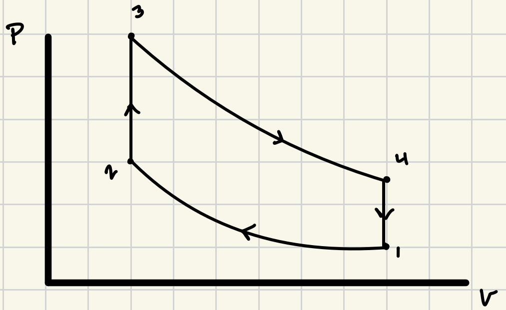
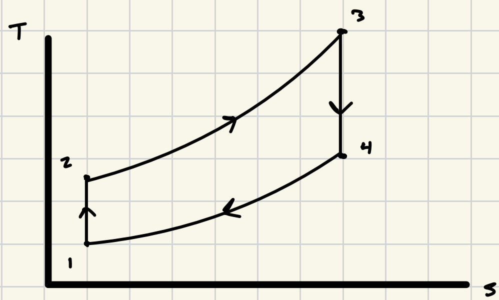
HW 1.3 Chapter 9- 33, 36, 46, 57, 59, 80

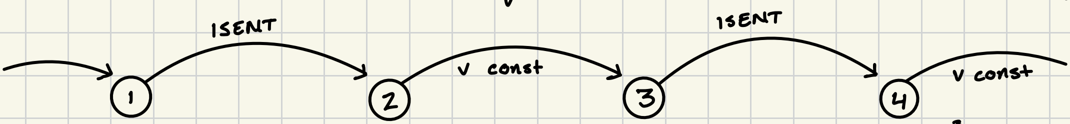
9–33 An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at 95 kPa and 27°C, and 750 kJ/kg of heat is transferred to air during the constant-volume heat-addition process. Taking into account the variation of specific heats with temperature, determine (*a*) the pressure and temperature at the end of the heat-addition process, (*b*) the net work output, (*c*) the thermal efficiency, and (*d*) the mean effective pressure for the cycle. *Answers:* (*a*) 3898 kPa, 1539 K, (*b*) 392.4 kJ/kg, (*c*) 52.3 percent, (*d*) 495 kPa

variable spec heats?

$r = 8$ $R = 287$







State 1

$P_1 = 95\,kPa$

$T_1 = 300\,K$

$v_1 = .91\,m^3/kg$

State 2

$T_2 = 673.1\,K$

$P_2 = 1705.18\,kPa$

$v_2 = 1.99\,m^3/kg$

State 3

$v_3 = 1.99\,m^3/kg$

$T_3 = 1540\,K$

$P_3 = 3898.8\,kPa$

State 4

$v_4 = .91\,m^3/kg$

$T_4 = 775.3\,K$

$P_4 = 244\,kPa$

$\varnothing$ $\dfrac{P_2}{95} = \dfrac{24.92}{24.46}$

$P_2 = \dfrac{P_1 T_2}{T_1}\left(\dfrac{v_1}{v_2}\right)$

values for interpolation

$\dfrac{1}{8} = \dfrac{v_{r_1}}{v_{r2}}$

$\rightarrow v_{r_2} = 77.65$

	x	y	y'	
1	670	78.61	24.46	488.8
	673.3	77.65	24.92	491.2
2	680	75.5	25.85	496.6
		v_r	P_r	u

$u_3 = 491.2 + 750$

$\Rightarrow u_3 = 1241.2$

$\therefore T \cong 1540$

$P = \dfrac{P_2 T_3}{T_2}$

$\dfrac{v_{r_4}}{6.57} = 8$

$v_{r_4} = 52.56$

	y	x
1	760	55.54
	775.3	52.56
2	780	51.64

$P = RT/v$

a) $\boxed{T_3 = 1540K,\ P_3 = 3898.8\,kPa}$

values pulled from table A-17

b) $w_{net} = q_{2\text{-}3} - q_{4\text{-}1} \rightarrow q_{4\text{-}1} = (571.69 - 214.07)\,kJ/kg = 357.62\,kJ/kg$

