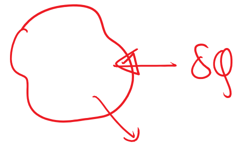


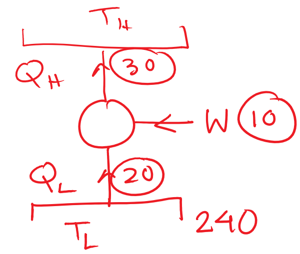
δQ $\quad dS = \left(\dfrac{\delta Q}{T_b}\right)_{Rev}$

δQ is +ve

δQ −ve

$\delta Q - \delta W = dU$

$T = C$ $\quad 0 \quad 0$

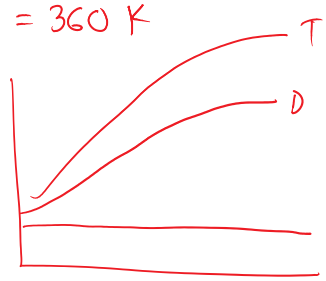


$$\frac{Q_H}{T_H} = \frac{Q_L}{T_L}$$

$$\frac{30}{T_H} = \frac{20}{240} \Rightarrow T_H = 360\ K$$

$$\boxed{\oint \left(\frac{\delta Q}{T_b}\right) \leq 0}$$

Rev $\quad$ irrev

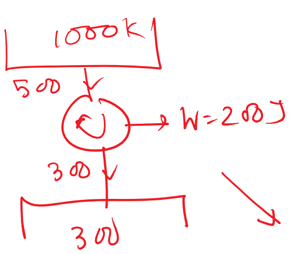


$Q - W = \Delta U$ $\quad$ isochoric $\quad Q = \Delta U = C_v \Delta T$

$Q - W = \Delta U$ $\quad$ isobaric $\quad W = p\Delta V = R\Delta T$

$$\frac{C_v \Delta T}{R \Delta T} = \frac{\cancel{R}}{(\gamma-1)\cancel{R}} \frac{\cancel{\Delta T}}{\cancel{\Delta T}}$$

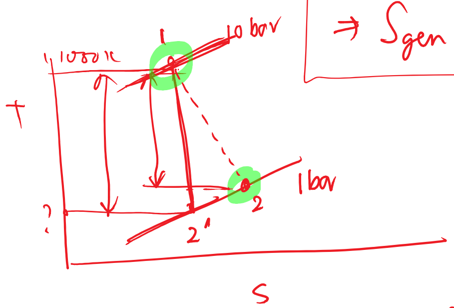
$$= \frac{1}{\gamma - 1}$$



$$\cancel{\Delta S} = \sum Q/T_b + S_{gen}$$

$$0 = \frac{+500}{1000} + \frac{-300}{300} + S_{gen}$$

$$\Rightarrow S_{gen} = 1 - \frac{1}{2} = 0.5$$



$$\frac{T_2'}{T_1} = \left(\frac{p_2'}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow T_2' =$$

$$\Delta S = \underbrace{S_2 - S_1}$$

$$= C_p \ln \frac{T_2}{T} - R \ln {p_2}/{p_1}$$

$$\eta_{ism} = \frac{h_1 - h_2}{h_1 - h_2'} = \frac{C_p (T_1 - T_2)}{C_p (T_1 - T_2')}$$

$$\eta = \quad T_1 - T_2$$

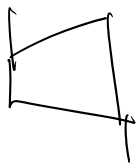
$\Delta s = s_2' - s_1$

$= C_p \ln \frac{T_2}{T_1} - R \ln P_2/P_1$

$= 1 \ln T_2/T_1 - 0.287 \ln 0.1$

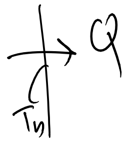
$\eta_{isen} = \frac{h_1 - h_2}{h_1 - h_{2'}} \quad \frac{C_p(T_1 - T_2)}{C_p(T_1 - T_{2'})}$

$0.9 = \frac{T_1 - T_2}{T_1 - T_{2'}} \Rightarrow T_2 =$ ✓

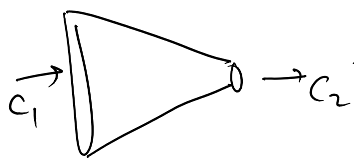


$\cancel{\frac{dS}{dt}} = \sum \cancel{\dot{Q}/T_b} + \dot{S}_{gen} + \dot{m}(s_1 - s_2)$

