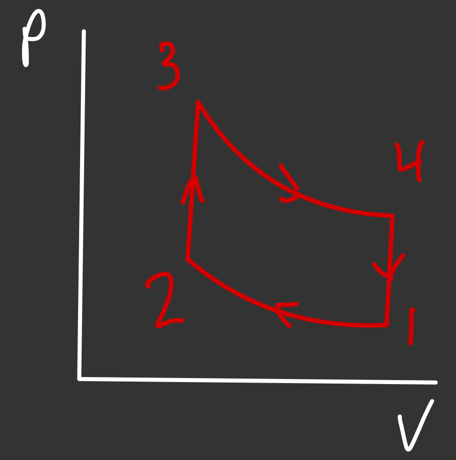
9–33 An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at 95 kPa and 27°C, and 750 kJ/kg of heat is transferred to air during the constant-volume heat-addition process. Taking into account the variation of specific heats with temperature, determine (*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

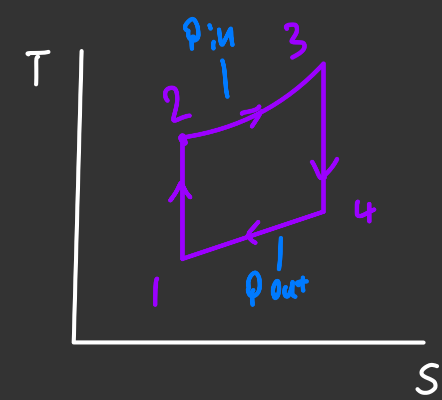
$Cr = 8$

Variable specific Heats.

$R = 0.287 \ kJ/kg \cdot °K$

$Q_{in} = 750 \ kJ/kg$





① isentropic → ② V const. → ③ isentropic → ④ V const.

$P_1 = 95 \ kPa$ | $P_2 = 1705 \ kPa$ | $P_3 = 3901 \ kPa$ | $P_4 =$

$T_1 = 300.15 \ °K$ | $T_2 = 673 \ °K$ | $T_3 = 1540 \ °K$ | $T_4 = 775 \ °K$

$u_1 = 214 \ kJ/kg$

Table A-17

$V_{r_2} = \frac{1}{8}(V_{r_1})$

$V_{r_2} = \frac{1}{8}(621.2)$

$V_{r_2} = 77.65$

via linear Interp.

$T_2 = 673 \ °K$

$u_2 = 491.2 \ kJ/kg$

$$\frac{P_2 V_2}{T_2} = \frac{P_1 V_1}{T_1}$$

$$P_2 = 8\left(\frac{673}{300}\right) \cdot 95$$

$$P_2 = 1705 \ kPa$$

$$u_3 = u_2 + Q_{in}$$

$$u_3 = 491.2 + 750$$

$$u_3 = 1241 \ kJ/kg$$

$$T_3 = 1540 \ °K$$

$$\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3}$$

$$P_3 = \left(\frac{1540}{673}\right) 1705$$

$$P_3 = 3901 \text{ kPa}$$

A)

$P_3 = 3901 \text{ kPa}$

$T_3 = 1540 \text{ °K}$

B) $Q_{out} = u_4 - u_1$

$Q_{out} = 572 - 214$

$Q_{out} = 358 \text{ KJ/kg}$

$W_{net} = Q_{in} - Q_{out}$

$W_{net} = 750 - 358$

$W_{net} = 392 \text{ KJ/kg}$

Table A-17

$$V_{r_4} = 8 (V_{r_3})$$

$$V_{r_4} = 8 (6.57)$$

$$V_{r_4} = 52.56$$

via linear Interp.

$T_4 = 775 \text{ °K}$

$u_4 = 572 \text{ KJ/kg}$

C) $\eta_{th} = \frac{W_{net}}{Q_{in}}$

$$\eta_{th} = \frac{392}{750}$$

$\eta_{th} = 0.52 = 52\%$

D) ???

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.

