

Thermodynamics
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Lecture 65
Tutorial Problems (2 numbers)

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An engine works on a Carnot cycle. It rejects 30 % of the heat it absorbed from the source. The sink is at 25 degrees C. Calculate the source temperature.

$Q_L = 30\% Q_H = 0.3 Q_H$
 $T_L = 25^\circ\text{C} = 298\text{ K}$
 $T_H = ?$

Carnot engine

$$\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$$

$$\frac{0.3}{1} = \frac{298}{T_H} \Rightarrow T_H = \frac{298}{0.3} = 993.3\text{ K}$$

$$\eta = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{Q_L}{Q_H} = 1 - 0.3 = 0.7$$

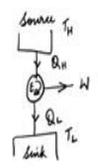






Figure 1.

Solution of the problem in Fig. 1:

$$Q_L = 0.3 Q_H, T_L = 25^\circ\text{C} = 298\text{ K}, T_H = ?$$

A schematic of the engine is shown in Fig. 1.

Since the engine runs on the Carnot's cycle,

$$\frac{Q_L}{Q_H} = \frac{T_L}{T_H} \rightarrow T_H = 993.3\text{ K}$$

$$\eta = 1 - \frac{Q_L}{Q_H} = 1 - 0.3 = 0.7$$

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A heat engine operates between a hot reservoir at 500 K and a cold reservoir at 300 K. It absorbs 3500 J and rejects 2500 J of heat. Calculate the work done, efficiency and the maximum possible efficiency.

Heat engine

$T_H = 500 \text{ K}$
 $T_L = 300 \text{ K}$
 $Q_H = 3500 \text{ J}$
 $Q_L = 2500 \text{ J}$

$W = ?$
 $\eta = ?$
 $\eta_{\text{max}} = ?$

First law for the engine $\oint \delta Q = \oint \delta W$

$W = Q_H - |Q_L|$
 $= 3500 - 2500$
 $W = 1000 \text{ J}$

$\eta = \frac{W}{Q_H} = \frac{Q_H - |Q_L|}{Q_H} = 1 - \frac{|Q_L|}{Q_H}$
 $\eta = \frac{1000}{3500} = 28.6\%$

$\oint \delta Q = \oint \delta W$
 $\sum Q = \sum W$
 $Q_H - |Q_L| = W$

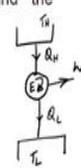



Figure 2.

Solution of the problem in Fig. 2:

$T_H = 500 \text{ K}, T_L = 300 \text{ K}, Q_H = 3500 \text{ J}, Q_L = 2500 \text{ J}$

The first law for a heat engine, $\oint \delta Q = \oint \delta W$.

Hence, $W = Q_H - |Q_L| = 3500 - 2500 = 1000 \text{ J}$

max. possible $\eta \rightarrow \eta_{\text{Carnot engine}}$

$\eta = \frac{W}{Q_H} = \frac{Q_H - |Q_L|}{Q_H}$
 $\eta = 1 - \frac{|Q_L|}{Q_H}$
 $\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$
 $\eta_{\text{Carnot}} = 1 - \frac{T_L}{T_H}$
 $= 1 - \frac{300 \text{ K}}{500 \text{ K}} = 0.4 = 40\%$

$\sum W = \sum Q$
 $W = Q_H + Q_L$




$\eta_{\text{actual}} = 1 - \frac{|Q_L|}{Q_H} = \frac{W}{Q_H} = \frac{1000}{3500} = 28.6\%$

Out of all the engines operating between the given temperature sources, the Carnot's engine or a reversible engine has the maximum efficiency. For the Carnot's engine,

$$\eta_{Carnot} = 1 - \frac{Q_L}{Q_H} = 1 - \frac{T_L}{T_H} = 0.4 = 40 \%$$

$$\eta_{actual} < \eta_{Carnot}.$$