$\rightarrow w_{net} = 750 - 357.6 \Rightarrow \boxed{w_{net} = 392.4\,kJ/kg}$

c) $\eta_{TH} = w_{net}/q_{in} = 392.4/750 \Rightarrow \boxed{\eta_{TH} = 52.3\%}$

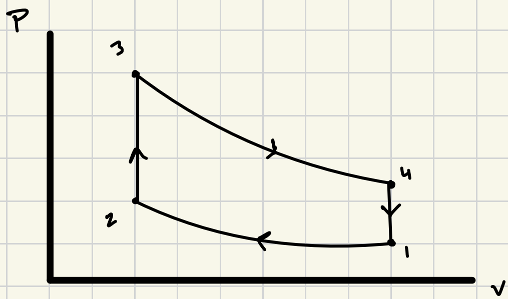
d) $MEP = w_{net}/(v_1 - v_2) \rightarrow 392.4/(.91 - 1.99) \Rightarrow \boxed{MEP = 362\,kPa}$

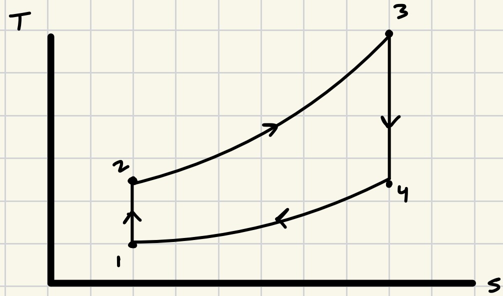
9–36E A six-cylinder, four-stroke, spark-ignition engine operating on the ideal Otto cycle takes in air at 14 psia and 105°F, and is limited to a maximum cycle temperature of 2400°F. Each cylinder has a bore of 3.5 in, and each piston has a stroke of 3.9 in. The minimum enclosed volume is 9.8 percent of the maximum enclosed volume. How much power will this engine produce when operated at 2500 rpm? Use constant specific heats at room temperature.

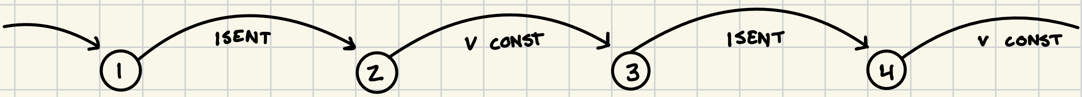
$v_1 = .098\,v_2$

$v_4 = .098\,v_3$

$R = .73024$







$P_1 = 14\,psia$

$T_1 = 105\,°F = 564.7R$

$v_1 = 37.5\,in^3$

$v_2 = 3.67\,in^3$

$T_2 = 1430.8R$

$P_2 = 284.7$

$\frac{T_2}{564.7R} = \left(\frac{37.5\,in^3}{3.67\,in^3}\right)^{1.4-1}$

$T_3 = 2859.7R$

$v_3 = 37.5\,in^3$

$v_4 = 3.67\,in^3$

$T_4 = 1129.6R$

$T_4 = 2859.7\,(1/10.2)^{.4}$

$$\dot{w}_{net} = c_v(T_3 - T_4) - c_v(T_2 - T_1) = .171(2859.7 - 1129.6) - .171(1430.8 - 564.7)$$

$$\rightarrow \dot{w}_{net} = 147.74$$

$$m = 6 \cdot \frac{\pi(3.5/12)^2(3.9/12)/4}{14.95} \Rightarrow m = .008714$$

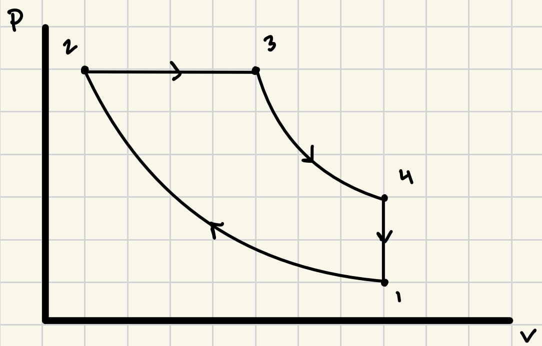
$$\text{Power} = \frac{w_{net} \cdot n}{\#\ \text{rev}} \Rightarrow P = \frac{147.74 \cdot .008714\ (2500/60)}{2} = 26.8\ \text{BTU}/s$$

