In this experiment, we will use an electrical calorimeter to measure the heat energy released from a resistor. This energy is the energy delivered to the resistor by the electric circuit.

When a current runs through a resistor, there is a voltage drop across the resistor according to \( \Delta V = IR \). This voltage drop is precisely the change in energy per unit charge as the current pushes through the resistor:

\[ \Delta V = \frac{W}{q} , \]

where \( W \) is the change in potential energy of the charges in joules (i.e., the energy the charges lost). It follows that the amount of energy a current gives up to a resistor when an amount of charge \( q \) flows through it is:

\[ W = IRq \]

Since \( q = I \times t \), where \( t \) is the time interval, a steady current gives up an amount of energy

\[ W = I^2Rt \]

in a time \( t \). The factor \( I^2R \) is called the power – energy per time – delivered by the power source to the resistor (this will be a light bulb in our experiment). It will be convenient to measure the voltage rather than the resistance, so we will use \( R = \frac{V}{I} \) to express the power as

\[ P = IV \]

And the energy delivered to the bulb as

(1) \[ W = IVt \]

**Measuring the heat released by the resistor**

The calorimeter consists of a 35 watt light bulb with banana plug connections, a plastic jar and a Styrofoam jacket. When the jar is filled with water and the bulb connected to a power source, the water will begin to heat. (See diagram below.)

The energy gained by the water can be calculated from the specific heat of water – 1.00 calorie per gram per degree Celsius: \( Q = mc \Delta T \)
where $Q$ is the heat energy in calories, $m$ is the mass of the water, $c$ is the specific heat of water and $\Delta T$ is the change in temperature.

$$Q = (m_{\text{water}} + m_{\text{eq}})c\Delta T$$

**Diagram 1: Electrical Equivalent of Heat setup.**

We must also consider the heat energy absorbed by the calorimeter itself. For this purpose, we can consider the calorimeter as equivalent in its heat capacity to a certain amount of water. By measurement, the calorimeter is equivalent to 23 grams of water. This is called the *mass equivalent* of the calorimeter. Thus the water and the calorimeter will take up an amount of energy given by

$$Q = (m_{\text{water}} + m_{\text{eq}})c\Delta T$$

**Electrical Equivalent of Heat**

The ratio of the energy given up by the current (measured in joules) to the energy taken up by the calorimeter and the water (measured in calories) is the electrical equivalent of heat, $J$:

$$J = \frac{W}{Q}$$

The accepted value for $J$ is 4.186 joules/calorie.
Procedures

Safety notes:

- Never turn on the voltage to the light bulb unless it is immersed in water. The bulb will blow out if it is lit outside the water.
- Never let the voltage exceed 13 VDC. This will also blow the bulb.
- Never put a hot bulb into cold water.
- Do not fill the plastic jar beyond the 200 mL indicator line.

1. Set up & preliminary measurements

- Remove the plastic jar from the Styrofoam calorimeter. Weigh the jar, lid and light bulb together. Record the mass.
- Using ice water and tap water, prepare about 225 mL of cool water at about 10 degrees below room temperature in a beaker.
- Unscrew the lid from the plastic jar and fill the jar with the cool water up to slightly below the 200 mL line. Do not overfill. Make sure there is no ice in the water.
- Add 10 drops of India ink to the water in the jar. This is to capture the light energy from the light bulb. The water should be almost opaque. The lamp filament should be just barely visible when it is lit.
- Screw the lid with bulb back onto the jar. Insert the jar back into the calorimeter.
- Connect the circuit in Diagram 1. Connect one DMM in series as an ammeter. Connect a second DMM across the light bulb banana sockets as a voltmeter.
- Before turning on the power supply, set the current knob on the power supply to three-fourths full.
- Now prepare the power supply to deliver 11.5 volts. Briefly turn on the power supply, adjust the voltage to 11.5 volts as quickly as you can, then turn the power supply off. You don’t want to heat the water yet.

2. Time the heating of the water.

- With the thermometer probe, gently stir the water in the calorimeter to make sure it is at a uniform temperature. Read the temperature of the water immediately before you start the experiment. Record your measured value for the initial temperature of the water.
- Turn on the power supply and start the stopwatch simultaneously.
- Record the voltage and the current.
- Monitor the voltage and current throughout the heating. Adjust the voltage back to 11.5 if it drifts. Record the current at five minute intervals and use the average value of the current in your calculations. (The current should be constant, but it may drift.)
• When the temperature of the water is as far above room temperature as it was below to start, stop the stopwatch and turn off the power supply. Record the elapsed time.
• Stir the water gently with the thermometer probe. The temperature will probably continue to rise as warmer water is mixed with cooler. Record the peak temperature.
• Finally, remove the plastic jar from the calorimeter and weigh the jar, lid and water together.

3. Calculations & analysis

• Calculate the mass of the water in the calorimeter.
• Calculate the change in temperature of the water, $\Delta T$.
• Calculate the heat energy picked up by the water, $Q$, using equation (2). The mass equivalent of the calorimeter is 23 grams and the specific heat of water is 1.00 calorie/gram/degree C.
• Calculate the average current.
• Calculate the electrical energy delivered to the lamp using equation (1).
• Calculate the electrical equivalent of heat using equation (3).