1) Please answer the following questions briefly. (5% each)

   a) State the zeroth law of thermodynamics.

   b) Express the first law of thermodynamics by an equation and also state the law in words.

   c) Give physical definition and units for enthalpy and latent heat, respectively.

   d) From the figure in Problem 5), explain how to obtain the saturated water vapor pressure for a given temperature.

   e) What is an equation of state? Please distinguish between the ideal gas law and the van der Waals equation.

   f) State the second law of thermodynamics for a non-isolated system.

2) Describe a Carnot cycle on a *P-V* diagram. On the diagram please indicate the temperature and the type of thermodynamic process for each stage in the whole cycle. (10%)

3) State the definition of heat capacity first, and then show that the heat capacity at constant pressure C_P exceeds the heat capacity at constant volume C_V by R (the universal gas constant) for one mole of an ideal gas (i.e., $C_P = C_V + R$). (15%)

4) Please show an example to explain the process of free expansion. If an ideal gas underwent a free expansion process, how much did its energy change? Is free expansion an isentropic process? Also, give the reasons to support your answer. (15%)

5) At the right hand side is a phase diagram for H_2O. Based on the concept of Gibbs free energy, please first derive the Clausius-Clapeyron relation (or Clapeyron relation) for the phase boundary between two phases, and then explain why the slope of the water/steam phase boundary line is positive and the slope of the ice/water phase boundary line is slightly negative. (15%)

6) From the ideal gas law and the first law of thermodynamics, please find out the work required to compress an ideal gas isothermally from volume V_i to V_f and the relation between temperature and volume if the gas is compressed adiabatically. (15%)