Sample Problem:

A four-cylinder, 2.5 liter, SI automobile engine operates at WOT on a four-stroke air-standard Otto cycle at 3,000 RPM. The engine has a compression ratio of 8.6:1, a mechanical efficiency of 86%, and a stroke-to-bore ratio S/B = 1.025. Fuel is isooctane with AF = 15, a heating value of 44,300 kJ/kg, and combustion efficiency of 100%. At the start of the compression stroke, conditions in the cylinder combustion chamber are 100 kPa and 60 °C. It can be assumed that there is a 4% exhaust residual leftover from the previous cycle.

Find the following:

a. Volume Clearance
b. Bore and Stroke Value
c. Mass of Air, Fuel, and Exhaust
d. Peak Temperature and Peak Pressure
e. Net Work
f. Thermal Efficiency

Given:

$$V_{TD} = 2.5\ liter$$
$$n = 4$$
$$N = 3,000\ RPM$$
$$r_k = 8.6$$
$$\eta_m = 86\%$$
$$\frac{S}{B} = 1.025$$
$$AF = 15$$
$$Q_{HV} = 44,300\ \frac{kJ}{kg}$$
$$\eta_c = 100\%$$
$$P_1 = 100\ kPa$$
$$T_1 = 60\ ℃ + 273.15 = 333.15\ K$$
$$\%\ exhaust = 4\%$$

Solution:

a. Volume Clearance

$$V_{TD} = 2.5\ liter = 0.0025\ m^3$$
$$V_D = \frac{V_{TD}}{n} = \frac{0.0025\ m^3}{4}$$
$$V_D = 0.000625\ m^3$$

$$V_D = V_1 - V_C$$
$$V_1 = V_D + V_C$$
$$V_2 = V_C$$
$$r_k = \frac{V_1}{V_2}$$
$$r_k = \frac{V_D + V_C}{V_C}$$
$$r_k = \frac{V_D}{V_C} + 1$$
$$V_C = \frac{V_D}{r_k - 1} = \frac{0.000625\ m^3}{8.6 - 1}$$
$$V_C = 0.00008223684\ m^3$$

b. Bore and Stroke Value

$$\frac{S}{B} = 1.025$$
$$S = 1.025B$$
$$V_D = \frac{\;}{4} B^2 S = \frac{\;}{4} B^2 (1.025B)$$
$$B = \sqrt[3]{\frac{4(V_D)}{1.025}} = \sqrt[3]{\frac{4(0.000625\ m^3)}{1.025}}$$
$$B = 0.0919084461\ m$$
$$S = 1.025\ (0.0919084461\ m)$$
$$S = 0.09420615725\ m$$

c. Mass of Air, Fuel, and Exhaust Residual

$$V_1 = V_D + V_C = 0.000625\ m^3 + 0.00008223684\ m^3$$
$$V_1 = 0.000707236842105263157894 7\ m^3 \text{ -- A}$$

$$P_1 V_1 = mRT_1$$
$$m = \frac{P_1 V_1}{RT_1}$$
$$m = \frac{100\ kPa(0.000707237\ m^3)}{0.287\ \frac{kJ}{kg\text{-K}}(333.15\ \text{K})}$$
$$m = 0.00073967878\ kg$$

$$\eta_t = 1 - \frac{333.15 \text{ K}}{706.83149097084 \text{ K}}$$

$$\eta_t = 0.52867125439$$

$$\eta_t = 52.867125439\ \%$$

When in doubt again

$$\eta_t = 1 - \frac{1}{(r_k)^{k-1}}$$

$$\eta_t = 1 - \frac{1}{(8.6)^{1.34957369062-1}}$$

$$\eta_t = 0.52867125439$$

$$\eta_t = 52.867125439\ \%$$