Constant specific heats

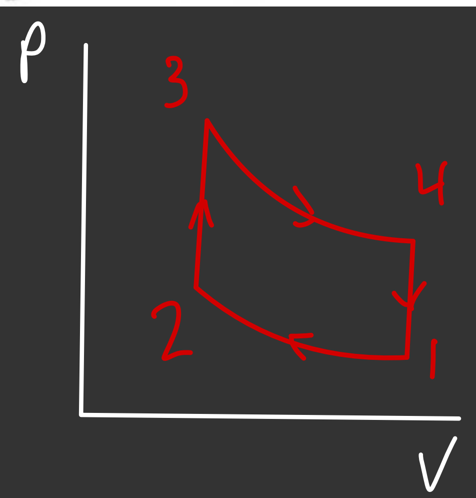
$R = 0.37$

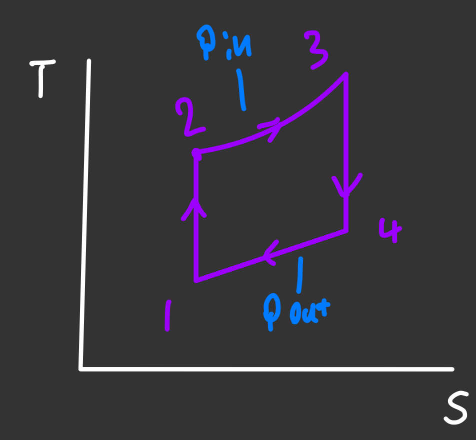
$C_p = 0.24$

$C_v = 0.171$

$k = 1.4$

$r = \frac{1}{0.098} = 10.2$





(1) isentropic → (2) V const. → (3) isentropic → (4) V const.

$P_1 = 14$ psia	$P_2 = 361.5$ psia	$P_3 = 4085$ psia	$P_4 = 158$ psia
$T_1 = 565$ °R	$T_2 = 1430.5$ °R	$T_3 = 2860$ °R	$T_4 = 1130$ °R
$v_1 = 14.9$ ft³/lb			$v_4 = 14.9$ ft³/lb

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = \left(\frac{v_1}{v_2}\right)^{k-1}$$

$$T_2 = 565(10.2)^{1.4-1}$$

$$T_2 = 1430.5 \text{ °R}$$

$$P_2 = 361.5 \text{ psia}$$

$$P_3 = 4085 \text{ psia}$$

$$T_4 = 2860(0.098)^{1.4-1}$$

$$T_4 = 1130 \text{ °R}$$

$$P_4 = 158 \text{ psia}$$

A)

$$w_{net} = c_v(T_3 - T_4) - c_v(T_2 - T_1)$$

$$w_{net} = 0.171(2860 - 1130) - 0.171(1430 - 565)$$

$$w_{net} = 147.9 \text{ Btu/lb}$$

$$m = n\left(\frac{\Delta V}{V_1}\right)$$

$$m = 6\left(\frac{\pi\left(\frac{3.5}{12}\right)^2 \cdot \left(\frac{3.9}{12}\right)/4}{14.9}\right)$$

