VL-H2: CALIBRATION OF A GIVEN THERMOCOUPLE

Objectives:

- To understand the calibration curve of a given thermocouple.
- To determine unknown temperature using the calibration curve.

System requirements:

Computer (Desktop/Laptop), Operating system: Windows, Thermocouple_vle (zipped) File.

Advise:

Students are advised to follow the **procedures written in this manual very strictly** while performing the experiment. D**o not try to explore anything else during the experiment.**

Theory:

In 1821, T. J. Seebeck observed that if wires of two different metals, such as copper and iron, are joined together to form a closed loop and if two junctions are kept at different temperatures, an electric current begins to flow in the loop. This phenomenon is called thermoelectric effect, and generation of current in the loop due to difference in temperatures is called Seebeck effect. The loop comprising the two metals is referred to as a thermocouple. The existence of current implies that there is an electromotive force (emf) acting in the circuit. This is known as thermo-electromotive force and the electric current produced in this way is called thermo-electric current.

When one junction of a thermo-couple is maintained at $0°C$ and the other junction is heated to a higher temperature $\theta°C$ as in Fig. 1, then thermo-electromotive force is developed in the circuit. The direction of the emf depends on the pair of metals used and the temperatures of the junctions. The magnitude of emf that developed in the circuit can be calculated by balancing it against a potential drop in certain length of a potentiometer.

Let e be the potential drop per unit length of the potentiometer wire having a total length of L cm. Now, if E' be the emf developed in a thermo-couple, which is balanced against a length l cm of the potentiometer wire then,

$$E' = el \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

The potential drop per unit length of the potentiometer wire is given by the relation,

$$e = \frac{E}{R + R_P} \times \frac{R_P}{L} \ volts\ per\ cm \dots\dots\dots\dots\dots\dots\dots (2)$$

Where, E =emf of the driver battery in the potentiometer circuit

R_P =total resistance of the potentiometer wire of length L

From equation (1) and (2) we get,

$$E' = el = \frac{E}{R + R_P} \times \frac{R_P}{L} \times l \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Hence, by determining the balancing length l, thermo-electromotive force developed at a given temperature can be calculated from equation (3).

By measuring the thermo-electromotive force developed for different temperatures of the hot junction, a graph can be plotted with the temperature of the hot junction as the abscissa and the emf as the ordinate. This is known as the calibration curve for the thermocouple.

After a thermocouple has been calibrated in this manner, it can be used to measure any unknown temperature by measuring the emf produced at any unknown temperature and then reading off the temperature from the calibration curve corresponding to the measured emf.

If the cold and hot junctions of a thermocouple are kept at 0°C and θ°C, respectively, then the e.m.f. developed in the thermocouple is given by,

$$E' = a\theta + b\theta^2 \; \dots\dots\dots\dots\dots (4)$$

For small θ, $E' \approx a\theta$

Hence, the calibration curve for the given thermocouple will approximately be a straight line.

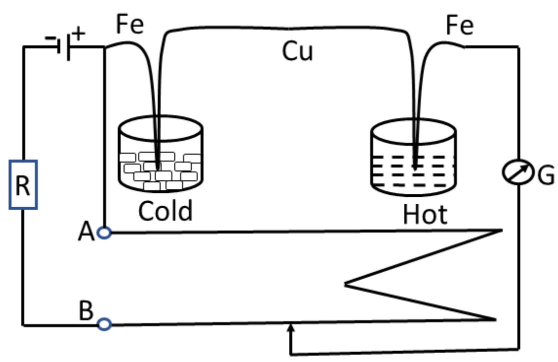

Fig. 1. Experimental setup for measuring the emf of a thermocouple.

Procedures:

1. At first unzip "**Thermocouple_vle (zipped)**" File. Click on the executable file "**Thermocouple_vle**", then a window will open as shown in Fig. 2.

