Temperature measurement

1. Resistance temperature detector (RTD) or Resistance thermometer
2. Themistor
3. thermocouple
4. Bimetallic strip sensor. or Bimetallic thermometer.
5. Solid state temperature sensor.
6. Radiation pyrometer

1. Resistance thermometer :. Resistance of a conductor changes when its temperature is changed. This property is utilized for measurement of temperature.

$$\boxed{R = \rho \frac{l}{A}}$$

$R \rightarrow$ Resistance (Ω)

$\rho \rightarrow$ Resistivity (Ω-m)

$$\frac{1}{R} = \frac{1}{\rho} \frac{A}{l}$$

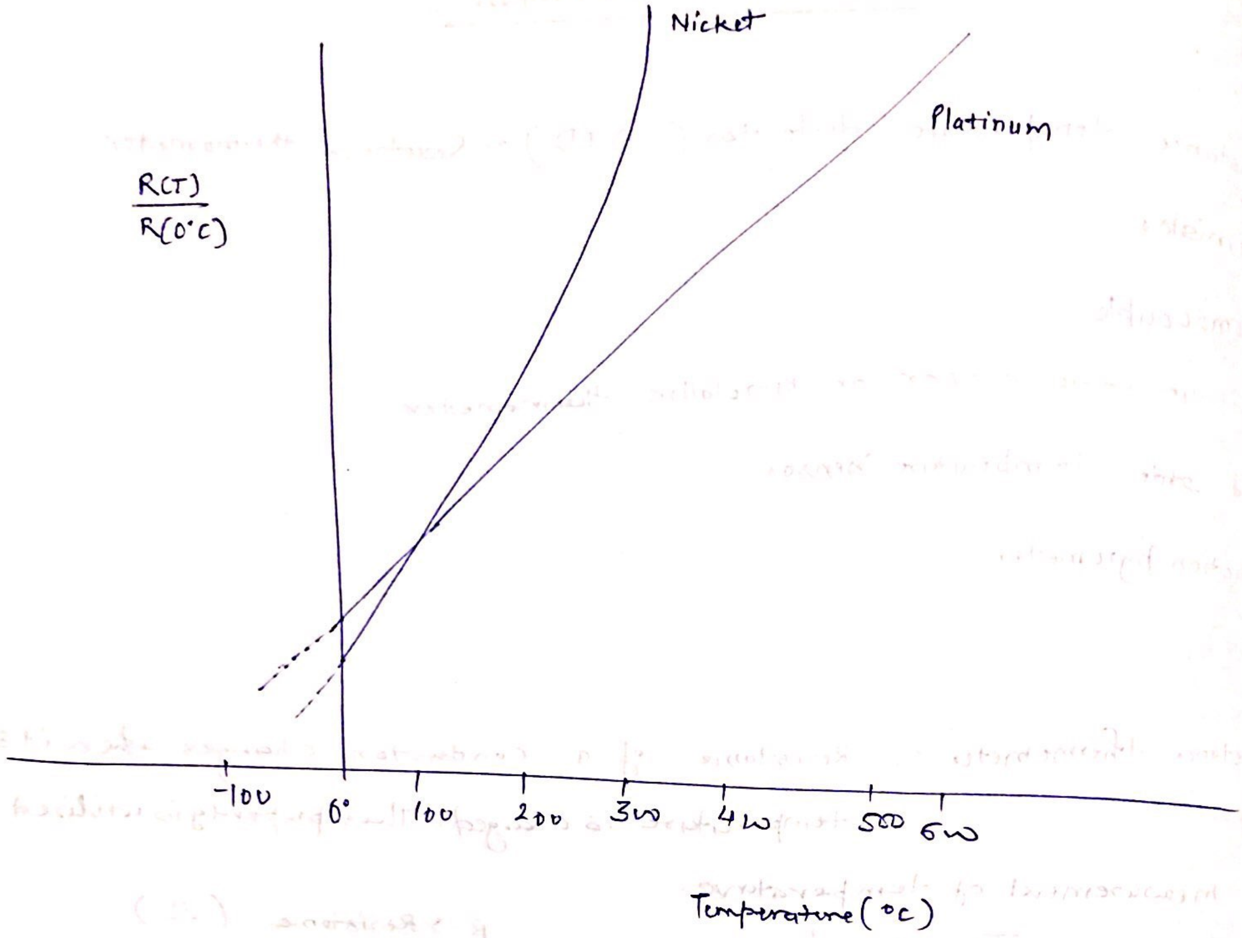
$$\boxed{G = \sigma \frac{A}{l}}$$

$G \rightarrow$ Conductance

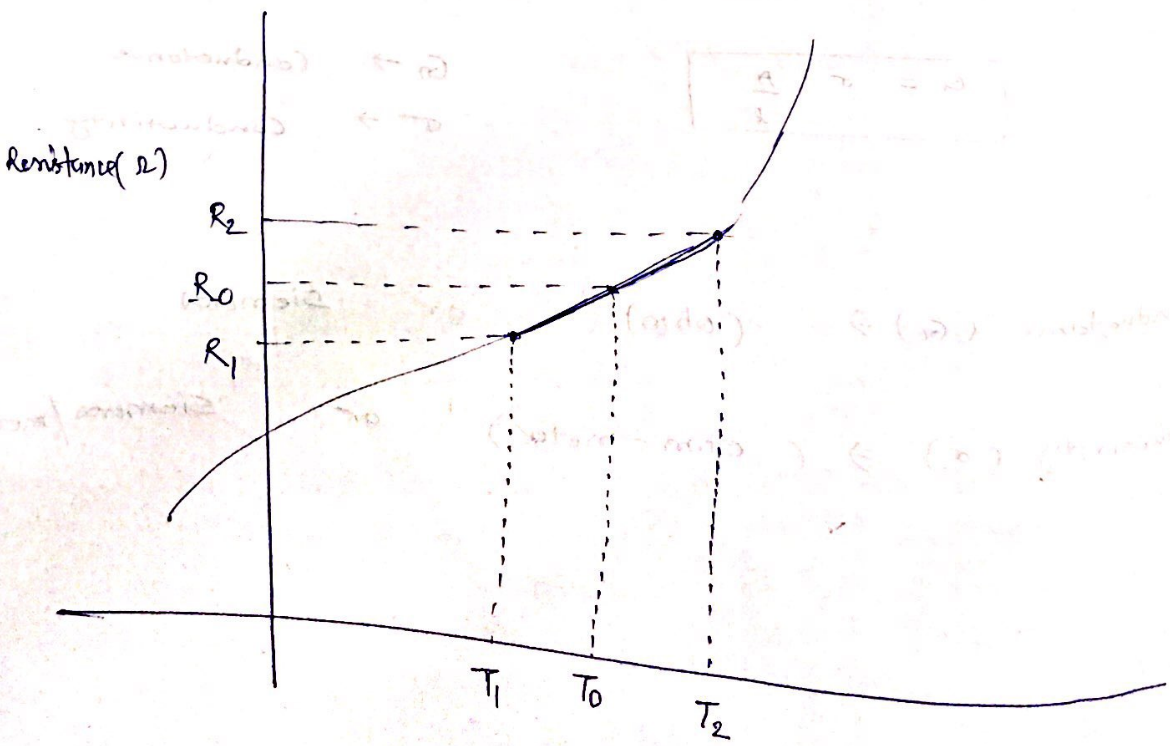
$\sigma \rightarrow$ Conductivity

Conductance (G) $\Rightarrow$ $(\text{ohm})^{-1}$ or Siemens

Conductivity (σ) $\Rightarrow$ $(\text{ohm - meter})^{-1}$ or Siemens/meter



Resistance versus temperature approximation:



A straight line has been drawn between the points of the curve that represent temperature T_1 and T_2 as shown and T_0 represents the mid point temperature.

$$\boxed{R(T) = R(T_0)\left[1 + \alpha_0 \, \Delta T\right]} \qquad T_1 < T < T_2$$

$R(T)$ = approximation of resistance at temperature T

$R(T_0)$ = resistance at temperature T_0

$\Delta T = T - T_0$

α_0 = fractional change in resistance per degree of temperature at T_0.

[resistance temperature co-efficient at temperature T_0].

$$\alpha_0 = \frac{1}{R(T_0)} * (\text{Slope at } T_0)$$

$$\boxed{\alpha_0 = \frac{1}{R(T_0)} * \left(\frac{R_2 - R_1}{T_2 - T_1}\right)}$$

R_2 = resistance at temperature T_2

R_1 = resistance at temperature T_1

Quodratic approximation-

$$R(T) = R(T_0)\left[1+\alpha_1\,\Delta T + \alpha_2\,(\Delta T)^2\right]$$

$R(T)$ = quadratic approximation of the resistance at T

$R(T_0)$ = resistance at T_0

α_1 = linear fractional change in resistance with temperature

α_2 = quadratic fractional change in resistance with temperature

$\Delta T = T - T_0$

Q: A sample of metal resistance versus temperature has the following measured values.

T(°F)	R(Ω)
60	106
65	107.6
70	109.1
75	110.2
80	111.1
85	111.7
90	112.2

Find the linear approximation of resistance versus temperature between 60° and $90^\circ F$.

