The pressure at point B is

$$\begin{aligned} p_B &= p_A\left(\frac{V_A}{V_B}\right)^k \\ &= (101.3\ \text{kPa})(5)^{1.4} \\ &= 964.2\ \text{kPa} \end{aligned}$$

At point C,

$$T_A = 820°C + 273° = 1093K$$

$$p_c = p_a = 964.2\ \text{kPa}$$

At point D, the pressure is 101.3 kPa. Since C-D is an isentropic process, the temperature at point D is

$$\begin{aligned} T_D &= T_C\left(\frac{p_D}{p_C}\right)^{(k-1)/k} = (1093K)\left(\frac{101.3\ \text{kPa}}{1093\ \text{kPa}}\right)^{(1.4-1)/1.4} \\ &= 554K \end{aligned}$$

From *NCEES Handbook:* Temperature-Dependent Properties of Air (SI Units), $c_p = 1.009$ kJ/kg·K for both compressor and turbine. Using *NCEES Handbook:* Open Thermodynamic Systems, the actual work for the compressor is

$$\begin{aligned} W_{actual} &= \frac{W_{rev}}{\eta_{isen}} = \frac{c_p(T_A - T_B)}{\eta_{isen}} \\ &= \frac{\left(1.009\ \frac{\text{kJ}}{\text{kg·K}}\right)(289K - 550.2K)}{0.83} \\ &= -317.59\ \text{kJ/kg} \end{aligned}$$

The actual work for the turbine is

$$\begin{aligned} W_{actual} &= \eta_{isen} W_{rev} = \eta_{isen} c_p(T_C - T_D) \\ &= (0.92)\left(1.009\ \frac{\text{kJ}}{\text{kg·K}}\right)(1093K - 554K) \\ &= 500.3\ \text{kJ/kg} \end{aligned}$$

Rearrange the expression to find the actual T_B'.

$$\begin{aligned} c_p(T_A - T_B') &= \frac{c_p(T_A - T_B)}{\eta_{isen}} \\ T_B' &= T_A - \frac{T_A - T_B}{\eta_{isen}} \\ &= 289K - \frac{289K - 550.2K}{0.83} \\ &= 603.7K \end{aligned}$$

As in *NCEES Handbook:* Power Cycles, the cycle efficiency is

$$\begin{aligned} \eta_{cycle} &= \frac{\eta_{isen}c_p(T_C - T_D) - \dfrac{c_p(T_A - T_B)}{\eta_{isen}}}{c_p(T_C - T_B')} \\ &= \frac{(0.92)(1093K - 554K) + \dfrac{289K - 550.2K}{0.83}}{1093K - 603.7K} \\ &= 0.33 \quad (33\%) \end{aligned}$$

The answer is (A).

3. *Customary U.S. Solution*

Since specific heats are constant, use ideal gas equations rather than air tables. To convert temperatures, use *NCEES Handbook* table "Conversion Table for Temperature Units."

At A:

$$\begin{aligned} T_A &= 60°F + 460° = 520°R \quad \text{[given]} \\ p_A &= 14.7\ \text{psia} \quad \text{[given]} \end{aligned}$$

From *NCEES Handbook:* Closed Thermodynamic Systems, at B:

$$\begin{aligned} T_B &= T_A\left(\frac{\upsilon_A}{\upsilon_B}\right)^{k-1} = (520°R)(5)^{1.4-1} = 989.9°R \\ p_B &= p_A\left(\frac{\upsilon_A}{\upsilon_B}\right)^k = (14.7\ \text{psia})(5)^{1.4} \\ &= 139.9\ \text{psia} \end{aligned}$$

To convert temperatures, use *NCEES Handbook* table "Conversion Table for Temperature Units" for isentropic processes, at D:

$$\begin{aligned} T_D &= 1500°F + 460° = 1960°R \quad \text{[given]} \\ p_D &= p_B = 139.9\ \text{psia} \end{aligned}$$

To convert temperatures, use *NCEES Handbook* table "Conversion Table for Temperature Units" for isentropic processes, at E:

$$\begin{aligned} p_E &= 14.7\ \text{psia} \quad \text{[given]} \\ T_E &= T_D\left(\frac{p_E}{p_D}\right)^{(k-1)/k} = (1960°R)\left(\frac{14.7\ \text{psia}}{139.9\ \text{psia}}\right)^{(1.4-1)/1.4} \\ &= 1029.6°R \end{aligned}$$

18. Equipment that is purchased for $12,000 now is expected to be sold after ten years for $2000. The estimated maintenance is $1000 for the first year, but it is expected to increase $200 each year thereafter. The effective annual interest rate is 10%. The present worth is most nearly

(A) $16,000

(B) $17,000

(C) $21,000

(D) $22,000

19. A new grain combine with a 20-year life can remove seven pounds of rocks from its harvest per hour. Any rocks left in its output hopper will cause $25,000 damage in subsequent processes. Several investments are available to increase the rock-removal capacity, as listed in the table. The effective annual interest rate is 10%. What should be done?

rock removal rate	annual probability of exceeding rock removal rate	required investment to achieve removal rate
7	0.15	0
8	0.10	$15,000
9	0.07	$20,000
10	0.03	$30,000

(A) Do nothing.

(B) Invest $15,000.

(C) Invest $20,000.

(D) Invest $30,000.

20. A mechanism that costs $10,000 has operating costs and salvage values as given. An effective annual interest rate of 20% is to be used.

year	operating cost	salvage value
1	$2000	$8000
2	$3000	$7000
3	$4000	$6000
4	$5000	$5000
5	$6000	$4000

The economic life of the mechanism is most nearly

(A) one year

(B) two years

(C) three years

(D) five years

21. A salesperson intends to purchase a car for $50,000 for personal use, driving 15,000 miles per year. Insurance for personal use costs $2000 per year, and maintenance costs $1500 per year. The car gets 15 miles per gallon, and gasoline costs $1.50 per gallon. The resale value after five years will be $10,000. The salesperson's employer has asked that the car be used for business driving of 50,000 miles per year and has offered a reimbursement of $0.30 per mile. Using the car for business would increase the insurance cost to $3000 per year and maintenance to $2000 per year. The salvage value after five years would be reduced to $5000. If the employer purchased a car for the salesperson to use, the initial cost would be the same, but insurance, maintenance, and salvage would be $2500, $2000, and $8000, respectively. The salesperson's effective annual interest rate is 10%. With a reimbursement of $0.30 per mile, approximately how many miles must the car be driven per year to justify the employer buying the car for the salesperson to use?

(A) 20,000 mi

(B) 55,000 mi

(C) 82,000 mi

(D) 150,000 mi

22. Alternatives A and B are being evaluated. The effective annual interest rate is 10%.

	alternative A	alternative B
first cost	$80,000	$35,000
life	20 years	10 years
salvage value	$7000	0
annual costs		
years 1–5	$1000	$3000
years 6–10	$1500	$4000
years 11–20	$2000	0
additional cost		
year 10	$5000	0

Plant Design