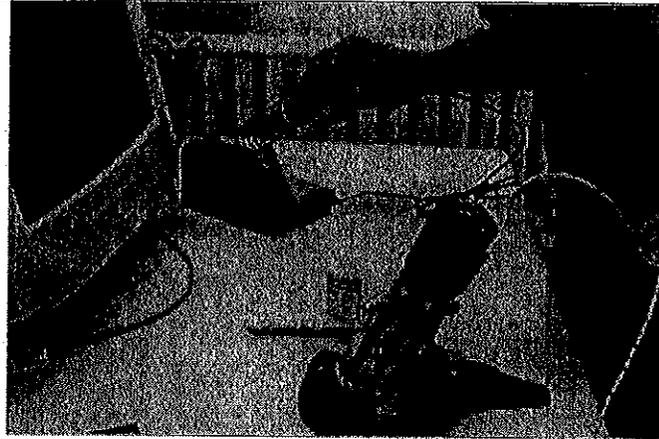


Figure 14: Tether wire soldered to motor

PROCEDURE:

1. On one end of the tether cable, strip off about 15" (38cm) of the outer sheath, being careful not to nick any of the inner wires. This can most easily be done with an Ethernet cable stripper. If using scissors, use extreme care not to cut the insulation on the inner wires. Using a knife is not recommended.
2. Separate the four twisted pairs in the stripped section, as shown in Figure 15 on the next page. The brown pair is not used, and can be left hanging for now.
3. Thread about 4" (10cm) of twisted pair through the hole in each film cap, and tie a knot **INSIDE** the cap for strain relief (Figure 16B).
4. Strip about 1/4" (7mm) of insulation from the end of each wire, for all 3 pairs.
5. Take a pair of wires with attached cap, and one of your taped motors. Solder one wire onto each of the two terminals on the motor: colored wire to (+), and white wire to (-). Repeat for each motor and tether wire pair. (Figure 16C).
6. Check that all solder connections are good with the test wires **BEFORE** moving on to waterproofing. Attach test wires to appropriate wires at the control box end of the tether (Pos to Pos, Neg to Neg). This will also insure that you did not cut any of the inner wire pairs when stripping the outer sheath of the tether.

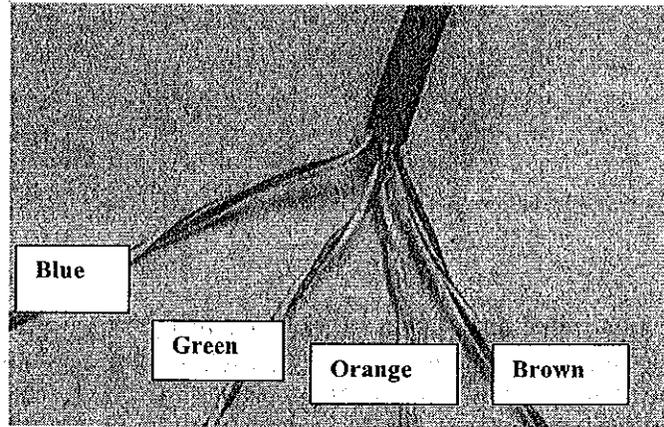
SEE FIGURES ON THE NEXT PAGE...

Soldering Safety:

Always wear safety glasses when soldering. Most solder is made of lead, which is poisonous. Avoid breathing the fumes, don't put it in your mouth, and wash your hands after working with it.

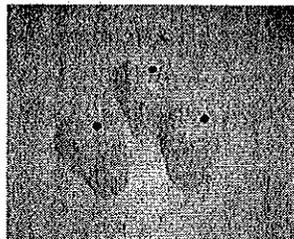
Soldering Technique:

If you have not soldered before, have your instructor show you how, and practice on some pieces of scrap wire. For best results, always twist the inner copper threads of a wire together right after you strip off the insulation, so that they don't fray and break off. Then poke the wire through the hole in the motor terminal, and twist it back around itself to make a good mechanical connection. Apply heat with the soldering iron to get the wire and the terminal up to solder melting temperature. Applying a little solder to the tip of the soldering iron helps transfer heat. Be careful not to get it so hot that you melt any surrounding plastic, or wire insulation. Once the parts are up to temperature, apply the solder wire between the soldering iron and the connection, and melt a small drop of solder onto the connection. Remove the solder wire, but keep the soldering iron on the connection for a moment to allow the solder to "soak in", then remove the soldering iron. Try to keep the connection still until the solder cools and hardens (turns dull).

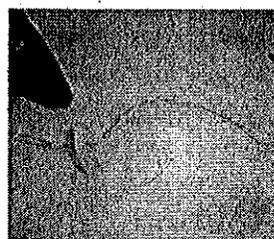


POSITIVE (+)	NEGATIVE (-)	THRUSTER
Green	Green & White	Starboard (right)
Blue	Blue & White	Port (left)
Orange	Orange & White	Vertical
Brown	Brown & White	Not Used

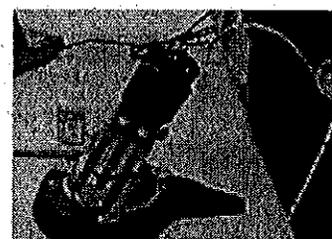
Figure 15: Tethered wire color index



A:
Film cans drilled
with 3/32" drill bit



B:
Tether wire threaded
through film cap

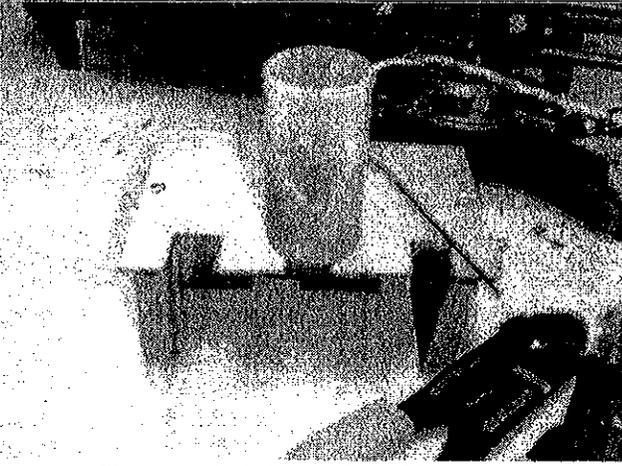


C:
Tether wire soldered
to motor

Figure 16A-C: Wiring the 12 volt DC motors

STEP 6

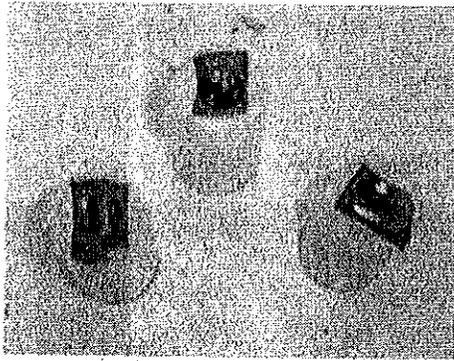
PURPOSE: Potting (waterproofing) the motors with wax.

<p>MATERIALS: 3 Drilled Film cans Wax bowl ring (½ ring) Electrical tape Sealed motors Water</p> <p>TOOLS: Metal cup(s) Lead Sinkers Electric hotplate Potting holder Pliers Scissors Eye Protection Paper Towels (for cleanup)</p>	 <p data-bbox="726 859 1157 890">Figure 17: Motor placed into wax</p>
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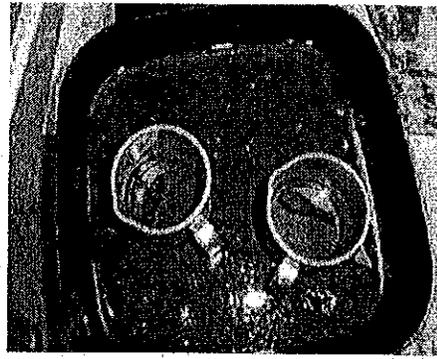
PROCEDURE:

1. Put a small piece of electrical tape over the hole in the bottom of each of your 3 motor containers (film cans). The tape should be tapped on **VERY LIGHTLY**, so that it keeps the molten wax from flowing out the hole, but pushes aside easily when the motor shaft pokes through the hole. (Figure 18A)
2. Your instructor will probably have wax melted for you. (Figure 18B) If not, follow the steps under “Wax Melting Tips” on the following page.
3. Put on your **SAFETY GLASSES** and apron before working with hot wax.
4. Using pliers to lift a cup of molten wax, fill one film can with about 1/4 inch (7mm) of wax, not more! (Figure 18C)
5. Quickly but carefully place one of your sealed motors in the wax. Wiggle the motor until the shaft pokes through the hole in the bottom of the film can. It may take a little wiggling to get the shaft to go through, but **DO NOT** push so hard that you poke another hole in the can! This happens more easily than you might think, since the plastic softens when heated by the wax. Get the motor in the container and the motor shaft through the hole quickly, since the wax cools and hardens rapidly when the cold motor touches it (Figure 18D). The wax should push partway up around the sides of the motor, but should not fill in above the motor.
6. Repeat for each of your 3 motors.
7. Let the wax cool and harden. One end of your motor is now sealed in the wax, so be careful not to push on the motor shaft and break the seal.

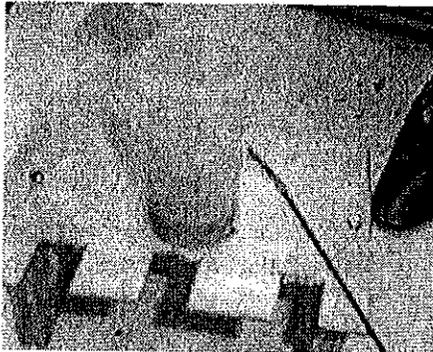
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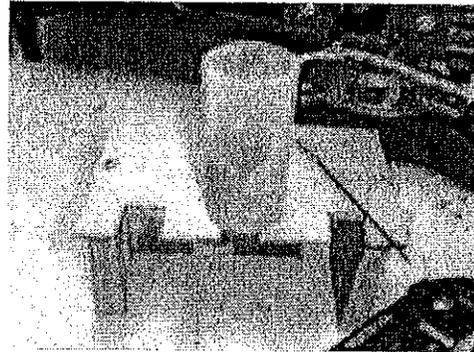
A: Film cans with tape over holes



B: Melting wax in metal cups



C: Film can partially filled with wax



D: Motor placed into wax

Figure 18 A-D: Potting the motors—first wax

Wax Melting Tips:

Always wear SAFETY GLASSES when working with hot wax. The soft wax used in this project can get very sticky. An apron and gloves (latex, nitrile, etc.) are highly recommended. To facilitate cleanup, put a drop cloth on the work bench, on the ground below it, and on the wall behind it. Avoid getting wax on your clothes. To get wax off your skin, wash with warm water and dish soap.

1. Fill the electric hot plate or pan with a small amount of water, about 1/2" (1.5cm) deep. Make sure to keep adding water to the pan as it evaporates. DO NOT let the pan boil dry, as the wax will get VERY hot.
2. Turn the heat on to low or medium. It should get hot but not quite boil the water.
3. Place a couple lead sinkers or other small weights in your wax melting cup(s), to keep it from floating in the water. Fill the cup(s) with wax and place the cup(s) into the water in the hotplate. The wax will melt slowly. (Figure 18A)
4. The molten wax is hot, but should not be hot enough to burn the thick skin on your the palms of your hands. More sensitive skin or large quantities of hot wax may cause burns. In case of a burn, quickly rinse the area with LOTS of cold water.
5. One wax ring will usually pot about 6 motors (enough for 2 SeaPerch ROVs).

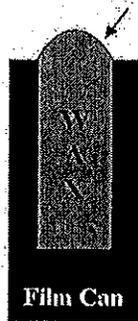
8. Once all three of your containers have a motor in them, we will fill them the rest of the way with wax, in 2 steps. (Note, this is different from the old procedure, where we mounted the propeller before filling the containers with wax.)
 9. Using pliers to lift the hot cup of wax, fill the container with wax up to 1/2 inch below the top (Figure 19A & B). (We fill them up only partway, since the wax shrinks as it cools, and we want to make sure everything is filled with wax, not air pockets.) Pour the wax so that it fills in all the air spaces around the motor.
 10. Lift your container and look at it from the side to see if you have any air bubbles. Get out any air bubbles while the wax is still liquid by squeezing the container.
 11. Set the container up on your potting stand to cool, and repeat for the other two.
 12. While you are waiting for your wax to cool, make sure your SAFETY GLASSES are on, and put on an apron and gloves since the wax often squirts out during the next steps!
 13. Once the wax has cooled, push the caps up to the knots in the wires and coil the wires into the cans. Make sure the caps go on well, and then remove them again.
 14. Using pliers to lift the hot cup of molten wax, fill one container to the top with wax, creating a positive meniscus (Figure 19C).
 15. Quickly but carefully roll the cap onto the container, leaving as little air inside as possible (Figure 19D). Watch for wax squirting out the hole in the cap!
 16. Repeat these steps for the other 2 motors, and let the wax cool and harden.
- *TIP- Once wax is hardened, recheck motors with test wire to make sure connections are still good, and wax did not seize the motor.**



A: Second wax layer



B: Filled part way



C: Positive meniscus



D: Filled all the way

Figure 19 A-D: Potting the motors – Final two wax steps

STEP 7

PURPOSE: Mounting the propellers on the motors.

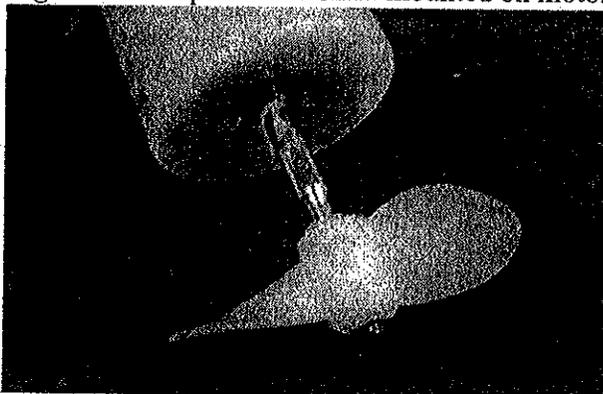
MATERIALS:

3 propellers
3 prop shafts
6 small brass nuts
3 potted motors

TOOLS:

Epoxy
Mixing stick
Paper Towels
Rubbing Alcohol

Figure 20: Propeller and shaft mounted on motor.



The procedure for mounting the propeller on the motor has changed (August 2007), from one using a bushing and a vice to push it on, to one using a propeller shaft adapter, nuts, and epoxy to secure them.

PROCEDURE:

1. **WIPE ALL WAX OFF** of the motor shaft with a paper towel and rubbing alcohol (if available).
2. Look at the propeller and note that the side of the propeller with the groove in it is the side that goes towards the motor.
3. Screw one of the brass nuts onto each propeller shaft, as far as they will go.
4. Prepare your workspace to quickly glue everything, since with many epoxies (including the one specified in the parts list), you will only have about **3 minutes** of working time before they get too stiff to use. Lay out your three potted motors, your propeller shafts with a nut on each, your three propellers, and your three remaining nuts (Figure 21).

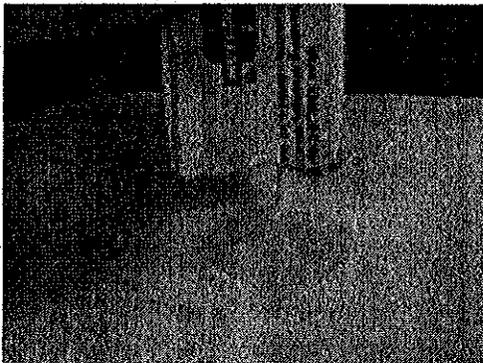


Figure 21: Parts ready to assemble

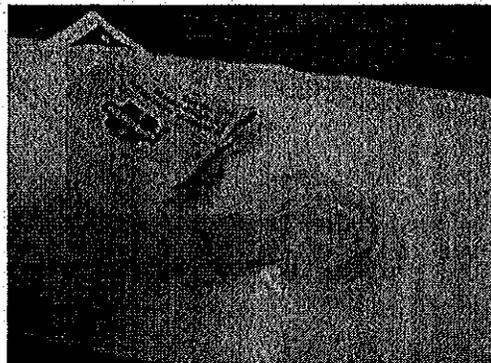
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5. Get out your epoxy, mixing stick and a sheet of paper to mix on.
 6. Mix the epoxy. If you are using the packets specified in the parts list, fold the packet so that the two halves are together. Tear off one end and squeeze the contents of both halves onto your piece of paper (Figure 22A). Quickly mix the contents together with the mixing stick until they are fairly uniform (Figure 22B).
 7. Use the mixing stick to put a drop of epoxy on the propeller shaft and the nut, to hold the nut in place. Put another drop of epoxy on the threaded part of the shaft to hold the propeller (Figure 22C).
 8. Place the propeller onto the threaded part of the shaft, grooved side first (Figure 22D). Put a drop of epoxy on the end where the threads stick out, and screw the remaining nut on finger tight, making sure it is held by epoxy (Figures 23A & B).
 9. Place a drop of epoxy on the hollow end of the propeller shaft, and on the tip of the motor shaft (Figure 23 C). Push the hollow end of the propeller shaft onto the motor shaft, but **do not let the epoxy or the propeller shaft touch the motor canister!** (Figure 23D).
 10. Repeat steps 6 to 8 for the other two motors before the epoxy hardens.
- *TIP- It is a good idea to share epoxy between groups of students, as each packet can mount up to ~10 prop shafts**

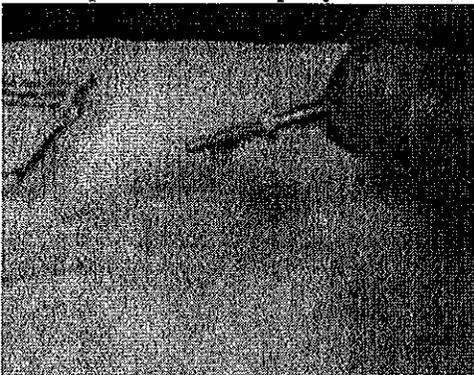
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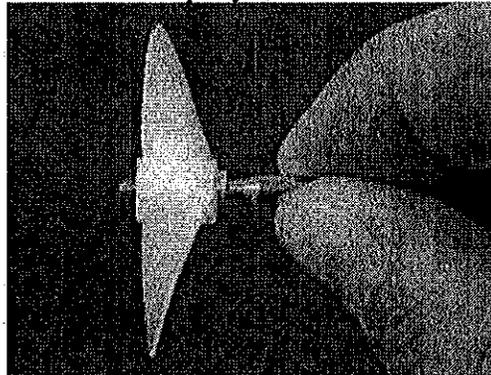
A: Squeeze out the epoxy



B: Mix the epoxy



C: Drop epoxy on nut and threads

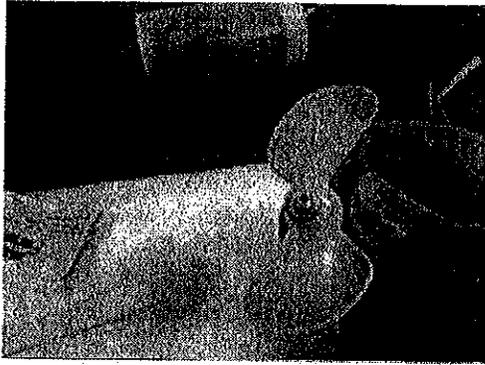


D: Place propeller on the shaft

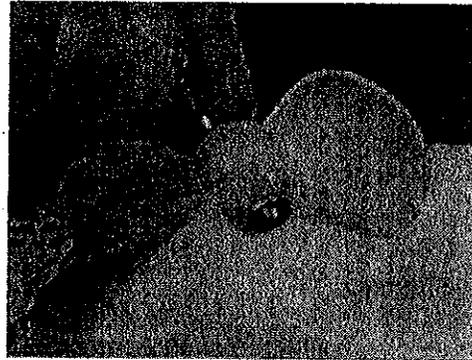
Figure 22 A-D: Mixing epoxy and attaching propeller.

