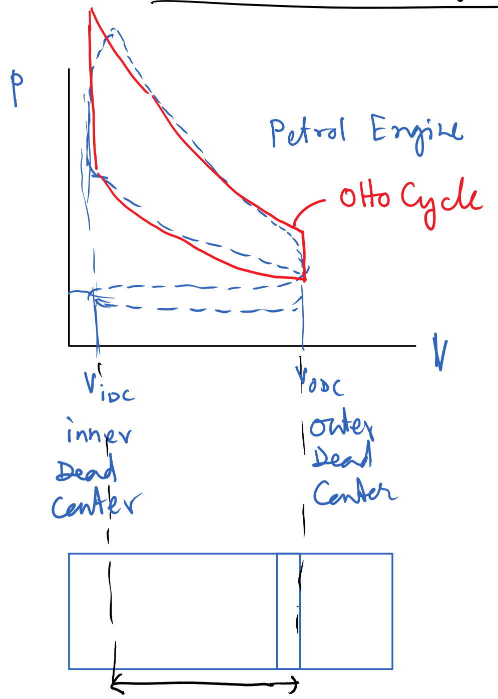
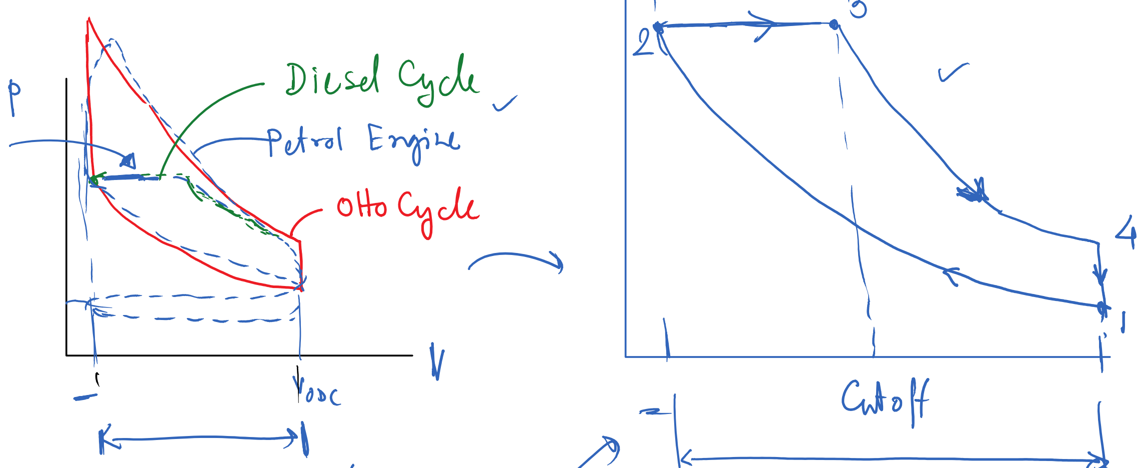
Air Standard Cycles → Representing idealized cycles for

1) IC Engines
(Internal Combustion Engines)
Reciprocating internal combustion Engines

- → Petrol/Gasolene Engine
- → Diesel "



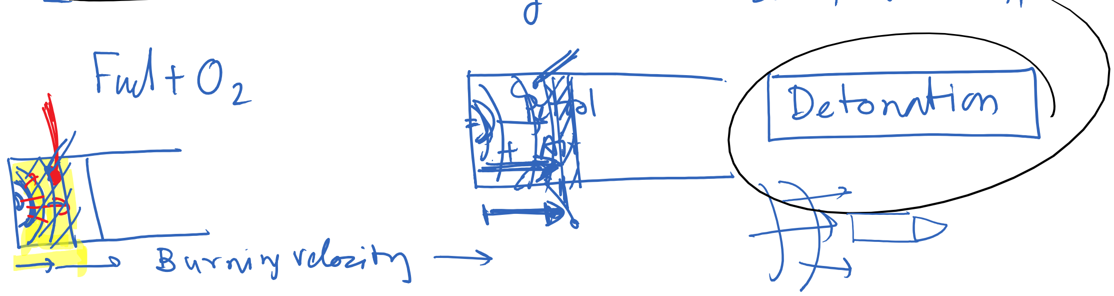


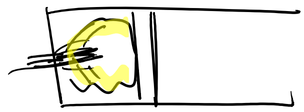
$r = V_{ODC} / V_{IDC}$

Features of Petrol & Diesel

- Petrol Has a high Ignition temp & high ignition delay
- Diesel has a low Ignition " & low "

