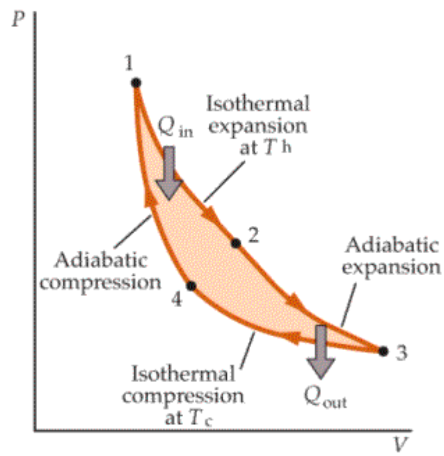

Figure 1: Problem 1

___ 1 The diagram in Fig. 1 illustrates a Carnot engine. Along which two path segments of the cycle is the work done by the gas positive.

A) $1 \to 2,\ 2 \to 3$ B) $4 \to 1,\ 1 \to 2$ C) $2 \to 3,\ 3 \to 4$ D) only $1 \to 2$ E) $3 \to 4,\ 4 \to 1$

Solution:

The work done by the gas is positive (negative) when the gas expands (contracts).

The correct answer is: A

___ 2 A Carnot engine operating between reservoir temperatures of 460 °C and 48 °C has an efficiency of

A) 28.% B) 84.% C) 68.% D) 42.% E) 56.%

Solution:

The efficiency is $(T_{\rm H} - T_{\rm C})/T_{\rm H} = (733 - 321)/733 = 56.\%$.

The correct answer is: E

___ 3 A car of mass 2500 kg is traveling at 18 m/ s on a day when the temperature is 23 °C. The driver steps on the brakes and stops the car. The wheels do not slide on the road surface. By how much does the entropy of the universe increase?

A) 1.4 kJ/ K B) 1.8 kJ/ K C) 0.55 kJ/ K D) 0.68 kJ/ K E) 2.7 kJ/ K

Solution:

The kinetic energy of the car is converted to heat. The resulting increase in entropy is $\Delta S = \frac{1}{2}mv^2/T = 0.5 \times 2500\,\text{kg} \times \left(18\,\text{m}\,\text{s}^{-1}\right)^2 / 296\,\text{K} = 1.4\,\text{kJ/K}$.

The correct answer is: A

___ 4 A steam power plant with an efficiency of 55% of the maximum thermodynamic efficiency operates between 250 °C and 40 °C. What is the change in the entropy of the "universe" when this plant does 1.00 kJ of work?

A) 1.31 J/ K B) 2.61 J/ K C) 4.97 J/ K D) 106. J/ K E) 19.9 J/ K

Solution:

Let $Q_{\rm H}, Q_{\rm C}$ and W be the heat out of the hot reservoir, the heat into the cold reservoir and the work done during one cycle of the engine. $T_{\rm C}$ and $T_{\rm H}$ are the temperatures of the cold and hot reservoirs, respectively.

The question states that the efficiency, defined to be $\dfrac{W}{Q_{\mathrm{H}}} = 0.550\left(1 - \dfrac{T_{\mathrm{C}}}{T_{\mathrm{H}}}\right)$. So if $W = 1.00\,\mathrm{kJ}$, then

$Q_{\mathrm{H}} = \dfrac{1.00\,\mathrm{kJ}}{0.550\left(1 - \dfrac{313}{523}\right)} = 4.53\,\mathrm{kJ}$, and $Q_{\mathrm{C}} = Q_{\mathrm{H}} - W = 3.53\,\mathrm{kJ}$.

The entropy change of the "universe" is the sum of the entropy changes of the two reservoirs only, since the working substance is in the same state at the end of a cycle as at the beginning and therefore has the same entropy.

$\Delta S_{\mathrm{U}} = \Delta S_{\mathrm{H}} + \Delta S_{\mathrm{C}} = \dfrac{Q_{\mathrm{C}}}{T_{\mathrm{C}}} - \dfrac{Q_{\mathrm{H}}}{T_{\mathrm{H}}} = 2.61\,\mathrm{J/K}$

The correct answer is: B

___ 5 An amount of 2 mole of an ideal gas undergoes a reversible isothermal expansion from a volume of 1 L to a volume of 3 L. The change in entropy of the gas in terms of the universal gas constant R is

A) $2R\ln 3$ B) $2R\ln\frac{1}{3}$ C) All other choices are wrong
D) $\frac{2}{3}R$ E) $6R$

Solution:

$\Delta S = nR\ln(V_2/V_1) = 2R\ln 3$

The correct answer is: A

___ 6 Three moles of a gas at $T = 250\,\mathrm{K}$ expand reversibly and adiabatically from an initial volume of 20 L to a final volume of 60 L. The change in entropy of the gas during this expansion is ($R = 8.314\,\mathrm{J/mol\cdot K}$)

A) $-27.4\,\mathrm{J/K}$ B) $54.8\,\mathrm{J/K}$ C) $-54.8\,\mathrm{J/K}$ D) $27.4\,\mathrm{J/K}$ E) 0

Solution:

For a reversible process $\Delta Q = T\Delta S$ and for an adiabatic process $\Delta Q = 0$, which implies that $\Delta S = 0$ for a reversible, adiabatic process.

The correct answer is: E

1. A
2. E
3. A
4. B
5. A
6. E