Assignment No.1

Basic Concepts

1. Discuss microscopic and macroscopic point of view in thermodynamics.

   OR

   How classical thermodynamics does differs from statistical thermodynamics.

2. Define system and control volume. Explain types of system with appropriate examples.
3. Define following terms with diagram (wherever necessary).
   a. Thermodynamic Equilibrium
   b. Point function and path function
   c. Intensive and extensive property
   d. Thermodynamic equilibrium
   e. Displacement work and flow work
4. Explain quasi static process with necessary diagrams.

Assignment No.2
First law of Thermodynamic

Theory

1. State 1st Law of thermodynamics. Write down expressions for the first law applied to (i) a cycle and (ii) a process. What is difference between heat and work? Explain the conventional meanings for positive-ness and negative-ness for heat and work interactions between thermodynamic system and its surroundings across the system boundary.
2. Define "internal energy" and prove that it is a property of the system.
3. Write continuity equation. Derive the general steady flow energy equation.
4. Write steady flow energy equation for the following engineering devices and reduce the same by making suitable assumptions:
   a. Nozzle/Diffuser
   b. Heat Exchangers:
      i. Evaporator and
      ii. Condenser
   c. Steam or Gas Turbine
   d. Hydraulic Turbine
   e. Reciprocating Compressor
   f. Rotary Compressor
   g. Centrifugal Water Pump

Examples
Part 1 – Non Flow Processes

1. 0.2 m^3 of an ideal gas at a pressure of 2 MPa and 600K is expanded isothermally to 5 times the initial volume. It is then cooled to 300K at constant volume and then compressed back polytropically to its initial state. Determine the net work done and heat transfer during the cycle. [Ans: 181.88kJ, 0]
2. A cylinder contains 0.45 m^3 of gas at 1 x 10^5 N/m^2 and 80°C. The gas is compressed to a volume of 0.13m^3. The final pressure being 5 x 10^5 N/m^2. Assume γ=1.4, R=294.2 J/Kg°C. Calculate mass of gas, index of compression n, increase in internal energy of gas, heat rejected by gas during compression.

   [GTU–OCT2012][Ans:
3. A rigid and insulated tank of 1 m^3 volume is divided by partition into two equal volume chambers having air at 0.5 M Pa, 27 °C, and 1 M Pa, 500 K. Determine final pressures and temperature if partition is removed.

   [GTU – DEC 2013][Ans: 0.7499MPa, 409.09K]
4. Calculate the final temperature, pressure, work done and heat transfer if the fluid is compressed reversibly from volume of 6m^3 to 1 m^3 when the initial temperature and pressure of fluid as 20°C and 1 bar respectively. Assume the index of compression as and 1.4, C_p = 1.005 and C_v = 0.718 and R = 0.287 KJ/kg-K.

   [GTU – DEC 2014][Ans: 599.968K, 12.286bar, -1.5715MJ,

Part 2 – Steady Flow Energy Equation

1. In a steam plant, 1 kg of water per second is supplied to the **boiler**. The enthalpy and velocity of water entering the boiler are 800 kJ/kg and 5 m/s. The water receives 2200 kJ/kg of heat in the boiler at constant pressure. The steam after passing through the **turbine** comes out with a velocity of 50 m/s, and its enthalpy is 2520 kJ/kg. The inlet is 4 m above the turbine exit. Assuming the heat losses from the boiler and the turbine to the surroundings are 20kJ/s, calculate the power developed by the turbine. Consider the boiler and turbine as single system.

   [Ans: 458.8 kW] [3.35, R.K.Rajput]

2. In a test of water cooled **air compressor**, it is found that the shaft work required to drive the compressor is 175 kJ/kg of air delivered and the enthalpy of air leaving is 70 kJ/kg greater than that entering and that the increase in enthalpy of circulating water is 92 kJ/kg. Compute the amount of heat transfer to the atmosphere from the compressor per kg of air. [Ans: 13 kJ/kg] [3.41, R. K. Rajput]

3. A **nozzle** is a device for increasing the velocity of a steadily flowing stream. At inlet to a certain nozzle, the fluid parameter are Enthalpy = 2850 kJ/kg, velocity = 50 m/s, area = 0.1 m^2, specific volume = 0.18 m^3/kg at the discharge end enthalpy is 2650 kJ/kg and the specific volume is 0.49 m^3/kg. Make calculation for the velocity of fluid at exit from the nozzle, mass flow rate of fluid and the exit area of the nozzle. The nozzle is horizontal and there is negligible heat loss from it.

