|| Jai Sri Gurudev ||

Sri AdichunchanagiriShikshana Trust®

SJB INSTITUTE OF TECHNOLOGY

(Affiliated to Visvesvaraya Technological University, Belagavi & Approved by AICTE, New Delhi. Accredited with NAAC ‘A’ grade)

Department of Mechanical Engineering

QUESTION BANK

BASIC THERMODYNAMICS

Semester &Section: **3rd Semester ‘A’ section**

Subject Name: **Basic Thermodynamics**

Subject Code: **18ME33**

Faculty Name: **Naveena kumar R. R.**

Designation: **Assistant Professor**

Academic year**: ODD Semester-2021-2022**

CONTENTS

Vision of the Institute

- To become a recognized technical education center with global perspective.

Mission of the Institute

To provide learning opportunities that fosters students ethical values, intelligent development in science & technology and social responsibility so that they become sensible and contributing members of the society.

Vision of the Department

- To become a center of excellence and a platform in diversified fields for the aspirants in Mechanical Engineering.

Mission of the Department

- To impart comprehensive education in the field of mechanical engineering to produce highly accomplished graduates
- To endow high profile technical & soft skill trainings to foster professionalism and ethical values among students
- To inculcate innovative thinking among students through projects and research work

PROGRAMOUTCOMES

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineeringfundamentals, and an engineering specialization to the solution of complex engineeringproblems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineeringsciences.
3. **Design/development of solutions**: Design solutions for complex engineering problemsanddesignsystemcomponentsorprocessesthatmeetthespecifiedneedswithappropriate consideration for the public health and safety, and the cultural, societal, andenvironmentalconsiderations.
4. **Conduct investigations of complex problems**: Use research-based knowledge andresearch methods includingdesign ofexperiments, analysisand interpretation ofdata,andsynthesisoftheinformationtoprovidevalidconclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, andmodernengineeringandITtoolsincludingpredictionandmodelingtocomplexengineeringactivitieswithanu nderstandingofthelimitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge toassesssocietal,health,safety,legalandculturalissuesandtheconsequentresponsibilitiesrelevanttotheprofessi onalengineeringpractice.
7. **Environment and sustainability**: Understand the impact of the professional engineeringsolutions in societal and environmental contexts, and demonstrate the knowledge of, andneedforsustainabledevelopment.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities andnormsoftheengineering practice.
9. **Individual and teamwork**: Function effectively as an individual, and as a member orleaderindiverseteams, andinmultidisciplinarysettings.
10. **Communication**: Communicate effectively on complex engineering activities with theengineering community and with society at large, such as, being able to comprehend andwrite effective reports and design documentation, make effective presentations, and giveand receiveclearinstructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of theengineering and management principles and apply these to one’s own work, as a memberandleaderinateam, tomanageprojectsandinmultidisciplinaryenvironments.
12. **Life-long learning**: Recognize the need for and have the preparation and ability toengage in independent and life-long learning in the broadest context of technologicalchange.

PROGRAM EDUCATIONAL OBJECTIVES (PEO'S)

Enable the Graduates in Mechanical Engineering to:

PEO-1: Progress their career as a professionalin mechanical engineering and Inter-disciplinary fields.

PEO-2: Become successful entrepreneur with social responsibilities and ethical values.

PEO-3: Pursue higher education and involve in research of allied areas in Mechanical Engineering.

