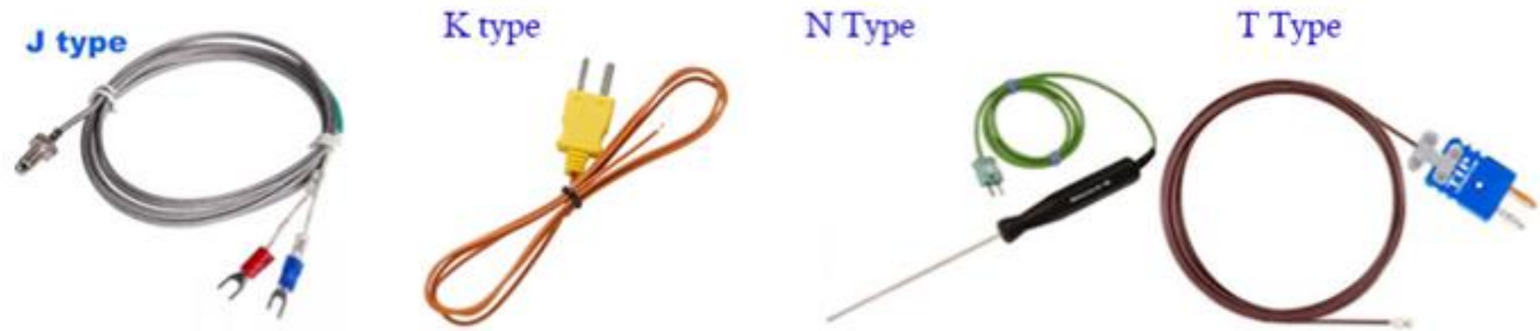
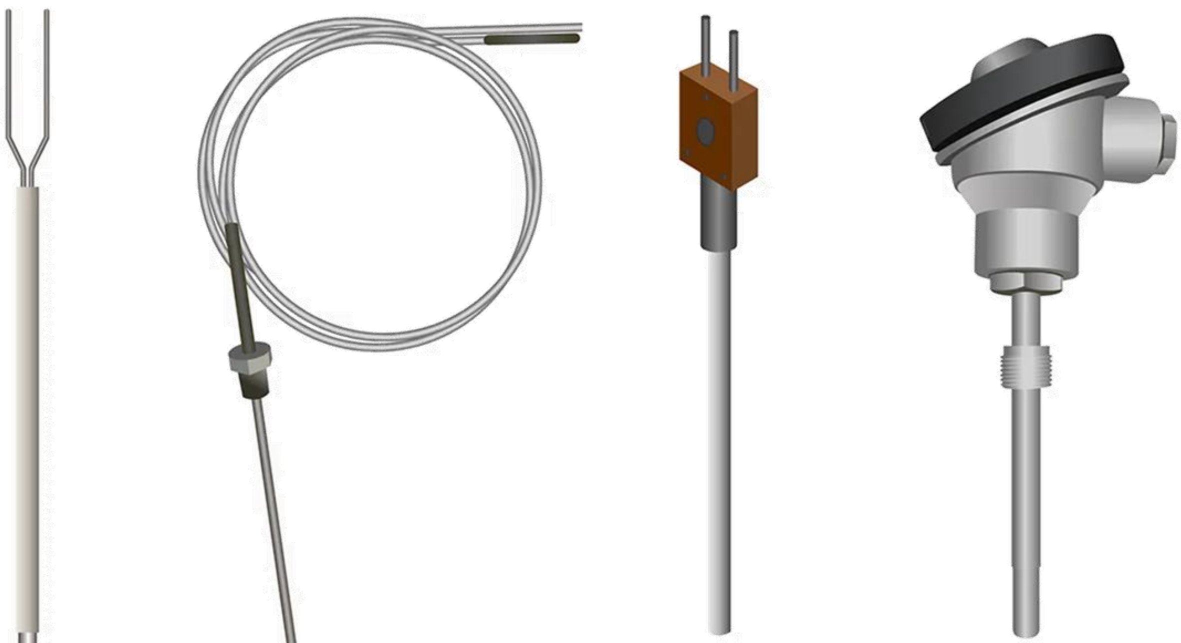
# THERMOCOUPLE

