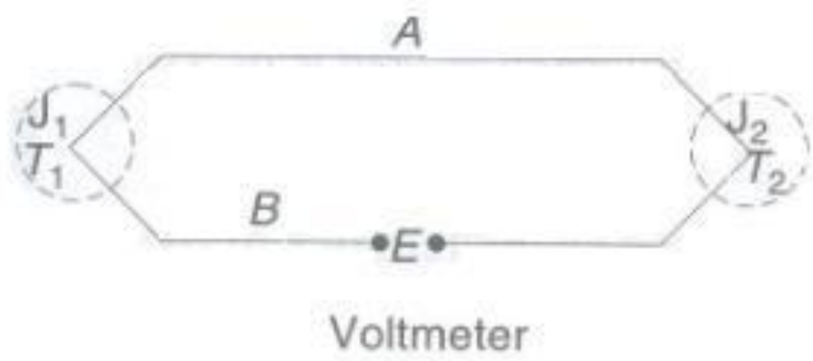
Thermo-electric Sensors (Thermocouple)

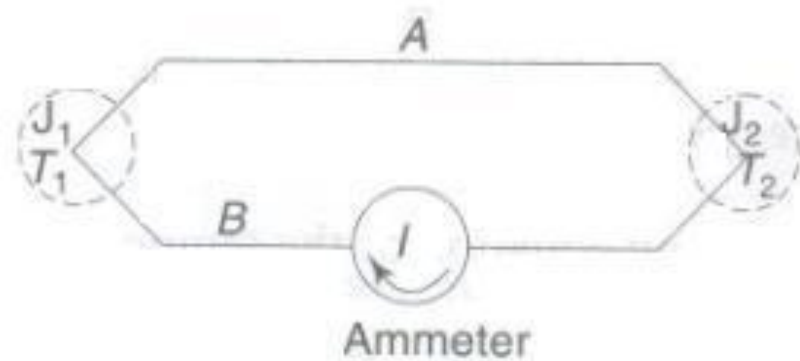
- Thermocouple is a temperature transducer that develops an emf which is a function of temperature between hot junction and cold junction.
- Consists of two wires of different metals twisted and brazed or welded together with each wire covered with insulation of

  – mineral (MgO) insulation for normal duty.

  - ceramic insulation for heavy duty.
- Basic principle of thermocouple was discovered by Seebeck in1821.
- When two conductors of dissimilar metals, say A &B, are joined together to form a loop (thermocouple) and two unequal temperatures T_1 & T_2 are interposed at two junctions J_1 & J_2 resp. then an infinite resistance voltmeter detects the electromotive force E, or if a low resistance ammeter is connected, a current flow I is measured.

- <u>Seebeck Effect</u> – the overall relation between emf E and Temperatures T_1 and T_2 forms the basis for thermoelectric measurements.



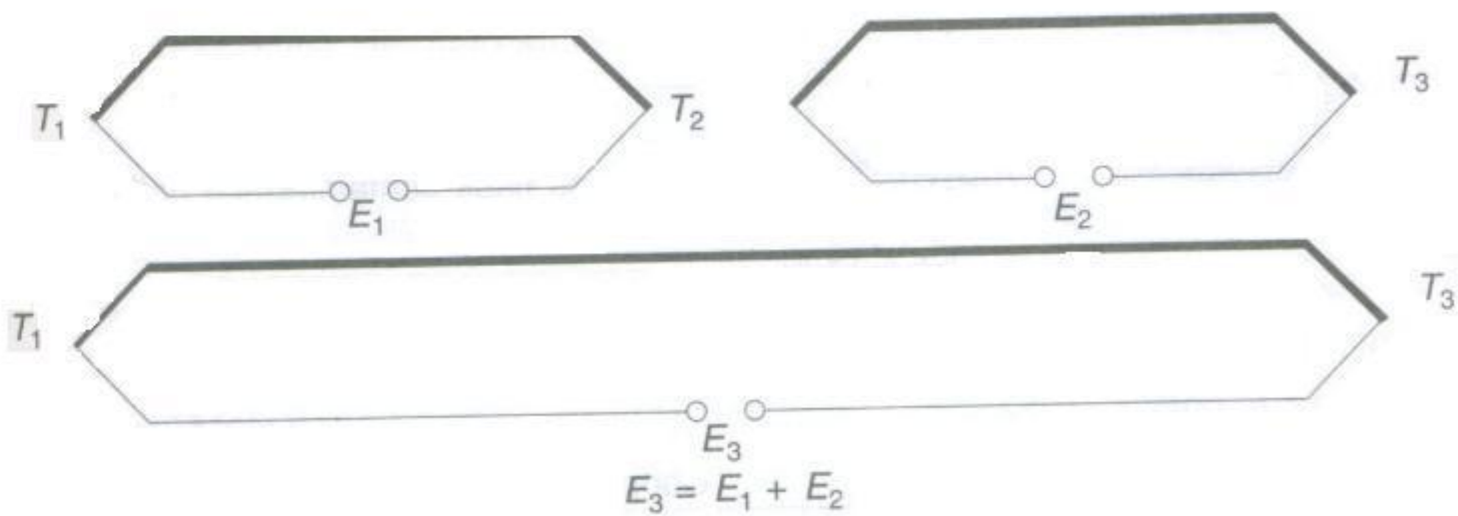


- For convenience & standardization, one of the two junctions is usually maintained at some known temperature (usually ice point) and measured emf then indicates temperature difference relative to reference temperature.

