SAFETY:
When completing the Chemical Processes Lab activities students must wear their goggles at all times while in the lab. You must also wear long pants and sturdy, closed-toe shoes. Please use oven mitts and potholders when removing hot pots from the heat sources. Failure to comply with these safety requirements may result in earning no credit for the lab activity.

OVERVIEW:
Effective transfer and conversion of energy is an extremely important consideration in almost all products of engineering—engines, drive trains, heating, air conditioning, chemical manufacturing, materials production, electricity production—the list is endless. Efficiency translates into $$$.

How the energy is supplied, from what source, how it is moved to another place, and what losses are incurred in the process are all contributors to efficiency.

In this experiment, we’re interested in energy as heat. Energy as heat is transferred by three mechanisms: conduction, convection, and radiation. Conduction occurs when two static systems at different temperatures are brought in contact with one another. Heat flows from the higher temperature system to the lower temperature system through the materials themselves. For example, your hands holding a cup of hot soup become warm by being in contact with the hot cup. Convection is the physical transport of heat via fluid medium. It can be “natural convection” associated with density differences—the plume of warm air over a fire—or it can be forced convection as in a forced-air furnace system, which uses a fan to circulate air. Finally, radiation is the transport of energy as electromagnetic waves with no need for a transporting medium—like the heat from the sun. These waves are absorbed by the receiving body, which gets warmed.

In this experiment you will heat a pot of water with a hotplate and deduce the efficiency of transferring the input energy (electrical) to the output product (hot water). Electrical energy flows through a resistance element atop the hotplate to cause “Ohmic heating” or “resistance heating”. This element heats its surroundings through conduction, convection, and radiation. The idea is to convert as much of this electrical energy to heat the water. You are interested in the efficiency of this energy transfer between the electrical energy input to the hotplate and the temperature rise of the water. Additionally, you are interested in determining how putting a lid on the pot of heating water effects the efficiency.
**Procedure**

1. Plug the “Kill A Watt” monitor into an electrical outlet. Press the appropriate button so that “watt” shows on the screen.
2. Weigh the empty pot.
3. Add 500 mL of water to the pot and weigh the pot and water.
4. Place the pot of water on the hotplate.
5. Record the room temperature and the temperature of the water.
6. Set the heating dial on the hotplate to high and connect it to the outlet terminal of the “Kill A Watt”.
7. Record the watts, temperature of the water and time every 30 seconds until the water temperature reaches 80 - 90°C (the watt readings should be relatively constant).
8. Shut off the electrical input
9. Weigh the pot and water after the experiment is concluded.
10. Repeat the experiment but this time put a lid on the pot. Start with a cool pot and cool hotplate.

**Questions and write-up**

1. Calculate the total electrical energy input (from the time you turned on the heating unity until the time that you turned it off) for both experiments (with and without the lid):
   \[ \text{Energy (Joules)} = \text{average watts} \times \text{seconds}. \]
2. Make a plot of watts versus time (it should be relatively uninteresting).
3. Calculate the water’s energy increase for both experiments:
   \[ q = m \times c \times \Delta T \]
   where:
   - \( q \) = heat energy (Joules)
   - \( m \) = mass of the water (g)
   - \( c \) = the heat capacity of water = 4.186 J/(g°C)
   - \( \Delta T \) = temperature change of the water (°C)
   \[ E(\text{Joules}) = \text{water mass} \times \frac{4.186J}{\text{g} \times \text{°C}} \times (T_f - T_i) \]
4. Calculate the overall efficiencies with and without the lid: 
   \[ e = \frac{\text{water's energy increase}}{\text{total electrical energy input}} \]
5. Calculate the efficiency as a function of time and plot the data.
6. What difference did putting a lid on the pot make?
7. If the efficiency is less than 1.0, where did the remaining energy go? Try to think of all possible “losses”. How much energy went into heating the pot?
8. How could you improve the efficiencies? Bigger heating element? Smaller pot? Try to envision all the heat transfer that is taking place.
9. Explain any differences you found between the before and after weights of the pot and water.
10. Explain the efficiency vs. time plot.