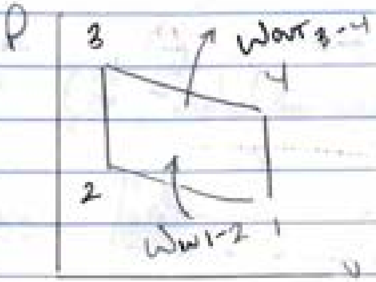
9-33 Ideal Otto Cycle

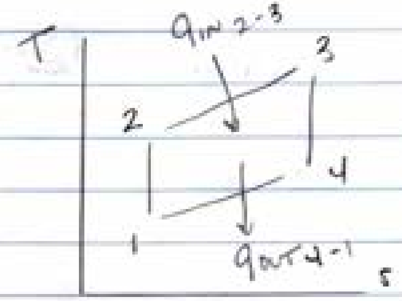
compression ratio → $r = 8$

$P_1 = 95\,kPa$, $T_1 = 27°C \rightarrow 300K$

q_{IN} during constant heat addition proc. $= 750 \frac{kJ}{kg}$

$R = 0.287\ kJ/kg\text{-}K$





ISENTROP. V = CONST. ISENTROP. V = CONST

1

$P_1 = 95\,kPa$

$T_1 = 300K$

A-17 @ 300K

$u_1 = 214.07\ kJ/kg$

$V_{r1} = 621.2$

2

$r = \frac{V_{r1}}{V_{r2}}$

$V_{r2} = \frac{621.2}{8}$

$= 77.65$

T_2 = INTERPOLATE A-17

$= 673.09K$

u_2 = INTERPOLATE A-17

$= 491.22 \frac{kJ}{kg}$

$P_2 = P_1(r)\left(\frac{T_2}{T_1}\right)$

$= 1705.15\,kPa$

3

$q_{IN} = (u_3 - u_2)$

$u_3 = q_{IN} + u_2$

$= 1241.22 \frac{kJ}{kg}$

T_3 = INTERPOLATE A-17

$= 1539K$

$V_{r3} = 6.59$

$P_3 = P_2\left(\frac{T_3}{T_2}\right)$

$= 3899\,kPa$

4

$V_{r4} = r V_{r3}$

$= 52.7$

T_4 = INTERPOL

$T_4 = 775K$

u_4 = INTERP

$= 571.74 \frac{kJ}{kg}$

a. P_3 | $\boxed{3899\,kPa}$

T_3 | $\boxed{1539K}$

b. NET WORK OUTPUT

$W_{NET} = q_{IN} - q_{OUT} \rightarrow q_{IN} - (u_4 - u_1) = \boxed{392.33\ kJ/kg}$

c. THERMAL EFFICIENCY

$$\eta_{TH} = \frac{W_{NET}}{q_{IN}} = 0.523 \rightarrow \boxed{52.3\%}$$

d. MEP

$$MEP = \frac{W_{NET}}{V_1 - V_2} \rightarrow \frac{W_{NET}}{V_1\left(1 - \frac{1}{r}\right)} \rightarrow rw \frac{P_1}{RT_1(r-1)}$$

$$\boxed{MEP = 495\,kPa}$$

9-36E A six-cylinder, 4-stroke, spark-ignition ideal Otto cycle

$P_1 = 14$ psia, $T_1 = 104°F + 460 \rightarrow 565 R$

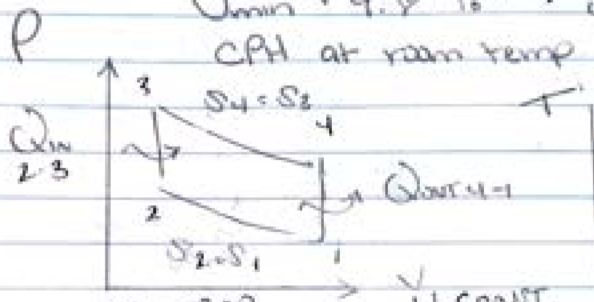
$T_{max} = 2400°F + 460 \rightarrow 2860 R$

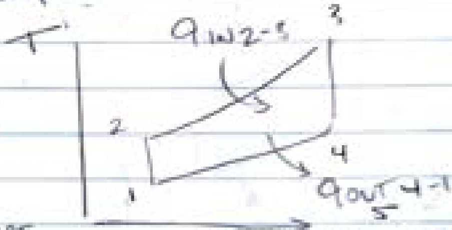
$D = 3.5 in \rightarrow \left(\frac{ft}{12}\right) = 0.2917 ft$

