DHANALAKSHMI SRINIVASAN

COLLEGE OF ENGINEERING AND TECHNOLOGY

MAMALLAPURAM, CHENNAI

DEPARTMENT OF AERONAUTICAL ENGINEERING

COURSE CODE	**:**	**C202**
SUBJECT CODE	**:**	**AE3351 (R-2021)**
SUBJECT NAME	**:**	**AERO ENGINEERING THERMODYNAMICS**
YEAR / SEMESTER	**:**	**II / III**

ASSIGNMENTS

ASSIGNMENT – 1

1. i) One kg of air is expanded in piston-cylinder system from a specific volume of v = 0.2 m^3/kg and temperature of 580 K to a specific volume of v = 0.8 m^3/kg and a temperature of 290 K. The expansion process is given by $pv^{1.5} = 0.75$ (p in bar and v in m^3/kg). Determine the work and heat interaction. (8)

   ii) Give the expression for work done during the following reversible expansion processes, isothermal and adiabatic. (5)

2. Air enters a compressor at 10^5Pa and 25°C having volume of 1.8m^3/kg and it compressed to 5x10^5 Pa isothermally, determine

   i) Work done

   ii) Change in internal energy

   iii) Heat supplied.

3. A unit mass of Nitrogen gas undergoes an expansion process as per the relation $P = aV+bV^2$ where a =1. 1bar/m^3 and b is a constant (bar/m^6), from an initial pressure of 15 bar and temperature 100°C to a final volume of 100 liters. Calculate the displacement work done by the gas and also the heat exchange with the surroundings if the container walls are not insulated. Given Specific heat at constant volume as 0.7kJ/kgK.

4. 85kJ of heat is supplied to a system at constant volume. The system rejects 90kJ of heat at constant pressure and 20kJ of work is done on it. The system is brought to its original state by an adiabatic process. Determine also the value of internal energy at all end states if initial value is 100kJ. (13)

5. One kg of air is expanded at a constant pressure of 2.5 bar from a volume of 0.3m^3 to a volume of 0.45m^3 Find (1) external work done by the gas; (ii) internal energy of the gas; and (iii) heat transferred during the process.

ASSIGNMENT – 2

1. i) Explain the process involved in Carnot cycle with neat P-V and T-S diagram and obtain an expression for Carnot efficiency.
   ii) 10 Kg metal piece with constant specific heat of 0.9 kJ/kg-K at 200°C is dropped into an insulated tank which contains 100 kg of water at 20°C. Determine the final equilibrium temperature and the total changes in entropy for the process.

2. i) Show that heat transfer through a finite temperature difference is irreversible. (6)
   (ii) Which is the more effective way to increase the efficiency of a Carnot engine: to increase T_1 keeping T_2 constant: or to decrease T_2, keeping T_1 constant? (7)

3. A fish freezing plant requires 50 tons of refrigeration. The freezing temperature is -10^0 C while the temperature is 35^0 C. If the performance of the plant is 15% of the theoretical reversed Carnot cycle working within the same temperature limits, calculate the power required. Take 1 ton = 210 kJ/min. (13)

4. A rigid cylinder containing 0.006m^3 of nitrogen (molecular weight 28) at 1.04 bar, 15^0 C is heated reversibly until the temperature is 90^0 C. Calculate the change of entropy and the heat supplied. Sketch the process on the T-S diagram. Take the isentropic index, γ, for nitrogen as 1.4, and assume that nitrogen is a perfect gas. (13)

5. A reversible heat engine operates between two reservoirs at temperatures of 600°C and 40°C. The engine drives a reversible refrigerator which operates between reservoirs at temperatures of 40°C and -20°C. The heat transfer to the heat engine is 2000 kJ and the network output for the combined engine v refrigerator is 360 kJ. (i) Calculate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40°C. (ii) Reconsider (i) given that the efficiency of the heat engine and the C.O.P. of the refrigerator are each 40 per cent of their maximum possible values

ASSIGNMENT – 3

1. 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 the compression ratio is 15. The amounts of heat added at constant volume and at constant pressure are equal. Compute the air standard thermal efficiency of the cycle. Take 7 = 1.4 for air. (13)

2. What is an Otto cycle? Show that the efficiency of the Otto cycle depends only on the compression ratio. (7)
   (ii) Derive an expression of optimum pressure ratio for maximum network output in an ideal corresponding cycle efficiency?

3. (i) A gas-turbine power plant operating on an ideal Brayton cycle has a pressure ratio of 8. The gas temperature is 300 K at the compressor inlet and 1300 K at the turbine inlet. Utilizing the air-standard assumptions, determine
   (1) the gas temperature at the exits of the compressor and the turbine
   (2) the back work ratio, and
   (3) the thermal efficiency.

4. An engine working on the Otto cycle is supplied with air at 0.1 Mpa, 35°C. The compression ratio is 10. Heat supplied is 2400 kJ/kg. Calculate the maximum pressure and temperature of the cycle, the cycle efficiency and the mean effective pressure. (Take for air Cp = 1,005 kJ/kgK, Cv = 0.718 kJ/kg and R = 0.287 kJ/kg K).

5. An air-standard Diesel cycle has a compression ratio of 18, and the heat transferred to the working fluid per cycle is 1800 kJ/kg. At the beginning of the compression stroke, the pressure is I bar and the temperature is 300 K. Calculate: (i) Thermal efficiency, (ii) The mean effective pressure.

ASSIGNMENT – 4

1. Steam is initially at 1.5 MPa, 300°C expands reversibly and adiabatically in a steam turbine to 40°C. Determine the ideal work output of the turbine per kg of steam. Sketch the process in T-s and h-s diagrams. (13)

2. A rigid tank of 0.03 m3 volume contains a mixture of liquid water and water vapor at 80 kPa. The mass of the mixture in the tank is 12 kg. Calculate the heat added and quality of the mixture when the pressure inside the tank is raised to 7 MPa.

3. i) Describe a simple ideal Rankine cycle with a schematic diagram. Explain the processes involved by T-s diagram. (6)
   (ii) A Steam power plant operates between a boiler pressure of 4 MPa and 300°C and a condenser pressure of 50 kPa. Determine the thermal efficiency of the cycle assuming the cycle to be a simple ideal Rankine cycle.

4. i) A pressure cooker contains 1.5 kg of steam at 5 bar and 0.9 dryness when the gas was switched off. Determine the quantity of heat rejected by the 'pressure cooker when the pressure in the cooker falls to 1 bar. (7)
   (ii) Steam at 19 bar is throttled to 1 bar and the temperature after throttling is found to be 150°C. Calculate the initial dryness fraction of the steam.

5. A steam power station uses the following cycle:
   Steam at boiler outlet – 150 bar, 550°C
   Reheat at 40 bar to 550°C
   Condenser at 0.1 bar.
   Using the Mollier chart and assuming ideal processes, find the
   i) quality at turbine exhaust, (4)
   ii) cycle efficiency, and (4)
   iii) steam rate. (5)

ASSIGNMENT – 5

1. Air enters a compressor operating at steady state at a pressure of 1 bar, a temperature of 290 K and a velocity of 6 m/s through an inlet with an area of 0.1 m2. At the exit, the pressure is 8 bar, the temperature is 450 K and the velocity is 2 m/s. Heat transfer from the compressor to the surroundings occurs at the rate of 180 kJ/min. Employing the ideal gas model, calculate the power input to the compressor. (7)

2. A reactor's wall 320 mm thick is made tip of an inner layer of firebrick (k = 0.84 W/m°C) covered with a layer of insulation (k = 0.16 W/m°C). The reactor operates at a temperature of 1325°C and the ambient temperature is 25°C. (i) Determine the thickness of firebrick and insulation which gives minimum heat loss, and (ii) Calculate the heat loss presuming that the insulating material has a maximum temperature of 1200°C. (13)

3. State Planck's laws of radiation and prove that the value of Stefan-Boltzmann constant is 5.67 x 10^8 W/m^2-K^4.

4. An aircraft flies at 90 km/hr. One of its turbojet engines takes in 40 kg/s of air and expands the gases to the ambient pressure. The air-fuel ratio is 50 and the lower calorific value of the fuel is 43 MJ/kg. For maximum thrust power, determine: jet velocity, thrust, specific thrust, thrust power, propulsive and thermal efficiencies. (13)

5. A room is maintained at 27°C while the surroundings are at 2°C. the temperature of the inner and outer surfaces of the wall (k = 0.71 W/mK) are measured to be 21°C and 6°C respectively. Heat flows steadily through the wall 5 m x 7 m in cross-section and 0.32 m in thickness. Determine (i) the rate of heat transfer through the wall, (ii) the rate of entropy generation in the wall, and (iii) the rate of total entropy generation with this heat transfer process.

