Quiz #4 Ch.#20 T131-Sec. 7-9-v1

Student ID:......... ...... Student Name:........... .... Section # ....

Q#1: A 1.0 kg of water at 90 °C is mixed with 1.0 kg of water at 30 °C. What is the total entropy change in the process? The specific heat of water is 4190 J/kg.K. (A) + 35 J/K

to Calculate $T_f \rightarrow m_w \times C_w \times (90 - T_f) = m_w \times C_w \times (T_f - 30) \rightarrow 90 - T_f = T_f - 30$

$T_f = \frac{90+30}{2} = 60^\circ C$

$$\Delta S_{tot} = \Delta S_{90^\circ} + \Delta S_{30^\circ} = m_w \times c_w \times \left[\ln\left(\frac{60+273}{90+273}\right) + \ln\left(\frac{60+273}{30+273}\right) \right]$$

$$= 1 \times 4190 \times \left[\ln\left(\frac{333}{363}\right) + \ln\left(\frac{333}{303}\right) \right]$$

$$\Delta S_{tot} = -361.4 + 395.6 = +34.2 \text{ J/K}.$$

Q#2: Consider an ideal engine that operates between two reservoirs at 300 K and 600 K and absorbs 1.44×10^6 J per cycle. What is the power output of this engine if it completes 10 cycles per minute? A) 120 kW

$Q_H = 1.44 \times 10^6$ J/Cycle., $T_L = 300$ K, $T_H = 600$ K

$W = \epsilon \times Q_H$; $\epsilon = \frac{600 - 300}{600} = 0.5$

$W(\text{per Cycle}) = \epsilon \times Q_H = 0.5 \times 1.44 \times 10^6$

# of Cycles per sec $= 10$ Cycles/min $= \frac{10}{60 \text{ sec}} = \frac{1}{6}$ Cycle/sec.

Work/sec $= W(\text{per Cycle}) \times$ # of cycles per sec $= \frac{0.5 \times 1.44 \times 10^6}{6}$

$= 120 \times 10^3 \text{ W} = 120 \text{ kW}$

Q#3: ~~Q19~~. An ideal refrigerator operates between 230 K and 300 K. In every cycle, the motor does 210 J of work. How much heat is rejected to the room? A) 900 J

$T_L = 230$ K, $T_H = 300$ K, $K = \frac{T_L}{T_H - T_L} = \frac{230}{300-230} = 3.29$

$W = 210$ J

$K = \frac{Q_L}{W} = \frac{Q_H - W}{W} \Rightarrow Q_H = KW + W = W(K+1)$

$Q_H = W(K+1) = 210(3.29+1) = 900$ J

Quiz #4 Ch.#20 T131-Sec. 7-9-v3

Student ID:.............. Student Name:..................... Section # ....

Q#1: A system consists of two thermal reservoirs in contact with each other, one at a temperature of 300 °C and the other at a temperature of 200 °C. If 6000 J of heat is transferred from the 300 °C reservoir to the 200 °C reservoir, what is the change in entropy of this system? A) +2.2 J/K

$$\Delta S_H = \frac{\Delta Q_H}{T_H} = \frac{-6000}{300+273} = -10.47 \text{ J/K}$$

$$\Delta S_L = \frac{\Delta Q_L}{T_L} = +\frac{6000}{200+273} = +12.68 \text{ J/K}$$

$$\Delta S_{net} = \Delta S_H + \Delta S_L = -10.47 + 12.68 = +2.21 \text{ J/K}$$

Q#3 A Carnot engine whose cold reservoir is at 15 oC has an efficiency of 34%. Then, the temperature of the hot reservoir is fixed while that of the cold reservoir is decreased. What should the temperature of the cold reservoir be in order to make the efficiency of this engine equal to 36%? A) 6.3 o C

$$\epsilon_c = 0.34 \;;\; \epsilon_c' = 0.36 \;,\; T_L = 15^\circ C = 288 \text{ K}$$

$$\epsilon_c = 0.34 = \frac{T_H - T_L}{T_H} = \frac{T_H - 288}{T_H} \Rightarrow 0.34\, T_H = T_H - 288$$

$$T_H = \frac{288}{0.66}$$

$$\epsilon_c' = 0.36 = \frac{T_H - T_L'}{T_H} \Rightarrow T_L' = T_H(1 - 0.36) = \frac{288}{0.66} \times 0.64$$

$$T_L' = 279.3 \text{ K} = 6.3^\circ C$$

Q3A Carnot air conditioner takes heat from a room at 21 °C and transfers it to the outdoors, which is at 35 °C. For each two joules of electric energy required to operate the air conditioner, how many joules are removed from the room in the form of heat?
A) 42 J

