INSTITUTEOFAERONAUTICALENGINEERING

(Autonomous)

Dundigal, Hyderabad-500043

AEROSPACE PROPULSION

TUTORIAL QUESTION BANK

Course Title	Aerospace Propulsion				
Course Code	AAEB08				
Programme	B.Tech				
Semester	IV	AE			
Course Type	Core				
Regulation	IARE - R18				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	Dr. Maruthupandiyan, Associate Professor				
Course Faculty	Dr. Maruthupandiyan, Associate Professor Ms. Ragha Leena, Assistant Professor				

COURSE OBJECTIVES:

The course should enable the students to:	
I	Analyze parametric cyclic analysis, performance parameters, efficiency, and specific impulse of all air breathing engines.
II	Know the design and performance of subsonic and supersonic inlets, types of combustion chambers and factors affecting the combustors
III	Discuss the types of nozzles, flow conditions in nozzles, interaction of nozzle flow with adjacent surfaces and thrust reversal
IV	Explain different types of compressors and turbines, work done, velocity diagrams and stage Efficiency calculations.

COURSE OUTCOMES (COs):

CO 1	Gain knowledge about the various types of gas turbine engine basic function and their performance analysis
CO 2	Understand the various inlets and combustion chamber performance parameters affecting it
CO 3	Gain knowledge about theory of flow through isentropic convergent, convergent-divergent nozzles and their operating conditions
CO 4	Understand basic principle operations of axial and centrifugal compressors, and their design
CO 5	Understand basic principle operations of axial and radial turbine, and their design.

COURSE LEARNING OUTCOMES (CLOs):

CLO 1	Apply knowledge and understand the essential facts, concepts and principles of Thermodynamics.
CLO 2	Understand the basic function of all aircraft engine components and how they work.
CLO 3	Analyze the engine performance parameters and parameters influencing them.
CLO 4	Understand the impact of performance parameters on endurance and range how they affect the Aircraft performance.
CLO 5	Demonstrate different type's aircraft engine operating principle.
CLO 6	Understand step by step procedure of engine parametric cycle analysis.
CLO 7	Understand steps involved in performance analysis of all aircraft engine.
CLO 8	Describe operational modes of subsonic inlets and parameters influencing it.
CLO 9	Analyze diffuser performance, losses in it and their impact on engine performance.
CLO 10	Describe supersonic inlets, starting problem in it and their operating modes.
CLO 11	Understand different types of combustion chamber and functions of all the components.
CLO 12	Analyze combustion chamber performance and parameters influencing them.
CLO 13	Describe theory of flow in isentropic nozzle and physics behind nozzle operation.
CLO 14	Understand different nozzle operating conditions for convergent and divergent nozzle.
CLO 15	Describe principle of operation of axial and centrifugal compressor.
CLO 16	Understand different design of compressor and limitations of each method.
CLO 17	Analyze performance characteristics of axial and centrifugal compressor.
CLO 18	Describe principle of operation of centrifugal and axial flow turbine.
CLO 19	Understand different design of axial and centrifugal turbine.
CLO 20	Design of ramjet engine and steps involved in it.

TUTORIAL QUESTION BANK

MODULE -I				
AIR-BREATHING ENGINES				
Part - A(Short Answer Questions)				
S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
1	Write different types of gas turbine engine?	Remember	CO 1	CLO 1
2	Differentiate ramjet and turbojet engine.	Remember	CO 1	CLO 1
3	What is the type of engine that would be used in a helicopter	Remember	CO 1	CLO 2
4	How is a turboprop different from a turbojet?	Remember	CO 1	CLO 2
5	What is the type of engine that powers most of today's airliners and why?	Remember	CO 1	CLO 3
6	What is the difference between ramjet and scramjet engine?	Remember	CO 1	CLO 3
7	Define bypass ratio.	Remember	CO 1	CLO 4
8	Define thermal efficiency	Understand	CO 1	CLO 4
9	Define propulsive efficiency	Understand	CO 1	CLO 5
10	Write thrust equation for simple turbojet engine.	Remember	CO 1	CLO 5
11	Define specific thrust	Remember	CO 1	CLO 6
12	Describe specific fuel consumption	Understand	CO 1	CLO 7
13	Define specific impulse	Understand	CO 1	CLO 4
14	What is the need for after burner?	Understand	CO 1	CLO 7
15	What is the difference between turboprop and turbojet engine?	Understand	CO 1	CLO 6
16	What is air-breathing engine?	Understand	CO 1	CLO1
17	What is non-air breathing engine?	Understand	CO 1	CLO1
18	What are the factors that affect engine thrust?	Remember	CO 1	CLO7
19	Why turbo fan has better propulsive efficiency?	Remember	CO 1	CLO6
20	What is mean by combined cycle engine	Remember	CO 1	CLO5
Part - B (Long Answer Questions)				
1	Compare between turboprop, turbofan, and turbojet engines (draw figures to illustrate their configurations).	Understand	CO 1	CLO 1
2	Compare ramjet engines and scramjet engines and highlight their differences based on principle of operation.	Understand	CO 1	CLO3
3	Draw and explain in detail the functions of all the major components in the turbojet engine.	Understand	CO 1	CLO 2
4	Derive thrust equation for ideal turbojet engine and clearly explain the nomenclature of each equation.	Remember	CO 1	CLO 3
5	Illustrate with proper label the scramjet engine and explain the functions of all the components.	Remember	CO 1	CLO 4
6	Write short notes on performance parameters of gas turbine engine and give an equation for any one performance parameter.	Remember	CO 1	CLO 2
7	Explain the need for an air breathing engine. Is an air-breathing engine different from a non-air-breathing engine? explain	Understand	CO 1	CLO 6
8	Derive isentropic efficiencies of a simple turbojet engine components.	Understand	CO 1	CLO 7
9	Sketch a neat and labeled diagram of a turbofan engine and explain its working principle.	Understand	CO 1	CLO 3
10	Explain in detail the working of a ramjet engine. Also, explain how a ramjet engine is different from a scramjet engine.	Understand	CO 1	CLO 1
11	Explain and draw a detailed diagram of a turboprop engine with neat sketch. Is a turboprop different from turbofan? Justify	Remember	CO 1	CLO 3

