

Electrical Equivalent of Heat

Name _____ Box _____

Purpose: To determine the specific heat of water.

Theory:

The energy released by moving charge is

$$\Delta E = qV$$

where q is the amount of charge passing through a potential change, V . If we divide both sides of the equation by time, we get

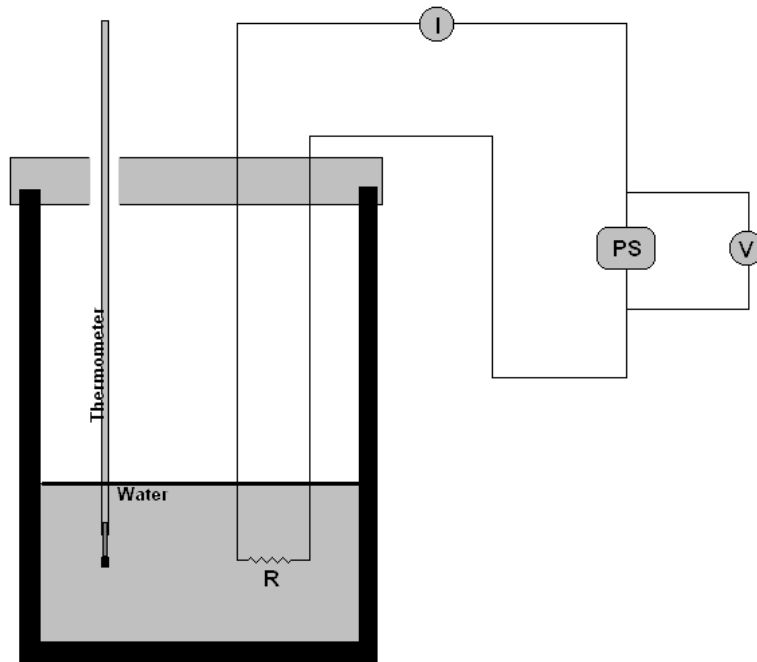
$$P = IV$$

because the time rate of energy change is power, and the time rate of moving charge change is current.

In the case of a resistor, the energy released is in the form of thermal energy. So we can use heat transfer to measure the specific heat of water. We need to measure the current, voltage, and temperature change of a system where a resistor is submerged in water.

In the diagram we have a thermometer and a resistor submerged in a known mass of water. The resistor is powered by a Power Supply (PS). The current in the circuit and the voltage of the power supply are continuously monitored by the ammeter (I), and the voltmeter (V), respectively.

The apparatus is in an insulated container with what we hope is a vanishingly small heat capacity. Heat used to warm the apparatus or heat that escapes the apparatus will both distort the result and increase the %Error.



Analysis:

1. Construct a graph of Temperature (vertical axis) vs. Time (horizontal axis). The result should be a straight line. Determine the slope of the line with the function button. Set the .

slope of the line = $\Delta T/t =$ _____ degrees per second

2. The heat that went into the water came from the resistor, so

$$\text{Power out of the resistor} = \text{Power into the water}$$

Because $Q = mc\Delta T$, dividing both sides by time yields

$$\text{Power input} = Q/t = mc \Delta T/t = (mc)(\text{slope})$$

so

$$IV = (mc)(\text{slope})$$

Now solve for c , the specific heat of water. The accepted answer is 4186 joules/kg °C.

Experimental value of c of water = _____

%Error = _____

Analysis Questions for the Electrical Equivalent of Heat *(Answer these questions on a separate sheet.)*

1. Suppose you put a 100-watt light bulb in a container of water and used it to heat the water. How long would it take to change 150 grams of water at 25°C to 100°C?

2. There are little submerging heaters for tea mugs. Suppose you have 130 grams of water at 25°C and heat it to 100°C in 2 minutes with the heater plugged into the wall (110 volts). What is the resistance of the heater?

3. The formula for a hot object radiating heat is $\text{Power} = \sigma eAT^4$.

σ is called the Stefan-Boltzmann constant = 5.67×10^{-8} watts/meter²/Kelvin⁴

e is a constant called emissivity and is a number between zero and one. e approaches one for objects that are dark and rough and approaches zero for objects that are silvered and shiny.

A is the surface area of the object.

T is the absolute (Kelvin) temperature.

Determine the power output of a stove-top burner glowing red hot at 750°C. Assume the burner is a disk with two sides and a radius of 11 cm and that its emissivity is 1.00. The stove is plugged into a high-voltage outlet (220 volts). Now determine the resistance and the current in this typical stove-top burner.