Prof. Vidya Sagar
Department of Physics
Raja Singh College, Siwan

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Paper-II

Absolute Scale of temperature:-

A temperature scale which is independent of the properties of any particular substance is called an absolute scale of temperature. No scale furnished by any thermometer is absolute because it depends upon the properties of the thermometric substance.

According to Carnot's theorem, the efficiency of a reversible engine is independent of the working substance and depends only on the two temperatures between which it is working. Taking this hint, Lord Kelvin defined a temperature scale which does not depend upon the properties of any particular substance. This is the Kelvin's absolute thermodynamics scale of temperature.

Let a reversible engine take in heat Q_1 from a source at temperature t_1 and give out heat Q_2 to a sink at temperature t_2, where the temperature t_1 and t_2 have been measured on any scale. The efficiency of this engine $e = 1 - \frac{Q_2}{Q_1}$ which depends on t_1 and t_2 only, we may thus write.

$$e = 1 - \frac{Q_2}{Q_1} = f(t_1, t_2)$$

where f is an unknown function. From this, we may also say that Q_1/Q_2 must be a function of t_1 and t_2 only. Thus

$$\frac{Q_1}{Q_2} = f'(t_1, t_2) \quad \text{———} (1)$$

Where f' is some other unknown function.

Similarly, for a reversible engine taking in heat Q_2 at temperature t_2 and giving out heat Q_3 at temperature t_3, we have

$$\frac{Q_2}{Q_3} = f'(t_2, t_3) \quad \text{———} (2)$$

where the function f' remains unchanged.

The heat Q_2 given out by the first engine is taken in by the second. Thus both engines, working together, from a third engine which takes in heat Q_1 at temperature t_1 and gives out heat Q_3 at temperature t_3, where.

$$\frac{Q_1}{Q_3} = f'(t_1, t_3) \quad \text{———} (3)$$

since $\dfrac{Q_1}{Q_2} = \dfrac{Q_1/Q_3}{Q_2/Q_3}$ (from eqn (1), (2), and (3))

$$f'(t_1, t_2) = \frac{f'(t_1, t_3)}{f'(t_2, t_3)} \quad \text{———} (4)$$

This equation does not contain t_3 on the left-hand side. It means that the function f' must be such that t_3 cancells out in the right hand side also. Hence we choose f' in the following form –

$$f'(t_1, t_3) = \frac{\phi(t_1)}{\phi(t_3)}$$

and

$$f'(t_2, t_3) = \frac{\phi(t_2)}{\phi(t_3)}$$

Where ϕ is some other function. If we substitute these values of $f'(t_1, t_3)$ and $f'(t_2, t_3)$ in the right-hand-side of equation (4) we shall have

$$f'(t_1, t_2) = \frac{\phi(t_1)}{\phi(t_2)} \quad \text{———} \quad (5)$$

Now from equation (1) and (5), we get

$$\frac{Q_1}{Q_2} = \frac{\phi(t_1)}{\phi(t_2)}$$

We know that $Q_1 > Q_2$. Hence the function $\phi(t_1) > \phi(t_2)$ when $t_1 > t_2$. It means that the function $\phi(t)$ increases as the temperature rises. Hence it can be used to measure temperatures.

Let us suppose that $\phi(t)$ denotes a temperature θ on a new scale. Then we may write

$$\frac{Q_1}{Q_2} = \frac{\theta_1}{\theta_2}$$

$$\text{or,} \quad \frac{\theta_1}{\theta_2} = \frac{Q_1}{Q_2} \quad \text{———} \quad (6)$$

This equation defines the Kelvin's absolute thermodynamic scale of temperature. That is, the ratio of any two temperatures measured on this absolute scale is equal to the ratio of the quantities of heat taken in and given out by a Carnot's reversible engine working between these temperature. It is dependent of the properties of any particular substance.

In order to complete the difinition of the Kelvin's absolute scale, we assign the arbitary value of 273.16 K to the temperature of the triple point of water.