Temperature Measurement

Temperature Measuring Devices

Glass Thermometers:

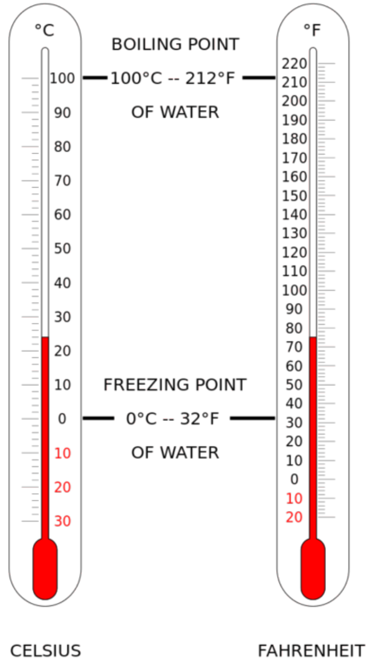
Work on principle of expansion of liquids like mercury, alcohol, pentane and other organic liquids. Eg. Mercury in glass thermometer.

Pressure Gauge Thermometers:

Produce a pressure output on account of vapours or liquids which work as actuating liquids.

Differential Expansion Thermometers:

Output due to differential expansion of two dissimilar metals produced by the temperature.



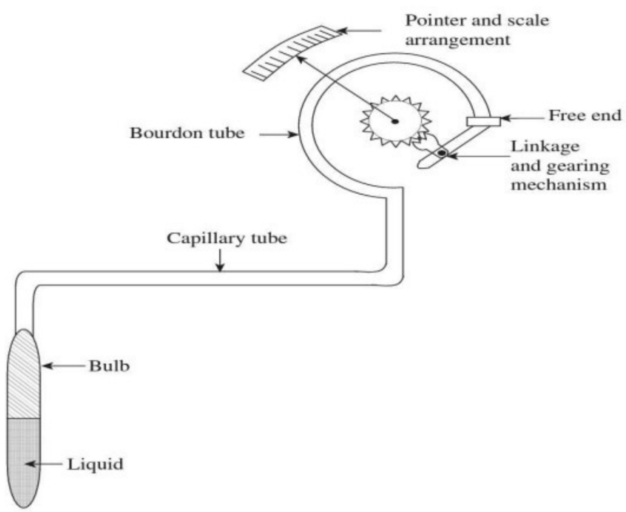
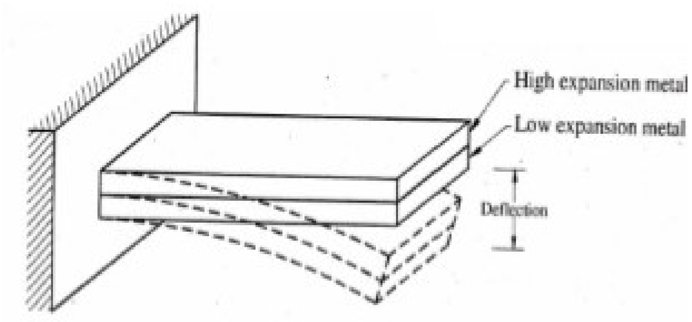


Fig. 15.11 Pressure thermometer



Temperature Measuring Devices

Electrical Resistance Thermometers:

Temperature is indicated by change in resistance.

Thermocouples:

Temperature is indicated by production of an EMF.

Optical Pyrometers:

Temperature is determined by matching the luminosity of the radiation of the hot body with that of the calibrated source.

Radiation Pyrometers:

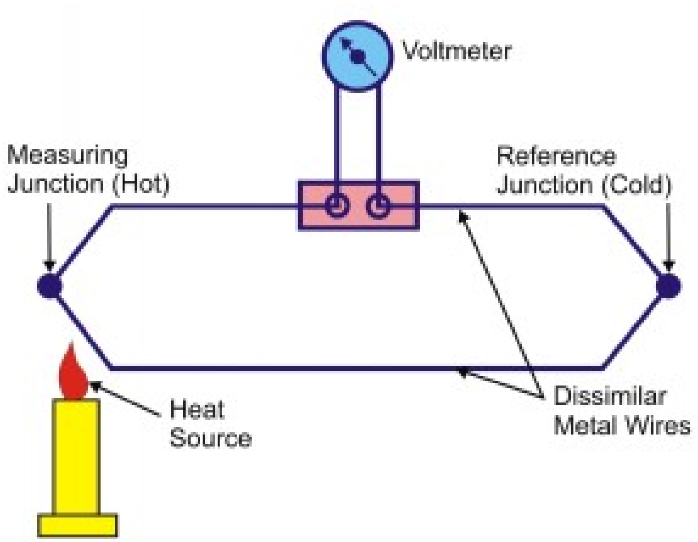
Estimated by absorbing radiation of all wavelengths upon a small body and determining the temperature of the source from the temperature attained by absorber.