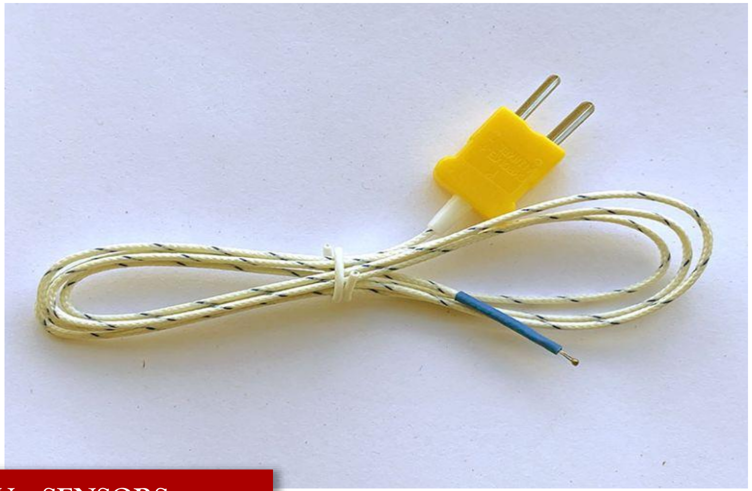


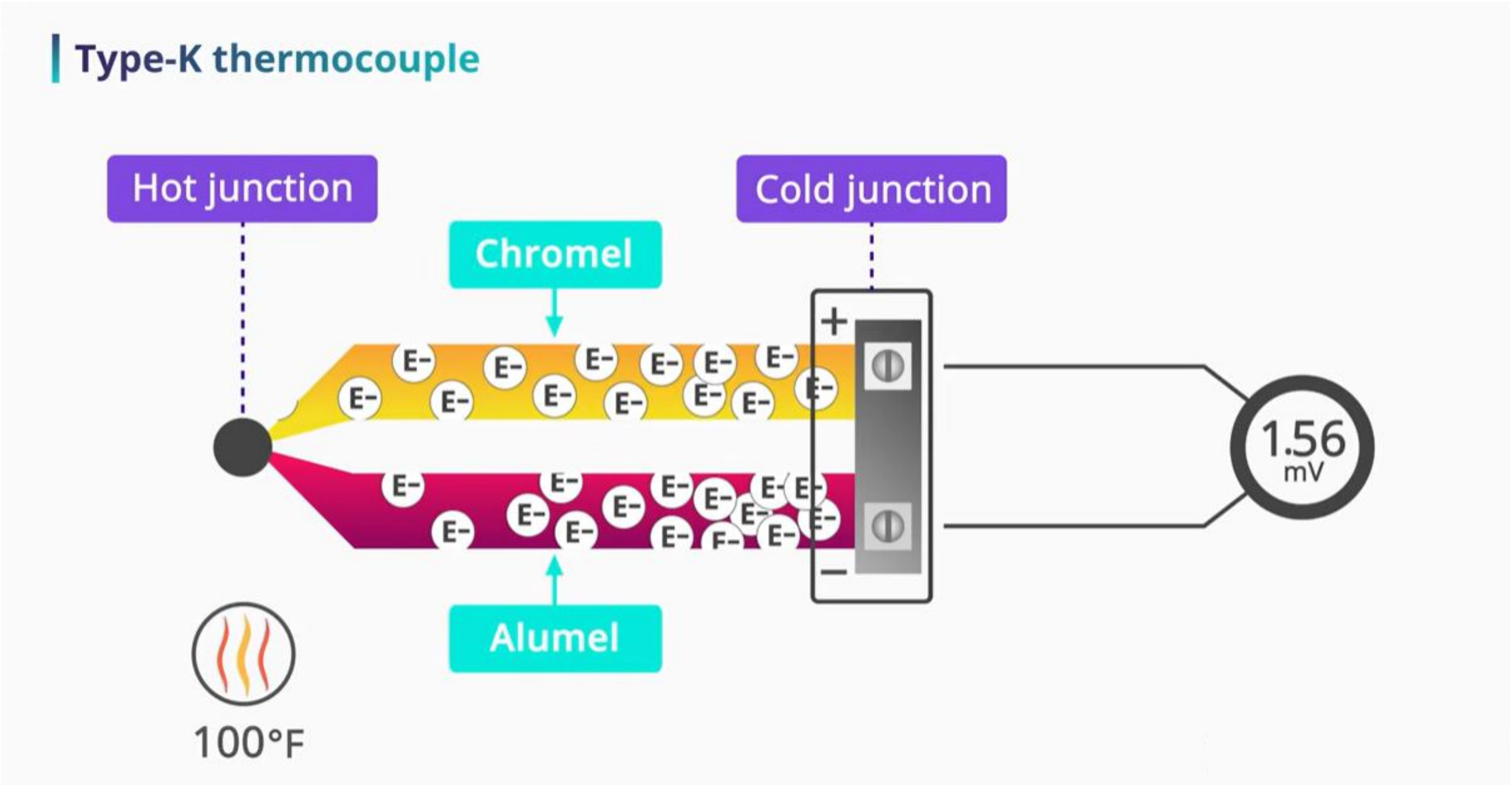



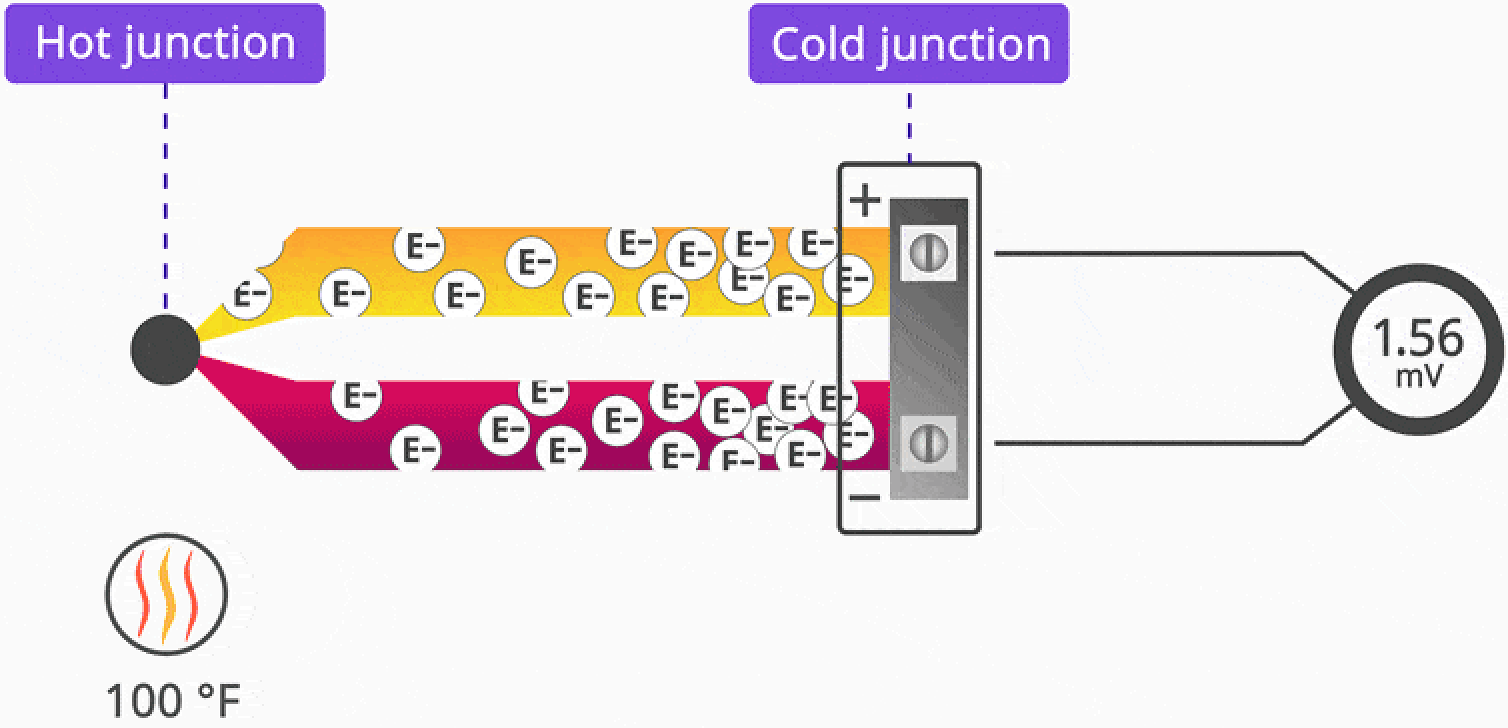
# Thermocouple

also called as thermal junction,
thermoelectric thermometer ,
thermal temperature-measuring device

**Thermocouples** are a widely used type of temperature sensor and can also be used as a means to convert thermal potential difference into electric potential difference.



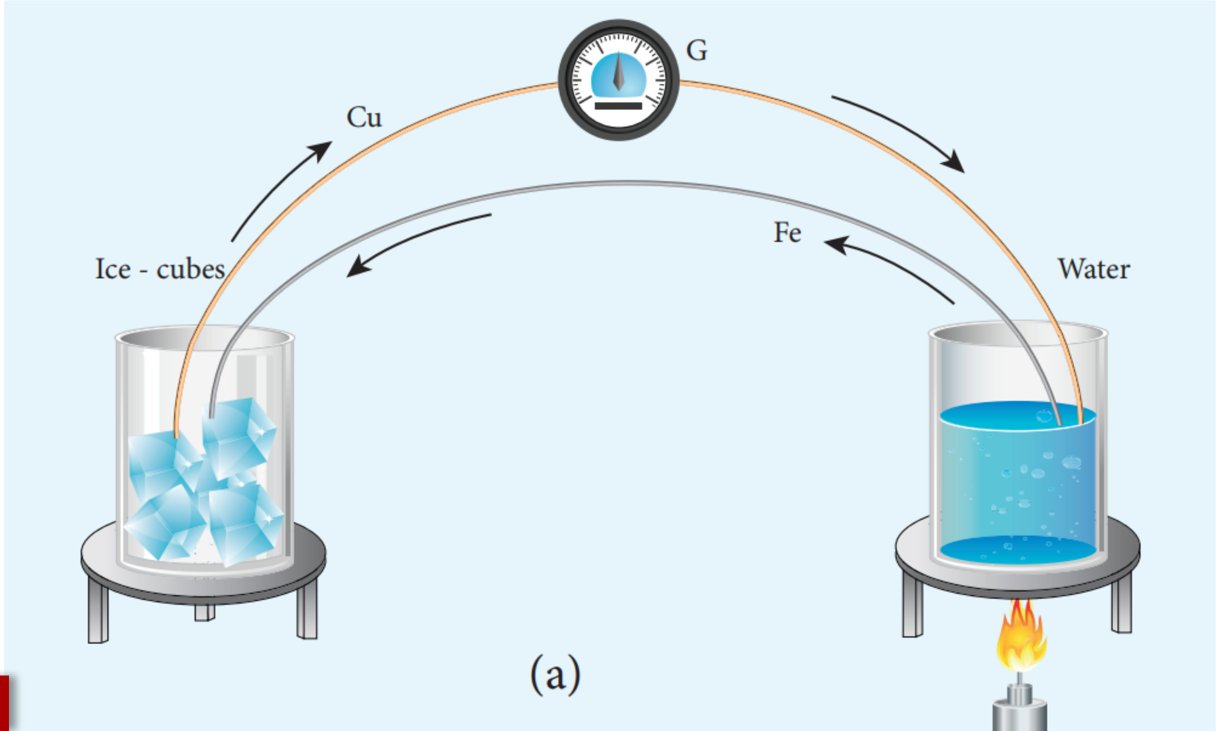

Type-K thermocouple
Hot junction
Cold junction
Chromel
Alumel
+
−
1.56
mV
100°F


Hot junction
Cold junction
+
−
1.56
mV
100 °F

# Working Principle

In 1821,the German-Estonian Physicist Thomas Johann Seebeck discovered it

- Two wires of different metals joined at two junctions
- One junction is placed where the temperature is to be measured
- The other is kept at a constant lower temperature.

