MUZAFFARPUR INSTITUTE OF TECHNOLOGY

COURSE FILE

OF

THERMODYNAMICS

FACULTY NAME:

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ASSISTANT PROFESSOR

DEPARTMENT OF MECHANICAL ENGINEERING

CONTENTS

B. Tech. IV Semester (MECHANICAL)

ME- 021407 Engineering Thermodynamics

L T / P/D Total Max Marks: 100

3-1-0 4 Final Exams: 70 Marks

Seasonal: 20 Marks

Internals: 10 Marks.

UNIT-I

Basic concept: Thermodynamic system and their properties, thermodynamic equilibrium, quasi-static and non-quasi-static process, zeroth law and temperature equilibrium concepts.

UNIT-II

First law of thermodynamics: concept of heat and work, first law applied to closed and open system, internal energy and enthalpy, flow work, laws of perfect gas, specific heat, first law applied to flow & non flow process.

UNIT-III

Second law of thermodynamics : concept of heat engine, refrigerator, heat pump and their range of working temperature, Kelvin-Planck's and Claussius statements and their equivalence, Entropy, calculation of entropy change for processes, reversibility, entropy principles, in equality of claussius, available and unavailable energy.

UNIT-IV

Properties of pure substances: Properties of steam and process with steam, Use of steam tables and mollier charts. Helmholtz and Gibb's function, Maxwell's relation.

UNIT-V

Ideal cycles: Air standard cycles, Otto, Diesel, Dual and Brayton cycle, Comparison of Otto, Diesel and Dual cycle.

UNIT-VI

Vapour cycle: Carnot and Rankine cycle, Regenerative and reheat cycle.

UNIT-VI

Non reacting mixture: Mixture of two ideal gases and their properties. Psychometry : Air and water-vapour mixture and their properties, adiabatic saturation, Use of psychrometry charts, Simple introduction to psychometric process.

GATE SYLLABUS

Thermodynamics Engineering

Basic concept: Thermodynamic system and their properties, thermodynamic equilibrium, quasi-static and non-quasi-static process, zeroth law and temperature equilibrium concepts.

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Ideal cycles: Air standard cycles, Otto, Diesel, Dual and Brayton cycle, Comparison of Otto, Diesel and Dual cycle.

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Psychometry : Air and water-vapour mixture and their properties, adiabatic saturation,

Use of psychrometry charts, Simple introduction to psychometric process.

COURSE PLAN

1. Scope and Objective of Course:

The study of energy, its forms and transformations, and the interactions of energy with matter is defined as the Thermodynamics. Hence thermodynamics is concerned with:

- Concept of energy.
- The law that governs the conversion of one form of energy into another.
- The properties of the working substance or the media used to obtain the energy conversion.

Thermodynamics has extremely extensive range of applications. For example, it is utilized by the mechanical engineer in the design of energy converting devices such as steam and gas turbines, internal combustion engines, fuel cells, thermoelectric generators as well as refrigerators and air-conditioning equipment.

2. Textbooks

TB1: Cengel, Yunus A., and Michael A. Boles. "Thermodynamics: an engineering approach"

TB2: Nag, P. K. Engineering thermodynamics

3. Reference Books

RB 1:R.K Rajput

RB 2:D.S Kumar

5. Evaluation Scheme:

Component 1 Mid Semester Exam 20 Component 2 Attendance /Assignment Evaluation 10 Component 3** End Term Examination** 70

Total 100

** The End Term Comprehensive examination will be held at the end of semester. The mandatory requirement of 75% attendance in all theory classes is to be met for being eligible to appear in this component.

Mechanical Engineering Department

Thermodynamics

ASSIGNMENT: 1

Q 1: When a stationary mass of gas was compressed without friction at constant pressure its initial state of 0.4 m3 and 0.105 MPa was found to change to final state of 0.20 m3 and 0.105 MPa. There was a transfer of 42.5 kJ of heat from the gas during the process. How much did the internal energy of the gas change?

Q 2: cylinder containing the air comprises the system. Cycle is completed as follows:

(i) 82000 N-m of work is done by the piston on the air during compression stroke and 45 kJ of heat are rejected to the surroundings. (ii) During expansion stroke 100000 N-m of work is done by the air on the piston.Calculate the quantity of heat added to the system.

Q 3: A tank containing air is stirred by a paddle wheel. The work input to the paddle wheel is 9000 kJ and the heat transferred to the surroundings from the tank is 3000 kJ.Determine:

(i) Work done; (ii) Change in internal energy of the system.