$$W = 2\text{ J} \;;\; T_L = 21^\circ C = 273 + 21 = 294 \text{ K}$$

$$T_H = 35^\circ C = 308 \text{ K}$$

$$K = \frac{Q_L}{W} \qquad K = \frac{294}{308 - 294} = 21$$

$$Q_L = K \times W = 21 \times 2 = 42\text{ J}$$

$$Q_L = 42\text{ J}$$

Quiz #4 Ch.#20 T131-Sec. 7-9-v2

Student ID:......... ...... Student Name:........... .... Section # ....

Q#1: Two moles of an ideal gas undergo an adiabatic free expansion from an initial volume of 0.60 L to 1.2 L. Calculate the change in entropy of gas. A) + 12 J/K.

$$\Delta S = nR\ln\left(\frac{V_f}{V_i}\right) = 2\times 8.314\times\ln\left(\frac{1.2}{0.6}\right)$$
$$= 11.52\ J/K.$$

Q#2A heat engine is connected to two heat reservoirs: one is steam at 100 oC, and the other is ice at 0.0 oC. The engine runs by condensing 1.0 g of steam and melting 5.0 g of ice. What is the efficiency of this engine? A) 0.26

$$T_H = 100^\circ C = 373\ K,\quad T_L = 0^\circ C = 273\ K$$

$$\varepsilon = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H}$$

$$Q_H = m_{Stea}L_V = 10^{-3}\times 2225\times 10^{3}\ J;\quad Q_L = m_{ice}L_F = 5\times 10^{-3}\times 333\times 10^{3}\ J$$

$$\varepsilon = \frac{Q_H - Q_L}{Q_H} = \frac{2225 - 5\times 333}{2225} = 0.252$$

Q#3: During each cycle, a refrigerator expels 625 kJ of heat to a high-temperature reservoir and takes 550 J of heat from a low-temperature reservoir. What is the coefficient of performance of the refrigerator? A) 7.3

$$K = \frac{Q_L}{Q_H - Q_L} = \frac{550}{625 - 550} = 7.33$$

Quiz #4 Ch.#20 T131-Sec. 7-9-v4

Student ID:……… …… Student Name:……… …………. Section # ……….

Q1: A piece of iron of mass 2.00 kg at a temperature of 880 K is thrown into a large lake whose temperature is 280 K. Assume the lake is so large that its temperature change can be ignored. If the change in entropy of the **iron-lake system** is 898 J/K, calculate the specific heat of iron. A) 450 J/kg K

$$\Delta S_{lake} = \frac{\Delta Q}{T} = \frac{m_{Fe} \times C_{Fe} \times (880 - 280)}{280} = \frac{2 \times C_{Fe} \times 600}{280} = 4.29 \times C_{Fe}$$

$$\Delta S_{Fe} = m \times C_{Fe} \times \ln\left(\frac{T_f}{T_i}\right) = 2 \times C_{Fe} \times \ln\left(\frac{280}{880}\right) = -2.29 \times C_{Fe}$$

$$\text{but } \Delta S_{tot} = \Delta S_{lake} + \Delta S_{Fe} = 4.29 \times C_{Fe} - 2.29\, C_{Fe} = 2 \times C_{Fe}$$

$$\text{but } \Delta S_{tot} = 2 \times C_{Fe} = 898 \Rightarrow C_{Fe} = \frac{\Delta S_{tot}}{2} = \frac{898}{2} = 449.95 \text{ J/k}$$

Q#2: A heat engine operates between a hot reservoir at 1500 K and a cold reservoir at 500 K. During each cycle, 1.0×10^5 J of heat is removed from the hot reservoir and 5.0×10^4 J of work is performed. The actual efficiency of this engine is: A) 75 % of the maximum efficiency

$$\epsilon = \frac{W}{Q_H} = \frac{5 \times 10^4}{1 \times 10^5} = 0.5 \quad ; \quad \epsilon_c = \frac{T_H - T_L}{T_H} = \frac{1500 - 500}{1500} = \frac{1000}{1500} = 0.67$$

$$\frac{\epsilon}{\epsilon_c} = \frac{0.5}{0.67} = 0.75 = 75\% \text{ of maximum efficie.}$$

Q#3: A Carnot refrigerator is placed in a kitchen. The temperature inside the refrigerator is 2.0 °C, and the temperature of the kitchen is 22 °C. The rate of heat flow from the refrigerator to the kitchen is 24.7 kW. What power is needed to operate this refrigerator? A) 1.8 kW

$$T_L = 2^\circ C = 275 \text{ K} \; ; \; T_H = 22^\circ C = 295 \text{ K}$$

$$K = \frac{Q_L}{W} \; ; \; W = \frac{Q_L}{K} \; ; \; K = \frac{T_L}{T_H - T_L} = \frac{275}{295 - 275} = 13.72$$

$$W = \frac{Q_L}{K} = \frac{24.7 \times 10^3}{13.72} = 1.8 \text{ kW}$$

Quiz #4 Ch.#20 T131-Sec. 7-9-v5

Student ID:........... Student Name:........... .... Section # ....