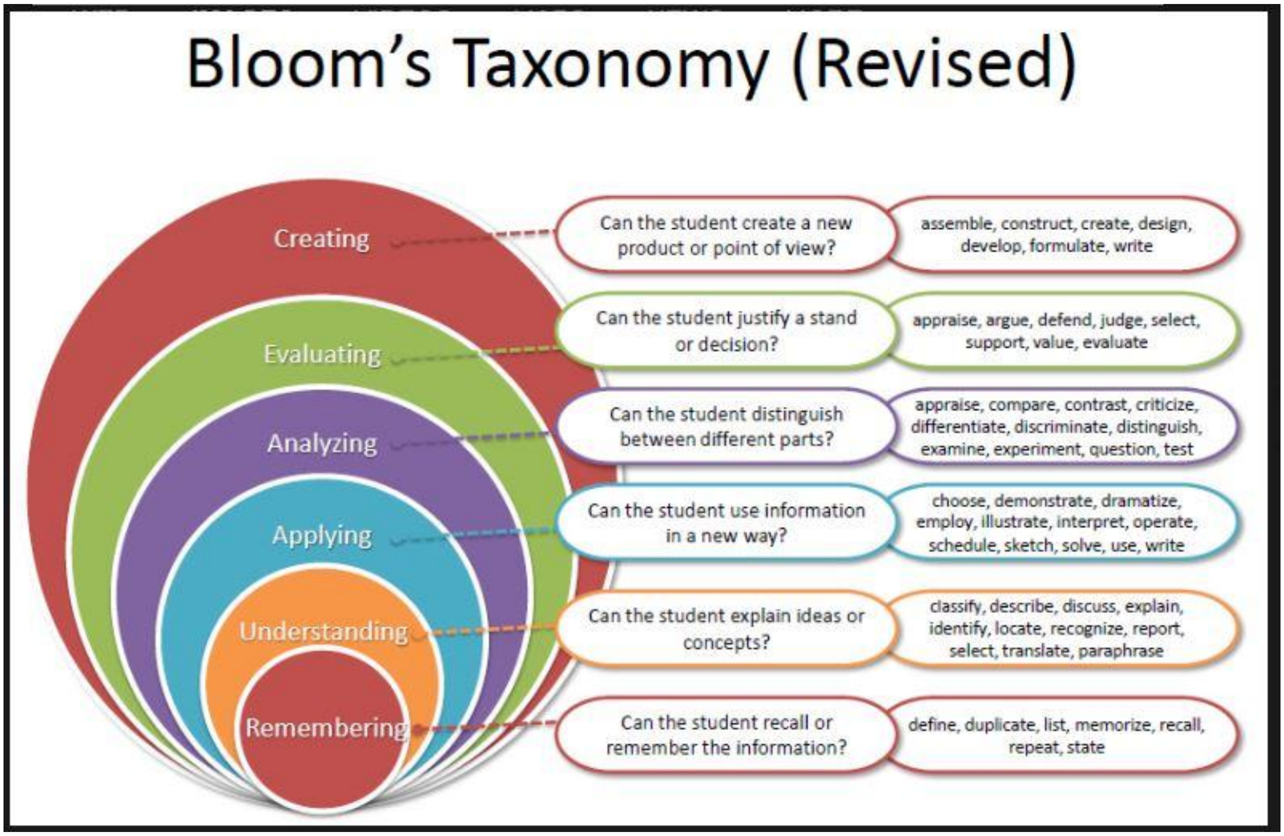
PROGRAM SPECIFIC OUTCOMES (PSO'S)

After successful completion of Mechanical Engineering program, the graduates will be able to:

PSO1: Apply the Knowledge & Skill of Mechanical Engineering on Design, Manufacturing and Thermal platforms to address the real-life problem of the society.

PSO2: Design and implement new ideas with the help of CAD/CAM and Industrial Automation tools.

Blooms Taxonomy



B. E. MECHANICAL ENGINEERING
Choice Based Credit System (CBCS) and Outcome Based Education (OBE)
SEMESTER - III
BASIC THERMODYNAMICS

Course Code 18ME33 CIE Marks 40
Teaching Hours/Week (L:T:P) 3:0:0 SEE Marks 60
Credits 03 Exam Hours 03

Course Learning Objectives:

- Learn about thermodynamic system and its equilibrium
- Understand various forms of energy - heat transfer and work
- Study the basic laws of thermodynamics including, zeroth law, first law and second law.
- Interpret the behaviour of pure substances and its application in practical problems.
- Study of Ideal and real gases and evaluation of thermodynamic properties

Module-1

Fundamental Concepts & Definitions: Thermodynamic definition and scope, Microscopic and Macroscopic approaches. Some practical applications of engineering thermodynamic Systems, Characteristics of system boundary and control surface, examples. Thermodynamic properties; definition and units, intensive, extensive properties, specific properties, pressure, specific volume, Thermodynamic state, state point, state diagram, path and process, quasi-static process, cyclic and non-cyclic; processes; Thermodynamic equilibrium; definition, mechanical equilibrium; diathermic wall, thermal equilibrium, chemical equilibrium, Zeroth law of thermodynamics, Temperature; concepts, scales, international fixed points and measurement of temperature. Constant volume gas thermometer, constant pressure gasthermometer, mercury in glass thermometer.

Module-2

Work and Heat: Mechanics, definition of work and its limitations.Thermodynamic definition of work; examples, sign convention. Displacement work; as a part of a system boundary, as a whole of a system boundary, expressions for displacement work in various processes through p-v diagrams. Shaft work; Electrical work. Other types of work. Heat; definition, units and sign convention. Problems.