Put your motors aside and allow the epoxy to harden to handling strength (60 minutes for the specified epoxy) before touching them again.

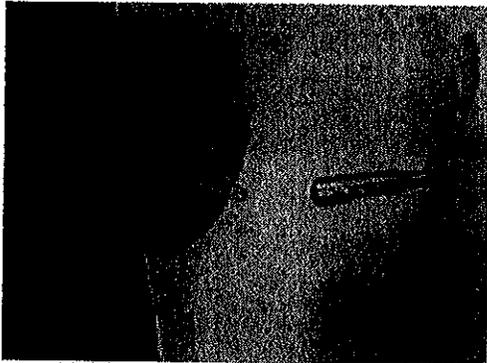
11. It takes most epoxies about 24 hours to harden to final strength. Do not turn on the motors or otherwise stress the epoxied connections until this time has passed.



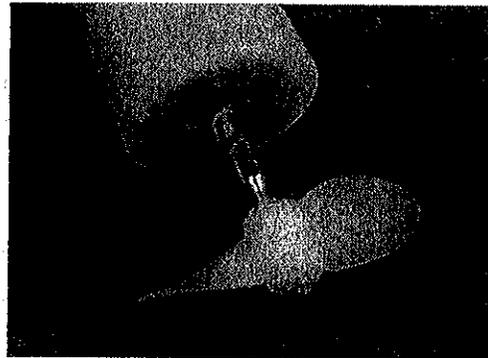
A: Place nut and epoxy on prop



B: Prop epoxied to shaft



C: Epoxy on motor and prop shafts



D: Prop shaft mounted on motor

Figure 23 A-D: Attaching prop to shaft and shaft to motor

BE CAREFUL that props do not push back due to hydraulic pressure, if this happens lightly push the shaft towards the motor for three minutes, until the epoxy dries and the shaft no longer slides away from the motor.

STEP 8

PURPOSE: Mount the thrusters on the vehicle frame.

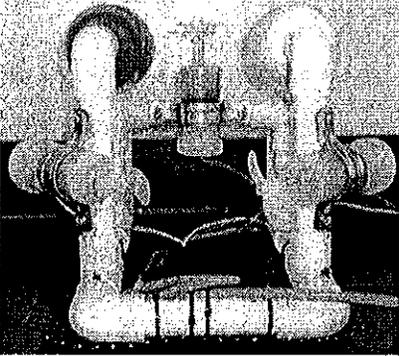
<p>MATERIALS: Assembled thrusters Assembled frame</p> <p>TOOLS: Phillips Screwdriver</p>	
--	--

Figure 24: Mounted thrusters

Note: This step should only be done after the epoxy on the propellers has hardened to handling strength (60 minutes for the specified epoxy), but may be rushed as long as you do not turn the propeller shafts or stress the newly epoxied connection.

PROCEDURE:

1. Using the screwdriver, remove the motor mounts from the frame.
2. Place a thruster inside each motor mount, according to the table below. The motor mount should go over the back end of the motor. It should not be over the back of the can where there is only wax, or over the center of the motor, where it might squeeze the motor casing, but over the back end of the motor, which will best resist the pressure of the motor mount.
3. Reattach motor mounts to the frame. It's OK if the motor cans get squeezed a little. Tighten screws just enough to hold the motor firmly, but be careful not to strip the hole in the PVC (tighten screws equally, three turn top, three turns bottom, etc., this will avoid stripping the PVC, and give you a tighter fit). If you do, re-drill the holes on another side of the PVC. It is fine if motor cases look "pinched" between the mount and the PVC.
4. You can now use pliers to turn the PVC that the motors are mounted on to get the motor angles you want. This is a good time to think about thrust, vectors and propulsion. How do the angles of the motors affect the performance of the ROV? What angles will get you the best forward and backward thrust? What angles will get you the best turning ability? What is the best compromise for your mission needs?

***TIP** It is easier to mount center thruster first, then mount the two side thrusters

POSITIVE (+)	NEGATIVE (-)	THRUSTER
Green	Green & White	Starboard (right)
Blue	Blue & White	Port (left)
Orange	Orange & White	Vertical
Brown	Brown & White	Not Used

STEP 9

PURPOSE: Waterproof the tether cable.

MATERIALS:

Completed frame with thrusters
Butyl Rubber tape
Electrical tape

TOOLS:

Scissors

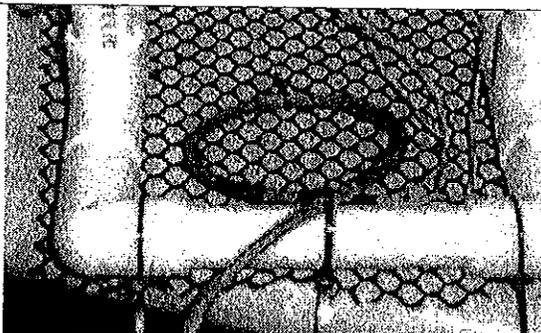


Figure 25: Waterproofed tether tied in strain relief loop

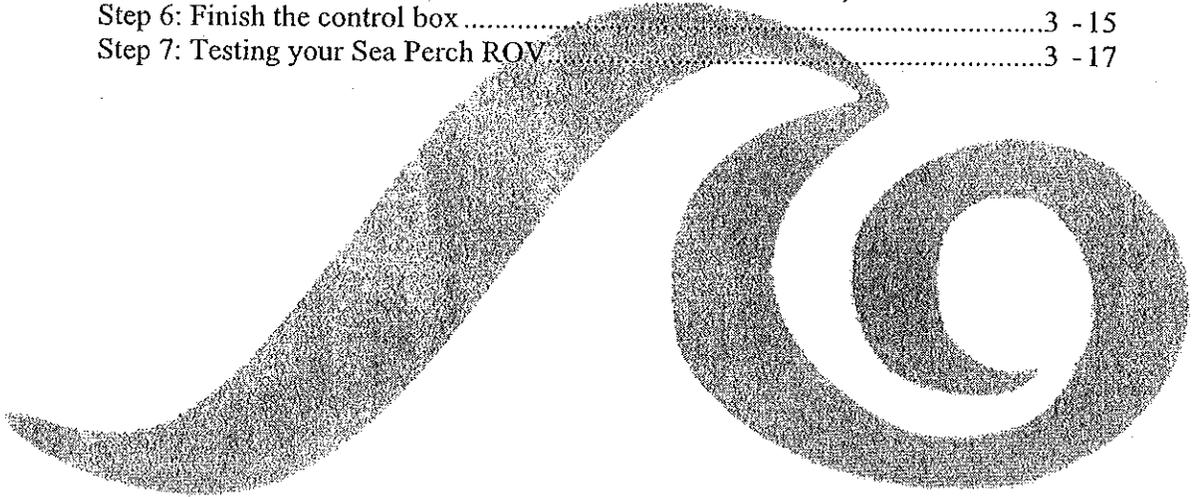
PROCEDURE:

1. Once the thrusters have been mounted, follow the wire pairs from the thrusters, to where they meet inside the tether sheath.
2. Take a small piece (about 1" or 2.5cm) of the butyl rubber tape (aka. monkey dung) and press it over the wire pairs and the sheath.
3. Knead and work it in well, so that it seals both around and between the wires and sheath, preventing water from getting into the tether cable.
4. Wrap electrical tape over the Butyl Rubber tape to keep it from sticking to anything.
5. After water proofing the tether, make a loop in the tether and attach to the vehicle frame with tie wraps (aka. Zip ties). Make sure the tether comes off from the center of the frame to avoid pulling our ROV to one side once in the water. This is "strain relief", intended to prevent any pulling on the tether cable from pulling on the motors. (Figure 25).

Note: Since butyl rubber tape IS electrically conductive, make sure it DOES NOT touch any exposed wires. If you find that the wires are nicked where you cut the tether cable (exposing the inner copper wire), you must either seal them with electrical tape (if possible), or re-do the wiring for the motors.

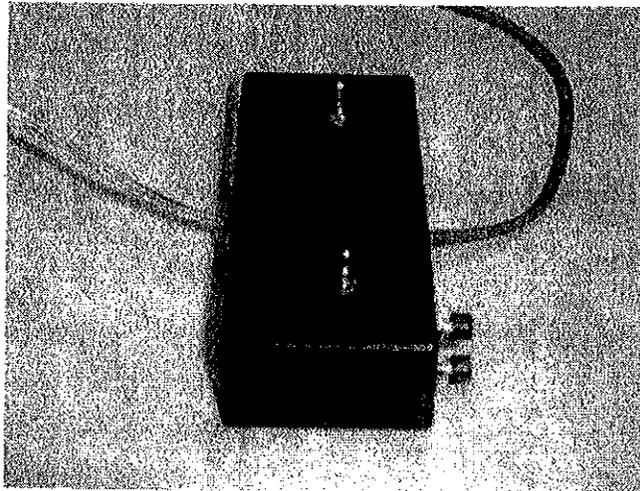
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UNIT 3

ASSEMBLY OF SUBSYSTEM THREE: THE CONTROL BOX



FOR THIS TASK YOU WILL NEED:

TOOLS	MATERIALS
Soldering iron Drill 1/4" drill bit Nut driver Wire cutter Wire stripper Small Phillips Screwdriver	Control box 2 push-button switches 2 toggle switches 2 alligator clips with sleeves (one red one black) Fuse cap wire Fuse (10 A slow blow fuse) Speaker wire 1 loose red wire (#24 stranded hookup wire) 1 loose black wire (#24 Stranded hookup wire)
<p>Time: Unit 3 requires approximately 6 hours to complete:</p> <ul style="list-style-type: none"> 1 class period to gather parts and prepare the control box (ergonomic design) 1 class period to make the power cable 1 class period to wire button switches 1 class period to wire the toggle (pole) switches 1 class period to finish the control box 1 class period to test Sea Perch in a "dry run" in the classroom 	
<p>WARNING: SOLDERING IRONS GET VERY HOT AND CAN CAUSE SERIOUS BURNS. HOT SOLDER MAY SPATTER. WEAR EYE PROTECTION!!! TAKE CARE TO NOT SHORT BATTERIES OR SHOCK YOURSELF!</p>	

Sea Perch Circuit Diagram

In this section, you will build the control box for your Sea Perch ROV. Below is a circuit diagram which shows all the electrical connections that will be made. This diagram is a technical representation, to show the connections, but is not drawn to scale, and leaves out everything but the wires and electrical components. You can always refer back to this diagram to understand how and why the wiring should work. The individual steps have their own circuit diagrams, which are simply parts of this complete diagram. They also have wiring diagrams, which will help you understand what the wiring actually looks like.

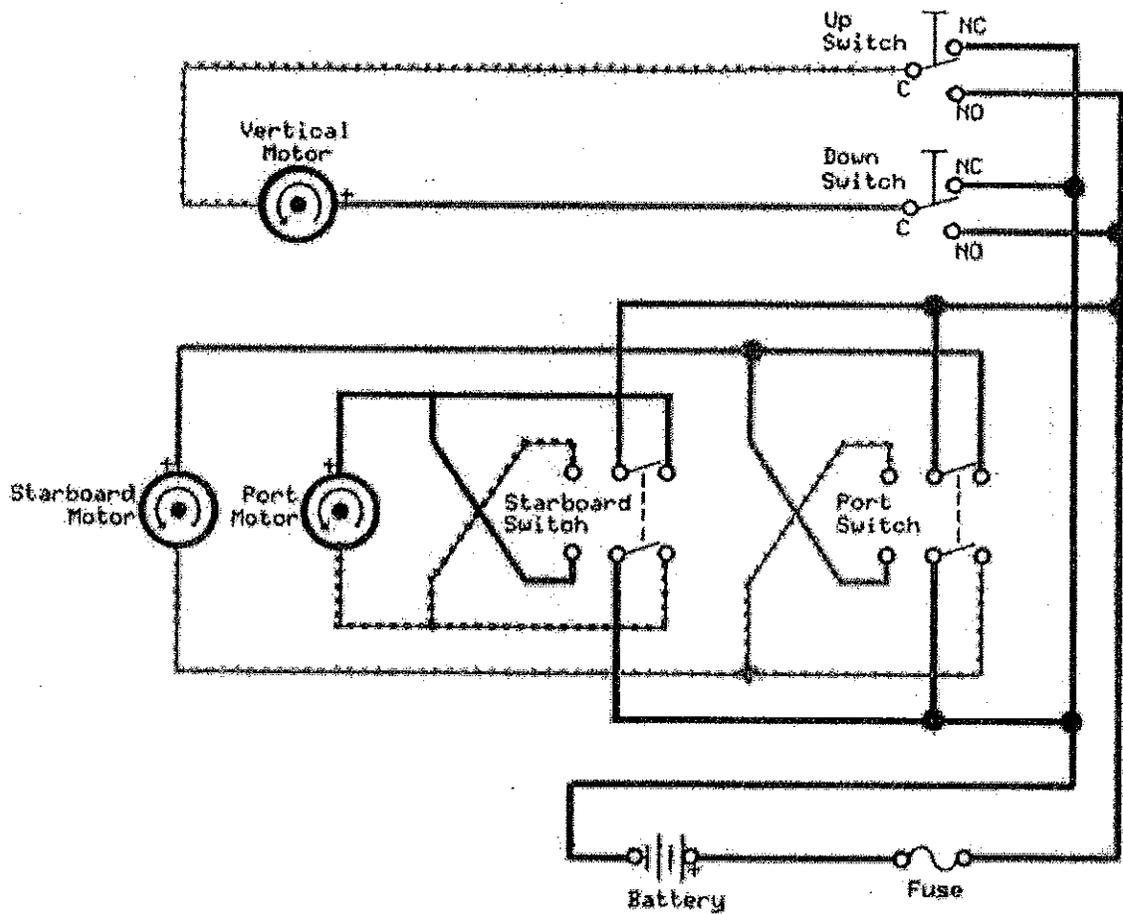


Figure 26: Sea Perch ROV Circuit Diagram

STEP 1

PURPOSE: Gather the parts for the control box assembly.

MATERIALS:

Control box
2 push-button switches
2 toggle switches (pole switches)
2 alligator clips
1 red alligator clip sleeve
1 black alligator clip sleeve
Fuse cap wire
Fuse (10 A slow blow fuse)
Speaker wire
1 loose red wire
1 loose black wire

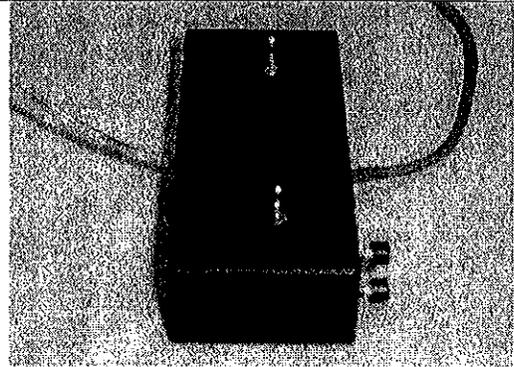


Figure 27: Completed control box assembly.

PROCEDURE:

1. Find the test wires that you used to test your motors in the previous unit.
2. Remove the alligator clips from the test wires. The alligator clips will be used on the power cable, and the wires will be used for the control box circuitry.
3. Gather the other parts required for the control box assembly, as shown in the diagram on the next page:

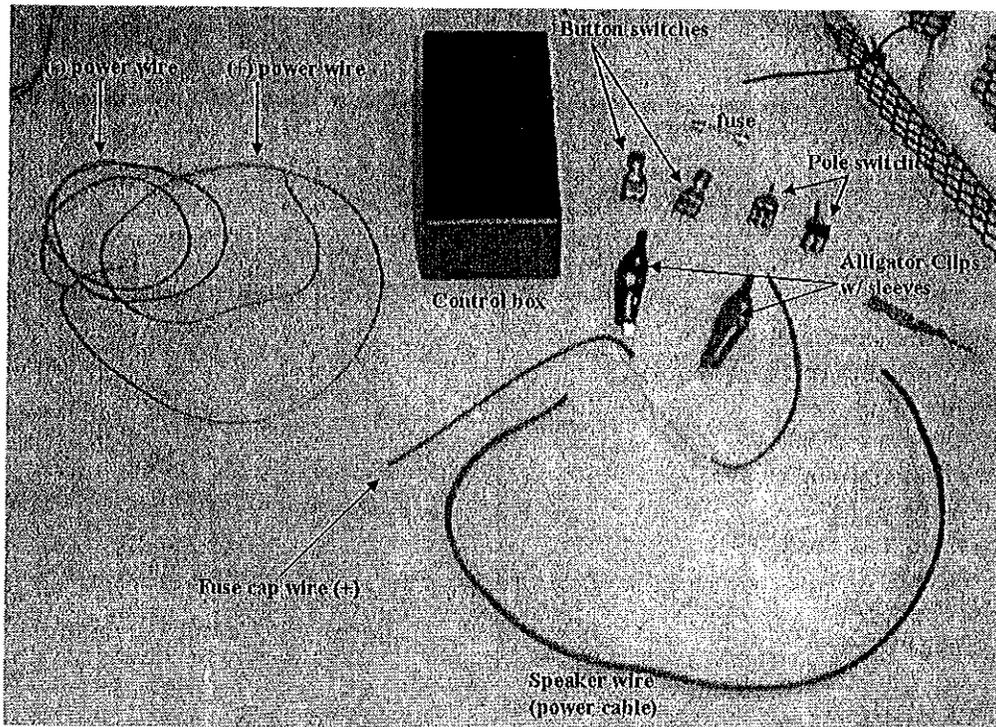


Figure 28: Parts for the control box assembly.
NOTE: Speaker wire/power cable may be WHITE (instead of brown)

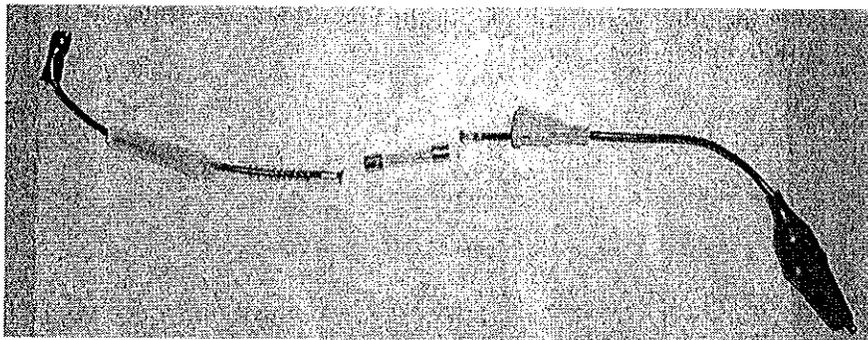
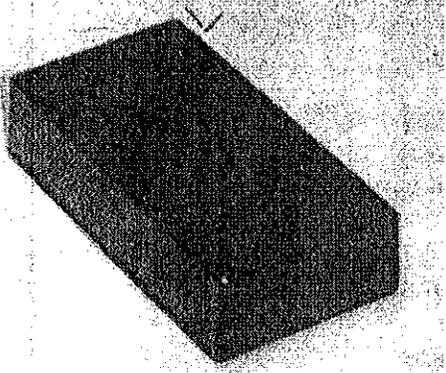


Figure 28a: This is what the Fuse Cap Wire looks like when taken apart, some of these wires may fall apart during transport of the kits. If you find these pieces in your kit, reassemble them in the order shown above.