Q 4: When a system is taken from state l to state m, in Fig. 4.18, along path lqm, 168 kJ of heat flows into the system, and the system does 64 kJ of work:

(i) How much will be the heat that flows into the system along path lnm if the work done is 21 kJ? (ii) When the system is returned from m to l along the curved path, the work done on the system is 42 kJ. Does the system absorb or liberate heat, and how much of the heat is absorbed or liberated? (iii) If U_l= 0 and Un = 84 kJ, find the heat absorbed in the processes.

Q 5: The power developed by a turbine in a certain steam plant is 1200 kW. The heat supplied to the steam in the boiler is 3360 kJ/kg, the heat rejected by the system to cooling water in the condenser is 2520 kJ/kg and the feed pump work required to pump the condensate back into the boiler is 6 kW. Calculate the steam flow round the cycle in kg/s.

Mechanical Engineering Department

Thermodynamics

ASSIGNMENT 2

Q 1: 1kg of gaseous CO_2 contained in a closed system undergoes a reversible process at constant pressure. During this process 42 kJ of internal energy is decreased. Determine the work done during the process.Take c_p = 840 J/kg°C and c_v = 600 J/kg°C.

Q 2: A fluid is contained in a cylinder by a spring-loaded, frictionless piston so that the pressure in the fluid is a linear function of the volume ($p = a + bV$). The internal energy of the fluid is given by the following equation $U = 42 + 3.6\,pV$ Where U is in kJ, p in kPa, and V in cubic metre. If the fluid changes from an initial state of 190 kPa, 0.035 m^3 to a final state of 420 kPa, 0.07 m^3, with no work other than that done on the piston, find the direction and magnitude of the work and heat transfer.

Q 3: 90 kJ of heat is supplied to a system at a constant volume. The system rejects 95 kJ of heat at constant pressure and 18 kJ of work is done on it. The system is brought to original state by adiabatic process. Determine:

(i) The adiabatic work;

(ii) The values of internal energy at all end states if initial value is 105 kJ.

Q 4: 0.2 m^3 of air at 4 bar and 130°C is contained in a system. A reversible adiabatic expansion takes place till the pressure falls to 1.02 bar. The gas is then heated at constant pressure till enthalpy increases by 72.5 kJ. Calculate:

(i) The work done;

(ii) The index of expansion, if the above processes are replaced by a single reversible polytropic process giving the same work between the same initial and final states.

Take c_p = 1 kJ/kg K, c_v = 0.714 kJ/kg K.

Mechanical Engineering Department

Thermodynamics

ASSIGNMENT 3

Q 1: A fish freezing plant requires 40 tons of refrigeration. The freezing temperature is – 35°C while the ambient temperature is 30°C. If the performance of the plant is 20% of the theoretical reversed Carnot cycle working within the same temperature limits, calculate the power required.

Given: 1 ton of refrigeration = 210 kJ/min.

Q 2: A Carnot cycle operates between sources and sinks temperatures of 250°C and – 15°C. If the system receives 90 kJ from the source, find: (i) Efficiency of the system; (ii) The net work transfer; (iii) Heat rejected to sink.

Q 3:A reversible heat engine operates between two reservoirs at temperatures 700°C and 50°C. The engine drives a reversible refrigerator which operates between reservoirs at temperatures of 50°C and – 25°C. The heat transfer to the engine is 2500 kJ and the net work output of the combined engine refrigerator plant is 400 kJ.

(i) Determine the heat transfer to the refrigerant and the net heat transfer to the reservoir at 50°C

(ii) Reconsider (i) given that the efficiency of the heat engine and the C.O.P. of the refrigerator are each 45 per cent of their maximum possible values.

Q 4: Two Carnot engines work in series between the source and sink temperatures of 550 K and 350 K. If both engines develop equal power determine the intermediate temperature.

Q 5: A Carnot heat engine draws heat from a reservoir at temperature T_1 and rejects heat to another reservoir at temperature T_3. The Carnot forward cycle engine drives a Carnot reversed cycle engine or Carnot refrigerator which absorbs heat from reservoir at temperature $T_2$and rejects heat to a reservoir at temperature T_3. If the high temperature $T1 = 600$ K and low temperature T_2= 300 K, determine:(i) The temperature T_3such that heat supplied to engine Q_1 is equal to the heat absorbed by refrigerator Q_2.(ii) The efficiency of Carnot engine and C.O.P. of Carnot refrigerator.

