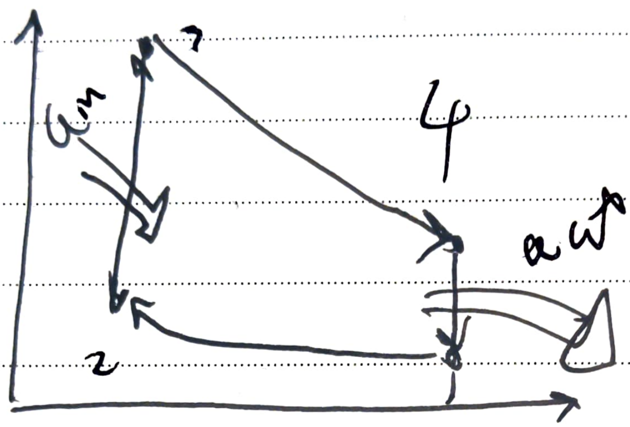
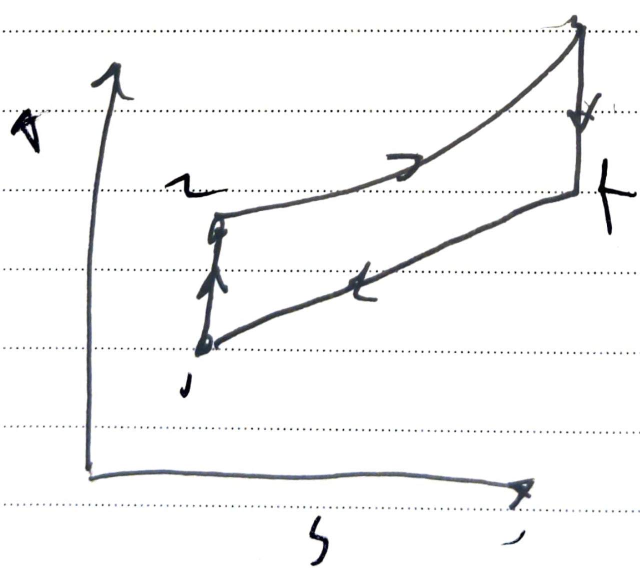
Problem set 6

a) Otto Cycle

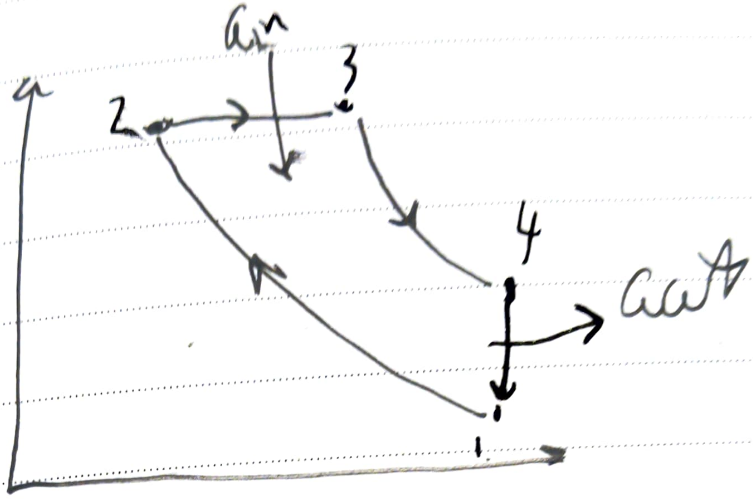


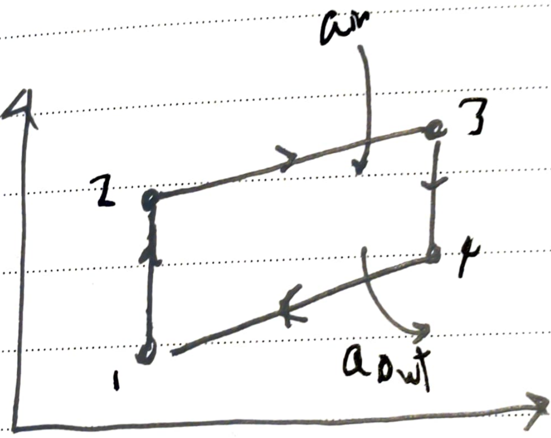
1-2 Isentropic compression
2-3 Isochoric heating
3-4 Isentropic expansion
4-1 Isochoric ~~out~~ heat rejection



