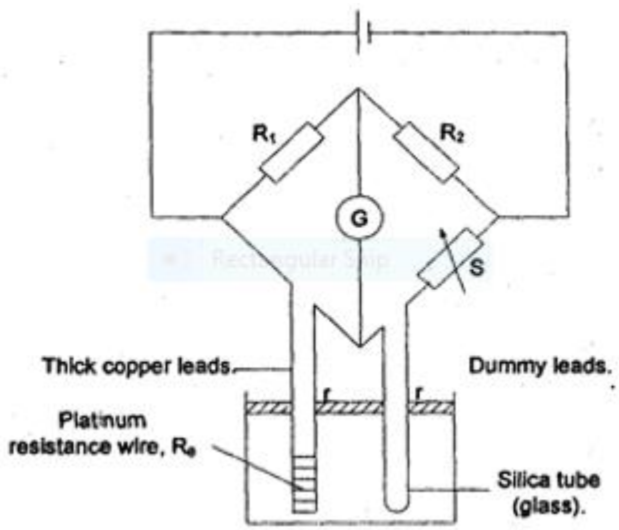
PLATINUM RESISTANCE THERMOMETERS

The thermometric property used in this thermometer is **electrical resistance of an electrical conductor** such as a platinum wire.



Construction

Thermometer consists of a platinum wire wound on a mica and immersed in a silica tube. The resistance of the platinum wire is measured by using a Wheatstone bridge circuit. The thermometer is connected to the Wheatstone bridge circuit by means of copper leads.

Mode of operation

Resistance R_1 is made equal to R_2. The resistance **r** of the dummy leads is equal to the resistance **r** of the copper leads . The resistance R**s** of ***S*** is adjusted until no current flows through the galvanometer G. At balance, $\frac{R_1}{R_2} = \frac{R_\theta + r}{R_s + r}$ since $R_1 = R_2$, then $R_\theta =$ Rs.

In this way, the resistance of the platinum wire is determined.

The silica tube is first immersed in ice-water mixture and the resistance R_0 is measured at ice-point is measured and recorded. The tube is then immersed in a steam bath at one atmosphere pressure and the resistance R_{100} at steam point is measured and recorded. The tube is now brought into contact with the body of unknown temperature θ and the resistance R_θ at that temperature is measured and recorded. The unknown temperature θ is then calculated from

$\theta = (\frac{R_\theta - R_0}{R_{100} - R_0})x100^0C$. This equation defines the Celsius scale of temperature of the platinum resistance thermometer.

Advantages of a platinum resistance thermometer

- It can be used to measure small steady temperature differences

- It's used over a wide temperature range (-200°C to -1200^{0}C).

- It's very accurate though not as accurate as the constant volume gas thermometer.

- It's less cumbersome to use compared to the constant volume gas thermometer.

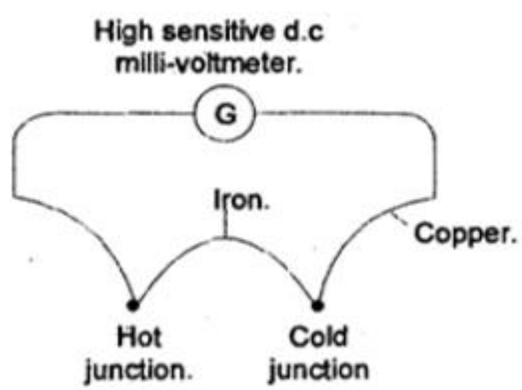
Disadvantages of a platinum resistance thermometer

- It can't be used to measure rapidly changing temperatures,

- It can't measure temperatures at a point due to the large size of silica tube.

THERMOCOUPLE

A thermocouple is made by joining two wires made of different materials to form two junctions. When the junctions are exposed to different temperatures an e.m.f is set up the magnitude of which depends on the temperature difference between the junctions.