Q 6: A heat pump working on a reversed Carnot cycle takes in energy from a reservoir maintained at 5°C and delivers it to another reservoir where temperature is 77°C. The heat pump derives power for its operation from a reversible engine operating within the higher and lower temperatures of 1077°C and 77°C. For 100 kJ/kg of energy supplied to reservoir at 77°C, estimate the energy taken from the reservoir at 1077°C.

Mechanical Engineering Department

Thermodynamics

ASSIGNMENT 4

Q 1:A vessel having a capacity of 0.05 m3 contains a mixture of saturated water and saturated steam at a temperature of 245°C. The mass of the liquid present is 10 kg. Find the following:

(i) The pressure, (ii) The mass, (iii) The specific volume, (iv) The specific enthalpy,(v) The specific entropy, and (vi) The specific internal energy.

Q 2: What amount of heat would be required to produce 4.4 kg of steam at a pressure of 6 bar and temperature of 250°C from water at 30°C ? Take specific heat for superheated steam as 2.2 kJ/kg K.

Q 3: If a certain amount of steam is produced at a pressure of 8 bar and dryness fraction 0.8. Calculate: (i) External work done during evaporation.(ii) Internal latent heat of steam.

Q 4: A piston-cylinder contains 3 kg of wet steam at 1.4 bar. The initial volume is 2.25 m3. The steam is heated until its temperature reaches 400°C. The piston is free to move up or down unless it reaches the stops at the top. When the piston is up against the stops the cylinder volume is 4.65 m3. Determine the amount of work and heat transfer to or from steam.

Q 5: 1. Define the co-efficient of:

(i) Volume expansion (ii) Isothermal compressibility

(iii) Adiabatic compressibility.

Mechanical Engineering Department

Thermodynamics

ASSIGNMENT 5

Q 1: A steam engine operates on ideal Carnot cycle using dry saturated steam at 20.5 bar. The exhaust takes place at 0.05 bar into condenser. Assuming that the expansion and compression are isentropic and liquid enters the boiler as saturated liquid, find (a) The power developed by the engine if the steam consumption is 15 kg/min (b) The efficiency of the operating cycle.

Q 2: In a Rankine cycle, the steam at inlet to turbine is saturated at a pressure of 30 bar and the exhaust pressure is 0.25 bar. Determine (i) The pump work (ii) Turbine power (iii) The Rankine efficiency (iv) The dryness at the end of expansion. Assume flow rate 10 kg/s.

Q 3: Explain why the Rankine cycle rather than carnot cycle is used as a standard reference for the performance of steam plants and sketching both cycles on the same T-S diagram.

Q 4: A simple Rankine cycle use water as the working fluid. The boiler operates at 6000 KPa and the condenser at 50 KPa. At the entrance to the turbine, the temperature is 450°C.The isentropic efficiency of the turbine is 94 %,pressure and pump losses are negligible, and the water leaving the condenser is sub cooled is 6.3°C.The boiler is sized for a mass flow rate of 20 kg/s. Determine the rate at which heat is added in the boiler ,the power required to operate the pumps, the net power produced by the cycle, and the thermal efficiency.

Q 5: Prove that the thermal efficiency of a Rankine cycle using superheated steam is greater than the thermal efficiency of a corresponding Rankine cycle using saturated steam. Both the cycles operate between the same boiler and condenser pressure.

Q 6: Steam at 20 bars, 360°C is expanded in a steam turbine to 0.08 bars. If then enters a condenser, where it is condensed to saturated liquid water. The pump feeds back the water into the boiler. (a)Assuming ideal processes, find per kg of steam the net work and the cycle efficiency. (b)If the turbine and the pump have each 80% efficiency, find the percentage reduction in the net work and cycle efficiency.

Q 7: In a steam power plant the condition of steam at inlet to the steam generator is 20 bar and 300°C and the condenser pressure is 0.1 bar. Two feed water heaters operate at optimum temperature. Determine (a)The quality of steam at turbine exhaust

(b)Net work per kg of steam

(c)Cycle efficiency

(d) The steam rate. Neglect pump work

Mechanical Engineering Department

Thermodynamics

Tutorial: 1

Q 1: A closed system of constant volume experiences a temperature rise of 25°C when a certain process occurs. The heat transferred in the process is 30 kJ. The specific heat at constant volume for the pure substance comprising the system is 1.2 kJ/kg°C, and the system contains 2.5 kg of this substance. Determine:

(i) The change in internal energy;

(ii) The work done.