Thermocouple

What are thermocouples?

Principle: A circuit made by connecting two dissimilar metals produces a measurable voltage when a temperature gradient is imposed between one end and the other.

- When two different metals are joined together, two junctions are formed and there exists a flow of current when these junctions are kept at different temperature.
- This current can be converted into potential difference whose magnitude is proportional to the difference of temperature.
- **Active Transducers**



Eth is proportional to difference in temp.

$$Eth = S_{th}\,(T(hot) - T(cold))$$

Where,

S_{th} = Seebeck Coefficient or sensitivity of thermocouple

What are thermocouples?

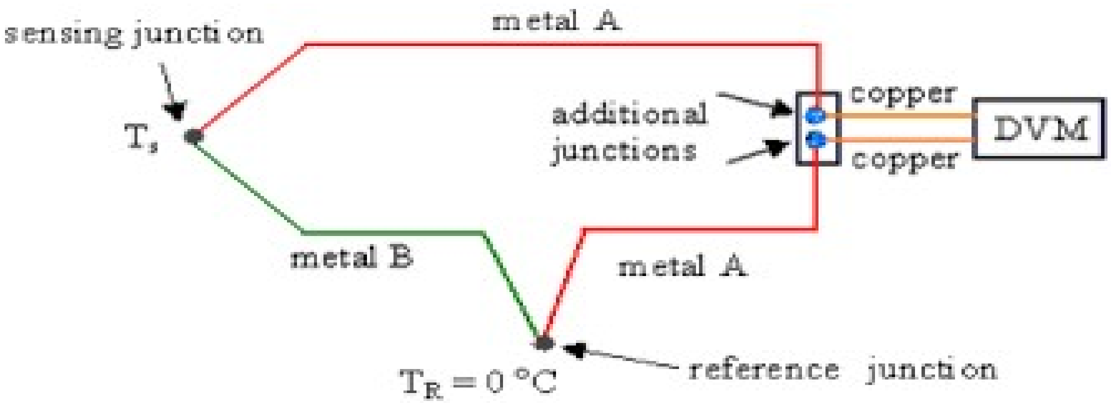
Seebeck effect:

- When two unlike metals are joined together at two junctions, an emf is generated at the two junctions
- The amount of emf generated is different for different combinations of the metals

Peltier effect:

- When two unlike metals are joined together to form two junctions, the potential axis within the circuit due to temperature gradient is along the entire length of the conductors within the circuit