Soln $\Rightarrow$

mid point $T_0 \Rightarrow \dfrac{60+90^\circ}{2}$

$$T_0 = \frac{150^\circ}{2}$$

$$T_0 = 75^\circ$$

$$R(T_0) = R(\text{at } 75^\circ) = 110 \cdot 2$$

$$\alpha_0 = \frac{1}{R(T_0)} * \frac{R_2 - R_1}{T_2 - T_1}$$

$$= \frac{1}{110 \cdot 2} * \left(\frac{112 \cdot 2 - 106 \cdot 0}{90 - 60}\right)$$

$$= 0 \cdot 001875 \ /^\circ F$$

Thus the linear approximation for resistance is :.

$$\boxed{R(T) = 110 \cdot 2 \left[1 + 0 \cdot 001875 \, (T - 75)\right]} \ \Omega$$

Q: Find the quadratic approximation of resistance versus temperature for the data given in example (previous Q) between 60° and 90°F.

Solⁿ:

Since $T_0 = 75°C$ mid point

$R(T_0) = 110.2\ \Omega$

To find α_1 and α_2, two equations can be setup using the end points of the data, namely $R(60°F)$ and $R(90°F)$.

$$112.2 = 110.2\left[1+\alpha_1(90°-75)+\alpha_2(90°-75)^2\right]$$

$$106.0 = 110.2\left[1+\alpha_1(60-75)+\alpha_2(60-75)^2\right]$$

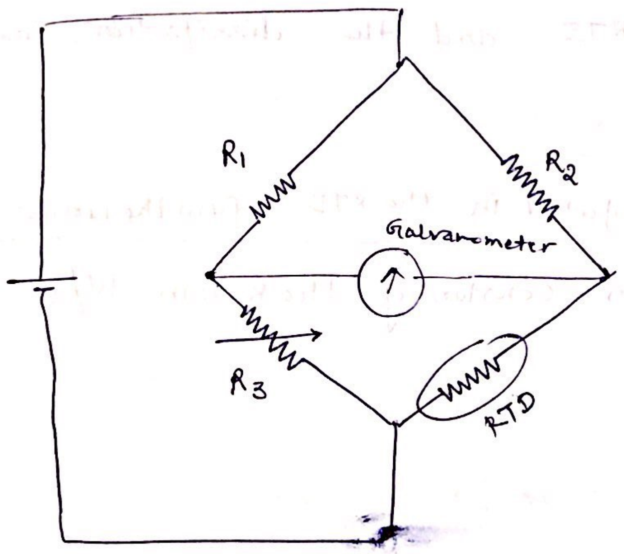
After solving

$\alpha_1 = 0.001875\ /°F$

$\alpha_2 = -44.36\times10^{-6}\ /(°F)^2$

$$R(T) = 110.2\left[1+0.001875\,(T-75) - 44.36\times10^{-6}\,(T-75)^2\right]$$

Measurement of temperature :.



Dissipation constant - Because the RTD is a resistance, there is an I^2R power dissipated by the device itself that causes a slight heating effect, a self heating. This may also cause an erroneous reading or even upset the environment in delicate measurement conditions. Thus the current through the RTD must be kept sufficiently low and constant to avoid self heating.

Typically, a dissipation constant is provided in RTD specifications. this number relates the power required to raise the RTD temperature by one degree of temperature. Thus a 25 m-W/°C dissipation constant shows that if I^2R power losses in the RTD equal to 25 mW, the RTD will be heated by 1°C

Q

* The self heating temperature rise can be found from the power dissipated by the RTD and the dissipation constant

S

$$\Delta T = \frac{\text{Power dissipated in the RTD from the circuit in W}}{\text{Dissipation constant of the RTD in W/°C}}$$

$$\boxed{\Delta T = \frac{P}{P_D}}$$

P = Power dissipated in the RTD from the circuit in W.

P_D = Dissipation constant of the RTD in W/°C

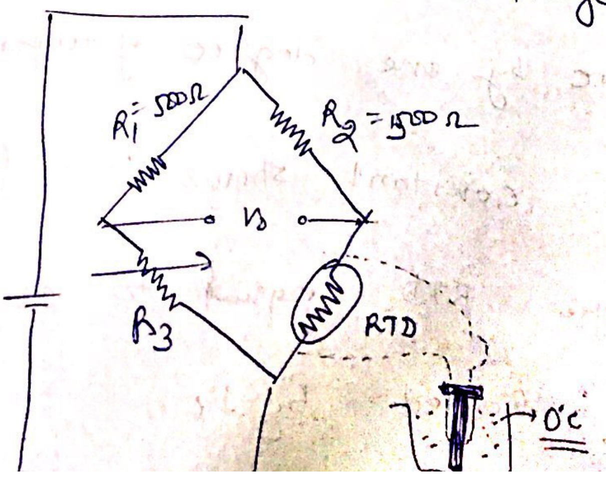
Q: An RTD has $\alpha_0 = 0.005/°C$

$R = 500\Omega$

dissipation constant $P_D = 30\ mW/°C$

at 20°C

The RTD is used in a bridge circuit such that as shown in figure with $R_1 = R_2 = 500\Omega$ and R_3 a variable resistor is used to null the bridge. If the supply voltage is and the RTD is placed in bath at 0°C, find the value of R_3 to null the bridge.



Solⁿ:

$$R_{RTD}(T) = R(T_0)\left[1 + \alpha(T - T_0)\right]$$

$$R_{RTD}(T) = 500\left[1 + 0.005(T - 20)\right]$$

$$R_{RTD} = 500\left[1 + 0.005(0 - 20)\right]$$

$R_{RTD} = 450\Omega$ [RTD resistance at 0°C without including the effect of dissipation.]

Except for the effects of self heating, we would expect the bridge to null with R_3 equal to 450Ω.

$\therefore R_3 = 450\Omega$

** Let us see what self - heating does to this problem. first we find the power dissipated in the RTD from the circuit, assuming the resistance is still 450Ω.

$$\text{Power } P = I^2 R$$

$$I = \frac{V}{R} = \frac{10}{500 + 450} = 0.011\ \text{A}$$

$$P = (0.011)^2 * 450 = 0.054\ W$$

$$\Delta T = \frac{P}{P_D} = \frac{0.054}{0.030} = 1.8^\circ C$$

Thus the RTD is not actually at the Bath temperature of 0°C but at a temperature of 1.8°C. We must find the RTD resistance:

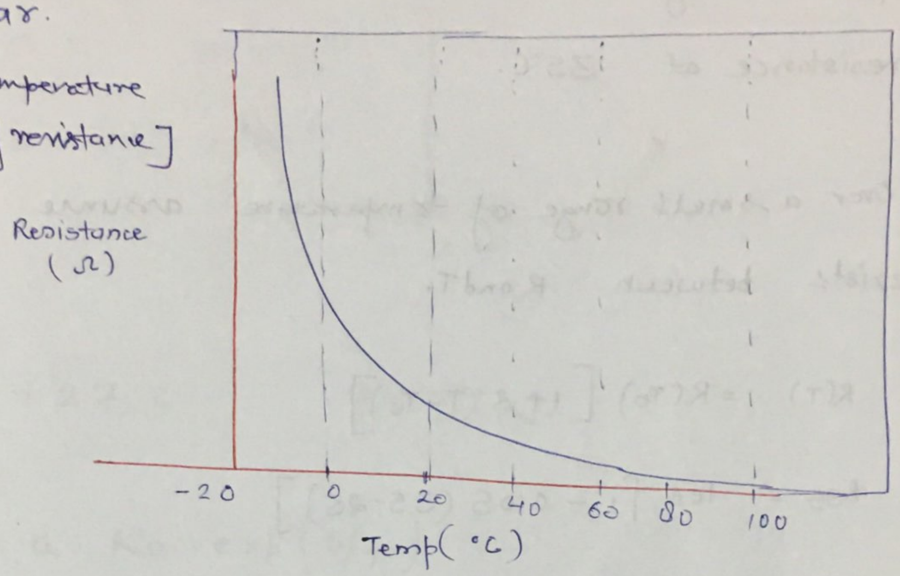
$$R_{RTD} = 500\left[1+0.005\left(1.8-20\right)\right]$$

$$R_{RTD} = 454.4\,\Omega$$

Thus the bridge will null with $R_3 = 454.5\,\Omega$

Thermistor —

* these are generally composed of semi-conductor materials.
* Mostly thermistors have a negative temperature coefficient of resistance
* highly sensitive
* highly non-linear.
* [NTC → negative temperature coefficient of resistance]



$$R_{T_1} = a R_0 e^{b/T_1}$$

$$R_{T_2} = a R_0 e^{b/T_2}$$

$$\frac{R_{T_2}}{R_{T_1}} = \frac{a R_0 e^{b/T_2}}{a R_0 e^{b/T_1}}$$

$$R_{T_2} = R_{T_1} e^{b/T_2 - b/T_1}$$

$$\boxed{R_{T_2} = R_{T_1} \exp\left[b \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \right]}$$

R_{T_1} = Resistance of thermistor at T_1

R_{T_2} = Resistance of thermistor at T_2

R_0 = Resistance of thermistor at ice point.

a, b ⇒ constants

Q: A thermistor has a resistance temperature co-efficient of -5% over a temperature range of 25°C to 50°C. If the resistance of the thermistor is 100Ω at 25°C what is the resistance at 35°C.