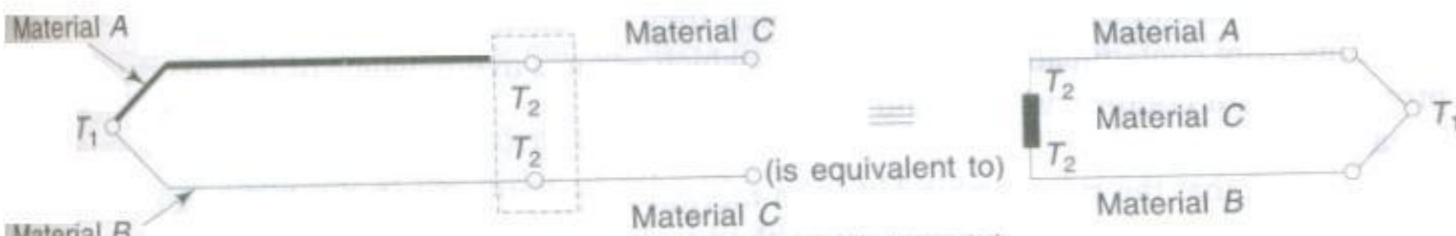
- Peltier effect – Temperatures T_1 & T_2 of junctions J_1 & J_2 are slightly altered if thermoelectric current is allowed to flow in the circuit.
- Heat is generated at cold junction and is absorbed from the hot junction thereby heating cold junction slightly and cooling the hot junction slightly. This phenomenon is termed as Peltier effect.
- This effect is avoided if no current flows, i.e. by measuring voltage with potentiometer.

- Thomson effect - The junction emf may be slightly altered if a temperature gradient exists along either or both the materials. This is known as Thomson effect.

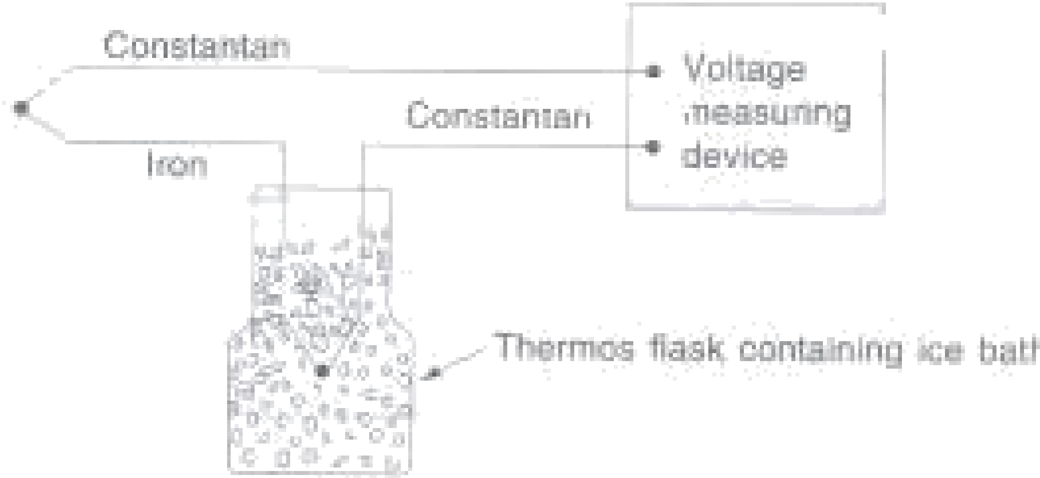
- <u>Law of Intermediate Temperatures-</u> This states that the emf generated in a thermocouple with junctions at temperatures T_1 & T_3 is equal to the sum of the emf's generated by similar thermocouples, one acting between temperatures T_1 & T_2 and other between T_2 & T_3 when T_2 lies between T_1 & T_2 .