Assumptions: Air-standard — Ideal, Perfect gas
- ΔKE & ΔPE are negligible
- values of specific heats is available

b) Deisel Cycle

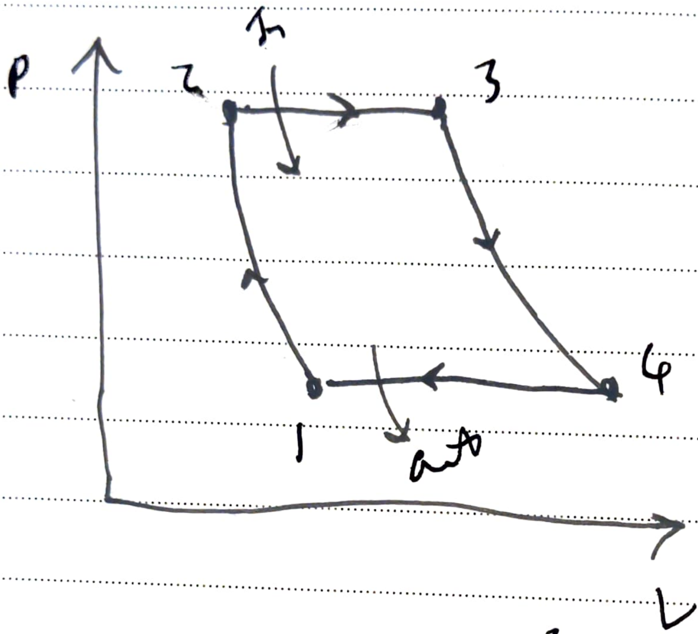


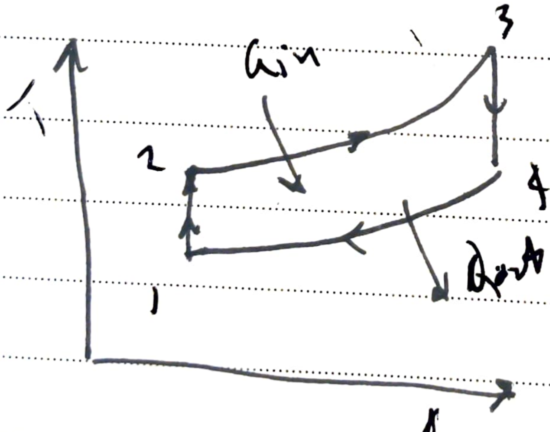


Assumptions: Standard air stuff
ΔKE & ΔPE are negligeable

1-2 Isentropic compression
2-3 ~~[illegible]~~ Isobaric heat addition
3-4 Isentropic expansion
4-1 Isochoric heat rejection