QUESTION BANK

Subject Code & Name: AE3351 – AERO ENGINEERING THERMODYNAMICS

Year / Sem : II / III

UNIT I – FUNDAMENTAL CONCEPT AND FIRST LAW			
Q. No	**Question**	**BT Level**	**Competence**
PART – A			
1.	Bring out the differences between microscopic and macroscopic modes in thermodynamic studies	L2	Understanding
2.	What is the difference between a nozzle flow and a throttle process?	L2	Understanding
3.	How the properties are classified?	L1	Remembering
4.	What is meant by quasi-equilibrium process?	L1	Remembering
5.	State the conditions for thermodynamic equilibrium of a system.	L1	Remembering
6.	Differentiate between intensive and extensive properties.	L1	Remembering
7.	A mixture of gasses expands from 0.03 m^3 to 0.06 m^3 at a constant pressure of 1 MPa and absorbs 84 KJ of heat during the process. Find the change of the internal energy of the mixture.	L2	Understanding
8.	Define insulated system.	L1	Remembering
9.	Define Polytropic process.	L1	Remembering
10.	Define the Perpetual Motion Machine of the first kind.	L1	Remembering
11.	What is the difference between working substance and pure substance?	L1	Remembering
12.	State the principle of thermometry How it is used for the measurement of temperatures?	L1	Remembering
13.	What are the differences between the boundaries of a closed system and a control volume?	L1	Remembering
14.	Temperature measurement is based on which law of thermodynamics? State the law.	L1	Remembering
15.	Differentiate the sensible energy and latent energy.	L1	Remembering
16.	What are the deficiencies of first law of thermodynamics?	L2	Understanding
17.	Discuss briefly about thermodynamic system and its types?	L1	Remembering
18.	Define Continuum?	L1	Remembering
19.	What is system and surrounding?	L1	Remembering
20.	Distinguish between the Open and Closed system?	L1	Remembering
21.	Define Isolated system?	L1	Remembering
22.	Define properties of the system?	L1	Remembering
23.	What is the change of state of a system?	L1	Remembering
24.	Distinguish between the Homogeneous and Heterogeneous system?	L1	Remembering
25.	What is a point function and path functions? Give examples.	L2	Understanding
26.	What is meant by a diathermic wall?	L2	Understanding
27.	Define Specific heat and Latent Heat?	L2	Understanding
28.	State First Law of thermodynamics.	L1	Remembering

PART – B			
1.	(i) A piston-cylinder containing air expands at a constant pressure of 150 kPa from a temperature of 285 K to a temperature of 550 K. The mass of air in the cylinder is 0.05 kg. Determine the system heat and work for the process as well as the net work available if the surrounding pressure acting on the piston is 101.3 kPa. (8) (ii) Explain in detail about the types of thermodynamic equilibrium. (5)	L3	Apply
2.	(i) In a remote area, water is to be supplied from underground water source, whose free surface is 100 m below ground level, using a water pump. This water is to be stored in a water tank at a height of 10 m from the ground level. This pump is connected with an inlet pipe of diameter 20 cm and outlet pipe of diameter 30 cm. Determine the power input to this pump for steady water supply of 20 I/s. Assume no heat interaction during this process. (8) (ii) State Zeroth law of thermodynamics and demonstrate it with neat illustration. (5)	L3	Apply
3.	i) One kg of air is expanded in piston-cylinder system from a specific volume of v = 0.2 m^3/kg and temperature of 580 K to a specific volume of v = 0.8 m^3/kg and a temperature of 290 K. The expansion process is given by $pv^{1.5} = 0.75$ (p in bar and v in m^3/kg). Determine the work and heat interaction. (8) ii) Give the expression for work done during the following reversible expansion processes, isothermal and adiabatic. (5)	L3	Apply
4.	i) An adiabatic air compressor compresses 10 lit/s of air at 120 KPa and 20°C to 1000 KPa and 300°C.. Determine the work required by the compressor in kJ/kg, and the power required to drive the air compressor in kW. (8) ii) Nitrogen gas flows into a convergent nozzle at 200 kPa, 400 K and very low velocity. It flows out of the nozzle at 100 kPa, 330 K. If the nozzle is insulated, find the exit velocity. (5)	L3	Apply
5.	In an air compressor air flows steadily at the rate of 0.5 kg/s through an air compressor. It enters the compressor at 6 m/s with a pressure of 1 bar and a specific volume of 0.85 m^3/kg and leaves at 5 m/s with a pressure of 7 bar and a specific volume of 0.16 m^3/kg. The internal energy of the air leaving is 90 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 60 kJ/s. Calculate (i) The power required to drive the compressor. (8) (ii) The inlet and output pipe cross-sectional areas. (5)	L3	Apply
6.	(i) The following data refer to a 12-cylinder single acting and two stroke marine diesel engine: Speed 150 rpm, cylinder diameter = 0.8 m, stroke of the piston = 1.2 m. area of the indicator diagram 5.5 x 104 m^2, length of the diagram 0.06 m. Spring value = 147 MPa per m. Find the net rate of work transfer from the gas to the piston in kW. (8) (ii) Make a comparison between heat and work. (5)	L3	Apply
7.	State the first law of thermodynamics and prove that for a non flow process, it leads to the energy equation $Q = \Delta U + W$	L2	Understanding
8.	Air enters a compressor at 10^5Pa and 25°C having volume of 1.8m^3/kg and it compressed to $5x10^5$ Pa isothermally, determine	L3	Apply

	i) Work done ii) Change in internal energy iii) Heat supplied.		
9.	A closed system undergoes a cycle consisting of two processes. During the first process 40 kJ of heat is transferred to the system while the system does 60 kJ of work. During the second process, 40 kJ of work is done on the system. Determine the heat transfer during the process and network and heat transfer for the cycle.	L3	Apply
10.	What are steady flow engineering devices? Obtain steady flow energy equation for these devices.	L2	Understanding
11.	A highly elastic ball released from rest from an initial height of z_o m, bounces a large number of times on a rigid horizontal surface before coming to rest such that the height attained after each bounce is 'φ' times the height before the bounce (φ<1). The surface of the plane is adiabatic and the ball is made of a diathermic material with mass 'm' and specific heat 'c'. Derive an expression for the temperature rise "ΔT" of the ball after "X" number of bounces.	L3	Apply
12.	A unit mass of Nitrogen gas undergoes an expansion process as per the relation $P = aV+bV^2$ where a =1. 1bar/m³ and b is a constant (bar/m^6), from an initial pressure of 15 bar and temperature 100°C to a final volume of 100 liters. Calculate the displacement work done by the gas and also the heat exchange with the surroundings if the container walls are not insulated. Given Specific heat at constant volume as 0.7kJ/kgK.	L3	Apply
13.	(i) In a gas turbine the gas enters at the rate of 5 kg/s with a velocity of 50 m/s and enthalpy of 900 kJ/kg leaves the turbine with a velocity of 150 m/s and enthalpy of 400 kJ/kg. The loss of heat from the gases to the surroundings is 25 kJ/kg. Assume for gas R = 0.285 kJ/kgK and Cp = 1.004 kJ/kgK and inlet conditions to be at 100 kPa and 27°C. Determine the power output of the turbine. (8) (ii) Air at 500 kPa is expanded to 100 kPa in two steady flow cases. Case one is a nozzle and case two is a turbine, the exit state is the same for both cases. What can you say about the specific turbine work relative to the specific kinetic energy in the exit flow of the nozzle?	L3	Apply
14.	(i) A piston cylinder contains 0.1 kg nitrogen at 100 kPa, 27°C and it is now compressed in a polytropic process with n = 1.25 to a pressure of 250 kPa. Find the heat transfer. (8) (ii) A piston cylinder contains 0.5 kg air at 500 kPa, 500 K. The air expands in a process so P is linearly decreasing with volume to a final state of 100 kPa, 300 K. Find the work in the process. (5)	L3	Apply
	Explain the adiabatic process. Derive an expression for the work done during the adiabatic compression and expansion of an ideal gas.	L2	Understanding
15.	A system contains 0.15 m^3 of a gas at a pressure of 3.8 bar and 150°C. It is expanded adiabatically till the pressure falls to 1 bar. The gas is then heated at a constant pressure till its enthalpy increases by 70 kJ. Determine the work done. Take Cp = 1 kJ/kg K and Cv = 0.714 kJ/kg K.	L3	Apply
16.	i) A fluid at a pressure of 3 bar and with specific volume of 0.18 m^3/kg, contained in a cylinder behind a piston expands reversibly to a	L3	Apply