First Law of Thermodynamics: Joules experiments, equivalence of heat and work. Statement of the First law of thermodynamics, extension of the First law to non - cyclic processes, energy, energy as a property, modes of energy, Extension of the First law to control volume; steady flow energy equation(SFEE), important

Module-3

Second Law of Thermodynamics: Limitations of first law of thermodynamics, Thermal reservoir, heat engine and heat pump: Schematic representation, efficiency and COP. Reversed heat engine, schematic representation, importance and superiority of a reversible heat engine and irreversible processes, internal and external reversibility. Kelvin - Planck statement of the Second law of Thermodynamics; PMM I and PMM II, Clausius statement of Second law of Thermodynamics, Equivalence of the two statements; Carnot cycle, Carnot principles. Problems

Entropy: Clausius inequality, Statement- proof, Entropy- definition, a property, change of entropy, entropy as a quantitative test for irreversibility, principle of increase in entropy, entropy as a coordinate.

Module-4

Availability, Irreversibility and General Thermodynamic relations. Introduction, Availability (Exergy), Unavailable energy, Relation between increase in unavailable energy and increase in entropy. Maximum work, maximum useful work for a system and control volume, irreversibility. Pure Substances: P-T and P-V diagrams, triple point and critical points. Sub-cooled liquid, saturated liquid, mixture of saturated liquid and vapor, saturated vapor and superheated vapor states of pure substance with water as example. Enthalpy of change of phase (Latent heat). Dryness fraction (quality), T-S and H-S diagrams, representation of various processes on these diagrams. Steam tables and its use. Throttling calorimeter, separating and throttling calorimeter.

Module-5

Ideal gases: Ideal gas mixtures, Daltons law of partial pressures, Amagat's law of additive volumes, evaluation of properties of perfect and ideal gases, Air- Water mixtures and related properties.

Real gases: Introduction, Van-der Waal's Equation of state, Van-der Waal's constants in terms of critical properties, Beattie-Bridgeman equation, Law of corresponding states, compressibility factor; compressibility chart. Difference between Ideal and real gases.

Course Outcomes: At the end of the course, the student will be able to:

CO1: Explain fundamentals of thermodynamics and evaluate energy interactions across the boundary of thermodynamic systems.

CO2: Evaluate the feasibility of cyclic and non-cyclic processes using 2nd law of thermodynamics.

CO3: Apply the knowledge of entropy, reversibility and irreversibility to solve numerical problems and apply 1st law of thermodynamics to closed and open systems and determine quantity of energy transfers and change in properties.

CO4: Interpret the behavior of pure substances and its application in practical problems.

CO5: Recognize differences between ideal and real gases and evaluate thermodynamic properties of ideal and real gas mixtures using various relations.

Question paper pattern:

- The question paper will have ten full questions carrying equal marks.
- Each full question will be for 20 marks.
- There will be two full questions (with a maximum of four sub- questions) from each module.
- Each full question will have sub- question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbooks

1. Basic and Applied Thermodynamics, P.K.Nag, Tata McGraw Hill 2nd Ed., 2002

2. Basic Engineering Thermodynamics, A.Venkatesh Universities Press, 2008

3. Basic Thermodynamics,, B.K Venkanna, Swati B. Wadavadagi PHI, New Delhi 2010

Reference Books

1. Thermodynamics- An, Engineering Approach, YunusA.Cenegal and Michael A.Boles Tata McGraw Hill publications 2002

2. An Introduction to Thermodynamcis, Y.V.C.Rao Wiley Eastern 1993,

3. Engineering Thermodynamics .B.Jones and G.A.Hawkins John Wiley and Sons.

Module 1

FUNDAMENTAL CONCEPTS AND DEFINITIONS

1 Define a thermodynamic system. Differentiate between open system, closed system and an isolated system.

Distinguish between

a) Intensive and extensive properties.

b) Microscopic and Macroscopic approaches.

c) Homogeneous system and heterogeneous system.

d) Thermal mechanical and chemical equilibrium.

e) Diathermic and adiabatic wall.

2 Explain briefly zeroth law of thermodynamics.

3 Explain quasi-static process.

4 Explain the following terms:

(i) State (ii) Process, (iii) Cycle (iv) Properties (v) path

5 Differentiate between work and heat

6 Derive a work done equation for the following process: a) P = Constant, b) V= constant, c) PV = Constant, d) PV^n = constant with p-V diagram.

7 Briefly explain about first law of thermodynamics.

8 Differentiate between Point function and path function.

9 Derive an expression for displacement work for polytropic process.

10 Show that work and heat are path functions.

11 The emf in a thermocouple with the test junction at t^0 C on gas thermometer scale and reference junction at ice point is given by:

$$\varepsilon = 0.20 \times t - 5 \times 10^{-4} \times t^2$$

The milli-voltmeter is calibrated at ice and steam points. What will this thermometer read in place where the gas thermometer reads 50^0 C.