   [Ans: 634.43 m/s, 27.78 kg/s, 214.6 cm^2] [6.1, D.S.Kumar]

4. A perfect gas flows through a **nozzle** where is expends in a reversible adiabatic manner. The inlet conditions are 22 bar, 500 ^{0}C, 38 m/s. at exit the pressure is 2 bar. Determine the exit velocity and exit area if the flow rate is 4 kg/s. take R = 190 J/kg- K and γ=1.35 [Ans: 726 m/s, 2.167 E-3 m^2] [6.2, D.S.Kumar]

5. A **steam turbine** operates under steady flow conditions receiving steam at the following state:

   pressure 15 bar, internal energy 2700 kJ/kg, specific volume 0.17 m^3/kg and velocity 100 m/s. the exhaust of steam from the turbine is at 0.1 bar with internal energy 2175 kJ/kg, specific volume 0.15 m^3/kg and velocity 300 m/s. The intake is 3 meters above the exhaust. The turbine develops 35 kW and heat loss over the surface of turbine is 20 kJ/kg. Determine the steam flow rate through the turbine.

   [Ans: 0.0614 kg/s] [6.6, D. S. Kumar]

6. In a **centrifugal compressor**, the suction and delivery pressures are 100 kPa and 550 kPa respectively. The compressor draws 15 m^3/min of air which has a specific volume of 0.77 m^3/kg. At delivery pt, the specific volume is 0.20 m^3/kg. the compressor is driven by a 40 kW motor and during passage of air through the compressor, the heat lost through the surrounding is 30 kJ/kg of air. Neglecting changes in the potential and kinetic energy, make calculation for increase in internal energy per kg of air. [Ans: 60.23 kJ/kg] [6.4, D.S.Kumar]

7. A **centrifugal pump** delivers 2750 kg of water per minute from initial pressure of 0.8 bar absolute to a final pressure of 2.8 bar absolute. The suction is 2 m below and the delivery is 5 m above the center of pump. If the suction and delivery pipes are 15 cm and 10 cm dia. respectively, make calculation for the power required to run the pump. [Ans: 12.942 Kw][6.9, D.S.Kumar]

8. A **turbo jet engine** is in flight at 250 m/s in the atmosphere at -15^{0}C. The engine operates with fuel-air ratio of 0.018 and the fuel used has a calorific value of 44000 kJ/kg. Due to incomplete combustion of fuel, only 95 % of energy is liberated by fuel. The engine losses 20 kJ/kg of air, and the measurements indicate that temp. of gases at exit from the nozzle is 600 ^{0}C and the enthalpy values for air and gases are 250 kJ/kg and 900 kJ/ kg respectively. Neglecting potential energy changes for the flow streams, Make calculations for the velocity of exhaust jet.

[Ans: 437.55 m/s] [6.14, D.S.Kumar]

9. Air at 290 K temp. passes through a **heat exchanger** at 30 m/s velocity and its temp. gets raise to 1100 K. Subsequently the heated air enters a **turbine** with the same velocity and its expansion continuous till the temp. drops to 900 K. After exit from the turbine at 45 m/s further expansion occurs in the **nozzle** and the temp. falls to 790 K. If mass flow rate of air is 2 kg/s, determine :

(a) Rate of heat transfer to air in the heat exchanger

(b) Power output from the turbine and

(c) Velocity at exit from the nozzle.

Assume no heat loss and take Cp = 1.005 kJ/kg K for air.

[Ans: 1620 kJ/s; 398.87 kW; 471.2 m/s] [6.17, D.S.Kumar]

Assignment No.3

Second law of thermodynamics

Theory

1. Write limitations of 1^{st} law of thermodynamics.
2. Give Kelvin-Plank and Clausius statement of 2^{nd} law of thermodynamics and prove their equivalency.

OR

Prove that violation of Kelvin-Plank statement leads to violation of Clausius statement and violation of Clausius statement leads to violation of Kelvin-Plank statement.

3. What is irreversibility? Discuss causes (reasons) of irreversibility's OR elements of irreversibility's.
4. Explain external and internal irreversibility's. How mechanical reversibility differs from thermodynamic reversibility?
5. Explain Carnot cycle. Justify that Carnot cycle is not practical.

