Marwari College Darbhanga

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Kelvin's scale of temperature

In the investigation and measurement of temperature all scales pepend upon the properties of a particular substance.
eg :- Expansion of mercury with rise of temperature.
The nature of the substance and the property used for finding the temperature influence the value of temperature measured.
So the temperature measured are arbitrary and show a remarkable degree of disagreement.

Lord kelvin, from a study of the efficiency of a reversible heat engine and application of Second law of thermodynamics, obtained a new temperature scale which is independent of the properties of any particular substance and is, therefore, non-arbitrary. Such a scale is called the absolute, work or kelvin scale or thermodynamic scale of temperature.

The efficiency of all reversible carnot engines, working between the two temperature is a function of those two temperatures alone.

If Q_1 is the quality of heat absorbed at a higher temperature θ_1 and Q_2 is the quantity of heat given out at a lower temperature θ_2.
where θ_1 and θ_2 are the temperature measured on any arbitrary scale the efficiency η Can be written as,

$$\eta = \frac{Q_1 - Q_2}{Q_1} = f(\theta_1, \theta_2)$$

$$\eta = 1 - \frac{Q_2}{Q_1} = f(\theta_1, \theta_2)$$

$$\therefore \quad \frac{Q_1}{Q_2} = F(\theta_1, \theta_2) \quad \text{——} \quad (1)$$

where $F(\theta_1, \theta_2) = \dfrac{1}{1 - f(\theta_1, \theta_2)}$

Similarly if we have another reversible heat engine working between the temperatures θ_2 and θ_3 $(\theta_2 > \theta_3)$, then

$$\frac{Q_2}{Q_3} = F(\theta_2, \theta_3) \quad \text{——} \quad (2)$$

multiplying (1) and (2) we get

$$\frac{Q_1}{Q_3} = F(\theta_1, \theta_2) \times F(\theta_2, \theta_3) \quad \text{——} \quad (3)$$

Now if we have a reversible heat engine, working between the temperature θ_1 and θ_3, such that it absorbs an amount of heat Q_1 at a temperature θ_1 and rejects an amout of heat Q_3 at a temperature θ_3, then

$$\frac{Q_1}{Q_3} = F(\theta_1, \theta_3) \quad \text{——} \quad (4)$$

comparing (3) and (4) we get

$$F(\theta_1, \theta_3) = F(\theta_1, \theta_2) \times F(\theta_2, \theta_3) \quad \text{——} \quad (5)$$

In equation (5) we find that θ_2 is not present on the left-hand side, but is present in both the factors on the right-hand side.

Therefore the form of $F(\theta_1, \theta_3)$ must be given by

$$F(\theta_1, \theta_2) = \frac{\phi(\theta_1)}{\phi(\theta_2)} \quad \text{—— (6)}$$

and

$$F(\theta_2, \theta_3) = \frac{\phi(\theta_2)}{\phi(\theta_3)} \quad \text{—— (7)}$$

where ϕ is another unknown function of θ. multiplying (6) and (7), we get

$$F(\theta_1, \theta_2) \times F(\theta_2, \theta_3) = \frac{\phi(\theta_1)}{\phi(\theta_2)} \times \frac{\phi(\theta_2)}{\phi(\theta_3)}$$

$$= \frac{\phi(\theta_1)}{\phi(\theta_3)} = F(\theta_1, \theta_3)$$

Representing $\phi(\theta)$ by τ, the temperature on the thermodynamic scale, we get:

$$\frac{Q_1}{Q_2} = \frac{\tau_1}{\tau_2}$$

Thus thermodynamic or kelvin scale of temp. is that scale on which any two temperatures are in the same ratio as the quantities of heat absorbed and rejected by Carnot's reversible heat engine operating between these two temperatures.