MECHANICAL EQUIVALENT OF HEAT
(ELECTRICAL METHOD)
with solar power optimization competition

<u>OBJECT</u>

To measure the mechanical equivalent of heat by an electrical method.

<u>APPARATUS</u>

Heating coil, calorimeter and stirrer, DC voltmeter and ammeter, switch, connecting wires, temperature sensor (brass or plastic), resistor boxes (1 kilo-ohm step, 100 ohm and 10 ohm step), distilled water, ice, balance, cork, computer temperature and time program.

<u>THEORY</u>

Potential difference is defined as work per unit charge given by the expression

$$V = W/Q \qquad (1)$$

where W is the work done in moving the charge Q through the circuit.

In the practical (mks) system V is expressed in volts, W in joules, and Q in coulombs.

Equation (1) may be written as

$$W = VQ \qquad (2)$$

And recalling that

$$I = dQ/dt \quad \text{or} \quad I\ \Delta t = Q \qquad (3)$$

$$V = I\ R \qquad (4)$$

we may rewrite equation (1) using these substitutions as

$$W = VQ = VIt = IR(I)t = I^2\ Rt \qquad (5)$$

This equation indicates that if an electric current of 1 ampere is sent through a coil of wire of resistance 1 ohm for 1 second, then 1 joule of work has been expended in maintaining this current. This energy is transformed into heat.

If the coil is submerged in a calorimeter containing water, the number of calories of heat produced can be obtained by the usual method of calorimetry. In a circuit containing only resistance, a direct proportion exists between the expenditure of the electric energy W and the heat H developed. This fundamental law is represented by the conservation of energy equation

$$W = JH \qquad (6)$$

where J is the proportionality factor called the mechanical equivalent of heat, or the number of joules required to produce one calorie of heat.

By referring to the experiments on calorimetry you will derive an expression for H, the heat developed, so that the value of J can be found from the work equation

$$J = \frac{W}{H} = \frac{VIt}{H} \qquad (7)$$

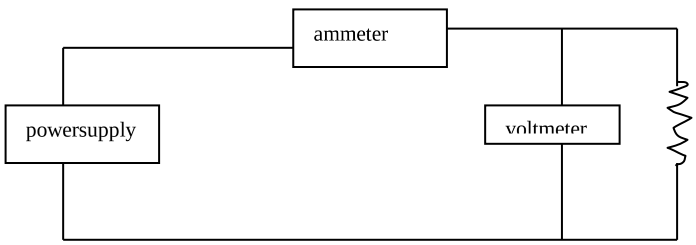


Figure 1

PROCEDURE1:

CAUTION: Never close the switch unless the heating coil is immersed in water.
With the switch open,

1. Weigh the empty calorimeter cup to hundredths of a gram. Then fill it about ¾ full of water. Cool the water with ice if necessary so that its temperature is about 5° C below room temperature. Weigh the cup and water after cooling. The difference between these weights is the mass of the water.

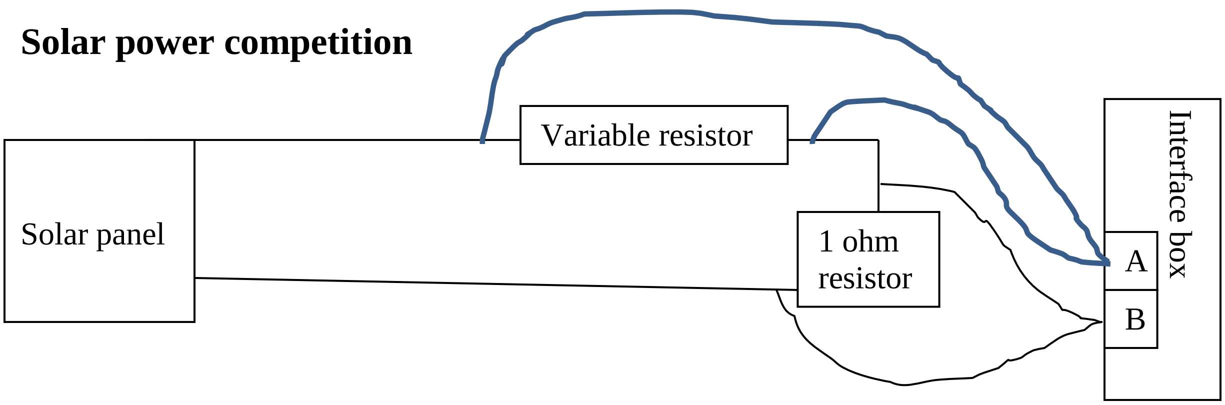
2. Place the heating coil assembly and the temperature sensor in the calorimeter. Read the initial temperature of the water, T, stirring the water to achieve the equilibrium value.