Solⁿ: Over a small range of temperature assume linear relationship exists between R and T.

$$R(T) = R(T_0)\left[1+\alpha(T-T_0)\right]$$

$$R_{35} = 100\left[1-0.05(35-25)\right]$$

$$\boxed{R_{35} = 50°C}$$

Q: A thermistor has a resistance of 3980Ω at ice point (0°C) and 794Ω at 50°C. The resistance temperature relationship is given by $R_T = a R_0 \exp(B/T)$. Now calculate a and B. Calculate the range of resistance to be measured in case of temperature varies from 40°C to 100°C

Solⁿ: $R_T = aR_0 \exp(B/T)$

$R_0 = 3980Ω$ $T = 0°C = 273°K$

$$3980 = a * 3980 \exp\left[b/273\right]$$

$$1 = a \exp\left(B/273\right) \quad \text{—— (1)}$$

$T = 50^\circ C = 50+273 = 323^\circ K$

$$794 = a\ 3980 * \exp(b/323) \quad \text{——} (2)$$

Solving (1) and (2)

$$\left[\begin{array}{l} a = 30\times10^{-6} \\ b = 2843 \end{array}\right]$$

$40^\circ C = 40+273 = 313^\circ K$

$$R_T = a\ R_0 \exp(b/T)$$

$$R_T = 30\times10^{-6} * 3980 * \exp\left(\frac{2843}{313}\right)$$

$$= 1051\,\Omega$$

$100\,C = 100+273 = 373$

$$R_T = 30\times10^{-6} * 3980 * \exp\left[\frac{2843}{373}\right]$$

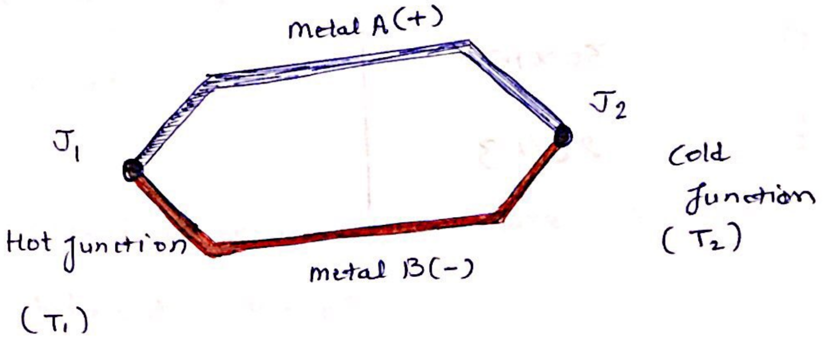
$$= 244\,\Omega$$

Thus range of resistance is $244\,\Omega$ to $1051\,\Omega$.

Ans

Thermocouple

* If two dissimilar metals are joined and junction is put at different temperature, then current will flow through it. if circuit is not close then emf will be genererated.



$$E = \alpha (T_1 - T_2)$$

$$\boxed{E = \alpha \Delta T}$$

α = Constant

$\Delta T = T_1 - T_2$ = hot jun temp − Cold junction temp

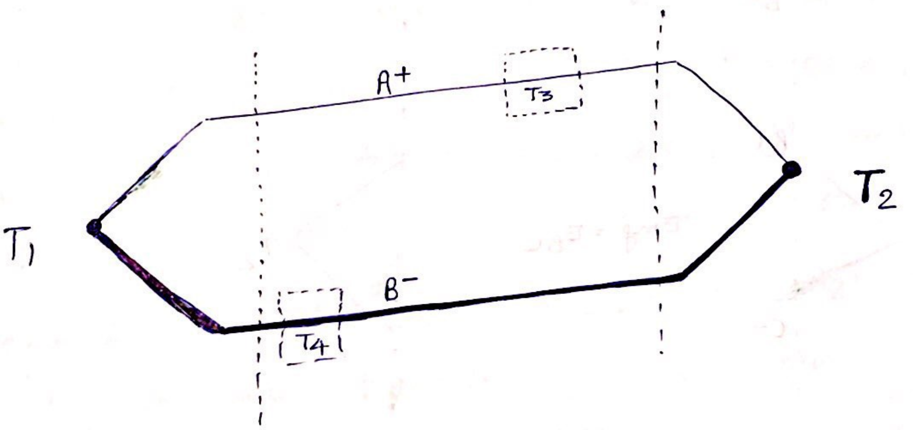
* This effect is called "Seebeck effect".

Peltiereffet : We constrcct a close loop of two different metals A and B. When an external voltage is applied to the system to cause a current to flow in the circuit. It is found that one of the Junctions will be heated and other cooled. This process is referred as the Peltier effect.

Thermoelectric laws -

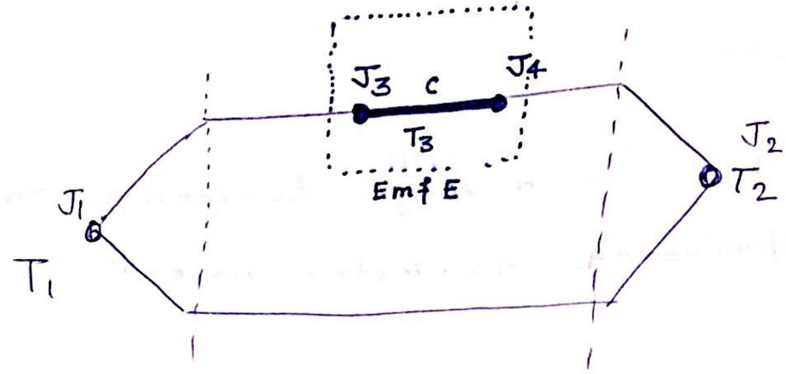
1- The application of heat to a single homogeneous metal is in itself not capable of producing an electric current.

2- A thermoelectric emf is produced when the junctions of two dissimilar homogeneous metals are kept at different temperatures. This emf is not affected by temperature gradient along the conductors are shown in figure.



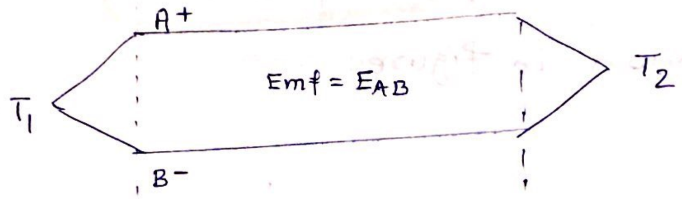
$T_1 > T_2$

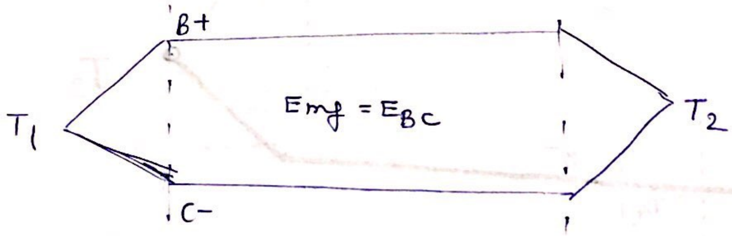
3- Law of intermediate metals - In a circuit consisting of two dissimilar homogeneous metals having the junctions at different temperatures, the emf developed will not be affected when a third homogeneous metal is made a part of the circuit, provided that the temperature of its two junctions are the same as shown in figure. This is called Law of Intermediate Metals.

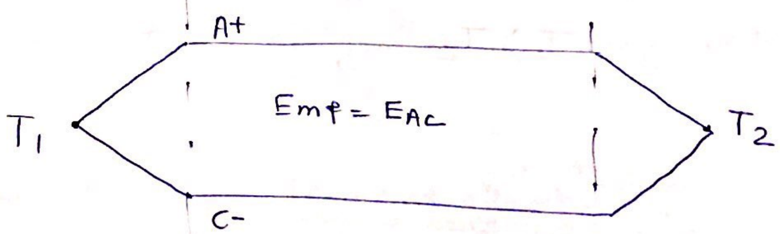


$T_1 > T_2$

Note → Application of Low of intermediate metal –







$T_1 > T_2$

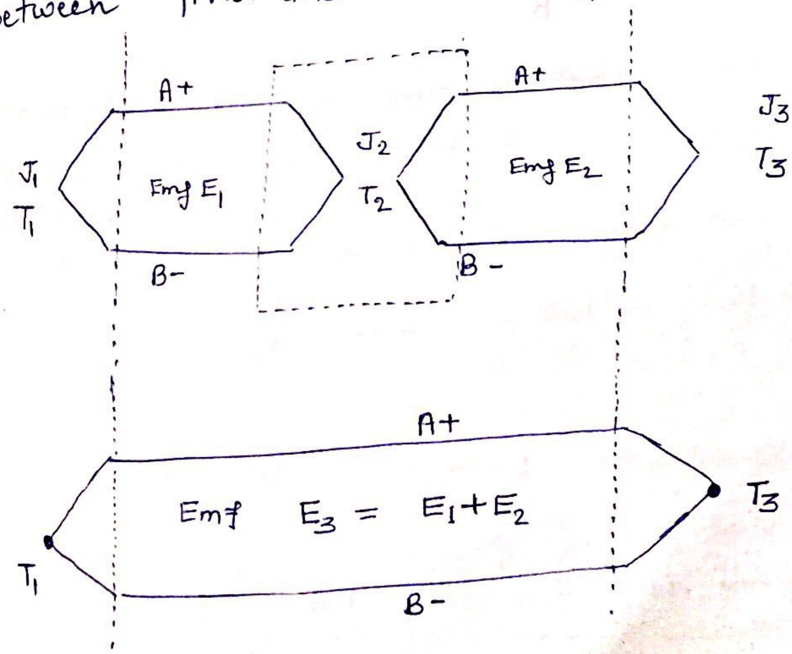
$$\boxed{E_{AC} = E_{AB} + E_{BC}}$$

The thermal emf of any two homogeneous metals with respect to another is the algebraic sum of their individual emfs with respect to a third homogeneous metal.