S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
12	List and explain the various factors that affecting the engine thrust with neat sketch.	Remember	CO 1	CLO 4
13	What is the difference between ram jet and turbojet and enumerate their advantages and disadvantages.	Understand	CO 1	CLO 7
14	Explain the flight limit and operational limits for different engines with neat sketch.	Understand	CO 1	CLO 3
15	Write short notes on air-breathing and non-air-breathing engines and describe about gas generator.	Understand	CO 1	CLO 1
16	Plot and explain in detail about variation of pressure temperature and velocity across turbojet engine.	Understand	CO 1	CLO 7
17	What are the advantages and disadvantages of turbojet, turbo prop and turbo fan engines.	Understand	CO 1	CLO 2
18	What is the need for after burner? Draw and explain the T-S diagram for turbojet engine with and without after burner cycle.	Understand	CO 1	CLO 6
19	Write short notes on combined cycle engine and explain any one of combined cycle engine with neat sketch.	Understand	CO 1	CLO 2
20	Derive the equation for propulsive efficiency and explain the reason for turbofan having better propulsive efficiency.	Understand	CO 1	CLO 5
	Part - C (Analytical Questions)			
1	Air flows through a turbojet engine at the rate of 50.0 kg/s and the fuel flow rate is 1.0 kg/s. The exhaust gases leave the jet nozzle with a relative velocity of 600m/s. Compute the velocity of the airplane, if the thrust power is 1.5 MW in the following two cases: 1. Pressure equilibrium exists over the exit plane 2. If the pressure thrust is 8 kN	Understand	CO 1	CLO 4
2	A fighter airplane is powered by two turbojet engines. It has the following characteristics during cruise flight conditions: Wing area (S) = 49.24 m^2 Engine inlet area A_i = 0.06 m^2 Cruise speed V_f = 243 m/s Flight altitude = 35,000 ft Drag and lift coefficients are C_D=0.045, C_L=15 C_D Exhaust total temperature T_0=1005K Specific heat ratio and Specific heat at exit are γ =1.3, Cp = 1100 J/(kgK) It is required to calculate: 1. Net thrust 2. Weight 3. Jet speed assuming exhaust pressure is equal to ambient pressure if Pe=Pa 4. Static temperature of exhaust Te 5. Exhaust Mach number Me	Understand	CO 1	CLO 4
3	A turbojet engine is powering a fighter airplane. Its cruise altitude and Mach number are 10 km and 0.85, respectively. The exhaust gases leave the nozzle at a speed of 600 m/s and a pressure of 0.75 bar. The outlet area of exhaust nozzle is A_e =0.24 m^2. The air mass flow rate is 40 kg/s and fuel to air ratio is 0.02. It is required to calculate: (a) The specific thrust ($T/\dot{m}_a$) (b) The propulsive efficiency using the different expressions	Understand	CO 1	CLO 4
4	A gas turbine operating at a pressure ratio of 11.314 produces zero net work output when 473.35 kJ of heat is added per kg of air. If the inlet air temperature is 300 K and the turbine efficiency if 71%, find the compressor efficiency.	Understand	CO 1	CLO 4

