Student Code Number: ________________

Thermodynamics
Ph.D. Qualifying Exam

Department of Mechanical Engineering

Michigan State University

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Directions: Work all four problems. Problems are equally weighted. Students are allowed one book, calculator, and five sheets of notes

Problem # 1

The initial condition for the compression process of a cold air-standard Otto cycle, are $p_1 = 1$ bar, $T_1 = 290$ K, $V_1 = 400$ cm^3.
The maximum temperature in the cycle is 2200 K and the compression ratio is 8.
Using a specific heat ratio of k=1.4, determine the:

a) **Heat addition, in kJ.**
b) **Net work, in kJ.**
c) **Thermal efficiency.**
d) **Mean Effective Pressure, in bar.**
e) **Exergy transferred to the air during the heat addition, in kJ.**
f) **Devise and evaluate an exergetic efficiency for the cycle. Let $T_0 = 290$ K, $p_0 = 1$ bar.**

Problem # 2

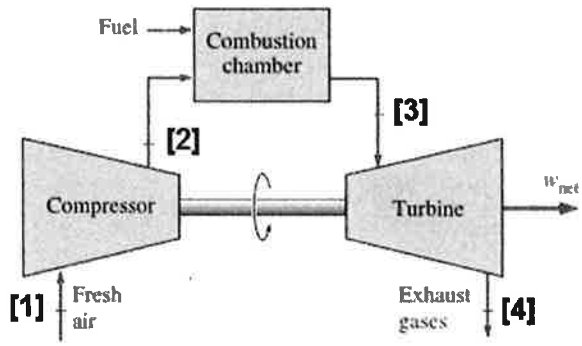
Air enters the compressor of an ideal Brayton refrigeration cycle at 100 kPa, 300 K. The compressor pressure ratio is 3.75, and the temperature at the turbine inlet is 350 K. Determine the:

a) **Net work input, per unit mass of air flow, in kJ/kg.**
b) **Refrigeration capacity, per unit mass of air flow, in kJ/kg.**
c) **Coefficient of performance.**
d) **Coefficient of performance of a Carnot refrigeration cycle operating between thermal reservoirs at $T_C = 300$ K and $T_H = 350$ K, respectively.**

Problem # 3

a) **Air initially at 0.125 MPa and 52^{0}C is compressed in a polytropic process to 0.30 MPa and 227^{0}C. Find the specific work (KJ/kg) required in this process.**

b) **As shown below, through port 1 air enters the compressor of a gas-turbine-power-plant at 101.35 kPa, 15^{0}C and at a rate of 1150m^3/min. It is compressed to 410 kPa at [2], then heated [2] – [3] and finally expanded through a turbine and exhausted at [4] with 101.35 kPa and 260^{0}C. The net power output of the plant $\dot{W}_{net}$ is 3MW. Neglecting kinetic energy changes, Determine the rate heat amount $\dot{Q}_{net}$ added to the air at [2] – [3].**



Problem # 4

a) **A piston–cylinder device contains 0.024 kg of air in a volume of 0.02 m^3 initially at 0.1 MPa. The air is first compressed at constant volume to a pressure of 0.42 MPa, then it is further compressed at constant pressure, and finally it is expanded isothermally to the initial state.**

  (i) **Determine the change in entropy for each process,**
  (ii) **Determine the total change in entropy for all process, and**
  (iii) **Sketch the total process on a T-S diagrams**

b) **A piston/cylinder setup contains air at 100 kPa, 400 K, which is compressed to a final pressure of 1000 kPa. Consider two different processes:**

  (i) **a reversible adiabatic process and**
  (ii) **a reversible isothermal process.**

Find the final temperature and the specific work for both processes.