STEP 2

PURPOSE: Prepare the control box

<p>MATERIALS: Control box</p> <p>TOOLS: Marker Drill 1/4" drill bit Vise or clamp</p>	 <p>Figure 29: Control Box</p>
---	---

PROCEDURE:

1. Using the marker, mark the locations of the holes on your control box, as shown (approximately) in Figure 30 below. Make sure holes are at least 1/2" away from edges to allow switches to fit inside. There should be one in the center of the back for the power to come in, one in the center of the front for the tether cable to go out, two on the right hand side of the front for the vertical thruster controls, and two on top for the horizontal thruster controls. Make sure that the holes for the vertical thrusters leave enough room for the switches against the sides of the box. Ask your teacher if you are unsure.
2. Secure the control box in a vise or clamp and drill holes with the 1/4" drill bit in the marked locations.

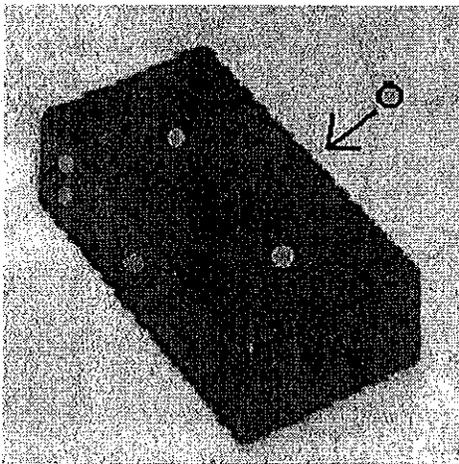


Figure 30: Control Box hole locations

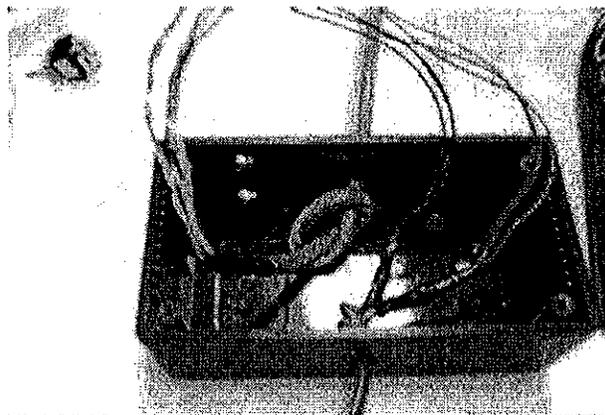


Figure 31: Cables in holes (see steps 3 & 4)

STEP 3

PURPOSE: Assemble the power cable

MATERIALS:

Speaker wire (5-10' long)
2 alligator clips with sleeves
Fuse cap wire
Solder
Electrical tape
Loose red wire
Loose black wire

TOOLS:

Soldering iron
Wire cutter
Wire strippers
Small scissors
Vise or clamp

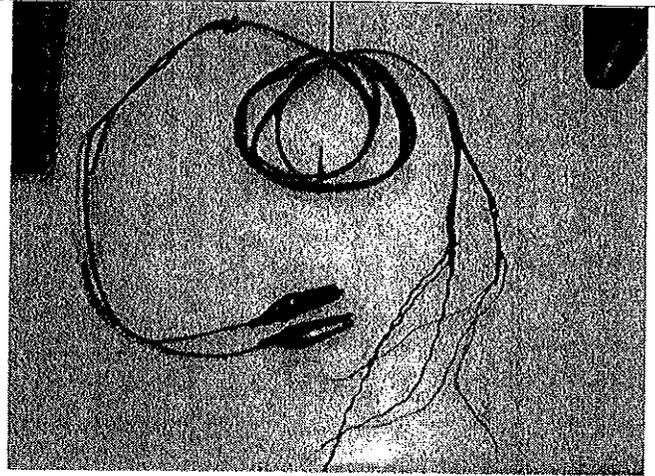


Figure 32: Completed power cable

In this step you will build the power cable for your control box. A wiring diagram of the finished power cable is shown in Figure 33.

PROCEDURE:

1. Cut about 3" (7.5cm) of wire off of the end of the red and black loose wires. Set these short pieces aside for a later use with the toggle switches.
2. Cut the remaining red and black wires into four equal length pieces each (4 black and 4 red). If your pieces will be less than 5" (12.5cm), then ask your instructor for extra wire.
3. Strip about 1/4" (6mm) of insulation from each end of each piece. Twist the inner wires (strands) on each end to prevent fraying and breaking.

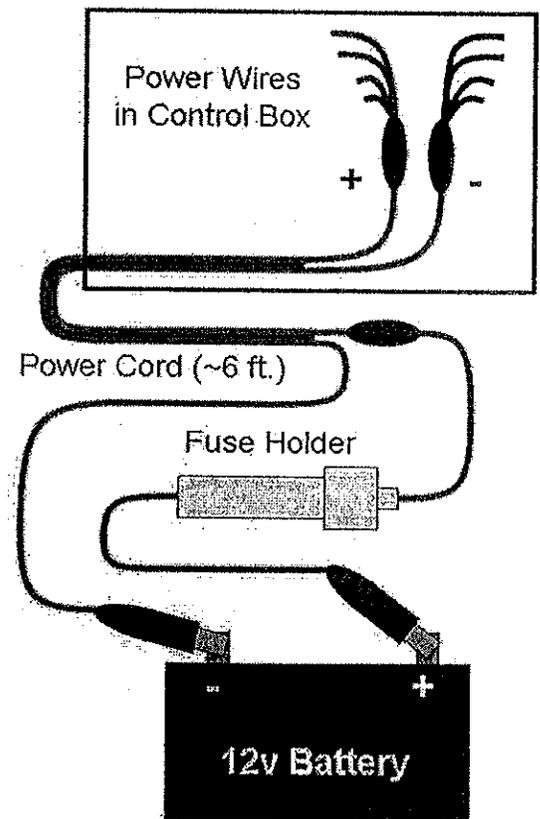


Figure 33: Power Cable wiring diagram.

4. Take one end of each of the four red wires and twist them all together, as shown in Figure 34 below.
5. Do the same with the black wires. These spliced wire bundles will distribute power in your control box.

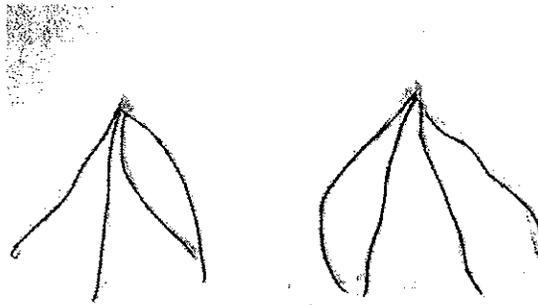


Figure 34: Spliced wire bundles

6. Find the power cable (speaker wire), and determine which side of it is positive and which is negative. Notice that there are two conductors inside, each with its own insulation, and attached to each other with a thin web of insulation material. Usually the insulation on one side is ribbed (like corduroy) and the other is smooth. Other times, one is marked with white or black stripes, or other indicators. We will call the ribbed or marked side the positive (+) side.
7. On each end of the speaker wire (power cord), carefully separate the two conductors for about 1" (2.5cm). This is best done by snipping the thin web of plastic between the wires with a small pair of scissors, or a fine pair of wire cutters. Be careful not to nick the insulation on the conductors.
8. On one end of the power cord, leave the separated section only 1" (2.5cm) long. On the other end, pull the two wires apart for about 14" (35cm).
9. On the part of the cord that you just separated, find the positive (ribbed or marked) side and cut off 13" (33cm) of the positive wire. This section will be replaced with the fuse cap wire, as shown in Figure 35 below.

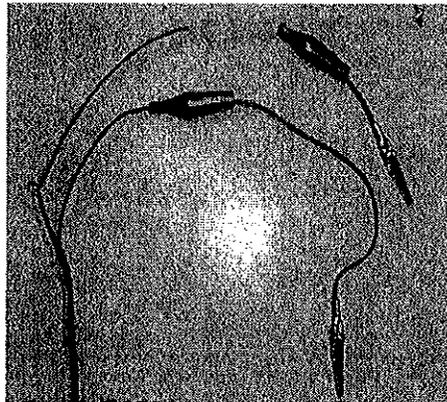


Figure 35: Battery end of the power cable.

10. Strip 1/2" (1.3cm) of insulation off both ends of the fuse cap wire. The fuse cap wire does not have a positive and negative side... it will work either way.
11. Strip 1/2" (1.3cm) of insulation off of all four ends of the power cord (speaker wire). Twist the conductor strands on each end together to prevent fraying and breaking.
12. Attach the fuse cap wire to the positive (ribbed/marked) side of the speaker cable, (where you cut off the 13"/33cm piece). Twist the wires together, solder the connection, and cover it with electrical tape.
13. Slide the red alligator clip sleeve onto the loose end of the fuse cap wire, and the black alligator clip sleeve onto the negative side of the power cord.
14. Attach alligator clips to the fuse cap wire (+), and to the negative side of the power cord (-). Stick the wire in through the back of the clip, and up through the hole near the screw. Loosen the screw and wrap the wire around it clockwise. Tighten the screw. You can solder the connection if you want to. At this point, your power cable should look like Figure 35.
15. Push the sleeves down over the alligator clips and put the fuse into the fuse cap.
16. Pass the loose end of the power cable (no alligator clips) through the hole in the back of your control box. Tie a strain-relief knot about 6" (15cm) up the cord, inside the control box. (Fig. 31)
17. Take the spliced bundle of 4 red (+) wires, and twist the bundled end onto the positive (ribbed/marked) side of the speaker wire. Take the spliced bundle of 4 black (-) wires and twist the bundled end onto the negative (smooth) side of the speaker wire. Solder the connections and cover them with electrical tape, as shown in Figure 36. **ALWAYS USE A VISE OR CLAMP TO HOLD WIRES WHEN SOLDERING!**

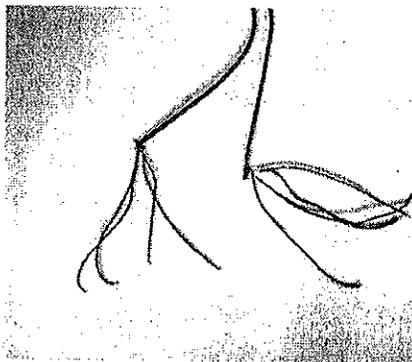


Figure 36:
Wire bundles soldered to end of power cord.

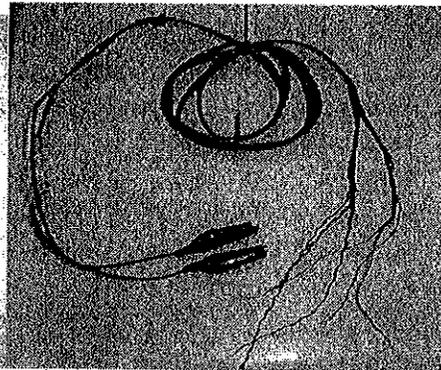


Figure 37:
Completed power cable assembly (without the control box).

STEP 4

PURPOSE: Wire the push-button switches (vertical thruster controls)

MATERIALS:

2 button switches
Solder
Prepared control box
Assembled power cable

TOOLS:

Soldering iron
Vise or clamp

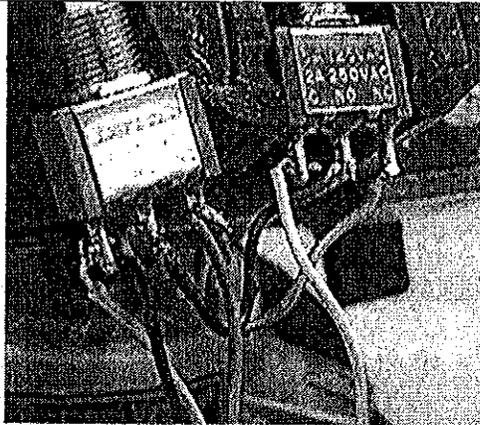


Figure 38:

Vertical thrusters with tether wire and power connections.
(Note: The switches in this photo are wired using the old method. The wiring described below will look slightly different.)

PROCEDURE:

1. Refer to Figures 39 and 40 on the following pages for a circuit diagram and wiring diagram for the vertical thruster controls (the pushbutton switches).
2. Pull the end of the tether cable through the hole in the front of the control box. Tie a strain-relief knot about 8" (20cm) down the cable, inside the box.
3. Strip about 6" (15cm) of sheath off of the tether cable, being very careful not to nick the insulation on the inner wires.
4. Separate the four twisted pairs. We will be using the orange pair for the vertical thruster, so wrap up the others for now so they are out of the way.
5. Locate the terminal labels above the wire terminals on each switch. "C" stands for common, "NO" stands for normally open, and "NC" stands for normally connected.
6. Take one of the red (+) wires from your power cord (inside the control box), and twist it onto the NO terminal of one of the pushbutton switches. Repeat for the other switch.
7. Twist the two black (-) power wires to the NC terminals on the two pushbutton switches. **(ONE black wire to each switch—See Fig 40 on next page)**
8. Now take the orange wire pair from the tether cable and untwist the pair for about 2" (5cm). Strip 1/8" to 1/4" (3-6mm) of insulation off the end of both the orange wire and the white & orange wire.

9. Twist the **orange (+)** wire to the **C** terminal on **ONE** of the switches. (This switch will move the sea perch downward.)
10. Twist the **white & orange (-)** wire to the **C** terminal on the other switch. (This switch will move the sea perch upward.)
11. Once you have attached all the wires to the switches, ask your teacher to check your wiring, as it's much easier to correct it before you solder.
12. Solder the connections on the three terminals on each switch, being careful not to create any solder bridges between the terminals, and making sure to snip off any frayed pieces of wire sticking out toward other wires.

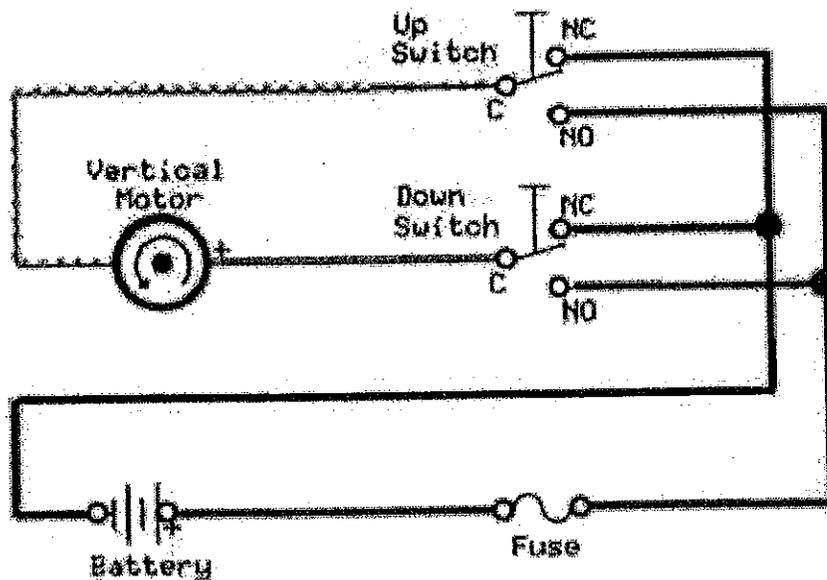


Figure 39: Vertical thruster circuit diagram.

*TIP- It can be useful to pre-mark switches for students

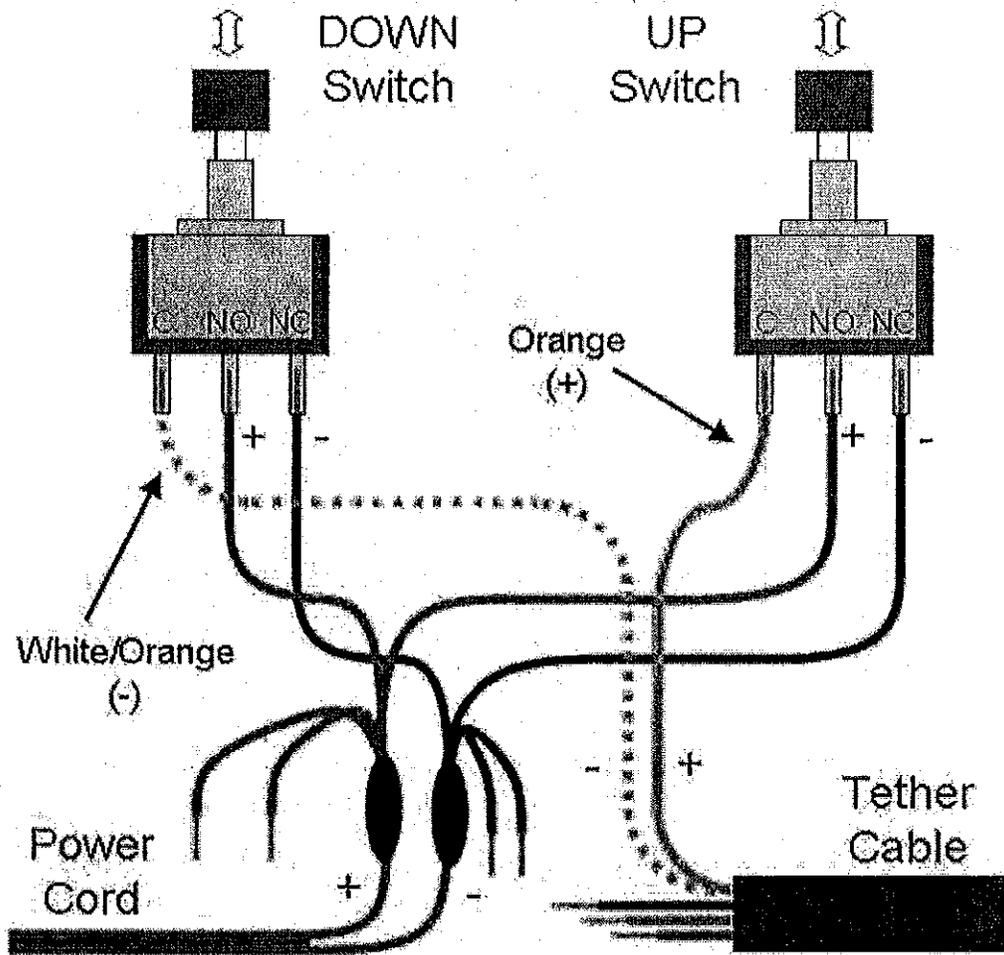


Figure 40: Vertical thruster control / pushbutton switch wiring diagram.