	pressure of 0.6 bar according to a law, $P = C/v^2$ where C is a constant. Calculate the work done by the fluid on the piston. (7) ii) Derive the expression for work done by an adiabatic expansion process and state the relationship between P-V-T for an adiabatic process. (6)		
17.	Air at a temperature of 20°C passes through a heat exchanger at a velocity of 40 m/s where its temperature is raised to 820°C. It then enters a turbine with same velocity of 40 m/s and expands till the temperature falls to 620°C. On leaving the turbine, the air is taken at a velocity of 55 m/s to a nozzle where it expands until the temperature has fallen to 510°C. If the air flow rate is 2.5 kg/s, calculate: i) Rate of heat transfer to the air in the heat exchanger (4) ii) The power output from the turbine, assuming no heat loss (4) iii) The velocity at exit from the nozzle, assuming no heat loss. (5)	L3	Apply
18.	85kJ of heat is supplied to a system at constant volume. The system rejects 90kJ of heat at constant pressure and 20kJ of work is done on it. The system is brought to its original state by an adiabatic process. Determine also the value of internal energy at all end states if initial value is 100kJ. (13)	L3	Apply
19.	One kg of air is expanded at a constant pressure of 2.5 bar from a volume of $0.3m^3$ to a volume of $0.45m^3$ Find (1) external work done by the gas; (ii) internal energy of the gas; and (iii) heat transferred during the process.	L3	Apply
20.	0.016 m^3 gas at constant pressure 2055kN $/m^3$ expands to a pressure of 215kN $/m^2$ by following the law $pv^{1.35} = C$ Determine the work done by the gas during expansion process.	L3	Apply
PART – C			
1.	(i) Air expands through a turbine from 500 kPa, 520˚C to 100 kPa, 300˚C. During expansion 10 kJ/kg-K of heat is lost to the surroundings which is at 98 kPa, 20˚C. Neglecting the K.E and P.E changes, determine per kg of air (1) the decrease in availability, (2) the maximum work and (3) the irreversibility. (8) (ii) Air enters a compressor operating at steady state at a pressure of 1 bar, a temperature of 290 K and a velocity of 6 m/s through an inlet with an area of 0.1 m^2. At the exit, the pressure is 8 bar, the temperature is 450 K and the velocity is 2 m/s. Heat transfer from the compressor to the surroundings occurs at the rate of 180 kJ/min. Employing the ideal gas model, calculate the power input to the compressor. (7)	L3	Apply
2.	A quantity of gas occupies a volume of 0.4 m^3 at a pressure of 100 kN/m^2 and a temperature of 20°C. The gas is compressed isothermally to a pressure 450 kN/m^2 and then expanded adiabatically to its initial volume. Determine, for this quantity of gas : i) The heat transferred during the compression, (5) ii) The change of internal energy during the expansion, (5) iii) The mass of gas. (5)	L3	Apply

UNIT II – SECOND LAW AND ENTROPY			
Q. No	**Question**	**BT Level**	**Competence**
PART – A			
1.	Compare two heat engines receiving the same Q, one at 1200 K and the other at 1800 K, they both reject heat at 500 K. Which one is better?	L2	Understanding
2.	What is meant by Clausius inequality?	L2	Understanding
3.	Define reversibilities.	L1	Remembering
4.	State Clausius inequality for a cyclic process.	L1	Remembering
5.	Give some examples of ideal reversible processes.	L2	Understanding
6.	Summarize the characteristics of entropy.	L1	Remembering
7.	What are PMM1 and PMM2?	L1	Remembering
8.	What is heat pump?	L2	Understanding
9.	Define ‘Entropy’	L1	Remembering
10.	Write Clausius statement of Second Law of Thermodynamics?	L1	Remembering
11.	State Kelvin-Plank statement.	L1	Remembering
12.	State thermodynamic advantage of heat pump over direct heating?	L1	Remembering
13.	State the Carnot’s theorem.	L1	Remembering
14.	State the second law of thermodynamics.	L1	Remembering
15.	Why is an isentropic process not necessarily an adiabatic process?	L2	Understanding
16.	A refrigerator removes 1.5 kJ from the cold space using 1 kJ work input. How much energy goes into the kitchen and what is its coefficient of performance?	L2	Understanding
17.	Assume a heat engine with a given Q_H. Can you say anything about Q_L if the engine is reversible? And if it is irreversible?	L2	Understanding
18.	What is a thermal energy reservoir? Give some examples	L2	Understanding
19.	What is meant by the increase of entropy principle?	L2	Understanding
20.	What do you understand by the entropy principle?	L2	Understanding
21.	What is meant by availability?	L2	Understanding
22.	What is the difference between a refrigerator and a heat pump?	L2	Understanding
23.	What are the assumptions made on heat engines?	L2	Understanding
24.	What is meant by reversible process?	L2	Understanding
25.	What is meant by irreversible process?	L2	Understanding
26.	How do you distinguish between internal and external irreversibility’s?	L2	Understanding
27.	Show that the COP of a heat pump is greater than the COP of a refrigerator by unity.	L2	Understanding
28.	What is absolute entropy?	L2	Understanding
29.	Summarize the characteristics of entropy?	L2	Understanding
30.	Explain the term source and sink?	L2	Understanding

31.	Assume a heat engine with a given QH. Can you say anything about QL.? If the engine is reversible? And if it's irreversible?	L2	Understanding
32.	When a substance has completed a cycle v, u, h and s are unchanged. Did anything happen'? Explain	L2	Understanding
	PART – B		
1.	(i) What is a Carnot cycle? Describe the processes involved in a Carnot cycle using P-v and T-s diagrams. Derive an expression for its thermal efficiency. (7) (ii) Demonstrate the equivalence of Kelvin-Planck and Clausius statement. (6)	L3	Apply
2.	A quantity of air undergoes a thermodynamic cycle consisting of three processes. Process 1-2: constant volume heating from p_1 = 0.1 MPa, T1 = 16°C, V_1 = 0.02 m^3 to p_2 = 0.42 MPa.; Process 2-3: Constant pressure cooling. Process 3-1: Isothermal heating to initial state. Employing the ideal gas model with Cp = 1.05 kJ/kgK, evaluate the change of entropy for each process. Sketch the cycle on P-v and T-s coordinates. (13)	L3	Apply
3.	A Carnot heat engine receives heat from a reservoir at900°C at a rate of 15 kW and rejects the waste heat to the ambient air at 25°C. The entire work output of the heat engine is used to drive a refrigerator that removes heat from the refrigerated space at 10°C and transfers it to the same ambient air at 25°C. Determine the maximum rate of heat removal from the refrigerated space. (8) ii) With necessary sketches, demonstrate the equivalence of the Clausius and Kelvin-Planck statements of the second law. (5)	L3	Apply
4.	i) Show that thermal efficiency of an irreversible power cycle is always less than the thermal efficiency of a reversible power cycle when each operates between the same two thermal reservoirs. (7) ii) 2kg of water at 80°C is mixed adiabatically with 3 kg of water at 30°C in a constant pressure process of 1 atm. Find the increase in entropy of the total mass of water due to the mixing process. (Take Cp of water = 4.187 kJ/kgK). (6)	L3	Apply
5.	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 the temperature is 77°C. The heat pump derives power for its operation from a reversible engine operating within the higher and lower temperature of 1077°C. For 100 kJ/kg of energy supplied to the reservoir at 77°C. Estimate the energy taken from the reservoir at 1077°C. (13)	L3	Apply
6.	Air is flowing steadily in an insulated duct. The pressure and temperature measurement of the air at two stations A and B are given below. Property Station A Station B Pressure 130 kPa 100 kPa Temperature 50°C 13°C Establish the direction of flow air in the duct. Assume for air Cp = 1.005 kJ/kg.K, h = CpT and v/T= 0.287/p, where p, v and T are pressure (in kPa), volume (in m^3/kg) and temperature (in K) respectively.	L3	Apply
7.	The minimum power required to drive a heat pump which maintains a house at 20°C is 3 kW. If the outside temperature is 3°C, estimate the	L3	Apply