$$m = 0.0087 \text{ lb}$$

$$W = m \cdot w_{net}$$

$$W = 0.0087 \cdot 147.9$$

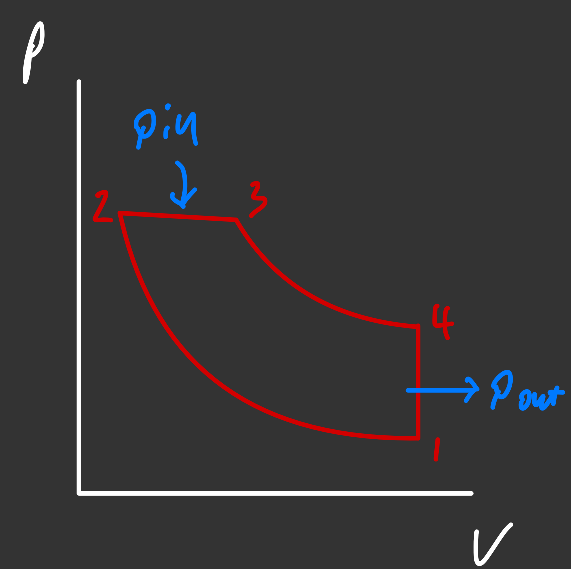
$$W = 1.29 \text{ Btu/cycle}$$

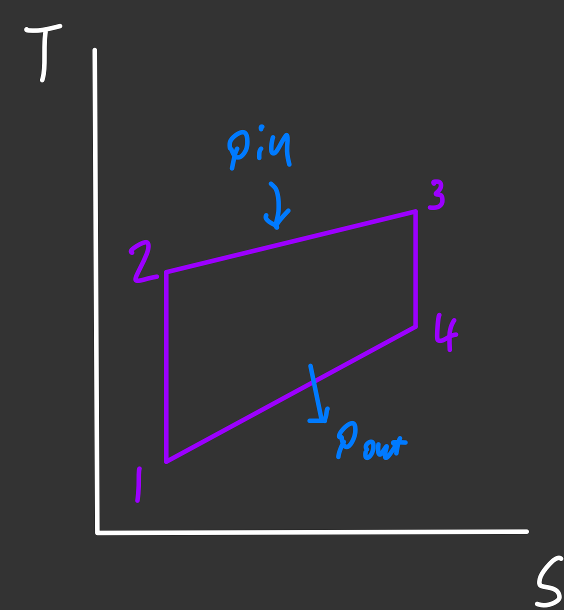
4 stroke = 2 revolutions/cycle

Power = 38 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

$r = 16$
$r_c = 2$
$R = 0.287$
Variable c_p, c_v





① isentropic → ② P const. → ③ isentropic → ④ V const.

①	②	③	④
$P_1 = 95$ kPa	$P_2 = 4366$ kPa	$P_3 = 4366$ kPa	$P_4 = 276$ kPa
$T_1 = 300.15$ °K	$T_2 = 862$ °K	$T_3 = 1724$ °K	$T_4 = 880$ °K
	$h_2 = 891$ kJ/kg	$h_3 = 1910$ kJ/kg	

Table A-17

$V_{r_2} = \frac{1}{16}(V_{r_1})$

$V_{r_2} = \frac{1}{16}(621.2)$

$V_{r_2} = 38.825$

via linear Interp.

$T_2 = 862$ °K

$P_{r_2} = 63.7$

$h_2 = 891$ kJ/kg

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

$P_2 = 95\left(\frac{63.7}{1.386}\right)$

$P_2 = 4366$ kPa

$T_3 = r_c T_2$

$T_3 = 2(862)$

$T_3 = 1724$ °K

$V_{r3} = 4.5$

$V_{r4} = \frac{16}{2}(V_{r_3})$

$V_{r4} = 8(4.5)$

$V_{r4} = 36$

$T_4 = 880$ °K

$P_4 = P_3\left(\frac{P_{r4}}{P_{r_3}}\right)$

$P_4 = 276$ kPa

A)

$T_3 = 1724\ °K$

B)

$q_{in} = h_3 - h_2$

$q_{in} = 1910 - 891 = 1019\ kJ/kg$

$q_{out} = u_4 - u_1$

$q_{out} = 660 - 214 = 446$

$\eta_{th} = 1 - \frac{q_{out}}{q_{in}}$

$\eta_{th} = 1 - \frac{446}{1019} = 0.56 = 56\ \%$

C) ??

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.