In figure the emf of metal A with respect to B is E_{AB} and that of B with respect to C is E_{BC} and therefore the emf of A with respect to C is E_{AC}

$$\boxed{E_{AC} = E_{AB} + E_{BC}}$$

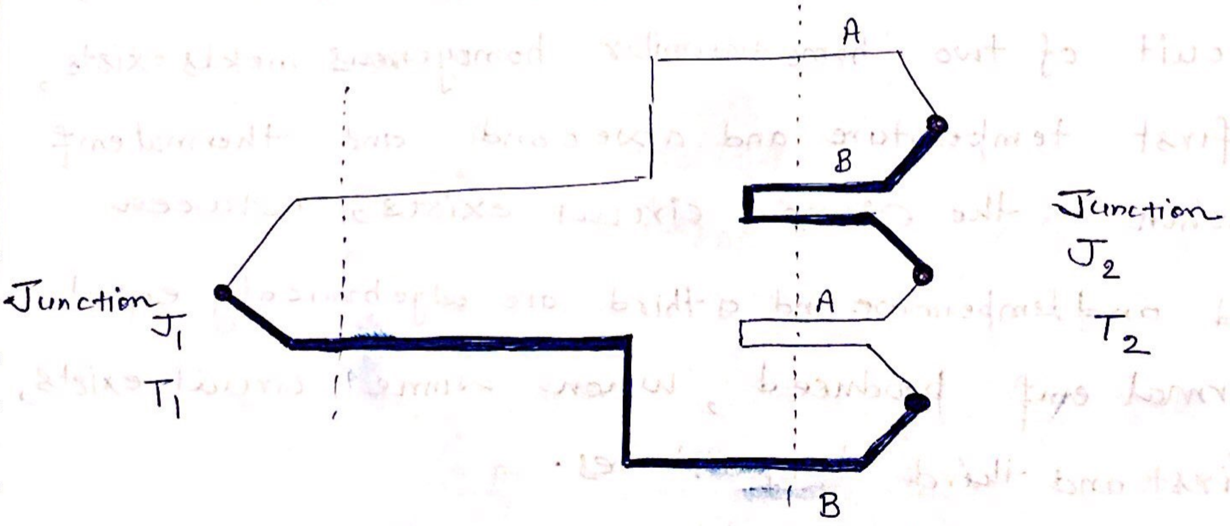
4- Law of intermediate temperature - The thermal emf produced, when a circuit of two dissimilar homogeneous metals exists, between a first temperature and a second and thermal emf produced when the same circuit exists, between the second temperature and a third are algebraically equal to the thermal emf produced, when same circuit exists, between first and third temperature.



$$E_3 = E_1 + E_2$$

5- The algebraic sum of the emfs produced in a circuit containing two or more thermocouples all at the same temperature is zero.

6. The net emf of a circuit, containing two thermocouples, is unaffected by the addition of more thermocouples at the same temperature as any of the others as shown in figure.



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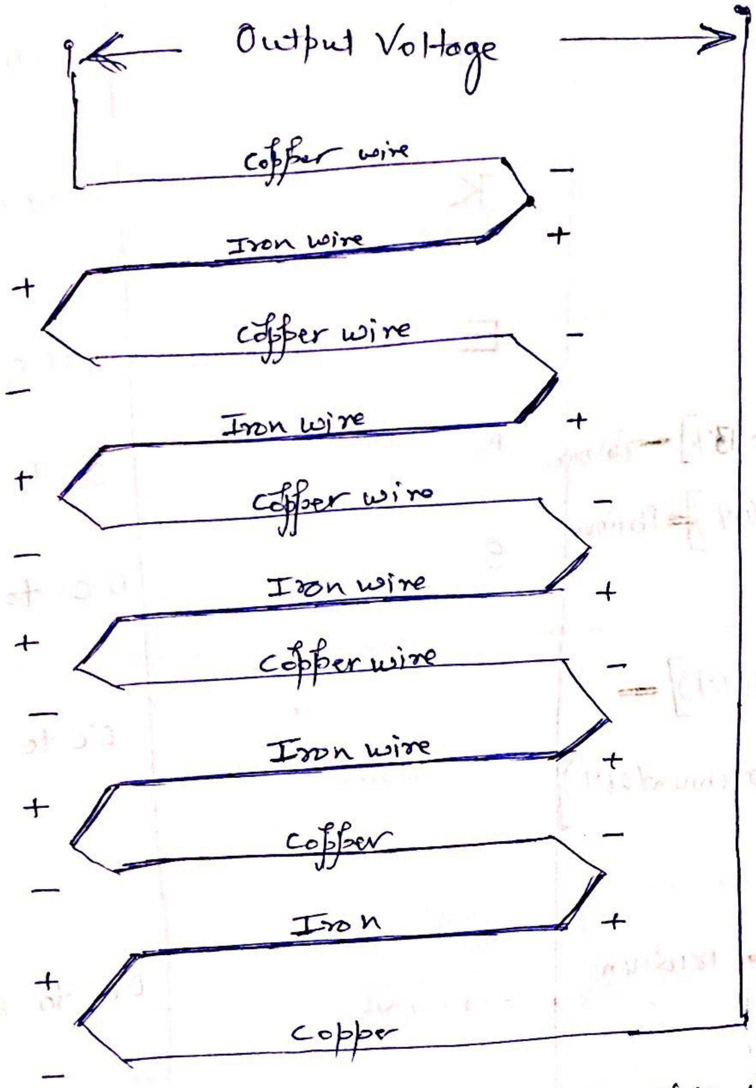
Thermopile — It consists of a group of very small thermocouples so connected in series that their emfs are additive. This gives an increased sensitivity.



* In the above figure one side is heated and other side is cooled, the resulting total output voltage is equal to the sum of junction voltage differentials.

Bolometer — * It is used for detecting and measuring the heat and radiation of microwave energy.

* used for energy measurement or power measurements

* used for measuring the power of incident electromagnetic radiation.

Standard thermocouple

Materials	Type	Range
1. copper — constantan	T	-200°C to 371°C
2. Iron — constantan	J	- 190°C to 760°C
3. chromel — alumel	K	-190°C to 1260°C
4. chromel — constantan	E	-100°C to 1260°C
5. [Platinum (87%) + rhodium 13%] — Platinum	R	0°C to 1482°C
[Platinum (90%) + rhodium (10%)] — Platinum	S	0°C to 1482°C
6. [Tungsten (95%) + rhenium 5%] — [Tungsten (72%) + rhenium (26%)]		0°C to 2600°C
7 [Rhodium + iridium] — iridium		0°C to 2100°C

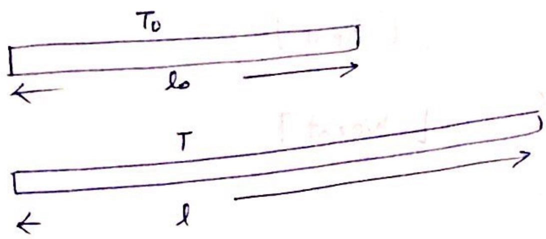
Sensitivity: Thermocouple sensitivity is generally in $\mu V/^\circ C$.

$J = 0.05 \ mV/^\circ C$ [Best]

$S = 0.006 \ mV/^\circ C$ [Worst]

Cold junction compensation —

Bimetallic thermometer –



* $T > T_0$

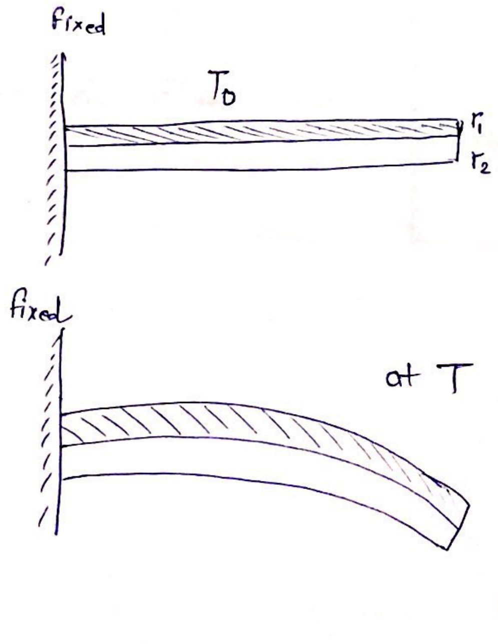
$l > l_0$

$$l = l_0[1 + r\,\Delta T]$$

r = linear thermal expansion coefficient.

l_0 = initial length at T_0

l = length at temp T.



