**Department of Mechanical Engineering**

**Thermodynamics (ESC209)**

**Assignment 1**

1. An ideal gas is heated at constant volume until its temperature is 3 times the original temperature, then it is expanded isothermally till it reaches its original pressure. The gas is then cooled at constant pressure till it is restored to the original state. Determine the heat transfer and change in internal energy with each process and the net work done per kg of gas if the initial temperature is 350 K. Also, represent the cycle on P-v plane.
2. A closed cylinder of 0.25 m diameter is fitted with a light frictionless piston. The piston is retained in position by a catch in the cylinder wall and the volume on one side of the piston contains air at a pressure of 750 kN/m2. The volume on the other side of the piston is evacuated. A helical spring is mounted coaxially with the cylinder in this evacuated space to give a force of 120 N on the piston in this position. The catch is released and the piston travels along the cylinder until it comes to rest after a stroke of 1.2 m. The piston is then held in its position of maximum travel by a ratchet mechanism. The spring force increases linearly with the piston displacement to a final value of 5 kN. Calculate the work done by the compressed air on the piston.
3. A compressor takes in 500 kg/min of air at 0.98 bar and 291 K and deliver it at 5.5 bar and 341 K. The diameters of inlet and delivery pipes are respectively 450 mm and 200 mm. The power input is 1000 kW. Determine the rate and direction of heat flow.
4. An evacuated bottle ofvolume is slowly filled from atmospheric air at 1.0135 bars until the pressure inside the bottle also becomes 1.0135 bar. Due to heat transfer, the temperature of air inside the bottle after filling is equal to the atmospheric air temperature. Determine the amount of heat transfer.
5. How does energy conversion affect the environment? What are the primary chemicals that pollute the air? What is the primary source of these pollutants?
6. What is the greenhouse effect? How does the excess CO2 gas in the atmosphere cause the greenhouse effect? What are the potential long-term consequences of greenhouse effect? How can we combat this problem?

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**Assignment 2**

1. A reversible heat engine operates between 873 K and 313 K and derives a reversible refrigerator operating between 313 K and 255 K. Still there is a net output of work equal to 370 kJ, while the heat received by the engine is 2100 kJ. Determine the cooling effect.
2. 0.5 kg of air (ideal gas) executes a Carnot power cycle having a thermal efficiency of 50 percent. The heat transfer to the air during the isothermal expansion is 40 kJ. At the beginning of the isothermal expansion the pressure is 7 bar and the volume is. Determine the maximum and minimum temperatures for the cycle, in K, the volume at the end of isothermal expansion, in, and the work and heat transfer for each of the four processes, in kJ.
3. Two identical bodies of constant heat capacity are at the same initial temperature. A refrigerator operates between these two bodies until one body is cooled to the temperature. If the bodies remain at constant pressure and undergo no change of phase, obtain an expression for the minimum amount of work required to achieve this.
4. Steel balls used in ball bearing are quenched by suddenly dropping the hot balls in cold oil bath. Steel ball of 50 kg mass initially at and with specific heat 0.45 kJ/kg.K are quenched in an oil bath of initial temperature and specific heat 2.8kJ/kg.K. During the quenching, a paddle wheel driven by 200 W motor is activated to stir the oil. Thermal equilibrium is established after 20 minutes, when the final temperature is. Determine the mass of the oil and entropy generated during the process. Consider the tank containing the oil to be well insulated and of negligible mass.

3

1

2

Flash Evaporator

A geothermal supply of hot water at is fed to an insulated flash evaporator at the rate of 1.5 kg/s. A stream of saturated liquid at 200 kPa is drained from the bottom of the chamber and a stream of saturated vapour at 200 kPa is drawn from the top and fed to a turbine. Find the rate of entropy generation in the flash evaporator. Properties of water are given in the table below:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| P, kPa | t,  |  kJ/kg |  kg/kg |  kJ/kg.K |  kJ/kg.K |
| 200 | 120.20  | 504.68 | 2706.63 | 1.5300 | 7.1271 |
| 500 | 151.53 | 640.08 | 2746.60 | 1.8603 | 6.8202 |
| 500 | 150 | 632.18 |  | 1.8417 |  |

1. 500 kJ of heat is removed from a constant temperature heat reservoir maintained at 835K. The heat is received by a system at constant temperature of 720K. The temperature of the surrounding, the lowest available temperature is 280K. Illustrate the problem by T-S diagram and calculate the net loss of available energy as a result of this irreversible heat transfer.

