TURBOMACHINERY (ME732PE)
COURSE PLANER

COURSE OVERVIEW:

This Course provides a simple understanding of the gas power systems. Due to the extensive usage of Gas turbines, study of turbomachinery has increased. This course addresses the working of various turbo machinery components like turbine, compressor. This course studies the various compressor, it's performance. Also studies the performance of radial and axial machines, turbines and its design, performance. Learner able to understand the working, perform the calculations for various turbines and compressor. The gas turbine cycle, working of gas turbines and a glimpse on jet propulsion and the working principle of rockets.

PREREQUISITE(S):

Students are expected to know the fundamentals of thermodynamics, the laws of thermodynamic. Basics of fluid mechanics and hydraulic system, compressors.

COURSE OBJECTIVES:

The objectives of the course are to enable the student

- Provide students with opportunities to apply basic flow equations
- Train the students to acquire the knowledge and skill of analyzing different turbo machines.
- How to compare and chose machines for various operations

I. COURSE OUTCOMES

CLO's	Description	Bloom's Taxonomy Levels
CO1	Ability to design and calculate different parameters for turbo machines	L3: APPLY
CO2	Prerequisite to CFD and Industrial fluid power courses	L4: ANALYZE
CO3	Ability to formulate design criteria	L5: EVALUATE
CO4	Ability to understand thermodynamics and kinematics behind turbo machines	L2: UNDERSTAND

II. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Level	Proficiency assessed by
PO1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Presentation on real-world problems
PO2	**Problem analysis**: Identify, formulate, review research literature, and analyze engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	Assignments
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	2	Assignments

PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	3	Mini/Major Projects
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.	3	Mini/Major Projects
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	-	-
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	-	-
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	-	-
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.		-
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.		-
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	-	-
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	-	-

VI. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		**Level**	**Proficiency assessed by**
PSO1	The student will be able to apply the knowledge of Mathematics, Sciences and engineering fundamentals to formulate, analyze and provide solutions for the problems related to Mechanical engineering and communicate them effectively to the concerned.	2	Assignments
PSO2	Design mechanical systems in various fields such as machine elements, thermal, manufacturing, industrial and inter-disciplinary fields by using various engineering/technological tools to meet the mercurial needs of the industry and society at large.		

PSO3	The ability to grasp the latest development, methodologies of mechanical engineering and posses competent knowledge of design process, practical proficiencies, skills and knowledge of programme and developing ideas towards research.		

VII. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Course Learning Outcome	Program Outcomes (PO)											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3	2	-	-	-	-	-	-	-		-
CO2	2	2	3	3	-	-	-	-	-	-	-	-
CO3	2	2	3	3	-	-	-	-	-	-	-	-
CO4	2	2	-	-	-	-	-	-	-	-	-	-
AVG	**2.25**	**2.25**	**2.66**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

CO's	**PSO1**
CO1.	**-**
CO2.	2
CO3.	**-**
CO4.	**-**
Average	2

VIII. SYLLABUS:

UNIT - I

Introduction to Turbomachinery: Classification of turbo-machines, second law of thermodynamics applied to turbine and compressors work, nozzle, diffuser work, fluid equation, continuity, Euler's, Bernoulli's, equation and its applications, expansion and compression process, reheat factor, preheat factor

UNIT – II

Fundamental Concepts of Axial and Radial Machines: Euler's equation of energy transfer, vane congruent flow, influence of relative circulation, thickness of vanes, number of vanes on velocity triangles, slip factor, Stodola, Stanitz and Balje's slip factor, suction pressure and net positive suction head, phenomena of cavitation in pumps, concept of specific speed, shape number, axial, radial and mixed flow machines, similarity laws.

UNIT - III

Gas Dynamics: Fundamental thermodynamic concepts, isentropic conditions, mach numbers, and area, Velocity relations, Dynamic Pressure, Normal shock relation for perfect gas. Supersonic flow, oblique shock waves. Normal shock recoveries, detached shocks, Aerofoil theory. Centrifugal compressor: Types, Velocity triangles and efficiencies, Blade passage design, Diffuser and pressure recovery. Slip factor, Stanitz and Stodolas formula's, Effect of inlet mach numbers, Pre whirl, Performance

UNIT - IV

Axial Flow Compressors: Flow Analysis, Work, and velocity triangles, Efficiencies, Thermodynamic analysis. Stage pressure rise, Degree of reaction, Stage Loading, General design, Effect of velocity, Incidence, Performance Cascade Analysis: Geometrical and terminology. Blade force, Efficiencies, Losses, Free end force, Vortex Blades.