STEP 5

PURPOSE: Wire the toggle switches (horizontal thruster controls)

MATERIALS:
2 pole switches
Prepared control box
Solder

TOOLS:
Soldering iron
Vise or clamp

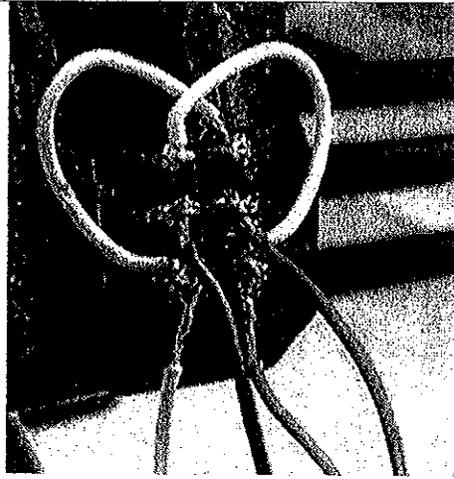


Figure 41:
Cross wired toggle switch with tether and power cable connections

PROCEDURE:

1. Refer to Figures 45 and 46 on the following pages for a circuit diagram and wiring diagram for the horizontal (port & starboard) thruster controls (the toggle switches).
2. Before you solder anything on the toggle switches, attach ALL the wires by wrapping them through and/or around the terminals. Since some of the terminals have more than one wire connected to them, it is best to solder at the end, when ALL the wires are attached.
3. Cut four 1.5" (3.5cm) pieces of wire from either the small pieces wire you saved in an earlier step, some pieces of the brown tether wire, or other scrap wire. Strip 1/8" to 1/4" (3-6mm) of insulation off all of the ends.
4. Attach one of these pieces across the opposite corner terminals of each pole switch, making an "X" wiring pattern, as shown in Figure 42.

Switch Soldering Tips:

When soldering the switches, be very careful to avoid shorting out the many wires which end up in close proximity in the back of the switch. Attach all of the wires to the switch before soldering anything. Make sure that the wire strands are well twisted together, to avoid fraying strands that may short out against other wires or terminals. Solder quickly, so that the wires do not get too hot, and melt their insulation. Do not use too much solder, which could stick out and touch other connections.

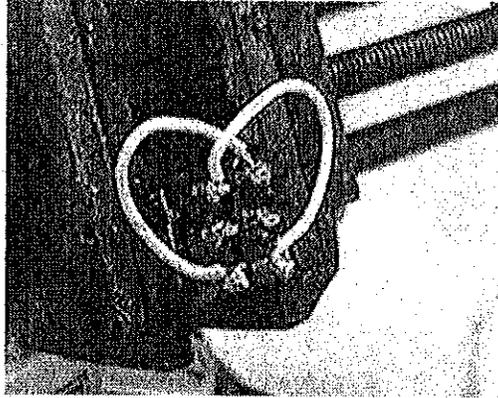


Figure 42: Cross-wired toggle switch.

5. The pole switch terminals are arranged into 2 columns with 3 terminals in each column. Use the RIGHT column for positive (+) connections, and use the LEFT column for negative (-) connections.
6. Un-twist about 2" (5cm) of the blue and green tether wire pairs. Strip 1/8" to 1/4" (3-6mm) of insulation off of each wire end.
7. Attach the green (+) wire to the right corner terminal on your first pole switch. Attach the white and green (-) wire onto the terminal adjacent to it, as shown in Figure 43. Repeat with blue wires for the second switch.

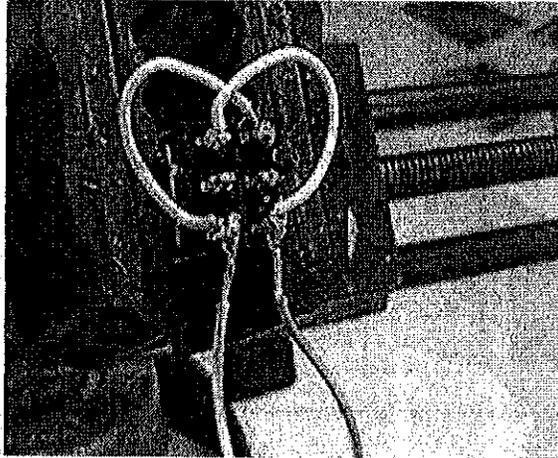


Figure 43: Cross-wired toggle switch with tether connections

8. Attach one red (+) power wire to the middle terminal of your first switch, on the same side as the solid-colored wire. Attach a black (-) power wire to the middle terminal on the other side, as shown in Figure 44. Repeat for the other switch.

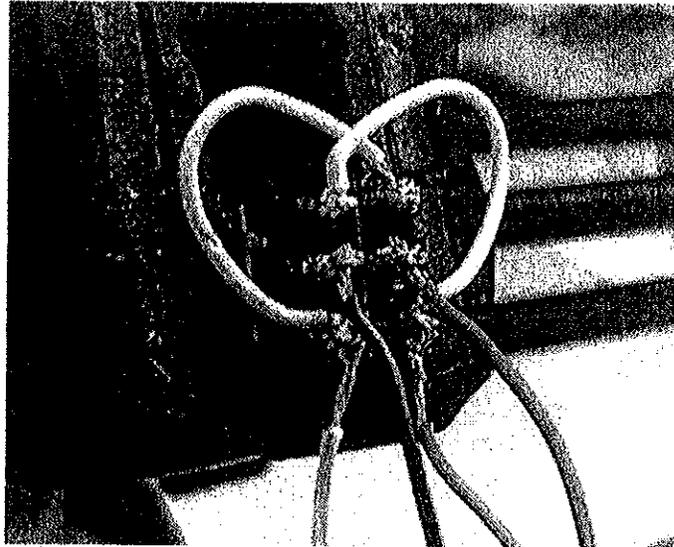


Figure 44:

Toggle switch with cross-wires, tether connections, and power connections.

9. Once all of the wire connections are made, check that the connections are clean, without fraying wire strands or other short circuits. Have your teacher check your wiring, and then carefully solder all of the connections on both toggle switches.
10. After soldering the connections, go back and check again that there are no shorts (touching wires or solder) between the switch terminals. If you find a short, desolder and re-do it before continuing.

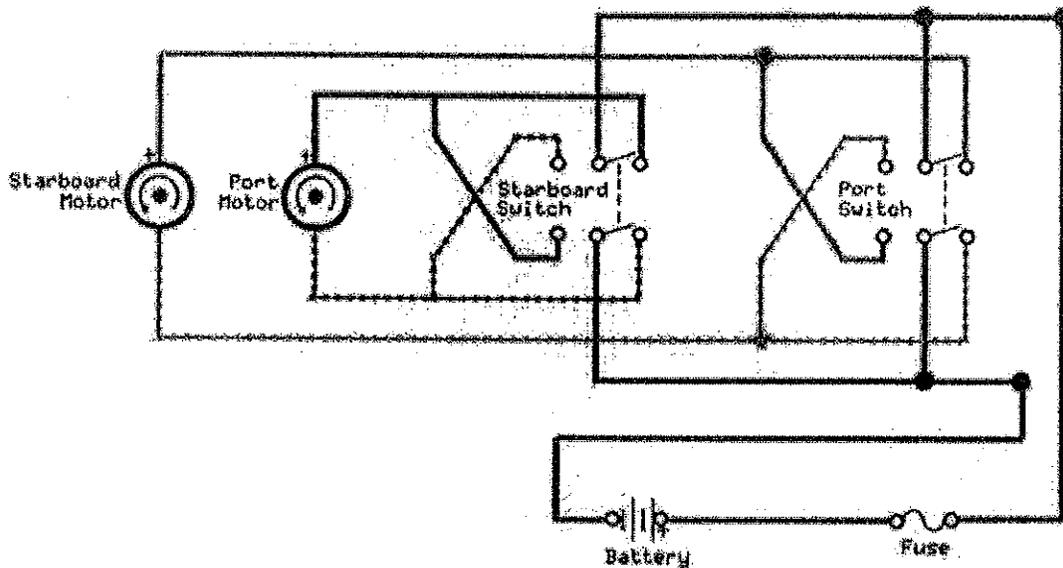


Figure 45: Circuit diagram for horizontal (port & starboard) thruster controls.

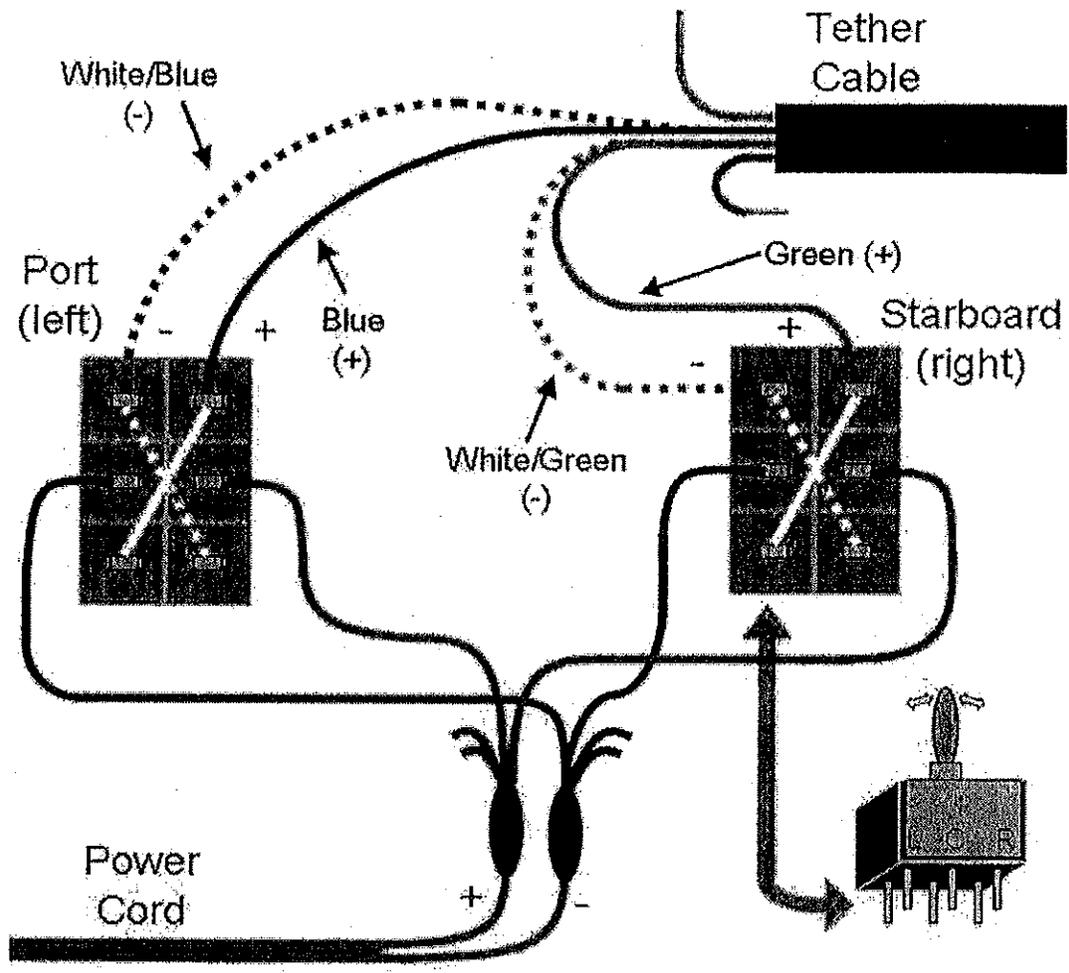


Figure 46: Toggle switch/Port and Starboard thruster wiring diagram

STEP 6

PURPOSE: Finish the control box

MATERIALS:

Control box
Wired Switches

TOOLS:

Phillips Screwdriver
5/16" Nut driver or
Pliers

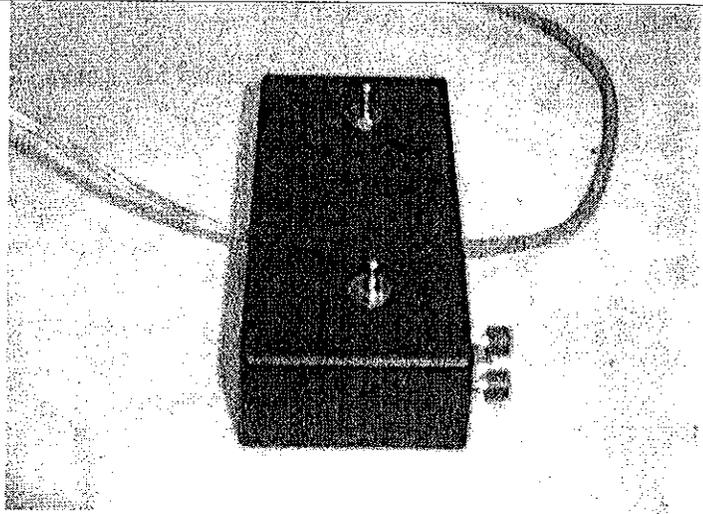


Figure 47: Completed control box

PROCEDURE:

1. Place the pole switches in corresponding holes in the control box. Check the direction that the switches move the motors before securing them into place, (ex. Pressing forward will make the ROV move forward, etc.) Tighten into place with a nut driver or pair of pliers.
2. Remove the red button caps from the button switches by pulling up hard on the red caps. Be careful not to break the white stem.
3. Place button switches through the 2 holes next to the tether cable. Again, check the direction of the switches before securing into place. Tighten with nut driver or pliers. Replace the red button caps by pushing them on very snugly.

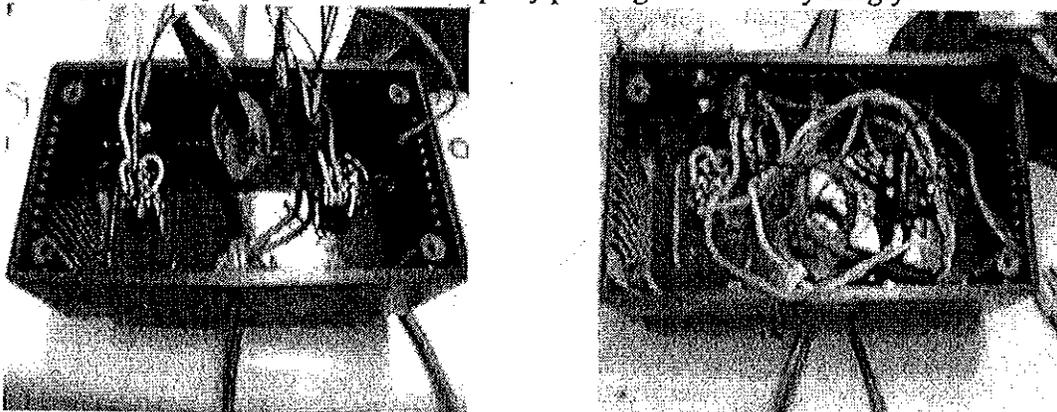


Figure 48: Control box with toggle switches and then all switches installed.

4. Screw the back onto the control box using the screwdriver.
5. Place the fuse in the fuse holder.
6. Congratulations, you have completed your Sea Perch ROV! (Figure 49).

NOTE: The direction of the forward/reverse thrusters will affect the efficiency of your Sea Perch. Play around with the direction of your thrusters when you test your Sea Perch to see what works the best!

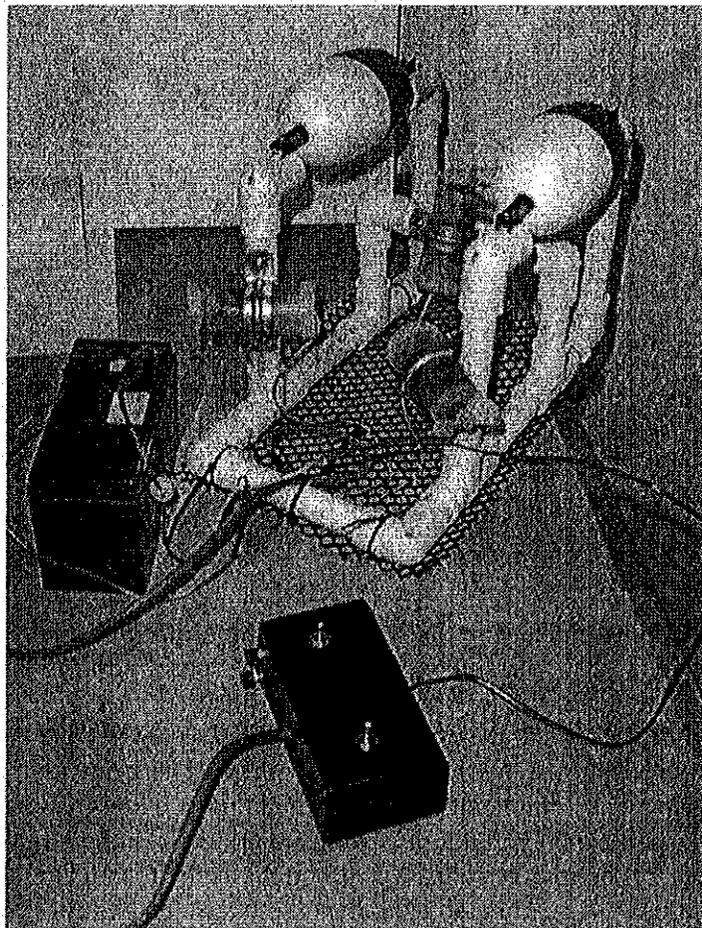


Figure 49: Finished Sea Perch ROV

STEP 7

PURPOSE: Testing your Sea Perch ROV

MATERIALS:
Completed ROV

TOOLS:
12 volt battery

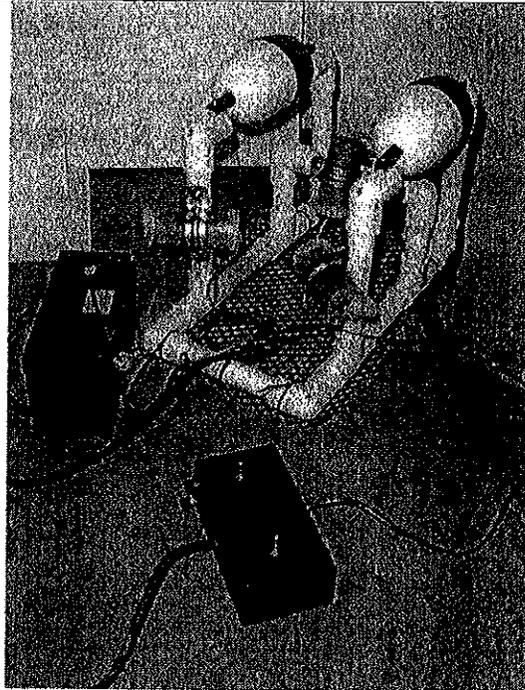


Figure 50: Completed Sea Perch ROV

The first time you power-up your Sea Perch ROV, there are a few steps you should take to make sure everything is working properly:

1. Before beginning, make sure that you have a good fuse installed, and that all of the switches on your control box are turned off – pushbutton switches are not pressed, and toggle switches are in the center position.
2. The first time you attach the power cable to the battery, clip the black (-) alligator clip onto the Negative (-) terminal on the battery. Then, quickly tap the red (+) alligator clip against the Positive (+) terminal on the battery. You should NOT get a large spark when you do this. A tiny spark is ok, but a large spark indicates a possible short in your system. A short circuit can wreak havoc on your Sea Perch, as it may cause wires to heat up and melt, in the control box, or worse, inside the tether cable or the motors.
3. If you do get a large spark, check that your switches are all off, and try again. If you still get a large spark, unclip the black alligator clip from the battery, use a multi-meter to find where the short is in your system, and fix the short. The circuit diagram at the beginning of this section, and the wiring diagrams in the previous steps are good references for troubleshooting.
4. Once you have confirmed that there are no initial shorts, clip both alligator clips onto their corresponding battery terminals. Quickly tap the switches (rapidly on

and off) one at a time, and listen if a motor turns each time you do. If all of the switches satisfactorily engage a motor, then your system is ready to run. If a motor does NOT turn when you activate each switch, you have either a broken connection (blown fuse, unclipped battery, broken wire, broken solder joint, etc.), or you have a short circuit somewhere.