12 The temperature T on a thermometer scale is defined in terms of property K by the relation:

T = a ln(k) + b, where a and b are constants

The values of K are found to be 1.83 and 6.78 at the ice point and steam point the temperature of which are assigned the numbers 0 and 100 respectively. Determine the temperature reading corresponding to a reading of K equal to 2.42 on the thermometer.

13 Two thermometers one Centigrade and other Fahrenheit immersed in a fluid read the same

numerical value. Fine the temperature of the fluid expressed in ^{0}K and ^{0}R. Also find the identical numerical value shown by the thermometers.

14 Calculate the non-flow work done for a gas which expands from initial pressure 5bar and volume 4m^3 to final volume 20m^3 under the following reversible process. Show the process in P-V diagram

a) P = Constant b) V = Constant c) PV = Constant d) PV^{γ} = Constant, γ = 1.4

e) PV^n = Constant, where n = 1.25

15 The work supplied to a closed system is 160 kJ. The initial volume is V_1 = 0.80m^3 and pressure of the system change as 'P = 7 – 3V', where P is in bar and V is in m^3. Determine the final volume and pressure of the system.

16 A fluid undergoes the following process in sequence to complete a cycle.

a) Heated reversible at constant pressure of 1.05 bar until it has a volume of 0.02m^3.
b) It is then compressed reversible according to a law, PV = Constant, to a pressure of 4.2 bar.
c) It is then allowed to expand reversible according to a law, PV1.3 = constant.
d) Finally it is heated at constant volume back to initial condition.

If the work done during the constant pressure process is 515 N-m, calculate the net work done on or by the cycle. Sketch also the cycle on the P-V diagram.

Module 2:

Work and Heat, First Law of Thermodynamics

1. Derive Energy is a property of the system.
2. Derive the steady flow energy equation.
3. Explain a unsteady flow process.
4. Define perpetual machine of first kind.
5. A fluid system, contained in a piston and cylinder machine, passes through a complete cycle of four processes. The sum of all heat transferred during a cycle is -340 kJ. The system completes 200 cycles minutes. Complete the following table showing the method for each item, and compute the net rate of work output in Kw.

Process	Q (Kj/min)	W (Kj/min)	ΔE (Kj/min)
1-2	0	4340	-
2-3	42000	0	-
3-4 -	42000	-	73200
4-1	-	-	-

6. When the state of a system changes from state 1 to state 3 along the path 1-2-3 as shown in figure, 80 Kj of heat flows into the system and the system does 30 Kj of work. (a) How much heat flows into the system along the path 1-4-3 if work done by the system is 10 Kj (b) when the state of the system is returned from state 3 to state 1 along the curved path, the work done on the system is 20 Kj. Does the system absorb or liberate heat? Find its magnitude. (c) If U1 = 0 and U4 = 40Kj, find the heat absorbed in the process 1-4 and 4-3 respectively.
7. Air flows steadily at the rate of 0.4 kg/s through an air compressor entering at 6 m/s with a pressure of 1 bar and a specific volume of 0.85 m3/kg, and leaving at 4.5 m/s with a pressure of 6.9 bar and a specific volume of a 0.16 m3/kg. The internal energy of air leaving is 88 Kj/kg greater than that of the air entering. Cooling water in a jacket surrounding the cylinder absorbs heat from the air at the rate of 59 Kj/s. Calculate the power required to drive the compressor and the inlet and outlet pipe cross sectional areas.
8. The compressor of a large gas turbine receives air from the surroundings at 95 Kpa and 200C. The air is compressed to 800 Kpa according to the relation Pv1.3 = constant. The inlet velocity is negligible and the outlet velocity is 100 m/s. The power input to the

compressor is 2500 Kw, 20% of which is removed as heat from the compressor. What is the mass flow rate of the air? Take Cp = 1.01 Kj/kg0K for air.

9. A petrol engine develops 50 Kw brake power. The fuel and air flow rates are 10 kg and 107 kg/hr. The temperature of fuel air mixture entering the engine is 20 0 C and temperature of gases leaving the engine is 500 0 C. The heat transfer rate from the engine to the cooling water circulated is 50Kj/s and that to the surroundings 10 Kj/s. Evaluate the increase in the specific enthalpy of the mixture as it flows through the engine.

10. Gas from a bottle of compressed helium is used to inflate a balloon originally folded completely flat, to a volume of 0.25 m^3. If the barometer reads 760 mm of mercury, how much work is done by the system comprising the helium initially in the bottle, if the balloon is light and requires no stretching. Sketch the system before and after the process.