UNIT – V

Axial Flow Gas Turbines: Work done. Velocity triangle and efficiencies, Thermodynamic flow analysis, Degree of reaction, Zweifels relation, Design cascade analysis, Soderberg, Hawthrone, Ainley, Correlations, Secondary flow, Free vortex blade, Blade angles for variable degree of reaction. Actuator disc, Theory, Stress in blades, Blade assembling, Material and cooling of blades, Performances, Matching of compressors and turbines, off design performance.

TEXT BOOKS:

1. Principles of Turbo Machines/DG Shepherd / Macmillan
2. Turbines, Pumps, Compressors/Yahya/ Mc Graw Hill

REFERENCE BOOKS:

1. A Treatise on Turbo machines / G. Gopal Krishnan and D. Prithviraj/ SciTech
2. Gas Turbine Theory/ Saravanamuttoo/ Pearson
3. Turbo Machines/ A Valan Arasu/ Vikas Publishing House Pvt. Ltd.

NPTEL RESOURCES:

Introduction to turbomachinery: https://onlinecourses.nptel.ac.in/noc21_me127/preview

GATE SYLLABUS:

Thermal sciences: Power Engineering: Air and gas compressors; gas power cycles, concepts of regeneration and reheat. Turbomachinery: Impulse and reaction principles, velocity diagrams.

IES SYLLABUS:

Turbines, velocity diagrams, Impulse and Reaction principles, Steam and Gas Turbines, Theory of Jet Propulsion – Pulse jet and Ram Jet Engines. Brayton cycles with regeneration and reheat, Fuels and their properties, Flue gas analysis.

Lecture No.	Unit No.	Topics to be covered	Content to be covered in each topic	Link for PPT	Link for PDF	Title of Small Projects	Course learning outcomes	Teaching Methodology	Reference
1	I	Introduction to Turbomachinery	Basic principle of turbomachinery, Classificatio	https://docs.google.com/presentation/d/1Mm7RWtHEcLv_BGcynxf4uuKtz5DcIFfD/edit#slide=id.p1+F7:F16	https://drive.google.com/drive/u/2/folders/1nzTW6QLzo-W7nFnqM4XlEUO-jcChcWS8	Case study on applications of bornoulli's Equation	CLO4	Chalk and Talk PPT, Assignments, Videos	T1, R3
2		second law of thermodynamics	Steady flow energy equation, Kelvin planck and				CLO4		

3		Turbine,	application				CLO4		
4		fluid equation	Derivation of energy equation				CLO4		
5		Continuity	fluid flow problem				CLO4		
6		Euler's Equation	Derivation of Eulers equation				CLO4		
7		Bernoulli's, equation	Derivation of Energy equation				CLO4		
8		Applications	Application of bernoullis equation				CLO2, CLO4		
9		expansion and compression process,	Process occurance, effect				CLO2		
10		Reheat factor, preheat	Effect of reheating and preheating				CLO2		
11	**II**	**Fundamental Concepts of Axial and Radial Machines**	**working principle of Axial and radial machines**	https://docs.google.com/presentation/d/1jC4jHLNvxsSu4blj5DhDgHXAm3GyJPil/edit#slide=id.p1	https://drive.google.com/drive/u/2/folders/1nzTW6QLzo-W7nFnqM4XlEUO-jcChcWS8	**Evaluating power generation by velocity triangle**	CLO4	Chalk and Talk PPT, Assignments, Videos	**T2, R2**
12		Euler's equation of energy transfer, vane	Derivation of Eulers equation				CLO1		

		compressors work, nozzle, diffuser	of all the components						
14		number of vanes on velocity triangles	Calculation of power using velocity triangles				CLO3		
15		slip factor,	Stodala				CLO1		
16		Balje's slip factor	various factors effecting efficiency				CLO1, CLO3		
17		**Mock Test – I**							
18	**II**	suction pressure and net positive suction head	Basic terms, its factors	https://docs.google.com/presentation/d/1jC4jHLNvxsSu4blj5DhDgHXAm3GyJPil/edit#slide=id.p1	https://drive.google.com/drive/u/2/folders/1nzTW6QLzo-W7nFnqM4XlEUO-jcChcWS8	**Cavitation its effect**	CLO3	Chalk and Talk PPT, Assignments, Videos	
19		phenomena of cavitation in pumps,	Cavitation, priming				CLO2		
20		concept of specific speed, shape number	Specific speed, efficiency calculation				CLO1		
21		axial, radial and mixed flow machines, similarity	axial, radial and mixed flow machines, similarity				CLO4		
22	**III**	**Gas Dynamics**: Fundamental thermodyna	Basic concepts of TD	https://docs.google.com/presentation/d/1Kq-UPpxrPy6j4	https://drive.google.com/drive/u/2/folders/1nzTW6QLzo-	**Evaluating power generation by velocity**	CLO4	Chalk and Talk PPT,	**T1, R2**