5. Turn on each motor one by one, and check that it is turning in the correct direction. If not, the easiest way to fix this is to physically re-position the switch in the control box. This is usually simpler than re-soldering the wires.

You are now ready to run your Sea Perch ROV!

To run the Sea Perch, clip the alligator clips onto the corresponding terminals on the battery (red +, black -). Be careful not to short the battery. If the Sea Perch stops working, first check the fuse to see if it has blown.

Place Sea Perch in the water and attach weights to the payload netting until it has just slightly positive buoyancy, meaning that it sits in the water with the floats just out of the water by about 1/4" (5mm) or less. A typical Sea Perch without cameras or other sensors on board usually requires about 4 to 10 ounces (125 to 300 grams) to achieve proper buoyancy. If your Sea Perch sinks without applying the downward thruster, it is too heavy. If your Sea Perch has trouble diving, or floats up to the surface very quickly, then it is too light.

The motor angles can be adjusted for optimal thrust, maneuverability, or stability, as described in Unit 1.

Make sure to charge your battery after using it. Lead-acid batteries will last much longer if they are not left discharged.

Always make sure to rinse your Sea Perch with fresh water when you have finished operating it. Pay special attention to the motor shafts as they are often the first place to rust. Clean all seaweed and other buildup off of the motor shafts, **and rinse them well with fresh water.**

The Sea Perch website (<http://seaperch.mit.edu>) has many resources and ideas for using Sea Perch ROVs for fun and education. Don't forget to take some photos of your expeditions. If you send them to us, we may be able to put them on the website!

Remember to be safe when working around the water.

Have Fun!

5.0 Testing Your Vehicle and Using it in the Field

5.1 Where to Test Your Vehicle

Testing

You will want to test your vehicle in your classroom throughout the construction process. This will ensure that your connections are correct in each stage. Be sure all 3 motors are functioning properly *before* you pot them in wax and *after*. This will confirm that all of your soldered connections are correct. Once you have completed your Sea Perch, run it “dry” on the lab bench until all the propellers are running at the same speed.

Now you will want to test the vehicle in water. A large tupperware storage container or garbage can be used in the classroom. Fill the container $\frac{1}{2}$ full with freshwater so you can test your vehicles before moving out to “open” water. Let students run all 3 motors to be sure all is running correctly.

You are now ready to enter “open” water! Salt or fresh water is fine since all the connections have been water proofed. Suggestions for places to take the students/vehicles for their first deployment:

- Local pool: school, YMCA, another school in your area, community pool
- Local pond/lake
- Ocean: beach, dock, pier
- River (one with slow flow rates)

** Be sure to have students work out their buoyancy It will be different between the fresh and salt water!!

After you have tested the vehicles and completed your troubleshooting, it will be fun to have a “Mission” for the students to tackle with their Sea Perch.

Examples:

- If you are in a pool, you can set up an obstacle course with floating pool toys through which students can navigate their Sea Perch
- You can have students collect different data using sensors, plankton nets, video, cameras, hydrophone, etc. (See Using your Sea Perch in the Field)
- Time trials
- Have students design and develop a way to pick up an object from the bottom of the body of water with their Sea Perch. (i.e., weighted pool toys, rings and sticks, can be picked up by taping or adding a PVC attachment to the front of your vehicle.)

5.2 Sensors

What is a sensor?

A sensor is an input device. It converts the tangible world into a series of signals that a processor can understand. Be it the sense of smell with a nose sensor and its processing by the human brain, distance with sonar and a bat brain, or electrical current with an ammeter and a computer, it all works by measuring the property of interest with a tool, then converting it into an electrical

signal that the brain of the animal or computer processes. With this processed information, the animal or computer can better understand its surroundings and environment.

There are an infinite number of sensor types in the world, and if a sensor doesn't exist but is needed, one can be built custom. Some standard sensors include:

- Available light (photo diode, eyes)
- Distance (infrared range sensor, acoustic range sensor)
- Magnetic heading (digital compass)
- Acceleration (accelerometer, gyroscope, inner ear)
- Temperature (thermocouple, skin)
- Touch (pressure sensitive switch, hair)
- Electrical current (ammeter)
- Angle (inclinometer, inner ear, eyes)

And they all work by measuring the parameter of interest and converting it into an electrical signal the appropriate processor can understand.

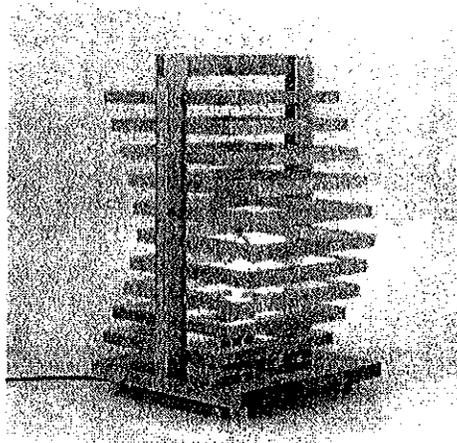
Can a computer understand its environment?

Humans are optimized for sensing, each of us is built with eyes, ears, a nose, highly receptive and reactive skin, and a tongue. We also have the ability to learn from experience, so if we sense something we are not familiar with, it is possible for us to determine what it is, how dangerous it is, how far away it is, or what its material properties are – we can make sense of what we sense. We even have the ability to describe sensations to other humans or even computers. But can we get a computer to do all the sensing itself?

The short answer is no. While computers are amazing machines with the ability to process anything and run programs, they have two major flaws: they crash when programmers have forgotten to tell them even minor details about their work and they must rely on digital copies of everything that exists in the real world. In other words computers don't have any sense if you don't give it to them and they can't make sense of the real world, only simulations of it.

Digital, what's that?

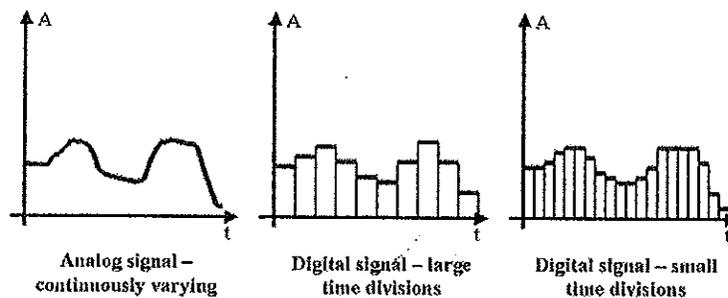
Before analyzing digital items, let's first look at what isn't digital. The opposite of a digital item is an analog item. An analog item is something that can be described using partial values, in other words, something that exists between a maximum and minimum measurable value. Take a lamp for instance; when the lamp is on, it glows yellowish, somewhere between orange and yellow. At the same time, it is quite warm, but not as hot as the sun. It's also bigger than a chess piece, but smaller than a refrigerator. The lamp's color, size and the strength of its light output can all be described in both precise and relative terms. This makes it analog.



Digital items work a lot differently. A digital item is binary, it has only two values, completely on, or completely off, yes absolutely or absolutely no. Some examples of this are the switch on the lamp, eating, and being in one place. The lamp is either on, or off, but never in the middle; in the act of eating, you are either doing it or not, and by being in one place, you are either there, or somewhere else. Since computers can only understand binary input (read "how switches work" to learn about binary {link to switches}) they are very well suited to understanding digital inputs, but since they only take in on/off values it is very difficult to describe an analog experience in digital terms.

So how do you input analog values into a digital computer?

It starts with logic. First you need to choose exactly what analog parameters are needed to accurately describe the real item (i.e. size, color, texture). Next you need to determine how big the range of each parameter is. So if the parameter is size, what is the biggest it can be, and what is the smallest it can be, and how many different size ranges should exist between the two. Obviously there are an infinite number of size options between the biggest thing and the smallest thing, but computers need a discrete integer value as their input (i.e. the number could be 7 on a scale of 0 to 256, but could not be 8.56 from 0 to 10).



After you have your parameters and ranges, you need to describe your item. If the item is a cell phone, the parameters may be how much blue color exists, how much red color exists, how much green color exists, size, distance, altitude, and weight, and the ranges could be 0 to 256 for all of these parameters. If it is a teal green phone on a counter, the parameters may look like the following table:

Parameter	Range	Value
Blue	0-256 (off to on)	256 (bright blue)
Red	0-256 (off to on)	0 (no red)
Green	0-256 (off to on)	256 (bright green)
Size	0-256 (1in ³ to 10in ³)	40 (3in ³)
Distance	0-256 (0ft to 5ft)	100 (2 ft way)
Altitude	0-256 (0ft to 5ft)	200 (4 feet off ground)
Weight	0-256 (0lb to 1lb)	128 (0.5lb)

But how do those get into the computer?

First, they need to be converted into binary numbers, or a representation of the number using several ones and zeros. If you need more info on this, check out "switches" {link to switches}. Once you have these numbers in binary, you can send them through a serial port on the computer and the computer will store them in a file. Once there, the file can be accessed, read, and manipulated, and the computer can now tell you all of the details about the phone you had measured.

Light and Temperature Logger http://onsetcomp.com/data_logger (The sensor shown in the workshop can be found under HOBO pendant logger)

Underwater Camera Systems:

Allantis Camera: <http://www.atlantiscamera.com/home.html>

SeaView Systems: <http://store.seaview.com/catalog/>

Aqua-Vu: <http://www.naturevisioninc.com/aquavu/>

Cabella's: <http://www.cabelas.com/>

Bass Pro Shop: <http://www.basspro.com/>

Hydrophones:

You can build your own hydrophone with basic parts from Radio Shack for about \$40. See this lesson from URI's Office of Marine Programs, Sound in the Sea website:

<http://www.dosits.org/teacher/activity/hydro/hydro1.htm>

5.3 Lessons on How to use Sea Perch in the Field

Using Your Sea Perch in the Field

Your Sea Perch can become an environmental monitoring device, a fish spy or underwater robot, - whatever you desire! Just by adding a sensor, an underwater camera or a manipulator arm, you can use your Sea Perch to explore any aquatic environment.

Using the Web

We have put together an interactive website that will allow you and your class to take your Sea Perch further. Check out seaperch.mit.edu to learn how to make sensors, add-ons for your perch, hack, and how to use our digital oceans database, which will allow you to upload water quality data into our global GIS database.

This section has a series of lessons developed by teachers on using a Sea Perch in the field. Topics are:

- Biological Sampling Device (plankton)
- Measuring the Depth of the Ocean
- Sampling the Water (water sampler construction)
- Exploring Underwater Habitats and Environments (hydrophone with underwater camera)
- Attenuation of Light in Water (using a light sensor)
- Student-Designed Modification of Sea Perch

***** We encourage everyone to submit lesson plans they develop. We will post these lessons as resources on our Sea Perch website. Please send any material to olivo@mit.edu***

Biological Sampling Device Using a Sea Perch

Submitted by Howard Chen, Cranston H.S. East, RI; Scott Dickison, Rogers High School, RI; and Christine Kirch, West Warwick High School, RI

Overview

This lesson is to be used as an extension activity with the Sea Perch. It is designed to utilize the Sea Perch to study the aquatic food chain. Scientists use ROVs like the Sea Perch to study the health of aquatic environments.

Grades: 11th – 12th

Time

1 day construction/test

1 day collection

Up to a week for microscope analysis/identification

Objective

The students will:

- Construct plankton nets to be towed by the Sea Perch
- Modify their Sea Perch to tow the plankton net
- Collect specimens to be examined and analyzed in the classroom

Skills Attained

- Develop research skills by collecting and analyzing an aquatic sample
- Manipulate Sea Perch for biological sampling
- Construct sampling device
- Write lab reports
- Interpret, identify, and analyze samples
- Collect data as a team

National Science Education Standards

Content Standard A - Science as an Inquiry

- Ability necessary to do scientific inquiry
- Crosses disciplines and grade levels

Content Standard C – Life Science

- Interdependence of organisms
- Matter, energy, and organization in living systems

Content Standard E – Science and Technology

- Abilities of technological design

Content Standard F – Science in Personal and Social Perspectives

- Population growth
- Environmental growth
- Natural and human induced hazards

Content Standard G – History and Nature of Science

- Science as a human endeavor

Lesson

Plankton is the collective term used to describe the smallest animals and plants in the sea. It is a vast and diverse group with approximately 10,000 species. They are called plankton because they all have similar lifestyles:

- Most exist in the top 30 meters of the sea in an area scientists call the “photic zone”.
- Most are incapable of free swimming and drift on the ocean currents.

The word plankton comes from a Greek word, which means “to wander”. Plankton are found at all depths and are comprised of both plant (phytoplankton) and animal (zooplankton) forms. Plankton are important as indicators of the health of our oceans as they are the primary producers of the ocean. They are also a key factor in climate change. Plant plankton (phytoplankton) produces ~50% of the total photosynthesis of plants on Earth, sucking the greenhouse gas carbon dioxide (CO₂) from the atmosphere.

In the marine environment, climate and weather patterns affect the rate of photosynthesis, and therefore the primary production in that area of the sea. There are distinct differences between the seasonal cycles in temperate Atlantic waters and tropical seas. This distinction is based on thermoclines.

By collecting samples of plankton along with the temperature of your sample site, you can assess the health of the aquatic environment, which impacts the local fish and shellfish population. Marine biologists and ecologists are constantly monitoring plankton levels at critical areas of the ocean to determine global climate change and its impact on our ocean resources (commercial fishing, etc.).

Materials

Sea Perch

Plankton Net

8” to 10” embroidery hoop – plastic

Small plastic bottle with lip (i.e., pill bottle, small soft drink bottle)

Zip ties

Panty hose OR Paint Strainer for 1- gallon bucket

Harness : Braided Dacron line – 60-lb test OR Kite string or strong nylon string

1 / 2 ” PVC T’s

1 / 2” PVC, 2 feet

Safety Tips

Don’t fall in water

Use Person Floatation Device if entering the water

Use common sense

Don’t drink water

Procedure

1. Dry demo of Sea Perch/warm up
2. Discuss the aquatic food chain
3. Create a food chain for the body of water you are going to test
4. Modify Sea Perch to tow plankton net – be careful to not let the net get caught in the propellers
5. Conduct biological collection in local waters
6. Microscope ID, drawings

Assessment

- Test on plankton identification
- Written reports and/or presentations

Resources

Plankton of Narragansett Bay

Plankton ID web sites

- <http://www.lighthouse.chtrak12.ma.us/plankton/intro.htm>
- <http://www.earthwindow.com/zoo.html>
- http://www.intandon.com/NewBrideSite/Asia/Lesson7/Lesson7_3.html

Possible Interdisciplinary Connections

English – lab reports

Art – drawing of specimens and illustration of food chain

Technology – Power Point

Display student work

Measurement of the Depth of the Ocean

Submitted by John Langella East Providence SR High School, RI; , Mike Jarret, Chariho High School, RI; t and Joyce Doblmeier, RI School for the Deaf, RI

Overview

This lab will result in students designing, building and testing a simple mechanical depth gauge used to measure the depth of the ocean. This would be a “beyond” lesson after building the Sea Perch. This lesson is geared toward high school students and lends itself to physical and mathematical analysis.

Grades: 8th-12th

Time: Five 45-minute periods.

Objectives

The students will:

- Comprehend the physical properties of pressure and Boyle’s Law as demonstrated by the designing of a depth gauge
- Construct a capillary depth gauge
- Calculate the calibrated depth marks of the capillary tube
- Determine the margin of error of the depth gauge

Skills

- Design, build and calibrate a measuring device
- Calculate the margin of error of a measuring device

National Science Content Standards Addressed:

Unifying Concepts and Processes

- Evidence, models, and explanation
- Constancy, change, and measurement

Content Standard A – Science as Inquiry

- Understanding about scientific inquiry
- Abilities necessary to do scientific inquiry

Content Standard E – Science and Technology

- Abilities of technological design
- Understanding about science and technology

Lesson

Materials:

Clear tubing – 3.5 inches (aquarium style tubing)

Hot melt glue

Colored backboard

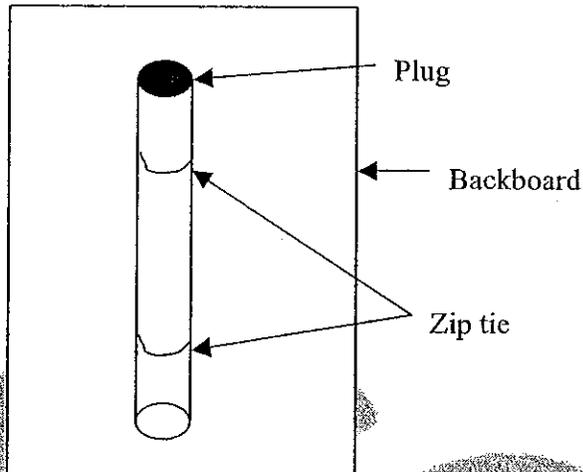
Permanent marker

Line with depth measurements

Meter stick

Calculator

Sea Perch with Camera attached



Diagram

Procedure

1. Attach the tubing on the backboard in a vertical orientation with hot melt glue.
2. Plug the upper end of the tube with glue.
3. Calculate the bubble size for a depth at 17 feet.
4. Place the various calibration marks from 17 feet to 0 feet deep.
5. Attach the capillary depth gauge to the Sea Perch so that camera sees the calibrated depth marks and the gauge is in a vertical position.
6. Submerge the ROV underwater to a known depth. Observe and record the capillary gauge reading.