OR

Derive an expression for Carnot efficiency with usual notations.

OR

Why the Carnot engines is the most efficient engine for a given source and sink temperature? Explain.

6. State Carnot theorem and explain its corollaries.
7. Explain thermodynamics temperature scale.

Examples

Heat engine, Refrigerator and Heat Pump

1. A refrigerator operating on reversed Carnot cycle whose C.O.P is 5. The evaporator is maintained at a temperature of -6^0C and the power required to run the refrigerator is 3.5 kW. Determine the refrigerating effect and the condenser temperature of the refrigerator.
[Answer: (1) R.E (Q_2) = 17.5 kW; (2) T_1 = 320.4 K] [D.S Kumar 203/7.9]
2. Which is more effective way to increase the efficiency of a Carnot heat engine: Case-(i) to increase the source temperature T_1 while the sink temperature T_2 is held constant or Case-(ii) to decrease the sink temperature by the same amount while the source temperature is held constant? How this result would be affected in case of a Carnot heat pump?

[Answer: <u>for heat engine</u>: Case-(ii) is more effective, <u>for heat pump</u>: Case-(i) is more effective] D.S Kumar 206/7.16

Carnot Theorem

3. An inventor claims that his engine has the following specifications: Source temperature = 450K
Sink temperature = 280K

Powerdelivered = 0.15kWh

Heatsupplied = 1200kJ

Asapatentofficer,wouldyouissuesapatentforsuchanengine?Giveyour clarification.

[Answer: Claim is false; the patent is not to be issued] D.S Kumar 211/7.19

Clausius Theorem & Clausius Inequality

4. An inventor claims that his engine absorbs 300 kJ of energy from a thermal reservoir at 325 K and delivers 75 kJ of work. The inventor also states that his engine has two heat rejections: 125 kJ to a reservoir at 300 K and 100 kJ to a reservoir at 275 K. Check the validity of his claim.

[Answer: Claim of inventor is intolerable] D.S Kumar 217/7.22

5. A reversible engine is supplied 900 kJ of heat from a heat source at 500 K. The engine develops 300 kJ of net work and rejects heat to two heat sinks at 400 K and 300 K. Determine thermal efficiencyandmagnitudeofheatinteractionwitheachof the sink.

[Answer: (1) η = 33.3%; (2) Heatrejectedtosinkat 400 K = 240 kJ, heatrejectedat 300 K = 360 kJ] D.S Kumar220/7.26

6. A heat engine work between hot and cold reservoir at 600 K and 300 K. The engine receives 300 kW of heat. Identify which of the following heat rejections represents reversible, irreversible and impossible cycle:

(i) 250 kW, (ii) 60 kW, (iii) 150 kW

[Answer: (1) Irreversible cycle; (2) Impossible cycle; (3) Reversible cycle]

Heat Engines in Series

7. Areversibleheatenginereceivesheatfromhightemperaturereservoirat T_1 Kand rejects heat to a low temperature sink at 800 K. A second reversible heat engine receivestheheatrejectedbythe firstengineat800Kandrejectstoacoldreservoir at280K.Makecalculationsfortemperature T_1: (i) forequalthermalefficienciesof thetwoengines; (ii) forthetwoenginestodeliversthesame amountofwork. [Answer: (1) for equal thermal efficiencies, T_1 = 2285.7 K; (2) for same amount of work, T_1 = 1320 K] D.S Kumar 224/7.31

Combined Heat Engine and Refrigerator

8. Areversibleheatengineoperateswithinthehigherandlowertemperaturelimitsof 1400 Kand 400 K respectively. The entire output from this engine is utilized to operate a heat pump. The pump works on reversed Carnot cycle, extracts heat from a reservoir at 300 K and delivers it to the reservoir at 400 K. If 100 kJ/s of net heat is supplied to the reservoir at 400 K. Calculate the heat supplied to the engine by the reservoirat1400K. [Answer: (1) Q_1 = 29.168 kJ/s] [D.S Kumar 233/7.41]

Assignment No.4

Entropy

1. What is the meaning of word entropy? Prove that entropy is the point function (property) of the system.
2. State Clausius theorem. Explain Clausius inequality ( ) for r~~ev~~ersible and

irreversible cyclic processes.