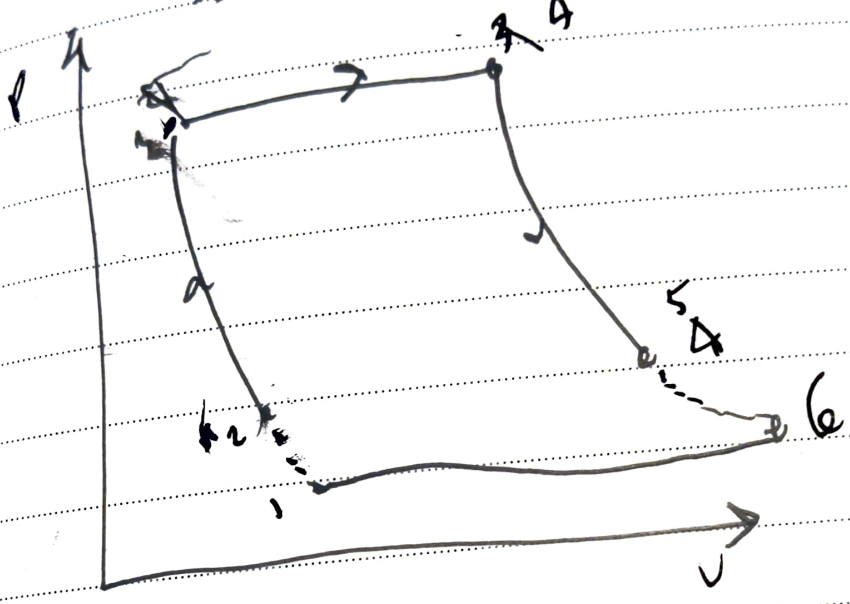
c) Brayton Cycle

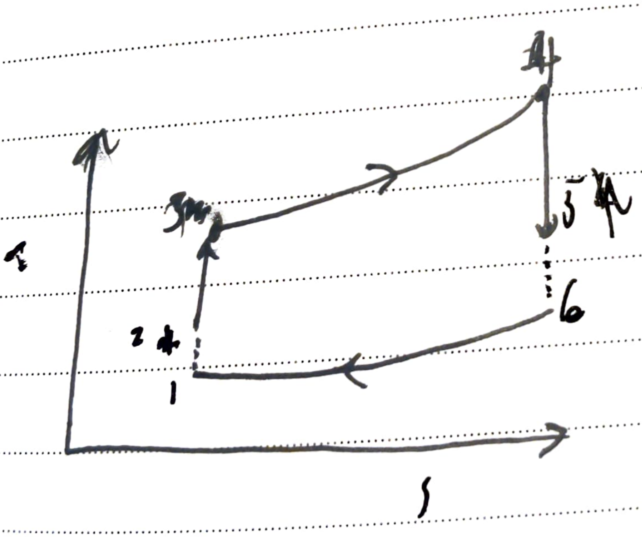




Assumptions: 1 - "Steady operating conditions"
2. The air standard assumptions are applicable
3. ΔKE & ΔPE are negligible
~~4. [illegible]~~
~~[illegible]~~ ~~Because~~ Because Exhaust will return to atmosphere pressure

d) Jet - Propulsion cycle





Assumptions : Standard air assumptions

555 K

a) [illegible] on otto cycle

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

$$\frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{k-1} = \left(\frac{v_3}{v_4}\right)^{k-1} = \frac{T_4}{T_3}$$

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

[illegible]

[illegible] 90 kpa inl 40°C

$$Pv = RT$$

$$v = \frac{RT}{P}$$

[illegible] rpm 90 kw at

$$\eta_{th,otto} = 1 - \frac{1}{r^{k-1}}$$

$$= 1 - \frac{1}{10.5^{1.4-1}}$$

0.95

$$= 0.6\cancel{8}\cancel{4}0$$

$$\eta_{mech} = \frac{W_{net}}{a_{in}}$$

$$a_{in} = \frac{W_{net}}{0.6095}$$

$$\approx 147.66\ kW$$

Q3 ~18.2

~~[illegible]~~ [illegible] [illegible] ~~[illegible]~~ [illegible] [illegible] 27°C @ 100 kPa

c) $r_c = \frac{V_3}{V_2}$

$$\eta_{th,\,diesel} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_c^{\,k} - 1}{k(r_c - 1)}\right]$$

$$V_2 = \frac{V_1}{r}$$

[illegible] process 2-3 $P_2 = P_3 = C$ T_3 = [illegible]