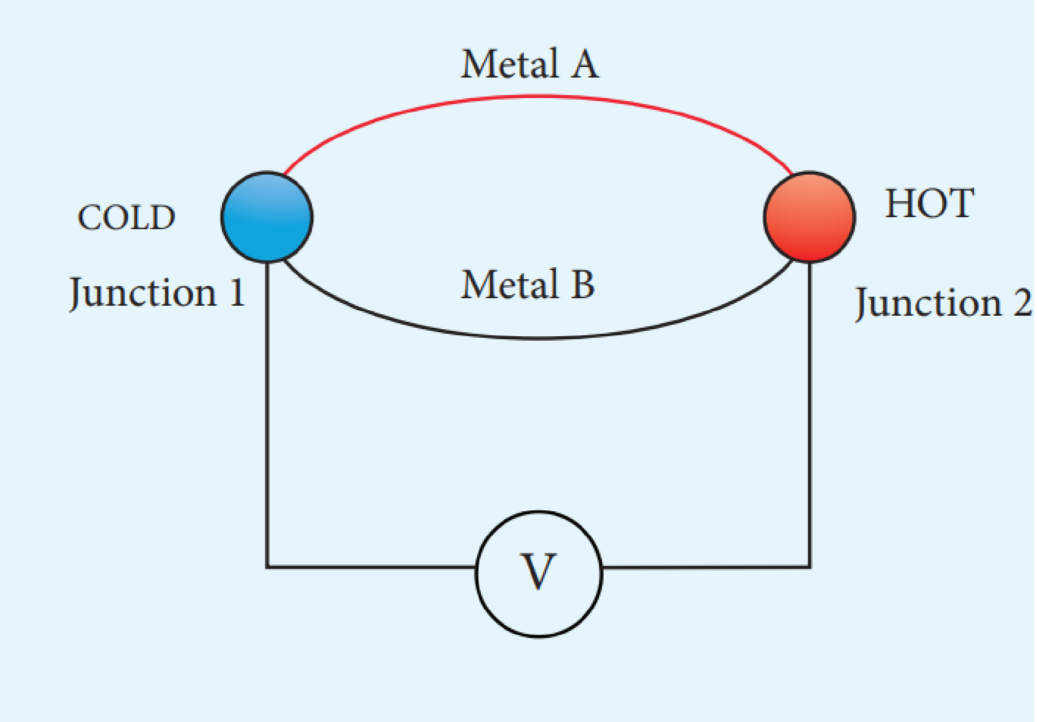


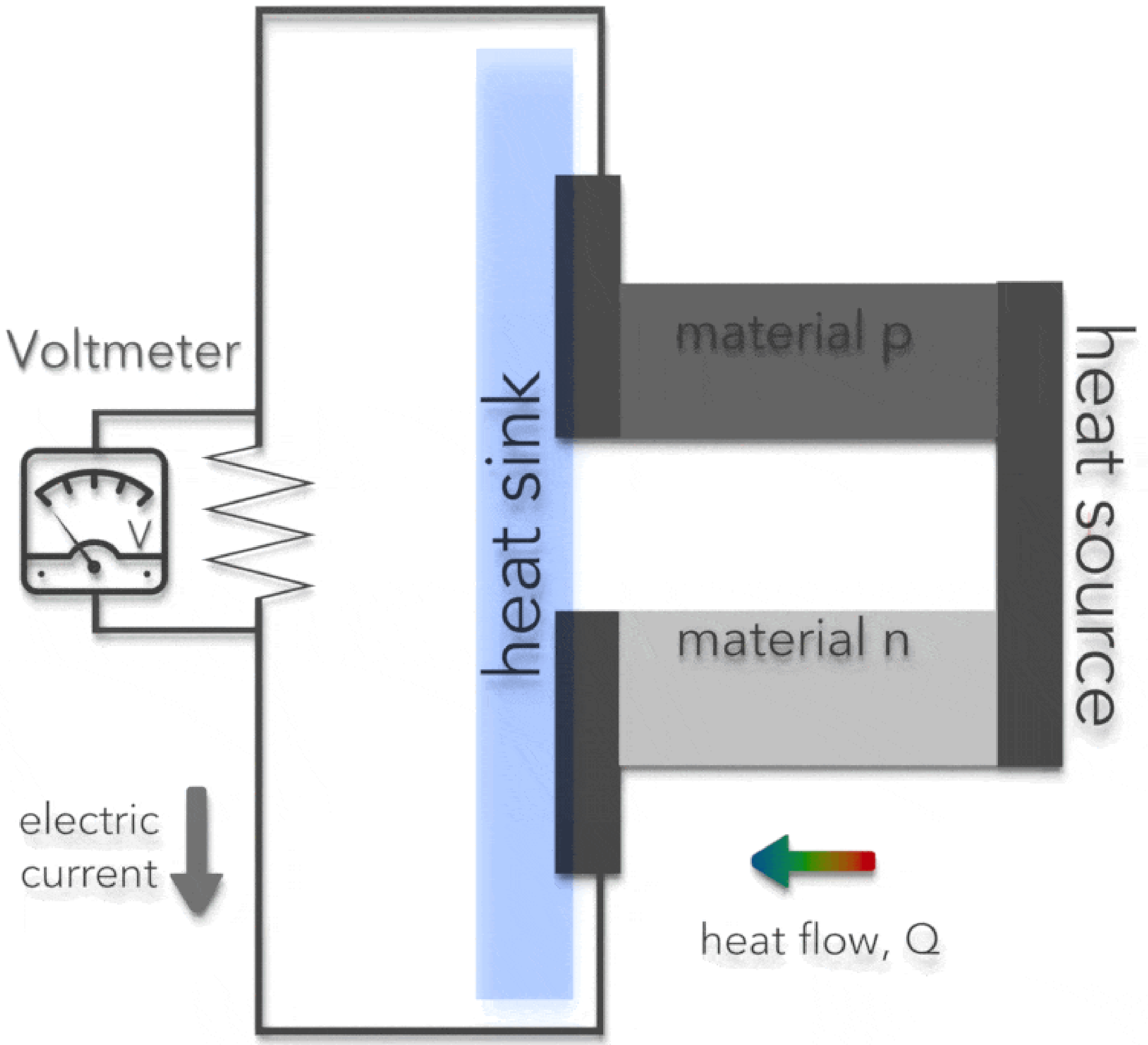

(a)

# Working Principle

A measuring instrument is connected in the circuit

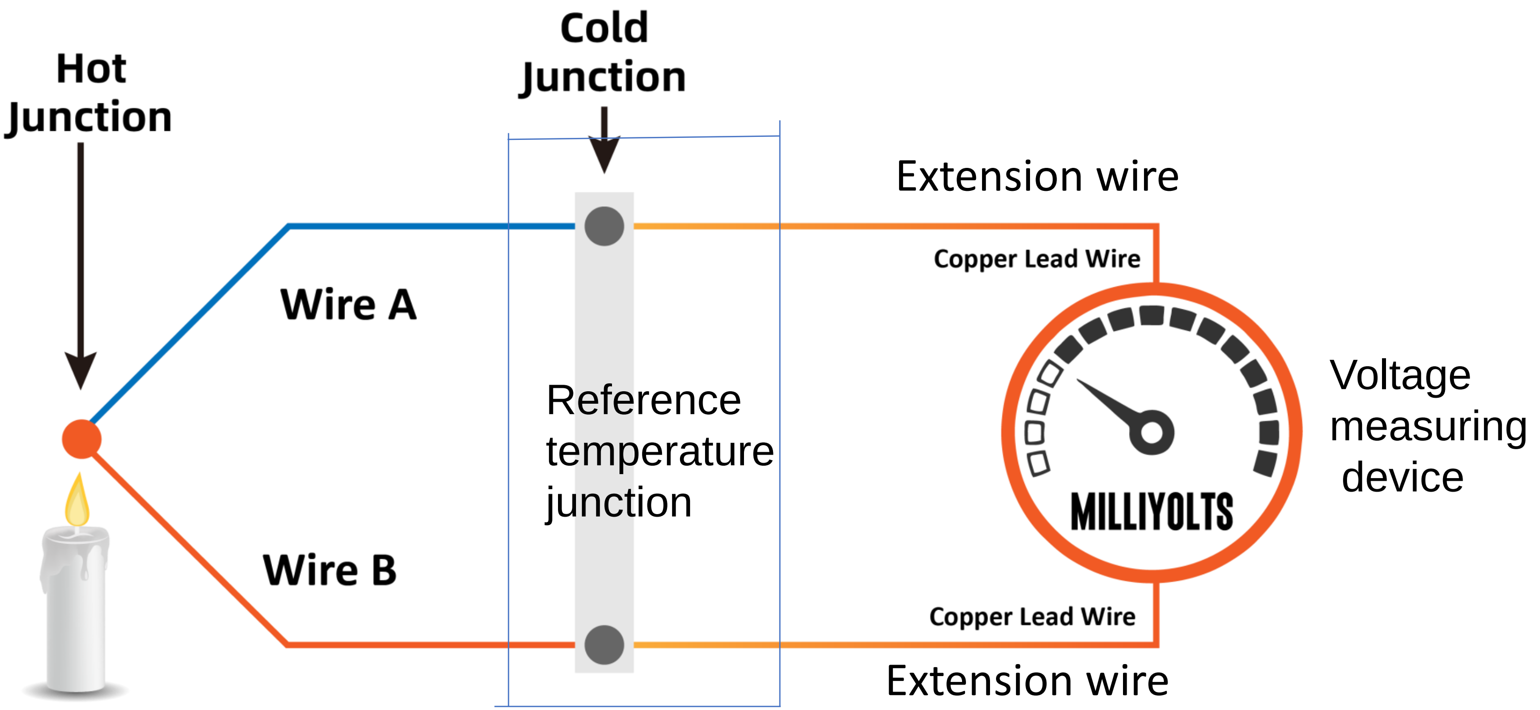
- The temperature difference causes the development of an electromotive force (known as the Seebeck effect)
- That is approximately proportional to the difference between the temperatures of the two junctions.