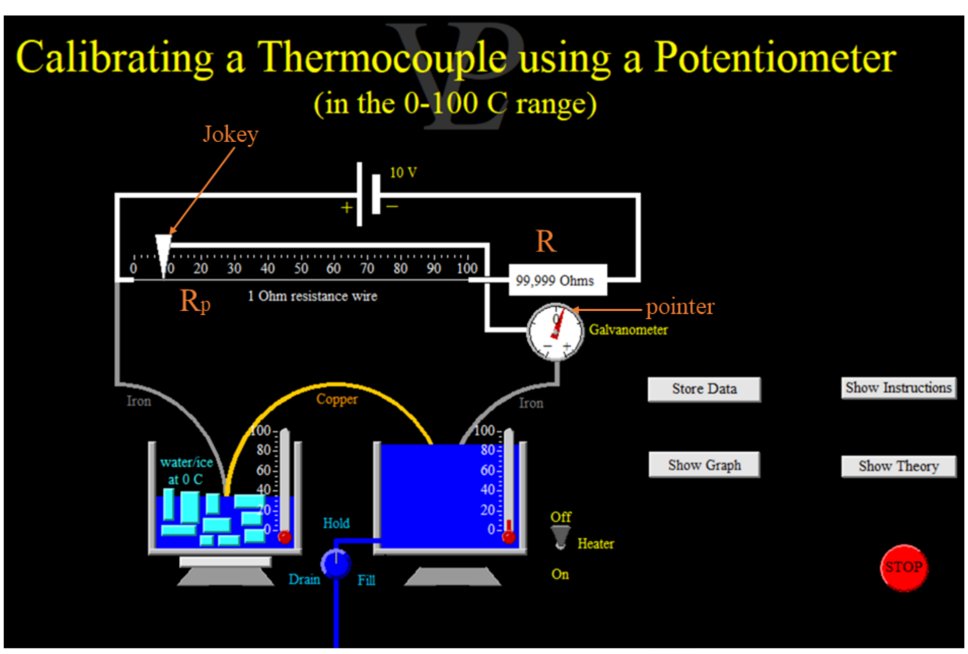

Fig: 2. VP Lab Experimental setup.

2. Fill the right-hand beaker completely with water using the blue knob by keeping the pointer at '**Fill**' position and hold the water into the beaker by keeping the pointer at '**Hold**' position as shown in Fig. 2.

3. Drag the jokey of the potentiometer in such a way that the pointer of the galvanometer remains left of zero.
4. Then turn the heater '**on**' by clicking it. As the water warms up, an electromotive force (emf) will be produced and the balancing point of the Galvanometer will move.
5. During heating, try to keep always the galvanometer pointer left to zero by moving the jokey. When the pointer will come to zero position (null point), take the reading by pressing the knob '**store data**'.
6. As the temperature rises, the value of e.m.f. produced will be changed and galvanometer pointer will be shifted. Follow the step 5 repeatedly (15 times) and take the reading until you reach a temperature about 100℃.
7. Press the 'show graph' knob and see the relationship between the thermo-emf (as ordinate) and the temperature (as abscissa). It is to be noted that the experimental value of temperature and e.m.f. can only be obtained from the analysis of the graph.
8. For getting the experimental data from the graph, right click on the graph and it will display different options. Go to 'show' and select the 'cursor display' option [as shown in Fig.3 (a)]. It will display two cursors but they are locked. Unlock any cursor by clicking on the locked button and then it will look like Fig.3 (b) and you will see two cursor pointers (two yellow lines) along X- and Y-axes. Drag the cursor pointers to select one data point [as shown in Fig.3 (c)]. Then, you will observe data value in the cursor display. For example, in Fig.3 (c), the value of the selected data point is displayed as (17.52, 19.78). Move the cursor to the next data point and take the value. In this way, make the data table of emf and corresponding temperature of the hot junction.