$$\boxed{\dot{S}_{gen} = \dot{m}(s_2 - s_1)}$$



$S_{gen} = Q/T_b = \frac{700}{1400}$ kJ/K



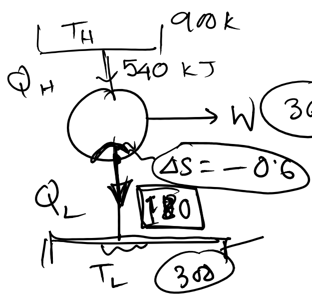
$\Delta H = \dot{m}\,\Delta KE$

$$\boxed{\Delta h = \frac{1}{2}\left[C_2^2 - C_1^2\right]}$$

$C_p \Delta T \approx 450 = \frac{1}{2}(C_2^2 - C_1^2)$

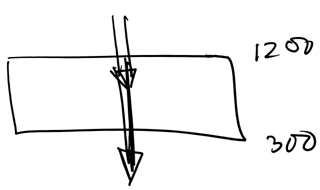
$900 = C_2^2 - \cancel{C_1^2} \to 0$

$\boxed{C_2 = 30}$ m/s



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

$\Rightarrow Q_L = T_L \Delta S = -180$ kJ



$\dot{S}_{gen} = \dot{Q}\left[\frac{1}{T_c} - \frac{1}{T_H}\right]$

$= 4\left[\frac{1}{300} - \frac{1}{1200}\right]$

Dec. 20

Extra Class on 27/11 → 10:00 am

Properties of Steam :

Steam Table with Mollier Chart ✓

Steam → Not an ideal gas → Ramalingam

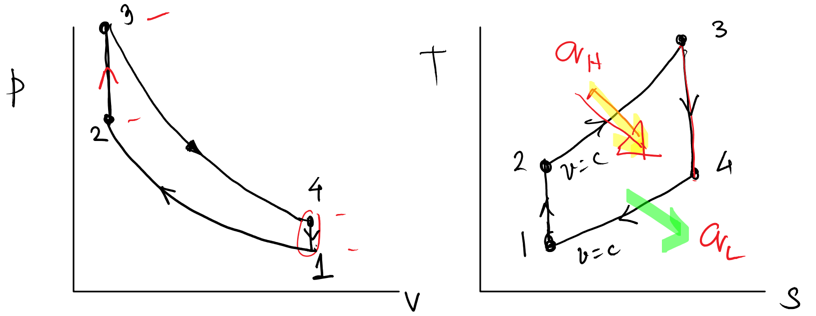
→ Ramalingam

u → must

Otto Cycle

Compression Ratio

$$r = \frac{V_{max}}{V_{min}} = \frac{v_1}{v_2}$$



1-2 Adiabatic Compression
2-3 Const. vol. heat addition
3-4 Adiabatic expansion
4-1 Constant vol. heat rejection

$$\eta_{otto} = \frac{w}{q_H} = \frac{q_H - q_L}{q_H}$$

$$= 1 - \frac{q_L}{q_H}$$

known: p_1, T_1, r, T_3

$$q_L = c_v(T_4 - T_1)$$

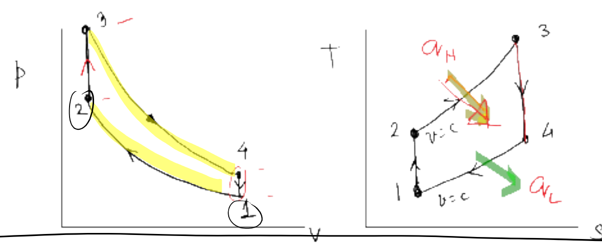
$$q_H = c_v(T_3 - T_2)$$

Compression ratio $= r = v_1/v_2 = v/v_4$

$$\eta_{otto} = 1 - \frac{T_4 - T_1}{T_3 - T_2}$$

$$= 1 - \frac{\cancel{(T_4/T_1 - 1)}\, T_1}{\cancel{(T_3/T_2 - 1)}\, T_2}$$

$$= \left(1 - T_1/T_2\right)$$



$$\boxed{r^{\gamma-1} = \frac{T_2}{T_1}} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} \quad \text{For adiabatic prc. 1-2}$$

$\hookrightarrow r$

$$\frac{T_3}{T_4} = \left(\frac{v_4}{v_3}\right)^{\gamma-1} = \left(\frac{v_1}{v_3}\right)^{\gamma-1} = r^{\gamma-1}$$

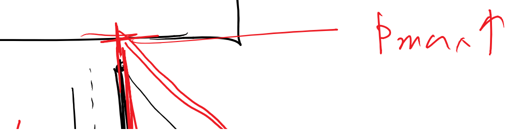
$$\Rightarrow \frac{T_2}{T_1} = \frac{T_3}{T_4} \Rightarrow \boxed{\frac{T_4}{T_1} = \frac{T_3}{T_2}}$$