Voltmeter
V
heat sink
material p
material n
heat source
electric
current
heat flow, Q

# Basic Thermocouple circuit

Extension wires are used when measuring device is placed far away
Extension wires are made with same material of thermocouple element

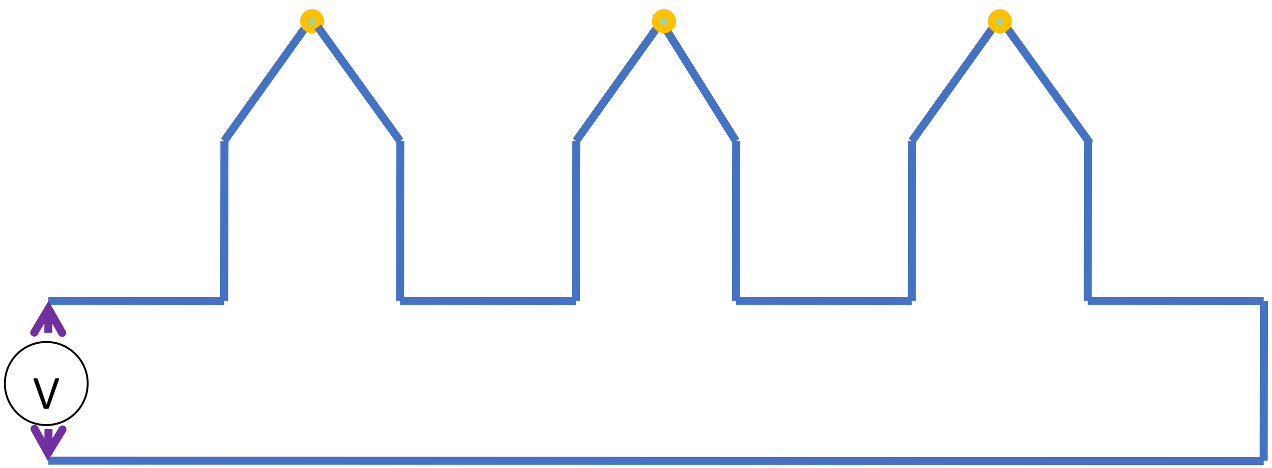


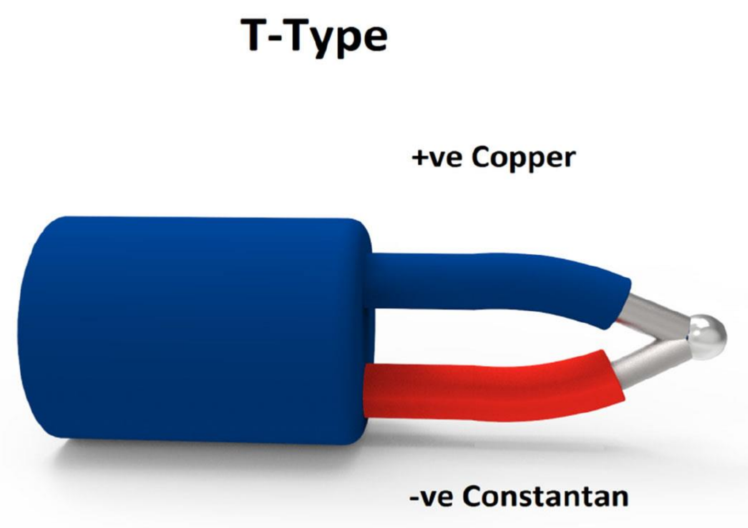

Thermocouple junctions are made by soldering or welding without lux
Thermocouple junctions are protected by enclosing them in Protective sheath

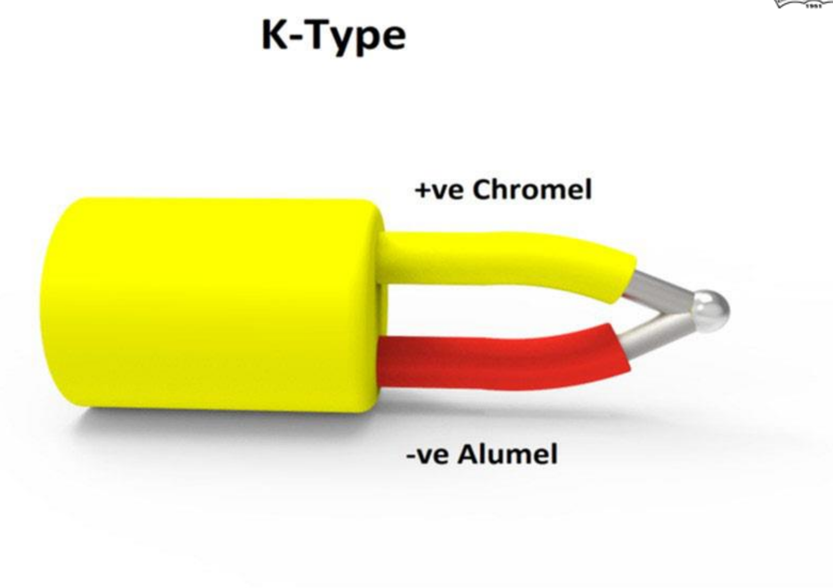
# Basic Thermocouple circuit

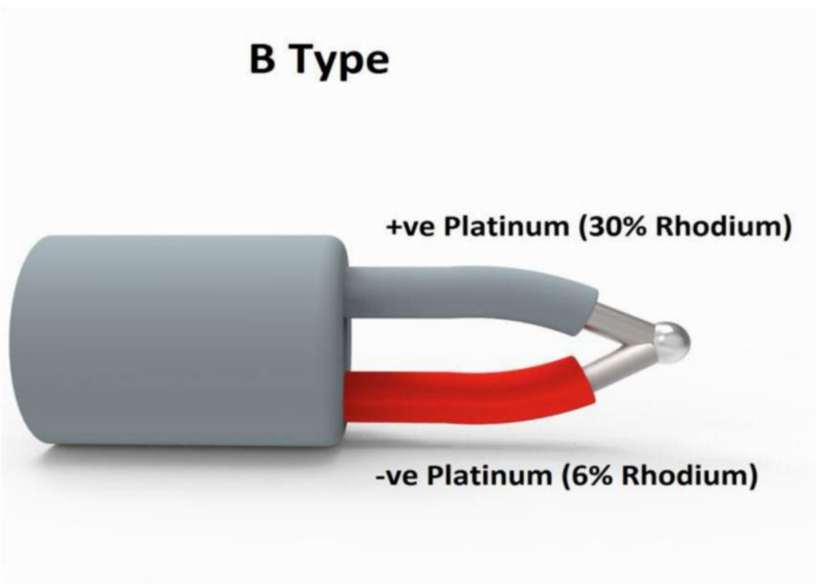
- For achieving high sensitivity several Thermocouples may be connected in series

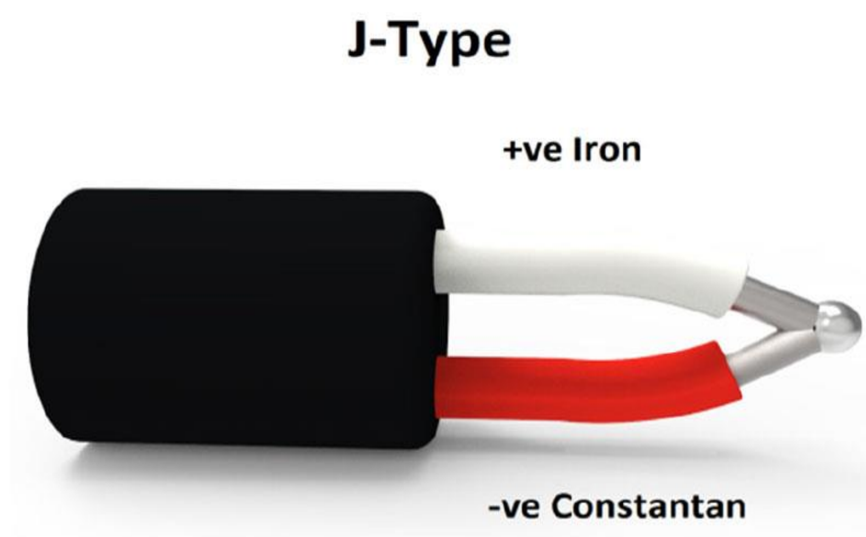
- A series of thermocouples connected together is called a Thermopile



