NAVAL HISTORY STEM-H LESSON PLAN

Density of Seawater = 1025 kg/m3 1 meter cubed = 264.172 gallons 1m = 3.281 feet
A Free Body Diagram used for the purpose of calculating torques should consist of a line to represent the object being analyzed, a labeled axis of rotation, and labeled force arrows.

1. On the following image, label the Stern Planes, Bow Planes, and Sail, and draw in the Periscope.

2. Currently, the buoyant force on the submarine is 6.930×10^7 N.
   The mass of the submarine is 7.100 million kg.

   A) Draw a Free Body Diagram of the submarine.
   B) The Officer of the Deck needs the submarine to "hover" at a constant depth to shoot missiles, so he tells the Chief of the Watch to establish neutral buoyancy. What must the Chief of the Watch do: open a valve to allow seawater into one of the tanks, or pump seawater out of a tank back into the ocean? You may assume the tank is located near the center of gravity of the submarine, so rotational equilibrium is not affected.
   C) How many gallons of seawater must be transferred?
   D) Draw a new Free Body Diagram to represent the submarine after the water is transferred and comment on the vertical forces and whether or not the sub is in vertical equilibrium.

3. Assume that the submarine begins in a state of neutral buoyancy and zero net torque around the center of gravity. Then, over time, the Sanitary Tank level increases by 1250 gallons.

Tank	Horizontal position (feet) from the submarine's center of gravity
Sanitary tank	15.0 forward
Forward Trim Tank	50.0 forward
Centerline Trim Tank	0.0
Aft Trim Tank	90.0 aft

   A. Draw a submarine, label its bow and stern and its center of gravity (approximately in its geometric center), and a small rectangle to represent each of the tanks described in the table to the right. Don't measure… just draw them in about the right place.
   B. Define Rotational Equilibrium.
   C. Determine how many m^3 of liquid were added to the Sanitary Tank.
   D. On your Free Body Diagram of the submarine (label the weight of liquid in sanitary tank). Note: For several reasons you do Not need to draw arrows to represent its overall weight and the buoyant force it experiences (they are equal, and can both be assumed to act at the center of gravity, where we are locating our center of gravity)…. So only draw arrows for the weights of liquids in the tanks, since they cause torques. Note 1: assume all tanks are initially empty, except what we have said has been added to the sanitary tank. Note 2: For this problem, ignore forces that the flowing water exerts on the planes.
   E. What is the lever arm of the weight of the contents of the Sanitary Tank?

F. Calculate the net torque (in Nm) on the submarine.

G. Why is the submarine designed such that the Sanitary Tank is located close to the middle of the submarine (forward/aft)?

For the next two questions, do not worry about the effect your actions would have on the submarine's vertical equilibrium or neutral buoyancy.

H. Which of the following could the Chief of the Watch do to re-establish rotational equilibrium? Draw a new Free body Diagram, answer the question and also calculate the amount (gallons) of seawater.
   - Allow seawater into the submarine and put it in the fwd trim tank.
   - Allow seawater into the submarine and put it in the aft trim tank.

I. As an alternative, which of the following could the Chief of the Watch do to re-establish rotational equilibrium? You may assume there is water in all the trim tanks. Draw a new Free body Diagram, answer the question and also calculate the amount (gallons) of seawater.
   - Pump water from the fwd trim tank off the submarine into the ocean
   - Pump water from the aft trim tank off the submarine into the ocean

J. Assume that the Chief of the Watch chose one of the options in Part H (to allow seawater Into a trim tank). The submarine should now be in rotational equilibrium, but it is no longer neutrally buoyant. It will tend to sink or float.
   a. Which will it tend to do: sink or float?
   b. Explain what the Chief of the Watch could do to regain neutral buoyancy, while not affecting the sub's rotational equilibrium.