	amount of heat which, the house loses heat per minute.		
8.	i) Explain the process involved in Carnot cycle with neat P-V and T-S diagram and obtain an expression for Carnot efficiency. ii) 10 Kg metal piece with constant specific heat of 0.9 kJ/kg-K at 200°C is dropped into an insulated tank which contains 100 kg of water at 20°C. Determine the final equilibrium temperature and the total changes in entropy for the process.	L3	Apply
9.	Define heat engine and heat pump. Explain why the performance of heat engine is measured in terms of efficiency but that of heat pumps in terms of COP.	L3	Apply
10.	In an air turbine the air expands from 7 bar and 460°C to 1.012 bar and 160°C. The heat loss from the turbine can be assumed to be negligible. i) Show that the process is irreversible; ii) Calculate the change of entropy per kg of air.	L3	Apply
11.	Prove that the Kelvin Planck Statement of Second law of thermodynamics is equivalent to the Clausius statement.	L3	Apply
12.	A 50-kg block of iron block at a temperature of 500 K is cooled by dipping in a pool of water at a temperature of 285 K. The iron block eventually reaches thermal equilibrium with the pool water. Assuming an average specific heat of 0.45 kJ/kgK for the iron, determine (i) the entropy change of the iron block, (ii) the entropy change of the pool water, and (iii) the entropy generated during this process.	L3	Apply
13.	(i) An inventor claims to have developed an engine that takes in 105 MJ at a temperature of 400 K, rejects heat at a temperature of 200 K, and delivers 17.5 kWh of mechanical work: Would you advise investing money to put this engine in market? (8 (ii) Prove that the violation of Kelvin-Planck's statement violates the Clausius statement.	L3	Apply
14.	(i) Show that heat transfer through a finite temperature difference is irreversible. (6) (ii) Which is the more effective way to increase the efficiency of a Carnot engine: to increase T_1 keeping T_2 constant: or to decrease T_2, keeping T_1 constant? (7)	L3	Apply
15.	A fluid undergoes a reversible adiabatic compression from 4 bar, 0.3 m^3 to 0.08 m^3 according to the law, $pv^{1.25}$= constant. Determine: (i) Change in enthalpy and change in internal energy (ii) Change in entropy and Heat transfer (iii) Work transfer. (6+5+2)	L3	Apply
16.	i) Two Carnot engines work in series between the sources and sink temperatures of 550 K and 350 K. If both engines develop equal power determine the intermediate temperature. (6) ii) The specific heats of a gas vary linearly with absolute temperature according to the following relations: Cp = (0.85 + 0.00025 T) kJ/kg K, and Cv = (0.56 + 0.00025 T) kJ/kg K If the entropy of the gas at 1 bar pressure and 273 K is zero, find the entropy of the gas at 25 bar and 750 K temperature. (7)	L3	Apply
17.	A system has a capacity at constant volume Cv = AT^2 where A=	L3	Apply

	0.042 J/K^3. The system is originally at 200 K and a thermal reservoir at 100 K is available. What is the maximum amount of work that can be recovered as the system is cooled down to the temperature of the reservoir?		
18.	A fish freezing plant requires 50 tons of refrigeration. The freezing temperature is -10^0 C while the temperature is 35^0 C. If the performance of the plant is 15% of the theoretical reversed Carnot cycle working within the same temperature limits, calculate the power required. Take 1 ton = 210 kJ/min. (13)	L3	Apply
19.	A rigid cylinder containing 0.006m^3 of nitrogen (molecular weight 28) at 1.04 bar, 15^0 C is heated reversibly until the temperature is 90^0 C. Calculate the change of entropy and the heat supplied. Sketch the process on the T-S diagram. Take the isentropic index, γ, for nitrogen as 1.4, and assume that nitrogen is a perfect gas. (13)	L3	Apply
PART – C			
1.	A reversible heat engine in a satellite operates between a hot reservoir at T_1, and a radiating panel at T_2. Radiation from the panel is proportional to its area and T_2^4. i) For a given work output and value of T, show that the area of the panel T_2/T_1=0.75. T will be minimum when ii) Determine the minimum' area of the panel for an output of 1 kW if the constant of proportionality is 5.67x10^{-8} W/m²-K^4 and T_1, is 1000 K. (10+5)	L3	Apply
2.	Consider a compressor with air at 1 bar and 15°C compressing (a) isothermally to 27.59 bar, and (b) polytropically, the index being 1.3 to the same pressure. Compare the work done, heat exchange with the surroundings, the final temperature and the change in internal energy and entropy due to the compression per unit mass of air.	L3	Apply
3.	(i) Air expands through a turbine from 500 kPa, 520˚C to 100 kPa, 300˚C. During expansion 10 kJ/kg-K of heat is lost to the surroundings which is at 98 kPa, 20˚C. Neglecting the K.E and P.E changes, determine per kg of air (1) the decrease in availability, (2) the maximum work and (3) the irreversibility. (8) (ii) Air enters a compressor operating at steady state at a pressure of 1 bar, a temperature of 290 K and a velocity of 6 m/s through an inlet with an area of 0.1 m^2. At the exit, the pressure is 8 bar, the temperature is 450 K and the velocity is 2 m/s. Heat transfer from the compressor to the surroundings occurs at the rate of 180 kJ/min. Employing the ideal gas model, calculate the power input to the compressor. (7)	L3	Apply
4.	A reversible heat engine operates between two reservoirs at temperatures of 600°C and 40°C. The engine drives a reversible refrigerator which operates between reservoirs at temperatures of 40°C and -20°C. The heat transfer to the heat engine is 2000 kJ and the network output for the combined engine v refrigerator is 360 kJ. (i) Calculate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40°C. (ii) Reconsider (i) given that the efficiency of the heat engine and the C.O.P. of the refrigerator are	L3	Apply

	each 40 per cent of their maximum possible values.		

UNIT III – AIR STANDARD CYCLES

Q. No	Question	BT Level	Competence
PART – A			
1.	For a given compression ratio does an Otto cycle have higher or lower efficiency than a diesel cycle? Explain your answer.	L2	Understanding
2.	What is meant by detonation?	L2	Understanding
3.	State the assumptions that are made in the analysis of air standard cycles.	L1	Remembering
4.	What is meant by mean effective pressure?	L1	Remembering
5.	Draw the P-v and T-s diagram of otto cycle.	L1	Remembering
6.	Identify the processes in the Stirling cycle.	L1	Remembering
7.	Distinguish between Otto and Diesel cycle.	L1	Remembering
8.	Define dead state	L2	Understanding
9.	What is first law efficiency?	L2	Understanding
10.	State the four process of Diesel cycle.	L1	Remembering
11.	An ideal Bryton cycle operating between the pressure limits of 1 bar and 6 bar, minimum and maximum temperature of 300 K and 1500 K. The ratio of specific heat of the working fluid is 1.4. Find the approximate final temperature in Kelvin at the end of the expansion process.	L2	Understanding
12.	What are the assumptions in air standard cycle?	L1	Remembering
13.	Distinguish between Exergy and Irreversibility.	L1	Remembering
14.	Determine the entropy change for a reversible isochoric process.	L2	Understanding
15.	Why do you say the entropy of the universe is always increasing?	L1	Remembering
16.	Define work ratio of a gas turbine.	L1	Remembering
17.	What is the cutoff ratio? How does it affect the thermal efficiency of a Diesel cycle?	L1	Remembering
18.	Define the compression ratio for reciprocating engines.	L1	Remembering
19.	Define air standard efficiency.	L1	Remembering
20.	Draw the P-v and T-s diagram of Brayton cycle.	L1	Remembering
21.	What four processes make up the ideal Otto cycle?	L1	Remembering
22.	What is back-work ratio?	L1	Remembering
23.	Write the effect of compression ratio on engine thermal efficiency of an otto cycle with a suitable graph?	L2	Understanding
24.	What is the difference between spark-ignition and compression-ignition engines?	L2	Understanding
25.	Define Regeneration?	L1	Remembering
26.	Define Reheat?	L1	Remembering
27.	Define Intercooling?	L1	Remembering
PART – B			
1.	(i) An ideal Otto cycle has compression ratio of 8. At the beginning of the compression process, air is at 100 kPa and 17°C, and 800	L3	Apply