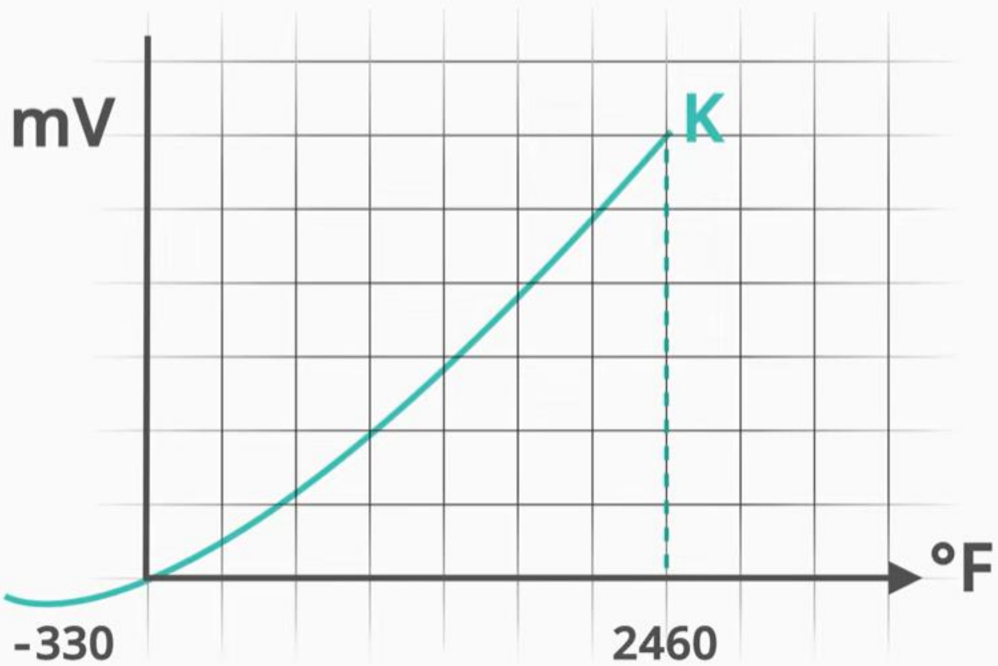

T-Type
+ve Copper
-ve Constantan

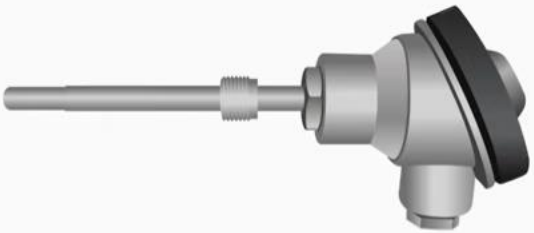

K-Type
+ve Chromel
-ve Alumel


B Type
+ve Platinum (30% Rhodium)
-ve Platinum (6% Rhodium)


J-Type
+ve Iron
-ve Constantan

## Type-K thermocouple



**Metal type: Chromel - Alumel**

**Range: -330 - 2460 °F**

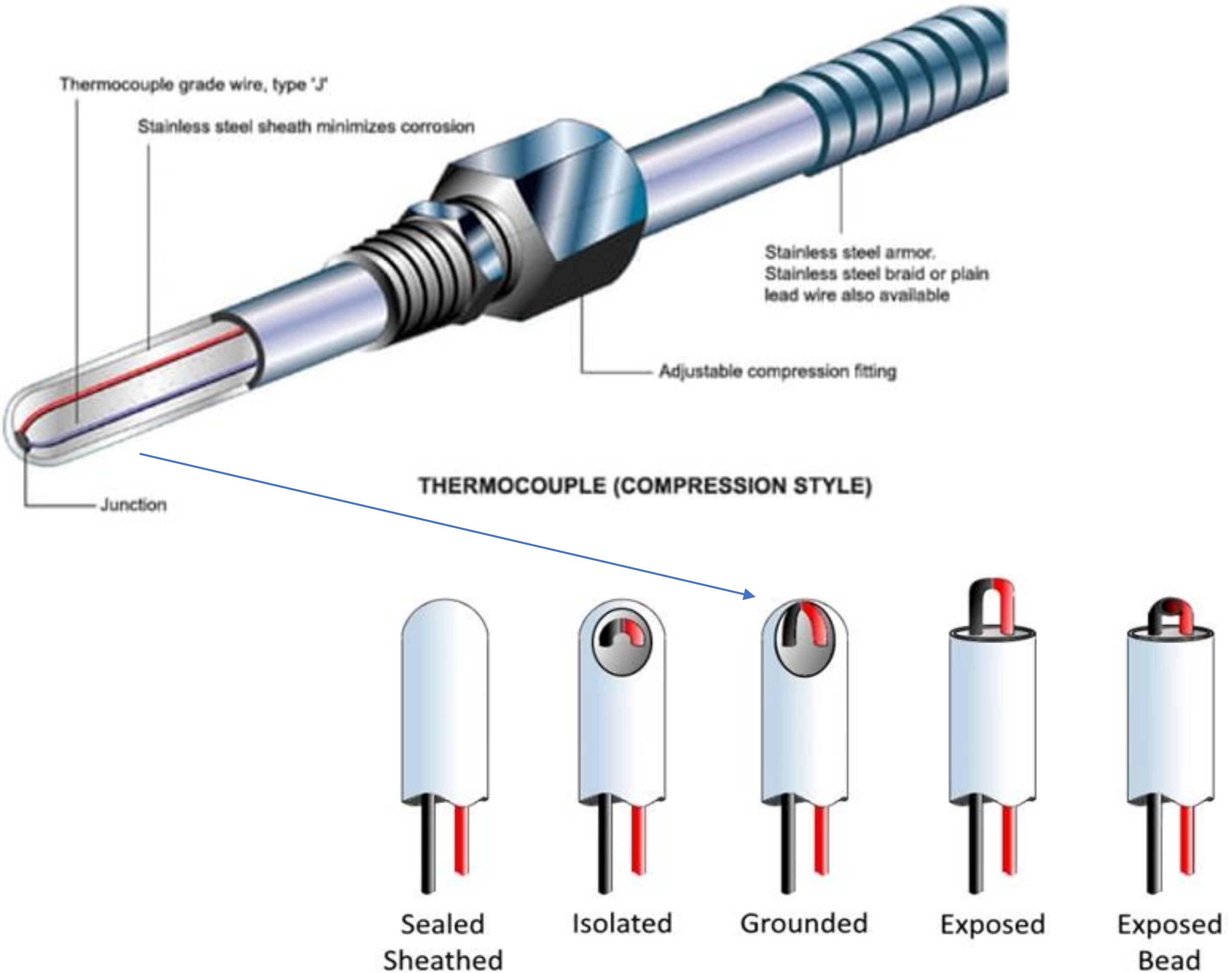
# THERMOCOUPLE

- Base Metal
  - Type K , J, T, E
- Noble Metal
  - Type N , S, R, B

| Thermocouples | Temperature Range (°C) |
|---|---|
| B Type | 1370 to 1700 |
| E Type | 0 to 870 |
| J Type | 0 to 760 |
| K Type | 95 to 1260 |
| N Type | 650 to 1260 |
| R Type | 870 to 1450 |
| S Type | 980 to 1450 |
| T Type | -200 to 370 |

