Temperature Dependence of a Noble Metal Resistor

Objective:

- Measuring the Ohmic resistance of a noble metal as a function of temperature at various points.
- Determining the temperature coefficient of resistance β.

Apparatus:

1	Noble metal resistor	586 80
1	Electric Oven, 220V	555 81
1	Thermometer	
1	Demonstration measuring bridge, 1m	536 02
1	Resistance box	536 77
	Connecting leads	501 20/25/33
1	Multimeter	531 52
1	Power supply	685 44

Theory:

The following equation applies to the resistance of "normal" metals within the first degree of approximation:

$$R_\theta = R_\circ(1+\beta\theta) \quad (1)$$

where

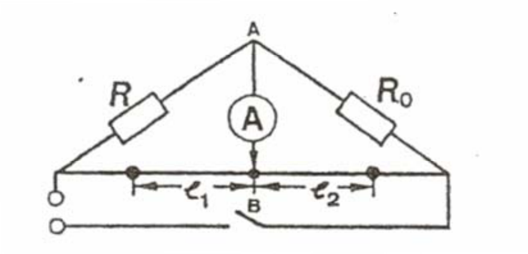
$R_\circ$: Resistance at 0

θ: Temperature in $^\circ C$

R_θ: Resistance at the temperature $\theta ^\circ C$

β: is the temperature coefficient of the resistor (resistance change per degree).

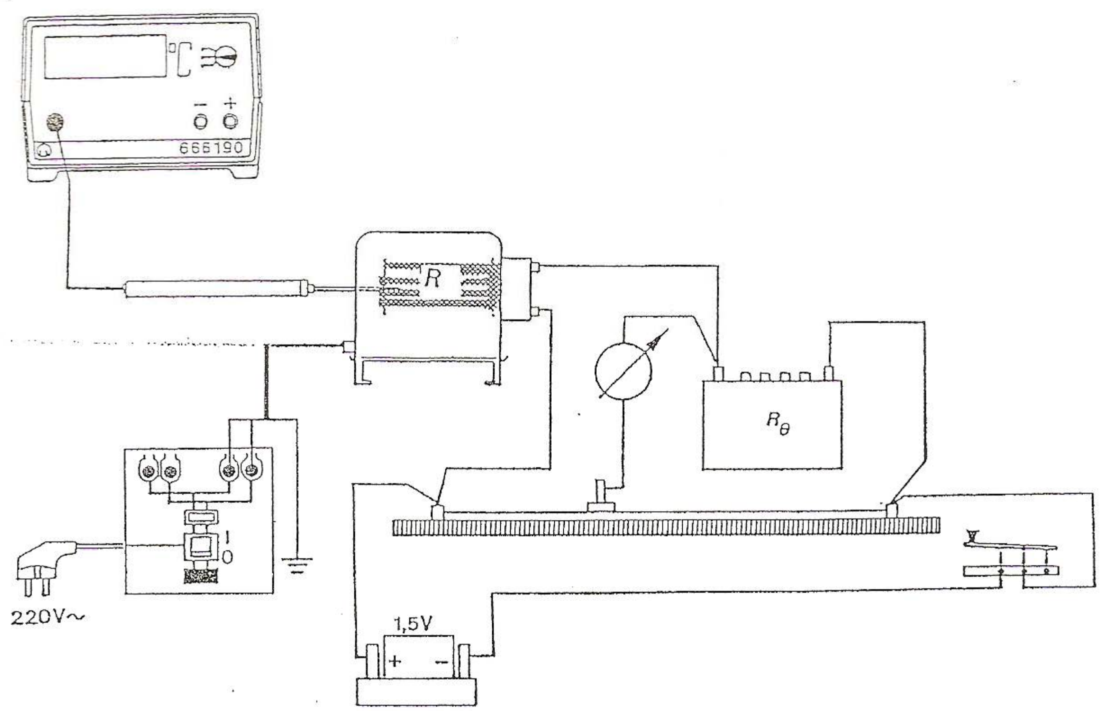
In the experiment described here, it will be demonstrated that the functional relationship between ohmic resistance R_θ and temperature θ is linear function, as required by equation 1. The ohmic resistance of a noble metal resistor will be measured at various temperatures (intervals from +25 to +230$^\circ C$) using a Wheatstone bridge circuit, consisting of a noble metal resistor, a resistance box and a measuring bridge.



If the Wheatstone bridge is balanced for the set temperature, i.e. the bridge branch AB is current-free, then R_θ is given by:

$$R_\theta = (L_1 / L_2) R \qquad (2)$$

The resistor is heated in an electric oven and cooled down to the room temperature.



