TEMPERATURE COEFFICIENT OF RESISTANCE

OBJECT

To measure the temperature coefficient of both thermistors and copper wire.

APPARATUS

Thermistor assembly, copper wire assembly, electrically heated water bath, temperature sensor, slide-wire Wheatstone bridge, galvanometer, Power supply, resistance box, eight wires

THEORY

Most metals used as electrical conductors exhibit a linear relation between resistance and temperature. The temperature coefficient of resistance α of such metals is defined by the expression

$$\alpha = \frac{R_t - R_o}{tR_o} \qquad (1)$$

where R_t: value of resistance of the metallic conductor at temperature t °C

R_o: value of resistance of the metallic conductor at temperature 0 °C

Of course, equation (1) may be rewritten as

$$R_t = \alpha R_o t + R_o \qquad (2)$$

when we recognize immediately that equation (2) is simply the slope-intercept form of a straight line, namely, y = mx+b. Thus, if we were to plot a series of values of resistance versus temperature for a given specimen, the resulting straight line would intercept the resistance axis at the value R_o while the attendant slope divided by R_o is the value of α. Most metals have a small positive temperature coefficient of resistance.

In contrast with metals, thermistors have large negative temperature coefficients. Moreover, with thermistors the change of resistance with a change in temperature is non-linear. The resistance of a thermistor is given by the equation

$$R = R_a \quad \varepsilon^{(1/t - 1/t_a)\beta} \qquad (3)$$

where R: resistance in ohms at temperature t (K)

R_a: resistance in ohms at the lowest temperature used, t_a (K)

β: a property of the material (K)

e: Naperian base, 2.718

Taking the logarithm of both sides of equation (3), we may rewrite that expression as

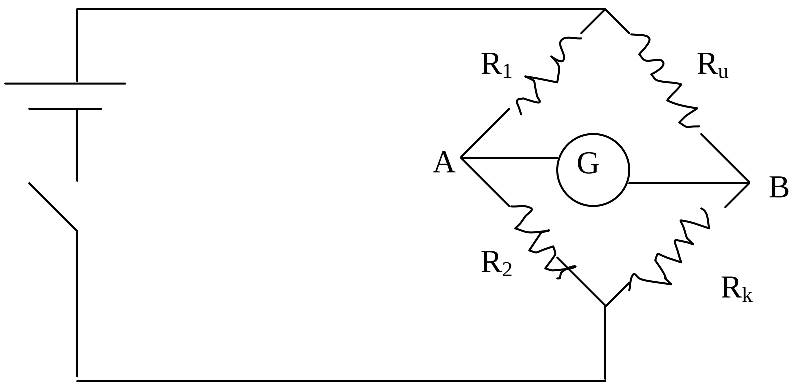
$$\ln R - \ln R_a = \beta x \qquad (4)$$

where X: l/t – l/t $_a$

When the resistance is measured at various temperatures, the plot of ln R versus 1/t yields a straight line whose slope is β. Demonstrate this fact conclusively by graphing ln R vs. 1/t in the written theory of your experiment.

Wheatstone Bridge

This section is provided so the student can study the wheatstone bridge before coming to class. G is symbol for galvanometer



The wheatstone bridge is used to make very accurate measurements of resistance.

$\frac{R_1}{R_2}$	taken from wire lengths
R_u	=R unknown
	=R of wire or thermister
R $_K$	=Known Resistance from resistor box which is accurately known

Warning: Make sure plugs go back in same hole in the resistor box.

Wire has uniform resistance per unit length. Therefore $\frac{R_1}{R_2}$ is very precisely known.

How this works:

1) adjust your wire contact until the galvanometer reads zero.
2) at null reading $\frac{R_u}{R_K} = \frac{R_1}{R_2}$
3) calculate Ru=Rk $\frac{R_1}{R_2}$