$r = 22$

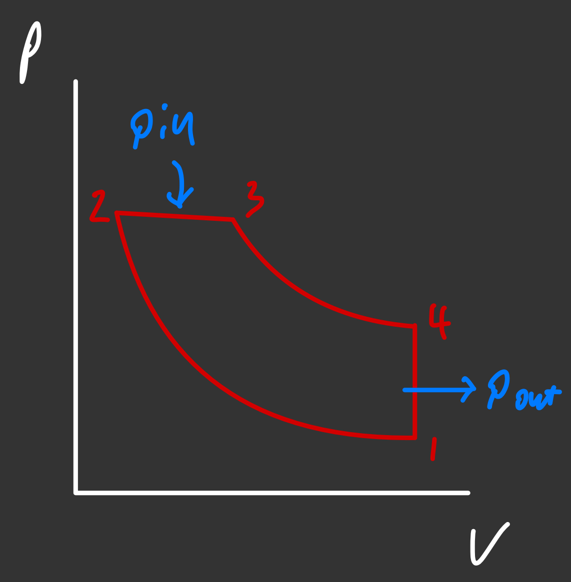
$r_c = 1.8$

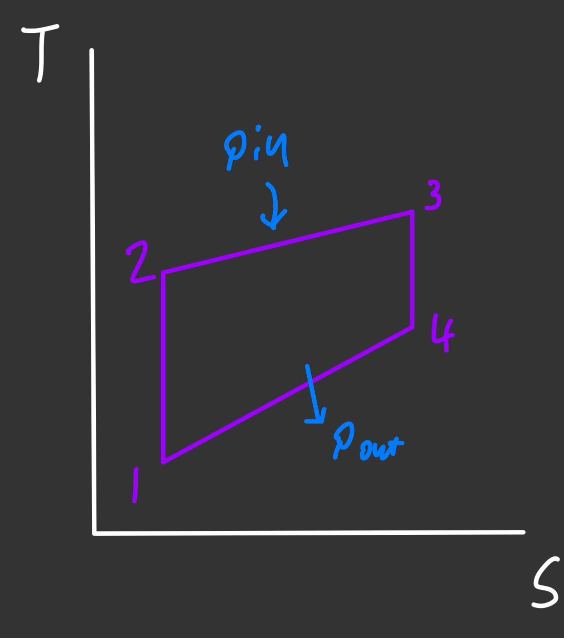
$R = 0.287$

$C_p = 1\ kJ/kg\ K$

$C_v = 0.718\ kJ/kg\ K$

$k = 1.4$





① isentropic → ② P const. → ③ isentropic → ④ V const.

$P_1 = 97\ kPa$

$T_1 = 343.15\ °K$ $\quad T_2 = 1182\ °K$ $\quad T_3 = 2128\ °K$ $\quad T_4 = 782\ °K$

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

$$T_2 = 343.15(22)^{0.4}$$

$$T_2 = 1182\ °K$$

$$T_3 = r_c \cdot T_2$$

$$T_3 = 1.8(1182)$$

$$T_3 = 2128\ °K$$

$$T_4 = T_3 \cdot \left(\frac{r_c}{r}\right)^{k-1}$$

$$T_4 = \left(\frac{1.8}{22}\right)^{0.4} \cdot 2128$$

$$T_4 = 782\ °K$$

A)