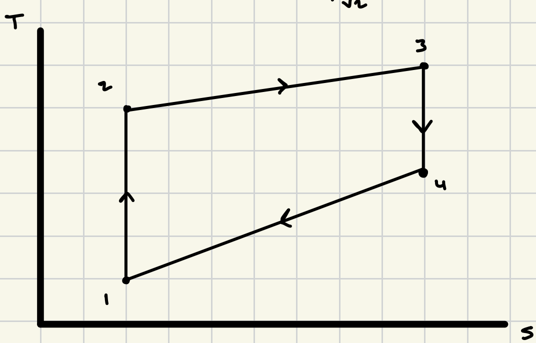
or $\boxed{37.9\ \text{hp}}$

9–46 An air-standard Diesel cycle has a compression ratio of 16 and a cutoff ratio of 2. At the beginning of the compression process, air is at 95 kPa and 27°C. Accounting for the variation of specific heats with temperature, determine (*a*) the temperature after the heat-addition process, (*b*) the thermal efficiency, and (*c*) the mean effective pressure.
Answers: (*a*) 1725 K, (*b*) 56.3 percent, (*c*) 675.9 kPa

$r = 16 \qquad r_c = \frac{V_3}{V_2} = 2$

$\frac{V_1}{V_2} = 16$ — or $\frac{V_4}{V_2}$





(1) —ISENT→ (2) —P CONST→ (3) —ISENT→ (4) —V CONST→

1	2	3	4
$P_1 = 95$ kPa	$V_2 = .057\ m^3/kg$	$P_3 = 4341$ kPa	$V_4 = .91\ m^3/kg$
$T_1 = 300°C$	$T_2 = 862.15$ K	$V_3 = .114\ m^3/kg$	$T_4 = 880$ K
$V_1 = .91\ m^3/kg$	$P_2 = 4341$ kPa	$T_3 = 1720.5$ K	$P_4 = 277.54$ kPa

$\frac{V_1}{V_2} = 16$

$\frac{V_3}{.057} = 2$

$\frac{.91}{.114} = \frac{v_{r_4}}{4.5878}$

$\frac{1}{16} = \frac{v_{r_2}}{621.2} \Rightarrow v_{r_2} = 38.825$

	x	y
1	39.12	860
	38.83	
2	36.61	880

	x	y
1	1700	4.761
	1720	
2	1750	4.328

$v_{r_4} = 36.622$

$\therefore T_4 \cong 880$ K

a) $\boxed{1720.5K}$

b) $q_{in} = h_3 - h_2 = 1910.6 - 890.9 = 1019.7$

pulled from A-17

$q_{out} = u_4 - u_1 = 659.7 - 214.07 = 445.63$

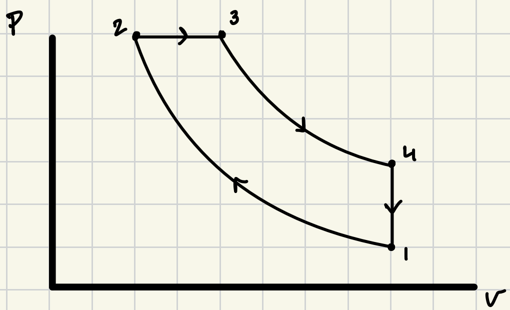
$\eta_{TH} = 1 - \frac{q_{out}}{q_{in}} \Rightarrow \boxed{\eta_{TH} = 56.3\%}$