Connection



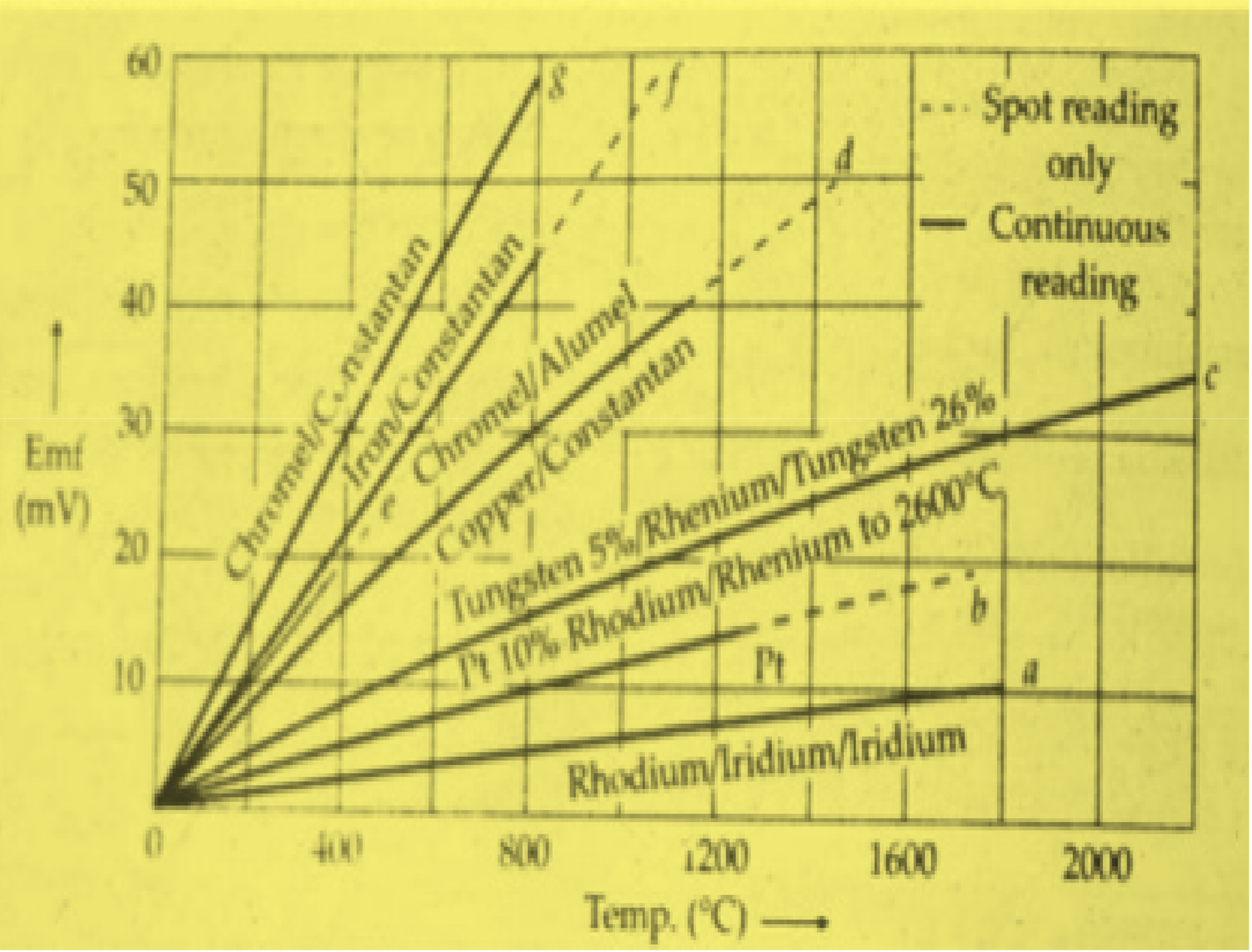
sensing junction
metal A
T_s
additional
junctions
copper
copper
DVM
metal B
metal A
$T_R = 0\ °C$
reference junction

Thermocouples Principle of Operation

Generally, a second order equation is used.

$$E = \alpha(T - T_o) + \beta(T - T_o)^2$$

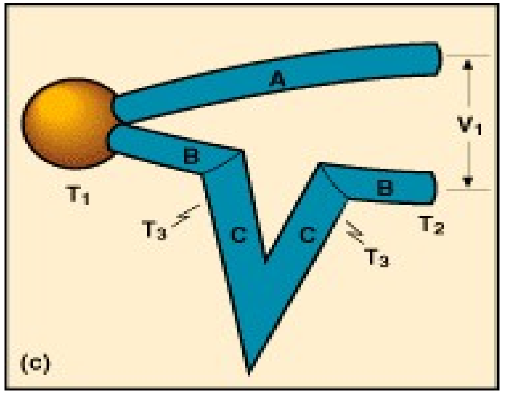
Temperature-EMF Curve



Type	Positive lead	Negative lead	Temperature range	Temperature coeff.variation µv/°C	Most linear range and sensitivity in the range
R	Platinum-Rhodium (87% Pt, 13% Rh)	Platinum	0-1500°C	5.25-14.1	1100-1500°C 13.6-14.1 µv/°C
S	Platinum-Rhodium (90% Pt, 10% Rh)	Platinum	0-1500°C	5.4-12.2	1100-1500 °C 13.6-14.1 µv/°C
K	Chromel (90%Ni, 10% Cr)	Alumel ($Ni_{94}Al_2$ Mn_3Si)	-200-1300°C	15.2-42.6	0-1000 °C 38-42.9 µv/°C
E	Chromel	Constantan (57%Cu, 43%Ni)	-200-1000°C	25.1-80.8	300-800 °C 77.9-80.8 µv/°C
T	Copper	Constantan	-200-350°C	15.8-61.8	nonlinear
J	Iron	Constantan	-150-750°C	21.8-64.6	100-500 °C 54.4-55.9

