FLUID PRESSURE

***SCUBA** = **S**elf **C**ontained **U**nderwater*
***B**reathing **A**pparatus*
***ScubaCat!* swims, scubas, and even skateboards!**

INTRODUCTION

Scuba diving is dangerous. Ignore for a moment the obvious *Shark Week!* peril of large, toothy, hungry fish and focus instead on not getting killed by our gear or our own ignorance. You might be surprised at how useful the gas laws are for keeping scuba divers alive. Take a deep breath, and fill your lungs. Now think about what happens to that air as you dive. Let's say you dive 33 feet (about 10 meters) below the surface. The pressure on you is **twice** atmospheric pressure! Well, according to Boyle's law, that pressure increase will decrease the volume of your air-filled lungs. Exhale, and take another lungful of air from your scuba tank. As you ascend back to the surface, should you hold your breath or exhale? If you hold your breath as you ascend, the air in your lungs will continue to obey Boyle's law and expand as the pressure decreases—which can result in serious injury! Always exhale as you rise to the surface.

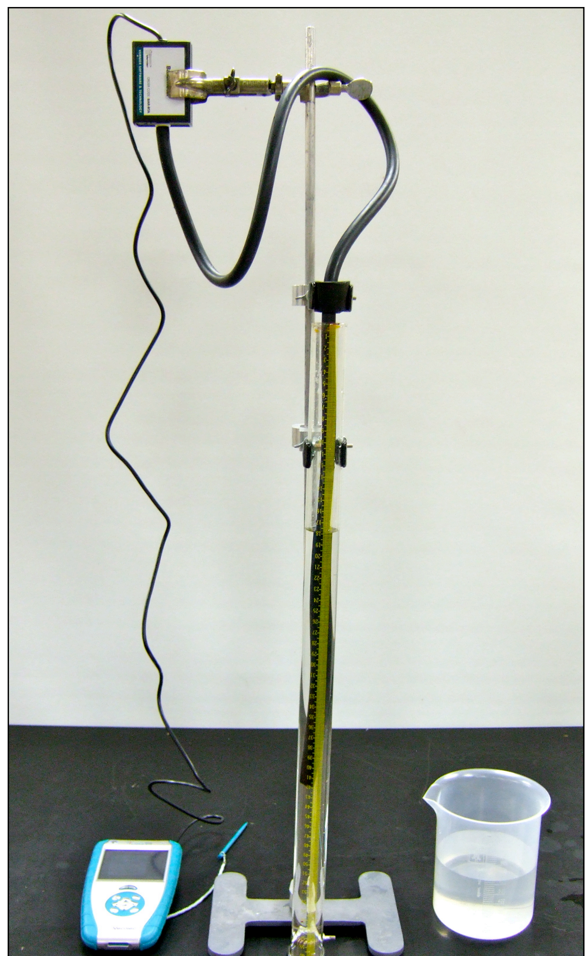
Scuba diving is dangerous. Even if you do not get eaten by a shark.

OBJECTIVES

- Record atmospheric pressure
- Practice unit conversions
- Measure fluid pressure as a function of depth
- Construct a graph of experimental data and determine the mathematical relationship
- Compare actual atmospheric pressure with the experimental prediction

EQUIPMENT

- Vernier LabQuest
- Barometer
- Rubber hose
- Glass tube
- Ring stand and clamps



The water line does not remain constant! It rises as the hose displaces more water. Always measure carefully from the bottom of the hose to the water line.

PROCEDURE

- Stopper the glass tube securely. Clamp it to the ring stand, and pour just a bit of water in. Make sure the water is not leaking at the stopper. When you are confident that the stopper is water-tight, fill the tube with water. Leave at least 25-30 cm of space at the top of the tube.
- Connect the barometer to the LabQuest, and switch the unit on. Attach one end of the rubber hose securely to the barometer valve. The display should be reading the atmospheric pressure in the room. ***Record this value!***
- Clamp the barometer to the ring stand as shown in the figure (do not clamp too tightly). It is very important for the hose to remain un-kinked, and for the connection between the hose and barometer valve to remain secure.
- Feed the free end of the hose through the stopper positioned above the mouth of the tube. The stopper should be clamped tightly enough to prevent the hose form slipping, but not so tightly as to close off the tube.
- Verify your set up by gradually submerging the hose into the tube. Watch the LabQuest display. If there is no change in pressure, make sure the hose is securely attached. Make a note of how deep you can submerge the hose before it displaces too much water (do not overflow the tube). Also notice by how much the pressure has changed.