$r_1 > r_2$

The bimetallic strip will bends toward the side where metal has a lower thermal expansion coefficient when there is increase in temperature and reverse happends when there is decrease in temperature

Radiation pyrometer — For the temperature above 650°C the heat radiations emitted from the body are of sufficient intensity to be used for measuring the temperature. Instruments that employ radiation principles fall into three general classes ⇒

1- Total radiation pyrometer

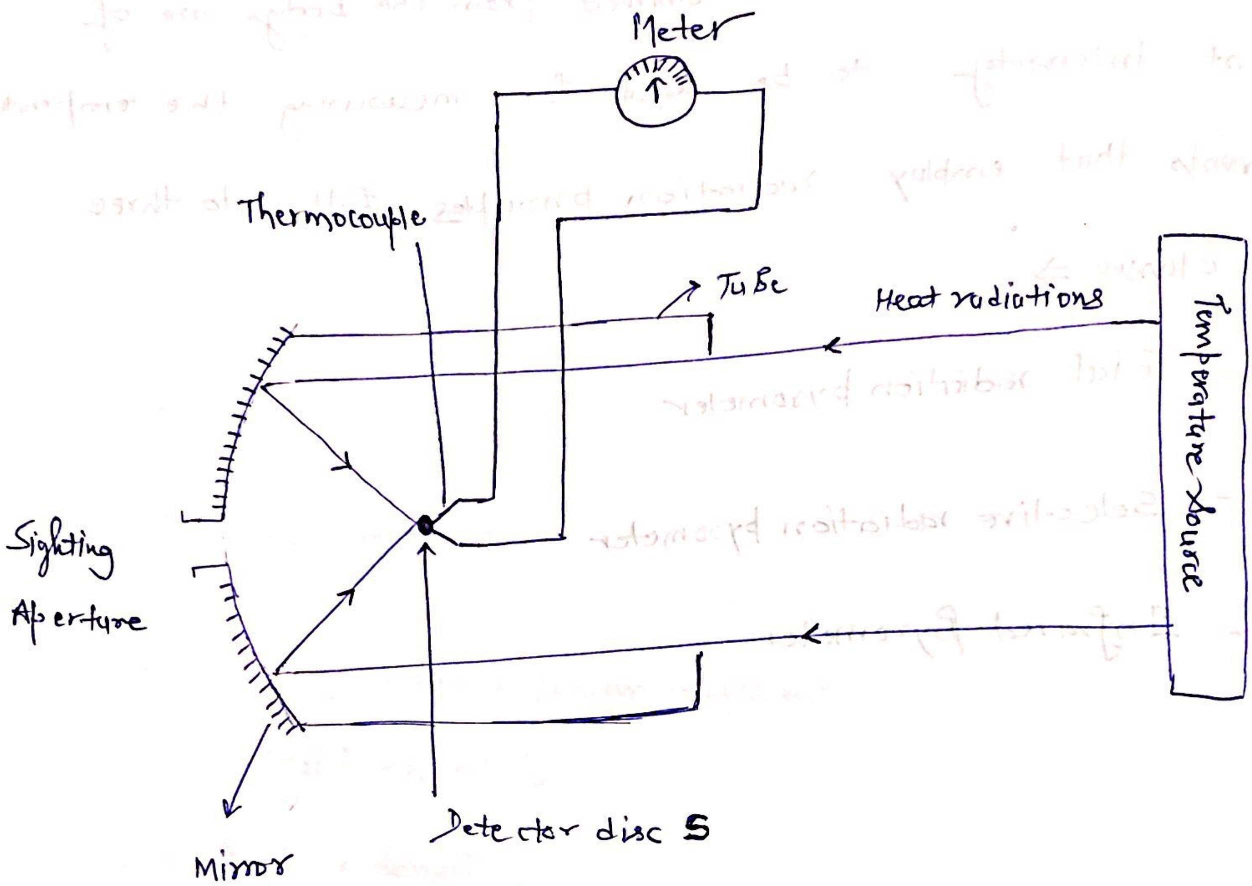
2- Selective radiation pyrometer

3- Infrared Pyrometer

1- Total radiation pyrometer — It receives a controlled sample of total radiation of a hot Body and focusses it on to a temperature sensitive transducer. The term 'total radiation' includes both visible (light) and invisible (infrared) radiations.

* Figure shows a schematic diagram of Fery's total radiation pyrometer. It consists of blackened tube T open at one end to receive the radiations from the object whose temperature is to be measured. The other end of the tube has a sighting aperture in which an adjustable eyepiece is usually fitted.

* The thermal radiations impinge on the concave mirror whose position can be adjusted suitably



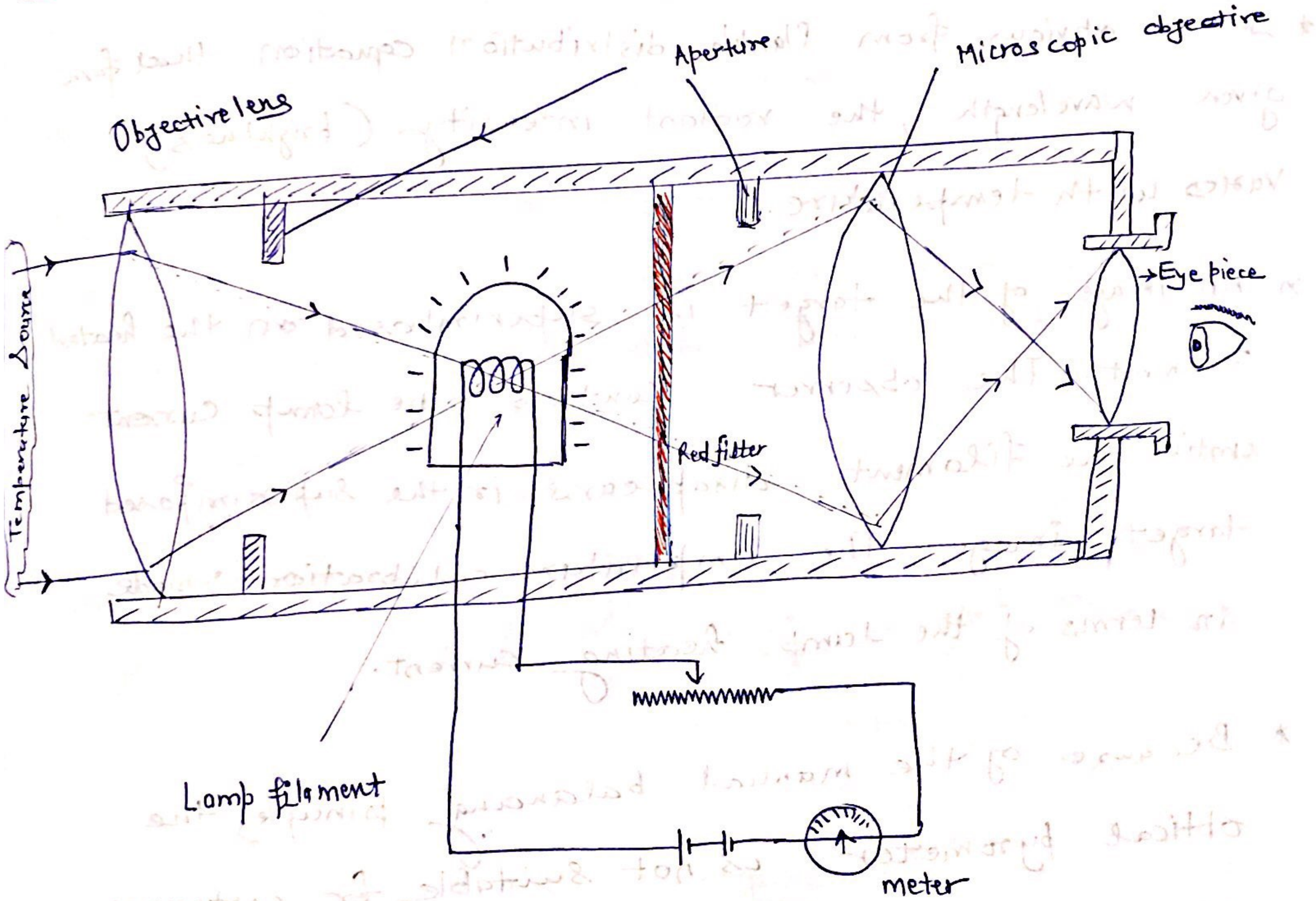
by a rack-and-pinion arrangement so as to get proper focusing of the thermal radiations on the detector disc S

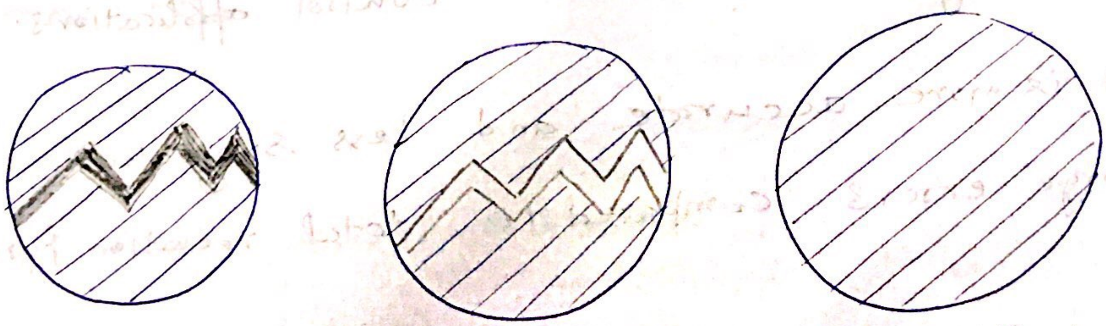
* The detector disc is usually of blackened platinum sheet/foil and is connected to a thermocouple junction or to a resistance thermometer bridge circuit.