23		isentropic conditions	Efficiency effect due to friction and process	uUeug8DepyjvaWqsafO/edit#slide=id.p1	W7nFnqM4XlEUO-jcChcWS8	**triangle**	CLO4	Assignments, Videos	
		Stodola, Stanitz	equation and slip factor						
25		Dynamic Pressure, Normal shock relation for	Dynamic Pressure, Normal shock relation for				CLO1		
26		Supersonic flow,oblique shock waves	Flow sonic, supersonic				CLO1		
27		Normal shock recoveries, detached shocks,	Aerofoil design				CLO2		
MID-I EXAMS									
28		**Centrifugal compressor** : Types, Velocity triangles	Working principle of compressor	-	-		CLO1, CLO4		
29		Blade passage design, Diffuser and pressure	Efficiency calculation, design parameters				CLO1, CLO4		
30		Slip factor, Stanitz and Stodolas formula's	Slip factor, Stanitz and Stodolas formula's				CLO1		
31		Effect of inlet mach numbers	Mach number and its influence				CLO2		

32		Prewhirl, Performance	performance of compressor				CLO3		
33		**Axial Flow Compressors**: Flow Analysis	working principle of axial compressor				CLO1		
34		Work, and velocity triangles, Efficiencies	Work, and velocity triangles, Efficiencies				CLO1		
35		Thermodynamic analysis	Thermodynamic analysis				CLO3		
36		Stage pressure rise, Degree of reaction, Stage	Stage pressure rise, Degree of reaction, Stage	https://docs.google.com/presentation/d/1Kq-UPpxrPy6j4uUeug8DepyjvaWqsafO/edit#slide=id.p1	https://drive.google.com/drive/u/2/folders/1nzTW6QLzo-W7nFnqM4XIEUO-jcChcWS8	**Compressor its performance**	CLO1	Chalk and Talk PPT, Assignments, Videos	
37	**IV**	General design, Effect of velocity, Incidence,	General design, Effect of velocity, Incidence,				CLO1, CLO3		
38		**Cascade Analysis**	**Cascade Analysis**				CLO4		
39		Geometrical and terminology	Geometrical and terminology				CLO4		**T1, R1**
40		Blade force, Efficiencies, Losses							
41		Free end force,Vortex Blades.	Various design of compressor				CLO1		

42		Axial Flow Gas Turbines: Work done. Velocity	Working principle of turbine, calculating work using				CLO1		
43		Thermodynamic flow analysis,Degree of reaction	Defination of degree of reaction and its calculation				CLO1		
44		Zweifels relation, Design cascade analysis,	Zweifels relation, Design cascade analysis,				CLO3		
45	**V**	Hawthrone, Ainley, Correlations, Secondary flow, Free	Hawthrone, Ainley, Correlations, Secondary flow, Free	https://docs.google.com/presentation/d/1Kq-UPpxrPy6j4uUeug8DepyjvaWqsafO/edit#slide=id.p1	https://drive.google.com/drive/u/2/folders/1nzTW6QLzo-W7nFnqM4XlEUO-jcChcWS8	**Design of turbine**	CLO1	Chalk and Talk PPT, Assignments, Videos	**T2, R2**
46		Actuator disc, Theory	Actuator disc, Theory				CLO3		
47		Stress in blades, Blade assembling, Material	Stress in blades, Blade assembling, Material and				CLO2		
48		Performances, Matching of compressors and	Performances, Matching of compressors and				CLO3		
49	**I-V**	Revision and practice	Revision and practice				CLO1-4		

QUESTION BANK:
DESCRIPTIVE QUESTIONS:
UNIT-I

S.NO	Question	Blooms Taxonomy Level	Course Outcome
Short Answer Questions-			
1		**Application**	**2**

