

# Thermodynamics of Energy Conversion

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## EXERCISES 5

**1) What gas should be used and how should the Stirling engine be constructed in order to optimize the efficiency?**

The smaller the term  $c_v / (R \cdot \ln(V_2/V_1))$  the larger the efficiency. Therefore, a monoatomic gas (He) and  $V_2$  as large as possible compared to  $V_1$ .

**2) What reduces the efficiency of a real Otto engine as compared to the calculated efficiency?**

*Temperature of the exhaust gas is higher than in the calculated cycle and the compression is limited due to self ignition.*

**3) The efficiency of the Diesel engine depends on the ratio  $V_1/V_4$  and the ratio  $V_2/V_1$ . Calculate how the efficiency is maximized?**

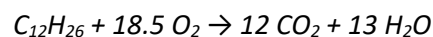
*By maximizing the compression ( $V_4/V_1$ ) up to 22 and minimize the injection ( $V_2/V_1$ ). Technically, minimize the weight of the piston and the valves.*

**4) Calculate the temperature increase in the adiabatic compression of a diesel engine (1:22) and compare it with the autoignition temperature of 600 F = 315°C.**

$$(T/T_0) = (p/p_0)^{R/(c_v+R)}$$
$$(T/T_0) = 22^{1/(3.5)} = 2.42$$
$$T = T_0 \cdot 2.42 = 293 \cdot 2.42 = 709 \text{ K}$$

The temperature is high enough for auto ignition.

**5) Calculate the adiabatic temperature of the combustion of diesel ( $C_{12}H_{26}$ ).**



$$\Delta H_R = c_p \Delta T$$

$$12\Delta H_f(CO_2) + 13\Delta H_f(H_2O, g) - \Delta H_f(C_{12}H_{26}) - 18.5\Delta H_f(O_2) = 12[c_p(CO_2) \cdot \Delta T + 13c_p(H_2O)] \cdot \Delta T$$

$$\Delta H_R = 13 \cdot (-241.8) + 12 \cdot (-393.51) - 1 \cdot (-291) = -7574.5 \text{ kJ}$$

*heat capacity of products in oxygen:*

$$c_p = 13 \cdot 34 + 12 \cdot 37 = 886 \text{ J/K}$$

$$\Delta T = \Delta H_R / c_p = 7574.5 / 886 = 8549 \text{ K}$$

*combustion in air (with nitrogen):*

$$c_p(N_2) = 74 \cdot 29 = 2146 \text{ J/K}$$

$$\Delta T = \Delta H_R / c_p = 7574.5 / (886 + 2146) = 2498 \text{ K}$$