$$v_1 = \frac{RT}{P}$$

$$= 0.861 \ \frac{m^3}{kg}$$

$$r = \cancel{\frac{v_2}{v_1}} \ \frac{v_1}{v_2}$$

$$v_2 = \frac{v_1}{r}$$

$$v_2 = \frac{0.861}{18.2}$$

$$= 0.0473 \ \frac{m^3}{kg}$$

$$P_2 = 100 \times 10^3 \left(\frac{v_1}{v_2}\right)^n$$

$$= 100 \times 10^3 \left(\frac{0.861}{0.047}\right)^{1.4}$$

$$= 5.86 \ MPa$$

$$T_2 = 300 \times \left(\frac{0.861}{0.0473}\right)^{0.4}$$

$$= 955.2 \ K$$

$$Pv = RT$$

$$Pv = RT$$

$$\frac{\cancel{R}T_2}{v_2} = \frac{\cancel{R}T_3}{v_3}$$

$$\left(\frac{455.2}{0.0473}\right)^{-1} \times 1700 = v_3$$

$$v_3 = 0.0842 \; m^3/kg$$

$$r_c = \frac{0.0842}{0.0473}$$

$$= 1.78$$

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

$$= 1700\left(\frac{0.0842}{0.861}\right)^{0.4}$$

$$= 670.7\,K$$

$670.7 \rightarrow 300$

For Process 4-1

work = 0 as $dV = 0$

$\therefore \ Q = \Delta U$

$u = c_p \Delta T$

$= 1005 \times -370.7$

$= -372.5 \text{ kJ}$

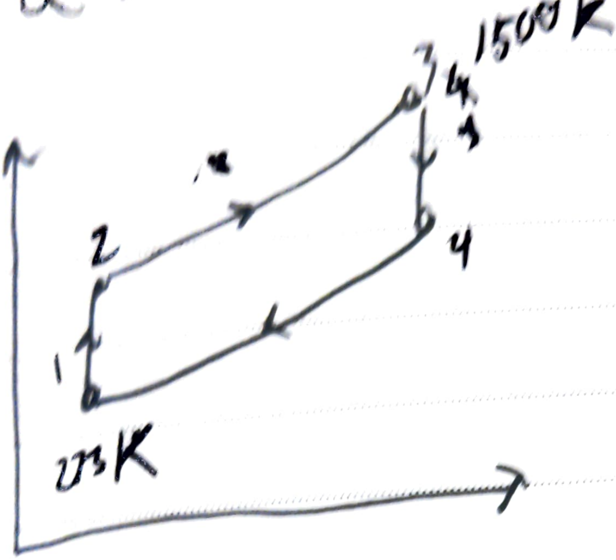
$\therefore$ 372.5 kJ is rejected from the system

c) $\eta_{\text{theoretical}} = 1 - \frac{1}{18.2^{(0.4)}} \left(\frac{1.79^{1.4} - 1}{1.4(1.74 - 1)} \right)$

$= 0.645$

4

Q 4



$$P_2 = r P_1$$
$$= 700 \text{ kPa}$$

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{0.4}{1.4}}$$

$$= 273 \left(\frac{700}{100}\right)^{\frac{0.4}{1.4}}$$

$$= 476.0 \text{ K}$$

$$\frac{P}{R} = \frac{T}{v}$$

$$\frac{T_2}{v_2} = \frac{T_3}{v_3}$$

$$v_2 = \frac{RT_2}{P}$$

$$= \frac{287 \cdot 476}{7000 \times 10^3}$$

$$= 0.0195$$

$$v_3 = \frac{T_3 v_2}{T_2}$$

$$= \frac{1500 \cdot 0.0195}{476}$$

$$= 0.0614$$

$\Delta T = 1024$

$$w_{rev} = \int v \, dP$$

$\therefore w_{rev} = 0$ as $dP = 0$

$$\overset{Q-W}{\cancel{Q-W_{rev}}} = \dot{m}(\Delta h + \Delta ke + \Delta pe)$$

$$\dot{Q} = \dot{m}(\Delta h)$$

$$\dot{Q} = \dot{m}\left(\underset{\dot{m}}{\underline{735 \times 10^3}}\right)$$