	Give the classification of Turbo machines.		
2	Write short notes a) Free vortex blades b) Slip factor in centrifugal compressor c) Thermodynamic analysis of steam turbines.	**Application**	**1**
3	Define stagnation pressure?	**Application**	**1**
4	What is meant by Isentropic process?	**Apply**	**3**
5	Define stagnation enthalpy?	**KNOWLEDGE**	**4**
6	Define stagnation temperature?	**Application**	**2**
7	Draw and explain Mach cone, Mach angle and Mach waves?	**Application**	**1**
8	What is mean by shock wave ?	**Application**	**1**
9	Calculate the maximum deflection angles for which the oblique shock remains attached to the wedge when M_1=2 and 3.	**Apply**	**3**
Long Answer Question			
10	Define total to total, total to static, static to static and static to total efficiencies for power developing and power consuming turbomachines and write the T-s Diagrams.	**understand**	**2**
11	What are the various types of nozzles and their function	**understand**	**2**

UNIT-II

S.NO	Question	Blooms Taxonomy Level	Course Outcome
Short Answer Question			
1	What is static and stagnation conditions of Turbo machines.	**knowledge**	**2**
2	Show Euler's isentropic and actual values of work in turbines and compressors on h-s coordinates. show the corresponding exit pressures in each case.	**Application**	**2**

3	Write the expression for energy balance in nozzles.	**Application**	**1**
Long Answer Question			
4	The inlet condition to a steam nozzle is 10 bar and 250C.The exit pressure is 2 bar. Assuming isentropic expansion and negligible inlet velocity, calculate the throat area, exit velocity and exit area of the nozzle.	**Apply**	**2**
5	Compute the minimum values of Mach number M_1 for which the oblique shock remains attached to the wedge for deflection angles at 20^0, 30^0 and 40^0.	**KNOWLEDGE**	**2**
6	Derive the polytropic compression efficiency through an infinitesimal compression stage.	**Application**	**2**
7	Discuss the effect of back pressure during flow through a converging diverging nozzle. Show variation of pressure, velocity and P exit as a function of back pressure.	**Application**	**2**

UNIT-III

S.NO	Question	Blooms Taxonomy Level	Course Outcome
Short Answer Question			
1	Draw the outlet velocity triangle for Axial flow compressor.	**Knowledge**	**1**
2	Define slip factor.	**Application**	**2**
3	What is super sonic flow in gas dynamics?	**Application**	**2**
Long Answer Question			
4	Derive the polytropic compression efficiency through an infinitesimal compression stage	**Apply**	**2**
5	Define incompressible, compressible, steady and unsteady, inviscid, viscuss, laminar and turbulent flows. Give examples of each of these flowsmin turbomachines.	**Apply**	**3**

6	Why is the radial tipped impeller most widely used in centrifugal compressor stages?	**Apply**	**2**
7	A Centrifugal impeller has 17 radial blades in the impeller of 45 cm diameter. The tip diameter of the eye is 25cm. Calculate the slip factor making use of the two different formulae. b) What is the purpose of inlet guide vanes and inducer blades in centrifugal compressor? explain briefly.	**Apply**	**3**
8	Write the four basic equations that satisfy the state points before and after abnormal shock . Show the shock on enthalpy and entropy diagram. b) A Centrifugal impeller has 17 radial blades in the impeller of 45 cm diameter. The tip diameter of the eye is 25cm. Calculate the slip factor making use of the two different formulae.	**Application**	**4**

UNIT-IV

S.NO	Question	Blooms Taxonomy Level	Course Outcome
Short Answer Question			
1	Define incidence in Axial flow compressor.	**knowledge**	**1**
2	Explain the concept of surging in an axial flow compressor. b) An axial compressor has a mean dia of 60m and runs at 15,000 RPM. Actual temperature rise of 30^0 C and pressure ratio developed is 1.3; calculate the power required to drive the compressor while delivering 60 kg/sec of air, if initial temperature is 35^0 C and mechanical efficiency as 88 %, stage efficiency and degree of reaction if the temperature at the rotor exit is 56^0 C.	**Application**	**2**
3	Prove that the turbine overall efficiency is greater than the turbine stage efficiency.	**Application**	**2**

Long Answer Question			
4	Draw the inlet and outlet triangles for an axial flow compressor for which given (a) Degree of reaction =0.5 b) inlet blade angle =400 (c)axial velocity of flow which is constant throughout = 125m/s (d) RPM =6500 (e) Radius = 0.2m. Calculate the power required in kW at an air flow rate = 15kg/s. Find fluid angles at inlet and outlet. Blade speed is same at exit and inlet.	**understand**	**2**
5	Explain the concept of surging in an axial flow compressor. b) Why is it necessary to employ multi stage axial compressors to obtain moderate to high pressure ratios?	**Application**	**2**
6	What is matching of compressor and turbine performance in axial flow gas turbines?	**Application**	**3**