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**Assignment 3**

1. A closed system consists of 1 kg of steam. This system undergoes three different reversible processes to constitute a thermodynamic cycle. The initial condition of steam pressure is 10 bar and dryness fraction is 0.40. The process 1-2 is constant volume heating till pressure becomes 35 bar. The process 2-3 is isothermal expansion up to pressure of 10 bar. The process 3-1 is constant pressure cooling to bring the system back to its initial state. Sketch the cycle on Mollier diagram. For each process, calculate (i) entropy change, (ii) heat transfer, and (iii) work done. Also find the cycle efficiency.
2. Derive Mayer relation and show that specific heat at constant pressure is always equal to or greater than the specific heat at constant volume.
3. Why is Carnot cycle not practicable for a steam power plant?
4. What do you understand by the mean temperature of heat addition? For a given lower temperature , show that the Rankine cycle efficiency depends on the mean temperature of heat addition.
5. In a single-heater regenerative cycle the steam enters the turbine at 30 bar, and the exhaust pressure is 0.10 bar. The feedwater heater is a direct-contact type which operates at 5 bar. Find (a) the efficiency and steam rate of the cycle, and (b) the increase in mean temperature of heat addition, efficiency and steam rate, as compared to the Rankine cycle (without regeneration). Neglect Pump work.

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**Assignment 4**

1. An ideal Otto cycle with a specified compression ratio is executed using (*a*) air, (*b*) argon, and (*c*) ethane as the working fluid. For which case will the thermal efficiency be the highest? Why?
2. An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at 95 kPa and 27°C, and 750 kJ/kg of heat is transferred to air during the constant-volume heat-addition process. Using constant specific heats at room temperature, determine (*a*) the pressure and temperature at the end of the heataddition process, (*b*) the net work output, (*c*) the thermal efficiency, and (*d*) the mean effective pressure for the cycle.
3. The compression ratio of an ideal dual cycle is 14. Air is at 100 kPa and 300 K at the beginning of the compression process and at 2200 K at the end of the heat-addition process. Heat transfer to air takes place partly at constant volume and partly at constant pressure, and it amounts to 1520.4 kJ/kg. Using constant specific heats at room temperature, determine (*a*) the fraction of heat transferred at constant volume and (*b*) the thermal efficiency of the cycle.
4. A simple Brayton cycle using air as the working fluid has a pressure ratio of 8. The minimum and maximum temperatures in the cycle are 310 and 1160 K. Assuming an isentropic efficiency of 75 percent for the compressor and 82 percent for the turbine, determine (*a*) the air temperature at the turbine exit, (*b*) the net work output, and (*c*) the thermal efficiency.
5. Consider a mixture of several gases of identical masses. Will all the mass fractions be identical? How about the mole fractions?
6. A mixture of ideal gases at a pressure of 150 kPa and 40°C contains 8 kg of nitrogen and 5 kg of oxygen. Determine for the mixture (i) average molecular weight, (ii) specific gas constant, and (iii) the two specific heats. for nitrogen may be taken as 0.70 kJ/kg-K and 1.037 kJ/kg-K, whereas for oxygen it is 0.75 kJ/kg-K and 1.04 kJ/kg-K.
7. air leaving the cooling section of an air-conditioning system at 14°C at a rate of 50 m3/min is mixed adiabatically with the outside air at 32°C and 60 percent relative humidity at a rate of 20 m3/min. Assuming that the mixing process occurs at a pressure of 1 atm, determine the specific humidity, the relative humidity, the dry-bulb temperature, and the volume flow rate of the mixture.