Code Number :.............

THERMODYNAMICS QUALIFYING EXAM

January 2016

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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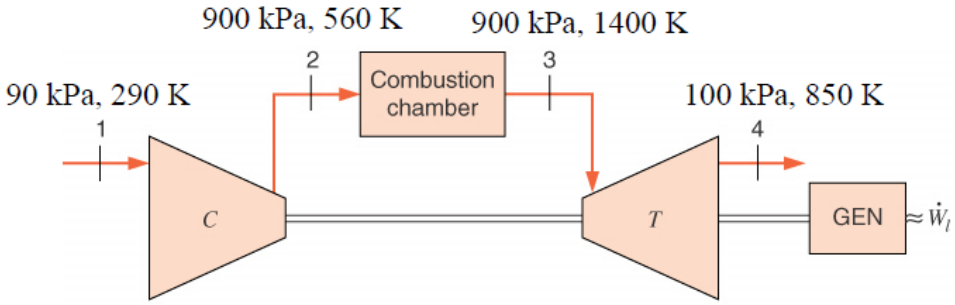
Question # 1

a) A gas turbine setup to produce power is shown below with inlet and exit pressure and temperature for each component. The turbine provides power to the air compressor and the electric generator. If the electric generator should provide 5 MW what is the needed air mass flow rate at State 1 and the combustion heat transfer between State 2 and 3?

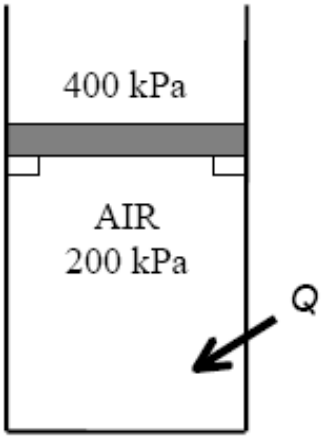


b) Consider a piston–cylinder device containing 3 kg of air at 200 kPa and 27°C, initially the piston is resting on a set of stops. The mass of the piston requires a pressure of 400 kPa to move it. Heat is now transferred to the air until its volume doubles. Determine:

i) The pressure and temperature P_2 and T_2 as heat is added and the piston is about to lift off the stops.

ii) The pressure and temperature P_3 and T_3 as heat is continued to be added and the the volume doubles.

iii) Also show the process on a *P-v* diagram.



Question # 2

a) An ideal cycle consists of 3kg of air undergoing a cyclic process:

- From 1➔2 polytropic compression, where p_1=150kPa, T_1=360K, p_2=750kPa and n=1.2
- From 2➔3 cooling @ $\boldsymbol{dp = 0}$
- From 3➔1 heating @ $\boldsymbol{dT = 0}$

Determine:

i) The entropy change for each state change: 1➔2, 2➔3 and 3➔1
ii) Sketch the T-S diagrams for the cycle.

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

Question # 3

It has been determined that there is a small amount of sulfur in a gaseous propane supply. It is to be burned in an engine with 150% theoretical air and exits the exhaust maniford at 130kPa. The air entering the engine is dry and burns according to the equation: $C_3H_8 + 7.5O_2 + 28.20 N_2 – 3CO_2 + 4H_2O + 2.5O_2 + 28.20 N_2$. To prevent corrosion of the exhaust system (sulfur can combine with water to form sulfuric acid) the exhaust is to be manitained in a gaseous condition. Calculate the temperature at which the combustion products must be maintained to avoid condensation of any type. State your assumptions.

Question # 4

Methane CH_4 is burned with atmospheric air. The analysis of the products on a dry basis (The equipment for analysis will not tolerate water) yields CO2= 10%, O2=2.37%, CO=0.53%, N2=87.10%. Calculate the Air/Fuel ratio on a mass basis.