Thermodynamics
Professor Anand T N C
Department of Mechanical Engineering
Indian Institute of Technology, Madras
Lecture 66
Tutorial Problems (1 numbers)

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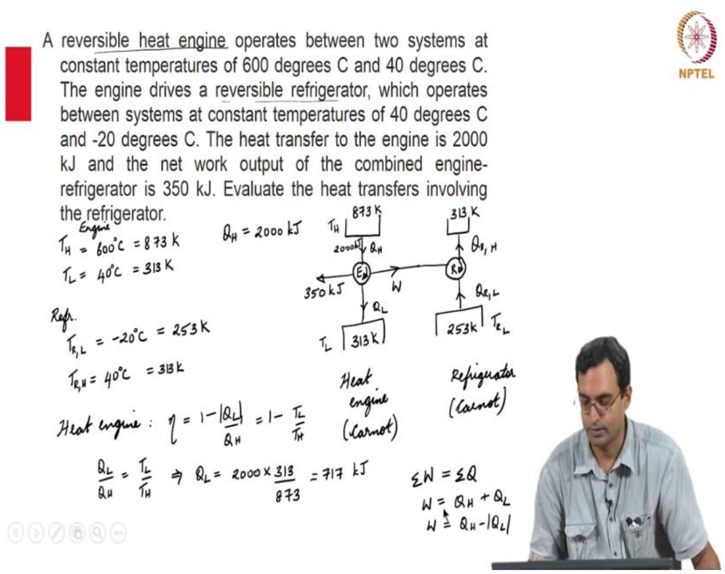
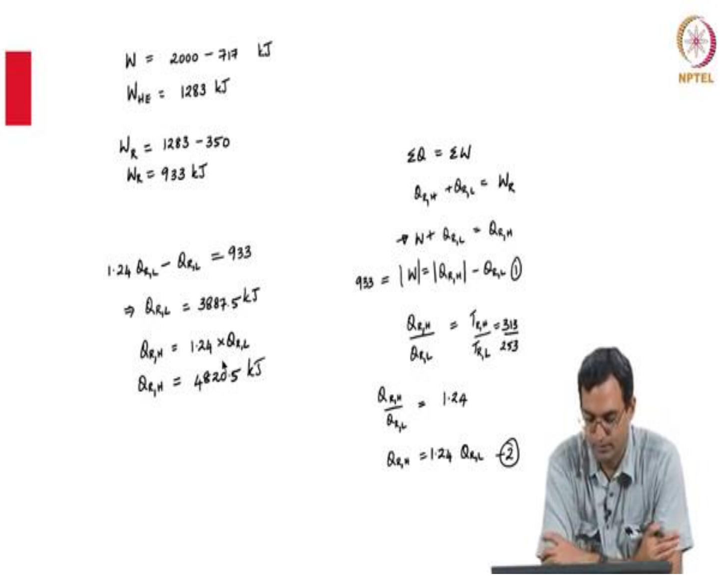


Figure 1.



Solution of the problem in Fig. 1:

For the reversible heat engine,

$T_H = 600\ ℃ = 873\ K, T_L = 40\ ℃ = 313\ K, Q_H = 2000\ kJ$

For the reversible refrigerator,

$T_{R,H} = 40\ ℃ = 313\ K, T_{R,L} = -20\ ℃ = 253\ K$

The schematic of the entire of system is drawn in Fig. 1.

Since the heat engine is reversible,

$$\frac{Q_L}{Q_H} = \frac{T_L}{T_H} \quad \rightarrow \quad Q_L = 717\ kJ$$

According to the first law for the heat engine,

$W_{HE} = Q_H - |Q_L| = 2000 - 717 = 1283\ kJ$ = net work output of the heat engine alone (positive for the engine).

Out of this net work output W_{HE}, some is used to run the refrigerator. The net work output of the combined heat engine-refrigerator system is 350 kJ.

Hence, the work input to the refrigerator is $W_R = W_{HE} - 350 = 933\ kJ$ (this is negative for the refrigerator).

Now, we know the work input to the refrigerator. According to the first law for the reversible refrigerator,

$$W_R + Q_{R,L} = Q_{R,H} \quad \rightarrow \quad |W_R| = |Q_{R,H}| - Q_{R,L} \text{....(1)}$$

Since the refrigerator is reversible,

$$\frac{Q_{R,H}}{Q_{R,L}} = \frac{T_{R,H}}{T_{R,L}} = 1.24 \quad \rightarrow \quad Q_{R,H} = 1.24\ Q_{R,L}$$

Now, equation (1) implies $933 = 1.24\ Q_{R,L} - Q_{R,L} = 0.24\ Q_{R,L} \quad \rightarrow \quad Q_{R,L} = 3887.5\ kJ$ and $Q_{R,H} = 4820.5\ kJ$