UNIT-V

S.NO	Question	Blooms Taxonomy Level	Course Outcome
1	What is an actuator disc? How is this concept used to predict the axial velocity distribution in the actuator disc flow region? How does it differ from radial equilibrium theory?	**knowledge**	**1**
2	Draw the inlet velocity triangle for Axial flow gas turbines.	**understand**	**2**
3	Define degree of reaction in axial flow gas turbines.	**understand**	**2**
4	Explain the principle of outward flow radial cascade. Describe its effects. b) What is matching of compressor and turbine performance in axial flow gas turbines?	**application**	**3**

OBJECTIVE QUESTIONS:

JNTUH:

UNIT-1

1.What is the relation between Velocity Coefficient (C_c) and Nozzle efficiency (η_n)

a. $C_c = (1/2)\,(\eta_n)$

b. $C_c = \sqrt{(\eta_n)}$

c. $C_c = (\eta_n)^2$

d. $C_c = (\eta_n)^3$

2. The gates of aerofoil section in between the outer and inner ring of guide wheel are called as ________.

a. guide gates
b. guide vanes
c. scrolling gates
d. scrolling vanes

3.The blade passages in a compressor are ________

4.Which of the following is NOT a type of rotary compressor?

a. Positive displacement type of compressor
b. Steady flow compressor
c. Both a. and b.
d. None of the above

5. The mass flow rate of air compressed in axial flow compressor is _____________centrifugal compressor.

a. lower than
b. higher than
c. same as
d. unpredictable

6. ___________ pump is also called as velocity pump.

The passage of uniformly varying cross-section in which the kinetic energy of steam increases at the expense of its pressure is called as__________

a. steam turbine
b. steam nozzle
c. steam area
d. all of the above

7. In which type of reaction turbine does the water flow in radial direction at the outer periphery of runner and leave at the centre in the direction parallel to the axis of rotation of runner?

a. Radial flow turbine
b. Axial flow turbine
c. Mixed flow turbine
d. All of the above

8. __________ turbines are also called as parallel flow turbine.

a. Radial flow
b. Axial flow
c. Both radial flow and axial flow
d. None of the above

9. The radial force in rotodynamic machine, which is developed by rate of change of momentum in radial velocity, is taken care by__________.

10. The product of force (F) and time (t) is called as________.

UNIT-II

1. The ratio of actual mass flow rate ($\dot{m}_a$) to ideal mass flow rate ($\dot{m}_i$) is called as________

a. nozzle coefficient
b. coefficient of nozzle friction
c. coefficient of discharge
d. coefficient of mass

2. ________ blades are attached to the rotor or spindle.

3. An axial flow compressors have _______.

4.A pair of fixed blade and rotor blade in axial flow compressor is called as _________

5. How is the variation of air velocity while passing through impeller followed by diffuser in centrifugal compressor?
a. Air velocity goes no increasing in impeller followed by diffuser
b. Air velocity goes no decreasing in impeller followed by diffuser
c. Air velocity increases in impeller and then decreases in diffuser
d. Air velocity decreases in impeller and then increases in diffuser
6. The function of _________ is to convert high kinetic energy of gases into pressure energy.
a. impeller
b. diffuser
c. casing
d. None of the above
7. Which compressors are suitable for large volume flow rates of above 1200 m^3/min
a. Centrifugal compressors
b. Axial flow compressors
c. Both a. and b.
d. None of the above

UNIT-III
1. What is the formula to calculate specific speed (N_s) of a turbine rotating at a speed of 'N' rpm that develops the power of 'P' kW at the heat of 'H' m?
a. $(N_s) = (\sqrt{N} \times P) \times (H)^{(5/4)}$
b. $(N_s) = (2 \sqrt{N} \times P) \times (H)^{(5/4)}$
c. $(N_s) = (N \sqrt{P}) \times (H)^{(5/4)}$
d. $(N_s) = (2N \sqrt{P}) \times (H)^{(5/4)}$
2. The basic principle of operation of axial flow compressor is _______that of the centrifugal compressor.
3. What is the ratio of isentropic work to Euler work in an centrifugal compressor called?
a. Work coefficient
b. Velocity coefficient
c. Pressure coefficient
d. Flow coefficient
4.The ratio of actual whirl velocity to the ideal whirl velocity in the centrifugal compressor is called as _________.
a. velocity factor
b. slip factor
c. work factor
d. none of the above
5.The diffuser blades are kept ______ the number of impeller blades .
a. 1/10 th of
b. 1/3 rd of
c. 10 times
d. 3 times
6.Vaneless diffusers are suitable for ___________.
a. only low pressure rise
b. only high pressure rise
c. both low as well as high pressure rise
7.Angular momentum of gas in the free vortex of vaneless diffuser ___________.
a. increases
b. decreases
c. remains constant
d. becomes unpredictable
8.Which of the following centrifugal pumps has higher specific speed than the others?