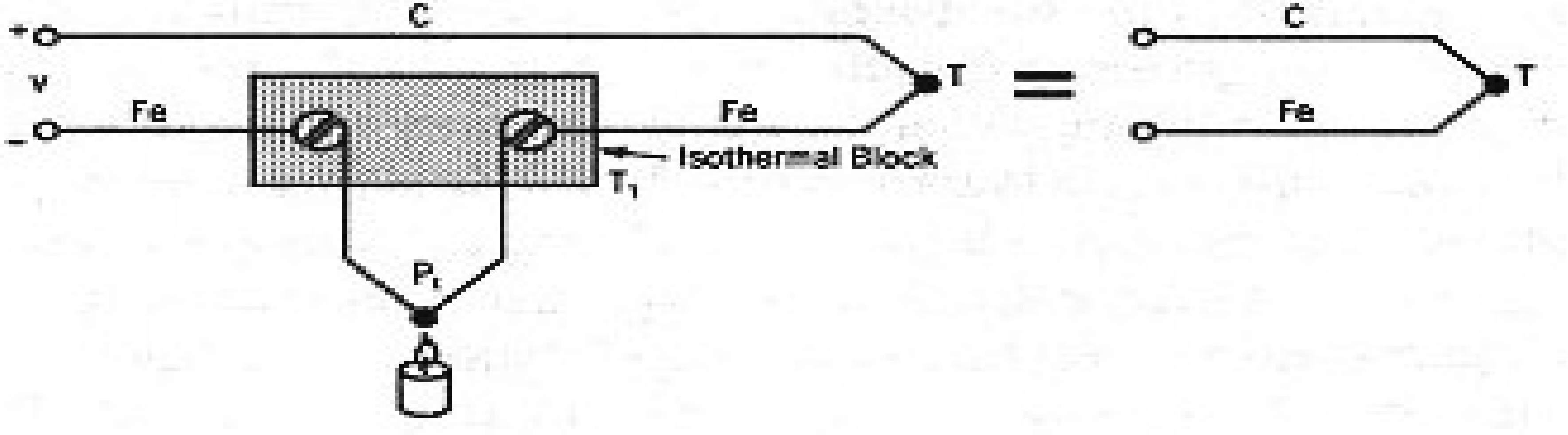
Law of Intermediate Metals

- Insertion of an intermediate metal into a thermocouple circuit will not affect the EMF voltage output so long as the two junctions are at the same temperature and the material is homogeneous.



- **Use: To add wires for data transmission**

- **Permits soldered and welded joints.**

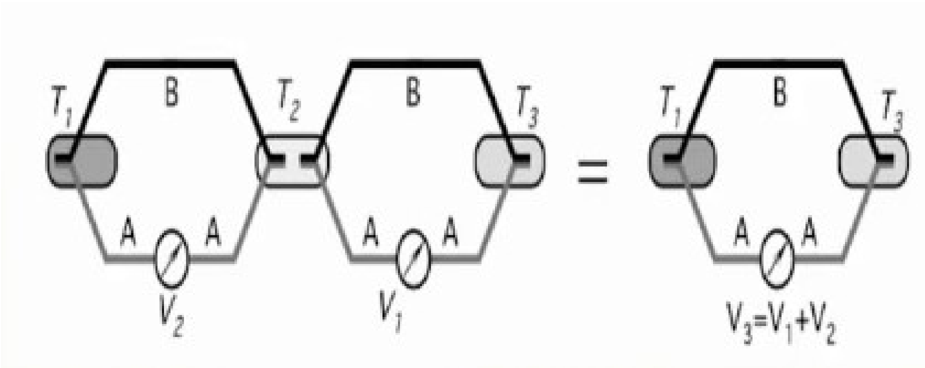


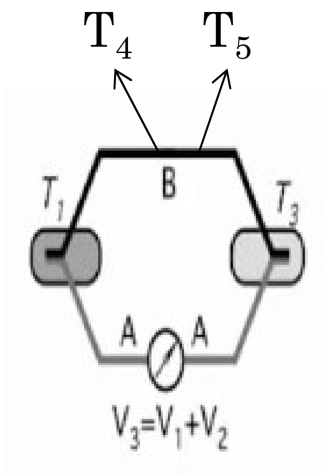
Law of Intermediate Temperatures

If a thermocouple circuit develops a net $emf_{1\text{-}2}$ for measuring Junction temperatures T_1 and T_2, and a net $emf_{2\text{-}3}$ for temperatures T_2 and T_3, then it will develop a net voltage of

$$\mathbf{emf_{1\text{-}3} = emf_{1\text{-}2} + emf_{2\text{-}3}}$$

when junctions are at temperatures T_1 and T_3.