* Meter is used to measure the thermoelectric emf or variation in electric resistance of the platinum foil.

2. Selective radiation pyrometer - (optical pyrometer) or disappearing filament type optical pyrometer.

* It is based on Plank's law which states that energy level in radiations from a hot body are distributed in the different wavelengths.





(a) Filament too dark

(b) Filament too bright

(c) Equal brightness

Appearance of filament images when filament temperature are (a) too high

(b) too low

(c) Correctly matched (null condition)

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* It is obvious from Plank's distribution equation that for a given wavelength, the radiant intensity (brightness) varies with temperature.

* An image of the target is superimposed on the heated filament. The observer controls the lamp current until the filament disappears in the superimposed target image. The temperature calibration is made in terms of the lamp heating current.

* Because of the manual balancing principle, the optical pyrometer is not suitable for continuous recording or automatic control applications.

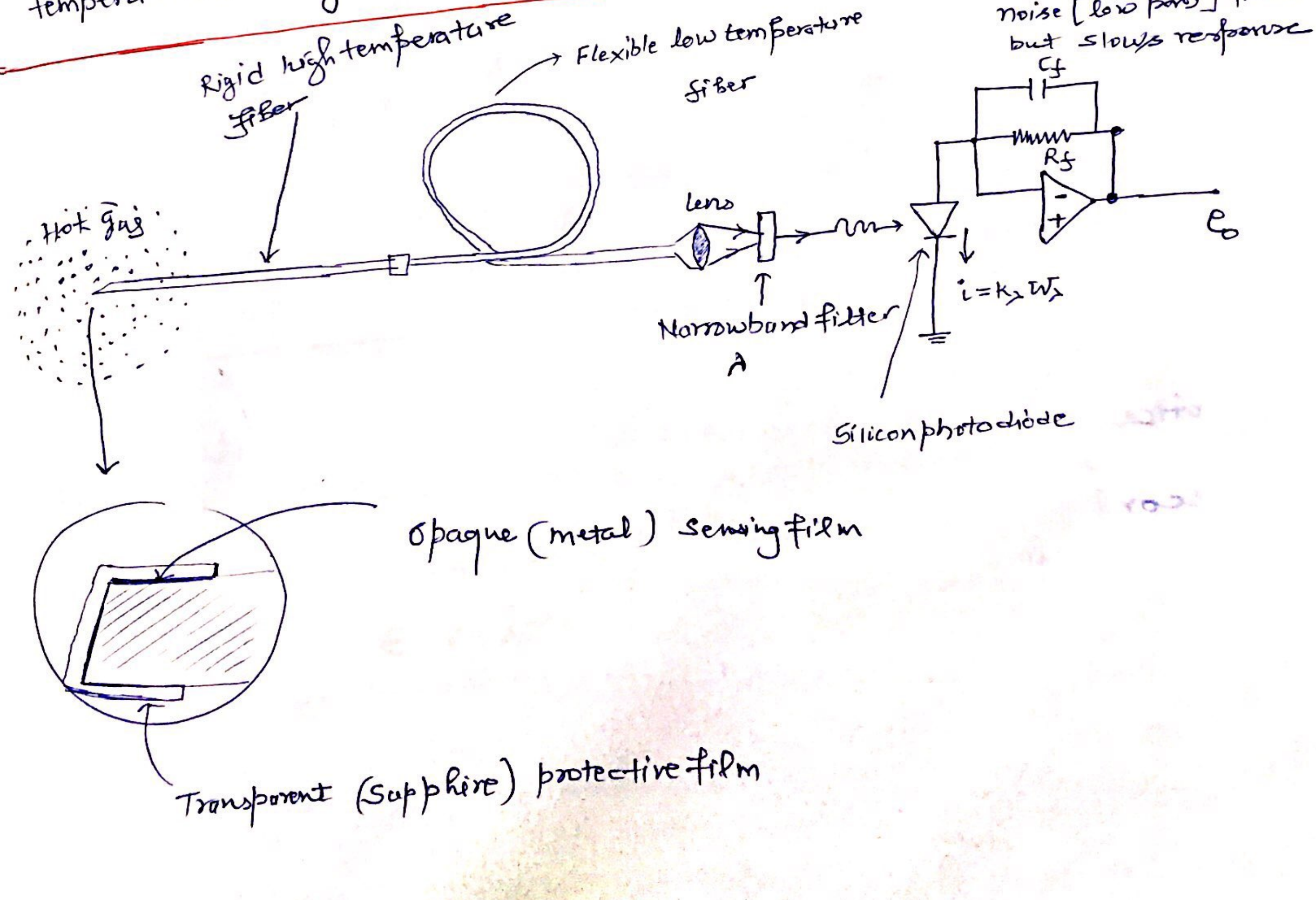
* It is more accurate and less subjected to large errors compared to total radiation pyrometer

Blackbody - tipped fiber optic radiation thermometer -

* Sensing probe is made from a single crystal aluminium oxide (Sapphire) optical fiber. A protective sapphire film is also formed over the metal sensing film.

* When probe is immersed in a hot gas, the sensing film receives heat by convection, conduction and radiation and its temperature rapidly approaches the gas temperature.

* Whatever temperature the sensing film achieves, it acts as a black-body cavity, projecting radiation characteristic of that temperature along the Sapphire fiber toward a silicon



Blackbody sensing tip

photodiode or photomultiplier detector.

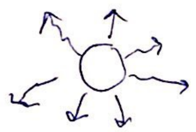
* The detector produces an output signal which is very linear with the radiant ~~input~~ power input.

Radiation fundamentals

Everybody above absolute zero in temperature emits radiation depend on its temperature. The ideal thermal radiator is called a blackbody. Such a body would absorb completely any radiation falling on it, and for a given temperature, emit the maximum amount of thermal radiation possible.

Stefan Boltzman Law :

$$\text{Rate of heat radiation} = \frac{dQ}{dt}$$



$$\frac{dQ}{dt} \propto A$$

$$\frac{dQ}{dt} \propto T^4$$

$$\boxed{\frac{dQ}{dt} = \sigma A T^4} \quad \text{—— (1)} \qquad (\text{For black body})$$

For any body (substance)

$$\boxed{\frac{dQ}{dt} = \epsilon \sigma A T^4} \quad \text{—— (2)}$$

ϵ = Emissivity of the substance

σ = Stefan constant $= 5.672 \times 10^{-8}\ J\,m^{-2}\,s^{-1}\,K^{-4}$

$\epsilon = 1$ (for blackbody)

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$$0 \leq \varepsilon \leq 1$$

② ÷ ①

$$\varepsilon = \frac{\text{Rate of radiation through unit area of the substance}}{\text{Rate of radiation through unit area of the black body under same Condition}}$$

Emissive Power – E = Rate of radiation emitted through a unit area of the material (at a certain temperature)

$$E = \frac{\text{Rate of radiation}}{\text{Area}}$$

$$= \frac{\left(\frac{dQ}{dt}\right)}{A}$$

$$= \frac{\varepsilon \sigma A T^4}{A}$$

$$\boxed{E = \varepsilon \sigma T^4}$$

$$\boxed{E = \sigma T^4}$$ if $(\varepsilon = 1)$

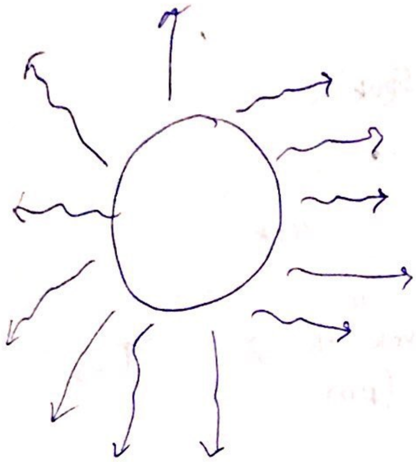
<u>Unit</u> :

$$E = \frac{\left(dQ/dt\right)}{\text{Area}} = \frac{\left(\frac{\text{Jule}}{\text{Second}}\right)}{m^2}$$

$$= \frac{\text{Watt}}{m^2} \quad \text{or} \quad \text{watt}/m^2$$

spectral emissive power — It is the emissive power at a particular wavelength. It is represent by:-

∴ W_λ.