Option:

Construct a depth gauge using various diameters of tubing as a comparison.

Assessment

- Compare the known depth to the observed reading on the capillary gauge.
- Analyze how close the observed reading is to the predicted measurement.
- Determine the margin of error, if any, for the capillary gauge.

Water Sampler

PURPOSE: Build and attach a water sampler to your ROV.

MATERIALS:

1 - Solenoid valve (normally closed, pre-potted, 1/8 inch pipe size)
(PART #5077111, MCMASTER)

Electrical tape

1 - 50ml canister with water-tight cap

6 in - 1/8 inch (inner diameter)

tygon tubing (PART #
5554K11, MCMASTER)

Butyl Rubber Tape (monkey dung)

2 - 5" pieces electrical wire (one (-), one (+))

1 - Brass Barbed Hose Fitting Barb X Male
Pipe for 1/8" Hose ID, 1/8" Pipe
(McMaster Part # 5346K61)

1 - 50 ml sample bottle (USPlastics Part #
70036)

Electrical tape

1 - Red push button switch (JAMECO
121304)

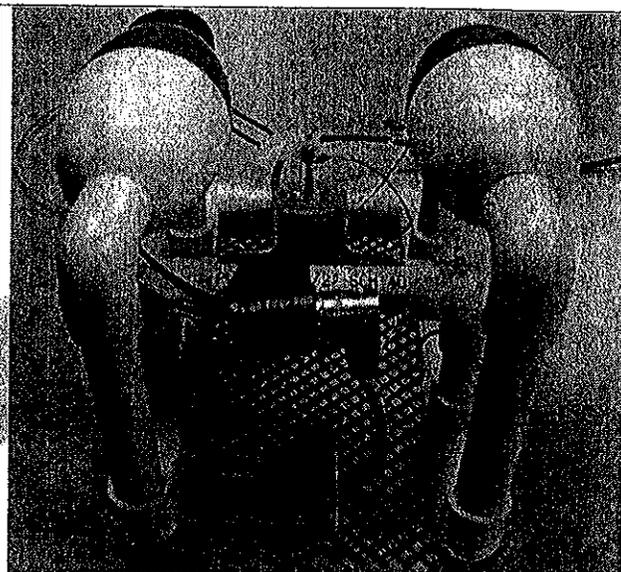
Zip ties

TOOLS:

Scissors

Drill with 3/32 and 1/4 inch drill bits

Soldering Iron



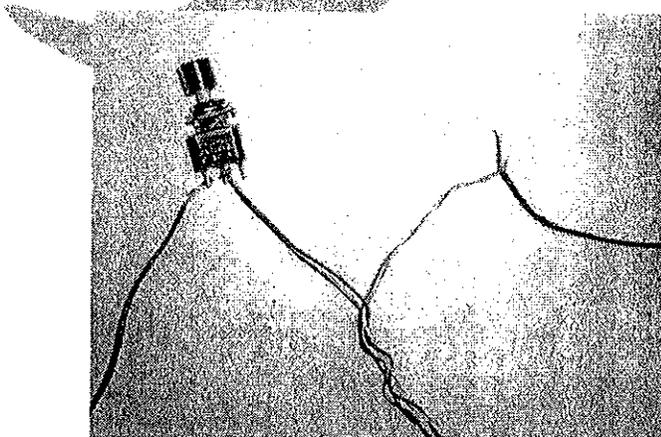
Procedure

1. Take your 50ml canister and drill a 1/4-inch hole in the lid.
2. Drill two 3/32-inch holes in the side of the canister as close to the top as you can. Thread the tubing through the hole in the lid of the canister until a little less than an inch is visible inside the canister. Waterproof the connection with monkey dung, cover with electrical tape. **MAKE SURE THIS SEAL IS GOOD!**
3. Attach the solenoid valve to the cross beam of the vertical thruster mount, by wrapping electrical tape tightly around the solenoid valve (or use a zip tie) and the crossbeam of PVC slightly to the left of the motor.
4. Screw male barb fitting into the solenoid. Attach the tube from the canister to male pipe tube adapter.

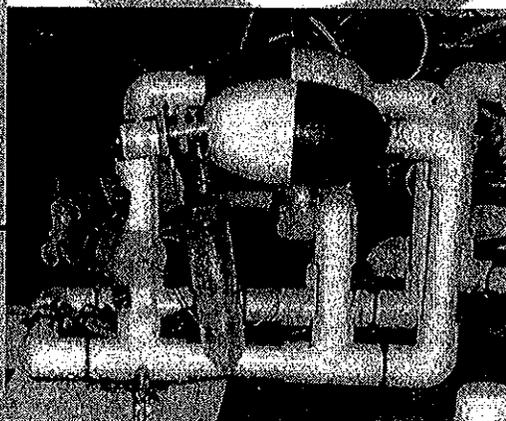
5. Lie the canister on its side (making sure that the hole on the side is facing up) and zip tie it to the netting. Be sure the tubing is securely connected to the canister and the solenoid. (OR PLACE VERTICALLY DEPENDING ON WHERE IT FITS BEST)
6. Add another ¼" hole to your control box (as you did in for the vertical thrusters Fig. 17a in your Construction Manual)

Wiring

7. You will need to add another power source to the control box. To do this, solder another black(-) and red(+) to the wire junctions you connected to the battery wires (Fig. 36 in your Construction Manual)
8. Take the BROWN wire (extra twisted pair from the tether) and attach to one wire on the solenoid (this will be your positive (+) wire) Attach the BROWN/WHITE wire to the other solenoid wire (this will become the negative (-) wire)
9. Solder and water proof both connections with monkey dung and electrical tape
10. At the control box end, thread the BROWN and BROWN/WHITE wires into the box
11. Connect the BROWN/WHITE (-) directly to the new (-) power source wire
12. Connect the BROWN (+) wire to the NO connection on the push switch
13. Connect the (+) power wire to the C connection on switch
14. Check that the solenoid works when switch is engaged
15. Solder connections and wrap with electrical tape
16. Add switch to the box in the same way as the vertical thruster switches
17. Dive to your desired depth and push the switch to take the sample, wait a few seconds or until you see the air bubbles stop, indicating the canister is full.



Solenoid switch wiring



Example of mounted solenoid

Exploring Underwater Habitats and Environments

Overview

In this lab, the students will make a hydrophone and attach it to their Sea Perch ROVs. They will use the hydrophones in conjunction with the underwater cameras on the ROVs to explore their local aquatic environments.

Grades: 8th – 12th

Time: 3 45-minute periods

National Science Education Standards:

Content Standard A - Science as an Inquiry

- Abilities necessary to do scientific inquiry
- Crosses disciplines and grade levels

Content Standard C – Life Science

- Interdependence of organisms
- Matter, energy, and organization in life systems
- Behavior of organisms

Content Standard E – Science and Technology

- Abilities of technological design
- Understanding about science and technology

Content Standard F – Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Natural and human-induced hazards

Content Standard G – History and Nature of Science

- Nature of scientific knowledge

Lesson:

Scenario

In order to understand the health of your local marine environment, you need to observe the environment. Use the camera to see how the fish and other marine animals interact with their environments and each other. Try to observe the diversity of the marine life. Using the hydrophone, listen to what can be heard within the environment. Are the noises more organic or mechanical? *Hint: Check around pilings to get better results.*

Materials:

Sea Perch with underwater camera attached

Hydrophone – constructed as per instructions from this website:

http://onip.gso.uri.edu/dosits/teacher/activity/hydrophone_instruc_w_image.pdf

Monitor to attach to the camera

Pen and paper to write down observations

Procedure:

1. Construct the hydrophone.
2. Attach the hydrophone on your Sea Perch in a secure place, preferably in the front of the vehicle.
3. Run the wire from the hydrophone along the tether from your Sea Perch. Attach the two wires (hydrophone and tether) together at periodic intervals with zip ties or tape in order to keep them neat.
4. Take the Sea Perch to a local water source, along with the hydrophone and the camera with monitor.
5. Launch the Sea Perch into the water and observe the local population.
6. Record your observations on data sheets or field notebooks.

Assessment:

- Compare the behaviors of the sea creatures to expected behaviors.
- Determine biodiversity of the area you examine.
- Analyze the sounds in the water and think about where they might be coming from.
- Write up a formal report with your observations.

Attenuation of Light in Water

This lesson is being used with permission from IScienceProject. Please see the original document at www.iScienceProject.com

Overview:

This lab may take a little while to set up, but it can yield some very interesting results. The idea is to stand a piece of PVC pipe on end, fill it with water, and shine a light into the opening at the top. A light intensity logger can then measure the intensity of the light at various depths. The results can be used to get an idea of the quantity of impurities in the water. You can then put the light intensity logger on your Sea Perch to gather data in the field and compare the data to your in-class experiments. This experiment lends itself to some interesting mathematical and physical analysis.

Grades: 9th-12th

Objectives:

- To construct a PVC model to hold water
- To understand what happens to light intensity as depth increases
- To understand what factors could influence the amount of light attenuation

National Science Education Standards:

Content Standard A - Science as an Inquiry

- Abilities necessary to do scientific inquiry

Content Standard B – Physical Science

- Conservation of energy and increase in disorder
- Interactions of energy and matter

Content Standard E – Science and Technology

- Understandings about science and technology

Content Standard F – Science in Personal and Social Perspectives

- Environmental quality

Content Standard G – History and Nature of Science

- Nature of scientific knowledge

Lesson

Background Theory

Consider the ideal situation of light as a point source. In this case, light intensity falls off as the square of the distance from the source. Assuming a lossless medium, the light provides energy E , a value that remains the same no matter how far you are from the source. However, as the distance r from the source increases, the energy gets spread out over a larger and larger area.

This area can be expressed as $4\pi r^2$, with r representing the distance to the source. So intensity $I(r)$ is given by $E_0/4\pi r^2$. If we let $k_1 = E_0/4\pi$, it follows that $I(r) = k_1/r^2$. Therefore, light intensity varies inversely with the square of the radius.

To simplify the analysis of our results, we will now take the logarithm of both sides of the equation. This will give us a linear relationship, which is much easier to work with. Using the logarithm rules yields:

$$\log(I) = \log(k_1) - \log(r^{-2}) = \log(k_1) - 2 \log(r)$$

The HOBO data logger will take measurements in units of log lumens per square meter, so this work has already been done for us. So, given an ideal point source, one would expect a plot of $\log(I)$ versus $\log(r)$ to be a straight line with intercept $\log(k_1)$ and slope -2 .

Now consider a tube with perfectly reflecting sides. Energy must still stay the same at all distances, but now intensity will also stay constant, because area is constant. A plot of $\log(I)$ versus $\log(r)$ in this case would yield a straight horizontal line. Specifically, $\log(I) = E_0/4\pi R^2$, where R is the radius of the tube. Note that I is not a function of r in this situation.

Pre-Lab:

If we measure intensity in air (before we add water to the tube), we expect a combination of these two cases. The inverse square relationship implied by a point source will occur; however, reflection from the walls of the tube (which are white) will lessen this effect. As a result, we expect to find a slope between -2 and 0 when we plot the log of intensity against the log of depth. We'll call this slope m and we'll refer to it later.

As a simple test of this reflection property, measure the light intensity at the bottom of the tube and then place the HOBO on the floor outside the tube, move the lamp over, and measure the intensity again. Is the intensity greater at the bottom of the tube?

Adding water to the situation gives us one more factor to consider: the attenuation of light in the water. Attenuation is a combination of absorption and scattering and we assume it to be zero when dealing with air. It is definitely not zero in the case of water, however. Assuming again a tube with perfectly reflecting sides, and also assuming a uniform medium, we expect energy to decrease as $E(r) = k_2 r E_0$. Here E_0 is the initial energy, r is distance, and k_2 is another constant. Since the area of the tube is constant, we expect intensity to be related to r in this same manner. So, $I(r) = k_3 r I_0$.

Again we want to take the logarithm of this equation, which gives

$$\log(I) = \log(I_0) + r \log(k_3)$$

If we plot $\log(I)$ against r (as opposed to plotting against $\log(r)$), we find a line with intercept $\log(I_0)$ and slope $\log(k_3)$.

Now we put this all together. In our tube filled with water, light is attenuated by the water, but it also decays as a result of the distance and reflection combination. There is also undoubtedly some light lost as a result of the plastic case that holds the HOBO. We want to focus on the attenuation of the water, so we need to eliminate these other effects. We know precisely the magnitude of these effects from our measure of the intensity in air. All we have to do then is add $m \log(r)$ to each of the measured intensities (in water), and the result is the corrected intensity measurement that takes only the attenuation effect into account. Specifically,

$$\log(I_{corr}) = \log(I_{meas}) + m \log(r)$$

We can now find the equation for I as a function of r taking into account only the attenuation affects of the water.

Materials:

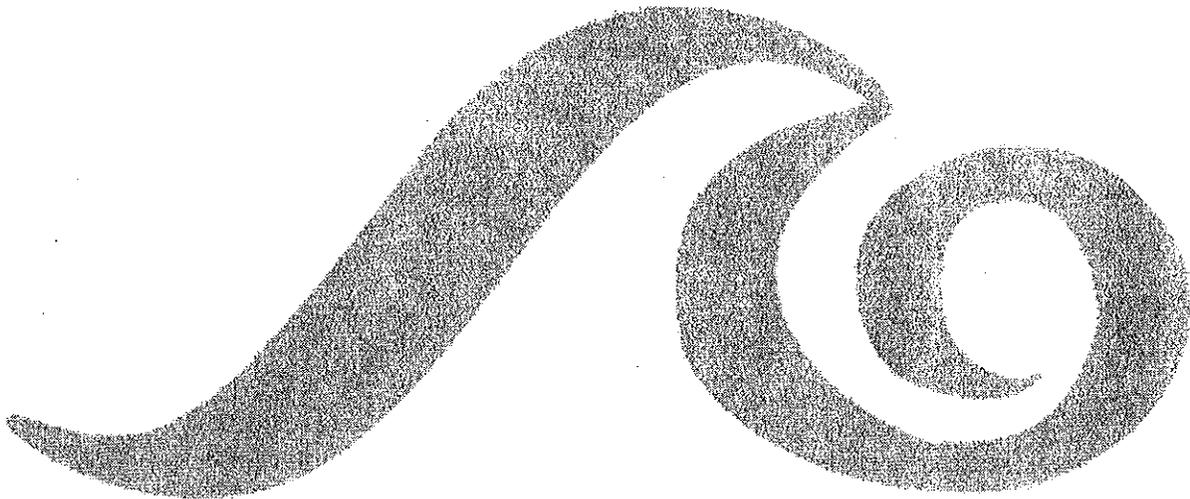
Sea Perch
A Stowaway Light Intensity data logger (SLA08)
Submersible case
A piece of 4" or 8" PVC pipe (2-3 meters long with cap on one end)
Tap water
Lamp
Fishing line
Weights
Ruler
Waterproof tape
Buckets (or a hose)

Procedure:

1. Glue a cap firmly to one end of the PVC tube to prevent leaking.
2. Secure the PVC tube vertically.
3. Position the lamp so it is shining straight down into the tube, placing it as close as possible to the opening.
4. Tie one end of fishing line, long enough to reach the bottom of the tube, to the submersible case with weights attached to the case as well.
5. Mark off the testing depths on the line with masking tape, every 20 cm for 2 meters; cover the masking tape with waterproof tape so it won't slip in the water.
6. Tie the other end of the line to something that will float.
7. Launch the HOBO to measure light intensity at half-second intervals.
8. Make sure that the weights are arranged so that the light sensor will be facing up when it is submerged.
9. Turn on the light source.
10. First, with no water in the tube, lower the HOBO to the first depth and hold it there for a

minute to gather data.

11. Repeat for all other depths.
12. After all depths are done, pull it out and look at the results. Save the data.
13. Fill the PVC tube with tap water, leaving a few centimeters at the top so it doesn't overflow when the HOBO is submerged.
14. Repeat the testing process. Check and save these results.
15. Go to a local water source and repeat the testing process again using your Sea Perch as the vehicle in which you can deploy your light meter. Check and save the results.



Student Designed Modification of Sea Perch

*Submitted by Sue Morash, South Meadow School, NH; Rex Roettger, Ramey School, PR;
and Jim Forsyth, Andrews Middle School, MA*

Overview:

This lesson plan is a follow-up activity to completion of Sea Perch.

- Students will brainstorm ideas for various modifications.
- Students will choose their “dream” modification (modification of choice) with stated objective in mind.
- Students will design and draw to scale a prototype of Sea Perch, plus its modification, to present to other students. Students will provide feedback to modification plan using a rubric.
- Students will web search for availability of appropriate parts and equipment needed, including cost.
- Students will incorporate ideas, design, costs, materials and equipment needed etc. into a formal business letter to look for funding for project.

Objective:

After building a submersible ROV, students will use their experience and ingenuity to create a beneficial modification through the standard design process. The project will culminate in a persuasive business letter that will motivate local merchants, corporations and others to support this design project to its completion as a prototype.

Skills attained:

- Students will recognize an existing problem/condition underwater that they would like to investigate.
- Students will identify what equipment would be needed to add to Sea Perch in order to collect data or analyze the identified problem/condition.
- Students will make scale plans of what the modification design will look like.
- Students will show/demonstrate their designs to other students.
- Students will critique each other’s design.
- Students will search the Internet for needed information, save web addresses, collect information and save.
- Students will organize information on modification and put it into a formal business letter.

National Science Content Standards Addressed:

Unifying Concepts and Processes

- Evidence, models, and explanation
- Systems, order, and organization

Content Standard A – Science as Inquiry

- Understanding about scientific inquiry
- Abilities necessary to do scientific inquiry

Content Standard E – Science and Technology

- Abilities of technological design
- Understanding about science and technology

Motivation:

Ownership: their modification needs to be solid “to peers and to prospective financial investors”

Assessment:

Rubric:

- Rough draft of drawing completed on time
- Scale drawing accurate
- Modification clearly explained
- Presentation
- Rough draft letter (paragraphs clearly explained)
- Final draft letter

Interdisciplinary Links:

- Language Arts – persuasive business letter
- Math – scale drawing
- Art – poster / background for scale drawing to give audience a feel for modification use
- Science
 - Probes
 - Robotic arm
 - Light source
 - Plankton net
 - Temperature
 - Pressure
 - Conductivity

6.0 Classroom Connections

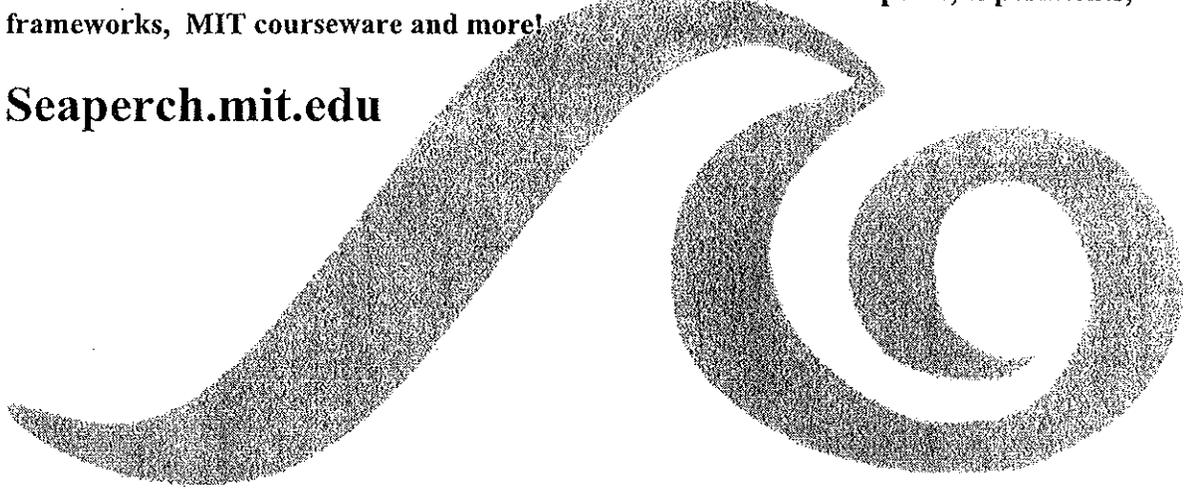
The Classroom Connections section contains additional lesson plans that relate to the topics of underwater technology and ocean exploration. The strength of the Sea Perch program is that it can link together many topics and disciplines by using the oceans as a realm of exploration. The past, present and future of ocean exploration allows one to teach this as an interdisciplinary project which will impact the students on a higher level.

