Dr. Hari Darshan Singh.
Asso Prof.
Deptt. of Physics
S.N.S.R.K.S. College Saharsa.

DP I. Lecture - ⑥

Kelvin's Thermodynamic Scale of Temperature:

The efficiency of reversible Carnot's engine depends only upon the two temperatures between (the source and the sink) which it works and is independent of the properties (nature) of the working substance. Using this property of Carnot's reversible engine which absolutely depends on temperature and nothing else. Lord Kelvin suggested a new scale of temp. known as 'absolute scale of temperature'.

Theory - Let us suppose a reversible engine absorbs heat Q_1 at temp. θ_1 and rejects heat Q_2 at temp. θ_2, measured on any arbitrary scale. Then being the efficiency of the engine a function of these two temperatures

$$\text{or, } \eta = f(\theta_1, \theta_2)$$

, where f is the function of θ_1 and θ_2

But we know,

$$\eta = \frac{Q_1 - Q_2}{Q_1}$$

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

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

or, $\frac{Q_1}{Q_2} = \frac{1}{1 - f(\theta_1, \theta_2}$.

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

Here let, F is some other fn. of θ_1 and θ_2.

Let another Carnot engine be working between a pair of temp. θ_2 and θ_3 where, $\theta_2 > \theta_3$, absorbing a heat Q_2 and rejecting Q_3, we may write

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

If it works between θ_1 and θ_3, where, $\theta_1 > \theta_3$. Then,

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

Multiplying eqn. (1) and (2)

$$\frac{Q_1}{Q_2} \times \frac{Q_2}{Q_3} = F(\theta_1, \theta_2) \times F(\theta_2, \theta_3)$$

or $$\frac{Q_1}{Q_3} = F(\theta_1, \theta_2) \times F(\theta_2, \theta_3).$$

Now, comparing with (3) we get

$$F(\theta_1, \theta_3) = F(\theta_1, \theta_2) \times F(\theta_2, \theta_3) \quad — (4)$$

This is called functional equation.
equation (4) does not contain θ_2 on the left hand side, therefore, function F should be so chosen that θ_2 disappears from the right hand side also. This is possible if.

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

and $$F(\theta_2, \theta_3) = \frac{\phi(\theta_2)}{\phi(\theta_3)}.$$

where ϕ is the another unknown fn. of temp.

From equation (4)

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

$$= \frac{\phi(\theta_1)}{\phi(\theta_3)}.$$

and $\phi(\theta_2) \propto \theta_2$.

We have,

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

or, This equation shows that the ratio of the two temperatures on this scale is equal to the ratio of the heat absorbed to the heat rejected. This new scale of temperature is called the absolute, or the work or the Kelvin's thermodynamic scale of temperature.

Since efficiency $\eta = \frac{Q_1 - Q_2}{Q_1}$

at, $Q_2 = 0$, $\eta = \frac{Q_1}{Q_1} = 1$.

Hence, efficiency of the engine is unity.

Thus the zero of the thermodynamic scale is that temperature of the sink at which no heat is rejected and all the heat taken from the source is converted into useful work. A temperature lower than absolute zero is not possible as