$$W_\lambda = \frac{c_1}{\lambda^5 \left[e^{c_2/\lambda T} - 1\right]}$$

W_λ = Hemispherical spectral radiant intensity

$$\left(\frac{\text{Watt}}{\text{cm}^2 \cdot \mu m}\right)$$

c_1 = 37,413 $W \cdot \mu m^4/cm^2$

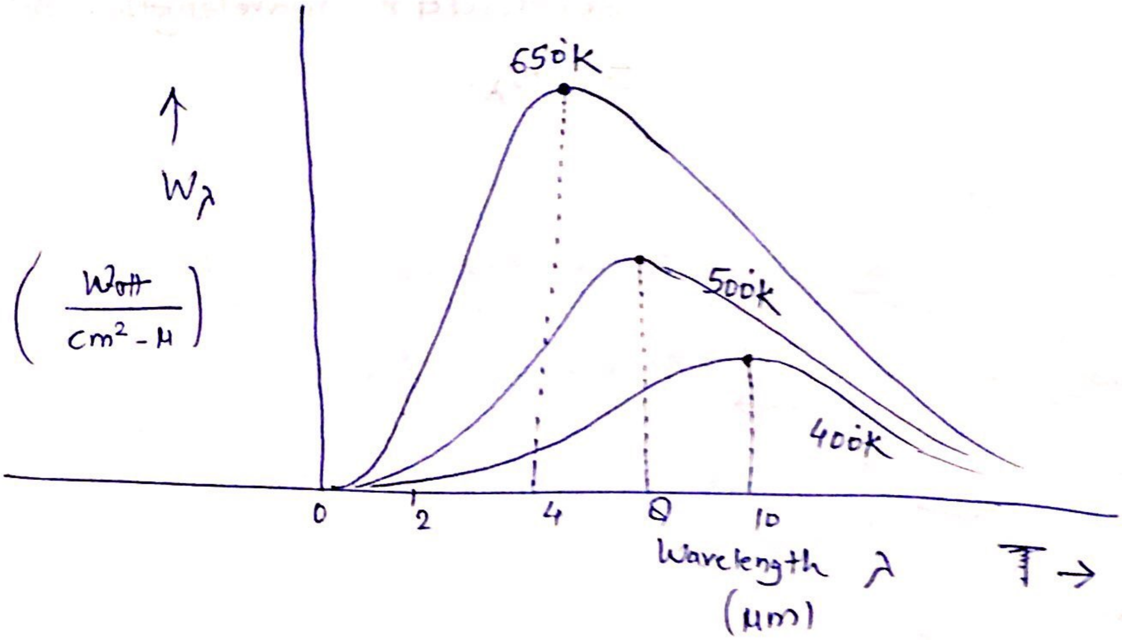
c_2 = 14,388 $\mu m \cdot K$

λ = Wavelength of radiation (μm)

T = Absolute temperature of black body (K)

* The quantity W_λ is the amount of radiation emitted from a flat surface into a hemisphere per unit wavelength, at a wavelength λ.

Wien's displacement law — Plot W_λ and λ | when T = Constant

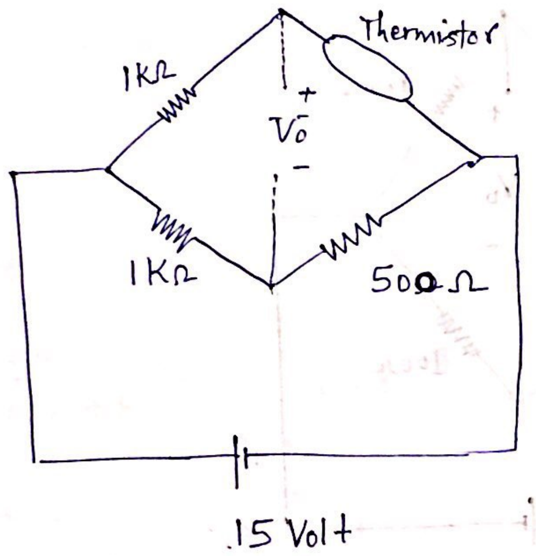


$$\lambda_{Peak} * T = Constant$$

$$\lambda_{Peak} * T = 2981 \qquad (\lambda_p \text{ in } \mu m)$$

$$\boxed{\lambda_{Peak} = \frac{2981}{T} \quad \mu m}$$

∴ Thermistor has a resistance of 500Ω at 30°C and its temperature coefficient is −5Ω/°C. Thermistor is used to measure the temperature of system with the following arrangement. If the temperature is increased by 10°C then the reading of voltmeter is ----- .



Sol^n

500Ω at 30°C

$$\therefore\ 500 - \frac{5\Omega}{°C} * 10°C$$

$$= 500 - 50\Omega$$

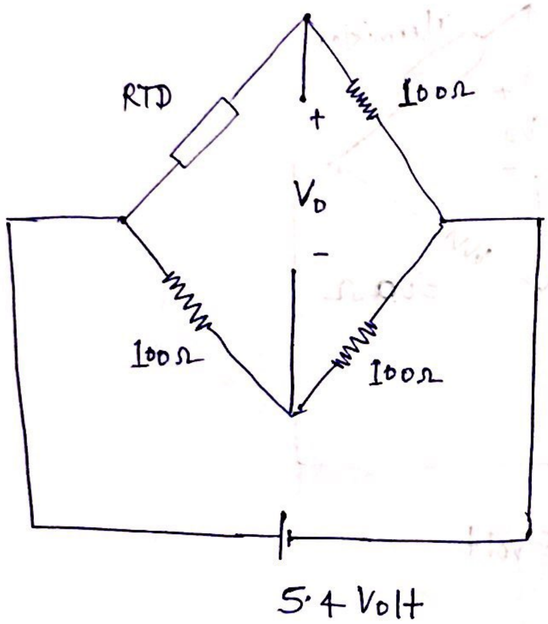
$$R_{new} = 450\Omega$$

$$V_o = \frac{450}{450+1000} * 15 - \frac{500}{500+1000} * 15$$

$$= 15\left[\frac{450}{1450} - \frac{500}{1500}\right] = 15\left[\frac{9}{29} - \frac{1}{3}\right]$$

$$= 15\left[\frac{27-29}{3 \times 29}\right] = \frac{-10}{29} V$$

Q: RTD having a sensitivity of $0.4\ \Omega/^\circ C$ connected to a d.c. Bridge with 100Ω fixed resistance in other three arms. The bridge is excited with 5.4 Volt. The bridge is balanced at $0^\circ C$. At room temperature the Bridge is unbalanced and the output voltage is 0.2 Volt. Find the room temperature.



Sol^n →

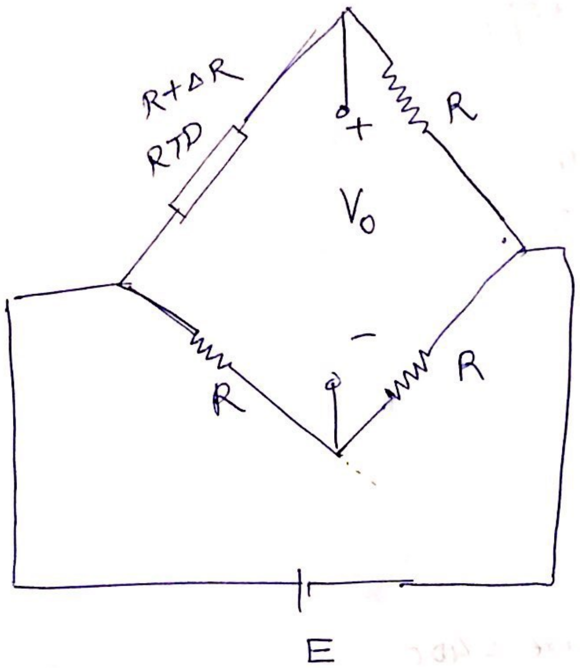
R_{RTD} at $0^\circ c$ $= 100\Omega$ [Because bridge is balanced]

At room temperature the bridge is unbalanced because of change in RTD resistance.

[illegible]

[illegible]

[illegible]



$$V_0 = V_A - V_B$$

$$= \frac{(R+\Delta R)}{(R+\Delta R)+R} E - \frac{R}{R+R} E$$

$$= \left[\frac{R+\Delta R}{2R+\Delta R} - \frac{1}{2}\right] E$$

$$= \left[\frac{\cancel{2R}+2\Delta R - \cancel{2R}-\Delta R}{2(2R+\Delta R)}\right] E$$

$$\boxed{V_0 = \frac{\Delta R}{4R+2\Delta R} * E}$$

$$0.2 = \frac{\Delta R}{4*100+2\Delta R} * 5.4$$

$$80 + .4\Delta R = 5.4\Delta R$$

$$5\Delta R = 80$$

$$\therefore \boxed{\Delta R = 16\,\Omega}$$

Sensitivity of RTD $= 0.4\Omega/°C$

$$\frac{0.4\Omega}{°C} = \frac{16\Omega}{x}$$

$$\therefore x = \frac{16}{0.4}$$

$$x = 40°C$$

$\therefore$ Room temperature $= 40°C$ Ans

case (ii)