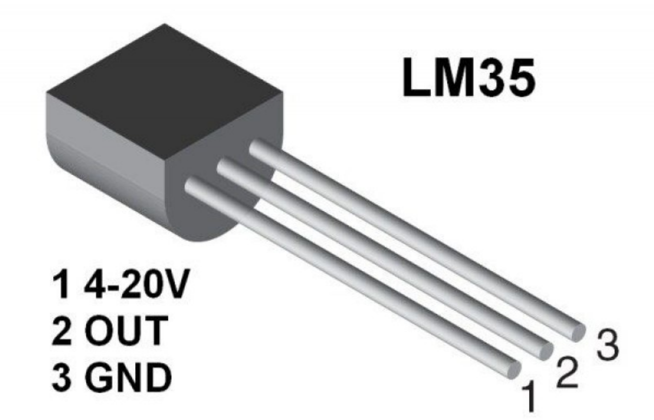


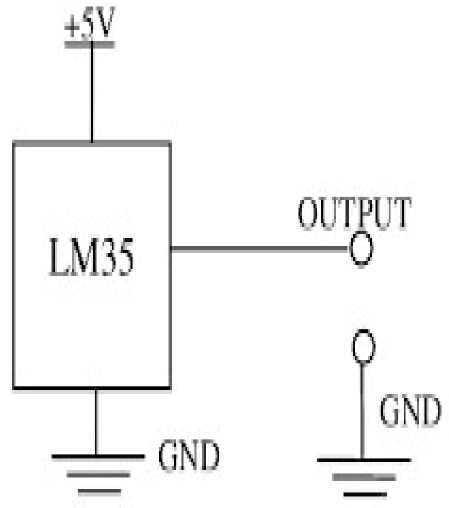


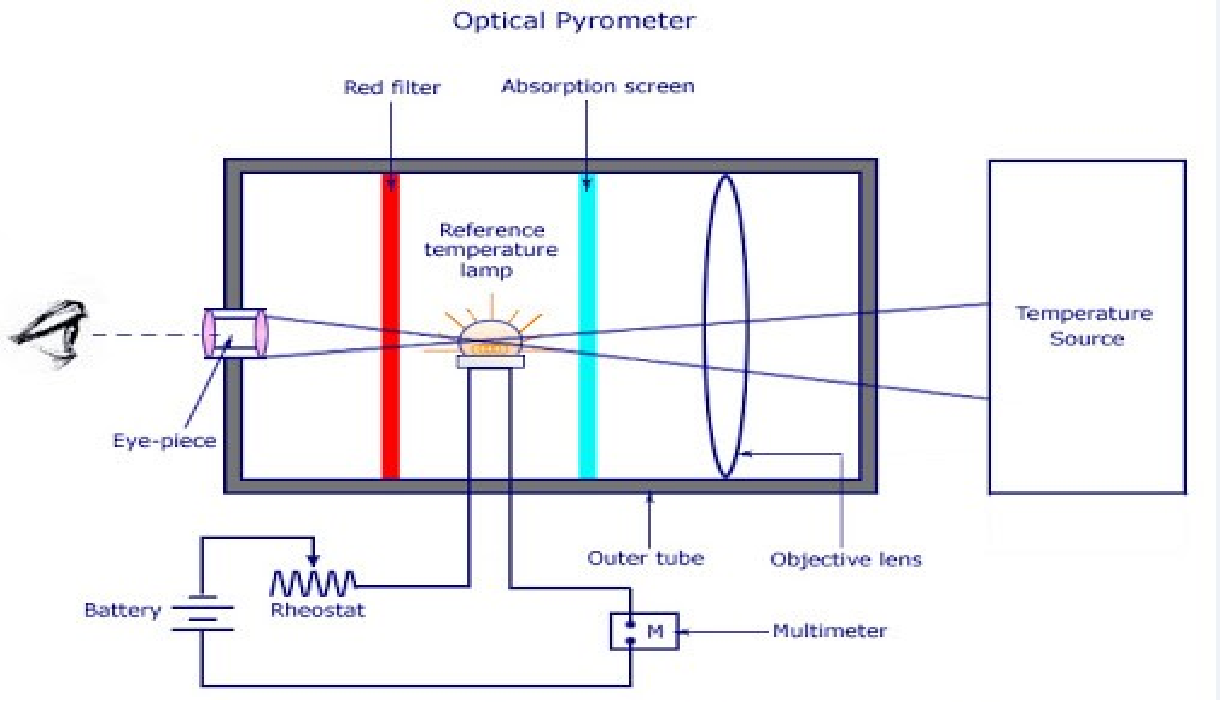
Thermo emf generated at the junction is not affected by different temperature along the metal conductors