	kJ/kg of heat is transferred to air the constant volume heat addition process. Assuming cold air standard assumption, determine (1) the maximum pressure and temperature that occur during the cycle, (2) the net work done, (3) thermal efficiency and (4) mean effective pressure for the cycle. (8) ii) Show that the thermal efficiency of Brayton cycle depends only on the pressure ratio. Also draw its P-v and T-s diagram. (5)		
2.	With a neat P–v and T–s diagram, explain the various processes involved in Dual cycle and also derive an expression for the efficiency of dual cycles. (13)	L2	Understanding
3.	An ideal Diesel cycle with air as the working fluid has a compression ratio of 18 and a cut-off ratio of 2. At the beginning of compression process, the working fluid is at 100 KPa, 27°C and 1917 cm^3. Determine: a) the temperature and pressure of air at the end of each process b) network output c) thermal efficiency and d) the mean effective pressure.	L3	Apply
4.	An air standard dual cycle has a compression ratio of 16 and compression begins at 1 bar, 50°C. The maximum pressure is 70 bar. The heat transferred to air at constant pressure is equal to that at constant volume. Estimate: a) the pressures and temperatures at the cardinal points of the cycle, b) the cycle efficiency and c) the MEP of the cycle. Take Cv = 0.718 kJ/kg K and Cp = 1.005 KJ/kg K.	L3	Apply
5.	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 the compression ratio is 15. The amounts of heat added at constant volume and at constant pressure are equal. Compute the air standard thermal efficiency of the cycle. Take 7 = 1.4 for air. (13)	L3	Apply
6.	Air enters the compressor of a gas turbine plant operating on Brayton cycle at 101.325 kPa, 27°C. The pressure ratio in the cycle is 6. Calculate the maximum temperature in the cycle and the cycle efficiency. Assume W_T =2.5 W_C where W_T and W_C are the turbine and the compressor work respectively. Take γ= 1.4.	L3	Apply
7.	Derive the expression for irreversibility or energy loss in a process executed by (i) a closed system and (ii) a steady flow system, in a given environment.	L2	Understanding
8.	What is an Otto cycle? Show that the efficiency of the Otto cycle depends only on the compression ratio. (7) (ii) Derive an expression of optimum pressure ratio for maximum network output in an ideal corresponding cycle efficiency?	L2	Understanding
9.	(i) A diesel engine has air before compression at 280 K, 85 kPa. The highest temperature and highest pressure is 2200 K and 6 MPa respectively. Find the volumetric compression ratio and the mean	L3	Apply

	effective pressure using cold air properties at 300 K.(8) (ii) An air-standard Ericsson cycle has an ideal regenerator. Heat is supplied at 1000°C and heat is rejected at 80°C. Pressure at the beginning of the isothermal compression process is 70 kPa. The heat added is 700 kJ/kg. Find the compressor work, the turbine work, and the cycle efficiency.		
10.	(i) A gas-turbine power plant operating on an ideal Brayton cycle has a pressure ratio of 8. The gas temperature is 300 K at the compressor inlet and 1300 K at the turbine inlet. Utilizing the air-standard assumptions, determine (1) the gas temperature at the exits of the compressor and the turbine (2) the back work ratio, and (3) the thermal efficiency.	L3	Apply
11.	Calculate the decrease in available energy when 25 kg of water at 95°C mix with 35 kg of water at 35°C, the pressure being taken as constant and the temperature of the surroundings being 15°C Cp of water is 4.8 kJ/kg K.	L3	Apply
12.	(i) Show that the efficiency of the Brayton cycle depends only on the pressure ratio. (7) (ii) What is a compression ignition engine? Why is the compression ratio of such an engine more than that of an SI engine? (6)	L2	Understanding
13.	Two kg of air at 500 kPa, 80°C expands adiabatically in a closed system until its volume is doubled and its temperature becomes equal to that of the surroundings which is at 100 kPa, 50°C. For this process, determine: i) the maximum work, (4) ii) the change in availability, and (4) iii) the irreversibility. (5)	L3	Apply
14.	The compression ratio for a single-cylinder engine operating on dual cycle is 9. The maximum pressure in the cylinder is limited to 60 bar. The pressure and temperature of the air at the beginning of the cycle are 1 bar and 30°C. Heat is added during constant pressure process upto 4 percent of the stroke. Assuming the cylinder diameter and stroke length as 250 mm and 300 mm respectively, determine : i) The air standard efficiency of the cycle ii) The power developed if the number of working cycles is 3 per second. Take for air Cv = 0.71 kJ/kg K and Cp = 1.0. kJ/kg K.	L3	Apply
15.	An ideal cycle using air as the working fluid has a compression ratio of 18 and cut off ratio of 3. The intake conditions are 150 Kpa, 25°C and 2500 cm^3. Determine: (i) The net work output. (6) (ii) Thermal efficiency of cycle. (6) (iii) The mean effective pressure. (4)	L3	Apply
16.	An engine working on the Otto cycle is supplied with air at 0.1 Mpa, 35°C. The compression ratio is 10. Heat supplied is 2400 kJ/kg. Calculate the maximum pressure and temperature of the cycle, the cycle efficiency and the mean effective pressure. (Take for air Cp = 1,005 kJ/kg K, Cv = 0.718 kJ/kg and R = 0.287 kJ/kg K).	L3	Apply
17.	1 kg of ice at 0°C is mixed with 10 kg of water at 30°C. Determine the net increase in the entropy and unavailable energy when the	L3	Apply

	system reaches common temperature. Assume that surrounding temperature is 10°C. Take, specific heat of water 4.18 kJ/kg K specific heat of ice = 2.1 kJ/kg K; latent heat of ice 333.5 kJ/kg. (13)		
18.	An air-standard Diesel cycle has a compression ratio of 18, and the heat transferred to the working fluid per cycle is 1800 kJ/kg. At the beginning of the compression stroke, the pressure is I bar and the temperature is 300 K. Calculate: (i) Thermal efficiency, (ii) The mean effective pressure.	L3	Apply
19.	36g of air in a piston–cylinder assembly undergo a Stirling cycle with a compression ratio of 6. At the beginning of the isothermal compression, the pressure and volume are 1 bar and 0.03 m^3, respectively. The temperature during the isothermal expansion is 1000 K. Assuming the ideal gas model and ignoring kinetic and potential energy effects, determine (a) The net work, in kJ. (b) The thermal efficiency. (c) The mean effective pressure, in bar	L3	Apply
20.	An air standard Ericsson cycle has an ideal regenerator. Heat is supplied at 1000^0 C and heat is rejected at 80^0 C. Pressure at the beginning of the isothermal compression process is 70kPa. The heat added is 700 kJ/kg. Find the compression work, the turbine work, back work ratio and the cycle efficiency.	L3	Apply
PART – C			
1.	With your understanding, analyse why piston engine is not able to replace jet engines used in large and high-speed aircrafts. (15)	L2	Understanding
2.	At the beginning of the compression process of an air-standard dual cycle with a compression ratio of 18, the temperature is 300 K and the pressure is 0.1 MPa. The pressure ratio for the constant volume part of the heating process is 1.5:1. The volume ratio for the constant pressure part of the heating process is 1.2:1. Determine : (i) the thermal efficiency and (ii) the mean effective pressure, in MPa.	L3	Apply
3.	In an engine working on Dual cycle, the temperature and pressure at the beginning of the cycle are 90°C and 1 bar respectively. The compression ratio is 9. The maximum pressure is limited to 68 bar and total heat supplied per kg of air is 1750 kJ. Determine: (i) Pressure and temperatures at all salient points (ii) Air standard efficiency (iii) Mean effective pressure	L3	Apply
4.	Air enters the compressor of a cold air-standard Brayton cycle with regeneration, intercooling, and reheat at 100 kPa, 300 K, with a mass flow rate of 6 kg/s. The compressor pressure ratio is 10, and the pressure ratios are the same across each compressor stage. The intercooler and reheater both operate at the same pressure. The temperature at the inlet to the second compressor stage is 300 K, and the inlet temperature for each turbine stage is 1400 K. The compressor and turbine stages each have isentropic efficiencies of 80% and the regenerator effectiveness is 80%. For γ=1.4, calculate (a) The thermal efficiency of the cycle. (b) The back work ratio.	L3	Apply

	(c) The net power developed, in kW.		