$S = 2.9 in \rightarrow \left(\frac{ft}{12}\right) = 0.225 ft$

$V_{min} = 9.8\% \rightarrow 0.098$

CPH at room temp





ISENTROP. — V CONST. — ISENTROP. — V CONST

1	2	3	4
$P_1 = 14$ Psia	$V_2 = 0.098 (V_1)$	$T_3 = 2860 R$	$V_4 = V_1$
$T_1 = 565 R$	$= 1.465 \frac{ft^3}{lbm}$	$V_3 = V_2$	$T_4 = T_3 \left(\frac{V_3}{V_4}\right)^{k-1}$
$V_1 = \frac{RT_1}{P_1} = 14.95 \frac{ft^3}{lbm}$	$\left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{k-1}$	$P_3 = \frac{RT_3}{V_3} = 723.1$ Psia	$= 1129 R$
	$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{k-1}$		$P_4 = \frac{RT_4}{V_4}$
	$= 1431 R$		$= 27.98$ Psia
	$P_2 = \frac{RT_2}{V_2} = 361.7$ Psia		

$W_{NET} = C_v (T_3 - T_4) - C_v (T_2 - T_1)$

$= 147 \frac{Btu}{lbm}$

$m = N_{cyl} \cdot \pi B^2 \frac{S}{2} / (V_1)$

$= (6) \cdot \pi \frac{(0.2917)^2 (0.225)^4}{14.95} = 0.08716$ lbm

NET WORK PER CYCLE

$W_{NET} = m \cdot w_{NET} = 0.8716(147.9) = 1.289 \text{ Btu}$

NET POWER PRODUCED

$$\dot{W}_{NET} = \frac{W_{NET} \cdot \dot{n}}{n_{REV}} = \frac{(1.289)(2500)}{(2)}\left(\frac{1}{60}\right) \cdot \left(\frac{1}{0.7068}\right)$$

$$= 38.00 \text{ HP}$$

9-46 Air - Standard Diesel Cycle

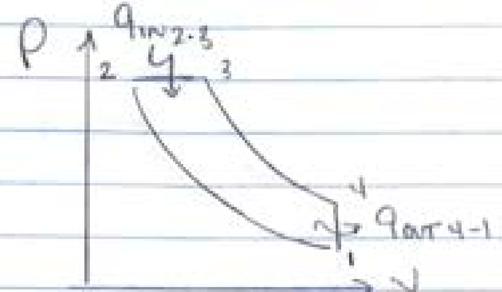
Compression Ratio = 16 = r

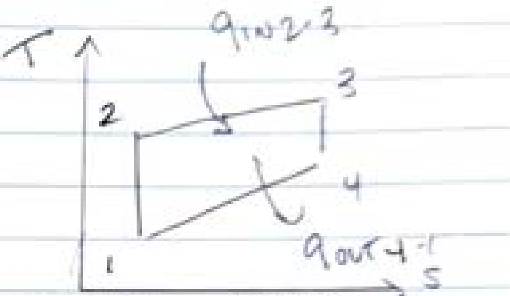
Cutoff Ratio = 2

$P_1 = 95 kPa$, $T_1 = 27°C \rightarrow 300K$

Variations of specific heats

$R = 0.287 \frac{kJ}{kg \cdot K}$





$1 \xrightarrow{\text{ISENTROP.}} 2 \xrightarrow{P\ \text{CONST.}} 3 \xrightarrow{\text{ISENTROP.}} 4 \xrightarrow{V\ \text{CONST.}}$

1	2	3	4
$T_1 = 300K$	$V_{r2} = \frac{V_2}{V_1} = \frac{1}{r} V_{r1}$	$P_3 = P_2$	$V_{r4} = \frac{V_4}{V_3} V_{r3}$
$P_1 = 95 kPa$	$= 38.825$	$T_3 = \frac{V_3}{V_2} T_2$	$= \frac{V_4}{2V_2} V_{r3}$
$U_1 = 214.07 \frac{kJ}{kg}$	T_2 = INTERPOLATE	$(2)(862.4)$	$= \frac{r}{2} V_{r3}$
$V_{r1} = 621.2$	$= 862.4K$	$= 1724.8K$	$= 36.37$
	h_2 = INTERPOLATE	h_3 = INTERPOLATE	$U_4 = 659.7 \frac{kJ}{kg}$
	$= 890.9 \frac{kJ}{kg}$	$= 1910.6 \frac{kJ}{kg}$	
		V_{r3} = INTERP.	
		$= 4.546$	

