For liquid / solid (incompressible) $c_p \approx c_v$

$\gamma = 1.4$ for air and $\gamma = \frac{c_p}{c_v}$

$R = \frac{\tilde{R}}{m}$ $\quad c_p = c_v + R$

$h = u + pV$ $\quad \frac{T_1}{p_1 V_1} = \frac{T_2}{p_2 V_2}$

Engines

Otto

- Isochoric Q so C_V
- $T_2 = T_1 r^{\gamma-1}$ as $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$
- $\eta = 1 - \frac{T_4 - T_1}{T_3 - T_2}$

General

- $\eta = \frac{|W|}{Q_1}$
- $COP = \frac{|Q_1|}{|W|}$
- fuel $Q = \dot{m}_f q_{cal}$
  - q_{cal} = calorific fuel value

Diesel

- $r_c = \frac{V_3}{V_2} = \frac{T_3}{T_2}$ → $\therefore \frac{r_c}{r} = \frac{V_3}{V_4}$
- $r = \frac{V_1}{V_2} = \frac{V_{max}}{V_{min}}$
- $T_4 = \left(\frac{r_c}{r}\right)^{\gamma-1} T_3$
- Isobaric Qin $\therefore C_p$
- Isochoric Qout $\therefore C_v$
- $T_2 = T_1 r^{\gamma-1}$
- $\eta = 1 - \frac{1}{\gamma}\frac{T_4 - T_1}{T_3 - T_2}$

Brayton

- $\eta = 1 - \frac{T_4 - T_1}{T_3 - T_2}$
- $\dot{m} = \rho A C$
- + Regenerator
  - $T_5 \leq T_4$
  - best : $T_5 = T_4$
  - $e = \frac{\text{heat transfer}}{\text{max q transfer}} = \frac{T_5 - T_2}{T_4 - T_2}$
- $T_2 = T_1 r_p^{\frac{\gamma-1}{\gamma}}$
- $T_4 = \frac{T_3}{r_p^{\frac{\gamma-1}{\gamma}}}$

Turbojet

- Brayton + nozzle / diffuser
- For diffuser from SFEE
  - $\dot{Q} = 0$ and $\dot{W} = 0$
  - $0 = \left[c_p(T_2 - T_1) - \frac{(c_2^2 - c_1^2)}{2}\right]$
  - $\therefore T_2 = T_1 + \frac{c_1^2}{2c_p}$
  - Nozzle
- for turbine / comp $\dot{Q} = 0$
- $\dot{W}_T = -\dot{W}_C$
- Thrust $F = \dot{m}(v_6 - v_1)$
- $\eta_C = \frac{\dot{W}'}{\dot{W}} = \frac{\dot{m}(h_2' - h_1)}{\dot{m}(h_2 - h_1)} = \frac{T_2' - T_1}{T_2 - T_1}$
- $\eta_T = \frac{\dot{W}}{\dot{W}'} = \frac{\dot{m}(h_2 - h_1)}{\dot{m}(h_2' - h_1)} = \frac{T_4 - T_3}{T_4' - T_3}$
- $r_p = \frac{P_3}{P_2}$
- $\dot{W}_T = -\dot{W}_C$
- $\therefore T_4 - T_5 = T_3 - T_2$

Entropy

- from fluid view: $\frac{\delta Q_1}{T_1} + \frac{\delta Q_2}{T_2} \dots \geq 0$
  - $\Delta S_1 + \Delta S_2 \geq 0$
- for engine: $\oint \frac{dQ}{T} \leq 0$
- for liquids and solids : $dv = 0$
  - $c_v = c_p$
  - $\Delta S_{12} = c \ln\left(\frac{T_2}{T_1}\right)$

Isentropic

- $dU = mc_v \Delta T$
- $dH = mc_p \Delta T$
- $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$
- $\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}$

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma} = \left(\frac{T_1}{T_2}\right)^{\frac{\gamma}{\gamma-1}}$$