$$V_0 = V_A - V_B$$

$$= \frac{R}{R+R+\Delta R} E - \frac{R}{R+R} E$$

$$= \frac{R}{2R+\Delta R} E - \frac{1}{2} E$$

$$= \left[\frac{R}{2R+\Delta R} - \frac{1}{2}\right] E$$

$$= \frac{2R - 2R - \Delta R}{2(2R+\Delta R)} E$$

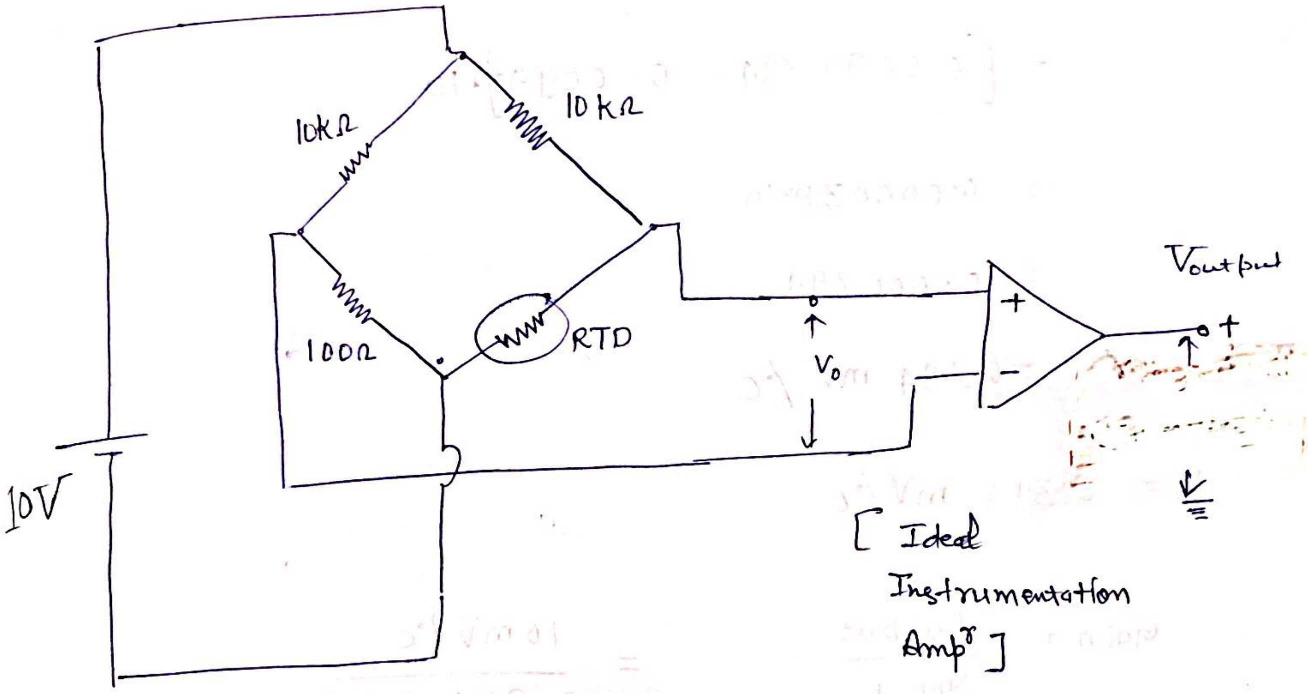
$$\boxed{V_0 = \frac{-\Delta R}{4R+2\Delta R} E}$$

$$\boxed{|V_0| = \frac{\Delta R}{4R+2\Delta R} * E} \quad \text{——— (2)}$$

From this expression we can continue to solve the value of ΔR.

Q: The temperature measurement system using RTD is shown below. Resistance of RTD at 0°C is 100Ω and temperature coefficient of resistance $\alpha = 0.00392\ /°C$.

Find the differential gain of amplifier to achieve the voltage sensitivity of $10\ mV/°C$ at 0°C.



[Ideal Instrumentation Ampr]

Solⁿ →

Let $\Delta t = 1°C$

$0°C \longrightarrow 1°C$

$$R_{T_2} = R_{T_1}\left[1 + \alpha\,(T_2 - T_1)\right]$$

$$= 100\left[1 + 0.00392\,(1°C - 0°C)\right]$$

$$= 100\left[1 + .00392\right]$$

$$= 100 * 1.00392$$

$$\boxed{R_{T_2} = 100.392}\ \Omega$$

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$$V_o = \left[\frac{R_{RTD}}{R_{RTD} + 10{,}000} - \frac{100}{100 + 10{,}000}\right] 10$$

$$= \left[\frac{100.392}{100.392 + 10{,}000} - \frac{100}{100 + 10{,}000}\right] 10$$

$$= \left[\frac{100.392}{10100.392} - \frac{100}{10{,}100}\right] 10$$

$$= [0.0099394 - 0.00990] * 10$$

$$= 0.0000394 \times 10$$

$$= 0.000394$$

$$= 0.394 \text{ mV}$$

$$V_o = 0.394 \text{ mV}/°C$$

$$\text{Gain} = \frac{\text{Output}}{\text{Input}} = \frac{10 \text{ mV}/°C}{0.394 \text{ mV}/°C}$$

$$= \frac{10}{0.394}$$

$$\boxed{\text{Gain} = 25.38}$$

Ans

Q: The table provides the thermo-emf sensitivity of five materials with reference to platinum around 273K.

Material	constantan	Nickel	Copper	Iron	Nichrome
Sensitivity ($\mu V/K$)	-35	-25	$+6$	$+18.5$	$+25$

(a) Find out the sensitivity of (i) platinum - constantan, (ii) Nichrome - constantan (iii) Nickel - constantan (iv) Copper - Nickel, thermocouple pair around 273K.

Note
$E = \alpha \Delta T$
if $\Delta T = 1K$.
then $E = \alpha$
Here with this way we are writing answer in emf form.

Soln:- (i) $E_{AC} = E_{AB} + E_{BC}$

$E_{Platinum-Constantan} = -E_{Constantan-Platinum}$

$= -[-35]$

$= +35$ (unit μV)

(ii) Nichrome - constantan

$E_{Nichrome-constantan} = E_{Nichrome-platinum} + E_{Platinum-constantan}$

$= +25 + (+35) = 60$

or $= E_{Nichrome-Platinum} - E_{Constantan-platinum}$

$= (+25) - (-35)$

$= 25 + 35$

$= +60$ (unit μV)

(iii) Nickel – constantan

$E_{Nickel-constantan} = E_{Nickel-Platinum} + E_{Platinum-Constantan}$

$= E_{Nickel-Platinum} - E_{Constantan-Platinum}$

$= (-25) - (-35)$

$= -25 + 35$

$= +10$ (unit μV)

(iv) Copper – Nickel

$E_{Copper-Nickel} = E_{Copper-Platinum} + E_{Platinum-Nickel}$

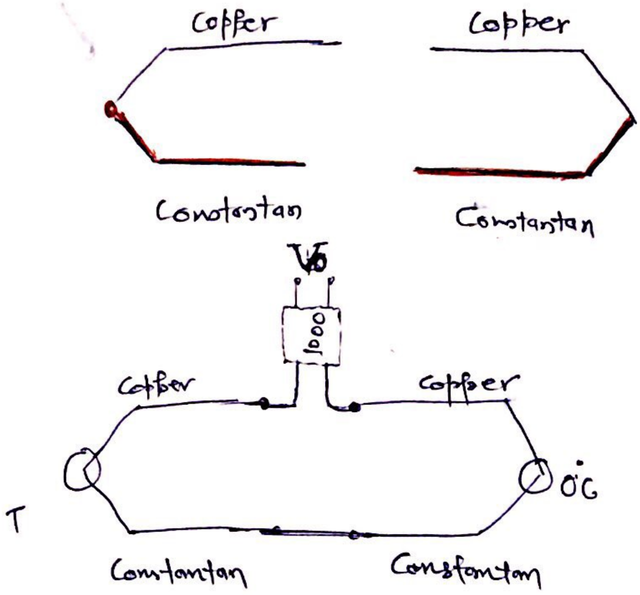
$= E_{Copper-Platinum} - E_{Nickel-platinum}$

$= (+6) - (-25)$

$= +6 + 25$

$= +31$ (unit μV)

(8) Two copper – constantan thermocouples are connected such that two constantan wires are joined together. The two copper wires are connected to the input of a low noise chopper stabilized differential amplifier having gain of 1000. One of the thermocouple junctions is immersed in a flask containing ice and water in equal proportion. The other thermocouple junction is at a temperature T. If the output of the amplifier is 2.050 V, then find out the temperature T.



$V_0 = 2.050$ Volt

output of thermocouple :.

$$Emf = \alpha \left(T_{hot} - T_{cold}\right)$$

$$\left(\frac{2.050}{1000}\right) = \alpha_{Copper-constantan} \quad (T - 273K)$$

$$\frac{2.050 \times 10^{-3}}{41 \times 10^{-6}} = T - 273K$$

$$\frac{2050}{41} = T - 273K$$

$$50 = T - 273K$$

$$T = 50 + 273K$$

$T = 323K$ } Ans

or $T = 50°C$ } Ans

$T_{cold} = 0°C$

$T_{cold} = 0 + 273K$

$T_{cold} = 273K$

Because sensitivity is given $\mu V/K$ therefore Thot and Tcold should be in K.

$\alpha_{copper-Constantan}$

$= +6 - (-35)$

$= 6 + 35 = 41 \frac{\mu V}{K}$