Temperature Sensor: LM35 Temperature Sensor with Analog Output

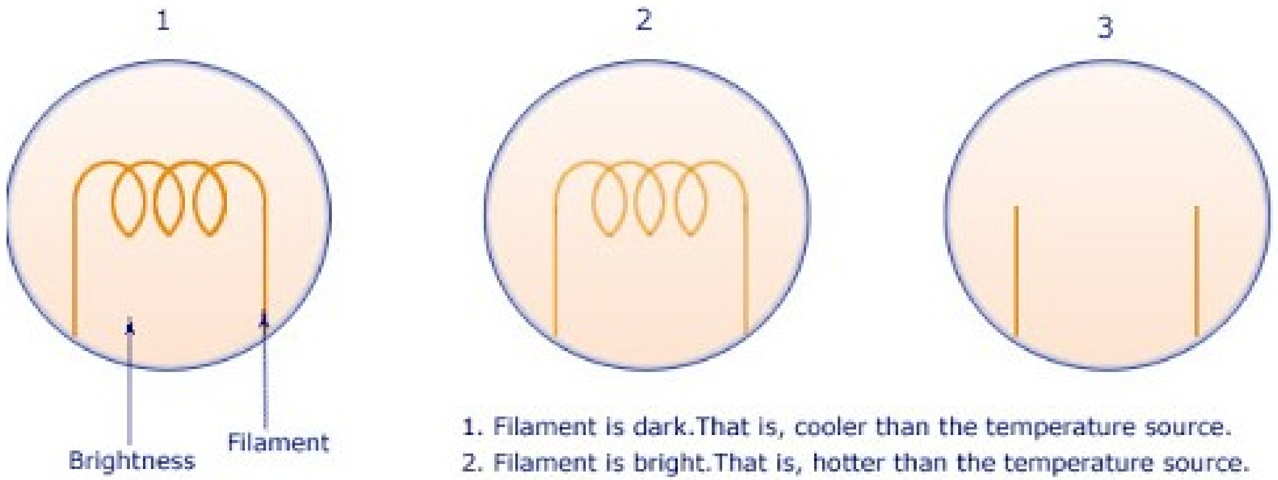
- **LM35** is an integrated analog temperature **sensor** whose electrical output is proportional to Degree Centigrade.
- Measures temperature between -55 to 150 degree C







Optical Pyrometer - Temperature Measurement



1. Filament is dark.That is, cooler than the temperature source.
2. Filament is bright.That is, hotter than the temperature source.
3. Filament disappears.Thus, equal brightness between filament and temperature source.

Precision Temperature Sensors

- More accurate than thermocouple elements
- Maintain accuracy over longer period of time
- Range up to 1200°F (650°C)