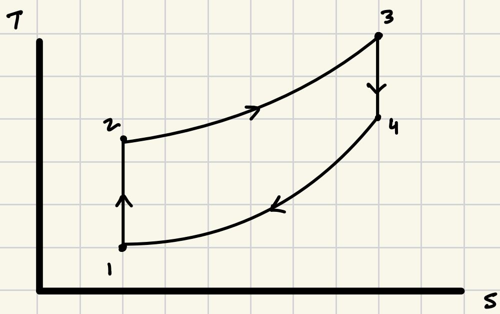
c) $MEP = \frac{w_{net}}{(v_1 - v_2)} = \frac{574.07}{(.91 - .057)} \Rightarrow \boxed{MEP = 673\text{ kPa}}$

9–57 A four-cylinder two-stroke 2.4-L diesel engine that operates on an ideal Diesel cycle has a compression ratio of 22 and a cutoff ratio of 1.8. Air is at 70°C and 97 kPa at the beginning of the compression process. Using the cold-air-standard assumptions, determine how much power the engine will deliver at 3500 rpm.

$r_p = 22 = v_1/v_2$

$r_c = 1.8 = v_3/v_2$





$\rightarrow (1) \xrightarrow{\text{ISENT}} (2) \xrightarrow{\text{P CONST}} (3) \xrightarrow{\text{ISENT}} (4) \xrightarrow{\text{V CONST}}$

1	2	3	4
$T_1 = 343K$	$T_2 = 1181.03K$	$P_3 = 6889.4\text{ kPa}$	$V_4 = 1.08\text{ m}^3/\text{kg}$
$P_1 = 91\text{ kPa}$	$v_2 = .049\text{ m}^3/\text{kg}$	$V_3 = .0885\text{ m}^3/\text{kg}$	$T_4 = 781.1K$
$v_1 = 1.08\text{ m}^3/\text{kg}$	$P_2 = 6889.4\text{ kPa}$	$T_3 = 2124.63K$	$P_4 = 207.57\text{ kPa}$

$22^{.4} = \frac{T_2}{343}$

$22v_2 = v_1$

$\left(\frac{.0885}{1.08}\right)^{.4} = \frac{T_4}{2124.63}$

$W = \frac{3500 \cdot 97 \cdot 2.4E{-3}}{60 \cdot .287}\left(1.005 \cdot 22^{.4}(1.8-1) - .718(1.8^{.4}-1)\right) \Rightarrow \boxed{w = 121.99\text{ kW}}$

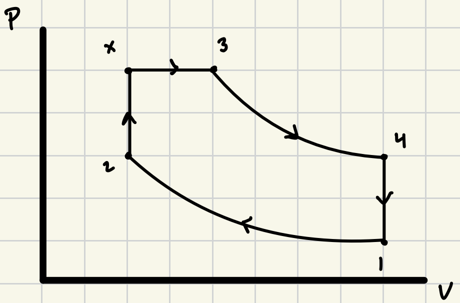
9–59E An ideal dual cycle has a compression ratio of 15 and a cutoff ratio of 1.4. The pressure ratio during constant-volume heat addition process is 1.1. The state of the air at the beginning of the compression is $P_1 = 14.2$ psia and $T_1 = 75°F$. Calculate the cycle's net specific work, specific heat addition, and thermal efficiency. Use constant specific heats at room temperature.

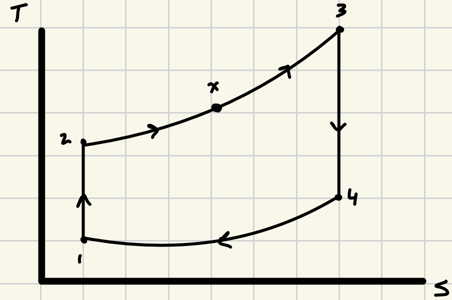
$r_p = 15 = v_1/v_2$

$\frac{P_2}{P_x} = 1.1$

$r_c = 1.4 = v_2/v_3$

$R = .73024$





$1 \xrightarrow{\text{ISENT}} 2 \xrightarrow{\text{V CONST}} x \xrightarrow{\text{P CONST}} 3 \xrightarrow{\text{ISENT}} 4 \xrightarrow{\text{V CONST}}$