Q2: A Spherical balloon of 1 m diameter contains a gas at 150 kpa the gas inside the balloon is heated until pressure reaches 450 kpa during the process of heating the pressure of gas inside the balloon is proportional to cube of the diameter of balloon find the work done by gas inside the balloon.

Q 3: During a non-flow quasi-static process, a gas held in a cylinder-piston assembly expands from 3 bar/0.18 m3/kg to a final volume of 0.6 m3/kg in accordance with the law P = CV–2 where C = constant. Determine the work done by the gas.

Q 4: A gas held in a cylinder-piston assembly expands quasi-statically from state 1 (0.2 m3/1000 kPa) to state 2 (1.2 m3/200 kPa), while its internal energy change in accordance with u = 1.5 PV – 85 kJ/kg and pressure P changes according to the linear relationship P = a + bV kPa whre V is its specific volume (m3/kg). Evaluate the net heat transfer and maximum internal energy change during expansion.

Mechanical Engineering Department

Thermodynamics

Tutorial: 2

Q 1: A centrifugal pump delivers 50 kg of water per second. The inlet and outlet pressures are 1 bar and 4.2 bar respectively. The suction is 2.2 m below the centre of the pump and delivery is 8.5 m above the centre of the pump. The suction and delivery pipe diameter are 20 cm and 10 cm respectively. Determine the capacity of the electric motor to run the pump.

Q 2: Derive a steady flow energy equation for a single stream entering and a single stream leaving a control volume and explain the various terms in it?

Q 3: 1 kg of Ethane [Perfect] gas is compressed from 1.1 bar,27°c according to a law $pv^{1.3}$ =Constant, until the pressure is 6.6 bar calculate the heat flow to or from the cylinder walls. Given Molecular weight of Ethane =30, Cp =1.75 kJ/kg k.

Q 4:10 kg of fluid per minute goes through a reversible steady flow process. The properties of fluid at the inlet are: p_1= 1.5 bar, ρ_1 = 26 kg/m3, C_1= 110 m/s and u_1= 910 kJ/kg and at the exit are p_2= 5.5 bar, ρ_2= 5.5 kg/m3, C_2= 190 m/s and u_2= 710 kJ/kg. During the passage, the fluid rejects 55 kJ/s and rises through 55 metres. Determine: (i) The change in enthalpy;

(ii) Work done during the process

Mechanical Engineering Department

Thermodynamics

Tutorial: 3

Q 1: 300 kJ/s of heat is supplied at a constant fixed temperature of 290°C to a heat engine. The heat rejection takes place at 8.5°C. The following results were obtained:

(i) 215 kJ/s are rejected.

(ii) 150 kJ/s are rejected.

(iii) 75 kJ/s are rejected.

Classify which of the result report a reversible cycle or irreversible cycle or impossible results.

Q 2: A steam power plant operates between boiler temperature of 160°C and condenser temperature of 50°C. Water enters the boiler as saturated liquid and steam leaves the boiler as saturated vapour. Verify the Clausius inequality for the cycle. Given: Enthalpy of water entering boiler = 687 kJ/kg. Enthalpy of steam leaving boiler = 2760 kJ/kg Condenser pressure = 0.124 × 105 N/m2.

Q 3: In a power plant cycle, the temperature range is 164°C to 51°C, the upper temperature being maintained in the boiler where heat is received and the lower temperature being maintained in the condenser where heat is rejected. All other processes in the steady flow cycle are adiabatic. The specific enthalpies at various points are given in Fig.. Verify the Clausius Inequality.

Q 4: An iron cube at a temperature of 400°C is dropped into an insulated bath containing 10 kg water at 25°C. The water finally reaches a temperature of 50°C at steady state. Given that the specific heat of water is equal to 4186 J/kg K. Find the entropy changes for the iron cube and the water. Is the process reversible? If so why?

Q 5: An ideal gas is heated from temperature $T_1$to T_2 by keeping its volume constant. The gas is expanded back to its initial temperature according to the law pvn = constant. If the entropy change in the two processes is equal, find the value of n in terms of the adiabatic index.

Mechanical Engineering Department

Thermodynamics

Tutorial: 4

Q 1: Derive the Maxwell relations and explain their importance in thermodynamics.

Q 2: Show that the relation between $C_p – C_v = T \beta 2\ v / K_T$ Define the terms β and K_T.

Q 3: Show the internal energy and enthalpy of an ideal gas are functions of temperature only.