11. Determine the work done by the air which enters an evacuated bottle from the atmosphere when the cork is opened, atmospheric air rushes into it. If the atmospheric pressure is 101.396 kPa and 0.6m^3 of air (measured at atmosphere conditions) enters the bottle.

12. A spherical balloon has a diameter of 25 cm and contains air at a pressure of 1.5 x 10^5Pa. The diameter of the balloon increases to 30 cm in a certain process and during this process the pressure is proportional to the diameter. Calculate the work done by the air inside the balloon during this process.

13. Gas from a bottle of compressed helium is used to inflate an inelastic flexible balloon, originally folded completely flat to a volume of 0.5 m^3. If the barometer reads 760 mm of Hg, what is the amount of work done upon the atmosphere by the balloon (50.66 kJ)

14. When the valve of the evacuated bottle is opened, atmosphere air rushes into it. If the atmosphere pressure is 101.325 KPa, and 1.2 m^3 of air (measured at atmosphere conditions) enters the bottle, calculate the work done by the air (-60.8 kJ).

15. A gas system, confined by a piston and cylinder, undergoes a change of state such that the product of pressure and volume remains constant. If the process begins at a pressure of 3 bar

and a volume $0.015m^3$ and proceeds until the pressure falls to half its initial value, determine the magnitude and direction of the work flow..

16. A certain amount of gas is compressed from 1 bar and $0.1m^3$ to 5 bar and $0.03m^3$. The process is according to the law $pV^n = K$. Determine the magnitude and direction of work.

17. A non-flow reversible process occurs for which $p = 3V^2 + 1/V$ where p is in N/cm^2 and V is in m^3. What is the work done when V changes from 0.5 m^2 to 1 m^3.

18. A system consists of a cylinder and piston machine. The external normal load applied to the piston is given by F = - 7000 + 15000L Newton’s, where L is the distance in mts from the closed and of the cylinder to the piston. How much work is done when the piston moves from the position L = 1m to L = 1.5 m. Sketch the p-V diagram for this process and show the work done.

19. An insulated system contains a mixture of ice and water. A paddle wheel is rotated in the system at 100rpm. Torque applied to the shaft is 3 N-m. In order to effect the transformation of 1 kg of ice to liquid water 300 kJ of heat must be transferred to the system. Determine the length of time the paddle wheel must be rotated in order to achieve 2.5 kg reduction in the quantity of ice.

20. A system containing 5 kg of a substance is stirred with a torque of 1 N-m at a speed of 500 rpm for 24 hrs. The system mean while expands from $1.5m^3$ to $2.0m^3$ against a constant pressure of 5 bar. Determine the magnitude and direction of net work transfer.

21. A mass of 1.5 kg of a substance is compressed in a quasi-static process from 0.1 MPa to 0.7 MPa. The initial pressure density of the substance is 1.16 kg/m^3. Determine the magnitude of work done on the substance if i) process is pV = C and $pV^{1\text{-}4} = C$

22. O_2 is compressed in a quasi static process according to the relation $pV^{1\text{-}2} = C$. The initial conditions are 98 KPa and 20^0 C and the final pressure is 1000 KPa. Assuming an ideal gas behaviour, determine the work required to compress 100 kg of O_2. Compare this work with the work of isothermal compression, i.e., pV = C.

Module 3:

Second Law of Thermodynamics, Entropy

1. Define Perpetual Motion Machine of first kind.

2. State.
    1) Kelvin – Planck statement
    2) Clausius statement

3. Proof of violation of the Clausius statement results in violation of the Kelvin – Planck statement.

4. Derive the efficiency expression of carnot cycle

5. A heat engine works on the Carnot cycle between temperature 900 ° C & 200 ° C. If the engine receives heat at the higher temperature at the rate of 60 kW, calculate the power of the engine.

6. An engineer claims to have developed an engine which develops 3.4 kW while consuming 0.44 Kg of fuel of calorific value of calorific value of 41870 kJ / kg in one hour. The maximum and minimum temperatures recorded in the cycle are 1400 ° C & 350 ° C respectively is the claim of the engineer genuine.

7. A reversible power cycle is used to drive heat pump cycle. The power cycle takes in Q_1 heat units at T_1 K and rejects Q_2 at T_2 K. The heat pump abstract Q_4 from the sink at T_4 k and discharges Q_3 units of heat to a reservoir at T_3 K. Develop an expression for the ratio Q_4 / Q_1 in terms of the four temperatures.