3. With usual notations prove that $dS \geq \delta Q/T$.
4. State principle of increase of entropy. Prove that $dS \geq 0$ OR Show that entropy of isolated system or universe is always increases.
5. Prove that two reversible adiabatic path never intersect each other.
6. Show that constant volume line on T-s diagram is steeper than constant pressure line.
7. Explain third law of thermodynamics.

<u>Examples</u>

1. 5 kg of water at 0:C is exposed to reservoir at 98:C. Calculate the change in entropy of water, reservoir and universe. Assume specific heat of water, C_{pw}=4.187 kJ/kgK. [Answer: dS_{water}=+6.4214 kJ/K; dS_{res}=-5.53 kJ/K; dS_{uni}=+0.8914 kJ/K]
2. A small piece of steel of mass 10 kg at 800:C is dropped in bath of oil has mass 110 kg at 25:C. The specific heats of steel and oil are 0.5 kJ/kg K and 3.55 kJ/kg K respectively. Find out the change in entropy of steel, oil and universe.

[Answer: dS_{steel} = -6.2438 kJ/K; dS_{oil} = +12.6324 kJ/K; dS_{uni} = +6.3886 kJ/K]

3. One inventor claims that when 2 kg of air is supplied to a magic tube at 4 bar and 20:C, two equal mass streams at 1 bar are produced , one at -20:C and the other at 80:C. Another inventor claims that it is possible to produce two equal mass streams, one at -40:C and the other at 40:C. Considering the system to be adiabatic, determine which claim is correct and why? Assume ambient conditions at 0:C.

D.S Kumar 268/8.28

[Answer: *Inventor 1*: $S_2>S_1$ Claim is acceptable, *Inventor 2:* $S_2<S_1$ Claim is false]

Entropy Change during Non Flow Thermodynamic Processes

1. One kg of air initially at 7 bar pressure and 360 K temperature expands polytropically

$pv^{1.2}$ = C until the pressure reduced to 1.4 bar. Determine: (1) Final specific volume and temperature; (2) Change in intern al energy, work done and heat transfer; (3) change in entropy. Take R = 0.287 kJ/kg K and γ = 1.4.

D.S Kumar 264/8.23 [Answer: (1) v_2 = 0.5641 m^3/kg, T_2 = 275 K; (2) du = -66.987 kJ/kg, W = +121.975 kJ/kg, Q = +60.988 kJ/kg; (3) dS_{1-2} = +0.1916 kJ/kg K]

2. A close system contains air at pressure 1 bar, temperature 290 K and volume 0.02 m^3. This system undergoes a thermodynamic cycle consisting of following three processes in series: Process 1-2: heating at constant volume till the pressure becomes 4 bar, Process 2-3: cooling at constant pressure, Process 3-1: heating at constant temperature to initial state. Represent the cycle on T-s & p-v plot and evaluate change in entropy for each process. Take R = 0.287 kJ/kg K and C_v = 0.718 kJ/kg K. D.S Kumar 271/8.32

[Answer: dS_{1-2} = +0.02389 kJ/K, dS_{2-3} = -0.0334 kJ/K, dS_{3-1} = +0.0095 kJ/K]

3. A 0.1 m^3 of air at pressure 1 bar and temperature 27:C is compressed to pressure 6 bar according to law of pv = C. Then heated at constant volume until the pressure is 10 bar. Calculate change in entropy of process.

[Answer: dS = -0.0171 kJ/K]

4. Air at 200°C and 1.05 bar occupies 0.025 m^3. The air is heated at constant volume until the pressure is 4.5 bar, and then cooled at constant pressure back to original temperature. Calculate (i) The net heat flow from the air (ii) The net entropy change. Also draw the processes on T-S diagram.

Assignment No.5

Energy

1. Explain exergy destruction in heat transfer process.

   OR

   Explain decrease in available energy when heat transfer to a definite temperature difference.

   OR

   Discuss that same amount of heat loss at higher temperature is more harmful than that at a lower temperature.
2. Derive the expression for availability in a closed system (non-flow) at a given state.
3. Derivetheexpressionforavailabilityinasteadyflow(open)systematagivenstate.
4. Explain Gouy-Stodola theorem and its applications.
5. Explain Second law of efficiency (Effectiveness).