UNIT IV – FUNDAMENTALS OF VAPOUR POWER CYCLES

Q. No	Question	BT Level	Competence
	PART – A		
1.	What is meant by sensible heating?	L2	Understanding
2.	Define critical point and triple point.	L1	Remembering
3.	Bring out the differences between Rankine cycle and Carnot cycle.	L1	Remembering
4.	How to improve the thermal efficiency of the Rankine cycle.	L2	Understanding
5.	State the ways to measure the dryness fraction of steam.	L2	Understanding
6.	What do you understand by triple line?	L1	Remembering
7.	Define pure substance.	L1	Remembering
8.	Write the four basic components of steam powerplant.	L1	Remembering
9.	What is meant by specific steam consumption in a Rankine cycle?	L2	Understanding
10.	What are the important parameters that need to be considered in the selection of a refrigerant.	L2	Understanding
11.	Identify the features of a pure substance with examples.	L2	Understanding
12.	What is meant by sublimation? Illustrate with an example.	L2	Understanding
13.	What is a critical point? Show it on T-S diagram	L2	Understanding
14.	Distinguish energy and anergy	L2	Understanding
15.	Define sensible heat of water	L2	Understanding
16.	Give the comparison between the Rankine cycle and Carnot cycle.	L2	Understanding
17.	Draw the schematic and T-S diagram for the open feed water regenerative Rankine cycle.	L2	Understanding
18.	What is the effect of reducing condenser pressure on the turbine in the steam power plant?	L2	Understanding
19.	What is meant by steam rate and heat rate?	L2	Understanding
20.	Define unit of refrigeration.	L2	Understanding
21.	Draw and explain a p-T (pressure-temperature) diagram for a pure substance.	L2	Understanding
22.	State the advantages of regenerative cycle/simple Rankine cycle.	L1	Remembering
	PART – B		
1.	(i) A pressure cooker contains 1.5 kg of saturated steam at 5 bar. Find the quantity of heat which must be rejected so as to reduce the quality to 60 % dry. Determine the pressure and temperature of the steam at the new state, the amount of total heat transferred. (7) (ii) Explain in detail about the formation of superheated steam from –20°C of ice with T-v diagram. Also explain the various processes involved in it. (6)	L3	Apply
2.	Consider a steam power plant operating on the ideal Rankine cycle. Steam enters the turbine at 3 MPa and 350°C and is condensed in the condenser at a pressure of 10 kPa. Determine (i) the thermal efficiency of this power plant, (ii) the thermal efficiency if steam is superheated to 600°C instead of 350°C and (iii) the thermal efficiency if the boiler pressure is raised to 15 MPa	L3	Apply

	while the turbine inlet temperature is maintained at 600°C. (13)		
3.	What is meant by property diagram? With neat sketches, explain the six different types of commonly encountered property diagrams in brief. (13)	L2	Understanding
4.	Steam is the working fluid in an ideal Rankine cycle. Saturated vapor enters the turbine at 8.0 MPa and saturated liquid exits the condenser at a pressure of 0.008 MPa. The net power output of the cycle is 100 MW. Determine for the cycle: a) the thermal efficiency b) the back work ratio c) the mass flow rate of the steam, in kg/h d) the rate of heat transfer, Qin, into the working fluid as it passes through the boiler, in MW e) the rate of heat transfer Qout, from the condensing steam as it passes through the condenser, in MW, if cooling water enters the condenser at 15°C and exits at 35°C. (13)	L3	Apply
5.	An insulated piston-cylinder device contains 5 litres of saturated liquid water at a constant pressure of 150 KPa. An electric resistance heater inside by the cylinder is now turned on and 2200 kJ of energy is transferred to the steam. Determine the entropy change of the water during this process. (10)	L3	Apply
6.	A simple Rankine cycle works between pressures 28 bar and 0.06 bar, the initial condition of steam being dry saturated. Calculate the cycle efficiency, work ratio and specific steam consumption. (13)	L3	Apply
7.	Steam is initially at 1.5 MPa, 300°C expands reversibly and adiabatically in a steam turbine to 40°C. Determine the ideal work output of the turbine per kg of steam. Sketch the process in T-s and h-s diagrams. (13)	L3	Apply
8.	A rigid tank of volume 0.5 m^3 contains 80 percent by volume of saturated liquid water and 20 percent by volume of saturated steam at 200°C. Now 140 kg of liquid water is pumped into the tank. If the final temperature of the fluid in the tank is 80°C, determine the final pressure.	L3	Apply
9.	A rigid tank of 0.03 m3 volume contains a mixture of liquid water and water vapor at 80 kPa. The mass of the mixture in the tank is 12 kg. Calculate the heat added and quality of the mixture when the pressure inside the tank is raised to 7 MPa.	L3	Apply
10.	Draw the phase equilibrium diagram for a pure substance on P-T coordinate. Justify the fusion on line for water have negative slope.	L2	Understanding
11.	A steam power plant works between 40 bar and 0.05 bar. If the steam supplied is dry saturated and cycle of operation is Rankine, determine Cycle efficiency and specific steam consumption.	L3	Apply
12.	An unknown quantity of super-heated steam is throttled from 10 bar and 200°C to 8 bar. Sketch the process on a T-v diagram. Calculate the following: (i) Final state of steam (1) Change in specific volume (iii) Increase in specific entropy. Given the specific heat at constant pressure of steam as 2.1 kJ/kgK.	L3	Apply
13.	Explain the P-v-T surface diagram for substances that expand on freezing with a neat labelled sketch.	L2	Understanding
14.	Draw the phase equilibrium diagram for a pure substance on p-T coordinates. Why does the fusion line for water have negative slope?	L2	Understanding

	(ii) What is quality of steam? What are the different methods of measurement of quality? Explain any one method. (7+6)		
15.	(i) Describe a simple ideal Rankine cycle with a schematic diagram. Explain the processes involved by T-s diagram. (6) (ii) A Steam power plant operates between a boiler pressure of 4 MPa and 300°C and a condenser pressure of 50 kPa. Determine the thermal efficiency of the cycle assuming the cycle to be a simple ideal Rankine cycle.	L3	Apply
16.	A closed, rigid container of volume 0.5 m³ 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: (i) the temperature, in °C, at each state. (ii) the mass of vapor present at each state, in kg. (i) if heating continues, determine the pressure, in bar, when the container holds only saturated vapor.	L3	Apply
17.	Steam is the working fluid in an ideal Rankine cycle with superheat and reheat. Steam enters the first-stage turbine at 8.0 MPa, 480°C, and expands to 0.7 MPa. It is then reheated to 440°C before entering the second-stage turbine, where it expands to the condenser pressure of 0.008 MPa. The net power output is 100 MW. Determine : (i) the thermal efficiency of the cycle (ii) the mass flow rate of steam, in kg/h (iii) the rate of heat transfer Qout from the condensing steam as it passes through the condenser, in MW. Discuss the effects of reheat on the vapor power cycle.	L3	Apply
18.	Steam at 7 bar and dryness fraction 0.95 expands in a cylinder behind a piston isothermally and reversibly to a pressure of 1.5 bar. The heat supplied during the process is found to be 420 kJ/kg. Calculate per kg (i) The change of internal energy (ii) The change of enthalpy (iii) The work done. (5+5+3)	L3	Apply
19.	A simple Rankine cycle works between pressures 28 bar and 0.06 bar, the initial condition of steam being dry saturated. Calculate the cycle efficiency, work ratio and specific steam consumption.	L3	Apply
20.	A vessel of volume 0.04 m3 contains a mixture of saturated water and saturated steam at a temperature of 250°C. The mass of the liquid present is 9 kg. Find the pressure, the mass, the specific volume, the enthalpy, the entropy and the internal energy.	L3	Apply
21.	A steam power station uses the following cycle : Steam at boiler outlet – 150 bar, 550°C Reheat at 40 bar to 550°C Condenser at 0.1 bar. Using the Mollier chart and assuming ideal processes, find the i) quality at turbine exhaust, (4) ii) cycle efficiency, and (4) iii) steam rate. (5)	L3	Apply
22.	A heat pump working on an ideal vapour-compression cycle using Freon-12 as the working fluid is used to heat a room. The condenser	L3	Apply