<table>
<tr><td>5</td><td>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
(a) The jet velocities of the cold air and hot gases
(b) The specific thrust
(c) The thrust specific fuel consumption (TSFC)</td><td>Remember</td><td>CO 1</td><td>CLO 5</td></tr>
<tr><td>6</td><td>A Boeing 747 aircraft has a lift-to-drag ratio of 17. The fuel-to-air ratio is 0.02 and the fuel heating value is 45,000 kJ/kg. The ratio between the weight of the aircraft at the end and start of cruise is 0.673. The overall efficiency is 0.35.
1. Calculate the range of aircraft.
2. What will be the fuel consumed in the cruise if the takeoff mass of aircraft is 385,560 kg?
3. If the fuel consumed during the engine start, warming, and climb is 4.4% of the initial aircraft weight and the fuel consumed during descent, landing, and engine stop is 3.8% of the aircraft weight at the end of cruise, calculate the fuel consumed in the whole trip.</td><td>Remember</td><td>CO 1</td><td>CLO 6</td></tr>
<tr><td>7</td><td>The airplane has turbojet engine which produces 12.12 KN thrust at an altitude of 9150 m, where the ambient conditions are 32 kPa and 240 K. The pressure ratio across the compressor is 12 and temperature at the turbine inlet is 1400 K. The aircraft speed is 310 m/s. Assume ideal operation for all components; assume un-choked nozzle and constant specific heat in all processes, Cp = 1005 J/kgK. The heating value of the fuel is 42,700 kJ/kg.
Determine
(a) The fuel-to-air ratio
(b) The velocity of the exhaust gases
(c) The air mass flow rate</td><td>Remember</td><td>CO 1</td><td>CLO 7</td></tr>
<tr><td>8</td><td>An aircraft having ideal turbojet engine flying at an altitude where the ambient conditions are 0.458 bar and 248 K. Speed of the aircraft: 805 km/h, Compressor pressure ratio: 4:1, Turbine inlet temperature: 1100 K, Nozzle outlet area 0.0935 m^2, Heat of reaction of the fuel: 43 MJ/kg. Find the thrust and TSFC assuming c_p as 1.005 kJ/kg K and γ as 1.4.</td><td>Remember</td><td>CO 1</td><td>CLO 3</td></tr>
<tr><td>9</td><td>A comparison between turbojet and turbofan engines is considered here. Both the engines have the same gas generator (compressor, combustion chamber, and turbine). It is required to calculate both the thrust and propulsive efficiency of them provided the following data:
<table>
<tr><td>Engine</td><td>Core air mass flow rate (kg/s)</td><td>Bypass ratio β</td><td>Flight speed (km/hr)</td><td>Fuel to air ratio</td><td>Exhaust speed for hot gases (km/hr)</td><td>Exhaust speed for cold stream (km/hr)</td></tr>
<tr><td>Turbo jet</td><td>20</td><td>0</td><td>1100</td><td>0.02</td><td>3000</td><td>0</td></tr>
<tr><td>Turbo fan</td><td>20</td><td>5</td><td>1100</td><td>0.015</td><td>2000</td><td>1460</td></tr>
</table></td><td></td><td></td><td></td></tr>
<tr><td>10</td><td>*DASSAULT MIRAGE G* is a two seat Strike and Reconnaissance fighter powered by one *SNECMA TF-306C* turbofan engine. It has the following characteristics:
Flight Mach number 0.8, Altitude 65,000 ft, Ambient temperature 216.7 K
Ambient pressure 5.5 kPa, Fuel heating value 42,700 kJ/kg
Thrust force 53.4 kN, Air mass flow rate 45 kg/s, Fuel mass flow rate 2.5 kg/s
Aircraft gross weight (65,000 ft) 156 kN, Aircraft takeoff weight 173.3 kN
Wing area 26.4 m^2, Fuel weight 5. kN, Maximum lift coefficient $C_{L\ max=1.8}$
C_{D0} = 0.012 K_1 = 0.2 K_2 = 0.0, Air density at take-off 1.225 kg/m3
Air density at 650,000 ft 0.88 kg/m3
Calculate:
1. The specific thrust
2. TSFC
3. The exit velocity</td><td>Remember</td><td>CO1</td><td>CLO5</td></tr>
</table>

S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
MODULE –II				
INLETS AND COMBUSTION CHAMBERS				
Part – A (Short Answer Questions)				
1	What is the function of diffuser?	Remember	CO 2	CLO 9
2	Draw neat sketch of operating conditions of subsonic inlet?	Remember	CO 2	CLO 9
3	Write some of major design variables for the inlet.	Remember	CO 2	CLO 10
4	Describe about inlet flow distortion.	Understand	CO 2	CLO 10
5	Write typical modes of supersonic inlet operation.	Understand	CO 2	CLO 8
6	What is mean by buzz?	Understand	CO 2	CLO 8
7	Classify types of combustion chamber.	Understand	CO 2	CLO 12
8	What are all the major components of combustion chamber?	Understand	CO 2	CLO 12
9	Differentiate between annular and cannular type combustion chamber?	Understand	CO 2	CLO 11
10	What is the function of fuel injector?	Remember	CO 2	CLO 11
11	Describe about flame holder and its function	Remember	CO 2	CLO 8
12	Define stoichiometric ratio.	Remember	CO 2	CLO 9
13	Define combustion efficiency.	Remember	CO 2	CLO 10
14	Define equivalence ratio	Understand	CO 2	CLO 11
15	Define combustion intensity	Understand	CO 2	CLO 12
16	Write different types of internal flow in straight walled diffuser.	Remember	CO 2	CLO 9
17	What is the function of swirl vanes in combustion chamber?	Remember	CO 2	CLO 10
18	Describe the function of liner in combustion chamber.	Understand	CO 2	CLO 11
19	Write different types of subsonic inlets.	Understand	CO 2	CLO 12
20	Write different types of supersonic inlets.	Remember	CO 2	CLO 9
Part - B (Long Answer Questions)				
1	Describe about subsonic inlet function and modes of operation with neat sketch.	Remember	CO 2	CLO 8
2	What is nacelle? What is its purpose? Explain the subsonic inlet nomenclature with neat and labeled sketch.	Remember	CO 2	CLO 8
3	What do you understand by isentropic efficiency of a diffuser? Does the change in enthalpy change the kinetic energy? Justify	Understand	CO 2	CLO 09
4	Write short note on starting problem in supersonic inlets. Are the problems predominant in any other forms of inlet?	Remember	CO 2	CLO 10
5	Write short notes on shock swallowing by area variation. What are the adverse effects of shocks? Explain.	Remember	CO 2	CLO 10
6	Write short notes on the different types of combustion chamber with neat and labeled sketch.	Understand	CO 2	CLO 12
7	What are the factors influencing combustion chamber design.	Remember	CO 2	CLO 11
8	What do you understand by stoichiometric ratio? Write short notes on flame stabilization in combustion chamber.	Remember	CO 2	CLO 12
9	Explain the functions of each component in gas turbine combustion chamber. Draw a suitable sketch for it.	Understand	CO 2	CLO 9
10	What do you understand by equivalence ratio? Write the advantages and disadvantages of the various types of combustion chamber.	Understand	CO 2	CLO 9
11	Explain in short about the combustion efficiency. Write in details about the properties desired for combustion chamber.	Remember	CO 2	CLO 10
12	Write short notes on a) Combustion process b) Ignition and c) Combustion stability.	Understand	CO 2	CLO 12
13	Write short notes on (i) Inlet total pressure ratio (ii) Inlet sizing (iii) Inlet flow distortion.	Remember	CO 2	CLO 11
14	Explain in detail about types of flow in straight-walled diffusers with neat and labeled sketch.	Remember	CO 2	CLO 12

