DIVING DOWN DEEP
TI-Nspire™ Lab Activity

Background

The Neutral Buoyancy Laboratory (NBL) is a deep pool located inside the NASA Sonny Carter Training Facility in Houston, Texas. The NBL is 61.6 m (202 ft) long, 31.1 m (102 ft) wide, and 12.2 m (40 ft) deep, which allows two different training activities to be performed simultaneously at either end of the pool. The NBL is large enough to hold full-sized models of International Space Station (ISS) modules, spacecraft (like the Orion Crew Multi-Purpose Crew Vehicle) and flight payloads.

The NBL uses neutral buoyancy to train astronauts for spacewalks. Being in a neutrally buoyant state is similar to the feel of weightlessness in space. In a neutrally buoyant state, an object has an equal tendency to float as it does to sink. Objects in the NBL, including humans, are made neutrally buoyant using a combination of weights and flotation devices. In such a state, even a heavy object can be easily manipulated, as is the case in the microgravity of space.

When training in the NBL, astronauts wear pressurized Extra-vehicular Mobility Unit (EMU) suits, the same as those worn in space. Out of the water, these EMU suits weigh approximately 127 kg (280 lbs). During training, the EMU-suited astronauts are assisted by at least four professional support divers wearing regulation SCUBA gear.

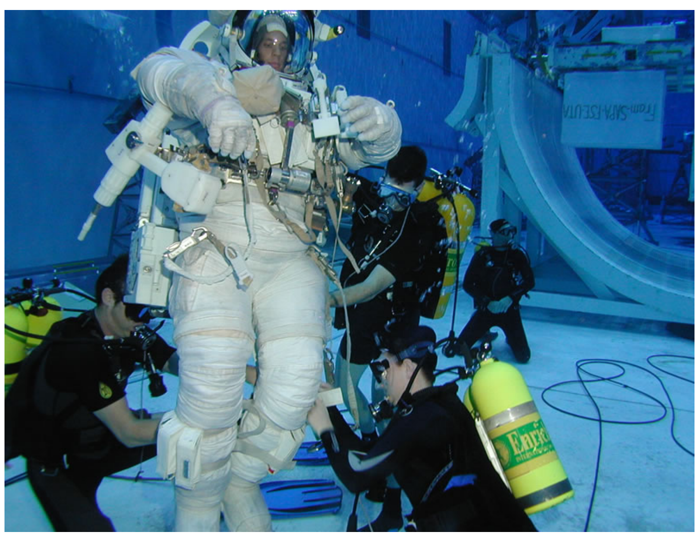

Figure 1: An astronaut and assisting SCUBA divers in the Neutral Buoyancy Laboratory

For every hour the astronaut is scheduled for a mission spacewalk, the dive team will spend seven hours training in the water. On a training day at the NBL, astronauts normally spend up to six consecutive hours in the pool. The support divers, however, are limited to five hours of dive time per day, broken into at least two different dives of two to three hours per session.

The support divers and the astronauts use a special mix of gas known as nitrox, allowing them to stay under water for their dive sessions without decompression. The nitrox mixture used by the NBL consists of 45% oxygen and approximately 55% nitrogen, and is compressed into two different sizes of dive tanks. The support divers wear a system containing either two small or two large dive tanks.

The smaller-sized tanks are each 6.95 liters in volume, and at standard temperature and pressure each tank contains 1,416 liters of compressed nitrox. The larger-sized tanks are each 11.1 liters in volume, and at standard temperature and pressure each tank contains 2,265 liters of compressed nitrox. The size of the diver and the depth of the dive both determine the rate of nitrox consumption for the dive. Divers use these factors to choose which size of tanks they will use for each dive.

Lab Objectives

In this lab, you will

- explore and apply gas laws;
- add pressure to a bottle and determine the moles of gas added using the ideal gas law;
- create and interpret a mathematical model as it relates to your experiment; and
- relate findings from the experiment to a real-world situation.

Materials/Equipment

- TI-Nspire or TI-Nspire CAS handheld
- TI-Nspire Lab Cradle or Vernier EasyLink™ cable
- Pressure probe
- Temperature probe
- Plastic bottle (with a volume of at least 0.5 L)
- Syringe and a three-way (or two-way) valve
- Pressure/fill cap: a two-hole stopper with two ports—one for the pressure probe and one for the syringe (Figure 2)
- Safety glasses and aprons

Figure 2: Bottle with pressure/fill cap

Safety Considerations

- Wear safety glasses and aprons.
- Under high pressure, the plastic bottle can fracture or the stopper can pop out of the bottle. Point stopper away from others.

Lab Procedure

With your lab partner, gather the required materials and equipment. On your TI-Nspire handheld, open the file, *Diving_Down_Deep*. Read the provided information and answer the pre-lab questions (TI-Nspire pages 1.1–1.5). You will then be ready to start the lab activity. Go to TI-Nspire page 2.1 and follow the provided instructions. After completion of the lab activity, proceed to the lab analysis on TI-Nspire pages 2.16–2.27.

Pre-Lab Questions (embedded within the TI-Nspire file)

1.4 Assume that a fixed volume container is kept at constant temperature. How can the pressure be increased?

1.5 What causes the pressure in (what appears to be) an empty bottle?

1.6 If more moles of gas are placed into the bottle at a constant temperature, what will happen to the pressure?

Lab Questions (embedded within the TI-Nspire file)

2.8 What happened to the pressure in the bottle with each pump?

2.9 What type of relationship is there between the number of pumps and the amount of pressure?

2.10 With each pump, what is happening to the gas inside the bottle? Choose all that apply.

2.11 The number of moles of gas is inversely related to the pressure. True or false? Explain your answer.

2.12 Determine the linear regression for the data.

On page 2.13, graph pumps on the *x*-axis (independent variable) and pressure on the *y*-axis (dependent variable), then press **Menu > Analyze > Regression > Linear** to determine the regression.

2.14 What does the slope of the linear regression model represent in context with this experiment?

2.15 What does the y-intercept of the linear regression model represent in this experiment?

Lab Analysis (embedded within the TI-Nspire file)

2.18 How many moles of gas were contained in the bottle before any additional pressure was added?

2.19 How many moles of gas were added with the first pump of the syringe?

2.20 What is the average number of moles of gas added per pump?

2.21 How many pumps would be required to fill a 6.95-liter dive tank at 25°C to 204.4 atmospheres of pressure?

At sea level, 1 atmosphere of pressure is acting on our bodies. When diving in the NBL, for approximately every 10 meters of water depth, an additional atmosphere of pressure is acting on the diver. With a water temperature of 37°C in the NBL, a support diver consumes, on average, 14.16 liters of gas per minute for every atmosphere of pressure.

2.23 How many liters of gas would be required to keep a support diver down for 3 hours at a depth of 8 m? Assume the surface of the NBL pool is at sea level.

2.24 How many moles of gas are consumed by a support diver during a 3-hour dive at a depth of 8 m?

2.25 Using a 2,832-liter twin cylinder dive tank system, how long could a support diver stay under water (at 8 m) before all the gas is used?

2.26 Using a 4,530-liter twin cylinder dive tank system, how long could a support diver stay at the bottom of the pool before all the gas was used?

2.27 Do the answers given in questions 2.25 and 2.26 give the maximum amount of time the support diver could stay at the depths listed? Explain your answer.