8. Derive clausius theorem.

9. Prove entropy is a property of the system.

10. Explain Principle of the increase of entropy.

11. One kg of water at 273 K is brought into contact with a heat reservoir at 373 K. When the water has reached 373 K, find the entropy change of water, the heat reservoir and of the universe.
12. Ten grams of water at 20 ^{0}C is converted into ice at - 10 ^{0}C at constant atmospheric pressure. Assuming specific heat of liquid water to remain constant at 4.184 J / g ^{0}C and that of ice to be half of this value, and taking the latent heat of fusion of ice at 0 ^{0}C to be 335 J / g, calculate the total entropy change of the system.

13. A gas enters a system at an initial pressure of 0.45 MPa and flow rate of 0.25 m^3/s and leaves at a pressure of 0.9 MPa and 0.09 m^3/s. During its passage through the system the increase in i.e., is 20 kJ/s. Find the change of enthalpy of the medium.

14. 12 kg of a fluid per minute goes through a reversible steady flow process. The properties of fluid at the inlet are p_1 = 1.4 bar, ρ_1 = 25 kg/m^3, V_1 = 120 m/s & u_1 = 920 kJ/kg and at the exit are p_2 = 5.6 bar, ρ_2 = 5 kg/m^3, V_2 = 180 m/s and u_2 = 720 kJ/kg. During the passage, the fluid rejects 60 kJ/s and raises through 60m. Determine i) the change in enthalpy ii) work done during the process.

15. In the turbine of a gas turbine unit the gases flow through the turbine at 17 kg/s and the power developed by the turbine is 14000 kW. The enthalpies of the gases at inlet and outlet are 1200 kJ/kg and 360 kJ/kg respectively, and the velocities of the gases at inlet and outlet are 60 m/s and 150 m/s respectively. Calculate the rate at which the heat is rejected from the turbine. Find also the area of the inlet pipe given that the specific volume of the gases at inlet is 0.5 m^3/kg.

16. Air flows steadily at the rate of 0.4 kg/s through an air compressor entering at 6 m/s with a pressure of 1 bar and a specific volume of 0.85 m^3/kg, and leaving at 4.5 m/s with a pressure of 6.9 bar and a specific volume of a 0.16 m^3/kg. The internal energy of air leaving is 88 kJ/kg greater than that of the air entering. Cooling water in a jacket surrounding the cylinder absorbs

heat from the air at the rate of 59 kJ/s. Calculate the power required to drive the compressor and the inlet and outlet pipe cross sectional areas.

17. An engineer claims to have developed an engine which develops 3.4 kW while consuming 0.44 Kg of fuel of calorific value of calorific value of 41870 kJ / kg in one hour. The maximum and minimum temperatures recorded in the cycle are 1400° C & 350° C respectively is the claim of the engineer genuine.
18. Two Carnot engines A and B are connected in series between two thermal reservoirs maintained at 100 k and 100 k respectively. Engine A receives 1680 kJ of heat from the high temperature reservoir and rejects heat to Carnot engine B. Engine B takes in the heat rejected by engine A and rejects heat to the low temperature reservoir. If engines A and B have equal thermal efficiencies determine (1) The heat rejected by engine B (2) The temperature at which heat is rejected by engine A and (3) The work done during the process by engines A and B respectively.

19. A reversible refrigerator operates between 35° C and -12° C. If the heat rejected to reservoir is 1.3 kW, determine the rate at which to heat is leaking into the refrigerator.

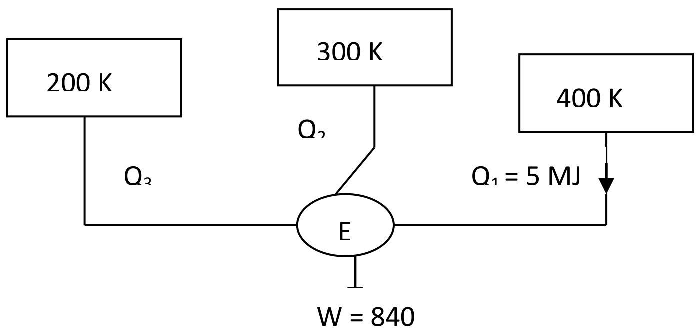
20. A Heat engine is used to drive a heat pump. The heat transfers from the heat engine and from the heat pump are used to heat the water circulating through the radiators of a building. The efficiency of the heat engine is 27% and the coefficient performance of heat pump is 4. Evaluate the ratio of heat transfer to the circulating water to the heat transfer to the heat engine.

21. Direct heat engine operating between two reservoirs at 327 ^{0}C and 27 ^{0}C drives a refrigerator operating between 27 ^{0}C and 13 ^{0}C. The efficiency of the heat engine and the COP of the refrigerator are each 70% of their maximum values. The heat transferred to the direct heat engine is 500 kJ. The net heat rejected by the engine and the refrigerator to the reservoir at 27 ^{0}C is 400 kJ. Find the net work output of the engine-refrigerator combination. Draw the schematic representation.