$\dot{Q}_{in} = 735.2 \times 10^3$ J/kg   1/3 kg/3

$$\eta_{Brayton} = 1 - \frac{1}{7^{\frac{0.4}{1.4}}}$$

$$= 0.426$$

$$\cancel{0.426 \times \dot{Q} \times \dot{m}} = \cancel{150 \times 10^6}$$

$$\eta = \frac{W_{net}\,\dot{m}}{\dot{Q}}$$

$$\frac{0.426 \times 735 \times 10^3}{150 \times 10^6} = \dot{m}$$

$$\dot{m} =$$

the effect &

Chapter 7.3 - 7.7

$$\tau = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_T$$

$$\tau_T = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_T$$

$$\tau_s = -\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_s$$

when $M > 0.3$ flow should be considered compressible

Assume adiabatic and body forces = 0

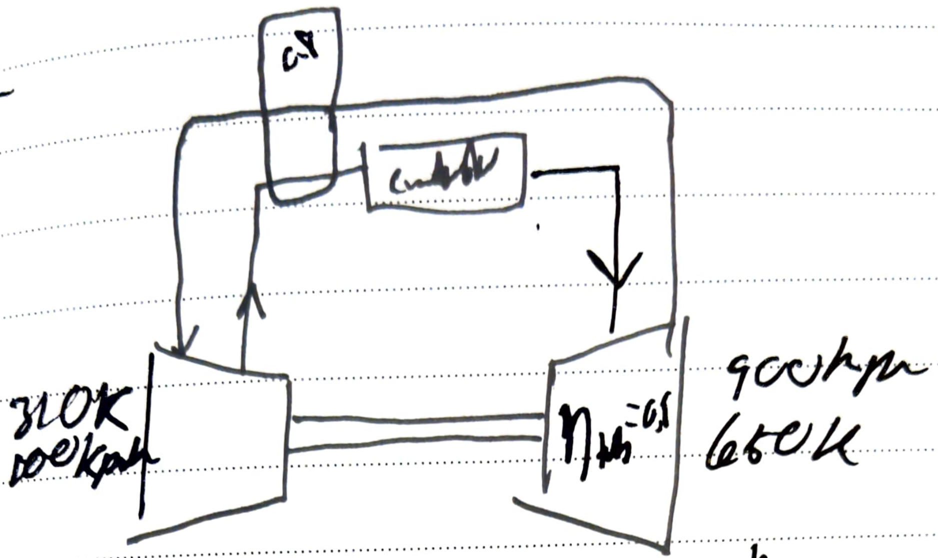
$$\rho \frac{D\left(e + \frac{V^2}{2}\right)}{dt} = -\nabla \cdot pV$$

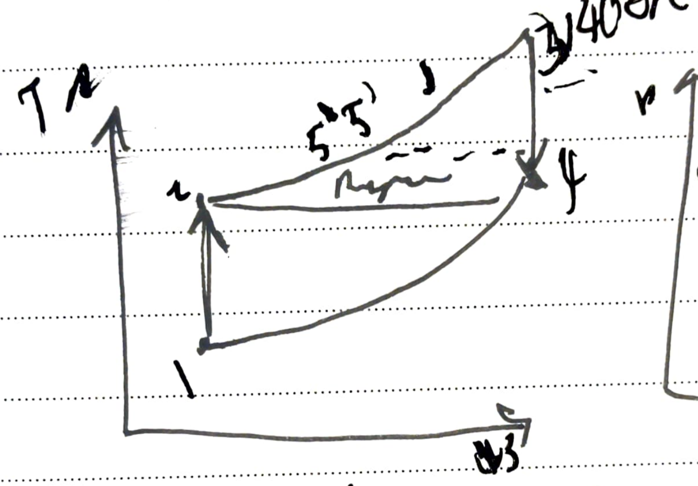
and $T_{01} = T_{02}$

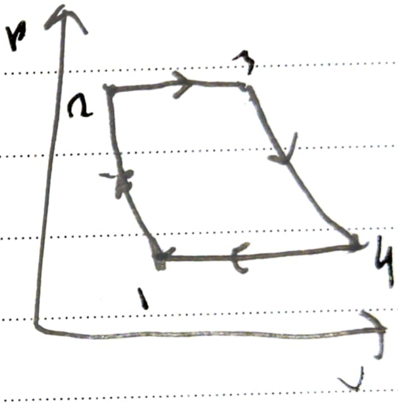
for adiabatic flow $h_{01} = h_{02}$ &

for isentropic flow $p_1 = p_2$ &

ce5







$$\varepsilon = \frac{\text{gain act}}{\text{max gain}} = \frac{h_5 - h_2}{h_4 - h_2}$$