S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
15	Write short note on combustion stability. Explain in detail about combustion chamber stability limits with neat sketch.	Understand	CO 2	CLO 9
16	Write short notes on flame tube cooling and fuel injection.	Understand	CO 2	CLO 9
17	Describe about the isentropic efficiency of a diffuser. Write short notes on inlet stalling and their effect on engine performance.	Understand	CO 2	CLO 9
18	Describe about operational modes of supersonic inlet with neat sketch.	Remember	CO 2	CLO 10
19	Write short notes on (i) Podded intake (ii) Integrated intake (iii) Flush intake	Understand	CO 2	CLO 12
20	Write short notes on performance characteristics of subsonic inlet during take-off and cruise.	Remember	CO 2	CLO 10
	Part - C (Analytical Questions)			
1	A turbofan engine during ground ingests airflowat the rate of $\dot{m}_\infty$ = 500 kg/s through an inlet area (A1) of 3.0 m^2. If the ambient conditions (T_∞, P_∞) are 288 K and 100 kPa, respectively, calculate the area ratio (A_∞/A_1) for different free stream Mach numbers. What is the value of the Mach number where the capture area is equal to the inlet area? Draw the air stream tube for different Mach numbers. (0.2,0.4, 0.6, 0.8, 1.0, 1.2)	Remember	CO 2	CLO 9
2	An aircraft powered by turbo fan engine flying at a Mach number of 0.9 and altitude of 11 km where the ambient temperature and pressure are respectively −56.5◦C and 22.632 kPa. The mass ingested into the engine is now 235 kg/s. If the diffuser efficiency is 0.9 and the Mach number at the fan face is 0.45, calculate the following: 1. The capture area 2. The static pressures at the inlet and fan face	Remember	CO 2	CLO 12
3	Explain about stall in subsonic inlets and their effect on engine performance.	Remember	CO 2	CLO 8
4	Write short notes on 1. Pressure loss 2. Combustion efficiency 3. Isentropic efficiency of a diffuser4. Combustion instability	Understand	CO 2	CLO 9
5	Classify combustion chambers and elaborate on each type of combustion chamber with highlights on each type.	Understand	CO 2	CLO 11
6	Explain about internal compression, external compression and mixed compression supersonic inlet with neat sketch.	Remember	CO 2	CLO 10
7	An aircraft flies at a Mach number of 0.75 ingesting an airflow of 80 kg/s at an altitude where the ambient temperature and pressure are 222 K and 10 kPa, respectively. The inlet design is such that the Mach number at the entry to the inlet is 0.60 and that at the compressor face is 0.40. The inlet has an isentropic efficiency of 0.95. Find (a) the area of the inlet entry (b) the inlet pressure recovery (c) the compressor face diameter.			
8	An aircraft powered by turbo fan engine flying at a Mach number of 0.9 and altitude of 11 km where the ambient temperature and pressure are respectively −56.5◦C and 22.632 kPa. The mass ingested into the engine is now 235 kg/s. If the diffuser efficiency is 0.9 and the Mach number at the fan face is 0.45, calculate the following: 1.The air speed at the same stations 2.The diffuser pressure recovery factor	Remember	CO 2	CLO 12
9	Elaborate on 1.Combustion stability 2. Combustion intensity	Understand	CO 2	CLO7