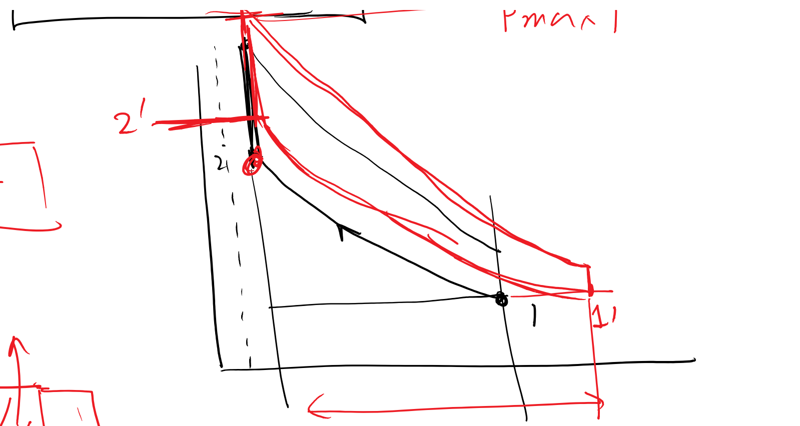
$$\eta_{otto} = 1 - \frac{T_1}{T_2}$$

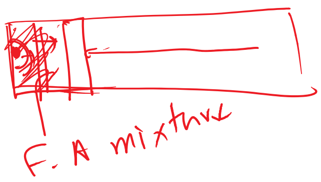
$$= 1 - \frac{1}{(T_2/T_1)}$$

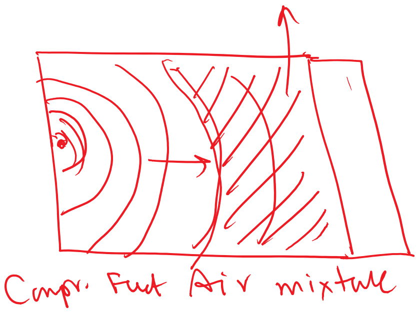
$$\boxed{\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}}}$$

$$\rightarrow \boxed{\eta_{otto} = f(r, \gamma)}$$









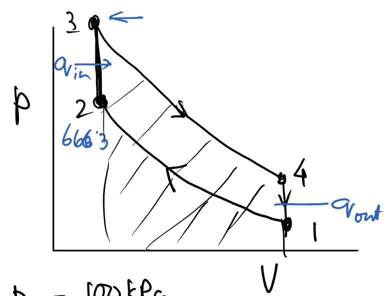
$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}} \leftarrow 1 - \frac{1}{8^{0.4}} = 0.564$$

EXAMPLE 9–2 **The Ideal Otto Cycle**

An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at 100 kPa and 17°C, and 800 kJ/kg of heat is transferred to air during the constant-volume heat-addition process. ~~Accounting for the variation of specific heats of air with temperature~~, determine (*a*) the maximum temperature and pressure that occur during the cycle, (*b*) the net work output, (*c*) the thermal efficiency, and (*d*) the mean effective pressure for the cycle.

Solution An ideal Otto cycle is considered. The maximum temperature and pressure, the net work output, the thermal efficiency, and the mean effective pressure are to be determined.

Assumptions 1 The air-standard assumptions are applicable. 2 Kinetic and potential energy changes are negligible. 3 The variation of specific heats with temperature is ~~to be accounted for.~~ neglected



$P_1 = 100$ kPa
$T_1 = 290$ K
$r = 8$

$$\boxed{q_{in} = 800 \text{ kJ/kg}}$$

$q_{in} = c_v (T_3 - T_2)$ $\quad w_{net} = (q_{in} - q_{out})$

$q_{out} = c_v (T_4 - T_1)$ $\quad \eta = 1 - \frac{q_{out}}{q_{in}}$

$C_p = 1.004$ kJ/kg K ?
$C_v = 0.707$ "

To find T_2

Adiabatic prc. 1 – 2

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} = r^{\gamma-1}$$

$$\Rightarrow T_2 = T_1 r^{\gamma-1} = 290 \times 8^{0.4} \text{ K}$$

$$\boxed{T_2 = 666.24}$$

To find T_3 :

$$q_{in} = c_v (T_3 - T_2)$$

$$T_3 - T_2 = \frac{800}{.707} \Rightarrow \boxed{T_3 = 1798 \text{ K}}$$

To find T_4

Adiabatic expansion 3 – 4

$$\frac{T_3}{T_4} = \left(\frac{v_4}{v_3}\right)^{\gamma-1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} = r^{\gamma-1}$$

- 782.68

$$\frac{T_3}{T_4} = \left(\frac{v_4}{v_3}\right) = \left(\frac{v_1}{v_2}\right) = r^{\gamma-1}$$

$$T_4 = T_3 / r^{\gamma-1} = \frac{1798}{2.29} = \underline{782.6K}$$

$$q_{out} = C_v \times (T_4 - T_1)$$

$$= 0.707(782.6 - 300)$$

$$= 341.2 \ \ kJ/kg$$

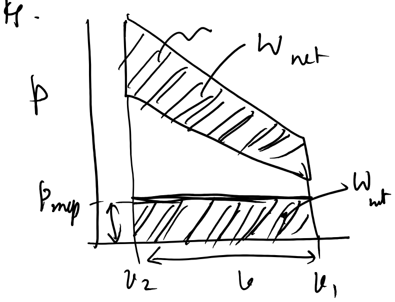
$$\boxed{\eta = 1 - \frac{341.2}{800} = 0.573 \text{ or } 57.3\%}$$

$$w_{net} = q_{in} - q_{out} = 808 - 341.2$$

$$= 458.8 \ \ kJ/kg.$$

$$W_{net} = \eta \times q_{in}$$

$$\boxed{\underline{MEP} = \frac{W}{(v_1 - v_2)} \ kPa}$$



$$v_2 = \frac{1}{8} v_1$$

$$v_1 = \frac{RT_1}{p_1} = \frac{0.287 \times 290}{100} =$$

$$v_2 = v_1/8$$

$$v_1 - v_2 = \ \checkmark$$