$v = \frac{RT}{P}$

~~it with~~

State 1 = 310K, 100kPa, 0.8897 $\frac{m^3}{kg}$

State 4 = 650K, 900kPa, 0.2072 $\frac{m^3}{kg}$

State 3 = 1400K, 1120.6kPa, 0.3586 $\frac{m^3}{kg}$

~~State 4B~~ 100kPa

~~$V_3 \ldots = T_2 = \ldots$~~

State 2 = 618.3K 1120.6 kPa 0.158 $\frac{m^3}{kg}$

$q_{regen\,max} = h_4 - h_2$

$h_4 = c_p\, dT$

$= 1005 \times 650$

$h = 653250$ kJ

$h_2 = 621391$

$h_3 = 1407000$

$h_? = 311550$

h_1

$q_{regen\,max} = 653250 - 621391$

$= 31859$ J

$q_{regen\,actual} = \varepsilon \cdot q_{regen\,max}$

$= 25487.2$ J

a) ∴ the regenerator transfers 25487.2 J of heat transfer to the combustor

$h_5 = q_{regen\,act} + h_2$

$= 646878.2$

$q_{in} = 760.122$ kJ

Wout

$$\dot{Q} - \dot{W} = \dot{m}(\Delta h + \Delta ke + \Delta pe)$$

$W = \Delta h$

$W_{out} = h_3 - h_4$

$= 753750 \text{ J}$

$W_{in} = -(W_1 - W_2)$

$= 309841 \text{ J}$

$W_{out\,tot} = 0.9 \times 753750 \text{ J}$

$= 838375 \text{ J}$

$W_{total} = 548534 \text{ J}$

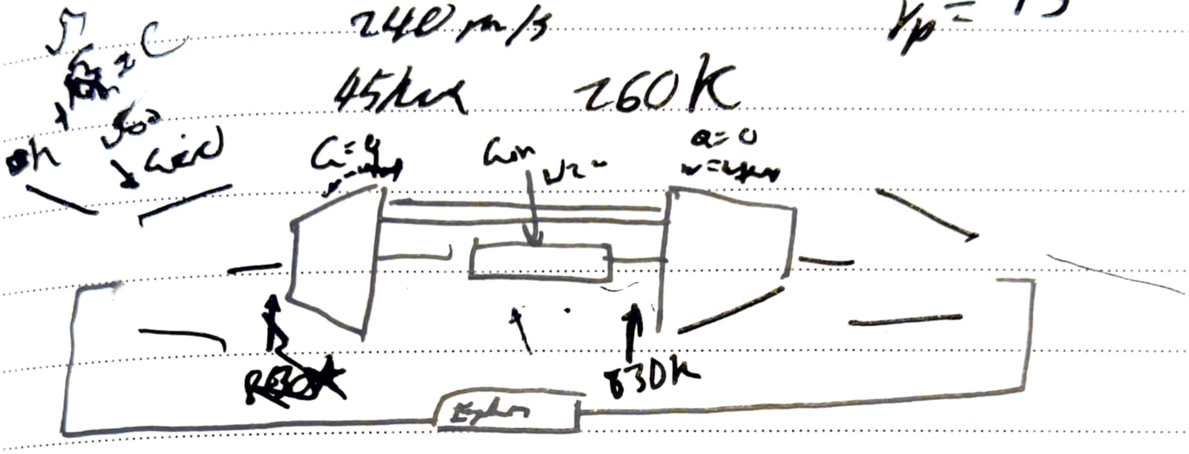
$$\eta_{overall} = \frac{548534}{760122}$$

$= 0.72$

$= 72\%$

$A_i = 2.01\ m^2$

$r_p = 13$



$$v = \frac{RT}{P}$$

$$= 1.658\ \frac{m^3}{kg}$$

$$\dot{V} = \vec{U} \cdot A$$

$$= 482.4\ m^3/s$$

$$\dot{m} = \frac{1}{v}\dot{V}$$

$$= 290.95\ kg/s$$

$W_{turb} = W_{comp}$

$h = 834150$

$r_p = \frac{P_2}{P_1} = \frac{P_3}{P_4}$

$$PV^\gamma = C \qquad P_m = 13 P_{at}$$

$$V_{at} = \frac{RT}{P_{at}} \qquad \frac{V_{at}}{13} = V_m$$

$$P_{at} = \frac{RT}{P_{at}}$$

$$0 = P_m V_m^\gamma - P_{at} V_{at}^\gamma$$

$$= 13 P_{at} V_m^\gamma$$

$$= 13 P_{at} \left(\frac{V_{at}}{13}\right)^\gamma - P_{at}$$