Newton's Cool in the Pool

Background

This problem is part of a series that applies mathematical principles in NASA's human spaceflight.

Human spaceflight is an important part of NASA's mission. From lunar exploration to the completion of the International Space Station (ISS), NASA has been preparing humans to explore the unknown. The research and innovation required to explore space has led to technological advancements on Earth. Space exploration has brought benefits to medicine, medical care, transportation, public safety, computer technology, and many other areas that enrich our everyday lives.

Exploring space is a complex endeavor, and missions that involve humans require extensive research, precise planning, and preparation. This includes spacewalks, which are critical for current and future missions.

To prepare for spacewalks, astronauts train at NASA's Neutral Buoyancy Laboratory (NBL) – the largest indoor pool in the world, located at the Sonny Carter Training Facility in Houston, Texas. Besides astronaut training and the refinement of spacewalk procedures, NASA also uses the NBL to develop flight procedures and verify hardware compatibility – all of which are necessary to achieve mission success.

The NBL is 202 ft (61 m) long, 102 ft (31 m) wide, and 40 ft (12 m) deep. It is sized to perform two suited test activities simultaneously, and it holds 6.2 million gallons (23.5 million liters) of water. Even at this size, the complete International Space Station, with dimensions of 350 ft (106 m) by 240 ft (73 m), will not fit inside the NBL (see Figure 1).

The water within the NBL is recycled every 19.6 hours. It is automatically monitored and controlled to a temperature of 82°-88° Fahrenheit to minimize the potential effects of hypothermia on support divers. It is also chemically treated to control contaminant growth while minimizing the long-term corrosion effect on training mockups and equipment.

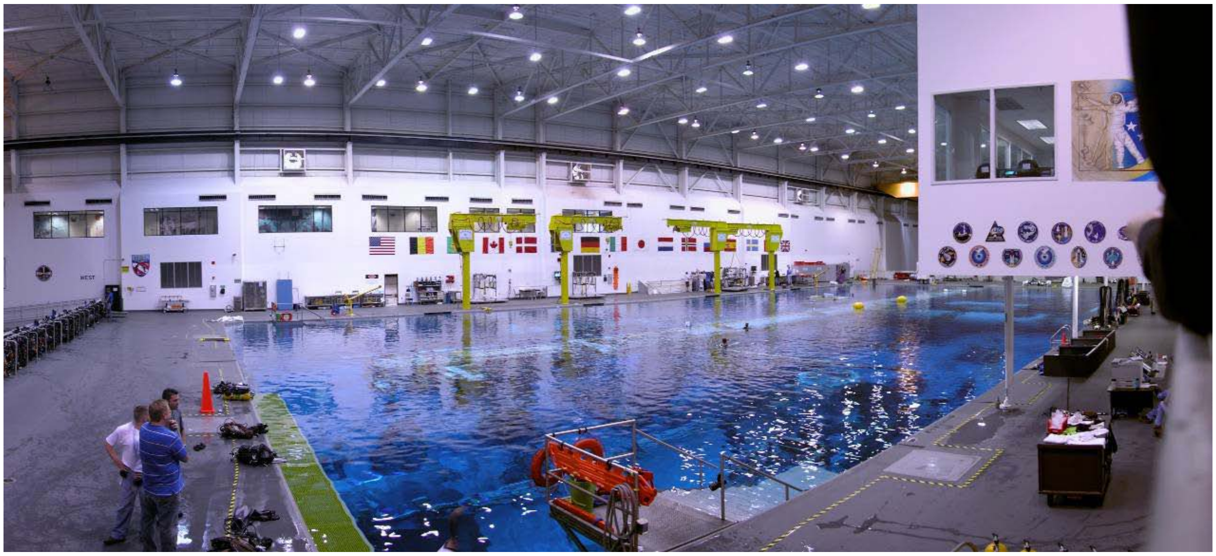

Figure 1: View of the entire pool at the Neutral Buoyancy Lab (NBL)

