"Problem 5.1 Limited Pressure Cycle.
This is a high compression diesel, so let's neglect residual mass"

f_cv = 0.5
f_cp = 1-f_cv

"Engine Properties"

r_c = 15

"Fuel properties"

Q_LHV = 43000 "[kJ/lg]"
FA = 0.045
AF = 1/FA
mfm = 1/(1+AF)

"Inlet Conditions - Point 1"

P_1 = 100 "[kPa]"
T_1 = 289 "[K]"
v_1 = volume(Air,T=T_1,P=P_1)
s_1 = entropy(Air,T=T_1,P=P_1)
u_1 = intenergy(Air,T=T_1)
gamma_1 = CP(Air,T=T_1)/CV(Air,T=T_1)

"Point 2 Conditions"

s_2 = entropy(Air,T=T_2,P=P_2)
s_2= s_1
v_2 = v_1/r_c
u_2 = intenergy(Air,T=T_2)
v_2 = volume(Air,T=T_2,P=P_2)
gamma_2 = CP(Air,T=T_2)/CV(Air,T=T_2)

"Heat Added per Kg mixture - const vol - Point 3a Conditions"

q_cv = f_cv*mfm*Q_LHV
u_3a = intenergy(Air,T=T_3a)
h_3a = enthalpy(Air,T=T_3a)
q_cv = u_3a - u_2
P_3a/P_2 = T_3a/T_2
v_3a = v_2
gamma_3a = CP(Air,T=T_3a)/CV(Air,T=T_3a)

"Heat Added per Kg mixture - constant press - Point 3b Conditions"

q_cp = f_cp*mfm*Q_LHV
h_3b = enthalpy(Air,T=T_3b)
s_3b = entropy(Air,T=T_3b,P=P_3b)
u_3b = intenergy(Air,T=T_3b)
q_cp = h_3b - h_3a
P_3b = P_3a
P_3b*v_3b = R*T_3b
v_3b/v_3a = T_3b/T_3a
gamma_3b = CP(Air,T=T_3b)/CV(Air,T=T_3b)

"Point 4 Conditions"

v_4 = v_2 * r_c
v_4 = volume(Air,T=T_4,P=P_4)
s_4 = entropy(Air,T=T_4,P=P_4)
s_3b=s_4
u_4 = intenergy(Air,T=T_4)
gamma_4 = CP(Air,T=T_4)/CV(Air,T=T_4)

"Totals of Heat Added and work done"

q_add = q_cv+q_cp

w_comp = u_2-u_1
w_exp = p_3b*(v_3b-v_3a) + u_3b - u_4
w_net = w_exp - w_comp

"Fuel Conversion Efficiency"

eta_f = w_net/q_add
gamma = (gamma_1+gamma_2+gamma_3a+gamma_3b+gamma_4)/5

eta_f1 = 1 - (T_4-T_1) / ((T_3a - T_2)+gamma*(T_3b-T_3a))

beta = v_3b/v_3a
alpha=P_3a/P_2

eta_f2 = 1-1/r_c^(gamma-1) * ((alpha*beta^gamma-1)/(alpha*gamma*(beta-1)+alpha-1))
pr = P_3a/P_1

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f_{cv} = 0.5

f_{cp} = 1 − f_{cv}

Engine Properties

r_c = 15

Fuel properties

Q_{LHV} = 43000 [kJ/lg]

FA = 0.045

$AF = \frac{1}{FA}$

$mfm = \frac{1}{1 + AF}$

Inlet Conditions - Point 1

$P_1 = 100$ [kPa]

$T_1 = 289$ [K]

$v_1 = \mathbf{v}['Air', T=T_1, P=P_1]$

$s_1 = \mathbf{s}['Air', T=T_1, P=P_1]$

$u_1 = \mathbf{u}['Air', T=T_1]$

$$\gamma_1 = \frac{\mathbf{Cp}['Air', T=T_1]}{\mathbf{Cv}['Air', T=T_1]}$$

Point 2 Conditions

$s_2 = \mathbf{s}['Air', T=T_2, P=P_2]$

$s_2 = s_1$

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

$u_2 = \mathbf{u}['Air', T=T_2]$

$v_2 = \mathbf{v}['Air', T=T_2, P=P_2]$

$$\gamma_2 = \frac{\mathbf{Cp}['Air', T=T_2]}{\mathbf{Cv}['Air', T=T_2]}$$

Heat Added per Kg mixture - const vol - Point 3a Conditions

$q_{cv} = f_{cv} \cdot mfm \cdot Q_{LHV}$

$u_{3a} = \mathbf{u}['Air', T=T_{3a}]$

$h_{3a} = \mathbf{h}['Air', T=T_{3a}]$

$q_{cv} = u_{3a} - u_2$

$$\frac{P_{3a}}{P_2} = \frac{T_{3a}}{T_2}$$

$v_{3a} = v_2$

$$\gamma_{3a} = \frac{\mathbf{Cp}['Air', T=T_{3a}]}{\mathbf{Cv}['Air', T=T_{3a}]}$$