Q 4: For an isentropic expansion of a gas with $C_p = a + KT$, $C_v = b + KT$, $C_p - C_v = R$, show that

$TdS = C_p dT – T\ v\ \beta dP$

Mechanical Engineering Department

Thermodynamics

Tutorial: 5

Q 1:40 m3 of air at 35°C DBT and 50% R.H. is cooled to 25°C DBT maintaining its specific humidity constant. Determine (i) Relative humidity (R.H.) of cooled air;

(ii) Heat removed from air.

Q 2: 120 m3 of air per minute at 35°C DBT and 50% relative humidity is cooled to 20°C DBT by passing through a cooling coil. Determine the following:

(i) Relative humidity of out coming air and its wet bulb temperature.

(ii) Capacity of cooling coil in tonnes of refrigeration.

(iii) Amount of water vapour removed per hour.

Q 3: Explain briefly with a neat sketch a 'sling psychrometer'.

Q 4. Describe briefly any two of the following processes:

(i) Sensible heating (ii) Cooling and dehumidification

(iii) Heating and humidification (IV) Heating and dehumidification.

Q 5: For the same compression ratio and heat rejection, which cycle is most efficient: Otto, Diesel or Dual? Explain with P-V and T-S diagrams.

Q 6: In an air standard Diesel cycle the compression ratio is 16and at the beginning of isentropic compression, the temperature is 15°c and the pressure is 0.1 MPa. Heat is added until the temperature at the end of the constant pressure process is 1480°c.Calculate

(i) The cut-off ratio

(ii) The heat supplied per kg of air

(iii) The cycle efficiency

(iv) The Mean effective pressure

Q 7: Saturated 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% 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 dry bulb temperature, and the volume flow rate of the mixture

Question Bank

Paper: Thermodynamics

Q.1 Short Questions

1. State Zeroth law of thermodynamics.
2. Write three different units of pressure.
3. Explain system and surroundings.
4. What is steady flow process?
5. Define: internal energy.
6. What do you mean by equation of state?
7. Define: Sensible heat.
8. Define: Latent heat of sublimation.
9. Define: Standard heats of formation.
10. Define: Standard heats of combustion.
11. Define: Standard heats of reaction.
12. Define: Entropy.
13. Define: Heat Pump.
14. What is Refrigeration?

Q.2: Give various statements of the second law of thermodynamics.

Q 3: Drive the equation for enthalpy and Entropy as functions of temperature and pressure.

Q.4: Prove that $Cp-Cv = R$

Q 5: A refrigeration process operating at a condenser temperature at 290K needs 1 kW of power per ton of refrigeration.

i) What is the coefficient of performance? ii) How much heat is rejected in the condenser? iii) What is the lowest temperature the system can possibly maintain?

Q.6: Define the first law of thermodynamics in its various forms. What are its limitations?

Q 7: For steady flow in a heat exchanger at approximately atmospheric pressure, what is the amount of heat required when 10 moles of SO2 is heated from 200oC to1100oC? Heat capacity of SO2 is given by: Cpig/R = 5.699 + 0.801 x 10 -3T – 1.015 x 105T -2 J/ (mol. K), T is in K

Q 8: A system consisting of some fluid is stirred in a tank. The rate of work done on the system by the stirrer is 2.25 hp. The heat generated due to stirring is dissipated to the surroundings. If the heat transferred to the surroundings is 3400 kJ/h, determine the change in internal energy.

Q.9: Derive Carnot equations for a Carnot cycle using an ideal gas.

Q 10: Show that COP of a heat pump is greater than COP of a refrigerator by unity.

Q 11: A diesel cycle operates at a pressure of 1 bar at the beginning of compression and the compression ratio is 16. Heat is supplied until the volume is twice the clearance volume. If □ = 1.4, find the mean effective pressure.

Q 12:An engine operates in an Otto cycle between the temperature limits of 1500 K and 300 K. Calculate the maximum power developed by the engine, assuming its intake air rate of 0.45 kg/min.

Q 13: Dry saturated stem is throttled from 25 bar to a pressure of 5 bar and is then allowed to expand adiabatically to 1 bar. Use the Mollier diagram to find the (a) dryness fraction of the stem in the final state. (b) temperature of the stem in the final state.(c) total enthalpy change.

Q 14:A steam sample at 2 MPa has a specific volume of 0.93 m3/kg. Determine the dryness fraction of the stem. Also, calculate the specific enthalpy and specific entropy of the sample.

Q 15: Define pure substance, critical point and triple points

Q 16: Derive the Maxwell relations

Q 17: Discuss the following power cycle: Rankine cycle, otto cycle, brayton cycle.