	and evaporator pressures are 1.6 and 0.32 Mpa, respectively. The heat transfer required for the condenser unit is 100 MJ/h. The Freon-12 is saturated at the beginning of compression and is at 55°C at the end of compression. Determine (i) the mass flow rate of the refrigerant, (ii) the quality of Freon-12 at the entry to the evaporator, and (iii) the power input to the compressor.		
23.	(i) What are the desirable properties of refrigerants? (4) (ii) Describe a Heat pump cycle with a reversing valve with a neat sketch. (6) (iii) An absorption refrigeration system receives heat from a source at 130°C and maintains the refrigerated space at –18°C. If the environment temperature is 30°C, determine the maximum possible COP for this system. (6)	L3	Apply
24.	(i) A pressure cooker contains 1.5 kg of steam at 5 bar and 0.9 dryness when the gas was switched off. Determine the quantity of heat rejected by the 'pressure cooker when the pressure in the cooker falls to 1 bar. (7) (ii) Steam at 19 bar is throttled to 1 bar and the temperature after throttling is found to be 150°C. Calculate the initial dryness fraction of the steam.	L3	Apply
25.	In a regenerative cycle the inlet conditions are 40 bar and 400°C. Steam is bled at 10 bar in regenerative heating. The exit pressure is 0.8 bar. Neglecting pump work. Determine the efficiency of the cycle.	L3	Apply
PART – C			
1.	Consider a steam power plant that operates on ideal reheat Rankine cycle. The plant maintains the boiler at 7000 KPa, the reheat section at 800 KPa and the condenser at 10 KPa. The mixture quality at the exit of both turbines is 93%. Determine the temperature at the inlet of high pressure and low-pressure turbine respectively.	L3	Apply
2.	In a Rankine cycle, steam enters the first stage turbine at 10 MPa and 500°C, expands to 0.1MPa. It is then reheated to 450°C before expansion in the LP turbine. It then expands to a condenser pressure of 0.01MPa. Net power developed is 100MW. Both the turbines have an efficiency of 80%. Calculate (i) Overall thermal efficiency of the cycle (ii) mass flow rate of steam.	L3	Apply
3.	(i) Determine whether water at each of the following states is a compressed liquid, a superheated vapor, or a mixture of saturated liquid and vapor. (8) (1) P= 10 MPa, v = 0.003 m^3/kg (2) 1 MPa, 190°C (3) 200°C, 0.1 m^3/kg (4) 10 kPa, 10°C (ii) A steam turbine has an inlet of 2 kg/s water at 1000 kPa, 350°C and velocity of 15 m/s. The exit is at 100 kPa, 150° C and very low velocity. Find the specific work and the power produced.	L3	Apply

UNIT V – BASICS OF PROPULSION AND HEAT TRANSFER			
Q. No	**Question**	**BT Level**	**Competence**
PART – A			
1.	Define specific thrust and TSFC.	L1	Remembering
2.	Define polytropic efficiency.	L1	Remembering
3.	What is meant by TSFC?	L1	Remembering
4.	Define thermal conductivity of a materials.	L1	Remembering
5.	List the benefit of thrust augmentation in a jet engine.	L1	Remembering
6.	List the characteristics of a black body.	L1	Remembering
7.	How much is the efficiency of Brayton's Cycle at unit compressor pressure ratio?	L1	Remembering
8.	Define specific impulse.	L1	Remembering
9.	Define conductive and convective resistance.	L1	Remembering
10.	Find optimum propulsion efficiency when the jet velocity is 500 m/s and flight velocity is 900 m/s.	L2	Understanding
11.	Comment on critical thickness of insulation.	L2	Understanding
12.	List the assumptions made for Fourier law of heat conduction.	L1	Remembering
13.	Give the differences between jet propulsion and rocket propulsion.	L1	Remembering
14.	Define thermal diffusivity.	L1	Remembering
15.	Why the thermal conductivity decreases as temperature increases for pure metals?	L2	Understanding
16.	How flight velocity does affect the thrust and propulsive efficiency?	L2	Understanding
17.	Define bypass ratio.	L1	Remembering
18.	State the law of conduction.	L1	Remembering
19.	What is specific impulse? Also state its significance.	L2	Understanding
20.	Mention some applications of radiation heat transfer.	L2	Understanding
21.	Give the difference between jet propulsion and rocket propulsion?	L2	Understanding
22.	What is thermal radiation? How does it differ from electromagnetic radiation?	L2	Understanding
23.	Define thermal efficiency?	L1	Remembering
24.	Define propulsive efficiency?	L1	Remembering
PART – B			
1.	With neat sketches, explain in brief about the various classifications of jet engines. (13)	L2	Understanding
2.	A turbojet aircraft flies at sea level at a Mach number of 1.5 at an altitude where ambient pressure and ambient temperature are 11.6 kPa and 205 K respectively. Mass flow rate is 50 kg/s, compressor pressure ratio is 1.2, temperature in combustion chamber is 1400 K. Assume the turbojet operates on ideal Brayton cycle. Take calorific value of fuel used as 45 MJ/kg, γ = 1.4 Cp = 1 kJ/kg-K. Calculate the thrust developed by the engine by assuming the nozzle exit	L3	Apply

	pressure is equal to the ambient pressure. (13)		
3.	Air enters a compressor operating at steady state at a pressure of 1 bar, a temperature of 290 K and a velocity of 6 m/s through an inlet with an area of 0.1 m2. At the exit, the pressure is 8 bar, the temperature is 450 K and the velocity is 2 m/s. Heat transfer from the compressor to the surroundings occurs at the rate of 180 kJ/min. Employing the ideal gas model, calculate the power input to the compressor. (7)	L3	Apply
4.	What are the various classification of jet engines? Explain them with neat sketches.	L2	Understanding
5.	i) A slab 0.2 m thick with thermal conductivity of 45 W/mK receives heat from a furnace at 500 K both by convection and radiation. The convection coefficient has a value of 50 W/m^2K. The surface temperature is 400 K on this side. The heat is transferred to surroundings at T_∞ both by convection and radiation. The convection coefficient on this side being 60 W/m2K. Determine the surrounding temperature. Consider $1m^2$ area and shape factor as 1 for radiation. (7) ii) A solid sphere of 0.09 m radius generates heat at 5×10^6 W/m^3. The conductivity of the material is 30 W/m–K. The heat generated is convected over the outer surface to a fluid at 160°C, with a convective heat transfer coefficient of 750 W/m^2K. Determine the maximum temperature in the material and the temperature at radius = 0.06 m. (6)	L3	Apply
6.	A reactor's wall 320 mm thick is made tip of an inner layer of firebrick (k = 0.84 W/m°C) covered with a layer of insulation (k = 0.16 W/m°C). The reactor operates at a temperature of 1325°C and the ambient temperature is 25°C. (i) Determine the thickness of firebrick and insulation which gives minimum heat loss, and (ii) Calculate the heat loss presuming that the insulating material has a maximum temperature of 1200°C. (13)	L3	Apply
7.	An aircraft flies at a speed of 520 kmph at an altitude of 8000 m. The diameter of the propeller of an aircraft is 2.4 m and flight to jet speed ratio is 0.74. Find the following: (i) The rate of air flow through the propeller (ii) Thrust produced (iii) Specific thrust (iv) Specific impulse (v) Thrust power.	L3	Apply
8.	Explain with a neat sketch of turbojet engine and with neat P-V and T-S diagram the working principle and also obtain an expression for thrust equation. (13)	L2	Understanding
9.	A composite plane wall of materials A and B have a thickness of L_A = 50mm and L_B = 25mm. The thermal conductivity of materials are K_A = 70W/m-K and K_B = 100W/m-K The outer surface of the wall A is perfectly insulated and the inside it, the heat is generated at an uniform rate of $2000kW/m^3$. The outer surface of the wall B is cooled by water at 20°C and h = $1kW/m^2K$. Determine the temperate at the insulated and cooled surfaces.	L3	Apply
10.	State Planck's laws of radiation and prove that the value of Stefan-Boltzmann constant is 5.67 x 10^8 W/m^2-K^4.	L2	Understanding

