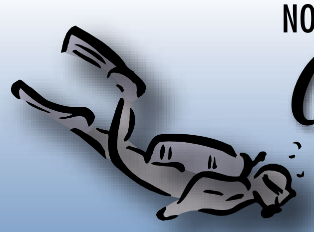
NOAA's

aquarius

America's Innerspace Station



Dive In!

Focus

Physics of underwater diving

Grade Level

9-12 (Physical Science)

Focus Question

How do buoyancy, pressure, and light affect the work of underwater scientists?

Learning Objectives

Students will be able to explain Archimedes' Principle, and explain how this principle applies to scientists working underwater.

Students will be able to identify the source of atmospheric and underwater pressure, and explain how these pressures vary with altitude and depth.

Students will be able to identify two ways in which light is affected when it passes through water.

Materials

- copies of "Student Worksheets for Underwater Physics," one copy for each student or student group

Part I: Buoyancy

- 1 ping pong ball
- 1 clear plastic drinking cup
- Tape (masking tape is better)
- 5-10 dimes
- Pencil
- Paper
- 1 golf ball
- 1 marble
- 16 paper clips
- Ruler
- Aluminum foil
- Bucket of water

Part II: Pressure

- Yardstick (or a meter stick)
- String (about 4 feet)
- 3 balloons (must be the same size)
- Scissors
- Heavy book or modeling clay
- 2 pencils (one to write with)
- Paper

Part III: Light

- Glass of water
- 2 pencils (one to write with)
- Paper
- Scissors
- Tape (masking is best)
- Short table or chair
- Flashlight
- Sheet of black construction paper, approximately 21 cm x 28 cm
- Sheet of white paper, approximately 21 cm x 28 cm

Audio/Visual Materials

None

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of 4-6 students

Maximum Number of Students

30

Key Words

coral reef
SCUBA
buoyancy
neutral buoyancy
buoyancy compensator
pressure
absolute pressure
bends
Boyle's Law
refraction
normal
turbidity
color
absorption

Background

Aquarius is an undersea laboratory owned by the National Oceanic and Atmospheric Administration (NOAA). Its purpose is to support research on oceans and coastal resources by allowing scientists to live and work on the seafloor for extended periods of time. Aquarius is presently deployed three and a half miles off-shore in the Florida Keys National Marine Sanctuary. It operates 62 feet beneath the surface at Conch Reef. Missions typically last ten days and aquanaut candidates undergo five days of specialized training before each mission starts. Visit http://www.uncw.edu/aquarius/ more information, including a virtual tour of the Aquarius laboratory.

Aquarius missions are focussed on understanding our changing ocean and the condition of coral reefs. Coral reefs are threatened locally, regionally, and globally by increasing amounts of pollution, over-harvesting of fisheries, disease, and climate change. Marine protected areas (MPAs) are recognized as an important management tool for marine conservation, and can help stop dwindling fish populations, conserve critical habitats and biodiversity, and manage sites to avoid conflicts among fishers, boaters, and divers. Effective design and management of MPA s to protect coral reefs requires specific information on the complex ecosystems typically associated with these reefs, particularly fish populations. In recent years, visual censuses by scuba divers have become increasingly important to marine conservation programs. In addition to research conducted by professional scientists, many fish population surveys are also done by volunteers. The Reef Environmental Education Foundation's Fish Survey Project, for example, allows volunteer SCUBA divers and snorkelers to collect and report information on marine fish populations. The data are collected using a standardized method, and are archived in a publicly-accessible database on REEF's Website (http://www.reef.org).

Aquarius scientists escape the limitations of conventional surface-based SCUBA diving through the use of a special technique called saturation diving. The most serious threat divers face when working underwater is related to "decompression sickness," also known as "the bends." This condition is caused by bubbles that form in the blood and tissues when divers stay down too long at a given depth and then ascend too fast (similar to the bubbles that form in a bottle of soda when the top is suddenly released). These microscopic air bubbles get caught in the joints and blood vessels, causing many symptoms that can include pain, paralysis, and ultimately death. Instead of coming to the surface after diving, scientists who use Aquarius return directly to the undersea laboratory. As long as the Aquanauts don't go back to the surface they can use special dive tables to greatly increase their bottom time—to nearly ten times over what they typically have using conventional surface-based diving techniques. Without Aquarius, researchers are forced to make multiple dives of short duration from the surface, which also leaves them vulnerable to the complications of daily boat trips, unpredictable weather, difficulties setting up seafloor experiments that require power and computers from the surface, and frequent deep dives that increase the likelihood of getting the bends. At the end of each mission, aquanauts go through a 17-hour "decompression," where the pressure inside Aquarius is slowly reduced from ambient (the pressure at the working depth of Aquarius is 2.5 times surface pressure, or nearly 44 pounds per square inch) back to surface pressure (14.7 pounds per square inch). At the end of decompression, the aquanauts "blow down" back to ambient depth inside Aquarius, are met by ascent divers in the wet porch, and are then escorted to the surface where they are picked up by boats and returned to shore.