a. TEMP IN HEAT ADDITION

$$T_3 = T_{max} = \boxed{1724.8K}$$

$$q_{in\ 2\text{-}3} = h_3 - h_2 = 1019.7 \frac{kJ}{kg}$$

$$q_{out\ 4\text{-}1} = U_4 - U_1 = 445.63 \frac{kJ}{kg}$$

b. THERMAL EFFICIENCY

$$\eta_{TH} = 1 - \frac{q_{out}}{q_{in}} = \boxed{56.3\%}$$

c. mep

$w_{NET} = q_{IN} - q_{OUT} = 574.07 \ kJ/kg$

$v_1 = \frac{R T_1}{P_1} = 0.906 \ m^3/kg = v_{max}$

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

$mep = \frac{w_{NET}}{v_1 - v_2} = \boxed{675.9 \ kPa}$

9-57 four cylinder, two stroke, 2.4L

Ideal Diesel Cycle

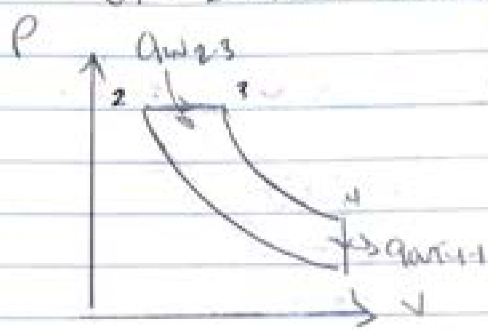
compression ratio = 22 = $\frac{V_1}{V_2}$ = r

cutoff ratio = 1.8 = $\frac{V_3}{V_2}$ = r_c

P_1 = 97 kPa, T_1 = 70°C → 343K

n = 3500 rpm

V_1 = 2.4L = 0.0024 m^3



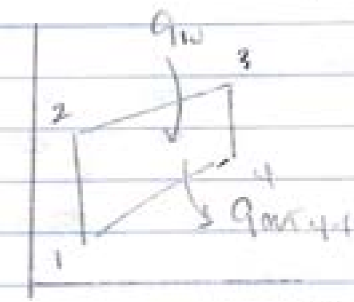
cold air standard

C_p = 1.005 kJ/kg-K

C_v = 0.718 kJ/kg-K

R = 0.287 kJ/kg-K

k = 1.4



1 $\xrightarrow{\text{isent.}}$ 2 $\xrightarrow{P = \text{const.}}$ 3 $\xrightarrow{\text{isent.}}$ 4 $\xrightarrow{V = \text{const.}}$

1	2	3	4
P_1 = 97 kPa	$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{k-1}$	$T_3 = T_2\left(\frac{V_3}{V_2}\right)^{k-1}$	$T_4 = T_3\left(\frac{V_3}{V_4}\right)^{k-1}$
T_1 = 343K	= 1181.04K	= 2125.87K	$= T_3\left(\frac{r_c}{r}\right)^{k-1}$
V_1 = 0.0024 m^3			= 781.01K

$m = \frac{P_1 V_1}{R T_1} \rightarrow \frac{97(0.0024)}{(0.287)\,343K} = 0.002365\ kg$

$$Q_{IN\,2\text{-}3} = m(h_3 - h_2) \rightarrow m\,C_p(T_3 - T_2)$$

$$= 0.002365(1.005)(2125.87 - 1187.04)$$

$$= 2.2456 \text{ kJ}$$

$$Q_{OUT\,4\text{-}1} = m(u_4 - u_1) \rightarrow m\,C_v(T_1 - T_4)$$

$$= 0.002365(0.718)(343 - 787.04)$$

$$= -0.7438 \text{ kJ}$$

a. POWER PRODUCED @ 3500 rpm

$$\dot{W}_{NET} = \dot{n}\,W_{NET}$$

$$W_{NET} = Q_{IN} - Q_{OUT} = 1.5018 \text{ kJ/rev}$$

$$= \left(\frac{3500}{60}\right)(1.5018)$$

$$\dot{W}_{NET} = 87.6 \text{ kW}$$

9-59E IDEAL DUAL CYCLE

compression ratio = 15 = r

cutoff ratio = 1.4 = r_c

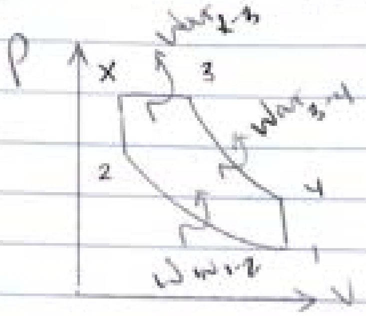
constant volume heat addition = 1.1

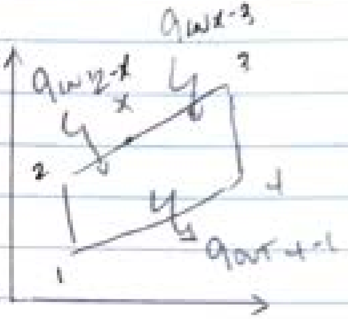
$P_1 = 14.2$ PSIA, $T_1 = 75°F$

constant specific heat @ 300K

$C_p = 1.005\ kJ/kg\text{-}K$, $C_v = 0.718\ kJ/kg\text{-}K$

$k = 1.4$





ISENT. COMP. — V = CONST. — ISENT. EXP. — V = CONST.

