## Quadrant II – Transcript and Related Materials

**Programme** : **Bachelor of Science (First Year)**

**Subject** : **Physics**

**Paper Code** : **PYC 102**

**Paper Title** : **Heat & Thermodynamics and Properties of Matter & Acoustics**

**Unit 4** : **Second Law of Thermodynamics**

**Module Name** : **Thermodynamic scale of temperature & its identity with perfect gas scale**

**Module No** : **22**

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**Notes**

## *Thermodynamic Scale of Temperature:*

It has been proved from Carnot's theorem that the efficiency of a Carnot's reversible engine is independent of the working substance but depends only on the temperature of the source and the sink. Lord Kelvin used this fact to construct the scale of temperature which is called thermodynamic scale or Kelvin scale or absolute scale of temperature. It is called absolute because it does not depend on the properties of any substance.

It is shown in the theory of Carnot's engine that the efficiency is given by;

$$\eta = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} ------------(1)$$

As efficiency is a function of two temperatures only, we may write:

$$\frac{Q_2}{Q_1} = \frac{1}{1-\eta} = f(\theta_1 - \theta_2) ------------(2)$$

Where $\theta_1$ *and* $\theta_2$ are the temperatures measured on any arbitrary scale.

Consider three Carnot's engines working between temperatures; (i) $\theta_1$ and $\theta_2$ (ii) $\theta_2$ and $\theta_3$ (iii) $\theta_1$ and $\theta_3$.

The first one taking heat $Q_1$ at temperatures $\theta_1$ and rejecting heat $Q_2$ at temperature $\theta_2$, the second taking heat $Q_2$ at temperature $\theta_2$ and rejecting heat $Q_3$ at temperature $\theta_3$; and the third taking heat $Q_1$ at temperature $\theta_1$ and rejecting heat $Q_3$ at temperature $\theta_3$.

Using equation (2);

$$\left.\begin{aligned}
\frac{Q_1}{Q_2} &= f(\theta_1,\ \theta_2) ------------(a) \\
\frac{Q_2}{Q_3} &= f(\theta_2,\ \theta_3) ------------(b) \\
\frac{Q_1}{Q_3} &= f(\theta_1,\ \theta_3) ------------(c)
\end{aligned}\right\} ---------(3)$$

It follows from equation (3) that;

$$\frac{Q_1}{Q_3} = \frac{Q_1}{Q_2} \times \frac{Q_2}{Q_3}$$

i.e. $f(\theta_1, \theta_3) = f(\theta_1, \theta_2) \times f(\theta_2, \theta_3)$---------------------------------------------(4)

This is possible only if the function 'f' is of the form;

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

Thus, it follows from equation (2) that;

$$\frac{Q_1}{Q_2} = \frac{F(\theta_1)}{F(\theta_2)} \text{-----------------------} (5)$$

The function F increases with the heat taken in or rejected and can be taken as the measure of temperature. Kelvin called this as absolute temperature $\tau$.

$$\therefore \frac{Q_1}{Q_2} = \frac{F(\theta_1)}{F(\theta_2)} = \frac{\tau_1}{\tau_2} \text{-----------------------} (6)$$

It is shown in the theory of Carnot's engine that:

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2} \text{------------------} (7)$$

Where $T_1$ and $T_2$ were temperatures measured on the ideal gas scale:

From equations (6) and (7), we see that;

$$\frac{\tau_1}{\tau_2} = \frac{T_1}{T_2} \text{------------------} (8)$$

Thus, the thermodynamic scale coincides with the ideal gas scale. From equation (7) we see that $T_2$ approaches zero as $Q_2$ tends to zero, that is the zero of the thermodynamic scale is that at which no heat is rejected to the cold reservoir. However, this is impossible as heat will be extracted only from the hot reservoir and all of it converted into work without affecting any other body which is in violation of the second law of thermodynamics hence it is impossible to produce absolute zero of temperature.