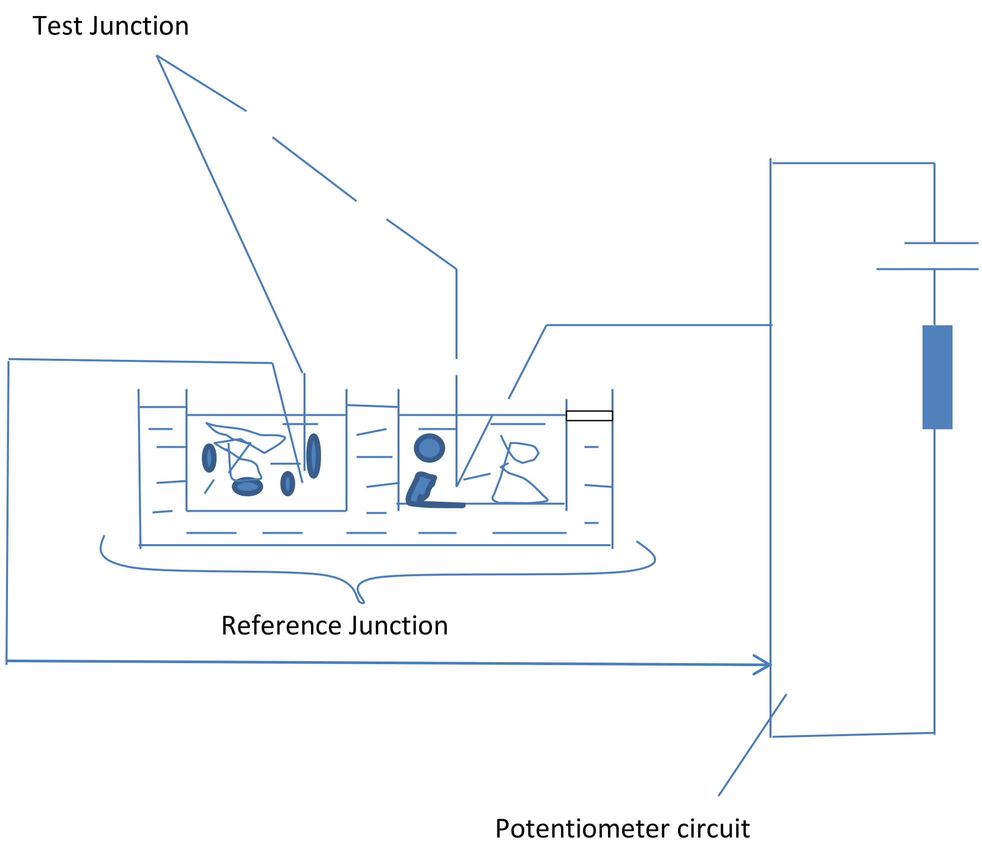


THERMOCOUPLE THERMOMETER

The thermometer uses **thermoelectric e.m.f** of a thermocouple as its thermometric property.

Construction

The thermocouple thermometer consists of two junctions; the reference junction which is immersed in an ice-water mixture and a test junction which is moved to systems whose temperatures are to be measured. The difference between the temperatures of the specimen body or system and the reference junction sets up an e.m.f that is accurately measured a potentiometer.

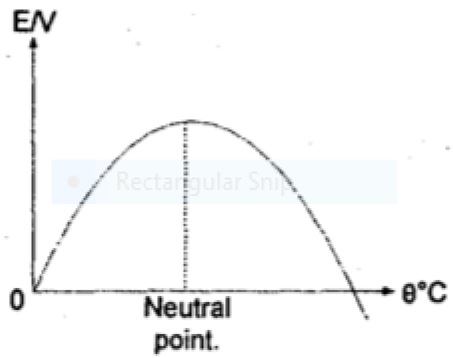


Mode of operation

The test junction is immersed in a steam bath at one atmosphere pressure and thermoelectric e.m.f , E_{100} measured using a potentiometer and recorded. The test junction is then transferred to a system whose temperature, θ is required. The corresponding thermoelectric e.m.f , E_{θ} is measured using a potentiometer and recorded. The unknown temperature θ is then determined from $\theta = \frac{E_{\theta}}{E_{100}} x100^{0}C$. This equation defines the Celsius scale of temperature on the thermocouple thermometer.

Calibration of a thermocouple thermometer.

The e.m.f at the cold junction is always the same and the meter is adjusted to allow for this e.m.f. The hot junction is brought into contact with a hot substance and the reading E on the meter noted. The temperature θ of the test substance is then obtained using a constant volume gas thermometer defined for a Celsius scale and the value of this temperature is noted. The procedure is repeated for different hot substances and for each substance under test, the value of temperature θ in °C and e.m.f E in volts is noted. The results are tabulated and a graph of e.m.f E against temperature θ is plotted. This graph constitutes the calibration curve and is as follows.



If the cold junction is at 0°C, the value of e.m.f E as a function of θ is given by
$E = a\theta + b\theta^2$ Where a and b are constants whose values depend on the type of the two metals used.