Additional advantages provided by the Aquarius saturation system include the sophisticated power and communication capabilities of the habitat. Experiments can be set up on the reef similar to what might be accomplished back at a shore-based laboratory bench. Scientists also have email, telephone, and video conferencing capability to anywhere in the world.

In these activities, students will explore some of the physical principles that affect the work of diving scientists.

Learning Procedure

[NOTE: These lessons were designed by Lucas Gillespie]

1. Briefly review background information on the Aquarius habitat, coral reefs, and ways in which these reefs are threatened (http://www.uncw.edu/aquarius and http://www.nos.noaa.gov/education/welcome.html provide "one-stop shopping" for this review). Briefly discuss saturation diving, and the advantages enjoyed by scientists who work from the Aquarius habitat. You may also want to have students review the New England Aquarium's book on coral reefs (http://www.uncw.edu/aquarius/education/coral_reefs/coral1.htm) and complete the "Coral Crossword Challenge" (http://www.uncw.edu/aquarius/education/lessons.html).

2. Distribute copies of "Student Worksheets for Underwater Physics," one copy for each student or student group. You may want to have students complete all three sections prior to discussion, or discuss each section as it is completed.

3. Discussions

Part I: Buoyancy

Discuss students' answers to questions 3, 4, 5, 6, 8, 12, 15, 17, 18, 21, 22, and the Buoyancy Math problems. Be sure students understand Archimedes Principle.

Ask students how scientist divers stay at a constant depth? Divers use two devices to achieve what is called "neutral buoyancy." Neutral buoyancy means a diver is neither sinking nor rising to the surface. To achieve this a diver must take into account several factors:

- Their weight and percentage of body fat
- The thickness and type of dive suit they're using
- The type of air tank they're using
- The weight or buoyancy of equipment they carry

To achieve neutral buoyancy, divers use a weight belt to add weight to themselves and counteract their tendency to float to the surface. But what if they're too heavy?

Divers also use a buoyancy compensator or BC to which they can add air if needed making them more buoyant. It is important that reef scientists don't sink and step on the corals they're studying!

Ask students what would happen if a diver filled a balloon with air and put it several feet underwater. Students should predict that the balloon would float to the top. Ask students why keeps Aquarius on the bottom since it also is full of air. Students should infer that the weight of the habitat is greater than its buoyancy. In fact, while Aquarius weighs about 80 tons in the air it is almost neutrally buoyant in water. But since it is attached to a base plate that weighs 120 tons, it stays firmly anchored to the ocean floor. The base plate supplies the extra weight (like the diver's weight belt) to keep Aquarius under water.

Part II: Pressure

Discuss students' answers to questions 5, 7, 8, 11, and the Pressure Math problems. Discuss the concepts of atmospheric pressure and water pressure.

From their experiments, students should realize that air has weight. The Earth's atmosphere is always pushing down on us with its weight. We define this weight as atmospheric pressure. Pressure is defined as force acting on a unit area. Scientists have calculated that the Earth's atmosphere exerts a force on our bodies equal to 14.7 pounds per square inch. Another way to think of it is that a one inch column of air as tall as the atmosphere would weigh 14.7 pounds. This measurement, of atmospheric pressure at sea level, is also known as 1 Atmosphere of Pressure, or 1 ATM.

Students should also realize that water has weight. Since water weighs much more than air, it exerts a greater pressure. A one inch column of water 33 feet tall weighs 14.7 pounds. This pressure, resulting from the weight of water is called hydrostatic pressure. So at a depth of 33 feet, a diver experiences atmospheric and hydrostatic pressure equal to twice the amount of atmospheric pressure. We call this 2 ATA, one from the atmosphere and one from the water. This is called absolute pressure. That means our diver is under a pressure of 29.4 pounds per square inch (psi). At 66 feet down a diver is at 3 ATA and experiences a pressure of 44.1 pounds per square inch, and so on.