Examples

Available Energy and Unavailable Energy

1. Alumpof800kgofsteelat1250Kistobecooledto500K.Ifitisdesiredtousethe steel as source of energy. Calculate the available energy and unavailable energy. Take C_{steel} = 0.5 kJ/kg K and T_0 = 300 K.

[Answer: AE = 190.0451 kJ, UAE = 109.955 kJ]

2. 1 kg of air is heated reversibly at constant pressure from 100^0C to 450^0C. The temperature of the surrounding is 27^0C. Specific heat of air is 1.005 kJ/kg K. Calculate (i) heat added, (ii) availableenergy,and(iii)unavailableenergy.

[Answer: (1) Q = 351.75 kJ, (2) AE = 152.20 kJ, (3) UAE = 199.53 kJ]

Decrease in Available Energy due to Heat Transfer through Finite Temperature Difference

3. A system at 500 K receives 2200 kJ/s heat from a heat source at 1200 K. the temperature of heat sink is 300 K. The temperature of both the system and source remain constant during heat transfer. Calculate: (1) net entropy change, (2) available energy of heat source and system, and (3) decrease in available energy after heattransfer.

[Answer: (1) dS_{net} = 2.5667 kJ/s K, (2) AE_{source} = 1650.01 kJ/s, AE_{sys} = 880 kJ/s, (3) ↓in AE = 770.01 kJ]

4. The exhaust gases from a gas turbine are used to heat water in an adiabatic counter flow heat exchanger. The external gases are cooled from 310^0C to 140^0C. The water enters in heat exchanger at 50^0C. The flow rate of gases and water are 0.5 kg/s and

0.6kg/s respectively. The specific heats at constant pressure of gases and water are 1.08 kJ/kgK and 4.187 kJ/kgK respectively. The temperature of atmosphere is 27^0C. Calculate: (1) exit temperature of water and (2) loss of available energy.

[Answer: (1) T_{w2} = 359.54 K, (2) Loss of AE = 24.9243 kJ/s]

Availability for Closed System

5. In piston cylinder arrangement, air expands from 8 bar at 120^0C to 1.2 bar at 27^0C. Assume the ambient temperature 25^0C and pressure 1 bar. Calculate maximum work per kg of air. Assume C_p = 1.0 kJ/kg K, C_v = 0.713 kJ/kg K.

   [Answer: W_{max} = 87.6985 kJ/kg]

6. Calculate the availability of air during non-flow process for the following states. Neglect K.E and P.E. Take C_p = 1.0 kJ/kgK, R = 0.287 kJ/kgK, C_v = 0.713 kJ/kgK, P_0 = 1 bar, T_0 = 27^0C.
   a. P = 6 bar, T = T_0 = 27^0C b. P = P_0, T = -120^0C,
   c. P = P_0, T = T_0 = 27^0C d. P = 0.5 P_0, T = 0.5
   e. P = 3P_0, T = 2T_0

[Answer: (a) 82.52 kJ/kg, (b) 55.0033 kJ/kg, (c) 0 kJ/kg, (d) 41.3142 kJ/kg, (e) 71.8464 kJ/kg]

Availability for Open (steady flow) System

7. In steady flow system, the air enters system at 12 bar, 200^0C with velocity of 150 m/s, and after adiabatic process it leaves system at 1.2 bar, 25^0C with velocity 60 m/s. The surrounding pressure and temperature are 1 bar and 25^0C respectively. Determine reversible work. Assume C_p = 1.005 kJ/kgK, R = 0.287 kJ/kgK.

   [Answer: W_{max} = 243.89 kJ/kg]

Assignment No.6

Vapour Power cycles

Theory

1. Derive an expression for an efficiency of Carnot vapor cycle with p-v, T-S, h-s and schematic diagram.
2. Why Carnot cycle is not practical for steam power plants? Explain in brief. Also give comparison of Carnot and Rankine vapor cycle.
3. Derive an expression for an efficiency of an ideal Rankine cycle with p-v, T-S, h-s and schematic diagram.
4. Explain effect of different operating variables on Rankine cycle performance.
5. With suitable T-S diagram explain any one method of improving efficiency of Rankine cycle. *(**Note:** Here explain **Reheat cycle** only)*
6. What is regeneration? Draw schematic and T-s diagram for an ideal regenerative cycle.

