Answer the following questions:

Question (1) [15 marks]
a) Prove that, the efficiency of Carnot engine, the ideal imaginary engine, is limited by the operating temperature of the engine.

b) Two moles of an ideal gas initially at 27°C and one atm are compressed reversibly to half its initial volume. Calculate q, w, ΔE and ΔH when the process is carried on isothermally.

Question (2) [15 marks]
a) Define each of the following:

b) The boiling point of water at 50 atm is 265°C. Compare theoretical efficiencies of a steam engine operating between 550°C and i) boiling point of water at 1 atm
ii) Boiling point of water at 50 atm

Question (3) [10 marks]
a) For an ideal prove that: \( C_p = C_v + R \)

b) Calculate the heat of formation of liquid methanol from the following data
\[
\begin{align*}
\text{C}_2\text{H}_5\text{OH} \, (l) + 3\text{O}_2 \, (g) &= 2\text{CO}_2 \, (g) + 2\text{H}_2\text{O} \, (l) & \Delta H &= -326.70 \, \text{k. cal} \, (1) \\
\text{C} \, (s) + \text{O}_2 \, (g) &= \text{CO}_2 \, (g) & \Delta H^\circ &= -94.05 \, \text{k. cal} \, (2) \\
\text{H}_2 \, (g) + \frac{1}{2} \text{O}_2 \, (g) &= \text{H}_2\text{O} \, (l) & \Delta H^\circ &= -68.32 \, \text{k. cal} \, (3)
\end{align*}
\]

Question (4) [15 marks]
a) For an adiabatic reversible ideal gas expansion prove that
\[
P_1V_1^{\gamma} = P_2V_2^{\gamma}
\]

b) Calculate ΔS for the reversible isothermal expansion of 2.00 moles of an ideal gas from 10.0 to 12.0 liters at 30°C.