Q#1: A system consists of two large thermal reservoirs in contact with each other, one at a temperature of 300 °C and the other at a temperature 200 °C. If 600 J of heat is transferred from the 300 °C reservoir to the 200 °C reservoir, what is the change in entropy of this system? A) 0.221 J/K

$T_H = 300\,^{\circ}C = 573\,K \; ; \; T_L = 200\,^{\circ}C = 473\,K$

$\Delta S_H = \frac{Q_H}{T_H} = \frac{-600}{573} = -1.047\ J/K$

$\Delta S_L = \frac{Q_L}{T_L} = \frac{+600}{473} = +1.268$

$\Delta S_{syst} = \Delta S_H + \Delta S_L = 1.268 - 1.047 = 0.221\ J/K$

Q#2:. A certain heat engine extracts 500 calories from a water bath at 27.0 oC and transfers 400 calories to a reservoir at a lower temperature. The efficiency of this engine is: A) 20.0 %

$e = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H} \; ; \; Q_H = 500\ cal. \quad Q_L = 400\ cal.$

$e = \frac{Q_H - Q_L}{Q_H} = \frac{500 - 400}{500} = 0.2 = 20\%$

Q3. A Carnot refrigerator is operated between two heat reservoirs at temperatures of 320 K and 270 K. In each cycle, the refrigerator extracts 415 J of heat from the cold reservoir. If the refrigerator completes 165 cycles each minute, what is the power input required to operate it?
A) 211 W

number of Cycles per Sec $= \frac{165}{60} = 2.75$ Cycle/sec

$Q_L = 415\ J \; ; \; T_L = 270\ K \; ; \; T_H = 320\ K$

$K = \frac{T_L}{T_H - T_L} = \frac{270}{320 - 270} = 5.4$

$W = \frac{Q_L}{K} = \frac{415}{5.4} = 76.85\ J/cycle.$

$P = W(\text{watt/cycle}) \times (\text{Cycles/sec}) = 78.85 \times 2.75$

$= 211.3\ J/s = 211\ W$

Quiz #4 Ch.#20 T131-Sec. 7-9-v6

Student ID:......... ...... Student Name:............ .... Section # ....

Q#1: A 3.47 mol sample of an ideal gas expands reversibly and isothermally at 400 K until its volume doubled. What is increase in entropy of the gas? A) 20.0 J/K

$n = 3.47$ mol, $T = 400$ K; $V_f = 2V_i$

$$\Delta S = nR\ln\left(\frac{V_f}{V_i}\right) = 3.47 \times 8.3 \times \ln\left(\frac{2V_i}{V_i}\right)$$

$$= 3.47 \times 8.31 \times \ln(2)$$

Q#2: Q18. A Carnot heat engine operates between two reservoirs at temperatures of 500 K and 375 K. If the engine does 4.50 × 10⁷ J of work per cycle, find the heat extracted per cycle. A) 18.0 ×10^7 J

$W = 4.50 \times 10^7$ J/s.)

$$\epsilon_c = \frac{T_H - T_L}{T_H}$$

$$\epsilon_c = \frac{500 - 375}{500} = 0.25$$

$$Q_H = \frac{W}{\epsilon_c} = \frac{4.50 \times 10^7}{0.25}$$

$$Q_H = 18 \times 10^7 \text{ J/s}$$

Q#3: A freezer has a coefficient of performance of 3.80 and uses 200 W of power. How long would it take to freeze 600 g of water at 0 °C? A) 4.4 minutes

$K = 3.80$

$Q_L = KW$

$W = 200$ W

$Q_L = 3.8 \times 200$ J/s

$$\Delta Q_L = dm \times L_F = 0.6 \times 333 \times 10^3 \text{ J}$$

$$\Delta Q_L = Q_L \times t$$

$$t = \frac{\Delta Q_L}{Q_L} = \frac{0.6 \times 333 \times 10^3}{3.8 \times 200} = 262.9 \text{ s}$$

$$= 4.38 \text{ min}$$

Quiz #4 Ch.#20 T131-Sec. 7-9-v7

Student ID:……… …… Student Name:………… ………. Section # ……….