S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
10	An aircraft powered by turbo fan engine flying at a Mach number of 0.8 and altitude of 11 km where the ambient temperature and pressure are respectively −55.5◦C and 23.32 kPa. The mass ingested into the engine is now 250 kg/s. If the diffuser efficiency is 0.89 and the Mach number at the fan face is 0.50, calculate the following: 1.The air speed at the same stations 2.The diffuser pressure recovery factor	Remember	CO 2	CLO 12
MODULE –III				
NOZZLES				
Part – A (Short Answer Questions)				
1	Define nozzle.	Understand	CO 3	CLO 13
2	Write types of nozzle.	Understand	CO 3	CLO 13
3	Write any three requirements a nozzle should fulfill.	Remember	CO 3	CLO 14
4	What is the condition for nozzle choking	Remember	CO 3	CLO 14
5	What is the maximum Mach number a convergent nozzle can deliver and why?	Remember	CO 3	CLO 14
6	Define characteristics Mach number.	Remember	CO 3	CLO 13
7	Describe correctly expanded nozzle.	Understand	CO 3	CLO 13
8	Describe under-expanded nozzle.	Understand	CO 3	CLO 13
9	Describe over-expanded nozzle.	Understand	CO 3	CLO 13
10	Define thrust vectoring?	Understand	CO3	CLO 14
11	Why oblique shock form at nozzle exit during over-expanded condition?	Understand	CO3	CLO 14
12	What is the need for variable area nozzle?	Understand	CO 3	CLO 13
13	Write different techniques used to create variable area nozzle.	Understand	CO 3	CLO 13
14	Describe about thrust reversal.	Remember	CO 3	CLO 14
15	What is the need for thrust reversal	Remember	CO 3	CLO 14
16	Why expansion fan forms at nozzle exit during under-expanded condition	Remember	CO3	CLO 14
17	What is the need for variable area nozzle?	Remember	CO3	CLO14
18	Define isentropic efficiency of nozzle.	Remember	CO3	CLO 13
19	What is mean by nozzle choking?	Understand	CO3	CLO 14
20	Plot the variation of pressure and velocity across chocked C-D nozzle.	Remember	CO3	CLO 13
Part - B (Long Answer Questions)				
1	Write short notes on flow through convergent nozzle and plot the variation of pressure and velocity.	Remember	CO 3	CLO 13
2	Explain theory of flow through convergent-divergent nozzle and plot the variation of pressure and velocity.	Remember	CO 3	CLO 13
3	Write brief note on nozzle choking and illustrate with a labeled diagram, the conditions.	Remember	CO 3	CLO 14
4	Writ short notes on 1. Cone 2. Bell 3. Annular convergent divergent nozzle	CO 3	CLO 14	
5	Derive Area velocity relation by assuming quasi-one dimensional flow through a passage.			
4	Draw with a labeled diagram and explain operating conditions of convergent-divergent nozzle.	Remember	CO 3	CLO 14
5	Explain various methods used for thrust reversal, with a labeled diagram for each process.	Understand	CO 3	CLO 14
6	Explain different technique available for producing variable Mach number at the nozzle exit.	Understand	CO 3	CLO 13
7	Write short notes on thrust reversal and illustrate with a labeled diagram for each case.	Understand	CO 3	CLO 14
8	Explain about various methods used for thrust reversal with a labeled diagram for each method.	Understand	CO 3	CLO 14
9	Write short notes on thrust vectoring and illustrate with a labeled diagram showing the various thrust vectoring methods.	Understand	CO 3	CLO 13

S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
10	Describe the theory of flow in isentropic nozzle and the working principle of the nozzle.	Understand	CO 3	CLO 13
11	A fixed area convergent-divergent nozzle can deliver different Mach number. Explain.	Remember	CO 3	CLO 14
12	Explain how over-expanded operating condition is possible for convergent nozzle.	Remember	CO 3	CLO 13
13	Will there be any wave formation in correctly expanded nozzle. Justify your answer.	Understand	CO 3	CLO 13
14	What is the condition for convergent-divergent nozzle to deliver supersonic Mach number?	Understand	CO 3	CLO 13
15	Brief about the theory of flow through nozzle and derive an equation for the showing the flow through nozzle.	Remember	CO 3	CLO 13
16	Write brief note on nozzle choking and illustrate with a labeled diagram, the conditions.	Remember	CO 3	CLO 14
17	Derive an equation for the flow through nozzle and explain its operating conditions with a diagram.	Remember	CO 3	CLO 14
18	How is thrust reversal achieved? Is thrust vectoring similar to thrust reversal? Justify your answer.	Understand	CO 3	CLO 14
19	What is the need for variable area nozzle? Explain your answer justifying the need to introduce such a nozzle.	Understand	CO 3	CLO 14
20	Write short notes on effective exhaust velocity. Determine why C* is an important characteristic in determining exhaust velocity.	Understand	CO 3	CLO 13
	Part - C (Analytical Questions)			
1	Aturbojet engine powering an aircraft flying at an altitude of 11,000mwhere Ta = 216.7K and Pa = 24.444 kPa. The flight Mach number is 0.9. The inlet conditions to the nozzle are 1000 K and 60 kPa. The specific heat ratio of air and gases at nozzle are 1.4 and 4/3. The nozzle efficiency is 0.98. Determine the thrust per inlet frontal area for C-D nozzle.	Remember	CO 3	CLO 14
2	Derive the equation for mass flow rate across nozzle as function of Mach number, total pressure and total temperature and get the equation for maximum mass flow rate.	Understand	CO 3	CLO 13
3	Derive area ratio and Mach number relation for convergent-divergent nozzle by assuming chocked condition.	Remember	CO 3	CLO 13
4	Prove that the force developed by thrust reversal during landing is given by $F = \dot{m}_a \left[(1+f)\, V_j \cos\beta + V_f\right]$	Remember	CO 3	CLO 14
5	A turbojet engine operates at an altitude where the ambient temperature and pressure are 216.7 K and 24.444 kPa, respectively. The flight mach number is 0.9 and the inlet conditions to the convergent nozzle are 1000 K and 60 kPa. If the nozzle efficiency is 0.98, the ratio of specific heat is 1.33, determine whether the nozzle is operating under choked condition or not. Determine the nozzle exit pressure.	Remember	CO 3	CLO 14
	A De Laval nozzle has to be designed for an exit Mach number of 1.5 with an exit diameter of 200 mm. Find the required ratio of exit area to throat area. The reservoir conditions are given as p_0 =1 atm T_0 = 20 ^{0}C. Find the maximum mass flow rate through the nozzle. What will be the exit pressure and temperature?	Remember	CO 3	CLO 14
6	Derive equation for nozzle efficiency and explain in detail, the losses in the nozzle, undermining the nomenclature.	Understand	CO 3	CLO 13
7	An aircraft which is flying at an altitude of 10,000m, is powered by a turbojet engine. where Ta = 218K and Pa = 25kPa. The flight Mach number is found to be 0.92. The inlet conditions to the nozzle were found to be 1010 K and 58kPa. The specific heat ratio of air and gases at nozzle are 1.4 and 4/3. The nozzle efficiency is 0.98. Find the thrust per inlet frontal area for C-D nozzle.	Remember	CO 3	CLO 14
8	Explain flow properties variation across convergent and divergent ducts using area velocity relation with neat sketch.	Remember	CO 3	CLO 13