Fuel + O_2



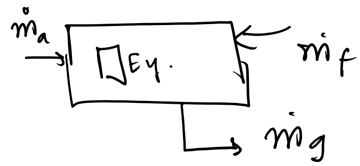


$\boxed{\text{Knocking}}$

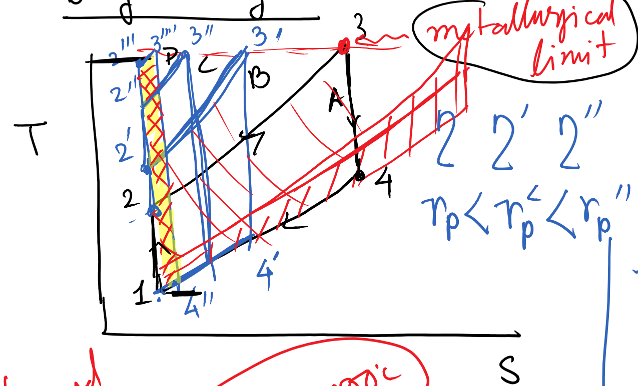
Four-stroke reciprocating IC Engines

Steady flow devices

$\boxed{60\ km/h}$



Brayton Cycle



$$W_{net} = \oint p\,dv = \oint \delta q$$

$$W_{net} = q_{in} - q_{out}$$
$$= C_p(T_3 - T_2) - C_p(T_4 - T_1)$$

2 2' 2''

$r_p < r_p' < r_p''$

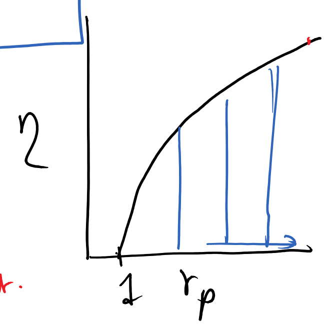
$$\boxed{\eta = 1 - \frac{1}{r_p^{(\gamma-1)/\gamma}}}$$

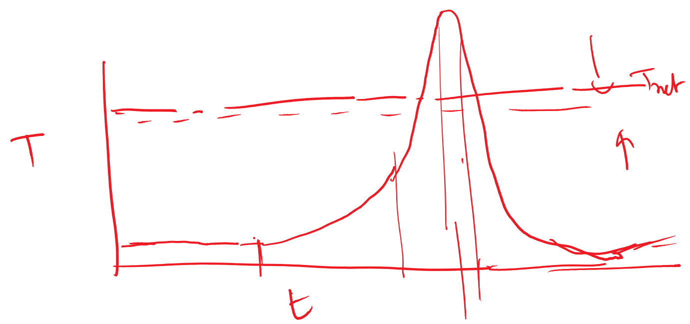
Petrol/Diesel Engine problems

$T_{max} \rightarrow$ 1800°c, 2000°c

(Short lived)

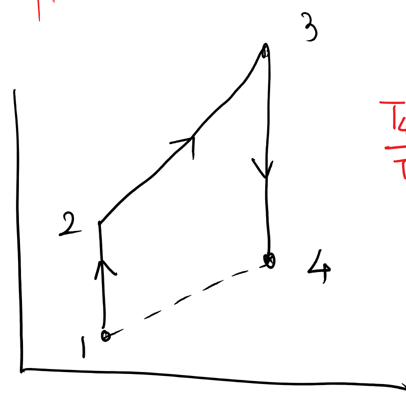
$r_p = 1$, $\eta = 0$





Net work done

$$\dot{W}_{net} = \dot{m}\left[(h_3 - h_4) - (h_2 - h_1)\right]$$
$$= \dot{m}C_p\left[T_3 - T_4 - T_2 + T_1\right]$$
$$= \dot{m}C_pT_1\left[\frac{T_3}{} - \frac{T_4}{} - \frac{T_2}{} + 1\right]$$



$$\frac{T_4}{T_3} = \frac{T_1}{T_2} = \frac{1}{C}$$

$$= \dot m C_p T_1 \left[\frac{T_3}{T_1} - \frac{T_4}{T_1} - \frac{T_2}{T_1} + 1\right]$$