Derivation

$$I_1R_1 + I_2R_2 = V_{in}$$
$$I_uR_u + I_kR_k = V_{in}$$

but

$$I_1 = I_2$$
$$I_u = I_k$$

and V_{in} same so

$$I_1(R_1 + R_2) = I_u(R_u + R_k).$$

Using the loop rule for voltage on the upper loop:
$R_1I_1 - R_uI_u = 0$,

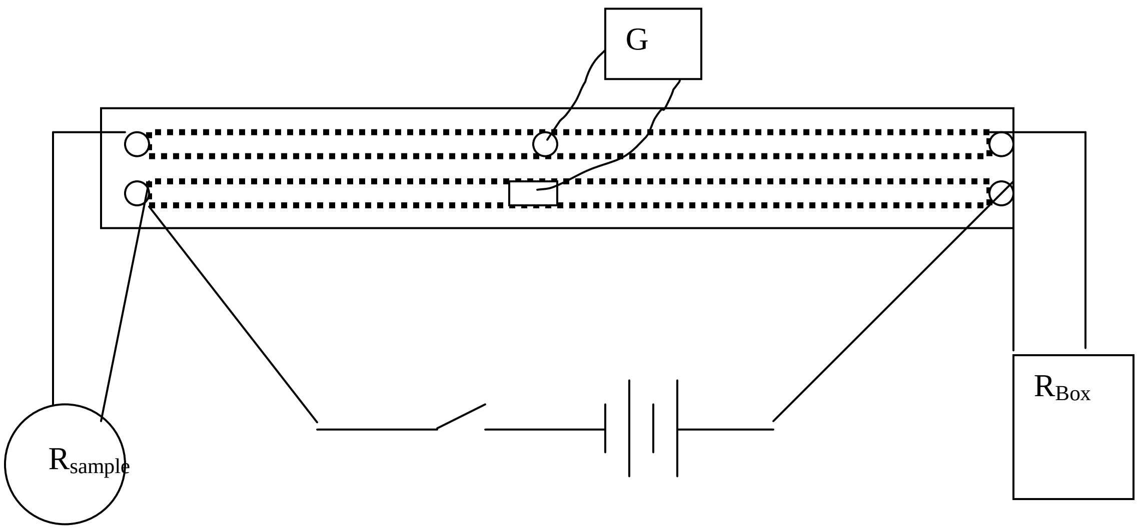
and therefore,

$I_u = \dfrac{R_1I_1}{R_u}$. Plug this into the equation above to get

$I_1(R_1 + R_2) = \dfrac{R_1I_1}{R_u}(R_u + R_k)$, which then becomes

$\dfrac{R_u}{R_K} = \dfrac{R_1}{R_2}$. In the diagram below $R_u = R_{sample} + R_{wires}$ and $R_K = R_{Box} + R_{wires}$.

Drawing (battery wires are short so make sure you use the right ones)



TAs should check resistance boxes with ohmmeter so that true resistance is being measured

PROCEDURE:

1. Fill the vessel of the apparatus with water to within an inch of the top and mount the thermometer through the hole in the bakelite cover of the unit to be tested. Place this unit in the vessel with the thermistor (or copper wire) completely immersed in water and tighten the two clamps to secure the unit and vessel in place.

2. Attach the connecting cord to the prongs of the heating unit and to the 115 volt A.C. power supply. The cord is provided with a momentary switch: “ON” when depressed, “OFF” when released. Connect the temperature sensor and run the datastudio program. Finally, connect the binding posts on the unit to the proper terminals on the Wheatstone bridge. Do not forget to measure the resistance of the connecting wires.

3. Measure the resistance of the unit below room temperature using ice. Record resistance values to a tenth of an ohm and temperature readings to a tenth of a degree. NOTE: In using the slide-wire bridge, greater accuracy may be obtained when the balance point is near the mid-point of the slide-wire (40 cm-60 cm range). <u>The resistance boxes require the half moon connectors to be inserted in the hole of the post to make good electrical contact.</u>

4. Increase the temperature of the water about 5 degrees. Turn off the heater one or two degrees before the desired temperature is reached, stirring well during heating. The temperature of the water will continue to rise for several degrees after the heater is turned off. Continue stirring until a maximum temperature is reached, at which time temperature and resistance measurements may be made. Stirring the water is especially important just before and during the time at which resistance measurements are made to insure that the temperature is constant. This is mandatory during the thermistor experiment since they are very sensitive to small temperature changes.

5. Repeat the measurements using steps of about 5°C until a temperature of 70°C is reached. Make sure that you have at least six (6) measurements for your analysis.

ANALYSIS OF DATA:

1. From the tabled data for the copper wire, plot values of R_{sample} versus temperature and from the resulting graph compute the value of α. Compare your value with the accepted value of 4.33×10^{-3} /°C.

2. From the thermistor data, plot a curve using R_{sample} as ordinates versus temperatures as abscissae to demonstrate the non-linear relation of resistance and temperature.

3. From the thermistor data, plot a curve using ln R_{sample} as ordinates (y) and ($l/t - l/t_a$) as abscissae (x) from which you will compute the value of β as given in equation (4). Compare your value with the manufacturer’s value of 3530 ± 80 K.