S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
9	The idling turbojet engines of a landing airplane produce forward thrust when operating in a normal manner, but they can produce reverse thrust if the jet is property deflected. Suppose that, while the aircraft rolls down the runway at 100 mph, the idling engine consumes air at 100 lbm/s and produces an exhaust velocity of 450 ft/s. (a) What is the forward thrust of the engine? (b) What is the magnitude and direction (forward or reverse) if the exhaust is deflected 90°and if the mass flow is kept constant?	Remember	CO1	CLO4
10	Calculate the dragging force developed by thrust reversers of the *two* engine aircraft in the following case $\dot{m}_a$ = 50 kg/s, f = 0.02, β = 60°, V_j= 600 m/s and V_f = 80 m/s.	Understand	CO 3	CLO 13
	MODULE -IV			
	COMPRESSORS			
	Part – A (Short Answer Questions)			
1	What is the function of compressor?	Remember	CO 4	CLO 15
2	What is the difference between axial and centrifugal compressor?	Remember	CO 4	CLO 15
3	What are the different diffusers used in centrifugal compressor?	Remember	CO 4	CLO 15
4	Describe about slip factor.	Remember	CO 4	CLO 16
5	Define compressor stall	Remember	CO 4	CLO 16
6	Define surge	Remember	CO 4	CLO 16
7	Describe about rotating stall	Understand	CO 4	CLO17
8	Define degree of reaction.	Understand	CO 4	CLO 17
9	What are Stage parameters you know?	Understand	CO 4	CLO 17
10	Define flow coefficient.	Understand	CO 4	CLO 15
11	Define stage loading	Understand	CO 4	CLO 16
12	How number of stages calculated in axial flow compressor.	Understand	CO 4	CLO 16
13	Define blade efficiency	Remember	CO 4	CLO 17
14	Define stage efficiency for compressor.	Remember	CO 4	CLO 17
15	Describe about compressor cascade.	Remember	CO 4	CLO 15
16	What do you understand by isentropic efficiency of a compressor?	Remember	CO4	CLO 15
17	Define polytropic efficiency of a compressor.	Remember	CO4	CLO 15
18	What do you understand by surge in compressor?	Remember	CO4	CLO 16
19	What is IGV and why is it provided?	Understand	CO4	CLO 16
20	Define hysteresis.	Understand	CO4	CLO 17
	Part – B (Long Answer Questions)			
1	Write short notes on principle of operation of centrifugal compressor and illustrate a labeled diagram of a compressor	Remember	CO 4	CLO 15
2	Explain about basic operation of axial flow compressor and illustrate a labeled diagram of a compressor	Remember	CO 4	CLO 15
3	Explain about factors affecting stage pressure ratio. Do you think that stage pressuring ratio is needed?	Remember	CO 4	CLO 17
4	Write (a) advantages of centrifugal compressor over axial flow compressor. (b)advantages of axial flow compressor over centrifugal compressor.	Understand	CO 4	CLO 15
5	Draw the velocity diagram of axial and centrifugal compressor, and neatly label each part.	Remember	CO 4	CLO 16
6	Write a brief note on performance characteristics of axial and centrifugal compressor.	Remember	CO 4	CLO 16
7	Write short notes on (a) Compressor stall (b) Surge (c) Rotating stall.	Understand	CO 4	CLO 16
8	Explain about the methods used to control surge. Also differentiate between stall and surge in a compressor.	Remember	CO 4	CLO 16
9	Explain in brief the functions of the components in a centrifugal compressor with a diagram	Remember	CO 4	CLO 17

