1. (20 pts) A rigid vessel contains two compartments of the same volume separated by a thin membrane and is in equilibrium with the surrounding temperature, \( T_{init} = T_{surr} = 25^\circ C \). One compartment contains 10 moles of ideal gas \( A \), having a heat capacity \( c_{p,A} = 3.2R \), while the other compartment contains 15 moles of ideal gas \( B \), having a heat capacity \( c_{p,B} = 1.5R \). Afterwards, the membrane ruptures and both gases mix completely, settling to one pressure and to the same surrounding temperature, \( T_{final} = T_{surr} = 25^\circ C \). Calculate the total change in entropy of the universe (in \( kJ/K \)) from the point before rupture to the point where it equilibrates to the final pressure and temperature.

2. (40 pts) An engine containing an ideal gas having molar heat capacity \( c_p = 3R/2 \) operates with a cycle shown in Figure 1. At point \( a \), the gas expands isobarically at \( P_a \) to point \( b \). Then it expands adiabatically from point \( b \) to point \( c \) where the pressure is at point \( c \) is given by \( P_c = 2P_b/3 \). Afterwards, it is compressed isobarically to point \( d \). Finally, it is compressed adiabatically back to point \( a \). All the paths are assumed to be reversible. The temperatures at points \( a \) and \( c \) were measured to be \( T_a = 110^\circ C \) and \( T_c = 250^\circ C \). Calculate the net work done by each mole of the gas (in \( kJ/mol \)) for one cycle and the molar heat input to the gas (in \( kJ/mol \)) as it expands from point \( a \) to point \( c \).

![Figure 1](image.png)

Figure 1. Engine cycle with paths \( a \to b \) and \( c \to d \) reversible isobaric, while paths \( b \to c \) and \( d \to a \) are reversible adiabatic.

(Note: More questions on the back page.)
3. (20 pts) A refrigerant with quality $x_{in} = 0.2$ flows adiabatically through the throttle from $P_{in} = 3$ bars and $T_{in} = 80^\circ C$ to $P_{out} = 2.5$ bars and $T_{out} = 60^\circ C$. Calculate the specific entropy change (in $kJ/(kg \cdot K)$) of the refrigerant as it undergoes the throttling process using the following data (based on a common reference condition):

Data:  
1) @ $(T_{in}, P_{in})$:

\[
\hat{h}_{in,vap} = 2824 \frac{kJ}{kg}; \quad \hat{s}_{in,vap} = 7.52 \frac{kJ}{kg \cdot K}
\]
\[
\hat{h}_{in,liq} = 450.7 \frac{kJ}{kg}; \quad \hat{s}_{in,liq} = 1.44 \frac{kJ}{kg \cdot K}
\]

2) @ $(T_{out}, P_{out})$:

\[
\hat{h}_{out,vap} = 2550 \frac{kJ}{kg}; \quad \hat{s}_{out,vap} = 8.31 \frac{kJ}{kg \cdot K}
\]
\[
\hat{h}_{out,liq} = 90.3 \frac{kJ}{kg}; \quad \hat{s}_{out,liq} = 0.687 \frac{kJ}{kg \cdot K}
\]

4. An ideal gas of $c_p = 3R/2$ inside a piston-cylinder undergoes a sudden pressure drop from initial pressure $P_{init}$ to a constant external pressure $P_{ext}$ causing an irreversible expansion of the gas. The final pressure is $P_{final} = (0.4 \, P_{init}) = P_{ext}$ and $T_{final} = T_{surr}$. The expansion ratio was also found to be $\hat{v}_{final}/\hat{v}_{init} = 3$.

a) (20 pts) Evaluate the molar change in entropy of the gas during the expansion process in $J/(mol \cdot K)$.

b) (Bonus: 5 pts) Will $T_{final} > T_{init}$ or $T_{init} > T_{final}$? Explain using equations.