Physics 467/667: Thermal Physics	**Spring 2019**

Lecture 14: Engines and Refrigerators

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14.1 Real Heat Engines

In the previous lecture, we have learned the theoretical limit of heat engines. It is useful to know the upper limit when we design an engine. However, one might also ask how it work in reality. Can we follow the Carnot cycle in practice?

Now, let's discuss a few of the engines used in the real world.

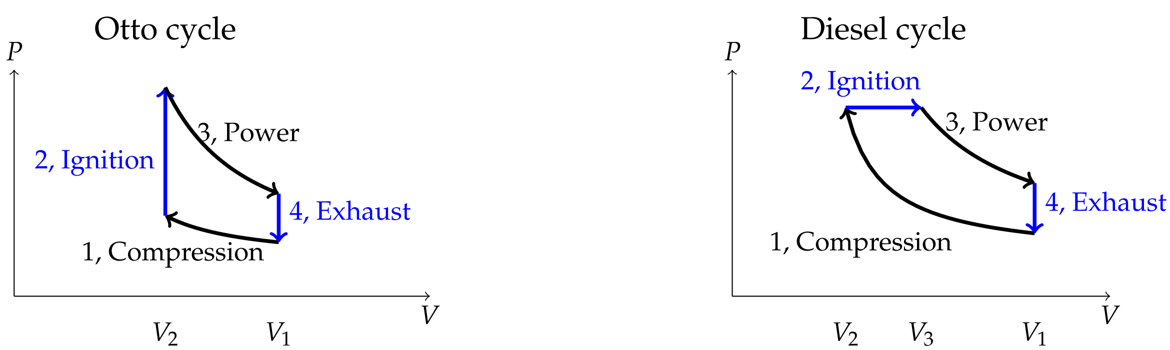

Figure 14.1: The Otto cycle and Diesel cycle.

Recalling what we learned about P-V diagrams in compression work, we can trivially derive the efficiency as a function of V

$$PV^\gamma = \text{const} \quad \rightarrow \quad e = 1 - (\frac{V_2}{V_1})^{\gamma-1} = 1 - \frac{T_1}{T_2} = 1 - \frac{T_3}{T_4} \qquad \text{(Otto cycle)} \tag{14.1}$$

$$PV = \text{const} \quad \rightarrow \quad e = 1 - \frac{V_2}{V_1} \qquad \text{(Diesel cycle)} \tag{14.2}$$

Discussion on Stirling Engines

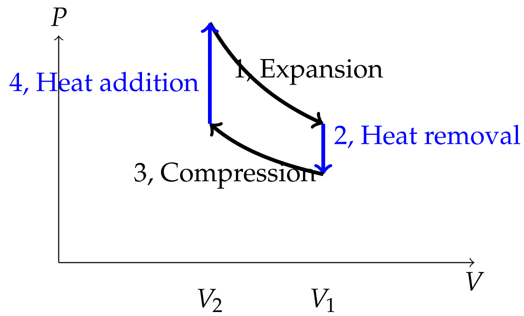

Figure 14.2: The idealized Stirling cycle.

14.2 Steam Engines and Real Refrigerators

A very different type of engine is the steam engine, in which the liquid water/steam is used as the work substance. It works as follows,

1. water is pumped to high pressure at nearly constant volume;
2. water flows into a boiler at constant pressure, then becomes steam;
3. steam hits the turbine, where it expands adiabatically, cools, the ends up at the original pressure;
4. the fluid is cooled further to become water.

On the other hand, a refrigerator works as follows,

1. gas is compressed to adiabatically;
2. gives up heat and become liquid at constant pressure;
3. passes through a throttling valve to
4. absorbs heat and turns back to a gas in the evaporator

$$e = 1 - \frac{Q_c}{Q_h} = 1 - \frac{H_4 - H_1}{H_3 - H_2} = 1 - \frac{H_4 - H_1}{H_3 - H_1} \tag{14.3}$$

$$\mathrm{COP} = \frac{Q_c}{Q_h - Q_c} = \frac{H_1 - H_4}{H_2 - H_3 - H_1 + H_4} \tag{14.4}$$

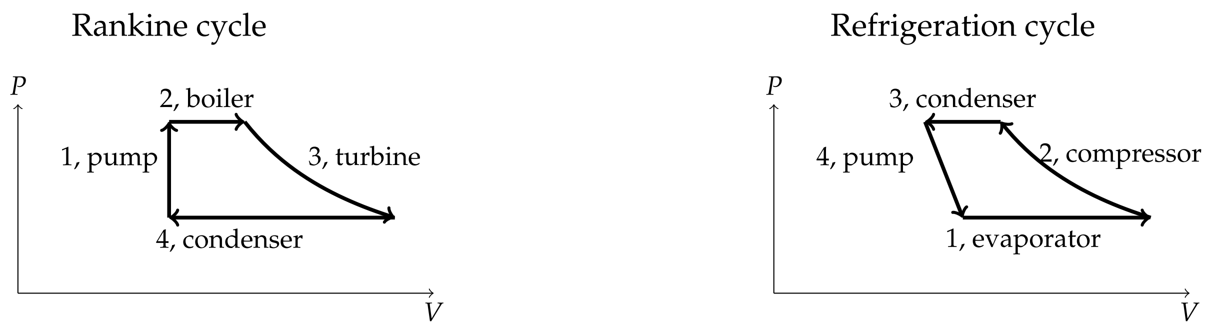

Figure 14.3: The Rankine cycle and Refrigeration cycle.

14.3 Homework

Problem 4.18, 4.21, 4.26, 4.27, 4.36