Heat Added per Kg mixture - constant press - Point 3b Conditions

$q_{cp} = f_{cp} \cdot mfm \cdot Q_{LHV}$

$h_{3b} = \mathbf{h}['Air', T=T_{3b}]$

$s_{3b} = \mathbf{s}['Air', T=T_{3b}, P=P_{3b}]$

$u_{3b} = \mathbf{u}['Air', T=T_{3b}]$

$q_{cp} = h_{3b} - h_{3a}$

$P_{3b} = P_{3a}$

$P_{3b} \cdot v_{3b} = R \cdot T_{3b}$

$\frac{v_{3b}}{v_{3a}} = \frac{T_{3b}}{T_{3a}}$

$\gamma_{3b} = \frac{\mathbf{Cp}['Air', T=T_{3b}]}{\mathbf{Cv}['Air', T=T_{3b}]}$

Point 4 Conditions

$v_4 = v_2 \cdot r_c$

$v_4 = \mathbf{v}['Air', T=T_4, P=P_4]$

$s_4 = \mathbf{s}['Air', T=T_4, P=P_4]$

$s_{3b} = s_4$

$u_4 = \mathbf{u}['Air', T=T_4]$

$\gamma_4 = \frac{\mathbf{Cp}['Air', T=T_4]}{\mathbf{Cv}['Air', T=T_4]}$

Totals of Heat Added and work done

$q_{add} = q_{cv} + q_{cp}$

$w_{comp} = u_2 - u_1$

$w_{exp} = P_{3b} \cdot [v_{3b} - v_{3a}] + u_{3b} - u_4$

$w_{net} = w_{exp} - w_{comp}$

Fuel Conversion Efficiency

$\eta_f = \frac{w_{net}}{q_{add}}$

$\gamma = \frac{\gamma_1 + \gamma_2 + \gamma_{3a} + \gamma_{3b} + \gamma_4}{5}$

$\eta_{f1} = 1 - \left[\frac{T_4 - T_1}{T_{3a} - T_2 + \gamma \cdot (T_{3b} - T_{3a})}\right]$

$\beta = \frac{v_{3b}}{v_{3a}}$

$\alpha = \frac{P_{3a}}{P_2}$

$$\eta_{f2} = 1 - \left[\frac{1}{r_c^{(\gamma - 1)}} \cdot \left(\frac{\alpha \cdot \beta^{\gamma} - 1}{\alpha \cdot \gamma \cdot [\beta - 1] + \alpha - 1} \right) \right]$$