Please visit NOAA's Ocean Explorer website for many great lesson plans to correlate to real world ocean exploration missions around the world!!!

<http://oceanexplorer.noaa.gov/welcome.html>

Be sure to check our MIT Sea Grant's Sea Perch website for lesson plans, experiments, frameworks, MIT courseware and more!

Seaperch.mit.edu



6.1 Scenarios

There are several scenarios in which you can integrate the Sea Perch project into your existing curriculum. Each scenario requires a different amount of time, resources and funds.

1. Build 1 Sea Perch for Class Exploration	
<p>a. Teacher builds 1 Sea Perch and class uses it to collect data. The teacher can either <u>a.)</u> Leave the Sea Perch in its 3 components and complete the final integration of the components with the class so they can witness how they work together to create a system OR <u>b.)</u> Teacher completely builds 1 out of class and shares final product with the class.</p>	<p><u>Time Requirement:</u> Out of class: 2 days to build Sea Perch (if you don't have one) In class: 1 day to introduce Sea Perch and its capabilities</p> <p><u>Resources:</u> http://web.mit.edu/seagrant/edu/scaperch/</p> <p><u>Funds:</u> ~\$60/Sea Perch + tools</p>
<p>b. Use Sea Perch as a class to explore local waterways. The Sea Perch can be one of many stations set up at a local pier, pond or beach access through which students are taking environmental and biological measurements of the ecosystem they are studying. You can add sensors and cameras to the payload area to collect the data.</p>	<p><u>Time Requirement:</u> 1-day field trip to explore local waters. 1 class period to analyze data</p> <p><u>Resources:</u> www.iscienceprotection.com for sensors</p> <p><u>Funds:</u> Field equipment, varies</p>
2. Build 1 Sea Perch as an Example of ROV Design	
<p>a. Teacher builds the separate 3 components of the Sea Perch. As a class, go over how the 3 units function independently and as a system. Finish the final assembly of the Sea Perch with class.</p>	<p><u>Time Requirement:</u> Out of class: 2 days to build Sea Perch (if you don't have one) In class: 1 day to introduce Sea Perch and finish assembling</p> <p><u>Resources:</u> http://web.mit.edu/seagrant/edu/scaperch/</p> <p><u>Funds:</u> ~\$60/Sea Perch + tools</p>
<p>b. Students then begin designing, on paper, their own ROV. This can be done as a contest, in which the best design (voted on by students using rubrics) gets to be constructed OR Students design and build their own unique ROV in groups.</p>	<p><u>Time Requirement:</u> 1 class period for discussing design ideas, needs, requirements of the ROV design process. 1 class period for student evaluation of designs; 2-4 class periods to building their designs; 1 day for testing ROVs</p> <p><u>Resources:</u></p>

	<p>Various PVC parts, tools, motors and controllers. Check with local hardware stores and industries for sponsorship.</p> <p>Funds: Varied – have students bring supplies from home, get sponsors.</p>
<p>c. Reference for constructing their own underwater robots: Build Your Own Under Water Robot and Other Wet Projects By Harry Bohm and Vickie Jensen, published by Westcoast Words, Vancouver, B.C. Canada. ISBN 0-9681610-0-6 http://www.westcoastwords.com/books_USD/details.php?book_ID=101</p>	<p>Time Requirement: n/a</p> <p>Resources: n/a</p> <p>Funds: ~\$22/book</p>
<p>3. Build several Sea Perches</p>	
<p>a. Students work in pairs/groups and build their own Sea Perch. This can be done in consecutive classes OR a few class times a month throughout the school year. Consecutive days are preferable as this allows students to remember what step they were on and the techniques/tools they learned.</p>	<p>Time Requirement: Requires ~ 20 hours of class time to complete 1 Sea Perch</p> <p>Resources: http://web.mit.edu/seagrant/edu/seaperch/</p> <p>Funds: ~\$50/Sea Perch + ~ \$200/set of tools</p>
<p>b. Students can monitor local waterways with multiple Sea Perches. Each Sea Perch can be equipped with a different monitoring device.</p>	<p>Time Requirement: 1-day field trip to explore local waters 1-class period to analyze data</p> <p>Resources: www.IScienceproject.com for sensors</p> <p>Funds: Field equipment, varies</p>

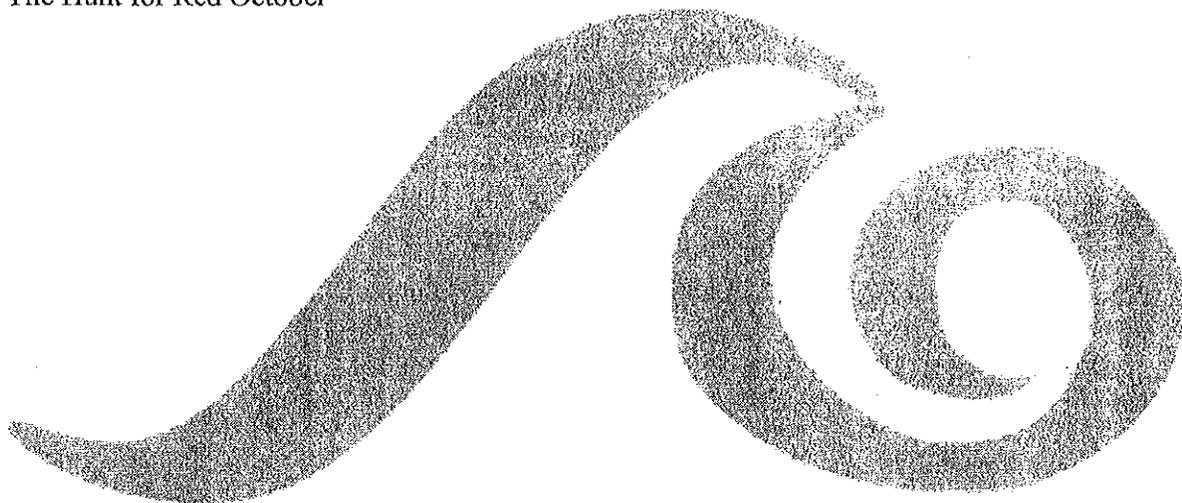
6.2 Making Sea Perch Interdisciplinary

This section contains lesson plan ideas on how to make the Sea Perch project an interdisciplinary effort. By incorporating more than one discipline to the Sea Perch, the students will grasp the concepts of ocean exploration and technology at a different level. Exposing students to different learning strategies (i.e. art, literature, presentations, research, and construction) will engage more students in the project.

The following lessons follow:

Ocean Exploration Time Lines

The Hunt for Red October



Ocean Exploration Time Lines

This lesson is being use with permission from Education World. Please view the original document at:

http://www.education-world.com/a_lesson/00-2/lp2080.shtml

Overview:

This lesson is to be used as an extension activity with the Sea Perch project. Students will learn about ocean exploration over the decades. Students will use suggested online or library sources to create time lines of various ocean explorations.

Grades: 6th – 12th

Time:

1 day construction/test
1 day collection
Up to a week for microscope analysis/identification

Objective:

Students will sequence ocean exploration events in chronological order.
Students will demonstrate research skills using the Internet and library sources.

National Standards:

Language Arts:

NL-ENG.K-12.1
NL-ENG.K-12.7
NL-ENG.K-12.8

Social Sciences:

NSS-WH.5-12.6

Materials:

Computers with Internet access; or
Student-researched library materials about ocean exploration or explorers
Paper, pens or pencils
PowerPoint software (optional)

Lesson:

Divide the class into small groups. Have students create time lines about aspects of ocean exploration using student-researched library sources or suggested websites. Here are a few websites to get students started:

Ocean Explorer. <http://oceanexplorer.noaa.gov/history/history.html>

Age of Exploration Time Line <http://www.mariner.org/educationalad/ageofex/>

Variation

Have students create their time lines as PowerPoint presentations.

Assessment

Students present their time lines to the class. Evaluate students' presentations.



English

The Hunt for Red October
By Tom Clancy

Submitted by Anne Doucette, Odyssey High, MA

Objective:

- Students should know and be able to do the following by the end of this unit:
- Shared reading of the text
- Literacy analysis using their background knowledge from their work on fiction (i.e., plot, characterization, and setting)
- Tie in some of the elements of fiction with nonfiction
- Present a cooperative report on the submarine disasters
- Identify and apply some of the vocabulary used in science concerning the Sea Perch project (i.e. sonar, thermal climes, pressure, temperature and depth)
- Critically view the video of *The Hunt for Red October*, and make a comparative study of the film and the book.

Materials:

- Text of *The Hunt for Red October*
- Audio tapes of *The Hunt for Red October*
- DVD of *The Hunt for Red October*
- Worksheets on fiction and non-fiction
- Poster board

Boston Public Standards:

- Standard 3: Oral Presentation
- Standard 8: Understanding a text
- Standard 9: Making connections
- Standard 12: Fiction
- Standard 13: Non-fiction
- Standard 24: Research
- Standard 26: Analysis of media

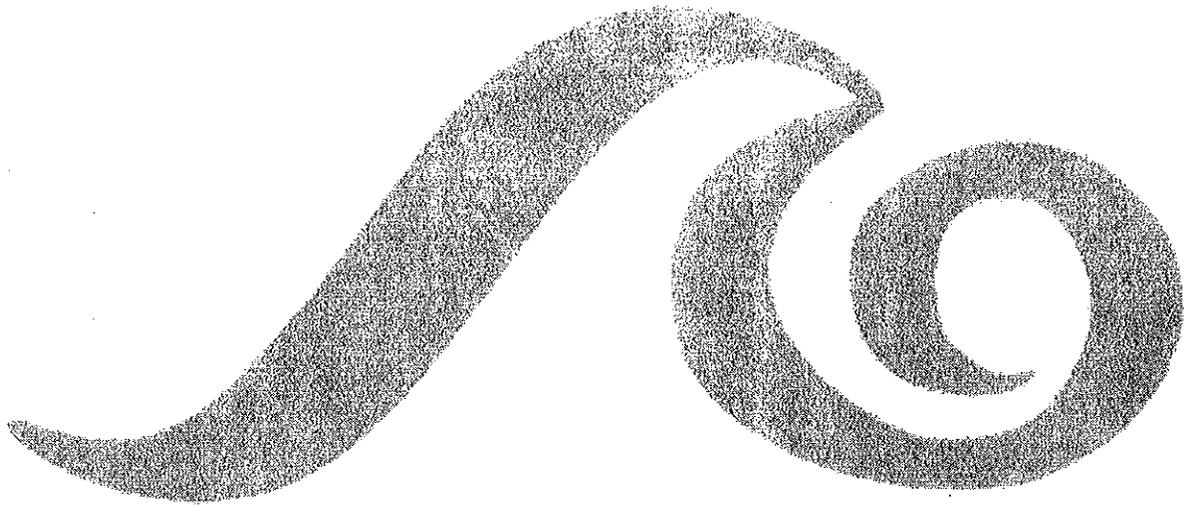
National Science Content Standards Addressed:

Content Standard G – History and Nature of Science

- Science as a human endeavor
- Historical perspectives

Lesson Plans:

- Use audio tapes for shared reading of Chapters 1 and 2 to identify the exposition of the novel
- Choose excerpts from the novel, using audio tapes to identify characterization and setting
- Have students research ocean settings that would help and/or hinder a submarine
- Have students research actual submarine disasters and share the stories in class
- Have students work cooperatively on displays of submarine disasters and their causes or outcomes

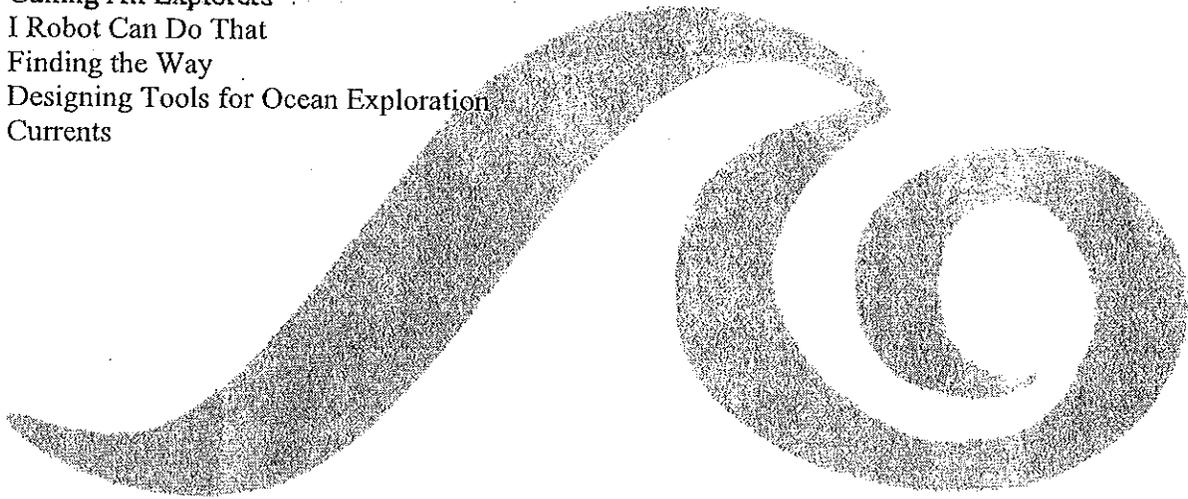


6.3 NOAA Ocean Exploration Lessons

NOAA's Ocean Exploration program has developed an interactive website that focus on the expeditions that NOAA has funded since 2001. The website complements the Sea Perch program because it offers real life scenarios as to how and why ocean technology is used. Please visit the website to learn more about the expeditions and the teacher resources available: <http://oceanexplorer.noaa.gov/>

The following lessons complement the Sea Perch program and give one an idea on how to integrate NOAA's Ocean Exploration website into their classroom.

Calling All Explorers
I Robot Can Do That
Finding the Way
Designing Tools for Ocean Exploration
Currents



7.0 Careers

Our goal for this project is not only to get students interested in math and science, but also to expose them to the types of careers available in the marine and ocean engineering fields. Please look at the "Careers" section of SEAPERCH.MIT.EDU for information and resources on careers in Science, Engineering and more.

Below is information from the Society of Naval Architects and Marine Engineers.

Naval Architecture, Marine Engineering, and Ocean Engineering

This section is used with permission from The Society of Naval Architects and Marine Engineers. Please view the original material from the SNAME website: www.sname.org

Naval architects, marine engineers, and ocean engineers design, build, operate, and maintain ships and other waterborne vehicles and ocean structures as diverse as aircraft carriers, submarines, sailboats, tankers, tugboats, yachts, underwater robots, and oil rigs. These interrelated professions address our use of the seas and involve a variety of engineering and physical science skills, spanning disciplines that include hydrodynamics, material science, and mechanical, civil, electrical, and ocean engineering.

What do they do?

* Naval architects are involved with basic ship design, starting with hull forms and overall arrangements, power requirements, structure, and stability. Some naval architects work in shipyards, supervising ship construction, conversion, and maintenance.

* Marine engineers are responsible for selecting ships' machinery, which may include diesel engines, steam turbines, gas turbines, or nuclear reactors, and for the design of mechanical, electrical, fluid, and control systems throughout the vessel. Some marine engineers serve aboard ships to operate and maintain these systems.

* Ocean engineers study the ocean environment to determine its effects on ships and other marine vehicles and structures. Ocean engineers may design and operate stationary ocean platforms, or manned or remote-operated sub-surface vehicles used for deep sea exploration.

These engineers are exploring and developing the natural resources and transportation systems of the ocean. Engineers in these fields are responsible for the design, construction and repair of ships, boats other marine vessels and offshore structures, both civil and military, including:

- * Merchant Ships - oil/gas tankers, cargo ships, cruise liners etc.
- * Passenger/vehicle ferries
- * Warships - frigates, destroyers, aircraft carriers, amphibious ships etc.
- * Submarines and underwater vehicles
- * Offshore drilling platforms, semi submersibles
- * High speed craft - hovercraft, multi hull ships, hydrofoil craft etc.
- * Workboats - fishing vessels, tugs, pilot vessels, rescue craft etc.
- * Yachts, power boats and other recreational craft

What types of jobs are there for someone with this major?

* Design	* Operations
* Construction and repair	* Regulations, surveying and supervising
* Consultant	* Research and development
* Marketing and sales	* Education and training

What subjects are important for a student looking to major in Marine or Ocean Engineering or Naval Architecture?

Math (calculus, trigonometry) Writing
Computers English
Physics Chemistry
Science Shop Class

What colleges have degrees in these engineering fields?