# Thermocouples consists of combination of different dissimilar metals for measurement of unknown temperatures

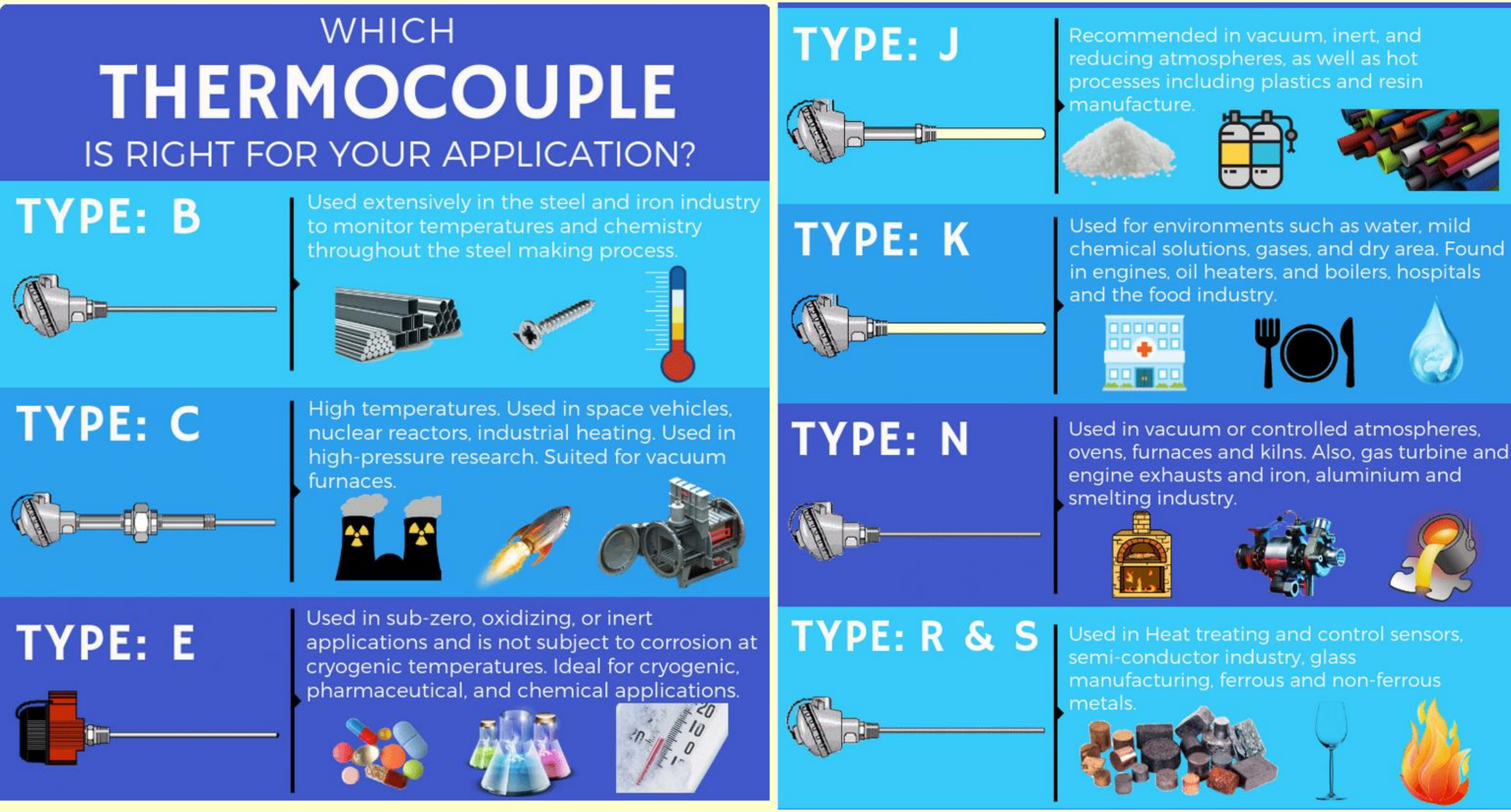
| Thermocouple Type | Composition | Temperature Range | Applications |
|---|---|---|---|
| **B-Type** | Platinum-Rhodium alloys | 1370 to 1700°C | High-temperature applications outside plastic molding |
| **E-Type** | Chromel and Constantan | 0 to 870°C | Inert conditions, shielded in sulfurous atmospheres |
| **J-Type** | Iron and Constantan | 0 to 760°C | Injection molding, vacuum and inert atmospheres |
| **K-Type** | Chromel and Alumel | 95 to 1260°C | Neutral or oxidizing environments, versatile |
| **N-Type** | Nicrosil and Nisil | 650 to 1260°C | Resistance to green rot and hysteresis, demanding operations |
| **R-Type** | Platinum with 13% Rhodium | 870 to 1450°C | High-temperature molding setups |
| **S-Type** | Platinum with 10% Rhodium | 980 to 1450°C | High-temperature processes, reliable performance |
| **T-Type** | Copper and Constantan | -200 to 370°C | Moist environments, inert atmospheres |


Thermocouple grade wire, type 'J'
Stainless steel sheath minimizes corrosion
Stainless steel armor.
Stainless steel braid or plain
lead wire also available
Adjustable compression fitting
Junction
THERMOCOUPLE (COMPRESSION STYLE)
Sealed Sheathed
Isolated
Grounded
Exposed
Exposed Bead

# Applications of thermocouples

- Measures temperature range up to 1800 °C.
- In the steel and iron industries and Electric arc furnace to monitor temperatures
- Heating appliances safety
- Scientific research
- Medical instrumentation

# Applications of thermocouples



## Advantages :

1.Cheap in cost
2.High speed of response
3.Rugged in construction
4.Good reproducibility

## Disadvantage :

1.Low accuracy
2.Very complex in construction
3.Need of protection from environment

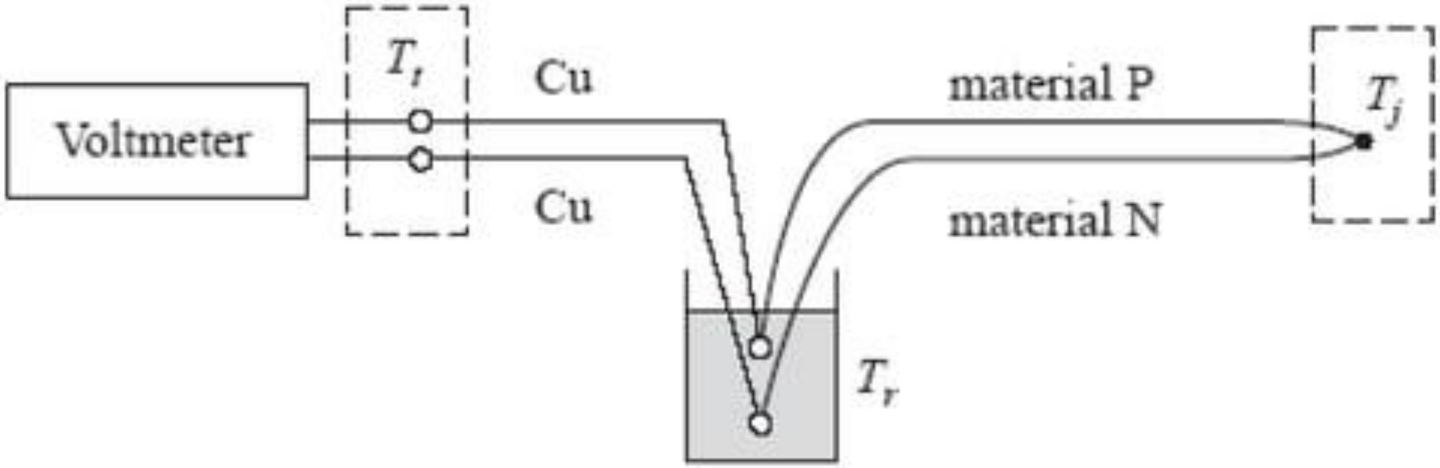
# Seebeck Effect

**Table 3.1** *Seebeck coefficients for various thermocouples*

| *Thermocouple Type* | *Seebeck Coefficient* [$\mu$V/ °C][a] |
|---|---|
| J | 50.2 {51 (5.1)} |
| K | 39.4 {40 (4.0)} |
| N | 26.2 {not available} |
| E | 58.5 {62 (6.2)} |
| T | 38.0 {40 (4.0)} |

[a]Bracket Values were obtained at 20 °C at a digital voltmeter sensitivity for 0.1 °C; Otherwise values are at 0 °C. The number in parentheses is interpreted as the voltmeter resolution in ($\mu$V) to detect a 0.1 °C change at 20 °C; for example, 4 $\mu$V resolution if a Type T thermocouple is used to detect a 0.1 °C change.