a. Axial flow
b. Radial flow
c. Mixed flow
d. All have same specific speed
9. The volute pumps and vortex volute pumps are __________ pumps with _________ shaft.
UNIT-IV
1 What is the effect of increasing flow coefficient (Φ) in an axial flow compressor on blade loading coefficient (Ψ)?
a. Blade loading coefficient (Ψ) increases
b. Blade loading coefficient (Ψ) decreases
c. Blade loading coefficient (Ψ) remains constant
d. Unpredictable
2. What is the effect of increasing number of stages in axial flow compressor on the mean work input factor (Ψ_w)?
a. Mean work input factor (Ψ_w) decreases
b. Mean work input factor (Ψ_w) increases
c. Mean work input factor (Ψ_w) remains constant
d. Unpredictable
3. What is the ratio of the actual work absorbed by an axial flow compressor to the theoretical work called
a. Work input factor
b. Workdone factor
c. Both a. and b.
d. None of the above
4. ___________ can be defined as the ratio of the pressure rise in rotor blades to the pressure rise in stages in an axial flow compressor.
a. Degree of pressure
b. Degree of reaction
c. Pressure ratio
d. Reaction ratio

UNIT V
1**.** Thermal efficiency of closed cycle gas turbine plant increases by
(*a*) Reheating (*b*) intercooling (*c*) Regenerator (*d*) all of the above.
2**.** With the increase in pressure ratio thermal efficiency of a simple gas turbine plant with fixed turbine inlet temperature
(*a*) Decreases (*b*) increases (*c*) first increases and then decreases (*d*) first decreases and then increases.
3**.** The thermal efficiency of a gas turbine cycle with ideal regenerative heat exchanger is
(*a*) Equal to work ratio (*b*) is less than work ratio
(*c*) Is more than work ratio (*d*) un-predictable
4**.** In a two stage gas turbine plant reheating after first stage
(*a*) Decreases thermal efficiency (*b*) increases thermal efficiency
(*c*) does not affect thermal efficiency (*d*) none of the above.
5. In a two stage gas turbine plant, reheating after first stage
(*a*) increases work ratio (*b*) decreases work ratio
(*c*) does not affect work ratio (*d*) none of the above.
6**.** In a two stage gas turbine plant, with inter-cooling and reheating

(*a*) both work ratio and thermal efficiency improve
(*b*) work ratio improves but thermal efficiency decreases
(*c*) thermal efficiency improves but work ratio decreases
(*d*) both work ratio and thermal efficiency decrease

GATE OBJECTIVE:

1. A gas turbine plant working on Joule cycle produces 4000 kW of power. If its work ratio is 40%, what is the power consumed by the compressor?
   a. 2000 Kw b. 4000 kW c. 6000 kW d. 8000 Kw
2. Consider the following statements in respect of gas turbines: A gas turbine plant with reheater leads to a
   1. Considerable improvement in the work output.
   2. Considerable improvement in the thermal efficiency.
   Which of the statements given above is/are correct?
   a. 1 only b. 2 only c. Both 1 and 2 d. Neither 1 nor 2
3. Which one of the following is correct? For the same net power output: a. the turbine used in gas turbine power plants is larger than that used in steam power plants b. the turbine used in gas turbine power plants is smaller than that used in steam power plants c. the same turbine can be used for both plants d. None of the above
4. If the cross-section of a nozzle is increasing in the direction of flow in supersonic flow then in the downstream direction: a. Both pressure and velocity will increase b. Both pressure and velocity will decrease c. Pressure will increase but velocity will decrease d. Pressure will decrease but velocity will increase
5. Which one of the following is the correct statement? To get supersonic velocity of steam at nozzle exit with a large pressure drop across it, the duct must: a. converge from inlet to exit b. diverge from inlet to exit c. first converge to the throat and then diverge till exit d. remain constant in cross-section
6. A 4-row velocity compounded steam turbine develops total 6400 kW. What is the power developed by the last row? a. 200 kW b. 400 kW c. 800 kW d. 1600 kW
7. Consider the following statements: 1. The speed of rotation of the moving elements of gas turbines is much higher than those of steam turbines. 2. Gas turbine plants. are heavier and larger in size than steam turbine plants. 3. Gas turbines require cooling water for its operations. 4. Almost any kind of fuel can be used with gas turbines. Which of the statements given above are correct? a. 1 and 2 b. 1 and 3 c. 1 and 4 d. 3 and 4
8. The air with enthalpy of 100 kJ/kg is compressed by an air compressor to a pressure and Y temperature at which its enthalpy becomes 200 kJ/kg. The loss of heat is 40 kJ/kg from the compressor as the air passes through it. Neglecting kinetic and potential energies, the power required for an air mass flow of 0.5 kJ/s is: a. 30 kW b. 50 kW c. 70 kW d. 90 kW
9. In turbo prop, the expansion of gases takes place approximately: a. 100% in the turbine b. 80% in the turbine and 20% in the nozzle c. 50% in the turbine and 50% in the nozzle d. 100% in the nozzle
10. The efficiency of a simple gas turbine can be improved by using a regenerator, because the: a. work of compression is reduced b. heat required to be supplied is reduced c. work output of the turbine is increased d. heat rejected is increased
11. Stoichiometric air-fuel ratio by volume for combustion of methane in air is: a. 15:1 b. 17.16:1 c. 9.52:1 d. 10.58:1