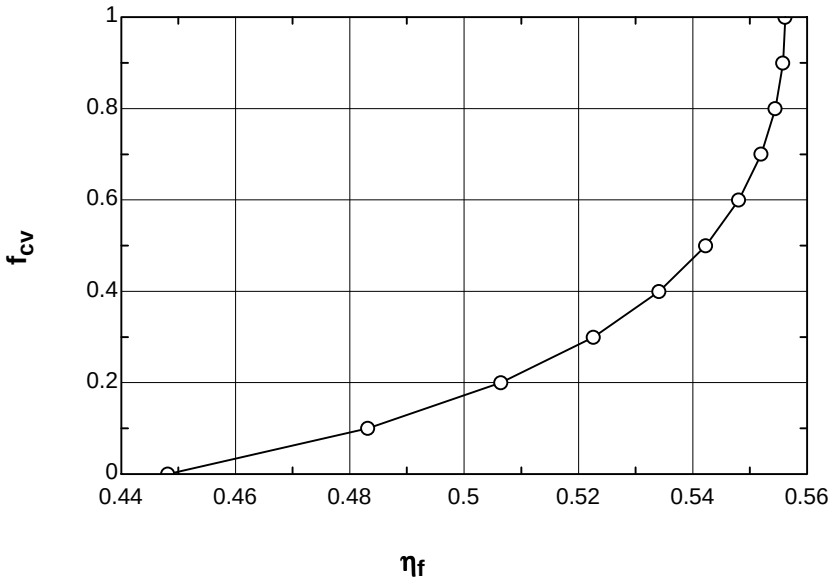
$$pr = \frac{P_{3a}}{P_1}$$

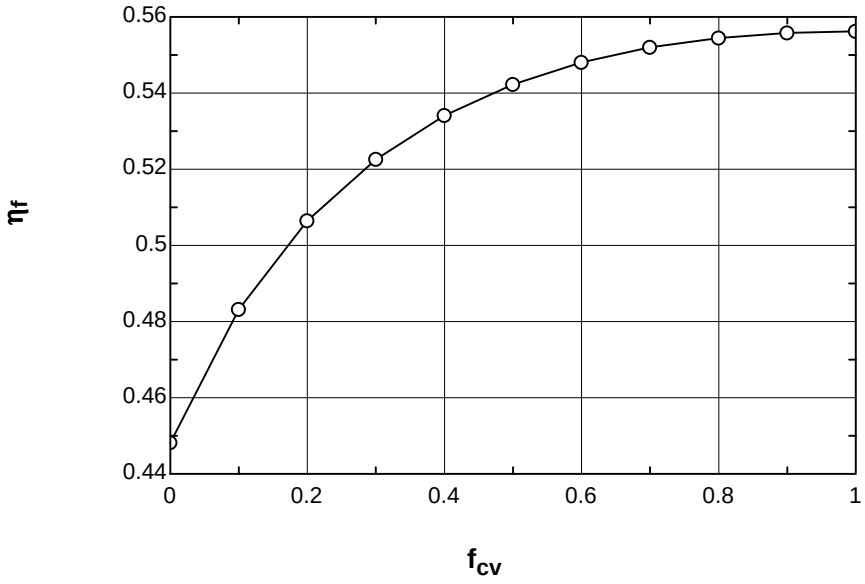
Unit Settings: [kJ]/[K]/[kPa]/[kg]/[radians]

AF = 22.22	α = 2.264	β = 1.398	η_f = 0.5798
η_{f1} = 0.5183	η_{f2} = 0.5817	FA = 0.045	f_{cp} = 0.5
f_{cv} = 0.5	γ = 1.333	γ_1 = 1.399	γ_2 = 1.352
γ_{3a} = 1.301	γ_{3b} = 1.29	γ_4 = 1.321	h_{3a} = 2062
h_{3b} = 2988	mfm = 0.04306	pr = 95.91	P_1 = 100 [kPa]
P_2 = 4236	P_{3a} = 9591	P_{3b} = 9591	P_4 = 435.2
q_{add} = 1852	q_{cp} = 925.8	q_{cv} = 925.8	Q_{LHV} = 43000 [kJ/lg]
R = 0.287 [kJ/(kg-K)]	r_c = 15	s_1 = 5.664 [kJ/kg-K]	s_2 = 5.664 [kJ/kg-K]
s_{3b} = 6.811	s_4 = 6.811	T_1 = 289 [K]	T_2 = 816.2
T_{3a} = 1848	T_{3b} = 2583	T_4 = 1258	u_1 = 206.4 [kJ/kg]
u_2 = 605.6	u_{3a} = 1531	u_{3b} = 2246	u_4 = 984.5
v_1 = 0.8295 [m^3/kg]	v_2 = 0.0553	v_{3a} = 0.0553	v_{3b} = 0.07729
v_4 = 0.8295	w_{comp} = 399.2	w_{exp} = 1473	w_{net} = 1074

Parametric Table: Table 2

	η_f	f_{cv}
Run 1	0.4969	0
Run 2	0.5286	0.1
Run 3	0.549	0.2
Run 4	0.563	0.3
Run 5	0.5728	0.4
Run 6	0.5798	0.5
Run 7	0.5847	0.6
Run 8	0.588	0.7
Run 9	0.5901	0.8
Run 10	0.5913	0.9
Run 11	0.5916	1


1
0.8
0.6
0.4
0.2
0
0.44
0.46
0.48
0.5
0.52
0.54
0.56
f_{cv}
η_f


0.56
0.54
0.52
0.5
0.48
0.46
0.44
0
0.2
0.4
0.6
0.8
1
η_f
f_{cv}