1) (25%)

For many practical applications, the polytropic process is used to described the pressure-volume relation in a system during the process, which can be described by

$PV^n = constant$

Where n is a specific constant. Now assume the system consisting of an ideal gas. Please

(i) **derive** the value (not necessarily the number) for the constant n for the following special processes: (a) isobaric process, (b) isothermal process, (c) constant-volume process, and (d) isentropic process. (Please note: you should derive the value not just giving the number from memory!!)

(ii) Argue that the isentropic process is the most "efficient" process among the special processes above. By "efficient" process, it implies that the process produces the largest work-to-heat ratio among the special processes during the expansion process.

2) (25%)

A control mass undergoes a three-process power cycle with air as the working fluid. The fluid undergoes an isothermal compression from state 1 to 2, a constant-pressure heating from state 2 to 3, and an isentropic process from state 3 to 1. Assume the specific heats are constant, and $P_1 = 1\ atm$, $T_1 = 20\ ℃$, and $P_2 = 6\ atm$. Please determine the specific heat transfer q and work w for each individual process and the cycle. (Note: the ideal gas approximation is accurate for the states in the cycle)

3) (25%)

Two constant-volume tanks, each filled with 50 kg of air, have temperatures of 900 K and 300 K. A heat engine placed between the two tanks extracts heat from the high-temperature tank, produces work, and rejects heat to the low-temperature tank. Determine (a) the maximum work that can be produced by the heat engine, (b) the final temperatures of the tanks, (c) the exergy (work potential) destroyed during the above heat transfer process. Assume constant specific heats at room temperature (300 K).

4) (25%)

(1) Please explain the physical meaning of the Joule-Thomson coefficient. Does the Joule-Thomson coefficient of a substance change with temperature at a fixed pressure?

(2) Starting with the relation $dh = Tds + vdP$, show that the slope of a constant-pressure line on an *h-s* diagram (a) is constant in the saturation region and (b) increases with temperature in the superheated region.

(3) Starting from the Maxwell relation, please derive the Clapeyron equation

$$(dP/dT)_{sat} = h_{fg}/(T\,v_{fg})$$