Definition of the Celsius scale using a thermocouple thermometer

$$\theta = \frac{E_\theta}{E_{100}} x100^0 C$$

Where E_θ is the e.m.f of the substance at a temperature θ in °C and E_{100} is the e.m.f of the substance at a 100°C.

Advantages of the thermocouple thermometer

-Thermocouple thermometers measure temperature over a wide range. (-200°C to -1600°C)
-Thermocouple thermometers can measure temperature at a point.
-Thermocouple thermometers can be used to measure rapidly changing temperatures.
-Readings of a thermocouple thermometer can be read remotely, stored or fed into a microcomputer.
-Thermocouple thermometer is compact, and easy to construct.

Disadvantages of the thermocouple thermometer

- Each thermocouple requires a separate calibration

- Accuracy depends on the purity of the wires used.

THERMODYNAMIC (KELVIN) SCALE

The scale **uses triple point of water** as its fixed point and **Kelvin** as the S.I unit.

Triple point of water is the temperature and pressure at which pure ice, pure water and saturated water vapour co-exist in equilibrium. The triple point of water is **273.16K**

Steps involved in Setting up the kelvin (thermodynamic) scale

-A suitable thermometric property say Y is identified

-The value Y_{tr} of the thermometric property at the triple point of water is measured using a suitable instrument and then recorded.

-The value Y_{θ} of the thermometric property at the unknown temperature θ of agiven body is then measured using a suitable instrument and then recorded.

-The unknown or required temperature θ of the given body or system is then determined from

$$\theta = \frac{Y_{\theta}}{Y_{tr}} x273.16K$$

Examples.

1. The pressure of a fixed mass of a gas in a constant volume gas thermometer at the triple point of water is $4.2 \times 10^4 Nm^{-2}$. Calculate the thermodynamic temperature when the pressure of the gas is $4.8 \times 10^4 Nm^{-2}$**. [Ans: 312.2K]**

2. The resistance of a wire at the triple point of water is 3.42 Ω. Find the temperature at which the resistance of the wire is 5.64 Ω. **[Ans:450.5K]**

REVISION QUESTIONS

1. The mercury length is 5cm at ice point and 20cm at steam point. What is the temperature if the mercury length is 8cm. **[Ans: 20^0c]**

2.The resistance of a platinum resistance wire is 2.00Ω at the ice point and 2.73Ω at steam point. What temperature on this thermometer corresponds to a resistance of 7.43Ω?
[Ans: 785^0C]

3. A constant mass of a gas at constant pressure has volume of $200cm^3$ at a temperature of pure melting ice and 273.2cm3 at the temperature of boiling water at standard pressure. Calculate the temperature which corresponds to $525.1cm^3$ in the same thermometer.
[Ans: 444.13K]

4. The pressure recorded by a constant volume gas thermometer at Kelvin temperature T is $4.8 \times l0^{-4} Nm^{-2}$. Calculate T if the pressure at triple point of water is $4.24 \times 10^4\ Nm^{-2}$
[Ans: 312.18K]

5. The resistance R_θ of platinum wire at temperature θoC measured on gas scale is given by, $R\theta = Ro = Ro\ (1 + a\theta + b\theta^2)$ where $a = 3.8 \times 10^{-3}$ and $b = -5.6 \times 10^{-7}$.What temperatures will the platinum thermometer indicate when the temperature on the gas scale is 200°C?
[Ans: 197.01^{0}C]

7. The resistance Rθ of platinum wire at temperature θ°C measured on scale of mercury thermometer is given by, $R_\theta = RO\ (1 + a\theta + b\theta^2), where\ a = 4.46\ x\ 10^3\ and\ b = 1.8\ x\ 10^{-6}$ Find the value of the temperature obtained from the thermometer when mercury thermometer reads 430^{o}C. Comment on the two thermometers. **[Ans: 450^{0}C]**

8. The volume V_θ of a fixed mass of mercury at temperature θ°C measured on a perfect gas scale is given by, $V_\theta = V\ (1 + a\theta + b\theta^2).where\ a = 1.818\ x\ 10^{-4} and = 0.8\ x\ 10^{-8}$ Calculate the temperature expected on the mercury thermometer when the temperature on the gas scale is 40°C.

9. A resistance R_θ of a platinum resistance thermometer is given by $R_\theta = R_0(1+ a\theta + b\theta^2)$ where $a = 1.3 \times 10^{-2} K^{-1}$, $b = 1.33 \times 10^{-6} K^{-1}$ R_0 is the resistance at 0°C. Calculate the temperature of the thermometer when the temperature on the constant volume gas thermometer is 400°C.