Q#1: Calculate the change in entropy of 1.0 kg of ice at 0.0 °C when its temperature is increased to 20.0 °C [$L_{fusion\text{-}ice}$ = 333 kJ/kg; c_{water} = 4190 J/kg.K] A) 1.5 × 10^3 J/K

$$\Delta S = \frac{m_{ice} \times L_F}{T_{ice}} + m_{ice} \times C_w \times \ln\left(\frac{T_f}{T_i}\right)$$

$$= m_{ice}\left[\frac{L_F}{273} + C_w \times \ln\left(\frac{T_f}{T_i}\right)\right] = 1 \times \left[\frac{333 \times 10^3}{273} + 4190 \times \ln\left(\frac{293}{273}\right)\right]$$

$$= 1 \times [1219.8 + 296.2] = 1516.0 = 1.5 \times 10^3 \text{ J/K}$$

Q#2: An ideal heat engine absorbs heat from a reservoir at 527 °C and rejects heat to a reservoir at 127 °C. What is the power produced by the engine if the rate at which heat is absorbed is 1500 W? A) 750 W

$$Q_H = 1500 \text{ J/s}$$

$$W = \epsilon_c \times Q_H$$

$$W = 0.5 \times 1500 = 750 \text{ J/s}$$

$$T_H = 527\,°C = 800 \text{ K}$$

$$T_L = 127\,°C = 400 \text{ K}$$

$$\epsilon_c = \frac{T_H - T_L}{T_H} = \frac{800 - 400}{800}$$

$$\epsilon_c = 0.5 = 50\%$$

Q#3: An ideal (Carnot) refrigerator has a coefficient of performance equal to 5.0. If the temperature inside the refrigerator is −20 oC, what is the temperature at which heat is rejected? A) 31 °C

$$K = 5.0$$

$$T_L = -20\,°C = 253 \text{ K}$$

$$K = \frac{T_L}{T_H - T_L} \Rightarrow K(T_H - T_L) = T_L$$

$$K T_H = K T_L + T_L$$

$$T_H = \frac{T_L(1+K)}{K}$$

$$T_H = \frac{T_L(1+K)}{K} = \frac{253(1+5)}{5} = 303.6 \text{ K} = 30.6\,°C$$

Quiz #4 Ch.#20 17 T131-Sec. 7-9-v8

Student ID:……… …… Student Name:……….. ………. Section # ……….

Q#1: A piece of metal at 80 oC is placed in 1.2 kg of water at 72 oC. The system is thermally isolated and reaches to a final temperature of 75 oC. Find the change in entropy for the metal. The specific heat of water is 4.19 kJ/kgK. (A) – 43.0 J/K.

$\Delta S_{metal} = m_{metal} \times C_{metal} \times \ln\left(\frac{T_f}{T_i}\right)$; $m_{metal} \times C_{metal}$ is not given but we get from the equation:

$m_{metal} \times C_{metal} \times (80-75) = 1.2 \times C_w \times (75-72) \rightarrow m_{metal} \times C_{metal} = \frac{1.2 \times 4190 \times 3}{5}$

$m_{metal} \times C_{metal} = \frac{1.2 \times 4190 \times 3}{5} = 3016.8$

$\Delta S_{metal} = m_{metal} \times C_{metal} \times \ln\left(\frac{348}{353}\right) = 3016.8 \times \ln\left(\frac{348}{353}\right) = -43.04\ J/K$

Q2. The efficiency of a car engine is 20% when the engine does 1.2 kJ of work per cycle. What is the energy |QL| the engine loses per cycle as heat? A) 4.8 kJ

$\epsilon = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H} \Rightarrow \epsilon Q_H = Q_H - Q_L$

$Q_L = Q_H(1-\epsilon)$; $Q_H = \frac{W}{\epsilon} = \frac{1.2 \times 10^3}{0.2} = 6 \times 10^3\ J$

$Q_L = 6 \times 10^3 (1 - 0.2) = 6 \times 0.8 \times 10^3\ J = 4.8\ kJ$

Q#3: The freezing compartment of a Carnot refrigerator is at 269 K while outside air in the room is at 298 K. If the power of refrigerator motor is 150 W, what is maximum amount of energy that can be extracted as heat from the freezing compartment in 10.0 min? (Ans: 8.35×10^5 J)

$K = \frac{Q_L}{W} \Rightarrow Q_L = KW$; $K = \frac{T_L}{T_H - T_L} = \frac{269}{298 - 269}$

$K = 9.28$

$Q_L = K \times W$

$= 9.28 \times 150 = 1391.4\ J/s$

heat extracted in 10 min $= Q_L \times 10 \times 60$

$= 1391.4 \times 600 = 8.35 \times 10^5\ J$

Quiz #4 Ch.#20 T131-Sec. 7-9-v9

Student ID:……… …… Student Name:……….. ………. Section # ……….