1

$T_1 = 75 + 459.67$

$= 534.67R$

$P_1 = 14.2$ PSIA

$P_1 V_1 = R T_1$

$V_1 = \frac{R T_1}{P_1}$

$= 10.8$

2

$V_2 = r V_1$

$= 162$

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

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

$T_2 = 1579.5R$

$P_2 = \frac{R T_2}{V_2}$

$= 2.8$ PSIA

x

$V_x = V_2$

$P_x = 1.1 P_2$

$P_x = 3.08$

$P_x V_x = R T_x$

$T_x = \frac{P_x V_x}{R}$

$T_x = 1738.5R$

3

$P_3 = P_x$

$V_3 = V_x r_c$

$V_3 = 226.8$

$T_3 = \frac{P_3 V_3}{R}$

$T_3 = 2433.9R$

4

$V_4 = V_1$

$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right.$

$= 720R$

$P_4 = \frac{RT}{V}$

$= 19.12$

a. $W_{NET} = Q_{in} - Q_{out}$

$= \underline{450.97} - C_v(T_4 - T_1)$

$= 288.42\ kJ/kg$

$\boxed{= 124\ \frac{Btu}{lbm}}$

b. Specific Heat Addition

$$= c_v (T_x - T_2) + c_p (T_3 - T_x)$$

$$= 450.97 = \boxed{193.9 \ Btu/lbm}$$

c. $\eta_{TH} = \frac{W_{NET}}{q_{IN}} = 0.639 \ \boxed{63.9\%}$

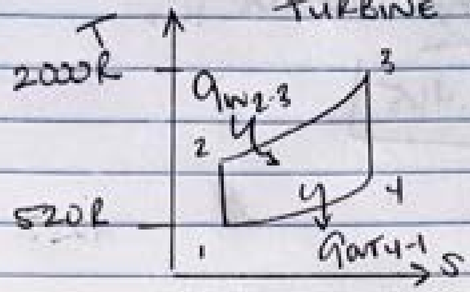
9-80 E

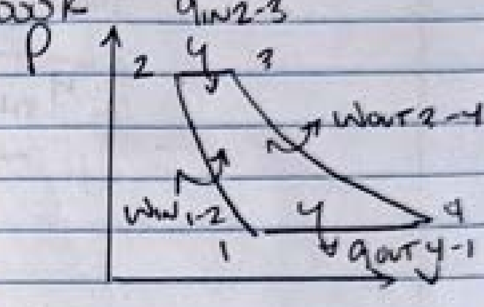
IDEAL BRAYTON CYCLE

pressure ratio = 10 = r_p

compressor @ 520R

TURBINE @ 2000R





ISENT. — P CONST. — ISENT — P CONST.

1

$T_1 = 520R$

$P_{r1} = A\text{-}17 = 1.2147$

$h_1 = 124.27 \frac{Btu}{lbm}$

2

$P_2 = 10P_1$

$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$

$P_{r2} = \left(\frac{P_2}{P_1}\right) P_{r1} = 12.147$

$T_2 = 996.48R$

$h_2 = 240.11 \frac{Btu}{lbm}$

3

$T_3 = 2000R$

$P_{r3} = A\text{-}17 = 174$

$h_3 = 504.71 \frac{Btu}{lbm}$

4

$P_4 = P_1$

$P_{r4} = \left(\frac{P_4}{P_3}\right) P_{r3} = 17.40$

$T_4 = 1099.31R$

$h_4 = 265.83 \frac{Btu}{lbm}$

a. TEMP @ COMP. EXIT = T_2

$$\boxed{T_2 = 996.48R}$$

b. $\frac{W_{comp}}{W_{exp}} = \frac{W_{in\,1\text{-}2}}{W_{out\,3\text{-}4}}$

$W_{1\text{-}2} = h_2 - h_1 = 115.84 \frac{Btu}{lbm}$

$W_{3\text{-}4} = h_3 - h_4 = 238.88 \frac{Btu}{lbm}$

$$\boxed{\frac{W_{comp}}{W_{exp}} = 0.485}$$

c. $\eta_{TH} = \frac{W_{NET}}{q_{IN}} = \frac{W_{OUT\,2-4} - W_{IN\,1-2}}{q_{IN_{2-3}}}$

$q_{IN\,2-3} = h_3 - h_2 = 264.60 \frac{Btu}{lbm}$

$\boxed{\eta_{TH} = 0.465}$