

To record and analyze the cooling temperature of a hot object as a function of time using a thermocouple and suitable data acquisition system:

- **Construction of thermo-couple:** A copper(Cu)-constantan(Cn) couple is employed for this experiment. To prepare this couple, three pieces of wires, each of one meter long are taken, of which one is of Cn, while the other two are of copper. The two ends of Cn wire are cleaned and are joined by twisting with one end of each of the copper wires. Then these junctions are soldered with minimum amount of solder covering a length of about 2-3 mm of each junction. Two glass tubes T_1 and T_2 (figure below, Fig. 1) are introduced in the copper wires to be sure that the metals touch at the junctions only.
- **Circuit Connections:**

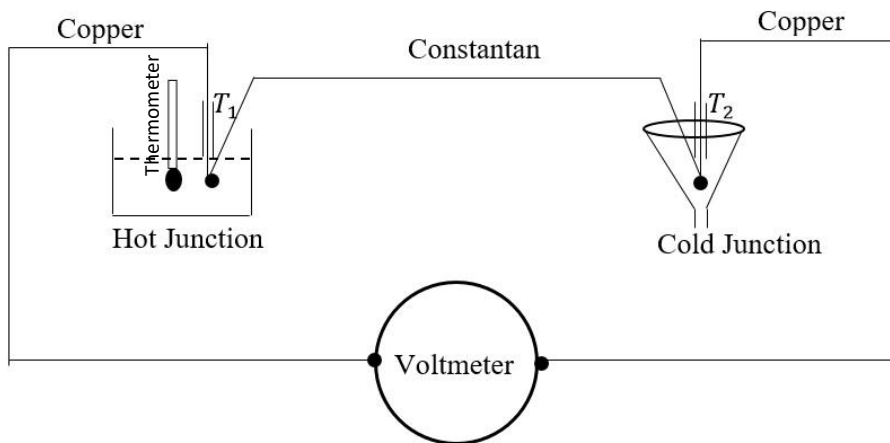


Figure 1

Ice is poured in the funnel (see Fig. 1) to cool the right hand junction to 0°C . The left hand junction is dipped inside a pot filled with water. The water temperature can be varied using a heater controllably and the corresponding temperature should be measured using a thermometer placed near the junction inside the water (see the figure). To measure the thermo-e.m.f a voltmeter (that can measure millivolt) is used.

- **Theory:** When one junction of a thermo-couple is kept at 0°C while its other junction is maintained at a higher temperature, thermo-e.m.f e will be developed in the couple. Magnitude of the thermo-e.m.f depends upon the temperature difference between the two junctions (here on the temperature of the hot junction only as the cold junction temperature is 0°C). Variation of the thermo-e.m.f can be studied by plotting the measured thermo-e.m.f using the voltmeter with temperature of the hot junction (i.e., with the temperature difference of its two junctions) measured using the thermometer. The thermo-e.m.f e versus temperature curve should be approximately linear over around up to 90°C (see Fig. 2). This plot can be used as a calibration curve, and later the hot junction of the thermo-couple can be used as a thermometer. If the hot junction is inserted into a body, a thermo-e.m.f (e_{hot}) will be generated in the thermo-couple, and the temperature (θ_{hot}) corresponding to that thermo-e.m.f can be found from the calibration curve. This thermo-couple

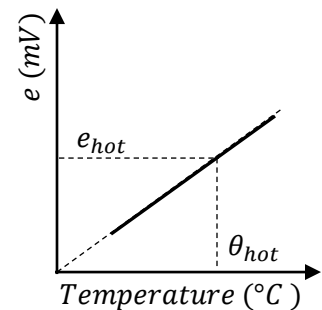


Figure 2: Calibration curve

thermometer thus also can be used to record and analyze the cooling temperature of a hot object as a function of time. The rate of cooling of a hot object usually follows the Newton's law of cooling, i.e.,

$$\frac{dQ}{dt} \propto (\theta_{hot} - \theta_{surr}),$$

when $(\theta_{hot} - \theta_{surr})$ is not very large. Here, Q is the heat content of the body at any time t , θ_{hot} and θ_{surr} are the temperatures of that hot body and the surroundings respectively at that time t . If m is the mass and s is the specific heat of the body then $Q = ms\theta_{hot}$. Therefore, $\frac{d\theta_{hot}}{dt} \propto (\theta_{hot} - \theta_{surr})$.

Therefore, we should see that the rate of decrease of the body temperature decreases too as θ_{hot} decreases with time.

• **Procedure:**

- The setup is constructed as described before.
- To create the cold junction, ice cubes are smashed and poured in the funnel ensuring that the junction is well covered by the ice so that the junction temperature becomes 0°C .
- Now a heater should be turned on to heat up the water in the left hand side pot to controllably increase the temperature of the hot junction.
- The thermometer in the pot should be used to measure the corresponding temperature.
- The connected voltmeter should be used to measure the generated thermo-e.m.f.
- The e.m.f should be recorded for temperatures from 25°C to 85°C in a step of 5°C (use the *Table 1*).
- Replace the hot water by cold water and repeat the measurement for three times and take the average.
- Now the recorded thermo-e.m.f (e) should be **plotted** against the measured temperature of the hot junction on a graph paper to create the **calibration curve**.
- From the calibration curve, note down the thermo-e.m.f (e_{85}) corresponding to 85°C .
- Now remove the thermometer from the setup. We are going to use the thermo-couple as a thermometer.
- Note down the thermo-emf when the water is at room temperature.
- Find out the corresponding temperature (θ_{surr}) using the calibration curve.
- Put the heater on to heat up the bath water which will be used as the hot object.
- Turn off the heater when the thermo-emf reaches e_{85} which corresponds to 85°C .
- Start measuring the thermo-emf with time in steps of 30 seconds for around 20 minutes (when the thermo-emf will almost become constant). Use a stopwatch to count time.
- From the calibration curve find out the temperatures corresponding to the recorded thermo-emfs (Use the table below).
- Plot the temperature of water with time.
- Plot $\frac{d\theta_{hot}}{dt}$ with $(\theta_{hot} - \theta_{surr})$ and verify the Newton's law of cooling.

Table 1 (Table to produce Thermo-e.m.f versus temperature graph, i.e., the calibration curve):

Temperature ($^{\circ}\text{C}$)	Thermo-e.m.f (mV)			Mean Thermo-e.m.f (mV)
	1 st Set	2 nd Set	3 rd Set	
25				
30				
...

Table 2 (*Table to record and study the cooling of a hot body with time*):

Time (s)	Thermo-e.m.f (mV)	Temperature in °C using the calibration curve
0
30		
60		
...		