22. One kg of water at 273 K is brought into contact with a heat reservoir at 373 K. When the water has reached 373 K, find the entropy change of water, the heat reservoir and of the universe.

23. Ten grams of water at 20 ^{0}C is converted into ice at - 10 ^{0}C at constant atmospheric pressure. Assuming specific heat of liquid water to remain constant at 4.184 J / g ^{0}C and that of ice to be half of this value, and taking the latent heat of fusion of ice at 0 ^{0}C to be 335 J / g, calculate the total entropy change of the system.

24. A reversible engine as shown in figure during a cycle of operation draws 5MJ from the 400 K reservoir and does 840 kJ of work. Find the amount and direction of heat interaction with other reservoirs.



25. A 5 kg copper block at a temperature of 200 ^{0}C is dropped into an insulated tank containing 100 kg of oil at a temperature of 30 ^{0}C. Find the increase in entropy of the universe due to this process when copper block and the oil reach thermal equilibrium. Assume that the specific heats of copper and oil are respectively 0.4 kJ /Kg K and 2.1 kJ /Kg K.

Module 4:

Availability, Irreversibility and pure substance

1. Give a neat sketch of “separating and throttling calorimeter” for dryness fraction measurement.
2. What is a pure substance?
3. Draw and explain a p-T (pressure-temperature) diagram for a pure substance.
4. What is a triple point ?
5. Explain with a neat diagram p-V-T surface.
6. Does wet steam obey laws of perfect gases ?
7. Describe the process of formation of steam and give its graphical representation also.

8. Explain the following terms relating to steam formation :
   (i) Sensible heat of water, (ii) Latent heat of steam,
   (iii) Dryness fraction of steam, (iv) Enthalpy of wet steam, and
   (v) Superheated steam.

9. Write short notes on the following;
   a. Sensible heating c. Latent heating
   b. Critical point d. Triple point

10. The steam is heated to raise its temperature to 150°C. Show the process on a sketch of the *p*–*v* diagram, and evaluate the pressure, increase in enthalpy, increase in internal energy, increase in entropy of steam, and the heat transfer. Evaluate also the pressure at which the steam becomes dry saturated.

11. The following observations were recorded in an experiment with a combined separatingand throttling calorimeter:
    Pressure in the steam main–15 bar
    Mass of water drained from the separator–0.55 kg
    Mass of steam condensed after passing through the throttle valve –4.20 kg

Pressure and temperature after throttling–1 bar, 120°C

Evaluate the dryness fraction of the steam in the main, and state with reasons, whether the throttling calorimeter alone could have been used for this test.

12. The steam is heated to raise its temperature to 150°C. Show the process on a sketch of the p–v diagram, and evaluate the pressure, increase in enthalpy, increase in internal energy, increase in entropy of steam, and the heat transfer. Evaluate also the pressure at which the steam becomes dry saturated.

13. Electric calorimeter and comes out at 1 bar, 130°C. The calorimeter has two 1 kW heaters and the flow is measured to be 3.4 kg in 5 min. Find the quality in the engine exhaust. For the same mass flow and pressures, what is the maximum moisture that can be determined if the outlet temperature is at least 105°C?

14. A sample of wet steam from a steam main flows steadily through a partially open valve into a pipeline in which is fitted an electric coil. The valve and the pipeline are well insulated. The steam mass flow rate is 0.008 kg/s while the coil takes 3.91 amperes at 230 volts. The main pressure is 4 bar, and the pressure and temperature of the steam downstream of the coil are 2 bar and 160°C respectively. Steam velocities may be assumed to be negligible.

    (a) Evaluate the quality of steam in the main.

    (b) State, with reasons, whether an insulted throttling calorimeter could be used for this test.

15. Combined separating and throttling calorimeter is used to determine quality of steam.

    Following observations are made;

    Steam inlet pressure = 1.4 MPa

    Pressure after throttling = 0.1 MPa

    Temperature after throttling = 120°C

    Water collected in separator = 0.45 kg

    Steam condensed after throttling = 6.75 kg

    Take specific heat of superheated steam = 2.1 kJ/kg.K

16. Draw a neat sketch of throttling calorimeter and explain how dryness fraction of steam is determined ; clearly explain its limitations.
17. Describe with a neat sketch a separating-throttling calorimeter for measuring the dryness fraction of steam

    20. A vacuum pump is used to evacuate a chamber where some specimens are dried at 500C.the pump rate of volume displacement is 0.5 m3/s with an inlet pressure of 0.1 kPa and temperature 323K. How much water vapor has been removed over 30 minutes period?