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

$$m = \frac{97 \cdot 0.0024}{0.287 \cdot 343.15}$$

$$m = 0.00236\ kg$$

$$Q_{in} = m \cdot c_p \cdot (T_3 - T_2)$$

$$Q_{in} = 0.0024(2128 - 1182)$$

$$Q_{in} = 2.236\ kJ$$

$$Q_{out} = m \cdot c_v (T_4 - T_1)$$

$$Q_{out} = 0.0024(0.718)(782 - 343)$$

$$Q_{out} = 0.745\ kJ$$

$$W_{net} = Q_{in} - Q_{out}$$

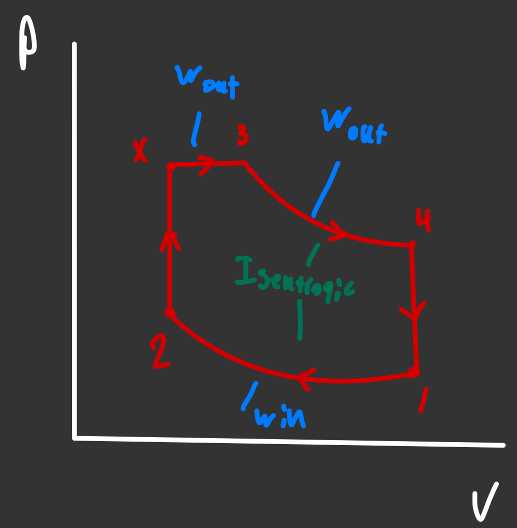
$$W_{net} = 2.236 - 0.745$$

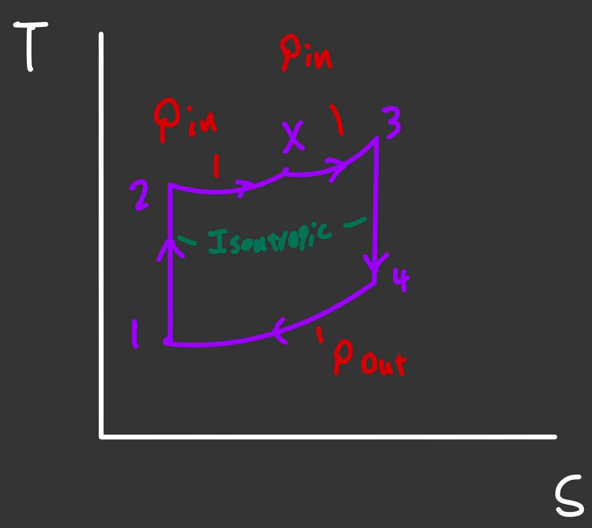
$$W_{net} = 1.5\ kJ/rev$$

$$\boxed{W_{net} = 88\ kW}$$

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.

$r = 15$
$r_c = 1.4$
$r_p = 1.1$
$c_p = 0.24$
$c_v = 0.171$
$R = 0.37$
$k = 1.4$





① Isent. → ② V const. → ⓧ P const. → ③ Isent. → ④ V const.

$P_1 = 14.2$ psia, $T_1 = 535$ °R

$P_2 = 629$ psia, $T_2 \doteq 1580$ °R

$P_x = 692$ psia, $T_x = 1738$ °R

$P_3 = 692$ psia, $T_3 = 2433$ °R

$P_4 =$, $T_4 = 942$ °R

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

$$T_2 = T_1 (r)^{k-1}$$

$$T_2 = 535 (15)^{0.4}$$

$$T_2 = 1580 \text{ °R}$$

$$P_2 = P_1 (r)^k$$

$$P_2 = 14.2 (15)^{1.4}$$

$$P_2 = 629 \text{ psia}$$

$$P_x = P_2 (r_p)$$

$$P_x = 629 (1.1)$$

$$P_x = 692 \text{ psia}$$

$$T_x = T_2 \left(\frac{P_x}{P_2}\right)$$

$$T_x = 1580 \left(\frac{692}{629}\right)$$

$$T_x = 1738 \text{ °R}$$

$$T_3 = T_x (r_c)$$

$$T_3 = 1738 (1.4)$$

$$T_3 = 2433 \text{ °R}$$

$$T_4 = T_3 \left(\frac{r_c}{r}\right)^{k-1}$$

$$T_4 = 2433 \left(\frac{1.4}{15}\right)^{0.4}$$

$$T_4 = 942 \text{ °R}$$

used excel

B10 | fx =D3*(B3-B2)

	A	B	C	D
1		Temp		
2	1	535		cv
3	2	1580		0.171
4	x	1738		
5	3	2433		cp
6	4	942		0.24
7				
8				
9	work			
10	1_2	178.695		
11	2_x	27.018		
12	x_3	47.955		
13	3_4	254.961		

