※ 考生請注意：本試題可使用計算機。 請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. The data listed below are claimed for a heat engine operating between reservoirs at T_H (600 K) and T_L (300 K). The engine receives heat Q_H (200 kJ) from high energy reservoir. For each of the following cases, determine the cycle is **Possible** or **Impossible**. (12%)
   (a) W_{cycle} = 120 kJ; Q_L =80 kJ
   (b) W_{cycle} = 100 kJ; Q_L = 100 kJ
   (c) W_{cycle} = 80 kJ; Q_L = 120 kJ
   (d) W_{cycle} =100 kJ; Q_L = 80 kJ
   (e) W_{cycle} = 0 kJ; Q_L = 200 kJ
   (f) W_{cycle} = 200 kJ; Q_L = 0 kJ

2. (a) Liquid water is compressed by a pump in an **irreversible**, steady-state, adiabatic process. What is the change in temperature (**increase**, **decrease**, or **constant**)? Why? (4%)
   (b) Ideal gas air is compressed by a compressor in a reversible, steady-state, adiabatic process. What is the change in temperature (**increase**, **decrease**, or **constant**)? Why? (4%)
   (c) A fixed amount of ideal gas air goes through an isothermal, reversible, expansion process. The process is **Heat addition** or **Heat rejection**? Why? (4%)

3. Air enters a compressor operating at steady state at 290 K, 1 bar and exits at a pressure of 5 bars. Kinetic and potential energy changes can be ignored. Assume air is an ideal gas, with constant specific heat, C_p = 1.004 kJ/kg-K, C_v = 0.717 kJ/kg-K, and R = 0.287 kJ/kg-K.
   (a) If there are no internal irreversibilities, which of the following processes: (i) polytropic with n=1.3; (ii) isothermal; (iii) adiabatic; requires the minimum compressor work? Demonstrate your answer by evaluating the work per unit mass of air flowing for each case. (18%)
   (b) Sketch the processes on the same P-v and T-s diagrams. (8%)

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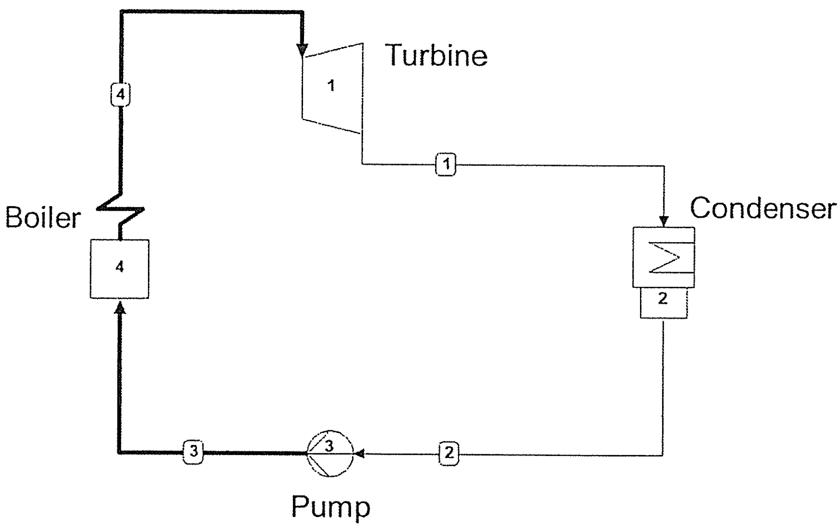
4. In a test rig, steam is replaced by CO_2 as the working fluid in a Rankine cycle as shown in the figure below. Supercritical carbon dioxide enters the turbine at 200 °C and 130 bar. The condenser pressure is 6.5 MPa, and the working fluid leaves the condenser at saturated liquid state. Critical temperature and pressure for CO_2 is 31 °C and 7.38 MPa, respectively. Properties of CO_2 required for solving the following problems are provided in Tables 4-1 and 4-2.



a) Sketch the temperature-entropy (T-s) diagrams of the cycle described above. Identify the supercritical region and all state points. Show the saturation dome on the same chart. (10%)
b) Determine the ideal thermal efficiency of the cycle. (10%)
c) If the measured pressure and temperature at the turbine exit are 6.5 MPa and 140 °C, respectively. Determine the turbine efficiency. (10%)
d) Supercritical reheat cycle is an effective approach to enhance efficiency of a supercritical Rankine cycle using steam. A reheat process is therefore proposed for the CO_2 test rig. The working fluid is first expanded through the first-stage turbine to 9 MPa, and then redirected back to the boiler to be reheated to 180 °C. A second-stage low pressure turbine is added to extract power from the reheated working fluid. Inlet condition of the first-stage turbine and conditions in the condenser remain the same. Assume no losses in all pipings and apparatuses. Determine if thermal efficiency is improved in the supercritical CO_2 reheat cycle. Show your calculations step by step and explain why the efficiency is or is not increased through the reheat process. (20%)

Table 4-1: Properties of Saturated CO_2.

Pressure (MPa)	Temperature (°C)	Liquid Density (kg/m^3)	Vapor Density (kg/m^3)	Liquid Enthalpy (kJ/kg)	Vapor Enthalpy (kJ/kg)	Liquid Entropy (kJ/kg-K)	Vapor Entropy (kg/kg-K)
5	14.284	827.32	156.67	237.87	417.66	1.1289	1.7544
5.5	18.269	791.13	181.43	250.13	411.28	1.1691	1.7221
6	21.978	751.03	210.88	262.85	403.32	1.2102	1.6862
6.5	25.442	703.62	248.33	276.72	392.84	1.2547	1.6436
7	28.683	638.31	304.03	293.88	376.91	1.3093	1.5844

Table 4-2: Properties of CO_2 at various states.

Temperature (°C)	Pressure (MPa)	Density (kg/m^3)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)
37.993	13	760.87	285.57	1.2547
133.35	6.5	95.189	570.37	2.1684
140	6.5	92.894	577.98	2.1870
149.13	6.5	89.969	588.35	2.2118
160.26	6.5	86.709	600.89	2.2411
163.66	9	122.66	593.4	2.1684
180	9	116.02	612.73	2.2118
200	13	162.29	621.59	2.1684