18. A sample of steam from a boiler drum at 3 MPa is put through a throttling calorimeter in which the pressure and temperature are found to be 0.1 MPa, 393K. Find the quality of the sample taken from the boiler.

19. A closed, rigid container of volume 0.5 m^3 is placed on a hot plate. Initially the container holds a two-phase mixture of saturated liquid water and saturated water vapor at P_1= 1 bar with a quality of 0.5. After heating, the pressure in the container is P_2=1.5 bar.
    Indicate the initial and final states on a T-v diagram, and determine:
    a) the temperature, in °C, at each state.
    b) the mass of vapor present at each state, in kg.
    c) if heating continues, determine the pressure, in bar, when the container holds only saturated

20. Two streams of steam, one at 2MPa, 573K and the other at 2MPa, 673K mixed in a steady flow adiabatic process. The rate of flow of two streams are 3 kg/min and 2 kg/min respectively. Evaluate the final temperature of the emerging stream, if there is no pressure drop due to the mixing process. What would be the rate of increase in the entropy of the universe?

21. Steam enters an engine at a pressure of 10 bar absolute and 523 K. it is exhausted at 2 bar. The steam at exhaust is 0.9 dry. Find drop in enthalpy and change in entropy.
22. Calculate the internal energy per kg of superheated steam at a pressure of 10 bar absolute and a temperature of 573 K. also find the change of internal energy if this steam is expanded to 1.4 bar absolute and dryness fraction 0.8

Module 5:
Ideal gases and Real gases

1. What is an ideal gas?
2. What is the difference between an ideal and a perfect gas?
3. What are semi-perfect or permanent gases?
4. Define 'Equation of state'.
5. State Boyle's and Charle's laws and derive an equation of the state for a perfect gas.
6. What is a *p-v-T* surface? Draw a portion of a such a surface.
7. Derive the relationship between the two principal specific heats and characteristic gas constant for a perfect gas.
8. Write a short note on Van der Waals' equation. the gas in the vessel. If the pressure of this gas is increased to 10.5 bar while the volume remains constant, what will be the temperature of the gas ? For the gas take R = 290 J/kg K.
9. The tyre of an automobile contains a certain volume of air at a gauge pressure of 2 bar and 20°C. The barometer reads 75 cm of Hg. The temperature of air in the tyre rises to 80°C due to running of automobile for two hours. Find the new pressure in the tyre. Assume that the air is an ideal gas and tyre does not stretch due to heating.
10. A tank made of metal is designed to bear an internal gauge pressure of 7 bar. The tank is filled with a gas at a pressure of 5.5 bar abs., and 15°C. The temperature in the tank may reach to 50°C when the tank stands in the sun.
    (*i*) If the tank does not expand with temperature, will the design pressure be exceeded on a day when atmospheric pressure is 1 bar and air in the tank reaches 50°C when exposed to hot sun?
    (*ii*) What temperature would have to be reached to raise the air pressure to the design limit?
11. A vessel of spherical shape is 1.5 m in diameter and contains air at 40°C. It is evacuated till the vacuum inside the vessel is 735 mm of mercury. Determine :
    (*i*) The mass of air pumped out ;

(*ii*) If the tank is then cooled to 10°C what is the pressure in the tank?

The barometer reads 760 mm of mercury. Assume that during evacuation, there is no change in temperature

12. Carbon Dioxide gas is stored in a 100 liter tank at 6 MPa and 30°C. Determine the mass of CO_2 in the tank based on (a) values obtained from the CO_2 tables of data, (b) the ideal gas equation of state, and (c) the generalized compressibility chart. Compare (b) and (c) to (a) and determine the percentage error in each case.

13. You may wonder why we would be interested in knowing the value of air pressure at 3000m altitude. In the following example we continue with the above development in order to evaluate the payload that can be lifted to an altitude of 3000m using a small hot air balloon (Volume =1000 m^3) having an empty mass of 100kg. Assume that the temperature of the air in the balloon is 100°C.

14. A piston-cylinder device contains 0.5 kg saturated liquid water at a pressure of 200 kPa. Heat is added and the steam expands at constant pressure until it reaches 300°C.

    a) Draw a diagram representing the process showing the initial and final states of the system.

    b) Sketch this process on a *T-v* (temperature-specific volume) diagram with respect to the saturation lines, critical point, and relevant constant pressure lines, clearly indicating the initial and final states.

    c) Using steam tables determine the initial temperature of the steam prior to heating.

    d) Using steam tables determine the final volume of the steam after heating

    e) Using the ideal gas equation of state determine the final volume of the steam after heating. Determine the percentage error of using this method compared to that of using the steam tables.