S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
10	Explain the variation of enthalpy, pressure, temperature across stator and rotor of axial flow compressor with neat sketch.	Understand	CO 4	CLO 17
11	What do you understand by surge in compressor? Is it similar to chocking condition in the compressor? Justify	Remember	CO4	CLO 16
12	Define slip factor. Obtain an equation along a labeled diagram showing the compressor staging.	Remember	CO4	CLO 16
13	Define hysteresis. Does it relate to stall in a compressor? Justify your answer with suitable reasoning.	Understand	CO4	CLO 17
14	What are the advantages of centrifugal flow compressor over the axial flow compressor? Justify with appropriate reasoning.	Understand	CO4	CLO 17
15	What is meant by free cortex method? What are the assumptions used for specific work and constant axial velocity?	Remember	CO4	CLO 16
16	Describe about basic operation of axial compressor and illustrate with a labeled diagram of a compressor	Remember	CO 4	CLO 15
17	Determine the factors affecting stage pressure ratio in a compressor. Is it important to stage for pressuring ratio?	Remember	CO 4	CLO 17
18	Draw a neat and labeled velocity diagram of axial and centrifugal compressor, and clearly label each section.	Remember	CO 4	CLO 16
19	Write a brief note on performance characteristics of axial and centrifugal compressor.	Remember	CO 4	CLO 16
20	Determine the methods used to control the surge in compressor. Is stall and surge same in a compressor.	Remember	CO 4	CLO 16
	Part - C (Analytical Questions)			
1	The following data are suggested as a basis for the design of a single-sided centrifugal compressor: Power input factor c 1.04, Slip factor s 0.9 Rotational speed N 290 rev/s, Overall diameter of impeller 0.5 m Eye tip diameter 0.3 m, Eye root diameter 0.15 m Air mass flow m 9 kg/s, Inlet stagnation temperature T01 295 K Inlet stagnation pressure p01 1.1 bar, Isentropic efficiency hc 0.78. (a) determine the pressure ratio of the compressor and thepower required to drive it assuming that the velocity of the air at the inlet is axial; (b) to calculate the inlet angle of the impeller vanes at the root and tip radii of theeye, assuming that the axial inlet velocity is constant across the eye annulus	Remember	CO 4	CLO 17
2	Derive the equation for work done and pressure rise across centrifugal compressor	Remember	CO 4	CLO 15
3	Explain in details about the methods used to control surge. Also differentiate between stall and surge in a compressor.	Understand	CO 4	CLO 15
4	Derive the equation for stage efficiency. What are the advantages of centrifugal flow compressor over the axial flow compressor? Justify with appropriate reasoning.	Understand	CO 4	CLO 16
5	Explain in details about the basic operation of axial flow compressor and illustrate a labeled diagram of a compressor.	Remember	CO 4	CLO 16
6	A basis for the design of a single-sided centrifugalcompressor gave the following data of power input factor c 1.03, slip factor s 0.9, rotational speed N 285 rev/s, overall diameter of impeller 0.4 m, eye tip diameter 0.3 m, eye root diameter 0.15 m, air mass flow m 10 kg/s, inlet stagnation temperature T01 296 K, inlet stagnation pressure p 12 bar, isentropic efficiency hc 0.79. Determine the following:- (a) Pressure ratio of the compressor (b) the power required to drive it assuming that the velocity of the air at the inlet is axial (b) The inlet angle of the impeller vanes at the root and tip radii of the eye, assuming that the axial inlet velocity is constant across the eye annulus	Remember	CO 4	CLO 17
7	Derive the equation for work done and pressure rise across centrifugal compressor	Remember	CO 4	CLO 15
8	Define slip factor. And obtain an equation along a labeled diagram showing the compressor staging.	Understand	CO 4	CLO 15
9	Derive the equation for blade efficiency of a compressor and the stage efficiency of a compressor	Understand	CO 4	CLO 16