Carrying out the experiment:

1. Set up the experiment as shown in figure.
2. Set the battery voltage to 1.5V by using the d.c. voltmeter.
3. Look for the balancing point by sliding the free end of the galvanometer over the meter bridge.
4. Make the balancing point in the middle of the meter bridge by adjusting the resistance from the resistance box (this is the adjustable resistance in the Wheatstone bridge)
5. Don't forget that the balancing point is the point at which the galvanometer points to zero.
6. Now, turn on the oven to heat the noble metal resistance.

CAUTION: The noble metal resistance temperature must not exceed 250^{o}C.

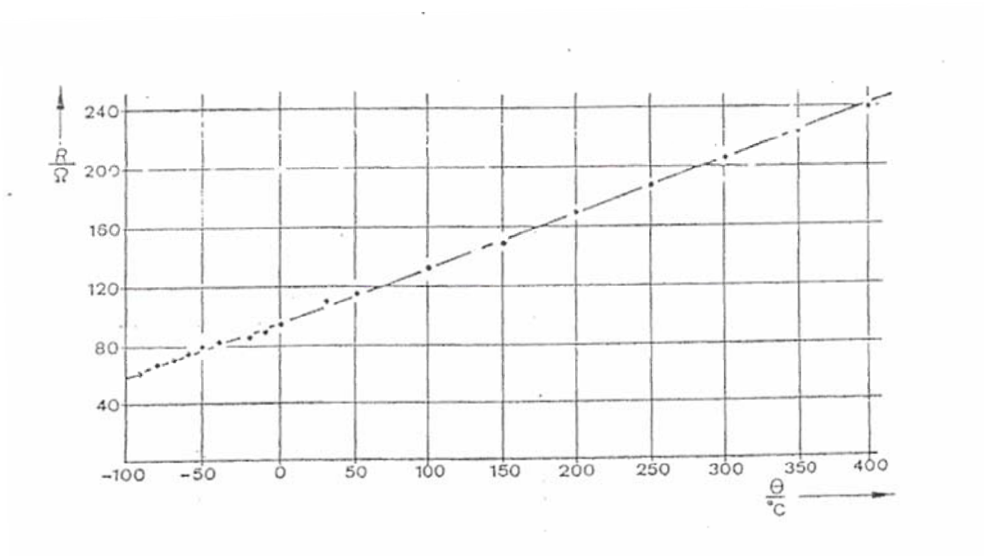
7. Measure L_1 at every $10C^o$ decrease in temperature by looking for the balancing point.
8. Deduce L_2 and calculate R_θ every time.
9. Plot R_T versus θ.
10. Calculate the slope.
11. Calculate the intercept (it represents the resistance at zero temperature) and hence the temperature coefficient of resistance β.

<u>Evaluation and Results:</u>

The measurements produce a linear relationship between temperature and resistance value for the noble metal resistor examined as shown in the following figure.

Then, the temperature coefficient of the resistor;

$$\beta = \frac{R_\theta - R_o}{R_o \cdot \theta}$$



where $\theta = 300^o C$,

$$R_\theta = 205\Omega$$

$$R_o = 94\Omega$$

$\therefore \beta = 0.0039$ per degree

<u>Note:</u>

The material used for the noble metal resistor is platinum. Values between 0.002 and 0.004 are specified for β depending upon degree of purity.

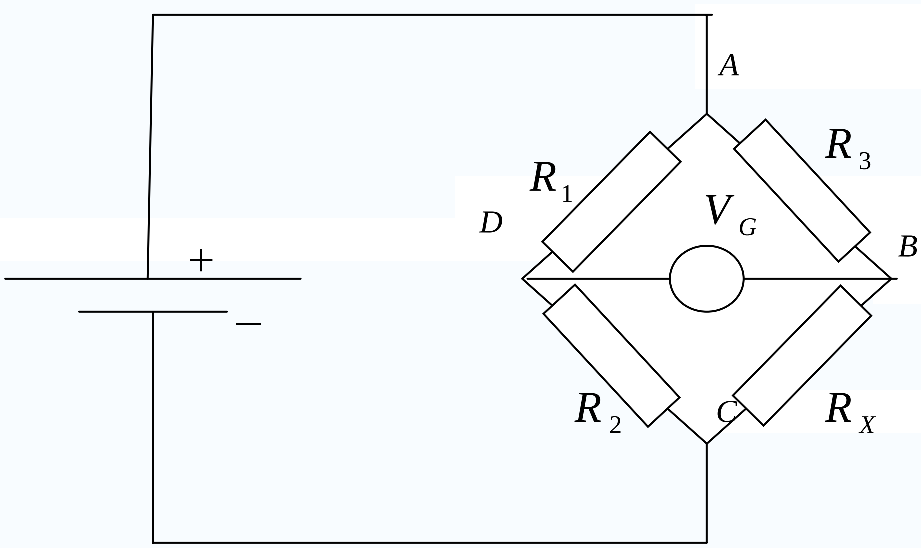
Questions:

- Describe the relationship between the noble metal resistance and the temperature?
- Explain why does the resistance of a noble metal resistance increase with increasing temperature?
- What does a noble metal mean?