Non-dimensional work

$$\frac{\dot W}{\dot m C_p T_1} = \left[T_3/T_1 - \frac{T_4}{T_3}\times\frac{T_3}{T_1} - \frac{T_2}{T_1} + 1\right]$$

$$c = r_p^{\frac{\gamma-1}{\gamma}}$$

$$= \left(t - \frac{1}{c}\times t - c + 1\right)$$

$$w = (t - t/c - c + 1)$$

$$\frac{dw}{dc} = +\frac{t}{c^2} - 1$$

$$\frac{d^2w}{dc^2} = -\frac{2t}{c^3} \Rightarrow w \text{ is max for } t = c^2$$

$$\text{or } c = \sqrt{t} \Rightarrow \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} = t^{1/2}$$

$$\text{or } \boxed{p_2/p_1 = \left(T_3/T_1\right)^{\frac{\gamma}{2(\gamma-1)}}}$$

EXAMPLE 9–5 **The Simple Ideal Brayton Cycle**

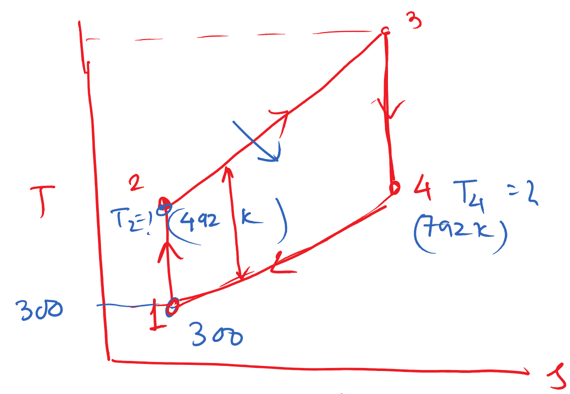
A gas-turbine power plant operating on an ideal Brayton cycle has a pressure ratio of 8. The gas temperature is 300 K at the compressor inlet and 1300 K at the turbine inlet. Utilizing the air-standard assumptions, determine (*a*) the gas temperature at the exits of the compressor and the turbine, (*b*) the back work ratio, and (*c*) the thermal efficiency.

Solution A power plant operating on the ideal Brayton cycle is considered. The compressor and turbine exit temperatures, back work ratio, and the thermal efficiency are to be determined.

Assumptions **1** Steady operating conditions exist. **2** The air-standard assumptions are applicable. **3** Kinetic and potential energy changes are negligible. **4** The variation of specific heats with temperature is to be considered.

Analysis The *T-s* diagram of the ideal Brayton cycle described is shown in Fig. 9–35. We note that the components involved in the Brayton cycle are steady-flow devices.

(*a*) The air temperatures at the compressor and turbine exits are determined from isentropic relations:



$$r_p = p_2/p_1 = p_3/p_4 = 8$$

Adiabatic pre. 1-2

$$T_2/T_1 = \left(p_2/p_1\right)^{\frac{\gamma-1}{\gamma}} = 8^{\frac{1.4-1}{1.4}} = 1.81$$

$$T_2 = 543$$

$$W_{compr.} = 1\times C_p \times (T_2 - T_1)$$
$$= 1\times 1.004(543 - 300)$$
$$= 244 \text{ kJ}$$

$$\frac{T_3}{T_4} = \left(\frac{p_3}{p_4}\right)^{\frac{\gamma-1}{\gamma}} = 1.81$$

$$W_{turbin} = 1\times C_p(1300 - 718)$$

$= 244 \text{ kJ}$

$$w_{turbine} = 1 \times C_p (1300 - 718) = 584.3$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\gamma} = 1.81$$

$$T_4 = T_3 / 1.641 = 718.23$$

$$W_{net} = 340 \text{ kJ}$$

$$\eta = \frac{W_{net}}{Q_{in}} = \frac{340}{757} = 44.9\,\%$$

$$Q_{in} = 1 \times C_p \times (T_3 - T_2) = 1 \times C_p \times (1300 - 543) = 757 \text{ kJ}$$

$$\eta = 1 - \frac{1}{r_p^{\frac{\gamma-1}{\gamma}}} = 1 - \frac{1}{8^{\frac{\gamma-1}{\gamma}}} = 1 - \frac{1}{1.181} = 44.7\%$$

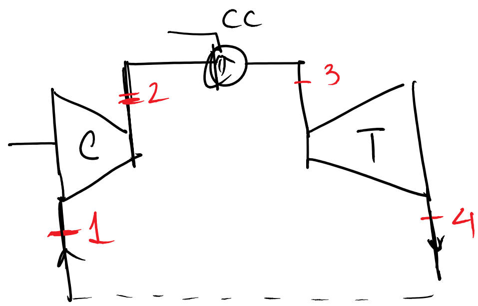
kJ

9.29 Air enters the compressor of an ideal air-standard Brayton cycle at 100 kPa, 300 K, with a volumetric flow rate of 5 m^3/s. The turbine inlet temperature is 1400 K. For compressor pressure ratios ranging from 2 to 20, plot → 10

(a) the thermal efficiency of the cycle. →

(b) the back work ratio.