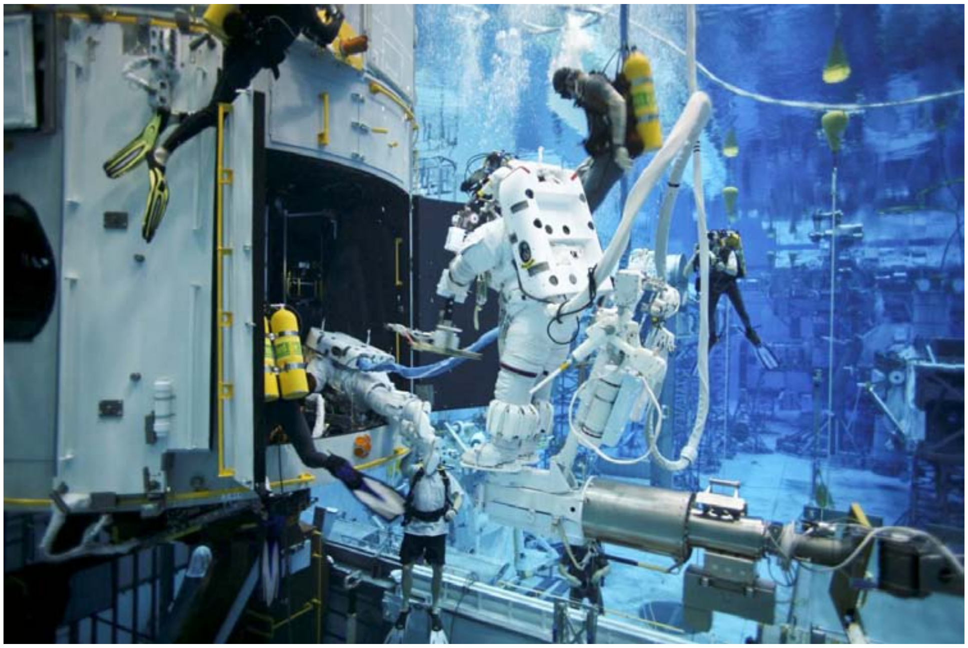

Figure 2: Astronauts practicing for a spacewalk to repair the Hubble Telescope in the NBL

The NBL allows crewmembers to properly train by experiencing the simulation of a weightless environment in space. With the assistance of divers, suited astronauts are weighted in the pool in order to perform simulated extra-vehicular activities (EVAs) on full mockups of parts of the International Space Station (ISS), the space shuttle cargo bay, and on various payloads.

You may wonder, what is neutral buoyancy and how does it resemble weightlessness? Neutral buoyancy is the equal tendency of an object to sink or float. If an item is made neutrally buoyant through a combination of weights and flotation devices, it will seem to hover under water. In such a state, even a heavy object can be easily manipulated, as is the case in microgravity of space. However, there are two important differences between neutral buoyancy (as achieved in the NBL) and weightlessness. The first is that suited astronauts training in the NBL are not truly weightless. While the suit/astronaut combination is neutrally buoyant, the astronauts can still feel their weight while underwater in their suits. The second is that water drag hinders motion, making some tasks easier to perform in the NBL than in microgravity. While these differences must be recognized by spacewalk trainers, neutral buoyancy is still the best method currently available to train astronauts for spacewalks.

Instructional Objectives

You will

- analyze temperature-loss data graphically;
- use Newton's Law of Cooling to predict temperature loss;
- solve the Newton's Law of Cooling formula for the exponential constant of cooling *(k)*; and
- determine the time required for tank temperature to equalize with room temperature.

Problem

On the TI-Nspire™ handheld, open the document, *NBL-Newton*, read through the problem set-up (pages 1.2-1.3), and use the temperature data in the table on page 1.4 to create a scatter plot on page 1.5. Then complete the questions embedded within the document.

Embedded Questions

1.7 Solve for *k* in the formula for Newton's Law of Cooling for each daily temperature difference. Use 73^{o} F as the ambient temperature. Round to the nearest thousandth.

1.8 Notice that the *k*-values are different for each day. Explain why the *k*-value is not constant in this situation.

1.9 Use the average of the calculated *k*-values to determine the pool temperature on Day 4. Round to the nearest tenth.

1.10 How close is the calculated temperature to the actual pool temperature on Day 4?

1.11 Find the function that represents the data on page 1.4 by substituting your average *k*- value into the Newton's Law equation. Write the function below, and then graph the function together with the scatter plot on page 1.5. (To graph the function, press **menu>analyze>plot function**.)

1.12 Determine the number of days it will take the pool to reach a temperature of 74° F. Round to the nearest day. Support your answer graphically on page 1.13.

1.13 Graph the function to show when the pool approaches ambient temperature. Adjust the window of the graph, and place the point and its coordinates on the graph.

1.14 What temperature would the pool reach in 10 days? Round to the nearest tenth.

Use the function found on page 1.11 to answer the following questions.

1.16 Is the function increasing or decreasing? How can this be determined from the function rule?

1.17 Is the function asymptotic? Explain.

1.18 What is the range of the function?

1.19 What is the range of the data?