# Standard Calibration Setup

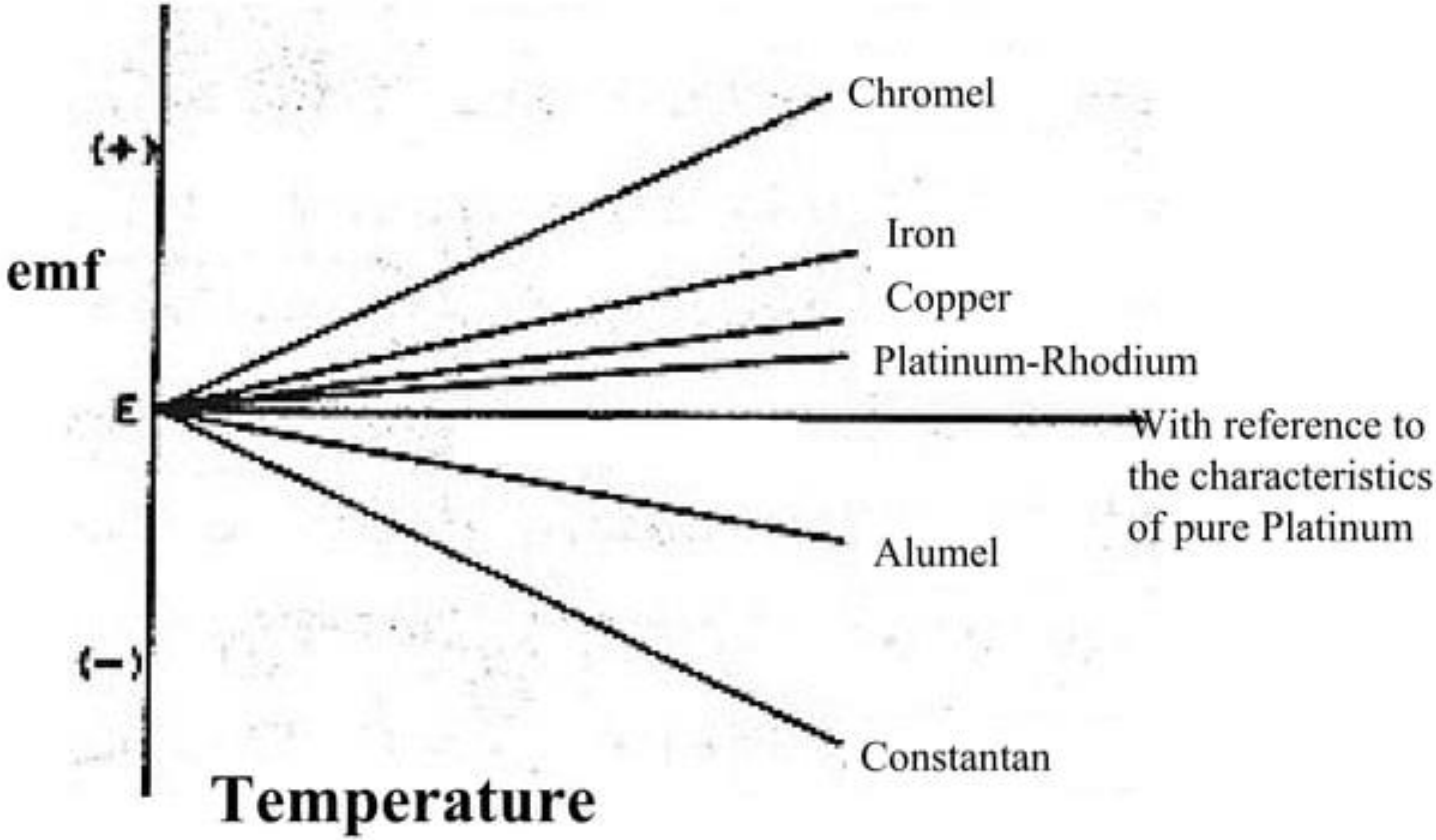



Ice-point

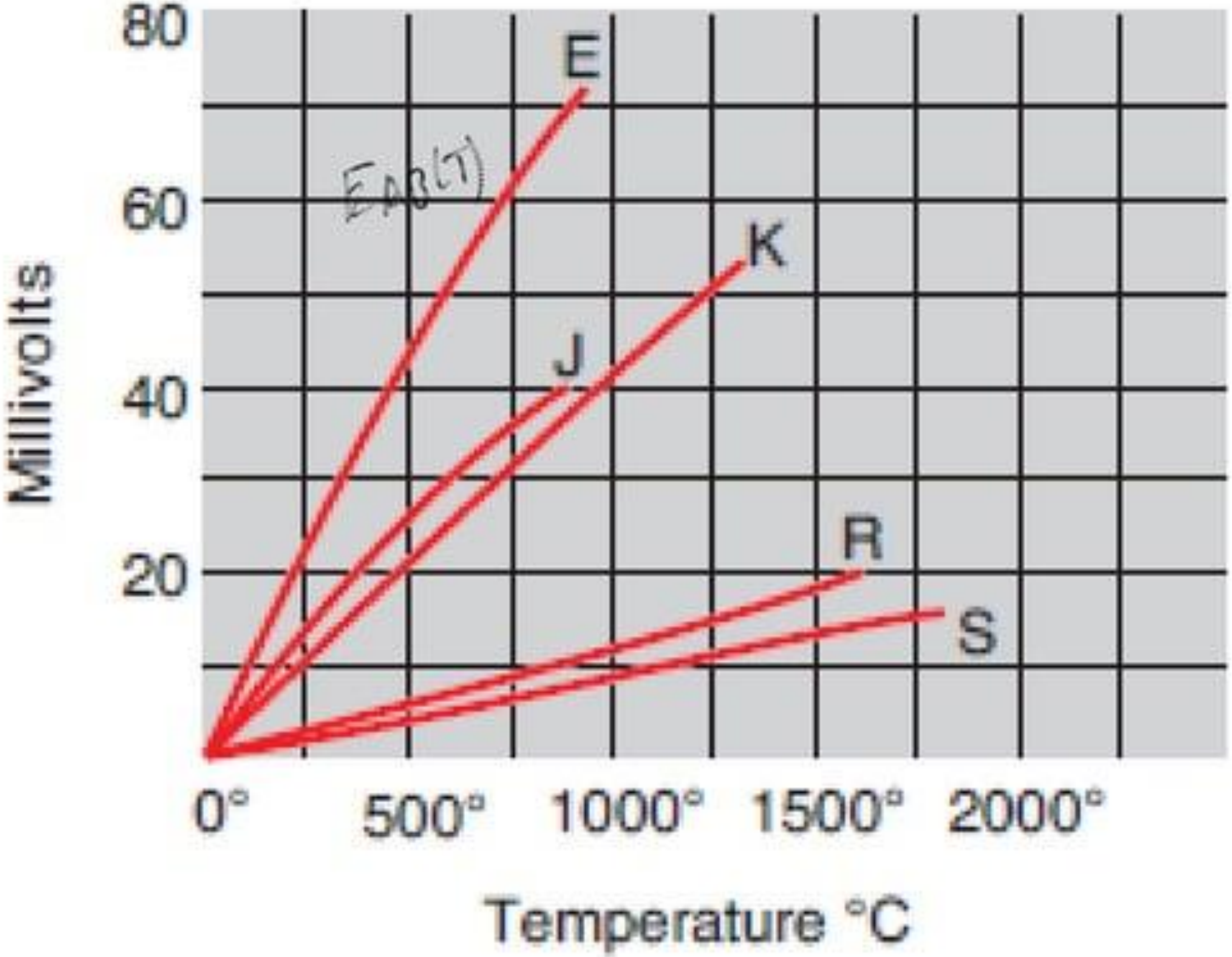
The result of the calibration is a table of EMF versus T values.
The integral is never directly evaluated.
Instead a polynomial curve fit to the calibration data gives:

$$E_{0j} = F\left(T_j\right) = b_0 + b_1 T_j + b_2 T_j^2 + \ldots\ldots + b_n T_j^n$$