California Maritime Academy - www.csam.edu
California State: Long Beach - www.csulb.edu
Florida Atlantic University - www.oel.fau.edu
Florida Institute of Technology - www.fit.edu
Maine Maritime Academy - www.maimaritime.edu
Massachusetts Institute of Technology - web.mit.edu
Massachusetts Maritime Academy - www.mma.mass.edu
Memorial University of Newfoundland - www.engr.mun.ca
State University of New York Maritime College - www.sunymaritime.edu
Texas A & M University - www.tamu.edu
Texas A & M University at Galveston - www.tamug.tamu.edu
U.S. Coast Guard Academy - www.cga.edu
U.S. Merchant Marine Academy - www.usmma.edu
U.S. Naval Academy - www.usna.edu
University of British Columbia in Vancouver - www.student-services.ubc.ca
University of California-Berkeley - www.coe.berkeley.edu/oceaneng
University of Michigan - www.engin.umich.edu/dept/name
University of New Orleans - www.uno.edu
Virginia Polytechnic Institute & State University - www.aoe.vt.edu
Webb Institute - www.webb-institute.edu

Additional source of marine careers can be found at:

<http://www.marinecareers.net/>

Careers in oceanography, marine science and marine biology

<http://scilib.ucsd.edu/sio/guide/career.html>

Ocean Careers to Inspire Another Generation of Explorers

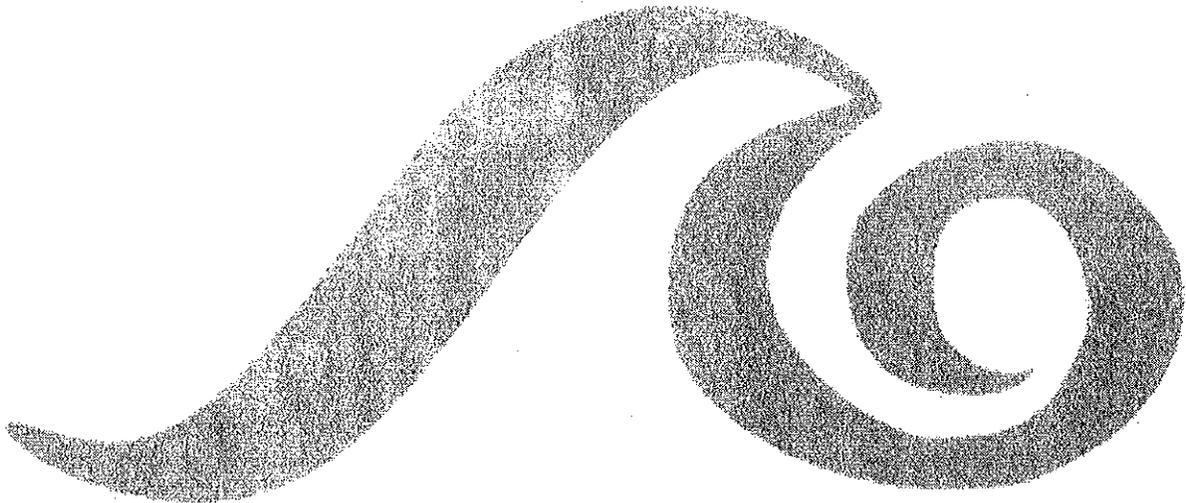
<http://oceanexplorer.noaa.gov/edu/oceanage/welcome.html>

8.0 Assessment

Assessment for any classroom project is very important. We have provided a variety of assessment tools in this section to allow you to monitor the progress of your students at the level appropriate for your class.

Included are:

- Pre/post survey that focuses on interest in math and science as well as concepts included in building the Sea Perch
- Open response rubric for building the Sea Perch



Name: _____ Grade: _____ Date: _____

Sea Perch: Integrating Ocean Exploration into the Classroom
Pre-test/Post-test

	Very High	High	Average	Low	Very Low
Describe your interest in science					
Describe your interest in math					
Describe your interest in designing, building and testing your own piece of equipment					
What is the chance that you would choose to take a science class?					
What is the chance that you would choose to take a math class?					
Describe your interest in leaning more about marine careers					
What is your interest in pursuing a career in engineering?					

1. What tool would you use to cut PVC piping?
 - a. Pipe cutter
 - b. Glue gun
 - c. Coping Saw
 - d. Drill

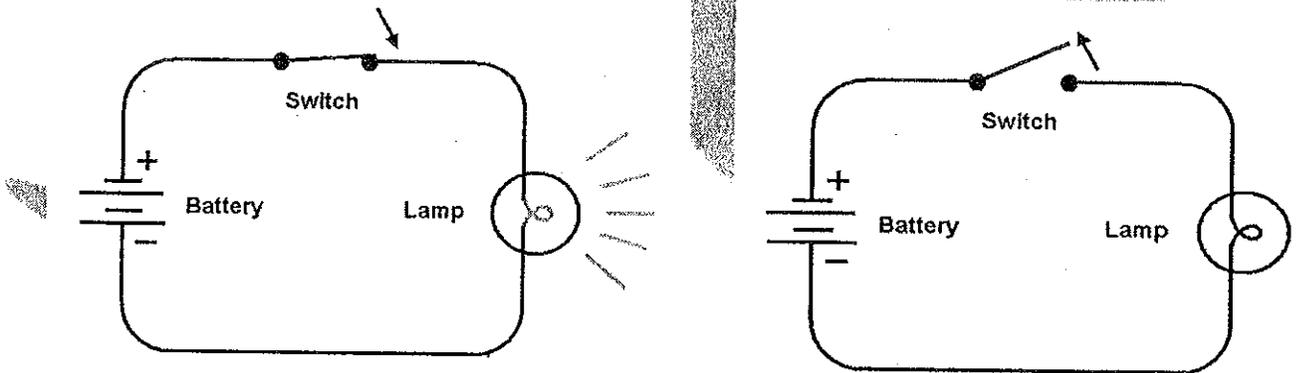
2. Which item is part of a propulsion system?
 - a. Lights
 - b. Floats
 - c. Thrusters
 - d. Plastruct H-beam

3. If you wanted to remove insulation from a wire, which tool would you use?
 - a. Wire stripper
 - b. Needle nose pliers
 - c. Screw driver
 - d. Soldering iron

4. If you wanted to join an electrical wire to a motor or a connection, which tool would you use?
 - a. Glue gun
 - b. Soldering iron
 - c. Scotch tape
 - d. Super-glue

5. Which tool would you use to bore a hole in a material?
 - a. Borer
 - b. Monkey wrench
 - c. Tap
 - d. Drill
6. In submersibles, which of the following items would be part of the structural subsystem:
 - a. Hull
 - b. Rudder & Propeller
 - c. Thrusters
 - d. Fins
7. The control subsystems in an aquatic vehicle can consist of:
 - a. Sail
 - b. Propeller
 - c. Rudder
 - d. Anchor

8. Circle of the following diagram that shows a completed circuit?



9. What characteristics of your construction materials must be considered when designing an aquatic vehicle?
 - a. Identify the materials you would choose.
 - b. Why did you make these choices?
10. Identify three important factors to consider when designing a vehicle for an aquatic environment.

Open Response Rubric

What characteristics of your construction materials must be considered when designing an aquatic vehicle?

a. Identify the materials you would choose. b. Why did you make these choices?

Score	Description
4	Response demonstrates sophisticated understanding of material characteristics by fully identifying and explaining the material choices made, and what favorable characteristics these construction materials would have (i.e., durability under the effect of forces, water resistance, ease of use- <i>cutting, shaping, assembling, joining, finishing, quality control, safety, and cost</i>) in designing a device for underwater travel.
3	Response demonstrates fairly sound understanding of material characteristics by mostly identifying and explaining the material choices made, and what favorable characteristics these construction materials would have (i.e., durability under the effect of forces, water resistance, ease of use- <i>cutting, shaping, assembling, joining, finishing, quality control, safety and cost</i>) in designing a device for underwater travel.
2	Response demonstrates rudimentary understanding of material characteristics by partially identifying and explaining the material choices made, and what favorable characteristics these construction materials would have (i.e., durability under the effect of forces, water resistance, ease of use- <i>cutting, shaping, assembling, joining, finishing, quality control, safety, and cost</i>) in designing a device for underwater travel.
1	Response demonstrates inadequate understanding of material characteristics by minimally identifying and explaining the material choices made, and what favorable characteristics these construction materials would have (i.e., durability under the effect of forces, water resistance, ease of use- <i>cutting, shaping, assembling, joining, finishing, quality control, safety and cost</i>) in designing a device for underwater travel.
0	Response is incorrect or contains some correct work that is irrelevant to the skill or concept being measured.
Blank	No response.

Identify three important factors to consider when designing a vehicle for an aquatic environment.

Score	Description
4	The response contains three supported important to designing a vehicle for movement in a water environment. The response choices demonstrate a sophisticated understanding of design considerations for underwater environments (i.e., effects of temperature, pressure, drag, load, upon maneuverability and upon vehicle subsystems - structural, propulsion, control).
3	The response contains two factors important to designing a vehicle for movement in a water environment. The response choices demonstrate a fairly sound understanding of design considerations for underwater environments.
2	The response contains one factor important to designing a vehicle for movement in a water environment. The response choices demonstrate a rudimentary understanding of design considerations for underwater environments.
1	The response contains one to three factors important to designing a vehicle for movement in a water environment that are not listed above.
0	The response is incorrect or contains some correct work that is irrelevant to the item or task
Blank	No Response.

9.0 Resources

The resource section contains a brief compilation of books, websites and videos that complement the Sea Perch project.

If you have suggestions of resources that would be helpful to other teachers, please submit them to: Sarah Olivo at olivo@mit.edu

9.1 Books

Build Your Own Under Water Robot and Other Wet Projects

by Harry Bohm and Vickie Jensen

Published by Westcoast Words, Vancouver, B.C. Canada

ISBN 0-9681610-0-6

With permission from Harry Bohm and Vickie Jensen, MIT Sea Grant has modified the instructions for the construction of the Sea Perch from this book. Buy it direct from the publisher: West Coast Words:

http://www.westcoastwords.com/books_USD/details.php?book_ID=101

Abandon Ship!: The Saga of the U.S.S. Indianapolis, the Navy's Greatest Sea Disaster

by Richard F. Newcomb

<http://www.alibris.com/search/search.cfm?qwork=73288&matches=156&qsort=r>

Near the end of World War II the Navy cruiser "U.S.S. Indianapolis" was sunk by a Japanese submarine and hundreds of lives were lost. The survivors spent five days adrift in the open sea before they were rescued. A court martial found the captain culpable, yet many of his crew thought he was not to blame and worked for years to clear his name.

The Silent World (National Geographic Adventure Classics)

by Jacques Cousteau

[http://www.amazon.com/exec/obidos/search-handle-url/index=books&field-author=Jacques Cousteau/102-8067021-2496148](http://www.amazon.com/exec/obidos/search-handle-url/index=books&field-author=Jacques+Cousteau/102-8067021-2496148)

U.S. Navy Ships and Coast Guard Cutters (A Naval Institute Book for Young Readers)

by M. D. Rear Admiral Van Orden, Arleigh A. Burke

For ages 10-16 – overview of life on a ship

[http://www.amazon.com/exec/obidos/search-handle-url/index=books&field-author=Burke%2C Arleigh A./102-0949244-4998558](http://www.amazon.com/exec/obidos/search-handle-url/index=books&field-author=Burke%2C+Arleigh+A./102-0949244-4998558)

The Hunt for Red October

by: Tom Clancy

"Somewhere under the Atlantic, a Soviet sub commander has just made a fateful decision: the Red October is heading west. The Americans want her. The Russians want her back. And the most incredible chase in history is on" A Clancy classic!

Before The Wind: The Memoir Of An American Sea Captain, 1808-1833

By Charles Tyng

Paperback; ; ISBN: 0140291911

<http://www.NetStoreUSA.com/tnbooks/014/0140291911.shtml>

9.2 Websites/Resources

NOAA Ocean Exploration

<http://oceanexplorer.noaa.gov/>

NOAA's Office of Ocean Exploration has created a website to support the expeditions they fund around the world. This site contains mission details, educational materials, images, videos and career information.

U-505 Submarine Exhibit

<http://www.msichicago.org/exhibit/U505/U505home.html>

Explore it online! The U-505 is a German World War II Type-IXc Unterseeboot (submarine) that was captured in battle on the high seas by boarding parties from the USS Guadalcanal task group 22.3 on 4 June 1944.

USS Constitution Museum

<http://www.usconstitutionmuseum.org/>

"Old Ironsides" is the oldest commissioned warship afloat in the world. Her history is rich and colorful and 200 years strong -- from fighting Barbary pirates on the "shores of Tripoli" to winning famous victories during the War of 1812.

Historic Ship Nautilus: Submarine Force Library and Museum

<http://www.usnnautilus.org/>

The Submarine Force Museum in Groton, Connecticut, home of the historic ship NAUTILUS (SSN 571), is the United States Navy's official submarine museum. The mission of the museum is to collect, preserve, interpret and present the history of the United States Submarine Force.

United States Naval Shipbuilding Museum

<http://www.usn-salem.org/>

"The USNSM is home to USS Salem CA-139, the world's only preserved heavy cruiser. The museum is located in the former Bethlehem Steel Quincy Fore River shipyard, once one of the nation's largest shipbuilding enterprises.

History of Oil Exploration in Turkey

<http://www.tpao.gov.tr/rprte/HISTORY2.HTM>

History of Oil Use

http://www.bydesign.com/fossilfuels/links/html/oil/oil_history.html

History of the World Petroleum Industry

<http://www.geohelp.ab.ca/world.html>

ROV Educational Materials

<http://www.rov.org/education.html>

Shipwreck Discovery

<http://shipwreck.net/preservationmag.html>

ROV role in the JASON project

http://www.jason.org/jason14/field/bstory_oceanexp2

Compilation of articles of Current ROV Uses

<http://www.diveweb.com/rovs/index.shtml>

Working in the Oil Industry

<http://www.questionline.co.uk/707.html>

National Center for Case Study Teaching in Science

<http://ublib.buffalo.edu/libraries/projects/cases/case.html>

Underwater Archaeology Shipwreck Technology

<http://www.abc.se/~m10354/publ/uwarcted.htm>

The Ocean Planet, Smithsonian Institution's National Museum of Natural History

http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/search_educational_materials.html

The Ocean Project

<http://www.theoceanproject.org/resource/educational.html>

The Maritime Aquarium at Norwalk, CT

Special exhibit: Into the Abyss: Extreme Deep Discovery Zone

http://www.maritimaquarium.org/whats_going_on/exhibits_special.html

The Technology of Propellers

http://www.mercurymarine.com/chapter_4_-_propeller_technology

Science and Technology from the Office of Naval Research

<http://www.onr.navy.mil/focus/ocean/>

9.3 Videos

Ocean Explorer

<http://oceanexplorer.noaa.gov/>

Mountains In The Sea

Exploring the New England Seamount Chain

<http://www.videoalive.com/explorethesea/easternseamountains.htm>

Sea Profiles CD-ROM Set

SEA PROFILES: An interactive journey of ocean exploration.

http://www.hboi.edu/docs/ed_products.html

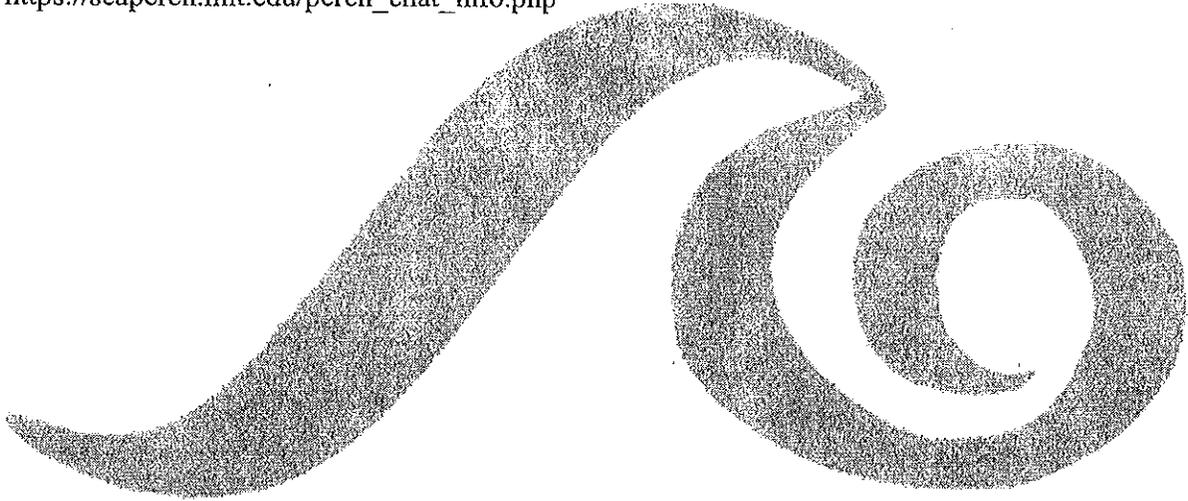
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A PerchChat discussion group has been set-up using Google Groups, where members can read and reply to each other's messages. In order to read the archives or post a message, you must be a member of the group.

Please visit our website for simple instructions on how to join:

https://seaperch.mit.edu/perch_chat_info.php



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http://www.mercurymarine.com/chapter_4_propeller_technology

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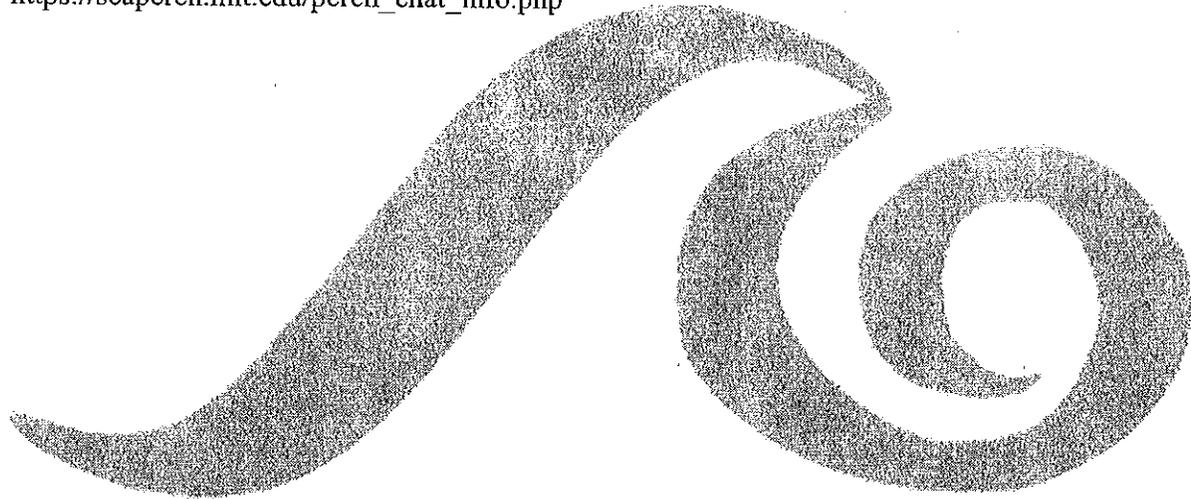
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10.0 Parting Thoughts and Public Relations

We hope that you have found the Sea Perch Project useful and are able to incorporate some of these ideas into your curriculum.

As you develop your plans, please remember to keep us informed on your progress. This is important for two reasons:

1. To keep our sponsors up to date, so that we can get additional funds to follow up with refresher courses and teach additional colleagues
2. To assist you with any questions/issues you might have while planning, building or testing.

We are certain you will also have occasion to give presentations, convey updates via your web site and, perhaps have interviews with the press. We would appreciate your acknowledgment of the appropriate partners in such cases. And please also let us know about these activities.

The **Office of Naval Research** provided the bulk of the funding for Sea Perch through its **National Naval Responsibility Initiative**. The specific project that enabled your training is **Recruiting the Next Generation of Naval Architects** (<http://nrc.aticorp.org>), run by the **MIT Sea Grant College Program** (<http://seaperch.mit.edu>).

Acknowledging the Office of Naval Research and the MIT Sea Grant College Program will be extremely helpful for us to continue with this project. Please forward any articles or information to:

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The Sea Perch training team wish you all the best!