12. Which of the following statements is/are true in case of one-dimensional flow of perfect gas through a converging diverging nozzle? 1. The exit velocity is always supersonic. 2. the exit velocity can be subsonic or supersonic. 3. If the flow is isentropic, the exit velocity must be supersonic. 4. If the exit velocity is supersonic, the flow must be isentropic. Select the correct answer using the codes given below: a. 2 and 4 b. 2, 3 and 4 c. 1, 3 and 4 d. 2 alone

IES OBJECTIVE:

1. Considering the flow of steam through a convergent-Divergent nozzle under real conditions, where super saturation occurs, the difference between the saturation temperature corresponding to the pressure and the supersaturated temperature is defined as degree of (a) Under cooling (b) Superheat (c) Reaction (d) Saturation
2. When a converging–diverging nozzle is operated at off–design conditions, a normal shock forms in the diverging portion. The nozzle can be assumed to be perfectly insulated from the surroundings. Then across the shock: (A) The velocity undergoes a jump but pressure and entropy remain unchanged (B) The pressure undergoes a jump but velocity and entropy remain unchanged (C) The velocity and pressure undergo a jump, but entropy remains unchanged because there is no heat transfer (D) Velocity, pressure and entropy all undergo a jump
3. In a two stage gas turbine plant, with inter cooling and reheating: (A) Both work ratio and thermal efficiency increase (B) Work ratio increases but thermal efficiency decreases (C) Thermal efficiency increases but work ratio decreases (D) Both work ratio and thermal efficiency decrease
4. A converging–diverging nozzle is operated at a pressure difference which is not the design value for isentropic flow. As a consequence a normal shock is formed in the diverging portion. In this situation the Mach number at the throat is: (A) Less than 1 (B) More that 1 (C) Exactly 1 (D) Could be less or more than 1 depending on the pressure difference
5. Frictional losses in the nozzle: (A) reduces the enthalpy of the fluid (B) increases the enthalpy of the fluid (C) no effect on enthalpy of the fluid (D) none of the above
6. In a nozzle designed for maximum discharge conditions, the flow velocity in the convergent section of the nozzle is: (A) Subsonic (B) Sonic (C) Supersonic (D) Depends on initial pressure and condition of steam
7. The thermal efficiency of a simple open gas turbine plant is improved by regeneration as this: (A) Decreases the temperature of the gases at the turbine inlet (B) Decreases the quantity of heat supplied in combustion chamber (C) Increases the turbine output (D) Lowers the work input to compressor
8. Consider a gas turbine supplied with gas at 1000 K and 5 bar to expand adiabatically to a 1 bar. The mean specific heat at constant pressure is 1.0425 kJ/kgK and constant volume is 0.7662 kJ/kgK. Calculate power developed in kW/kg of gas per second and exhaust gas temperature: (A) 462 kW/kg and 647 K (B) 362 kW/kg and 653 K (C) 462. KW/kg and 653 K (D) 362 kW/kg and 647 K
9. If absolute jet exit velocity from a jet engine if 2800 m/s and forward flight velocity is 1400 m/s, then propulsive efficiency is: (A) 33.33% (B) 40% (C) 66.66% (D) 90%
10. An air-breathing aircraft is flying at an altitude where the air density is half the value at ground level. With reference to the ground level, the air fuel ratio at this altitude will be: (A) ½ (B) 1 (C) 2 (D) 4
11. A gas turbine operating on Brayton cycle has the maximum temperature of 1200K and the minimum temperature of 300K. The cycle efficiency for the maximum work capacity will be: (A) 75% (B) 60% (C) 50% (D) 25%.
12. The gas in a cooling chamber of a closed-cycle gas turbine is cooled at: (A) constant volume (B) constant temperature (C) constant pressure (D) None of the above.
13. In a gas turbine power plant, reheating of gases between the high pressure and low pressure turbine stages will: (A) improve turbine output (B) decrease turbine output (C) increase compressor output (D) decrease compressor work
14. In a gas turbine plant, regeneration is done to: (A) increase compression work (B) decrease turbine work (C) limit the maximum temperature (D) improve plant efficiency