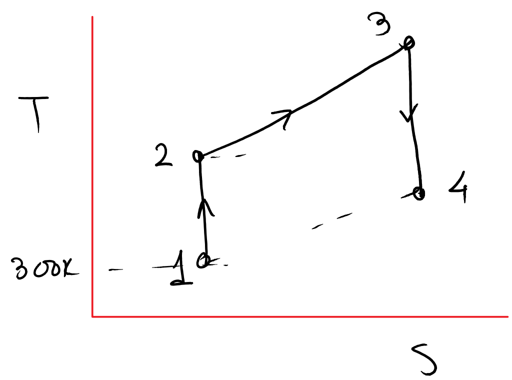
(c) the net power developed, in kW.



$$\dot{V} = 5\, m^3/s$$

$$\Rightarrow \dot{m} = \frac{\dot{V}}{v} \left[\frac{(m^3/s)}{(m^3/kg)} = \left(\frac{kg}{s}\right) \right]$$

$$= 5.8 \text{ kg/s}$$



$$\eta = 1 - \frac{1}{r_p^{\frac{\gamma-1}{\gamma}}} =$$

$$p_1 v_1 = R T_1$$

$$\Rightarrow v_1 = R T_1 / p_1 = \frac{0.287 \times 300}{100} = 0.861 \, m^3/kg$$

$$\dot{Q} = \dot{m}\, C_p (T_3 - T_2) = 5.8 \times 1.004 \times (1400 - 579.3) = 4780 \text{ kW}$$

[If Calorific value of the fuel is 10,000 kJ/kg find the fuel flow rate for the GT plant]

$$\dot{m}_{fuel} = \frac{\dot{Q}}{\quad} = \frac{4780}{\quad} \text{ kg/s}$$

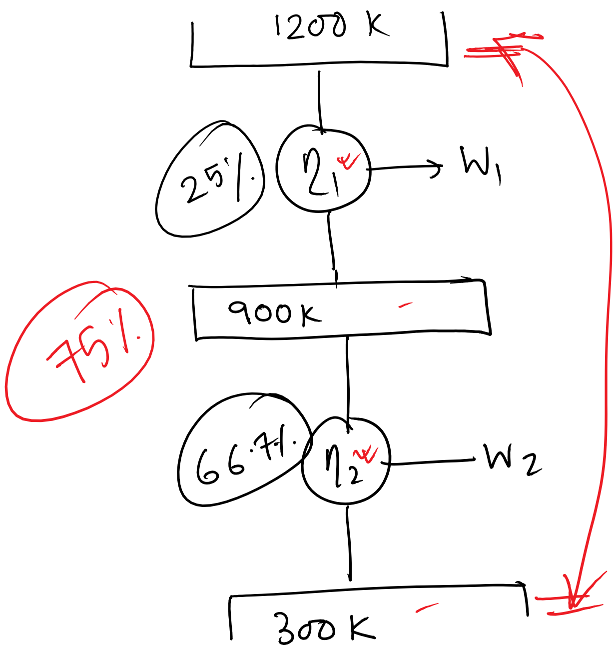
$$T_2 = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} T_1 = 1.93$$

$$\dot{m}_{fuel} = \frac{Q}{CV} = \frac{4780}{10000} \text{ kg/s}$$

$$= 0.478 \text{ kg/s}$$

$$T_2 = \left(\frac{p_2}{p_1}\right)^{r} T_1 = 1.93$$

$$= 579.3 \text{ K}$$



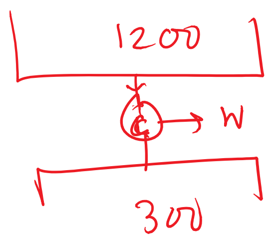
$$\eta_1 = 1 - \frac{\cancel{9}3}{\cancel{12}4} = 0.25 = \frac{1}{4}$$

$$\eta_2 = 1 - \frac{300}{900} = 0.67 = \frac{2}{3}$$

$$1 - \eta_{overall} = \left(1 - \frac{1}{4}\right)\left(1 - \frac{2}{3}\right)$$

$$= \frac{\cancel{3}}{4} \times \frac{1}{\cancel{3}} = \frac{1}{4}$$

$$\eta_{overall} = 1 - \frac{1}{4} = \frac{3}{4} = 75\%$$



$$\eta_{Carnot} = 1 - \frac{300}{1200} = 0.75$$