Code Number: ____________

THERMODYNAMICS QUALIFYING EXAM

January 2015

OPEN BOOK (only one book allowed) & CLOSED NOTES

Answer all four questions

All questions have equal weight

TIME: 3.0 hrs

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- **Take any required property from your book, approximate values if necessary.**
- **If you make any assumption to reach a solution state it clearly**

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Question # 1

a) A closed thermodynamic process for air consists of two parts. In the first process the air at a temperature of 15^0C, pressure of 105 kPa and a volume of 0.02 m^2, is heated at constant volume until the pressure is 420 kPa, and then the air is cooled at constant pressure to the original temperature. Assuming ideal gas, determine:

   i) The net heat flow to or from the air (kJ),
   ii) The net entropy change (kJ/K), and
   iii) Sketch the process on the T-S diagram.

b) A closed thermodynamic cycle for 3 kg air in a piston-cylinder device consists of three processes. In the first process, state 1 to state 2, the air at a temperature of 360 K and pressure of 150 kPa is compressed polytropically to a pressure of 750 kPa with a polytropic exponent n=1.2. In the second process, state 2 to state 3, the air is cooled at constant pressure to the original temperature. In the final process, state 3 to state 1, the air is heated at constant temperature to state 1, closing the cycle. Assuming ideal gas, determine:

   i) The cycle heat transfer (kJ),
   ii) The cycle work transfer (kJ), and
   iv) Sketch the process on the P-V diagram.

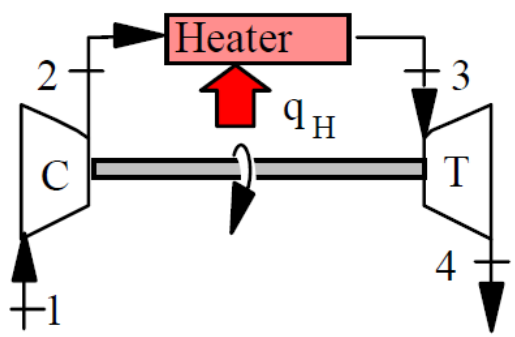
Question # 2

a) Inside a closed insulated environment two 5 kg each blocks of steel, one at 250^0C the other at 25^0C, are pressed in thermal contact. Assuming the specific heat of steel to be 0.4g kJ/kgK. Determine:

   i) The final temperature and
   ii) The total entropy generation in the process

b) A portable compressed air supply device, shown below, consists of a compressor, a heater (heat supplied from an outside source), and a turbine. The compression and expansion processes may be assumed to be adiabatic and reversible, and the heat addition is at constant pressure. Ambient air enters the compressor at 100 kPa, 300 K, and is compressed to 600 kPa. All of the power from the turbine goes into the compressor, and the turbine exhaust is the supply of compressed air. If this pressure is required to be 200 kPa. Determine:

   i) The temperature be at the exit of the heater, and
   ii) Sketch the process on a T-S diagram



Question 3

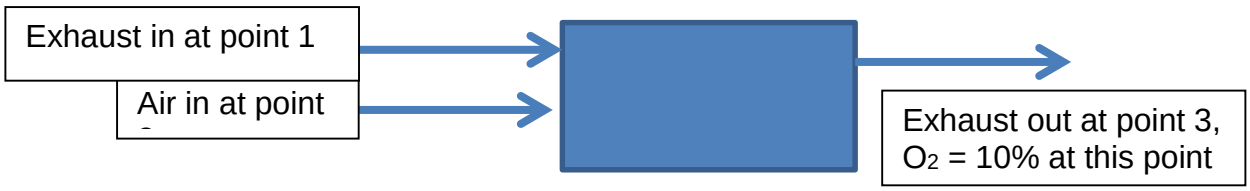
Two insulated tanks, A and B, are connected by a valve. Tank A has a volume of $3m^3$ and contains oxygen at 500kPa and 10^0C. Tank B has a volume of $10m^3$ and contains nitrogen at 200kPa, 50^0C. The valve is opened until the resulting gas mixture comes to a uniform state. Determine the final temperature and pressure.

Question 4

The hot exhaust gas from an internal combustion engine is analyzed and found to have the following percent composition on a volume basis

CO_2 = 10%
CO = 2%
H_2O = 13%
O_2 = 3%
N_2 = 72%

The gas is fed into an exhaust gas reactor and mixed with air as shown in the figure



It is decided that a mole fraction of O_2 of 10% in the mixture at point 3 will ensure that no CO remains. What is the ratio of air to exhaust into the reactor to ensure that no CO remains?