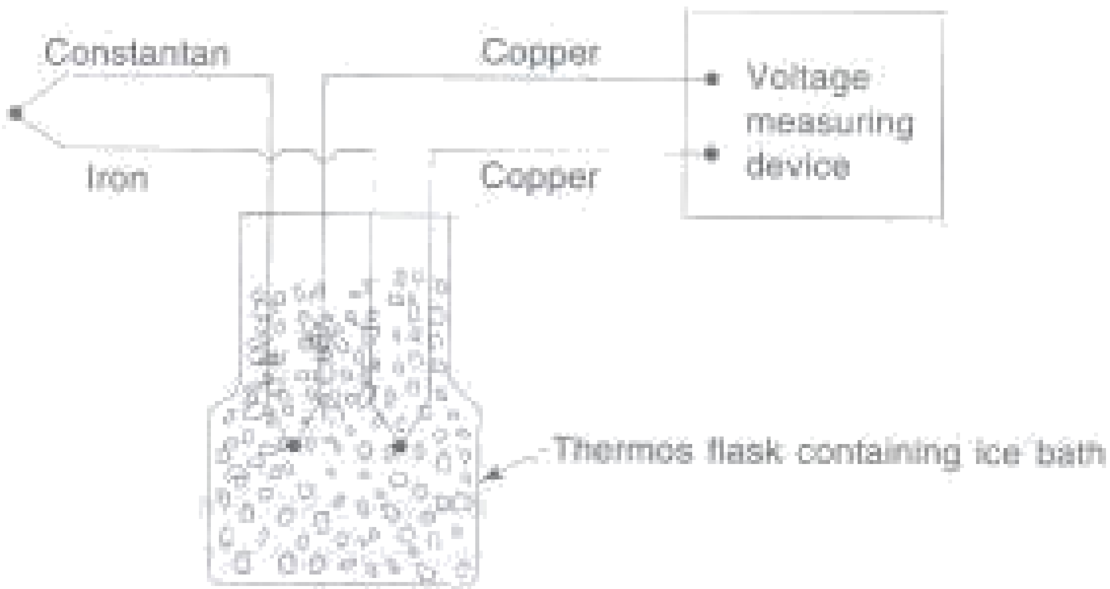
- <u>Law of Intermediate Metals</u> – If third wire is introduced in thermocouple, then three junctions are formed. And the emf generated remains unaltered if the two new junctions B-C and C-A are at the same temperature.
- Used when distance between instrument & reference junction is large.
- Maximum accuracy is obtained when leads are of same material as thermocouple element.



(b) A thermocouple with intermediate metal



(a) A thermocouple without extension leads



(b) Conventional method of establishing reference function temperature with copper extension leads

Thermocouple Materials:

Choice depends on

1. Ability to withstand temp. at which they are used
2. Immunity from contamination/oxidation, etc. which ensures maintenance of precise thermo-electric properties with continuous use.
3. Linearity characteristics.

S.No.	Type	Thermocouples material*	Approximate sensitivity in (μV/°C)	Useful temperature range (°C)	Approximate accuracy (%)
1.	T	Copper–Constantan	20 – 60	–180 to +400	± 0.75
2.	J	Iron–Constantan	45 – 55	–180 to +850	± 0.75
3.	K	Chromel–Alumel	40 – 55	–200 to +1300	± 0.75
4.	E	Cheromel–Constantan	55 – 80	–180 to +850	± 0.5
5.	S	Platinum–Platinum/10% Rhodium	5 – 12	0 to +1400	± 0.25
6.	R	Platinum–Platinum/13% Rhodium	5 – 12	0 to +1600	± 0.25
7.	B	Platinum/30% Rhodium–Platinum/6% Rhodium	5 – 12	+100 to +1800	± 0.25
8.	W5	Tungston/5% Rhenium–Tungston/20% Rhenium	5 – 12	0 to +3000	± 0.15

*Constantan = copper/nickel; chromel = nickel/chromium; alumel = nickel/aluminium

- Relation between thermoelectric emf & temp. is approximately parabolic. $E = aT + bT^2$

- Thermocouple can be broadly classified in two categories.

1. Base-metal thermocouple – Uses combination of pure metals & alloys of iron, copper, nickel to measure temp. upto 1450 K.
2. Rare-metal thermocouple – Uses combination of pure metals & alloys of platinum (upto 1600 ^{0}C) & tungsten, rhodium, molybdenum (upto 3000 ^{0}C)

- For high sensitivity thermocouples are attached in series. Output is sum of voltages of all thermocouples. This is known as Thermopile.

- When connected parallel output will be numerical average of all output voltages.

Advantages of Thermocouple Sensors:

- Dynamic response is fairly good.
- Less maintenance cost.
- Rugged type – withstand rough handling.
- Wide temp. range from -200 to 3000 ^{0}C.
- Output signal is electrical.
- Output emf is independent of length or diameter of wire.
- Good accuracy of the order of + 0.2 to + 0.75 % of f.s.d.
- Excellent stability for a long period of time.
- Can be conveniently mounted in a variety of temperature measurement situations.

Limitations of Thermocouple Sensors:

- Homogeneity of composition of thermocouple material & cold working of wires affect sensitivity of thermocouple.
- Require insulation covering while using them in conducting fluids.
- Output signal, emf requires amplification.