CM 3230
Fall 2015
Exam 1

Name _____

1. (25 pts) Let the Carnot efficiency of a Carnot cycle be $\eta_{orig} = 0.4$ based on a hot reservoir temperature, $T_{H,orig}$, and cold reservoir temperature, $T_{C,orig}$. It was determined that a new source of fuel can increase the hot reservoir temperature by 30%, i.e. $T_{H,new} = 1.3\, T_{H,orig}$. If the cold reservoir temperature is kept the same, i.e. $T_{C,new} = T_{c,orig}$, determine the Carnot efficiency based on the new temperatures.

2. (25 pts) An ideal Rankine cycle has steam entering the turbine at $P_1 = 30\ bar$ and $T_1 = 500°C$. The outlet stream is then condensed at a pressure $P_2 = 1\ bar$. Assume that the turbine and compressor operate isentropically. Determine the ideal Rankine engine efficiency and the mass flow rate (in kg/s) of the steam in the cycle to achieve a power rating of $100\ MW$.

Data: 1) @ (T_1, P_1): $\hat{h}_1 = 3456.5 \frac{kJ}{kg}$, $\hat{s}_1 = 7.2337 \frac{kJ}{kg \cdot K}$

2) @ P_2 and saturated condition:

$$\hat{h}_{2,vap} = 2675.5 \frac{kJ}{kg} \quad ; \quad \hat{h}_{2,liq} = 417.44 \frac{kJ}{kg}$$

$$\hat{s}_{2,vap} = 7.3593 \frac{kJ}{kg \cdot K} \quad ; \quad \hat{s}_{2,liq} = 1.3025 \frac{kJ}{kg \cdot K}$$

$$\hat{v}_{liq} = 0.001043 \frac{m^3}{kg}$$

3. (25 pts) 10 moles of metal block A (heat capacity $c_{P,A} = 3.2R$) initially at $T_{A,i} = 500K$ is put in thermal contact with 20 moles of metal block B (heat capacity $c_{P,B} = 1.5R$) initially at $T_{B,i} = 300K$ where both block are insulated from the surroundings. Afterwards, the insulation was removed and both blocks attain the surrounding temperature of $T_{surr} = 450K$. Calculate the total change in entropy of the universe from the point just before thermal contact to the final thermal equilibrium with the surrounding temperature.

4. (25 pts) An isolated rigid vessel has two compartments separated by a thin membrane. Initially, one compartment contains 4 $mol\ A$ and 6 $mol\ \ B$ at $P_{section1} = 2\ bar$, while the other compartment contains 7 $mol\ C$ and 3 $mol\ D$ at $P_{section2} = 1\ bar$. The temperature of both compartments are equal. After the membrane ruptures, the gases mix completely and settle to a common pressure. Determine the change in entropy of the universe due to this process.

5. (Bonus: 10 pts) An ideal gas of $c_p = 3R/2$ undergoes a cycle shown in Figure 1 where $P_a = P_c = 2P_b$ and $v_b = 2v_a = v_c$. Path $a \rightarrow b$ is isothermal, while the paths $b \rightarrow c$ is isochoric and path $c \rightarrow a$ is isobaric. Calculate the net work done by the system for one cycle per mole of the ideal gas for $T_a = T_b = 350K$.

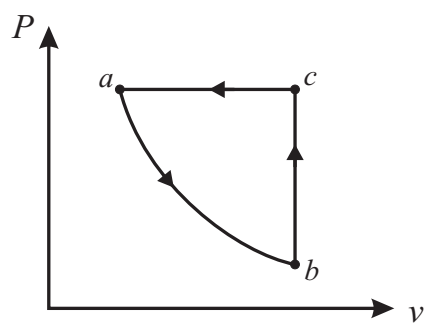

Figure 1. Cyclic process where $a \rightarrow b$ is isothermal.