11.	Derive an expression for the overall heat transfer coefficient between two fluids at different temperatures T_1 K and T_2 K respectively, separated by a plain wall of thermal conductivity 'K'. Assume that the convective heat transfer coefficient between the inner fluid and wall surface is 'h_1' and that between the outer fluid and wall surface is 'h_2' respectively.	L3	Apply
12.	Consider a composite wall that includes an 8 mm thick Oakwood siding (K = 0.36W/mK). Glass fiber insulation (K = 0.062W/mK) and a 12 mm layer of vermiculite wall board (K = 0.056W/mK). The layers are held together by 20 mm diameter and 40 mm long 0.5% carbon steel studs (K = 40W/mK) with 1 stud for every 1.5 m^2 area of the wall. What is the effective thermal resistance associated with a wall that is 2 m high by 3 m wide? Assume surfaces normal to the x-direction are isothermal. If the wall insulates a storehouse with inside temperature 40°C and outside temperature 15°C, find out the heat transfer across the wall	L3	Apply
13.	Derive an expression for overall heat transfer coefficient U, for a composite wall made up of number of layers.	L2	Understanding
14.	A spherical ball of 10 cm diameter maintained at a constant temperature of 1100 K is suspended in air. Assuming the ball to closely approximate a blackbody, determine (i) the total blackbody emissive power, (ii) the total amount of radiation emitted by the ball in 10 minutes, and (iii) the spectral blackbody emissive power at a wavelength of 3 μm.	L3	Apply
15.	Derive an expression for the net thrust produced by an aircraft gas turbine engine.	L2	Understanding
16.	(i) A plane wall is 150 mm thick and its wall area is 4.5 m^2. If its conductivity is 9.35 W/m°C and surface temperatures are steady at 150°C and 45°C determine: (1) heat flow across the plane wall; (2) temperature gradient in the flow direction. (8) (ii) A surface at 250°C exposed to the surroundings at 110°C convects and radiates heat to the surroundings. The convective coefficient and radiation factor are 75 W/m^2°C and unity respectively. If the heat is conducted to the surface through a solid of conductivity 10 W/m°C, what is the temperature gradient at the surface in the solid?	L3	Apply
17.	How does the thermodynamics differ from heat transfer? Explain the different modes of heat transfer with suitable examples. And discuss how does the heat conduction takes place in solid, liquid and gas phases.	L2	Understanding
18.	Explain in detail about the different modes of heat transfer.	L2	Understanding
19.	Draw the real and ideal, T-Sand P-V diagram for a gas turbine engine. Derive expression for the isentropic efficiency for compressor.	L2	Understanding
20.	An aircraft flies at 90 km/hr. One of its turbojet engines takes in 40 kg/s of air and expands the gases to the ambient pressure. The air-fuel ratio is 50 and the lower calorific value of the fuel is 43 MJ/kg. For maximum thrust power, determine: jet velocity, thrust, specific	L3	Apply

	thrust, thrust power, propulsive and thermal efficiencies. (13)		
21.	A cold storage room has walls made of 0.23 m of brick on the outside, 0.08 m of plastic foam, and finally 15 mm of wood on the inside. The outside and inside air temperatures are 22°C and -2°C respectively. If the inside and outside heat transfer co-efficients are respectively 29 and 12 W/m^2K and the thermal conductivities of brick, foam and wood are 0.98, 0.02 and 0.17 W/mK respectively determine (i) the rate of heat removal by refrigeration if the total wall area is 90 m, and (ii) the temperature of the inside surface of the brick.	L3	Apply
PART – C			
1.	Air at a temperature of 20°C passes through a heat exchanger at a velocity of 40 m/s where its temperature is raised to 820°C. It then enters a turbine with the same velocity of 40 m/s and expands until the temperature falls to 620°C. On leaving the turbine, the air is taken at a velocity of 55 m/s to a nozzle where it expands until the temperature has fallen to 10°C. If the air flow rate is 2.5 kg/s. calculate (i) The rate of heat transfer to the air in the heat exchanger, (ii) The power output from the turbine assuming no heat loss. (iii) The velocity at the exit from the nozzle, assuming no heat loss. Take the enthalpy of air as h = CpT, where Cp is the specific heat equal to 1.005 kJ/kg°C and T the temperature."	L3	Apply
2.	With your understanding, analyse why piston engine is not able to replace jet engines used in large and high-speed aircrafts. (15)	L2	Understanding
3.	A room is maintained at 27°C while the surroundings are at 2°C. the temperature of the inner and outer surfaces of the wall (k = 0.71 W/mK) are measured to be 21°C and 6°C respectively. Heat flows steadily through the wall 5 m x 7 m in cross-section and 0.32 m in thickness. Determine (i) the rate of heat transfer through the wall, (ii) the rate of entropy generation in the wall, and (iii) the rate of total entropy generation with this heat transfer process.	L3	Apply
4.	A reversible heat engine in a satellite operates between a hot reservoir at T_1, and a radiating panel at T_2. Radiation from the panel is proportional to its area and T_2^4. i) For a given work output and value of T, show that the area of the panel T_2/T_1=0.75. T will be minimum when ii) Determine the minimum' area of the panel for an output of 1 kW if the constant of proportionality is 5.67×10^{-8} $W/m^2\text{-}K^4$ and T_1, is 1000 K. (10+5)	L3	Apply
5.	A turbojet plane flies with speed of 1000 kmph and inducts air at the rate of 50 kg/s. Air fuel ratio is 52 and the expansion of gases occurs up to ambient pressure. Lower calorific value of fuel is 43100 kJ/kg. For maximum thrust the flight to jet velocity ratio is 0.5. Determine (i) jet velocity, (ii) maximum thrust, (iii) specific thrust. (iv) thrust power, (v) propulsive, thermal and overall efficiencies, (vi) Specific fuel consumption.	L3	Apply

6.	Explain briefly the history of jet engines and show the working of Ram jet engine using relevant sketches.	L2	Understanding
7.	A turbojet engine operates between the pressure limits of 35 kPa and 350 kPa. The inlet air temperature is -40°C and the upper temperature limit is 1370 K. Calculate the specific momentum thrust of the engine assuming isentropic compression and expansion and an inlet velocity of 100 m/s. Also, determine the heat input and the power delivered per unit mass. Take the gas to be equivalent to air and the velocity at the nozzle inlet to be negligible.	L3	Apply
8.	A gas turbine unit receives air at 1 bar and 300 K and compresses it adiabatically to 6.2 bar. The compressor efficiency is 88%. The fuel has a heating valve of 44186 kJ/kg and the fuel-air ratio is 0.017 kJ/kg of air. The turbine internal efficiency is 90%. Calculate the work of turbine and compressor per kg of air compressed and thermal efficiency.	L3	Apply
9.	Boeing 747 aircraft is powered by four CF-6 turbofan engines manufactured by General Electric Company. Each engine has the following data: Thrust force 24.0 kN Air mass flow rate 125 kg/s Bypass ratio 5.0 Fuel mass flow rate 0.75 kg/s Operating Mach number 0.8 Altitude 10 km Ambient temperature 223.2 K Ambient pressure 26.4 kPa Fuel heating value 42,800 kJ/kg If the thrust generated from the fan is 75% of the total thrust, determine i) The jet velocities of the cold air and hot gases (2) ii) The specific thrust (2) iii) The Thrust Specific Fuel Consumption (TSFC) (2) iv) The propulsive efficiency (3) v) The thermal efficiency (3) vi) The overall efficiency. (3)	L3	Apply
10.	With neat P-v and T-s Plots. Derive the expression for the Pressure Ratio for a two-stage air compression with intercooling for minimal compression work. Also define the isentropic efficiency of the compressor.	L2	Understanding
11.	The compressor of a large gas turbine inducts air at 95kPa and 15°C at the rate of 50m3/sec and exits at 1.2 MPa. The compression process is essentially adiabatic and changes in Kinetic and Potential energies are negligible. Calculate the power required to drive this compressor and the exit temperature assuming that the process is reversible and the compressor has an isentropic efficiency of 87%.	L3	Apply
12.	Calculate the heat flowing through a furnace wall 0.23 m thick, the inside and outside surface temperatures of which are 1000°C, and 200°C respectively. Assume that the mean thermal conductivity of the wall material is 1.1 W/mK. Assuming that 7 mm of insulation (k = 0.075 W/mK) is added to the outside surface of the wall and	L3	Apply

	reduces the heat loss 20%; calculate the outside surface temperature of the wall. If the cost of the insulation is Rs. 70 per sq m. What time will be required to pay for the insulation? Base the calculations on the 24 hours operation per day and 199 days per year. Heat energy may be valued at Rs. 10 per 1000 kWh.		

END