Examples

1. A **Carnot engine** contains 0.1 kg of water. During the heat addition process, saturated liquid is converted into saturated vapor. Heat addition occurs at 12 MPa and heat rejection occurs at 30 KPa. Determine:
   a. Quality of steam at the end of isentropic expansion and at the end of isothermal heatrejection.
   b. Heat added per cycle
   c. Net work developed in the cycle
   d. The efficiency of the cycle
   e. Work ratio.

   [Ans: 0.6676, 0.374, 119.75KJ/cycle, 51.2 KJ/cycle, 42.75%, 0.609]
2. In a **Rankine cycle**, the steam at inlet to turbine is saturated at a pressure of 35 barand the exhaust pressure is 0.2 bar. Determine:
   a. The pumpwork
   b. The turbinework
   c. The Rankineefficiency
   d. The condenser heat flow
   e. Thedrynessattheendofexpansion.

   Assume flow rate of 9.5 kg/sec.

   [Ans: 33.63kW; 7495.5kW; 30.93%; 16734.25kW; 0.747] [12.6; R.K.Rajput]
3. A steam power plant operates on a theoretical **reheat cycle**. Steam at 25 bar pressure and 400°C is supplied to the high pressure turbine. After its expansion to dry state, the steam is reheated at constant pressure to its original temperature. Subsequent expansion occurs in the low pressure turbine to a condenser pressure of
   bar. Considering feed pump work, make calculations to determine:
   a. Quality of steam at entry to condenser,
   b. Thermal efficiencyand

c. Specific steamconsumption.

[Ans: 0.945, 37%, 2.652 kg/kWh] [15.8, D. S. Kumar]

Assignment No.7

Gas Power cycles

1. Carnot cycle is not practical – Justify.
2. Derive an equation of air standard efficiency of following ideal gas power cycles with P-V, T-S and H-S diagram:
   a. Carnot Cycle
   b. Otto Cycle
   c. Diesel Cycle
   d. Joule (Brayton) Cycle
3. Compare Otto, Diesel and Dual cycle for different aspects.
4. Explain the effect of: (a) Inter-cooling and (b) Reheating, on Brayton cycle.
5. What is the effect of Regeneration on Brayton cycle efficiency? Define the effectiveness of Regeneration.

Examples

1. The following data pertains to an air standard **Carnot cycle**:
   Minimum temp. in the cycle = 290 K

Minimum pressure in the cycle = 100 kN/m^2 Pressure after isothermal compression = 350 kN/m^2 Pressure after isentropic compression = 1050 kN/m^2
Determine the efficiency and mean effective pressure for the cycle. Proceed to calculate the power output if the engine makes 2 cycles/sec.

[Ans: 26.9%; 53.132 kN/m^2; 76.872 kW] [12.2; D.S.Kumar]

2. An air standard **Otto cycle** is designed to operate with the following data: Maximum cycle pressure and temperature: 5 MPa and 2250 K Minimum cycle pressure and temperature: 0.1 MPa and 300 K

Determine the net work output per unit mass of working fluid and the thermal efficiency. [Ans: 614.65 KJ/kg; 53.20 %] [12.8; D.S.Kumar]

3. The minimum pressure and temperature in an **Otto cycle** are 100 kPa and 27 ^{0}C. The amount of heat added to the air per cycle is 1500 kJ/kg.
   (i) Determine the pressures and temperature at all points of the air standard Otto cycle.
   (ii) Also calculate the specific work and thermal efficiency of the cycle for a compression ration 8:1.

[Ans: T_2 = 681.9 K; p_2 = 18.379 bar; T_3 = 2772.4 K; p_3 = 73.94 bar; T_4 = 1206.9 K; p_4 = 4.023 bar; 847 kJ/kg; 56.47 %] [21.9; R. K. Rajput]

4. The upper and lower temperature limits for an **Otto cycle** are 1500 K and 300 K respectively. What compression ratio is required to develop maximum work? Estimate the maximum theoretical power developed by an engine working on this cycle when the air flow rated is 0.35 kg/min.

[Ans:7.476,1.92kW][12.11,D.S.Kumar]

5. In a **Diesel cycle**, air a 0.1 MPa and 300 K is compressed adiabatically until the pressure rises to 5 MPa. If 700 kJ/kg of energy in the form of heat is supplied at constant pressure, determine the compression ratio, cutoff ratio, thermal efficiency and mean effective pressure.