$W_{net} = W_{x-3} + W_{3-4} - W_{1-2}$

$W_{net} = 48 + 255 - 178.7$

$W_{net} = 124.3$ Btu/lbm

$Q_{in} = Q_{2-x} + Q_{x-3}$

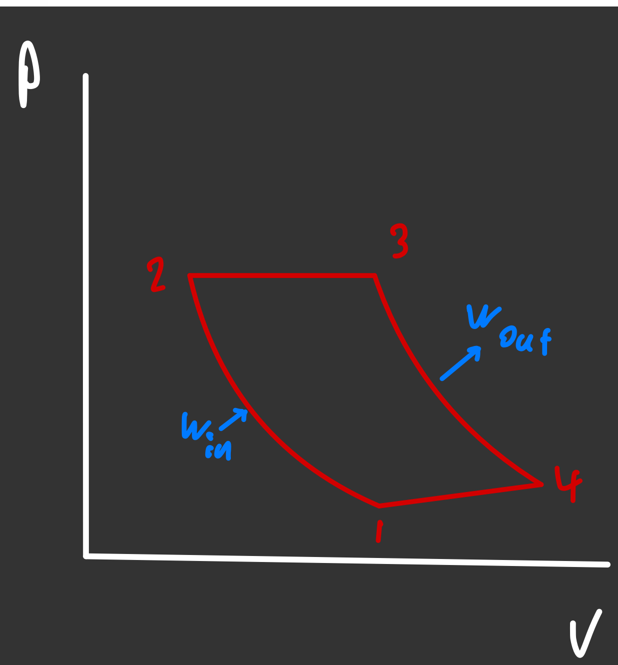
$Q_{in} = 27 + 166.8$

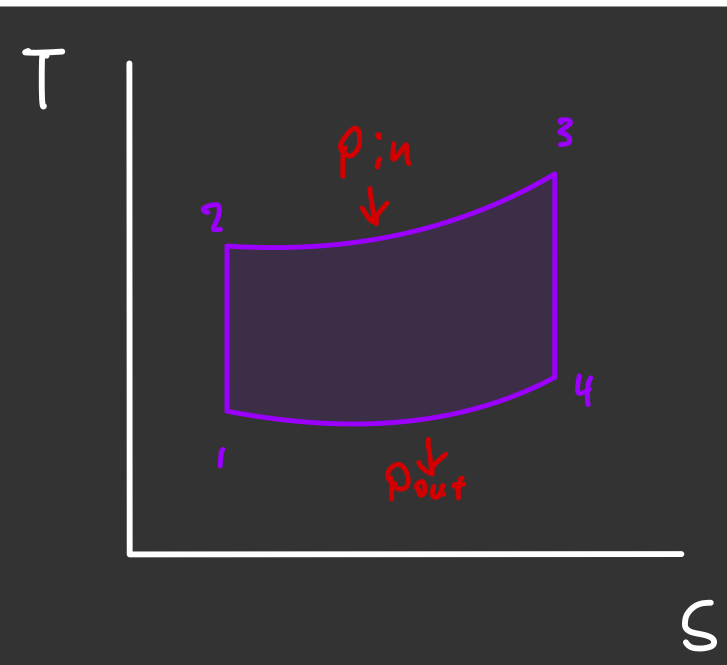
$Q_{in} = 193.8$ Btu/lbm

$\eta_{th} = \frac{W_{net}}{Q_{in}}$

$\eta_{th} = 0.64 = 64\%$

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.





const P → (1) → Isentropic (variable cp/cv) → (2) → const P → (3) → Isentropic (variable cp/cv) → (4) → const P

$T_1 = 520\,°R$ | $T_2 = 996.5\,°R$ | $T_3 = 2000\,°R$ | $T_4 = 1100\,°R$

$P_1 = 100$ kPa | $P_2 = 10 \cdot P_1$ | $P_3 = P_2$ | $P_4 = 100$ kPa

$h_1 = 124.3$ $h_2 = 240$ $h_3 = 505$ $h_4 = 266$

$$\frac{P_1}{P_2} = \frac{P_{r_1}}{P_{r_2}}$$

$P_{r_2} = 10(1.215)$

$P_{r_2} = 12.15$

A)

$T_2 = 996.5\ °R$

$P_{r_4} = \left(\frac{1}{10}\right)(174)$

$P_{r_4} = 17.4$

Interpolated

$T_4 = 1100\ °R$

$W_{in} = h_2 - h_1$

$W_{in} = 240 - 124.3$

$W_{in} = 115.7$ Btu/lbm

$W_{out} = h_3 - h_4$

$W_{out} = 505 - 266$

$W_{out} = 239$ Btu/lbm

$$R_{BW} = \frac{W_{in}}{W_{out}}$$

B)

$$R_{BW} = \frac{115.7}{239} = 0.484 = 48.4\%$$

$Q_{in} = h_3 - h_2$

$Q_{in} = 505 - 240$

$Q_{in} = 265$ Btu/lbm

$W_{net} = W_{out} - W_{in}$

$W_{net} = 239 - 115.7$

$W_{net} = 123.3$ Btu/lbm

$$\eta_{th} = \frac{W_{net}}{Q_{in}}$$

$$\eta_{th} = \frac{123.3}{265}$$

$\eta_{th} = 0.465 = 46.5\%$