15. Turbo prop-engine has the following additional feature over the turbojet: (A) Propeller (B) Diffuser (C) Starting engine (D) Turbine and combustion chamber
16. In rocket propulsion, the oxygen for combustion of its fuel is taken from: (A) Surrounding air (B) The rocket itself (C) Compressed atmospheric air (D) Surrounding air and compressed atmospheric air
17. In which modification of simple gas turbine cycle, is work ratio increased? (1) Regenerative gas turbine cycle (2) Gas turbine cycle with reheating (A) Both 1 and 2 (B) 1 only (C) 2 only (D) Neither 1 nor 2
18. Reheat between multi-stage expansions in Joule cycle increases (1) Overall work output (2) The work ratio (3) The thermal efficiency Which of the above are correct? 1, 2 and 3 (B) 1 and 2 only (C) 2 and 3 only (D) 1 and 3 only

19. Which of the following statements are correct for turbo-prop powered aircrafts? 1. The propulsion efficiency of turboprop is higher than that of turbo-jet and rockets for low speeds up to about 800 km/hr. 2. For the same thrust the turbine in the turbo-prop aircraft is smaller than in the turbo-jet aircraft 3. For the turbo-prop the flight velocity cannot exceed the jet velocity. (A) 1, 2 and 3 (B) 1 and 2 only (C) 2 and 3 only (D) 1 and 3 only
20. Which of the following statements are correct for rockets? 1. Unlike the turbo-jet aircraft, in rockets the flight velocity can exceed the jet velocity 2. In rockets gases having lower molecular weight increase the specific thrust 3. In rockets the gases are expanded in the nozzle up to the atmosphere pressure. (A) 1, 2 and 3 (B) 1 and 2 only (C) 2 and 3 only (D) 1 and 3 only

Directions: Each of the next eight (8) items consists of two statements, one labeled as the 'Assertion (A)' and the other as 'Reason (R)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(A) Both A and R are individually true and R is the correct explanation of A
(B) Both A and R are individually true but R is not the correct explanation of A
(C) A is true but R is false
(D) A is false but R is true

21. **Assertion (A):** The pressure compounded impulse steam turbine is the most efficient type of impulse turbine. **Reason (R):** It is because the ratio of blade velocity to steam velocity remains constant.
22. **Assertion (A):** Rocket engines are used for space research. **Reason (R):** They have high specific impulse.
23. **Assertion (A):** The modern electric power generating plants use only water tube boilers and not fire tube boilers. **Reason (R):** The water tube boilers are comparatively cheaper in first cost than fire tube boilers.
24. **Assertion (A):** Single stage impulse steam turbines are not used in practice. **Reason (R):** Single stage impulse steam turbines have very low revolutions per minute.
25. **Assertion (A):** The performance parameter 'Poly tropic efficiency' is used for axial flow gas turbines and air compressors. **Reason (R):** Poly tropic efficiency is dependent on the pressure ratio

WEBSITES:

1. www.nptel.ac.in
2. www.mit.edu

EXPERT DETAILS

1. Dr. A.V.S.S.K Guptha, Professor, JNTU, Hyderabad
2. Dr. S Nagasarada, Professor, JNTU, Hyderabad

JOURNALS:

1. ASME Journal of Energy Resource Technology
2. ASME Journal of Engineering for Industry
3. ASME Journal of Solar Energy Engineering
4. Australian Journal of Mechanical Engineering

STUDENTS SEMINARS:

1. Axial and radial machines
2. Compressors types
3. Rocket propulsion
4. Gas Turbines
5. Jet Propulsion

CASE STUDIES/SMALL PROJECTS:

1. Study of cavitation in turbines, BHEL ANNUAL REPORT
2. A demonstration on reaction turbine/gas turbine
3. Visit to textile industry/sugar cane industry-write report on it.