Wheatstone bridge

From Wikipedia, the free encyclopedia

A **Wheatstone bridge** is a measuring instrument invented by Samuel Hunter Christie in 1833 and improved and popularized by Sir Charles Wheatstone in 1843. It is used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component. Its operation is similar to the *original* potentiometer except that in potentiometer circuits the meter used is a sensitive galvanometer.



Wheatstone's bridge circuit diagram.

In the circuit at right, R_x is the unknown resistance to be measured; R_1, R_2 and R_3 are resistors of known resistance and the resistance of R_2 is adjustable. If the ratio of the two resistances in the known leg (R_2 / R_1) is equal to the ratio of the two in the unknown leg (R_x / R_3), then the voltage between the two midpoints (**B** and **D**) will be zero and no current will flow through the galvanometer V_g. R_2 is varied until this condition is reached. The current direction indicates whether R_2 is too high or too low.

Detecting zero current can be done to extremely high accuracy (see galvanometer). Therefore, if R_1, R_2 and R_3 are known to high precision, then R_x can be measured to high precision. Very small changes in R_x disrupt the balance and are readily detected.

At the point of balance, the ratio of $R_2 / R_1 = R_x / R_3$

Therefore,

$$R_X = (R_2 / R_1) R_3$$

Alternatively, if R_1, R_2, and R_3 are known, but R_2 is not adjustable, the voltage or current flow through the meter can be used to calculate the value of R_x, using Kirchhoff's circuit laws (also known as Kirchhoff's rules). This setup is frequently used in strain gauge and Resistance Temperature Detector measurements, as it is usually faster to read a voltage level off a meter than to adjust a resistance to zero the voltage.

Derivation:

First, we can use Kirchhoff's first rule to find the currents in junctions **B** and **D**:

$$I_3 - I_X + I_g = 0$$
$$I_1 - I_g - I_2 = 0$$

Then, we use Kirchhoff's second rule for finding the voltage in the loops **ABD** and **BCD**:

$$I_3 \cdot R_3 + I_g \cdot R_g - I_1 \cdot R_1 = 0$$

$$I_x \cdot R_x - I_2 \cdot R_2 - I_g \cdot R_g = 0$$

The bridge is balanced and $I_g = 0$, so we can rewrite the second set of equations:

$$I_3 \cdot R_3 = I_1 \cdot R_1$$

$$I_x \cdot R_x = I_2 \cdot R_2$$

Then, we divide the equations and rearrange them, giving:

$$R_x = \frac{R_2 \cdot I_2 \cdot I_3 \cdot R_3}{R_1 \cdot I_1 \cdot I_x}$$

From the first rule, we know that $I_3 = I_x$ and $I_1 = I_2$. The desired value of R_x is now known to be given as:

$$R_x = \frac{R_3 \cdot R_2}{R_1}$$

If all four resistor values and the supply voltage (V_s) are known, the voltage across the bridge (V) can be found by working out the voltage from each potential divider and subtracting one from the other. The equation for this is:

$$V = \frac{R_x}{R_3 + R_x} V_s - \frac{R_2}{R_1 + R_2} V_s$$

This can be simplified to:

$$V = \left(\frac{R_x}{R_3 + R_x} - \frac{R_2}{R_1 + R_2} \right) V_s$$

The Wheatstone bridge illustrates the concept of a difference measurement, which can be extremely accurate. Variations on the Wheatstone bridge can be used to measure capacitance, inductance, impedance and other quantities, such as the amount of combustible gases in a sample, with an explosimeter. The **Kelvin Double bridge** was one specially adapted for measuring very low resistances. This was invented in 1861 by William Thomson, Lord Kelvin. A "Kelvin One-Quarter Bridge" has also been developed. It has been theorized that a "Three-Quarter Bridge" could exist; however, such a bridge would function identically to the "Kelvin Double Bridge."

The concept was extended to alternating current measurements by James Clerk Maxwell in 1865 and further improved by Alan Blumlein in about 1926.