1. A heater with a mass of 5 grams is used to heat the water in a fishtank which contains 50 grams of water. The heater is made of several materials; the average specific heat (or heat capacity) of the heater material is $910 \frac{J}{kg \cdot ^\circ C}$. If the heater is turned off when the water reaches a temperature of 20°C (the upper control limit) and the heater has an average temperature of 70°C when it is turned off, then how much would you expect the water temperature to overshoot the upper control limit? 1.07°C

**HINT:** The heater will continue to transfer energy to the water even after the heater is turned off (since it has a higher temperature than the water). Eventually, the heater and the water will approach the same temperature as the heater cools and the water warms. The decrease in internal energy of the heater will be equal to the increase in internal energy of the water, assuming no heat is lost by heat transfer from the fishtank (through the PVC or at the surface of the water).

2. The temperature of a 1kg sample of an unknown material increases by 10°C when it absorbs 5,000J of energy. What is the specific heat of the material? $500 \frac{J}{kg \cdot ^\circ C}$

3. The temperature of a 2kg mixture of two materials increases by 10°C when the mixture absorbs 5,000J of energy. If the specific heat of material 1 is $100 \frac{J}{kg \cdot ^\circ C}$ and the specific heat of material 2 is $4,000 \frac{J}{kg \cdot ^\circ C}$, then what is the mass of material 1? 1.92kg
4. The circuits below should be implemented on your fishtank system in preparation for combined salinity and temperature control. Initially, just use the LED and 470Ω resistor (the 20Ω power resistor can be added later after everything is working well). If you add the 20Ω heater now, BE CAREFUL to never turn your heater on unless there is water in the system. Never leave your system plugged in with the 12V adapter unless you are actively working.

![Circuit Diagram]

**a.** Implement the circuits above on your fishtank system.

**b.** Write a sketch that reads the analog input from the thermistor circuit and displays the 0 to 1023 value on your computer monitor. Then, modify the program to make the LED go off when you heat the thermistor up by holding it between your fingers; the LED should come on when the thermistor cools back toward room temperature. That is, include an “if” statement that makes the LED come on when the analog input is less than a number (such as 500, but you’ll need to pick a number that works). This will be very similar to the program that you use to turn on the heater when the temperature drops below the setpoint. Provide your program listing.