- Position the hose so that the free end is approximately **2 cm** below the water surface. Measure this depth carefully, from the bottom of the hose to the water line. The stopper should be clamped securely enough that you should not need to hold the hose to keep it in position.
- Under the **Sensor** menu of the **Meter** tab, choose the **Data Collection** option. Select **Events with Entry** as the data collection mode. The **Number of Columns** should be **1**. Give it the name **Depth**, with units of **cm**. Tap **OK** to continue.
- To begin data collection, tap the **GO** button. You should notice a small **KEEP** icon appear directly next to it. To record data, tap the **KEEP** icon. When you are asked for the event name, type in the depth of the hose in centimeters and tap **OK**. Data collection resumes, and you can adjust the position of the hose to increase its depth.
- Move the hose 1 cm deeper, then re-measure the depth. *Because of the displacement of the water by the hose, you cannot assume that the new depth is exactly 1 cm greater than the previous measurement!* When you have the new depth measured, tap **KEEP** and record the new data. Continue to increase the depth by 1 cm increments, recording the pressure and depth values. Keep measuring and recording until you have 20 data pairs.
- End data collection by tapping the **STOP** button, then make sure to save the trial by tapping the **File Cabinet** icon.

Data & Analysis

If you have not already, record your data in a neat table in your lab notebook. ***Do not try to fill in the example table below; the depth values are approximate! Record your own accurate measurements of depth!***

Depth (cm)	Total Pressure (kPa)	Water Pressure (kPa)	Depth (cm)	Total Pressure (kPa)	Water Pressure (kPa)
2			12		
4			14		
6			16		
8			18		
10			20		

1. Calculate the amount of pressure due to the water alone by subtracting the atmospheric pressure from the total measured pressure you recorded:
$$water\ pressure = total\ pressure - atmospheric\ pressure$$
What happens to the water pressure when you double the depth? When the depth is tripled?
2. Convert your measured air pressure from kPa to atm:
$$atm = (0.00987)(kPa)$$
What is the pressure in the room in atmospheres? (Are you really surprised by this?) Now convert the pressure at the greatest depth below the surface from kPa to atm. By how much does the pressure increase?
3. Use the LabQuest to fit a curve to your data. Record the equation of the best-fit line in your notebook. Identify the slope and the intercept explicitly! Note that you have graphed the total pressure,not the water pressure. What would change if you graphed the water pressure? Would the slope be different? The y-intercept? Explain!
4. Make sense of the intercept: Where does the line cross the y-axis? What does this actually mean? Compare the intercept to your recorded value for the atmospheric pressure.
5. Make sense of the slope: How much does the pressure increase if the depth increases by 1 cm? If you dove to the bottom of the deep end of the pool (10 feet, or 305 cm, below the surface), what would the pressure be? Scuba divers easily dive to depths of 50 feet (1520 cm—and more). How much pressure are they subject to at this depth?
6. When you open a soda bottle, you can hear the *whzzt!* as you twist the cap. You will also see it start to fizz, bubbles rising through the liquid and popping at the surface. This happens because opening the bottle rapidly releases the pressure, and the CO_2 comes bubbling out of the soda solution. You have gases (notably, nitrogen) dissolved in your blood, just like CO_2 is dissolved in soda. Have you heard of "the bends?" Explain why scuba divers cannot ascend rapidly to the surface, but have to take "decompression breaks" at regular intervals as they rise. (Scuba diving is dangerous. Even if you do not get eaten by a shark.)