ME 121: Practice with Energy Balance Calculations

March 3, 2020

Units

1. Fill in the empty cells in the following table by making conversions between °F, °C and K (kelvin). Show your work. In other words, *do not* use an on-line conversion tool or built-in calculator function except to check that your hand calculations are correct.

T (°C)	10		
T (°F)		10	
T (K)			10

2. Ten joule of energy are transfered to a system in 10 minutes. What is the average rate of power transmission?

3. What must be the units of m, c, T and t be in order that

$$mc\frac{dT}{dt} = VI \tag{1}$$

has consistent units when V is in volt and I is in amp?

Analysis

1. Use an estimate for the mass of water in your fish tank to compute a value of K for your tank.

   Hint: What are the electrical characteristics of the power resistor used in the heater?

2. Given the value of K from the preceding step, how long should the heater be turned on to increase the temperature of the water by 0.5 °C?

3. If the volume of water in the fish tank is increased, e.g., by raising the location of the drain hole, the value of K will (pick one)

   a. Increase

   b. Decrease

   c. Not change

   d. not be known from the information given

4. Use analysis to justify your answer to the preceding question.

5. What is the percent change in K if the volume of the fish tank is increased by 10%? Yes, *this is computable without assuming any numerical values* other than a 0.1 change in K.

   Hint 1: Express the volume change symbolically as

$$\frac{\mathcal{V}_2 - \mathcal{V}_1}{\mathcal{V}_1} = \alpha \tag{2}$$

   where $\mathcal{V}_1$ is the volume before the change and $\mathcal{V}_2$ is the volume after the change, and α is the fractional change in volume. For the given problem, $\alpha = 0.1$, but there is no need to use that numerical value until the end of the analysis.

Hint 2: To answer the question, you will need to find the fractional (or percent) change in K

$$\frac{K_2 - K_1}{K_1} = \beta. \tag{3}$$

Hint 3: Use the energy equation

$$mc\frac{dT}{dt} = VI. \tag{4}$$

where m is the mass of water in the system, c is the specific heat of water, T is the temperature of the water, t is time, V is the voltage applied to the heater and I is the current flowing through the heater.

Answer: 9.1%. You will have to show whether this is an increase or decrease. Also note that $\beta \neq \alpha$, so don't just guess that an increase of volume by 10% leads to a change in K of 10%. That's guessing. Use analysis.

Energy Control

1. What should happen in the temperature control algorithm when the measured temperature exceeds the UCL.

2. What is the recommended response in the thermal control algorithm when the calculated time for turning on the heater exceeds the deadtime for the salinity control algorithm?