1	2	x	3	4
$P_1 = 14.2$ psia	$T_2 = 611.7R$	$T_x = 635.5R$	$T_3 = 727.1R$	$T_4 = 534.7$
$T_1 = 534.7R$	$v_2 = 19.64\ in^3$	$P_x = 21.87$ psia	$P_3 = 21.87$ psia	$P_4 = 9.67$ psia
$v_1 = 27.5\ in^3$	$P_2 = 19.88$ psia	$V_x = 21.22\ in^3$		

$1.4^{.4} = \frac{T_2}{534.7}$

$1.4^{.4} = \left(\frac{P_2}{P_1}\right)^{.4}$

$T_x = 1.1 \cdot T_2$

$\frac{P_x}{P_2} = 1.1$

$1.4^{.4} = \frac{T_3}{T_x}$

$1.4 P_x = P_3$

$1^{.4} = \frac{T_1}{T_4}$

$\frac{534.7}{727.1} = \left(\frac{P_4}{21.87}\right)^{.4}$

$C_p = .24$

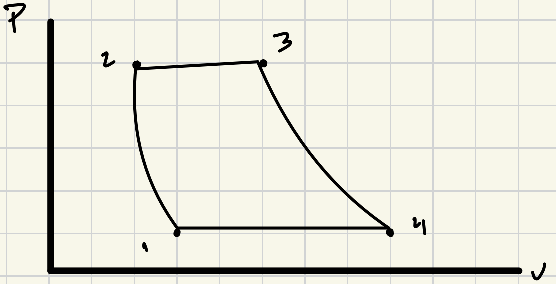
$C_v = .171$

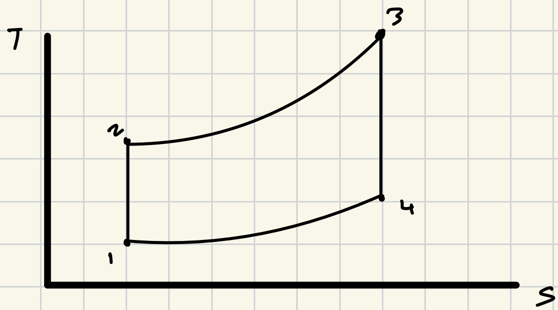
$.171(635.5 - 611.7) + .24(727.1 - 635.5) \Rightarrow$ b) 26.1 Btu/lb

$534.7R - .171(534.7 - 727.1) =$ a) 567 Btu/lb

$\eta_{TH} = \frac{288.52}{534.7} \rightarrow$ c) 54%

9–80E A simple ideal Brayton cycle with air as the working fluid has a pressure ratio of 10. The air enters the compressor at 520 R and the turbine at 2000 R. Accounting for the variation of specific heats with temperature, determine (*a*) the air temperature at the compressor exit, (*b*) the back work ratio, and (*c*) the thermal efficiency.





$$1 \xrightarrow{\text{ISENT}} 2 \xrightarrow{\text{P CONST}} 3 \xrightarrow{\text{ISENT}} 4 \xrightarrow{\text{P CONST}}$$

↳ run out of time for all states, /

$T_1 = 520R$ $\quad T_3 = 2000R$

$P_{r_3} = 174.0$

$\frac{P_2}{P_1} = \frac{P_{r_2}}{P_{r_1}}$ $\quad P_{r_2} = 12.147 \rightarrow$ interpolate

a) $T_2 = 996.5R$

b) $P_{r_4} = P_{r_3} \cdot P_1/P_2 \Rightarrow P_{r_4} = 17.4$

interp →

$T_4 = 1099.3$

$h_4 = 265.83$

$w_c = 240.11 - 124.3 \Rightarrow 115.84$

$w_t = 504.71 - 265.83 \Rightarrow 238.8$

A-17

$r_{bw} = w_c / w_t \Rightarrow r_{bw} = .484$

c) $\eta_{TH} = \frac{238.9 - 115.8}{264.6} \Rightarrow \eta_{TH} = 46.5\%$