# Material EMF versus Temperature



Thermocouple temperature vs. Voltage graph



# Seebeck coefficient vs. Temperature

$\frac{\partial \xi_{AB}}{\partial T} = \sigma_{AB}$

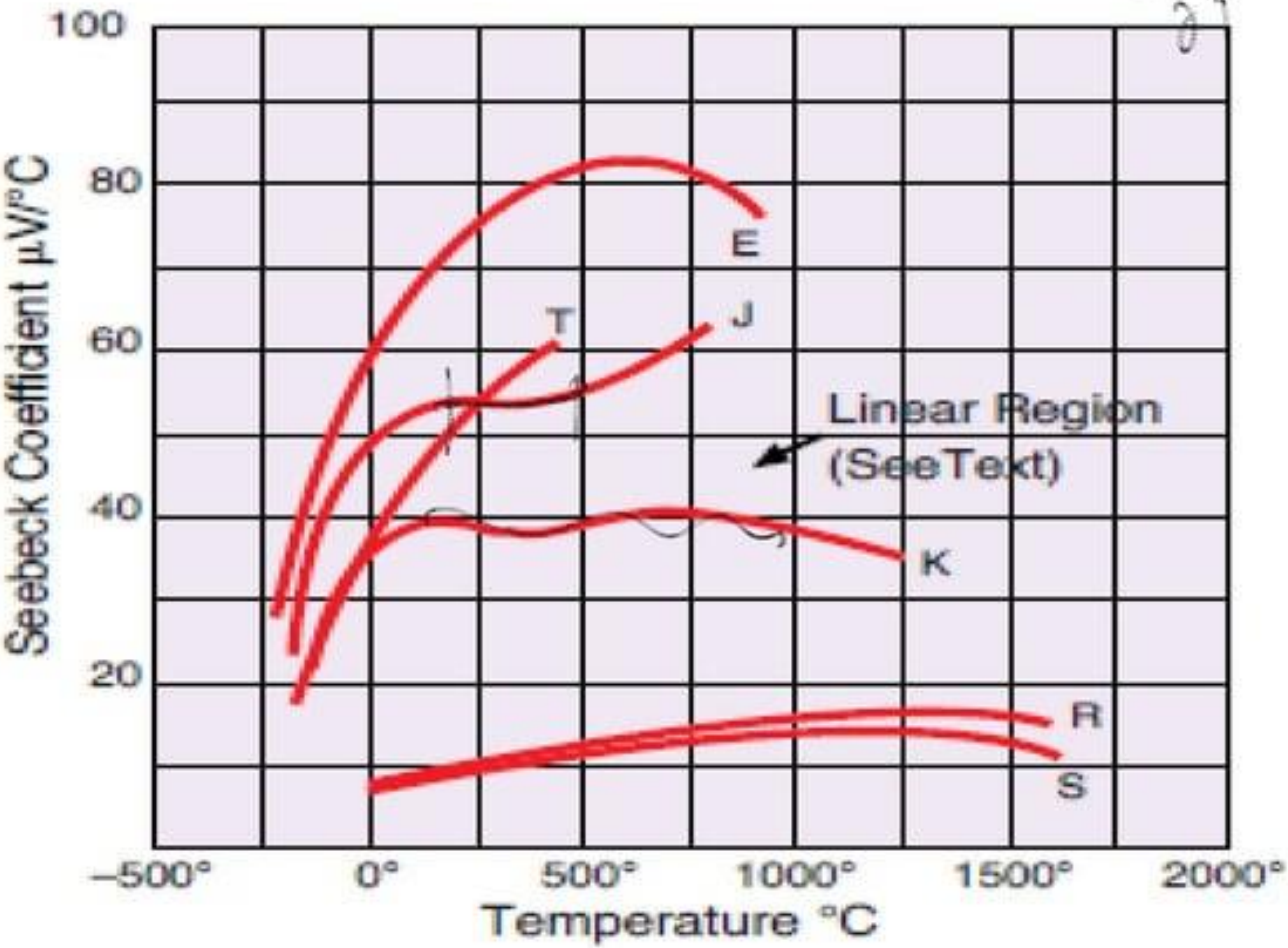
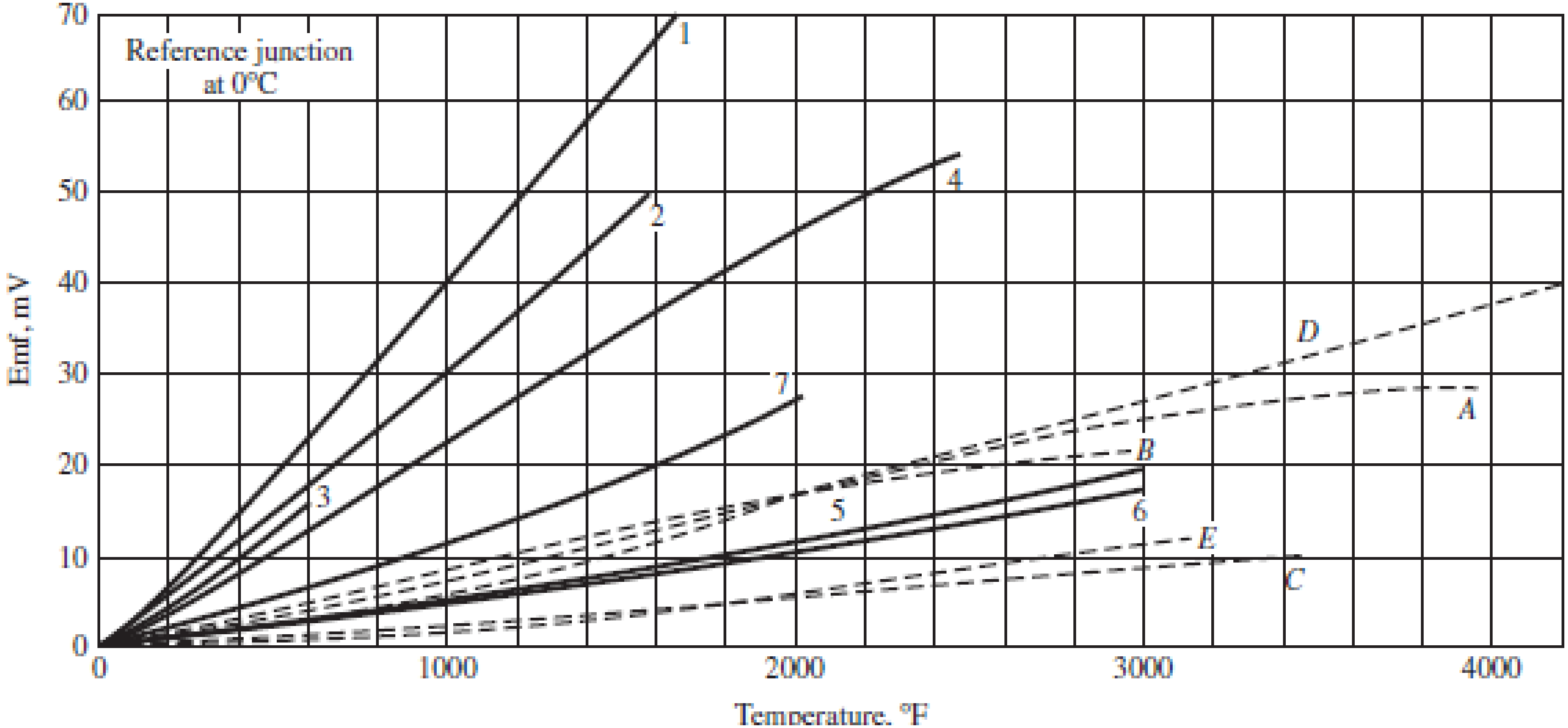


**Table 8.3c** Properties of common thermocouple materials

| Material | Thermal Conductivity, W/M · °C | Specific Heat, kJ/kg · °C | Density, kg/m$^3$ | Electric Resistivity, $\mu\Omega \cdot$ cm | Temperature Coefficient of Expansion, °C$^{-1}$ x 10$^6$ | Melting Point, °C |
|---|---|---|---|---|---|---|
| Alumel | 29.8 | 0.52 | 8600 | 29 | 12 | 1400 |
| Constantan | 21.7 | 0.39 | 8900 | 49 | −0.1 | 1220 |
| Chromel | 19.2 | 0.45 | 8700 | 70 | 13 | 1450 |
| Copper | 377 | 0.385 | 8900 | 1.56 | 17 | 1080 |
| Iron | 68 | 0.45 | 7900 | 8.6 | 12 | 1490 |



Reference junction
at 0°C
Emf, mV
Temperature, °F
0
10
20
30
40
50
60
70
0
1000
2000
3000
4000
1
2
3
4
5
6
7
A
B
C
D
E

**Table 8.4** Thermoelectric sensitivity $S = dE/dT$ of thermoelement made of materials listed against platinum, $\mu V{}^\circ C^{-1}$*
(Reference junction kept at a temperature of 0°C)

| | | | |
|---|---|---|---|
| Bismuth | −72 | Silver | 6.5 |
| Constantan | −35 | Copper | 6.5 |
| Nickel | −15 | Gold | 6.5 |
| Potassium | −9 | Tungsten | 7.5 |
| Sodium | −2 | Cadmium | 7.5 |
| Platinum | 0 | Iron | 18.5 |
| Mercury | 0.6 | Nichrome | 25 |
| Carbon | 3 | Antimony | 47 |
| Aluminum | 3.5 | Germanium | 300 |
| Lead | 4 | Silicon | 440 |
| Tantalum | 4.5 | Tellurium | 550 |
| Rhodium | 6 | Selenium | 900 |

*According to Lion [6].