

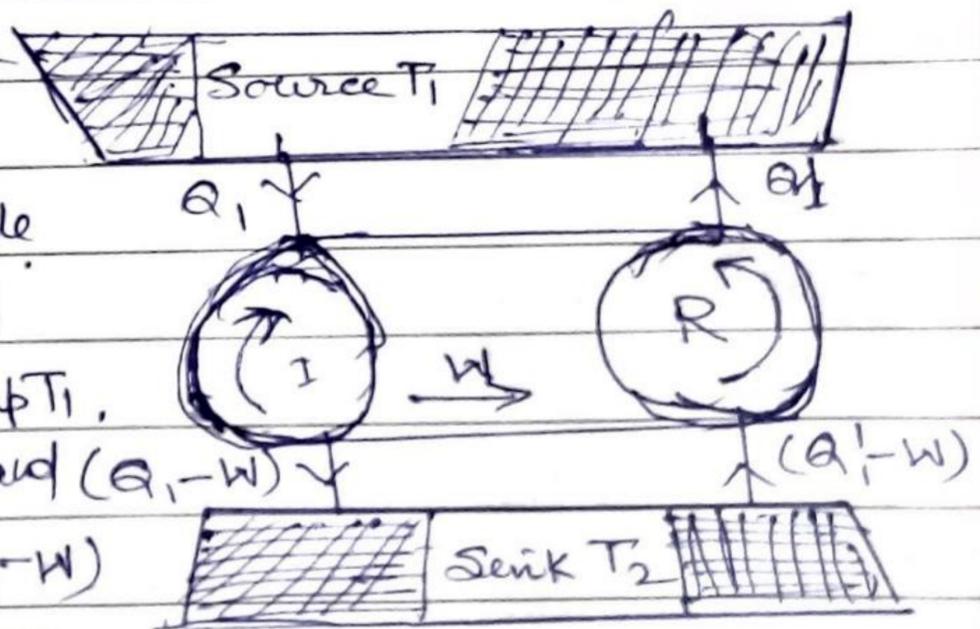
Notes for . . . - By - Dr. Bharat Singh  
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 Paper - 2 . . . Carnot's Theorem.

This theorem consists of two parts and may be stated as follows -

- (i) No engine working between two given temperatures can be more efficient than a reversible (Carnot) engine working between the same limits of temperature.
- (ii) All reversible engines working between the same limits of temperature have the same efficiency, whatever be the working substance.

Proof: - In order to prove the first part of theorem, let us consider two engines I and R working between the same limits of temperature have the same efficiency, whatever be the working substance. And working between the same source and sink. Let I be the ~~irreversible~~ <sup>irreversible</sup> and R be the reversible. Let the quantity of the working substance in the two engines be so adjusted that the work performed by them per cycle is the same. Let the irreversible

engine I absorb an amount of heat  $Q_1$  from the source at temp  $T_1$ , performed an external work  $W$  and  $(Q_1 - W)$  reject a quantity of heat  $(Q_1 - W)$  to the sink at temperature  $T_2$ .



Its efficiency  $\eta_1$  is then equal to  $W/Q_1$ . Similarly if the reversible engine R absorbs heat  $Q_1'$  from the source, does an external work  $W$  and rejects  $(Q_1' - W)$  heat to the

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→ Sink, then its efficiency  $\eta_R$  is equal to  $W/Q_1'$ . Suppose that irreversible engine I is more efficient than reversible engine R i.e.

$$\eta_I > \eta_R$$
$$\text{or, } \frac{W}{Q_1} > \frac{W}{Q_1'} \quad \text{or } Q_1' > Q_1$$

Thus  $(Q_1' - Q_1)$  is a positive quantity.

Now suppose that the two engines I and R are coupled together by a belt in such a way that as engine I works directly, engine R now works as a refrigerator driven by I, extracts heat  $(Q_1' - W)$  from the sink at temperature  $T_2$ , requires work  $W$  to be done upon it and gives out heat  $Q_1'$  to the source at temperature  $T_1$ . The work  $W$  required to be done on R is directly supplied by I, working directly and in this way the engine I and refrigerator R coupled together form a self acting device. The source now loses  $Q_1$  heat to I and gains  $Q_1'$  from R.  $\therefore$  Heat gained by the source =  $Q_1' - Q_1$ . The sink gains  $(Q_1 - W)$  heat from I and loses  $(Q_1' - W)$  to R.  $\therefore$  Heat loss by the sink =  $(Q_1' - W) - (Q_1 - W) = Q_1' - Q_1$  which is a +ve quantity.

Thus, a reversible Carnot engine operating between a given source and sink has maximum efficiency.

In order to prove the second part of the theorem, we imagine two reversible engines R and R' working between the same source and sink. Thus efficiency of all reversible engines, working between the same two temperatures, is the same irrespective of the nature and properties of the working substance. i.e. the efficiency of a perfectly reversible engine is independent of the nature of the working substance.