Electrical Equivalent of Heat

Equipment	Quan
Electrical Equiv. of Heat Apparatus	1
Low Voltage Power Supply	1
Thermometer	1
Triple Beam Balance	1
BB Wires	2
Ink Bottle	1

The specific heat capacity of water is about $4186\, J/(kg°C)$, which means that the energy required to raise one kilogram of water by one degree Celcius is $4186\, Joules$. In this experiment, we'll add heat to water electrically using an incandescent light bulb. Since the rate of energy flow into the bulb (power) is voltage times current,

$$P = IV$$

we can determine power to the bulb if we know the voltage and the current. We'll keep voltage constant during the experiment, making the calculation of total energy deposition simpler.

$$E = IVt$$

The rate of energy flow multiplied by the time that it flows gives the quantity of energy deposited in the bulb.

This energy will raise the temperature of the water according to the familiar heat capacity equation.

$$E = c_w m \Delta T$$

Thus we have:

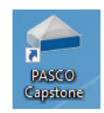
$$c_w m \Delta T = IVt$$

$$c_w = \frac{IVt}{m \Delta T}$$

So, after adding thermal energy to the water through the light bulb, we can calculate the specific heat capacity of water if we can measure the current, voltage, time of energy flow, mass of the water, and temperature change.

Setting up Temperature Sensor

1. Plug the temperature sensor into port B of the "ANALOG INPUTS" in the 850 data collection box. Note that the 8 pin DIN connector must be inserted with the arrows on top.
2. Double click the PASCO Capstone icon to start the software.



3. Click on the "Hardware Setup" icon.

4. You should see an image of the 850 box. Click on the port B plug in "ANALOG INPUTS," and choose "Temperature Sensor, Stainless Steel." A few of the temperature sensors in the lab room are of a different type, so if your temperature reading seems incorrect, it might be necessary to try choosing another type during this step.
5. Click again on "Hardware Setup" to dismiss it.
6. The "Record" button should now be red, indicating that the sensor can collect data.

7. Double click on the graph icon (on the right-hand side of the window) to bring up graph in the main page.

8. When the experiment is finished, you can kill the Capstone window. When you're asked whether to save changes, click "Discard."

Procedure

1. Weigh the plastic cup from the Electrical Equivalent of Heat apparatus.
$m_c =$ _________ kg
2. Fill the cup to the fill line with tap water.
3. Put 5-10 drops of ink into the water.
4. Weigh the full cup.
$m_{c\&w} =$ _________ kg
5. Calculate the mass of the water.
$m_w =$ _________ kg
6. The solid material inside the apparatus will also absorb as much heat as about $0.023\ kg$ of water. Thus raising m_w by this amount (the result we'll call m_{eff}) will account for the fact that some of the heat will go to heating the solids.
$m_{eff} =$ _________ kg
7. Assemble the apparatus: screw on the lid (with light bulb), insert the cup into the Styrofoam housing, and connect the apparatus to the power supply using two BB wires.
8. Insert the thermometer into the hole in the lid.
9. Turn on the power supply and set the voltage to around 12 volts (it doesn't have to be exactly 12 volts).
10. Without changing the voltage setting, turn off the power supply. **The voltage setting must not be changed for the rest of the experiment.**
11. Swirl the cup around until the temperature reading stabilizes, and then record this temperature.
$T_{low} =$ _________ $°C$
12. Before starting the experiment, keep in mind that while the current is flowing, you will need to record the voltage and current from the readouts on the power supply.
13. Using the wall clock or a stopwatch for timing, run the power for exactly $180\ s$ using the power switch on the power supply. After shutting off the power, swirl the water around so that heat from the bulb is released in to the water, and then record the final temperature when it stabilizes.
$V =$ _________ V
$I =$ _________ A
$T_{high} =$ _________ $°C$
14. Calculate the temperature change during the experiment.
$\Delta T =$ _________ $°C$
15. Using the equation below, find the specific heat capacity of water.
$$c_w = \frac{IVt}{m_{eff}\Delta T}$$
$c_w =$ _________ $J/(kg°C)$
16. Using $c_w = 4186\ J/(kg°C)$ as the known value, calculate the percent error of your value.
$\%\ error =$ _________ $\%$
17. Repeat the entire experiment, but leave out the ink.
$m_{eff} =$ _________ kg
$T_{low} =$ _________ $°C$
$V =$ _________ V
$I =$ _________ A
$T_{high} =$ _________ $°C$
$\Delta T =$ _________ $°C$
$c_{w2} =$ _________ $J/(kg°C)$
$\%\ error =$ _________ $\%$

Questions:

1. Why was the ink added?
2. Is water transparent to all wavelengths of light?
3. Which of the two heat capacity values (the first or the second) would you expect to be higher?
4. Provide a physical argument for your answer to 3.
5. Which one was actually higher?
6. In using this experimental procedure, we're assuming that all the electrical energy contributes to the raising of the water temperature. The table below contains a number of potential problems with the experimental setup that would affect the value of c_w. Use your understanding of the physical nature of the process to determine whether the problem would lead to an overestimate (O) of c_w, or an underestimate (U).

The wires connecting the apparatus and power supply become warm due to the current.	O U
The ink doesn't stop all the visible light.	O U
The timing clock runs slow.	O U
The voltage readout reads lower than the real V.	O U
The current decreases during the 120 seconds.	O U

7. The percent difference between your two calculated c_w is the percentage of the energy trapped by the ink. Calculate this percentage.

$$\%_{trapped} = \_\_\_\_\_\_\_\_\_\%$$