3. Connect the circuit as shown in Figure 1. Note that the ammeter (20 amp hole connection only) is placed in series with the coil, while the voltmeter is connected in parallel across its terminals. **Always have the coil immersed in the water before connecting the circuit!** Set the power supply to its maximum value of 3.2 amps then quickly turn it off. Have your connections approved by the instructor or laboratory assistant.

4. Run the temperature measuring program from datastudio. Read the voltage. Close the switch and read the time from the temperature program. Record the values of V, I and time at each change of one degree. Be sure to keep V and I constant at all times during the run.

5. Stir the water in the calorimeter gently and **continuously** until its temperature has increased until it is about as far above room temperature (5 degrees) as it was below at the beginning of the run. Continue to stir the water in the calorimeter and note accurately the highest temperature reached T_2. Record the elapsed time. **Turn off the power supply when changing the water.** Make a graph of ΔW vs. ΔQ. The Slope should approximately equal = (4.184 J/cal).

Solar power competition



This part of the lab is meant to simulate the output from the sun and you are meant to maximize the power from this varying light source with a single choice of load resistance. Obviously the best way to maximize power output would be pointing the panel directly at the sun and varying the load resistance with weather condition changes. Assuming these options are not available to you, the selection of a single load resistance which optimizes the power for varying conditions becomes an important problem.

1. Connect the voltage sensors to the solar cell with the variable load resistance and single ohm resistance as in the diagram above. The voltage sensor for channel B is used as an Ammeter with the volts proportional to the amps since the resistance is one ohm. The voltage from channel A gives the volts from the solar panel across the load with the ammeter resistance included as part of the load.

2. Observe that the datastudio program gives the power verses time graph (P = I V). Plot the power output as a function of resistance in an excel graph for a flashlight shining directly on the solar cell. Find the maximum of the power vs resistance and plot at least 3 points on each side of the maximum. **<u>Note that only the first 4 columns of resistors should be used on the left hand side of the resistance box</u>**. **<u>All the other resistance switches should be disconnected in the out position. Connections to the resistor box should be made using the holes in the posts, half-moon or cresent connectors cannot make contact when lying flat on the posts.</u>**

3. Change the light input to the solar cell, perhaps by using only the ambient room light to represent a cloudy day or lower angle of the sun. Find the maximum in the power vs resistance for the new light level and plot that peak on the same graph from part 2.

4. Decide on a load resistance which you believe will allow for the most power output from the solar cell for varying light levels. Bring your solar panel and load resistance to the test station in the front of the lab where power output for light impinging at different angles will be measured. .

ANALYSIS OF DATA:

1. Compute the number of joules of energy from the ammeter, voltmeter, and timer readings.

2. Compute the number of calories of heat absorbed by the calorimeter and heading assembly (the thermal capacity of the coil together with specifications on the stirrer will be supplied by the instructor).

3. Finally, calculate the number of joules required to produce one calorie of heat for each run and find the average. Compare your value with the accepted value of J (4.18 joules/calorie).

4. Calculate the amount of time required to raise temperature of your water sample by 50 degrees using the solar cell in ambient light at the maximum power output

5. Speculate about what type of circuitry and control of the load or charging battery resistance may be necessary to allow the maximum power output from solar panels under changing weather conditions and when they are locked in place and cannot remain pointed directly at the sun.