Aquarius scientists use gauges that measure their depth. When working underwater, it's always important for the diver to know their depth because this affects their air usage. These gauges work based on the water pressure. Gauge pressure is different from absolute pressure because it ignores the 14.7 pounds per square inch of the atmosphere. At sea level the gauge would read 0 feet, which is also considered 0 pressure.

Ask students what effects pressure might have on divers? Say that this is one of the most important aspects of underwater diving and is important to the safety and well-being of the diver. Ask students to explain the popping sensation in their ears that often happens when flying in an airplane or driving into the mountains. Students should realize that our ears have a space in them that is filled with air. If we change our altitude, the pressure exerted on us changes (just like the pressure changes the deeper in the water you go). The reason we experience this "popping" is due to the fact that gases are compressible. Basically that means there's space in between the molecules and it's possible to squeeze them closer together. This closeness of molecules is known as density.

Have students suppose that a diver takes a cup and inverts it so that it catches air, then dives underwater with it. As the diver descends, he (or she) notices that at 33 feet down (2 ATA) the container is only half full now. No air has escaped, so where has it gone? The air has become compressed by the surrounding water pressure. The air in our container is twice as dense as it is at the surface. Likewise, if the diver blew up a balloon and took it down, it would shrink to half its original size by the time he reached 33 feet of depth.

Now, what if the diver were at a depth of say 66 feet (3 ATA) and inflated a balloon. If the diver released it, what do you think would happen? It would float to the surface, of course, but what about the size of the balloon? Remember that the air that was put into the balloon was under pressure and was three times as dense as it would be at the surface. I was compressed. As the balloon ascends, the pressure decreases, the balloon expands, and might eventually burst! This takes us to an important rule of diving:

Never Hold Your Breath!

If divers hold their breath while ascending from depth, their lungs would expand just like the balloon and eventually burst, causing serious injury or death! However, if divers continue to breath normally as they ascend the expanding air will simply escape with each breath.

Tell students that this is an example of Boyle's Law, which states:
If the temperature remains constant, the volume of a given mass of gas is inversely proportional to the absolute pressure.

Boyle's Law explains the cup, balloon, and diver examples given above.

If you want to explore Boyle's Law in greater depth, the following discussion may be helpful:

We know from our previous examples that according to Boyle's Law, an inverse relationship exists between the volume and the pressure of a gas. Thus, pressure (P) times volume (V) will equal a constant (K).

That means that at any depth, whether at 20 feet or even 100 feet the pressure times the volume must be equal. We can put this into an equation where P1 and V1 are the pressure and volume at the first depth and P2 and V2 are the pressure and volume at the second depth:

$$P1 \times V1 = P2 \times V2$$

Let's try an example that uses this relationship. Let's say an Aquarius scientist has filled a balloon to one cubic foot at a depth of 66 feet. If our scientist wants to send it to the surface with a sample they collected, what will be the volume of the balloon at the surface? Let's plug our numbers in and see.

Recall from our previous lessons that seawater exerts a weight of 0.445 pounds per foot of depth. So, our pressure at the initial depth (P1) is equal to

$$0.445 \text{ pounds} \times 66 \text{ feet} = 29.37 \text{ psi}$$

This is gauge pressure, so we need to add an additional 14.7 psi to account for atmospheric pressure and get our absolute pressure, which is

29.37 psi + 14.7 psi = 44.07 psi

At the surface we know the pressure is 14.7 psi. This is our P2. Our initial volume is 1 cubic foot, our V1. So let's plug all these numbers into our equation:

44.07 psi x 1 cubic foot = 14.7 psi x V2

Now all we have to do is solve for V2:

44.07 psi / 14.7 psi = V2

V2 = 3 cubic feet

So, our balloon has expanded to three times its original size. As you can see, we can use the relationship, P1 x V1 = P2 x V2, to calculate pressure or volume at any depth.

Part III: Light

Discuss students' answers to questions 3, 4, 5, 7, 8, 16, 17, 18, and 19. Discuss the concept of refraction.