S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
10	Explain in detail about the compressor cascade with a neat and labeled diagram showcasing the cascading in a compressor.	Remember	CO 4	CLO 16
	MODULE -V			
	TURBINES			
	Part - A (Short Answer Questions)			
1	What is the function of turbine?	Remember	CO 5	CLO 18
2	What is the difference between axial flow and radial flow turbine?	Remember	CO 5	CLO 18
3	Write limitations of radial flow turbine.	Remember	CO 5	CLO 18
4	Differentiate between turbine and compressor.	Remember	CO 5	CLO 19
5	Define stage efficiency of turbine.	Remember	CO 5	CLO 19
6	What is the need for turbine blade cooling?	Remember	CO 5	CLO 18
7	Write different types of turbine blade cooling.	Understand	CO 5	CLO 19
8	Describe about profile loss in turbine blade.	Understand	CO 5	CLO 19
9	What is the function of guide vanes in turbine?	Understand	CO 5	CLO 18
10	What is the reason for decrease in total pressure across turbine?	Understand	CO 5	CLO 19
11	Define polytropic efficiency of a turbine.	Remember	CO5	CLO 18
12	What do you understand by profile loss?	Remember	CO5	CLO 18
13	Define annulus loss.	Understand	CO5	CLO 18
14	What do you understand by nacelle?	Remember	CO5	CLO 18
15	Define ramjet.	Remember	CO5	CLO 19
16	What is ramjet combustor?	Remember	CO5	CLO 19
17	Define axial flow.	Remember	CO5	CLO 19
18	Define radial flow.	Understand	CO5	CLO 20
19	What do you understand by flame?	Remember	CO5	CLO 20
20	Define vortex.	Understand	CO5	CLO 20
	Part - B (Long Answer Questions)			
1	Write short notes on principle of operation of axial flow turbine. Explain about the polytropic efficiency of a turbine.	Understand	CO 5	CLO 18
2	What do you understand by profile loss? Write short notes on work done and pressure rise by radial flow turbine	Understand	CO 5	CLO 18
3	What are the limitations of axial and radial flow turbine? Clearly differentiate the two with suitable justification.	Remember	CO 5	CLO 19
4	Write short notes on performance characteristics of turbine. Is an axial flow invariably different from a radial flow?	Remember	CO 5	CLO 19
5	Draw a neat and labeled sketch and explain the velocity diagram for axial flow turbine. Clearly mention the nomenclature.	Understand	CO 5	CLO 18
6	What do you understand by inlet total pressure? Explain limiting factors in turbine blade design.	Remember	CO 5	CLO 18
7	What is the need for turbine blade cooling and explain about different types of turbine blade cooling	Remember	CO 5	CLO 19
8	What do you understand by ramjet combustor? Explain about the step by step procedure to design a ramjet engine.	Understand	CO 5	CLO 20
9	Explain in brief about the combustion intensity. Write short notes on flame stability problems in ramjet combustors.	Remember	CO 5	CLO 20
11	What is the difference between axial flow and radial flow turbine? Draw a neat sketch for both the turbine.	Remember	CO 5	CLO 18
12	What do you understand by annulus loss? What is the reason for decrease in total pressure across turbine?	Remember	CO 5	CLO 18
14	What are the flame stability issues in a ramjet combustor? Elucidate on the issues and explain about the each in brief.	Remember	CO 5	CLO 19
15	Draw with a neat and labeled sketch of the radial turbine. Elaborate on the working principle of the radial turbine.	Understand	CO 5	CLO 18

S.NO	QUESTIONS	Blooms Taxonomy Level	Course Outcomes	Course Learning Outcomes
16	Define stage efficiency of a turbine. Write the limitations of the radial flow turbine and compare that with an axial turbine.	Remember	CO 5	CLO 18
17	Draw with a neat and labeled sketch of the axial turbine. Elaborate on the working principle of the radial turbine.	Understand	CO 5	CLO 18
18	Explain on the working principle of a turbine and a compressor. Elaborate on the differences between turbine and compressor.	Remember	CO 5	CLO 19
19	Differentiate between the closed and open cycle gas turbine. State the advantages of closed cycle gas turbine over an open cycle gas turbine.	Remember	CO 5	CLO 19
20	What is the need for turbine blade cooling? Explain about the various types of cooling methods available for turbine blade.	Remember	CO 5	CLO 18
	Part - C (Analytical Questions)			
1	A single stage gas turbine operates at its design condition with an axial absolute flow at entry and exit from the stage. The absolute flow angle at the nozzle exit is 70 deg. At stage entry, the total pressure and temperature are 311 kPa and 850oC respectively. The exhaust static pressure is 100 kPa, the total to static efficiency is 0.87 and mean blade speed is 500 m/s. Assuming constant axial velocity through the stage, determine (a) the specific work done (b) the Mach number leaving the nozzle (c) the axial velocity (d) total to total efficiency (e) stage reaction.	Remember	CO 5	CLO 18
2	Combustion gases enter the first stage of a gas turbine at a stagnation temperature and pressure of 1200 K and 4.0 bar. The rotor blade tip diameter is 0.75m, the blade height is 0.12 m and the shaft speed is 10,500 rpm. At the mean radius the stage operates with a reaction of 50%, a flow coefficient of 0.7and a stage loading coefficient of 2.5. Determine (a) the relative and absolute flow angles for the stage; (b) the velocity at nozzle exit; (c) the static temperature and pressure at nozzle exit assuming a nozzle efficiency of 0.96 and the mass flow.	Remember	CO 5	CLO 19
3	A single stage axial flow turbine operates with an inlet temperature of 1100 K and total pressure of 3.4 bar. The total temperature drop across the stage is 144 K and the isentropic efficiency of the turbine is 0.9. The mean blade speed is 298 m/s and the mass flow rate is 18.75 kg/s. The turbine operates with a rotational speed of 12000 rpm. If the convergent nozzle is operating under choked condition determine (a) blade-loading coefficient (b) pressure ratio of the stage and (c) flow angles.	Remember	CO 5	CLO 19
4	A multi-stage axial turbine is to be designed with impulse stages and is to operate with an inlet pressure and temperature of 6 bar and 900 K and outlet pressure of 1 bar. The isentropic efficiency of the turbine is 85 %. All the stages are to have a nozzle outlet angle of 75oand equal inlet and outlet rotor blade angles. Mean blade speed is 250 m/s and the axial velocity is 150 m/s and is a constant across the turbine. Estimate the number for stages required for this turbine.	Remember	CO 5	CLO 20
5	A pulsejet engine is employed in powering a vehicle flying at a Mach number of 2 at an altitude of 40,000 ft. The engine has an inlet area 0.084 m2. The pressure ratio at combustion chamber is P03/P02 = 9, fuel heating value is 43,000 kJ/kg, and combustion efficiency is 0.96. Assuming ideal diffuser (P02 = P0a), it is required to calculate	Remember	CO 5	CLO 18
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