2.42% CO; 7.5% O_2 and 82.82% N_2. Determine the composition of fuel on mass basis and percent of excess air used for combustion.

7 + 5 = 12

7. (a) The Berthelot equation of state is given by

$$\left(P + \frac{a}{Tv^2}\right)(v - b) = RT$$

Develop necessary relation to determine the parameters 'a' and 'b' in terms of critical constants T_c and P_c and then convert the equation in reduced form where compressibility factor, Z is only function of reduced pressure, P_r and reduced temperature, T_r.

(b) In the synthesis of ammonia, stoichiometric amounts of nitrogen and hydrogen are sent to a reactor where the following reaction occurs

$$N_2 + 3H_2 \leftrightarrow 2NH_3$$

The equilibrium constant for the reaction at 675 K is equal to 0.0002. Calculate the respective percentage conversion at 675 K and 200 bar.

8 + 4 = 12

Group - E

8. In a thermal power plant operating on reheat cycle, steam at 50 bar and 500°C enters a high pressure isentropic turbine and leaves at 10 bar. Then this steam is reheated to 500°C before it is fed to a low pressure isentropic turbine. The condenser is maintained at 0.05 bar. Calculate
   (i) thermal efficiency of the power plant.
   (ii) mass flow rate of steam for a net power output of 20 MW.
   (iii) quality of steam at the exit of the low pressure turbine.
   (Steam table may be allowed to use)

3 + 5 + 4 = 12

9. (a) What are the factors that affect the performance of a vapour compression refrigeration system?

(b) A vapour compression refrigeration cycle has a condenser temperature of 298 K while the evaporator temperature is 268 K. The relative efficiency of the cycle is 50% and 6 kg of Freon-12 refrigerant is circulated through the system per minute. The refrigerant enters the compressor at the dryness fraction of 0.6. Determine the capacity of refrigerator in tons. Use the following data for Freon-12,

Temperature, K	Enthalpy of liquid, kJ/kg	Latent heat, kJ/kg	Entropy of liquid, kJ/kg K
298	59.7	138	0.2232
268	31.4	154	0.1251

3 + 9 = 12

M.TECH/RE/2ND SEM/REEN 5202/2018

ADVANCED ENGINEERING THERMODYNAMICS (REEN 5202)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The sonic speed in ideal gas at constant temperature varies
(a) inversely as square root of absolute pressure
(b) directly as square root of absolute pressure
(c) inversely as square root of molecular weight
(d) directly as square root of molecular weight.

(ii) The stagnation pressure and temperature are
(a) less than their ambient counterparts
(b) more than their ambient counterparts
(c) equal to their ambient counterparts
(d) either 'a' or 'b' depends on case to case.

(iii) Which of the following cycle consists of two reversible isotherms and two reversible isobars?
(a) Otto cycle (b) Diesel cycle
(c) Brayton cycle (d) Ericsson cycle.

(iv) The value of $\oint \frac{dQ}{T}$ for an irreversible cyclic process
(a) is equal to 0 (b) is greater than 0
(c) is less than 0 (d) can't be determined.

(v) A heat engine is supplied with 2512 kJ/min of heat at 650°C. Heat rejection of 900 kJ/min takes place at 100°C. This type of heat engine is
(a) ideal (b) irreversible
(c) impossible (d) practical.

(vi) The difference between constant pressure specific heat and constant volume specific heat of pure substance
(a) approaches 0 at triple point
(b) approaches 0 as absolute temperature approaches 0 k.
(c) approaches 0 at critical point
(d) is always constant.

(vii) Joule-Thompson coefficient is the slope of.
(a) constant enthalpy lines on T-s diagram
(b) constant enthalpy lines on T-p diagram
(c) inversion curve of T-p diagram
(d) inversion curve of T-s diagram

(viii) Benzene is insoluble in water. The normal boiling point of Benzene and water are 353 K and 373 K respectively. At a pressure of 1 atm, the boiling point of a mixture of benzene and water
(a) is less than 353 K
(b) is greater 373 K
(c) is greater than 353 but less than 373 K
(d) can't be predicted.

(ix) The equilibrium constant of reversible chemical reaction depends on
(a) only pressure at equilibrium
(b) only temperature at equilibrium
(c) both temperature and pressure at equilibrium
(d) only number of moles of species involved in the reaction.

(x) The loss of available energy associated with transfer of 1000 kJ of heat from a constant temperature system at 600 K to another at 400 K when the atmospheric temperature is 300 K is
(a) 167 kJ (b) 667 kJ (c) 500 kJ (d) 250 kJ.

Group – B

2. (a) A gas cylinder initially containing a gas of mass m_i is connected to a supply line through which the same gas at temperature T and pressure P is flowing. The cylinder is filled with the gas till the gas pressure in the cylinder raises to P. Deduce an expression to determine the final mass of gas in the cylinder and its temperature.

(b) Show that in a two stage reciprocating compressor, the minimum total work results when the pressure ratios in each stage are equal and are given by square root of the overall pressure ratio.

6 + 6 = 12

3. (a) Derive the Bernoulli's equation for a compressible fluid flowing through a perfectly insulated pipe.

(b) For a normal shock wave in air (γ = 1.4) Mach number is 2. If the atmospheric pressure and air density are 26.5 kPa and 0.413 kg/m^3 respectively, then determine the following:
i. temperature and velocity of air before and after the shock wave.
ii. pressure and density after the shock wave.
Deduce all the equations that you require to solve the problem.

4 + (4 + 4) = 12

Group – C

4. (a) Develop a general entropy balance equation for an unsteady flow process applying control volume analysis.

(b) Why the second law efficiency has been introduced to evaluate the performance of a flow device?

(c) Deduce second law efficiency of the following devices:
(i) turbine, (ii) compressor, (iii) heat exchanger.

5 + 1 + (2 × 3) = 12

5. (a) Differentiate between availability function and Gibbs energy function.

(b) 8 kg of air at 650 K and 5.5 bar pressure is enclosed in a closed system. If the atmosphere temperature and pressure are 300 K and 1 bar respectively, determine:
(i) the availability, if the system goes through the ideal work producing process.
(ii) the availability and effectiveness, if air is cooled at constant pressure to atmospheric temperature without bringing it to complete dead state. Take, c_p = 1.005 kJ/kg K and assume that air behaves ideally.

3 + (5 + 4) = 12

Group - D

6. (a) It is found that at a particular hill station water boils at 95°C. The latent heat of vaporization (h_{fg} = 2256.94 kJ/kg) is constant over the range of pressure under consideration. Assuming, the atmosphere (γ = 1.4) to be adiabatic, determine the altitude of hill station above the mean sea level.

(b) A hydrocarbon fuel with unknown composition is burned with air and an Orsat analysis of combustion products gave 7.26% CO_2;