Students should realize that as light enters the water it changes speed and bends. This bending of light is called refraction, and is the reason that the pencil seemed disconnected or broken at the point where it entered the water. Light reflected from the portion of the pencil that is underwater is bent toward the "normal" (the "normal" is an imaginary line perpendicular to the surface of the water. This causes the portion of the pencil underwater to appear offset from the portion above the water.

From their experiments, students should also have found that when white light bends as it enters water, it separates into its different wavelengths, red, orange, yellow, green, blue, indigo, and violet. Refraction is also affected by turbidity, or the measure of cloudiness in the water, and scientists on board Aquarius use instruments that measure the bending of light to study the concentrations of dissolved materials and small floating plants and animals (plankton).

Students should also understand that light energy is absorbed by water. More light energy is absorbed as you descend into deeper waters. Remind students that white light is composed of all the colors of the spectrum together, but these colors have different amounts of light energy. As white light enters the water, red (with the least energy) is the first to be absorbed, followed by orange, yellow, green, and finally blue. Since blue light is scattered the most by water (because in comparison, the other colors are absorbed more than they are scattered), the oceans generally appear to have a blue tint. As light energy is absorbed, the surrounding water becomes darker. Below about 1000 feet no light penetrates, and the oceans are forever dark.

Ask students to speculate on what kind of life they think might be found in the deep ocean.

Point out that scientists working underwater at Aquarius deal with these phenomena everyday. The different absorption rates of the component colors of white light cause the underwater world of color below about 20 feet to be quite different from what you see on the surface. Reds and oranges are practically absent, until divers add illumination from underwater lights. Then they see the spectacular colors that give coral reefs their reputation as one of the most colorful ecosystems on earth. A recent Aquarius mission specifically studied underwater color and light. You may want to show some photographic or video images of coral reef communities (see "Resources").

Ask students what they see if they open their eyes underwater. The reason that everything seems blurred, is that the water refracts light differently than air. To see clearly underwater requires an airspace between the eyes and the water. That's why divers use masks. This has an interesting effect, however, because light entering the airspace from the water bends away from the normal causing objects to appear closer and 25% larger than they really are.

The Bridge Connection

www.vims.edu/bridge/– Click on "ocean science" in the navigation menu to the left, then "Chemistry" for links to information and activities relevant to underwater physics.

The "Me" Connection

Have students write a short essay about how buoyancy, water pressure, or refraction of light has been (or might be) of personal importance in their own lives.

Connections to Other Subjects

Earth Science, Life Science, English/Language Arts, Mathematics

Evaluation

Students' written answers to questions in Parts I, II, and III, as well as participation in oral discussions provide opportunities for assessment.

Extensions

1. Visit http://www.uncw.edu/aquarius/ to learn about other Aquarius missions and activities.

2. One of the key capabilities that makes underwater diving possible is the ability of divers to take their air supply with them. Air tanks used by divers contain compressed air. The larger air tanks hold about as much air as a typical walk-in closet crammed into a space about two feet long and six inches in diameter! The air pressure inside these tanks may be 3,000 pounds per square inch or more when the tanks are full. To be useful to divers, this pressure must be reduced in a controlled way. Have students research the history and operation of the SCUBA regulator.

Resources

http://www.uncw.edu/aquarius – The Aquarius project web site

http://www.onr.navy.mil/focus/ocean/ – Office of Naval Research website with information and activities on salinity, pressure, density, optics, acoustics, and temperature

http://www.marinebiology.org/science.htm – Odyssey Expeditions website, with lots of information about coral reefs and reef ecology

http://www.reef.org/ – Reef Environmental Education Foundation website

http://www.coralreefalliance.org/photogallery/frost/ – Online source of royalty-free photographs of coral reefs and reef organisms

http://www.nos.noaa.gov/education/corals/supp_coral_roadmap.html – National Ocean Service website's Roadmap to Resources about corals, with links to many other sources of coral reef data, background information, and reports

National Science Education Standards

Content Standard A: Science as Inquiry

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

Content Standard B: Physical Science

- Structure and properties of matter
- Motions and forces
- Interactions of energy and matter

Content Standard D: Earth and Space Science

- Energy in the earth system

Content Standard E: Science and Technology

- Abilities of technological design

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Environmental quality

Student Handout

Student Worksheet for Underwater Physics

Part I: Buoyancy

Scientists who study underwater have a challenge to stay in one place to conduct their work. Here's an experiment you can do to find out how they do it.