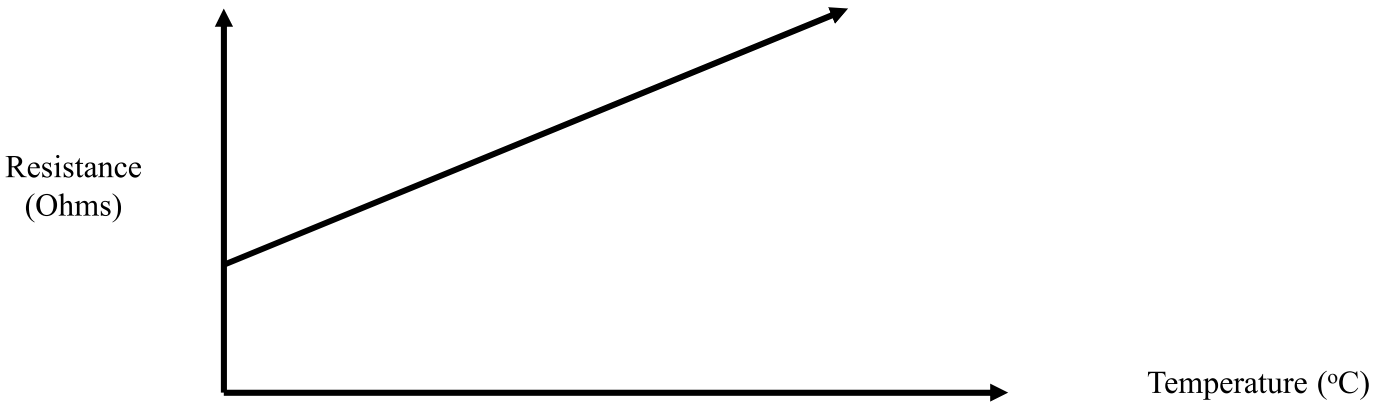
Styles

- Wire-Wound
- Thin film

Resistance Temperature Devices (RTD)

RTD's resistance ↑ as temp ↑

- Controller measures resistance value and converts to temp. reading, fairly linear relationship.
- Unlike thermocouple, no electrical signal generated
- Controller measures resistance by passing current through RTD



RTD Resistance Vs. Temp. Curve

Resistance Temperature Devices (RTD)

- The resistance of a conductor changes when its temperature is changed.
- The variation of resistance R with temperature T(deg/K) can be represented as

$$R = R_0(1 + \alpha_1 T + \alpha_2 T^2 + \ldots + \alpha_n T^n + \cdots)$$

Where,

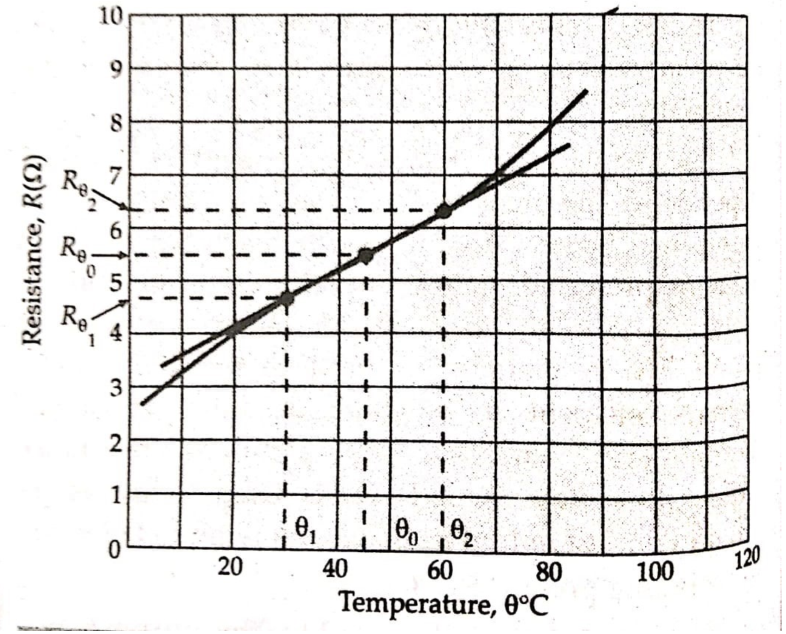
R_0 = Resistance at temperature T=0

$\alpha_1, \alpha_2, \alpha_n$ = Constants

RTD: Linear Approximation

- To develop an equation which approximates resistance versus temperature curve

- A straight line is drawn between the points of the curve which represent θ_1°C and θ_2°C with θ_0°C representing the mid point temperature θ °C



$$R_\theta = R_{\theta_0}(1 + \alpha_{\theta_0}\Delta\theta)$$

RTD: Requirements of conductor to be RTD

- The Change in resistance of material per unit change in temperature should be large

- The material should have high value of resistivity

- The resistance of materials should have a continuous and stable relationship with temperature

- The most common RTDs are made of either platinum, nickel or nickel alloys

RTD: Requirements of conductor to be RTD

Metal	Resistance temperature Co-efficient / °C	Temperature range °C		Melting point °C
		Min	Max	
Platinum	0.39	−260	110	1773
Copper	0.39	0	180	1083
Nickel	0.62	−220	300	1435
Tungsten	0.45	−200	1000	3370