UNIVERSITY OF GHANA

B.Sc ENGINEERING FIRST SEMESTER EXAMINATION: 2017/2018

SCHOOL OF ENGINEERING SCIENCES

FAEN 205: THERMODYNAMICS I (3 credits)

INSTRUCTIONS TIME: 2HRS

Please read the following INSTRUCTIONS carefully

[1] Answer TWO questions in SECTION A

[2] Answers to SECTION A must be written in an Answer Booklet

[3] Answer ALL questions in SECTION B

[4] Answers to SECTION B must be written on the question paper

[5] Write your STUDENT ID NUMBER on all the applicable question sheets and tie them inside the Answer Booklet

SECTION A

Answer TWO questions in this Section

1. A steam turbine operates adiabatically at a power level of 4,000 kW. Steam enters the turbine at 2,500 kPa and 500°C and exhausts from the turbine as saturated vapour at 20 kPa.
   a) What is the steam rate through the turbine?
   b) What is the turbine efficiency?

2. Propylene (assumed to be an ideal gas) is compressed adiabatically from 12.0 bar and 30 °C to 18 bar at the rate of 1 kg mol s^{-1}. If the compressor efficiency is 0.8, what is the power requirement of the compressor and what is the discharge temperature of the propylene? (R = 8.314 J/mol-K)

   a) What is the power requirement of the compressor?
   b) What is the discharge temperature of the propylene?

   [Take $\frac{(C_P^{ig})_S}{R} = \frac{(C_P^{ig})_H}{R} = \frac{C_P}{R} = 5$]

3. Carbon dioxide gas of upstream conditions $T_1 = 456.3\ K, P_1 = 59.04$ bar is throttled to a downstream pressure of 1.0 bar. Use the Lee/Kesler generalized method to estimate the downstream temperature to a first approximation. (R = 8.314 J/mol-K).

   For carbon dioxide:
   $T_C = 394.2\ K;\quad P_C = 73.8$ bar; $\quad \omega = 0.224$
   $\frac{C_P^{ig}}{R} = A + BT + DT^{-2}$
   $A = 5.457$
   $10^3 B = 1.045$
   $10^{-5} D = -1.157$

SECTION B:

Answer ALL questions in this Section 0

1. Write down an equation for the first law of thermodynamics for a closed system

2. Two types of experimental data are needed for thermodynamic analysis; namely:

   a)

   b)

3. Write down the defining expression for the compressibility factor, Z

4. A gas has a temperature of 50°C and vapour pressure of 45kPa, if the critical temperature and is 150°C what is the reduced temperature?

5. Water flows over a waterfall 80 m in height. For 2 kg of water what is the potential energy of the water at the top of the falls if acceleration due to gravity is 10 m/s^2.

6. If the heat capacity of gas is 20.785 J mol^{-1} K^{-1}, what is the enthalpy change if 2 moles go from 70°C to 150°C?

7. Write down the phase rule? How many degrees of freedom has a mixture of ice block in equilibrium with liquid water?

8. If air at 1 bar and 25°C is compressed to 4 bar at the same temperature, calculate the change in internal energy U, if the heat capacity at constant volume, C_v is given by 20.8 J/mol-K

9. State the mathematical definition of the Second law of Thermodynamics.

10. Write down the energy balance equation for steady-state flow processes for one entrance and one exit

11. Write down the mathematical expression for isothermal compressibility, κ_T

12. Write down the first three terms of the virial equation of state in volume

13. On a PV diagram, the critical isotherm exhibits a horizontal inflection at the critical point, leading to two derivative expressions. Write them down.

14. Write down the celebrated van der Waals equation of state.

15. The principle that correlates reduced temperature T_r and reduced pressure P_r of gases to their compressibility factor Z, is known as?

16. What is the compressibility factor of an ideal gas:

$Z =$

17. Write down the equation relating the heat capacities, C_v and C_p with the universal gas constant R for an ideal gas

18. If the hot and cold reservoir temperatures of a Carnot cycle are 500°C and 200°C respectively, what is the efficiency of the cycle?

19. Write down the defining equation for Helmholtz free energy, A.

20. Write down the Maxwell relation resulting from the following fundamental property relation: $dA = -PdV - SdT$

21. What are the *canonical* variables for the Gibbs free energy, G?

22. Write down the defining expression for the residual property of a generic thermodynamic function M. What is the residual entropy of an ideal gas, S^R?

23. State two methods for calculating residual properties of a gas

a)

b)

24. Write down the names of two cubic equations of state:

a)

b)

25. If the quality of a system with saturated-liquid and saturated-vapour coexisting in equilibrium is x^v, write down an expression for the enthalpy of the system.

26. If a process takes place reversibly and adiabatically in a system of 2kg mass, and the temperature changes from 100°C to 300°C, what is the change in its entropy ΔS?

27. Write down the equation that defines the efficiency of a turbine, in terms of enthalpies:

28. On a T-S diagram, draw the four steps of a Carnot cycle.

29. On a T-S diagram, draw the stages of a Rankine cycle.

30. a) For the same compression ratio, the Otto engine has a higher efficiency than the Diesel engine (True / False)

b) Otto engines use spark plugs, while Diesel engines do not. (True / False)