Here's What You'll Need:

- 1 ping pong ball
- 1 clear plastic drinking cup
- Tape (masking tape is better)
- 5-10 dimes
- Pencil
- Paper
- 1 golf ball
- 1 marble
- 16 paper clips
- Ruler
- Aluminum foil
- Bucket of water

Directions:

1. Use your pencil and paper to record all of your observations and answer any questions when necessary.

 ____

 ____

2. Take your glass or cup and fill it about 2/3 full of water. Mark the water level with a piece of your tape.

3. Now, place a ping pong ball in the water. What happens to it?

 ____

 ____

4. Push down on your ping pong ball. What do you feel? What happens if you quickly let go?

 ____

 ____

5. Push down again until 1/2 of the ping pong ball is under water and look at the water where you marked the water level with tape. What happens to the water level?

 ____

 ____

6. Tape a dime to the ping pong ball with your tape and return it to the water. Does it still float?

7. Find out how many dimes you need to tape to it before it sinks. Write that number down.

8. Once the ball is at the bottom of the cup or glass, look at your water level again. Why is it higher than before?

You Be The Scientist:

9. Write down what you think will happen if you put the golf ball or marble in the cup of water. (Hypothesis)

10. Try it. (Experiment)

11. Write down your observations. (Observations)

12. What happened? Why do you think that happened? (Conclusions)

Find Out More:

Try this activity out to see how a ship that weighs several tons can stay afloat.

13. Using your ruler to measure, cut two squares out of the aluminum foil that measures eight inches on each side.

14. Wrap eight of your paper clips with one of your squares of aluminum foil and squeeze it tightly.

15. Place it gently on the surface of the water in the bucket and let it go. What happened?

16. Fold the four sides of your other square up so that it forms a small plate and place the other eight paper clips into it. This is your boat!

17. Gently place this on the surface of the water and let it go. What happened to this one?

18. If the weights are the same between the ball and the boat, Why did one sink and one float?

You Be The Scientist:

19. Write down what you think will happen if you put a small hole in the bottom of your boat. (Hypothesis)

20. Try it. (Experiment)

21. What happened? (Observation)

22. Why do you think that happened? (Conclusion)

Try A Little Buoyancy Math!

Buoyancy is governed by something we call Archimedes Principle. It states that
"Any body completely or partially submerged in a fluid (gas or liquid) at rest is acted upon by an upward, or buoyant, force the magnitude of which is equal to the weight of the fluid displaced by the body."

The fluids that divers are most concerned with are fresh and salt water. It's necessary to distinguish between the two because equal volumes of the two have different weights. For example, a cubic foot of fresh water weighs approximately 62.4 pounds, but a cubic foot of salt water weighs approximately 64 pounds. Where does the extra weight come from? If you said the salt (and a few other minerals), you're right!

Let's Look At An Example:

Let's say you have a solid block that has a volume equal to one cubic foot and weighs 63 pounds. If you put into freshwater, will it sink or float?

We know freshwater has a weight of 62.4 pounds per cubic foot. Our block weighs 63 pounds and displaces 62.4 pounds of water. If we subtract 63 from 62.4 we get -0.6 pounds. This means our block is negatively buoyant and will sink.

What if we place the same object in seawater?

Seawater has an average weight of 64 pounds per cubic foot. Again, our block weighs 63 pounds which is less than the weight of the water displaced. If we do the math we find 63 pounds from 64 pounds gives us 1.0 pounds. Our block is positively buoyant and will float.

Trick Question: If you added one pound of weight to our block and placed it back in the seawater, would it sink or float?

The answer is neither! If we subtract 64 pounds from 64 pounds we get zero pounds. Our block would be neutrally buoyant!

You Try It:

1. Let's use a real-life example. Let's say an Aquarius scientist needed to send a sample of dead coral to the surface to be analyzed. The sample was calculated to weigh roughly 250 pounds and displaces 1.5 cubic foot of water. How big of an airlift bag (in cubic feet) would be required so we could lift this sample to the surface for retrieval?

2. Here's another. Another Aquarius scientists is collecting sediment samples from near the reef. He collects two cubic feet of sediment that weighs approximately 210 pounds. He also needs to send his samples to the surface for retrieval and has several airlift bags that have a volume of approximately one gallon. How many will he need to send his samples to the surface? (hint: one gallon of seawater weighs about 8 pounds)

Student Handout

Student Worksheet for Underwater Physics

Part II: Pressure

The depth at which Aquarius scientists work means they're under quite a bit of pressure, pressure exerted by water. This series of explorations will take you through something that all of us deal with but is especially important to underwater divers - pressure.