Q1 A cup holding 125 g of hot water at 100 °C cools to room temperature, 20.0 °C. What is the change in entropy of the room? Neglect the specific heat of the cup. A) + 143 J/K

$$\Delta S_{room} = \frac{\Delta Q}{T} = \frac{mc\Delta T}{T_{room}}$$

$$= \frac{0.125 \times 4190 \times 80}{293}$$

$$\Delta S_{Room} = +143 \text{ J/K}$$

Q#2: An ideal Carnot heat engine operates between 40 oC and 300 °C. If the engine absorbs heat at a rate of 40 kW, at what rate does it exhaust heat? A) 22 kW.

$$\epsilon_L = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H} \Rightarrow \epsilon Q_H = Q_H - Q_L$$

$T_H = 300°C = 573 K$

$T_L = 40°C = 313 K$

$$Q_L = Q_H(1-\epsilon_c) \; ; \; \epsilon_c = \frac{T_H - T_L}{T_H}$$

$$\epsilon_c = \frac{573 - 313}{573} = 0.454$$

$$Q_L = 40 \times 10^3 (1 - 0.454)$$

$$= 21849.9 \text{ J/s}$$

$$Q_L = 22 \times 10^3 \text{ J/s} = 22 \text{ kW}$$

Q#3: An ideal refrigerator has a coefficient of performance of 5. If the temperature inside the refrigerator is -20 °C, what is the temperature at which it releases heat? A) 31 °C.

$$K = 5 \; ; \; K = \frac{T_L}{T_H - T_L} \Rightarrow K(T_H - T_L) = T_L \; ; \; T_L = -20°C = 253 K$$

$$T_H = \frac{T_L(1+K)}{K}$$

$$T_H = \frac{T_L(1+K)}{K}$$

$$T_H = \frac{253(1+5)}{5} = 303.6 \text{ K} = 30.6 °C$$

Quiz #4 Ch.#20 T131-Sec. 7-9-v10

Student ID:……… …… Student Name:……….. ………. Section # ……….

Q#1 When ice, initially at 0.00 °C, is heated to 40.0 °C, its entropy is increased by 1.18 kJ/K. Find the mass of ice. A) 658 g

$$\Delta S_{ice} = \frac{\Delta Q}{T} + m_{ice} c_w \ln\left(\frac{T_f}{T_i}\right) = m_{ice}\left[\frac{L_F}{T} + c_w \times \ln\left(\frac{T_f}{T_i}\right)\right]$$

$$= m_{ice}\left[\frac{333\times10^3}{273} + 4190\times\ln\left(\frac{313}{273}\right)\right] = m_{ice}[1792.7]$$

$$\Delta S_{ice} = 1.18\times10^3 = m_{ice}\times 1792.7$$

$$m_{ice} = \frac{1.18\times10^3}{1792.7} = 0.6582 \text{ kg}$$

Q#2 A Carnot engine completes 4 cycles per second. In every cycle, it delivers a power 120 W and discharges 40 J. what is the efficiency of the engine? A) 43%

4 Cycles per sec.

$W = 120$ J/s then $W(\text{per cycle}) = \frac{W}{4} = \frac{120}{4} = 30$ J/Cycle

$Q_L = 40$ J

$\epsilon_c = \frac{W}{Q_H}$ but $Q_H = W + Q_L$

$$\epsilon_c = \frac{W}{W+Q_L} = \frac{30}{30+40} = \frac{30}{70} = 0.429 = 0.43$$

Q#3A refrigerator converts 7.0 kg of water at 0 oC inti ice at 0 oC in one hour. What is the coefficient of performance of the refrigerator if its power input is 300 W? Heat of fusion for water is 333 kJ/kg. A) 2.2

$$Q_L = \frac{\Delta Q}{t} = \frac{mL_F}{60\times60} = \frac{7\times333\times10^3}{3600} = 647.5 \text{ J/s}$$

$$K = \frac{Q_L}{W} = \frac{647.5}{300} = 2.16 = 2.2$$