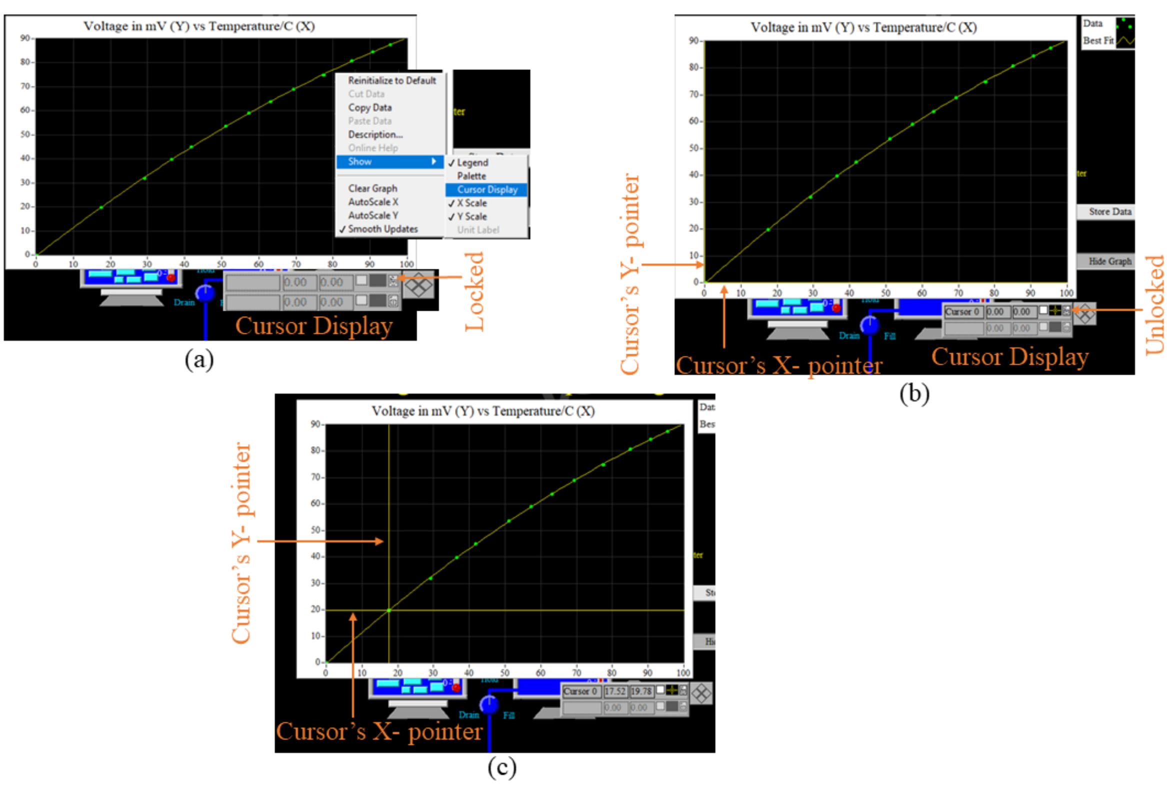

Fig: 3. Thermo-electromotive force versus temperature graph.

9. Draw the emf versus temperature graph in your graph paper. Draw a straight line that passes through the origin as shown in Fig. 4.

Data collection and graphs for analysis:

Table: The temperature dependent emf:

No.	Temperature θ (°C)	emf $E^{/}$ (mV)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

The graph of emf versus temperature is shown below:

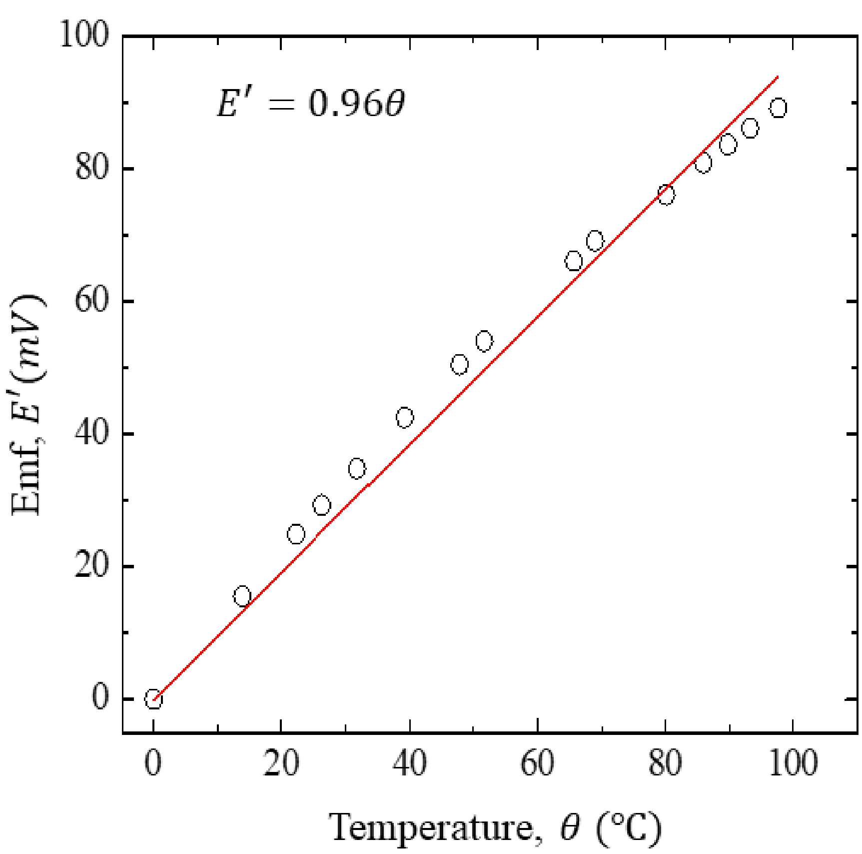

Fig. 4: The open circle is the experimental data and the straight line (red color) is the best fitting theoretical curve.

Calculation:

The best fitting curve follows the equation $E' = 0.96\theta$ [mV] from where you can obtain the unknown temperature for any known value emf (say 50 mV).

Result:

The graph of emf vs temperature produced a straight line that passes through the origin. This is the required calibration curve.

Discussion:

Based on your understanding from this experiment, answer the following questions:

1) On what factors does the direction of thermo electric current depend?
2) What is the importance of calibrating a curve?
3) Instead of water bath, use the sand bath (say, temperature of the hot junction can be raised up to 350 °C) and plot the temperature along x-axis and the thermo-emf along y-axis and draw a curve. What would be the nature of your graph?
4) How does the emf change when the temperature of the hot junction is continuously increased?
5) What is neutral temperature? Does it depend on the temperature of the hot junction?