Here's What You'll Need:

- Yardstick (or a meter stick)
- String (about 4 feet)
- 3 balloons (must be the same size)
- Scissors
- Heavy book or modeling clay
- 2 pencils (one to write with)
- Paper

Directions:

1. Write down all of your observations and the answers to any questions asked.

2. Use the heavy book or the clay to hold the pencil so the end hangs over the edge of the table.

3. Carefully cut the string into four equal pieces about 12 inches each.

4. You'll be using your yardstick as a balance, so tie a string to the center and the other end to the end of the pencil that's hanging over the edge of the table. Move the string on the stick until the stick hangs balanced.

5. Take two balloons, that aren't inflated and tie strings to them. Hang one on each end of the balanced yardstick an equal distance from the support string. Move them, if needed, until the stick is once again balanced. Why doesn't the stick tilt one way or another?

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6. Inflate the third balloon and tie the string to one end and make a loop in the other.

7. Remove one of the uninflated balloons and replace it with the balloon that's inflated. What happens to the yardstick?

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You Be The Scientist:

8. Get another balloon, the same size, and blow it up so that it's larger (or smaller) than the inflated one already hanging on the yardstick. What do you think will happen if you use this one to replace the other uninflated balloon hanging on the yardstick? (Hypothesis)

____

____

9. Replace the uninflated balloon with the the one you just blew up. (Experiment)

10. Write down what happened. (Observations)

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11. Why do you think that happened? (Conclusion)

____

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Try a Little Pressure Math!

Underwater pressure is a serious issues for the scientists working on Aquarius. They remain under pressure for several days while they carry out their experiments. Below are some practice problems dealing with underwater pressure. Give 'em a shot and then check your answers.

12. Aquarius sits on the ocean floor at a depth of about 60 feet. Calculate the absolute pressure at this depth.

13. A researcher working from Aquarius is collecting samples from the Conch Reef area. This researcher recently purchased new dive equipment and is wondering if his depth gauge is functioning correctly. If he's working at a pressure of 23.14 psi, what should his depth gauge read?

Student Handout

Student Worksheet for Underwater Physics

Part III: Light

What effect does water have on light? Why is water blue? This set of explorations should help you get a better understanding of seeing in the underwater world.

Here's What You'll Need:

- Glass of water
- 2 pencils (one to write with)
- Paper
- Scissors
- Tape (masking is best)
- Short table or chair
- Flashlight
- Sheet of black construction paper, approximately 21 cm x 28 cm
- Sheet of white paper, approximately 21 cm x 28 cm

Directions:

1. Fill a glass about 2/3 full of water and set it on the table.

2. Place a pencil in the glass and look at the glass and pencil from the side, paying close attention the the water's edge.

3. If you follow the pencil from above the water into the water with your eyes, what do you notice?

____

____

4. What happens if you move the pencil around while still looking at the point where it enters the water? Draw a picture of what you see.

____

____

You Be The Scientist:

5. What do you think will happen if you look at your hand behind the glass? (Hypothesis)

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6. Remove the pencil and put your hand on the other side of the glass. Move your hand close to and away from the glass. (Experiment)

7. Write down what you see. Does it look the same as it does normally? (Observations)

____

____

8. Why do you think this happens? (Conclusions)

____

Light is absorbed as it penetrates into the depths of the ocean. Some colors are filtered out before others. The next activity will help you continue to explore how water affects light.

Directions:

1. Cut a out a circle using the black construction paper large enough to completely cover the end of the flashlight.

2. In the middle of the circle cut out a thin rectangular slit that goes almost to the edge.

3. Tape this securely over the end of the flashlight.

4. Carefully set a glass of water on the edge of the table.

5. Turn on your flashlight and turn off the light in the room.

6. Have your partner hold the white paper next to the floor or the wall.

7. Hold the flashlight at an angle to the surface of the water and have your partner move the white paper into line with the light coming through the glass.

8. Your partner may need to move the paper closer or further from the glass to bring an image into focus. What color is the light coming out of the flashlight?

9. What color(s) are the images on the white paper?

10. Write a sentence that describes what happens to the light as it passes through the water and onto the paper.

11. Draw a diagram to represent your sentence.