[Ans:16.35;1.759;62.92%;0.545MPa][12.23;D.S.Kumar]

6. The volume ratio of compression and expansion for a **Diesel engine** as measured from an indicator diagram are 15.3 and 7.5 respectively. The pressure, temperature and volume at the begging of the compressor are 1 bar, 27 ^{0}C and 1 m^3 respectively. Assuming an ideal engine, determine the mean effective pressure, the ratio of maximum pressure to mean effective pressure and cycle efficiency. Also find the fuel consumption per kWh if the indicated thermal efficiency is 0.5 of ideal efficiency, mechanical efficiency is 0.8 and the calorific value of oil is 42000 kJ/kg. For air C_p =
1.005 kJ/kg-K, C_v = 0.718 kJ/kg-K and γ = 1.4.

[Ans:7bar;6.508;60.47%;0.354kg/kWh][12.26;D.S.Kumar]

7. An ideal diesel engine has a diameter 150 mm and stroke 200 mm. The clearance volume is 10% of the swept volume. Determine the compression ratio and air standard efficiency of the engine if cutoff takes place at 6% of the stroke. [Dec-2013]

8. In an ideal cycle for compression ignition engine, the cylinder is assumed to contain 1 kg of air initially at 1 bar and 320 K. this air is compressed adiabatically through the volume ratio of 16, heated at constant volume until the pressure is 70 bar further heated at constant pressure and then expanded adiabatically to the initial volume. Finally heat is transfer from the air at constant volume to return it to the initial state. If all the processes are reversible and the heat transfer to the air at constant pressure is equal to that transfer at constant volume, determine:
   a) The pressures and temperature at the cardinal points of the cycle,
   b) The cycle efficiency and
   c) The mean effective pressure.

[Ans: 970 K & 48.5 bar; 1400 K; 1707.2 K; 609.6 K & 1.905 bar; 66.3%; 4.7567 bar][12.30 ;D.S.Kumar]

An I.C. engine operating on the **Dual cycle** (limited pressure cycle) the temperature of the working fluid (air) at the beginning of compression is 27°C. The ratio of the maximum and minimum pressures of the cycle is 70 and compression ratio is 15. The amounts of heat added at constant volume and constant pressure are equal. Compute the air standard thermal efficiency of the cycle. State three main reasons why the actual thermal efficiency is different from the theoretical value.

Take γ for air = 1.4. [Ans: 65.3%] [21.27, R.K.Rajput]

9. Air enters the compressor of a gas turbine plant operating on **Brayton cycle** at 1 bar pressure and 300 K temperature. The pressure ratio is 5 and the maximum cycle temperature is limited to 1075 K if the compressor and turbine efficiency are 80 % and 85 % respectively. Make calculation for the net work output, cycle efficiency and work ratio.
[Ans: 118.46 kJ/kg; 21.2%; 0.349] [12.41; D.S.Kumar]

10. Air is drawn in a gas turbine unit at 15˚C and 1.01 bar and pressure ratio is 7:1. The compressor is driven by the H.P. turbine and L.P. turbine drives a separate power shaft. The isentropic efficiencies of compressor and the H.P. and L.P. turbines are 0.82, 0.85 and 0.85 respectively. If the maximum cycle temperature is 610˚C, calculate:
    a. The pressure and temperature of the gases entering the power turbine.
    b. The net power developed.
    c. The work ratio.
    d. The thermal efficiency of the unit. Neglect

    the mass of fuel and assume the following:

For compression process C_{pa} = 1.005 KJ/kg K and γ = 1.4
For combustion and expansion processes C_{pg} = 1.15 KJ/kg K and γ = 1.333.
[Ans: 1.363 bar, 654.4 K, 72.1 kW, 0.215, 18.8%] [13.45; R. K. Rajput]

Assignment No.8

Properties of gases and gas mixtures

Theory

1. Explain Dalton's law of partial pressure and Avogadro's law.
2. Explain briefly Dalton's law and Gibbs-Dalton law applied to mixture of perfect gases.
3. Define ideal gas? Prove ideal gas equation of state.
4. Write down Vanderwaal's real gas state equation. Explain the reduced properties of gas and obtain the Vander Waal's equation in reduced form OR Write down Vanderwall's equation of state. How does it differ from ideal gas equation?
5. Explain law of corresponding state.